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PROCEEDINGS OF THE HELMINTHOLOGICAL SOCIETY OF WASHINGTON

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On the Classification of the *Tylenchida,* new order (Nematoda, Phasmidia)

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The nemas commonly known as "tylenchs" have heretofore been assigned to the Order RHABDITIDA which includes those phasmidians possessing an esophagus which is divided into corpus, isthmus and bulbar regions. This classification brought together such divergent groups as the tylenchs, cephalobs and rhabditids which, in many respects, are vastly different from one another.

To one who has observed many thousands of specimens of RHABDITIDA, it has long been evident that the tylenchs are very remotely related to the other groups. There are certain differences in their general and detailed morphology which have been inadequately evaluated in formulating their taxonomy, and too much attention has been given to finding minor similarities and overemphasizing their importance. True, there may have been a common ancestry in remote antiquity but the lines through which the various groups developed have been separated so long that but little semblance remains.

Actions and habits of tylenchs readily separate them from other forms, and one well acquainted with the various groups should easily distinguish them by these points alone. Reactions to stains are most revealing and it generally is a simple matter to separate the tylenchs in a mixed collection by the particular tints of color which they exhibit, showing that their body tissues have distinctive qualities.

The classification here outlined is based upon more than 6,000 specimens representing almost 200 species from 28 genera of Tylenchoidea which have been assembled in the Division of Nematology collection at Salt Lake City, Utah, during the past 30 years. Collections have come in from 24 states, Alaska, and the Hawaiian Islands, with the greatest numbers from Utah, California, Nevada, Idaho and Colorado. Canada, Australia, England, Netherlands, Germany and 11 other foreign countries are represented. But even this wealth of material has many limitations and the outline presented doubtless will be found inadequate within a few decades, because probably not more than 20% of the genera and 5% of the species have been discovered and future workers will be forced to make some alterations and many additions. Suborders and additional superfamilies doubtless will be established as the group is expanded by global collecting. Let us hope that changes will be made on specimens actually in hand and not on theory. The task will not be one for the over-enthusiastic neophyte with just a few collections, but rather one for the experienced nematologist with thousands of specimens on which to base extremely careful work.

The illustrations accompanying the following diagnoses have been prepared just as carefully as was possible. Face views showing arrangements of the amphid apertures and cephalic papillae are necessarily somewhat schematic and frequently the prominence of these minute organs is exaggerated. Observations have been made through a 1.5 mm oil immersion objective and 5X and 10X oculars, from which all side lights have been eliminated by means of a heavy cloth screen fitted about the ocular. An observer working at an open table with side lights interfering with his vision would find it impossible to see many of the details shown in these face views. With equipment superior to that used by the writer and exceptionally good eyesight, someone may eventually locate and illustrate the cephalic papillae, deirids and phasmids which the writer has been unable to see on certain species. Improved staining techniques are especially desirable for this critical type of work and future workers should investigate their possibilities.

Generally observations have been made on specimens killed by gradual heat, fixed in formalin-alcohol-acetic acid solution and mounted in glycerin, although some specimens have been observed before killing and fixing while others were stained and mounted in balsam. Face views and cross sections were prepared by cutting off the desired portions with a very slender eye knife and mounting in hard glycerin jelly, a comparatively simple process when once one has mastered the technique.

The purposes of this paper are threefold: 1. To establish the order TYLENCHIDA and outline the general relationships of the free-living and plant parasitic nemas belonging in the superfamily Tylenchoidea. 2. To emend the diagnoses of some of the more common genera of Tylenchoidea. 3. To add new information on the morphology of tylenchs, especially those characters which have been found to be of value in making generic and specific diagnoses.

In the descriptions of species the ratios given are a combination of those used by de Man and Cobb. For α, β, and γ we have substituted a, b, c. These are the ratios, respectively, of body length to body diameter, to length at base of esophagus and to tail length. ''V'' is the position of the vulva as a percent of body length; superior figures indicate extent of ovary or uterus from vulva as a percent of body length. ''T'' is the extent of the male gonad anteriad from the anus.

No attempt has been made to cover the families and genera of Aphelenchoidea (Fuchs 1937). Likewise the Tylenchoidea parasites and associates of insects under the families Myenchidae, Pereira, 1931, and Allantonematidae Chitwood and Chitwood, 1937, have been omitted.

Order TYLENCHIDA, new order

Diagnosis.—Nematoda, Phasmidia. Stoma armed with a protrusile spear or stylet (except degenerate males of a few species). Basal portion of esophagus bulbar or lobe-like, without a sclerotized valvular apparatus.

Type superfamily.—Tylenchoidea Chitwood and Chitwood, 1937.

General description.—Cuticle marked by striae which usually are interrupted on the lateral fields by incisures or refractive bands. Deirids and phasmids frequently visible but almost as often very difficult or impossible to see. Excretory pore a conspicuous feature, usually located near the latitude of the nerve ring. Lip region typically with two circlets of papillae, visible only from a face view; one circlet consisting of six closely grouped about the vestibule; the other of eight located farther out on the contour of the lips. However the numbers of these papillae may be greatly reduced in some species or perhaps beyond the limits of the microscope used. Amphid apertures generally high on the lips and visible only from a face view when they are seen as minute refractive orifices (except the slit-like lateral apertures of *Psilenchus*).

Esophagus consisting of a corpus which may, or may not, contain a median bulb with a sclerotized valvular apparatus; a narrow isthmus encircled by the nerve ring; and an enlarged basal portion. This basal region may consist of a true bulb enclosing the three esophageal gland nuclei, or the glands may form a lobe and protrude back over the anterior end of the intestine. If a true basal bulb is present, there is also a valvular apparatus (cardia or esophago-intestinal valve) connecting the lumen of the esophagus with the intestine. If the esophageal glands are lobe-like, the junction of the lumen and the intestine is a minute, very obscure, muscular apparatus. The so-called ''dorsal gland'' may empty into the esophageal lumen near the base of the spear (Tylenchoidea) or into the median bulb (Aphelenchoidea) (Fig. 4, G, H). The two remaining glands empty into the median bulb, as recorded by Cobb (1923a) and Goodey (1929). The arrangement of the three esophageal gland nuclei does not follow any set pattern and they will be observed in greatly varying positions, even in individuals of the same species.

The cells of the simple intestine are generally well filled with refractive granules which obscure the details of the cell nuclei, except when stained and cleared. Preliminary observations through a ''Phase'' microscope revealed the cell nuclei very satisfactorily and the use of this type of instrument should be explored. It appears probable that the number and arrangement of the intestinal cells and their nuclei will prove to be of taxonomic value. The intestine ends in a distinct rectum leading to a small slit-like anus, except in certain Criconematidae in which the rectum and anus are most obscure, perhaps absent.

Ovaries one or two, outstretched, reflexed or coiled (Heteroderidae), most frequently made up of a single series of developing oögonia, but sometimes consisting of a compound series arranged about a rachis as in *Anguina.* Testis single except in certain forms of *Meloidogyne.*[1] Spicula simple, tapering, curved; resting on a plain trough-like gubernaculum. A telamon present in *Hoplolaimus.* Bursa present in Tylenchoidea except in Heteroderidae, Paratylenchinae, *Eutlyenchus* and *Tylenchulus.* Aphelenchoidea without bursa except in *Aphelenchus* and *Metaphelenchus.* Bursal ribs absent in Tylenchoidea, present in Aphelenchoidea.

Keys to superfamilies and families and subfamilies of Tylenchoidea have been prepared, together with a key to genera of Tylenchidae. For keys to the subfamilies, genera and species of Neotylenchidae the reader is referred to the writer's paper on that group (1941). The genera and species of Criconematinae were covered by Taylor (1936), except for the genus *Cacopaurus* Thorne, (1943) and the recent paper of Loos (1948) on *Hemicycliophora.*

Key to superfamilies of TYLENCHIDA

1. Dorsal esophageal gland emptying into lumen of esophagus near base of spear; bursa present, except in Heteroderidae and Paratylenchinae, and the genera *Eutylenchus* and *Tylenchulus;* bursa not supported by ribs. Tylenchoidea Chitwood and Chitwood, 1937.[2]

   Dorsal esophageal gland emptying into median bulb of esophagus; bursa absent except in *Aphelenchus* and *Metaphelenchus,* in which the bursa is supported by ribs .... Aphelenchoidea Fuchs, 1937

Key to families of Tylenchoidea

1. Median esophageal bulb greatly enlarged; isthmus and basal bulb reduced; spear strongly developed, except in degenerate males of certain species in which it is greatly reduced or absent. Cuticle generally heavily annulated

[1] Dr. B. G. Chitwood of the Division of Nematology is now engaged in a study of the Heteroderidae and this work will include the reestablishing of the genus *Meloidogyne* Göldi.

[2] Synonyms: Anguillulinoidea Pereira, 1931, in part.
Anguilluloidea Schuurmans—Stekhoven and Teunissen, 1938, in part (Designated as an order by the authors).

or squamose .... Criconematidae, new family

Median esophageal bulb small to moderate in size or absent; isthmus narrow, elongated; basal portion of esophagus a distinct bulb, or lobe-like, extending back over anterior end of intestine; cuticle not heavily annulated or squamose 2

2. Valvular median esophageal bulb absent .... Neotylenchidae, new family

Valvular median esophageal bulb present 3

3. Male tails short rounded; bursa absent; females pyriform or lemon-shaped. Heteroderidae, new family

Male tails conoid or elongated; bursa present, except in *Tylenchulus* and *Eutylenchus*; females typical active nemas, except saccate in *Tylenchulus* and *Nacobbus*, and reniform in *Rotylenchulus* ...... Tylenchidae Filipjev, 1934

Family NEOTYLENCHIDAE, new family

Diagnosis.—Tylenchoidea. Median esophageal bulb absent. Cephalic framework in either six or eight sectors. Basal portion of esophagus variable; joined directly to intestine (*Hexatylus*); an elongated glandular extension (*Deladenus*); short, lobe-like basal extensions (*Neotylenchus*); definite basal bulb with cardia (Neotylenchinae); or bearing a stem-like process extending into the intestine (Paurodontinae).

Obviously, this heterogeneous group is unsatisfactory for many reasons and the writer admits that it is merely a "catchall," established as a matter of taxonomic convenience until more extensive collecting enables future workers to arrange the many divergent forms properly into their respective groups.

Type Subfamily.—*Neotylenchinae* Thorne, 1941.

Type genus.—*Neotylenchus* Steiner, 1931.

Family HETERODERIDAE, new family

Diagnosis.—Tylenchoidea. Obligate plant parasites. Males with short, rounded tails. Bursa absent. Females lemon shaped or pyriform, saccate (*Meloidogyne*) or cyst-forming (*Heterodera*).

Type subfamily.—Heteroderinae Filipjev, 1934.

Type genus.—*Heterodera* Schmidt, 1871.

The advisability of establishing this family may be questioned, but these two genera have such distinctive characteristics that the writer deems it inadvisable to keep them in the Tylenchidae.

Family CRICONEMATIDAE Thorne, 1943

Diagnosis.—Tylenchoidea. Median esophageal bulb greatly developed; isthmus reduced or absent; basal bulb much reduced. Spear strongly developed, except in males of certain species in which it is reduced or absent. Cuticle frequently heavily annulated or squamose. Vulva near posterior end. Ovary single. Posterior uterine branch absent. Bursa present or absent.

Type subfamily.—Criconematinae Taylor, 1936.

Type genus.—*Criconema* Hofmänner and Menzel, 1914.

The name Criconematidae was first used without a diagnosis by the writer (1943).

Key to subfamilies of Criconematidae

1. Isthmus of esophagus absent or short and broad, cuticle strongly annulated. Criconematinae Taylor, 1936

Isthmus of esophagus short, narrow and distinct, cuticle finely annulated. Paratylenchinae, new subfamily

Subfamily PARATYLENCHINAE, new subfamily

Diagnosis.—Criconematidae. Cuticle with small annulations. Female body slender, active, (*Paratylenchus*), or obese (*Cacopaurus*). Female spear long, slender. Male spear reduced or absent. Esophagus with a short, distinct isthmus. Ovary single. Male without true bursa but ventrally flattened or concave in anal region so that when seen from a submedian angle there appears to be a narrow, thick bursa.

Type genus.—*Paratylenchus* Micoletzky, 1922.

Key to subfamilies and genera of Tylenchidae

1. Basal portion of esophagus lobe-like, extending back over anterior end of intestine 2
   Basal portion of esophagus forming a distinct bulb. Tylenchinae Filipjev, and genera of doubtful position 8
2. Lip region convex-conoid, $\frac{1}{3}$ to $\frac{1}{5}$ as wide as spear length, tails generally shorter than anal body diameter .... Hoplolaiminae Filipjev 3
   Lip region low, somewhat flattened, $\frac{1}{2}$ to $\frac{3}{5}$ as wide as spear length; tails at least twice as long as anal body diameter, except in *Nacobbus* and *Rotylenchulus* and in these genera the females are saccate or reniform. Pratylenchinae new subfamily 5
3. Cuticle of lip region divided into minute plates .... *Hoplolaimus* Daday, 1905
   Cuticle of lip region marked by plain annules only 4
4. Amphid apertures near oral opening .... *Rotylenchus* Filipjev, 1934
   Amphid apertures at base of lip region .... *Helicotylenchus* Steiner, 1945
5. Ovary one 6
   Ovaries two 7
6. Female a typical active nema .... *Pratylenchus* Filipjev, 1934
   Female saccate with elongated posterior .... *Nacobbus* Thorne & Allen, 1944
7. Female a typical active nema .... *Radopholus*, new genus
   Female reniform .... *Rotylenchulus* Linford and Oliveira, 1940
8. Head armed with setae 9
   Head not armed with setae 10
9. Cuticle with transverse striae only .... *Eutylenchus* Cobb, 1913
   Cuticle with transverse and longitudinal striae .... *Atylenchus* Cobb, 1913
10. Body greatly attenuated, a = 150 .... *Ecphyadophora* deMan, 1921
    Body not greatly attenuated, a = 40 or more 11
11. Base of spear furcate .... *Chitinotylenchus* Micoletzky, 1922
    Base of spear amalgamated, with or without basal knobs 12
12. Ovaries two 13
    Ovary one 16
13. Spear more than one-half as long as esophagus .... *Dolichodorus* Cobb, 1914
    Spear not more than one fourth as long as esophagus 14
14. Tails attenuated, amphid apertures slit-like .... *Psilenchus* deMan, 1921
    Tails conoid or blunt and rounded, amphid apertures pore-like 15
15. Female tails blunt, rounded .... *Tylenchorhynchus* Cobb, 1913
    Female tails pointed or subacute .... *Tetylenchus* Filipjev, 1936
16. Female saccate, male without bursa .... *Tylenchulus* Cobb, 1914A
    Female not saccate, male with bursa 17
17. Female body obese, largely immobile, gonad cells arranged about a rachis. *Anguina* Scopoli, 1777
    Female body slender, active, gonad cells not arranged about a rachis 18

18. Tails greatly elongated, filiform; bursa short, adanal; lip region striated. *Tylenchus* Bastian, 1865
Tails conoid, bursa enveloping one-fourth of tail or more; lip region not striated .... *Ditylenchus* Filipjev, 1934

Diagrammatic arrangement of the Tylenchoidea

- Tylenchoidea
  - Tylenchidae
    - Hoplolaiminae
      - Hoplolaimus
      - Rotylenchus
      - Helicotylenchus
    - Pratylenchinae
      - Pratylenchus
      - Nacobbus
      - Rotylenchulus
      - Radopholus
    - Tylenchinae
      - Tylenchus
      - Ditylenchus
      - Anguina
      - Psilenchus
      - Tetylenchus
      - Tylenchorhynchus
      - Chitinotylenchus
    - Genera of uncertain position
      - Eutylenchus
      - Atylenchus
      - Dolichodorus
      - Tylenchulus
      - Ecphyadophora
  - Heteroderidae
    - Heteroderinae
      - Heterodera
      - Meloidogyne
  - Neotylenchidae
    - Neotylenchinae
      - Neotylenchus
      - Hexatylus
      - Deladenus
    - Nothotylenchinae
      - Nothotylenchus
      - Thada
      - Boleodorus
      - Halenchus
    - Paurodontinae
      - Paurodontus
      - Stictylus
  - Criconematidae
    - Criconematinae
      - Criconema
      - Criconemoides
      - Hemicycliophora
    - Paratylenchinae
      - Paratylenchus
      - Cacopaurus
      - Macroposthonia ?

Subfamily HOPLOLAIMINAE Filipjev, 1934

Diagnosis emended.—Tylenchidae. Cephalic framework heavily sclerotized, frequently yellowish in color. Spear massive with strongly developed knobs, three to five times as long as width of lip region. Basal portion of esophagus lobe-like, extending back over anterior end of intestine. Ovaries two, outstretched. Tails of both sexes usually shorter than anal body diameter. Male tail enveloped by bursa. Phasmids usually opposite, or anterior to, the latitude of the anus.

Cuticle strongly striated. Lateral fields marked by at least four incisures. Neck tapering rapidly to the lip region which may be covered with minute plates (*Hoplolaimus*) or annulated (*Rotylenchus* and *Helicotylenchus*). Median esophageal bulb spheroid with small sclerotized valve. Junction of esophageal lumen and intestine very obscure, usually only a short distance posterior to the isthmus. Intestine packed with coarse granules. Vulva near middle of body. Female terminus hemispherical to convex conoid, sometimes bluntly digitate.

Type genus.—*Hoplolaimus* Daday, 1905.

Genus *Hoplolaimus* von Daday, 1905

Diagnosis emended.—Hoplolaiminae. Lip region set off, cap-like, with cuticle divided into minute blocks by transverse and longitudinal striae. Cephalic framework massive, yellowed. Spear massive, strongly knobbed, with anterior forward pointing processes to which the protrudor muscles are attached. Distal portion of gubernaculum protrusile, cephalated, bearing lateral "titillae."[3] Telamon present but very obscure in most specimens.

Cuticle coarsely annulated, the lateral fields marked by four incisures and frequently with fine transverse striae. Phasmids of the usual type present on *Hoplolaimus uniformis,* while on *H. coronatus* they are very large and located erratically on the lateral fields. Deirids not observed. Ovaries two, outstretched. Testis single, outstretched. Spicula strong, arcuate. Tails shorter than anal body diameter, that of the female hemispheroid to bluntly conoid; while that of the male is ventrally arcuate and enveloped by the bursa.

Type species.—*Hoplolaimus tylenchiformis* Daday, 1905.

Representative species.—*Hoplolaimus uniformis* n. sp.[4]

Daday's description of *Hoplolaimus tylenchiformis* is meagre and his figures are at first glance somewhat misleading. One of these illustrations is here reproduced (Fig. 7L), and obviously was made from a flattened specimen which apparently had been killed with cold fixative, causing the cuticle to shrink, and collapsing the anterior portion of the esophagus and the isthmus until the median bulb and basal gland lobe were forced forward near the spear, greatly shortening the neck. Specimens of *H. coronatus* killed in this manner are in the writer's collection and exhibit a similar condition, which an inexperienced observer might easily illustrate as Daday did.

Hoplolaimus coronatus Cobb, 1923

Cobb (1923) emended the generic diagnosis of *Hoplolaimus* in his description

[3] The term "titillae" is here proposed for these lateral processes on the distal, protrusile end of the gubernaculum of *Hoplolaimus.*

[4] Many nematode genera are based on type specimens which have not been preserved and the original descriptions and figures are meagre and require extensive emendation. In many instances there is little possibility of anyone's ever collecting topotypes (specimens secured in the exact locality in which the type was secured). Therefore, it is proposed that *representative species* be designated for such genera and that these species be described in detail and used as basic material for future comparative work. Designation of *representative species* would, of course, be superseded by an emended description of the type should later workers collect specimens.

of *H. coronatus* but failed to record certain important details concerning this species:

1. The three esophageal gland nuclei are contained in one large lobe which extends back over the anterior end of the intestine, generally in a dorsal position (Fig. 7I).

2. The "lateral organ" described by Cobb actually was a greatly enlarged phasmid, and one is present on each side of the body; they may be located anywhere between the neck and the tail. On one female observed, the left phasmid was located at a latitude near 16% while the right one was near 85%. On all three males examined, the left phasmids were near the tail (Fig. 7K), while the right ones were far forward between 30% and 50%. This erratic placement of the phasmids is a most unusual and interesting feature of the species.

3. The extrusile gubernaculum is distally cephalated and bears titillae similar to those of *Hoplolaimus uniformis* (Fig. 7K).

Hoplolaimus uniformis, new species

Fig. 1, A–M

♀: 1.4 mm; a = 31; b = 7.1; c = 80–120; V = ^{32} 54 ^{30}

♂: 1.4 mm; a = 38; b = 7.5; c = 49; T = 53

Annules of the cuticle vary in width from 3 μ near the base of the neck to about 2 μ near the posterior end of the body. Lateral fields marked by four incisures which occupy a space about one-fourth as wide as the female body near the vulva, while on the male they are about two-fifths as wide as the body. Frequently the lateral fields are marked by obscure extensions of the body striae. Deirids not seen. Phasmids of female generally located somewhat anterior to the latitude of the anus while on the male they usually are about opposite or slightly posterior to the anus. The male phasmids are located close to the terminus of the dorsal incisure of the lateral field, near the base of the bursa (Fig. 1, G, H, J); Fig. 1, J is somewhat schematic because the phasmids both are shown in the same plane as the anus when actually they rarely are directly opposite each other.

Lip region marked by about five annules which are divided into irregular sections which vary greatly in arrangement on the different specimens. These structures are easily observed from a face view but may be overlooked when the head is seen laterally. The face view also reveals a rather complicated 6-pointed cuticular structure about the vestibule which appears to be imbedded in the first annule. The purpose of this structure is problematical unless it serves as an anchor for some of the labial muscles. Arrangement of the amphids and labial papillae are apparently as illustrated (Fig. 1, D) but they are so infinitesimal that accurate observations are difficult. A cross section reveals the basal plate of the cephalic framework as being duplex in the dorsal and ventral sectors.

The esophageal glands of *Hoplolaimus* have been inadequately described in previous works and therefore they are shown here in considerable detail. Young specimens and sometimes males show a rather limited development of the gland lobe which generally lies dorsad in the body (Fig. 1, E), while adult females exhibit great development of the lobes, which are found more laterally and on either the right or left side of the body (Fig. 1, A). The junction of the esophageal lumen and the intestine lies far forward near the nerve ring (Fig. 1, F). Intestine packed with coarse granules which frequently obscure details of the reproductive system.

From the depressed transverse vulva the vagina leads in at right angles and from it the two branches of the reproductive system are outstretched. Unfortunately, the specimens in hand were not in the best of condition and certain details of the ovaries may not be exactly as illustrated (Fig. 1, A). Generally the posterior ovary is on the left side of the body. Eggs measure about $30 \times 100\ \mu$.

The testis begins as a cap cell followed by two cells in single file, then becomes a double line of spermatocytes for a distance equal to about four times the body width; when spermatogenesis is completed they become spermatozoa about $4\ \mu$ in diameter.

Structures of the male tail are most interesting. The simple, tapering spicula rest on a gubernaculum unlike that seen in any other tylench. The distal end is a knobbed structure with lateral titillae (Fig. 1, J). The telamon lies between the spicula and is very easily overlooked from the usual lateral view (Fig. 1, I). Cross sections through the bursal region show this organ to be much thicker and more strongly developed than is generally supposed (Figs. 1, J, K).

Genus *Rotylenchus* Filipjev, 1934

Diagnosis emended.—Hoplolaiminae. Lip region continuous with the neck contour, marked by four to eight transverse striae. Spear three to five times as long as width of lip region, with strongly developed basal knobs. Basal portion of esophagus lobe-like, variable in form and position. Vulva near middle of body. Ovaries outstretched with oöcytes arranged in single file except for a short region of multiplication. Gubernaculum trough-like, sometimes slightly cephalated or recurved, but not bearing lateral titillae like those of *Hoplolaimus.*

Cuticle strongly annulated with lateral fields marked by at least four incisures. Tails generally shorter than anal body diameter; that of the female hemispheroid to bluntly conoid, or sometimes digitate; while that of the male is ventrally arcuate and enveloped by the bursa. Phasmids varying in position, either anterior or posterior to the latitude of the anus. Deirids not observed. Median esophageal bulb spheroid with small refractive valvular apparatus. Intestine generally packed with coarse refractive granules which obscure details of the cellular structure. Spicula of the usual tylenchoid form.

Type species.—*Rotylenchus robustus* (deMan, 1880) Filipjev, 1934.

Filipjev (1934) established the genus *Rotylenchus* and designated the type species as *Rotylenchus robustus* (deMan, 1880), synonym *Tylenchus robustus* deMan, 1880, but gave no diagnostic characters. Later, (1936), he published a key to the genera of Tylenchinae in which the diagnostic characters were listed as follows: Head chitinized, cuticle strongly annulated, spear strong, ovaries paired, esophagus aphelenchoid. The use of ''aphelenchoid'' was, of course, an error but it appears obvious that he intended to convey the idea that the glands of the basal portion of the esophagus extended back over the anterior end of the intestine. Also, he intended this genus to include forms like the male figured by deMan, 1884, and the female illustrated by Goodey, 1932, because he used these two illustrations in his book on Agricultural Helminthology (1934a). (See also Fig. 121, A, B, p. 214 of Schuurmans-Stekhoven translation, 1941.)

Tylenchus robustus was described by deMan (1876) and his figure, 18a, of the anterior portion of the body shows a specimen which in some respects resembles a *Tylenchorhynchus* with a definite basal esophageal bulb containing two large nuclei. However, the accompanying figure, 18c, illustrates a rounded female tail slightly shorter than the anal body diameter, and unlike that of any known *Tylenchorhynchus.* DeMan's 1880 description was published without figures but in 1884 he published practically the same description and added excellent illustrations. The discrepancies between the 1876 and 1884 illustrations apparently prompted Filipjev to designate the 1880 description as the type of his genus *Rotylenchus.* This confusion can now be explained by examining figures 2 E and F of this paper which illustrate basal esophageal lobes lying laterally in the body and extending back over the anterior end of the intestine in a manner which the uninitiated worker might easily interpret as definite basal bulbs.

It is also probable that deMan had a mixture of closely related species of *Rotylenchus*. This conclusion has been reached after comparing specimens kindly sent by Dr. T. Goodey from England and Luxemburg, the latter collected by Dr. M. Simon. Dr. H. Goffart forwarded a specimen from Kitzeberg, Germany, and Dr. J. W. Seinhorst collected others in Holland. There is even a possibility that deMan confused specimens of *Hoplolaimus uniformis* with those of *R. robustus* because the two species closely resemble each other in many respects.

The accompanying female illustration is based on specimens from Luxemburg which, of all those examined, most closely resembled deMan's 1884 figures in the numbers of annules on the lip region and female tail. The few males examined differed from deMan's 1884, Fig. 92b, in the position of the phasmid which he illustrated as being well behind the latitude of the anus, these specimens generally having the phasmid located slightly anterior to the latitude of the anus (Fig. 2, G). However a male of *Rotylenchus erythrinae?* from England possessed a phasmid located almost exactly like that shown by deMan (Fig. 2, I).

Rotylenchus obviously represents a group of closely related species which will require extensive collecting and much careful work before their taxonomy can be presented in a satisfactory manner, because the principal diagnostic characters lie in the total body length, the number of annules on the lip region, and the forms of the tails. Most of the species formerly made synonyms of *R. robustus* doubtless represent valid species but specimens must again be collected and carefully evaluated before accurate diagnoses can be formulated.

The much debated question of the nature of the posterior portion of the esophagus with its three gland nuclei is now clarified. (Fig. 2, D, E, F.) These illustrations show that the basal lobes are most variable in form and position and rarely do two specimens present even similar development. Consequently this portion of the esophagus is of no specific diagnostic value.

Rotylenchus robustus (deMan, 1880) Filipjev, 1934

Synonyms.—*Tylenchus robustus* deMan, 1876, 1880; *Anguillulina robusta* (deMan, 1876) Goodey, 1932.

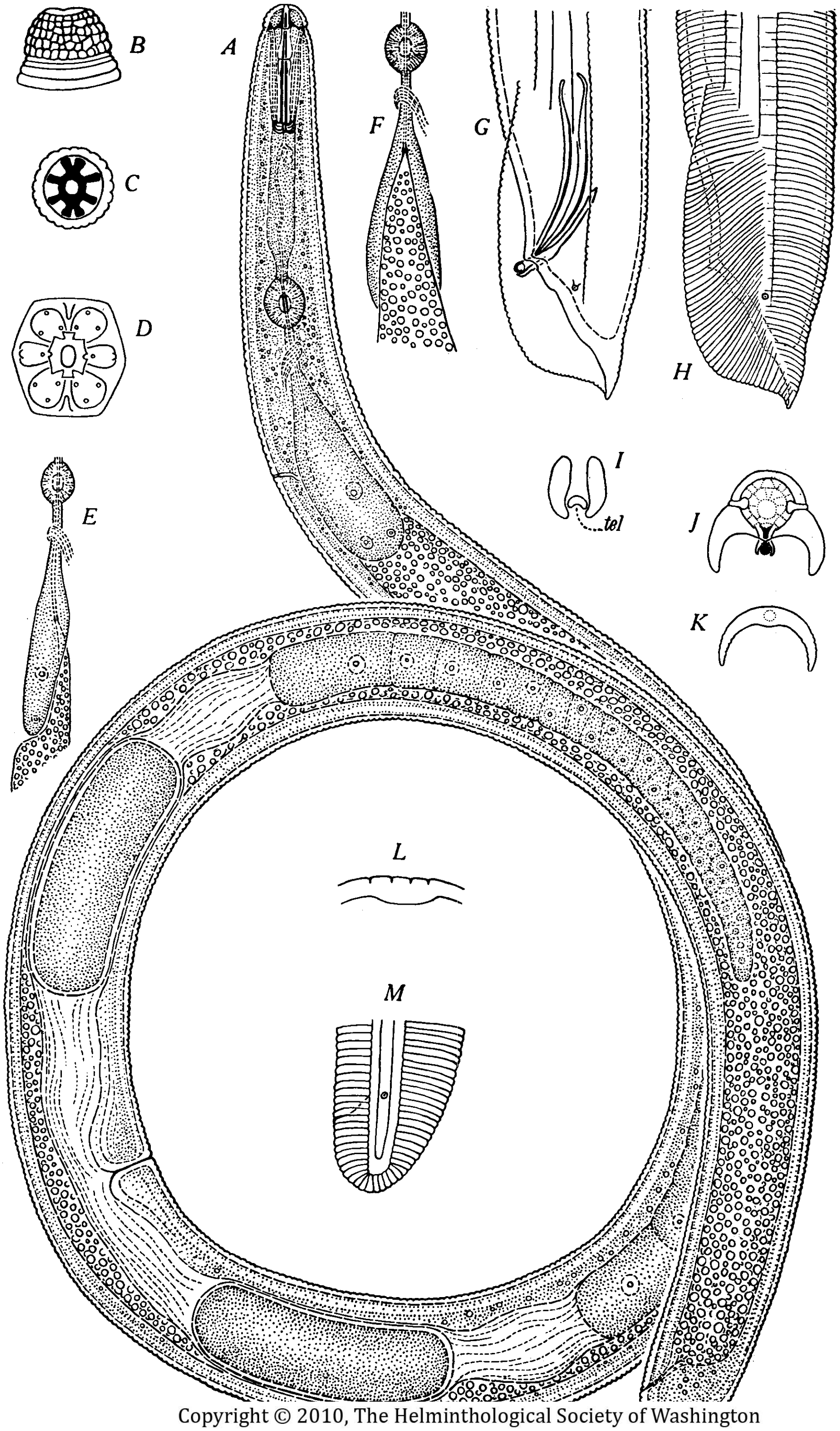
Fig. 2, A–H

♀ : 1.0–1.2 mm; a = 28–36; b = 6–8; c = 50–60; V = ^{32} 54–62 ^{28}

♂ : 0.8–1.0 mm; a = 25; b = 6.1; c = 40–50; T = 40

Body tapering anteriorly to the narrow pointed lip region which is marked by five annules. Female tail hemispherical to bluntly conoid; male tail bent ventrally, with a broad enveloping bursa. Cuticle marked by coarse annules which are interrupted on the lateral fields by four incisures. Deirids not observed. Female phasmids generally located slightly anterior to the latitude of the anus, but occasionally observed back near the middle of the tail. Male phasmid most frequently located near the latitude of the anus but sometimes it may be back on the tail proper, near the base of the bursa.

