

MINISTERIE VAN ONDERWIJS, KUNSTEN EN WETENSCHAPPEN

ZOOLOGISCHE MEDEDELINGEN

UITGEGEVEN DOOR HET

RIJKSMUSEUM VAN NATUURLIJKE HISTORIE TE LEIDEN

DEEL XXXVII, No. 18

3 november 1961

ON SOME SPECIES OF THE ORIENTAL EARTHWORM GENUS *PHERETIMA* KINBERG, 1867¹

by

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Pheretima long has been known to have more species than any other oligochaete genus though no one has yet been in a position to determine how many of them have any real claim to recognition even as old-fashioned museum taxa. Intrageneric relationships are unknown primarily because somatic anatomy was derogated in the classical system of the Oligochaeta. Accordingly, if one wishes to learn whether any specimen at hand is of a known or undescribed taxon it is necessary, first of all, to check through appropriate portions of a 16-page table in Michaelsen's monograph (1900) where species are grouped according to location of the spermathecal pores. If identification is impossible, as often must be the case, a laborious search through the literature of the last sixty years is required. Pertinent contributions are scattered through numerous journals and books many of which seemingly have not been available to those who have been studying earthworms in various parts of the world. A similar knowledge of the literature is required even when identification is possible from Michaelsen's monograph as, for example, long synonymized names still are in use for common forms. Two keys have been published (Gates, 1937 and 1958) but they are regional and include only congeries of exotic forms introduced by man into India and the Americas.

Clarification of some of the problems posed by one of the smaller groups, comprising forms with spermathecae opening at or near intersegmental furrow 5/6, now is possible because of assistance given by Dr. Y. Kondo,

1) From research supported by the National Science Foundation.

Dr. L. B. Holthuis and Dr. W. Vervoort, to whom the author's thanks are extended for making this contribution possible.

MEGASCOLECIDAE

The definition of this family has been radically revised (Gates, 1959) to exclude all genera that do not have a pheretima kind of prostate which is of mesoblastic origin. Excluded genera, with tubular prostates of ectoblastic origin, were placed in the holonephric Acanthodrilidae and the meronephric Octochaetidae according to condition of their excretory systems.

Pheretima Kinberg, 1867

Pheretima urceolata (Horst, 1893)

- Perichaeta urceolata* Horst, 1893, Notes Leyden Mus., 15, p. 322. (Type locality, Lampongs, Sumatra. Types, 9, in the Leiden Mus.).
- Perichaeta urceolata*, Beddard, 1895, A Monog. of the Order of Oligochaeta, Oxford, pp. 398, 432.
- Perichaeta urceolata*, Rosa, 1898, Ann. Mus. Sto. Nat. Genova, 39, p. 65. (Kupang, Timor, 1 specimen possibly in the Genoa Mus.).
- Amyntas urceolatus*, Beddard, 1900, Proc. Zool. Soc. London, 1900, p. 619.
- Pheretima urceolata*, Michaelsen, 1900, Das Tierreich, 10, p. 311.
- Pheretima urceolata*, Michaelsen, 1903, Die Geogr. Verbr. Oligochaeten, Berlin, p. 100.
- Pheretima baweanensis* Michaelsen, 1924, Treubia, 5, p. 389. (Type locality, Bawean Island, Java Sea. Types 2, possibly still at the Buitenzorg Mus.).
- Pheretima (Pheretima) ditheca* + *urceolata*, Michaelsen, 1928, Ark. Zool. Stockholm, 20A (3), pp. 45, 50. (Type locality of *P. ditheca*, Birang River in Beran District, Dutch Northeast Borneo. Type presumably in the Stockholm Mus. The specimen from Seratok, Sarawak, referred to *P. urceolata* may be in the same museum.).
- Pheretima baweanensis*, Gates, 1940, Treubia, 17, p. 409. (After examination of a hitherto undissected type from the Buitenzorg Mus.).

SPECIMENS FROM SUMATRA

EXTERNAL CHARACTERISTICS. Length, 70-80 mm. Diameter, ca. 4 mm. Segments, 74, 76, 86 (very recent posterior amputees), 86 (recent posterior amputee), 92, 94, 99 (2 specimens), 102, 104. Prostomium, epilobous, tongue open (II). Setae, present from ii, vi/17,20,18,14,18,15,19,19,18,19, xviii/9,9, 9,10,10,11,11,12,11,9, 40,36,38,41/xii, on one specimen as follows: 43/xx, 42/xxv, 42/xxx, 42/xxxv, 41/xl, 41/xlv, 36/lxx, 39/lxxx, 40/lxxxv, 56/xc, 56/xcv. First dorsal pore, at 12/13 (11 specimens).

Clitellum, dorsal pores and intersegmental furrows as well as setae apparently lacking, sometimes not quite reaching levels of 13/14 and 16/17 (those furrows unrecognizable) as indicated by positions of dorsal pores.

Spermathecal pores, large and transverse slits, somewhat less than 1/2C apart, one pair (II), at 5/6. Female pore, median (II). Copulatory chamber apertures, large transverse slits at eq/xviii (11 specimens), ca. 1 mm. apart.

Genital markings, lacking (II).

INTERNAL ANATOMY. Septa, at none of the levels especially muscular, 5/6-6/7 may appear to be thickened but because of the blood glands and nephridia massed against their anterior faces, 8/9 present and complete (1), partly recognizable (the type) and quite possibly complete originally, 9/10 lacking (3).

Gizzard, obviously in viii. Intestinal origin apparently in xvi (1). Typhlosole, rudimentary and rounded in xvi-xxvi, lamelliform from xxvii posteriorly but rather low, ending abruptly in 73d of 102 segments. Caeca, simple, margins smooth except at septal constrictions, arising in xxvii and extending forward into xxiii or xxi, one caecum turns posteriorly in xxvi and passes back into xxvii. Blood glands present in v-vi. Lymph glands recognizable only behind xxvii.

Dorsal blood vessel, single throughout, complete, passing under brain and there bifurcating, the branches passing ventrally along with the nervous commissures. Supra-esophageal trunk, present in ix-xiii. Extra-esophageal trunks, median to hearts, passing off from gut in xiv. Subneural trunk, adherent to parietes, in large part empty. Hearts of x-xiii latero-esophageal. Heart of ix, lateral, on left side (1) or right side (1). Hearts of viii, aborted ventrally, dorsal portions passing to gizzard. Hearts of vii-vi, lateral.

