... soon become the habitat of a succession of various organisms, animal as well as vegetable, so that at the end of a period of use it is no exaggeration to say that the sand through which the water percolates swarms with them. To state a definite case quantitatively, it has been shown during these examinations that such filter-bed sand may contain hundreds of millions of nemas per acre in the top three inches. Each of these nemas is excreting material of which the soluble portions must pass into the city's water supply, and if in the course of its passage through the filters, flumes, and delivery pipes this soluble matter is not precipitated or otherwise altered, it is present in every glass of drinking-water.

### FLAVOR OF DRINKING WATERS

*Drinking-water Connoisseurs?* The excreta of any given filter-bed organism must be different from that of any other, and though the differences may be slight between similar organisms, there are good reasons for thinking that the differences among the organisms of the filter-beds of different cities are great enough to cause material differences in the nature of their excreta. Such soluble parts of the excreta as pass into the drinking-water must play a rôle in imparting to the water its flavor and other qualities. This is enough to make one wish that we had connoisseurs to assist us in the selection and control of drinking-water, as we have connoisseurs in wine and tea,—connoisseurs or experts capable of distinguishing minute differences in the flavor of drinking-waters. At first thought this may seem too fine-spun, and yet when we think of the care exercised in selecting wines, teas, and other beverages, and compare their actual importance with that of drinking-water, it may not be going too far to suggest that consideration be given to the possibility of determining the qualities of drinking-water by flavor and other tests in addition to those now in use. I think experienced persons with a delicate sense of taste will bear out the statement that the drinking-water of each city has its characteristic flavor. If half a dozen glasses of fresh drinking-water could be assembled from the water supplies of as many cities, I have little doubt that a person with a delicate sense of taste would be able to tell one from another blindfolded, at any rate where the differences were most pronounced.

In this discussion it matters little that the amount of the dissolved substances thus suggested as a possible cause of differences in the physiological action of drinking-water is minute, for it is a well-established fact that very minute quantities of various substances may have a pro-



# NEMATODES OF THE SLOW SAND FILTER-BEDS OF AMERICAN CITIES

(Including new genera and species)

## WITH NOTES ON HERMAPHRODITISM AND PARTHENOGENESIS*

CONTRIBUTIONS TO A SCIENCE OF NEMATOLOGY, VII

BY N. A. COBB 1918

*United States Department of Agriculture*

The nemas here described were collected from the filter-beds o several American cities, incident to a rather extensive investigatio of nemas of economic interest. A study of them has afforded me suc an interesting and suggestive glimpse of the biological conditions i slow sand filter-beds that I venture to think an account of it may b of some slight use to sanitarians, and to engineers connected with cit and town water works. The biological observations, more particu larly those on the vanishing series of spermatozoa in syngones, ma prove of interest to zoologists and geneticists.

### NATURE AND NUMBER OF THE ORGANISMS FOUND

*Few Green Organisms.* Comparatively few green organisms occu in covered slow sand filter-beds, especially if the water passes throug a subsidence reservoir before entering the beds. Practically all th living forms found are colorless or nearly so, and most of the larger one are animal. To me the most striking organisms in every sample o sand examined were the nemas.

*Period of Use. Renewal.* From time to time a few inches of th topmost sand of slow filter-beds is renewed; the old sand is removed an fresh sand spread in its place. The period of use, the time betwee any two successive renewals, varies from a few weeks to a few month according to the practice of the engineer in charge. Toward the en of a period of use the number of nemas in the topmost three inches of bed often mounts to hundreds of millions per acre, and sometime exceeds a thousand millions per acre. At this latter figure each gla of drinking water must percolate through sand containing at lea about a thousand nemas.

*Dozens of Species Found.* Often the nema population is of a mixe character, but sometimes it is comparatively homogeneous. O

* Waverly Press, Baltimore, Jan. 11, 1918.

of the nemas to consist of but a single species. About thirty species were found inhabiting the various beds examined, twenty-five species being found to inhabit the beds of one city. My observations make no pretence of being exhaustive, and I presume further research may easily double these numbers. Most of the species are of only occasional occurrence; those figuring prominently in the activities of the beds are only about half a dozen in number, and of these not all are equally important.

### THE MORE COMMON SPECIES

*Commonest Species Carnivorous.* Of the four more important species, (1) *Mononchus longicaudatus*, (2) *Ironus ignavus*, (3) *Tripyla monohystera* and in a lesser degree (4) *Ironus longicaudatus*, I have shown that all are carnivorous, that they feed upon a variety of living organisms, and that no one of them confines itself to a single kind of food. *Mononchus longicaudatus*, for instance, feeds upon several species of nemas, upon rotifers, and upon a variety of protozoa. The same is true of *Tripyla monhystera*. In the struggle among these filter-bed organisms it appears that sometimes one species may almost annihilate others. This accounts for such cases as that in which *Mononchus longicaudatus* constituted ninety-six per cent of the nema population of a bed.

### ROTATION OF THE FLORA AND FAUNA

*Seasonal Fluctuations.* I know little about the seasonal fluctuations; merely that they exist and that sometimes they are very marked. For instance, on January 6 samples of sand were gathered from various locations on a Washington filter-bed. This bed had been in operation about six months, a period longer than in the case of any previous examination (summer collections). About the same range of species was found in this sand as had been found in all previous experience taken together, but the smaller nemas, including *Monhystera*, were much more abundant in this than in previous collections, and seemed to be thriving. A large *Dorylaimus* that had been extremely rare in previous collections was fairly common in this January collection. *Achromadora minima* was also more common. Finally there were one or two small species not hitherto found, *Cylindrolaimus obtusus* and a *Rhabdolaimus*. Whether these faunal differences were due to the winter season or to the long time the bed had been in use remains in certain instances undetermined,—very likely some of them were due to both causes.

*Economic Bearings.* Apart from seasonal fluctuations, there is a rotation in the fauna and flora incidental to the management of the



beds. Beginning with a new period of use, it appears that
species, e.g., bacteria and protozoa, having a short life cycle and suited to the new conditions, first make their appearance; these multiply and become the food of succeeding species, which in their turn give place to others. The problems presented are of great biological interest, and may not be without some bearing on public health. Beyond doubt they have a more or less important relation to the economical and effective management of the filter-beds.

### DETERMINING FACTORS OF FILTER-BED POPULATION

*Organisms other than Nemas.* Many other kinds of organisms are found in filter-beds, some of them in far greater numbers than the nemas. Bacteria, fungi and protozoa occur, of course, in abundance, and are, I believe, the organic basis on which is built up the later animal population consisting of organisms of larger size, such as the nemas. Rotifers are not uncommon. Small oligochaetes,—earthworms,—occur, especially after long use, but never in such myriads as in sewage. Small crustaceans, such as daphnia and cyclops, sometimes occur, but I have never seen them in large numbers. Occasionally aquatic insects are found. The filter-beds of each city present biological peculiarities dependent upon the source of the water supply, for the biological characteristics of filter-beds depend to a considerable extent on the climatic and geological conditions prevalent on the water-shed from which the supply is drawn.

### PHYSIOLOGICAL SIGNIFICANCE OF FILTER-BED NEMAS

*Illness from Change of Water.* It is a well-accepted idea among physicians, as well as laymen, that a change of drinking-water may cause intestinal disorders; why they are thus caused is not always clear. If the waters in question are widely different in composition, for instance one soft and the other hard, it is easy to understand how intestinal derangements might follow a change from one to the other; but are the derangements due to change of water always associated with such marked chemical differences? Do not intestinal disturbances follow changes of water in which the usual tests would show but very slight differences?

*Soluble Excreta in Drinking-water.* Is it possible that slight quantities of organic substances found in drinking water and of a character as yet unknown, might, under some circumstances, exert a powerful physiological influence? If this question be answered affirmatively, a wide field of investigation is opened up in connection with potable waters, and it is in this connection that the present researches are found effect upon the human organism. Such reflections lead to the suggestion that the study of filter-bed organisms is one that should be prosecuted more vigorously. We have developed a few excellent chemical tests, and, so far as it goes, an excellent system for determining the bacterial content of drinking-water. Why not go a step farther and make at least an attempt to determine the nature of the minute quantities of soluble organic substances of physiological significance which may be present, and the origin and nature of these substances.

## POSSIBLE CONTROL OF FILTER-BED ORGANISMS

If it should be found that the presence of a particular micro-organism in filter-beds is deleterious, is it possible so to manage the beds as to exclude the micro-organism, or counteract its effect? Already I feel sufficiently conversant with some of the facts to predict that such control will prove feasible, at least in some instances. In the case of *Mononchus longicaudatus* for instance, as soon as we know the natural distribution of the *Mononchus;* its relationship to the seasons of the year, if it has any significant relationship of that kind; the period of its life cycle; its rate and method of reproduction; its food; its enemies; then, almost beyond doubt we shall be able to suggest means for its control. So with other organisms.

To secure a reliable filter-bed census it is necessary to examine the sand as soon as collected. After a short period under laboratory conditions the population begins to change: e.g., sand which at the time it was removed from the bed contained many specimens of *Mononchus* and a few of *Ironus ignavus*, after ten days yielded no *Mononchus*, though it continued to yield *Ironus*, and in addition a few adult specimens of *Tripyla* and *Monhystera*,—differences no doubt due in part to the fact that in stagnant collections *Mononchus longicaudatus* is subject to the attacks of a variety of fatal diseases caused by fungi and microbes.