FIG. 1. *Hoplolaimus uniformis*. A—Female; ×360. B—Cuticle pattern of lip region; ×1080. C—Cross section of head through basal plate; ×1080. D—Face view; ×2160. E—Esophageal gland region of young female; ×360. F—Right side of gland region shown in A; ×360. G—General structures of posterior portion of male; ×720. H—Cuticle pattern of posterior portion of male; ×720. I—Section through spicula and telamon; *tel.* telamon; ×1080. J—Section through anal region of male showing gubernaculum and phasmids; ×1080. K—Cross section through bursa near terminus; ×1080. L—Cross section through lateral field; ×1080. M—More conoid type of female tail; ×540.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From a face view the amphid apertures are seen near the outer margin of the lateral lips; and fourteen papillae are visible, although exceedingly minute and difficult of resolution. Cephalic framework heavily sclerotized, sometimes yellowish in color; the basal plate somewhat duplex in the dorsal and ventral sectors. Spear massive with strongly developed basal knobs. Dorsal gland aperture close to base of spear. Median esophageal bulb spheroid with small sclerotized valvular apparatus. Isthmus comparatively short. Basal lobe of esophagus variable in size and position (Fig. 2, D, E, F). Junction of esophageal lumen and intestine very obscure and impossible to determine on many specimens.

Vulvă a broad, depressed, transverse slit. Ovaries outstretched with oöcytes arranged in single file except for a short region of multiplication. Testis single, outstretched. Gubernaculum thin, trough-like, with recurved distal portion.

Diagnosis.—*Rotylenchus* with the above measurements and general description. Distinctive because of the five annules of the lip region and broad, rounded female tail; and the recurved distal portion of the gubernaculum.

Subfamily PRATYLENCHINAE, new subfamily

Diagnosis.—Tylenchidae. Lip region one-half to three-fifths as wide as spear length, frequently low, flattened. Tails at least twice as long as anal body diameter, except in *Nacobbus* and *Rotylenchulus* and in these two genera the females are saccate or reniform respectively. Bursa enveloping tail. Phasmids located well behind the latitude of the anus. Deirids not observed. Spear strong with well developed knobs. Median esophageal bulb spheroid. Basal portion of esophagus consisting of an elongated lobe extending back over the anterior end of the intestine; greatly variable in form and position, and containing the three large esophageal gland nuclei. Ovaries one or two.

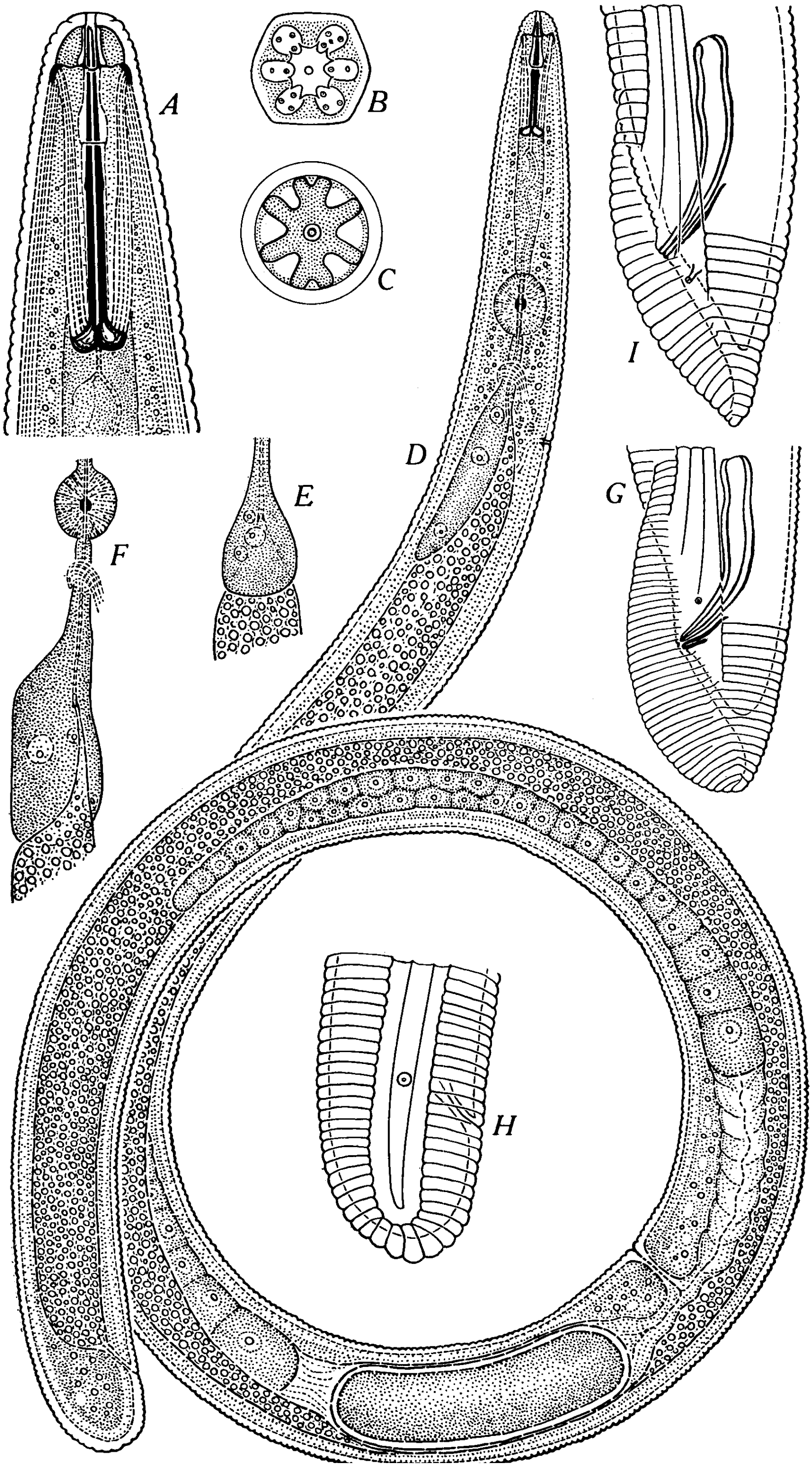
Type genus.—*Pratylenchus* Filipjev, 1934.

The Pratylenchinae include those rather broad headed plant parasitic nemas which form a very natural group because of the close similarities of the larval stages, and of the structures of the head, spears, esophagi and male tails. However there are divergent characteristics which eventually may necessitate raising the group to family rank and separating off such aberrant genera as *Nacobbus* and *Rotylenchulus* from the more simple forms like *Pratylenchus* and *Radopholus*. The greater number of species of this subfamily appear to come from the warmer climates and extensive collecting in the tropics should reveal many more genera and species.

Genus *Pratylenchus* Filipjev, 1934

Diagnosis emended.—Pratylenchinae possessing a single outstretched ovary and a rudimentary posterior uterine branch. Bursa enveloping entire tail. Phasmids located one-third of the tail length or more, behind the latitude of the anus. Deirids not observed. Esophageal gland nuclei arranged in a single lobe which extends back over the anterior end of the intestine, and varies greatly in size, form and position. Junction of esophageal lumen and intestine obscure, generally about one body-width posterior to the median esophageal bulb. Lip region annulated, set off by a narrowing of the head. Cephalic framework sclerotized, refractive. Spear strong with massive basal knobs. Median bulb of esophagus slightly ovate, half or more the width of the neck. Cephalic basal plate with expanded dorsal and ventral processes.

FIG. 2. A–H *Rotylenchus robustus.* A—Head; ×1320. B—Face view; ×1760. C—Section through cephalic basal plate; ×1760. D—Female; ×440. E—Basal lobe of male esophagus lying laterad in body; ×660. F—Female esophagus with greatly developed basal lobe; ×660. G—Male tail; ×880. H—Female tail; ×880. I—*Rotylenchus erythrinae* ?. Male tail; ×1320.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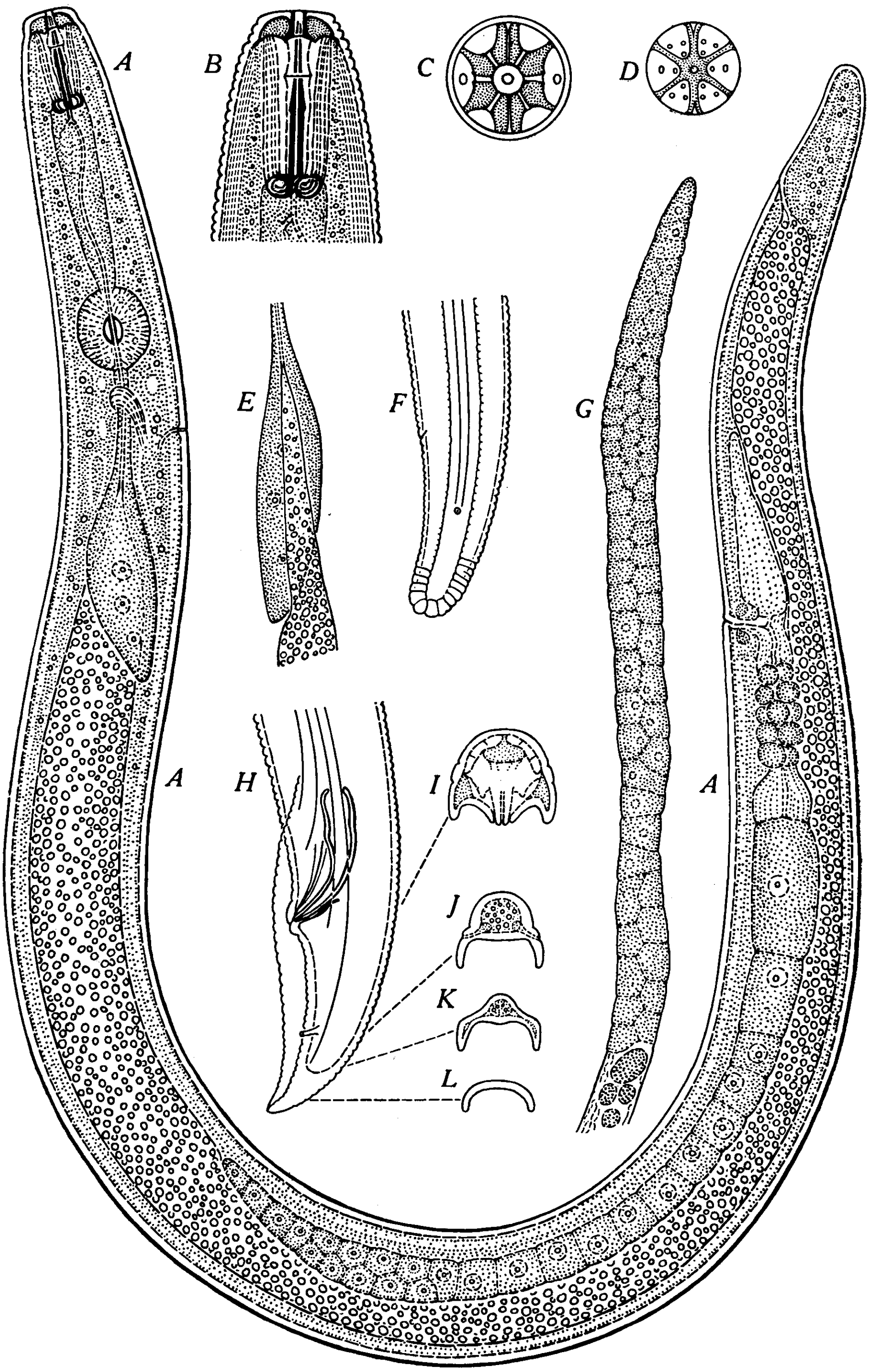


FIG. 3. *Pratylenchus pratensis.* A—Female; ×800. B—Female head; ×1400. C—Cross section through cephalic base plate; ×1600. D—Face view; ×1600. E—Basal portion of esophagus showing connection with anterior end of the intestine; ×800. F—Female tail showing phasmid and lateral field; ×1200. G—

Type species.—Pratylenchus pratensis (deMan, 1880) Filipjev, 1936.

Pratylenchus is composed of a group of very closely related species which are most difficult to separate, the principal differentiating characters being the form and annulation of the lip region and the tail.

Tylenchus obtusus Bastian, (1865, Figs. 117, 118, 118a) appears to be a *Pratylenchus.* The total length of 0.87 mm is greater than that of any known species of this genus and were it not for this extreme length, this form might well be considered similar, if not identical, to *Pratylenchus pratensis.* If Bastian erred in this measurement, *P. pratensis* might then be a synonym of *P. obtusus.* Unfortunately, it has not been possible to secure collections from the type locality near Broadmoor, Berks., England.

Soltwedel (1888) described *Tylenchus sacchari* from Java and Filipjev, (1936) placed the species in *Pratylenchus.* The form represents what doubtless is a new, undescribed genus among the Pratylenchinae, because of the blunt rounded tail of the male with its adanal bursa, and the anterior location of the excretory pore only slightly behind a point opposite the base of the spear. However, Soltwedel's meagre description and figures are insufficient evidence on which to base a satisfactory diagnosis and the writer leaves the task of emending the species description and erection of a new genus to the fortunate individual again collecting this interesting form.

Pratylenchus pratensis (deMan, 1880) Filipjev, 1936

Synonyms.—Tylenchus pratensis deMan, 1880; *Anguillulina pratensis* (deMan, 1880) Goodey, 1932.

Fig. 3, A–L

♀ : 0.6 mm; a = 22; b = 4.6; c = 21; V = ^{38} 82 ^{3}

♂ : 0.53 mm; a = 22; b = 4.2; c = 20; T = 46

Cuticle marked by distinct transverse striae which average about 1 μ apart. Lateral fields marked by four incisures, the outer ones being slightly crenate. Lip region set off by a narrowing of the head contour and bearing two striae which form three annules. On the female tail the striae extend completely around the terminus (Fig. 3, F). From a face view the six sectors of the lip region are easily visible, the two lateral ones being distinctly wider than the submedian four. Each sector bears a minute papilla located close to the oral disc, and the four submedian lips each have two additional very obscure papillae. The amphid apertures are located near the outer margin of the lip region. The basal plate of the cephalic framework is six-pointed (Fig. 3, C), the dorsal and ventral processes being much wider and somewhat duplex in structure. This wider structure is reflected in the dorsal and ventral cephalic arches (Fig. 3, D). Knobs of the strong spear are almost one-third as wide as the head at that point. Dorsal esophageal gland orifice about 2 μ behind the spear base. Median esophageal bulb slightly ovate with strong refractive valvular apparatus. Esophageal glands forming a large lobe extending well over the anterior end of the intestine in which the three gland nuclei can generally be observed. Usually this lobe lies on the right side of the body. The actual junction of the esophageal lumen and the anterior end of the intestine is very obscure and located about one body-width behind the median bulb (Figs. 3, A, E). Granules of the intestine so dense that details of the intestinal cell structure usually cannot be observed.

Anterior branch of the female reproductive system composed of a cellular ovi-

Testis; ×800. H—Male tail showing phasmid and lateral field; ×1200. I, J, K, L—Cross sections through anal region, phasmids and posterior parts of tail as indicated; ×1200.

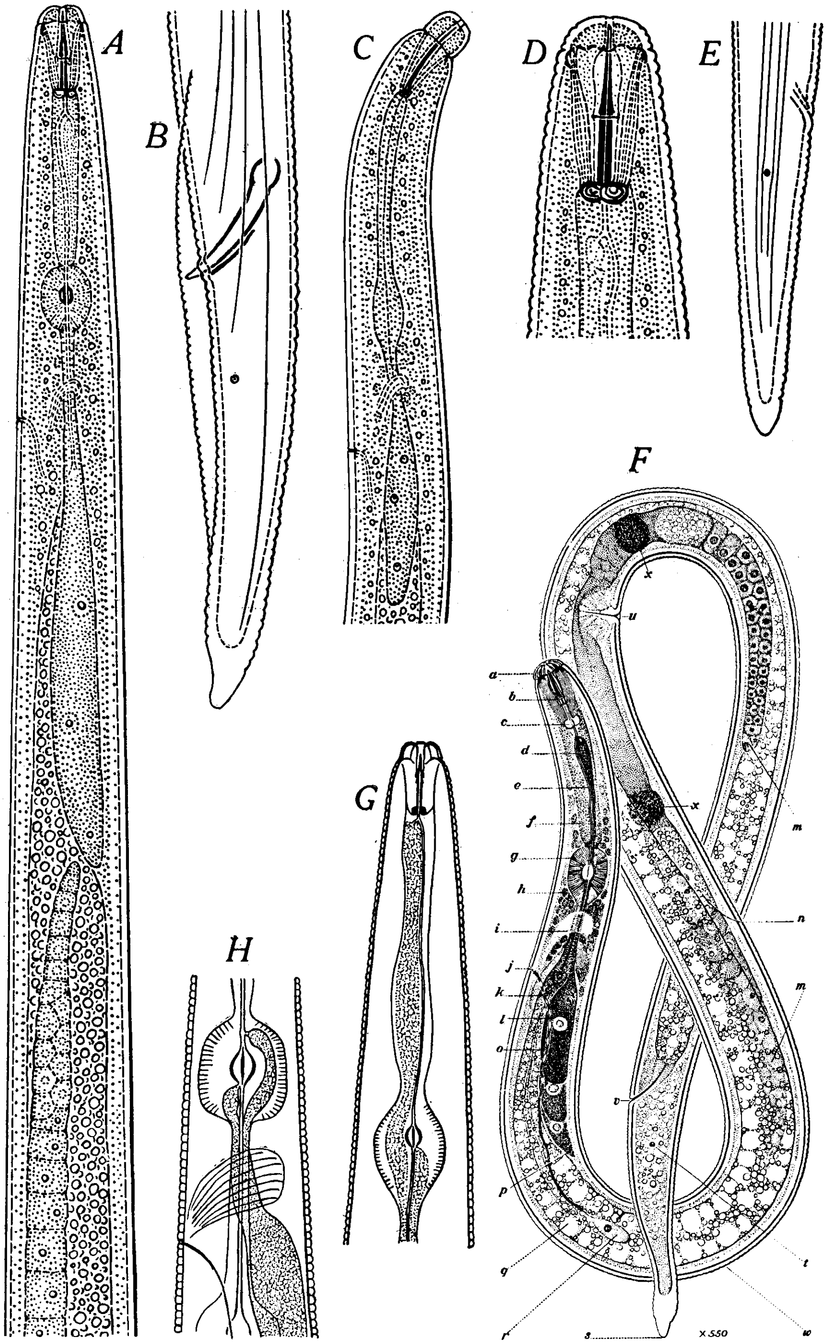


FIG. 4. A–F—*Radopholus similis.* A—Anterior portion of female; ×750. B—Male tail; ×7000. C—Anterior portion of male; ×750. D—Female head; ×1500. E—Female tail; ×750; Originals. F—Young female; ×550: *a,* Lip region; *b,* spear guide; *c,* 3-bulbed spear;*d,* ampulla, salivary gland; *e,* esophageal lumen; *f,* esophagus; *g,* median bulb; *h,* nerve cells; *i,* nerve ring; *j,* excretory

duct and an outstretched ovary made up of a series of developing oöcytes arranged in single file except for a short region of multiplication near the anterior end. Posterior uterine branch extending one-third to one-half the distance back to the anus.

Female phasmids located near the middle of the tail. Male phasmids near the base of the bursa, four-sevenths of the tail length behind the anus. In cross section, the tail is seen to be flattened ventrally posterior to the anus and the phasmids extend out through this flattened portion but do not enter the bursa proper (Figs. 3, H, J). Cross sections show the bursa to be of surprising thickness (Figs. 3, I, J, K, L). The single outstretched testis is made up of developing spermatocytes most of which are arranged in two rows (Fig. 3, G). Spicula arcuate, hafted, resting upon a simple trough-shaped accessory piece.

Diagnosis.—Pratylenchus with the above measurements and general description, distinctive because of the three annules in the lip region; and the striae extending completely around the terminus of the femal tail.

The above description from specimens kindly collected for the writer by Dr. T. Goodey from a meadow in the vicinity of Sydenham, England, where deMan made his type collection. These individuals so closely resemble the type description that there appears to be no doubt concerning their identity.

Radopholus, new genus

Pratylenchinae. Two ovaries present. Head of female resembling that of *Pratylenchus pratensis*, with low lip region set off by a slight narrowing of the head contour, about half as wide as base of neck. Female spear also very much like that of *P. pratensis*, about twice as long as lip region width with strong basal knobs. Esophageal gland lobe extending back over intestine. Phasmids of both sexes prominent, located well back of the tails. Deirids not observed. Bursa enveloping only about four-fifths of tail. Tails of both sexes elongate-conoid to the rounded or irregular shaped terminus.

Type speices.—Radopholus similis (Cobb, 1893) new combination.

This genus is established to receive those didelphic species which most closely resemble nemas of the genus *Pratylenchus*. One other species is included: *Radopholus oryzae* (v. Breda de Haan, 1902) new comb. Synonyms: *Tylenchus oryzae* v. Breda de Haan, 1902; *Anguillulina oryzae* (v. B. de Haan, 1902) Goodey, 1932; *Rotylenchus oryzae* (v. B. de Haan, 1902) Filipjev and Schuurmans-Stekhoven, 1941. See Goodey, 1936, for emended description and figures. *T. apapillatus* Imamura, 1931, probably is a synonym of this species.

Radopholus similis (Cobb, 1915) new combination

Synonyms.—Tylenchus similis Cobb, 1893; *Tylenchus biformis* Cobb, 1907; *Anguillulina similis* (Cobb, 1893) Goodey, 1932; *Rotylenchus similis* (Cobb, 1893) Filipjev, 1936.

Fig. 4, A–F

♀: 0.65 mm; a = 22; b = 5.9; c = 10; V = ^{43}54^{38}

♂: 0.5 mm; a = 29; b = 5.2; c = 8.7; T = 32

Female.—Lip region rounded, marked by three striae, set off by a slight narrowing of the head contour. Cuticle distinctly striated. Lateral fields marked by four incisures, the lateral ones minutely crenate. Deirids not observed. Phasmids a little less than one body-width behind the latitude of the anus. Tail conoid

pore; *k.* initial intestinal cells; *l,* anterior salivary gland; *m,* end of ovary; *n,* ovum; *o,* renette duct; *p,* posterior salivary gland; *q,* fat granule, intestine; *r,* renette cell ?; *s,* terminus; *t,* phasmid; *u,* vulva; *v,* anus; *w,* crenate cuticle; *x,* spermatozoa. After Cobb, 1915. G, H—Arrangements of esophageal gland outlets. (G—Tylenchoidea. H—Aphelenchoidea.) After Goodey, 1929.

to the blunt, rounded terminus. Spear strong with well developed knobs. Median bulb of esophagus subspherical with a small valve slightly anterior to the center. Isthmus about as long as the body-width. Junction of esophageal lumen and intestine very obscure. Basal lobe of esophagus from two to four times as long as the body-width, extending back over the anterior end of the intestine. This lobe usually is in dorsal position, and contains the three gland nuclei. Anterior ovary frequently extending forward to the median bulb of the esophagus. Posterior ovary sometimes reaching into the tail and occasionally reflexed forward one to three body-widths. Oöcytes in single file except for a short region of reproduction. Eggs about twice as long as body diameter.

Male.—Lip region sub-spheroid, unstriated, set off by constriction. Cuticle distinctly annulated. Lateral fields marked by four incisures, ending on the tail as illustrated (Fig. 4, B). Phasmids near base of bursa, about one body-width posterior to the latitude of the anus. Bursa crenate, rising at a point well in front of the spicula and extending two-thirds the length of the tail.

Spear very slender with tiny basal knobs. Esophagus reduced, the median bulb apparently being valveless. Testis outstretched, one-fourth to one-third the body-length. Spicula slightly arcuate, cephalated, distally acute. Gubernaculum thin, trough-like, slightly less than half as long as spicula.

Description and figures from specimens collected from the roots of sugarcane, *Saccharum officinarum,* collected near Honolulu, Hawaii, and kindly forwarded by Dr. M. B. Lindford; and two females from roots of pepper, *Piper nigrum,* East Indies, sent by Dr. T. Goodey. The basal lobe of the esophagus was much more developed in the specimens from pepper (Fig. 4, A) than in those from sugarcane.

Cobb (1915) stated "The lip region also is minutely transversely striated, the number of labial striae being about 8 or 10." This statement does not agree with the writer's observations which revealed only three striae (Fig. 4, D). Cobb's figure of the female (Fig. 4, F) shows the three esophageal gland nuclei in separate lobes, where actually they are in one elongate lobe (Fig. 4, A).

Genus *Tylenchorhynchus* Cobb, 1913

Synonym.—Bitylenchus Filipjev, 1934.

Diagnosis emended.—Tylenchinae. Lip region set off by constriction or continuous with head contour. Lateral fields marked by four or six incisures. Phasmids conspicuous, located well behind the anal region. Deirids generally not visible. Spear strong with large basal knobs. Basal bulb of esophagus well developed, connected with the intestine by a large cardia. Vulva near midde of body. Ovaries two, outstretched. Female tail blunt, rounded, usually two or more times as long as anal body diameter. Male tail slightly arcuate, enveloped by the bursa. Spicula and gubernaculum of the usual tylenchoid form.

Type species.—Tylenchorhynchus dubius (Bütschli, 1873) Filipjev, 1936.

Tylenchorhynchus dubius (Bütschli, 1873) Filipjev, 1936

Synonyms.—Tylenchus dubius Bütschli, 1873; *Tylenchorhynchus cylindricus* Cobb, 1913; *Anguillulina dubia* (Bütschli, 1873) Goodey, 1932.

Fig. 5, A–G

♀: 0.9 mm; a = 33; b = 5.5; c = 22; V = ^{28} 54 ^{31}

♂: 0.9 mm; a = 36; b = 5.5; c = 17; T = 54

Lip region set off by a distinct constriction, marked by five annules. Lateral fields one-fourth as wide as body near middle, marked by four incisures. Phasmids prominent on both sexes (Fig. 5, C, F, G). Deirids not observed. From a face view the cephalic papillae are so minute that exact numbers and locations could not

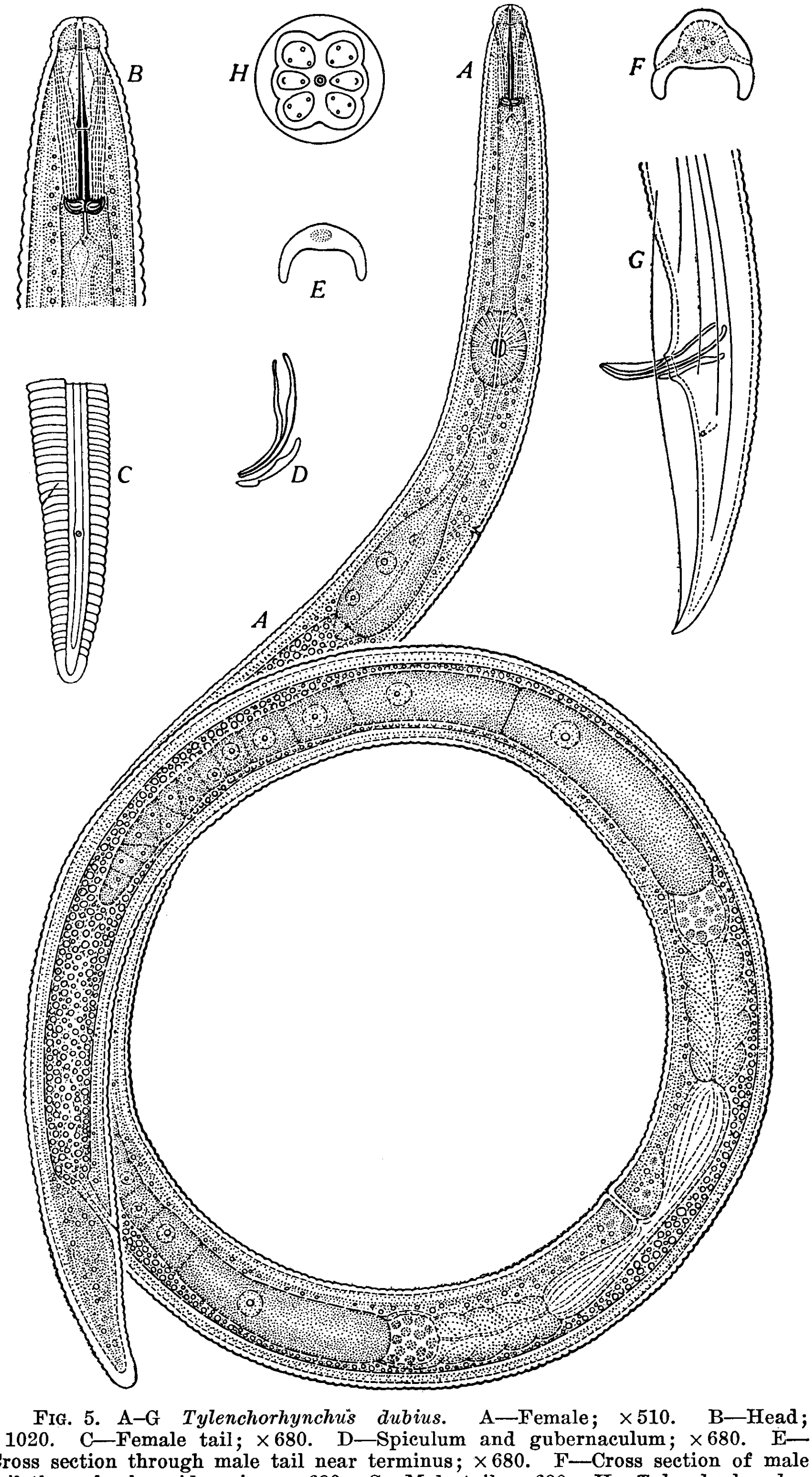


FIG. 5. A–G *Tylenchorhynchus dubius*. A—Female; ×510. B—Head; ×1020. C—Female tail; ×680. D—Spiculum and gubernaculum; ×680. E—Cross section through male tail near terminus; ×680. F—Cross section of male tail through phasmid region; ×680. G—Male tail; ×680. H—*Tylenchorhynchus* sp.; face view

be determined. However, on a large species of the genus the papillae and amphid apertures were arranged as illustrated (Fig. 5, H). Spear more than three times as long as lip region width, bearing strongly developed basal knobs. Median esophageal bulb slightly ovoid; basal bulb well developed, joined to intestine by a large, conoid cardia. Excretory pore slightly posterior to nerve ring. Vulva near middle of body. Ovaries outstretched, with oögonia arranged in single file. Testis single, outstretched. Spicula of typical tylenchoid form. Gubernaculum trough-like, cephalated. Bursa enveloping tail.