Holandric (2). Testis sacs, paired, in x-xi, distended by coagulum, reaching well upward alongside esophagus, space between sacs of a pair fairly wide, posterior sacs not reaching 10/11 but each with a stalk passing forward from sac to septum. Seminal vesicles, large, in i-xii. Prostates, in xviii or xvii-xviii. Male gonoducts, without epididymis, apparently unite in xii and pass into ental end of prostatic duct.

Spermathecae, fairly large, reaching up above dorsal face of gut. Duct, shorter than ampulla, barrel-shaped, somewhat narrowed at parietes, with nephridial investment. Diverticulum with a seminal chamber of about the same length as the stalk which passes to lateral face of the duct entally but can be dissected off or out from duct for some distance before it opens into duct near parietes.

REPRODUCTION. Iridescence on male funnels of one specimen is brilliant but is lacking on a central and translucent tubercle. Iridescence is recognizable in seminal chambers of spermathecae of two specimens. As sperm had been matured and exchanged in copulation, reproduction is assumed to be biparental.

REGENERATION. A tail regenerate of three segments apparently is present at 91/92 of the 94-segment worm.

INGESTA. Humus.

REMARKS. Only one of the ten specimens had been opened by Horst. A drastic dissection was made on a second worm.

The type, most unusually, has the copulatory chamber of the right side completely everted though the other chamber is completely retracted. The penis thus disclosed is rather conical but anteroposteriorly flattened and has anteriorly as well as posteriorly at dorsal end a rather reniform and transverse protuberance. Pores were not recognizable. Internally, the right prostatic duct passes directly into the parietes without intervention of a chamber.

One additional specimen has been available for study. Characteristics identical to those of the Sumatran worms need not be repeated, the eleventh specimen mentioned above being this worm.

SPECIMEN FROM THE PHILIPPINE ISLANDS

Mt. Apo, east slope at 6200 feet, Davao Province, Mindanao, November 1946, 0-0-1.
H. Hoogstraal.

EXTERNAL CHARACTERISTICS. Length, 66 mm Diameter, 4 mm. Segments, 75, the last seven small and perhaps regenerated. Pigment traces still recognizable in dorsum (alcoholic preservation), especially in front of the clitellum. Setae, 37/viii, 45/xii, 44/xiii, 46/xx, 38/lxv, vi/11, xviii/4. Clitellum, annular, not quite reaching 13/14 and crossing slightly in xvii.

INTERNAL ANATOMY. Septum 8/9 represented only by a membranous ventral rudiment (dorsal portion ruptured in pinning out the worm?), 9/10 lacking, none thickly muscular, muscularity of 5/6-7/8 decreasing posteriorly. Pigment, red, in circular muscle layer, dense anterior to clitellum. Special muscle band at mD distinct from 11/12 though no trace of a pore is recognizable at that level. Intestinal origin, posteriorly in xvi. Typhlosole, not well developed and unrecognizable behind xlix. Hearts of ix, lateral, the left one aborted ventrally.

Male funnels, large, plicate. Pseudovesicles vertically elongated but rudimentary in xiii, still smaller and represented by small lumps just above level of dorsal margin of oviducal funnels in xiv. Prostatic ducts, 1 + mm long, sigmoid, rather thick, with marked muscular sheen, passing to dorsal face of copulatory chamber. The chamber is longitudinally ellipsoidal though this is not recognizable until tissues have been cleared away from it and from the prostatic duct. Lumen, narrowly and vertically slit-like, lateral wall thin, the anterior and posterior walls very thick. Male pore, minute, at ventral end of a rather conical but anteroposteriorly flattened penis pendent from roof of the chamber. A distinct, smooth-surfaced disc is present on the anterior wall as well as on the posterior wall but no pore is recognizable thereon.

Spermathecae, medium-sized, ca. 2 mm long, in vi. Duct about as long as ampulla, with irregular lumen due to presence of longitudinal ridges one of which is much higher. Diverticulum, nearly as long as main axis, comprising an elongately ellipsoidal seminal chamber and a stalk with muscular sheen passing into lateral face of duct and opening into duct lumen near parietes alongside the high ridge. The lining of the stalk is raised into numerous fine, closely crowded, annular ridges. Ovaries, fan-shaped and with numerous egg strings.

REPRODUCTION. Iridescence on male funnels is brilliant. A similar iridescence characterizes contents of spermathecal seminal chambers but not the coagulum in the ampulla. Reproduction, inasmuch as sperm had been matured and exchanged in copulation, is assumed to be sexual.

INGESTA. Humus.

REMARKS. Reproduction of *P. urceolata* very probably is biparental not only in Sumatra, Bawean, Borneo, Mindanao, but also, since evidence to the contrary is lacking, in Timor as well as Sarawak. Accordingly, individual and geographic variation are the sorts (cf. Gates, 1960) likely to be of taxonomic importance in the present instance. The material available (16 specimens from 5 islands) is insufficient to permit distinguishing one sort of variation from the other.

Preservation of three specimens (Sumatra and Bawean) was such as to allow recognition of a complete septum at 8/9. This delicate membrane is so easily destroyed, merely by the stretching involved in pinning out a dorsally opened worm, that absence or incompleteness cannot be assumed in specimens where it is unrecognizable. Other characters, such as those that were thought to justify specific status for types of *P. ditheca* and *P. baweanensis*, are now known to be subject to variation in certain species. The differences involved are all quantitative; in relative lengths of stalk and seminal chamber, of main axis and spermathecal diverticulum, in relative thicknesses of duct and diverticulum, in level at which diverticulum passes to duct (but not necessarily involving any difference in level of opening into duct), in amount of dorsal distention of testis sacs. The extremes in soma size, 44×1.8 mm (*P. ditheca*) and 170×5 mm (*P. baweanensis*), do seem unusual but the small type may have been incomplete or from a very unfavorable environment. Little is known about variation of soma size in *Pheretima* or, indeed, in any other earthworm genus. Morphological evidence for presence of more than one species in the material that has been studied certainly seems to be lacking.