## NEMAS A CLUE TO THE FLOW

*Nemas Unequally Distributed in Beds.* The distribution of organisms in filter-beds is not uniform. For example, if a series of samples be collected, one each from near the main drain-pipe, near a lateral, between the laterals, and at the margin of the bed, the numbers and kinds of nemas will be found to differ in the various samples. This unequal distribution is doubtless a function of the flow of the water, for where the flow is rapid the biological environment differs from that where it is slower; there is a greater supply of oxygen, a greater supply of water-soluble food, and a greater supply of such free micro-organisms as may pass between the grains of sand. It follows that to some extent the and nature of the filtration.

The general appearance of the sand in any particular part of the bed is a clue to the rate and nature of the filtration there, but this rough method is capable of refinement through the aid of a biological census. The difficulty is we do not yet know what significance to attach to the presence or absence of particular species. Should an attempt be made to devise and apply such a method, it might be found that the presence or absence of a few species would constitute a sufficient test.

## PARTIAL LIST OF THE NEMAS FROM AMERICAN SLOW SAND FILTER-BEDS*

| | |
|---|---|
| *Achromadora minima* Cobb | Washington, D. C. |
| *Actinclaimus radictus* Cobb | Washington, D. C. |
| *Aphanolaimus* ? | Philadelphia |
| *Aphelenchus* sp | Pittsburg |
| *Atylenchus* sp | New Bedford |
| *Cephalobus* sp | Philadelphia |
| *Cylindrolaimus obtusus* Cobb | Washington, D. C. |
| *Dorylaimus fecundus* Cobb | Washington, D. C. |
| *Dorylaimus* sp | Washington, D. C. |
| *Dorylaimus* sp | Philadelphia |
| *Dorylaimus* sp | Philadelphia |
| *Dorylaimus* sp | Washington, D. C. |
| *Iota simile* n. sp | Washington, D. C. |
| *Ironus americanus* Cobb | Philadelphia |
| *Ironus ignavus* Bastian | Washington, D. C. |
| *Ironus longicaudatus* de Man | Washington, D. C. |
| *Monhystera subfiliformis* n. sp. | Washington, D. C. |
| *Monhystera dispar* Bastian | Washington, D. C. |
| *Monhystera* sp | Philadelphia |
| *Monhystrella plectoides* n. subg., n. sp. | Washington, D. C. |
| *Mononchulus ventralis* n. g., n. sp. | Washington, D. C. |
| *Mononchus longicaudatus* Cobb | Washington, D. C. |
| *Mononchus* sp | Philadelphia |
| *Plectus cirratus* Bastian | Washington, D. C. |
| *Prismatolaimus* sp | Philadelphia |
| *Rhabditis* sp | Philadelphia |
| *Rhabdolaimus* sp | Washington, D. C. |
| *Spilophora* sp | Harrisburg |
| *Teratocephalus* sp | Pittsburg |
| *Trilobus longus* Leidy | Philadelphia. |
| *Tripyla monohystera* de Man | Washington, D. C. |
| *Tylencholaimus* sp | South Bethlehem, Pittsburg |
| *Tylenchus filiformis* Bütschli (?) | Washington, D. G. |
| *Tylenchus* sp | Philadelphia |
| *Xiphinema americanum* Cobb | Philadelphia |

* The larger number of species from the Washington beds is due to the examination of a larger number of samples than from beds elsewhere. The more important of these species are described below. The drawings are from nature and were made under the author's personal supervision by Mr. W. E. Chambers.

### MONONCHUS Bastian 1865

1. Mononchus longicaudatus Cobb (See p. 161). The feeding habits of *Mononchus* are distinctly different from those of either of its frequent companions, *Tripyla* and *Ironus*. In capturing food *Mononchus* depends largely upon the grip of its powerful jaws. *Tripyla* depends upon its agility and its flexibility, and possibly coils itself about its victim, after the manner of a boa constrictor. *Mononchus* and *Tripyla* bolt their food, but *Ironus* feeds in an entirely different way; attaching its lips to its food, it rips a hole in the external layers by the outward stroke of its three, extremely sharp, radially acting onchi. As these move forward their points move outward, and two or three such movements serve partially to imbed the head of the *Ironus*. It would appear that then the more or less fluid parts only are imbibed, for the contents of the intestine of *Ironus* hardly ever present optically identifiable substances. It is manifest, however, that the contents of the intestine are animal in character, and so it seems beyond reasonable question that *Ironus* is carnivorous. I have never found the contents of the intestine to respond to the starch test.



intestine of *Mononchus longicaudatus*.

*Renette*. When this well-known mononch was stained *intra vitam* with trypan blue, the ampulla and a short portion of the duct of the renette was so distinctly seen as to leave almost no shadow of doubt that this portion of the renette structure is normal. I am inclined to think that the duct soon takes a lateral turn, and possibly becomes connected with the lateral field; thus far it has not been possible to follow it more than a distance about equal to the radius of the neck, so that the size and structure of the glandular part remain unknown.

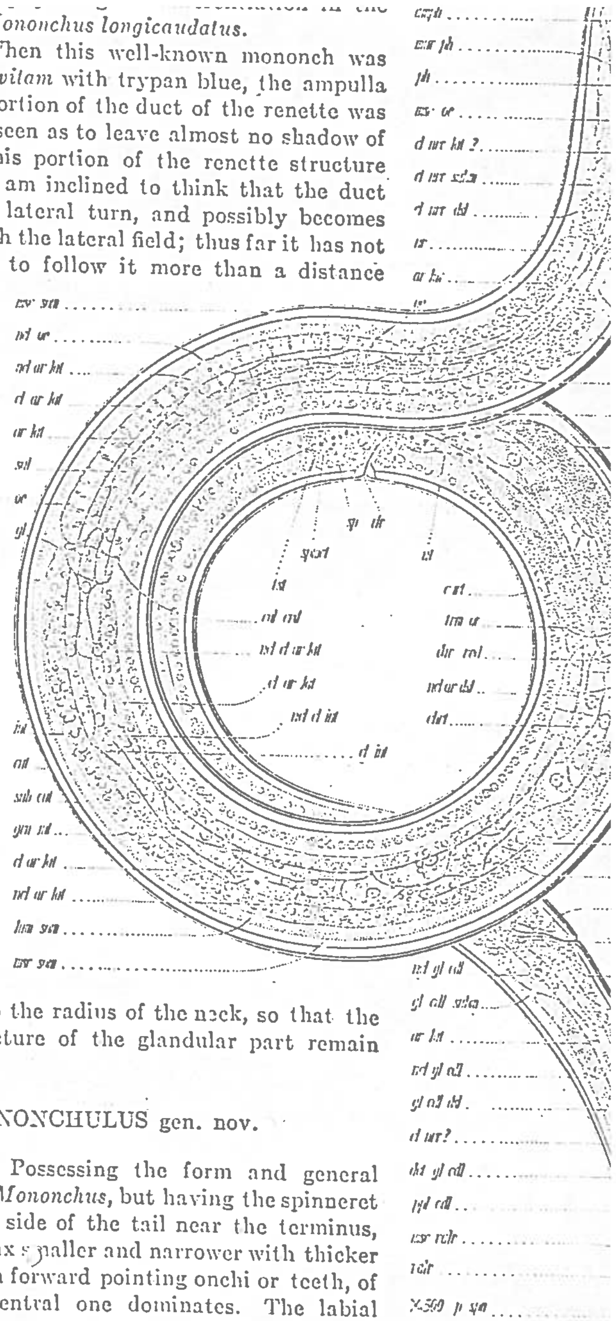


Fig. 1. *Mononchulus ventralis*, a very interesting nema, found in the Washington filter-beds. The lateral fields are shown with great clearness; they are made up of about three rows of cells, *cl or lat*, each cell with an egg-shaped nucleus, *ncl ar lat*. The intestinal nuclei, of about the same size, are shown darker. Oesophageal glands, *sal*, as in *Mononchus*. The small posterior gonad, apparently serving as a testis, is shown at *tst*. Nearly the whole of the testis is shown in the illustration. The spinneret is unusually large, and gives us for the first time some clue to the structure and mechanics of this organ. The details are more fully illustrated in Fig. 2. For abbreviations see p. 212.

### MONONCHULUS gen. nov.

*Characters*. Possessing the form and general appearance of *Mononchus*, but having the spinneret on the ventral side of the tail near the terminus, and the pharynx smaller and narrower with thicker walls, and with forward pointing onchi or teeth, of which a subventral one dominates. The labial papillae are smaller than is usual in *Mononchus*, in fact are barely vis

Anterior gonad reflexed. Posterior gonad outstretched, very small, producing spermatozoa. The development of the oöcytes follows about the same course as that of the spermatocytes, which they resemble to a certain extent, though they are larger. Occasionally the oöcytes so closely resemble the spermatocytes that it is rather difficult to make a clear distinction. The very youngest stages of the female gonad have not been seen, but in the youngest stages observed there were no indications of spermatozoa;—yet at the same time spermatozoa were developing in the minute posterior straight gonad.

2. Mononchulus ventralis n. sp. $\frac{1.6}{2.1}\ \frac{9.}{9.9}\ \frac{26.}{3.8}\ \frac{M\ 60?}{9.8}\ \frac{69.}{2.6}$ 1. The thick layers of the transparent, colorless, naked cuticle appear to be devoid of any but the very finest of transverse striae; but longitudinal striations are visible throughout the length of the body. Six rather thoroughly amalgamated lips of considerable thickness arch together over the pharynx and normally nearly close the mouth opening. There are six slightly spreading inconspicuous papillae scarcely interfering with the rounded contour of the front of the head; in addition, surrounding the mouth, there are six forward pointing papillae. There are no eye-spots. Very inconspicuous amphids occur opposite the middle of the largest pharyngeal tooth in the form of small semi-circumferences opening backward and having a breadth about one-fifth as great as that of the corresponding part of the head. The anterior main thick-walled portion of the pharynx is about as long as the head is wide. When the pharyngeal organs are at rest this front cavity is comparatively well filled by the large, acute, forward pointing right submedian tooth. There are two other teeth, a small dorsal, forward pointing tooth having its apex near the middle of the pharynx, and an exceedingly minute inward pointing tooth, or spur, in the left submedian portion of the cavity near the base. Opposite the anterior portion of the main tooth the walls of the pharynx are armed with several dozens of minute, rasp-like teeth or denticles.

