

REDESCRIPTION OF *PHAGOCATA PAPILLIFERA*  
(IJIMA et KABURAKI, 1916), A SUBTERRANEAN  
PLANARIAN FROM CENTRAL JAPAN,  
WITH A COMPARATIVE DESCRIPTION OF KARYOTYPES  
OF THIS SPECIES AND ANOTHER JAPANESE  
SUBTERRANEAN SPECIES *PHAGOCATA SUGINOI*  
KAWAKATSU, 1974  
(Turbellaria, Tricladida, Paludicola)

by

MASAHARU KAWAKATSU, HISAO SUGINO, IWASHIRO OKI,  
SACHIKO TAMURA and ISAO HORIKOSHI

**INTRODUCTION**

In November, 1889, specimens of a slightly pigmented planarian were collected by the late Dr. Ichirō SHISHIDO from an old, unused well at Ichigaya, Shinjuku-ku, Tōkyō. Later, the animals (and their cocoons) were reobtained by him on several occasions from the same locality. This planarian was described by IJIMA & KABURAKI (1916, pp. 162-163, figs. 14 and 15) under the name of *Planaria papillifera*. A more detailed redescription of this species, accompanied by color illustrations, was given by KABURAKI (1922, pp. 17-21, text-figs. 6 and 7, pl. 1, figs. 7 and 8). As was already noted by S.-I. UENO (1957, pp. 290-291, 1967, p. 302), this species is the first hypogean animal described from Japan.

The taxonomic history of this species is clear. KENK (1930, p. 293) tentatively placed this species in the genus *Fonticola* KOMÁREK, 1926. TU (1940, p. 216) also followed Dr. KENK's classification. In 1937, HYMAN demonstrated that the generic name *Fonticola* KOMÁREK, 1926, is a synonym of the genus *Phagocata* LEIDY, 1847. KATŌ (1943, p. 16; see also KAWAKATSU, 1983, p. 5), who introduced HYMAN's opinion in Japan, classified *Fonticola* (olim *Planaria*) *papillifera* as *Phagocata papillifera* (IJIMA et KABURAKI, 1916). Later, OKUGAWA (1953, p. 38) listed the species as *Phagocata papillifera* IJIMA et KABURAKI, 1915) (the correct year of the publication of the original description is 1916).

In 1964, HORIKOSHI and his students authored a Japanese article on the subterranean fauna in the vicinity of Toyo'oka-chō in Mitsukaidō, Ibaraki Pref., and they listed a turbellarian species. KAWAKATSU, interested in their record, asked HORIKOSHI to send him samples of this uncertain species. Thus, KAWAKATSU had a chance to examine preserved specimens from the Toyo'oka populations in the summer of 1965. Surprisingly, the animal from these localities (hand-dug wells at Messrs. Y. ISHIZUKA's and T. OJIMA's residences at Hō'onji of Toyo'oka-chō) was identical with *Phagocata papillifera*. The rediscovery of this most interesting Japanese freshwater planarian was thus made 75 years after its first collection. Preliminary notes of the taxonomy and ecology of this species based upon the material from the Toyo'oka populations are found in papers by KAWAKATSU & HORIKOSHI (1966) and HORIKOSHI (1966, 1967, 1975;

and several other Japanese articles published in newspapers). KAWAKATSU (1966) gave a Japanese name to this species (kantō-ido-uzumushi).

Two monochrome photographs of live specimens of *Phagocata papillifera* taken by KAWAKATSU were first printed in a book by UENO & KASHIMA (1978, p. 69). The first color photograph of a live specimen of this species was published by MIYAZAKI & KAWAKATSU (1984, p. 50).

Recently, SUGINO, who has a special interest in karyotype comparisons of *Phagocata papillifera* and *Phagocata suginoi*, reported that both subterranean species have very similar karyotypes; their chromosome numbers are  $2n=24$  and  $n=12$  (cf. SUGINO, MURAYAMA & HORIKOSHI, 1978; see also SUGINO, KAWAKATSU & MURAYAMA, 1976; KAWAKATSU, 1977, 1979). These preliminary data have already been cited by TESHIROGI, HASEBE & ISHIDA (1980), TESHIROGI, ISHIDA & NIMURA (1979), and TESHIROGI & SASAKI (1977).

The purpose of the present paper is first to give a detailed redescription of *Phagocata papillifera* by KAWAKATSU based upon animals from the Toyo'oka populations, together with discussions of this rare species. Secondly, we give descriptions of the chromosomal analysis of two Japanese subterranean species, *Phagocata papillifera* and *Phagocata suginoi*, based upon SUGINO's preliminary data as well as additional karyological data observed by OKI and TAMURA. Thirdly, we add also ecological observations on *Phagocata papillifera* based on the field notes of HORIKOSHI.

## MATERIALS AND METHODS

Following are the data of the samples examined taxonomically. The Specimen Lot Numbers given for each collection are number registered in KAWAKATSU's fixing notebook according to his permanent recording system. All these specimens of *Phagocata papillifera* were collected from the 2 localities mentioned below (see KAWAKATSU, 1969, pp. 62-63, fig. 8 a and b).

No. 1. Specimen Lot No. 487. A single asexual specimen fixed with 3% formalin solution. A hand-dug well at Mr. ISHIZUKA's residence of Hō'onji, Toyo'oka-chō, Mitsukaidō, Ibaraki Pref., Kantō Region, Honshū (alt. 20 m; the first locality). 7 mm long and 0.8 mm wide. Sept. 10, 1963. Coll. I. HORIKOSHI.

No. 2. Specimen Lot No. 488. Five sexual and asexual specimens fixed with 3% formalin solution. The first locality. 6-8 mm long and 0.8-1 mm wide. July 1, 1965. Coll. I. HORIKOSHI.

No. 3. Specimen Lot No. 526. Eight sexual and asexual specimens fixed with Bouin's fluid. The first locality. 7-8 mm long and 0.9-1 mm wide. Aug. 25, 1965. Coll. I. HORIKOSHI.

No. 4. Specimen Lot No. 561. Many sexual and asexual specimens fixed with Bouin's fluid (October material only) and 70% ethanol. The first locality. 6-13 mm long and 0.8-2 mm wide. Oct. 5, 1965-Feb. 28, 1966. KAWAKATSU visited the locality on October 14, 1965; the other collections were made by HORIKOSHI.

No. 5. Specimen Lot No. 562. Three asexual specimens fixed with 3% formalin solution. A hand-dug well at Mr. OJIMA's residence of Hō'onji (the second locality). 6-7 mm long and 0.8-1 mm wide. Jan. 26, 1966. Coll. I. HORIKOSHI.

No. 6. Specimen Lot No. 640. Many sexual and asexual specimens fixed with 70% ethanol. The first locality. 8-13 mm long and 1-2 mm wide. Feb. 11-26, 1967. Coll. I. HORIKOSHI.

No. 7. Specimen Lot No. 1483. Many sexual and asexual specimens fixed with Bouin's fluid. The first locality. 8-13 mm long and 1-2 mm wide. Jan. 5-Apr. 27, 1978. Coll. I. HORIKOSHI.

No. 8. Specimen Lot No. 1484. A single asexual specimen killed by SUGINO's method and fixed with Nozawa's fluid. The first locality. 8 mm long and 1 mm wide. Jan. 15, 1978. Coll. I. HORIKOSHI.

No. 9. Specimen Lot No. 1540. Many sexual and asexual specimens fixed with Bouin's fluid. The first locality. 8-13 mm long and 1-2 mm wide. Apr. 4-May 25, 1978. Coll. I. HORIKOSHI.

KAWAKATSU photographed several live specimens, and Mr. T. MIYAZAKI also prepared color transparencies of live specimens for KAWAKATSU. About 50 sets of serial sagittal, transverse, and horizontal sections at 7-8 micrometers were prepared in KAWAKATSU's laboratory. The sections were stained with Delafield's hematoxylin and erythrosin.

The live specimens used for the chromosomal analysis of *Phagocata papillifera* and *Phagocata suginoi* were collected mainly by SUGINO on several occasions in cooperation with HORIKOSHI or Mr. H. MURAYAMA. Their regenerating somatic cells were observed according to the technique described in previous papers (cf. OKI, TAMURA & KAWAKATSU, 1976; OKI, TAMURA, YAMAYOSHI & KAWAKATSU, 1980; KAWAKATSU, OKI, TAMURA & SUGINO, 1976). Meiotic figures in spermatogenesis were also observed. These studies were performed both in SUGINO's former laboratory of Ôsaka Christian College and OKI and TAMURA's laboratory at their home institution.

### SPECIES DESCRIPTION

#### Order TRICLADIDA

#### Suborder PALUDICOLA or PROBURSALIA

#### Family Planariidae STIMPSON, 1857

#### Genus *Phagocata* LEIDY, 1847

#### ***Phagocata papillifera* (IJIMA et KABURAKI, 1916)**

*External features.* — This is a small, slender, and slightly pigmented species with two small eyes inhabiting shallow underground waters. The general appearance of living, fully sexually mature specimens is as shown in photographs in Fig. 1 (A-D). The largest sexually mature specimen measured 13 mm in length and 2 mm in width in an elongated state. Many other sexual specimens have a length of 10 to 12 mm.

In life the head has a subtruncated form; the anterior end is slightly protruding and the anterolateral corners are slightly projected but rounded (Figs. 1 A-F; 2 E-J; 3 A-F). Auricular sensory organs are recognizable as a pair of pigment-free slips (Figs. 1 G and H; 2 I and J). Behind the head, the body gradually widens toward the regions of the pharynx and the copulatory apparatus; the posterior end of the body is bluntly pointed (Figs. 1 A-D; 2 A-C). The rather long pharynx is situated behind the middle of the body and is nearly one-fifth as long as the body. The genital pore is situated at the mid-ventral level of the postpharyngeal region (Fig. 2 F). In some fully sexually mature specimens, the spermiducal vesicles were recognized as a pair of opaque, white structure lying on either side of the midline between the mouth and copulatory apparatus.

There is a pair of very small eyes situated close together and farther from the frontal margin than from the lateral margins; the distance between them is about one-fifth the width of the head at the level of eyes (Figs. 1 A-D; 2 E, H-J; 3 A). In some specimens examined, supernumerary eyes were found (Fig. 3 D-F). No pigment-free ocular areas are found around the eyes (Fig. 1 G). The living specimens are whitish gray to pale pink-brownish gray in color on the dorsal surface of the body, and are whitish color on the ventral side. Microscopically, there could be seen numerous small, irregularly-sized pigments spots (Figs. 2 I and J; 4 C and D).