P. urceolata is the only bithecal species with pores at 5/6 that has coelomic copulatory chambers. Although deep invagination of the male pores need not be of great importance there seems to be no good reason at present for

believing that *P. urceolata* is closely related to any of the bithecal species herein considered. Other relationships scarcely warrant consideration because of our ignorance of so much of the faunae of the regions in which *P. urceolata* was secured. Just how much of a range that extends from Sumatra through Bawean and Timor to Borneo and Mindanao is attributable to transportation by man also must be determined. For the present the species apparently can be defined as below.

DEFINITION. Bithecal, pores large, superficial, somewhat less than $\frac{1}{2}$ C apart, at 5/6. Female pore, median. Male pores, minute, invaginate, each on an antero-posteriorly flattened and rather conical penis pendent from roof of an eversible copulatory chamber with thick (and glandular?) anterior and posterior wall. (Gennital markings lacking). Setae, 36-44/viii, 36-45/xii, 43-56/xx, vi/13-20, xviii/9-12. First dorsal pore, at 12/13. Prostomium, epilobous, tongue open. Pigmentation, red, (restricted to dorsum?), denser anteriorly. Segments, 89-108. Size, 44-170 by 2-5 mm.

Septum 8/9 complete (always?) but membranous, 9/10 lacking. Intestinal origin, in xvi. Caeca, simple, lateral, from xxvii into region of xxiii-xxi. Typhlosole, simply lamelliform, from xxvii into region of 1-lxxiii. Hearts, of vi-vii and one or both sides of ix lateral, in x-xiii latero-esophageal, commissures of viii aborted ventrally but dorsal portions passing to gizzard. Holandric, testis sacs paired and not in contact mesially. Seminal vesicles, large, in xi-xii. Prostates, extending through some or all of xvi-xx, ducts 1 + mm long. Spermathecae, medium-sized to large, with thick duct shorter than ampulla and slightly narrowed at parietes, diverticulum with an ellipsoidal seminal chamber and an unlooped stalk passing to lateral face of duct.

DISTRIBUTION. Sumatra, Bawean, Timor, Borneo, Mindanao.

Pheretima sp.

Perichaeta urceolata (part) Horst, 1893, Notes Leyden Mus., 15, p. 322.

A worm with a pair of smaller spermathecae opening at 6/7 and referred by Horst to *P. urceolata* was not among the ten types only one of which had been dissected. As reproduction in *P. urceolata* appears to be biparental, genital polymorphism involving bithecal and quadrithecal morphs is unlikely. Whether the quadrithecal individual Horst referred to *P. urceolata* could have provided clues as to the relationships of the species is unknown as the worm has been lost. The specimen would be of special interest as none of the known quadrithecal species with pores at 5/6-6/7 have copulatory chambers.

Pheretima minima (Horst, 1893)

Perichaeta minima Horst, 1893, in: Weber, Zool. Ergeb. Reise Niederl. Ost-Indien, 3,

- p. 66. (Type locality, Tjibodas, Java. Type and only specimen in the Leiden Mus.).
- Perichaeta pusilla* Ude, 1893, *Zeitschr. Wiss. Zool.*, 57, p. 63. (Type locality, Buitenzorg, Java. Type, unique, originally in the Göttinger Zool. Inst.).
- Perichaeta minima* + *P. pusilla*, Beddard, 1895, *A Monog. of the Order of Oligochaeta*, Oxford, pp. 388, 398, 394, 400, 433.
- Amyntas minimus* + *A. pusillus*, Beddard, 1900, *Proc. Zool. Soc. London*, 1900, p. 549.
- Pheretima minima* + *P. pusilla*, Michaelsen, 1900, *Das Tierreich*, 10, pp. 284, 297.
- Pheretima minima* + *P. pusilla*, Michaelsen, 1903, *Die Geogr. Verbr. Oligochaeten*, Berlin, pp. 98, 99.
- Pheretima enchytraeoides* Michaelsen, 1916, *K. Svensk. Vet. Akad. Handl.* 52 (13), p. 33. (Type locality, Cedar Creek, Cairns District, Queensland, Australia. Type, unique, presumably in the Stockholm Mus.).
- Pheretima humilis* Gates, 1942, *Bull. Mus. Comp. Zool. Harvard College*, 89, p. 120. (Type locality, soil in pots with plants, Judson College, Rangoon, Burma. Type locality and types destroyed during World War II).

SPECIMENS FROM HAWAII

Manoa Valley, Oahu, banana plantation, March 8, 1959, 0-0-4. Y. and K. Kondo.

EXTERNAL CHARACTERISTICS. Length, 21, 24, 28 mm. Diameter, ca. 1.5 mm, of type ca. 2 mm. Segments, 55 (posterior amputee), ca. 80 (type), 85, 85, 89. Pigment, probably lacking, a slight reddening of i-iv (3 specimens) shortly after preservation presumably due to distention of parietal capillaries by blood. Prostomium, epilobous, tongue open (4). Setae, present from ii on which the circle is complete, small, closely spaced, slightly larger and further apart posteriorly, circles without obvious gaps at mD and mV, ca. 55/ii, ca. 75/vi, 46/xii, 38-40/xx, 11,3,10,12/xvi (ventrally), xviii/10, 6, 9, 10. First dorsal pore, unrecognizable on type. ?12/13 (2 specimens), ?13/14 (2). Clitellum, annular, on xiv-xvi.

Spermathecal pores, unrecognizable, obviously minute, superficial and at 5/6. Female pore, median (5 specimens). Male pores, minute, superficial, each at center of a small, circular, distinctly demarcated disc.

Genital markings, small, circular, distinctly demarcated, each with a wide peripheral band and a central area of greyish translucence. A pair of presetal markings on vii, ca. 12 intersetal intervals median to supposed sites of spermathecal pores and separated from each other mesially by a space about equal to 7 intersetal intervals (just as on the type). A similar marking on the right side of viii. About at mL on each side there is a kidney-shaped tumescence of the anterior margin of vi into the concavity of which fits a circular tumescence of the posterior margin of v (Specimen No. 1). A rather indistinct marking, postsetal on left side of vi (No. 2). A presetal median marking on xxi (No. 3). A presetal median marking on xx, a presetal marking on vi slightly left of mV (No. 4).

INTERNAL ANATOMY. Septa 5/6-7/8 and 10/11-11/12 somewhat strengthened, 8/9 represented only by a ventral rudiment (3 specimens) or complete but

membranous (1 specimen), 9/10 lacking (4). No pigment is recognizable in sections through the body wall or in the special longitudinal muscle band at mD which is unrecognizable anterior to 11/12.

