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ERRATA.

P. 219, in the table of measurements at the bottom of page, *for* " Longueur totale. .13 " *read* " Longueur totale. 130 "

P. 221, under Région inframandibulaire line 4 left column, *for* " lobe chagriné les saillant " *read* " lobe chagriné à supprimes saillant"

P. 438, lines 7 and 8, *for* " Pänge " and " Latria " *read* " Länge " and " Patria "

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[*N.B.*—An asterisk (*) preceding a line denotes a new variety or sub-species; a dagger (†) indicates a new species; a double dagger (‡) a new genus or sub-genus; synonyms are printed in italics.]

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ANATOMY OF *MYSORELLA COSTIGERA* KUSTER.

By R. V. SESHAIYA, *Mahant's High School, Tirupati, S. India.*

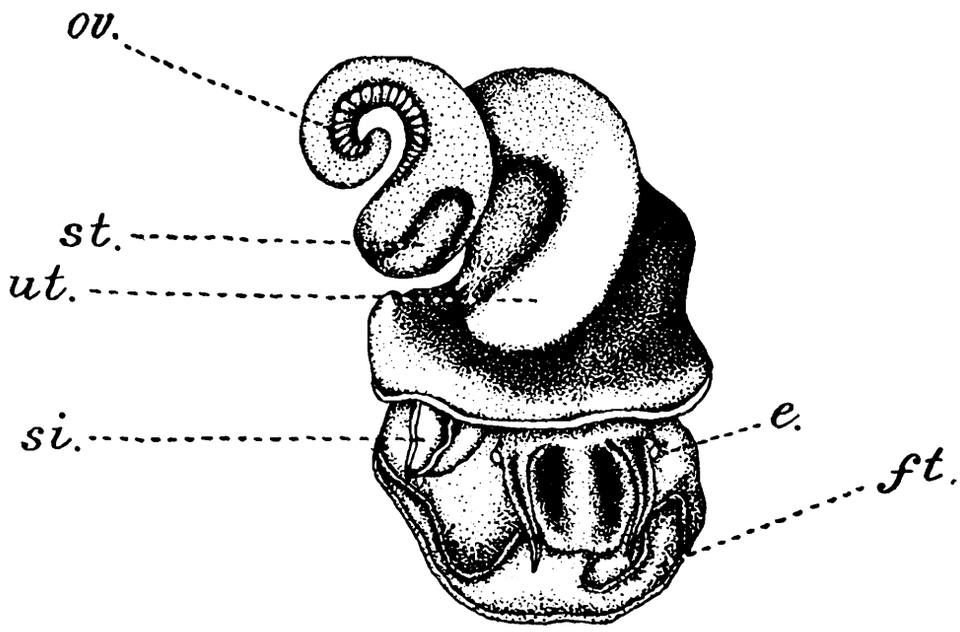
This paper is an elaboration of a note which I read before the annual session of the Indian Science Congress at Madras in January, 1929. My best thanks are due to Dr. Baini Prashad for guidance and encouragement, and for helping me with a translation of portions of Bregenzer's paper on *Bythinella* (3). I am also greatly indebted to the Syndicate of the Madras University for the award of a research grant to meet the expenses of my investigations.

Mysorella costigera is a small Hydrobiid mollusc, easily recognised by the spiral ridges on its shell. It inhabits shallow pools and tanks in which clay predominates in the soil at the bottom. The animal spends its time crawling on the bottom and does not float at the surface of the water, as is the case with *Amnicola* (*Alocinma*) or *Bithynia*. A fair number of specimens of *M. costigera* can be found in pools in which it lives by searching in the clayey silt at the bottom at about 3 or 4 ft. from the margin of the pool. They are often seen near the margin of the pool and as a rule crowd towards the side of the tank which is exposed to sunshine. Evidently warmth makes the animals active, for I have often observed that inactive specimens contained in a basin of water can be rendered active by exposing the basin to moderate sunshine. The food of the animal seems to consist almost entirely of diatoms along with minute clay particles. Specimens were kept alive for about six months in my laboratory, and they were fed on clayey silt from tanks. When the tanks and pools dry up, the species retreats deeper into the mud or into the moist situations underneath stones. Specimens taken from such situations can be revived within ten to fifteen minutes by placing them in water. A single shower of rain results in small collections of water in the pools and is quite enough to bring the animals out from their retreats and render them active. The breeding season lasts from September to December and is dependent on the water-supply in the pools. The eggs are laid in a single row, in tough gelatinous capsules, on hard substrata like stones or shells of other molluscs. The number of eggs in a capsule may vary from two to fourteen or more. The egg-capsules resemble in all respects the capsules of *Amnicola* (*Alocinma*).

The Animal.

The body of the animal after removal from the shell (fig. 1) is seen to be spirally twisted and consists of three to three and a half whorls. It is roughly divisible into the head, foot and visceral mass. In the living condition the head and foot alone can be extended out of the shell. Near the free edge of the mantle the colour is yellow; the head and foot are light grey in colour with yellow coloured spots interspersed here and there. In the female, on the right side of the body whorl, except

for a short distance near the free edge of the mantle, the thick uterus is seen bulging through it. The ctenidium cannot be distinguished



TEXT-FIG. 1.—*Mysorella costigera*. The animal removed from the shell; the foot is seen in the contracted condition. *e*. eye; *ft*. foot; *ov*. ovary; *si*. pseudo-epipodium; *st*. stomach; *ut*. uterus.

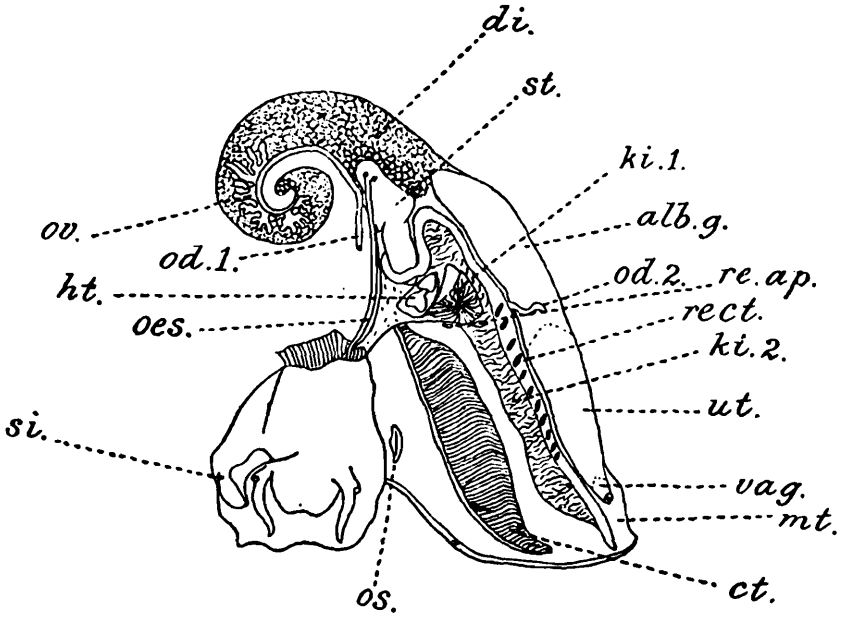
through the thickness of the mantle, but if the animal has been actively feeding, the rectum, owing to its being packed with cigar-shaped faecal pellets, is visible on the right side of the animal, to the left of the uterus in the female and in a corresponding position in the male. The region of the digestive gland is greenish-brown in colour and the genital gland at the apex of the visceral mass is yellow in the adult female, and orange in the adult male. In the male the apical whorls often show a black pigmentation to a varying extent.

The head projects forwards as the partly contractile snout and bears at its anterior end the vertical slit-like mouth. Starting from the base of the head and slightly dorsally placed are the two tentacles, one on either side. The tentacles are of the same colour as the snout, but show a central core of a blackish-brown colour. In the contracted condition, they extend but little beyond the snout, but when extended they are much longer than the snout. On the outer side of each tentacle, near its base, is the sessile eye.

Projecting over the foot immediately from behind the right tentacle is the pseudo-epipodial flap which, as in *Vivipara* (10), forms a spout-like siphon into the mantle cavity. Starting from behind the right tentacle it passes forwards and downwards, and projects over the foot on the right side. It then runs backwards and upwards and terminates near the right ventral attachment of the mantle with the foot. In the living animal, by the approximation of the anterior descending and posterior ascending margins, this siphonal opening regulates the flow of water into the mantle cavity, and can be observed to vary in size from time to time. The flap is covered by rather elongate ciliated cells and the main thickness of the flap is composed of connective tissue, blood spaces and longitudinal and transverse muscles.

The foot of the animal is roughly triangular in outline with rounded angles. It is extensile and its shape varies with the movements of the

animal. Near its anterior margin it shows a small transverse groove (fig. 4*a*, *gr.*). As the animal creeps a trail of mucus, the secretion of the well-developed pedal gland in the foot, is left behind. The operculum is attached to the foot postero-dorsally and the shell, when the animal crawls, rests on the operculum. There is nothing special in the general arrangement of the muscles of the foot. The lower part of the foot is composed of a close network of muscles. The upper portion consists posteriorly of the muscle-fibres of the columellar muscle and in the anterior part of the upper portion the network of muscles, which is less dense than in the ventral portion, contains the pedal ganglia and statocysts. The ventral surface or sole is covered by a ciliated epithelium consisting of columnar cells with oval nuclei.



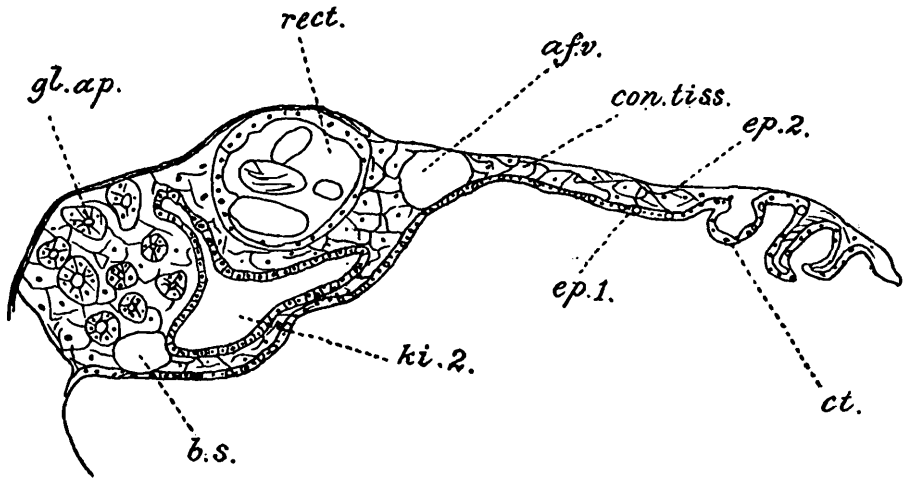
TEXT-FIG. 2.—Diagram of a partial dissection of a female animal; the anterior extension of the kidney is cut open. *alb. g.* albumen gland; *ct.* ctenidum; *di.* digestive gland; *ht.* heart; *ki. 1.* kidney; *ki.* 2. anterior extension of the renal organ; *mt.* mantle; *od.* 1, *od. 2.* cut ends of the oviduct; *oes.* oesophagus; *os.* osphradium; *ov.* ovary; *re. ap.* opening of the kidney into the mantle cavity; *rect.* rectum; *si.* pseudo-epipodium; *st.* stomach; *ut.* uterus; *vag.* vagina.

As stated above, the foot possesses a well-developed pedal gland. This is best developed in the region of the transverse groove and lies slightly anterior to it. In this region it appears as a deeply staining mass. It lies immediately below the ventral epithelium, and consists of several gland masses arranged irregularly. The cells of the pedal gland, when filled with their thick granular secretion, stain deeply and it is not possible to distinguish the structures in this condition. In the resting condition, however, the cells appear as irregularly rounded structures with a clear round nucleus and a homogeneously staining granular cytoplasm.

The columellar muscle is of the usual type. It consists of whitish muscles, most of which are attached to the columella, but some are also attached to the inside of the penultimate whorls of the shell. The fibres of the columellar muscle run down to become continuous with the hinder portion of the foot, and are finally attached to the boss of the operculum.

The Mantle and Mantle cavity.

The colour of the mantle has been described already. Its attachment and general disposition are similar to what is the case in other Prosobranchs. Ventrally it is attached to the foot, leaving a narrow free fringe in front of the attachment. The mantle edge is somewhat thickened, the thickened area consisting of connective tissue, blood spaces, glands and muscles.



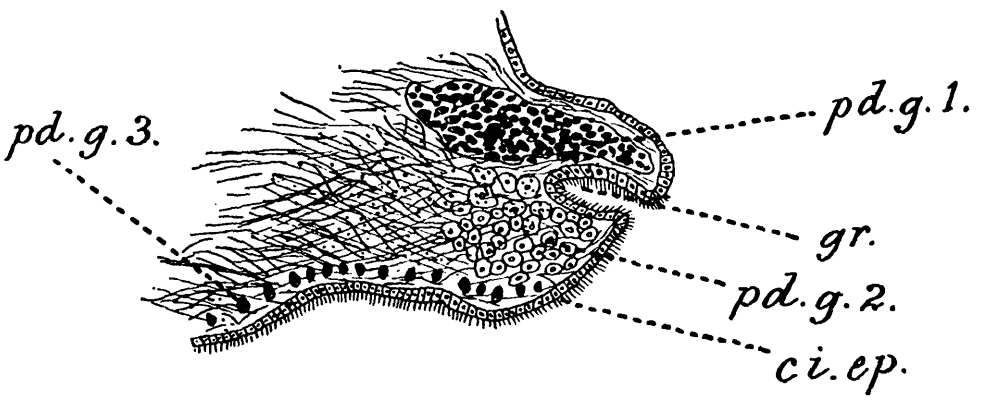
TEXT-FIG. 3.—Section through the roof of the mantle cavity of a male animal. *af. v.* afferent ctenidial vien ; *b.s.* blood sinus returning blood from the right side of the mantle ; *con.tiss.* connective tissue in the thickness of the mantle ; *ct.* ctenidium ; *ep.* 1 *ep.* 2. inner and outer epithelia of the mantle ; *gl. ap*, glandular attachment of the vas deferens ; *ki.* 2. anterior extension of the kidney lying in the roof of the mantle cavity ; *rect.* rectum.

The mantle cavity encloses the osphradium, the ctenidium, the rectum, the anterior extension of the renal organ, the uterus in the female, and the lower part of the glandular attachment of the vas deferens and the penis in the male. The rectum, the anterior prolongation of the renal organ and the lower part of the uterus in the female, and the glandular attachment of the vas deferens in the male lie along the roof of the mantle cavity and are not free in the mantle cavity. The organs are embedded in a connective tissue mass which forms the thickness of the mantle (fig. 3). The mantle is bounded dorsally by an outer layer of epithelium and ventrally by an inner layer. The cells of the epithelium separating the above mentioned organs from the mantle cavity, as also those to the right of the ctenidium, are slightly elongate. Large numbers of gland-cells are also found in between the epithelial cells, but it may be noted that no definite hypobranchial gland can be distinguished. The gland-cells in this region are not appreciably different from similar cells on the left side of the mantle.

The osphradium is situated on the left side of the mantle cavity close to the junction of the mantle with the body. The efferent ctenidial vessel and the ctenidium lie to the right of the osphradium. The osphradium is a simple ridge-like structure, somewhat lanceolate in shape. It is about 1 mm. long and 0·33 mm. wide. A shallow groove is usually visible in the middle of its upper surface, but this is probably due to shrinkage during preservation.

The anal opening, which lies in the mantle cavity, is situated at a little distance posterior to the free edge of the mantle. The female

genital opening lies close to but somewhat posterior to the anus. The renal opening is placed at the apex of the mantle cavity (fig. 2, *re. ap.*).

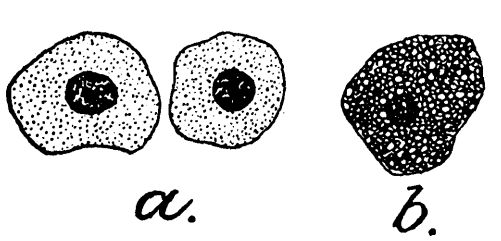


TEXT-FIG. 4*a*.—Vertical section of the anterior part of the foot. *ci. ep.* cillated epthelium of the sole of the foot; *gr.* groove near the anterior margin; *pd. g*.1. dark staining glandular mass; *pd. g*.2. empty gland-cells (without secretion); *pd. g*.3. scattered gland-cells.

The ctenidium lies to the right of the osphradium and extends from the mantle edge to near the pericardium. It is monopectinate and consists of about 90 lamellae. The lamellae in the middle region of the ctenidium are of the greatest width, those near the ends being very short and narrow. Each lamella is roughly triangular in shape (fig. 5), and is attached to the mantle by its base. The straight afferent side of the ctenidial leaflets is short, while the efferent side is very long and slightly curved. The histology of the lamellae resembles, in general features, that of other Prosobranchs. The epithelium of each lamella consists of (1) ciliated and (2) non-ciliated cells with gland-cells scattered in between them. The ciliated cells are confined to the upper portion of the lamella in a line parallel to the efferent side. The ciliated cells, like those of *Pila*, are columnar, but are shorter and have more prominent oval nuclei; the cilia on the other hand are longer than those in *Pila*. The space between the lamellae is occupied by connective tissue and a few muscle-fibres as in *Bythinella*. At the base of each lamella there is a definite lacunar space which receives its blood from the afferent ctenidial vein and the blood-space at the apex is connected with the efferent ctenidial vein.

The Alimentary Canal.

The mouth is a vertical slit placed at the anterior end of the snout; it is not provided with definite lips and the area around it is smooth. The mouth leads into the short oral cavity. The oral cavity is lined by cylindrical epithelium of the general surface of the snout. The cells of the oral epithelium have elongate nuclei and are lined on their free edges by a thin cuticle. Posteriorly, the cuticle becomes thick in the dorsal area and the oral cavity shows a ventro-lateral diverticulum on either side (fig. 7).



TEXT-FIG. 4*b*.—Cells of the pedal gland. In *b* the cell is filled with secretion. In *a* the cells are empty.

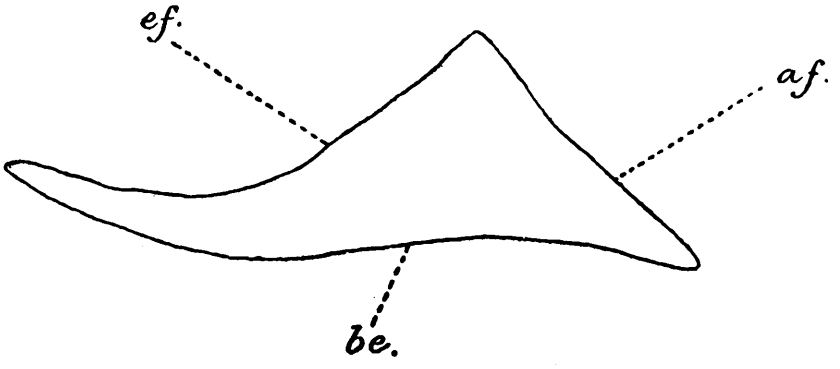
At a distance of about 1 mm. from the mouth the jaws are situated, one on either side. When viewed in section, each jaw appears to consist of a number of columnar chitinous pieces, each piece being the secretion of an underlying cell. The cuticular pieces are longer than the corresponding underlying cells. The jaws stain deep red with eosin.

Surrounding the epithelium of the mouth and the jaws is a connective tissue consisting of polygonal cells with rounded nuclei and containing some brown pigment. These cells constitute what Bregenzer (3) termed labial cartilages in *Bythinella*. The greater part of this connective tissue lies on either side of the oral region.

The oral region is provided with a thick layer of circular muscles and some of the connective tissue cells lie between these muscle fibres. The contraction of these muscles brings about the approximation of the jaws. The separation of the jaws and the retraction of the oral tube is effected by a number of very slender muscles, running from the sides of the oral tube to the roof of the buccal region of the head.

The buccal bulb is very muscular and is pyriform in shape. The dorso-median and the dorso-lateral muscles are very slender threads arising from the anterior parts of the buccal mass. On the ventral surface a transverse band of superficial muscles and some longitudinal muscles can also be made out. The sphincter muscle running round the anterior part of the buccal bulb is more conspicuous dorsally.

The retractor muscles of the buccal mass are stout and club-shaped ; muscles of a slightly red colour, which arise from the buccal mass near the posterior edge of the buccal cartilage of each side and pass between the cerebropedal and cerebropleural commissures, become attached ventrally to the body-wall. A pair of anterior retractors are also present; they are similar in position to those of *Vivipara* (10) and arise from the ventral surface of the buccal mass and run backwards dorsally to the pedal commissure.