Habitat.—A cosmopolitan species. The form illustrated here was collected near Goshen, Utah, from desert soil. The male phasmids are slightly farther forward than those figured by Bütschli but otherwise the specimens correspond closely to the type.

Genus *Tetylenchus* Filipjev, 1936

Diagnosis emended.—Tylenchidae without sclerotized cephalic framework. Cuticle finely striated. Ovaries two, outstretched. Spear of moderate size, with or without basal knobs. Tails of both sexes tapering to an acute or subacute terminus. Deirids and phasmids present, generally easily visible. Bursa sub-caudal, extending almost to the terminus. Distance from anterior end to valve of median bulb shorter than that from valve to base of esophagus. Esophagus with elongate-ovate median bulb; unusually long slender isthmus, and elongate-pyriform basal bulb containing the usual three gland nuclei. Cardia usually discoid. Spicula tylenchoid; gubernaculum a simple trough-like plate.

Type species.—*Tetylenchus tenuis* (Micoletzky, 1922) Filipjev, 1936.

Representative species.—*Tetylenchus joctus,* new species.

Key to species of Tetylenchus

1. Spear without basal knobs .... *abulbosus,* n. sp.
   Spear with basal knobs 2
2. ♀ Tail eight times as long as anal body diameter .... *tenuis* Micoletzky
   ♀ Tail only four or five times as long as anal body diameter 3
3. Spear twice as long as lip region width .... *joctus,* n. sp.
   Spear one and one-fourth times as long as lip region width .... *productus,* n. sp.

Tetylenchus joctus, new species

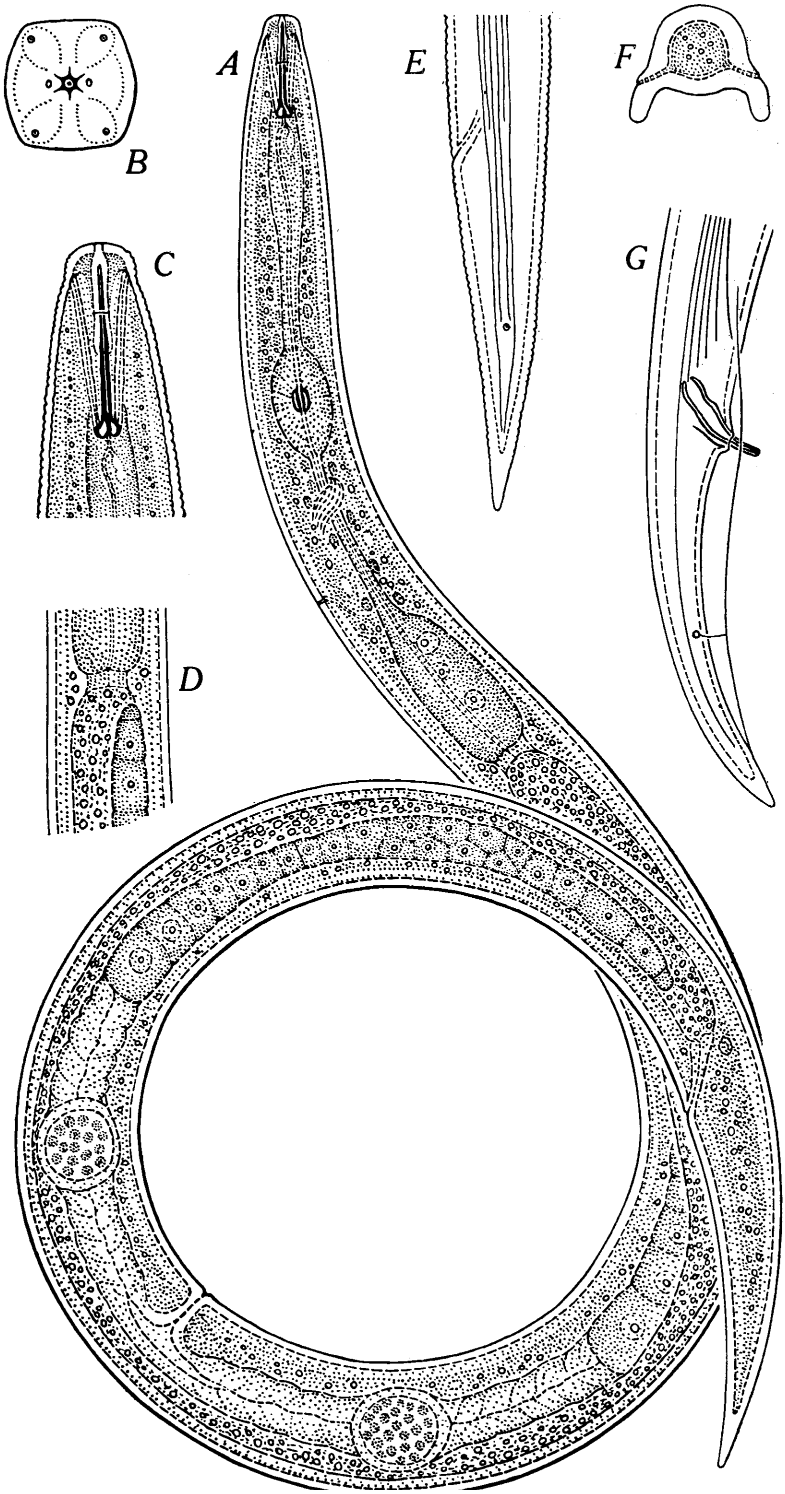
Fig. 6, A–G

♀: 0.7 mm; $a = 30$; $b = 4.5$; $c = 9.4$; $V = {}^{31}55^{38}$

♂: 0.6 mm; $a = 30$; $b = 4.5$; $c = 9.0$; $T = 70$

Cuticle finely striated. Lateral fields marked by six minute incisures. Deirids about opposite base of esophagus. Phasmids of both sexes slightly posterior to middle of tail. Lip region set off by a slight narrowing of the body contour, marked by six fine striae. There is no sclerotized cephalic framework. Spear about 15 μ long, its protrudor muscles attached to refractive elements at the side of the head. From a face view the lip region is seen to be slightly hexagonal. Amphid apertures minute, located close to the oral opening. Four prominent submedian papillae present on the outer contour of the lips; if other papillae were present they were beyond the limits of visibility. Esophagus with elongate-ovate median bulb, long, slender isthmus, and well developed basal bulb containing the usual three esophageal gland nuclei. Cardia discoid. Intestine with scattered fine granules.

FIG. 6. *Tetylenchus joctus.* A—Female; ×750. B—Face view; ×3000. C—Head; ×1500 D—Right side of cardiac region of specimen shown in A; ×750 E—Cuticle pattern of female tail; ×750. F—Cross section through male tail in phasmid region; ×1500. G—Cuticle pattern of male tail; ×750.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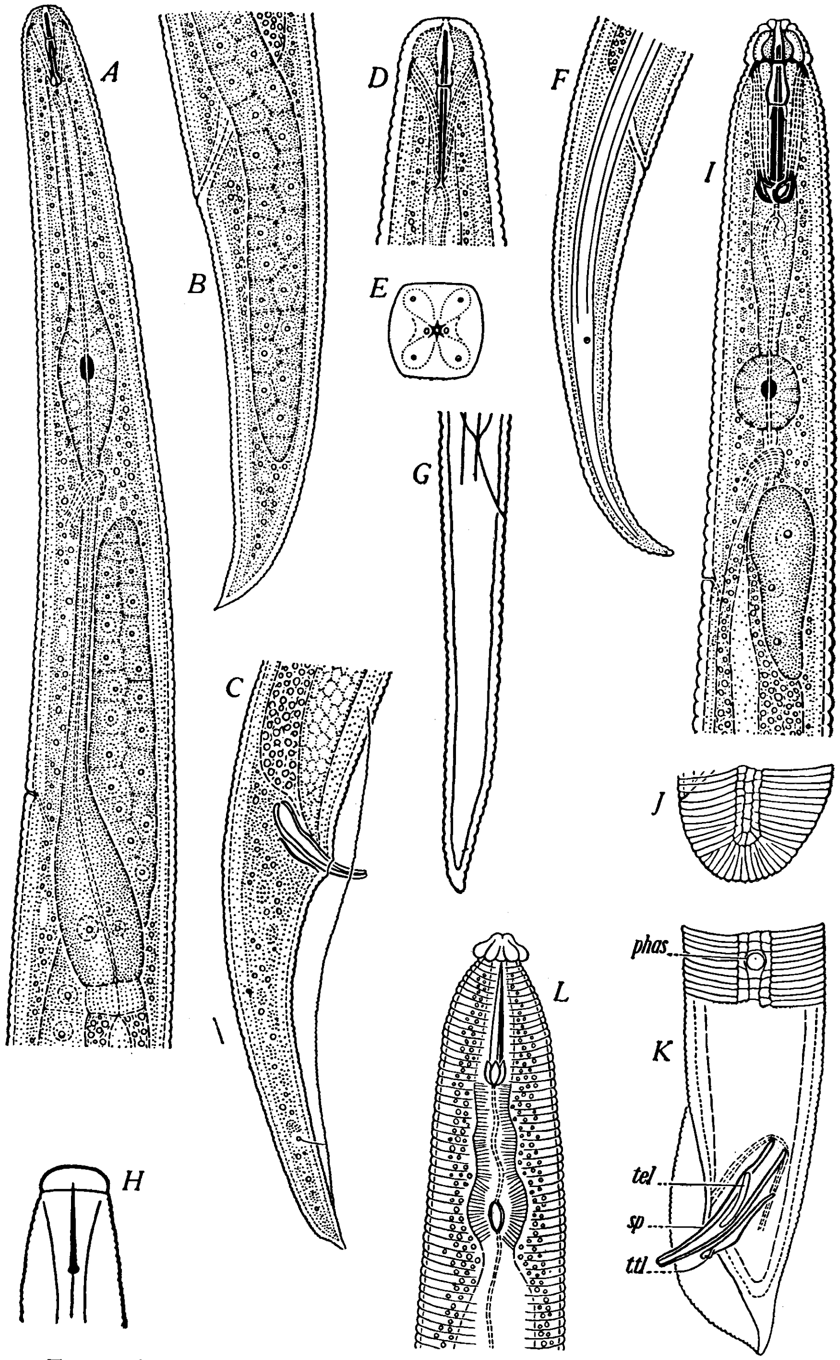


FIG. 7. A–C—*Tetylenchus productus.* A—Anterior portion of body; ×800. B—Female tail; ×800. C—Male tail; ×800. D–F—*Tetylenchus abulbosus.* D—Head; ×1200. E—Face view; ×1600. F—Female tail; ×600. G, H—*Tetylenchus tenuis.* G—Female tail. H—Head. After Micoletzky. I–K—*Hoplolaimus coronatus.* I—Anterior portion of body; ×400. J—Cuticle pattern of female

Vulva a transverse slit. Anterior ovary extending almost to base of esophagus, posterior reaching almost to rectum. The specimens were not yet gravid, but had they been fully developed and producing eggs the ovaries doubtless would have been even longer. A conspicuous feature in each uterus was the spherical spermatheca. Oöcytes arranged in single file except for the usual short region of multiplication. Spicula tylenchoid, with thin, trough-like gubernaculum. Bursa subcaudal, an accentuated stria extending from the phasmid to the border of the bursa.

Diagnosis.—*Tetylenchus* with the above measurements and general description. Distinctive because of lip region set off by slight narrowing of body contour; terminus of tail subacute; lateral fields marked by six incisures; phasmids slightly posterior to middle of tail; spear about 15 μ long with small but distinct basal knobs. Spermatheca spherical.

Habitat.—Soil about roots of grass and weeds, Wrangell, Alaska, collected by Miss Jocelyn Tyler, August, 1932. The letters *joc* and *t* from her name are used as a root for the specific designation *joctus.*

Tetylenchus productus, new species

Fig. 7, A–C

♀: 1.2 mm; $a = 25$; $b = 7.1$; $c = 17$; $V = {}^{45}53^{42}$

♂: 1.0 mm; $a = 33$; $b = 7.1$; $c = 14$; $T = 72$

Body tapering both ways from near the middle. Head rounded, the lips not set off in any manner. Terminus acute, sometimes almost mucronate. Lateral fields marked by six incisures that are generally easy to see. Deirids about opposite base of esophagus. Phasmids of female slightly posterior to middle of tail; on male about two-thirds the distance from anus to terminus. Lip region without sclerotized framework, the protrudor muscles of the spear attached to sclerotized elements at the side of the head. From a face view the vestibule is seen to be slightly sclerotized with six minute radiating elements. Amphid apertures very minute, located close to the oral opening. Four submedian cephalic papillae were easily seen but the others were either absent or beyond the limits of visibility. Spear about 12 μ long, slender, with small basal knobs. Median bulb of esophagus elongate with small valvular apparatus. Isthmus long and slender, ending in an elongated bulb with the three gland nuclei grouped more closely together than is usual. Cardiac valvular apparatus about one-third as wide as the body. Intestine with small scattered granules. Vulva a broad, transverse slit. Ovaries a conspicuous feature of the body, the anterior one frequently extending well past the base of the esophagus while the posterior may reach far into the tail. Adjacent to the cap cell the ovary appears to be made up of about four lines of developing oöcytes which may be arranged about a rachis, but this point was not definitely determined. Following this region of multiplication the oöcytes are arranged in the usual single file.

Habitat.—A single collection from hillside soil near mouth of Ogden Canyon, Utah. Three other attempts to find specimens in the same locality have failed.

Tetylenchus abulbosus, new species

Fig. 7, D–F

♀: 1.0–1.4 mm; $a = 39$; $b = 6.6–7.4$; $c = 10$; $V = {}^{34}52^{30}$

Lip region rounded, striated, not set off from body contour. Body striae varying from 1 to 2 μ apart. Lateral fields about one-third body width, appearing as

tail; ×400. K—Longitudinal section through male tail showing telamon, *tel,* gubernaculum, *gub,* right spiculum *sp,* and titilla, *ttl.* Upper portion shows cuticle pattern and left phasmid, *phas;* ×400. L—*Hoplolaimus tylenchiformis.* After Daday.

bright, refractive crenate bands marked by two fine incisures. Deirids about opposite base of esophagus. Phasmids near ventral side of lateral fields. Cephalic framework not visible. Face view shows lip region laterally constricted with amphid apertures located close to oral opening. Spear slender without basal knobs, its protrudor muscles attached to sclerotized elements at sides of head. Distance from anterior end to valve of median bulb equal to two-thirds that from valve to base of esophagus. Esophagus with elongate-ovate median bulb, long slender isthmus and elongate pyriform basal bulb. Cardia disc-like. Intestine with coarse scattered granules. Ovaries outstretched with oöcytes arranged in single file except for a short region of multiplication. Eggs about twice as long as body diameter. Males unknown but females contained spermatozoa, indicating that males do exist.

Diagnosis.—*Tetylenchus* with the above measurements and general description. Distinctive because of the rounded, striated lip region, continuous with body contour. Spear without basal bulbs. Tail arcuate to the small bluntly conoid, subacute terminus. Lateral field a broad refractive crenate band with two obscure incisures. Phasmid located near the ventral border of the lateral field.

Habitat.—A single collection made from soil in a wheat field near Downey, Idaho, by C. W. McBeth, March 7, 1936.

Tetylenchus tenuis (Micoletzky, 1922) Filipjev, 1936

Synonyms.—*Tylenchus tenuis* Micoletzky, 1922; *Anguillulina tenuis* (Micoletzky, 1922) Goodey 1932.

Fig. 7, G, H

♀ : 0.69 mm; a = 47.7; b = 3.8; c = 11.2; ^{24} 52 ^{23}

Body slender, tapering toward both ends. Striae about 1.5 μ apart near middle of body; 0.7 μ toward anterior end. Lateral fields distinct, about one-fourth the body width. Head slightly set off, convex, without papillae. Spear short, weakly knobbed. Esophagus very long with elongated bulbs. Nerve ring and excretory pore two-fifths the distance from anterior end to base of esophagus. Esophagus distinctly set off from intestine. Anus indistinct, rectum longer than anal body diameter. Ovaries paired and symmetrical. Tail bluntly conoid. Male unknown.

Habitat.—Alpine moss, Steiermark, Zirbitzkogel, Austria, at about 1,800 meters elevation.

Genus *Psilenchus* deMan, 1921

Diagnosis emended.—Tylenchidae with prominent striae on both cuticle and subcuticle. Lip region, without a sclerotized frame-work. Amphid apertures elongated, slit-like, conspicuous; located well below the contour of the lip region. Spear elongated, slender, with or without basal knobs; the protrudor muscles attached to lateral sclerotized plates. Outlet of dorsal esophageal gland very close to base of spear. Deirids prominent, located near the latitude of the nerve ring. Phasmids generally easily observed, situated two to five body-widths posterior to the anal region. Lateral fields with incisures or, rarely, consisting of plain refractive bands. Tails of both sexes elongated, filiform; frequently clavate. Distance from anterior end of body to center of median esophageal bulb greater than that from center of bulb to base of esophagus, except in *Psilenchus magnidens* in which these measurements are about equal. Esophagus with distinctly set off pyriform basal bulb. Cardia well developed, discoid to pyriform. Ovaries one to two, outstretched; the developing oöcytes arranged in single file. Testis single with spermatocytes in single file. Spicula tapering, arcuate, cephalated. Gubernaculum thin, trough-like, slightly curved.

Members of this genus are immediately distinguished by the elongated, slit-like amphid apertures; slender, frequently clavate tails of both sexes; prominent deirids and phasmids; elongated spears; absence of a sclerotized labial frame-work and by the fact that the distance from the anterior end to the center of the median bulb is equal to, or greater than, the distance from the center of the bulb to the base of the esophagus.

Specimens of *Psilenchus* are found widespread in cultivated and virgin soils of the Western United States but usually in small numbers. The divergent species here presented indicate that eventually the group will merit a family rank.

Key to species of Psilenchus

1. Terminus bulbous or clavate; two ovaries present 2
   Terminus filiform, one ovary present 4
2. Lip region plain, not striated 3
   Lip region distinctly striated .... *striatus*, n. sp.
3. Spear with small basal knobs .... *clavicaudatus* Micol.
   Spear without basal knobs .... *hilarulus* deMan
4. Spear plain without basal knobs .... *magnidens*, n. sp.
   Spear with distinct basal knobs 5
5. Spear straight, knobs symmetrical .... *gracilis*, n. sp.
   Spear curved, knobs asymmetrical .... *aberrans*, n. sp.

Psilenchus hilarulus deMan, 1921
Fig. 8, A–G

♀: 1.1–1.5 mm; $a = 33–38$; $b = 6.5–7.1$; $c = 8.0–8.5$; $V = {}^{32}47^{32}$

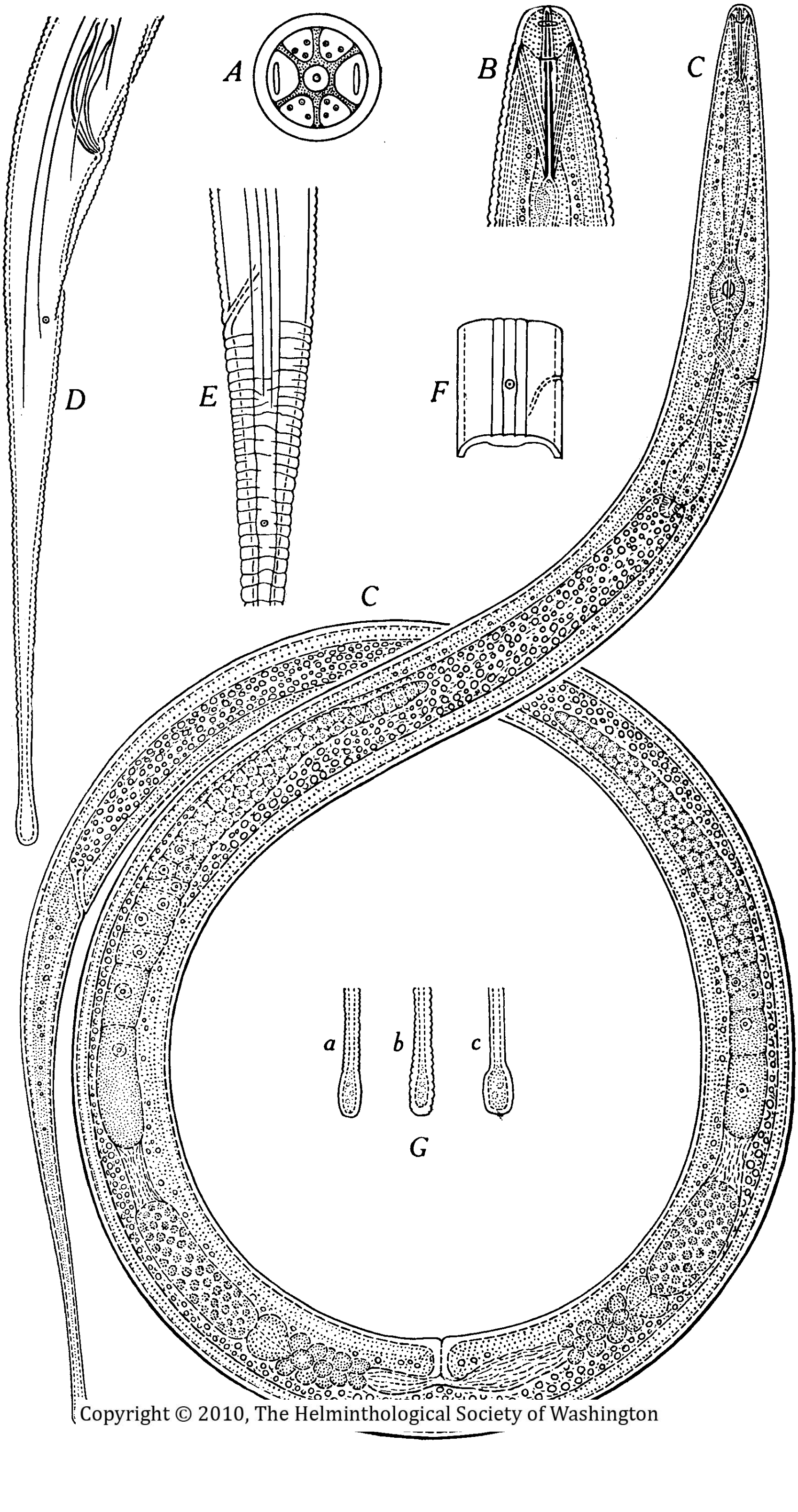
♂: 1.0–1.2 mm; $a = 32–36$; $b = 6.0–6.8$; $c = 6.0–6.6$; $T = 42$

Cuticle marked by striae which average about 1 μ apart near the head, slightly less on the body proper and generally much finer on the tail, although occasionally specimens occur on which the caudal striae are variable in width and sometimes extend completely to the terminus as described by deMan for his type specimens. Lateral fields marked by four incisures except near the head and on the tail where they are reduced to two. Deirids prominent, opposite the nerve ring. Phasmids easily seen two or three body widths posterior to the anus. The elongated tails taper to the terminus which varies from cylindrical to clavate. (Fig. 8, G.) Amphid apertures elongate, slit-like, located below contour of lips. From a face view the lateral sectors of the head are observed to be widened to make room for these broad amphids. Three papillae were observed on each of the four submedian head sectors but none was seen on the lateral ones. The slender spear is devoid of basal knobs, the protrudor muscles being attached to the walls of the posterior portion. The dorsal esophageal gland opens into the lumen of the esophagus at the base of the spear. Median bulb ovate with conspicuous valvular apparatus; posterior bulb pyriform with the usual three gland nuclei. Excretory pore opposite the nerve ring. Cardia conoid, submerged in the anterior end of the intestine. Lumen of intestine narrow with distinct walls. Intestinal granules of variable size, usually densely packed.

Vulva a transverse slit. Ovaries paired, outstretched. Spicula curved, tapering, cephalated, resting on a plain, thin, trough-like gubernaculum. Bursa crenate, rising near a point about opposite the proximal ends of the spicula and extending past the anus a distance equal to about twice the anal body diameter. Male phasmids located near the posterior ends of the bursa.

This species is readily distinguished among the didelphic forms by the unstriated lip region and slender, knobless spear.

Habitat.—Type specimens described by deMan from moist soil on bank of River Mark near Breda, Netherlands. A rather rare inhabitant of virgin and culti-


A
B
C
D
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vated soils from numerous points in Utah; sugar beet field, Fort Collins, and alfalfa field, Grand Junction, Colorado; potato field, Aberdeen, Idaho; and cotton fields near Bard and Arvin, California. Also collected near Reno, Nevada, by Dr. Merlin W. Allen.

Psilenchus striatus, new species

Fig. 9, D, E

♀: 1.6 mm; a = 35; b = 7.6; c = 14, V = ^{28} 50 ^{28}

Lip region striated, continuous with head contour. Body assuming an open "C" form when killed by gradual heat. Lateral fields consisting of plain, refractive bands, about one-third as wide as body. Deirids conspicuous, located about opposite nerve ring. Phasmids easily observed about two anal body-diameters posterior to anus. Tail elongate clavate to the rounded terminus. Spear, 23 μ long, slender, without basal knobs, the anterior end somewhat expanded with a prominent aperture. Distance from anterior end to valve of median bulb much longer than from valve to intestine, the proportions being about 6: 4. Intestinal cells filled with coarse refractive granules. Vulva a broad depressed slit from which the symmetrical ovaries are outstretched. Anus a depressed transverse slit. Male unknown.

Diagnosis.—*Psilenchus* with the above general description and measurements. Immediately distinguished by the body length, annulated lip region, slender knobless spear with expanded aperture, plain band-like lateral fields and open "C" posture when killed by gradual heat.

Habitat.—One female from soil about roots of walnut trees, Santa Clara, California.

Psilenchus clavicaudatus (Micoletzky, 1922), new combination

Synonyms.—*Tylenchus clavicaudatus* Micoletzky, 1922; *Anguillulina clavicaudata* (Micoletzky, 1922) Goodey, 1932; *Tetylenchus clavicaudatus* (Micoletzky, 1922) Filipjev, 1936.

Fig. 9, L

♀: 1.23 mm; a = 37; b = 10; c = 9.3; V = ^{26} 52.5 ^{26}

Head one-fifth as wide as maximum body width; lip region without sclerotized framework; annules 0.8–1.2 μ wide on body, 2.5–4.0 μ on tail; lateral fields one-seventh as wide as body; spear long, one-sixth the neck length, slightly knobbed at base; intestine with large granules in anterior portion; ovaries paired, symmetrical, outstretched, tail slender with very characteristic clavate terminus.

Habitat.—Pasture land, Bukowina, Czernowitz—Stadt, Austria.

Except for the slightly knobbed spear, this species appears to closely resemble *Psilenchus hilarulus.*

Psilenchus magnidens, new species

Fig. 9, A–C

♀: 0.9 mm; a = 36; b = 6.6; c = 5.6; V = ^{38} 66

Body assuming an almost straight position when killed by gradual heat; lateral fields, deirids and phasmids more difficult to see than they usually are in *Psilenchus;* amphid apertures located near base of lips, about half as long as head width; spear with a broad lumen, without basal knobs and sometimes slightly bent in anterior portion. Distance from anterior end to valve of median esophageal bulb about equal to that from valve to base of esophagus; cardia large, discoid.

FIG. 8. *Psilenchus hilarulus.* A—Face view; ×2600. B—Head; ×1300. C—Female; ×440. D—Male tail; ×660. E—Cuticle pattern of female tail; ×660. F—Deirid region. G—Variations in female terminus: a—Bard, California; b—Reno, Nevada; c—Lewiston, Utah.

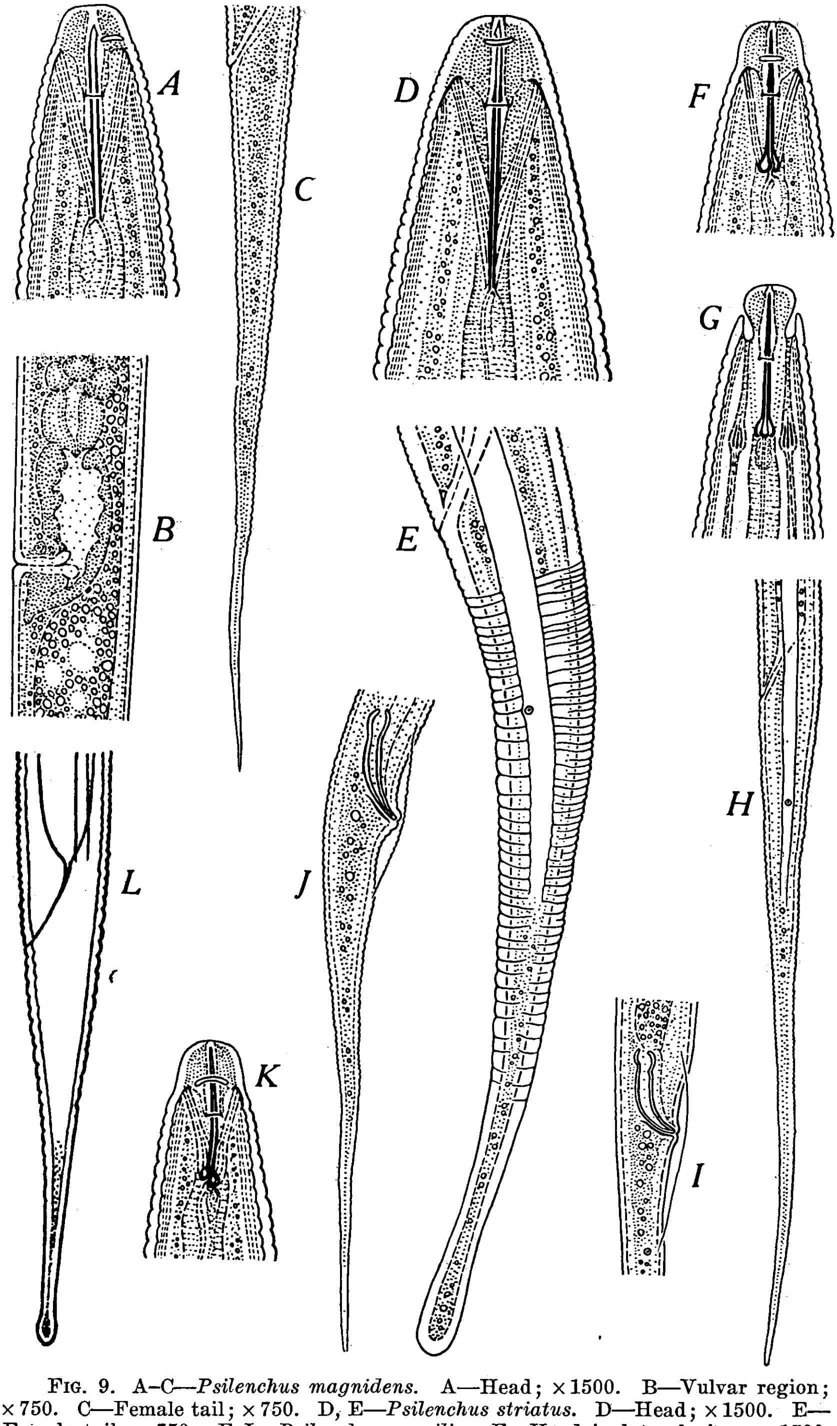

FIG. 9. A–C—*Psilenchus magnidens.* A—Head; ×1500. B—Vulvar region; ×750. C—Female tail; ×750. D, E—*Psilenchus striatus.* D—Head; ×1500. E—Female tail; ×750. F–I—*Psilenchus gracilis.* F—Head in lateral view; ×1500. G—Head in dorso-ventral view; ×1500. H—Female tail; ×750. I—Bursa region of male; ×750. J, K—*Psilenchus aberrans.* J—Male tail; ×750. K—Head; ×1500.