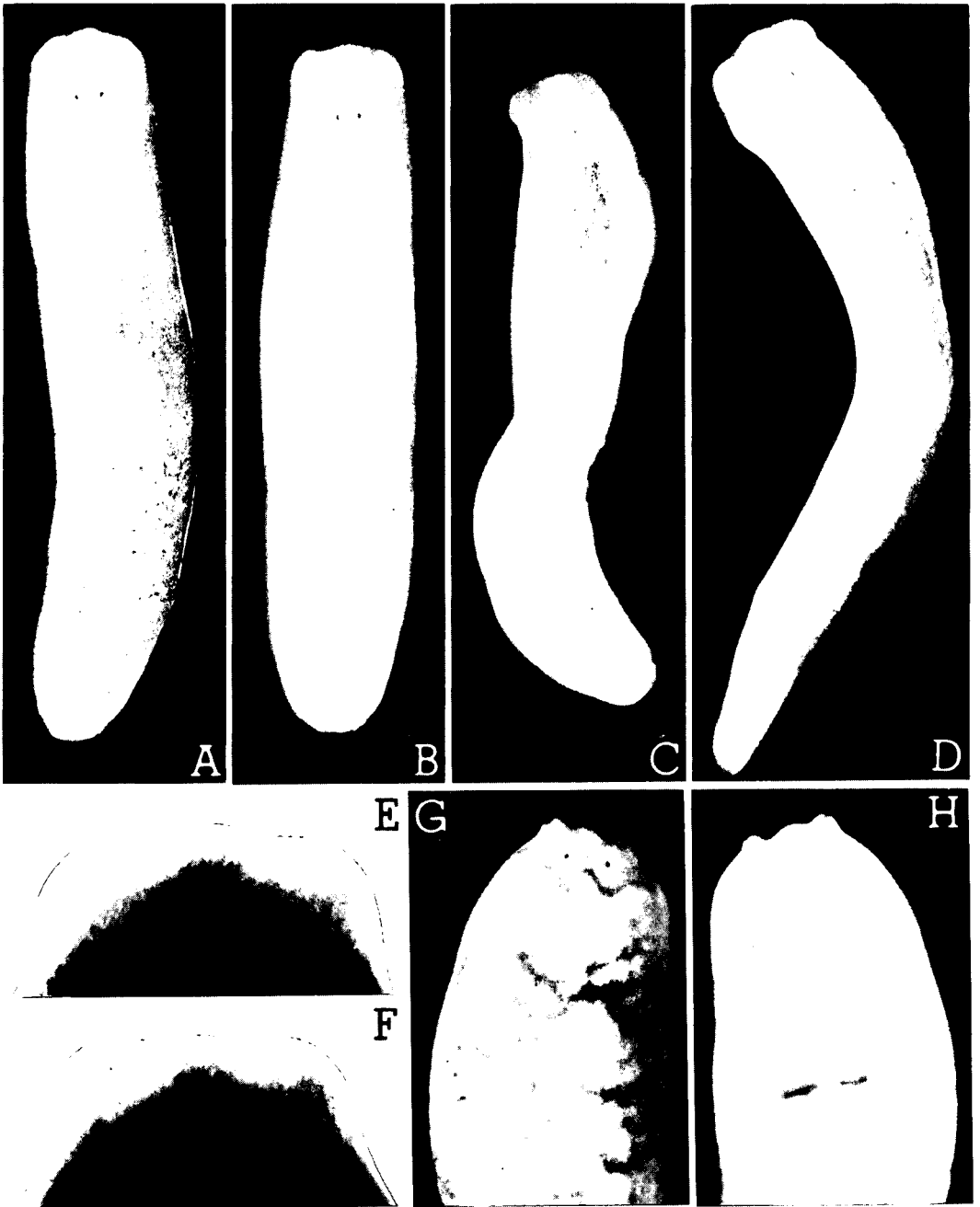
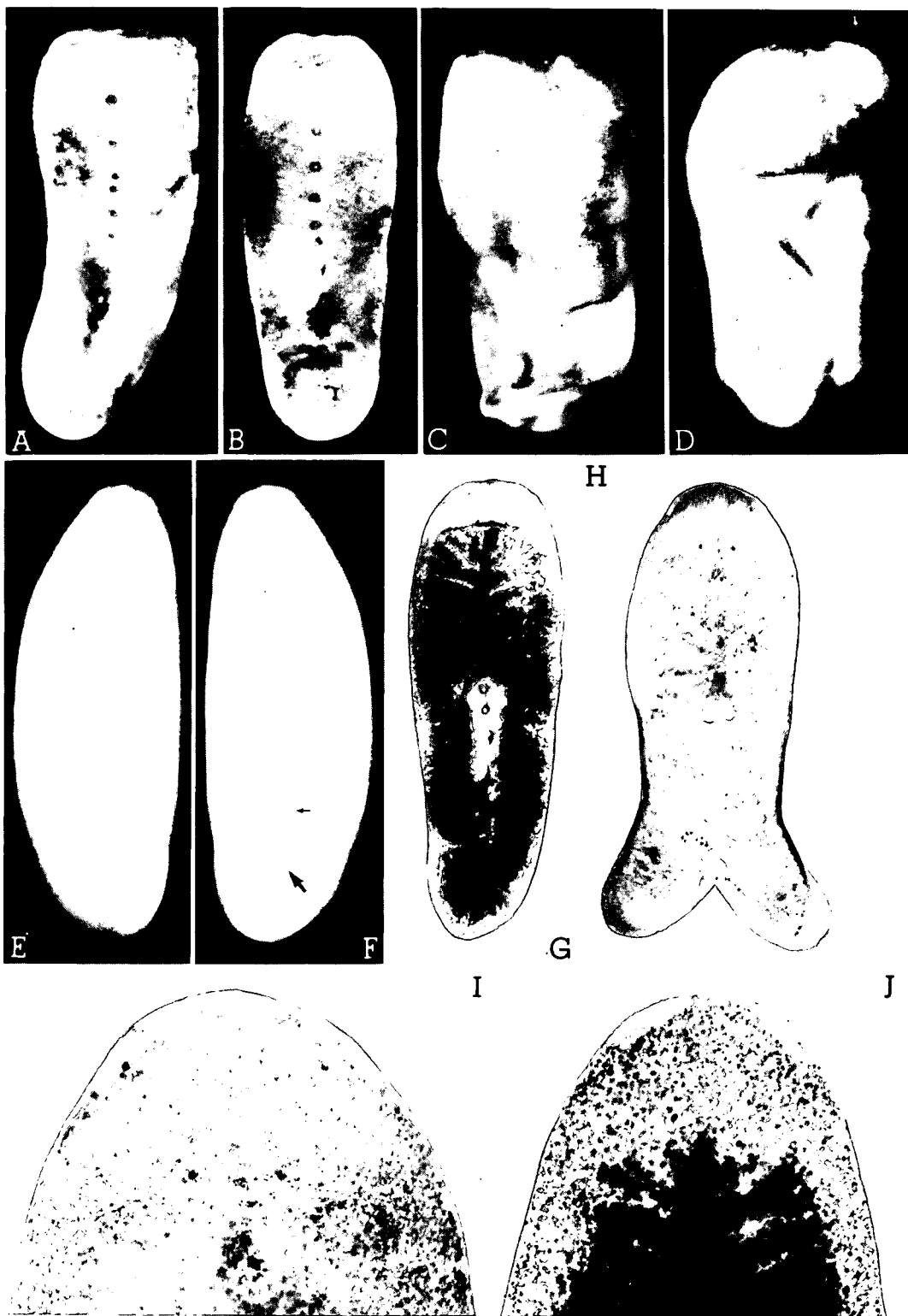


Fig. 1. *Phagocata papillifera* (IJIMA et KABURAKI, 1916), photographs of live (A-F) and preserved (G and H) specimens. A-D : Dorsal view of 4 sexually mature specimens. E and F : Head of 2 specimens. G and H : Head of dorsal and ventral views of a sexually mature specimen (Specimen Lot No. 561).

Fig. 2. *Phagocata papillifera*, photographs of preserved specimens. A-D : Dorsal and ventral views of 4 sexually mature specimens (Lot No. 561). E and F : Dorsal and ventral views of a sexually mature specimen (Lot No. 640). Small arrow indicates the mouth ; large arrow indicates the genital pore. G : Dorsal view of a non-sexual specimen (No. 488-e). H : Dorsal view of a bicau-



dal, non-sexual specimen (No. 488-f). I: Head of a non-sexual specimen (No. 488-f). J: Head of a non-sexual specimen (No. 526-f). Photomicrographs of G, H, I, and J were taken from the whole mounts.

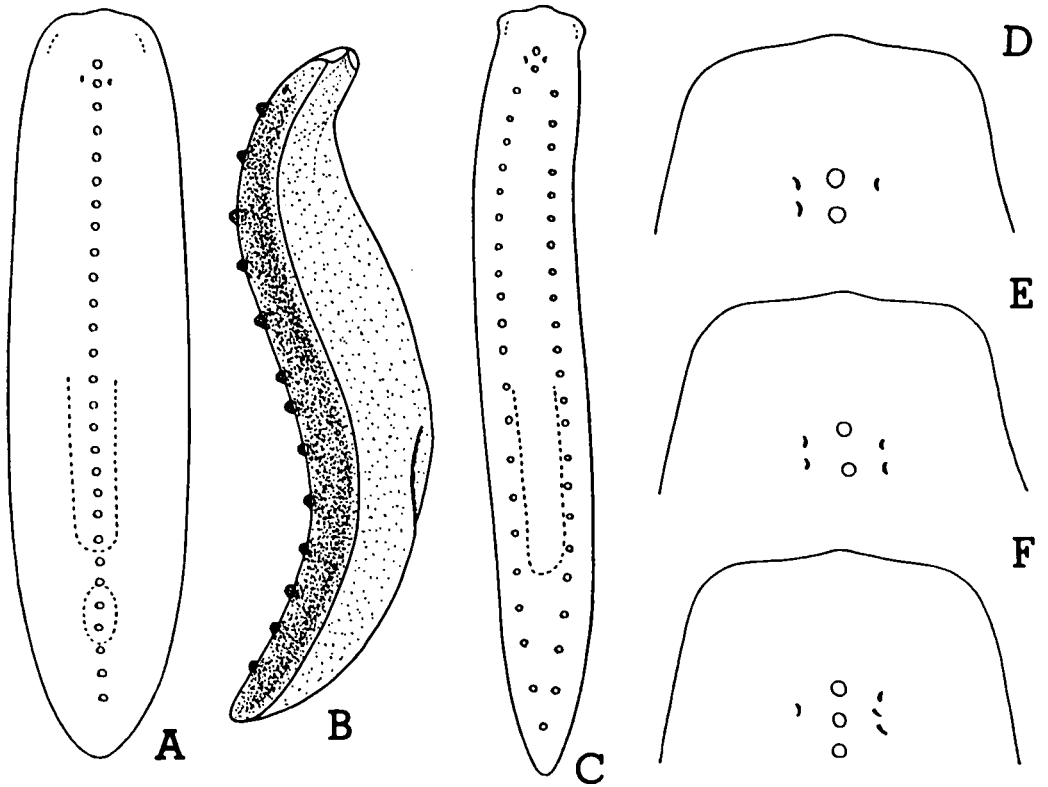


Fig. 3. General appearance in life of *Phagocata papillifera*. A and B: Two normal specimens. C: A deformed specimen having papillae arranged in two longitudinal rows. D-F: Head of 3 specimens having supernumerary eyes.

The species has many small papillae along the middorsal line of the body. This character is conspicuous in both live and preserved specimens (Figs. 2 A-D, G; 3 A; 4 B-D). They are arranged at the equal intervals from a level just anterior to the eyes to almost the posterior end of the body (Fig. 3 A and B). Their total number in the large specimens is estimated to be between 15 to 29. Small sized specimens have papillae of 10 to 13 or more in numbers. A single deformed specimen has papillae arranged in two longitudinal rows on either side of the midline of the body (Fig. 3 C). Another specimen shown in Fig. 2 (H) is apparently a bicaudal form due to the heteromorphogenesis. In live specimens, each papilla assumes a low conical shape; its basal portion is surrounded by more darker pigments than any part of the dorsal surface (Fig. 4 B-D). Under highpowered stereomicroscopic examination, the top of each papilla is seen to be whitish in color and slightly translucent.

The external characters of *Phagocata papillifera* from the Toyo'oka locality described above is coincident with the figures of "*Planaria papillifera*" from the type locality (cf. IJIMA & KABURAKI, 1916, p. 162, fig. 14; KABURAKI, 1922, p. 19, text-fig. 6, pl. 1, figs. 7 and 8; see Fig. 4 A). Due to the difficulty in executing accurate color paintings of live planarians, KABURAKI's (op. cit.) and KAWAKATSU's (1969, p. 89, pl. VII, fig. 7) color illustrations are rather different from the natural color of *Phagocata papillifera*. Its real coloration is paler than those illustrations cited above (cf. MIYAZAKI & KAWAKATSU, 1984, p. 50, color print reproduced from a color transparency).

In general appearance, *Phagocata papillifera* has a great resemblance to *Phagocata suginoi*

(especially, in shape of the head, position of small eyes, and slight pigmentation) (cf. KAWAKATSU, MURAYAMA & NIMURA, 1974, p. 149, fig. 1 A and B). The former, however, can be easily distinguished from the latter by its possession of the dorsal papillae.