Close scrutiny of that part of the wall of the pharynx immediately behind the rasp-like area discloses that it is transversely striated to near the base. These pharyngeal striae can be seen only with the highest powers of the microscope under favorable circumstances. Behind this anterior portion of the pharynx is a narrower, unarmed portion, of equal length, making the total length of the pharynx about twice as great as the diameter of the head. The cells of the thick walled, narrow-lumened intestine contain scattered brownish granules. There are three unicellular caudal glands; two opposite each other immediately behind the anus, and a third, more or less dorsally located, behind and between the first two but emptying through a submedian ampulla and hence really submedian. The single reflexed ovary, except when pushed forward by the presence of an egg in the uterus, reaches nearly back to the vulva.

Habitat: This interesting digonic species has been found in peat soil, west of Fort Lauderdale, Fla., along a canal for drainage of land formerly covered with water, and at Miami, Fla.; in the sand of the filter beds at Washington, D. C.; and also in the Potomac River.

A species that appears to belong to the genus *Mononchulus* is described by Daday under the name *Prismatolaimus nodicaudatus*, n. sp., in his "Mikroskopische Süsswasserthiere aus Deutsch Neu Guinea."



I am not aware that anyone has ever attempted to explain the mechanis the spinneret of nemas. Manifestly the flow of the caudal secretion is contr at will. Watching this operation as performed by a free-living nema, o forcibly reminded of the facility with which spiders regulate the operatio their spinnerets, and, as in spiders, so in nemas, there must be a definite trollable mechanism for performing these operations. The structure of spinneret in *Mononchulus ventralis* may at least suggest the mechanical ciples exemplified.

*The Needle-Valve.* As a rule the nema spinneret is so extremely minute its details cannot be deciphered. In *Mononchulus ventralis* the spinner relatively large and its elements more or less resolvable, but since it is ve in this species instead of terminal, as is usual, its form may not be entirely typ In *M. ventralis* we find the duct of the spinneret to end externally in a conical depression near the end of the tail. This conical depression leads to a short oblique tube terminating internally at the valve of the spinneret, *vlv-vlv*, Fig. 2. The valve belongs to the class known as needle-valves, and the needle, if such it be called, is an acute, fusiform affair, duplex in cross section, and nearly half as long as the terminus of the tail is wide. It is placed at an angle of about 45 degrees with the axis of the tail, and while its acute free distal end lies loose in a cavity of obverse mold, its more or less cephalated proximal end is connected with the dorsal side of the tail by means of oblique muscular fibres. The proximal part of the valve is located in the midst of a vesicle (?) to the dorsal side of which its proximal extremity seems to be attached; the embryological development has not been investigated, but conceivably the needle is formed by an invagination of the wall of the "vesicle." Into the base of the more or less ellipsoidal "vesicle" the ducts of the caudal glands empty. The operation of the needle-valve is now easily understood. The internal body pressure will of itself keep the needle-valve closed. Contraction of the muscular fibres already described serves to pull the needle loose from the mouth of the valve, and so permit an outflow of the secretion. The "needle" is composed o elongated, ceratinous lateral elements joined side by side, and the orifice c valve is composed of three elements, disposed in the form of a hollow about the distal half of the needle.

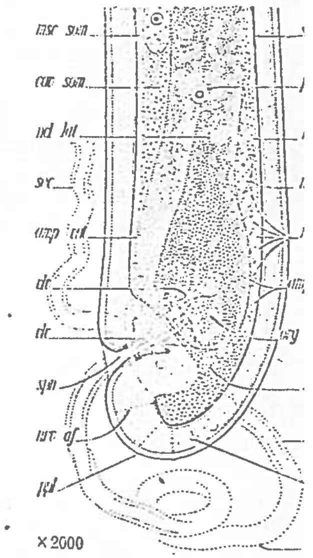



Fig. 2. Spinneret of *Mononchulus ventralis*, with coagulated secretion att: The valve is partly open and the sec is pouring out. The three ampullae into a common space round the pro part of the spindle-shaped valve *vlv-vlv*, so that the body pressure, sumably assisted by the elasticity surrounding parts, (*org. elast*) hold spinneret valve shut except when pulled open by the muscle, *msc vl* the smaller nuclei shown are believed nerve nuclei. For abbreviations see

*Nervous Apparatus of Valve.* Most of the foregoing features are sho Fig. 2. Necessarily the apparatus is supplied with the appropriate sensor motor nerves. The details of these latter have not yet been made out through a dorsally left submedian duct. Of the two longer and paired glands, one, the left submedian, empties through a ventral ampulla, while the other empties through a dorsally right submedian one; the details of the debouchment remain somewhat obscure and no attempt has been made to indicate all of them in the illustration. The three pores, however, are just in front of the "equator" of the valve.

*Digonic.* This species presents the unusual peculiarity for an hermaphroditic nema of developing its ova in one gone, and its sperm in another gone of much smaller size,—in a word is digonic. So great is the disparity between these two branches of the sexual apparatus that at first glance one almost inevitably concludes that the very small posterior branch is a mere functionless vestige. A careful examination seems to prove that only ova are produced in the anterior branch, while the very small outstretched posterior gonad functions as a testis; the evidence for this latter conclusion being the occurrence of spermatozoa and spermatocytes in small numbers arranged in the order to be expected if the organ were a small gonad devoted solely to the production of sperm. The cells in this minute gonad are so few that their precise order is not a striking feature, and yet an examination of a series selected from among individuals in which the ova in the anterior gonad are still quite young and small, enables one to demonstrate that the cells near the blind end of the small gonad correspond in structure with primary spermatocytes, and that the succeeding cells, sometimes as few as two to three in number, represent successive steps in the development of the spermatozoa. Occasionally one finds here a pair of gonic cells lying side by side, each containing about six chromosomes, practically as definite as those to be seen in the testes of male individuals of typical free-living amphigonic nemas. Often the perfected spermatozoa appear not to exceed eight to twelve in number. There is an obscure tendency for them to be located in groups of four, such as should exist if they were produced *in situ* in quartets in the manner characteristic of the spermatozoa of nemas. Once an egg was observed containing near its equatorial periphery a body corresponding in size and staining properties to one of the spermatozoa to be seen free in the uterus. The nucleus of this egg showed signs of being affected by the presence of the spermatozoön, though it appeared not yet to have produced polar bodies. All these appearances are in harmony with the supposition that the posterior branch of the sexual apparatus, small as it is, functions as a testis.

## TRIPYLA Bastian 1865

3. Tripyla monohystera de Man. $\frac{1.5}{1.6}\ \frac{6.7}{1.9}\ \frac{20.}{2.}\ \frac{{}^{16}77^{2}}{2.2}\ \frac{92.}{1.6}\ 1.4\ mm$ Few nemas are more agile than this. Its movements are extremely rapid, especially those of the head end. It is unusually flexible, coiling and uncoiling all parts of its body with great rapidity. It is of a restless disposition, at least so appears when brought under the microscope for examination.

I have often seen this *Tripyla* attach itself to glass and then exhibit the evolutions characteristic of nemas possessing well developed spinnerets, but in spite of careful examination of living specimens, and specimens preserved both in glycerine and balsam, I have seen no definite traces of caudal glands. The cephalic setae are segmented and consist of two or more joints.

*Harbors a Parasite.* *Tripyla monohystera* of the Washington filter-beds often contains what appears to be a peculiar spherical parasite. The parasites (?)



in almost all cases where their number is few they are confined to the tail. See Fig. 3. Thence they seem to work their way forward, especially along the lateral fields, so that finally they may occur throughout the length of the body in hundreds of thousands. These objects are extremely minute and can be satisfactorily examined only with the aid of the highest powers of the microscope. At first sight they appear to be crescent shaped, a deception due to their peculiar refractive properties. Careful focusing shows that the greater portion of the sphere, an eccentric portion, is but slightly refractive. The remaining

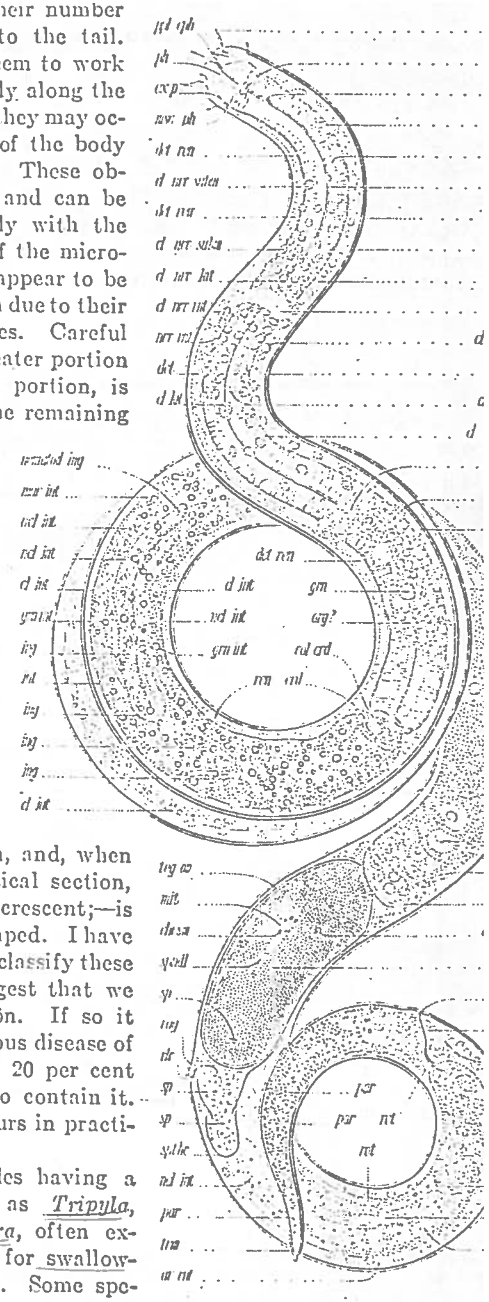


Fig. 3. *Tripyla monohystera.* This active, voracious little nema is very common in filter-beds. Often the remains of several other nemas are to be found in its intestine. The specimen figured had been feeding on a variety of microzoa. To be seen in the intestine are a nema, *nemated ing*: the "gizzard" of a rotifer, *rot ing*; and a number of protozoa, *ing.* The egg shown has just received one of the syngonic sperm cells *sp*, and has thrown off the first polar body, *corp plr I.* The beginning of a sporozoön (?) infestation is shown in the tail, *par.* The renette of this nema (*ren; ex p*) has hitherto remained unknown. An organ of considerable size, but of unknown significance, *org ?*, is also now for the first time shown to exist in the neck. For abbreviations see p. 212.