Ovary extending forward nearly to base of esophagus; an egg was about four times as long as body width. Vulva a depressed transverse slit; posterior uterine branch about half as long as body width. Tail tapering uniformly to the acute terminus. Male unknown and a gravid female contained no spermatozoa, therefore males probably are rare or do not occur.

Diagnosis.—*Psilenchus* with the above general description. Immediately distinguished by the broad lumen of the knobless spear.

Habitat.—Alfalfa field near Holladay, a suburb of Salt Lake City, Utah. Also collected from potato field near Reno, Nevada, by M. W. Allen. A young female from soil collected by J. A. Pinchard, State College, Miss., belongs to this, or a closely related, species.

Psilenchus gracilis, new species
Fig. 9, F–I

♀: 0.65 mm; a = 35; b = 6.2; c = 4.8; V = ^{34} 63
♂: 0.62 mm; a = 33; b = 6; c = 6; T = 40

Body assuming a rather straight position when killed by gradual heat. Cuticle marked by the usual distinct striae which are rather uniformly spaced throughout the body, except near the terminus where they become excessively fine and gradually disappear. Lateral fields about one-fourth as wide as the body, appearing as plain bands with only occasionally minute traces of the usual two middle incisures. Deirids and excretory pore about opposite the nerve ring. Phasmids located two or three anal body diameters posterior to the anus. Amphid apertures about half as wide as the head and located at the base of the rounded lip region. Spear very slender with an exceedingly narrow lumen and bearing well developed basal knobs. Median bulb of esophagus ovate with indistinct valve; basal bulb elongate-pyriform. Cardia large, discoid to hemispherical. Distance from anterior end to valve of median bulb only slightly greater than that from valve to base of esophagus.

Vulva a broad depressed slit from which the vagina leads in at right angles. Posterior uterine branch about half as long as body width. Spicula cephalated, curved; gubernaculum, thin, flat, slightly curved.

Diagnosis.—*Psilenchus* with the above general description. Distinctive because of the straight, well knobbed spear; slender tapering tail which is longer than the vulva-anus distance; plain, band-like lateral fields; and rather straight posture of the body when killed by gradual heat.

Habitat.—Cultivated fields near Midvale, Utah. 2♀, 1♂

Psilenchus aberrans, new species
Fig. 9, J, K

♀: 0.66 mm; a = 36; b = 6.0; c = 7.6; V = ^{42} 66
♂: 0.61 mm; a = 32; b = 6.4; c = 7.1; T = 43

Body assuming an open "C" form when killed by gradual heat. Cuticle marked by the usual transverse striae which become excessively fine toward the terminus. Lateral fields about one-third as wide as body with two fine, but distinct, incisures visible the larger part of their length. Excretory pore and deirids about opposite the nerve ring. Phasmids two or three anal-body diameters posterior to the anus. Lip region unstriated. Amphid apertures almost half as wide as head, located near base of lip region. Spear slender, with very fine lumen; slightly bent ventrically in its posterior third. Dorsal knob of spear larger than the submedian and extending somewhat farther back. Median esophageal bulb ovate with obscure valve; posterior bulb elongate-pyriform. Cardia discoid to hemispherical. Vulva a depressed slit from which the vagina extends in at right angles to the body axis. Ovary outstretched. Posterior uterine branch rudimentary, less than half as long as the body width. Spicula arcuate, cephalated; resting on a thin, flat, slightly curved gubernaculum. Bursa rising about opposite proximal ends of spicula and extending back somewhat more than one anal body diameter past the elevated anus. Terminus minutely rounded.

Diagnosis.—Psilenchus with the above measurements and general description. Distinctive because of the slightly curved, asymmetrically knobbed spear, open "C" form of body when killed by gradual heat; and vulva-anus distance greater than tail length.

Habitat.—Sugar beet fields near Fort Collins and Wellington, Colorado, and alfalfa field near Holladay, a suburb of Salt Lake City, Utah.

Genus *Tylenchus* Bastian, 1865

Diagnosis emended.—Tylenchinae. Tails filiform. Lip region striated. Vulva well behind middle of body. Anterior ovary outstretched. Posterior uterine branch short, rudimentary. Bursa short, adanal. Developing oöcytes and spermatocytes usually arranged in single file. Deirids generally prominent, located near the latitude of the conspicuous excretory pore. Phasmids not observed.

Cuticle striated, lateral fields marked by incisures. No sclerotized cephalic framework present. Spear well developed with basal knobs; the protrudor muscles anchored to the cephalic walls. Median esophageal bulb ovate with refractive valvular apparatus. Isthmus long, slender, ending in a somewhat pyriform basal bulb containing the usual three nuclei. Cardia present. Intestinal cells usually packed with coarse granules which obscure details of the cell nuclei.

Type species.—Tylenchus davainii Bastian, 1865.

Tylenchus davainii Bastian, 1865

Synonym.—Anguillulina davainii (Bastian, 1865) Goodey, 1932.

Fig. 10, A–G

♀: 1.0–1.3 mm; $a = 25–35$; $b = 6–7.5$; $c = 5.5–7.2$; $V = {}^{36}65^{2}$

♂: 0.9–1.1 m; $a = 37$: $b = 5.5$; $c = 6$; $T = 46$

Tails elongated, filiform, ventrally bent. Cuticle strongly striated. Lateral fields with crenate borders, marked by two incisures. Deirids prominent, located near the latitude of the sclerotized excretory pore. Phasmids not observed, either absent or beyond the limits of visibility. Lip region striated, set off by a slight narrowing of the body contour. Spear strongly knobbed with protrudor muscles attached to the walls of the head. From a face view the amphids were observed to be located near the margin of the lateral lips, and a single papilla was seen on each of the four submedian lips. Median esophageal bulb ovate with refractive valve. Isthmus slender, ending in a somewhat pyriform bulb which contains the usual three gland nuclei. Cardia conoid. Anterior cells of intestine hyaline, but the remainder of the cells are packed with coarse dark granules.

Vulva a depressed slit. Anterior ovary outstretched with oöcytes usually arranged in single file. Posterior uterine branch rudimentary, shorter than the body diameter. Spicula of the usual tylenchoid type. Gubernaculum thickened near the middle. Bursa crenate, about three times as long as the anal body diameter. Testis single, outstretched, with spermatocytes arranged in single file.

Description derived from specimens collected in Ogden Canyon, Utah. A widely distributed species from valley and mountain soil of the western states.

Genus *Ditylenchus* Filipjev, 1934

Diagnosis emended.—Tylenchinae. Ovary single. Rudimentary posterior

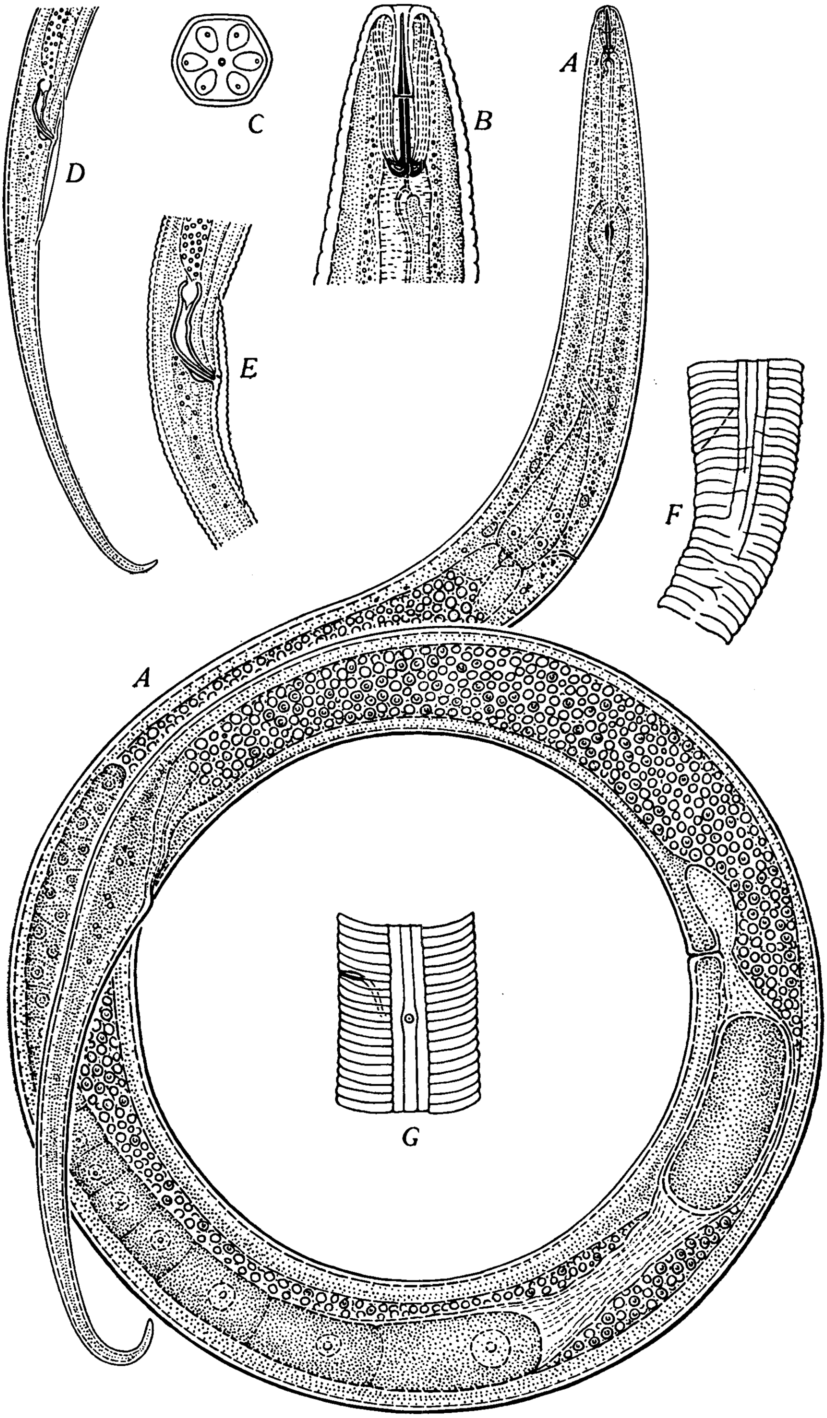

FIG. 10. *Tylenchus davainii.* A—Female; ×400. B—Head; ×1200. C—Face view; ×1600. D—Male tail; ×400. E—Bursa region; ×800. F—Cuticle pattern of female anal region. G—Cuticle pattern of deirid region.

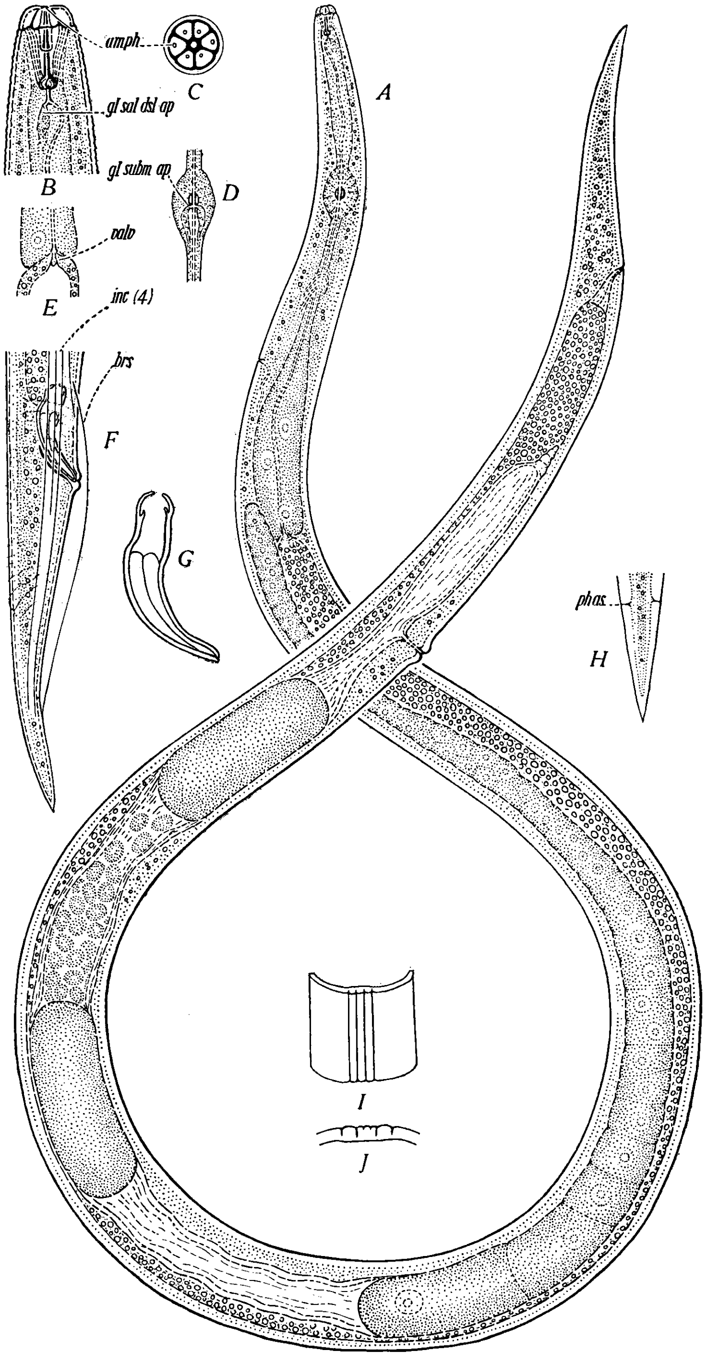

FIG. 11. *Ditylenchus dipsaci.* A—Adult female; ×330. B—Head of female; *amph,* amphid; *gl sal dsl ap,* aperture of dorsal salivary gland; ×1000. C—Face view showing arrangement of amphids and 4 labial papillae; *amph,* amphid; ×1000. D—Dorsal view of median esophageal bulb; *gl subm ap,* apertures of sub-

uterine branch present. Lip region plain, not annulated. Gonad cells in one or two lines, not arranged about a rachis. Lateral fields marked by four or six incisures. Basal portion of esophagus a distinct bulb, occasionally with a short lobe extending back over anterior end of intestine. Deirids small but usually visible. Phasmids exceedingly minute if visible at all. Bursa enveloping one-fourth to three-fourths of the tail. Tails elongate-conoid to an acute or sub-acute terminus.

Type species.—Ditylenchus dipsaci (Kühn, 1857) Filipjev, 1936.

Ditylenchus dipsaci (Kühn) Filipjev, 1936

Synonyms.—See Thorne, 1945.

Fig. 11, A–J

♀: 1.0–1.3 mm; a = 36–40; b = 6.5–7.1; c = 14–18; V = $^{60-70}$ 80 ^{7}

♂: 1.0–1.3 mm; a = 37–41; b = 6.5–7.3; c = 11.5–14.5; T = 65–72

Body marked by transverse striae about 1 μ apart which are easily visible under the oil immersion at any point on the body. Lateral field marked by four incisures; cross sections of the body from certain favorable specimens show the center element is marked by two minute incisures which may indicate that an ancestor once possessed six (Fig. 11, J). Deirids usually visible near base of neck. Phasmids exceedingly obscure and visible only from a dorsal or ventral view on favorable specimens. Amphid apertures located on the apices of the lateral lips where they appear as minute refractive dots which are best seen from a face view (Fig. 11, B, C). Spear with strongly developed knobs from which protrudor muscles lead to the well-sclerotized labial framework. Basal bulb of esophagus with the usual three prominent gland nuclei. Anterior end of intestine extending into the base of esophagus where it joins the lumen with a very small muscular valvular apparatus.

The outstretched ovary sometimes reaches as far as the median bulb of the esophagus but more generally ends near the basal bulb; rarely reflexed. The developing oöcytes largely lie in tandem and develop into eggs which are from 2 to 3 times as long as the body width. The rudimentary posterior uterine branch extends about half-way back to the anus. Vulva-anus distance equal to from 1¾ to 2¼ times the length of the tail. Terminus always acute

Testis outstretched with spermatocytes arranged in single file except in a short region of growth. From a perfectly lateral view the spicula exhibit a sclerotized pattern that apparently is characteristic of the species, but the proper angle of observance is so difficult to obtain on the various specimens that this pattern rarely is of taxonomic help (Fig. 11, G). Bursa well developed, rising about opposite the proximal ends of the spicula and extending about three-fourths the length of the tail. Lateral incisures forming a pattern similar to that illustrated (Fig. 11, F).

Diagnosis emended.—Obligate plant-parasitic *Ditylenchus* with the above measurements and general description. Lateral field marked by four incisures; base of esophagus extending but slightly over the anterior end of the intestine; gonads outstretched, their cells lying in tandem. Eggs two to three times as long as the body diameter. Spicula with characteristic pattern as figured. Terminus acute.

Type host.—Dipsacus fullonum, fuller's teasel.

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median esophageal glands; ×500. E—Junction of intestine and esophageal lumen; *valv*, muscular valvular apparatus in anterior end of intestine; ×500. F—Posterior portion of male; *inc*, 4 incisures of lateral field; *brs.* bursa; ×500. G—Spiculum; ×1000. H—Terminus; *phas*, phasmid (much exaggerated); ×500. I—Section of cuticle at mid-body showing 4 incisures; ×330. J—Cross section of lateral field (note the 2 minute incisures in the central element); ×1000.

Genus *Anguina Scopoli*, 1777[5]

Diagnosis emended.—Tylenchinae. Robust, stout species with female body generally arcuate or spiral in form. Cuticle marked by fine striae which frequently are visible only on the neck and lip region. Lateral fields appearing as plain bands or as bands bearing four or more minute incisures. Deirids and phasmids not observed. Lip region distinctly set off with amphid apertures appearing as minute refractive elements at the apices of the lateral lips. Six minute papillae surround the oral opening with four submedian ones located on the outer margins of the submedial lips. Spear small with well developed basal knobs. Median bulb of esophagus with distinct valvular apparatus; basal bulb made up of glandular tissues which frequently may become greatly swollen and irregular in form. Ovary extending forward, generally with one or two flexures. Oöcytes in multiple series, arranged about a rachis. Posterior uterine branch rudimentary. Spicula joined together, arcuate, without definite cephalation, the blades generally as wide, or wider than the haft. Gubernaculum trough-like, slightly curved. Testis with spermatocytes developing in multiple rows about a rachis. Bursa enveloping tail or nearly so. Typical parasites of the seeds and stems of plants.

Anguina is distinguished from *Ditylenchus* by the caudal bursa, multiple rows of oöcytes and spermatocytes arranged about the rachis, more robust, amalgamated, wider spicula, and by the distended, almost immobile bodies of the females.

Anguina tritici (Steinbuch, 1799) Filipjev, 1936
Fig. 12, A–J

♀: 3.8 mm; $a = 20$; $b = 13$; $c = 31$; $V = {}^{83}91^{3}$

♂: 2.4 mm; $a = 25$; $b = 9$; $c = 30$; $T = 80$

Obligate plant parasite with obese body; that of the female being spiral in form and largely immobile, while the male generally is more active. Striae usually visible only on the neck region. Lateral fields indistinct, consisting of narrow bands marked by numerous minute incisures. Spear greatly reduced with small basal knobs. Esophagus of gravid female frequently with grossly developed glandular structures as shown (Fig. 12, A). Between the nerve ring and the basal bulb is a secondary ''storage'' gland, set off from the bulb by a definite constriction, in which the dorsal gland secretions apparently collect until it may become greatly distended; or the secretions may be used and the gland reduced to a small ovate swelling. Cardia small, often obscure. Ovary greatly developed with one or two flexures, the oöcytes arranged about a rachis. In cross section the ovary appears as pulpy cellular tissue surrounded by a relatively thin layer of developing oöcytes (Fig. 12, J). A spherical spermatheca lies adjacent to the outlet of the ovary, and the posterior uterine branch also serves as a spermatheca. Several eggs may be present at one time in the oviduct, each about as long as the vulva body width.

Testis with one or two flexures, the spermatocytes arranged about a rachis. Spicula broad, short, amalgamated; the only instance of amalgamation observed in the Tylenchidae. Gubernaculum thin, trough-like. Bursa enveloping tail.

The above description based on specimens from infested wheat collected in Georgia by Mr. A. L. Taylor.

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[5] Chitwood (1935) reestablished *Anguina* as a valid genus and made *Anguillulina* Gervais and van Beneden a synonym, in accordance with the international rules of zoological nomenclature which do not invalidate old genera which were described without mention of a specific name.

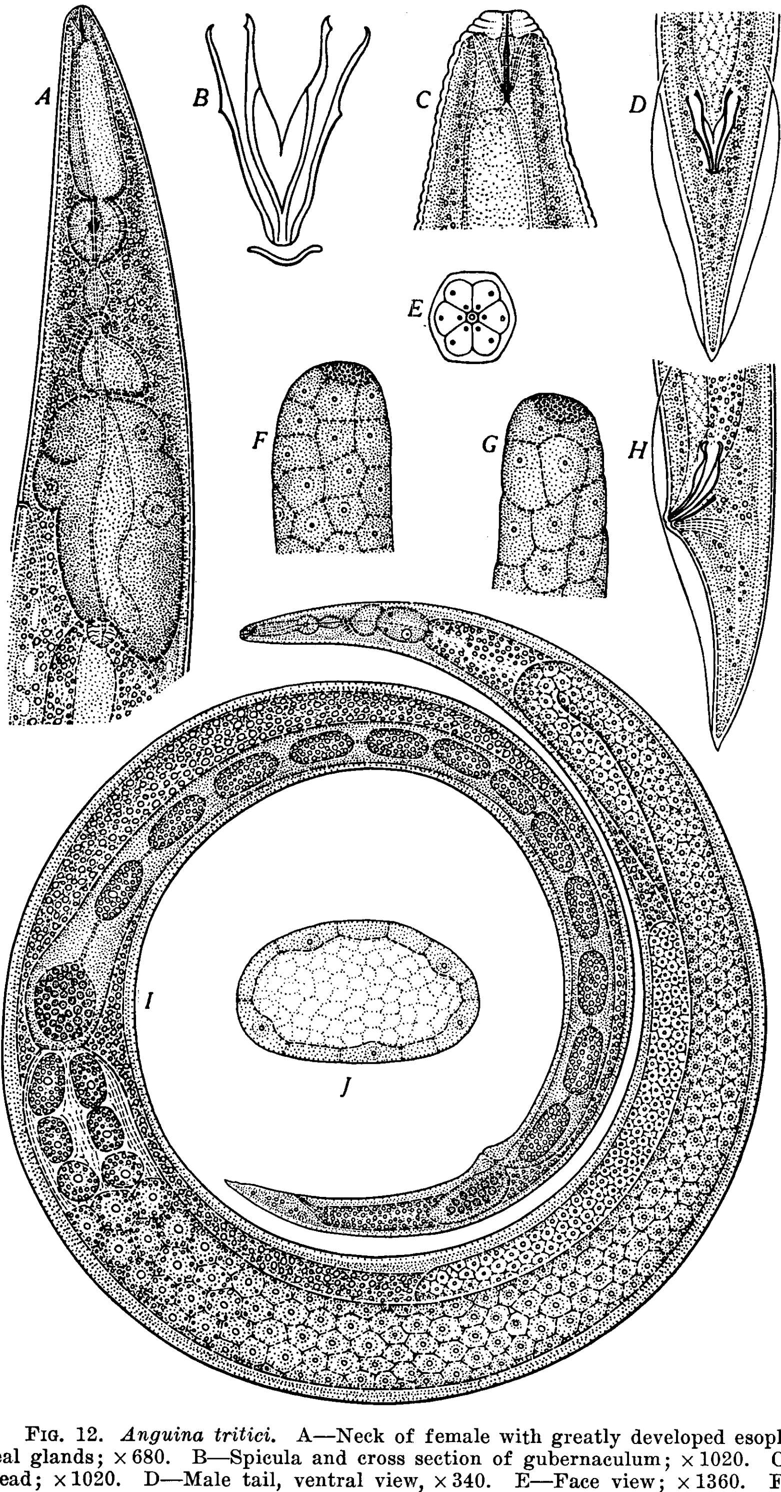

FIG. 12. *Anguina tritici.* A—Neck of female with greatly developed esophageal glands; ×680. B—Spicula and cross section of gubernaculum; ×1020. C—Head; ×1020. D—Male tail, ventral view, ×340. E—Face view; ×1360. F—End of ovary [illegible]; ×340. H—Male tail, [illegible]; ×1020.

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Studies on Potential Snail Hosts of *Schistosoma japonicum*. I. Notes on the Amnicolid Snails *Blanfordia, Tricula* and a New Genus, *Fukuia* from Japan

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INTRODUCTION

During World War II considerable attention was devoted to schistosomiasis japonica. This was inevitable, since the disease was known to be endemic in the Philippines, Japan and China. Not only was the epidemiology of the disease restudied and evaluated in both the Philippines and Japan (Sullivan and Ferguson, 1946; Faust, Wright, McMullen and Hunter, 1946; Wright et al. 1947; Hunter, Dillahunt and Dalton, MMS) but also the ecology of the known snail intermediate hosts was investigated (McMullen, 1947; Abbott, 1945, 1946, 1948, 1948a, 1948b; Hunter, Bennett, Ingalls and Greene, 1947). The Armed Forces also published various data on these areas. One such (TB Med 160) stated that Fukui Prefecture on Honshu Island was reported to be a schistosomiasis area. If this were so, then it constituted a new endemic center for the disease. Consequently, it was decided to make an epidemiological survey in Fukui Prefecture to

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determine, among other things, the presence or absence of schistosomiasis (Hunter, Ritchie, et al. 1948 and MMS).

In addition to *Oncomelania nosophora* (Hobson), four species of amnicolid snails were collected in Japan which were looked upon as potential hosts of *Schistosoma japonicum.* These were forwarded alive and preserved in alcohol to the U. S. National Museum for further study by the senior author of this paper. Observations were made on the living animals and dissections made for anatomical details. In addition, their habitat ecology was studied in the field. The four species included *Blanfordia simplex* Pilsbry, *Tricula minima* (Bartsch) (+ *Schistosomophora minima*), and a new genus containing two undescribed species. The discovery in Japan of a new genus of mollusks, *Fukuia,* which resembles *Oncomelania nosophora,* the only demonstrated intermediate snail host of schistosomiasis in those islands, adds to the difficulties of the epidemiologists and parasitologists. Surveys for disease-carrying snails or infection experiments cannot be carried out successfully unless the various species of snails are readily recognizable by the investigator. With so many innocent species possessing shells which superficially resemble those carrying disease, mollusk students have turned more and more to animal characters such as length of tentacles, shape of copulatory organ, number of gill lamellae, and so forth. Although this is a healthy departure from the old-fashioned approach in which shell characters alone were used and in which radulae were worshipped as unvarying and infallible earmarks to speciation, care must be taken not to over-emphasize the newly championed anatomical methods. An attempt had been made here to utilize all useful morphological features.

Shells are undoubtedly the most indicative and the most useful characters for species determination, but they often fail as clues to generic and higher categories and even to species. This is especially true in such distantly related genera as *Oncomelania, Syncera, Blanfordia* and *Paludinella* where convergent evolution has expressed itself in the simplification of shells. Here, animal characters, and sometimes radula structure, are the only reliable earmarks of the genus. In addition, it should be noted that verges, mantle patterns, gill lamellae, like radulae, are also prone to considerable variation. The present trend is to consider all characters.

BLANFORDIA A. Adams 1863

Blanfordia A. Adams 1863, Ann. Mag. Nat. Hist., ser. 3, **12**: 424, pl. 7, figs. 11–12 (Genotype: *Tomichia bensoni* Adams by subsequent designation of Nevill 1878, Hand list, p. 254).

Vicina Pilsbry 1924, Proc. Acad. Nat. Sci. Phila., **76**: 12 (subgenotype: *Pomatiopsis hirasei* Pils. = *B. bensoni* Adams).

Vicinia Bequaert 1934, Jour. Parasit., **20**(5): 282 (error for *Vicina*).

There are four recognized species in the Japanese genus *Blanfordia,* namely *japonica* (A. Adams) from Sado Island, *bensoni* (A. Adams) from Hokkaido Island, *simplex* Pilsbry and *integra* Pilsbry from Honshu Island. For the first time, an adequate description of the animal and habitat is given here for *Blanfordia.* Although this genus is now known to belong rightfully to the family Amnicolidae and the subfamily Hydrobiinae, its relationship to the American *Pomatiopsis* is shown to be rather distant. Abbott (1948a) described in detail the snail, *Pomatiopsis,* and assigned it to *Hydrobiinae.* It is shown to be very closely allied to *Oncomelania.* This eliminated the subfamily *Pomatiopsiinae.* The present observations and experiments bear out the earlier contentions of Annandale (1924) and Bartsch (1936) that the genus *Blanfordia* is not to be considered an intermediate host of schistosomiasis.

Blanfordia simplex Pilsbry, 1902
(Plate 1, fig. 3, plate 2, figs. 1–3, 6)

Blanfordia japonica var. *simplex* Pilsbry 1902, Proc. Acad. Nat. Sci., Phila. **54**: 26–27 (Nishigo, Uzen, Japan)

Blanfordia simplex Pilsbry, Bartsch, 1936, Smith. Misc. Coll. 95(5): 14–15, pl. 1, fig. 10, pl. 2, fig. 4, pl. 3, fig. 6.

