American Museum Novitates

PUBLISHED BY THE AMERICAN MUSEUM OF NATURAL HISTORY
CENTRAL PARK WEST AT 79TH STREET, NEW YORK 24, N.Y.

NUMBER 1888 MARCH 21, 1958

On Some Species of the Oriental Earthworm Genus *Pheretima* Kinberg, 1867, with Key to Species Reported from the Americas

By G. E. Gates

This contribution presents further results of a study that was begun some 10 years ago of unidentified earthworms belonging to the American Museum of Natural History.

The author's thanks are extended to the authorities of the Museum for the loan of the material as well as for use of the library, to the Rockefeller Foundation for financial support during a portion of the period in which the work was under way, and to the following individuals for assistance rendered in various ways: Mr. Joseph Myers, Prof. L. B. Clark, Prof. Walter Harman, Prof. Wm. A. Niering, Dr. G. E. Pickford, and Dr. Libbie Hyman.

Pheretima agrestis (Goto and Hatai, 1899)

Pheretima agrestis, Gates, 1953, Breviora, vol. 15, p. 5.

Specimens Examined: Schenectady, New York, from compost heap in garden of Union College, September 18, 1956, 0-0-1, Joseph Myers per L. B. Clark and Libbie Hyman. Riverside, Greenwich, Connecticut, on lawn after application of fertilizer, September 3, 1956, 0-0-1, Theodore Bott. Shreveport, Louisiana, 0-0-4, Walter Harman.

Internal Anatomy: Pigment is present in the longitudinal muscle band at mD and in the circular muscle layer appears to be deposited in annular striae. Pigment appears to be as dense at segmental setal equators as elsewhere.

The subneural trunk is adherent to the parietes rather than to the nerve cord in preserved specimens. The brain and most of the circumpharyngeal connectives are left, by a transverse section exactly along 3/4, in iii.

Male deferent ducts have no epididymis. Male terminalia, as in all previous American specimens, lacking. Seminal vesicles large and soft just as at sexual maturity.

Ovaries fan-shaped, each with several egg strings. Spermathecae probably are of normal size. The diverticulum on one spermatheca of vi (one specimen) is shortly digitiform, without differentiation into stalk and seminal chamber. Seminal chambers may be translucent (Schenectady) or filled with a firm white coagulum.

REPRODUCTION: The clitellar tumescence is maximal. Ova in the egg strings appear to be mature. The texture and size of the seminal vesicles suggest profuse sperm production. Nevertheless, in these as well as in previous American specimens, there is no evidence, on male funnels or in spermathecae, of presence of mature sperm. Spermatogenesis presumably is prematurely terminated and completely. Reproduction must be parthenogenetic.

REMARKS: *Pheretima agrestis* had been reported previously from Albany, Baltimore, Boston, and New York City. Albany and New York City worms were secured from culture beds and from greenhouses. The original home of the species is to be sought in Japan, whence the worms probably were brought along with plants. Horticulturalists, florists, and gardeners probably were then responsible for subsequent distribution through the country. Successful colonization followed escape from greenhouses. Earthworm culturists in recent years and also anglers doubtless have assisted in extending the American range, much of which presumably remains to be discovered.

An R morph is the only one as yet recognized in America.

Pheretima agrestis was erected on a hundred anarsenosomphic Japanese specimens, a few of which (from Oarai) had a pair of presetal genital papillae on xviii. The species supposedly is distinguished by the presence ventrally in (iv-v)vi–viii(ix) of paired or unpaired regions where the epidermis is thin, setae are lacking, and a special brown color may in life be visible. Those brown patches were absent on a few of the originals, but how such inornate individuals were identified is unknown. Two specimens with one or two presetal papillae on xviii, in a Korean series of 246 (Kobayashi, 1938), along with each papilla, had a male pore. The bilaterally arsenosomphic worm (presumably with brown patches) could have provided data as to anatomy

of the ancestral H morph. Unfortunately, however, the male terminalia and even the male porophores were not adequately characterized. Arsenosomphic individuals supposedly are in a majority at Sapporo (Japan), but if the needed information has been recorded it is available only in ideographs. The intermediates that will provide the proof of conspecificity for H and R morphs probably can be found at Sapporo.

Pheretima hataii Ohfuchi, 1937, arsenosomphic, with a pair of presetal genital papillae on xviii and distinguished from *agrestis* only by absence of brown patches on viii, may then be the extant representative of the H morph from which the *agrestis* R morph is descended.

An A morph has not been recognized in Japan, the probable home of the species, and an AR probably would not have been distinguished, if inornate, from that of any other manicate species.

A precis will be included in a subsequent paper.

Pheretima brevicincta, new species

SPECIMEN EXAMINED: Guadalcanal Island, Solomon Islands, 0-1-8, F. C. Cilley. (Holotype, A.M.N.H. No. 3504.)

EXTERNAL CHARACTERISTICS: Length, 56–95 mm. Diameter, 3–4 mm. Segments, 77 (No. 8), 93–98. Prostomium epilobous, *ca.* ½. Pigment present in dorsum, possibly brown, though one specimen has the dark blue appearance often associated with dense deposition in the circular muscle layer of a red pigment. Setae present from ii, more closely spaced ventrally in preclitellar segments; 18/ii, 23/iii, 28/iv, 29/v, 27/vi, 36/vii, 34/viii, 45/ix, 50/xii, 47/xvi, 48/xxi, v/15, vi/14, vii/18, viii/17, xvii/19, xviii/9, xix/16, xviii/9–13, circle of xvi complete (eight specimens). First dorsal pore at ?11/12 (one specimen), 11/12 (four specimens), 12/13 (three specimens), ???13/14 (No. 8). Clitellum annular, extending forward well towards 13/14 and back to or nearly to eq/xvi, setae lacking on xiv–xv, intersegmental furrows 14/15–15/16 obliterated, sites of dorsal pores usually unrecognizable.

Spermathecal pores minute and superficial, nearly ½C apart, five pairs, on 4/5–8/9. Female pore median (eight specimens, probably median on aclitellate specimen). Male pores minute and superficial, rather widely separated but less so than the spermathecal apertures, each at center of a small, circular (No. 8), or slightly conical and smooth-surfaced porophore that is distinctly delimited by a circumferential furrow. Just in front of and just behind each porophore of each specimen there is a transversely crescentic, raised, distinctly delimited area without translucence. The areas are concave towards the

porophores, and on each side of the body, their median ends are almost in contact, the lateral ends more widely separated.

Genital markings paired but not closely, presetal, on viii, xviii, xix, xx (nine specimens), xvii (two specimens), and xxi (one specimen). Each marking has a gray translucent center and an opaque marginal band. Width of preclitellar and of postclitellar markings, respectively, four to six and three to six intersetal intervals. Postclitellar markings median to male pore levels, markings of xviii more closely paired, in one worm almost in contact at mV. An additional pair of presetal markings in contact at mV, in one worm, on xix.

INTERNAL ANATOMY: Septa 5/6–7/8 membranous; 8/9 lacking (four specimens); 9/10 and succeeding septa membranous (four specimens). Longitudinal muscle band at mD with dense pigmentation.

Intestinal origin in xv. Esophagus in xiv and anteriormost portion of xv valvular, with low, closely crowded, vertical lamellae gorged with blood on inner wall in xii–xiii. Intestinal caeca simple, constricted by septa 24/25 and 25/26 but without other incisions of ventral sides, in xxvi–xxiv or xxvii–xxiv (No. 8). Typhlosole lacking or quite rudimentary and then present only from xxvii posteriorly. Slight roughenings of intestinal roof at mD (one specimen) are all that is recognizable.

Heart of ix (lateral) on right side (two specimens), left side (two specimens), both hearts of x present (four specimens), hearts of x–xii lateroesophageal (four specimens).

Holandric. Testis sacs of x well above nerve cord, the ventral blood vessel between the sacs and in or on the longitudinal subesophageal mesentery. One or both (No. 8) of the sacs may be vertical, reaching up to level of dorsal face of gizzard and somewhat resembling a seminal vesicle. Horizontal sacs may be just as large, pushing 9/10 anteriorly. The testis sac of xi, also above the nerve cord, is U-shaped, horizontally placed and with transverse limb just in front of 11/12, or of a squarish to oblong shape. The ventral blood vessel is on or in the roof of the sac. Seminal vesicles medium-sized or (No. 8) large and filling coelomic cavities, acinous, each with a slender dorsal protuberance of variable length. The appendix is usually slightly widened at distal end, at which there may be a few small lobulations or protuberances. Prostates in xvii, xviii–xxi, xxii. Prostatic duct with marked muscular sheen, in a U-shaped loop with closed end anteriorly (in xvii), ectal limb thicker, more slender ental limb with one to three sinuosities. Male gonoduct passes into ental end of prostatic duct.

Spermathecae medium-sized (No. 8) or fairly large, in v–vii in con-

tact above the gut. Duct about as long as ampulla. Diverticulum, from anterior face of duct near parietes, reaching well up onto ampulla, slenderly club-shaped. Ovisacs (?), in xiv, finely acinous, each lobe of about the same size as large ovarian eggs.