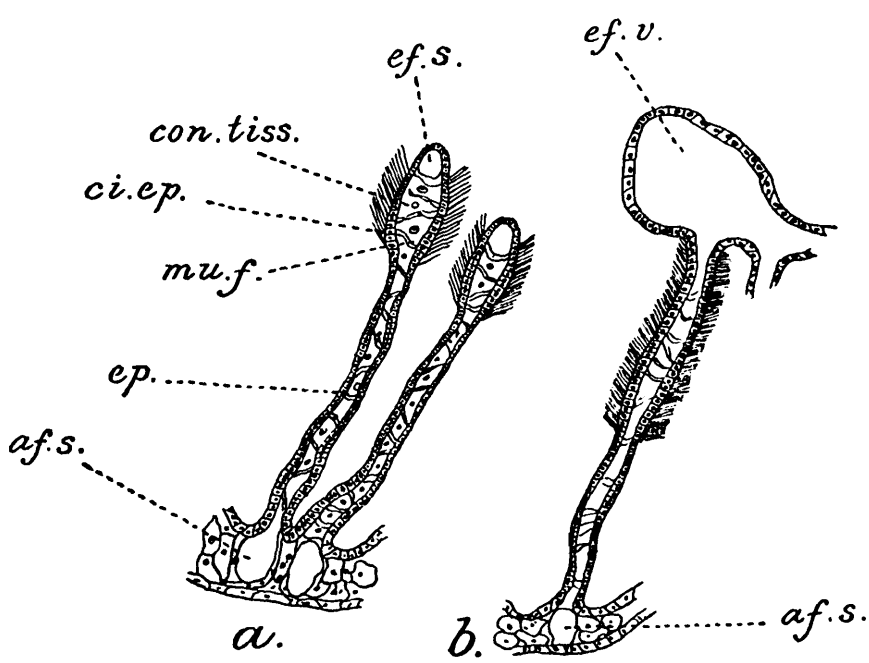


TEXT-FIG. 5.—A single lamella of the ctenidium.
af. afferent side ; *be.* base ; *ef.* efferent side.

The oral cavity leads into the pharyngeal cavity, which resembles, in general, that of *Bythinella* and *Paludestrina*. In a transverse section, it is seen to consist of three parts, (1) a median unpaired dorsally directed cavity, (2) the dorso-lateral expansions, and (3) the ventro-lateral expansions. The median cavity to some extent resembles that of *Bythinella* in shape and is more elongated than in *Paludestrina*. Its lateral walls are ciliated, but no cilia were found on the roof. In the

region of the openings of the salivary glands there is a short dorso-lateral diverticulum on either side of the median cavity into which the salivary glands open. These diverticula also are ciliated but in between the ciliated cells there are a few flask-shaped gland-cells of the same type as are found in other parts of the alimentary canal. The cells of the ventral epithelium of the buccal cavity are shorter than those of the dorsal epithelium, and have a well-developed cuticle. In the middle line the ventral epithelium of the pharyngeal cavity passes into that of the radular sac.

The buccal cavity contains a single pair of buccal cartilages, which, when viewed from above, appear as obliquely placed and rather L-shaped structures. The buccal cartilages almost meet in front but diverge posteriorly. The anterior portions are narrower and are situated at a higher level than the posterior portions. Ventrally they are connected by a pair of broad muscles, one of which is more anterior and dorsal than the other. The other important muscles of the cartilages are (1) the dorso-lateral muscles, which connect the cartilages and the elastic membrane, (2) the circular, and (3) the longitudinal muscles. The longitudinal muscles arise posteriorly and ventrally and pass forwards partly on the inner side of each cartilage. External to these longitudinal muscles are what Bregenzer (3) and Robson (6) termed the circular muscles in *Bythinella* and *Paludestrina*. The circular muscles arise ventrally and run up on the inside of each cartilage to the elastic membrane.



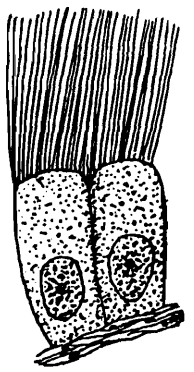
TEXT-FIG. 6*a*.—A section through two gill lamellae. *af. s.* afferent vessel at the base of the lamella; *ci. ep.* ciliated epithelium; *con. tiss.* connective tissue; *ef. s.* efferent vessel of the lamella; *ep.* non-ciliated epithelium; *mu. f.* muscle fibres.

6*b*.—Section to show the course of blood through the gill lamella. *af. s.* afferent vessel; *ef. v.* efferent vein taking away blood from the ctenidium.

The minute structure of the buccal cartilages agrees with that of other forms in which they have been described. Each buccal cartilage consists of polygonal cells with slightly oval nuclei. The cytoplasm surrounding the nuclei is sparse and fibrillar and extends from the centre

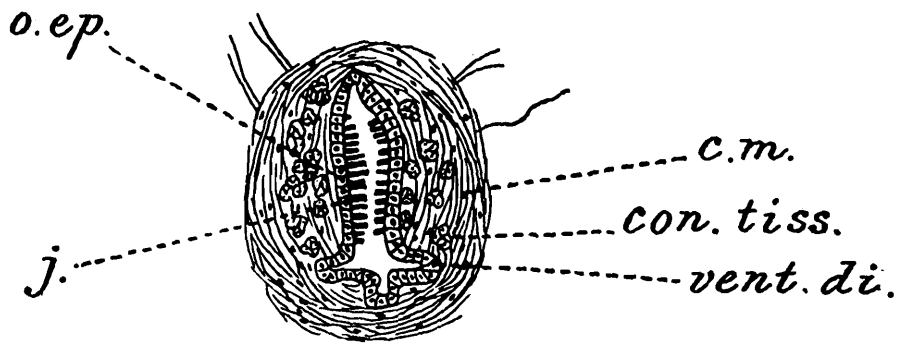
as very thin strands towards the cell wall; it is feebly stained by cytoplasmic stains but the rest of the cell substance remains colourless.

The radula has the typical taenioglossid formula 2, 1, 1, 1, 2. There are about fifty transverse rows of teeth in the radula. The central tooth is prominent. It is roughly trapezoidal in outline. The base or the posterior edge is broader, while the anterior edge is slightly reflexed and bears a central triangular denticle with three smaller denticles on either side. Often a fourth denticle is also to be distinguished on either side. The central tooth bears in addition a downwardly directed lateral process on either side. In many cases I also noticed an additional process behind each lateral process and in some specimens two additional lateral porcesses were present. This is of interest, as considerable taxonomic importance was attached by Annandale (1) to the presence of a single downwardly directed process on the central tooth of the radula in the genus *Mysorella*. The lateral tooth is larger than the central. It is roughly triangular in shape and its base is prolonged on one side, but not to the same extent as in *Bythinella*. The cutting edge has four denticles on either side of a central denticle. The denticles can only be seen when the tooth is viewed from the ventral or the cutting surface. The outer marginal is narrow and roughly sickle-shaped in side-view. Its base is broad, while the upper portion is narrow and has six to eight triangular denticles. The inner marginal is broader than the outer. Its base is narrower than the upper cutting edge, which is broad and has 15-20 very minute teeth.



TEXT-FIG. 6c.—Ciliated cells of the ctenidium.

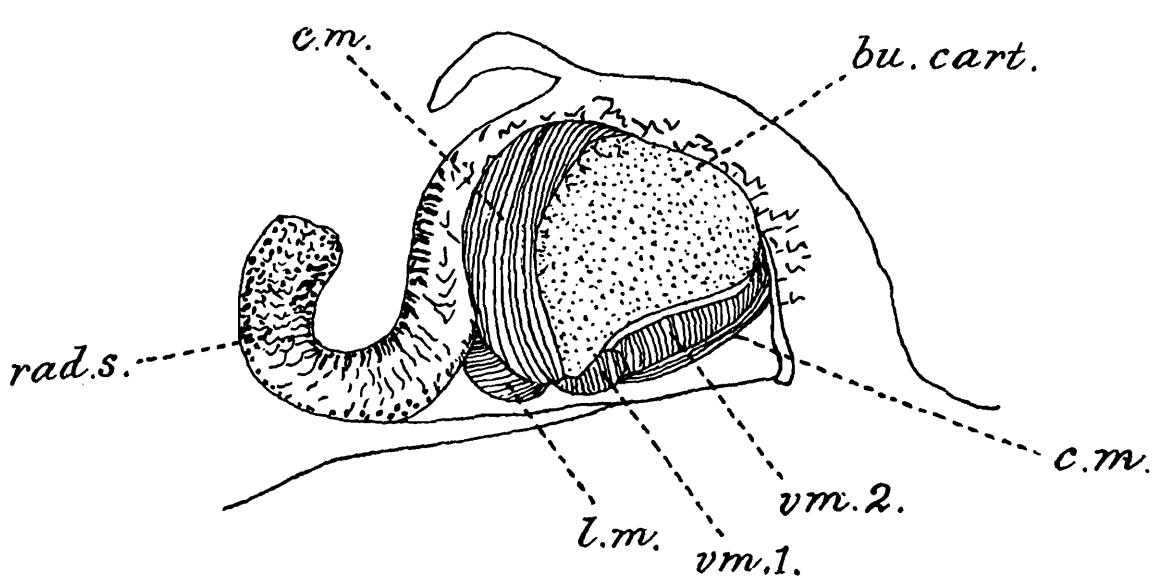
The salivary glands are simple tubular structures. Their posterior portions are a little flattened and wider than the anterior portions and lie over the cerebral ganglia and extend a little beyond them. The narrow anterior part of each gland constitutes the duct, while the posterior part is the gland proper. There is, however, no difference in the histological structure of the anterior and posterior parts. They consist of glandular non-ciliated epithelium, comprised of cylindrical gland-cells with large oval nuclei placed basally in the cells and of narrow supporting cells lying between them. The supporting cells stain red with eosin. The gland-cells consist of a homogeneously staining granular cytoplasm.



TEXT-FIG. 7.—Transverse section through the oral region. *c.m.* circular muscles; *con. tiss.* connective tissue; *j.* jaw; *o. ep.* oral epithelium; *vent. di.* ventro-lateral diverticula.

The oesophagus starts from the dorsal surface of the posterior part of the buccal mass and descends to pass under the cerebral commissure. It then runs somewhat obliquely and opens on the ventral surface of the stomach, close to its left posterior margin. The part of the oesophagus lying alongside the stomach runs almost parallel to it. It has a thick investment of circular and longitudinal muscles, but the muscular coats are thinner in the posterior than in the anterior part of the oesophagus. The epithelial wall of the oesophagus consists of ciliated cells with a few gland-cells interposed between them.

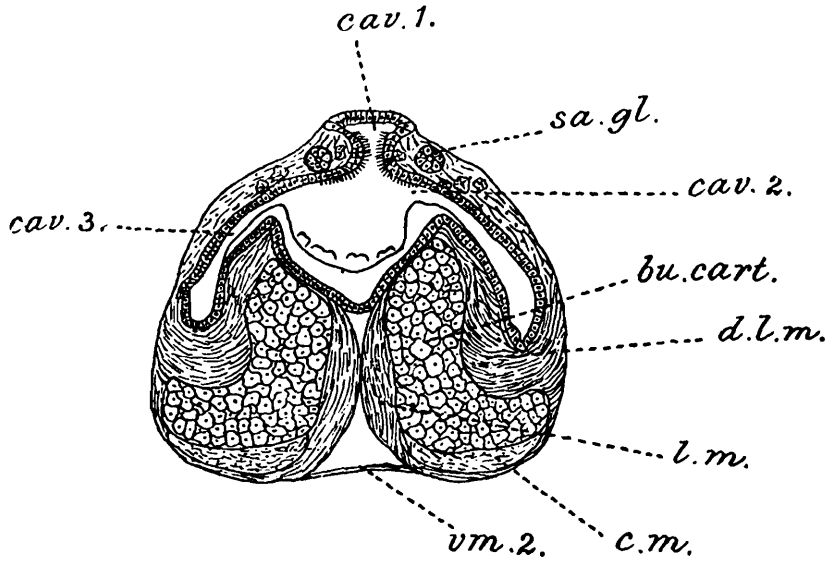
The posterior or gastric portion of the stomach is rather irregularly shaped. The posterior end is rounded and the right corner of the anterior side (fig. 11) is protruding. The openings of the digestive gland are two in number and lie close to the oesophageal opening. On opening the posterior chamber, the ventral wall shows some elevations or thickenings (fig. 12) which are really folds of the wall. Near the posterior end of the stomach and close to the openings of the oesophagus and the digestive gland is a small roughly pyriform fold with a central groove, dividing its surface into two portions. Near the left margin of the ventral wall there is a fold similar in shape and disposition to the one designated by me as the marginal fold in *Paludomus* (8). The anterior end of this fold, as in *Paludomus*, is V-shaped. The V-shaped bend abuts on the oesophageal opening. The function of this fold seems to be to prevent the contents of the oesophagus from passing directly into the pylorus and to direct these to be subjected to the action of the free end of the style, which lies on the right side of the pyriform fold.



TEXT-FIG. 8.—Longitudinal section through the buccal bulb. *bu. cart.* buccal cartilage; *c. m.* circular muscles; *l. m.* longitudinal muscles; *rad. s.* radular sac; *vm.*1, *vm.*2. muscles connecting the cartilages ventrally.

The ciliation and development of the cuticle on the stomach wall are worth mentioning. The epithelium of the posteriormost portion of the gastric chamber is ciliated all over. In the region of the pyriform fold the right side has a strongly developed cuticle and this extends along the right side of the ventral wall. Anterior to this fold also, the stomach epithelium dorsally and ventrally is covered with a cuticular covering, while the dorsal epithelium is somewhat folded. The cuticular

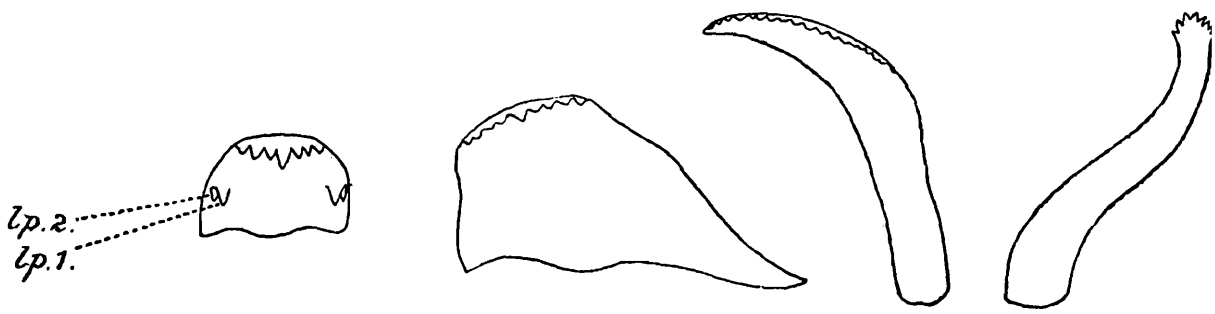
investment of part of the pyriform fold and the epithelium to the right of it appears as a tooth-like investment and constitutes the gastric shield. Robson (6) and Bregenzer (3) do not refer to the details of these folds but so far as can be judged from the figures of the latter author and the description by the former, the stomach of *Mysorella* resembles that of *Bythinella* and *Paludestrina*. The ciliated cells of the stomach are cylindrical and glands of the usual type are found between them. In the cells underlying the cuticle a brownish pigment is present as in the case of *Paludomus* and *Melanoides*. The stomach has a thin investment of muscles surrounded by a connective tissue layer.



TEXT-FIG. 9.—Transverse section through the buccal bulb. *bu. cart.* buccal cartilage ; *cav.*1. dorso-median cavity ; *cav.*2. dorso-lateral expansion of the pharyngeal cavity; *cav.*3. ventro-lateral expansion of the pharyngeal cavity ; *c. m.* circular muscles ; *d. l. m.* dorso-lateral muscles ; *l. m.* longitudinal muscles ; *sa. gl.* salivary gland ; *vm.*2. posterior ventral muscle connecting the two cartilages.

The intestine on leaving the pylorus takes a loop over the ventral aspect of the style-sac, and after running up towards the posterior chamber, turns round and passes to the roof of the mantle cavity as the rectum. The portion over the style-sac is stouter than the remaining portion of the intestine. The posterior part of the ascending portion of the intestinal loop is situated slightly dorsal to the style-sac. A well marked typhlosole is developed in the dorsal wall of the intestine, both in the transverse and the ascending portions ; it appears crescentic in transverse sections. In transverse sections the rectum shows a number of villi-like elevations of its epithelial wall, projecting into the rectal cavity. As a result of these projections, the distal part of the intestine, like the oesophagus, has a number of longitudinal grooves. These projections are more numerous and thinner than similar folds in the oesophagus. In places where the rectum is distended with faecal matter, these folds are obliterated. The transition from the proximal part of the intestine to the rectum is gradual. In the beginning of the descending part of the intestinal loop, only two longitudinal grooves and projections are seen and their number increases gradually in the lower or anterior part. The intestine also has a thin muscular coat and its epithelium consists

of cylindrical ciliated cells with interposed gland-cells; these gland-cells are more numerous in the distal part of the intestine.

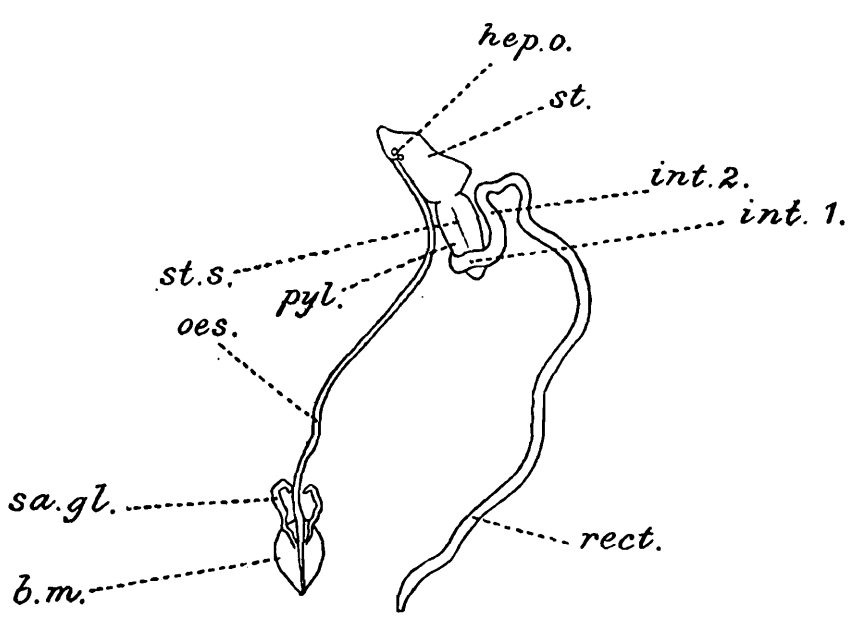


TEXT-FIG. 10.—The teeth of the radula.
lp.1. lateral process ; *lp*.2 accessory lateral process.

The faecal pellets in the rectum, as noted already, are cigar-shaped. They usually consist of minute clayey particles, and are a source of trouble in sectioning the intestine of animals that have been actively feeding.

The Digestive Gland.

The digestive gland is similar to that of other Prosobranchs. It is situated in the apical whorls of the visceral mass and is spirally coiled. The anterior part of the digestive gland lies on the ventral surface of the stomach and extends as far as the origin of the intestine from the pylorus, while its posterior portion embraces the posterior end of the stomach. The gland is of a greenish-brown colour, and consists of a large number of tubules bound together by connective tissue. There are two main ducts of the digestive gland, which open into the stomach. The posterior duct runs on the columellar side of the gland, and is a some-



TEXT-FIG. 11.—Outline diagram of the alimentary canal.
b. m. buccal mass ; *hep. o.* openings of the digestive gland ; *int.*1, *int.* 2, *rect.* intestine ; *oes.* oesophagus ; *pyl.* pylorus ; *sa. gl.* salivary gland ; *st.* posterior or gastric part of the stomach ; *st. s.* style sac.

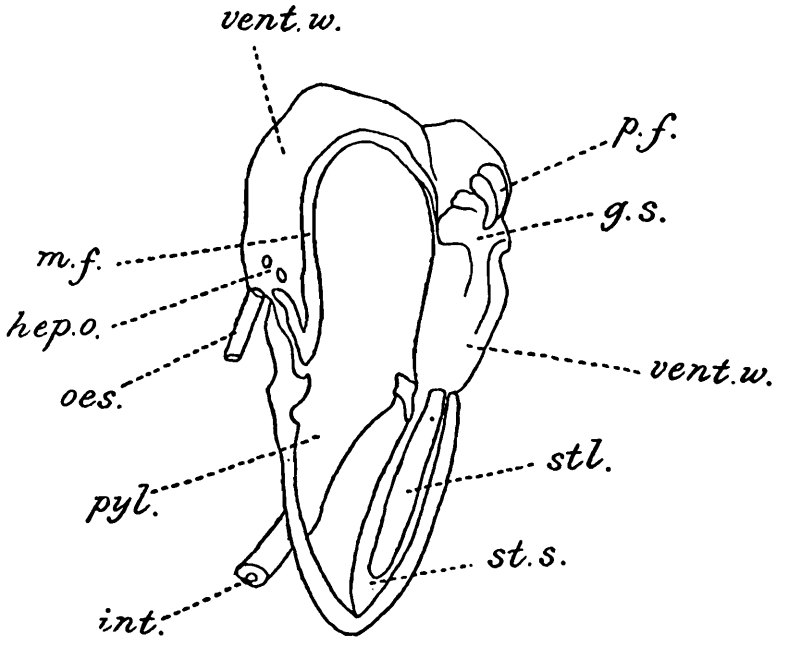
what stout duct. It opens on the ventral surface of the stomach immediately posterior to and in apposition with the oesophageal opening.

The anterior duct runs on the ventral side of the stomach and opens into it anteriorly and to the left of the oesophageal opening. Both the openings of the digestive gland are circular.

The tubules of the digestive gland are roughly circular in transverse sections and are lined by two kinds of cells, the gland-cells and the ferment-cells. The gland-cells are cylindrical, and have slightly oval nuclei placed in the lower part of the cells. There is a distinct nucleolus and the cytoplasm is granular. The ferment-cells are large and conspicuous. They are ovoid in section and possess a large nucleus with a distinct nucleolus. Their protoplasm is granular, the granules being large and staining deeply. A big vacuole is often present in the ferment-cells and it contains usually one but sometimes more than one (I have seen four) secretory bodies. These bodies are of a solid nature, round to ovoid in shape, and chocolate brown in colour. In the ferment-cells containing these secretions, the lower parts of the cells stain feebly. The connective tissue between the tubules contains a fair number of blood vessels. The blood supply of the digestive gland, as is discussed further, is from a distinct branch of the posterior aorta.