portion is more easily seen, and, when it comes into view in optical section, presents the contour of a crescent;—is therefore in reality bowl-shaped. I have made no serious attempt to classify these objects and can only suggest that we have here a new sporozoön. If so it may be the cause of a serious disease of the nematode; often 10 to 20 per cent of the individuals appear to contain it. In some collections it occurs in practically every individual.

*Nemativorous.* Nematodes having a plain oesophagus, such as *Tripyla*, *Mononchus*, and *Monhystera*, often exhibit a marvelous capacity for swallowing relatively large objects. Some species of *Monhystera* are able to swallow diatoms one-half to two-thirds as w themselves, and one-fifth to one-sixth as long. *Tripyla monhystera* is as wide as itself; and the partly digested remains of several such may sometimes be seen in its intestine. (See Fig. 3.)

## IRONUS Bastian 1865

### 4. Ironus longicaudatus de Man.

stoma = 59 µm

$$\frac{3.7}{1.6}\quad\frac{7.3}{1.9}\quad\frac{15.}{2.}\quad\frac{^{12}36^{12}}{2.2}\quad\frac{66.}{1.2}\quad 1.6$$

As regards the pronounced dorso-ventral differences in the intestine of *Ironus longicaudatus*, when specimens of this species are stained in acid carmine it is noticeable that the large granules characteristic of the dorsal side take the stain. From an examination of living specimens one would think these granules probably fatty in their nature. The fact that they stain as they do seems to exclude this supposition.

*No Sperm Seen.* In spite of very careful examination I was unable to discover spermatozoa in the females of this species. Nevertheless I am strongly inclined to think that further investigation will reveal the presence of spermatozoa, and show that this species also is syngonic. I have seen no males.

I believe the food-habits of *Ironus longicaudatus* to be much the same as those of *Ironus ignavus*, but having had less opportunity to investigate them I have fewer data from which to form an opinion.

Habitat: Washington filter-beds; sometimes abundant. Quite active.

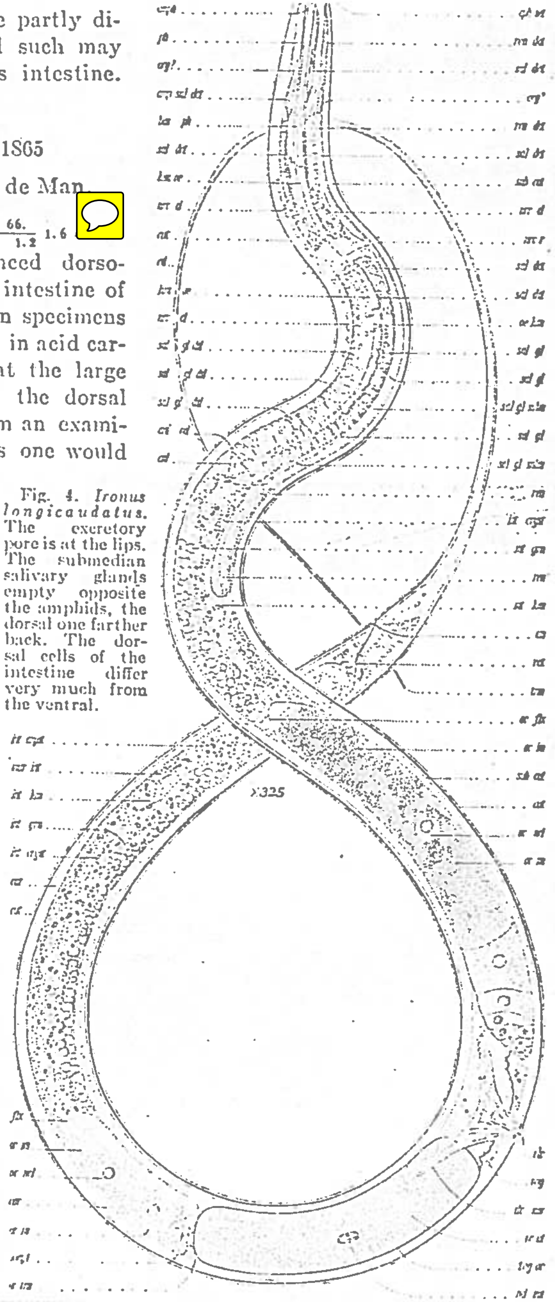



Fig. 4. *Ironus longicaudatus.* The excretory pore is at the lips. The submedian salivary glands empty opposite the amphids, the dorsal one farther back. The dorsal cells of the intestine differ very much from the ventral.

onchi are tissue tearers. The three onchi of *Ironus ignavus* are of unequal and size. At first glance they appear equal, but even when the onchi are d in and the head viewed in profile it is sometimes possible to see that the d onchus differs from the other two in being duplex. When the onchi are exs the expansion necessary to this operation throws the two apices of the d onchus wide apart, and they can then with ease be brought separately focus. A front view of the head also emphasizes this double structure o dorsal onchus. Either half of this onchus when seen in profile seems to almost exactly the same size and contour as one of the submedian onchi. action of the onchi in *Ironus* is like that in some species of *Diplogaster*, of species of *Axonolaimus* and of one or two other marine genera, and is the reverse of that of the onchi of *Enoplus* and its relatives. The outward a of the onchi in *Ironus* is adapted to tearing open the tissues upon which it f the fluid and semi-fluid portions of which are then imbibed. In har with this is the liquid or finely divided character of the contents of the inte in *Ironus*. *Enoplidae*, on the other hand, bolt their food. The moven of the onchi do not appear to be so quick as those of the onchi of *Diplog* The outward throw and return occupied about one-quarter second in a spec which though stained *intra vitam* with neutral red, yet appeared to be as a as the average living specimen.

*Characteristic Intestinal Crystals.* The doubly refractive crystals fou the intestinal cells of *Ironus* are different from those found in certain *Rhabdit* which I have given the name Rhabditin. The doubly refractive crystals of *I* are not spherical,—on the contrary are distinctly angular in contour and h definite polyhedral form. These doubly refractive bodies are absent fro anterior part of the intestine for a distance about equalling half the length neck, indicating a different physiological condition here. Some of the inte cells are very distinctly specialized. (See Fig. 5.)

*Carnivorous.* The following are strong reasons for regarding *Ironus* a nivorous; (1) Recognizable plant remains are rarely if ever found in the inte (2) *Ironus* abounds in places where there is little plant food of any kind, but animal food is plentiful. (3) The peculiar mouth parts can hardly b plained in any other way than by supposing them to be special organs fo ping open tissues of the food, and the only filter-bed plants that could fu adequate food for *Ironus* are entirely too small to be operated upon by mouth parts.

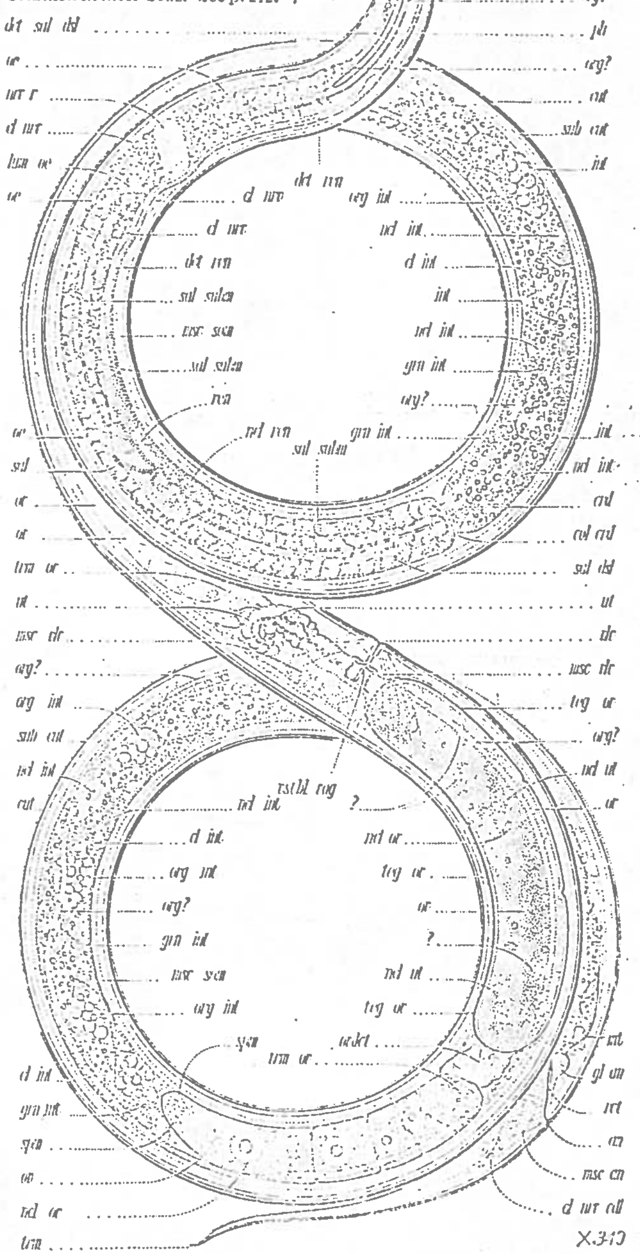
A very noticeable feature in the development of the eggs of *Ironus ig* is the appearance in the ripening ova of numerous protoplasmic structures stain rather strongly in acid carmine. Toward a dozen of these struc may be seen in the full grown ovum when about to turn and pass into the u The younger ovum immediately following it also shows these same struc more closely packed together, but of about the same size. After the eg passed into the uterus these bodies sometimes completely disappear.