Blanfordia japonica echizenensis Kuroda 1933, Venus 4(3): 173 (Echizen) *nude name.*

Shell.—Small, about 6 to 7 mm. in length, elongate-ovate, thin, semitranslucent, and colored a yellowish brown to light brown. Nuclear whorls usually eroded. Postnuclear whorls 4 to 5, well rounded. Suture strongly indented. Aperture obliquely ovate. Lip thickened, behind which on the outside of the last whorl is a moderately developed varix. Peristome adnate to the parietal wall, bordered by a thickening of dark brown periostracum. Umbilicus fairly well developed, round, and partially obscured by the columella. Axial sculpture consists of numerous irregularly spaced and sized growth lines. Spiral sculpturing absent, although fine spiral streaks of lighter and darker color often give the illusion of spiral sculpture lines. The interior of the aperture in some specimens is slightly stained with dark brown. Operculum thin, chitinous, translucent tan and paucispiral. Radula formula $\frac{1-1-1}{3-3}$ or $\frac{2-1-2}{3-3}$; 2–1–3 or 1–1–3; 5–6; 6. Bartsch (1936) has also given $\frac{2-1-2}{4-4}$; 2–1–3; 7; 6 which is well within the range of variation shown in similar species.

Animal.—Small with a simple foot which, however, appears divided when the animal is progressing out of water. Animal a pale yellowish brown. The upper section of the foot, below the head and back, bears on each side a prominent groove or concave channel which runs back from the point where the proboscis and foot join. Proboscis fairly long, bilobed in front. Eye peduncles well developed with a short, stubby, triangular tentacle projecting forward 45° to the axis of the proboscis. Heavy, yellow color granules are clumped laterally and posteriorly to the small black eye. Proboscis lightly dusted with gray. Red tinge shows through from the buccal mass. Foot grayish, with minute yellowish dots on the sides. Mantle cream with varying amounts of black, cobweb mottlings. Gill lamellae very much reduced, only 10–12 in number. Verge in adult males a simple curved prong with strong serrations on the inner, concave edge. Tip blunt, tinted with rose. The serrations are absent in small, immature males.

Ecology and Habits.—*Blanfordia simplex* Pilsbry is found along the wooded coastal regions near the Japan Sea. Its habitat consists of damp, decomposed thatch, or masses of leaves and straw found on the soil around stones, rocks and boulders. These snails apparently require little moisture as the environment was not muddy or particularly damp. Furthermore, the habitat was on a hillside where the run-off of rain water was rapid. Because of their habitat, it was obvious that they could not play a role in the transmission of schistosomiasis.

TRICULA Benson 1843

Tricula Benson 1843, Calcutta Journ. Nat. Hist., 3(12): 467. (Genotype: *Tricula montana* Benson).

Hypsobia Heude 1890, Men, Hist. Nat. Emp. Chinois, p. 173, pl. 33, fig. 12. (Genotype. *Hypsobia humida* Heude). Typo. error, *Hypsobya,* on plate.

Tricula Benson, Prashad 1921, Rec. Ind. Mus., **22**: 67.

Tricula Benson, Annandale 1924, Amer. Journ. Hyg., Monogr. 3: 278–280.
Tricula Benson, Rao 1928, Rec. Ind. Mus., 30: 431.

This is a genus of very small freshwater mollusks which has a wide distribution in eastern Asia. A half dozen species have been described from India, Burma and China. Examination of living specimens of "*Schistosomorphora*" *minima* Bartsch has led the authors to include that species in the genus *Tricula*. The genus is related to *Oncomelania*, but its shells differ in being extremely small, with hardly a trace of an umbilicus and no strong varical thickening. The animal of *T. minimi* (Bartsch) has slender tentacles and yellow color granules behind the eyes. It differs from *Oncomelania* in having 28–30 gill lamellae instead of about 60. *Tricula* species are inclined to be more aquatic than *Oncomelania*.

Tricula minima (Bartsch, 1936)
(Plate 1, figs. 7 and 8)

Schistosomophora minima Bartsch 1936, Smiths. Misc. Coll., 95(5): 33–34, pl. 1, fig. 9, pl. 2, fig. 7, pl. 3, fig. 3 (Noto, Honshu, Japan).

Shell.—Adults very small, about 3 mm. in length, ovate-conic in shape, although in the majority of specimens the eroded spire gives the shell a squat appearance. Color of shell a semitranslucent light brown or in some colonies stained green from algal growths. Whorls convex. Suture well indented. Nuclear whorls smooth. Umbilicus weakly developed or absent. Axial sculpture consists of very weak lines of growth. Spiral sculpture absent. Aperture obliquely ovate. Peristome sharp, fragile, occasionally exhibiting a slight thickening, adnate to the parietal wall. In older specimens, peristome marked by a dark brown, periostracal line. Operculum, thin, translucent, paucispiral. Radula formula of Hirase's specimens from Noto at the Museum of Comparative Zoology, Harvard: $\frac{1\text{–}1\text{–}1}{2\text{–}2}$ and $\frac{2\text{–}1\text{–}2}{2\text{–}2}$; 3–1–3 and 2–1–3; 12–13; 7–9. Fresh material from Nanao gave: $\frac{2\text{–}1\text{–}2}{2\text{–}2}$; 2–1–3 and 3–1–3; 11–13; 8–9. Bartsch gave $\frac{2\text{–}1\text{–}2}{2\text{–}2}$; 2–1–3; 9; 6. Re-examination of his type slide gave $\frac{2\text{–}1\text{–}2}{2\text{–}2}$; 2–1–3; and 3–1–3; 10–12?; 9?;

Measurements of shell in mm:

length	width	no. of whorls	shells not eroded
2.8	1.4	5.2	U.S.N.M. 488541
2.5	1.3	5.0	
2.9	1.5	4.7	U.S.N.M. 488542

length of last whorl	width	spire missing
2.1	1.9	U.S.N.M. 488541
2.2	1.8	
2.0	1.6	
2.2	1.8	
2.5	1.8	
2.5	2.1	U.S.N.M. 420950 (holotype)
2.4	2.0	U.S.N.M. 346039 (paratype)

PLATE 1. Fig. 1—*Blanfordia japonica* (A. Adams). Sotokaipu, Sado Id., Japan. Fig. 2—*Blanfordia bensoni* (A. Adams) Ojima, Hokkaido Id., Japan. Fig. 3—*Blanfordia simplex* Pilsbry. Ayukawa-mura, Honshu Id., Japan. Fig. 4—*Syncera japonica* (Martens). Inland Sea, Japan. Fig. 5—*Fukuia multistriata*. Left, holotype, female. Right, paratype, male. Fig. 6—*Fukuia kurodai*. Left, holotype. Right, paratype. Fig. 7—*Tricula minima* (Bartsch). Fujinose, Honshu Id., Japan ×10. Fig. 8—*Tricula minima* (Bartsch) Debaba, Honshu Id., Japan ×10. Fig. 9—*Paludinella conica* Quadras. Pago Bay, Guam Id. Fig. 10—*Oncomelania nosophora* (Robson). Okayama, Honshu Id., Japan. Fig. 11—*Truncatella gueruii* Villa. Mauritius. (All figs. magnified ×5 except 7 and 8.)

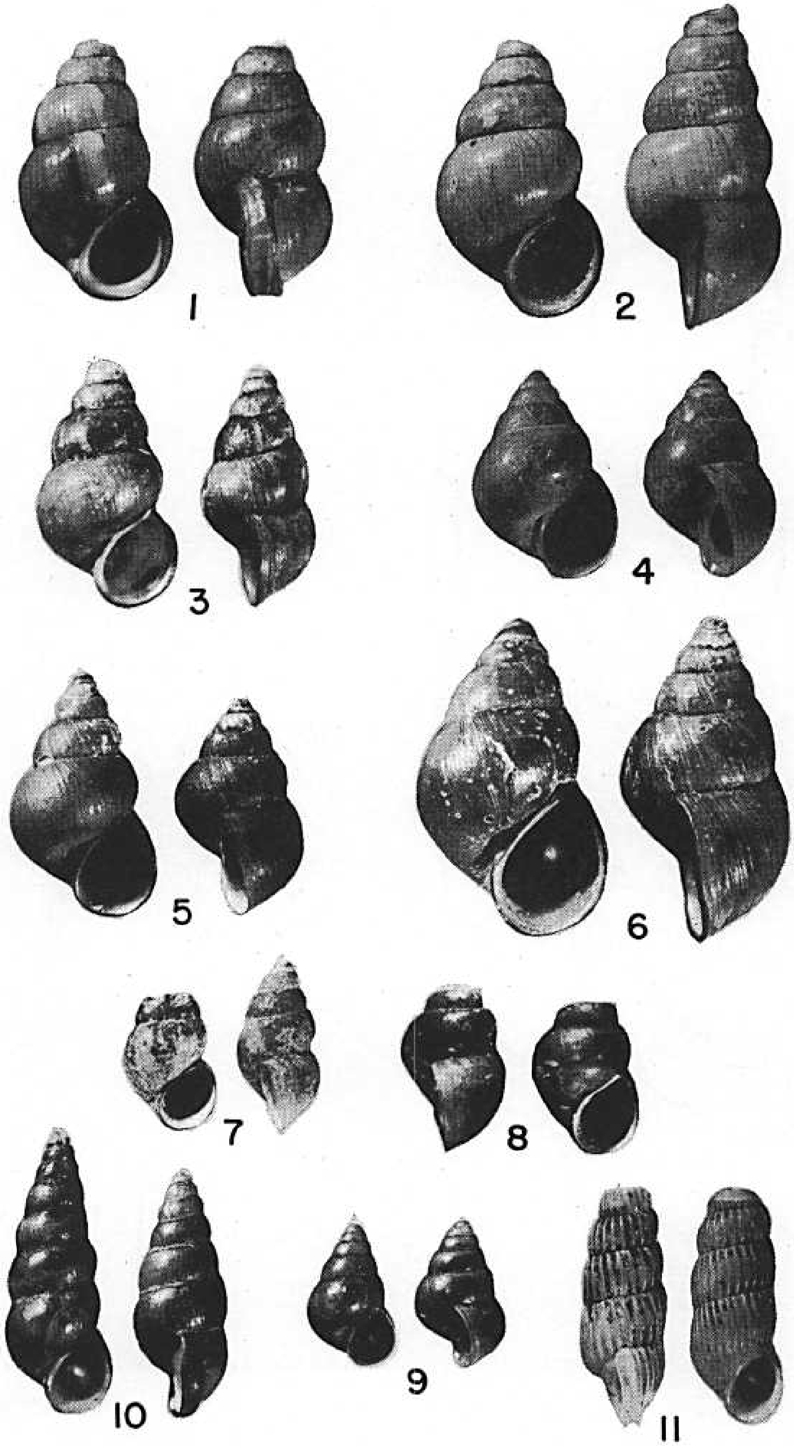

PLATE 1. For explanation of figures see opposite page.

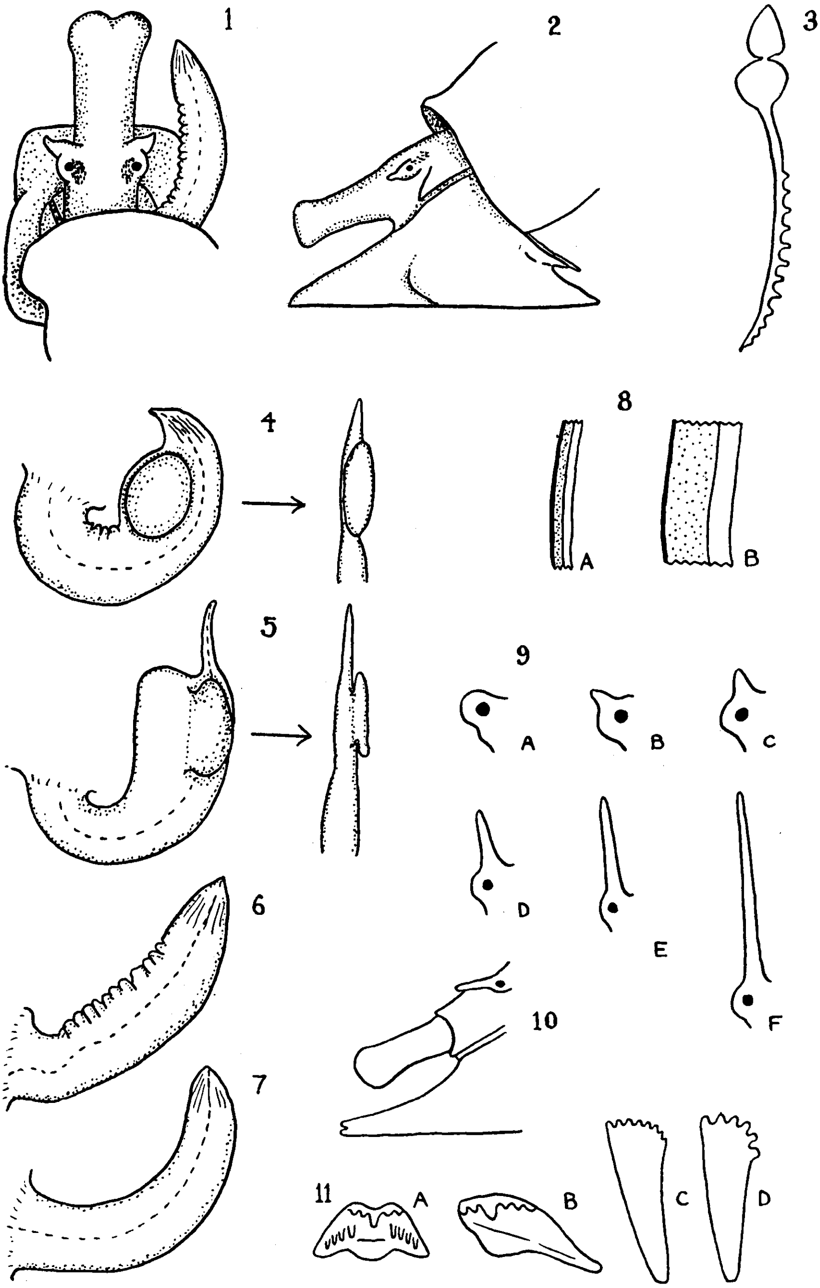

PLATE 2. For explanation of figures see opposite page.

Animal.—Very small, colored a dark grayish black. Foot simple. Tentacles fairly long, very slender, black with an outer rim of clear flesh. Color granules behind eyes yellow and sparse. Mantle dusted with black specks which become black splotches farther back, with the gill area solid black. Verge a single, curved, blunt prong. Gill lamellae well developed, 28–30 in number.

Type locality.—Noto, Honshu Island, Japan. Y. Hirase, leg.

Locality records.—Honshu Island; Noto (U.S.N.M. 346039) and the holotype U.S.N.M. 420950; at Fujinose, Natauchi-Mura near Nanao City, Ishikawa Prefecture (U.S.N.M. 488542); at Debaba, Natauchi-Mura near Nanao City (U.S.N.M. 488541).

Ecology and Habits.—This species was collected at Fujinose in a small stream which in the rainy season flows swiftly, but in the fall completely dries up at times. These minute snails were distributed in the stream in September in small shaded, muddy pools, usually on the underside of rocks or decaying vegetation such as reeds and leaves. This stream flowed down the hillside and emptied into rice paddies. A few of the snails were found in the shaded areas of the paddies. The pH of the water ranged from 7.3 to 7.4. The habitat at Debaba differed somewhat in that the water supply was more plentiful. The water emerged from a hillside spring and flowed along at the side of the road at a width of about 18 inches and a depth of less than 3 inches. The snails lived in the ditch close to the water line (pH 6.6) and occurred on sand, rocks or decaying vegatation; they were occasionally encountered in muddy pools. A nearby fast flowing mountain brook (3–4 feet wide and 4–8 inches deep, pH 7.1) did not support this species so far as we could ascertain.

FUKUIA, new genus

A group of pectinibranch gastropods of the family Amnicolidae and subfamily Hydrobiinae whose shells superficially resemble those of *Syncera*. Shell ovate-conic, between 5 and 10 mm. in length, thick and hard, glossy, and reddish brown in color. Umbilicus moderately developed. Whorls well rounded. Suture sharply but not deeply indented. Aperture ovate. Outer lip sharp and without thickened varix. Inner lip well developed and adnate to last whorl. Columella slightly curved and rounded. Spiral sculpturing consists of numerous microscopic incised lines. Operculum chitinous paucispiral, relatively thick. Animal with simple foot, without a lateral groove on each side of body. Tentacles very short. Yellow color granules embedded under epidermis behind eyes. Gill lamellae moderately developed, 30 to 45 in number. Verge is a single prong bearing a rather large, button-like gland on the upper side. Radula much like that of *Blanfordia* with a formula of $\frac{1\text{–}1\text{–}1}{4\text{–}4}$; 2–1–4; 8–10; 6–8.

Genotype.—*Fukuia kurodai* Abbott and Hunter.

PLATE 2. Animal characters of Japanese amnicolids. Fig. 1—Dorsal view of *Blanfordia simplex* Pilsbry showing verge protruding from right side of mantle cavity. ×10. Fig. 2—Left side view of *B. simplex* ×10. Fig 3—Ventricle, auricle and efferent blood vessel showing the reduced gills in *B. simplex*. ×25. Fig. 4—Top and side view of verge in *Fukuia kurodai* Abbott and Hunter. ×15. Fig. 5—Top and side view of verge in *Fukuia multistriata* Abbott and Hunter. ×15. Fig. 6—Verge in *Blanfordia simplex*. ×15. Fig. 7—Verge in *Tricula minima* (Bartsch) (similar to that of *Oncomelania nosophora* (Robson)). ×15. Fig. 8—Comparative shell thickness in (A) *Blanfordia simplex* and (B) *Fukuia kurodai*. ×25. Fig. 9—Left tentacles in living specimens of (A) *Syncera*, (B) *Blanfordia*, (C) *Fukuia*, (D) *Paludinella*, (E) *Truncatella* and (F) *Tricula* and *Oncomelania*. ×15. Fig. 10—Side view of *Paludinella* showing cephalic cape hanging over proboscis. ×10. Fig. 11—Radula of *Fukuia multistriata*, (A) rachidian, (B) lateral, (C) inner marginal, (D) outer marginal. ×100.

Remarks.—The genus *Fukuia* contains two species both of which are found in Fukui Prefecture, Japan. The shells of this genus may be readily distinguished from those of *Blanfordia* and *Oncomelania* by the absence of a varix behind the outer lip, the much more ovate shape, the presence of distinct, spiral, microscopically incised lines, and in being much harder and thicker. The opercula of the two species of *Fukuia* are strongly tinted with rose while those of *Blanfordia, Oncomelania* and *Tricula* are translucent, tan or colorless. The short tentacles are slightly longer than those found in *Blanfordia,* but very much shorter than those of *Oncomelania. Syncera* differs in having no gills, in having the rounded tentacles completely welded to the eye peduncle, and in having a bulbous mucus gland on the dorsal side of the anterior region of the foot. The verge of *Fukuia* is unique in being a single, curved prong with a disc- or bean-shaped gland on the upper side.

Fukuia kurodai, new species
(Plate 1, fig. 6, plate 2, fig. 4)

Shell.—Small, about 9 mm. in length, broadly ovate, thin, but strong, color a reddish brown. Nuclear whorls eroded; postnuclear whorls 5, well rounded. Suture sharply indented. Aperture obliquely ovate; peristome slightly expanded, sharp, and adnate at the parietal wall. Thin periostracum discolors edge of peristome a dark brown. Columella fairly short, arched basally and slightly rounded. Umbilicus moderately developed, round, but partially obscured on one side of the columella. Interior of aperture glossy, and colored a light tan. Axial sculpture consists of numerous, fine, irregular growth lines. Spiral sculpturing consists of numerous fine, incised lines which are more prominent on the top whorls and the upper half of each whorl. Operculum chitinous, translucent, relatively thick, paucispiral with obscure excentric nucleus, and tinted with rose. Radula taenioglossate with a formula of $\frac{1-1-1}{4-4}$; 2–1–4 or 2–1–5 or rarely 3–1–5; 9 to 10; and 8.

Measurements of shells in mm:

length	width	no. of whorls	
9.0	5.4	6.0	U.S.N.M. 593365 (holotype)
9.0	5.5	eroded	U.S.N.M. 488538 (paratype)
8.5	4.9	5.3	
9.1	5.4	eroded	
8.7	5.2	6.0	
7.2	4.5	eroded	
7.5	4.3	5.0	
8.7	5.1	eroded	U.S.N.M. 488517 (paratype)
7.0	4.2	5.5	

Animal.—Small, with a simple foot. Color of body a dark blackish brown. Eye peduncles fairly large, bulbous with a very short, pointed tentacle facing forward. Proboscis, eye peduncle and tentacle black brown. Two small areas of heavy yellow, coarse granules embedded in skin, one immediately behind the black eye, the other a little more posterior. Colorless rim along the anterior edge of proboscis and around tentacle. Mantle usually white to cream, occasionally speckled with gray. Under side of foot grayish white. Gill lamellae low, extending across mantle, 40–45 in number. Verge on center of back of male a single curved prong with a large, round, disc-shaped, opaque whitish gland. The gland is not greatly raised. Verge with light gray dusting on surface.

Type locality.—Takeda mura, along Takeda River, near Maruoka City, Fukui

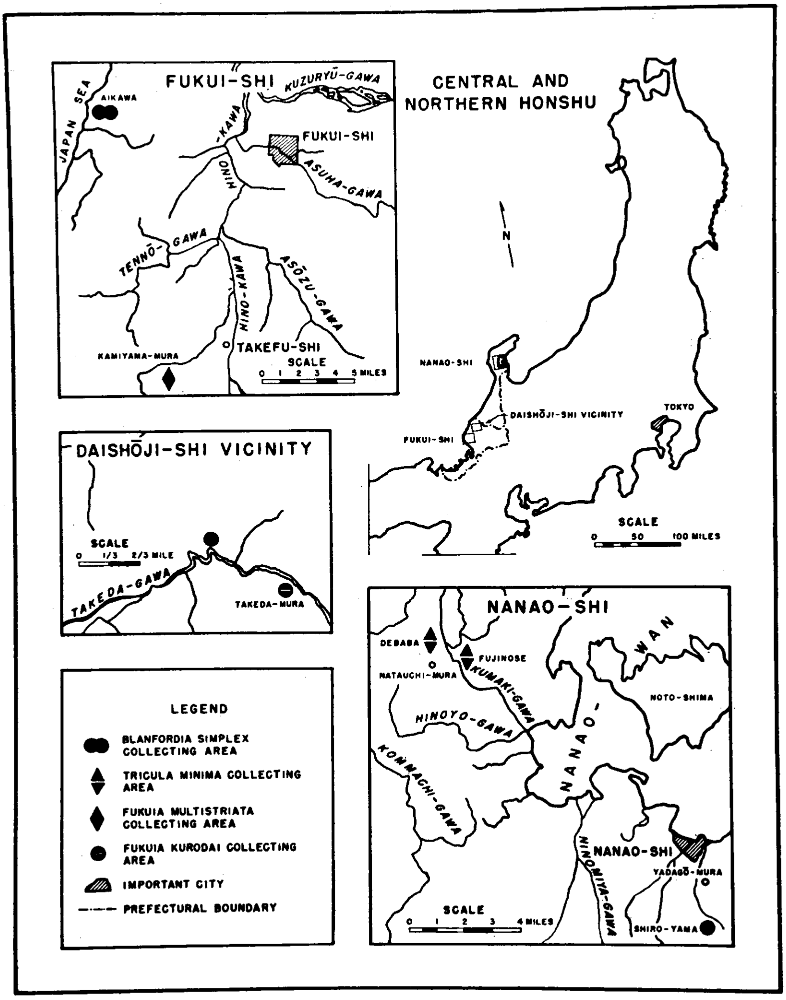

PLATE 3. Map of areas where snails were collected in Fukui and Ishikawa Prefectures, Japan.

Prefecture, Honshu Island, Japan. George W. Hunter, III, leg. Sept. 16, 1947. Found on steep, wet, cliffs.

Types.—From the above locality: holotype U.S.N.M. 593365, paratypes 488538. Paratypes from an area to the north of Fukui City, Fukui Prefecture, U.S.N.M. 488517. Others were collected at Shiroyama of Yadagomura (near Nanao City), Ishikawa Prefecture, Honshu Island, September 28, 1947.

Remarks.—This species is named for the Japanese malacologist, Dr. Tokubei Kuroda. Specimens of this species came to hand three years ago labelled "*Blanfordia castanea* Kuroda MS." Since no description has appeared to date, we have, through the necessity of applying a name to the species which was used in our experiments, described and, with pleasure, named it after its discoverer. For comparison with other species see under Synopsis of Distinguishing Characters.

Ecology and Habits.—*Fukuia kurodai* was collected in two localities on rocky walls of steep valleys which were accessible only from below. The cliffs are from 50 to 60 feet high and covered with ferns, slime molds, bryophytes, mosses and grasses. In the Shiroyama area, the sandstone face consists of a 40 to 60 foot "dripping" waterfall. The snails were found on the bare face of the cliffs, in crevices, or clinging to living vegetation. Moisture and shade seemed essential. When the water ceased to drip down over the face of the cliff in drier weather, the snails crawled into crevices and cracks where the humidity was higher, and so became much more difficult to collect. The pH of the water varied between 6.6 and 6.8, which undoubtedly accounts for the eroded spires of the shells. From our observations, it appears that *F. kurodai* requires less moisture than *F. multistriata.* It is interesting and perhaps significant to note that *F. kurodai* did not occur unless freshwater crabs were present. Among the animals associated with this species were freshwater crabs, isopods, amphipods, spiders, "red mites," earthworms, crickets, and fly larvae. The plants associated with the snails were the ferns, *Adiantum pedatum* Linn. and *Polystichum tripteron* Presl; the nettles, *Urtica thunbergiana* Sieb. and Zucc. and *Boehmeria tricuspis* Makino; the liverwort, *Pellia epiphylla* Dum.; mosses, slime molds and *Houttuynia cordata* Thunb.

Fukuia multistriata, new species
(Plate 1, fig. 5, plate 2, figs. 5 and 11).

Shell.—Small, about 5 to 7 mm. in length, broadly ovate, thin but strong, and colored a dark chestnut to reddish brown. The shell is extremely close to *F. kurodai,* differing only in its smaller size, more pronounced spiral incised lines, darker color and slightly more globose shape. The shells of the males are smaller and more globose than those of the females.

Operculum thin, chitinous, paucispiral, translucent and very faintly tinged with tan-rose. The radula formula is similar to *F. kurodai* and in our specimens is $\frac{1\text{–}1\text{–}1}{4\text{–}4}$ or $\frac{2\text{–}1\text{–}2}{4\text{–}4}$; 2–1–4; 8–9; 8.

This and the preceding species, *F. kurodai,* are apt to be confused with *Blanfordia integra* Pilsbry which, however, averages 5 mm. in length, is more fragile and thinner, is more elongate with rounder whorls and with a more deeply indented suture, and has a much thicker periostracum. The spiral incised lines in *B. integra* are extremely fine, and sometimes absent, while in *Fukuia* they are pronounced. *B. integra* lacks the reddish tinge in the shell and possesses much coarser lines of growth.

Measurements of shell in mm:

length	width	no. of whorls	
7.1	4.1	6.0	U.S.N.M. 594185 (holotype)
6.9	4.0	5.7	female U.S.N.M. 488540
6.8	3.9	5.7	female
6.7	3.8	5.6	female
6.0	4.0	5.5	male
5.6	3.6	4.8	male
5.9	3.8	5.7	immature
5.0	3.2	5.0	immature
4.2	2.8	4.7	immature
3.5	2.5	4.4	immature

Animal.—Similar in gross anatomy to that of *F. kurodai,* but differing strikingly in verge characters, mantle color and in having 30 to 33 gill lamellae instead of 40 to 45. The mantle is heavily suffused with gray which becomes reddish black over the gill area. A bright maroon color-band is found on the visceral whorls, a feature absent in *F. kurodai*. The verge is a simple, curved prong with a bean-shaped gland on the upper side which in moments of excitation is prominently raised.

Type locality.—Takefu in Kamiyama-Mura, Nanjo-Gun, Fukui Prefecture, Honshu Island, Japan. George W. Hunter, III, leg. Sept. 16, 1947 (U.S.N.M. 488540); also from Echizen, Kuroda, leg. (U.S.N.M. 487383).

Types.—Holotype U.S.N.M. 594185, paratypes U.S.N.M. 488540, both lots from Fukui Prefecture. Paratypes also from Echizen, U.S.N.M. 487383.

Ecology and Habits.—*Fukuia multistriata* Abbott and Hunter, another moisture loving snail, was collected from dripping rocks near Takefu in Kamiyama-Mura in Fukui Prefecture. The snails were limited to a single rocky face which prior to 1934 had been covered by a waterfall. Little water was present and the ledge was moistened by small trickles of water, the pH of which was 7.6. Like *F. kurodai*, this species of snail requires much shade, moisture and cool water. When insufficient moisture was present the snails crawled into the cracks between the rocks. When adequate moisture was present these snails were found on the underside of decaying vegetation. This is in marked contrast to *F. kurodai* which was typically associated with living vegetation. Leafy mosses, slime molds, bryophytes, pteriodophytes and spermatophytes composed the vegetation. The snail, *Semisulcospira libertina* (Gould), (specimens of which were forwarded to the U. S. National Museum) was also present in the wetter parts of this habitat. Unlike *F. kurodai*, freshwater crabs were absent. *F. multistriata* was only found in this one region.

SYNOPSIS OF DISTINGUISHING CHARACTERS

Tricula minima (Bartsch)

Adult shell very small, less than 3 mm. in length, varix absent, scarcely umbilicate. Most of spire eroded away. Animal black. Mantle with soot-black band. Yellow color granules behind eyes. Tentacles long. 28–30 gills. Radula: inner marginal with 12 to 14 denticles.

Blanfordia simplex Pilsbry

Adult shell about 6 mm. in length, elongate-ovate, moderate varix present, umbilicus well developed. Animal pale. Tentacles very short, triangular. Yellow color granules behind eyes. Mantle cream with black, cobweb splotches. 10–12 short gills. Verge a single prong, serrated on one side.

Fukuia multistriata Abbott and Hunter

Adult shell about 6 mm. in length, very hard, chestnut to reddish brown in color, varix absent, and with strong microscopic spiral, incised lines. Tentacles very short. Yellow color granules behind eyes. Animal blackish brown. Wide band of dark maroon color on visceral mass. Verge with small, raised bean-shaped gland on side. 30–32 gills.

Fukuia kurodai Abbott and Hunter

Adult shell about 9 mm. in length. Other characters much the same as in *F. multistriata* except: verge with large, flat disc-shaped gland on one side. No maroon band on visceral mass. Mantle usually cream, 40 to 45 gills.