The Excretory System.

A portion of the kidney is visible through the epithelium on the dorsal surface of the animal as a triangular, greenish-yellow organ, situated at the upper extremity of the body whorl. This portion of the kidney, which is bounded by the pericardium, the rectum and the mantle cavity, does not constitute the whole renal organ, for, in sections, it is found that the kidney has an anterior extension lying to the left of and slightly ventral to the rectum, and enclosed together with it and part of the re-

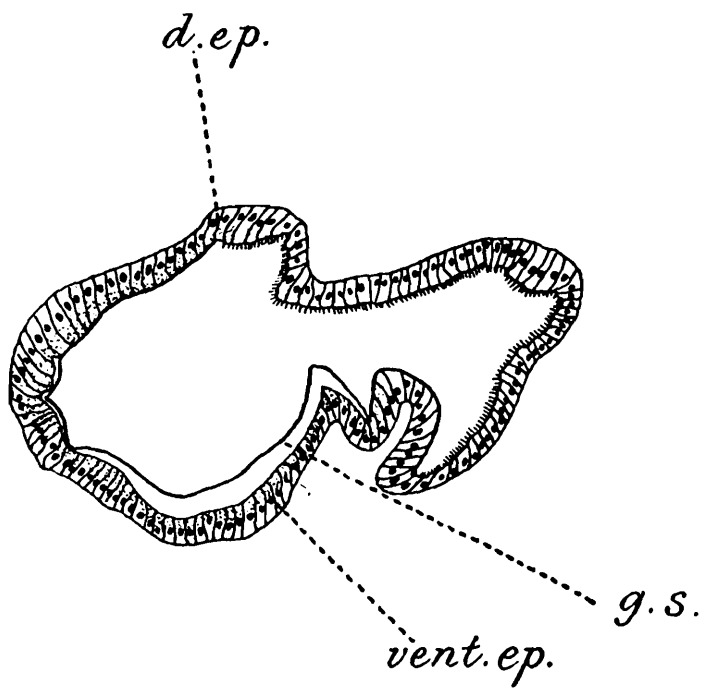


Text-fig. 12.—Diagram of a dissection of the stomach. The ventral wall of the stomach is cut open a little to the right of the oesphageal opening. *g. s.* gastric shield; *hep. o.* openings of the digestive gland; *int.* intestine; *m. f.* marginal fold; *oes.* oesophagus; *pyl.* pylorus; *p. f.* pyriform fold; *stl.* style; *st. s.* style sac.

productive system by the inner surface of the mantle. The posterior extension of the kidney runs for some distance between the ascending

and descending parts of the intestinal loop, and lies posteriorly by the side of the stomach.

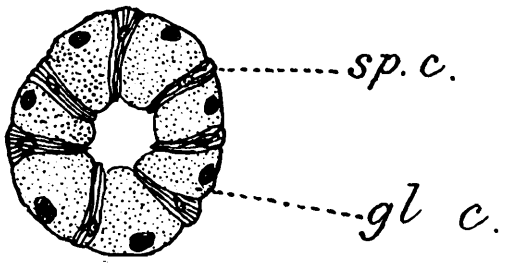
The greater part of the kidney, when seen in a surface view, shows a number of striations corresponding to the lamellae present inside. In the anterior extension of the kidney these lamellae under a low magnification appear as transverse folds. The portion lying in the pericardial region of the animal is much thicker than the other parts, and, viewed from the ventral surface, is seen to have a spongy appearance. It presents on the ventral surface a number of lines or striations radiating from a blood vessel situated in the centre. The spongy appearance is due to this part constituting a " blood gland ". Posterior to this portion and about the level of the anterior termination of the style-sac is a conspicuous triangular lamellar portion which passes forwards obliquely to the pericardium, and opens there at its tip. The posterior extension of the kidney, which can be made out only in sections, has a spacious cavity more or less triangular in outline. Bregenzer does not speak of any such prolongations of the kidney in *Bythinella* (3). In *Paludestrina* (7) the kidney is said to send ramifications among some of the viscera, but its exact relations have not been described.



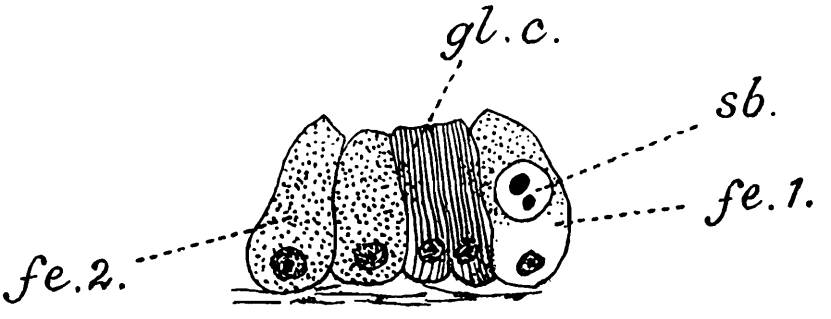
TEXT-FIG. 13.—Transverse section through the stomach.
d. ep. dorsal epithelium ; *g. s.* gastric shield ; *vent. ep.* ventral epithelium.

The kidney opens into the apex of the mantle cavity a little to the right of the root of the ctenidium. The renal aperture is slit-like and is provided with rather thick lips. It is ciliated and is provided, as in *Paludestrina* and *Bythinella*, with dilator and sphincter muscles. The kidney also communicates with the pericardium. Bregenzer (3) does not refer to the existence of a reno-pericardial aperture in *Bythinella* and none could be found by Robson in *Paludestrina* (7). In *Mysorella*, however, a definite aperture is present on the same side of the pericardium as the renal vein but more ventrally to it. The portion of the kidney leading to this aperture is narrow and canal-like.

The portion of the kidney lying in the pericardial region, as stated already, possesses a "blood gland" on its dorsal side. The blood gland consists of branched blood vessels, connective tissue, and blood sinuses. The blood gland is separated from the general renal cavity by an epithelium consisting of somewhat short oval cells from the inner surfaces of which arise stiff and straight protoplasmic threads. A fair number of these threads pass to one or other of the branches of the blood vessels in the blood gland. The nuclei of the epithelial cells of the blood gland are oval and each cell usually has one process. The connective tissue of the blood gland consists mostly of irregular cells surrounded by blood sinuses. A few large cells with round nuclei are also seen. The blood channels in some of the lamellae of the kidney communicate with the blood gland. A blood gland has been mentioned both in *Paludestrina* and *Bythinella.*



TEXT-FIG. 14.—Transverse section of the salivary duct. *gl. c.* gland-cell; *sp. c.* supporting cell.



TEXT-FIG. 15.—Cells of the digestive gland.
*fe.*1. ferment-cell containing solid secretory bodies; *fe.*2. ferment-cell with granular section; *gl. c.* gland-cell; *sb.* secretion bodies lying in a vacuole.

The kidney receives the blood from the general venous system, while the renal vein from the kidney opens directly into the auricle. The lamellae traversing the cavity of the renal organ are folds of renal epithelium with blood channels between them. The renal epithelium consists of cubical cells with round and clear nuclei. Many of the cells show vacuoles of varying size and cell contents in various stages of disintegration. The renal epithelium passes gradually into the ciliated epithelium of the aperture which opens into the mantle cavity. In the transitional portion, the cells are cylindrical and narrower than the cells of the general renal epithelium. Their distal ends are slightly broader than their basal ends, and the nuclei are oval. The ciliated cells are longer than these cells. The reno-pericardial passage is lined by short narrow non-ciliated cells and here also the transition from the renal epithelium is gradual.

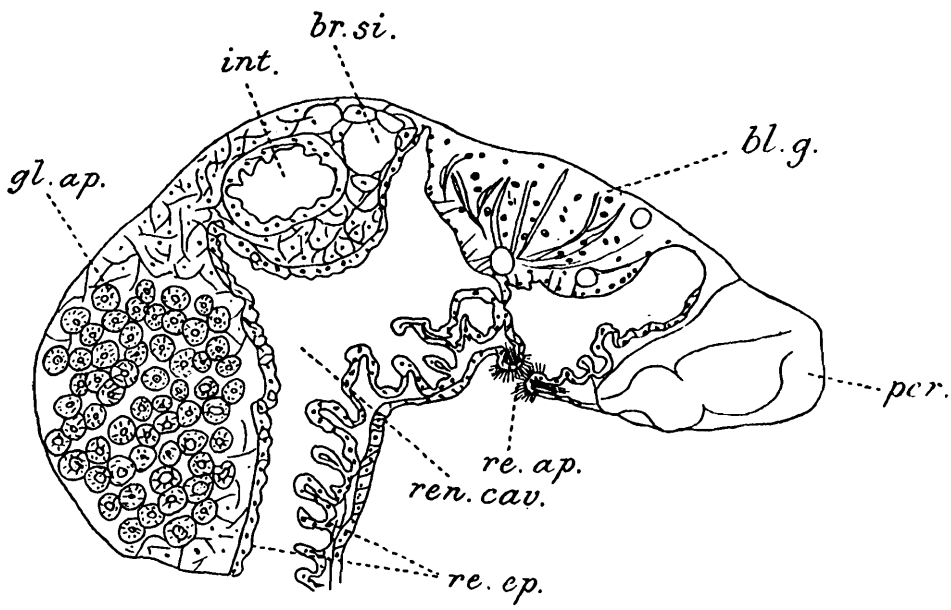
The Circulatory System.

The heart lies in the roughly triangular pericardial cavity and is bounded by the style-sac, the kidney and the mantle cavity. The wall

of the pericardium is composed of a thin epithelium, surrounded by muscle-fibres. The reno-pericardial opening has been described already.

The heart consists of a single auricle and a ventricle. The auricle varies in shape from conical to ovoid-pyramidal, according to the extent of its distension. In the systolic condition, the auricle is seen attached to the ventricle by a slender stalk-like portion, which becomes obliterated in the diastolic condition.

The auricle receives two blood vessels, the efferent renal vein and the efferent ctenidial vein, which open into its base on the right and left sides respectively. The auricle is lined by a thin endothelium and there are a few muscles passing from the base to the apex, but it is not muscular like the ventricle.

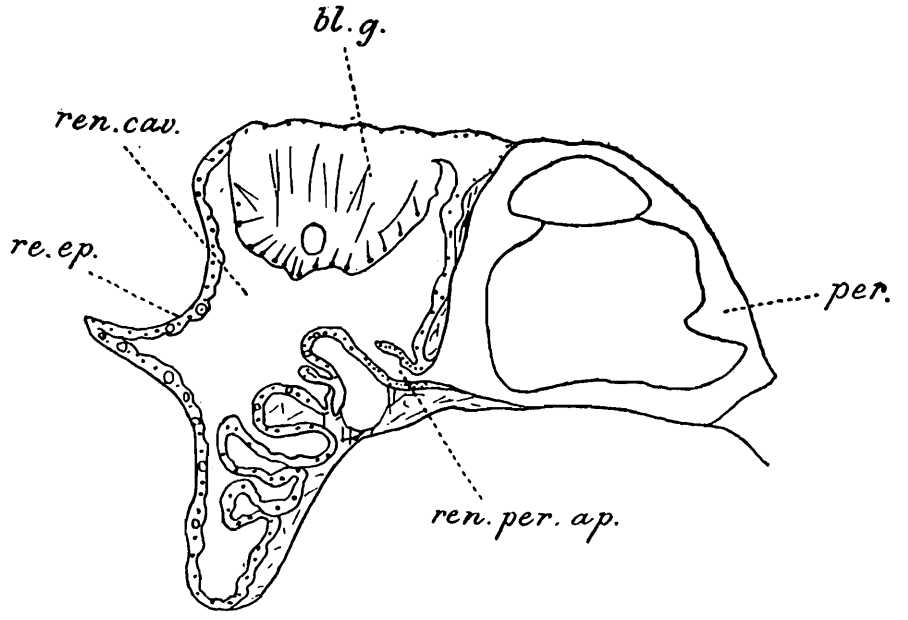


TEXT-FIG. 16.—Section of the animal through the kidney region to show the renal opening into the mantle cavity. *bl. g.* blood gland; *br. si.* branchio-renal sinus; *gl. ap.* glandular attachment of the vas deferens; *int.* intenstine; *per.* pericardium; *re. ap.* renal aperture; *ren. cav.* cavity of the renal organ; *re. ep.* renal epithelium.

The ventricle is pyriform in shape, and the opening of the auricle into the ventricle is guarded by two muscular semi-lunar valves, which arise from the auricle. These allow of the passage of blood from the auricle to the ventricle, but not in the opposite direction. Bregenzer (3) does not make any mention of auriculo-ventricular valves. Robson (7) only found traces of auriculo-ventricular valves in *Paludestrina.* The wall of the ventricle, which is lined by endothelium, is thick and muscular. The muscles of the ventricle are better developed on one side and project into the ventricular cavity forming a sort of incomplete longitudinal partition extending from the base to the apex. Besides these, there are muscles traversing the cavity in different directions.

A short truncus arteriosus arises from the ventricle, and its origin is guarded by two muscular valves. Similar valves have not been noticed either by Bregenzer in *Bythinella* or by Robson (7) in *Paludestrina.* The short truncus arteriosus divides into the posterior or visceral aorta and the anterior or cephalic aorta. The course of the former is better defined and consequently it can be made out with less difficulty.

It passes by the side of the stomach between it and the kidney. It gives off a short branch to the style-sac and, further up, it recedes from the stomach and comes to lie close to the genital duct. It then gives off a branch to the digestive gland, but its further course is not clear.



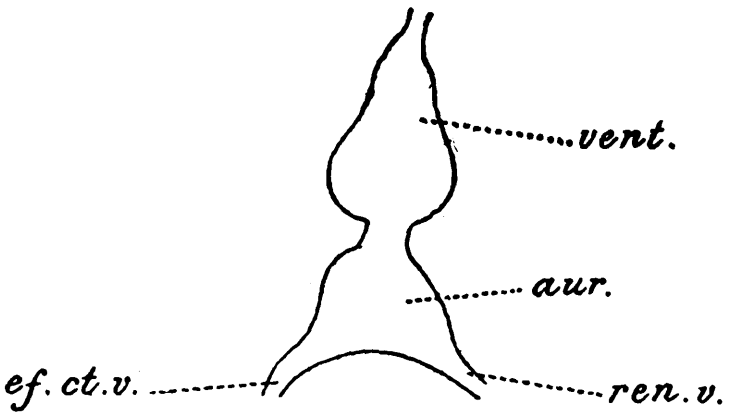
TEXT-FIG. 17.—Section through the kidney and the pericardium to show the reno-pericardial passage. *bl. g.* blood gland; *per.* pericardium; *ren. cav.* cavity of the renal organ; *re. ep.* renal epithelium; *ren. per. ap.* reno-pericardial passage.

The cephalic artery passes by the side of the oesophagus. Further forwards, it becomes dorsal to the oesophagus and gives off a branch to the foot. I have not been able to trace its further distribution.

The arterial blood opens into a system of lacunae in the different parts of the body. The blood from the lacunae passes into sinuses, which return the blood to the heart. The principal sinuses which I have made out in *Mysorella* are (1) an anterior or cephalopedal sinus, (2) a posterior sinus, and (3) a sinus corresponding to the branchio-renal sinus of *Pila*. Besides these, a small definite sinus lies by the side of the lower part of the glandular appendage of the vas deferens in the male and the uterus in the female (fig. 3). It joins the anterior cephalic sinus posteriorly.

The cephalic sinus collects the venous blood from the anterior parts of the body in the head and the anterior part of the alimentary canal, etc. A small sinus is also found in the penis near the penial nerve. The tentacles also possess sinuses, which open into the cephalic sinus. The coils of the penial gland and the cephalic portion of the vas deferens lie in a well-developed sinus beneath the floor of the mantle cavity. This sinus communicates posteriorly with the cephalic sinus, but anteriorly the two are separated by connective tissue. A pedal sinus collects the blood from the foot and is separated from the cephalic sinus anteriorly, but posteriorly the two communicate and form the cephalo-pedal sinus. The small sinus lying by the side of the glandular appendage of the vas deferens in the male, and the uterus in the females joins the anterior sinus posteriorly. It collects blood from the right side of the mantle.

The venous blood from the visceral mass is collected in a posterior sinus. The genital gland also lies in a sinus. The sinuses from the liver, stomach, etc., all unite to form the posterior sinus. The anterior and posterior sinuses unite to form the abdominal sinus in the region of the pericardium.



TEXT-FIG. 18*a*.—The heart.
aur. auricle ; *ef. ct. v.* efferent ctenidial vein ; *ren. v.* efferent renal vein ; *vent.* ventricle.

The kidney receives the blood from the abdominal sinus, and from the kidney the blood, after the removal of the excretory products, passes to the auricle by the efferent renal vein opening into the base of the auricle on the right side. The renal vein passes between the kidney and the apex of the mantle.

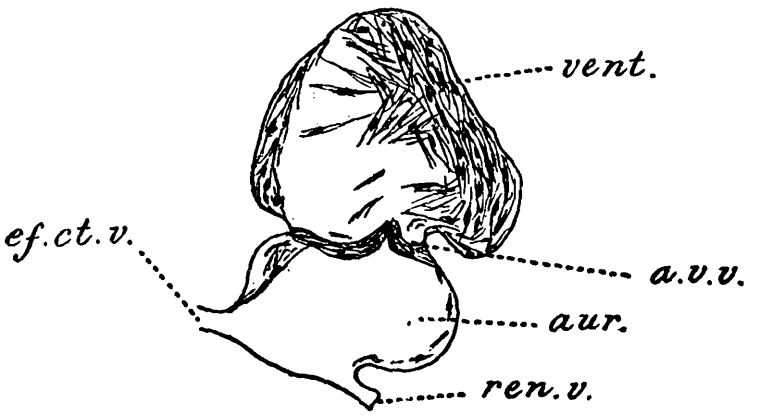
The branchio-renal sinus begins dorsal to the intestine in the region of the blood gland (fig. 16) and it receives in its course blood from a part of the kidney also. It accompanies the rectum and forms the efferent ctenidial vessel. From the efferent ctenidial vessel the blood passes along the roof of the mantle cavity into a definite lacuna at the base of each gill-lamella. After oxygenation the blood from the ctenidium passes into the efferent ctenidial vein, which opens into the base of the auricle on the left side.

The Nervous System.

The nervous system of *Mysorella* (fig. 19), like that of *Bythinella*, *Bithynia* and *Paludestrina* is characterised by the approximation of the superior and lateral centres. The cerebral ganglia are pear-shaped and are situated dorsal to the oesophagus immediately behind the posterior end of the buccal mass and ventral to the salivary glands. The two cerebral ganglia are connected with one another by a short thick commissure. The apex of each cerebral ganglion is anterior and somewhat ventro-laterally directed. It gives off four nerves, the innermost of which is the buccal nerve. The other nerves supply the oral region and the dorsum of the snout. The buccal nerve is long, and after passing forward from the cerebral, turns round under the buccal muscles and ends in the buccal ganglion.

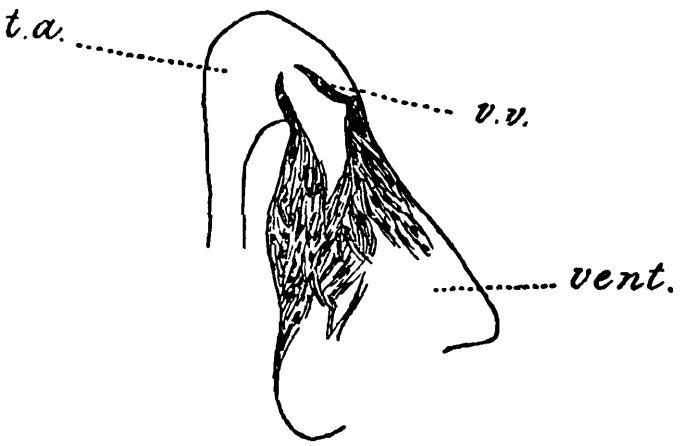
The buccal ganglia are oval and are connected by fairly long commissures. They are situated ventral to the oesophagus, one on either side, immediately after its origin from the buccal mass. Each buccal

ganglion gives off a nerve to the buccal mass. *Mysorella* resembles *Bythinella* and differs from *Paludestrina* in having the buccal ganglia separated from the cerebrals by long connectives.



TEXT-FIG. 18*b*.—A section of the heart showing the auriculo-ventricular valves. *aur.* auricle ; *a. v. v.* auriculo-ventricular valves ; *ef. ct. v.* efferent ctenidial vein ; *ren. v.* efferent renal vein ; *vent.* venrticle.

Besides the four nerves at the anterior end, each cerebral ganglion gives off nerves to the tentacles and the eyes. The tentacular nerve arises dorsally from the external face of the cerebral ganglion and runs to the tentacle somewhat parallel to the ocular nerve. In the tentacle the first branch arises from the tentacular nerve about the level of the eye. Higher up it gives off more branches. No tentacular ganglion, such as has been described for *Bythinella* and *Paludestrina*, is found in *Mysorella*. The ocular nerve is distinct from the tentacular ; it also arises dorsally from the cerebral ganglion posterior to the tentacular nerve.