Intestinal origin in xv (4 specimens). Intestinal caeca, simple, with smooth dorsal and ventral margins, apparently arising in xxvi and extending anteriorly through three or four segments. Typhlosole, rather high, simply lamelliform from caecal segment, height decreasing somewhat posteriorly, still recognizable at 55th segment (posterior amputee) or ending abruptly in 54th of 85 segments.

Dorsal blood vessel, single and complete, as is the ventral trunk. Unaborted dorsal portions of hearts of viii pass to gizzard. Heart of ix, lateral, on left side (1 specimen) or right side (3). Hearts of x-xi seemingly esophageal (no connective to dorsal trunk recognizable), hearts of xii-xiii latero-esophageal (but no blood present in cords passing to dorsal trunk).

Holandric, testes discoidal (4 specimens). Testis sacs, U-shaped to annular, enclosing hearts of x-xi and in xi also enclosing seminal vesicles. Male funnels small but plicate. Male gonoducts, without epididymis, pass into prostates near emerging ducts. Seminal vesicles, rather small vertical bodies in xi-xii. Pseudovesicles, lacking. Prostates, rather small, in xvii-xix or confined to xviii. Ducts, slender, without muscular sheen, ca. $1\frac{1}{2}$ -2 mm long, with a C-shape or in two U-shaped loops.

Spermathecae, relatively rather large, nearly 2 mm long, passing back into vii and under or over the nerve cord into left side. Duct, longer than rather small ampulla and without muscular sheen. Diverticulum, longer than main axis, with shortly ovoidal seminal chamber only slightly thicker than the stalk and narrowing to a short and slender neck. Diverticular stalk, also without muscular sheen, of about same thickness as duct which is joined near the parietes, the duct ectal to that junction quite slender (spermathecal pores unrecognizable externally even after approximate position had been determined from the dissection). Lumen in diverticular stalk small and apparently narrower than duct lumen. Ovaries, fan-shaped and with numerous short egg strings.

Delicate tissues on coelomic face of parietes above sites of genital markings may be glandular but stalks are not distinguishable.

REPRODUCTION. The clitellum appears to be about at maximal tumescence. Ovaries appear to be fully mature. The testes, on the contrary, appear to be juvenile and undischarged. Spermathecal ampullae are not normally thin-walled but do contain some coagulum similar to that present in the seminal chambers. Spermatozoal iridescence is lacking on male funnels and in the spermathecae. These conditions, along with the smallness of the seminal

vesicles, usually are associated with male sterility. Reproduction then is uniparental and parthenogenetic. Confirmation is provided by variation in genitalia of a sort that usually eventuates after reproduction has become asexual.

POLYMORPHISM. Each of the Hawaiian worms is of a different parthenogenetic morph. Two, having no spermathecae, are of A morphs (cf. Gates, 1956, for terminology). Two specimens, each with but a single spermatheca and that on the right side are of first order intermediate morphs. The type, with a pair of more or less normal spermathecae, is for the present assumed to be of an Hp morph.

The left spermatheca of the type is much the shorter. Its diverticulum is rudimentary. The shorter axis of the right spermatheca presumably is the diverticulum. Each axis is slightly widened entally.

Any portion of a spermatheca, after reproduction has become parthenogenetic, may be reduced, aborted, lengthened or otherwise modified. Probably none of the spermathecae in the material now examined is of normal conformation. What the norm is, remains to be learned.

REMARKS. Tumescences at mL of specimen No. 1 were thought, during external examination, to mark site of spermathecal pores but rudiments of spermathecae were not found in the parietes after the longitudinal musculature had been stripped off.

Six nearly spheroidal bulges of diverse sizes on the spermathecal diverticulum of the fourth worm may be of foreign origin though other evidence for presence of parasites was not recognized.

Genital markings are of the sort present in *P. diffringens* (Baird, 1869), *P. hawayana* (Rosa, 1891), *P. morrisoni* (Beddard, 1892), etc., and, as in those species, probably are associated with small glands having stalks that are concealed within the parietes or that are protuberant more or less conspicuously into the coelomic cavities. Such markings vary little in size and though sometimes rather closely crowded remain discrete. The differences in intrasegmental as well as regional situation of genital markings shown by so few specimens as the five just examined indicate that a single, simple or fixed pattern of GM location is unlikely to be found when further material is secured. In this respect also, the present species appears to be like more common ones such as *P. hawayana*. Indistinctness of some markings and the condition of associated tissues, in the Hawaiian worms, warrants a suspicion that glands as well as the markings may be disappearing in some lineages. Inornate individuals (without the genital markings) then can be expected and perhaps as frequently as in *P. diffringens*.

P. minima was erected on four specimens. The original description, never

supplemented or corrected, provides no information as to dorsal pores, septa, intestinal origin, location of intestinal caeca, the typhlosole, circulatory system, testes, testis sacs and seminal vesicles. The gizzard was said to be in ix-x and the spermathecae in vii. Three of the four specimens have disappeared. The other, which Horst had opened by a mid-dorsal incision from the anterior end, now is rather brittle and very dark. Though probably unpigmented the worm, in the preservative, appears to be black. Along with this darkening and likewise due to the alcoholic preservation, little structure, except for the hearts of xiii, is recognizable in the mass of optically undifferentiated tissue behind the gizzard. The gizzard of course is referable to viii though 8/9-9/10 are unrecognizable. Spermathecae obviously are in vi, attribution to vii by Horst presumably due to adhesion to each other of 6/7-7/8 which were still in contact when the worm was examined by the writer. Spermathecal pores, no trace of which is recognizable externally, obviously must be widely separated and at 5/6. The supposed spermathecal porophores on vii are genital markings of the same kind as in the Hawaiian worms and located almost exactly as in one of them. Prostates appear to have been confined to xvii-xix. Spermathecae, as already noted, are abnormal and no iridescence was recognized.