*Newly Discovered Organs.* Among the numerous new facts here broug light in connection with *Ironus* none appear more interesting than the nounced dorso-ventral differentiation of the intestine. In both *ignavu* *longicaudatus* this differentiation is pronounced, especially in the latter, from one end of the intestine to the other the difference in structure betwe dorsal and ventral sides is very striking. In *ignavus* the same quality o but the cells having the coarser structure are more scattered. They nevertheless are here also commonly dorsal or sub-dorsal.

What seems to be a very long and narrow tubular organ (*org ?*) exists in *ignavus*. I have been unable to determine the function of this interesting organ. The mycelium of various parasitic fungi is not altogether uncommon in the bodies of fresh water nemas, and sometimes presents highly deceptive appearances, but it did not seem possible to me that this tubular structure could be other than an integral part of the *Ironus*.

It is interesting to note that the most common species of *Ironus* in American filter-beds are identical with those of Europe. *Ironus ignavus* is widely spread in the United States, as I have collected it from spring, lake and river waters of many of the northern states, from the Atlantic as far west as Colorado and from widely varying altitudes.

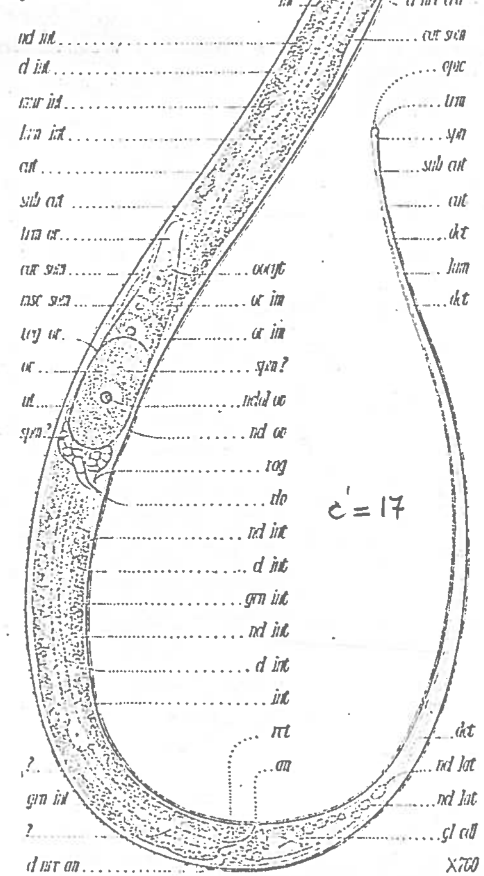
*longicaudatus*, q. v. The differentiation of the intestinal cells though marked is not so pronounced as in *longicaudatus*. Common in filter-beds. See p. 212.



X 340

loides n. subg. n. sp. For some distance in front of the nerve-ring the oesophagus is distinctly though slightly altered.

A critical review of the Monhysteras so far discovered and described will undoubtedly result in the establishment of a number of fairly well defined groups, some of subgeneric rank, some of generic. The divisions may be made on the basis of the anatomy of the male organs as well as on that of the mouth parts. These anatomical differences are the outward expression of differences in food habits, and of special activities due to differences in habitat. The Monhysteras constitute a huge group, of considerable biological significance. Some species are specially adapted to studies of problems in genetics. The mode of development of the spermatozoa of certain species is worthy of study.



X 760

*Subgeneric characters.* I
general form and appeara
*Monhystera*, but differs in t
lowing respects:—The phar
more elongated, somewhat
bling that of *Cylindrolaim*
tapers slightly. The oeso
is not quite of uniform dia
in this respect somewhat
bling that of *Plectus* in th
rior part, but with all the
tions less pronounced, so t
first glance, the oesophagu
to be rather uniform in st
from the pharynx backwar
cardiac swelling. There
rather distinct pyriform
swelling, with clear indi
of the presence of glands
its muscular tissues. One
problematical unicellular
exist in the lateral fields
side of the body some
in front of the anus. Ot
very much as in *Mon*
Possibly *Monhystera bulb*
Man belongs to this sul

6. Monhystrella plectoid

| 1.2 | 10. | 17. | 35.44. | 65 |
|---|---|---|---|---|
| 1.5 | 2.4 | 2.6 | 3.1 | 2 |

The rather thin, tran
colorless cuticle is trave
exceedingly fine transvers
resolvable only with high
under most favorable con
The thin-shelled eggs ap
be deposited before segm
begins.

Habitat: Sand, Wa
filter beds; uncommon.
of the character represe
Monhystrella and Monhys
largely, if not entirely,
rian. As a rule they
abundant in covered s
filter beds. On one
however, after a long
winter use, I found suc
to be fairly abundant.

... are more common in open filter beds and in reservoirs, where they appear to feed principally on green unicellular algae, which naturally do not flourish in covered filter beds, since sunlight, direct or diffused, is necessary to their growth.

## IOTA Cobb 1913

7. Iota simile, n. sp. $\frac{12.5}{8.9}$ $\frac{20.}{9.9}$ $\frac{24.}{/9.9}$ $\frac{63\text{–}93.}{7.2}$ $\frac{95.}{6.6}$ .6 mm The colorless layers of the thick cuticle are traversed by ninety to one hundred plain, transverse striae of such a nature as to give a relatively coarse serrate-crenate appearance to the contour of the body. The annules of the cuticle are complete rings. Only at rare intervals is there a trace of anastomosis; occasionally it will happen that two semi-annules on one side of the body are joined to one on the other. The convex-conoid neck ends in a somewhat rounded head surmounted by a flat lip region composed probably of six very flat lips placed in the slightly depressed front surface of the first annule. The first two or three annules are packed closely together, and the prevalent crenate-serrate appearance of the contour begins probably with the fourth annule, possibly with the third. No labial papillae have been seen. Nothing is known concerning the amphids.

*Spear.* The spear is rather more slender than in most Iotas, and tapers throughout the main portion of the shaft, which constitutes fully two-thirds of the length. Where it reaches its maximum development this shaft has a diameter about half as great as the width of one of the neighboring annules of the cuticle. Behind the shaft the hilt of the spear has a diameter only a trifle larger than that of the main portion of the shaft. The hilt increases in diameter steadily posteriorly, and finally expands suddenly into a large three-fold bulb nearly one-fourth as wide as the corresponding portion of the neck. The central canal of the spear is plainly visible, and is continuous with that of the oesophagus.

*Oesophagus and Intestine.* The oesophagus is about as wide as the base of the spear, and appears to present no very definite median bulb, though there is a slight change near the middle of the neck which probably indicates the position of some such structure. The details of the intestine are somewhat obscure, but it appears to begin as a tube about half as wide as the body, and to continue at this width for some distance. The anus seems to be located between the fourth and fifth annules, counting from the posterior extremity. The excretory pore is located near the twenty-sixth annule counting from the head end where the annules first become distinctly developed; this means probably at about the thirtieth annule counting from the mouth itself. The tail is conoid to the blunt terminus, which is destitute of a spinneret.

*Sexual Organs.* The depressed vulva is located at about the seventh annule from the caudal extremity. The vagina leads inward and forward a distance fully equal to the corresponding body width. In front of this is the uterus, which appears to be once and one-half to twice as long as the corresponding body-diameter. The ovary extends directly forward and its blind end lies some little distance behind the base of the neck. The eggs occur one at a time in the uterus. They are thin-shelled, a little longer than the corresponding body diameter and about half as wide as long.

Habitat: Aberrant in filter beds, Washington, D. C.; roots of grape-vine, Herman, Mo. Synonymous with *Iota* are *Ogma* Southern and *Criconema* Hofmänner and Menzel. *Iota* consists of many species. I have specimens and full MS. descriptions of a number of new species collected during the last twenty years in widely different parts of the world. All are -f and have the vulva hidden among the annules near the anus; tiny, wide nemas with retrorse annules.

8. M. subfiliformis n. sp. $\frac{.8}{1.4}$ $\frac{8.6}{2./}$ $\frac{21.}{2.3}$ $\frac{^{22}63.}{2.2}$ $\frac{75.}{1.8}$ .7 mm

This form, which appears to be new, is closely related to *Monhystera filiformis* Bastian, but differs from the descriptions given by various authors in the following respects:—There are 10 cephalic setae on *subfiliformis* instead of six. The amphids are somewhat larger than given by most authors for *filiformis*. In the cardiac region I have noticed in the single specimen of the present species so far examined, a very definite pseudobulb. There is a definite renette, as shown in the figure, with an excretory pore opposite the nerve ring. The eggs are relatively larger than described for *filiformis*. The anatomical details are clearly shown in Fig. 7. This species also shows a certain amount of resemblance to *Monhystera vulgaris*, de Man, but differs in having setae on the body, and in having 10 cephalic setae, and in the amphids being slightly different in position, form and size. The tail of *vulgaris* also seems to be more slender.