No glands recognizable on parietes over sites of genital markings.

REPRODUCTION: Spermatozoal iridescence on male funnels shows that three of the dissected specimens are mature. A similar iridescence in spermathecal diverticula and in an ectal portion of the mass filling the spermathecal ampulla shows that copulation had been completed. Reproduction, then, presumably is sexual.

Iridescence, at ental ends of spermathecal diverticula in No. 8, is slight.

REGENERATION: Tail regenerate, at 75/76, with a terminal anus, has furrows presumably indicating an early stage of differentiation of five segments. The last three segments of No. 8, and the last few segments of some other specimens, may be regenerate. One posterior amputee had not regenerated.

REMARKS: The aclitellate specimen, with setae on xiv–xv, may be postsexual.

Pheretima solomonis (Beddard, 1899), erected on five specimens from Narrowol and New Georgia, Solomon Islands, differs from *brevicincta* as follows: Larger size, 140 by 9 mm. Genital markings are in transverse rows of three to six, in x–xi as well as other segments, with some of the markings median. A muscular septum was thought to be 8/9 but it may have been 9/10, as hearts are unlikely to have been present in a gizzard segment. Testis sacs of x were mistaken for seminal vesicles, and the relationships between testis sacs and vesicles of xi were not determined. Intestinal caeca were said to be present and are for the present assumed to have the same locations as in apparently related species.

Pheretima bifida Gates, 1937, erected on four specimens from Ugi, differs from the new species as follows: Spermathecae are doubled, i.e., there are two pairs opening at each intersegmental level. Female pores are paired. Genital markings are in xi–xii as well as in xvii–xix. Testis sacs are vertically U-shaped, the posterior one including the vesicles of xi. Septa 10/11–12/13 are muscular.

Pheretima lavangguana Gates, 1957, erected on specimens from several localities in Rennell Island, Solomon Islands, differs from *brevicincta* in these ways: Spermathecae are in paired groups of two to four, with an average of nearly 28 per specimen. Genital markings, present in xvii–xx and less frequently in xxi–xxii, xvi, ix–xi, are in four longi-

tudinal ranks. Testis sacs are paired, vertical, the posterior sacs including the vesicles of xi.

The four taxa, known only from original descriptions of a few specimens secured at single sites or from rather small areas, share the following characters: Spermathecae, about as described above, opening to exterior at 4/5–8/9. Clitellum short, a complete circle of setae present on xvi. Genital markings, without glands, presetal. Even the crescentic to reniform area immediately before and behind each male porophore appears to be common. Male pores minute and superficial. Septum 8/9 lacking or quite rudimentary, 9/10 present. Intestinal caeca simple, short, in xxvii or xxvi. Hearts lacking in xiii. Holandric.

Worms with those characteristics also have been found in the Philippine Islands. On specimens from the mountains of Benguet Province, Luzon, there were erected *P. orientalis, albobrunnea, sodalis,* and *pauaiensis* Beddard, 1912, all of which are known only from the original inadequate descriptions. The *orientalis* complex may prove to be but a single species in which genital markings are subject to considerable individual variation.

The Solomon Islands species must have gotten there from the west, hence perhaps from the Philippines. Subsequent isolation may then have enabled evolution of a battery of doubly paired spermathecae (*bifida*) and later on of the polythecal battery (*lavangguana*). The polythecal battery now appears to have evolved at various times, in several regions, and in different evolutionary lines.

PRECIS: Decathecal, pores minute, superficial, widely separated to nearly $\frac{1}{2}$C apart, at 4/5–8/9. Female pore median. Male pores minute, superficial, each at center of a small porophore. Genital markings paired but not closely except on xviii, presetal, on viii, xviii–xx, and less frequently on xvii, xxi. Clitellum reaching well towards 13/14 and to or nearly to eq/xvi. Setae, in a complete circle on xvi, 23/iii, 34/viii, 50/xii, 48/xxi, vi–viii/14–18, xviii/9–13. First dorsal pore at 11/12 or 12/13. Prostomium epilobous. Pigment red (?). Segments, 93–98. 56–95 by 3–4 mm.

Septum 8/9 lacking, 9/10 membranous, none thickly muscular. Intestinal origin in xv. Caeca simple, in xxvii or xxvi–xxiv. Typhlosole lacking or rudimentary. Hearts, lateral in ix, latero-esophageal in x–xii. Holandric; testis sacs of x horizontal or vertical, testis sac of xi U-shaped and horizontal. Prostates in xvii, xviii–xxi, xxii, duct muscular and thicker ectally. Spermathecae medium-sized to larger, diverticulum from anterior face of duct close to parietes, slenderly club-shaped and reaching well onto ampulla. (GM glands lacking.)

Pheretima copulata Gates, 1937

Pheretima copulata GATES, 1937, Bull. Mus. Comp. Zoöl. Harvard College, vol. 80, p. 315. (Type locality, Ugi. Type in Museum of Comparative Zoölogy.)

SPECIMEN EXAMINED: Guadalcanal Island, Solomon Islands, 0-0-1, F. C. Cilley.

EXTERNAL CHARACTERISTICS: Length, *ca.* 115 mm. Diameter, 7 mm. Segments, 104. Pigmentation unrecognizable (alcoholic preservation). Prostomium broad (prolobous?). Setae present from ii; 51/xii (*ca.* 70 if gray spots presumably indicating apertures of follicles from which setae had been dehisced are counted), vii/2, viii/4, ix/4, xvii/6, xviii/2, xix/6. First dorsal pore at 12/13. Clitellum annular, setae lacking, intersegmental furrows obliterated, sites of occluded dorsal pores recognizable, covering all of xiv–xvi.

Spermathecal pores minute, superficial, separated mesially by about the same distance as are the male pores. Paired female pores present. Male pores very small, transverse, superficial slits, each at center of a circular, smooth-surfaced field without definite boundary that reaches well towards 17/18 and 18/19.

Genital markings paired, in line with male pore areas. Four transversely elliptical, raised, clearly delimited markings without central translucence on xviii, two just behind 17/18 and two just in front of 18/19. Circular, presetal markings, each with a gray translucent center, on xvii, xix, right sides of xx and xxi.

INTERNAL ANATOMY: Typhlosole broad and flat in region of caecal origin, narrowing anteriorly, lamelliform posteriorly and ending abruptly about in liv.

Hearts of ix lateral, both present. Hearts of x–xiii latero-esophageal. Lymph glands unpaired, recognizable from xxxii posteriorly.

Testis sacs ventral, the ventral blood vessel quite obviously in a median space between the sacs. Seminal vesicles, in xii, acinous. Prostates small, in xvii–xviii. Prostatic duct, narrowed entally, with marked muscular sheen, straight, nearly 2 mm. long. Male gonoduct passes into ental end of prostatic duct.

Spermathecae rather small, below the gut. Duct slender. Diverticulum, from anterior face of duct at parietes, small, shorter than the duct, with very short, slender stalk and ovoidal to shortly ellipsoidal seminal chamber. The chamber of five spermathecae is more or less deeply bifid entally.

REMARKS: *Pheretima copulata* has been known hitherto only from

the holotype collected at another of the Solomon Islands (Ugi). The two specimens differ as to presence and absence of clitellar setae, and number, shape, and location of genital markings.

The species has several of the characters shared by the *brevicincta* group but is less advanced than *brevicincta* with respect to female pores (and clitellum?) but more specialized with respect to hearts and typhlosole.

Pheretima elongata (Perrier, 1872)

Pheretima elongata, GATES, 1937, Bull. Mus. Comp. Zoöl. Harvard College, vol. 80, p. 352.

SPECIMEN EXAMINED: Georgetown, British Guiana, soil rich in humus, 1957, 0-0-1, J. R. Ramsammy.

This species, of Malaysian origin, has not yet been found in the mainland states.

Reproduction, in the A morph and in the first order intermediates which have been found in tropical portions of the Americas, probably is parthenogenetic.

Pheretima stelleri (Michaelsen, 1891), type species of the subgenus *Polypheretima*, is not distinguishable from *elongata* and probably will fall into the synonymy.

The proposed subgenus is distinguished only by a combination of two characters: absence of intestinal caeca, grouped (instead of paired) spermathecae. Many acaecal species have paired spermathecae, and the polythecal condition is now known from various caecal species. (Cf. p. 5.)

Pheretima garama, new species

SPECIMENS EXAMINED: Kapingamarangi, Tokongo Islet, Caroline Islands (southern), under piles of decayed coconut husks, July 16, 1954, 1-8-7, Wm. A. Niering. (Holotype A.M.N.H. No. 3569.)

EXTERNAL CHARACTERISTICS: Length, 47–66 mm. Diameter, 3–4 mm. Segments, 86, 90 (three specimens, including one clitellate specimen), 91, 92, 94 (except as noted all aclitellate). Prostomium epilobous, tongue rather broad and short, open. Pigmentation red, except in first two to four segments, restricted to dorsum. Setae present from ii on which the circle is complete, *a–c* of some or all of iv–ix enlarged and more widely separated but size decreasing from *a* laterally, beyond *c* apparently much smaller, complete circles present on xiv and xvi as well, sometimes, as on xv, dorsal gap in circles lacking or insignificant;

xvii/13, xviii/11, xix/13, 28/iii, 36/viii, 47/xii, 53/xx; xviii/11, 33/iii, 40/viii, 58/xii, 59/xx. First dorsal pore at 11/12 (two specimens). Clitellum annular, lacking or quite thin behind eq/xvi and in front of eq/xiv, dorsal pores occluded, intersegmental furrows obliterated.