P. pusilla was erected on a single individual that lacked some tail segments, perhaps twenty or more. Little information was vouchsafed as to internal anatomy but the species was believed to be distinguished from *P. minima* by the location of spermathecal pores on papillae at 5/6 instead of anteriorly on vii and by the form of the spermathecae. A further difference was presence of genital markings behind the clitellum rather than anteriorly. That distinction was shown to be unimportant by one of the Hawaiian worms which has markings in both regions. Indistinctly delimited areas of the type and on xvii and xix in line with the male porophores may have been rudiments of disappearing genital markings. Supposed spermathecal porophores may well have been tumescences of the sort noticed on one athecal Hawaiian worm and if so Ude may not have seen the spermathecal pores. The number of spermathecal setae suggests that pores were located about as they are now known to be in *P. minima*. Text and illustration unfortunately are little help in guessing at spermathecal characters. The spheroidal diverticulum shown in Ude's figure 10 could be at middle of the ampulla or at ental end of an unusually thick duct but the drawing tempts one to wonder what might have been seen on the other side if the spermatheca had been turned over. A globular diverticulum sessile entally on a duct as thick as the ampulla might be characteristic of a distinct species but there is at present little reason to assume that spermathecae were normal or that supposed differences in shape

of the organ are of any taxonomic importance. Other evidence for retention of *P. pusilla* is lacking.

P. enchytraeoides is known only from the original description of a macerated amputee that may have lacked twenty or more tail segments. No information was provided as to dorsal pores, septa 8/9-9/10, intestinal origin and caeca, typhlosole, circulatory system and seminal vesicles. Male funnels were believed to be free in coelomic cavities. Distinction from *P. pusillus*, whether varietal or specific, was thought to be shown by absence of clitellar glandularity on a posterior portion of xvi, location of spermathecal and male pores somewhat closer to mV and lack of genital markings. Absence of testis sacs in *Pheretima* is unlikely except after establishment of male sterility. Seminal vesicles presumably were lacking or else too rudimentary to be recognized which provides further support for parthenogenesis. Other supposed differences from *P. minima* are quantitative and, in the circumstances, require no further comment. The type is unlikely now to be in better condition than in 1917 and may well be useless.

Presence of the species in Australia is likely to have resulted from transportation, presumably by man and as for Hawaii.

P. humilis is known only from the original description which provides information about external characteristics of six specimens and about internal anatomy of four. Records of ten additional worms were destroyed during World War II along with the specimens and the type locality. The spermathecal diverticula of the four dissected worms are similar to the one figured by Horst except for length which is about equal to or even greater than that of the main axis. As absence of genital markings by itself no longer provides adequate evidence for specific distinctness there seems to be no contra-indication to an identification of the Rangoon worms as *P. minima*. Absence of mature sperm and the juvenile condition of the seminal vesicles in fully clitellate individuals connote male sterility and of course parthenogenesis. Although male terminalia appeared to be normal, the same certainly cannot be said of the spermathecae. Importation into Burma, perhaps only shortly before the specimens were secured, seems possible.

All of the worms considered above are of parthenogenetic strains, clones or morphs. How their genitalia differ from the structural norm of sexual individuals remains to be learned. The biparental morph presumably should be sought first among the bithecal taxa that also have their spermathecal pores at or near 5/6. Two of the species, *P. papilio* Gates, 1930, and *P. urceolata* probably do reproduce sexually but here require no consideration. Other species are discussed in the next section. For the present *P. minima* can be characterized only as follows.

DEFINITION. Bithecal, pores minute, superficial, widely separated, at 5/6. Female pore, median. Male pores, minute, superficial, each in a circular disc. Genital markings, when present, small, circular tubercles with central translucence, paired and presetal in vii-viii or postsetal in vi, unpaired and median, presetal in xx, xxi. Setae, 40-55/ii, 40-47/iii, 75/vi, 60/vii, 54-58/viii, 46-52/xii, 3-12/xvi (ventrally), 38-44/xx, v/26-29, vi/27-33, xvii/10-12, xviii/6-10, xix/10-12. First dorsal pore, at 11/12-12/13. Prostomium, epilobous, tongue open. (Unpigmented). Segments, 75-89. Size, 20-28 by 1.5-2 mm.

Septum 8/9 complete (always?) but membranous, 9/10 aborted. Intestinal origin, in xv. Caeca, simple, lateral, from xxvii anteriorly through 3-4 segments. Typhlosole, simply lamelliform, from xxvii to region of 50th segment or posteriorly. Hearts, of x-xi (latero-?)esophageal, of xii-xiii latero-esophageal, of one side or the other of ix lateral, unaborted dorsal portions of commissures of viii passing to gizzard. Holandric, testis sacs unpaired, U-shaped to annular, hearts of x-xi and anterior vesicles included. Seminal vesicles, small (juvenile?), in xi-xii. Prostates, in some or all of xvi-xix, ducts 1-2 mm long, twisted or in a hairpin loop. Spermathecae, large, diverticulum from median face of duct near parietes (ental portion moniliform, constricted into two or three seminal chambers?). (GM glands, stalked and coelomic?).

REPRODUCTION. Presumably parthenogenetic.

DISTRIBUTION. Rangoon, Burma. Buitenzorg and Tjibodas, Java. North Queensland, Australia. Oahu, Hawaii.

HABITATS. Soil, in flowers pots (Rangoon), in banana grove (Hawaii).

ON THE SPECIES OF *PHERETIMA* WITH SPERMATHECAL PORES AT OR NEAR INTERSEGMENTAL FURROW 5/6

Amyntas phakellotheca Michaelsen, 1899 (Mitt. Naturhist. Mus. Hamburg, 16, p. 47), erected on a single specimen from Celebes. Testis sacs may be annular and the anterior seminal vesicles may be included. Penes may be present in some sort of parietal invaginations or in small copulatory chambers. However, the numerous spermathecal pores are unlikely to have been much enlarged to permit entry of a penis during copulation because of limitations of space. Somatic characters (cf. key), contraindicate relationships with *P. minima*.

Amyntas lompobatangensis Michaelsen, 1899 (Mitt. Naturhist. Mus. Hamburg, 16, p. 33), erected on three specimens from Celebes. Testis sacs probably have dorsal extensions that were mistaken for seminal vesicles and the anterior vesicles may be included. Location of intestinal caeca was not

recorded and nothing is known about the circulatory system though presence of hearts in xiii seems probable. Relative sizes of testis sacs and vesicles as indicated in a figure certainly warrant a suspicion that the vesicles still are juvenile at maturity. Parthenogenesis then would be anticipated. Retention of dorsal pores as far forward as region of 5/6-7/8 and persistence of septum 9/10 contraindicate close relationship to *P. minima*. Further evidence will be provided if the conical papillae bearing the male pores prove to be permanent organs protrusible from and retractile into small and well-like parietal invaginations.