Key to Animal Characters of the Intermediate Snail Hosts of Oriental Schistosomiasis and Genera Likely to be Confused with them

Verge or male copulatory organ absent
- Females with uterine brood pouch .... *Semisulcospira*
- Females without uterine brood pouch
  - "Females" with neck brood pouch .... *Thiara*
  - Females without any brood pouch .... *Hua*

Verge or male copulatory organ present
 Verge with finger-like, side appendage .... *Bulimus, Parafossarulus, Alocinma*
 Verge without long side appendage
  Cephalic cape (hanging over proboscis) present .... *Paludinella*
  Cephalic cape absent
   Tentacles absent (closely welded to eye peduncle); gills absent .... *Syncera*
   Tentacles present; gills present
    Tentacles as long as or longer than proboscis
     Number of gills 28 to 30 .... *Tricula*
     Number of gills 50 to 60 .... *Oncomelania*
    Tentacles not as long as proboscis
     Tentacles half the length of proboscis .... *Truncatella*
     Tentacles less than half the length of proboscis ....
      Verge with button-like gland; 30–45 gills .... *Fukuia*
      Verge without this gland; 10 to 12 gills .... *Blanfordia*

SUMMARY

In order to identify certain potential snail hosts of *Schistosoma japonicum* in infection experiments in Japan, a study is made of the shells, animals and habitats of four molluscan species. *Blanfordia simplex* Pilsbry, 1902, and *Tricula minima* (Bartsch, 1936) (formerly placed in the genus *Schistosomophora* Bartsch, 1936) are redescribed. A new genus, *Fukuia*, of the subfamily Hydrobiinae, is described with two new species, *F. kurodai*, the selected genotype, and *F. multistriata*. A key is given to the animal characters of the intermediate hosts of Oriental schistosomiasis and genera likely to be confused with them. Recent or generally overlooked additions to the bibliography of *Oncomelania* are given.

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Studies on Potential Snail Hosts of *Schistosoma japonicum.* II. Infection Experiments on Amnicolid Snails of the Genera *Blanfordia, Tricula* and *Fukuia*

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With the Technical Assistance of

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INTRODUCTION

As indicated in Hunter, Ritchie et al (1948) and Abbott and Hunter (MMS) the proven snail host, *Oncomelania nosophora,* was not found in Fukui Prefecture or in the Nanao Peninsula region of Ishikawa Prefecture. Furthermore a careful search of malacological literature failed to reveal any records of this species in this area. Therefore, it seemed that if schistosomiasis were indigenous to Fukui Prefecture, some other snail must serve as the intermediate host. With this in mind, the assistance of Japanese malacologists was sought and arrangements were made to collect specimens from three genera which were considered to be close to *Oncomelania.* Four species of freshwater gastropod snails, *Blanfordia simplex* Pilsbry, 1902, *Tricula minima* (Bartsch, 1936) and *Fukuia kurodai* Abbott and Hunter and *F. multistriata* Abbott and Hunter were collected in as great numbers as possible and their morphology and taxonomic positions studied. Both living and preserved snails were shipped to the United States National Museum. These results are reported by Abbott and Hunter in the preceding paper. The remainder were crushed or were set aside for infection experiments with the miracidia of *S. japonicum* to determine their possible role in the transmission of this disease. The results of these studies are found in the present paper.

METHODS

Separate laboratory aquaria were set up for each species of snail. In an attempt to duplicate as nearly as possible the habitat of *Tricula minima,* an aeration apparatus was constructed along the lines of that described by Cantino and Hatfield (1946). The pH of the water was adjusted to 7.5 and water plants and a few dead leaves were added. Aquaria for the *Fukuia* species were identical, consisting of clay flower pots filled with soil and a few small rocks. Bits of decaying leaves and sticks, together with plants taken from the collecting areas, were added. The pots were then placed in water kept constant to a depth of about 1 inch. Moisture seeping up through the holes in the bottoms of the pots (which had been partially blocked by loosely fitting corks) and that which filtered through the porous clay from the sides kept the soil in a damp condition at all

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times. A small amount of water was sprayed over the leaves and snails daily. Complete room temperature records were not kept, but the average mid-morning temperature for the laboratory over the period of several weeks was 70–75° F. The aquaria were kept out of the direct sunlight but were exposed to the artificial illumination from the ceiling lights of the laboratory during working hours.

Stools from Japanese passing eggs of *S. japonicum* were obtained and the miracidia hatched according to the method described by Ingalls, Hunter, McMullen and Bauman (1949). All species of snails were exposed to miracidia of *S. japonicum*. Each snail was exposed to two or more miracidia of *S. japonicum* in a drop of water and was closely watched to determine whether or not the miracidia disappeared. After checking the drop of water the snails were removed to their proper terraria or aquaria. Although the miracidia disappeared in all cases this cannot be considered tantamount to penetration since it is always possible that some of the miracidia may have disintegrated or merely been retained within the shell of the snail. Snails were collected in both 1947 and 1948. Both young and adult snails were used in these experiments so as to eliminate the possible criticism that a particular age group was used that might have been refractive to the miracidia of *S. japonicum*. It is interesting to note that both species of *Fukuia* appeared to ''excite'' the miracidia of *S. japonicum* and the miracidia soon disappeared into the mantle cavity within a few minutes. Upon the other hand the presence of *Tricula minima* seemed to have little if any effect upon the miracidia.

DISCUSSION OF RESULTS

The results of the examination of these four species of snails by crushing or by laboratory infections must be considered as negative since no mature daughter sporocysts or cercariae of *S. japonicum* were encountered (Table I). A few partially developed, degenerating mother sporocysts were found in *Tricula minima* in 1947. It was not possible to secure any infection in 1948 even though collections were made from the same area and both juvenile and adults were tested.

TABLE 1.—*Summary of crushing and experimental infections of potential snail hosts for* S. japonicum

SPECIES	No. Examined by Crushing			No. Exposed			No. Positive		No. of days following exposure that snails were examined
	1947	1948	TOTAL	1947	1948	TOTAL	1947	1948	
Blanfordia simplex Pilsbry 1902	369	....	369	80	....	80	0	......	10–82
Tricula minima Bartsch 1936[a]	249	163	412	114	376	490	12[b]	0	7–71
Fukuia kurodai Abbott and Hunter 1949	75	37	112	12	63	75	0	0	13–85
Fukuia multistriata Abbott and Hunter 1949	117	68	185	12	199	211	0	0	10–82

[a] Collected from Debaba and Fujinose.
[b] Contained degenerating mother sporocysts.

In view of the above facts and the report of the epidemiological survey in

Fukui Prefecture by Hunter, Ritchie, Nagano et al (1948 and MMS) it appears that the statement on schistosomiasis in Fukui Prefecture in the TB Med 160 (1945) is in error. It is highly probable that it was due to a translator's error as there were no cases nor history of cases of the disease encountered, no *O. nosophora* found and no new snail hosts experimentally infected.

In determining the presence or absence of schistosomiasis in Fukui Prefecture, evidence was sought from several sources. First of all, information was obtained from Japanese health offices in such cities as Mikata, Tsuruga, Ono and other communities where records had not been destroyed by the ravages of war. The members of the various medical societies were queried, and information was also sought through the newspapers. No evidence was obtained from any of these sources to indicate that schistosomiasis was indigenous to Fukui Prefecture.

Next, a diligent search was made in likely environments for the presence of the known intermediate host of *S. japonicum* in Japan, *Oncomelania nosophora.* None were found. Furthermore, the malacologists had no evidence of the existence of this snail host in this area (Hunter, Ritchie, Nagano et al 1948 and MSS).

Conversations with the malacologists resulted in the suggestion that possibly members of the genus *Blanfordia* might serve as snail hosts. Through the cooperation of several malacologists, arrangements were made to collect *Blanfordia* from its known habitats throughout Fukui and Ishikawa Prefectures. It will be seen from a study of the description of the habitats of *Fukuia kurodai, F. multistriata* and *Blanfordia simplex* that from an epidemiological standpoint, these species would not likely serve as agents for the dissemination of cercariae of *S. japonicum.* The habitat on the rocky cliffs makes it virtually impossible for these snails to come into contact with infected stools containing eggs of *S. japonicum.* In the case of *B. simplex* there would scarcely ever be enough water to bring about the hatching of schistosome eggs even if infected persons should defecate near them (Abbott and Hunter). Consequently, on epidemiological grounds these three species must be ruled out as being of any importance in the distribution of schistosomiasis, even if they had been capable of harboring the parasite.

It will be seen from Table I that a considerable number of snails of all four species were crushed and examined for sporocysts and cercariae of *S. japonicum.* No evidence of any infection was found. Furthermore, all attempts to infect these species under experimental conditions resulted in failure. Even though the numbers exposed were not great because of the scarcity of the snails, the negative results secured when considered with all the other factors previously mentioned, strongly indicate that it is impossible for these snails to play a role in the transmission of schistosomiasis.

No formal epidemiological survey was made on the Nanao Peninsula or elsewhere in Ishikawa Prefecture. However, two species of snails were collected in the Nanao area, *Tricula minima* (Bartsch) and *F. kurodai* Abbott and Hunter. As in the case of *F. kurodai* collected in Fukui Prefecture, the habitat eliminated these snails from being of any epidemiological importance in schistosomiasis as they were found only on the face of dripping cliffs where exposure to miracidia or an adequate environment for the emergence of cercariae did not occur.

However, on epidemiological grounds, it is necessary to consider *T. minima* further since the habitat of this species did not completely rule it out as a potential intermediate host of *S. japonicum. Tricula minima* was collected from a roadside ditch in Debaba and from a rivulet coming down a hillside in Fujinose. These water sources could, and even at this season of the year, did flow into paddies. Fecal contamination of the environment was possible but rather unlikely.

A total of 412 *T. minima*, 269 from Debaba and 143 from Fujinose, were dissected but all were negative for sporocysts and cercariae of *S. japonicum*. Nearly 500 specimens were exposed to varying numbers of miracidia of *S. japonicum* (2–5) in 1947 and 1948 (Table I). These laboratory exposed snails were maintained between 8 and 71 days. Most of these were sacrificed before they became moribund. It was felt that sufficient time was given to permit the detection of any infection that might occur. A total of 114 were exposed in 1947. Upon dissection 7–14 days after exposure eight snails from Debaba and four from Fujinose contained degenerating mother sporocysts. These resembled laboratory infections of *S. japonicum* recovered from *O. nosophora*. However, at this early stage of development positive identification was not possible while in other cases the process of degeneration had gone too far. Since the snails were healthy, this was interpreted as indicating the inability of the parasites to survive in this species of snail. In order to check this further, 376 specimens were secured in 1948 from both localities and exposed to varying numbers of miradicia of *S. japonicum*. Especial care was taken to include both juvenile and adult snails. However, no infections of any sort were obtained (Table I) and the controls were negative. This led to the interpretation that, although the miracidia of *S. japonicum* gave evidence of being able to penetrate the host, they were unable to continue development beyond an early stage. From this it was concluded that *T. minima* (Bartsch) was not capable of serving as an intermediate host of *S. japonicum*.

SUMMARY

A careful check of records, medical groups and indigenous persons failed to reveal the existence of cases of schistosomiasis japonica in Fukui and Ishikawa Prefectures. A search for *Oncomelania nosophora* failed to yield any specimens. Other possible snail hosts of Fukui and Ishikawa Prefectures were examined by crushing and by exposure to miracidia of *S. japonicum*. *Blanfordia simplex*, *Tricula minima*, *Fukuia multistriata*, and *F. kurodai* were tested and found incapable of serving as intermediate snail hosts of *S. japonicum*.

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"Root-Knot Nematodes"—Part I. A Revision of the Genus *Meloidogyne* Goeldi, 1887.

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INTRODUCTION

In 1887 Goeldi described a nematode, under the name *Meloidogyne exigua* new genus and species, as the cause of root galling of coffee trees in Brasil. This genus was synonymized with *Heterodera* Schmidt, 1881 (type *H. schachtii,* Schmidt, 1881, the well-known sugar-beet nematode) by many subsequent authors. The species *M. exigua* was generally considered a synonym of *Heterodera radicicola* (Greeff, 1872) Müller, 1884, of authors. Goodey (1932) showed that the nematode described by Greeff as *Anguillula radicicola* causing root galls of *Poa annua, Triticum repens,* and *Sedum* spp., is not closely related to either *Heterodera* or *Meloidogyne.* This species was placed in the genus *Anguillulina* by Goodey, later in the genus *Ditylenchus* by Filipjev. Goodey called the root-knot nematodes *Heterodera marioni* (Cornu, 1879) Goodey, 1932. Cobb (1924) made a new genus *Caconema* for the root-knot nematodes, separating them from the genus *Heterodera* through the presence of two lateral cheeks on the head and two testes in the male of *Caconema* and no cheeks and 1 testis in *Heterodera.*

Several specific names have been applied to root-knot nematodes. Cornu (1879) described *Anguillula marioni,* a root-gall-forming nematode on *Onobrychis sativa* from Chateauneuf-sur-Loire, France. Neal (1889) named one from various plants in Florida, U.S.A., *Anguillula arenaria.* Lavergne (1901) named one from grapevine roots, Chile, *Heterodera vialae.* Kofoid and White (1919) named a nematode from the feces of soldiers in Texas *Oxyuris incognito.* This nematode was synonymized with *Heterodera radicicola* by Sandground (1923).

Many workers on root-knot nematodes have noted conflicting evidence as to behavior and range of hosts. Neal (1889) and Atkinson (1889) expressed diametrically opposed views as to the status of *Amaranthus spinosus* and *Lespedeza striata* as hosts of the root-knot nematode. Tyler (1941) published a list and discussion of ''Plants Reported Resistant or Tolerant to Root Knot Nematode Infestation.'' Recently Christie and Albin (1944), Christie (1946), and Christie and Havis (1948) have established experimentally beyond doubt that we are dealing here with several diverse kinds of nematodes.

Our studies of the morphology of these organisms have convinced us that they indeed constitute a valid genus; several species may be distinguished. An attempt has been made to obtain specimens from the type host and locality of each of the named species. Unfortunately these attempts have usually been unsuccessful. Since the original description of none of the species provides sufficient information to identify beyond the genus, we risk the hazard of creating more synonyms. However, it seems better to establish the species with new descriptions than to continue the present confusion. It is hoped that the present separations may serve as a basis on which to build more detailed morphological work in the future.

Members of the genus *Meloidogyne* are extremely adaptable and their morphological characters show considerable variation. In fact we have not as yet seen two identical specimens. Nevertheless general pattern series and other structures show similarities, and progenies from individual females are relatively consistent both as to morphology and host range.

Genus *Meloidogyne* Goeldi, 1887

Type species.—*Meloidogyne exigua* Goeldi, 1887.

Synonym.—*Caconema* Cobb, 1924. (Type species *C. radicicola* of authors.)

Diagnosis.—Heteroderinae: Sexual dimorphism marked. Males eel-shaped, females pear-shaped to spheroid with elongate neck. Male with head bearing two lateral cheeks; with one or two testes. Female soft bodied, cuticle never forming a tough leathery cyst. Vulva subterminal, with two hemispherical lips. Anus situated at edge of posterior lip of vulva. Cuticle of female with simple transverse striae forming a fingerprint-like pattern in perineal region but never with lace-like pattern. Eggs never retained but deposited in mucoid minutely fibrous mass. Hatched larva with rather plain head, (i.e. with no distinct striations or with 2–3 faint striations and no hexagonal markings); stylet usually about 10 μ long. Characteristically causing root-swellings or knots on suitable hosts; females tending to live inside roots at maturity.

The genus *Heterodera* may be differentiated as follows: Female body wall forms a remarkably tough durable cyst; the layered cuticle is quite thick and usually there is a lace-like pattern and punctation. Eggs are at least partly retained in the female body which acts as a protective cyst. A mucoid mass may or may not be formed at the vulva. The male has no lateral cheeks but the head has ridges dividing the labial region into six sectors; these ridges and sectors are also present in the hatched larva; annular striations in cephalic region prominent in both male and larva. Stylet of larva 20–29 μ long. The anus of the females varies in position but is never situated at the edge of the posterior vulva lip. Usually does not form galls on any hosts; females tend to be located on external surface of roots at maturity.

Key to Recognized Species of MELOIDOGYNE *Goeldi, 1887*

1. Female with single lateral ridges, set off on each side by a longitudinal groove, very pronounced in perineal region; transverse striation (annulation) usually interrupted by these ridges, from perineal region up to at least cervical region .... *M. javanica* (Treub, 1885) n. comb.
   Female without lateral ridges, but sometimes showing single lateral longitudinal grooves in perineal region; transverse striation (annulation) in perineal region tending to anastomose laterally 2
2. Transverse striation (annulation) in latero-anal region of female tightly-whorled, as illustrated .... *M. exigua* Goeldi, 1887
   Transverse striation (annulation) in latero-anal region of female not tightly-whorled, but, at most, forming sublateral loops or single post-anal whorl 3
3. Stylet knobs of male clearly set off from stylet, prominent. (Female with transverse striation (annulation) in post-anal and post-vulvar regions often folded, or in post-anal region a distinct whorl; hatched larva with prominent stylet knobs, and with dorsal gland orifice 2 to 2.5 μ posterior to base of stylet, at which point esophageal lining is usually sharply-hooked) 4
   Stylet knobs of male not clearly set off from stylet, but passing very smoothly into stylet. (Female with transverse striation (annulation) in post-anal and post-vulvar regions not folded, and in the post-anal region without whorl; hatched larva with weak stylet knobs, with dorsal gland orifice 3 to 4 μ posterior to base of stylet, and with esophageal lining not hooked) 5
4. Transverse striation (annulation) of female in post-anal region a distinct whorl .... *M. incognita* (Kofoid & White, 1919) n. comb.
   Transverse striation (annulation) of female in post-anal region not whorled, with perineal transverse striae usually showing folds.
   M. incognita var. *acrita* n. var.
5. Female with stylet 12 to 15 μ long; transverse striation (annulation) in perineal region showing rather even, unbroken, more or less circular pattern. Male

with stylet 17 to 21 μ long .... *M. hapla* n. sp.

Female with stylet 16 to 18 μ long; transverse striation (annulation) in perineal region showing somewhat broken, more or less circular pattern. Male with stylet 20 to 24 μ long (usually 23 to 24 μ).

M. arenaria (Neal, 1889) n. comb.

Meloidogyne exigua Goeldi, 1887
(Figs. 1, T–X and 6, D)

Male.—1.1 mm long; α 27; β and γ not determined. Labial annule wide and flat in lateral view; lateral cheeks 4 μ long; post-labial annule with 1 or 2 faint striae in dorso-ventral view, none in lateral view. Stylet 17.5–18 μ long; knobs rounded, 4.5–5 μ across by 2.5–3 μ long; orifice of dorsal gland 3–3.5 μ posterior to base of stylet. Spicules 27 μ, measured on chord of their arc. Testes and phasmids not observed.

Female.—No gross measurements (material in poor condition). Stylet 14 μ (?) long; knobs flattened anteriad; dorsal gland orifice (?) 3 μ from base of stylet. Perineal transverse striation (annulation) rather continuous, straight across posterior to anus; paired tight lateral whorls on each side posterior to vulva; transverse striae broken laterally anterior to lateral whorls. Transverse striation toward vulva pronounced; vulvar lips simple.

Egg.—77–89 μ long by 39–49 μ wide.

Larva.[1]—281–337 μ long; α 31–33; β 6.1–6.4; γ (?) 8.6 (no details of anatomy visible).

Present materials.—Nematology Coll. V2–24.

Type host.—*Coffea* sp., roots, Province of Rio de Janeiro, Brasil.

This organism was first observed by Jobert (1878) as a cause of a malady of coffee roots in Brasil. The description by Goeldi is erroneous in many respects but it is adequate to place the genus. It is quite possible that coffee may be attacked by more than one species of root-knot nematode. The present material was collected by E. A. Arzberger in 1926 at the New York Botanical Garden.

Meloidogyne javanica (Treub, 1885) n. comb.
(Figs. 2, A–CC and 6, C)

Synonym.—*Heterodera javanica* Treub, 1885. [All measurements in Treub's original description must be multiplied by 10.]

Male.—0.94 to 1.44 mm long; α 26–42; β 7–13. Head with 3 post-labial annules; labial annule wide and rather flat; lateral cheeks 4 μ long. Stylet 20 to 21 μ long; stylet shaft cylindrical; knobs prominent and rounded, 3–3.5 μ long by 5 μ across; dorsal gland orifice 3 μ posterior to base of stylet. Spicules 30–31 μ long (measured on chord of their arc.) Phasmids unequal, preanal to latero-anal. Testes, 2.

Female.—545 to 800 μ long by 300 to 545 μ wide (original description 850 by 450 μ). Usually with tapering neck. Stylet of female 16 μ long, knobs abrupt, rounded, 4 to 5 μ across by 2 μ long; dorsal gland orifice 3 to 4 μ posterior to base of stylet. Pattern of perineal region relatively simple, with transverse striae (annulation) interrupted laterally by conspicuous double incisures edging lateral ridges (alar residues); this interruption extends laterally to cervical region. Incisures fade out posterior to anus and at this position the transverse striae form a small whorl. Perineal transverse striae pointing toward vulva. Phasmids about 19 μ apart.

[1] *Larva* refers to the hatched or preparasitic stage. In some instances this is thought to be the second stage larva but observers have seen a molt within the egg only in a few instances and we do not feel justified in generalizing.

Egg.—76–100 μ long by 31–40 μ wide (original description 125 by 45 μ).

Larva.—340–400 μ long; α 24–26; β 8; γ 5.8–6.6. Stylet 10 μ long, knobs prominent, orifice of dorsal gland 4 μ behind base of stylet.

Type host.—*Saccharum officinarum* (sugar cane).

Type localities.—Cheribon and Buitenzorg, Java.

Topotypes.—Nematology Coll X–13 and X–14. Buitenzorg, Java.

Discussion.—The present material was collected by Dr. J. van der Vecht, Head of the Institute for Plant Diseases and Pests, Buitenzorg, Java. Since we have found, upon examination, that there is more than one species of root-knot nematode in Java, it seems possible that Treub may have dealt with more than one species, even in his investigations on sugar cane. In order to fix the name we therefore designate the present material from type host and locality as topotypes. Galls on sugar cane are quite small and may easily be overlooked.

Observations in U. S. A.—The root-knot populations termed 11A and 11C by Christie and Havis (1948) originally collected from Yunnan variety peach roots and "resistant" peach roots from Tifton and Fort Valley, Georgia, have been identified with this species. Other records of the occurrence of root-knot nematodes on Shalil and Yunnan peach understocks include those discussed in Clayton (1947).

This species has been identified on Lovell and Shalil peach understocks collected by T. Clayton on two farms near Candor, N. C. The same species has also been identified from lima bean roots, Sanford, Florida, sent in by J. R. Christie; Tifton, Georgia, sent in by J. H. Machmer; and Jacksonville, Texas, sent in by W. H. Brittingham. This species has also been identified from garden balsam (*Impatiens balsamina*), Los Angeles, California; potatoes from Gainesville and Fort Myers, Fla.; cabbage and broccoli collected by W. H. Thames, near Indiantown, Fla.; and carnations (greenhouse grown) from Suffolk County, N. Y., sent in by R. H. Brewster. Populations from lima beans (Texas), garden balsam (California) and carnations (New York)[2] transferred to and reproduced on Yunnan peach roots. Since the U. S. A. materials have presented a better object for study than imported materials, the population termed 11C by Christie and Havis (1948) is described as follows:

Male.—.88–1.25 mm long; α 22–34; β 8–12; head usually lies in dorso-ventral view when fixed; labial region very narrow in this view but quite wide and flat in lateral view; head elongate with 2 to 3 inconspicuous post-labial annules; lateral cheeks 4 μ long by 2 μ wide. Stylet usually 22.5–23 μ long, rarely 20–24 μ; stylet shaft not tapering; knobs prominent, rounded, 5 μ across by 3 μ long; dorsal gland orifive 3 μ posterior to stylet knobs. Spicules 31 μ along chord of their arc (abnormal specimens 28 μ). Testes 2. Intersexes common (true males rare), ranging from vagina rudimentary to vulva well-developed; longitudinal incisures on lateral fields vary from 4 to 10. Phasmids variable in position.

Female.—0.57–1.06 mm long by 400–515 μ wide, neck usually well developed, set off. Stylet 16–17 μ long; knobs projecting backward, 3.5–4 μ across by 1.8–2 μ long; dorsal gland orifice 3.5–4 μ posterior to base of stylet, phasmids 21–26 μ apart.

Egg.—84–101 μ long by 32–45 μ wide.

Larva.—440–465 μ long; α 29–35; β 6.3–7.5; γ 8–13. Stylet 10 μ long, knobs well marked, projecting backward, 2 μ across by 1 μ long, orifice of dorsal gland 4 μ posterior to stylet base.

[2] One of the females of the carnation population (which apparently represented a single species), when propagated on Yunnan variety peach, had a clear lateral ridge on one side of the body and none on the other.

Galls.—In general the galls formed by this species are moderately large. The posterior end of the female *does not project from the root* at all in garden balsam nor to any extent on large roots of peach or lima beans, but on the small feeding roots of peach and tomato they do project.

Meloidogyne hapla n. sp.
(Figs. 3, A–Z, 4 and 6, A)

Male.—1.0–1.33 mm long; α 30–40; β 12–15. Head with labial annule rounded, narrower than post-labial annule; lateral cheek 3.5–4 μ long. Stylet 17–18 μ long, stylet shaft tapers; knobs weak, rounded, 1.7–2.0 μ long by 3.5–4 μ across; dorsal gland orifice 4–6 μ posterior to knobs; spicules moderately arcuate, 29–31 μ long (chord of their arc); phasmids unequal, latero-anal to post-anal; 2 or 1 testis.

Female.—550–790 μ long by 400–450 μ wide; stylet 12–14 μ long (usually 13 μ); knobs weakly rounded, 1.5–2 μ long by 3 μ across; dorsal gland orifice 5–6 μ posterior to base of stylet. Transverse striae (annulation) in perineal region extremely smooth, tending to form a rounded hexagon, lines rather continuous posterior to anus, tending to be parallel and more widely spaced than elsewhere, sometimes with slight shoulder at level of phasmids, but without continuing lateral incisures. Pattern of these striae with no post-anal whorl, sometimes with one right or left lateral loose loop, sometimes with paired lateral loops. Phasmids 17–21 μ apart.

Egg.—84–108 μ long by 32–43 μ wide.

Larva.—395–466 μ long; α 28–35; β 6.5–7.3; γ 7.5–8.2 (living); 331–372 μ long; α 25–31; β 6–8; γ 6.8–8 (formalin fixed). Stylet 10 μ long, normally withdrawn from labial region; knobs minute, rounded, 1.5 μ across; dorsal gland orifice 3–4 μ behind its base. Tip of tail variable within progeny of single female, bifid or simple.

Type host.—Green Mountain variety potato.

Syntypes—Nematology Coll. X–11 and X–12.

Type locality.—Bridgehampton, L. I., New York.

Discussion.—This species was studied extensively by Cunningham (1936) in potatoes of Long Island. Subsequently it was investigated by Christie and Albin (1944) and Christie (1946). The latter author labelled the root-knot nematode from Long Island potatoes population 3D. A similar nematode from Falls Church, Va., parsnips, he called population 5. A third nematode, from Pitt Co., North Carolina, peanuts, he called population 4. All of these populations were found to make small galls on tomatoes, the posterior end of the females tended to project from the tomato roots and all three populations reproduced on the peanut variety Virginia Runner. *M. hapla* appears to be general in potato fields from Maine to Minnesota to Illinois, West Virginia and Virginia.

Gross size of the organisms is given, not as limits of the species, but merely examples of the approximate size. Size and shape of adults vary with age and host.

Within the population produced by a single egg mass it is possible to get several female perineal patterns of the transverse striae (See Fig. 3, J–N), males with 1 or with 2 testes, and perhaps other variants. The various types may breed true in populations from one egg mass and segregate in populations from another egg mass. Thus we have all the indications that these differences are based on genetic factors. Whether or not these factors are correlated with host range, climate, and rate of reproduction is unknown. Minor differences have been found in the shape of the labial annule, length of stylet and position of dorsal gland orifice in the male, and differences in length of stylet and position of dorsal gland orifice of the female. The full significance of these differences is unknown. Possible recombinations of these differences with those of female perineal pattern and males with 1 and 2 testes would seem to provide unlimited numbers of forms within the species. Host selection, climatic conditions, etc., may easily provide a mechanism for the breeding of pure lines. The differences in perineal pattern and number of testes appear to be repeated in collections from numerous localities, without regard to host or geographic distribution. Hence it is concluded that they are based on genetic factors. Stylet length, position of dorsal gland orifice and shape of the male labial annule appear at the present time to be associated with host or geographic distribution. However, with the shipment of nursery plants it is possible to have more than one of these kinds in a given locality.

Varieties.—The nematode from Pitt Co., N. C., peanuts, called population 4 by Christie and Albin differs from the type (Fig. 3, X–Y) in that the labial annule of the male is a bit squarer, the male stylet 20–21 μ (rather than 17–18 μ) long and the female stylet 14–15 μ (rather than 12–14 μ) long. The dorsal gland orifice and other characters are as in the type.

Another nematode, sent in by Paul H. Millar on *Abelia grandiflora*, from Jacksonville, Arkansas, differs from the type in only one character, namely, that the dorsal gland orifice is only 3 μ (rather than 4–6 μ or 4–5 μ) posterior to base of stylet in males and females.

Still another kind of root-knot nematode sent in by Wilfred S. Craig, on spirea var. Anthony Waterer and on red barberry, from Wentzville, Missouri, differs from the type in that the labial annule of the male is somewhat squarer, the male stylet 20 μ (instead of 17–18 μ) long, and the male dorsal gland orifice 3–3.5 μ (instead of 4–6 μ) posterior to base of stylet, although the female stylet is like the type in being 12.5–13 μ long and the female dorsal gland orifice like the type, 5–6 μ posterior to base of stylet.[3]

The species *Meloidogyne hapla* may be a synonym of *Anguillula marioni* Cornu, 1879. Despite the widespread occurrence of this nematode in the U. S. and the fact that we have evidence of its existence in North America at least as far back as 1917, we have no evidence that it is native. Specimens have been received from peonies originating in Holland, *Piptanthus nepalensis* (England) and mulberry (Bahamas). *M. hapla* may, therefore, eventually be found to be a synonym of *Anguillula marioni* Greeff but we are not justified in drawing such a conclusion without material from the type host and locality in France. *M. hapla* could have been introduced from Europe on nursery stock, as is being done today, or it could have been taken to Northern Europe from here in early colonial days. [See discussion of *M. arenaria.*]

Meloidogyne incognita (Kofoid and White, 1919) n. comb.
(Figs. 5, A–M and 6, E)

Synonym.—*Oxyuris incognito* Kofoid and White, 1919.

Male.—1.2–2.0 mm long; α 39–48; β 8–17. Head with 3 more or less distinct post-labial annules, lateral cheeks 6 μ long. Stylet 23–26 μ long (usually 25–26 μ); knobs, 5.5–6.5 μ across by 3–3.5 μ long, rounded into stylet, not pronouncedly set off, sometimes apparently bilobed anteriad; dorsal gland orifice

[3] Mr. Paul H. Millar has pointed out that the particular variety of *M. hapla* which he submitted from Arkansas reproduces poorly on okra. The same has been found true of the variety from Missouri. Both these varieties reproduce well on peanut as do all other sources of *M. hapla* tested thus far. We may further note that *M. hapla* is thus far the only root-knot nematode known to reproduce on strawberry plants.

1.7–3.5 μ from base of stylet (mean 2.5 μ). Head very difficult to obtain in lateral view, usually lying dorso-ventral in mount of preserved material. Spicules 34–36 μ, measured along chord of their arc; 2 or 1 outstretched testis (progeny of same female).