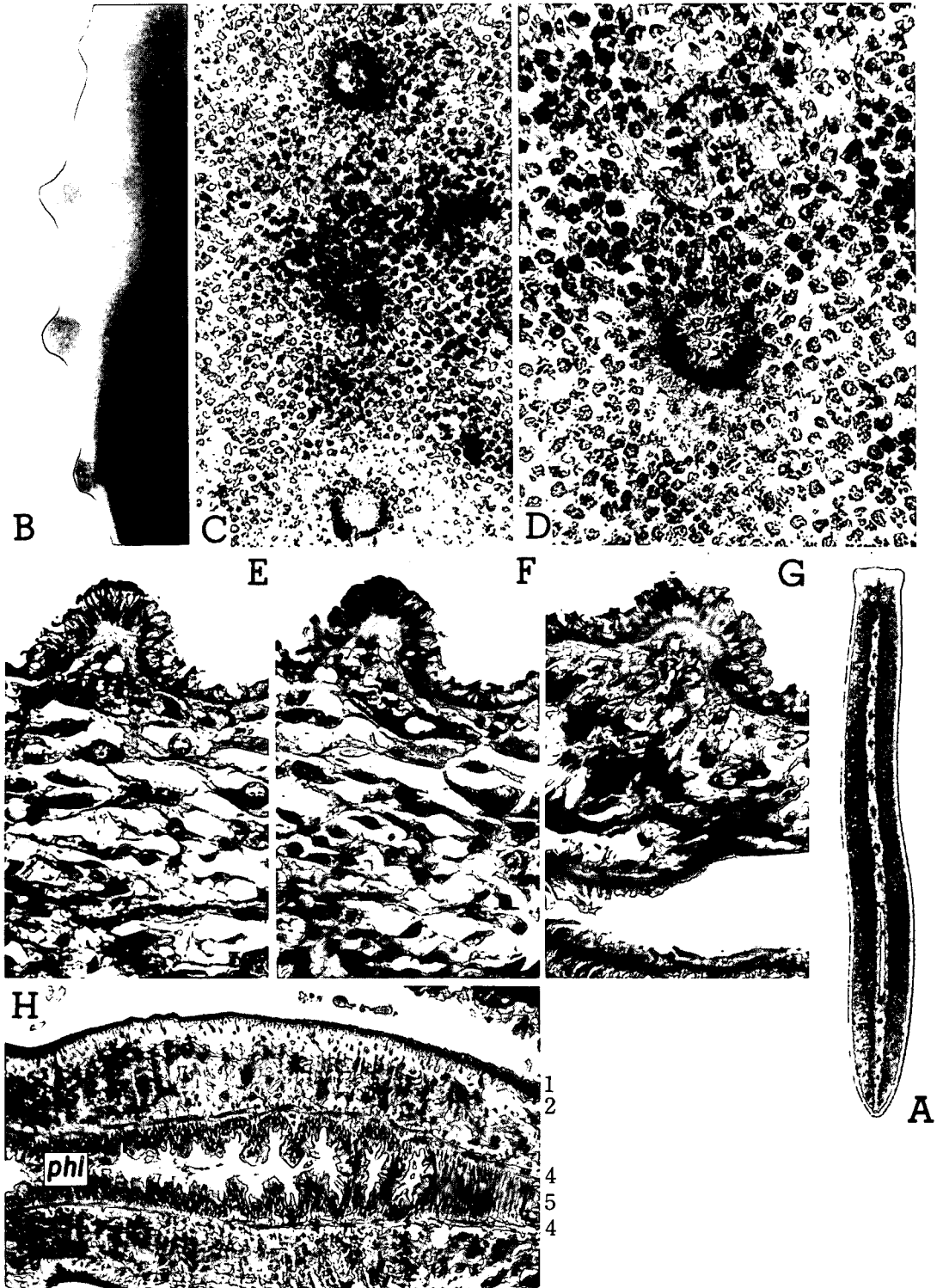


Fig. 4. For explanation see page 86.

*Internal characters.* — In histological sections, it was found that the epithelium is caved in the center of the ventral anterior of the head. The cells here lack cilia and rhabdites and are pierced by the erythrophilic gland ducts (Figs. 6; 9 A). Its structure is very similar to that of *Phagocata albata* ICHIKAWA et KAWAKATSU, 1962, a subterranean non-pigmented form from North Hokkaidō (cf. ICHIKAWA & KAWAKATSU, 1962 a, p. 31, fig. 2).

The histology of the dorsal papillae was given only briefly by IJIMA & KABURAKI (1916) and KABURAKI (1922). As Figs. 4 (A-G) and 5 indicate, the epithelium is much thicker at the region of the papilla than the remainder of the body. The nucleate epithelial cells contain rhabdites. Beneath the epithelial basement membrane, there are two layers of subepithelial muscle fibers except at the tip of the papilla, *i. e.*, a thin outer layer of circular fibers and a slightly thick inner layer of longitudinal ones.

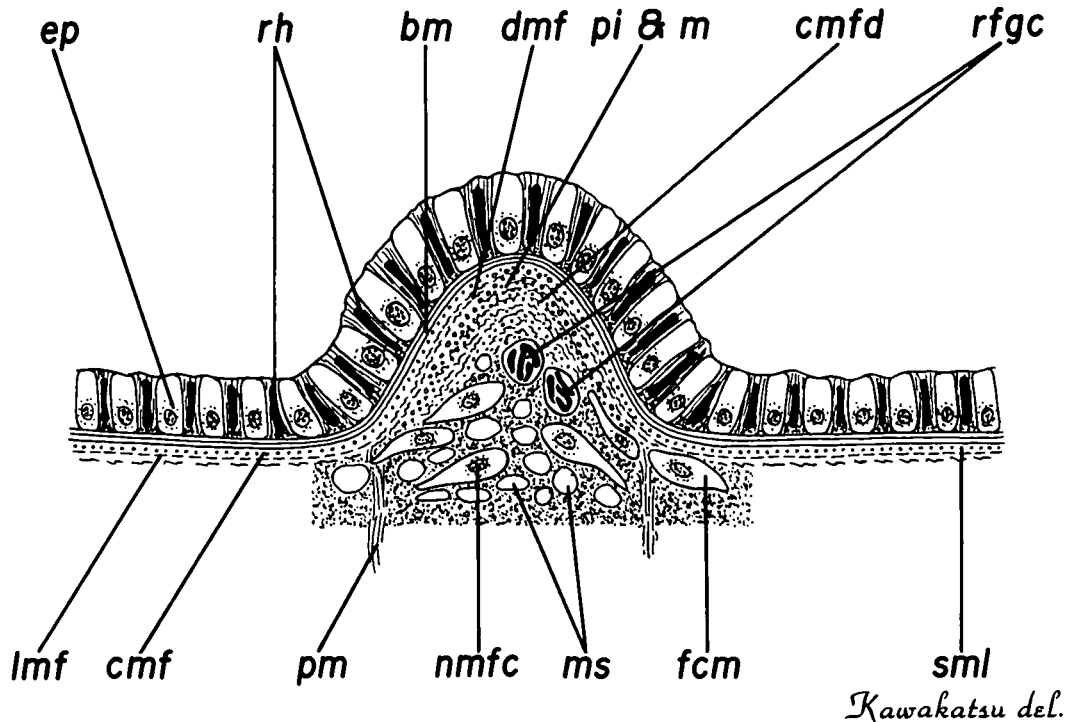


Fig. 5. *Phagocata papillifera*, drawing of the papilla from serial sagittal sections (No. 561-f). See Fig. 4 (E-G). **bm**, basement membrane; **cmf**, circular muscle fibers; **cmfd**, circular muscle fibers with diagonal ones intermingled; **dmf**, diagonal muscle fibers; **ep**, epidermis; **fcm**, free cells of mesenchyme; **lmf**, longitudinal muscle fibers; **ms**, mesenchymal syncytium; **nmfc**, nucleus of mesenchymal free cells; **pi & m**, pigments and muscle fibers; **pm**, parenchymal muscles; **rfgc**, rhabdite-forming gland cells; **rh**, rhabdite; **sml**, subepithelial muscle layers.

Fig. 4. *Phagocata papillifera*. A: General appearance (reproduced from a color illustration given by KABURAKI in his 1922 paper). B: Parts of papillae (photomicrograph taken from a live specimen). C and D: Photomicrographs of papillae (No. 526-e); D, enlarged. E-G: Photomicrographs of sagittal sections of papillae (No. 561-f). H: Photomicrograph of sagittal section of the pharynx (No. 640-b). **phl**, pharynx lumen; **1**, longitudinal fibers of outer muscle zone; **2**, circular fibers of outer muscle zone; **4**, longitudinal fibers of inner muscle zone; **5**, circular fibers of inner muscle zone.