Habitat: Sand, Washington filter beds; usually uncommon. Of the numerous species of Monhystera I have had occasion to examine with respect to their food habits, all appear to be largely if not wholly vegetarian. The various species specialize to a considerable degree in the matter of food. For instance, many marine species feed almost exclusively on diatoms. If the filterbed Monhysteras are not an exception to the rule, they would seem to be dependent on fungi and bacteria as a source of food, except in open beds, where of course they would find an abundance of green microphytes.

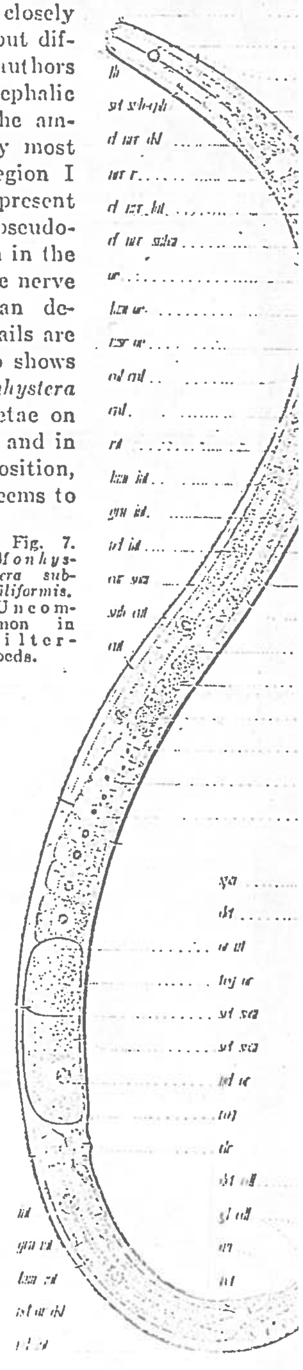


Fig. 7. *Monhystera subfiliformis.* Uncommon in filter-beds.

## CYLINDROLAIMUS de Man 1884

*Sexual Organs.* *Cylindrolaimus* typically has but a single outstretched ovary; from the observations of various authors it would appear that this may extend either forward or backward, usually forward. As there is some doubt about the shape of the organ in the type species *communis*, it is desirable that specimens of that species be reëxamined. Inasmuch as the male of only one of the six true species of *Cylindrolaimus* has been seen, it would seem that the genus is typically glycerine specimens of *obtusus* lead me to conclude that this species at least is probably digonic; if it is syngonic we are confronted with the phenomenon of the ovary first acting as a testis and sending over into the rudimentary posterior part spermatocytes, probably primary spermatocytes, there to continue their development.

9. Cylindrolaimus obtusus Cobb.

$\frac{3.2}{2.?}\ \frac{10.}{2.6}\ \frac{22.}{3.3}\ \frac{[illegible]\text{–}55?}{3.5}\ \frac{87.}{2.8}$ .6 mm

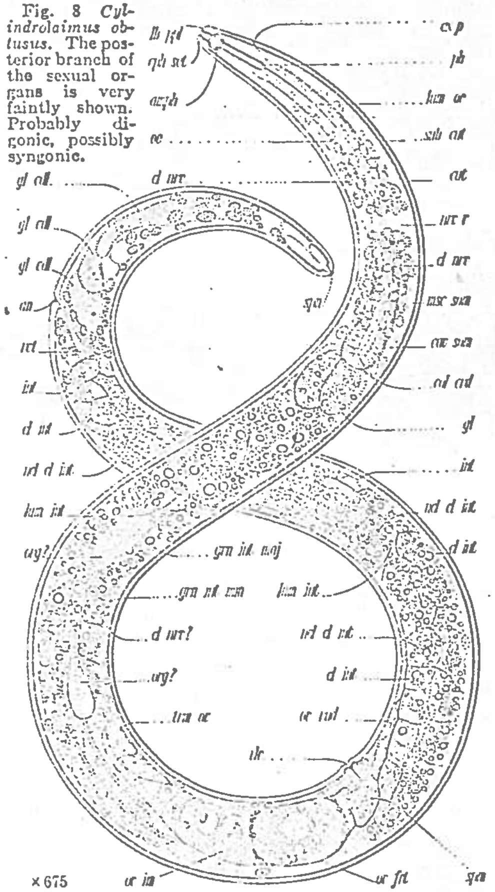



Fig. 8 *Cylindrolaimus obtusus.* The posterior branch of the sexual organs is very faintly shown. Probably digonic, possibly syngonic.

The moderately thin cuticle is traversed by five to six hundred transverse striae, which do not appear to be further resolvable. In glycerine specimens there are very faint indications of longitudinal striations, which are more pronounced toward the anterior extremity; these may be due merely to the attachments of the somatic muscles. There appear to be no very distinct lips, though probably minute lips are present,—so small and so closely amalgamated as easily to escape observation. Occasionally six excessively minute papillae have been seen immediately round the mouth opening; though no doubt always present, these papillae usually escape observation. When the lips are closed the small mouth opening appears as a simple pore in the middle of the front of the head, where there is an exceedingly minute depression. Four submedian, somewhat papilla-like, widely-spreading cephalic setae occur on the margin of the head about half way between the anterior extremity and the front of the amphids; each of these setae is about one-fourth as long as the corresponding diameter of the head. The well-developed lateral fields are about one-third as wide as the body. There do not appear to be any distinct wings.

*Intestine. Ovary.* The somewhat cylindroid cardia is of relatively large size, and is separated from the oesophagus by a constriction; it is about two-fifths as wide as the base of the neck, and is surrounded by about seven unicellular organs, probably glandular in nature. There is a small posterior branch of the sexual apparatus, extending backward a distance about equal to the length of the body diameter, serving either as a testis or spermatheca, apparently the former. The ellipsoidal, thin-shelled, smooth eggs are five-sixths as wide as



in the uterus one at a time and seem to be deposited before segmentation be[gins].

Habitat: Sand, Washington filter beds, early in January 1916, at the [...] of about five months' use. Not common. No males seen.

## PLECTUS Bastian 1865

10. Plectus cirratus, Bastian. $\frac{5.}{2.5}\ \frac{9.9}{3.4}\ \frac{20.}{4.3}\ \frac{[illegible]\text{‘}48\text{’}[illegible]}{6.6}\ \frac{59.}{2.8}$ 1. mm Taking th[e de]scriptions and figures of de Man as the basis of his identification, M[aupas] made numerous and very careful observations upon this species; he [never] found males, and concluded from this and his other observations that the s[pecies] is purely parthenogenetic. As my own observations do not agree with th[ose of] Maupas, it is well to consider carefully whether the species observed by us a[re the] same. My specimens came from the Potomac River near Washington, D. C., U[...] and in size and proportions agree in all respects with the figures and descri[ptions] of de Man. The anatomy of my specimens also appears to agree in all ess[ential] respects with that set forth by de Man. There is a little uncertainty abo[ut the] number of cephalic setae as reported by de Man;—in one instance he says [...] in another six. Bastian's original description, made from specimens [...] long, says four. In the description in which de Man placed the number [...] his corresponding illustrations are possibly open to the interpretation tha[t four] only were present. The Potomac specimens always present four cephalic [setae]. The caudal setae of the Potomac specimens are not so prominent as indica[ted in] de Man's figures. My specimens present the amphids at precisely the [place] indicated by de Man, and of very nearly the same size. De Man does not [give] a very clear indication of the shape of the amphids, but I see no reason to co[nsider] the two forms specifically or varietally different on the basis of the sha[pe or] position of the amphids. There exists, therefore, only the uncertainty [with] regard to the cephalic setae, and this may not in fact be a discrepancy. M[aupas] shows five eggs in each uterus. It is uncommon for the Potomac specim[ens to] present as many eggs as this in the uterus; the common number is one or tw[o, though] it may rise to four. De Man describes the egg-shells as smooth; Maupas, ho[wever,] says they are covered with minute points. The Potomac specimens [agree] with Maupas' description. I am therefore most strongly inclined to believ[e that] the forms examined by Maupas and myself are the same.

Maupas, in his description of the development of the egg, notes the fol[lowing] points: In one case only among a large number of developing ova exa[mined] did he see more than a single nuclear figure. He considers this an imp[ortant] point in his demonstration of the parthenogenetic character of the de[velop]ment. He observed that when the egg entered the uterus it lost its [...] nucleus for an hour or more, and concluded that during this period th[e polar] bodies were formed, although, as he says, he never saw any polar bodi[es. He] observed amoeboid movements in the ovum during the absence of the n[ucleus]. Maupas says that it was with much difficulty that he convinced himself t[hat no] spermatozoa were present in the sexual organs of this *Plectus*, but that i[n spite] of careful examination he never succeeded in seeing any. Nor did he s[ee the] slightest trace of spermatozoa on removing the sexual organs and treatin[g them] with acetic acid. He therefore took the species to be parthenogenetic. [Never]theless, he noted occasionally in the distal end of the uterus refractive [bodies] of exceedingly small size. As will appear later, it is not at all improbal[ble that] these minute bodies were really spermatozoa which he failed to recognize [...]

conditions, it is possible to see the spermatozoa of *Plectus cirratus* in living specimens of the right age and condition. The most suitable age for such observations appears to be that at which the spermatozoa are about to enter the uterus,—the stage when the sexual organs appear quite simple, and the uterus has the form of a rather narrow empty tube. On searching for spermatozoa or spermatocytes near the large or proximal end of the ovary it will usually be possible to find them without examining many specimens. It may be necessary to view the specimens at a particular angle, and it may require a number of trials to secure a favorable specimen. Fixation with hot corrosive sublimate, followed by an acid carmine stain and long destaining, demonstrates the presence of spermatozoa at almost any stage after they are formed, up to the time when all have been utilized. Using such material, I have been able to trace the spermatozoon into the egg, and show that the spermatozoon displays about six chromosomes at a time when its two centrosomes appear on the side next the egg-nucleus, which under its influence divides, and forms two distinct groups of chromosomes consisting of six each. Indefinite bodies are formed in the vicinity of the egg nucleus which appear to have the significance of polar bodies; see Fig. 9, where one is shown faintly at *corp plr (I)*.