Female.—510–690 μ long by 300–430 μ wide. Stylet 15–16 μ long; knobs rounded but not sharply set off from shaft, 4–5 μ across by 1.8–2 μ long; dorsal gland orifice 2–4 μ (mean 3 μ) behind base of stylet. Perineal pattern of transverse striae (annulation) characterized by distinct arch containing a whorl not interrupted laterally, markings of anal plaque tending to be vertical as illustrated (i.e. longitudinal) Fig. 5, F–G; transverse striae toward vulva distinct.

Egg.—80–98 μ long by 30–38 μ wide.

Larva.—360–393 μ long; α 29–33; β 5.6–6.4; γ 8–9.4. Post-labial annules 3; stylet 10 μ long, knobs deeply rounded and 2 μ across by 1.3–1.5 μ long; gland orifice 2–2.5 μ behind base of stylet. Tail simple.

Type host.—Man. (Probably a parasite of carrots.)

Type locality.—Texas. (Present material from carrots, El Paso.)

Topotypes.—Nematology Coll. V2–20.

The above description is based on materials representing J. R. Christie's population 11D, from Lovell peach roots, Fort Valley, Georgia.

Kofoid and White (1919) described eggs encountered in fecal samples of soldiers at Camp Travis, Texas, and various military units of the Southern Department (Texas, Oklahoma, New Mexico and Arizona) under the name *Oxyuris incognito.* Sandground (1923) pointed out that these eggs agreed in all known respects with those of the nematode then known as *Heterodera radicicola*, i.e., root-knot nematode. We have obtained eggs of the root-knot nematode from *Daucus carota* var. *sativa* which do not differ in any respect from the original description. Furthermore, we have evidence that this is the native and predominant root-knot nematode of the territory discussed.

This nematode was referred to by Christie and Havis (1948) as population 11D. It reproduces on Yellow Globe onions and cotton, but does not reproduce on peanuts or Yunnan and Shalil peach roots. Galls formed on most hosts are massive. Similar nematodes were sent in on celery by J. R. Christie from Sanford, Fla.; on lima beans by H. H. White from Cape May, N. J., by J. R. Christie from Sanford, Fla., by H. B. Cordner from Stillwater, Oklahoma, and by H. W. Reynolds from Sacaton, Arizona; on peppers by W. H. Thames from Lake Worth, Fla.; and on Cactus sp., from Cadereyta, Mexico, by port interception of the Bureau of Entomology and Plant Quarantine, U.S.D.A.

The species *M. incognita* appears to be general (probably native) in the southern United States and various subtropical American islands. There seems to be a number of varieties differing from one another in mean position of dorsal gland orifice and number of distinct post-labial annules in the males. However, there is some variation in the position of the dorsal gland orifice in the progeny from the egg mass of a single female. The mean measurements of this position from various egg masses differ and we may well interpret this as genotypic segregation.[4] Pending evidence of fixed varieties with their host ranges, we are not justified in going further into subdivision.

On the basis of distribution, one might expect this nematode to be the same as that described from coffee by Goeldi, namely *M. exigua*, but attempts to infect coffee seedlings failed.

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[4] In a population of this type obtained from gardenia in Beltsville, Md., and Long Island, N. Y., greenhouses, the dorsal gland orifice in adults of both sexes tends to be further posteriad (3–5 μ posterior to base of stylet). The host range and stability has not been investigated.

Meloidogyne incognita var. *acrita* n. var.
(Figs. 5, N–U and 6, F)

Male.—1.0–1.6 mm long; α 39–46; β 11–13. Head moderately long; labial annule wide and rather flat in lateral view; 3 faint post-labial annules; lateral cheeks 4 μ long. Stylet 20–24 μ long (usually 23–24 μ), stylet shaft cylindrical; knobs extremely prominent, globoid with anterior concavity in some views, 3–3.5 μ long by 5–6 μ across; dorsal gland orifice 2–4 μ posterior to base of stylet (usually 2–3 μ). Spicules 29–34 μ along chord of their arc. Phasmids preanal to latero-anal; 2 or 1 testis.

Female.—440–670 μ long by 364–545 μ wide. Stylet 16 μ long; knobs very prominent, rounded, and even appearing bilobed in some views, 2 μ long by 5 μ across; dorsal gland orifice 3–5 μ posterior to base of stylet. Perineal pattern devoid of sub-lateral incisures pattern of transverse striae (annulation) somewhat squared in latero-anal plane, with squarish post-anal whorl, sometimes an exaggerated whorl; markings on anal plaque tending to be transverse.

Egg.—82–93 μ long by 36–39 μ wide.

Larva.—345–396 μ long; α 22–28; β 6.1–7.1; γ 7.0–7.5. Stylet 10–11 μ long; knobs prominent, rounded, 1.0–1.5 μ long by 2 μ across; dorsal gland orifice 2–2.5 μ posterior to base of stylet.

Type host.—Sea Island cotton, *Gossypium barbadense.*

Type locality.—Tifton, Georgia.

Syntypes.—Nematology Coll. X–15.

The type material was collected by J. H. Machmer, December 14, 1948. This nematode did not infect Jumbo peanuts but developed readily on cotton with rather small galls, the egg masses subglobular, outside the roots. On tomatoes the galls are massive, confluent, egg masses chiefly inside the roots. It also reproduced well on Lovell peach and Yellow Globe onions. This variety differs from the type in that the transverse striae (annulation) in the post-anal region tend to be straight instead of arched, and the knobs of the stylet are more set off in both sexes.

It would be remiss not to mention that twice we have encountered individual females in which the perineal pattern on one side of the body was that of *M. incognita* and on the other side it was in one instance *M. i. acrita* and in the other case it was *M. javanica.* Both cases occurred in mixed natural populations. Male stylets of *M. javanica* are very similar to those of *M. incognita* and of course the whole anatomy of *M. incognita* and *M. i. acrita* is very similar.

Meloidogyne arenaria (Neal, 1889), n. comb.
(Figs. 1, A–H and 6, B)

Synonym.—*Anguillula arenaria* Neal, 1889.

Male.—1.27–2.00 mm long; α 44–65; β 11–16. Labial annule very wide, squarish in lateral view; 1 distinct, wide, undivided, or 3 faintly separated, post-labial annules. Lateral cheeks 4–5 μ long. Stylet 20–24 μ long, stylet shaft not tapering; knobs smoothly rounded to stylet, not set off, 4–5 μ across by 3 μ long; dorsal gland orifice 4–7 μ posterior to base of stylet. Spicules 31–34 μ on chord of their arc. Phasmids preanal to latero-anal. Testes 2, outstretched or reflexed at tip.

Female.—510 μ–1.00 mm long by 400–600 μ wide. Stylet 14–16 μ long; knobs rounded to stylet, 4–5 μ across by 2 μ long; dorsal gland orifice 4–6 μ posterior to base of stylet. Perineal pattern of transverse striae (annulation) characterized by lines tending in post-anal region to be straight instead of arched, usually squared to form somewhat of a shoulder laterally; no clear lateral incisures.

Some transverse striae bending toward vulva, as illustrated. Phasmids 28–31 μ apart.

Egg.—77–105 μ long by 32–44 μ wide.

Larva.—450–490 μ long; α 26–32; β 7.2–7.8; γ 6.0–7.5. Stylet 10 μ long; knobs 2 μ across by 1 μ long, taper into stylet; dorsal gland orifice 3 μ posterior to base of stylet.

Type host.—Peanut.

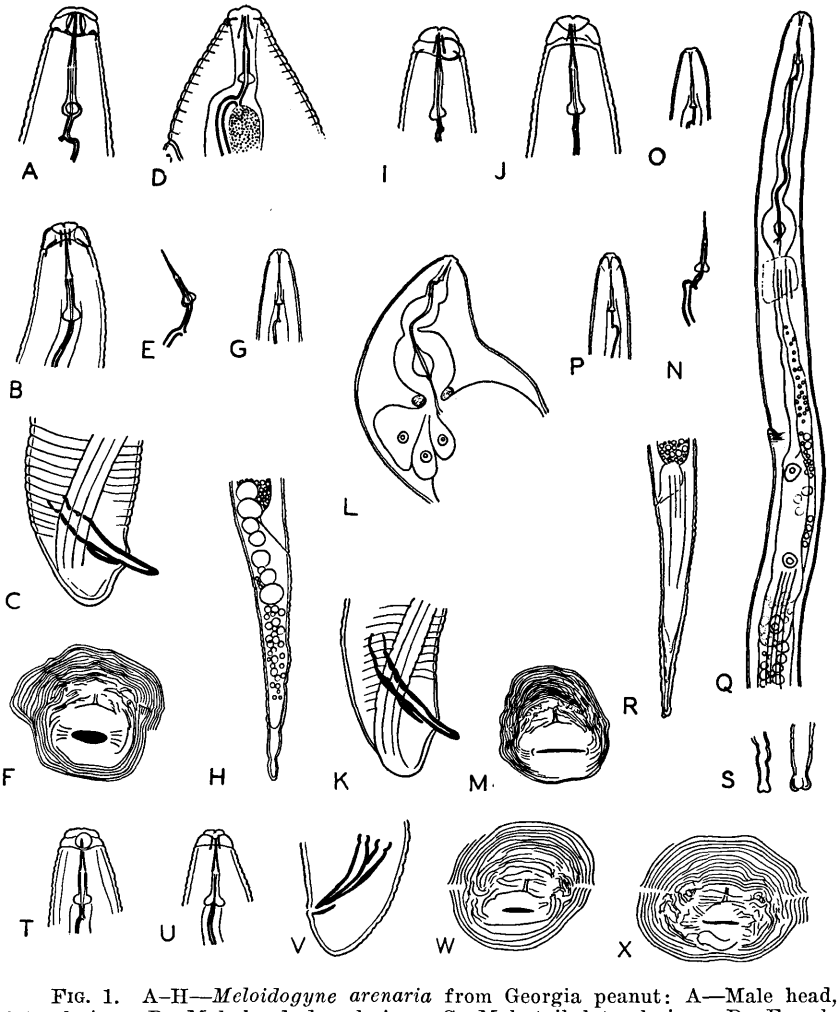

FIG. 1. A–H—*Meloidogyne arenaria* from Georgia peanut: A—Male head, lateral view. B—Male head, dorsal view. C—Male tail, lateral view. D—Female head, lateral view. E—Female stylet, lateral view. F—Female perineal pattern. G—Head of larva. H—Tail of larva, lateral view. I–S—*Meloidogyne arenaria* from *Boehmeria* (Florida): I—Male head, lateral view. J—Male head, dorsal view. K—Male tail, lateral view. L—Female head, lateral view. M—Female perineal pattern. N—Female stylet, lateral view. O–P—Larva, heads, lateral view. Q—Larva, esophageal region, lateral view. R—Larva, tail, lateral view. S—Larva, variants in tip of tail. T–X—*Meloidogyne exigua* from coffee, N. Y. Botanical Garden: T—Male head, lateral view. U—Same, ventral view. V—Male tail, lateral view. W–X—Female perineal patterns.

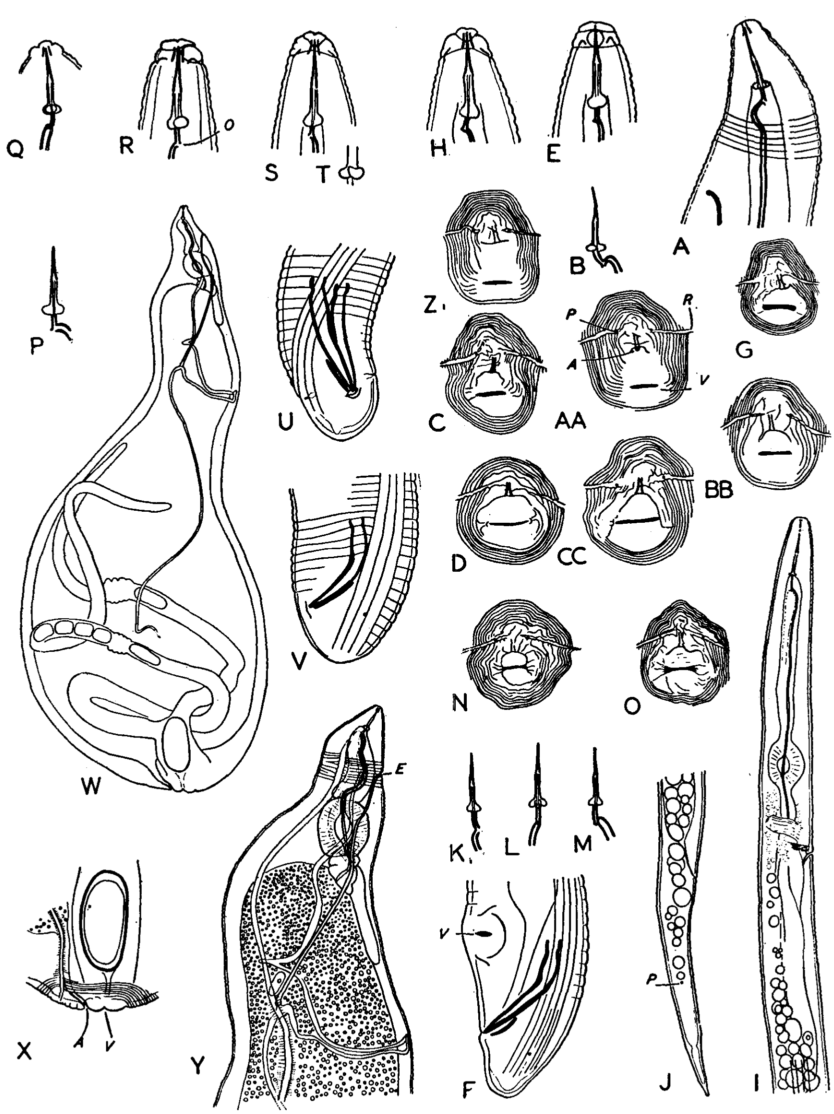

FIG. 2. *Meloidogyne javanica.* A–D—From *Saccharum officinarum,* Java: A—Female head. B—Female stylet. C–D—Female perineal pattern. E–G—From *Ageratum conyzoides,* Java: E—Male head, lateral view. F—Male tail, lateral view. G—Female perineal pattern. H–O—From Yunnan peach, Georgia: H—Male head, dorsal view. I—Larva, esophageal region. J—Larva, tail. K–L–M—Female stylets. N–O—Female perineal patterns. P–BB—From lima beans, Texas: P—Female stylet, lateral view. Q—Female stylet, dorsal view. R—Male head, oblique view. S—Male head, median view. T—Male stylet knobs. U–V—Male tails. W—Young female, lateral view. X—Detail of vulvar region, lateral view. Y—Detail of esophageal region of female. Z–AA–BB—Female perineal patterns. CC—From garden balsam, California: Female perineal pattern.

A, anus; *P,* phasmid; *V,* vulva; *O,* dorsal gland orifice; *E,* excretory pore.

Type locality.—Archer, Fla., or Lake City, Fla.

Present materials.—Nematology Coll. V2–4.

In 1889 Neal described *Anguillula arenaria* as a parasite causing galls on the roots of numerous plants. Inasmuch as he was untrained in the subject of nematode anatomy, many of his statements are found incorrect. Nevertheless, he was

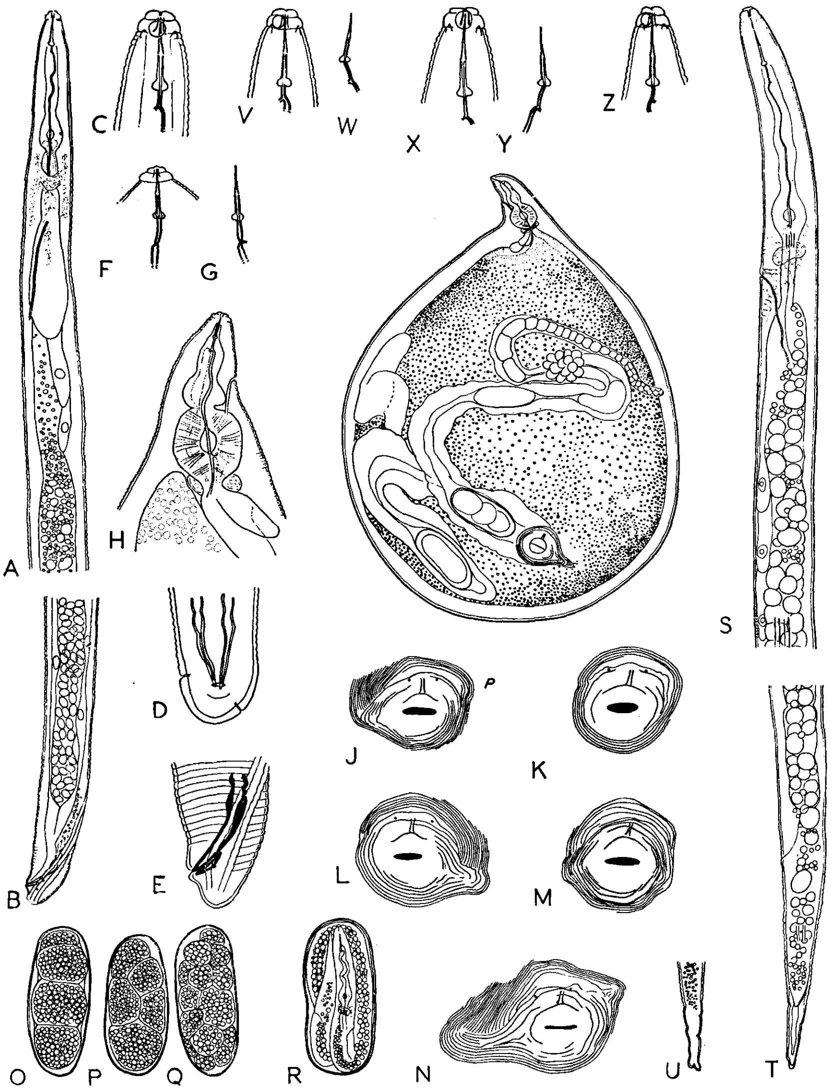

FIG. 3. *Meloidogyne hapla* n. sp. A—Male esophageal region, ventral view. B—Male tail, lateral view. C—Male head, lateral view. D—Male tail, ventral view. E—Male tail, lateral view. F—Female head, ventral view. G—Female stylet, lateral view. H—Female esophageal region. I—Entire female. J–N—Female perineal patterns. O–R—Eggs. S–U—Hatched larva. V–W—From Arkansas: V—Male head, lateral view. W—Female stylet, lateral view. X–Y—From peanut, North Carolina. X—Male head, lateral view. Y—Female stylet, lateral view. Z—From Missouri: male head, lateral view.

a fine clinical observer and his work contained a great deal of merit. We now realize that Neal dealt with several different nematodes. It therefore becomes necessary to make some selection. On page 17 he states "In a field near my place . . . the roots of peanut became masses of knotty roots, the worst cases of

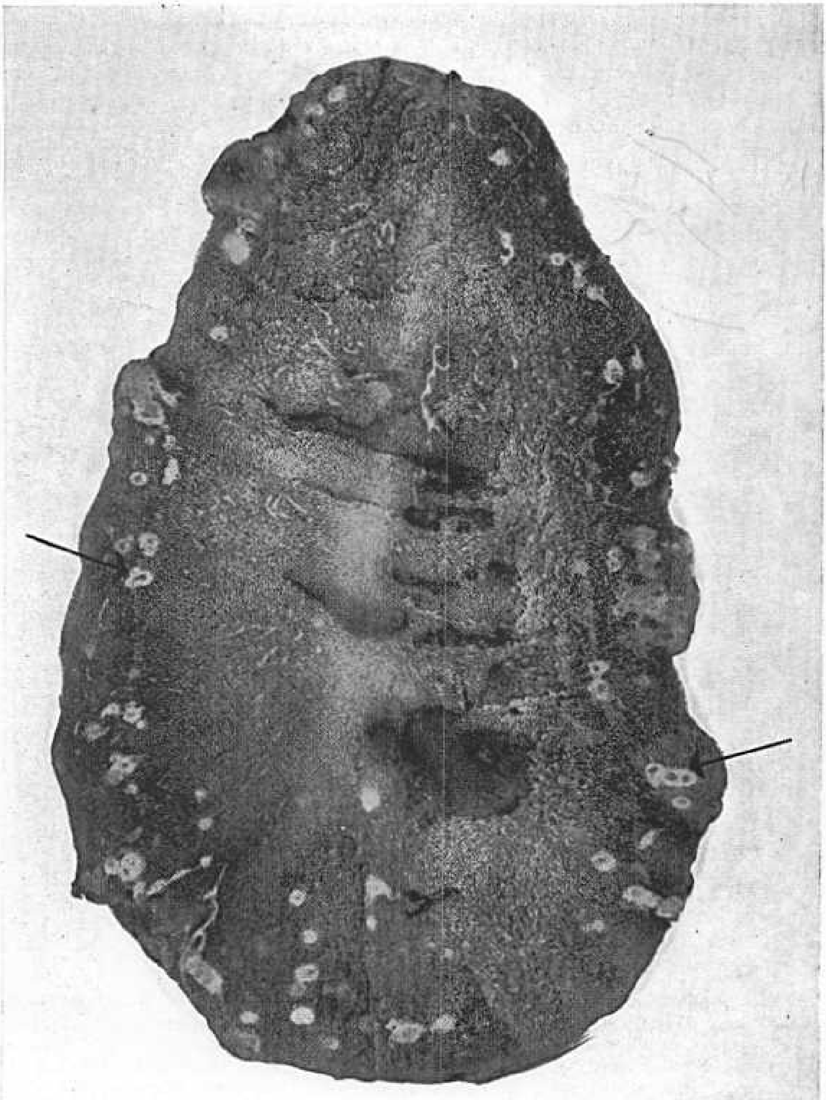

FIG. 4. Green Mountain variety of potato, from Suffolk County, N. Y. Sectioned potato treated with iodine. Note clear areas surrounding nematode (arrow) which are devoid of starch.

the disease I ever saw, and peach trees growing in the field are ruined." On the basis of this statement, peanuts are selected as the type host. Whether or not he was dealing with a single species in the field to which he refers does not particularly matter. The present material was collected by J. H. Machmer. It is being tested for pathogenicity to Lovell peach understock. In one controlled test with five replications this nematode did considerable damage to Lovell peach seedlings but there was no evidence of reproduction thereon.

A very similar nematode was sent in by W. H. Thames from ramie, *Boehmeria utilis,* collected at Canal Point, Florida. It differed from the *M. arenaria* in the peanut material designated as type host in that the dorsal gland orifice was only 3 μ behind the stylet base in both males and females. In a single controlled test (5 pots) this organism did not reproduce on Spanish peanuts. This matter is being investigated further.

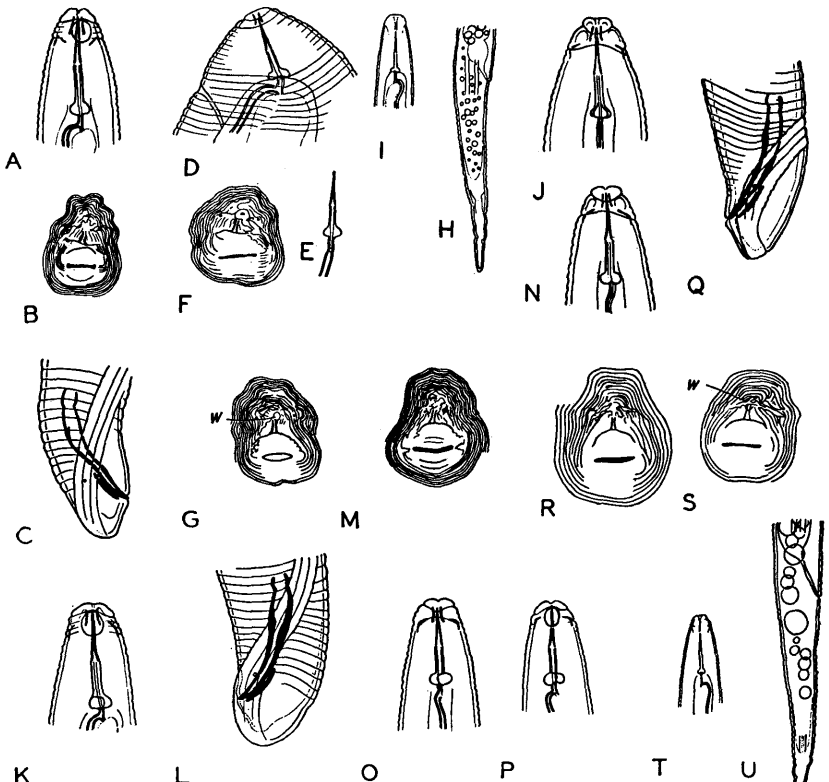

FIG. 5. *Meloidogyne incognita.* A–C—From Texas carrot: A—Male head, lateral view. B—Female perineal pattern. C—Male tail, lateral view. D–L—From Georgia peach (population 11 D): D—Female head, lateral view. E—Female stylet, dorsal view. F–G—Female perineal patterns; *W,* whorl. H—Larva, head, lateral view. I—Larva, tail, lateral view. J—Male head, dorsal view. K—Male head, lateral view. L—Male tail, lateral view. M—From Mexican cactus: female perineal pattern. N–U—From Georgia cotton: N—Male head, ventral view. O—Male head, median view. P—Male head, lateral view. Q—Male tail, lateral view. R–S—Female perineal patterns; *W,* whorl. T—Larva, head, lateral view. U—Larva, tail, lateral view.

M. arenaria is unquestionably closely related to *M. hapla* and like *M. hapla* it may be a synonym of *Anguillula marioni.* It would appear, however that *M. arenaria* and *M. hapla,* if introduced from Europe, represent separate introductions. If *M. arenaria* was introduced, we might well suspect the introduction to date back to the Spanish Invasion of Florida.

M. arenaria from *Boehmeria* may be a local variant or, according to information supplied by Mr. W. H. Thames, this organism may have been introduced into

FIG. 6. Photomicrographs of female perineal regions taken with phase microscope. A—*Meloidogyne hapla*. B—*Meloidogyne arenaria*. C—*Meloidogyne javanica*. D—*Meloidogyne exigua*. E—*Meloidogyne incognita*. F—*Meloidogyne incognita* var. *acrita*.

Florida from Mexico with its host plant. Regardless of these various possibilities, we can be fairly certain of one thing, namely, that *M. arenaria*, *M. arenaria* from *Boehmeria* and *M. hapla* were at one time the same organism.

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Host-parasite Relationships of the Root-knot Nematodes, *Meloidogyne* spp. III. The Nature of Resistance in Plants to Root Knot[1]

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What we have been calling *Heterodera marioni* (Cornu) Goodey is not a single species but includes several species and varieties differing from one another

[1] Revision of a paper presented at the meetings of the Association of Southern Agricultural Workers, Bàton Rouge, La., February 1, 1949.

in certain respects. Chitwood (1949[2]) discusses the taxonomic aspects of the situation, gives the distinguishing morphological characters of some of the species, and places them in the genus *Meloidogyne* Goeldi, 1887. In the present paper the members of this genus are referred to as ''the root-knot nematodes'' while the term ''root knot'' is used to designate the disease caused by these parasites.

Plants generally regarded as highly resistant to root knot, such as *Crotalaria spectabilis* Roth, peanut, marigold, etc., are resistant to most species of *Meloidogyne* although there are at least two species (*M. hapla* Chitwood and *M. arenaria* (Neal) Chitwood) to which the peanut is susceptible. The tomato is highly susceptible to most species; I experimented at one time however, with a population of root-knot nematode secured from Klamath Falls, Oregon, that I failed to establish on tomato though I made repeated attempts. Hence, in any discussion of the susceptibility or resistance of any particular plant to root knot, statements must be qualified as applying to most species of *Meloidogyne* or to the one involved in the instance cited.

Tyler (1941) defined susceptibility in a plant as its condition of being a suitable host for a given parasite. However, she did not define resistance in a plant as its condition of being an unsuitable host, but as the ability to obstruct the invasion of parasites. Obviously, Tyler conceived resistance to root knot as some condition in a plant whereby larvae either failed to enter the roots or entered in small numbers, a conception that probably reflected the view taken by most investigators at that time. This conception is no longer tenable. Barrons (1939), in the most important contribution that has been made to this phase of the subject, demonstrated that, when both plants were given an equal opportunity to become infected, just as many larvae entered the roots of *Crotalaria spectabilis* as entered the roots of tomato. For the 24 resistant plants with which he worked, resistance became manifest, not through failure of larvae to enter the roots, but through failure of larvae to survive after entering.

We must recognize the possibility that all resistant plants are not necessarily resistant for the same reason. In experiments with the entrance of larvae into roots, I found that when both were equally exposed to infection, the roots of alfalfa were heavily invaded by larvae of a certain species but only very rarely were the roots of lantana entered. These results suggest the existence of plants whose roots may not be invaded freely by larvae of all species. Insofar as the matter has been investigated, however, it seems probable that most resistant plants fall in the same category as those with which Barrons worked.

Referring to the nematode parasites of animals, LaPage (1937) lists the criteria of resistance as: ''(1) Failure of the nematode to live inside the host or its early death in it. (2) Decrease in its production of eggs or larvae. (3) Inhibition of its growth or development, so that . . . the adults require longer to mature and do not live so long when they are mature, sometimes being stunted and smaller.'' As a result of his work with *Heterodera rostochiensis* Wollenweber, Gemmell (1943) concludes that ''these criteria can be applied to plant parasitic nematodes. . . .'' LaPage's criteria very clearly apply to the *Meloidogyne* group and they probably apply to at least all the nematodes that are sedentary plant parasites.

In a highly suitable host for a given species of *Meloidogyne*, growing at a temperature optimum for rapid development of the parasites, the first females to mature begin to lay eggs in from 25 to 30 days after they enter the roots as larvae. In a slightly less suitable host there is a slight increase in this period of development. In a still less suitable host there is a further increase in the period of development and females tend to lay fewer eggs. As we pass along the

[2] Proc. Helminth. Soc. Wash., this issue.

scale to increasingly more unsuitable hosts, a point is reached where only occasional females ever reach maturity and these are small, ill-nourished individuals that lay very few eggs or none at all. In a highly unsuitable host very few invading larvae ever reach the molting stage.

Although larvae will enter almost any part of a plant that is in contact with moist soil and into which they can penetrate, most of them enter near root tips. They usually assume a more or less oblique position with the head protruding slightly into the region that will eventually become the vascular cylinder and with the tail extending into the cortex. The parasites feed like all other plant-parasitic nematodes, by puncturing cells and sucking out the content (Linford, 1937). The root-knot nematodes, however, are sedentary parasites i.e., once the larvae become located within the root they remain in the same place throughout the parasitic phase of development; if males, until their final molt and metamorphosis; if females, throughout the remainder of their life. The stylet is not exceptionally large or powerful and is capable of puncturing only comparatively thin-walled cells. Although the stylet is located at the end of a protrusile neck, the nematode can reach only those cells that are within a short distance of its head. Under the influence of a secretion produced by the nematode (Linford, 1937), profound changes occur in the morphology and physiology of the surrounding plant tissues, the so-called giant cells are formed (Christie, 1936), and the plant obliges by bringing food to the parasite (Kostoff and Kendall, 1930).