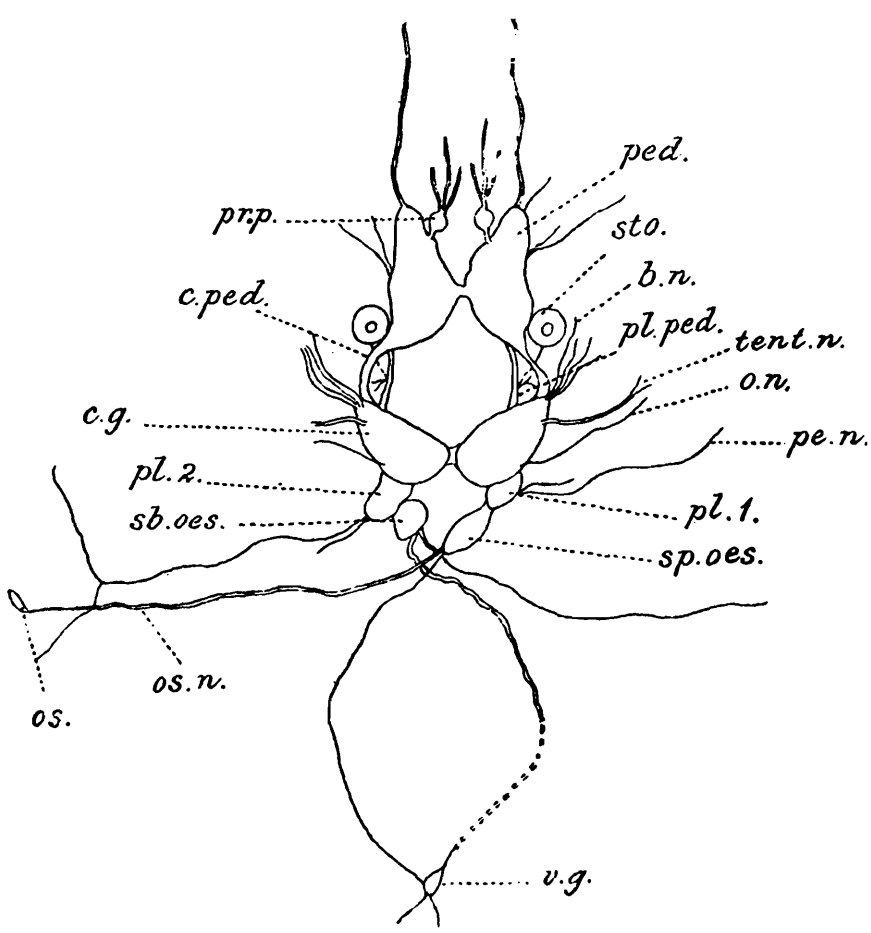


TEXT-FIG. 18*c*.—Section of the ventricle showing valves at the commencement of the truncus arteriosus.
t. a. truncus arteriosus ; *vent.* ventricle ; *v. v.* valves at the commencement of the truncus arteriosus.

The pleural ganglia lie in close contact with the cerebrals and there are no distinct cerebro-pleural connectives. The right pleural ganglion is oval in shape and its anterior part lies under the right cerebral ganglion. From its outer face a slender nerve runs to the mantle. In the male, besides this nerve, a long, thick nerve passes into the penis between the penial gland and the vas deferens. In the penis this nerve runs by the side of the vas deferens. The left pleural ganglion is larger

than the right, while the reverse is the case in *Paludestrina.* It is cylindrical in shape and, on account of a slight constriction, appears to consist of two parts. It gives rise to two nerves, the posterior of which is very slender and supplies the mantle. The anterior one is stouter and passes towards the mantle edge after anastomosing with the osphradial nerve from the supra-oesophageal nerve.

The supra-oesophageal and the right pleural ganglia lie close together, while in *Paludestrina* they are separated by a fairly long connective. The supra-oesophageal ganglion is elongate, somewhat oblong to elliptic in outline. From its distal end two nerves arise, one of which passes to the visceral ganglion, while the other, which passes to the mantle, is the osphradial nerve. The osphradial nerve, which is a long, fairly thick nerve, anastomoses with the pallial nerve by one or two branches. After this anastomosis, it gives off a slender branch, which passes to the mantle in the direction of the ctenidium, while the main nerve passes to the osphradium where it swells into an elongate ganglion. Bregenzer (3) represents the osphradial nerve as quite short in *Bythinella,*



TEXT-FIG. 19.—The nervous system (slightly diagrammatic).
b. n. buccal nerve; *c. g.* cerebral ganglion; *c. ped.* cerebro-pedal connective; *o. n.* ocular nerve; *os.* osphradium; *os. n.* osphradial nerve; *ped.* pedal ganglion; *pe. n.* penial nerve; *pl.*1, *pl.*2. right and left pleural ganglia; *pl. n.* pallial nerve; *pl. ped.* pleuro-pedal connective; *pr. p.* propodial ganglion; *sb. oes.* sub-oesophageal ganglion; *sp. oes.* supra-oesophageal ganglia; *sto.* statocyst; *v. g.* visceral ganglion.

but in *Mysorella* the osphradial ganglion is more removed from the supra-oesophageal and the nerve is fairly long.

The sub-intestinal ganglion is a round ganglion and gives rise to two nerves, one of which is stout and forms the sub-intestinal nerve. The sub-intestinal nerve in the first part of its course is wavy, while in the next part of its course it runs in the ventral body wall of the animal. The other nerve from the sub-intestinal ganglion passes to the right side of the mantle and supplies the region of the lower part of the genital duct and rectum.

The pleuro-pedal and cerebro-pedal connectives are of moderate length and are distinct from each other. The cerebro-pedal connective is thicker than the pleuro-pedal. From each pleuro-pedal a nerve arises and divides into two branches. On the right side, one of these nerves seems to pass to the siphon.

The pedal ganglia are triangular with their bases directed outwards, and their vertices joined by a short thick commissure. As in *Paludestrina* and *Bythinella*, three chief nerves arise from each pedal ganglion, an anterior, a lateral and a ventral. The anterior nerve arises from the anterior face of the pedal ganglion and immediately after its origin swells into the propodial ganglion. From the propodial ganglion two branches arise, while the main nerve passes to the anterior part of the foot. The postero-lateral supplies the muscles of the posterior-lateral region of the foot. No definite ganglia could be made out on the ventral nerve and there was no trace of a metapodial commissure.

The visceral ganglion is elongate and lies immediately posterior to the columellar region a little anterior to the pericardium. It gives off two nerves which supply the visceral mass.

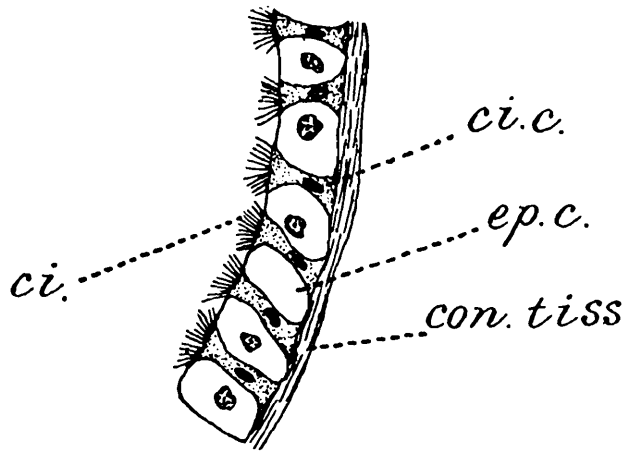
Sense organs.

The statocysts lie on the outside of the upper part of the pedal ganglia. The nerve of the statocyst is very slender and crosses the pleuro-pedal where the latter gives off the pallial branch described above. Its further course was not clearly traceable in any of the specimens. Probably it arises from the cerebral ganglion close to its attachment with the pleural ganglion. Each statocyst is spherical and is surrounded by connective tissue. The wall of the statocyst (fig. 20) consists of two kinds of cells : (1) narrow, somewhat hour-glass-shaped cells, which stain deeply and carry at their free ends cilia spread in a fan-like manner, and (2) lying between the sensory cells are cubical cells which do not stain. The interior of these cells often shows a rounded nucleus surrounded by a structureless cytoplasm. In the statocysts of *Paludestrina* and *Valvata* cilia have not been noticed and no reference is made to them in the case of *Bythinella*. A single statolith of a moderate size is present in the statocyst.

The position and appearance of the osphradium have already been described. The osphradium overlies an elongate ganglion and its epithelium consists, as in *Bythinella* and *Paludestrina*, of sensory and ciliated cells. The ciliated cells are mainly found along the sides of the osphradium. The non-ciliated cells are cylindrical and have an oval nucleus.

The eyes, whose position has already been described, do not call for special remark. As in other gastropods, they are closed vesicles.

The outer cornea is slightly thinner than the adjacent epithelium of the base of the tentacle.



TEXT-FIG. 20.—Portion of the wall of the statocyst.
ci. cilia ; *ci. c.* ciliated cells ; *con. tiss.* connective tissue ; *ep. c.* non-ciliated cells.

The tentacles are lined by columnar epithelium with a thin cuticle with oval nuclei. Beneath the epithelium is the basement membrane and the main mass of the tentacles consists of longitudinal muscles, branches of the tentacular nerve, connective tissue and blood vessels. The connective tissue consists of polygonal cells and those lying in the centre of the tentacle contain a dense blackish-brown pigment, which appears in the entire tentacle as a dark pigmented central part.

The Reproductive System.

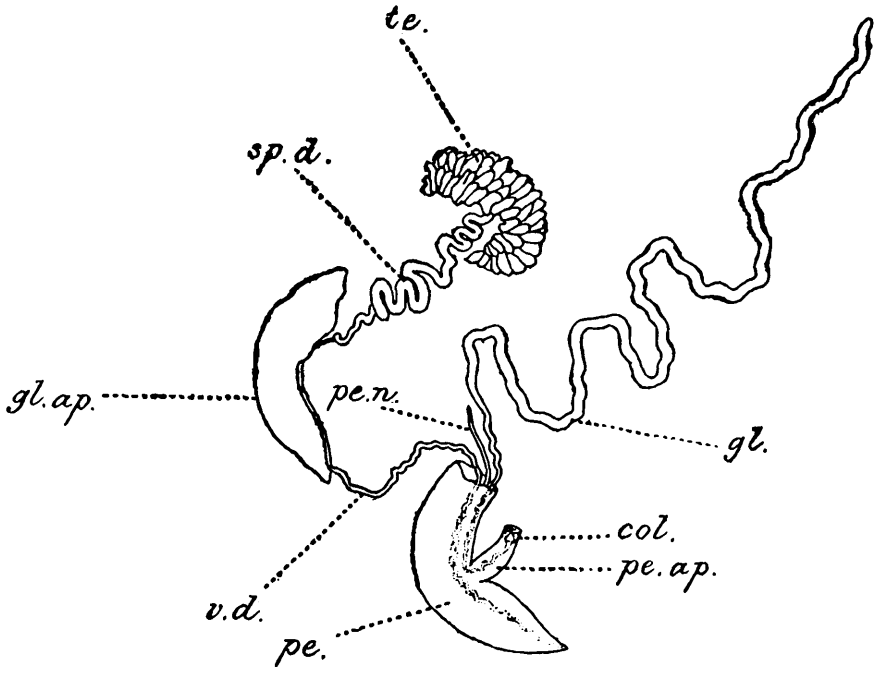
Mysorella is dioecious. The specimens of the two sexes, except in the greater width of the body whorl of the shell in the female, do not show any marked difference externally. After the removal of the shell, the males can easily be recognised not only by the conspicuous penis projecting forwards at the anterior end of the animal, but also by the presence of a black pigmentation in the apical whorls from the region of the stomach to the apex of the animal.

Male Reproductive System.

The testis is situated on the columellar side of the apical whorls 1 and 1½, and extends to a length of about 2 mm. It consists of numerous branched tubular follicles and in the mature condition is of an orange colour.

The sperm duct (fig. 21, *sp. d.*) arises from the middle of the testis and after taking about ten close loops, of which the middle ones are the stoutest, it shows about the level of the kidney a glandular attachment which is about 3 mm. long. The sperm duct runs on one side of this glandular attachment, and emerging at the lower end passes to the right side of the neck of the animal. The total length of the duct is 1·25 mm. and for a part of its course it lies in the epithelium covering the right side of the neck of the animal. The vas deferens then enters the

penis on the dorsal side of the neck or junction of the foot and head, and running excentrically in the penis, opens at its anterior end.



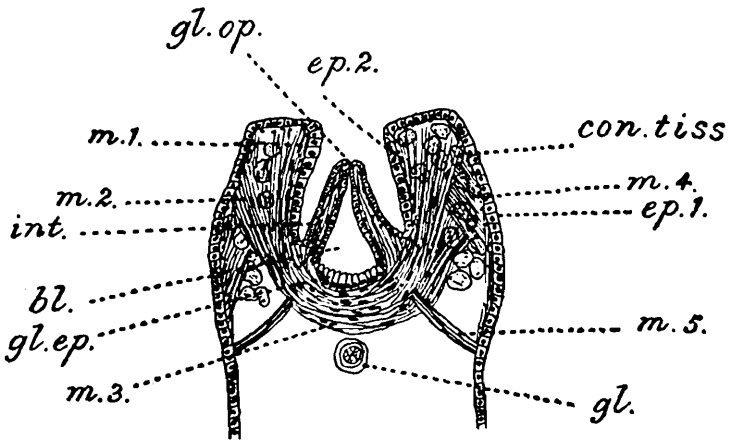
TEXT-FIG. 21.—Male reproductive system. The penial gland (gl.) is uncoiled and partly stretched.
col. collar-like thickening of the penial appendage ; *gl.* penial gland ; *gl. ap.* glandular attachment of the vas deferens ; *pe.* penis ; *pe. ap.* penial appendage ; *pe. n.* penial nerve ; *sp. d.* sperm duct ; *te.* testis ; *v. d.* lower part of the male genital duct.

The penis is a whitish, sickle-shaped, dorso-ventrally flattened organs about 3 mm. long and projecting from the mantle cavity over and beyond the head of the animal. It is developed from the floor of the mantle cavity immediately posterior to the pseudo-epipodium. Its free end bearing the external male opening is usually directed to the left. The left side of the penis about its middle possesses a laterally directed finger-shaped appendage (fig. 21, *pe. ap.*), about ·75 mm. long, and termed by Bregenzer (3) the " gland rute." Its distal portion has the appearance of a collar-like thickening (fig. 21, *col.*) and bears at its apex the opening of a long tubular glandular structure of a total length of over 20 mm., of which the major portion lies as a much convoluted tubular structure beneath the dorsal epithelium of the neck of the animal. This gland complex has about twelve loops and its posterior portion extends nearly to the columellar region of the animal. Anteriorly it becomes narrow and enters the penis, where, after a wavy course, it turns aside into the lateral penial appendage and opens at its apex.

The portion of the penis near the left margin, which is traversed by the gland and the vas deferens, is less opaque and consequently the course of these structures can to some extent be distinguished through the wall of the penis.

The terminal portion of the penial appendage is of interest. Bregenzer (3) described this appendage in *Bythinella* as a cylindrical structure of nearly constant thickness. In his figure, however, he represents the terminal portion of the appendage as having the appearance of a collar-like thickening. He has not described the internal anatomy

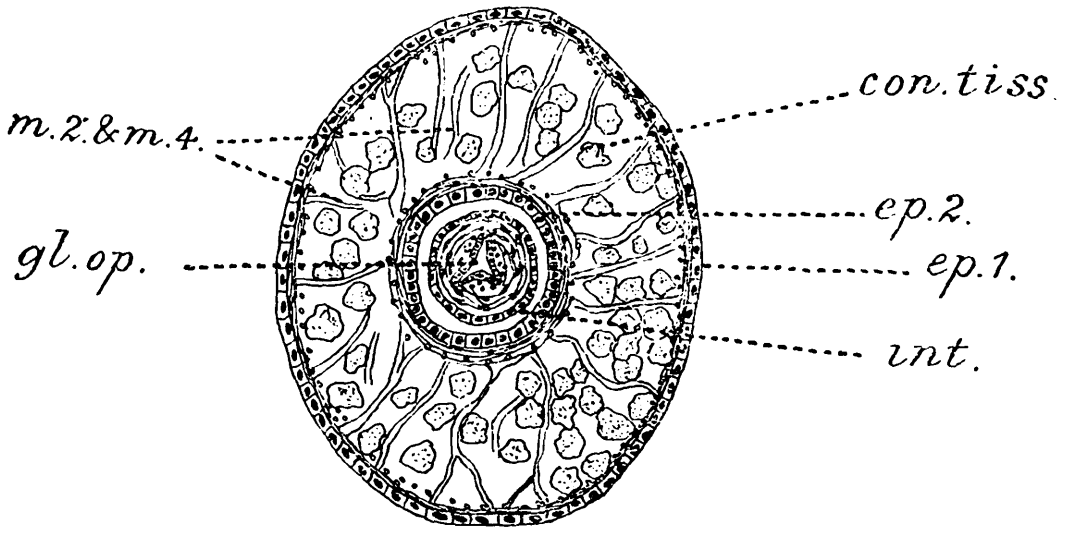
of this portion of the appendage. The collar-like external appearance is due to a partial invagination of the terminal portion of the appendage. In a longitudinal section of this portion in the retracted condition, one finds a double wall enclosing a hollow conical protrudable portion (fig. 22,



TEXT-FIG. 22.—Longitudinal section through the distal portion of the penial appendage. *con. tiss.* connective tissue cells ; *ep.* 1. outer epithelium ; *ep.* 2. inner epithelium ; *gl.* gland cut transversely ; *gl. ep.* glandular epithelium ; *gl. op.* external opening of the protrudable portion ; *int* central protrudable portion ; *m.*1. longitudinal muscles ; *m.*2. oblique muscles passing up from the base ; *m.*3 circular muscles at the base : *m.* 4. oblique muscles passing between the outer and inner epithelium in the invaginated condition ; *m.* 5. muscles passing downwards to the body wall.

int.) bearing at its apex a short canal (fig. 22, *gl.op.*) leading to the exterior. The gland opens into the base of this structure. The lower portion of the cavity is lined by a glandular epithelium, continuous with that of the gland complex, while the remaining portion of the cavity leading to the exterior is lined by an ordinary epithelium consisting of short, cubical cells. The wall of the central protrudable portion of the appendage consists of outer and inner layers of short cubical epithilial cells, underlying which are layers of circular muscles and longitudinal muscles. The circular muscles are very well developed, especially round the base of the protrudable portion (fig. 22, *m.* 3). From its base muscles run upwards obliquely and also longitudinally (fig. 22, *m.* 1, *m.* 2) to the walls of the penial appendage. There are also a few muscle-fibres (fig. 22, *m.* 5) running downwards to the wall of the appendage from the base of the protrudable portion. Besides these, there are muscle strands (fig. 22, *m.* 4) which run obliquely between the outer and inner layers of the double wall and surround the central part in its invaginated condition. The space between these two walls in the invaginated condition is seen to be filled with polygonal connective tissue cells (fig. 22, *con. tiss.*), which may serve as supporting tissue in the protraction and retraction of the central portion. The outer epithelium of the terminal portion of the penial appendage is similar to that covering the rest of the appendage, and consists of short cubical cells. Underlying this are thin layers of circular and longitudinal muscles. The inner wall is covered with similar cells, but the cell nuclei are more prominent. In the retracted condition, which alone I have observed, the whole structure resembles an acrecbolic introvert as figured by Pelseneer (4) for a proboscidiferous gastropod (p. 87, fig. 72, *f.*). The secretion of the

gland collects in the base of the cavity of the protrudable portion, which is really the swollen termination of the gland itself. By the contraction of the oblique and longitudinal muscles running upwards from the base of the bladder to the wall of the penial appendage, a partial



TEXT-FIG. 23.—Transverse section through the distal portion of the penial appendage ; lettering as in fig. 22.

evagination resulting in the protrusion of the central portion can be brought about. At the same time, the well-developed circular muscles, as also the longitudinal muscles by their contraction, can effect the exudation of the glandular secretion through the narrow canal at the apex. The muscles running downwards from the base of the central protrudable portion, and the oblique muscles seen running between the outer and inner epithelium in the invaginated condition, by their contraction would bring about the partial invagination. Bregenzer (3) says that he observed the secretion of the gland oozing out of the opening of the gland-rute in the act of copulation. I have not had an opportunity of observing this phenomenon in *Mysorella* but probably the conditions are similar in this form. The arrangement described above would enable the terminal portion of the penial appendage to be thrust forward and to expel the secretion of the gland during the act of copulation.

I often found the gland filled with its secretion in the proximal portion but near its termination in the appendage the gland often had a clear, empty cavity in the centre, thus indicating the recent expulsion of the contents of the gland.

The penial nerve arises from the right pleural ganglion and enters the penis between the gland and vas deferens. In the penis it accompanies the vas deferens. Judging from its origin and inervation, the penis of *Mysorella* is neither cephalic nor pedal.