Spermathecal pores small, open, transverse slits, each in translucent central portion of an unpigmented area close to mD, in or just lateral to *zy*, three pairs, on 5/6–7/8. Female pore median (seven specimens), almost equatorial. Male pores small, transversely crescentic slits, each with a slight swelling of posterior lip and on a very small protuberance from gray translucent central area of a distinctly delimited, transversely elliptical porophore.

Genital markings paired, crescent-shaped, in line with male porophores, presetal (one pair) and postsetal (one pair) on xviii. Each marking has a gray translucent center and at full development reaches slightly onto xvii or onto xix, with the intersegmental furrow continued across the opaque margin.

INTERNAL ANATOMY: Septa 10/11–12/13 somewhat strengthened, none thickly muscular, 8/9–9/10 probably lacking. Pigment lacking in longitudinal muscle band at mD.

Intestinal origin in xv (six specimens). Acaecal (six specimens). Typhlosole, a low simple lamella, begins gradually in region of xx and is unrecognizable behind li (posterior amputee of 63 segments). A typhlosole is lacking in a broken-off tail portion comprising L27S.

Heart of ix (lateral) on left side (two specimens), right side (four specimens). Hearts of x–xii, though branch to dorsal trunk is represented only by a white cord, presumably latero-esophageal. No hearts in xiii (six specimens). Subneural trunk quite unrecognizable. Lymph glands paired, acinous, preseptal, recognizable only behind region of xxvi.

Holandric. Testis sacs large, distended by coagulum, paired (?) or unpaired and then U-shaped, in x horizontal and with limbs anteriorly directed, in xi vertical and with limbs dorsally directed. Male funnels small but rather thick, slightly plicate. Seminal vesicles all of same rather small size, firm, those of xi (but not the hearts) included in posterior testis sac. Vesicles of xii embedded in coagulum and each within a membranous pouch much like a testis sac. Pseudovesicles vertically strap-shaped, apparently lacking in xiii (six specimens) but present in xiv (six specimens). Prostates small, leaf-shaped, in xvii–xviii or confined to xviii. Prostatic duct at most 2 mm. long, slender entally, thicker ectally, and with obvious muscular sheen. Male gonoducts ap-

parently pass into ental end of thicker muscular portion of prostatic duct and hence well away from margin of prostate gland.

Spermathecae small. Duct (including parietal portion) nearly as long as ampulla, not recognizably narrowed in body wall. Diverticulum, from anterior face of duct close to parietes, much shorter than main axis, comprising a very short and slender stalk and a spheroidal to shortly ellipsoidal seminal chamber. Ovaries, as well sometimes as the oviducal funnels, seem to be unusually small.

No glandular tissues recognizable on parietes over male porophores or genital markings.

REPRODUCTION: Spermatozoal iridescence is unrecognizable on male funnels (four specimens, testis sacs of other dissected worms not opened) and in spermathecae (seven specimens). The ampullae have a dark reddish color (six clitellate and one aclitellate specimens). The seminal chamber of each diverticulum is filled with opaque white material. A similar substance or coagulum is present in spermathecae of some parthenogenetic lumbricid worms preserved during the reproductive period, but whether it arises *in situ* or is received in a copulatory act is unknown. Testis sacs and seminal vesicles appear to be in the same condition and of the same size in clitellate and aclitellate individuals. Ampullary content may become translucent after the breeding season (and with a pink color after certain types of preservation), but no other indications of postreproductive regression were recognized.

As no proof of maturation or exchange of sperm was found, the possibility of parthenogenetic reproduction requires consideration.

REGENERATION: Tail regenerates; of seven or eight segments at 75/76, of eight or nine segments at 81/82, at 73/74 with terminal anus but still unsegmented and unpigmented, at 44/45 an early blastema without invagination (aclitellate specimen). The last five segments of some worms, though small, may not be regenerate.

Clitellate worms, with one exception, are recent posterior amputees or have a tail regenerate.

REMARKS: Location of the first dorsal pore is not determinable, in most of the specimens, without some bending or pressure which, because of the condition, is undesirable.

Location of spermathecal pores near mD and the shorter clitellum, at present, appear to be specializations. Absence of intestinal caeca and of hearts in xiii, in the genus *Pheretima,* usually has been thought to be primitive.

Relationships to be considered are with *P. carolinensis* Michaelsen, 1910, erected on two specimens from the "Carolinen-Archipel" and 30

years later recorded from Angaul Island. That species was included by Michaelsen in *Polypheretima*. The subgenus "by definition" is acaecal and polythecal. The present worms, with singly paired spermathecae, must then go in some other subgenus. Additional known differences from *carolinensis* (smaller size, fewer segments, fewer setae per segment) are not, however, too great to fall within limits of intraspecific variation. If reproduction is sexual, *garama* and *carolinensis* may be related in somewhat the same way as *brevicincta* and *lavangguana* now appear to be. If, however, reproduction is uniparental *garama* may be only a parthenogenetic clone in which mutational reversal of previous evolution has reduced spermathecal groups to single pairs. Parthenogenetic clones of just that sort have been found, though but rarely, in *P. elongata*.

PRECIS: Sexthecal, pores small slits close to mD, at 5/6–7/8. Female pore median. Male pores small transverse slits in paired porophores. Genital markings crescentic, one just in front of and one just behind each male porophore. Clitellum between eq/xiv and xvi/eq. Setae in complete circles on xiv and xvi, 28–33/iii, 36–40/viii, 47–58/xii, 53–59/xx, xviii/11. First dorsal pore at 11/12. Prostomium epilobous, tongue open. Pigment red. Segments, 86–94. 47–66 by 3–4 mm.

Septa 8/9–9/10 lacking. Intestinal origin in xv. Acaecal. Typhlosole low, lamelliform. Hearts, lateral in ix, latero-esophageal in x–xii. Holandric, testis sacs paired or U-shaped and then horizontal in x but vertical in xi, the posterior sac including the seminal vesicles but not the hearts of xi. Prostates small, in xviii or xvii-xviii, ducts *ca.* 2 mm. long. Spermathecae small, diverticulum shorter than main axis, from anterior face of duct at parietes, comprising a short, slender stalk and a spheroidal to ellipsoidal seminal chamber. (GM glands lacking.)

Pheretima hilgendorfi (Michaelsen, 1892)

Pheretima hilgendorfi, GATES, 1954, Bull. Mus. Comp. Zoöl. Harvard College, vol. 111, p. 230.

SPECIMEN EXAMINED: Lake Charles, Louisiana, May 9, 1955, 0-0-10, Walter Harman.

EXTERNAL CHARACTERISTICS: Male terminalia, as in all previously examined American specimens, are lacking (anarsenosomphy). GM patches are present, at usual sites, in viii–ix. Tubercles, one for each GM gland, are numerous in the posterior patch but are few in the anterior one: two (one specimen), three (three specimens), five (one

specimen), six (four specimens), and seven (one specimen).

INTERNAL ANATOMY: Seminal chambers of spermathecal diverticula are filled with a white coagulum as at height of reproductive activity in sexual worms but spermathecal ampullae are empty and collapsed. Seminal vesicles are small, firm. Vasa deferentia end, without opening to the exterior, in xxii.

REPRODUCTION: These worms, like the previous American specimens, appear to be male sterile. Reproduction must be parthenogenetic.

Proof of uniparental reproduction was obtained by Kobayashi (1937) who found that anarsenosomphic Korean worms isolated from "the time of larval stage" deposited cocoons from which "normal larvae" hatched. Self fertilization appears to have been suspected. Even if sperm had been matured in the Korean worms, and as profusely as in the R morph of *P. anomala* Michaelsen, 1907, escape seems unlikely from the closed system constituted by the testis sacs, seminal vesicles, and male gonoducts. The latter, when an external aperture has not been acquired, attenuate so as to deny further passage to the gametes.

REMARKS: All American records of this species are recent and of worms from natural habitats. Although as yet unrecorded from greenhouses, importation and distribution presumably occurred in the same way as for *agrestis*.

Spermathecal ampullae, in some worms recently received from a Middleburgh (Virginia) site, have a content which is in part granular and in part a translucent jelly.

GM patches (presetal and median), in one of those specimens, are present in xvii–xviii.

All American material available to date has been of five R morphs:

With postclitellar GM patches:

1. Patches in xvii–xviii.

Without postclitellar GM patches:

2. Patches in viii only. This appears to be the most common morph in the United States.
3. Patches in viii–ix. More common in the United States perhaps than any other morph except 2. Elimination of the GM glands in the anterior patch may be under way in the Louisiana strain.
4. Patches in viii–x.
5. Patches in viii–xi.