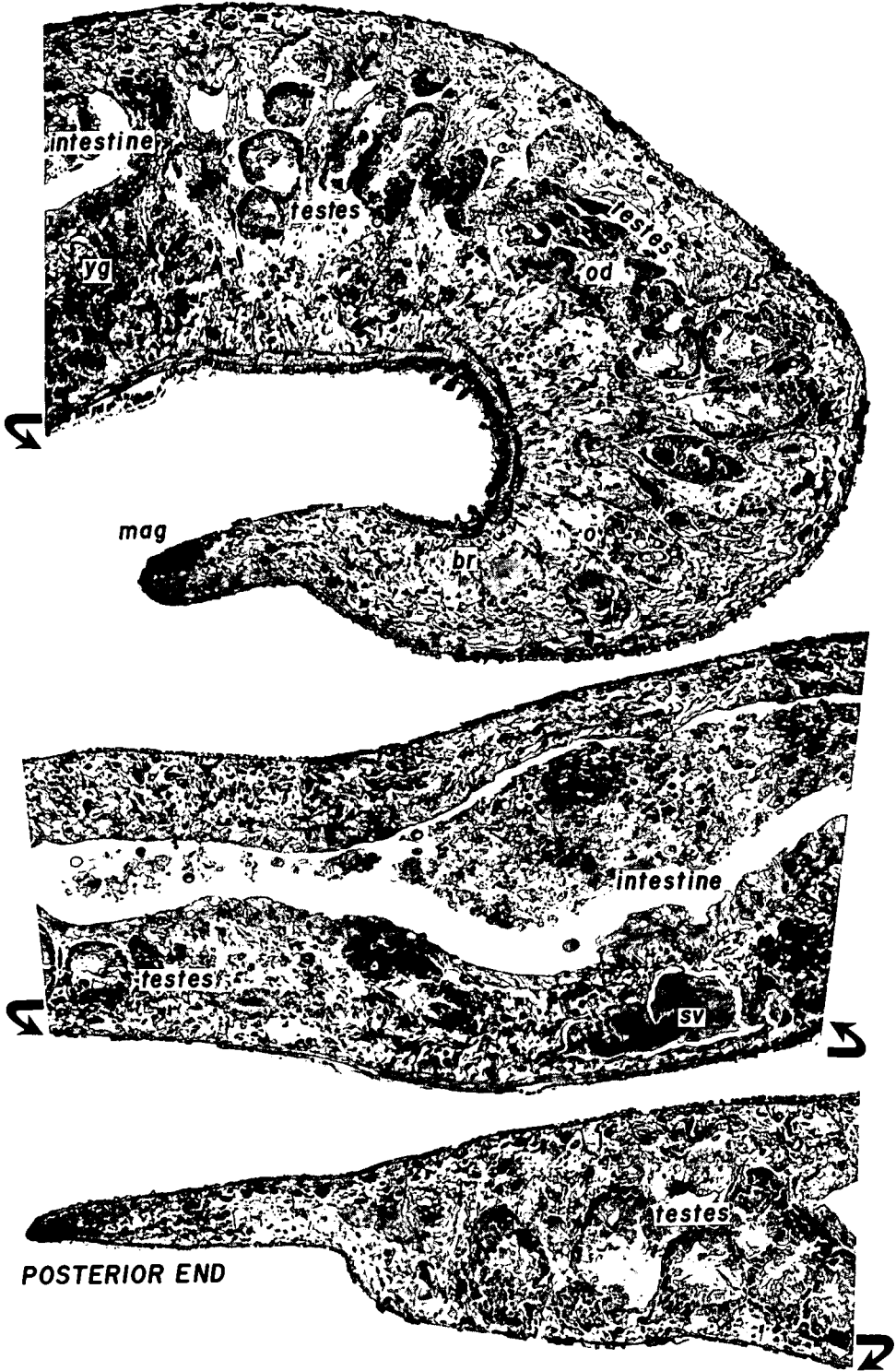
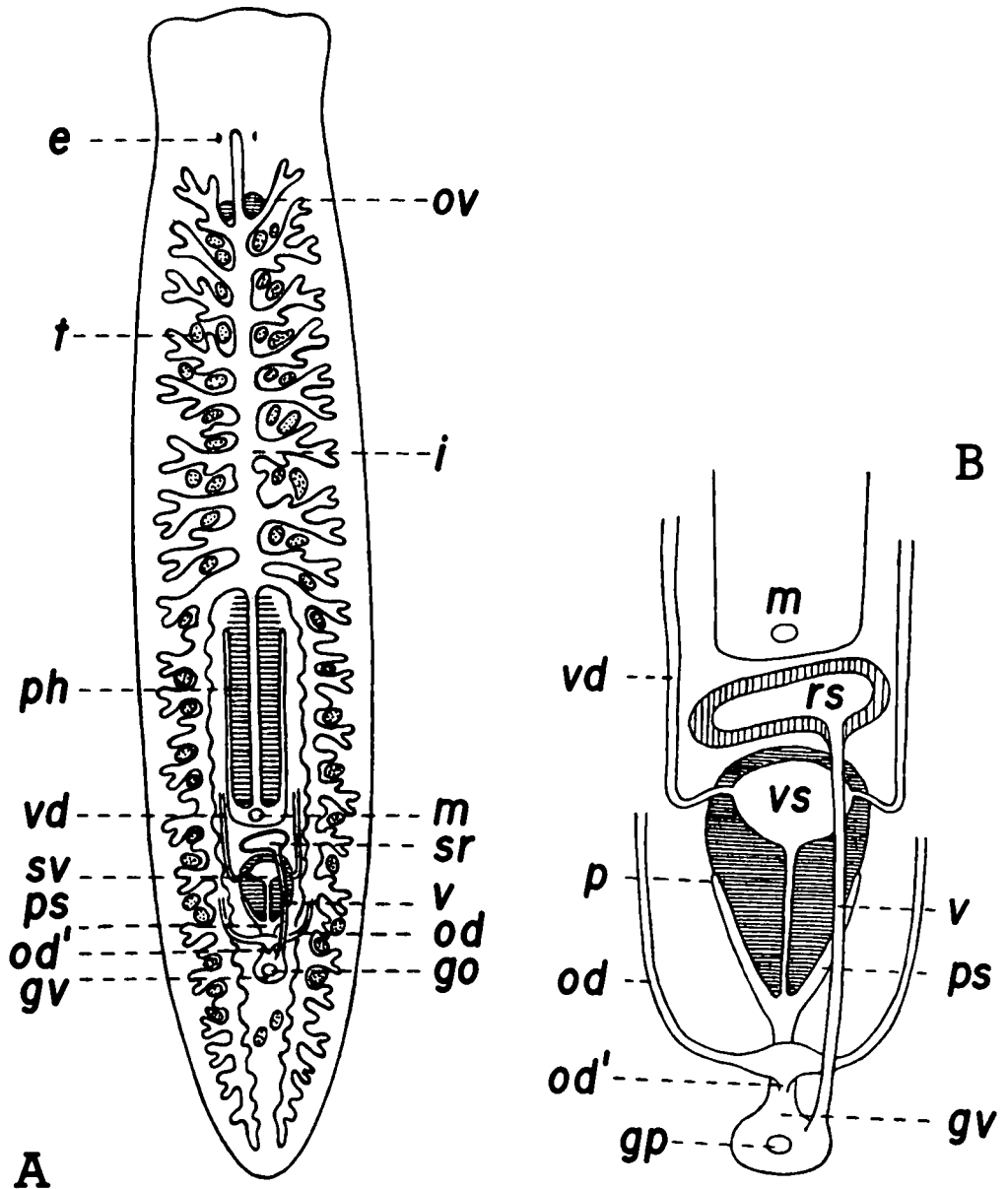


Fig. 6. *Phagocata papillifera*, photomicrograph of near midsagittal section (No. 640-b). br, brain; mag, marginal adhesive gland; o, ovary; od, ovovitelline duct; sv, spermiducal vesicle; yg, yolk gland.

Diagonal muscle fibers and pigments are also seen. At the central portion of the papilla, there is subepithelial musculature consisting mainly of thick circular fibers. Numerous pigment granules are distributed here. The inner part of the papilla contains a thick layer of circular muscle fibers and intermingled diagonal muscle fibers along with many feebly erythrophilous granules. Beneath these muscles, there are rhabdite-forming gland cells and free cells of mesenchyme.

The pharynx is structurally typical of the genus *Phagocata* and of the family Planariidae (Fig. 4 H). In the large specimens the anterior intestinal trunk bears 8 to 10 branches on each side; each posterior trunk has 10 to 13 short lateral branches.

A pair of medium-sized ovaries is situated in the usual ventral space between the first and the second intestinal diverticula (Fig. 6). Numerous yolk glands (or vitellaria) are distributed throughout the body (Fig. 6).



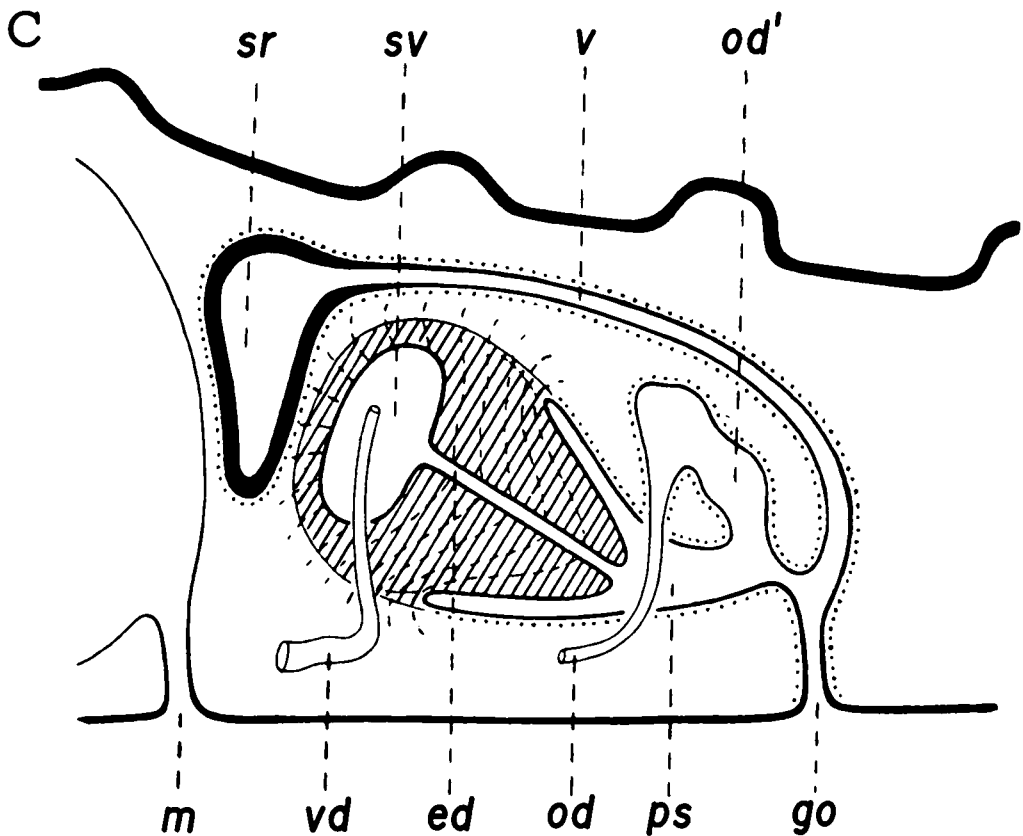


Fig. 7. General structure and diagrammatic figures of the copulatory apparatus of "*Planaria papillifera*" (= *Phagocata papillifera*) reproduced from IJIMA & KABURAKI (1916; B) and KABURAKI (1922; A and C). Slightly retouched. Abbreviations of the original figures were used (new terms used in the present paper are shown in parentheses). **e**, eye; **ed**, ejaculatory duct; **go**, genital opening (genital pore); **gp**, genital pore; **gv**, genital vestibulum (common genital antrum); **i**, intestine; **m**, mouth-opening (mouth); **od**, oviduct (ovovitelline duct); **od'**, unpaired common oviduct (expanded common ovovitelline duct); **ov**, ovary; **p**, penis; **ph**, pharynx; **ps**, penis-sheath (male genital antrum); **sr**, seminal receptacle (copulatory bursa); **sv**, seminal vesicle (bulbar cavity); **t**, testis; **v**, vagina (bursal stalk); **vd**, vas deferens (sperm duct and spermiducal vesicle); **vs**, vesicula seminalis (bulbar cavity).

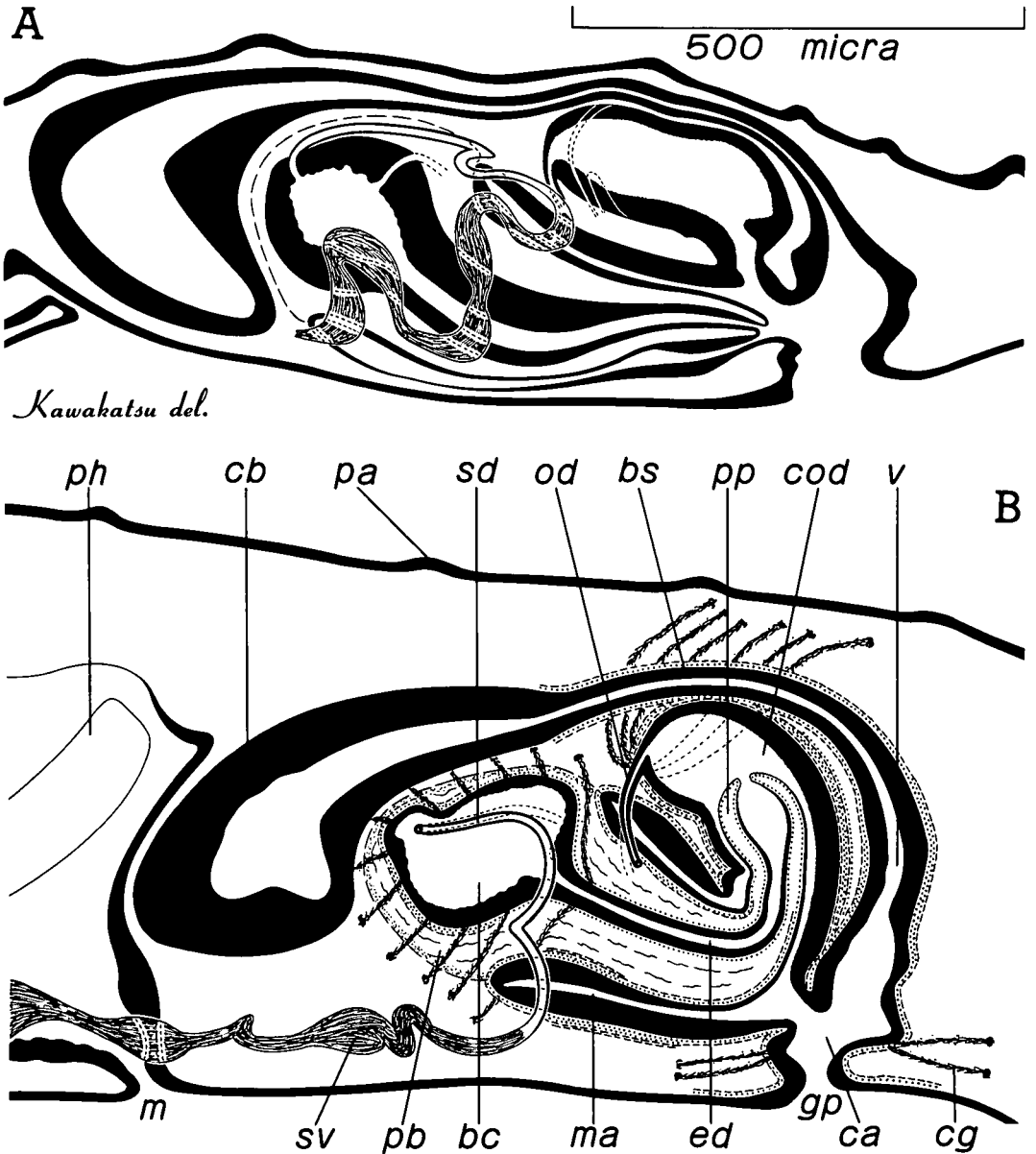
Testes are moderate to large in size and occupy the ventral half of the mesenchyme, extending from a level just posterior to the ovaries nearly to the posterior end of the body. They are arranged on either side of the midline in 2 to 3 longitudinal zones (Fig. 6). Some of the large testes occupy two-thirds or more of the dorsoventral space. Behind the level of the genital pore, testes are also distributed in the parenchyma in the space between the two posterior intestinal trunks (Fig. 9 B). The total number of testes is estimated to be about 120 to 150 in the large specimens. The spermiducal vesicles on either side of the middle and posterior parts of the pharynx (and the copulatory apparatus) are well developed (Figs. 6; 11 C and F).