Pheretima voeltzkowi Michaelsen, 1907 (in: Voeltzkow, Reise Ostafrika, Wiss. Ergeb., 2, p. 45), erected on macerated specimens from Comoro to which the species must have been taken by man. Supposedly meroandric, the types are more likely to be holandric as seminal vesicles were said to be present in both xi and xii. The anterior vesicles may be included in a testis sac or sacs. Absence of intestinal caeca and of hearts in xiii, just as in the case of *P. phacellotheca*, indicate that this species belongs in a more primitive section of the genus than does *P. minima*. Retention of 9/10 as well as of 8/9 also may be primitive but perhaps not the marked muscularity of the former. The genital polymorphism, at least two morphs (thecal and athecal) present in the sample, shows that reproduction is most likely to be parthenogenetic.

Pheretima nugalis Gates, 1931 (Rec. Indian Mus., 33, p. 402), erected on three specimens from a trans-Salween Burmese village. Apparently procurable if one knows where to look for it but rare as only two specimens were found by the original collector several years later on a special return trip to the type locality. Absence in all other Burmese collections seems puzzling unless the species had been introduced. However, the village is not one where rare foreign imports would be expected. More information about setal numbers and gradients as well as about spermathecal structure than could be provided by the five specimens is needed. Differences from *P. minima* are few, presence of pigment, retention of dorsal pores anteriorly from the region of 5/6-7/8, and in the genitalia, larger male porophores as well as exclusion of seminal vesicles from testis sacs that remain subesophageal. Reproduction is assumed to be sexual as sperm are matured and exchanged in copulation.

Pheretima zoysiae Chen, 1933 (Cont. Biol. Lab. Sci. Soc. China, Zool., 9, p. 288), erected on 43 specimens from a town in Chekiang Province, China. Three morphs, at least, were represented in the type series, bithecal (2 specimens), monothecal (12 specimens), athecal (29 specimens). Spermathecae obviously are abnormal, ampullae "enormous", thick-walled and undistended or collapsed, at least one diverticulum moniliform entally as in some speci-

mens of *P. minima*. Seminal vesicles are rudimentary, those of xi within an unpaired testis sac. Reproduction must be parthenogenetic. Male sterility is anticipated though presence or absence of mature sperm was not mentioned. Prostates are large and male terminalia may have undergone little or no post-parthenogenetic modification. Whether male porophores are retractile into and protrusible from small parietal invaginations or are superficial as in *P. nugalis* but capable of some temporary and rather conical elevation is unknown. Differences from *P. minima* are quantitative, more segments (70-108), fewer setae in preclitellar segments.

Pheretima limella Gates, 1935 (Smithsonian Misc. Colls., 93 (3), p. 11), Suifu and Chungking, China. Seminal vesicles are small and prostates sometimes are confined to xviii. Records as to presence or absence of sperm no longer are available but parthenogenesis is suspected. Septum 8/9 was muscularized (instead of aborted) in one individual of a male sterile morph of *P. anomala*. Accordingly, muscularization of 8/9-9/10 in *P. limella* might be a postparthenogenetic modification though at present this does seem unlikely. Differences from *P. minima*; larger soma (to 120 by 5 mm), more segments (106-110), larger numbers of setae in region of viii-xxv, retraction of male porophores into parietal invaginations with thin lateral walls, muscularization of septa 8/9-9/10, subesophageal testis sacs from which the anterior seminal vesicles are excluded.

Pheretima wui Chen, 1935 (Cont. Biol. Lab. Sci. Soc. China, Zool., 11, pp. 109, 120), erected on two specimens, possibly quite immature (clitellum "feebly glandular"), from Amoy, China. Seminal vesicles are small but whether they are juvenile or functionless as in parthenogenesis is unknown. Spermathecae may not have been sufficiently developed to enable recognition of taxonomically important characters, especially of the diverticulum. Intestinal origin was placed in xvi but that location, because of the difficulties attendant on a correct determination and the mistakes of the past, requires confirmation. GM glands have long coelomic stalks that are said to be "smooth and shining", presumably referring to the sheen that is indicative of a well marked muscularization. Such a development is presently unknown in *P. minima*. Other differences are quantitative, slightly greater length (45-50 mm), a few more segments (98), larger genital markings.

Pheretima fungina Chen, 1938 (Cont. Biol. Lab. Sci. Soc. China, Zool., 12, p. 389), erected on three specimens from a Hainan locality. The small size of the seminal vesicles and the thick ampullar walls of the spermathecae warrant a suspicion of parthenogenesis. Anterior vesicles are within a testis sac. Preclitellar genital markings are of the same sort as in *P. minima* and are similarly located. Postclitellar markings are larger, possibly associated

with more stalked glands and seemingly like the markings of *P. wui*. If so, the *P. fungina* types contraindicate distinguishing *P. wui* from *P. minima* and *P. fungina* from either of them merely by the genital markings. Tumescences of the anterior margin of vi are related to the spermathecal pores as in *P. minima*. Differences from the latter are quantitative, slightly larger soma (50-65 by 2½-3 mm), more segments (121-126), more setae in vi-viii and perhaps also posteriorly.

Pheretima muta Chen, 1938 (Cont. Biol. Lab. Sci. Soc. China, Zool., 12, p. 391), erected on ten specimens from another Hainan locality. The small size of the seminal vesicles and the absence(?) of spermatozoal iridescence in coagulum within the spermathecal seminal chambers warrants a suspicion of parthenogenesis. The anterior vesicles are within a testis sac. Genital markings, paired, apparently are small tubercles and situated as in Ude's type of *P. pusilla*. Differences from *P. minima* are quantitative, slightly larger size (50-80 by 2½-3 mm), more segments (85-135).