Other morphs exist in Japan, the probable original home of the species, but their characteristics cannot be sorted out from generalized

descriptions and tabulations. R morphs probably constituted the bulk of those specimens for which data were provided in the literature. A and AR morphs have not been recognized, though third-order intermediates (evolving from R to AR), which were referred to another species, warrant expectation of finding them. Pseudo-intermediates, those not in direct line of evolution between the standard morphs, may be as common as in the Burmese *P. anomala* Michaelsen, 1907. The male terminalia in *anomala* may be translocated in either direction, but for *hilgendorfi* only anterior shifts, into xvii or xvi, have been recorded. Arsenosomphic individuals that have been seen in Japan may be of H or H_p morphs, but the male terminalia as well as other organs await adequate description.

Pheretima hilgendorfi is presently distinguishable only by the characteristic presetal patches of genital markings. Identifications as *hilgendorfi* of worms without such patches are unacceptable (cf. Gates, 1954, p. 233) and probably were in most cases erroneous. Accordingly, *hilgendorfi* of Michaelsen, 1892 (in part), 1899 (at least in part), 1900 (in part), 1903 (in part), 1916, and 1924 must be excluded from the synonymy or indicated as doubtful.

Pheretima yunoshimensis Hatai, 1930, erected on 64 specimens of which 63 were anarsenosomphic (male porophores and terminalia of the sixty-fourth specimen not described), has the characteristic patches and is not distinguishable from *hilgendorfi*. The quadrithecal individuals are third-order intermediates, the spermathecae abnormal, more or less rudimentary, and almost certainly functionless. Some of the specimens of *yunoshimensis* are said to have one or two spermathecae opening at 5/6. If the characteristic patches were present, the identification is acceptable. One or two spermathecae may be added at either end of a series, in uniparental and biparental taxa, but in parthenogenetic lineages such mutational additions are much more rare than the subtractions. In *yunoshimensis,* uniparental reproduction clearly is required by the organ deficiencies, and parthenogenesis is probable.

Pheretima glandularis (Goto and Hatai, 1899), known only from the original description of a single specimen presumably, has an apparently characteristic patch but on vii. Although arsenosomphic, the worm may have been parthenogenetic and accordingly could have been aberrant or markedly variant from the specific norm for genital markings.

A precis will be included in a subsequent paper.

Pheretima hirudinaria, new species

SPECIMEN EXAMINED: New Guinea, 0-0-1, M. C. Kurtz. (Holotype, A.M.N.H. No. 3506.)

EXTERNAL CHARACTERISTICS: Length, 133 mm. Diameter, maximum, in middle of body, *ca.* 15 mm., dorsoventral thickness in the same region *ca.* 10 mm. Body elliptical in cross section except at tapering ends which are curved dorsally. Segments, 98 (posterior amputee?). Pigmentation unrecognizable (alcoholic preservation). Prostomium epilobous, tongue open and with a median groove that is continued anteriorly and then down onto the ventral face. Secondary annuli present from x posteriorly, behind the clitellum the presetal furrow more distinct than the postsetal. Setae present from ii, circles without definite gap at mV but with slight gap at mD; viii/*ca.* 16, xviii/11, 155/xx. Dorsal pores first recognizable from 17/18. Clitellum annular, apparently pinkish to unaided eye but color unrecognizable under binocular, intersegmental furrows deep, setae lacking (?), on xiv–xvi.

Spermathecal pores minute, superficial, four pairs, on 5/6–8/9. Female pore minute, median, in a slight elevation just behind the presetal secondary furrow. Male pores minute, superficial, in setal circle of xviii, each in a slightly tumescent, smooth-surfaced area without distinct boundaries. A slight depression is noticeable behind each male porophore and about at 18/19.

Genital markings, rather indistinctly bounded, transversely elliptical areas of slight epidermal modification, paired but not closely, presetal, on left side of xvii, on xviii, xix, xx, and right side of xxi.

INTERNAL ANATOMY: Septa 6/7–7/8 muscular, 8/9–10/11 complete but membranous, 9/10 and 10/11 adherent to each other except close to parietes and near the gut where they are separated by hearts of x, 11/12–14/15 thickly muscular.

Gizzard in viii. Intestinal origin in xvii (?). Intestinal caecum of left side simple, short, but fairly broad, confined to xxvii. (Right caecum lacking or quite unrecognizable.) No typhlosole.

Commissures of viii, lateral to extra-esophageal trunks as are the hearts, connect the dorsal and ventral trunks. Hearts of ix both present. Last hearts in xiii. Lymph glands fairly large, almost transversely band-like, adherent to anterior faces of septa and the dorsal vessel, present at least from xxix posteriorly.

Holandric. Testis sacs unpaired, small, above the nerve cord and with the ventral blood vessel in or just under the roof, nearly filled by male funnels and testes (no coagulum). Seminal vesicles small, deep

down in coelomic cavities, those of xi acinous ventrally and with a clearly marked, yellowish dorsal ampulla, bound by connective tissue to the septa and to the testis sac. Pseudovesicles still smaller, present in xiii. Prostates small, confined to xviii. Prostatic duct *ca.* 2 mm. long, straight, rather slender, without muscular sheen.

Spermathecae elongately and rather slenderly club-shaped. An ental portion, slightly more than a half, filled with a firm translucent substance (pink color probably a preservation artifact). Diverticulum, from anterior face of duct within parietes, just reaching into coelomic cavity, with a slender, very short stalk and a shortly ovoidal seminal chamber.

REPRODUCTION: Spermatozoal iridescence on male funnels and in spermathecal diverticula is slight. Some sperm obviously had been matured and also received in copulation. The pink translucence of spermathecal ampullae, absence of coagulum in the testis sacs, and the yellowish color of the vesicle appendages may be indicative of a post-sexual stage, in which case the intersegmental furrows may have reappeared in the clitellum, though the epidermis obviously still is thickened.

Reproduction is, for the present, assumed to be sexual, though small-sized prostates and vesicles as well as empty testis sacs often are associated with parthenogenesis, as well, of course, as with immaturity.

REMARKS: Brown discs are present and numerous in coelomic cavities of the postclitellar portion of the body (possibly indicative of a postreproductive stage?).

Testis sacs were found only after some probing, among the opaque tissues, which destroyed an important part of the organization of the type. Avoidance of such destruction presumably has been responsible for inadequate, probably often erroneous, characterization of taxonomically important organs and relationships. That certainly seems now to be true with reference to testis sacs and their relationship to the seminal vesicles in many of the New Guinea species.

The shape of the body is unusual and, if normal, may prove to be diagnostic.

One octothecal, holandric species, *P. tamiensis* Ude, 1932, known only from the type, already had been recorded from New Guinea. From that species *hirudinaria* is distinguished by the larger somatic size as well as the unusual shape of the body, the muscularity of 11/12–14/15, the presence of intestinal caeca (but possibly sporadic as in some species of the Oriental genus *Eutyphoeus* rather than specific?), the presence of hearts in xiii, and by the unpaired testis sacs.

Characterization adequate for taxonomic needs usually cannot be obtained from a single individual. If the condition were perfect with respect to all characters (presumably an impossibility), necessity for retention of a type in as undamaged a state as possible would prohibit the securing of important data. Much of oligochaete taxonomy, as in the present instance, has had to be typological and, perforce, must continue to be subjective until such time as much more material than a casually obtained individual or the accidental spoil of other activity becomes available.

Pheretima houlleti (Perrier, 1872)

Pheretima houlleti, GATES, 1937, Rec. Indian Mus., vol. 39, p. 203.

SPECIMEN EXAMINED: Seven kilometers north of Vinales, Cuba, under stones, September 18, 1913, 0-0-1, F. E. Lutz.

EXTERNAL CHARACTERISTICS: First dorsal pore at 9/10. Genital markings lacking externally. Size and segment number typical.

INTERNAL ANATOMY: Typhlosole, continued anterior to caecal segment as a well-marked, pre-typhlosolar ridge that still is recognizable in xv, ends abruptly in lxx (worm with 94 segments, the anal segment possibly regenerated).

The penial body, within the copulatory chamber, is typical and has three or possibly four small genital markings basally. Penial setae are lacking, apparently also glands on posterior face of the copulatory chamber. One stalked gland, in addition to the anterior gland, is present and passes to the posterior face of the spermathecal invagination.

REMARKS: The previous American record of *houlleti* (cf. Gates, 1937) was of Bahama worms which proved to be referable to *meridiana* Gates, 1932.

The *houlleti* complex comprises two other taxa, *meridiana* and *campanulata* (Rosa, 1890), of uncertain status and interrelationships. The three forms differ from one another as to somatic size, segment number, location of first dorsal pore, presence or absence of external genital markings and of penial setae, shape and ornamentation of penes, presence or absence of GM glands on posterior faces of copulatory chambers, and number of glands attached to each spermatheca. Size and segment number are, of course, subject to individual variation, and there is some overlapping. Individual divergence from the usual anatomy occasionally is encountered. The Cuban specimen deviates from the *houlleti* norm in two ways, one of which (presence on spermathecae of the posterior GM glands characteristic of the other two taxa) has been responsible for some past misidentifications. Those

mistakes could have been avoided if penial characters had been determined, which requires a dissection, preferably under higher powers of the binocular, of the copulatory chamber. Such dissection showed that penial setae are lacking in the Cuban worm (thus ruling out *campanulata*) and that the penes are of the *houlleti* sort.