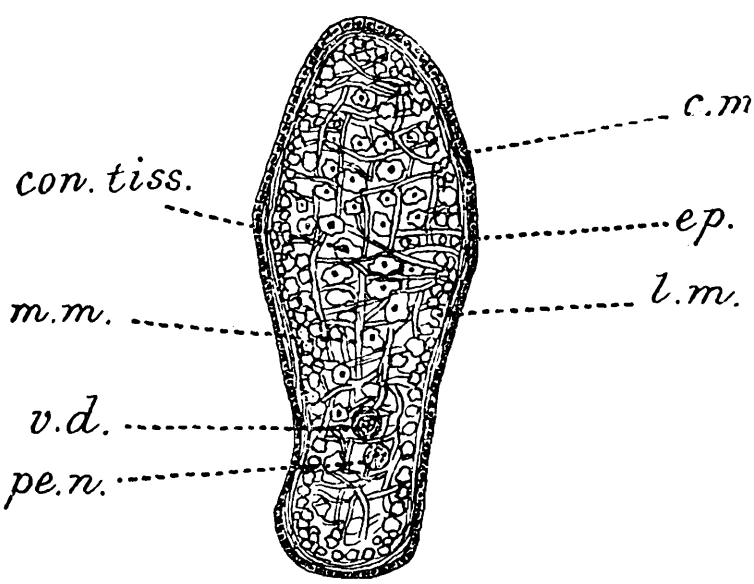
Histology.—The testis consists of a large number of tubes bound together by connective tissue. It is covered by an epithelium which is continuous with the general body epithelium and under which is the connective tissue containing blood vessels. Each tubule has a thin layer with nuclei and sperm mother cells. The spermatozoa are of the eupyrene type only. They are pointed in front. I could not make out a

distinct middle piece. The anterior portion of the sperm excluding the tail is about ·0025 mm., while the tail is about 18μ. long.

The commencement of the sperm duct is lined by somewhat squarish cells with large rounded nuclei. Further on the epithelium consists of flattened cells. The part of the sperm duct lying against the liver is stout in mature individuals and contains numerous sperms.

The portion lying on the glandular appendage is narrow and its epithelium consists of short cubical ciliated cells with slightly oval nuclei. It is surrounded by circular muscles. In the next portion of the vas deferens also the same structure prevails. But in the portion of the vas deferens traversing the penis, the investing circular muscles form a very thick sheath.

The glandular appendage is a much convoluted tubular structure. Its cells are cylindrical and the nuclei are more or less oval and have clear nucleoli. The cells show a dense collection of secretory products. The gland seems to communicate with the vas deferens in various places. The supporting cells are narrow and have elongate nuclei.



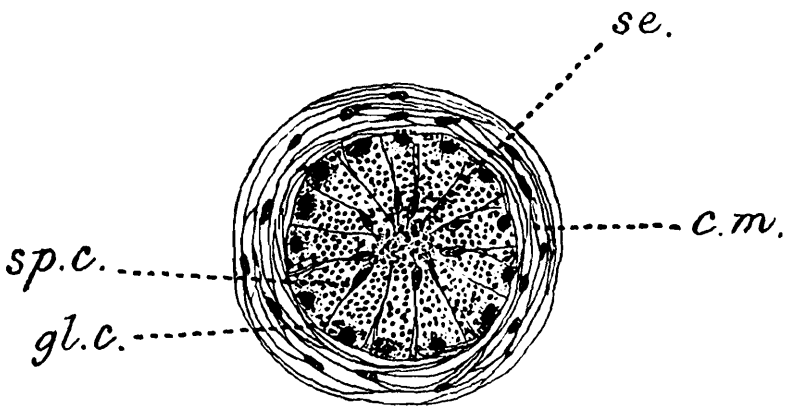
TEXT-FIG. 24.—Transverse section through the penis.
c. m. circular muscles ; *con. tiss.* connective tissue cells ; *ep.* epithelium ; *l. m.* longitudinal muscles ; *m. m.* mesh work muscles ; *pe. n.* penial nerve ; *v. d.* vas deferens.

The epithelium of the penis (figs. 23, 24) consists of cubical cells with oval nuclei. Beneath the epithelium are layers of circular and longitudinal muscles. The rest of the penis is filled with a loose parenchymatous tissue in which there are longitudinal and transverse muscle fibres having in their meshes feebly staining connective tissue cells with rounded nuclei. The tissue around the vas deferens, owing to the presence of a penial sinus, is more loose in texture, and consequently the course of the sperm duct is discernible through the wall of the penis.

The structure of the penial appendage (gland-rute) has been dealt with already.

The gland (fig. 25) has a thick sheath of circular muscles and is composed of cylindrical gland cells with narrow, oval, basally situated nuclei. The general appearance of these cells is similar to those of the glandular appendage of the vas deferens. The cytoplasm round the nuclei stains

more deeply than the rest. The cells are filled with products of secretory activity, and the centre of the gland, especially in its proximal



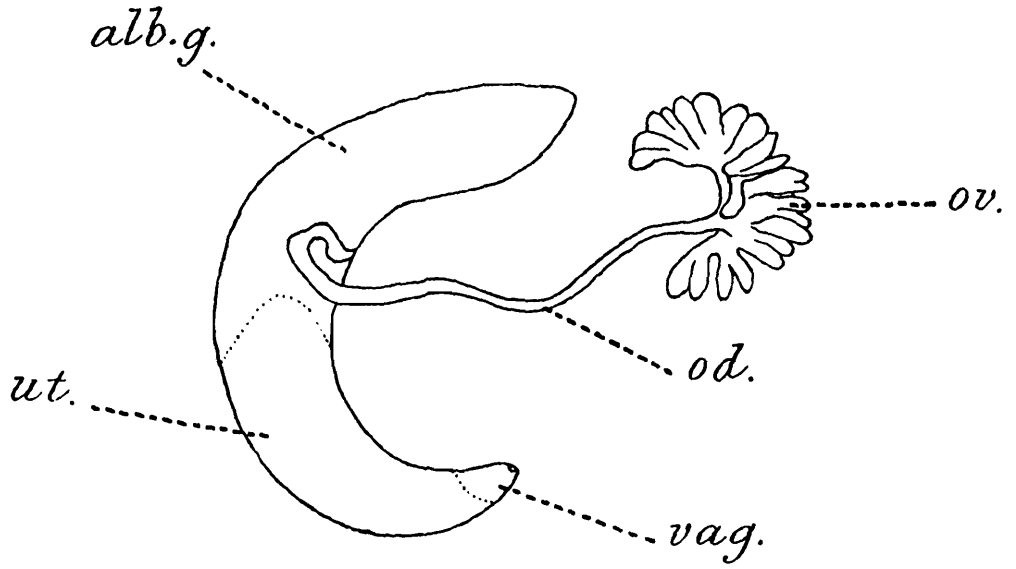
TEXT-FIG. 25.—Transverse section of the penial gland.
c. m. circular muscles; *gl. c.* gland cells; *se.* secretion; *sp. c.* supporting cells.

portion, shows a collection of the secretion (fig. 25, *se.*) of the cells. The supporting cells are conspicuous. They are narrow, elongate, with correspondingly shaped nuclei which are placed at the distal ends of the cells near the centre of the gland. The blunt ends of these narrowly oval nuclei are directed towards the centre of the gland.

Female Reproductive System.

The female reproductive system of *Mysorella,* in contrast to the male reproductive system, is simple.

The ovary (fig. 26, *ov.*) is situated in a position corresponding to that of the testis in the male and extends to about a length of 2 mm. In the mature condition, it is yellow in colour. It consists of branched tubular follicles usually about a dozen in number. From each follicle



TEXT-FIG. 26.—Female reproductive system.
alb. g. albumen gland; *od.* oviduct; *ov.* ovary; *ut.* uterus; *vag.* vagina.

a small duct arises, and the small ducts so formed unite to form the oviduct. The oviduct (fig. 26, *od.*) is 4 mm. long, and unlike the sperm

duct is not convoluted. It passes by the side of the stomach in the region of the kidney to the albumen gland (fig. 26, *alb. g.*). Near the albumen gland the oviduct becomes stouter and on the albumen gland it is doubled on itself.

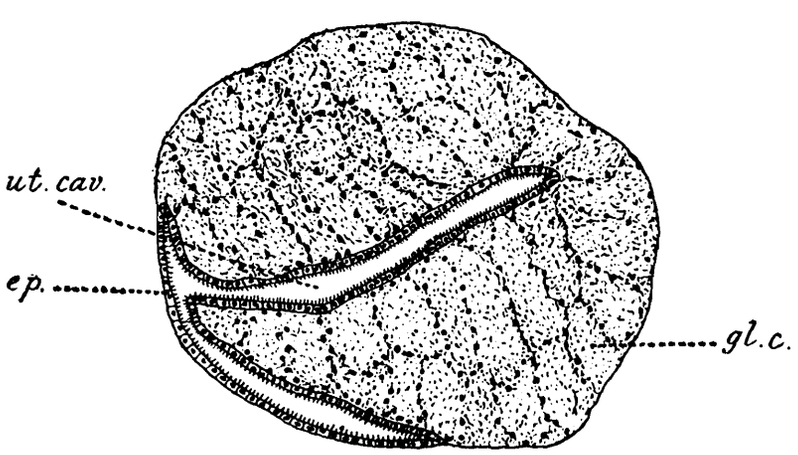
Lying to the right of the intestine in the animal is a stout elongated structure having somewhat a sickle-shaped outline, and extending from about the posterior end of the stomach nearly to the free edge of the mantle. The posterior portion of the structure is the albumen gland, and its lower part surrounds the oviduct as the latter passes into the uterus. The portion anterior to the albumen gland, about 3 mm. long, forms the uterus (fig. 26, *ut.*) and the vagina. The albumen gland has a slightly translucent appearance in the living animal, while the uterus is opaque. The distal portion of the female reproductive system for about ·75 mm. of its length is of the same colour as the albumen gland and constitutes the vagina.

The distal part of the oviduct after passing the albumen gland leads into the uterus. The cavity of the uterus is elongated, narrow, and roughly V-shaped in transverse section (fig. 26). The female genital opening is situated in the mantle cavity posterior to the anal opening.

Histology.—The epithelial covering of the ovary is continuous with that of the general body epithelium. Under the epithelium is the connective tissue containing a few blood vessels. The general epithelium consists of short cubical cells, with rounded, basally placed nuclei. Each tubule has a thick basement membrane surrounding the germinal epithelium, which is composed of cubical cells with round nuclei basally placed. Ova in various stages of growth can be seen in mature individuals, either attached to the germinal epithelium or in the cavity of the tubule.

The oviduct has a thick investment of circular muscles and is lined by ciliated cells with round basally placed nuclei.

The albumen gland in the adult stains very deeply with haematoxylin and owing to its brittle nature its structure cannot be made out properly. It consists of polygonal portions containing rounded bodies resembling



TEXT-FIG. 27.—Transverse section of the uterus.
ep. epithelium of the uterus ; *gl. c.* gland cells ; *ut. cav.* uterine cavity.

flat globules. In the young or immature individuals it is thin, and is composed of tubular masses of glandular structures consisting of

cylindrical cells with large rounded nuclei and distinct nucleoli. The cytoplasm of the cells contains deep staining granules and globules.

The cavity of the uterus, as stated above, is roughly V-shaped in transverse sections. The epithelium (fig. 27) lining it consists of ciliated cells with rounded, centrally placed nuclei. One arm of the V-shaped cavity and the inner side of the other arm are invested with glandular cells lying beneath the epithelium. The thickness of the uterine wall is due to the gland-cells which are cylindrical and have rounded, basally placed nuclei and a granular cytoplasm. In mature individuals these do not usually show any definite cell limits, and the nuclei are arranged in a striking manner, as a result of which the uterine wall in the transverse section appears as if it were divided into four to six-sided areas.

The structure of the vaginal wall differs from that of the uterine wall in that its cells, which are really the same as those of the uterine wall, are filled with a dark staining secretion.

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A REVISION OF THE INDIAN SIPHONAPTERA.

PART I.—FAMILY PULICIDAE.

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INTRODUCTION.

This paper on the fleas of the family Pulicidae is the first part of a revision of the Indian fleas on which I have been engaged for some time. The collection of fleas of the other families of Siphonaptera at my disposal is unfortunately small; it represents only a few of the genera and species known from the Indian Region. I am, however, getting together collections of these forms and other papers in this series will appear as material becomes available.

The study of fleas of the family Pulicidae, owing to their importance as the vectors of the virus of bubonic plague between rat and rat and rat and man, has become very popular with parasitologists, but no comprehensive and up-to-date monograph on the group has been published so far. The published descriptions of the various Indian species are poor and incomplete, and are further scattered in not easily accessible journals published in different languages. In this paper I have redescribed all the species, as in most cases the previous descriptions, in view of the recent increase in the number of species and of our knowledge of this group, are of little value for separating the different species.

In my descriptions I have used the same terminology as is used by Jordan and Rothschild in their latest papers on fleas[1]. I have laid especial stress on characters which are of use for separating the different species, and have ignored others which are neither constant nor of any use in this connection. I attach a great importance to chaetotaxy, even though it is not especially valuable for systematic purposes; it has, however, been found very useful by several recent workers on this group for separating the different species. In giving the number of bristles in a row on a tergite or sternite I have counted the bristles on both sides of the plate, as the record of the number of bristles on only one side gives a wrong idea of the exact number of bristles on the plate.

The number of species belonging to this family recorded from a big country like India is rather small. This I believe is due to lack of interest in the collection of fleas both by the Indian entomologists and general collectors. When I started my work there were hardly more

[1] For accounts of the general structure of fleas and terminology employed by workers on fleas the accounts in Patton and Cragg's *A Textbook of Medical Entomology*, pp. 434-446, pls. liii-lv. (London, 1913), Fox's *Insects and Disease of Man*, pp. 112-130 (London, 1925), introduction to Jordan and Rothschild's papers published in *Parasitology* I, pp. 17-33 (1908) and in *The Thompson Yates and Johnston Laboratories Report* (n. s.) VII, pp. 19-41 (1906), may be consulted.

than a dozen tubes of fleas in the collection of the Indian Museum, and the collections which I received for examination from various Medical, Veterinary and Agricultural institutes of this country were also similarly poor. The greater portion of the collection on which I have worked was got together during 1927, through a circular letter sent at my request by Lt.-Col. R. B. Seymour Sewell, Director, Zoological Survey of India, to the heads of the Public Health and the Civil Veterinary Departments in the different provinces of India, requesting them to arrange for fleas to be especially collected for me. The results were not over encouraging as only about three hundred tubes of fleas, mostly from common animals such as the cat, dog, cattle, sheep, goat and rat from places sparsely scattered all over India and Burma were obtained.

I owe my best thanks to Mr. T. Bainbrigge Fletcher, Imperial Entomologist to the Government of India, who was kind enough to lend me his card-catalogue of the Indian fleas which has been of great use to me during my study of the group, and the collection of fleas in the Imperial Agricultural Research Institute, Pusa. I am thankful to Dr. C. Strickland, Professor of Medical Entomology, who lent me the identified and unidentified collections of the Calcutta School of Tropical Medicine and Hygiene for examination. The identified collection mostly consisted of specimens identified by the late Hon. N. Charles Rothschild, and has proved of great help in identifying other specimens. I am also obliged to the following gentlemen for sending me collections belonging to their respective institutions for examination :—Mr. M. A. Hussain, Entomologist to the Government of the Punjab, Lyallpur ; Mr. P. B. Richards, Entomologist to the Government of the United Provinces, Cawnpore ; Major H. E. Shortt, Director of the Kala-Azar Commission, Camp Gauhati, Assam ; Major H. H. King, Director, King Institute, Guindy ; Major S. S. Sokhey, Director, Haffkine Institute, Bombay ; the Director, Imperial Institute of Veterinary Research, Muktesar ; the Director, Central Research Institute, Kasauli.

The present work was undertaken at the suggestion of my chief Lt.-Col. R. B. Seymour Sewell, and I am obliged to him for the interest he has taken in my work. Dr. B. Prashad has kindly read through and revised my manuscript and made several valuable suggestions for which I am indebted to him.

The text-figures illustrating this paper are all camera-lucida drawings and were finished from my pencil sketches by Babu Subodh Mondul, one of the artists of the Zoological Survey of India.

PULICIDAE.

The family Pulicidae was up till recently considered separate from the Tungidae (=Sarcopsyllidae), but Jordan[1], in view of the similarities between the genera *Echidnophaga* Olliff and *Pulex* Linnaeus, has combined the two. Jordan divides the family into two subfamilies, *viz.*, Pulicinae and Spilopsyllinae. The subfamily Pulicinae is divided into

[1] Jordan, *III. Internationaler Entomologen-Kongress Zürich, Juli 1925*, II, pp. 601, 602 (Weimar, 1926).

two tribes—Tungicae [1] and Pulicicae—while the subfamily Spilopsyllinae consists of the three tribes—Archaeopsyllicae, Xenopsyllicae and Spilopsyllicae.

The family is represented in India by seven genera, thirteen species and one subspecies; of these, two species are described in this paper for the first time.

The following is a key to the Indian genera of the family Pulicidae :—

I. Mesopleura without internal rod-like incrassation from insertion of coxa upwards separating episternum from epimerum.

A. Antennal groove open; club of antenna elliptical, its first segment neither free nor foliaceous; falx absent; hind coxa without spinelets on inner side; antepygidial bristle absent; pygidium with eight grooves on each side; in male tergite VIII without manubrium and clasper with only two processes; in female anal stylet and stigmata on tergites I—III absent .. . . *Tunga.*

B. Antennal groove closed; club of antenna subglobular, its first segment free and foliaceous; falx present; hind coxa with a comb of spinelets on inner side; antepygidial bristle present; pygidium with fourteen grooves on each side; in male tergite VIII with manubrium and clasper with three processes; in female anal stylet and stigmata on tergites I—III present.

I. Frons angulate; labial palpus with one feebly chitinised segment; genal edge produced downwards into a triangular ventral lobe situated behind mouth-parts; without a row of short hairs along hinder margin of antennal groove; thoracic tergites together shorter than first abdominal tergite; mesosternite produced posteriorly into a small obtuse lobe; hind coxa produced into a prominent and truncate lobe at apex anteriorly .. .. *Echidnophaga.*

II. Frons not angulate; labial palpus with four strongly chitinised segments; genal edge not produced into a triangular lobe but usually provided with 1-3 short spines; with a row of short hairs along hinder margin of antennal groove; thoracic tergites together much longer than first abdominal tergite; mesosternite without any lobe; hind coxa without any apical lobe .. . .. *Pulex.*

II. Mesopleura with internal rod-like incrassation from insertion of coxa upwards separating episternum from epimerum.

A. Without pronotal and genal combs.

I. Anterior angle of genal margin with a large backwardly directed and pointed process; pronotum much longer than mesonotum . .. *Pariodontis.*

II. Genal margin of head without any such process; pronotum shorter than mesonotum.

A. Metepisternum fused with metasternum; apex of ejaculatory tube curved upwards . .. *Synosternus.*

B. Metepisternum separated from metasternum; apex of ejaculatory tube straight or curved downwards .. . . *Xenopsylla.*

B. With a pronotal and a genal comb running horizontally along lower border of gena .. .. *Ctenocephalus.*

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[1] I have adopted the name Tungicae in place of Jordan's Sarcopsyllicae as the latter name is not permissible according to the International Rules of Zoological Nomenclature, for the generic name *Sarcopsylla* Westwood had long ago been replaced by the older generic name *Tunga* Jarocki.

Genus **Tunga** Jarocki.

1838. *Tunga*, Jarocki, *Zoology, or General Description of Animals in accordance with the Latest System* VI, p. 50.
1906. *Dermatophilus*, Jordan and Rothschild, *Rept. Thompson Yates Labs* (n. s.) VII, pp. 18, 65-67.
1921. *Tunga*, Rothschild, *Ectoparasites* I, pp. 129, 130.
1925. *Tunga*, Fox, *Insects and Disease of Man*, p. 130.

Of the three known species of this genus only two are found in the Old World. *Tunga caecigena* [1] Jordan and Rothschild has been described from China and *T penetrans* (Linnaeus) has occasionally been recorded from the western ports of India.

Tunga penetrans (Linnaeus).

1758. *Pulex penetrans*, Linnaeus, *Systema Naturae* (X. ed.), pp. 614, 615.
1838. *Tunga penetrans*, Jarocki, *Zoology* VI, pp. 50-52, pl. ii, figs. 10-13.
1896. *Sarcopsylla penetrans*, Osborn, *Bull. U. S. Dept. Agric., Divis. Entom.* (n. s.) No. 5, pp. 142-144, text-fig. 77.
1906. *Dermatophilus penetrans*, Jordan and Rothschild, *Rept. Thompson Yates Labs.* (n. s.) VII, pp. 67-70, text-fig. *f*, pl. iv, fig. 28.
1910. *Dermatophilus penetrans*, Rothschild, *Bull. Entom. Res.* I, p. 90.
1913. *Dermatophilus penetrans*, Patton and Cragg, *A Textbook of Medical Entomology*, pp. 448, 449, pl. lvi, fig. 4.
1925. *Tunga penetrans*, Fox, *Insects and Disease of Man*, pp. 130, 131, text-fig. 58.

Head.—The rostrum is very long and reaches one-half to three-fourths the length of the fore femur. The fourth segment of the maxillary palp is nearly as long as the second. The oral edge is either as long or slightly longer than the genal edge. The frons is without any stout bristle but has a hair-like bristle in front of the eye. The eye is large and strongly pigmented. There are no bristles on the occiput, but there are 8 minute hairs representing the subapical row of bristles of other fleas.