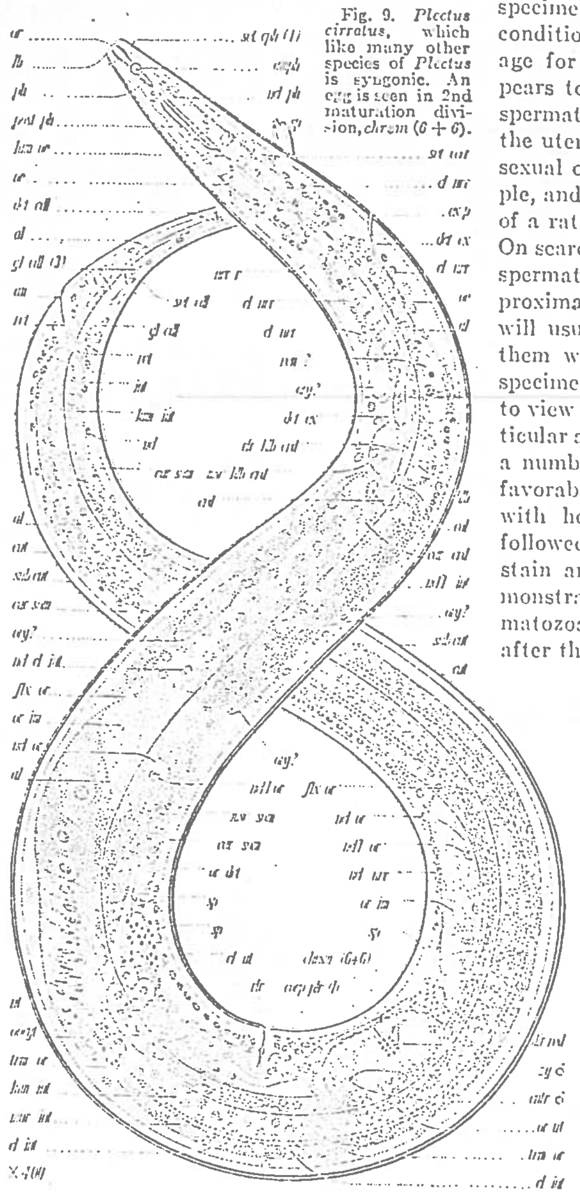


Fig. 9. *Plectus cirratus*, which like many other species of *Plectus* is syngonic. An egg is seen in 2nd maturation division, *chrom* (6 + 6).

*Syngonic.* My observations leave me without the slightest doubt that this *Plectus* is syngonic, and that the spermatozoa are functional. Rather casual observations I have made on other species of *Plectus* prove that syngonism is or their equivalent,—and we might therefore expect such eggs to be, as they are, "resistant" to sperm. Whether or not this suggestion has a basis of fact, the theory of cryptogenesis harmonizes with what is known about the incompatibility of parthenogenesis and fertilization. Of course ova may be too young to be fertilized, or too old to be fertilized, and their parts may be so acted upon by a variety of forces as to bring them into a more responsive or less responsive condition; needless to say, these various facts must also be taken carefully into account in any such speculation as the foregoing.

### *Abbreviations Used in the Illustrations*

*amp*, ampulla
*amp sal dct*, ampulla of salivary duct
*amp subm*, submedian ampulla
*amp vnt*, ventral ampulla
*amph*, amphid
*an*, anus
*an gl*, anal gland
*apic*, apiculum
*ar dnt*, rasp
*ar lat*, lateral field
*ar vnt*, ventral field

*bas ph*, base of pharynx
*blb crd*, cardiac bulb

*cav som*, body cavity
*chrsm*, chromosome
*cl ar lat*, cell of the lateral field
*cl crd*, cell of cardia
*cl int*, intestinal cell
*cl lat*, lateral cell
*cl msc*, muscle cell
*cl nrv*, nerve cell
*cl nrv an*, anal nerve-cell
*cl nrv cdl*, caudal nerve-cell
*cl nrv crd*, cardiac nerve-cell
*cl nrv dsl*, dorsal nerve-cell
*cl nrv lat*, lateral nerve-cell
*cl nrv subm*., submedian nerve-cell
*cl nrv vnt*, ventral nerve-cell
*cntr*, centrosome
*corp pol I*, 1st polar body
*cph ppl*, cephalic papilla
*cph set*, cephalic seta
*crd*, cardia
*cst ph*, pharyngeal rib
*cut*, cuticle

*dct*, duct
*dct gl cdl*, duct of caudal gland
*dct ren*, renette duct
*dct sal dsl*, dorsal salivary duct
*div red*, reduction division
*dnt*, denticles

*ex p*, excretory pore

*flx ov*, flexure of ovary
*flx ovr post*, flexure of posterior ovary

*gl*, gland
*gl an*, anal gland
*gl cdl*, caudal gland
*gl cdl subm*, submedian caudal gland
*gl oe*, oesophageal gland
*gl sal*, salivary gland
*gng*, ganglion
*grn*, granule
*grn int*, intestinal granule
*grn int maj*, larger intestinal granule
*grn int min*, smaller intestinal granule

*ing*, ingested material
*ing nematod*, ingested nematode
*int*, intestine
*int cryst*, intestinal crystal
*int lum*, intestinal lumen

*jnc*, junction

*lam lb*, labial lamina
*lb*, lips
*lb ppl*, labial papilla
*lum*, lumen
*lum int*, intestinal lumen
*lum oe*, oesophageal lumen
*lum som*, body cavity

*mit*, mitosis figure
*msc an*, anal muscle
*msc oe*, oesophagus muscle
*msc ph*, pharyngeal muscle
*msc som*, body muscle
*msc valv*, valve muscle
*msc vlv*, vulva muscle
*mur int*, intestinal wall
*mur ph*, pharyngeal wall
*mur ut*, wall of uterus

*ncl*, nucleus
*ncl ar lat*, nucleus of lateral field
*ncl cl int*, nucleus of intestinal cell
*ncl cl nrv*, nucleus of nerve cell
*ncl gl cdl*, nucleus of a caudal gland
*ncl lat*, lateral nucleus
*ncl msc*, nucleus of muscle
*ncl nrv*, nerve nucleus
*ncl oe*, oesophageal nucleus
*ncl ov*, nucleus of egg
*ncl ov im*, nucleus of ovum
*ncl ren*, renette nucleus
*ncl ut*, nucleus of an uterine cell
*ncl vlv*, nerve nucleus of valve
*ncl vnt*, nucleus of the ventral field
*nr*, nerve
*nrv*, nerve
*nrv af*, afferent nerve
*nrv r*, nerve ring
*nrv vnt*, ventral nerve

*oe*, oesophagus
*oes lum*, oesphageal lumen
*on*, onchus
*on dsl*, dorsal tooth
*on rtr dsl*, retrorse dorsal onchus
*on rtr subm*, retrorse submedian tooth
*on submd rt*, right submedian tooth
*on subm snst*, left submedian tooth
*oöcyt*, oöcyte
*org?*, organ of unknown significance
*org elast*, elastic organ
*org int*, intestinal organ
*ov*, ovum

*ov dct*, oviduct
*ov frt*, fertilized egg
*ov im*, immature egg
*ovr rud*, rudimentary ovary
*ov ut*, uterine egg

*p spn*, mouth of spinneret
*par*, parasite
*ph*, pharynx
*ph str*, pharyngeal striae
*por* or *p*, pore
*por gl oe*, pore of oesophageal gland
*por sal*, mouth of the salivary gland
*por sal dsl*, mouth of dorsal salivary gland
*ppl*, papilla
*ppl cdl*, caudal papilla
*ppl cph*, cephalic papilla
*ppl intr*, interior papilla
*ppl lat*, lateral papilla
*ppl lb*, labial papilla
*ppl lb extr*, exterior labial papilla
*ppl subm*, submedian papilla
*ppl subm sec*, secondary submedian papilla
*ppl trm*, terminal papilla

*rcpt sem*, seminal receptacle
*rct*, rectum
*reg vnt*, ventral field
*ren*, renette
*rot*, rotifer
*rot ing*, ingested rotifer

*sal*, salivary gland
*sal dct*, salivary gland duct
*sal dsl*, dorsal salivary gland
*sal gl dsl*, dorsal salivary gland
*sal subm*, submedian salivary gland
*sec*, secretion
*sec cdl*, caudal secretion
*set*, seta
*set cph*, cephalic seta
*set sub-cph*, subcephalic seta
*sp*, spiculum
*spm*, spermatozoa
*spn*, spinneret
*spndl*, spindle
*spthc*, spermatheca
*str mur ph*, striae of pharyngeal wall
*subcut*, subcuticle
*sut lb*, labial suture

*trm*, terminus
*trm ov*, terminus of ovary
*trm ovr*, blind end of ovary

*ut*, uterus

*vag*, vagina
*vag msc*, vaginal muscle
*valv*, valve
*vlv*, vulva, valve
*vstbl vag*, vestibule of vagina

other species, but thus far I have no proof that in these other species the sper tozoa are functional. These results lend additional emphasis to my suggest made in previous papers, that parthenogenetic species in general be reëxami with a view to ascertaining whether some of them do not present spermato of minute size. As in the present case, species hitherto regarded as parthe genetic may prove to be syngonic. Probably thousands of nemas are syngo

*Hermaphroditism in Nemas.* Dr. E. Maupas in 1900 summarized to that a list of 34 hermaphroditic species belonging to 12 different genera, as follow *Rhabditis*, *Diplogaster*, *Cephalobus*, *Plectus*, *Allantonema*, *Bradynema*, *Mi laimus*, *Angiostomum*, *Strongyloides*, *Dorylaimus*, *Aphelenchus*, and *Alaimu* four of them parasitic, the remainder free-living. These 34 species repre varying degrees of hermaphroditism,—from species with two sexes, both fu tional, but presenting also females capable of developing their own spermato to those in which only female forms are known, but in the gonads of which spermatozoa then ova are produced, the spermatozoa serving to fertilize from the same gonad. Of these 34 species, over half belong to *Rhabditis*.