Pheretima hupeiensis (Michaelsen, 1892)

Pheretima hupeiensis, GATES, 1937, Bull. Mus. Comp. Zoöl. Harvard College, vol. 80, p. 356.

Pheretima hupeiensis, GRANT, 1955, Proc. U. S. Natl. Mus., vol. 105, p. 49.

SPECIMENS EXAMINED: Beltsville, Maryland, Greenhouse 3, Range 3, Plant Industry Station, May 15, 1956, 6-1-3, May 1957, 21-10-3, Dewey Stewart. Pelham, New York, Pelham Country Club, July 14–29, 21-18-15, G. E. Pickford. Orono, Maine, in earth with rocks under plant benches of University of Maine greenhouses, October 25, 1952, 5-2-2-1, and June 18, 1956, 1-3-2, G. E. Gates.

EXTERNAL CHARACTERISTICS: Segments in some of the Beltsville juveniles, 128–137. The green coloration disappears in both formalin and alcohol, probably later in the formalin, and is extracted almost at once when the live worm is dropped into acetone. The dark band at mD (behind xii) may still be visible some weeks after preservation in formalin.

Rudiments of the genital markings, when first recognizable in late juveniles, appear to be mostly at the anterior margins of xviii and xix, but intersegmental furrows 17/18 and 18/19 already are unrecognizable in the region of epidermal modification. The furrows obviously end abruptly against median and lateral margins of the markings, in well-preserved older specimens, so that the markings appear to belong equally to two segments. Because of that symmetry, markings usually are said to be at or on 17/18 and 18/19. Secondary furrows on xvii–xix, in strongly contracted clitellate specimens, often are much more obvious than the intersegmental furrows and may then lead to misidentification of marking locations unless the intersegmental furrows are traced from the dorsal pores down to the ventrum.

Spermathecal pores, as in the previous specimens (Gates, 1954, p. 234), are not on protuberances.

INTERNAL ANATOMY: Color is lacking in the very obvious muscle band at mD, even in worms that have been in formalin less than 10 days. The rest of the parietes, after the longitudinal musculature (the circular musculature could not be peeled off) was stripped off, has a dark greenish brown appearance, but pigment flecks are not distin-

guishable, and the color does not appear to be any darker in the region where a band formerly was visible.

The intestinal origin is in xv (15 specimens), the esophageal valve anteriorly in xv or perhaps reaching slightly into xiv. The typhlosole is fairly high, lamelliform, opaque anteriorly, dark posteriorly where it is gorged with blood, and ends quite abruptly in the eighty-third to ninety-second segment (cf. table 1).

The dorsal blood vessel when distended with blood can be traced forward to the brain where it bifurcates, each branch passing ventrally along the nervous commissure. The ventral trunk also bifurcates, over the subpharyngeal ganglia. The subneural trunk, adherent to the parietes, usually is empty and then unrecognizable along a considerable portion of the axis, but when distended by blood anteriorly can be traced to the subpharyngeal ganglia. Hearts as well as the dorsal portions of the segmental "loops" are distended with blood (which is lacking in the ventral and subneural trunks) in most of the dissected specimens, so that determination of various relationships has been much less difficult than usually is the case. Hearts of x–xiii are all latero-esophageal, blood present in the dorsal bifurcations (those to the dorsal trunk) as well as in the ones to the supra-esophageal vessel, except in x. There, as usually, the dorsal bifurcation is without color. Hearts of ix are lateral, obviously passing without dorsal narrowing or bifurcation directly to the dorsal trunk. The heart on one side of ix usually is vestigial and possibly not a complete loop. A lower portion of the functional loop of ix, below an opaque white "joint," is much narrower and usually empty but is easily traced to the ventral trunk. Loops of vi–viii, as well as of v (in two specimens), are as thick as they emerge from the dorsal trunk as the functional loop of ix. The loops of viii, except in three worms, are filled with blood and obvious until well out onto the gizzard where they abruptly attenuate and shortly become unrecognizable. The opaque "joint" in the loops of v–vii is at varying depths below which the loop usually seems to attenuate, but when blood is present below the joint the loop can be traced to the ventral trunk. Brain, circumpharyngeal connectives, and the subpharyngeal ganglia in part are left, by a transverse section exactly along 3/4, in iii (10 specimens).

Male funnels are small, only slightly plicate, and appear to be very much like those figured by Chen (1933, p. 253) from worms collected in the lower Yangtze Valley. Such funnels, in a number of the American worms, are quite obviously smaller than the female funnels. Male gonoducts of a side usually come into contact just behind 11/12 and

join the anterior non-muscular branch of the prostatic duct. Seminal vesicles are so small as to be almost rudimentary (15 specimens) and are of about the same size in older juvenile, aclitellate, and fully clitellate specimens. Prostates are of medium size, apparently mature (i.e., not juvenile), and extend through xvi or xvii to xix or xx. The muscular prostatic duct is 2–3 mm. long.

Ovaries are fan-shaped, each with numerous egg strings which may at maturity have five or more ova.

ABNORMALITY: Right spermatheca of vii lacking (one specimen). Spermathecal diverticula digitiform, without differentiation into stalk and seminal chamber (several specimens).

Testes do not appear to be normal (15 specimens). The gonads of xi in several specimens resemble ovaries and contain bodies much like ova though slightly smaller than those in the egg strings in xiii.

Abnormal metamerism was noted only in the intestinal region of one of the Pelham worms.

REPRODUCTION: No sperm had been matured. Spermathecae are empty. The material examined to obtain information on spermatogenesis included the following: one juvenile, two prereproductive aclitellate, 18 clitellate, two postreproductive aclitellate Pelham specimens, three aclitellate and five clitellate Maryland specimens, and four clitellate Maine specimens, preserved in spring, early summer, and late fall. These worms, unless their life history is very much different from that in the rest of the genus, are all male sterile. Feminization of testes, rudimentary seminal vesicles, and incomplete development of spermathecal diverticula usually are associated, as are small-sized male funnels, with parthenogenesis.

REMARKS: The original home of *P. hupeiensis* is to be sought on the Asiatic mainland, possibly in China, but the worms may have come to this country from Japan. Introduction, some time prior to 1910, and early distribution may well have been with plants grown here in greenhouses. More recently the American range may have been extended considerably by inclusion in shipments of turf and by transport of cocoon-containing earth on the machines used at the country clubs. Officers of golf associations have maintained that the species is present all the way down the Atlantic seaboard into Florida from Connecticut.

PRECIS: Sexthecal, pores minute, superficial, on the anterior margins of vii–ix. Female pore median. Male pores minute, superficial, each in a small circular disc in the setal circle of xviii. Genital markings small, slightly more median than male porophores, two pairs, on 17/18 and

18/19. Setae small, closely crowded, usually present in ventrum of clitellar segments, 60–100/iii, 74–120/viii, 62–100/xii, 68–88/xxv, viii/10–22, xviii/8–18. First dorsal pore at 11/12–12/13. Prostomium epilobous, tongue open. Green in life. Segments, 97–138. 40–220(?) by 3–6 mm.

Septa 8/9–9/10 muscular. Intestinal origin in xv. Caeca simple, in xxvii–xxiv. Typhlosole, simply lamelliform, ending in region of eighty-third to ninety-second segments. Hearts, of ix lateral, of x–xiii latero-esophageal. Holandric, testis sacs unpaired, U-shaped and vertical or annular, hearts of x–xi and anterior vesicles included. Prostates in xvi, xvii–xix, xx, ducts 2–3 mm. long. Spermathecae medium-sized, duct shorter than ampulla, diverticulum from anterior face of duct at parietes and much longer than the main axis (seminal chamber?). GM glands sessile on parietes.

DISTRIBUTION: United States; Japan; Korea; China (Chekiang, Kiangsu, Kiangsi, Anhwei, Hupei, Szechwan provinces); Manchuria.

HABITATS: Sandy soil, especially along water courses (China); greenhouses and golf courses (United States).

TABLE 1

TYPHLOSOLE TERMINATION AND SEGMENT NUMBER IN *Pheretima hupeiensis*

Serial Number	Typhlosole Terminates in Segment	Number of Segments Without Typhlosole	Number of Segments	Remarks
1	83	30	113	Posterior amputee
2	83	35	115	Late juvenile
3	84	39	123	Aclitellate
4	85	40	125	
5	86	34	120	
6	86	38	124	
7	86	39	125	
8	87	38	125	
9–10	87	40	127	
11	88	35	123	
12	88	38	126	
13	89	35	124	
14	89	40	129	
15–16	90	37	127	
17	90	38	128	
18	91	36	127	
19	92	37	129	

Pheretima javanica (Kinberg, 1867)

Pheretima javanica, GATES, 1940, Treubia, vol. 17, p. 413.

SPECIMEN EXAMINED: Tjibodas, Java, forest at altitude of 4500 feet, January 11, 1938, 0-0-1 (macerated posterior amputee).