Pheretima infantilis Chen, 1938 (Cont. Biol. Lab. Sci. Soc. China, Zool., 12, p. 392), erected on 17 specimens from yet another Hainan locality. Two morphs, at least, were represented in the series, athecal (the majority apparently) and thecal. Seminal vesicles are rudimentary but relationship of the anterior pair to the testis sac of xi was not indicated. The genital polymorphism almost certainly is postparthenogenetic and male sterility is anticipated. This species was believed to be the smallest in the genus. Average length of a segment must be less than 0.3 mm. Information as to what has happened to the excretory and nervous systems during this evolutionary miniaturization will be of interest. Genital markings are of the same sort and similarly located as in *P. minima*. Relationships probably are close. Prostates, as apparently in *P. anomala*, may have been translocated posteriorly prior to appearance of parthenogenesis.

Pheretima varians Chen, 1938 (Cont. Biol. Lab. Sci. Soc. China, Zool., 12, p. 385), erected on 17 specimens from three Hainan localities. Spermathecae are lacking in two of the worms and when present usually are rudimentary. Pores are at 5/6-6/7 or 5/6 only, paired or present only on one side or the other. Male terminalia are absent (3 specimens), present only on one side or the other (2 specimens), normally developed or represented only by the porophore and penis (prostate and its duct lacking). Every specimen may, indeed, be of a quite different and readily distinguishable morph. Such highly evolved genital polymorphism guarantees parthenogenesis. Male sterility is anticipated in some at least of the morphs. The anterior seminal vesicles are included in a testis sac. Conspecificity of all individuals was believed to be proved by four characters most important of which is presence of a complete

circle of setae in the peristomium. Several setae occasionally have been seen in the first segment of head regenerates in species of the perichaetin *Perionyx* but presence of the same number as in ii appears to be unique in the earthworms. As the clitellum of *Pheretima varians* is on xiv-xvi and the male pores are in xviii union of segments i-ii without elimination of the setae of ii was not involved and identical regeneration by seventeen specimens seems highly improbable. Variability also was indicated for several somatic characters; length (15-130 mm), thickness (1-4 mm), segment number (78-148), and number of setae (45-76/iii, 52-90/vi, 54-96/viii), size of genital markings. Between the extremes provided by so few specimens of *P. varians* fall all measurements and setal counts of each taxon considered in this section. Obviously, then, much smaller quantitative differences in those somatic characters presently are unacceptable evidence for specific distinction from *P. minima*.

Pheretima ishikawai Ohfuchi 1941, known only from the original description of three specimens, is not distinguishable from *P. minima*.

Pheretima subtilis Gates, 1943 (Ohio Jour. Sci. 43, p. 104), erected on a worm (destroyed during World War II) from the Shan Plateau of Burma near the Chinese border. The necessity for retaining a unique type in as near perfect condition as possible negated the drastic sort of dissection that might have provided additional data of taxonomic importance. If future happenings could have been known in time an attempt would have been made to obtain more definite information about hearts of x-xi and the GM glands (possibly not of the same sort as in *P. minima*) before the type was thrown out with the rubbish. Seminal vesicles are indeed small and the anterior pair is included in a testis sac but as sperm had been matured and exchanged in copulation reproduction is assumed to be sexual and biparental. Invagination of the male pores distinguishes the species from *P. minima* as well as from *P. nugalis*.

Pheretima limellula Chen, 1946 (Jour. West China Border Res. Soc. B. 16, p. 127), erected on two specimens from Chungking, Szechuan Province, China. Seminal vesicles are small, the posterior pair included in a testis sac or sacs. Again, parthenogenesis is suspected. Intestinal origin, as for *P. zoy-siae*, *P. fungina*, *P. muta* and *P. wui*, is said to be in xvi. Differences from *P. minima* are quantitative and slight.

Pheretima elongata (Perrier, 1872) normally is polythecal, with pores at 5/6-6/7 but is mentioned here as several parthenogenetic morphs still have only some of the spermathecae that opened at 5/6. Seminal vesicles are small and the anterior pair is within the testis sac of xi.

Many of these species, 11 of the 17, are known only from a first descrip-

tion. In spite of the importance allotted to reproductive organs in the classical system, information about them still is needed and more especially about characters such as the following: Size of genital apertures. Spermathecal pores, whether primary apertures are superficial or invaginate and whether either sort is large enough to receive an intromittent organ during copulation. Primary male pores, whether they are superficial or invaginate and if superficial whether the porophores temporarily can be shaped into some sort of a substitute for a more definite intromittent organ. Size and nature of parietal and coelomic invaginations (when male pores are not superficial) as well as of therein contained organs, penes, setae, genital markings and associated glands. Pattern of GM location externally and structure of associated glands. Shape of ovary and number of egg strings. Condition of testes. Size of prostates and seminal vesicles as well as relationships of the latter to testis sacs. Enclosure of the anterior seminal vesicles by the posterior testis sacs often was unrecognized in the past and masses of testicular coagulum as well as dorsal extensions of the sacs frequently were mistaken for seminal vesicles. Even after his attention had been called by the writer to the relationship in his favorite *P. posthuma* Bahl was unable to distinguish the enclosed vesicles until he was persuaded to substitute for the microtome his dissecting instruments. The relationships may prove to be of considerable taxonomic importance since no intraspecific variation as to inclusion or exclusion was found during examination of many hundreds of Burmese worms belonging to other groups. The vesicles are enclosed in 8 of the present 17 species and probably are in three others. In three of the more recently erected species, exclusion is probable though the relationship was not stated (mention of negative characters in taxonomic descriptions often considered unnecessary). Vesicles certainly are excluded in *P. papilio*, *P. nugalis* and *P. urceolata*. In these three species, reproduction probably is biparental but the evidence is equally good for the same sort of reproduction in *P. subtilis* with included vesicles. Contrariwise, parthenogenesis is probable or is suspected in all but one of the species with included vesicles and is suspected only in two (*P. limella* and *P. infantilis*) where vesicles probably are excluded.

Information about genital characters is of especial significance now that species are defined as interbreeding populations. As a monoparental strain or clone is not a species and presumably should not bear a latin name indicative of specific status, any evidence for parthenogenesis is of particular interest to the taxonomist. Among the indications that may be recognizable in field-preserved material are: Retention of testes, seminal vesicles, prostates or spermathecae through adult maturity and the breeding season in a

rudimentary or juvenile condition. Oogenesis or maturation of sperm in testes. Small discoidal testes, bushy testes with early stages of spermatogenesis only, absence of spermatozoal iridescence on male funnels and in spermathecae as well as in seminal vesicles, all of course at maturity. Iridescence of male funnels does not, however, assure that reproduction is biparental as sperm still are matured and even profusely in some morphs (cf. Gates, 1956) where parthenogenesis is required by organ defects. Advanced genital polymorphism, as apparently in *P. varians*, by itself almost guarantees that reproduction is parthenogenetic.