The foregoing descriptions of the internal genital characters of the animals of *Phagocata papillifera* from the Hô'onji locality are in essential agreement with IJIMA & KABURAKI's (1916) and KABURAKI's

(1922) descriptions of "*Planaria papillifera*" from the type locality (see Fig. 7 A reproduced from KABURAKI's text-fig. 6 on p. 19).

Fig. 7 (B) is a reproduction of IJIMA and KABURAKI's figure of the copulatory apparatus of "*Planaria papillifera*"; Fig. 7 (C) is that of KABURAKI's (1922) figure. Sagittal views of the copulatory apparatus of 3 specimens of *Phagocata papillifera* from the Hō'onji locality (KAWAKATSU's Specimen Lot Nos. 561-f, 640-c and 640-g) are shown in Fig. 8 (A, B and C). Photomicrographs of the parts of the copulatory apparatus of several specimens from the same locality are also shown in Figs. 9 (B-D), 10 (A-D) and 11 (A-F).

In the diagrams of the copulatory apparatus shown in Fig. 8, Specimen No. 561-f (A) is preserved in an elongated condition but the posterior part of the penis bulb is slightly twisted against the anteroposterior axis of the body. In Specimen No. 640-c (B), the copulatory apparatus is in a moderately



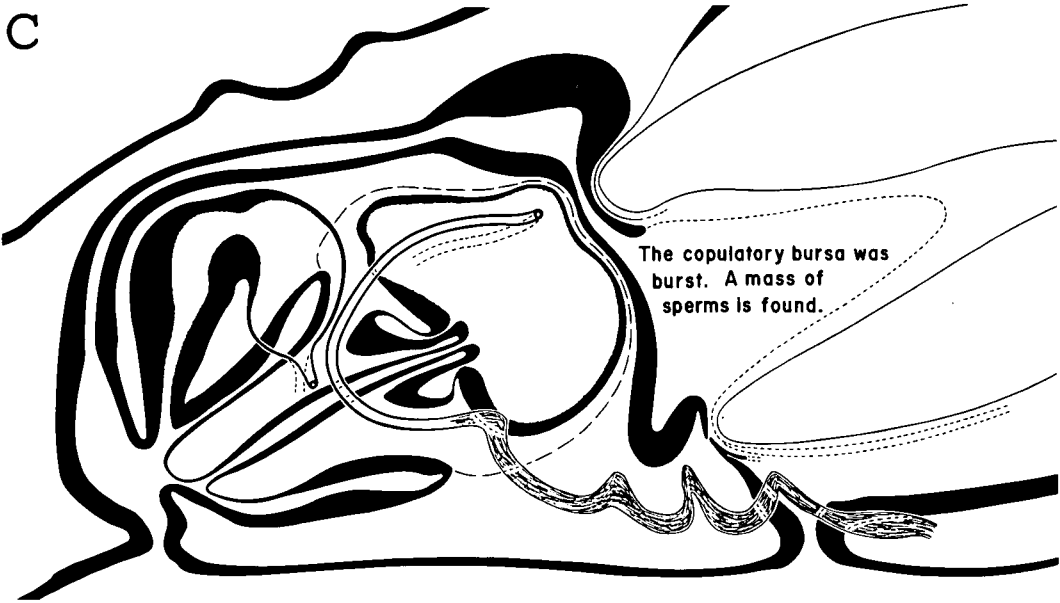


Fig. 8. *Phagocata papillifera*, semidiagrammatic sagittal views of the copulatory apparatus. A : No. 561-f (paraneotype). B : No. 640-c (neotype). C : No. 640-g (paraneotype). **bc**, bulbar cavity ; **bs**, bursal stalk ; **ca**, common genital antrum ; **cb**, copulatory bursa ; **cg**, cement gland ; **cod**, expanded common ovovitelline duct ; **ed**, ejaculatory duct ; **gp**, genital pore ; **ma**, male genital antrum ; **od**, ovovitelline duct ; **pa**, papilla ; **pb**, penis bulb ; **ph**, pharynx ; **pp**, penis papilla ; **sd**, sperm duct ; **sv**, spermiducal vesicle ; **v**, vagina.

elongated condition, but the tip of the penis papilla is inserted into the lumen of the common ovovitelline duct. In the Specimen Lot No. 640-g (C), the copulatory apparatus is in a rather contracted condition, and the anterior part of the copulatory bursa was burst by the pressure of the projecting pharynx when the animal was killed.

The penis has a moderate to large, spherical bulb embedded in the parenchyme and a large, long, corn-shaped papilla projecting into the common genital antrum. The bulb is weakly muscular and contains a very wide, rounded cavity (bulbar cavity or seminal vesicle) (Figs. 8 A-C ; 9 C and D ; 10 A-C ; 11 A-E). The spermiducal vesicles, well developed in the pharyngeal region, become narrow at the ventrolateral side of the posterior level of the penis bulb where they ascend vertically. They narrow to slender sperm ducts and curve anteriorly and inwardly through the penis bulb to finally open into the posterior part of the bulbar cavity separately from the dorsolateral side (Figs. 8 A-C ; 11 C). The bulbar cavity continues to the papilla as a long, rather narrow ejaculatory duct that opens at the tip of the penis papilla (Figs. 8 A-C ; 9 D ; 10 A-C ; 11 A, C and D). Although the ejaculatory duct opens in a slightly asymmetrical position in Specimen No. 640-g (Figs. 8 C ; 11 D), this is apparently due to the strong contraction of the animal. In this specimen, the basal part of the ejaculatory duct is also protruded into the posterior part of the bulbar cavity (Figs. 8 C ; 11 D). The bulbar cavity is lined with a nucleate glandular epithelium accompanied by numerous heavily erythrophilic granules, which are secreted by penis glands. The middle and anterior parts of the bulbar cavity are surrounded by two layers of muscle fibers, an inner slightly thick circular one and an outer thin longitudinal one. The posterior part of the bulbar cavity and the ejaculatory duct, lined with a nucleate glandular epithelium, are surrounded by a thin layer of circular muscle fibers.

The penis papilla is weakly muscular in nature. Its basal and middle parts are covered with a glandular, nucleate epithelium, below which there are two layers of muscle fibers, an outer circular one and an inner longitudinal one. The nucleate epithelium that covers the terminal part of the papilla becomes flat and thin toward the tip. Subepithelial circular muscle fibers are found only in this section.

The male genital antrum is an elongated, horn-shaped cavity that opens to the common genital

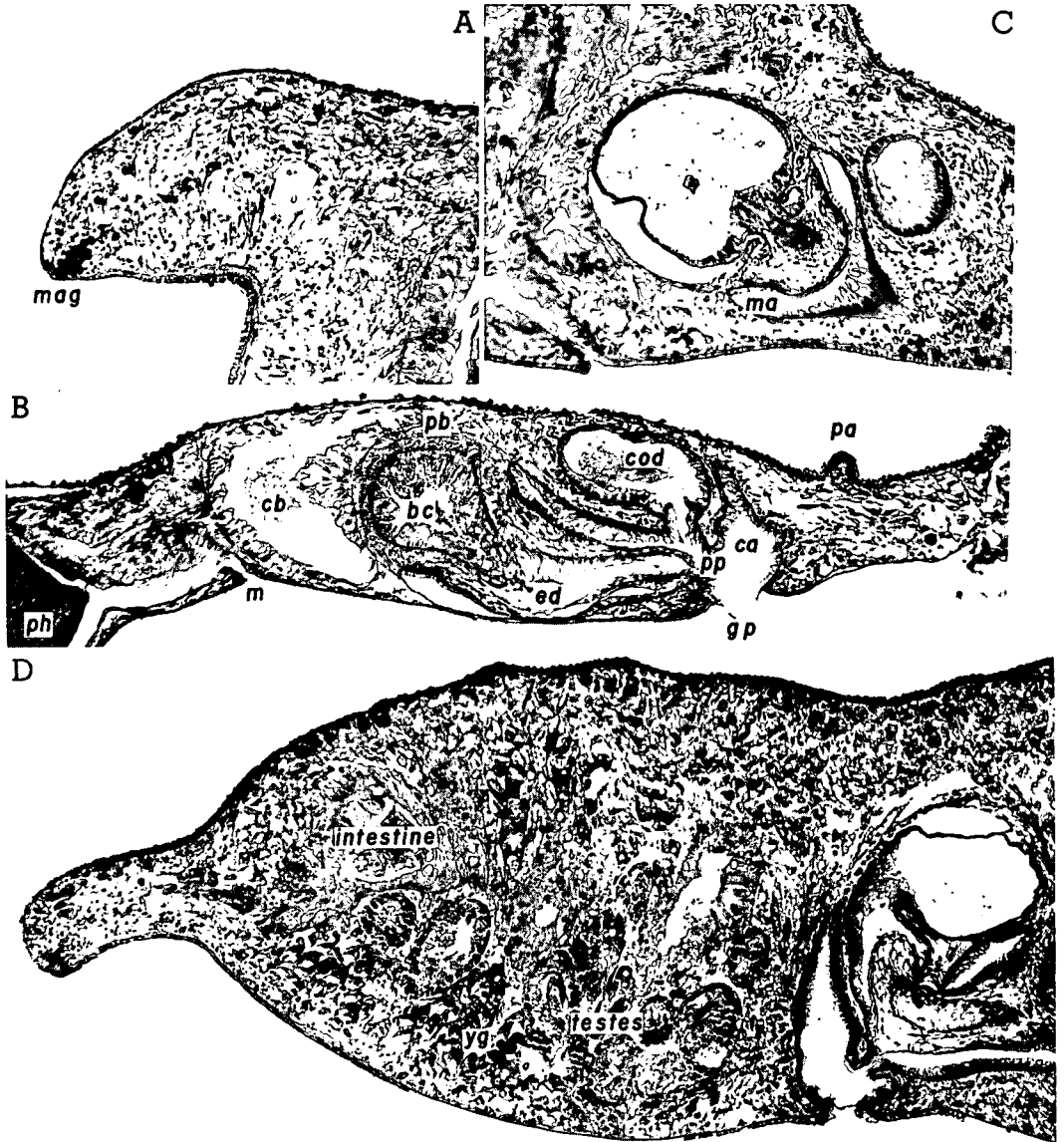
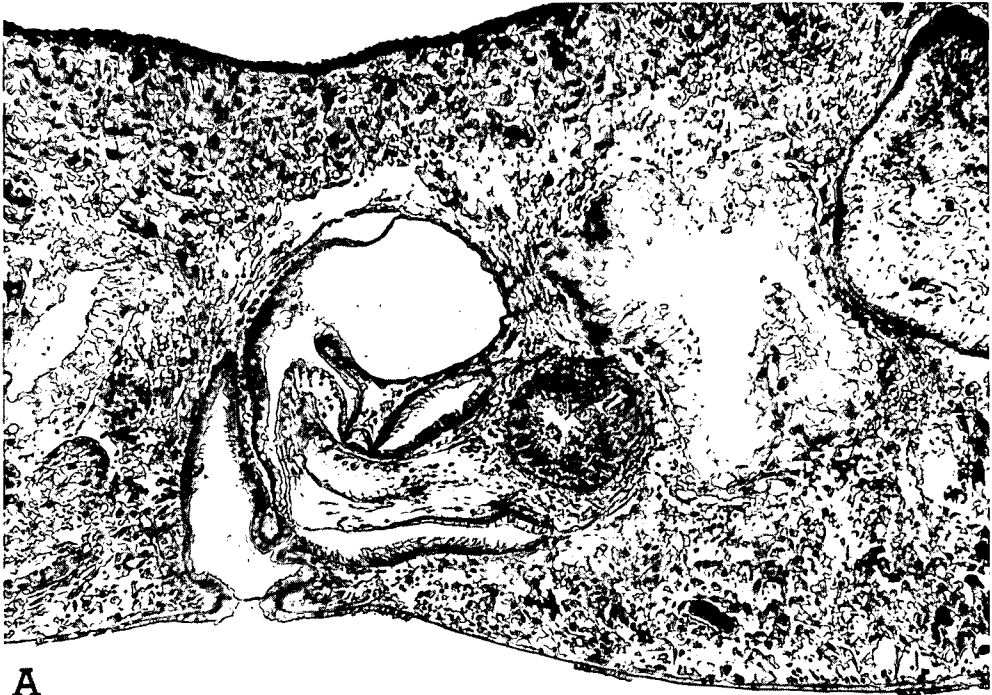