INTERNAL ANATOMY: The intestine apparently begins in xiv. Intestinal caeca simple, small, with slight incisions of ventral faces, apparently in xxvi–xxiii. Typhlosole low but lamelliform. Lateral typhlosoles, low but definite, extend through five segments.

REMARKS: "This animal," according to the collector's label, "was as active as a snake and hard to catch."

Pheretima levis (Goto and Hatai, 1899)

Pheretima levis, GATES, 1954, Bull. Mus. Comp. Zoöl. Harvard College, vol. 111, p. 234.

SPECIMENS EXAMINED: Schenectady, New York, from compost heap in garden of Union College, September 18, 1956, 0-0-1 (thecal) and 0-0-1 (athecal), October 11, 1951, 0-0-2 (thecal) and 0-0-8 (athecal), Joseph Myers per L. B. Clark and Libbie Hyman.

EXTERNAL CHARACTERISTICS: Pigment appears externally to be lacking in the equatorial bands where the setal circles are located.

Spermathecal pores are present on only one side of the body, the right, at 7/8 (one specimen), at 6/7 (two specimens). Each pore is located within a tubercle which also has one other minute aperture.

One genital marking, of the usual sort, is median to each spermathecal porophore and on the anterior margin of the segment.

INTERNAL ANATOMY: The subneural trunk is adherent to the parietes, in preserved material, rather than to the nerve cord. Brain, subpharyngeal ganglia, and the connectives between them left, by a transverse section exactly along 3/4, in iv. An epididymis is lacking in the male gonoducts. Ovaries are fan-shaped, with numerous egg strings.

Spermathecae are normal in two of the specimens. The ampullae are filled with a flocculent material. The seminal chambers are filled with a tough white coagulum. Two stalked glands, protuberant into the coelomic cavities, are associated with each spermatheca. The stalk of one gland passes, deep in the parietes, into the more slender portion of the spermathecal duct but probably is continued on to open independently through the second pore on the spermathecal tubercle. The other gland opens through the discrete tubercle.

ABNORMALITY: The spermatheca opening on the right side at 7/8,

presumably rudimentary, is represented only by a short, adiverticulate, club-shaped body that is opaque and possibly muscular. Associated with that vestige are two stalked glands.

REPRODUCTION: The dissected specimens (three), like all the previous ones (Gates, 1954), are male sterile. Reproduction must be parthenogenetic.

REMARKS: Acquisition of the contents of spermathecal ampullae and diverticula in a futile copulatory act as previously suggested (1954, p. 236) now seems quite unlikely. As the material is not received during copulation, it presumably is secreted *in situ* rather than in the prostate glands, the function of which is unknown, in the genus *Pheretima*.

Identification of the athecal anarsenosomphic individuals was made, with considerable hesitation, because of their association with identifiable individuals (thecal), absence of other species in the second lot, and because of the unpigmented equatorial stripes. These stripes have not been noticed in other American species with manicate intestinal caeca.

Seven parthenogenetic strains, if pigmentation permits identification, are recognizable in the United States:

1. Quadrithecal, anarsenosomphic (New York City)
2. Bithecal, pores on right side at 6/7–7/8 (New York City)
3. Monothecal, pore on right side at 6/7 (Schenectady)
4. Monothecal, pore on left side at 6/7 (New Jersey)
5. Monothecal, pore on right side at 7/8 (New York City and Schenectady)
6. Athecal, normal male terminalia present on left side (New Jersey)
7. Athecal, anarsenosomphic (New York City, Schenectady, New Jersey; cf. Davies, 1954)

The first strain is of an R morph (cf. Gates, 1956). Worms of strains 2–5 are all anarsenosomphic and are third-order intermediates in which evolution from the R to an AR morph is under way. Worms of the sixth strain are fifth-order intermediates in which evolution from the A to the R morph is under way. Worms of the seventh strain are of an AR morph which could have been reached through an A or an R morph or directly from an H_p morph by concurrent elimination of male terminalia and the spermathecal battery.

Worms with postclitellar genital markings may be of still other strains. Such markings, especially when appropriately located, may have been mistaken for male porophores and the associated glands for rudimentary prostates just as the same glands in preclitellar segments

of athecal worms were mistaken, on various occasions, for adiverticulate spermathecae.

Many morphs undoubtedly exist in Japan, the probable original home of the species, but their characteristics cannot be sorted out from generalized descriptions and tabulations. AR morphs certainly must be common. H_p morphs, if not an H, A, and R morphs appear to have been seen. ARZ morphs are expected, possibly Z morphs (without testes, male gonoducts, and seminal vesicles but with male terminalia and spermathecae) as yet unknown in the genus. Hologynous morphs, which have been recognized in one species of *Pheretima* (*anomala*), and indications of hypergyny as well as of hyperandry should be sought.

Pheretima levis was erected on anarsenosomphic quadrithecal specimens having pores on 6/7–7/8 and two or more genital papillae near each spermathecal pore. Each of the papillae appears to have been associated with a long-stalked and coelomic GM gland. Worms with those characteristics, in absence of definite contra-indications and if caeca are manicate, are all that can be certainly referred to *levis* at present.

Pheretima irregularis (Goto and Hatai, 1899) was erected on 55 athecal, anarsenosomphic, and inornate specimens. In worms that are so defective, parthenogenesis must be the method of reproduction, as it is in *agrestis, hilgendorfi,* and *levis.* Inornate AR morphs of those three species, so far as is determinable from the literature, cannot be expected to have been distinguishable from one another. The series on which *irregularis* was based may then have comprised individuals of asexual lineages deriving from three or even more sexual species. The type on which *P. ambigua* Cognetti, 1906, was erected is of an AR morph indistinguishable from *irregularis.*

Pheretima vittata (Goto and Hatai, 1898) was erected on anarsenosomphic, athecal specimens with seminal vesicles that now appear to have been juvenile or rudimentary. The worms probably were male sterile, but, if not, reproduction would have to be parthenogenetic because of organ defects. This AR morph, however, is ornate and distinguishable from that of *irregularis* and *ambigua* by the presence of GM glands that were mistaken for adiverticulate spermathecae. The glands open to the exterior through papillae in four transverse presetal rows, of three each, just lateral to mV on vii–viii. The papillae probably were larger than in *hilgendorfi* and were not in patches. The pattern also is quite different from any recorded for *agrestis* or *levis.* Genital markings, in specimens subsequently referred to *vittata,* have

been in the vicinity of spermathecal pores, sometimes even postclitellar but rarely were located as in the types. Male pores have been reported (porophores and terminalia not characterized) as well as spermathecae which were present at one to four of the *levis* locations. Thecal specimens with genital markings near the spermathecal pores rather than mV do not appear to be distinguishable from *P. levis*. Considerable variation as to number and location of genital markings is perhaps to be expected in *levis*. GM glands, in parthenogenesis, may be increased in number or eliminated (in part or *in toto*), and their locations may be shifted about considerably, even to sites of the male porophores. If the *vittata* GM pattern is found in conjunction with *levis* male porophores and/or the spermathecal battery, the later of the two names might be eliminated.

Pheretima schizopora (Goto and Hatai, 1898) is known only from the original description of a single anarsenosomphic specimen with a pair of spermathecae opening at 7/8 and with seminal vesicles that probably were juvenile or rudimentary. The type was not fully mature and was supposed to be inornate. Parthenogenesis is probable here also. The character that presumably was regarded as distinctive was presence on the spermatheca of three diverticula. That condition, of course, is not impossible, though there is greater probability for but one diverticulum which was, because of immaturity or mutation, incompletely differentiated into stalk and seminal chamber. The other two structures were GM glands the external porophores of which were overlooked or were not yet differentiated. Association of GM glands with the spermatheca is suggestive of *levis,* in which case an anterior pair of spermathecae, as well as the GM glands associated with them, already had been eliminated.

A precis will be included in a subsequent paper.

Pheretima pectenifera Michaelsen, 1931

Pheretima pectenifera, GATES, 1939, Proc. U. S. Natl. Mus., vol. 85, p. 460.

SPECIMENS EXAMINED: Soochow, China, 0-0-28, purchased from the Biological Supply Service of Soochow University by K. N. Bahl.

EXTERNAL CHARACTERISTICS: Prostomium epilobous, tongue open. Pigment in dorsum apparently blue.

Male pore chambers everted (28 specimens).

Genital markings of preclitellar segments of two sizes. Smaller markings crowded around spermathecal pores, boundaries distinguishable only under high magnification, one just in front of, one just lateral

to, and one just median to, each pore, occasionally one just behind the pore. Larger markings in four longitudinal rows, outer and inner rows on each side five to six and eight to nine intersetal intervals, respectively, median to levels of spermathecal pores, markings of outer ranks presetal, of inner ranks presetal and postsetal (except in ix), in vii–ix. From the pattern as thus characterized some deviation is shown by each individual in absence of one or more of the markings.

INTERNAL ANATOMY: Pigment, in sections through the body wall, appears to be red.