*Syngonic Forms.** I have recently taken occasion to look somewhat caref into the embryology of a number of species, all of which prove to be syng or digones. These are the filter-bed species *Mononchus longicaudatus* C *Ironus ignavus* Bastian, *Ironus longicaudatus* de Man, *Plectus cirratus* Bas and *Tripyla monohystera* de Man, all species that have been repeatedly inv gated by different observers in various parts of the world. To three of t males are unknown; in the case of the fourth, *Ironus ignavus*, the males have seen but rarely. In addition I have examined an interesting new genus, *Mo chulus*, also hermaphroditic. In the course of my investigations exten series of individuals have been examined, in nearly every case several hun all of which proved to be syngonic females (digonic in *Mononchulus*). most of the other hermaphroditic nemas, the spermatozoa are produced in young gonad and are early sent forward,—often to a special receptacle,—w they await the arrival of the ova.

*Potency of Syngonic Sperm.* In the light of recent researches on the fe zation of the ovum several interesting questions again arise in connection the origin, development and function of these spermatozoa produced by g which simultaneously or subsequently produce ova. Are these spermat functional? That is to say, do they fertilize the ova in the "regular" mar Do the syngonic spermatozoa enter the egg and behave in every respect like t produced in a separate male organism, or do they behave in some other To answer these questions, among other things the history of the chromos throughout the ripening of both sperm and ova should be accurately kn and then compared with the corresponding facts in typical amphigonic spe

*Vanishing Series of Spermatozoa.* Mainly, previous researches have g us the records of species in which the spermatozoa produced by syngonic fem were of the same size and form as those produced by the few males that occurred, that is to say relatively of very considerable size. In some specie males of which are unknown, the recorded spermatozoa, found in the fe are relatively small and difficult to observe. My own researches have le to cases more and more difficult to decipher, owing to the smaller and sm size of the spermatozoa discovered, and ended in cases in which I was left pletely in doubt as to the existence of spermatozoa; I could find none, bu nature of my experience did not permit me to conclude that therefore

*For the terminology used in the following discussion, see pp. 126, 127.

even under the best of conditions and with the best instruments used by experienced observers, as to lead me to begin to question the adequacy of the evidence upon which we base our belief in some cases of alleged parthenogenesis. May it not be that sperm cells, small and difficult to observe, have escaped notice?

*Potency.* As to the efficacy of these small spermatozoa, in all the cases I have observed there seems to be a fair volume of evidence that the eggs are fertilized by the entrance of a body so closely resembling one of these small spermatozoa as to leave either no or little doubt that, so far, the phenomena are identical with those of bisexual fertilization. Spindles and polar bodies are formed, though sometimes the evidence is not complete. Unfortunately, in most of the cases I have observed, the chromosomes are so small and crowded as thus far to preclude exact counting; I am therefore unable to say, on the basis of fully satisfactory observations, that fertilization always takes place in the same manner as in the case of females fertilized by copulation with males. I can only say that my evidence, as far as it goes, points that way in a considerable number of species.

In view of the present developments this would seem to be a matter in which it is well to keep clearly in mind that no amount of not seeing a thing proves that it does not exist. It is no longer the case, as it formerly was, that non-existence of males may be regarded as proof of parthenogenesis. We must prove that there are no functional spermatozoa produced by the females themselves. Has this always been done? I think the answer must be "No," or "Not satisfactorily."

*Road to Parthenogenesis?* With Maupas one may suspect syngonic nemas to be on the road to parthenogenesis. This suspicion may be justified on the ground that we find species producing two groups of sexual cells, one male, the other female, variously arranged with respect to each other all the way from amphigony to the most intimate syngony, a series at once suggesting the hypothesis that bisexual nemas may be evolving along this road to parthenogenesis. What would be the ulterior (post-parthenogenetic) steps in such an evolution?

Consider for a moment the origin of the gonic cells in a syngonic nema: At some time in the growth of its gone all the future ova and spermatozoa exist in the form of a single or primary gonic cell, destined to give rise both to spermatocytes and oöcytes. The spermatocytes usually take the lead in development and give rise to spermatozoa that are lodged in the uterus. In some cases almost simultaneously, in others only a few hours later, the oöcytes begin to develop, and give rise to ova, which in turn pass onward to be fertilized by the spermatozoa already produced by the same gone. Admitting the crudeness of the questions,—Is not this conceivably a wasteful method? Under the circumstances might it not be more "economical" to produce only one kind of cell, each such cell to contain both male and female elements? Why separate these complements only to bring them together again so soon? These queries are of course merely suggestive, and are not meant to outline the whole subject.

The original gonic cell of a syngone gives rise to both spermatozoa and ova; hence there exist in it, among other things, both male and female potentialities: these must have some physical embodiment,—of course not necessarily discernable. Should these potentialities, male and female,* be separately embodied in the original gonic cell in numbers suitable each to each, why might they not there and then, in ways harmonious with those familiar in amphigony, segregate their parts and regroup them, and afterward develop in the form of some fractional number of syncysts? Is this anything more than following to what would appear to be a logical conclusion, the tendencies apparently existing in

* "Potentialities, male and female", being, of course, merely members of a series of potentialities subject to heredity.

[...] suggested the name cryptogenesis,* will place parthenogenesis in a new light. Evidence for or against cryptogenesis should be sought in the structure and behavior of the "oöcytes" and "ova" of syncystic forms. From some forms of syngony it would appear to be hardly more than a few steps along this road to parthenogenesis, itself perhaps, as it were, a waystation en route to cryptogenesis.

There have been three main theories of natural parthenogenesis:

1. Owen's, that not all the germinal matter is necessary for the production of the new organism, and that after the new organism has matured, a left over portion of the germinal matter within it proceeds to develop new organisms.
2. Huxley's, that the parthenogenetic "egg" is not in reality an ovum, and that its development is comparable to the growth of an organism from a bud.
3. Hertwig's, that parthenogenesis is a degenerate fertilization.

Parthenogenesis as commonly understood may be said to be of three kinds: *a*, The resultant generation is all female (homocystic). *b*, The resultant generation is all male (homocystic). *c*, The resultant generation is heterocystic. Furthermore it may be divided into three cases:

1. The parthenogenetic generation alternates strictly with a bisexual one.
2. Several parthenogenetic generations occur between the bisexual ones.
3. Pure syncysty; i.e., no reproduction other than parthenogenesis is known.

A common supposition is that the parthenogenetic gamete is an ovum or macrogamete pure and simple. It seems more difficult to explain the three kinds of parthenogenesis on the supposition that the gamete of the parthenogenetic organism is essentially or only an ovum or macrogamete, than on the supposition that this gamete is syncystic; for this latter supposition makes it easy to imagine the different results of natural parthenogenesis to arise by processes similar to those already familiar in heterocysty.

Cryptogenetically considered even parthenogenesis may be conceived of as a concealed, (often perhaps unseeable or at least hitherto unseen) but more or less "normal" genesis.

A strict construction of the phase of cryptogenesis discussed rests on the supposition that what we have been calling parthenogenesis is one phenomenon, and not a collection of more or less related phenomena. My own present view is that this latter clause probably comes nearer the truth, and that parthenogenesis as we have broadly understood it may possibly cover cases in accord with most of the theories that have been proposed.**

Cryptogenesis may not exhibit all the phases investigation has disclosed in heterocysty; the suggestion is rather not only that all the results accomplished or supposed to be accomplished in natural parthenogenesis may be explicable along the lines of ordinary fertilization, but that parthenogenesis, and cryptogenesis if it exist, is not so much a distinct method of generation, or even a degenerate fertilization, as an evolved amphigony.

There is a certain amount of evidence often interpreted as showing that fertilization cannot be superimposed on parthenogenesis,—e.g., parthenogenetic eggs may "resist" sperm of the same species. In normal fertilization once an egg entered by a spermatozoon it thereafter "resists" the entrance of other spermatozoa. If what we have been calling parthenogenesis is, in any given case, in reality cryptogenesis, then the parthenogenetic eggs may be regarded as

* This conception differs from earlier ones in its space-and time-limits, (time, antecedent; space the confines of ancestral gonic cells), and in that its methods and mechanism are extended to possibly include all the phases known for, or postulated of, the forms of genesis from which it is supposed to be evolved.

** Here we seem unconsciously dominated by our terminology, some of which is outgrown and, as applied, even misleading. The facts and ideas need critical analysis, as well as the benefit of an adequate terminology, as Sir E. Ray Lankester has just indicated in the August number of "Nature" (1917).