Fig. 9. *Phagocata papillifera*, photomicrographs of near midsagittal sections. A : Anterior part of the body (No. 640-c; neotype). B : Copulatory apparatus (No. 561-f). C : Copulatory apparatus (No. 561-a). D : Posterior part of the body (No. 561-h). Abbreviations see Fig. 11.

Fig. 10. *Phagocata papillifera*, photomicrographs of near midsagittal sections of the copulatory apparatus. A : No. 561-h. B and C : No. 640-a. D : No. 640-b. Abbreviations see Fig. 11.



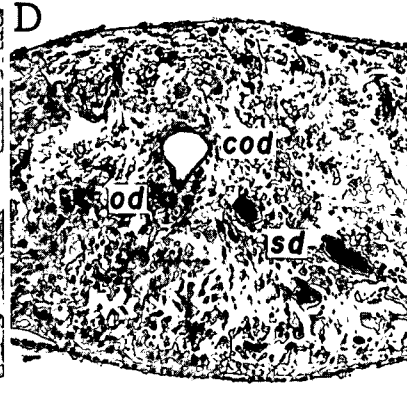
A



B



C



D

Fig. 10. For explanation see page 92.

antrum posteroventrally and to the mouth of the expanded common ovovitelline duct posterodorsally (Figs. 8 A-C; 9 B-D; 10 A-C; 11 A-D). The wall of the male antrum is covered with a tall, glandular, nucleate epithelium. The subepithelial muscle coat of the antrum consists of a somewhat thick layer of circular fibers and another thin layer of longitudinal ones.

*Phagocata papillifera* has a thick-walled and expanded common ovovitelline duct, or glandular

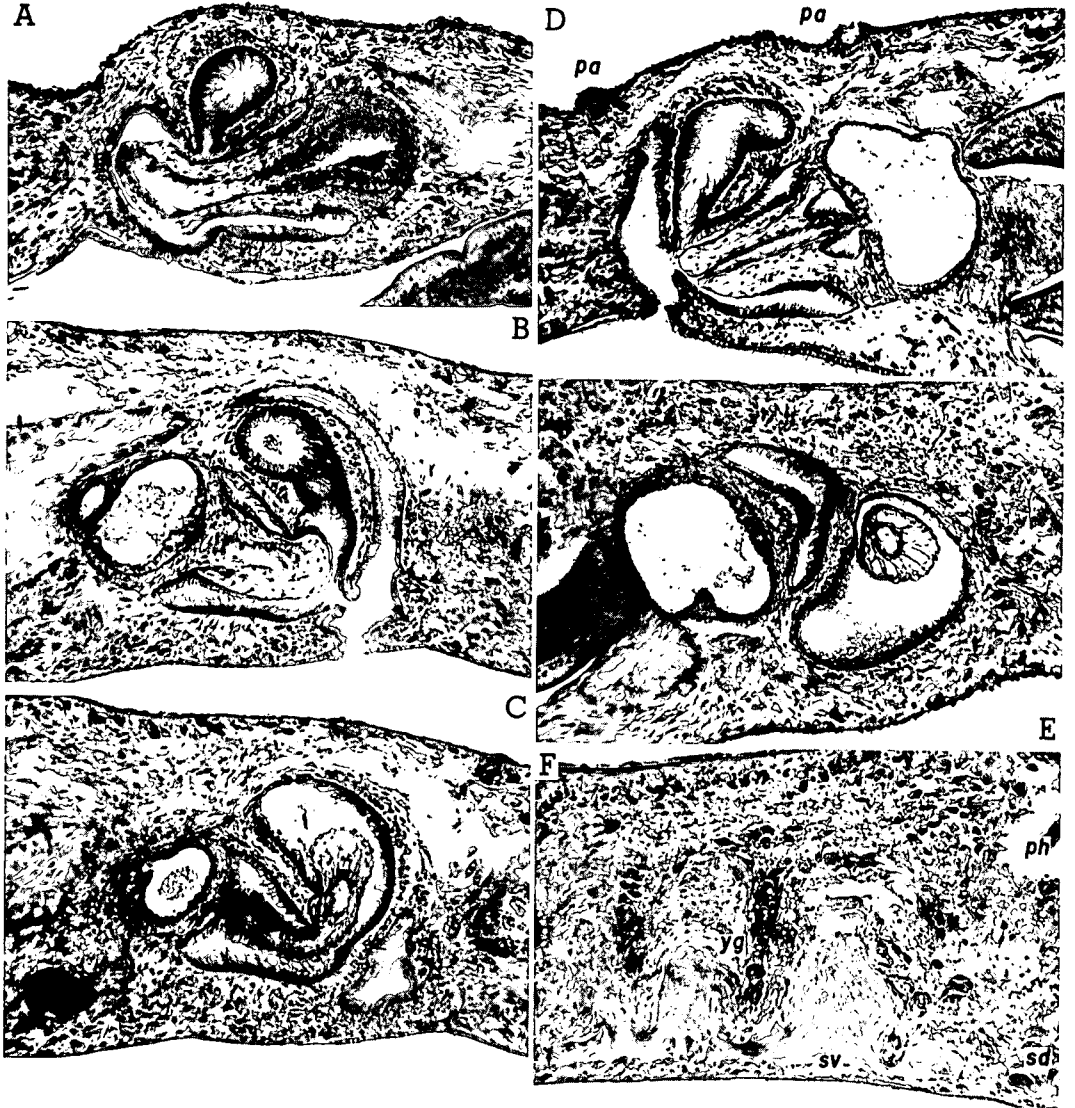


Fig. 11. *Phagocata papillifera*, photomicrographs of near midsagittal sections of the copulatory apparatus. A: No. 640-b. B, C and F: No. 640-c (neotype). D: No. 640-g. E: No. 640-f. **bc**, bulbar cavity; **bs**, bursal stalk; **ca**, common genital antrum; **cb**, copulatory bursa; **cod**, expanded common ovovitelline duct; **ed**, ejaculatory duct; **gp**, genital pore; **m**, mouth; **ma**, male genital antrum; **mag**, marginal adhesive gland; **od**, ovovitelline duct; **pa**, papilla; **pb**, penis bulb; **ph**, pharynx; **pp**, penis papilla; **sd**, sperm duct; **sv**, spermiducal vesicle; **v**, vagina; **yg**, yolk gland.



cavity of the female genital antrum (Figs. 8 A-C ; 9 C ; 10 B and C ; 11 A-E). It is an extraordinarily wide, long, and slightly curved organ (sometimes strongly curved when the copulatory apparatus is contracted), which opens into the roof of the posterior part of the male genital antrum. The lumen is covered with a tall, glandular, nucleate epithelium (Figs. 8 A-C ; 9 C ; 10 B and C ; 11 A-E). Its muscular coat consists of two layers, *i. e.*, a thin layer of longitudinal fibers adjacent to the epithelium of the lumen and a thick layer of circular fibers with a few longitudinal ones intermingled. The muscular coat is thicker at the posterodorsal side of the organ than in other regions. The anterior terminal portion of the lumen forms a pair of poorly developed bifurcate cavities on either side of the midline. The two ovovitelline ducts open separately into each cavity from the ventrolateral side (these openings are widely separated) (Figs. 8 A-C ; 10 D). Many erythrophilous gland ducts open into the bifurcate cavities (Figs. 8 B).

In many specimens examined, a mass of sperms was found in the lumen of the expanded common ovovitelline duct (Fig. 9 D). Moreover, in some specimens the tip of the penis papilla was inserted into the lumen (Figs. 8 B ; 10 A-C ; 11 B and C). This is due to the muscular contraction of the long penis papilla when the animal was killed.

The morphology, anatomy, and histology of the expanded common ovovitelline duct in *Phagocata papillifera* described above are very similar to those of that organ of *Phagocata suginoi* (cf. KAWAKATSU, MURAYAMA & NŌMURA, 1974, pp. 152-156, figs. 4 A-H, 5 B-D, and 6). In the present species, the organ may be more wider than that of the latter. The erythrophilous glands are, however, more developed in *Phagocata suginoi* than those of *Phagocata papillifera*.

Regarding the position of the ovovitelline duct openings in "*Planaria papillifera*", IJIMA & KABURAKI (1916, p. 63) wrote as follows: "Oviducts unite into a single short duct before opening into elongated atrial passage on the dorsal side" (on p. 163 ; see also "od" in fig. 15 on p. 162 which is reproduced in Fig. 7 B in the present paper). KABURAKI (1922, p. 21) gave a more detailed description of this feature as follows: "Slightly in front of the genital aperture the oviduct takes an inward and upward course to unite with its fellow of the opposite side into a wide single duct which opens into an elongated passage between the penis-sheath and the vestibulum on the dorsal side" (on p. 21 ; see also "od" in text-figs. 6 and 7 on pp. 19-20 which are reproduced in Fig. 7 A and C in the present paper). We consider the "short common ovovitelline duct" in "*Planaria papillifera*" described by the earlier Japanese turbellariologists to have resulted from observational errors of their slides.

The copulatory bursa, a medium-sized to large organ, is an elongated oval in shape, and it is situated in the space between the anterior end of the penis bulb and the posterior end of the pharyngeal chamber (Figs. 8 A-C ; 9 D ; 10 A-C ; 11 A and B). Its lumen is lined with a tall, glandular epithelium. The bursal stalk is a long and slender duct, which runs posteriorly and then curves ventrally to reach the genital pore (Figs. 8 A-C ; 10 B and C ; 11 B). The terminal section of the bursal canal is somewhat more expanded than the middle and anterior sections of the canal. The epithelial cells of the bursal canal are nucleate and glandular. The muscular coat of the bursal stalk consists of a layer of inner thin circular fibers and a layer of outer thin longitudinal ones. This muscular coat becomes slightly thicker at the terminal section of the stalk, which represents as a weakly developed vagina (Figs. 8 A-C ; 9 B and D ; 10 A-C ; 11 B and D). The common genital antrum can be differentiated near the genital pore (Figs. 8 A-C). Weakly erythrophilous cement glands can be seen near the genital pore.

Cocoons of *Phagocata papillifera* were not obtained in the Hō'onji locality. Although IJIMA & KABURAKI (1916, p. 163) and KABURAKI (1922, p. 17) mentioned cocoons of "*Planaria papillifera*", they did not describe their size and shape.