In better known cases of genital polymorphism even the most advanced morphs (genitalia reduced to a clitellum and a pair of ovaries with their oviducts) could be linked to a biparental population because of the existence of numerous intermediate morphs. Accordingly, it is proposed (Gates, 1960) that in earthworms a species be understood to comprise not only the original interbreeding population but also all recently evolved parthenogenetic strains that can be filiated with it. The sexual population, in the terminology devised (Gates, 1956) to obviate multiplication of latin names, constitutes an H morph, or morphs when subspecies are involved. H morphs of the parthenogenetic forms herein considered, presumably because collecting has been so scanty and random in most of the *Pheretima* domain, are unknown. Nevertheless, structure in some of the forms warrants an assumption that their parental sexual morphs are reproductively isolated from each other. Further collection in vicinity of the type localities of *P. fungina*, *P. muta*, *P. limellula* and *P. zoysiae* now seems less likely to reveal intermediate stages linking them to sexual morphs specifically distinguishable from those of the forms recognized in the key. The four omitted forms are species dubia. The sexual morph of *P. varians* is much more likely to be quadrithecal than bithecal. The unknown sexual morph of *P. elongata* undoubtedly also has spermathecal pores at 5/6-6/7. Sexual morphs of some of the bithecal strains may prove to be also quadrithecal. Exploration of that possibility in the case of *P. minima* would involve extending this discussion to cover some fifty odd species none of which is represented in material presently available for study.

The reproductive system, because of the evolutionary plasticity demonstrated in geographical as well as genital polymorphism and the rapidity of morphological change in parthenogenetic strains, is unlikely to provide much of the information that is needed to segregate several hundred species into natural intrageneric groupings. For that purpose we must, seemingly, rely more upon somatic structure. Even our scanty knowledge of those systems (cf. Gates, 1960) enables recognition in the present group of two sections: One, without intestinal caeca as well as hearts of xiii and presently con-

sidered primitive. The other, with intestinal caeca and having hearts in segment xiii. The more advanced section is unlikely to have evolved from the other. The group, and presumably also all that are distinguished only by location of spermathecal pores, is artificial.

The bithecal species now appear to be at the ends of evolutionary lines in which further organs were added to a primitive quadrithecal battery (in viii-ix), first in vii and then in vi, associated with loss of those opening at 8/9, 7/8, 6/7 and perhaps in that order though other sequences are of course possible. All presumably are of comparatively recent origin. None are larger than *P. urceolata* and many are at or nearer a size that seems to be minimal for earthworms. Species of the more advanced section may have originated in a region which includes the coastal region of southeastern Asia and some of the nearest islands. Except for *P. minima* which was taken to Burma by man, the Salween River has been crossed only by *P. papilio* which has reached the western boundary of endemicity for its genus and so must have been in Burma for some time. Possibly *P. nugalis* and *P. subtilis* are much more recent arrivals from the east where the closest relatives of so many Burmese pheretimas must be sought. Acaecal and polythechal species with pores at 5/6 may have originated further to the east.

Only one of the species, *P. papilio*, has been collected often enough to permit recognition of geographical variation.

KEY TO SPECIES OF *PHERETIMA* WITH SPERMATHECAL PORES
AT OR NEAR INTERSEGMENTAL FURROW 5/6

- | | |
|--|-------------------------|
| 1. Intestine acaecal, hearts absent (a) in xiii | 2 |
| Intestine with caeca, hearts present in xiii (b) | 4 |
| 2. Septum 9/10 thickly muscularized | <i>voeltzkowi</i> |
| Septum 9/10 membranous or aborted | 3 |
| 3. Genital markings lacking | <i>phacellotheca</i> |
| Genital markings present, paired | <i>elongata</i> (pm) |
| 4. Septum 9/10 complete | 5 |
| Septum 9/10 aborted | 6 |
| 5. Septa 8/9-9/10 membranous | <i>lompobatangensis</i> |
| Septa 8/9-9/10 markedly muscularized | <i>limella</i> |
| 6. Peristomium without setae | 7 |
| Peristomium with a circle of setae | <i>varians</i> (pm) |
| 7. Male pores superficial or not in chambers deeply invaginated
into the coelom | 8 |
| Male pores on penes in copulatory chambers invaginated
deeply into the coelom | <i>urceolata</i> |

8.	Male pores in segment xviii	9
	Male pores in segment xix	<i>infantilis</i>
9.	Spermathecal pores minute, at 5/6	10
	Spermathecal pores not minute, somewhat behind 5/6	<i>papilio</i>
10.	Seminal vesicles of xi excluded from subesophageal testis sac	11
	Seminal vesicles of xi included in a dorsally extended testis sac	12
11.	Dorsal pores present from region of 5/6-7/8, genital markings lacking	<i>nugalis</i>
	First dorsal pore at 11/12 or posteriorly, genital markings associated with long, muscular cords	<i>wui</i>
12.	Male pores superficial (c)	<i>minima</i>
	Male pores in small parietal invaginations with thin lateral walls (d)	<i>subtilis</i>

- (a) Hearts are present in xiii of some morphs of *P. elongata*.
 (b) Location of last pair of hearts was not recorded in *P. lompopatangensis*, *P. fungina* and *P. limellula* but they can be assumed, with some degree of probability, to be in xiii.
 (c) Also the species dubia *P. fungina*, *P. muta* and *P. limellula*.
 (d) Also the species dubia *P. zoyisiae* which may have slight parietal invaginations.
 (pm) Parthenogenetic morphs only.

PARTHENOGENESIS IN PHERETIMA

A list of species in which reproduction is (though not necessarily always) parthenogenetic that is appearing elsewhere (Gates, 1960) contains 17 names. Now added are the following: *P. infantilis*, *P. varians*, *P. voeltzkowi* and *P. zoyisiae*. A second list includes 17 species in which parthenogenesis is suspected or anticipated. To be added are the following: *P. fungina*, *P. limella*, *P. limellula* and *P. muta*.

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