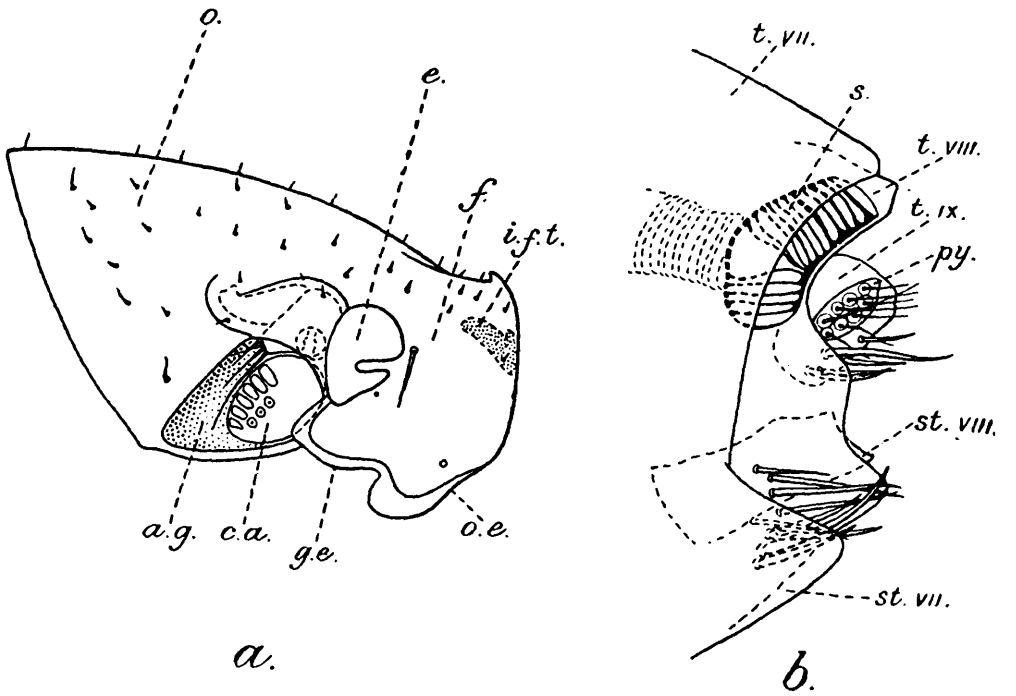
Thorax.—The bristles on the thorax are very minute and it is, therefore, difficult to determine their exact number on each sclerite. The pronotum bears 10-14 hair-like bristles in a row, the mesonotum and the metanotum have each 6-8 hair-like bristles in a row. Only the episternum of the metathorax possesses a slender bristle. The epimerum of the same segment is broad and is produced backwardly in the middle into a broadly rounded lobe. It bears 2 (rarely 3) bristles in a row, which represents the second row of other fleas.

Abdomen.—Tergite I has 2 bristles in a row. The other tergites also have each 2 bristles in a row, and each bristle is situated immediately above the stigmata of the same side. The bristles on the sternites are absent.

Legs.—The hind femur has a row of 7-9 bristles on the inner side and a single subapical ventral bristle on the outside. The hind tibia has no dorsal row of bristles on the outside but bears three notches including the apical. The longest bristle of the second segment of the hind tarsus extends beyond the tip of the fifth segment; the latter is of

[1] I have carefully compared Jordan and Rothschild's description [*Ectoparasites* I, pp. 131, 132, text-fig. 105 (1921)] of *Tunga caecigena* with Roubaud's description [*Bull. Soc. Path. Exotique* XVIII, pp. 399-405, text-figs. 4-6, pl. i (1925)] of *Dermatophilus lagrangei* and am of opinion that the latter is synonymous with the former.

uniform breadth throughout and is provided with 3 pairs of long and thin lateral bristles and 2 subapical ventral bristles.



Text-fig. 1.—*Tunga penetrans*: (*a*) ♂, head, × 150; (*b*) ♀, terminal segments of the abodomen, × 150.

a. g. antennal groove; *c. a.* club of the antenna; *e.* eye; *f.* frons; *g. e.* genal edge; *i. f. t.* internal frontal tuber; *o.* occiput; *o. e.* oral edge; *py.* pygidium; *s.* stigmata; *st. vii., st. viii.* seventh and eighth sternites; *t. vii., t. viii., t. ix.* seventh, eighth and ninth tergites.

Modified Segments.—♂. The eighth sternite is deeply cleft on each side. The dorsal portion of tergite IX bearing the pygidium is almost separated from the clasper. The manubrium is long and club-shaped. The two processes of the clasper form a pair of pincers, the upper arm of which is fused with the main body of the clasper and the lower arm articulates with the upper by a suture. The ninth sternite when viewed from the side appears like an elongated triangle with its apex pointing backwards. The terminal portion of the ejaculatory tube is bent downwards, so as to form a hook, and has a short ventral process in front of it. ♀. The eighth tergite bears a broad lobe-like projection in the middle having a concavity above and below it. It bears 7-9 bristles on the outside; of these the three bristles near the ventral margin are well-developed. The spermatheca is spiniform and the head portion gradually passes into the slightly bent tail; its wall is very thin. The ductus receptaculi seminis is of uniform breadth and opens into a short bursa copulatrix.

Distribution and Hosts.—This originally South American species has been introduced into other tropical countries. In America it is common in all countries between Mexico and the northern parts of Argentina and the West Indies. It is believed that the species is also found in Southern Florida and parts of Texas neighbouring on Mexico. In Bermudas [1] it was common fifty years ago, but has now disappeared. In Africa,

[1] *Vide* Balfour, *Brit. Med. Journ.* I, No. 3506, p. 447 (1928).

where it has been introduced since 1872 [1], it has propagated with astonishing rapidity. In this continent it has been recorded from Tunis, Senegal, Liberia, Cameroons, Angola, Belgian Congo, Italian Somaliland[2], Uganda, Kenya Colony, Tanganyika Territory, Madagascar, Mahé Island[3] and Seychelles. In East Africa it is so common that during the Great War[4] it was a source of great annoyance to the British Army. According to Patton and Cragg " It has been introduced into Bombay and Karachi with infected sailors, but owing to the great care which has been taken to isolate affected persons, and probably also to the damp climate of these ports, it has not succeeded in gaining a footing" According to Gaspar Affonso [5] this species existed in the sixteenth century in India ; but it is doubtful whether the specimens he examined were those of *T penetrans* imported into the sea-ports of India trading with South America or of *Echidnophaga gallinaceus* (Westwood), a species common in Peninsular India. It is chiefly found on man and pig but it attacks other mammals as well.

I have examined specimens mounted on four slides prepared by the late Major F. W. Cragg from the collection of the Central Research Institute, Kasauli ; the provenance of the specimens is not indicated.

Genus **Echidnophaga** Olliff.

1886. *Echidnophaga,* Olliff, *Proc. Linn. Soc. N. S. Wales* (2) I, p. 172.
1906. *Echidnophaga,* Jordan and Rothschild, *Rept. Thompson Yates Labs.* (n. s.) VII, pp. 18, 43-45.
1911. *Echidnophaga,* Jordan and Rothschild, *Novitates Zoologicae,* XVIII, p. 61.
1913. *Echidnophaga,* Patton and Cragg, *A Textbook of Medical Entomology,* p. 450.
1925. *Echidnophaga,* Fox, *Insects and Disease of Man,* p. 131.

The two Indian species of this genus can be distinguished by the following key :—

I. Fifth hind tarsal segment provided on each side with one heavy subbasal bristle, a thinner median one and a minute postmedian hair ; anal stylet in female about three times as long as broad .. .. *liopus.*

II. Fifth hind tarsal segment provided on each side with three heavy bristles and a fourth slender bristle ; anal stylet in female nearly as long as broad .. *gallinaceus.*

Echidnophaga gallinaceus (Westwood).

1875. *Sarcopsyllus gallinaceus,* Westwood, *Entom. Month. Mag.* XI, p. 246.
1906. *Echidnophaga gallinaceus,* Jordan and Rothschild, *Rept. Thompson Yates Labs.* (n. s.) VII, pp. 52-54, pl. i, fig. 1 ; pl. ii, fig. 14 ; pl. iii, fig. 21 ; pl. iv, fig. 27.
1910. *Echidnophaga gallinaceus,* Rothschild, *Bull. Entom. Res.* I, p. 90, text-fig. 1.
1913. *Echidnophaga gallinaceus,* Patton and Cragg, *A Textbook of Medical Entomology,* p. 450, pl. liv. fig. 1 ; pl. lvi, fig. 3.

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[1] Blanchard says [*Bull. Soc. Zool. France* XIV, p. 98 (1889)] " C'est ainsi que, depuis 17 ans, elle se trouve en Afrique, où elle était jusqu' alors totalement inconnue : introduite au Gabon, en 1872, par l'équipage du navire anglais *Thomas Mitchel,* qui revenait du Brésil, elle s'est propagée avec une étonnante rapidité.

[2] *Vide* Zavattari, *Ann. Mus. Civ. Stor. Nat. Genova* (3) VI, p. 139 (1914).

[3] *Vide* Addison, *Ann. Rept. Med. Dept. year 1914,* 13pp. (Victoria, 1915).

[4] *Vide* Jolly, *Ind. Med. Gaz.* LXI, pp. 164, 165 (1926).

[5] *Vide* França, *Trans. Roy. Soc. Trop. Med. Hyg.* XV, p. 57 (1921).

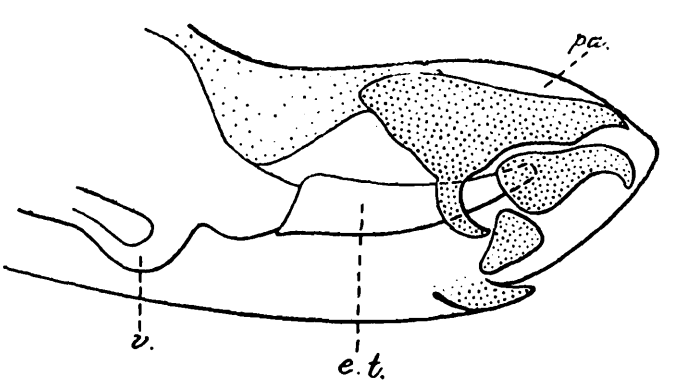
1914. *Echidnophaga gallinaceus*, Fletcher, *Some South Indian Insects*, pp. 365, 366, text-fig. 226 (Madras).
1915. *Echidnophaga gallinacea*, Bishopp, *Bull. U. S. Dept. Agric.* No. 248, pp. 19-21, text-figs.7, 8.
1925. *Echidnophaga gallinacea*, Fox, *Insects and Disease of Man*, p. 132, text-fig. 59.

Head.—The frons is strongly angulate [1] near the middle in both the sexes. The horizontal genal process is strongly chitinised and prominent in the female only. The occiput, which is nearly half the length of the frons, has 2 bristles behind the antennal groove. The hinder edge of the occiput of the female on each side is produced in the middle into a prominent lobe ; this is only feebly indicated in the male.

Thorax.—The pronotum bears 8-12 and the mesonotum 6-10 bristles. Only the pleurite of the mesosternum bears a single bristle, and the epimerum of the metathorax has a row of 4-6 bristles.

Abdomen.—The first tergite has 2 slender bristles in the first row and 2 or 3 strong bristles in the second row. Tergites II-VI have each 2 bristles, while tergite VII bears 4 bristles. As a rule only sternite VII has 2 or 3 bristles but in some cases sternite VI also bears 2 bristles.

Legs.—There are 14-25 spinelets on the inner side of the hind coxa. The hind femur has 4-6 hair-like bristles on the inner side. The hind tibia shows five notches including the apical one. The fifth hind tarsal segment has four pairs of bristles of which the fourth pair is not so well-developed as the remaining three pairs ; it also bears 2 subapical ventral bristles.



TEXT-FIG. 2.—*Echidnophaga gallinaceus* ♂ : terminal portion of the ejaculatory tube with paramere, × 350.

e. t. ejaculatory tube ; *pa.* paramere ; *v.* vesicle.

Modified Segments.—♂. The eighth sternite has 6 bristles in a vertical row and 2 bristles are found in front of this row. The upper process of the clasper has a long bristle near the apex on its ventral side. The broad distal portion of the lowest process of the clasper is longer than the narrow proximal portion. The terminal portion of the paramere is strengthened with sclerites ; its apical margin is dome-shaped and is provided with a ventral tooth-like process. The terminal portion of the ejaculatory tube, which is directed slightly upwards, narrows

[1] According to Jordan and Rothschild (*loc. cit.*) the frons is strongly angulate in the female and rotundate-angulate in the male ; but in all the specimens that I have examined it is nearly as angulate in the male as in the female.

gradually towards the apex. It is slightly constricted near the vesicle, and is unarmed. ♀. The broad portion of the eighth tergite is produced in the middle into a subtriangular lobe. It bears 3-6 bristles on its outer side, two of which come to lie near the ventral margin. There are 5-7 bristles on its inner side, the three upper ones of which are very strongly developed. The anal stylet is slightly longer than broad. The ductus obturatorius [1] is longer than the ductus receptaculi seminis and both these ducts join into a long common duct before opening into the bursa copulatrix.

Distribution and Hosts.—It is an Old World species but has been introduced into North America, where it has been recorded in the north up to Minnesota [2] and in the south to Panama[3] and Porto Rico[4]. According to Illingworth [2] it was not noticed by entomologists in Hawaii prior to 1913, and was probably introduced with poultry from California. In Africa it is found practically all over including Madagascar and the Mauritius Islands [5]. In Asia it has been recorded from Anatolia[6], Russian Armenia, Transcaspian provinces, Turkistan, India, Burma and Ceylon. It has also been reported from the Fiji Islands. It was first discovered in Western Australia in 1921[7], and has spread with so great rapidity that poultry imported from Western Australia into other parts of the Commonwealth is prohibited [8] unless accompanied by a certificate of freedom from *E. gallinaceus*. In spite of this measure it is spreading eastwards. Its chief host is poultry but it attacks other domestic animals as well. I have examined specimens from the following localities :—

Burma.—Natogyi (219/H6, ♀s, off dog ; 220/H6, ♀s, off cat), Myingyan district.

Madras Presidency.—Guindy (334/H6, ♀s, host ?), Madras district. Kilikarai (339/H6, ♂ ♀s, off poultry), Ramnad district. Kodaikanal (♀s, host ?), Madura district.

United Provinces.—Nawabganj, Cawnpore (337/H6, ♂ ♀s, off a young porcupine).

Bombay Presidency.—Belgaum (221/H6, ♀s, off Bandicoot ; 335/H6, ♂s ♀s, off cat). Mangalore (217/H6, ♂s ♀s, off hen), South Kanara district.

Mysore State.—Robertsonpet (338/H6, ♂♀, off cat), Kolar Gold Field district.

Travancore State.—Quilon (218/H6, ♀s, off dog).

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[1] For the diagram of spermatheca, bursa copulatrix and associated structures see Fox, *Treasury Dept. U. S. Publ. Heal. Serv., Hyg. Lab. Bull.* No. 97, pl. xvi, fig. 29 (1914).

[2] *Vide* Illingworth, *Hawaiian Forester and Agriculturist* XII, p. 130 (1915).

[3] *Vide* Dunn, *Amer. Journ. Trop. Med.* III, p. 340 (1923).

[4] *Vide* Cox, Carrion and Fox, *Publ. Hlth. Rept.* XLIII, pp. 611-616 (1928).

[5] *Vide* De Charmoy, *Mauritius Dept. Agric. Div. Entom.* 2 pp. (1914).

[6] *Vide* Vogel, *Centralbl. Bakt. Paras. Infekt.* (IIte Abt.) LXXI, pp. 313, 314 (1927).

[7] *Vide* Newman, *West. Australia Dept. Agric. Ann. Rept.* 1921-22, pp. 28-30 (1922).

[8] *Vide* Quarantine Proclamation, No. 153, *Commonw. Australia Gaz.* No. 3, 1 p. (1926).

Echidnophaga liopus Jordan and Rothschild.

1906. *Echidnophaga liopus*, Jordan and Rothschild, *Rept. Thompson Yates Labs.* (n. s.) VII, pp. 56, 57, pl. i, fig. 2 ; pl. iii, figs. 20, 26.
1910. *Echidnophaga liopus*, Rothschild, *Bull. Entom. Res.* I, p. 91, text-fig. 5.
1913. *Echidnophaga liopus*, Patton and Cragg, *A Textbook of Medical Entomology*, p. 450.

This species was originally described from Western Australia where it is very common on *Echidna aculeata*. It has only once been recorded off rats from Agra in India. I have not seen any specimen of this species.

Genus **Pulex** Linnaeus.

1758. *Pulex* (*en partim*), Linnaeus, *Systema Naturae* (X. ed.), p. 614.
1832. *Pulex* (*en partim*), Dugès, *Ann. Sci. Nat.* XXVII, p. 163.
1835. *Pulex* (*en partim*), Bouché, *Nova Acta Physico-Medica Acad. Caes. Leop. Carol.* XVII, pp. 501-503.
1844. *Pulex* (*en partim*), Gervais in *Walckenaer's Histoire Naturelle des Insectes Aptères* III, pp. 362-365.
1907. *Pulex* (*en partim*), Tiraboschi, *Arch. Parasitol.* XI, p. 580.
1908. *Pulex*, Jordan and Rothschild, *Parasitology* I, pp. 5-7.
1911. *Pulex*, Jordan and Rothschild, *Novitates Zoologicae*, XVIII, p. 62.
1913. *Pulex*, Patton and Cragg, *A Textbook of Medical Entomology*, pp. 452, 453.
1915. *Pulex*, Rothschild, *Entom. Month. Mag.* (3) I, pp. 55, 89.
1925. *Pulex*, Fox, *Insects and Disease of Man*, pp. 132, 133.

This the oldest of the Siphonapteran genera contains at present only two valid species. The genotype *Pulex irritans* Linnaeus has a world-wide distribution, while the other species *P. porcinus* was described by Jordan and Rothschild in 1923 [1] from Texas, United States of America. The other species, which were previously included in this genus, have been removed to other genera.

Pulex irritans Linnaeus.

1758. *Pulex irritans* (*en partim*), Linnaeus, *Systema Naturae* (X. ed.), p. 614.
1905. *Pulex irritans*, Liston, *Journ. Bombay Nat. Hist. Soc.* XVI, pp. 264, 265, pl. A, 1 fig. ; pl. B, 1 fig.
1908. *Pulex irritans*, Jordan and Rothschild, *Parasitology* I, pp. 7-12.
1910. *Pulex irritans*, Fox, in *The Rat and its Relation to the Public Health*, pp. 142, 143, pl. v. (Washington).
1915. *Pulex irritans*, Rothschild, *Entom. Month. Mag.* (3) I, pp. 55, 89, 90, pl. vii, fig. 2.
1915. *Pulex irritans*, Bishopp, *Bull. U. S. Dept. Agric.* No. 248, pp. 16-18, text-figs. 5, 6.
1916. *Pulex irritans*, Waterston, *British Mus. Econ. Ser.* No. 3, p. 18, 1 pl.

Head.—The rostrum extends to one-half to two-thirds the length of the fore coxa. There is one bristle (rarely 2) in front of the lower end of the eye and another bristle on the oral corner. The internal frontal tuber is absent. The antennal groove is short and broad. There is no sexual difference in the antenna of this species as is often the case in other species of the family ; it does not reach the vertex. The internal incrassation from the base of the antennal groove to the vertex is well-developed. Generally there is only one genal spine on each side. In both sexes there is a row of 7-14 short hairs behind the antennal groove.

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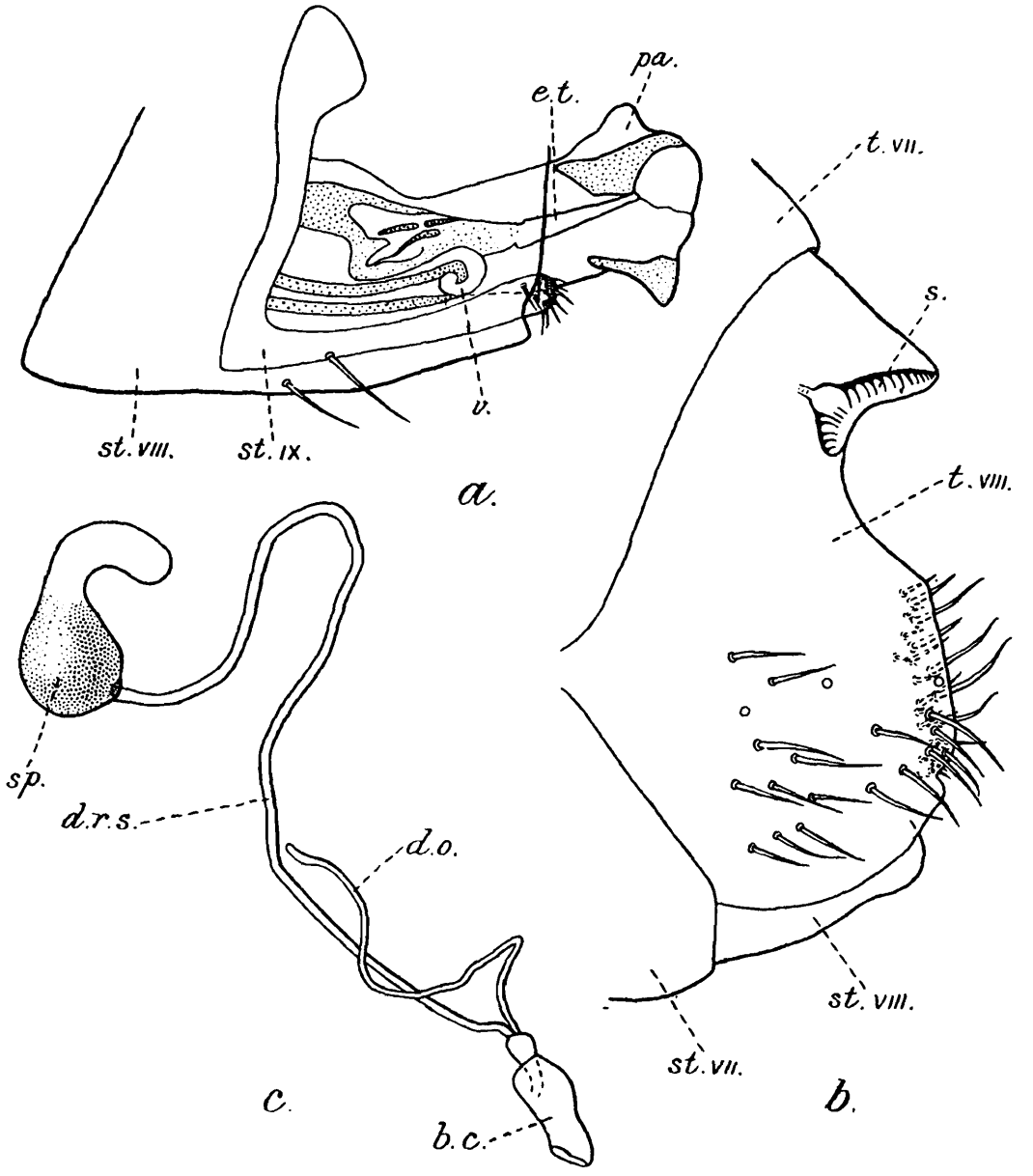
[1] Jordan and Rothschild, *Ectoparasites* I, pp. 312-314 (1923).