*Designation of the neotype-series.* — The type-series and other samples of Japanese turbellarians described by the late Prof. Dr. Isao IJIMA and the late Prof. Dr. Tokio KABURAKI are not stored in the

Department of Zoology, Faculty of Science, Tōkyō University (formerly the Imperial University of Tōkyō). KAWAKATSU can hardly avoid the conclusion that all of their materials have been lost. "An old unused well", the type locality of "*Planaria papillifera*", was located at Ichigaya, Shinjuku-ku, Tōkyō. The area is now in a subcenter of the Metropolis and the well where animals were collected was lost many years ago. Thus, the designation of a neotype-series of *Phagocata papillifera* based upon the Hō'onji material is necessary.

*Neotype.* — One set of sagittal serial sections (Specimen No. 640-c; 5 slides) is deposited in the Department of Zoology, National Science Museum (Nat. Hist.), Tōkyō. Five paraneotypes are also deposited in the same Museum: No. 561-f, sagittal sections; No. 561-k, transverse sections; No. 640-g, sagittal sections; No. 526-e and -f, whole mounts on one slide). The remaining paraneotypes including preserved specimens in 70% ethanol are retained in KAWAKATSU's laboratory, Fuji Women's College, Sapporo, Japan.

*Locality.* — A hand-dug well at Mr. Y. ISHIZUKA's residence of Hō'onji, Toyo'oka-chō, Mitsu-kaidō, Ibaraki Pref., Honshū, Japan. The neotype specimen was collected by I. HORIKOSHI in February, 1967. The other data of the specimens examined are listed in the foregoing section, "Materials and Methods". For locality data, see also the section "Ecological Notes".

*Taxonomic remarks and differential diagnosis.* — The known species of the genus *Phagocata* (sensu HYMAN, 1937, 1951; KENK, 1970 a, b, 1972) from the Japanese Islands are as follows: *Phagocata vivida* (IJIMA et KABURAKI, 1916) from Kyūshū, Shikoku, Honshū, and Hokkaidō; *Phagocata kawakatsui* OKUGAWA, 1956, from Shikoku and Central Honshū; *Phagocata teshirogii* ICHIKAWA et KAWAKATSU, 1962, from Northern Honshū; *Phagocata iwamai* ICHIKAWA et KAWAKATSU, 1962, from Hokkaidō; *Phagocata papillifera* (IJIMA et KABURAKI, 1916) from Central Honshū; *Phagocata suginoi* KAWAKATSU, 1974, from Central Honshū; *Phagocata albata* ICHIKAWA et KAWAKATSU, 1962, from Northern Hokkaidō; *Phagocata tenella* ICHIKAWA et KAWAKATSU, 1963, from Southeastern Hokkaidō. Among these 8 species, 4 of them (*vivida*, *kawakatsui*, *teshirogii*, and *iwamai*) are pigmented species inhabiting epigeal waters. The remaining 4 species (*papillifera*, *suginoi*, *albata*, and *tenella*) are inhabitants of subterranean waters; the distribution range of each species is very limited. Externally, *Phagocata papillifera* and *Phagocata suginoi* are slightly pigmented species. *Phagocata albata* and *Phagocata tenella* are non-pigmented species.

The shape of the head of *Phagocata vivida* and of *Phagocata tenella* is very different from that of the other 6 species. The shape of the head of 3 species, *Phagocata kawakatsui*, *Phagocata teshirogii*, and *Phagocata iwamai*, is also different from that of *Phagocata papillifera* in detail (cf. KAWAKATSU, MURAYAMA & NIMURA, 1974, p. 149, Fig. 1 D-F). Although there is no photograph of a live specimen of *Phagocata albata*, the margin of its head has a more gentle curve than that of *Phagocata papillifera* (cf. ICHIKAWA & KAWAKATSU, 1962 a, p. 30, fig. 1 A and B). The genital anatomy of the above-mentioned 6 species is different from that of *Phagocata papillifera* in many details.<sup>1)</sup>

*Phagocata papillifera* has great resemblance to *Phagocata suginoi* not only in general appearance but also in genital anatomy. Externally, the former can only be distinguishable from the latter by the possession of dorsal papillae. In genital anatomy, *Phagocata suginoi* has a dorsoventral arrangement of testes, a rather wide bulbar cavity, a wide ejaculatory duct with an isthmus which separates the bulbar cavity in the penis lumen, and non-existence of vagina and of common genital antrum. Although these anatomical characters in *Phagocata suginoi* are different from those of *Phagocata papillifera*, the differences between both species are subtle. Moreover, the anatomy and histology of the expanded common ovovitelline ducts are strikingly similar in the two species. *Phagocata papillifera*, however, can be distin-

1) The taxonomic redescription of *Phagocata vivida* is found in a paper by KAWAKATSU, TESHIROGI & ISHIDA (1982); that of *Phagocata kawakatsui* from several localities including the type locality is found in KAWAKATSU & IWAKI (1967).

guished from the most closely related species, *Phagocata suginoi*, in the details of the penial anatomy and of the anatomy and histology of the female genital organs (presence of a weakly-developed vagina and the position of openings of ovovitelline ducts into the expanded common ovovitelline duct).

The known *Phagocata* species from the Far East and the other Asiatic countries were listed and discussed taxonomically in some previous literature (cf. ICHIKAWA & KAWAKATSU, 1962 a, b, c, 1963; KAWAKATSU, MURAYAMA & NIMURA, 1974). Morphologically and anatomically, there are no relatives of *Phagocata papillifera* in Asia except for those in Japan.

In the genus *Phagocata*, *Phagocata fawcetti* BALL et GOURBAULT, 1975, a pigmented species with two eyes from intermittent streams of Santa Barbara, California, U. S. A., is the third species having an elongated and expanded common ovovitelline duct. Drs. BALL and GOURBAULT gave in their 1975 paper a very detailed discussion on the taxonomic similarity of their North American species and the several Japanese *Phagocata* species. Although they emphasized the anatomical and histological similarities between *Phagocata fawcetti* and *Phagocata suginoi*, these two species can easily be distinguished from each other in the details of their genital anatomy and histology. These authors, however, very correctly pointed out that their Californian *Phagocata* species shows close affinities with the Asiatic species of the genus. *Phagocata fawcetti* has 19 chromosome pairs ( $2x=38$ ,  $n=19$ ). Ecologically, the species withstands dry periods by a process of fragmentation and encystment. These karyological and ecological data in this North American species are utterly different from those of the Japanese *Phagocata* species (see the sections "Karyological Observation" and "Ecological Notes" in the present paper).

*Phagocata papillifera* is unique among all the known species of the families Dugesidae, Planariidae and Kenkiidae in its possession of papillae along the middorsal line. Although the function of papillae is uncertain, they seem to be rhabdite-forming organs. In the family Dendrocelidae, the species of the genus *Papilloplana* KENK, 1974 (syn. *Thysanoplana* VON GRAFF, 1916) reported from Lake Baikal in Siberia have dorsal papillae. This endemic genus in Lake Baikal now consists of 3 species: *Papilloplana leucocephala* (ZABUSOV, 1903) (olim *Sorocelis leucocephala*), *Papilloplana grisea* (ZABUSOV, 1903) (olim *Sorocelis grisea*), and *Papilloplana zebra* KENK, 1974 (olim *Planaria (Anocelis) tigrina* GRUBE, 1872). "*Planaria papillosa*" KOROTNEV, 1912, seems to be a synonym of *Papilloplana leucocephala* (cf. KENK, 1974, p. 39). *Papilloplana leucocephala* has numerous dark colored papillae over the entire dorsal surface of the body except for the head (see KOROTNEV, 1912, taf. II, figs. 73 and 74; PORFIRJEVA, 1973, p. 64, fig. 17 a, 1977, p. 50, fig. 21 a). *Papilloplana grisea* has a grayish-green-colored dorsum with numerous dark colored papillae on its entire surface. *Papilloplana zebra* has no papillae (see GRUBE, 1872, taf. XI, fig. 2; KOROTNEV, 1912, pl. II, fig. 27; PORFIRJEVA, 1973, p. 64, fig. 17 b, 1977, p. 50, fig. 21 b). The arrangement of dorsal papillae in the *Papilloplana* species is quite different from that of *Phagocata papillifera*.

*Phagocata papillifera* differs from the other members of the genus in combining the following characters: living animal small in size (10 to 13 mm in length) and slightly colored from whitish-gray to pale pink-brownish-gray above, white below; head subtruncated with slightly projecting, but rounded, anterolateral corners; having two small eyes situated close together (irregularities may occur) and without pigment-free ocular areas around the eyes; having many small, slightly pigmented, conical papillae along the middorsal line of the body (10 to 29 in numbers); marginal adhesive zone well-developed (caved-in epithelium is present in the center of the ventral anterior of the head); numerous middle-sized to large ventral testes lie in 2 to 3 rows on either side and extend close to the posterior end (sometimes dorso-ventral testes may occur); penis bulb medium-sized to large and weakly muscular with a very wide, rounded bulbar cavity into which sperm ducts enter separately from the dorsolateral side (spermiducal vesicles well-developed); symmetrical penis papilla large, long, corn-shaped, but weakly muscular; rather

narrow, long ejaculatory duct opening at the tip of the penis papilla; common ovovitelline duct entering the roof of the terminal part of the male genital antrum forms a long, extraordinarily wide, thick-walled cavity lined with a glandular epithelium (the position of the openings of the ovovitelline ducts widely separated); copulatory bursa medium-sized to large and of an elongated oval shape; bursal stalk long, slender, with the terminal portion forming a weakly developed vagina, which opens into the genital pore; common genital antrum recognizable near the genital pore.

### KARYOLOGICAL OBSERVATION

In *Phagocata papillifera*, 4 sexually mature and 7 immature specimens were examined cytologically. In *Phagocata suginoi*, 2 sexually mature and 23 immature specimens were also studied. These results are shown in Table 1. The idiograms of these 2 species are shown in Fig. 12. Photomicrographs of their chromosomes are shown in Fig. 13 (A-D).

Table 1. The result of the cytological study of *Phagocata papillifera* and *Phagocata suginoi*.

Species	No. of specimens examined cytologically			Chromosome nos. & the no. of cells studied in parentheses	
	Total	Sexual	Asexual	Meiosis	Mitosis
<i>Phagocata papillifera</i>	11	4	7	12 (13)	24 (179)
<i>Phagocata suginoi</i>	25	2	23	12 (12)	24 (127)

The chromosome number of the diploid cells of both species is  $2x=24$ . During meiosis 12 bivalents are found. The karyotype of *Phagocata papillifera* consists of one pair of very large metacentric chromosomes, one pair of medium submetacentric chromosomes, 5 pairs of small metacentric chromosomes, and 5 pairs of small submetacentric chromosomes (Fig. 12 A). The karyotype of *Phagocata suginoi* consists of one pair of very large metacentric chromosomes, one pair of medium submetacentric chromosomes, 4 pairs of small metacentric chromosomes, and 6 pairs of small submetacentric chromosomes (Fig. 12 B).