Typhlosole rudimentary in xx–xxvi, 2+ mm. high through a number of segments from xxvii, height decreasing posteriorly, ending abruptly in lxxvii (worm with 105 segments). High but short, paired, and probably segmental lateral lamellae unite anteriorly and ventrally with one another and with the median lamella, but ventral margins are free posteriorly.

Dorsal blood vessel single throughout, bifurcates under the brain. Hearts, lateral in ix, latero-esophageal in x–xiii (connectives to dorsal trunk white). Ventral trunk in or on roof of testis sacs which are above the nerve cord.

Male deferent ducts pass into ental ends of prostatic ducts.

REMARKS: Except for the two giant specimens considered below and for the two series belonging to Bahl, no Chinese material has been available since 1939. The data on Bahl's specimens, which are topotypical, are recorded in hope that they will assist in a determination of relationships between *pectenifera* and *yamadai* Hatai, 1930. Especially needed for estimating such relationships is information regarding somatic systems, as the reproductive organs appear to be subject to more individual variation as well as to more rapid evolutionary change.

Whether the male pores are in deep parietal invaginations or coelomic copulatory chambers remains unknown.

Pheretima queribunda, new species

SPECIMEN EXAMINED: Guadalcanal Island, Solomon Island, 0-0-1, F. C. Cilley. (Holotype A.M.N.H. No. 3505.)

EXTERNAL CHARACTERISTICS: Length, *ca.* 80 mm. Diameter, *ca.* 6 mm. Segments, *ca.* 135. Prostomium epilobous, *ca.* $\frac{1}{2}$, tongue open. Pigmentation unrecognizable (alcoholic preservation). Setae present from ii, small, closely spaced; *ca.* 95/xii, xviii/5, ix/43(*ca.*), circle of xvi complete. First dorsal pore at 12/13. Clitellum annular, extending forward well towards 13/14 and back nearly to eq/xvi; setae lacking, inter-

segmental furrows obliterated, sites of dorsal pores recognizable.

Spermathecal pores minute and superficial, widely separated, just beyond level of lateral margins of genital markings, five pairs, on 4/5–8/9. Paired female pores present (?). Male pores minute, each at center of a small, smooth-surfaced, rather broadly conical tubercle seated on a slight protuberance from which it is demarcated by a circular furrow.

Genital markings paired but not closely, protuberant, transversely elliptical, presetal, on vi–ix, xvii, xviii, xx, left sides of xxi–xxii, postsetal on xviii and left side of xvii (rudimentary?). Postclitellar markings in line with male porophores. Each marking has a translucent center and an opaque rim. Preclitellar markings, more widely separated, about 10 intersetal intervals wide.

INTERNAL ANATOMY: Septa 5/6–7/8 thickly muscular, 8/9 membranous but complete, 9/10 lacking, 10/11 and succeeding septa membranous.

Intestinal origin in xv. Intestinal caeca, either lateral or median, lacking. Typhlosole broadened and flattened in xxvi–xxvii, narrowing anteriorly, lamelliform posteriorly, apparently ending abruptly in region of lvi.

Hearts present in xi–xii, lacking in xiii and either x or ix.

Proandric. Testis sacs of x, filled with a compact coagulum, widely separated, vertically placed on anterior face of 10/11. Testis a fairly large, circular disc on anterior wall of sac. Testis sac of xi horseshoe-shaped, without coagulum and testes but containing seminal vesicles and male funnels. Seminal vesicles of xii lacking, of xi apparently united into a single horseshoe-shaped mass, with ventral ends much thicker than the portion above the gut. Prostates small. Prostatic duct with muscular sheen, ectal half much thicker, more slender ental half with two sinuosities. Male gonoduct passes into ental end of prostatic duct.

Spermathecae small. Duct short, slender, apparently almost confined to parietes. Diverticulum, from anterior face of duct at parietes and reaching well up onto ampulla, comprising an ellipsoidal seminal chamber and a very short, slender stalk.

No glands recognizable on parietes over sites of genital markings.

REPRODUCTION: Spermatozoal iridescence, on the male funnel of the anterior testis sac that was opened, is brilliant. No iridescence is recognizable on a funnel in the posterior testis sac. Sexual reproduction appears to be possible. Abortion of the posterior testes, after induction of development of male funnels but before induction of

vesicle growth, is common enough in parthenogenetic forms to warrant suspecting uniparental reproduction in the present worm.

REMARKS: A single specimen necessitates a choice between two alternatives: (1) obtaining information needed for specific characterization, (2) leaving important organs (such as testis sacs) undisturbed for future observation. Even careful pinning back of the body wall often results in destruction of delicate septa, and merely opening a testis sac frequently obviates subsequent recognition of its shape and extent. An additional complication is provided, in the present instance, by the brittleness of the type, traction on the epidermis around the supposed sites of female pores having failed to reveal patent apertures. The present condition of the specimen also prevented exact setal counts. Male porophores in their normal state may be discoidal and flat-surfaced, their present shape due to contraction at time of preservation. If, however, the conical form is permanent, the porophores presumably were "frozen" at preservation in a protruded state. In that case, and on complete protrusion, invaginations in which such porophores usually are contained would have become unrecognizable.

Six species of *Pheretima,* in each of which the method of reproduction is unknown, have been erected on proandric material. Five are known only from descriptions of single specimens, and little information is available as to the sixth. From all of them *queribunda* is distinguished by the decathecal spermathecal battery and by the absence of intestinal caeca.

Relationships of *queribunda* presumably are closest to those holandric, decathecal species that have no hearts in xiii and that lack intestinal caeca. These species are known, with one exception, only from the original material, and all of them are inadequately characterized for present needs. The group includes: *P. sentanensis* Cognetti, 1911, from New Guinea, supposedly with intestinal origin in xvi (no information as to typhlosole); *P. speiseri* Michaelsen, 1913, from the New Hebrides Islands, with intestinal origin in xv (no typhlosole); *P. pickfordi* Gates, 1957, from Rennell Island, with intestinal origin in xv (typhlosole present).

Pheretima subululata (Michaelsen, 1899), from Celebes, with intestinal origin in xv, may belong to the *sentanensis* group, but nothing is known about the hearts and the typhlosole. *Pheretima myriochaeta* Cognetti, 1911, from New Guinea, with intestinal origin supposedly in xvii, may belong in the same group, but nothing is known about the typhlosole, and even the andry is uncertain. Genital markings, in both of these species as well as in the *sentanensis* group (including

queribunda), are of the same sort and in about the same locations.

The proandry that distinguishes *queribunda* from each of the above-mentioned species has appeared in some parthenogenetic lumbricid strains (Gates, MSS). Sperm are known to be matured by some parthenogenetic lumbricids and megascolecids in which copulation does not take place or is futile because morphological defects prevent transfer of the male gametes.

Pheretima tschiliensis Michaelsen, 1928

?Amyntas asiaticus MICHAELSEN, 1900, Ann. Mus. Zool. Acad. Sci. St. Petersburg, vol. 5, p. 224.

Pheretima praepinguis GATES, 1935, Smithsonian Misc. Coll., vol. 93, no. 3, p. 15.

Pheretima praepinguis, GATES, 1939, Proc. U. S. Natl. Mus., vol. 85, p. 471.

SPECIMENS EXAMINED: Mt. Omei, Szechwan, China, at 4500 feet, 0-0-2, C. C. Liu.

EXTERNAL CHARACTERISTICS: Length, 410, 470 (+?) mm. Diameter, *ca.* 18 mm. Segments, *ca.* 154, 130 (+? posterior amputees). Setae, vii/27, 24, viii/28, 24, xviii/12, 10, not including the five or six setae present in each male invagination. First dorsal pore at 12/13 (two specimens). Clitellum of the larger specimen deep red (preservation artifact). The epidermis of the presetal secondary annulus of xvii also is red and slightly thickened. That portion of xvii may then have to be considered as included in the clitellum.

Spermathecal porophores retracted slightly into the parietes.

Genital markings: one usually present in front of the spermathecal porophore and on the posterior margin of the segment, one on each side of vii–ix on the anterior margin and somewhat median to spermathecal pore levels, one on the anterior portion of the setigerous ridge within each male invagination, one or two (one invagination only) dorsally on each of those ridges and just below the male porophore.

REMARKS: The cuticle at the hind end of one specimen is continued into the gut through at least three segments.

The soma size, in spite of the amputation, is the largest now on record for the Chinese mainland. *Pheretima magna* Chen, 1938, from the island of Hainan is larger, 700 by 24 mm.

Pheretima praepinguis was distinguished (Gates, 1935, p. 15) from *tschiliensis* "by the spermathecal invaginations and the genital markings therein." The invaginations, still confined to the outer half of the thick body wall in the single specimen, were thought to represent an

early stage of the evolutionary development that provided *P. grahami* Gates, 1935, with coelomic chambers large enough to reach back through most of a segment length. Some such development may, of course, have begun in the Omei giants, but the present specimens, with genital markings still external, show even less evidence of it. The variations in depth and size of the depression containing the spermathecal pore may be merely an expression of different degree of contraction. Hence there now appears to be no anatomical justification for specific separation of the three worms in American museums from the somewhat smaller Omei individuals that were referred to *tschiliensis*. If the Omei giants should prove to be reproductively isolated from the much smaller individuals of other populations, the only character (of the classical taxonomy) that will be available to distinguish the species will be somatic size.