The occiput on each side bears a single bristle, which represents the lowest bristle of the subapical row.

Thorax.—The number of bristles on the pronotum varies from 12 to 15, on the mesonotum from 12 to 15 and on the metanotum from 11 to 14. The mesosternite bears 1-3 (generally 2) bristles. The sternum of the metathorax bears one bristle and the episternum of the same segment 2 or 3 bristles. The metepimerum has 5-7 bristles in the first row and 4-7 bristles in the second row.



TEXT-FIG. 3.—*Pulex irritans*: (*a*) ♂, lower portion of the terminal genital segments, × 100; (*b*) ♀, eighth abdominal segment, × 83; (*c*) ♀, spermatheca, bursa copulatrix and associated structures, × 150.

b. c. bursa copulatrix; *d. o.* ductus obturatorius; *d. r. s.* ductus receptaculi seminis; *e. t.* ejaculatory tube; *pa.* paramere; *s.* stigmata; *sp.* spermatheca; *st. vii.*, *st. viii.*, *st. ix.* seventh, eighth and ninth sternites; *t. vii.*, *t. viii.* seventh and eighth tergites; *v.* vesicle.

Abdomen.—The first row on the first tergite consists of 3 or 4 bristles and the second row of 4-6 bristles. The numbers of bristles on the other tergites are as follows:—ii. ♂ 8-11, ♀ 9-12; iii. ♂ 8-10, ♀ 9-11; iv. ♂ 8-10, ♀ 9-12; v. ♂ 8-9, ♀ 9-11; vi. ♂ 6-9, ♀ 8-11; vii. ♂ 6-9, ♀ 6-10. The bristles on tergite VII are unusually small and weak. The bristles on the sternites are as follows:—ii. ♂ 0-2, ♀ 2; iii. ♂ 5-7, ♀ 9-11; iv.

♂ 4-7, ♀ 8-10 ; v. ♂ 4-7, ♀ 7-11 ; vi. ♂ 4-6, ♀ 7-11 ; vii. ♂ 4-7, ♀ 9-12. The abdominal stigmata are large and each of them is situated below the lowest bristle of the corresponding tergite.

Legs.—The comb on the hind coxa consists of 6-20 spinelets. The hind femur has a lateral row of 7-14 bristles on the inside and 2 subapical ventral bristles on the outside. The hind tibia shows 6 deep notches including the apical one, but in some cases an additional notch is present between the second and the third notch from the proximal end. The dorsal row of the hind tibia contains 4-8 bristles. The fifth hind tarsal segment widens considerably towards the apex and has very stout lateral bristles. The distance between the third and the fourth lateral bristles is double that between the second and the third. The fifth tarsal segment of the hind leg as also of the other legs have each two [1] unequal and long subapical ventral bristles.

Modified Segments.—♂. The eighth sternite bears on each side 4 slender bristles along the apical margin, 1-3 bristles in the middle and 3-6 bristles in the proximal row. The eighth tergite is provided with a manubrium on each side. The clasper has three separate processes ; the upper process is large, sub-semicircular in shape and hairy ; while the other two processes form a pair of very strong pincers below the upper process. The manubrium is broad and curved upwards. The paramere is strengthened by a dorsal and a ventral sclerite ; its apical margin is convex. The terminal portion of the ejaculatory tube, which is directed slightly upwards, gradually narrows towards the apex ; it is somewhat constricted near the vesicle and is unarmed. The spiral of the penis is very much coiled. ♀. The eighth tergite bears 2-5 bristles along the apical margin, 16-22 bristles arranged in 2 or 3 irregular rows on the inside and 8-15 bristles usually arranged in 2 or 3 vertical rows laterally. The anal stylet is short, being only about twice as long as broad. The spermatheca is inverted comma-shaped, with the head portion about one-half the length of the slender tail. The ductus receptaculi seminis and the ductus obturatorius open into a club-shaped sac, which in its turn opens into the small bursa copulatrix.

Distribution and Hosts.—This species has come to have an almost cosmopolitan distribution as a result of the increased modes of intercommunication between the different countries. Originally an Old World form it has spread from the North Temperate Region to various parts of both the Old and the New World with man, its chief host. Its absence from the Sahara and Haussa countries in Africa and other very hot regions is due to the fact that this flea cannot stand a constant temperature of over 85°F.[2] In India it is found mostly in the hilly regions, but is rare in the plains. It has previously been recorded from Lhassia and Ukhrul in the Manipur district in Assam, Darjeeling, Coonoor and Bombay. In addition to its chief host it attacks wild and domestic

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[1] In Wagner's diagram of the fifth segment of the hind tarsus of *P. irritans* [*Horae Soc. Entom. Ross.* XXXI, pl. viii, fig. 8 (1898)] three subapical ventral bristles are shown. In a few of the specimens, which I have examined, there are three subapical ventral bristles but in the majority the number is two.

[2] According to Lethem [*Journ. State Med.* XXXI, pp. 508-511 (1923)] this species dies at a temperature of over 85°F

animals. I have examined specimens of this species from the following localities :—

Burma.—Lomira (306/H6, ♂s ♀, off dog) and Takaw (312/H6, ♂ ♀, off dog), Southern Shan States.

Assam.—Shillong (♀, in a house). Ukhrul (336/H6, ♂s ♀s, in a house), Manipur district.

Bengal.—Darjeeling (1489/16, ♀, off dog) and Singla (477/H6, ♀s, host ?), Darjeeling district.

Bihar.—Jogidih (307/H6, ♀s, off *Canis pallipes* Sykes), Hazaribagh district.

Central Provinces.—Jubbulpore (303/H6, ♀, off rat).

Madras Presidency.—Pamban (314/H6, ♂ ♀s, found on the floor of a house and in sand), Mandapam (313/H6, ♂s ♀s, host ?) and Duripatam (310/H6, ♀, among crevices in the floor of a house), Ramnad district. Kodaikanal (308/H6, ♀s, host ?), Madura district.

United Provinces.—Muktesar (304/H6, ♀, off fox), Naini Tal district. Almorah (305/H6, ♀s, host ?). Chakrata (309/H6, ♀, off dog), Dehra Dun district.

Kashmir State.—Kashmir (♂, host ?).

North-West Frontier Province.—Bannu town (311/H6, ♂, off dog), Razmak (469/H6, ♀s, host ?), Bannu district.

Bombay Presidency.—Ahmednagar (♀, host ?).

Genus **Pariodontis** Jordan and Rothschild.

1908. *Pariodontis*, Jordan and Rothschild, *Parasitology* I, pp. 13, 14.
1911. *Pariodontis*, Jordan and Rothschild, *Novitates Zoologicae*, XVIII, p. 65.
1926. *Pariodontis*, Jordan, *III. Internat. Entom.-Kongress*, II, p. 603.

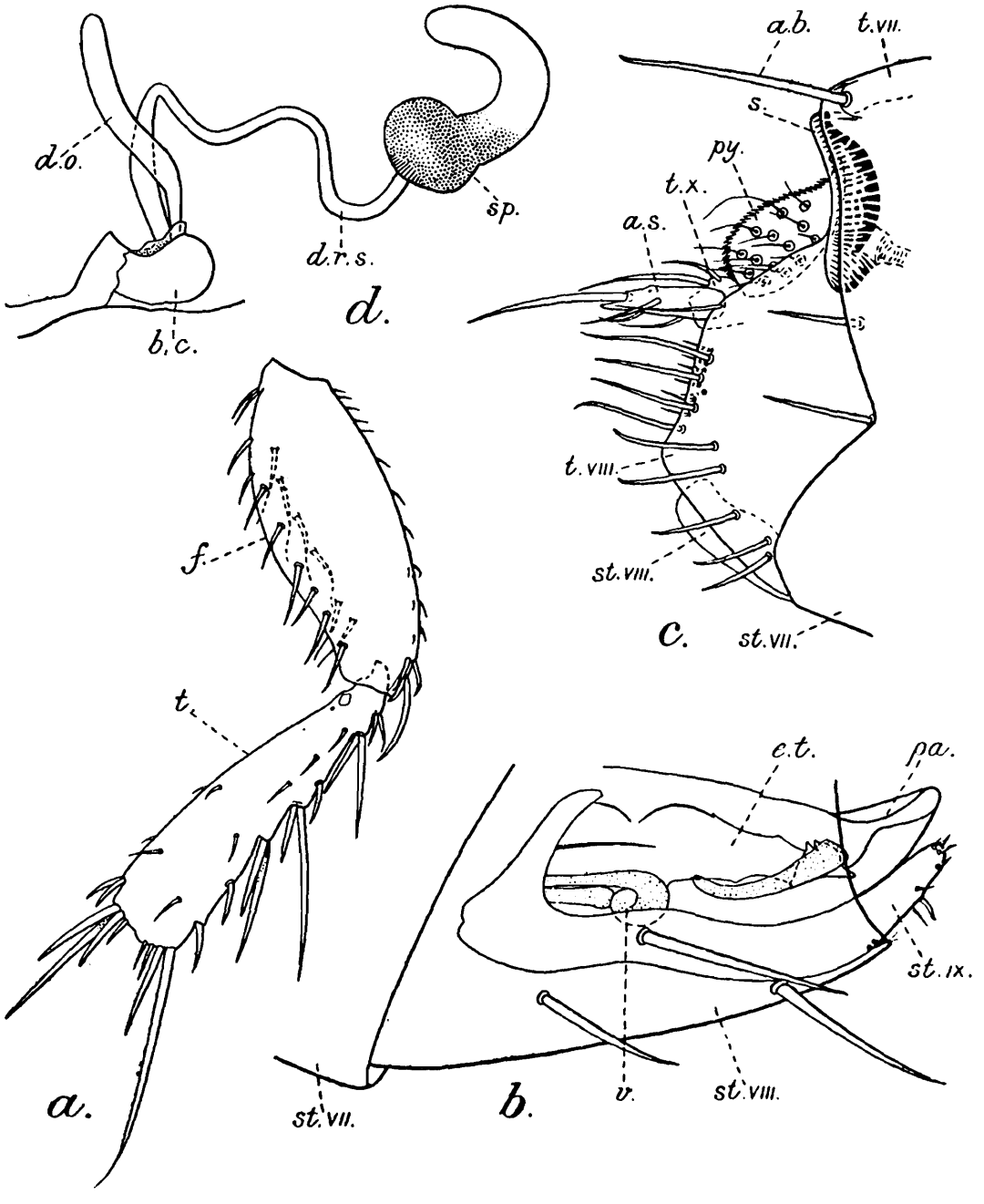
Of the two species of this genus only the genotype *P. riggenbachi* (Rothschild) has been reported from India. The other species *P. subjugis* Jordan, which was described in 1925 from the Malay Peninsula, differs from *P. riggenbachi* in having the end segment of the labial palpus slightly longer than the penultimate one.

Pariodontis riggenbachi (Rothschild).

1904. *Pulex riggenbachi*, Rothschild, *Novitates Zoologicae*, XI, pp. 611, 612, pl. viii, figs. 19, 20 ; pl. ix, fig. 24.
1908. *Pariodontis riggenbachi*, Jordan and Rothschild, *Parasitology* I, p. 14, pl. ii, fig. 1.
1911. *Pariodontis riggenbachi*, Jordan and Rothschild, *Novitates Zoologicae*, XVIII, p. 65.
1917. *Pulex ruptoris*, Weiss, *Bull. Soc. Hist. Nat. Afriq. Nord.* VIII, pp. 55-62, text-figs. 1-3.
1926. *Pariodontis riggenbachi*, Jordan, *III. Internat. Entom.-Kongress*, II, pp. 603, 604.

Head.—The rostrum extends beyond the apex of the fore coxa and its end segment is about twice as long as the penultimate segment. There are 15-22 stout hairs arranged in a row along the posterior margin of the antennal groove in the male, which are absent in the female. The occiput possesses two unequally long bristles behind the antennal groove, one near the base and the second almost in the middle. The subapical row of bristles of the occiput consists of 6-8 bristles.

Thorax.—The number of bristles on the pronotum is 8-12, on the mesonotum 8-10, and on the metanotum 8. The mesosternite bears 3 (rarely 4) bristles on the hinder margin of the epimerum and one bristle on the incrassation separating the epimerum and the episternum. The episternum and the sternum of the metathorax have each a single stout bristle. The first and the second rows on the metepimerum consist



TEXT-FIG. 4.—*Pariodontis riggenbachi* : (*a*) ♀, femur and tibia of the hind leg, ×43 ; (*b*) ♂, lower portion of the terminal genital segments, × 120 ; (*c*) ♀, terminal segments of the abdomen, × 60 ; (*d*) spermatheca, bursa copulatrix and associated structures, × 120.

a. b. antepygidial bristle ; *a. s.* anal stylet ; *b. c.* bursa copulatrix ; *d. o.* ductus obturatorius ; *d. r. s.* ductus receptaculi seminis ; *e. t.* ejaculatory tube ; *f.* femur ; *pa.* paramere ; *py.* pygidium ; *s.* stigmata ; *sp.* spermatheca ; *st. vii.*, *st. viii.*, *st. ix.* seventh, eighth and ninth sternites ; *t.* tibia ; *t. vii.*, *t. viii.*, *t. x.* seventh, eighth and tenth tergites ; *v.* vesicle.

of 3-7 and 5-9 bristles respectively. Two to four lower bristles of the second row are generally placed close to one another.

Abdomen.—The first row of bristles on the first tergite consists of 2 bristles in the male, but it is absent in the female. The second row on the same tergite has 4 (rarely 3 or 5) bristles in both the sexes. Tergites II—VI have each 10 (rarely 8) stout bristles in a row. The seventh tergite bears 8 (rarely 7) bristles. The numbers of bristles on the sternites are as follows:—

♂. ii. 0-2 ; iii. 2 ; iv. 2 ; v. 4 (rarely 3) ; vi. 4-6 ; vii. 6-8.
♀. ii. 0-2 ; iii. 2 ; iv. 4-6 ; v. 6-8 ; vi. 6-9 ; vii. 8-12.

The stigmata are large, and each is situated above the lowest bristle of the tergite in the male, while in the female each lies above the two lowest bristles of the tergites of segments III—VI.

Legs.—The comb of the hind coxa consists of 6-15 spinelets. The hind femur bears a row of 5-7 bristles on the inner side and a row of 4-7 bristles along the ventral margin on the outer side. There are 8 dorsal notches including the apical one on the hind tibia, and a row of 3-9 bristles on the outer surface. The fifth tarsal segment of all the legs has two equally strong subapical bristles on the ventral surface.

Modified Segments.—♂. The eighth sternite bears 3 long bristles on each side, of which two are along the ventral margin, while the third arises a little higher up between them. The manubrium of the clasper is much shorter than the distance from its base to the apex of the longest process of the clasper. The uppermost process of the clasper is the longest and subcylindrical. It bears 3-5 long and stout and 1 or 2 slender bristles at the apex ; it also has 2 slender bristles on its external surface. The middle process bears a few short bristles near the apex. The lowest process is broadly fused with the clasper and generally bears 7 slender bristles along its ventral margin. The apical margin of the paramere is oblique and its dorsal corner is produced into a broad lobe-like process. The apical portion of the ejaculatory tube is provided with two closely placed dorsal teeth and a third obsolete one further away from them. There is a forcep-like brown sclerite near the terminal portion of the ejaculatory tube. ♀. The eighth tergite bears 8-11 (generally 10) long bristles in the apical row, 7-9 (usually 8) short ones on the inner side and two well separated long bristles on the lateral surface. The anal stylet is very long, being three to four times as long as broad. It is produced apically into a prominent process. The spermatheca is inverted comma-shaped. The ductus obturatorius is much wider than the ductus receptaculi seminis and opens independently into the small bursa copulatrix.

I have not seen the specimen which was named *Pulex ruptoris* by Weiss but from his defective description of this species I have little doubt that his species is based on a female specimen of *Pariodontis riggenbachi.*

Distribution and Hosts.—The species has so far been recorded from Morocco, Tunis, Angola, Kenya Colony, Tanganyika Territory and Cape Colony in Africa, and in India. Its host is the porcupine (*Hystrix cristata* Linnaeus in Africa and *H. leucura* Sykes in India). I have examined specimens (299/H6, ♂ ♀s, off porcupine) from Pashok in the Darjeeling district, Bengal and two lots (300/H6, 301/H6, ♂s ♀s, off porcupine) from Cawnpore in the United Provinces.

Genus **Synosternus** Jordan.

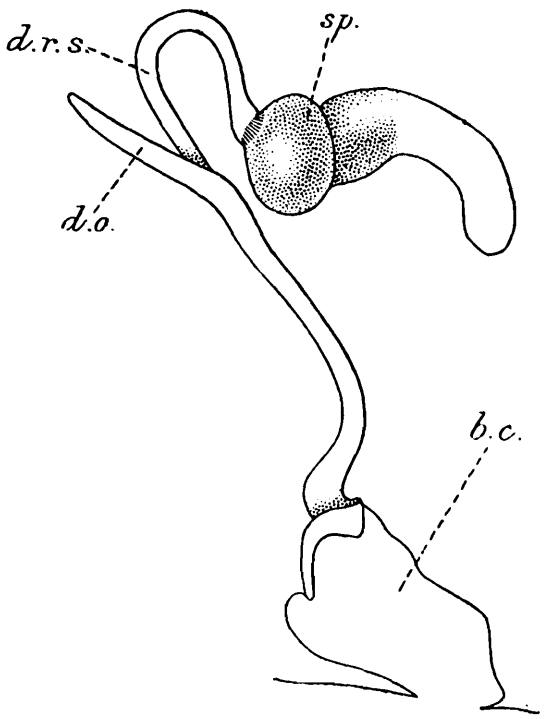
1880. *Pulex (en partim)*, Taschenberg, *Die Flöhe*, p. 64.
1908. *Loemopsylla (en partim)*, Jordan and Rothschild, *Parasitology* I, pp. 15, 16.
1909. *Xenopsylla (en partim)*, Rothschild, *Novitates Zoologicae*, XVI, p. 132.
1925. *Synosternus*, Jordan, *Novitates Zoologicae*, XXXII, p. 103.
1926. *Synosternus*, Jordan, *III. Internat. Entom.-Kongress*, II, p. 606.

It is predominantly an African genus but is represented in India by the genotype *S. pallidus* (Taschenberg).

Synosternus pallidus (Taschenberg).

1880. *Pulex pallidus*, Taschenberg, *Die Flöhe*, pp. 65, 66, pl. i, fig. 9.
1904. *Pulex pallidus*, Baker, *Proc. U. S. Nat. Mus.* XXVII, p. 437.
1908. *Loemopsylla pallidus*, Jordan and Rothschild, *Parasitology* I, pp. 35-37, pl. iii, fig. 4 ; pl. iv, fig. 9 ; pl. v, fig. 8.
1911. *Xenopsylla pallidus*, Jordan and Rothschild, *Novitates Zoologicae*, XVIII, p. 63.
1926. *Synosternus pallidus*, Jordan, *III. Internat. Entom.-Kongress*, II, p. 607.

Head.—The rostrum either reaches to or extends beyond the apex of the fore coxa. In the male there are about 14 small hairs behind the antennal groove, but there is no trace of these in the female. The subapical row of the occiput has 5 or 6 bristles ; the lowermost bristle of each side is separated by a fair space from the one above it.



TEXT-FIG. 5.—*Synosternus pallidus* ♀ : spermatheca, bursa copulatrix and associated structures, × 175.

b. c. bursa copulatrix ; *d. o.* ductus obturatorius ; *d. r. s.* ductus receptaculi seminis ; *sp.* spermatheca.

Thorax.—The pronotum bears 11 or 12, the mesonotum 9-11 and the metanotum 8-10 bristles. The number of bristles in the first row of the metepimerum is 3 in the male and 4 or 5 in the female ; in the second row there are 4 bristles in the male and 4 or 5 in the female.

Abdomen.—The first tergite bears two rows usually of 4 bristles in each. The numbers of bristles on the remaining tergites are as follows :— ii. 8-10; iii. 10; iv. 8-10; v. 8-9; vi. 8; vii. 6-8. Sternite II has one or two bristles on the ventral margin and sternites III—VII have each 4 bristles.

Legs.—The comb on the hind coxa has 8-12 spinelets. The hind femur, which possesses a distinct subbasal tooth, has a row of 7-15 bristles on the inside and a subapical ventral bristle on the outside. The hind tibia shows six notches including the apical one and a lateral row of 6-12 bristles along its dorsal margin. The fourth hind tarsal segment is nearly as long as broad. The fifth tarsal segment of all legs, in addition to the minute hairs on the ventral side, bears 2 slender subapical bristles of unequal size.