What would happen if the plant failed to oblige, if these changes did not take place, and the root proceeded in its normal development? The parasite would very soon be surrounded by the cells of the cortex and the highly specialized tissues of the vascular cylinder. Many of the cells would have exceedingly heavy walls that the stylet would be quite incapable of puncturing and most of the cells would be so highly vacuolated that, even though punctured, they would be useless as a source of food. In such a situation the nematodes would soon die of starvation. All the observed facts indicate, as Barrons suggested, that this is substantially what happens. Tissues at the region of invasion either fail to respond properly or respond so slowly that the parasites develop under the stunting influence of malnutrition or perish of starvation. Cross sections taken through marigold roots preserved six to eight days after invasion, showed a condition around the head of the parasite somewhat similar to that found in tomato roots one day after invasion. Giant cells had not formed and from six to eight days is about as long as larvae of most species survive in marigold roots. I am not suggesting that giant cells are an invariable requisite. The nematodes can and do feed on many kinds of non-vacuolated, thin-walled cells (Linford, 1937) and in some situations, as will be noted later, it seems probable that larvae can derive from such a source, sufficient food on which to reach maturity.

If a plant is a highly suitable host for a given species of this nematode, larvae usually do not cause much necrosis in the root tissues during early stages of parasitism, and subsequent breakdown and decay of the root system probably is caused largely by the secondary invasion of other organisms. If a plant is slightly to moderately resistant there is often a small necrotic area at the region of invasion suggesting that the salivary secretion of the nematode not only fails to exercise the proper stimulating effects on the surrounding tissues but actually kills them. That larvae fail to develop in resistant plants because they kill the tissues on which they depend for food is an attractive theory but one that, on close scrutiny, does not appear to be adequate. It seems probable, however, that this reaction of the tissues is *one* of the factors that make some plants unsuitable hosts and that *sometimes* it may be largely responsible for the death of larvae.

The extent to which the growth of a plant is affected by root knot depends on many factors but, in general, it is not necessarily the most susceptible plants that are the most severely injured. Under good growing conditions, especially where lack of moisture is not a critical factor, tomato plants may harbor a heavy infection yet make a surprisingly good growth. On the other hand, the growth of peach, pepper, cotton, and okra, all of them somewhat less suitable hosts to some species of root-knot nematodes than tomato, is usually quite sharply retarded, even by a moderate infection. In such cases there is an incompatibility between the host and the parasite that is detrimental to both. Highly resistant plants like *Crotalaria* and marigolds do not escape injury. When they are invaded by larvae in large numbers enough root tips may be killed or their growth terminated so as to stunt the plant, sometimes quite severely when in the seedling stage. Because easily recognized galling does not occur, this type of injury, though not uncommon or unimportant, has been generally overlooked. However, the parasites live but a short time and their effect is usually a temporary one from which the plant may soon recover, unless other more suitable hosts growing in the same soil continue to supply new larvae. Slightly less resistant plants, in which the parasites can live longer, are likely to be more severely injured. I believe that the plants likely to be the most severely injured are those that possess resistance to a degree that permits just enough females to reach maturity and lay sufficient eggs to provide a continuing source of infective larvae.

The food supply of the parasite will be influenced by its proximity to others and by its position in the root, i.e., the character of the tissues surrounding it and the extent to which these tissues have differentiated at the time of invasion. In this connection the following observations[3] are of interest. Rooted cuttings of the rose pelargonium, *Pelargonium graveolens* (Thunb.) L'Hérit., were grown for a few months in soil infested with a root-knot nematode and then removed for examination. On their roots were a very few small, woody galls in most of which no parasite could be found although occasionally it was possible to recover a dead parasite or a small, partly developed living one. At the bases of several of the cuttings there had developed small, thimble-shaped, succulent outgrowths made up of thin-walled, more or less undifferentiated cells. Why these outgrowths occurred, whether or not they are of common occurrence, and what they should be called, I am not prepared to say. It was discovered, however, that they were studded with mature, normal egg-laying females of the root-knot nematode. Why did the parasites develop in these outgrowths at the base of the cutting yet fail to develop in the roots? The answer, I believe, is not far to seek. Larvae that entered the roots were surrounded by cells undergoing rapid differentiation and, in order to survive, were faced with the necessity of retarding and altering this differentiation and stimulating the formation of giant cells. This they were unable to do. On the other hand, larvae that entered the outgrowths at the base of the cutting were surrounded by cells that were not undergoing rapid differentiation but naturally remained in such a condition that they provided a suitable source of food. In such a situation the larvae were able to develop to maturity.

Barrons (1939) suggests "as a speculative hypothesis . . . that resistance may be due to certain chemicals within the roots of resistant plants that counteract or neutralize the giant-cell-inducing effect of the salivary secretions of the nematodes." By this hypothesis Barrons believes it is possible to account for all the known facts concerning resistance. Various degrees of resistance, for example, would be due to differences in the ability of different plants to synthesize this neutralizing substance. When large numbers of larvae are crowded into a small

[3] Observations by J. H. Machmer, Div. of Nematology, BPISAE.

section of root the amount of this hypothetical substance might be insufficient to neutralize the combined secretions of all the parasites and a few might be able to undergo at least partial development. Inability of some plants to synthesize this substance while young would account for the apparent increased susceptibility of these plants while in the seedling stage. In any event, tissues of different plants, or different tissues of the same plant, react differently to a given stimulus and herein lies the reason why some plants are suitable and some are unsuitable hosts for a given species of *Meloidogyne*.

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The Incidence of Ascarids (*Ascaris lumbricoides*) in Midwestern Swine

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Although the large intestinal roundworm, *Ascaris lumbricoides*, is known to be widespread among pigs in the United States and is considered to be one of the most injurious of the worm parasites that infest swine, there is comparatively little recent information of a precise nature as to the number of swine that actually harbor these parasites. One of the earliest investigations to ascertain the incidence of ascarids in swine in this country was conducted by Ransom and Foster (1920). These investigators examined the small intestines of 2,583 swine slaughtered in various meat packing establishments in Chicago, Illinois, and found ascarids in 41.1 percent; the age of the animals examined was estimated to range from 1 month to 4 years. Spindler (1934) examined post-mortem 348 swine that originated in the Southeastern States and were slaughtered in a meat packing establishment in that region; 74 percent harbored ascarids. The age of these swine at slaughter ranged from 4 months to several years, the majority being between 6 and 12 months old. Andrews and Connelly (1945) examined post-mortem 129 hogs belonging to the herd of the Georgia Coastal Plain Experiment Station; 68 percent harbored ascarids. The average weight of the animals examined was approximately 225 pounds, and the average age was about 6 months.

A much lower incidence of ascarids in swine has been observed in farm-raised pigs examined in the Division of Veterinary Medicine at Iowa State College, ac-

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cording to Dr. E. A. Benbrook (1947). In a personal communication to the junior author of this paper, Dr. Benbrook stated that during the period 1928 to 1944, 14,573 pigs were autopsied and only 8.5 percent found to harbor ascarids. Most of the pigs examined were less than 1 year old and, as stated in the personal communication, ''All these pigs were, of course, sick for one reason or another.''

During the course of an investigation to test the efficacy of sodium fluoride in removing ascarids from swine, which was carried out in Chicago during the period 1945 to 1948 (Allen, 1945; Allen and Jones, 1946; and Allen and Andrews, 1948), examinations for ascarid eggs were made of the feces of a series of swine selected at random from the general run of hogs received in the stockyards of a large meat packing establishment. The examinations were made for the purpose of procuring infested animals that could be used in treatment tests. Inasmuch as the examinations extended over a period of several months and involved hogs known to have originated in various States of the Middle West, it is considered that the findings are significant in connection with the question of the prevalence of ascarids in swine originating in that region, which is the important swine-producing area of the United States.

It should be emphasized that these findings were incidental to the accomplishment of the aforementioned anthelmintic tests. The methods used were those that could be carried out under rather adverse conditions in a relatively short time. This fact, together with the inherent weaknesses of any method of determining incidence by fecal examination, make it necessary to consider the incidence as here reported as minimum rather than true incidence.

METHODS

During the months February to October, 1945, both inclusive, and during August, 1947, an examination for ascarid eggs was made on a rectal sample of feces from each of 505 swine; most of the animals examined weighed from 180 to 225 pounds and, presumably, were 6 to 8 months old or older. In 429 of the swine, the direct smear technique of examination was used, a single smear being made from the one sample taken from each animal. In the remaining 76 animals there was employed a centrifugal flotation technique, utilizing a levitation medium composed of equal parts of a saturated solution of magnesium sulphate and a saturated solution of sodium chloride[2]. Because of its cumbersomeness, the flota-

TABLE 1.—*The incidence of ascarids in swine originating in the Middle West as determined by fecal examination*

Month	Year	Method of Examination	Number examined	Number infected	Percentage incidence
February	1945	direct smear	26	11	42
March	1945	do	64	23	36
April	1945	do	119	37	31
May	1945	do	57	23	40
August	1945	flotation	76	20	26
September	1945	direct smear	27	12	45
October	1945	do	111	32	29
August	1947	do	25	19	76
Totals		....	505	177	35

[2] This flotation medium is one that has been used for a number of years by workers of the North Shore Animal Hospital, Evanston, Illinois.

tion method was abandoned in favor of the direct smear technique. It will be noted from the data (Table 1) that the hogs examined by the flotation method showed a lower incidence of ascarids than any of the other groups examined by direct smear. However, since comparative tests of the two methods were not made on any one group of pigs, it is not possible from the data at hand to evaluate as to the superiority of one method of examination over the other.

RESULTS

The findings are summarized in Table 1. As can be seen from the data, 177 (35 percent) of the 505 swine examined harbored ascarids, as shown by the finding of the eggs in the feces. During February and extending through October, 1945, 480 of the 505 animals were examined; 158 (33 percent) of these harbored ascarids. There was no significant monthly variation in the number of parasitized animals during the period named. During August, 1947, however, 25 hogs were examined; ascarid eggs were found in the feces of 76 percent (Table 1).

DISCUSSION

In view of the different techniques employed by previous investigators in examining hogs for ascarids, and in view of the wide range of ages of the animals dealt with, it is difficult to compare the findings set forth in this paper with those that have already been published. A few comparisons of a very general nature may be made, however. In the case of the 1920 survey by Ransom and Foster, it was reported that 1,062 of the swine examined were from 5 to 12 months of age. Of these, 43.2 percent harbored ascarids. In contrast to these findings, 35 percent of the swine of a comparable age examined by us were passing ascarid eggs in the feces in sufficient numbers to be detected by the method of examination utilized. The differences between our findings and those of Ransom and Foster, whose results were based on post-mortem examination, may be accounted for, perhaps, by the fact that fecal examination is inherently imperfect both from the standpoint of the number of eggs that must be present in the feces before they can be detected, and from the standpoint that examinations of the feces for eggs will not detect an infection composed wholly or largely of immature and/or male worms.

It will be noted that the data provided by Benbrook and cited elsewhere in this paper show an incidence of ascarids in farm-raised pigs much lower than that found by us. It has been mentioned that Benbrook's pigs were reported as being "sick" prior to the time they were autopsied. Possibly the various "sicknesses" affecting these pigs provided conditions in the host unfavorable for ascarids and, as a result, the worms were possibly expelled from the host. On the other hand, swine management practices under which these pigs were reared and the premises on which they were maintained may have been unfavorable to acquisition of ascarids.

Our results, when compared with those of Spindler (1934) and Andrews and Connelly (1945), indicate that ascarids are less prevalent in midwestern hogs than in those originating in the Southeastern States, possibly because of climatic and other differences between the two regions, as well as differences in swine management practices.

It is interesting to compare the incidence of ascarids in swine in this country with that reported by investigators in other countries. In Canada, Choquette and Swales (1944), in reporting on the incidence of ascarids in purebred "bacon pigs," concluded, on the basis of fecal examinations, that approximately 75 percent of the animals examined had acquired ascarids some time between the ages of 2 and 6 months.

Payne, Ackert and Hartman (1925) reported that from 3.5 to 10.8 percent of 469 hogs which they examined in Trinidad harbored ascarids; these data were derived from post-mortem examinations as well as from fecal examinations, but no information was given concerning the ages of the pigs in question.

Roberts (1934) stated that in Queensland, Australia, approximately 20 percent of 46,433 pigs, very few of which were under 5 months of age at the time of slaughter, were found to harbor ascarids at slaughter, and he added that this percentage should be considered an absolute minimum for the general run of hogs originating in that region. Roberts personally examined 654 pigs marketed at Brisbane and found that 34 percent were parasitized with ascarids. In 1940 he further reported that the incidence of ascarids in 243 ''bacon pigs'' (at least 6 months old) that originated in Queensland was 21.4.

Peterson in Denmark reported (1941) that of 100 pigs examined the intestines of 93 were infested. The abstract of this paper gave no information concerning the ages of the pigs examined.

In the Philippines, Schwartz (1922) found on post-mortem examination of 29 presumably farm-raised pigs of all ages, that 24 percent harbored ascarids; of 7 wild pigs examined, none was infected. Alicata (1947) made fecal examinations of 103 ''grown'' pigs in Hawaii and found ascarid eggs in 21 percent.

In Puerto Rico, Spindler (1940) observed 19 infections of ascarids in 100 pigs of all ages at the time they were slaughtered in abattoirs.

On the basis of data presented in Table 1, it seems reasonable to assume that at least one-third of the hogs raised in the Middle West may harbor ascarids at the time they are marketed. The adverse effect of ascarids on the health of growing pigs is well known (Ransom, 1927; Schwartz, 1937; Spindler, 1947 and others). In addition, the occurrence of lesions in the livers of infected swine (Schwartz and Alicata, 1930, 1932) is responsible for considerable economic loss through condemnation of the affected organs (Roberts, 1934, and Peterson, 1941). In addition, Spindler (1948) pointed out that ascarids are a cause of condemnation of swine carcasses due to generalized icterus resulting from occlusion of the bile ducts by these worms. In view of the damage known to be inflicted on swine by ascarids and the widespread occurrence of these parasites in swine in the Corn-Belt herein reported, it may be concluded that losses are being sustained by swine raisers and others as a result of infection of swine with this nematode. These considerations suggest the need for wider use on farms of control measures which are known to be effective against this parasite.

SUMMARY

1. During the course of anthelminthic tests conducted at Chicago, 505 pigs were examined for *Ascaris lumbricoides* by fecal examination involving mainly the direct smear method.

2. The results, obtained in 1945 and 1947, showed that 35 percent of the pigs were passing *Ascaris* eggs in the feces.

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A Description of the Male of *Chitwoodiella ovofilamenta* Basir, 1948 (Nematoda: Thelastomatidae)[1]

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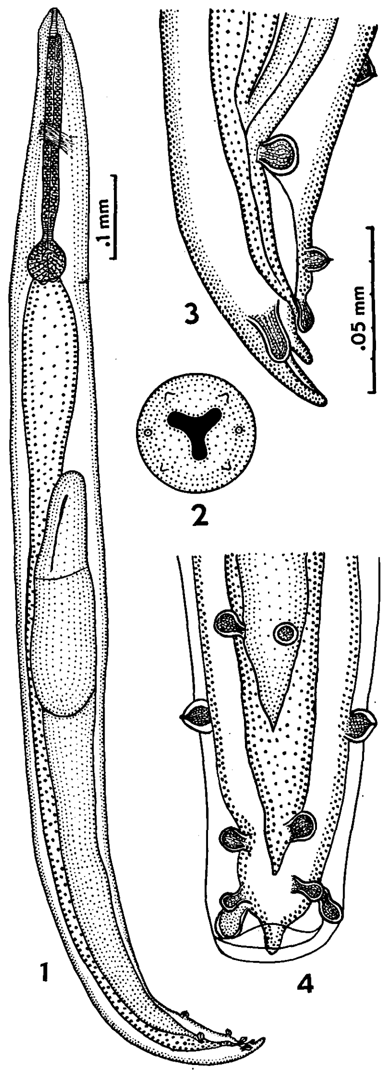
The description of *Chitwoodiella ovofilamenta* was confied to females only as no males were found in the original collection from India. During this year a small collection of nematodes recovered from mole crickets was sent to us at our request by Dr. E. McC. Callan of the School of Tropical Agriculture, B.W.I. This collection contained both males and females of this species. The author wishes to express his gratitude to Dr. McC. Callan, and also wishes to thank Dr. B. G. Chitwood who very kindly helped him in the study of the head views of these worms.

Chitwoodiella ovofilamenta Basir, 1948

Male.—Body 1.3 to 1.48 mm. long, smaller than that of the females. In the following description measurements are taken from a worm 1.38 mm. long by 110 μ in maximum width. Body almost cylindrical, tapering anteriorly in the oesophageal

[1] Contribution from the Institute of Parasitology, Macdonald College of McGill University, Que., Canada.
[2] At present at the Institute of Parasitology, Macdonald College of McGill University, Que., Canada.

region and posteriorly in the region of the tail. Mouth opening sub-triangular. Head bears four very small papillae; amphids present. Buccal wall similar to that of the female, bearing striations. It is 30 μ long by 10 μ in maximum width. Oesophagus 302 μ long (almost one-fourth of the total body length) consisting of a corpus 232 μ long by 20 μ wide, a narrow isthmus, 20 μ long by 10 μ wide, and a posterior valvate bulb 50 μ long by 45 μ wide. The intestine is dilated anteriorly



FIGS. 1–4. Morphological details of the male of *Chitwoodiella ovofilamenta* Basir. 1—Entire, lateral view. 2—*En face* view. 3—Tail end, lateral view. 4—Tail end, ventral view.

to form a slight cardia. Anus is situated 34 μ from the posterior extremity. Nerve ring lies near middle of oesophagus, 145 μ from the anterior end of the body. The excretory pore is situated slightly posterior to the base of oesophagus. Testis single, reflexed anteriorly, 230 μ behind base of oesophagus. Tail almost truncated, bearing distinct caudal alae. There are 5 pairs of caudal papillae of which 3 pairs are preanal and two pairs postanal. Both the latter pairs are distinctly pedunculated; of the 3 pairs of preanal papillae, the anteriormost pair is ventral in position and lies 70 μ anterior to anus; the second pair is laterally situated and is 50 μ anterior to anus; the third pair is again ventral and is 10 μ from the anus. The stalks of the preanal papillae are very short. In addition to these caudal papillae, there is a median ventral, rod-like, bluntly-pointed projection jutting out backwards from the tail just behind the anus. This projection is 18 μ long.

Host.—*Scapteriscus vicinus* Scudder (Gryllidae).

Location.—Presumably intestine.

Locality.—B.W.I.

The family Thelastomatidae is distinguished from the family Oxyuridae only by head characters. The former is characterized by the presence of 8 cephalic papillae while the latter possesses only 4. The description of the majority of thelastomatids is based on the study of the females only. In most cases males are not known and where they are known, their head structures differ from those of the females and therefore cannot be relied upon for taxonomic consideration. In a few cases recent authors have studied the head structures, but usually such descriptions have not been available. The usual tendency has been to group arthropod parasites which have oxyurid characters into the family Thelastomatidae, on the presumption that they would belong there. However, the present study shows that the male head of the species under study bears only 4 cephalic papillae. Although the number of papillae on the male head is not of much significance, this fact led the author to restudy the female head. The head in these worms is so small and the papillae are so obscure that a final conclusion could not be arrived at, but it is doubtful if the female has 8 papillae. On re-examination only 4 papillae could be traced in the female also. If that observation is correct then these worms cannot be retained in the family Thelastomatidae but will have to be transferred to the family Oxyuridae. The author also suspects that there might be other members at present standing in the Thelastomatidae which likewise really belong to the Oxyuridae. But at present the matter is kept *subjudice* until further study can be made.

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Paradistomum samoensis n. sp., a New Dicrocoeliid from Samoan Lizards

ELON E. BYRD

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During 1943 the writer had occasion to examine several specimens of two species of Samoan lizards, *Emoia nigra* Hombron and Jacquinot and *E. samoensis* Dumeril, from the island of Tutuila. About 75 per cent of the lizards examined proved to harbor a species of dicrocoeliid trematode in the gall bladder and bile duct. This trematode occurred in the lizard host in all stages of development from recently acquired, very small worms to fully developed, sexually mature specimens. Since many of the specimens were small and without ova in the developing uterus the material was very favorable for working out the details of the excretory system. Subsequent study based on this material indicates the species is new to science. The form is described herein under the proposed name of *Paradistomum samoensis* n. sp., and the details of the excretory system are given.

Paradistomum samoensis n. sp.

(Figures 1–3)

Description.—Dicrocoeliinae: Dicrocoeliidae. Body thin and semi-transparent in life, elongated leaf-like, a little more than twice as long as broad, 1.80–3.93 mm. long by 0.77–1.03 mm. wide, being broadest in zone of ovary and vitellaria. Cuticle marked by rather prominent transverse striations and a few inconspicuous papillae. Cuticular papillae present on cephalic third of body. Oral sucker subterminal, muscular, 0.17–0.30 mm. long by 0.22–0.32 mm. wide. Acetabulum muscular, in caudal limits of cephalic third of body, with its anterior margin 0.36–0.73 mm. behind anterior end of body: it measures 0.19–0.27 mm. in diameter. Average ratio of suckers about 1: 1.1. Prepharynx absent. Pharynx muscular, about one-half exposed behind caudal margin of oral sucker, 0.06–0.08 mm. in diameter. Esophagus slender, slightly flexed in preserved specimens, approximately one and one-half times as long as pharynx, bifurcating into ceca in advance of level of acetabulum. Ceca large, 0.20 mm. in maximum width, undulating slightly in descending to near posterior end of body, with one cecum usually a little longer. Testes at about the same level, widely separated, usually lying ventral to ceca or with inner margins in intracecal area. Testicular zone overlaps posterior portion of zone of acetabulum by about one-half the length of a testis. They are transversely oval (rarely with long axis parallel to long axis of body), 0.11–0.19 mm. long by 0.10–0.31 mm. wide for right and 0.08–0.20 mm. long by 0.10–0.22 mm. wide for left testis (left testis absent in one specimen). Vasa efferentia arising from medio-cephalic border of testes and passing forward laterally to acetabulum to unite a short distance in front of acetabulum. Vas deferens short, entering posterior end of cirrus pouch. Cirrus pouch weakly muscular, 0.16 mm. long by 0.07 mm. in maximum width, containing slightly dilated and coiled seminal vesicle (occupying posterior half of pouch), a pars prostatica with very few gland cells and a short, muscular, unarmed cirrus. Genital pore ventral in position, at or in front of intestinal bifurcation, usually displaced slightly to right of body midline. Ovary sub-median in position, displaced slightly to right of midline, with lateral margin pressed closely against inner margin of right cecum, 0.11–0.23 mm. behind level of acetabulum, ovoid to squarish in outline, with smooth to slightly irregular borders, 0.15–0.21 mm. long by 0.10–0.23 mm. wide, with longer axis more often diagonal to long axis of body. Seminal receptaculum dorsal to medial margin of ovary, about one-third as large as ovary. Shell gland median, immediately behind zone of ovary. Laurer's canal present. Vitellaria follicular, lateral in position, composed of about 18–36 follicles on each side of the body in extracecal area, with a few follicles invading area of ceca, beginning in young specimens in zone of testes while in fully mature individuals the follicles may begin as far posterior as zone of ovary, terminating at a level 0.50–0.68 mm. behind ovarian zone. Transverse vitelline ducts emerging from near cephalic limits of the glands, passing inward to become fused into a small, sub-median yolk reservoir near caudal limits of the shell gland. Uterus greatly convoluted, convolutions generally forming transverse loops across body, filling intracecal, cecal and extracecal areas of body from posterior limits of vitellaria to caudal extremity. Ascending uterus passing forward to level of ovary by following course similar to that of descending uterus, forming many short loops to left of ovary, then turns laterally to invade cecal and extracecal area in front of vitellaria on that side of body, from whence it forms transverse loops across the body to fill all available space between cephalic limits of the vitellaria and anterior margin of the acetabulum (in some specimens the uterus does not completely enmesh one or the other testis (Fig. 3) and in these the transverse loops do not cross the body in front of the acetabulum, while in other individuals both testes become completely surrounded by uterine coils and the entire area of the body dorsal to the acetabulum is filled by the ascending uterus. In these latter individuals one or two complete transverse loops of the uterus lie in front of the acetabulum). Uterus ultimately approaching midline and ascending through a few minor coils to the genital pore. Near the caudal limits of the cirrus pouch the uterus develops a weakly muscular wall, the metraterm, and this takes a sharp bend to one or other side of midline so that it approaches the genital pore from the right or the left side. Ova numerous, dark-brown in color, operculated, fully embryonated when oviposited and measure 36–48 μ in length by 20–28 μ in width. Excretory system bilaterally symmetrical. Bladder median, undulating slightly in passing through posterior half of body, with two short, dilated cornua at cephalic end. Flame cells twenty-four in number (Fig. 2), grouped into twelve pairs, with six pairs on each side of the body and these are equally divided between the anterior and posterior halves of the body. Flame cell pattern $2[(2+2+2)+(2+2+2)]$, or $2 \times 6 \times 2 = 24$ flame cells.

Hosts.—*Emoia nigra* Hombron and Jacquinot and *E. samoensis* Dumeril.

Habitat.—Gall bladder and bile duct.

Locality.—Tutuila, Samoa.

From the standpoint of its general anatomy the present species more closely resembles *Paradistomum trachysauri* (MacCallum, 1921) Dollfus, 1922, than is true for the other members of the genus. The new species can be separated from this form by its smaller suckers, its smaller ovary and testes, the more posterior distribution of the vitellaria in the sexually mature specimens and by the more extensive coiling of the uterus in the region of the acetabulum. In regards to this last named character the new species displays certain similarities to members of the genus *Euparadistomum* Tubangui, 1931. The nature of the coiling of the uterus in the region of the acetabulum together with the distribution of the vitellaria behind the level of the testes prevent the inclusion of the new species in the genus *Euparadistomum*.

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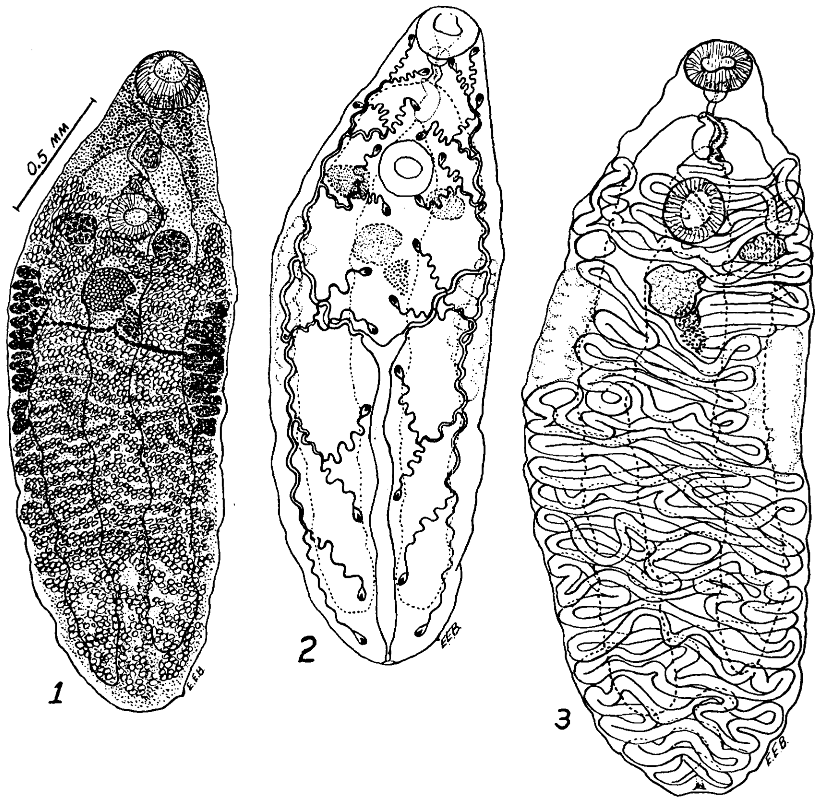

FIGS. 1–3. *Paradistomum samoensis* n. sp. 1—Ventral view of a complete worm showing the general details and organization of the internal anatomy. (Camera lucida.) 2—Details of the excretory system. (Camera lucida sketch of body: excretory system semi-diagrammatic.) 3—Outline sketch of a second specimen showing the more extensive development of the uterus in the area of the acetabulum. (Camera lucida sketch of body and organs: loopings of the uterus semi-diagrammatic.)

Report of the Brayton H. Ransom Memorial Trust Fund

FUNDS ON HAND, Jan. 1, 1948	$1640.93
RECEIPTS: interest rec'd in 1948	58.48
DISBURSEMENTS: expenses and grant to Helminthological Society of Washington	31.00
BALANCE ON HAND, Dec. 31, 1948	$1668.41

Eloise B. Cram,
Secretary-Treasurer

MINUTES

Two Hundred Seventy-seventh to Two Hundred Eighty-fourth Meetings

The 277th meeting was held October 13, 1948, at The Catholic University of America, Washington, D. C. The following were elected to membership: Dr. E. H. Marchant, Dr. Khan M. A. Basir, Mr. A. C. Tarjan, and Mr. R. F. Harrington. Papers were presented by Griffin, Cram, Baernstein, and Spindler.

The 278th meeting was held November 17, 1948, at the Station of the Zoological Division, U. S. Bureau of Animal Industry, Beltsville, Maryland. Mr. Earl H. Fife and Mr. Elmer F. Chaffee were elected to membership. Papers were presented by Tittsler, Young, Shorb, Tarjan, Goldberg, and Lucker.

The 279th meeting was held at The Catholic University of America, Washington, D. C., on December 15, 1948. The following officers were elected to serve in the year 1949: B. G. Chitwood, President; L. J. Olivier, Vice-president; Edna M. Buhrer, Corresponding Secretary-Treasurer; J. C. Lotze, Recording Secretary. A. O. Foster was re-elected to serve as representative in The Washington Academy of Sciences. Papers were presented by Cornfield and Chitwood.

The 280th meeting was held January 12, 1949, at The Catholic University of America, Washington, D. C. D. A. Shorb was appointed to serve as member-at-large on the Executive Committee. G. Steiner was elected as a member of the Editorial Board of the *Proceedings*. Papers were presented by Tarjan, Spruyt, and Spindler.

The 281st meeting was held at The Catholic University of America, Washington, D. C., February 16, 1949. Mr. Aaron Goldberg and Rev. F. William Spaeth were elected to membership. Papers were presented by Farr, Price, Reinhard, Wehr, and Chitwood.

The 282nd meeting was held at The National Institute of Health, Bethesda, Maryland, March 9, 1949. Mr. Merle L. Colglazier and Mr. James H. Turner were elected to membership. Papers were presented by von Brand, Lund, C. Horton-Smith of England, and Tarjan.

The 283rd meeting was held at The Johns Hopkins University, Baltimore, Maryland, April 22, 1949. Papers were presented by Otto, Whorton, Rozeboom, Dikmans, C. C. Tang of China, Velat, M. Sasa of Japan, and Chernin.

The 284th meeting was held May 21, 1949, in the form of an annual picnic meeting at the Plant Industry Station, Beltsville, Maryland. Mr. Charles R. Youngson was elected to membership.

John C. Lotze,
Recording Secretary

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