The differences between the karyotypes of these 2 subterranean *Phagocata* species are minor. Although these 2 species have different morphological and anatomical characters, it might be difficult to separate them by their karyotypes. TESHIROGI & SASAKI (1977) and TESHIROGI, ISHIDA & NIMURA (1979) reported the karyotypes of *Phagocata teshirogii* ICHIKAWA et KAWAKATSU, 1962, and *Phagocata kawakatsui* OKUGAWA, 1956, respectively. According to them, the basic chromosome number of these 2 epigeal species is  $2n=24$  ( $n=12$ ). Their karyotypes consist of one pair of large metacentric chromosomes, one pair of medium submetacentric chromosomes, 4 pairs of small metacentric chromosomes, and 6 pairs of submetacentric chromosomes. Karyologically, these 4 *Phagocata* species seem to be rather close relatives. On the other hand, *Phagocata vivida* (IJIMA et KABURAKI, 1916), a common Japanese (and Korean) planarian inhabiting cold epigeal waters, has a basic chromosome number of  $2x=36$  ( $n=18$ ; cf. TESHIROGI, HASEBE & ISHIDA, 1980). Among the 7 described Japanese *Phagocata* species, the following 3 species are not yet studied karyologically: *Phagocata iwamai* ICHIKAWA et KAWAKATSU, 1962 (epigeal form), *Phagocata albata* ICHIKAWA et KAWAKATSU, 1962 (subterranean form), and *Phagocata tenella* ICHIKAWA et KAWAKATSU, 1963 (subterranean form). More light could be thrown on the taxonomic and systematic

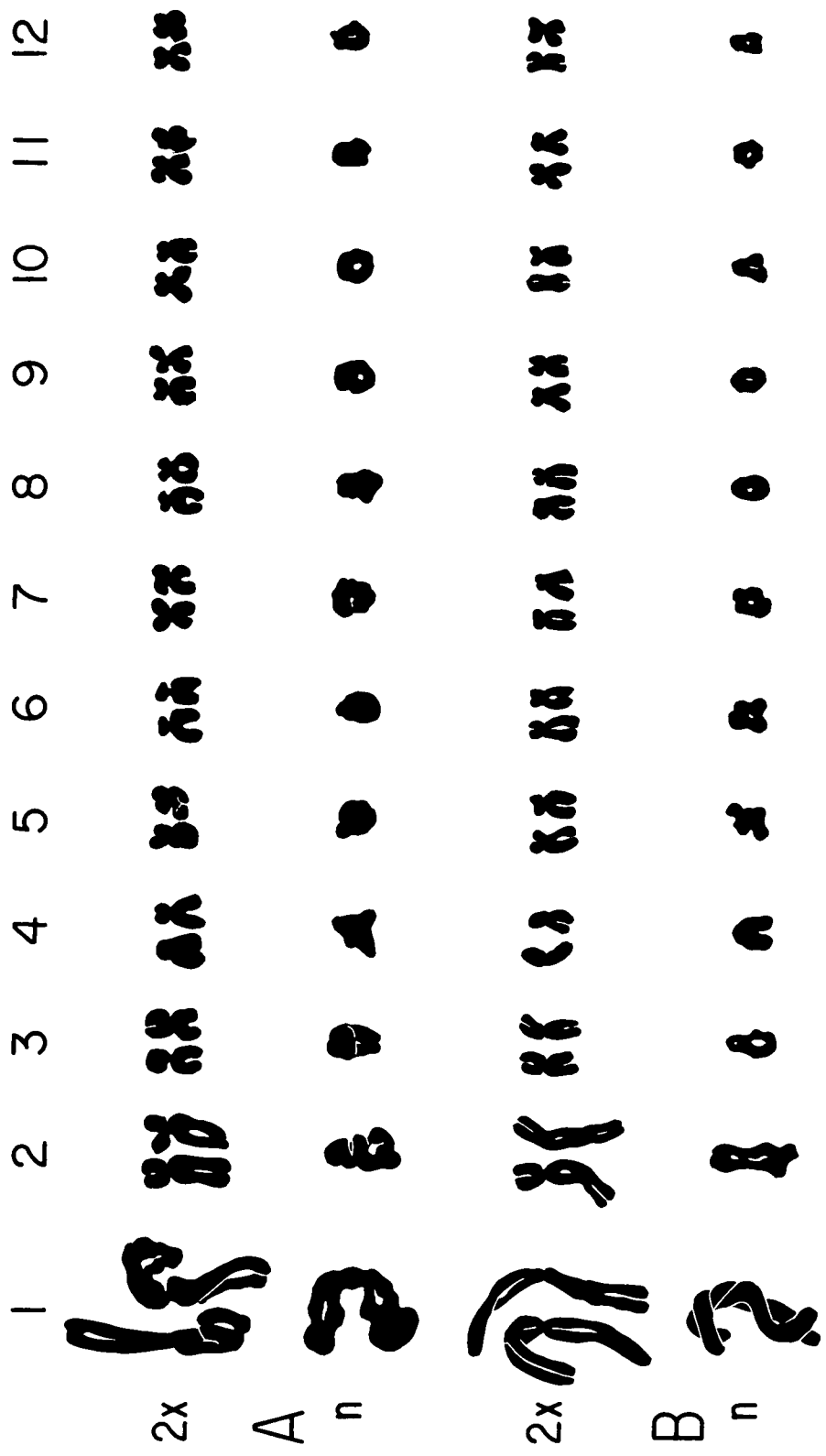


Fig. 12. Idiograms of *Phagocata papillifera* (JMA et KABURAKI, 1916) (A) and *Phagocata suginoi* KAWAKATSU, 1974 (B). Same magnifications.

affinities of the *Phagocata* species distributed in the Far East by additional, thorough karyological analyses.

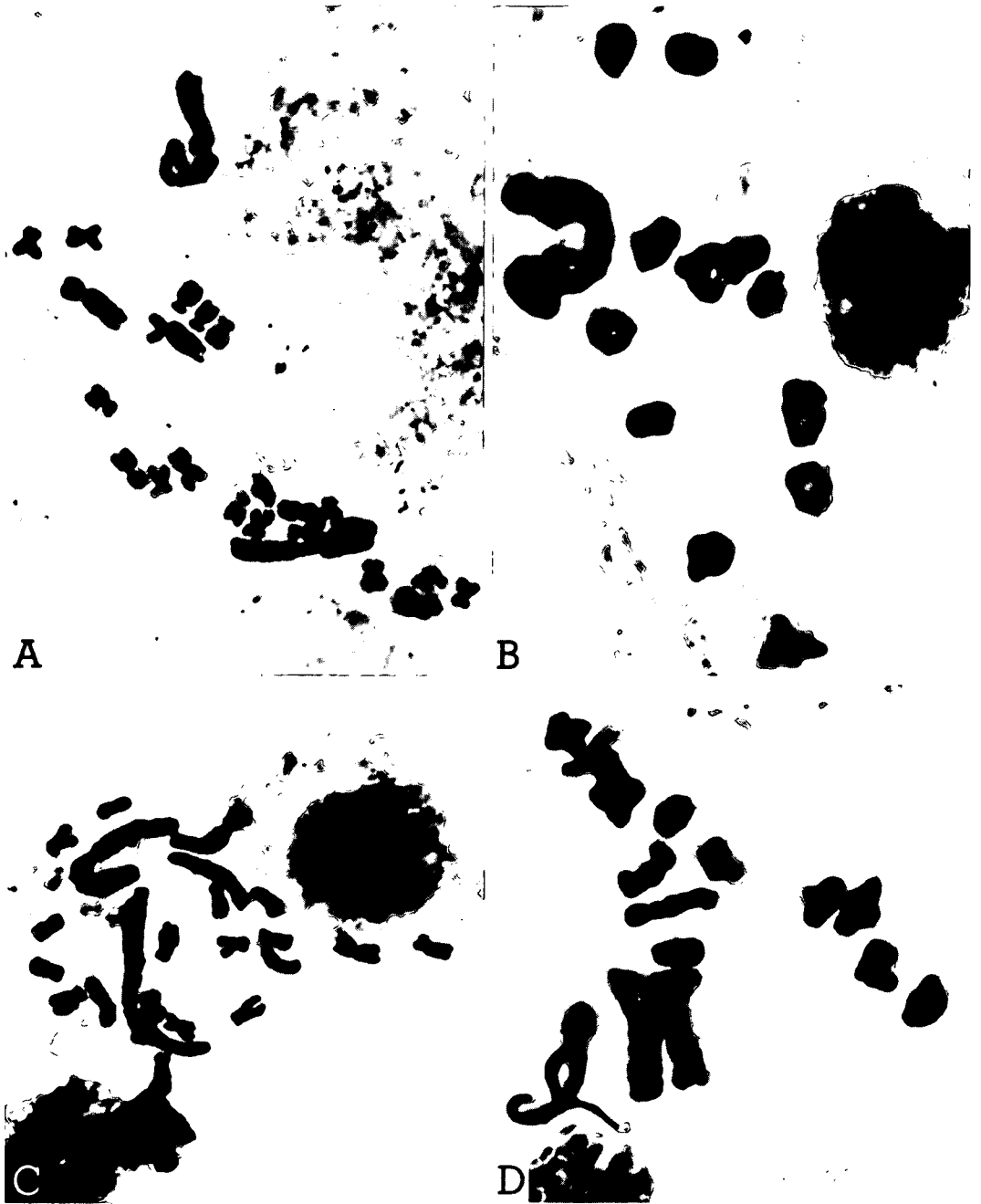


Fig. 13. Photomicrographs of the chromosomes of *Phagocata papillifera* (A,  $2x=24$ ; B,  $n=12$ ) and *Phagocata suginoi* (C,  $2x=24$ ; D,  $n=12$ ). Same magnifications.

## ECOLOGICAL NOTES

The hand-dug well at Mr. ISHIZUKA's residence (the first locality) where *Phagocata papillifera* was obtained by HORIKOSHI is about 1 meter in diameter and 4 meters in depth (the water is about 2 m in depth). The well is covered with a wooden plate and is provided with hand and motorized pumps for daily use. This well was dug about 75 years ago. The Toyo'oka district (location of Mr. ISHIZUKA's residence) in Mitsukaidō is in the central area of an alluvial fan formed by the lower streams of the Tonegawa River and the Kinu-gawa River. Geologically, the area is covered with the Kantō loam stratum formed by volcanic ashes from eruptions during the Pleistocene (ca. 0.1 ~ 1 million years ago). The well at Mr. OJIMA's residence (the second locality) is located only 40 meters from the first locality. These 2 localities are located about 50 kilometers NE of the type locality of "*Planaria papillifera*".

HORIKOSHI recorded collection data at the first locality from 1965 to 1979. In summary of these data, the range of the seasonal variation of the water temperature of the well varies from 10 to 18°C (pH 5.6-6.2). The chemical contents of water are: Ca (44.53 mg/l), Mg (52.65 mg/l), Cl (95.0 mg/l), HCO<sub>3</sub> (37.1 mg/l), and NO<sub>2</sub> (0.002 mg/l) (cf. HORIKOSHI, 1967).

At the first locality, 2 to 3 specimens were consistently found per day. If well water were pumped up about 300 times, 10 to 20 or more specimens could be obtained. Animals were usually found in evening and in early morning. Although sexually mature specimens could be collected throughout the year, their numbers are usually increased from late autumn to early spring. Several species of subterranean animals (*Pseudocrangonix yezonis* AKATSUKA et KOMAI, water fleas, water mites, etc.) were also common at this locality.

## SUMMARY

*Phagocata papillifera* (IJIMA et KABURAKI, 1916) (Turbellaria, Tricladida, Paludicola), a little known species, is redescribed in the present paper based upon material from the Hō'onji locality, Kameoka-chō, Mitsukaidō, Ibaraki Pref., Honshū (the Kantō Region), Japan. This slightly pigmented, subterranean species with two eyes is unique among species of the genus *Phagocata* in the family Planariidae (and also among all the known genera of the families Dugesiidae and Kenkiidae) in its possession of papillae along the middorsal line. This species has a wide, elongated and thick-walled common ovovitel-line duct as does the other Japanese subterranean species *Phagocata suginoi* KAWAKATSU, 1974. These 2 species have 12 chromosomal pairs ( $2x=24$ ,  $n=12$ ).

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*Addresses of the Authors :*

Dr. Masaharu KAWAKATSU, Professor of Biology, Biological Laboratory, Fuji Women's College, Kita-16, Nishi-2, Kita-ku, Sapporo (Hokkaidō) 011, Japan.

Dr. Hisao SUGINO, Professor Emeritus of Ōsaka Kyōiku University, Shindachi-Makino 170, Sen'nan, Ōsaka Prefecture 590-05, Japan.

Dr. Iwashiro OKI and Mrs. Sachiko TAMURA, Ōsaka Prefectural Institute of Public Health, Nakamichi 1 chō-me 3-69, Higashinari-ku, Ōsaka 537, Japan.

Mr. Isao HORIKOSHI, Mitsukaidō Dai'ichi High School, Kameoka-chō 2543, Mitsukaidō, Ibaraki Prefecture 303, Japan.

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