Pheretima tschiliensis probably is a synonym of *P. asiatica,* but further information about the types of the latter, or about the earthworm fauna of its type locality, is needed.

Pheretima upoluensis (Beddard, 1887)

Pheretima upoluensis, GATES, 1937, Bull. Mus. Comp. Zoöl. Harvard College, vol. 80, p. 332.

SPECIMENS EXAMINED: Tahha Island, New Hebrides, December 1936, 0-0-2 (macerated), L. Macmillan.

EXTERNAL CHARACTERISTICS: Pigmentation unrecognizable (alcoholic preservation). Prostomium epilobous, tongue open. Setae: viii/8, 13, xvii/15, 15, xvii/4, 4, xix/17, 17. First dorsal pore at ?12/13. The clitellum of one specimen does not quite reach 16/17.

Spermathecal pores transverse and fairly widely separated, much larger than the female pore (minute) though appearing to be rather small. The glistening surface of a vertical tubercle with central vertical furrow is disclosed, within the parietes anteriorly, by slight traction on the margin of the spermathecal aperture. Female pore median. Male pores minute, about at setal equator of xviii, each at center of a smooth, dark, indistinctly delimited field that appears to be closer to 18/19 than to 17/18.

Genital markings small, circular, each with a distinctly delimited presetal on xvii, xviii, xix, xx; paired, about in line of male pores and postsetal on xvii; two or three markings on each side of xviii close to central portion. Markings of one specimen: unpaired and median, male pore areas. Unpaired, median markings lacking on the other

specimen which has two postsetal markings on xvii in *BB* and a single postsetal marking on xviii in *AB,* and other markings on xviii close to the male pore areas. The pattern of distribution around male pore areas appears to be symmetrical though varyingly incomplete, two presetal and two postsetal with two just median and two just lateral to the area.

INTERNAL ANATOMY: Intestinal caeca simple, with smooth ventral faces. Typhlosole low, simply lamelliform.

Spermathecal duct and diverticular stalk have a marked muscular sheen. The diverticulum comes off from the duct ental to the parietes and about midway between the two ends and has in the more slender ental portion of the stalk one or two short loops.

The prostatic duct appears to pass into the parietes in the postsetal half of xviii.

REGENERATION: A tail regenerate with terminal anus on one of the specimens is metamerically unsegmented. The posterior portion of the other worm also may be regenerate.

REMARKS: Characteristics of testis sacs and relationships of sacs to anterior seminal vesicles, because of the condition, could not be determined. Hearts of x–xi also were not recognizable.

The taxonomic status of *upoluensis* remains uncertain.

Pheretima vulgaris Chen, 1930.

Pheretima vulgaris, GATES, 1939, Proc. U. S. Natl. Mus., vol. 85, p. 497.

SPECIMENS EXAMINED: Soochow, China, 0-0-22, purchased from the Biological Supply Service of Soochow University by K. N. Bahl.

INTERNAL ANATOMY: Typhlosole rudimentary in xx–xxvi, from xxvii 1.5 to 2 mm. high and simply lamelliform, enlarged posteriorly and provided with low diagonal ridges, ending abruptly in lxxviii (worm with 111 segments), lxxx (one with 112 segments). Height of the typhlosole in the second specimen gradually decreases to lv, then increases again, reaching the final maximum in lxxii.

Dorsal blood vessel single throughout, bifurcates under the brain. Supra-esophageal trunk present in vii–xiii. Subneural trunk recognizable only in viii–xiii where it has often been thought to be lacking. Hearts lateral in ix, latero-esophageal in x–xiii, but connectives to dorsal trunk in x–xi more slender than in the other two segments. Ventral blood vessel within the testis sacs which are above the nerve cord. Lymph glands recognizable only from xxvii posteriorly.

KEY TO THE AMERICAN SPECIES OF *Pheretima*[1]

1. Acaecal 2
   Caecal 3
2. Male pores superficial, spermathecal pores on viii ..... *taprobanae**?
   Male pores invaginate, spermathecal pores at 5/6–6/7 ..... *elongata**
3. Intestinal caeca arising in xxii ..... *bicincta*
   Intestinal caeca arising well behind xxii 4
4. Intestinal caeca simple 5
   Intestinal caeca manicate 14
5. Quadrithecal 6
   Not quadrithecal 8
6. Spermathecal pores at 5/6–6/7 ..... *morrisi*
   Spermathecal pores at 7/8–8/9 7
7. Male pores superficial, genital markings present ..... *robusta**
   Male pores invaginate, genital markings absent ..... *californica*
8. Sexthecal 9
   Not sexthecal 12
9. Spermathecal pores at 5/6–7/8 ..... *hawayana*
   Spermathecal pores at or just behind 6/7–8/9 10
10. Male pores superficial ..... *hupeiensis**
    Male pores invaginate and in copulatory chambers 11
11. Tip of penial body bilobed and with one genital marking ..*meridiana**?
    Tip of penial body not bilobed and without genital markings ..*houlleti**?
12. Spermathecal pores dorsal ..... *rodericensis*
    Spermathecal pores ventral 13
13. Male pores invaginate, genital markings two pairs in setal circles of xvii and xix ..... *posthuma*
    Male pores superficial, genital markings not so located ..... *diffringens**
14. Male pores in copulatory chambers ..... *schmardae*
    Male pores not in coelomic copulatory chambers 15
15. Genital tubercles lacking, at least in the preclitellar region, spermathecal pores at 5/6–7/8 ..... *agrestis**
    Genital tubercles present, spermathecal pores at 6/7–7/8 16
16. Tubercles small, closely crowded into median, presetal patches ..... *hilgendorfi**
    Tubercles somewhat larger, not crowded into patches, usually in vicinity of spermathecal pores ..... *levis**

[1] For explanation of the terminology, see Gates (1937, p. 342). Reproduction in those species that are marked with an asterisk (*) is parthenogenetic. Reproduction in those species that are marked with an asterisk and a question mark (*?) may prove to be parthenogenetic. All the evidence that is available indicates sexual and biparental reproduction in five species, with which *schmardae* may belong. All organs that provide characters used in the key, except the intestinal caeca, are liable to elimination after reproduction has become parthenogenetic. Advanced morphs of polymorphic species cannot be keyed. Less advanced morphs probably could have been keyed if data had been available for some of the organs that are lacking in the more advanced morphs.

DISCUSSION

Reproduction in six species of *Pheretima* recently was shown (Gates, 1956) to be parthenogenetic and in two more it is believed (Gates, 1957) to be asexual. Three further species, considered above, as well as *P. robusta* (Perrier, 1872), also are parthenogenetic. Each of the 12 parthenogenetic forms has been transported, presumably by man, and is, in the usual terminology, more or less widely peregrine. In the Americas any pheretima is exotic. Seven of the 17 species that have been recorded from this hemisphere (cf. key) are, in this part of the world at least, parthenogenetic, and, as indicated in the key, there now is some reason for believing that three more are asexual.

That uniparental method of reproduction has been thought to facilitate post-introduction colonization of earthworms in foreign areas. However, little information is available as to the exotic ranges of transported pheretimas, the niches occupied, the size of populations in newer natural environments (as opposed to artificial ones such as greenhouses), and as to results of the ensuing competition with native and other introduced forms. One temperate zone species, for example, has been known from British greenhouses for nearly a century, but there is as yet no record of its occurrence in natural environments in the British Islands.

Parthenogenesis permits a rapid accumulation of mutations that results in drastic morphological modifications in the genital system such as elimination of parts of organs, of entire organs, or even of whole sets of structures, as well as intersegmental translocation of organs, examples of which have been provided in a recent publication (Gates, 1956). Another change, feminization of male gonads, is reported above for the first time in a species of *Pheretima* (for possible instances of that change in two other genera, cf. Gates, 1958). Change in sex of gonads may have been involved in the phylogeny of the microdrilous oligochaetes, possibly also in the ancestry of some sexual earthworms, but further consideration of this matter is postponed.

The organs that are translocated, modified, or eliminated after reproduction becomes parthenogenetic are just those structures that are of most importance in the classical system of the Oligochaeta. The artificiality of that taxonomy, which has recently been shown for several families, also characterizes *Pheretima*. For instance, reduction in the number of spermathecae in *P.* (*Polypheretima*) *elongata* has gone so far as to require inclusion of certain affected strains in another subgenus, though unaffected strains must remain in *Polypheretima*.

Moreover, elimination of all spermathecae as well as of the male terminalia in parthenogenetic strains of other species has made it impossible, at least for the present, to identify affected individuals specifically as well as subgenerically.

Division of *Pheretima* into more natural subgenera probably should be postponed indefinitely, until more information regarding long-neglected somatic systems has been accumulated. Some of that much-needed information cannot be secured from ordinary museum specimens. Segregation of some species groups should be possible before long. Considerable revision of species in light of the increasing knowledge regarding postparthenogenetic evolutionary changes may be possible. Some suggestions have been made above, but further consideration of this matter is reserved for a future contribution.

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