Modified Segments.—♂. The eighth sternite bears 5-7 short bristles on each side. The clasper has three processes of which the upper and outer is the longest. The ninth sternite is bent apically into a short hook-shaped structure. The brush-like structure below the apex of the ejaculatory tube is very prominent. The apical margin of the paramere is oblique and the apex of the paramere is produced into a narrow dorsal process. The terminal portion of the ejaculatory tube is strongly bent upwards; its surface is minutely denticulated and it has a strongly developed process on its dorsal surface. ♀. The apical edge of the eighth tergite is almost straight and bears 6-8 bristles in the apical row, 12-15 short bristles on the inside and 3-6 bristles on the lateral surface. The head of the spermatheca is broader than the basal portion of the tail. The ductus obturatorius is short, it is as broad as the ductus receptaculi seminis.

Distribution and Hosts.—This species has so far been recorded from certain parts of Africa (excepting the south, south-east and the north), Mesopotamia, Transcaspia and India. It has been recorded only once from Rio de Janerio in Brazil[1] where probably it had been imported. In India it has been recorded from Cutch (off *Vulpes* sp.) and Karachi (7488/16, ♂ ♀s, off *Erinaceus collaris* Gray and Hardwicke). The latter specimens are in the Indian Museum.

Genus **Xenopsylla** Glinkiewicz.

1907. *Xenopsylla*, Glinkiewicz, *Sitzungsb. Math.-Natur. Klas. K. Akad. Wiss Wien*, CXVI, p. 385.
1908. *Loemopsylla* (*en partim*), Jordan and Rothschild, *Parasitology* I, pp. 15, 16.
1909. *Xenopsylla* (*en partim*), Rothschild, *Novitates Zoologicae*, XVI, p. 132.
1911. *Xenopsylla* (*en partim*), Jordan and Rothschild, *ibid.* XVIII, p. 63.
1913. *Xenopsylla* (*en partim*), Patton and Cragg, *A Textbook of Medical Entomology*, p. 453.
1915. *Xenopsylla* (*en partim*), Rothschild, *Entom. Month. Mag.* (3) I, pp. 54, 89.
1926. *Xenopsylla*, Jordan, *III. Internat. Entom.-Kongress*, II, p. 609.

This genus is represented in India by two new and three previously described species, *viz.*, *X. cheopis* (Rothschild), *X. astia* Rothschild and *X. brasiliensis* (Baker). The distribution of the three previously known species in this country is of great importance from the epidemiological

[1] *vide* Pinto, *Bull. Soc. Path. Exotique*, XXI, p. 106 (1928).

point of view, since *X. cheopis* is the most important vector of plague. A determination of the exact proportion of the three species for a place at different seasons of a year is, therefore, of great value for the control of outbreaks of plague.

For previous detailed records of the three species in this country the papers by Cragg[1], Hirst[2], Mital and Dunn[3], and Goyle [4] may be consulted.

The Indian species of this genus can be separated with the help of the following key :—

I. Male.
- A. Antepygidial bristle situated on a marginal cone; bristles on P^1. of clasper stout, one of them being elbowed or twisted, P^2. curved upwards at tip .. *brasiliensis.*
- B. Antepygidial bristle submarginal in position and not situated on a marginal cone ; bristles on P^1. of clasper not stout, none of them twisted or elbowed, P^2. straight or slightly curved down at apex.
  - *I.* Horizontal portion of sternite IX club-shaped ; occipital groove less deep, its outline regular ; 6-8 bristles on central abdominal sternites .. *cheopis.*
  - *II.* Horizontal portion of sternite IX ribbon-shaped, very thin and transparent laterally and dorsally ; occipital groove deep, its outline more or less wavy ; 10 or more bristles on central abdominal sternites.
    - *A.* Paramere slanting with a separate dorsal process ; manubrium one and a half times as long as the distance from its junction with the clasper to the longer process .. . *astia.*
    - *B.* Paramere subtriangular, its apex produced into a long spout-like process, no separate dorsal process ; manubrium only as long as the distance from its junction with the clasper to the longer process .. .. .. *hussaini*, sp. nov.

II. Female.
- A. Head of spermatheca wider than base of tail.
  - *I.* Head of spermatheca much wider than base of tail, pigmentation only confined to its dilated base ; 13 or 14 bristles on central abdominal tergites and 7-9 bristles on central abdominal sternites ; 2 ventral subapical bristles on fifth segment of pro and mid tarsus ; about 17 bristles on outer surface of tergite VIII .. .. .. *brasiliensis.*
  - *II.* Head of spermatheca slightly wider than base of tail, pigmentation extends beyond dilated portion of tail ; 15-18 bristles on the central abdominal tergites and 13-16 bristles on central abdominal sternites ; 3 ventral subapical bristles on fifth segment of pro and mid tarsus ; about 30 bristles on outer surface of tergite VIII .. .. *sewelli.* sp. nov.
- B. Head of spermatheca not wider than base of tail.
  - *I.* Base of tail of spermatheca much wider than head ; 10 or more bristles on central abdominal sternites.. *astia.*
  - *II.* Base of tail of spermatheca nearly as wide as head ; 6-8 bristles on central abdominal sternites *cheopis.*

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[1] Cragg, *Ind. Journ. Med. Res. Special Ind. Sci. Congr.* No. 1920, pp. 29-34 (1920) ; *Ind. Journ. Med. Res.* IX, pp. 374-398 (1921) and X, pp. 953-961 (1923).

[2] Hirst, *Ceylon Journ. Sci. (Sect. D.)* I, pp. 155-271, pl. xxvi (1926) ; and pp. 277-455, charts 1-4, 5 maps (1927).

[3] Mital and Dunn, *Report on the geographical distribution and seasonal prevalence of rats and rat-fleas in the United Provinces*, pp. 1-9, 4 maps, 14 g. charts (Lucknow, 1926).

[4] Goyle *Ind. Journ. Med. Res.* XV, pp. 837-860 (1928).

Xenopsylla cheopis (Rothschild).

1903. *Pulex cheopis*, Rothschild, *Entom. Month. Mag.* (2) XIV, pp. 85, 86, pl. i, figs. 3, 9 ; pl. ii, figs. 12, 19.
1905. *Pulex cheopis*, Liston, *Journ. Bombay Nat. Hist. Soc.* XVI, p. 265, pl. A, 1 fig. ; pl. B, 1 fig.
1908. *Loemopsylla cheopis* (*en partim*), Jordan and Rothschild, *Parasitology* I, pp. 42-45, pl. i ; pl. ii, fig. 8 ; pl. iv, fig. 8 ; pl. vi, fig. 1.
1910. *Loemopsylla cheopis*, Fox in *The Rat and its Relation to the Public Health*, pp. 138-140, pl. iii.
1910. *Xenopsylla cheopis*, Rothschild, *Bull. Entom. Res.* I, p. 92, text-figs. 9,11.
1911. *Xenopsylla cheopis*, Jordan and Rothschild, *Novitates, Zoologicae*, XVIII, p. 63.
1913. *Xenopsylla cheopis*, Patton and Cragg, *A Textbook of Medical Entomology*, p. 455, pl. lv, figs. 2, 3, 5, 7 ; pl. lvi, fig. 6.
1914. *Xenopsylla cheopis*, Fletcher, *Some South Indian Insects*, p. 366, text-fig. 227.
1914. *Xenopsylla cheopis*, Rothschild, *Bull. Entom. Res.* V, pp. 84, 85, text-figs. 2, 5.
1915. *Xenopsylla cheopis*, Rothschild, *Entom. Month. Mag.* (3) I, pp. 54, 89, pl. vii, figs. 1, 9, 12.
1916. *Xenopsylla cheopis*, Waterston, *Brit. Mus. Economic Ser.* No. 3, p. 7, text-figs. 1, 5, 6.
1925. *Xenopsylla cheopis*, Sinton, *Ind. Journ. Med. Res.* XII, pp. 473, 474, pl. xxxv, fig. 4 ; pl. xxxvi, figs. 11, 14.
1926. *Xenopsylla cheopis*, Jordan, *III. Internat. Entom.-Kongress*, II, pp. 614, 615, pl. xix, fig. 60 ; pl. xx, fig. 71.

Head.—In the male only there is a row of 10-17 short stout hairs along the hinder margin of the antennal groove. The subapical row on the occiput in both the sexes consists of 11-13 bristles.

Thorax.—There are 12-15 bristles in a row on the pronotum, 12-14 bristles on the mesonotum and 11-13 bristles on the metanotum. The epimerum of the metathorax has two rows of 5-7 bristles in each row.

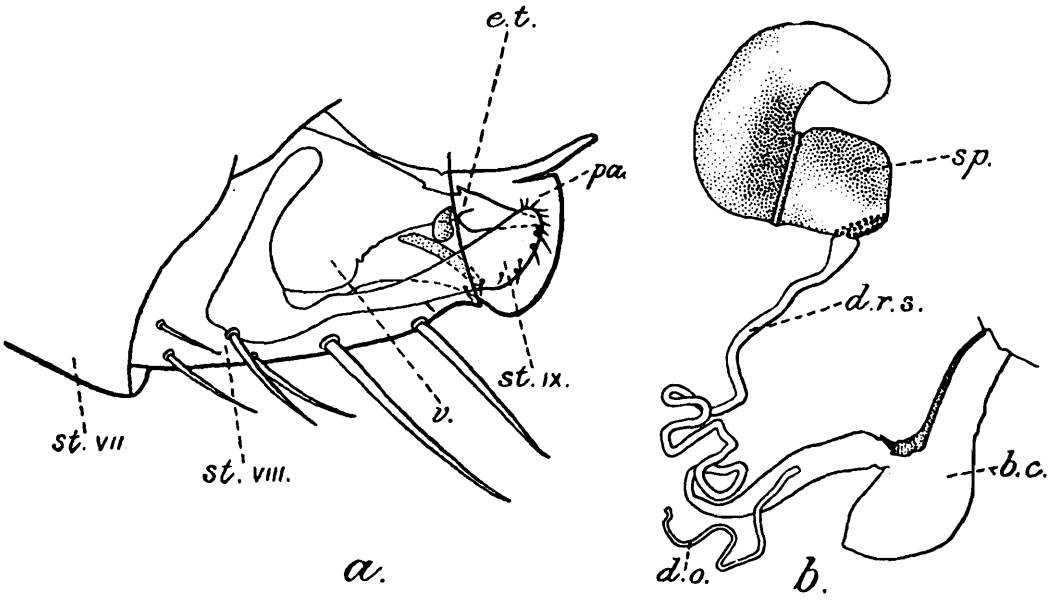
Abdomen.—The chaetotaxy as given by Jordan and Rothschild (1908) for this species shows a considerable range of variation ; this, however, is not the case in the very large series from India examined by me. In the specimens that I have examined I found the following range of variation.

The first row on the first tergite has 5-8 bristles and the second row 6 or 7 bristles. Tergites II—V have each a row of 13-16 bristles and tergites VI, VII have each a row of 12-15 bristles. Sternite II has 2 bristles and sternites III—VII have each a row of 6-8 bristles (generally 6 in ♂ and 8 in ♀). The seventh sternite has in addition 2-5 slender bristles in front of the row.

Legs.—The comb on the hind coxa has 4-10 spinelets. The hind femur bears a row of 5-9 bristles on the inner surface and 2 (rarely 3) subapical ventral bristles on the outer surface. The hind tibia has 6 notches including the apical one. There are 6-9 bristles in a row on its outer side and a row of 2 or 3 bristles between it and the dorsal margin. The fifth segment of the fore and mid tarsus has 3 subapical bristles in addition to the several minute hairs on its ventral surface ; these are long and slender in the female and short and spiniform in the male. The fifth segment of the hind tarsus has only 2 unequal and slender subapical bristles on its ventral surface in both the sexes.

Modified Segments.—♂. The eighth sternite bears on each side a row of 4 or 5 bristles along the ventral margin ; the two posterior ones of these are very strong and the last one is slightly farther from the apex

than from the preceding one, and 3-6 bristles on its lateral surface. The manubrium is narrow and is as long as or shorter than the distance from its junction with the clasper to the tip of the longer process (P^{2}·).



TEXT-FIG. 6.—*Xenopsylla cheopis*: (*a*) ♂, lower portion of the terminal genital segments, × 150; (*b*) ♀, spermatheca, bursa copulatrix and associated structures, × 150.

b. c. bursa copulatrix; *d.o.* ductus obturatorius; *d. r. s.* ductus receptaculi seminis; *e. t.* ejaculatory tube; *pa.* paramere; *sp.* spermatheca; *st. vii.*, *st. viii.*, *st. ix.* seventh, eighth and ninth sternites; *v.* vesicle.

The outer process of the clasper (P^{1}·) is short and sole-shaped and bears 9-12 moderately strong bristles on its dorsal and apical margins. The horizontal portion of sternite IX widens gradually towards the apex so as to look like a club. Its dorsal and ventral margins are equally chitinised, and its apex is not distinctly curved upwards. The paramere possesses a separate long pointed dorsal process, and its apical margin is evenly rounded. The apical portion of the ejaculatory tube, which is straight, is provided with a dorsal tooth and a small blunt ventral lobe. It possesses a small V-shaped brown sclerite on its ventral side. ♀. The eighth tergite bears 9-13 bristles along the apical margin and 6-8 short ones on the inner side. The lateral row contains 6-9 bristles and besides there are 2-5 bristles between the lateral row and the apical. The anal stylet is short and is almost twice as long as broad. The head of the spermatheca is nearly as large as the base of the tail, which is long and widens gradually towards its base. About one-half of the tail portion is pigmented. The ductus obturatorius opens in the middle of the dilated portion of the ductus receptaculi seminis.

Distribution and Hosts.—It is predominantly an Indo-African species, but has also been recorded from some places all over the world between 40° N. and 40° S. Its wide distribution is due to the fact that its chief host—the rat—can transfer itself with ease from ship to shore and *vice versa*. This flea in various stages of its development has as a result been carried from place to place amongst grain and with other forms of merchandise. It has been introduced into America but is not common. It has been recorded there from certain places between Boston in the north and Buenos Aires in the south, where the species has become established only in the port towns and in a few cases in the interior.

It has also been introduced into the West Indies. In Europe it has only been recorded from port towns and only in a few cases from large towns which carry on trade in grain with Africa and the Oriental Region. It is common all over Africa. In Asia it is very common in all countries below 40° N. In Japan it has only been recorded from port towns and has not penetrated into the interior. In Australia it has established itself only along the coast and is not found in the interior.

In India, where it is now very common, the species has, in my opinion, been introduced. Before 1896 there is no record of plague in India and this, owing to *X. cheopis* being the chief vector of plague, naturally leads one to believe that this species was very scarce or not found in India before the advent of plague. According to Hirst [1] it was absent from Ceylon before 1914 when plague first made its appearance in Ceylon. At present it is very common all over India, but is comparatively rare in places where the climate is warm and moist, especially along the coast of the Bay of Bengal. It has been suggested [2] that it is comparatively rare in the plains of Bengal and Madras Presidencies, Burma and the Bundelkhand division. In the hilly regions of Northern India it is the only rat-flea of the genus *Xenopsylla*, but in the hilly regions of Central and Peninsular India it is, along with *X. brasiliensis*, the common parasite of the rat.

Cragg's [3] statement " while *astia* is the predominant species in those areas which have remained free from the disease or have suffered only lightly " has to be accepted with some caution as in most of the hilly regions *X. cheopis* [4] is the only rat-flea, and still there is no plague in those regions.

Probably the original home of this species is the Nile Valley and its vicinity, and from this area it has spread into the Mediterranean Subregion and the Oriental Region.

I have examined about 80 lots from all over India and a few specimens from Basra in Mesopotamia.

Xenopsylla astia Rothschild.

1911. *Xenopsylla astia*, Rothschild, *Novitates Zoologicae*, XVIII, pp. 117, 118, text-fig. 1.
1914. *Xenopsylla astia*, Rothschild, *Bull. Entom. Res.* V, pp. 84, 85, text-figs. 3, 6.
1925. *Xenopsylla astia*, Sinton, *Ind. Journ. Med. Res.* XII, p. 474, pl. xxxvi, figs. 12, 15.
1926. *Xenopsylla astia*, Jordan, *III. Internat. Entom.-Kongress*, II, p. 618, pl. xix, fig. 54 ; pl. xx, fig. 64.

Head.—The occipital groove in the male is deeper than that in *X. cheopis* and its outline is more or less undulate. There are 17-20 short

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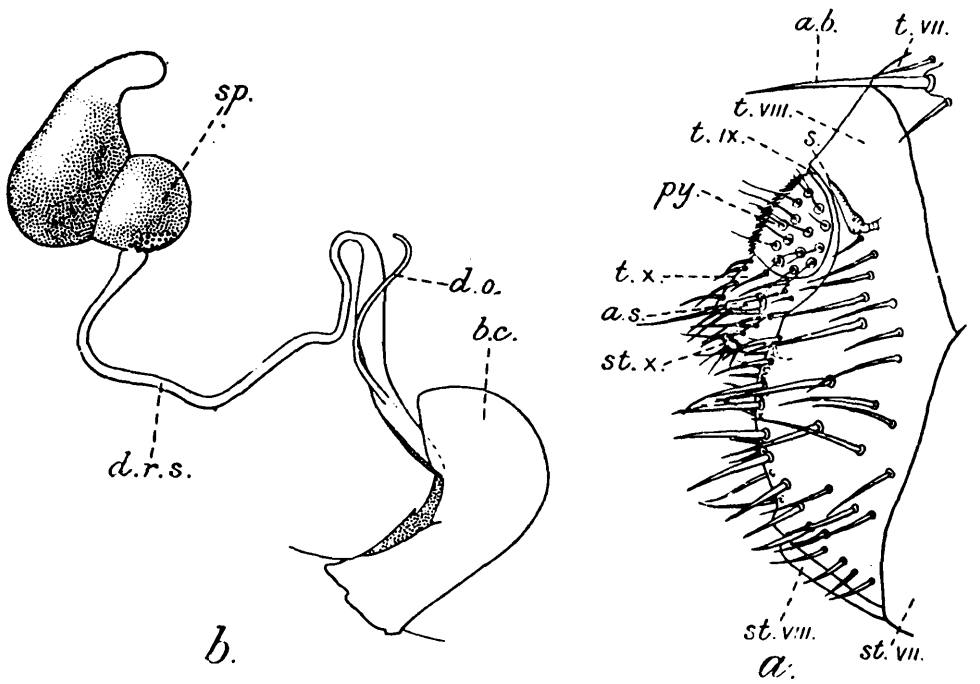
[1] Hirst, *Ceylon Journ. Sci.* (*Sect. D.*) I, p. 160 (1926).
[2] *Vide* Hirst, *Ceylon Journ. Sci.* (*Sect. D.*) I, p. 316 (1927).
[3] Cragg, *Ind. Journ. Med. Res.* IX, p. 394 (1921).
[4] According to Barraud [*Ind. Journ. Med. Res.* XV, pp. 519-521 (1927)] the only rat-flea which is found at Gauhati and Shillong in Assam is *X. cheopis* but no indigenous cases of plague have been recorded during the past few years from these places. According to Goyle [*Ind. Journ. Med. Res.* XV, p. 856 (1928)] *X. cheopis* also forms the bulk of the rat-flea at Naini Tal and Almora and the population does not suffer from plague epidemics. So it appears that hilly regions in India are free from plague even though *X. cheopis* greatly predominates over other species in these regions.

stout hairs along the hinder margin of the antennal groove in the male. The subapical row of the occiput contains 12-16 bristles in both sexes.

Thorax.—The pronotum and mesonotum possess each a row of 14-16 bristles and the metanotum has a row of 12-16 bristles. The epimerum of the metathorax has 6-9 bristles in the first row and 4-7 in the second row.

Abdomen.—The first row of the first tergite has 5-8 and the second 6-9 bristles. The numbers of bristles on the other tergites in both sexes are as follows :—ii. 16-20 ; iii. 16-21 ; iv. 16-18 ; v. 15-18; vi. 15-18 ; vii. 14-16. The numbers of bristles on the sternites are as follows :— ii. 2 ; iii. 10-13 ; iv. 10-15 ; v. 10-16 ; vi. 10-16 ; vii. 10-16. There is an additional row of 3 or 4 slender bristles in front of the postmedian row on sternite VII.

Legs.—As in *X. cheopis.*



TEXT-FIG. 7.—*Xenopsylla astia* ♀: (*a*) terminal segments of the abdomen, × 90 ; (*b*) spermatheca, bursa copulatrix and associated structures, × 150.

a. b. antepygidial bristle ; *a. s.* anal stylet ; *b. c.* bursa copulatrix ; *d. o.* ductus obturatorius ; *d. r. s.* ductus receptaculi seminis ; *py.* pygidium ; *s.* stigmata ; *sp.* spermatheca ; *st. vii.*, *st. viii.*, *st. x.* seventh, eighth and tenth sternities ; *t. vii.*, *t. viii.*, *t. ix.*, *t. x.* seventh, eighth, ninth and tenth tergities.

Modified Segments.—♂. The eighth sternite bears on each side a row of 7-9 bristles along the ventral margin ; of these the posterior 3 or 4 bristles are very strong and the distalmost is shorter than the two preceding it. There are 8-12 bristles on the lateral surface. The manubrium is very long and narrow and is about one and a half times as long as the distance from its junction with the clasper to the longer process (P^{2}·) of the clasper. The outer process (P^{1}·) is comparatively smaller than that of *X. cheopis* and bears 6-9 bristles on its dorsal side ; one of these bristles is longer than the others. The horizontal portion of sternite IX is only strongly chitinised on the ventral side and therefore has the appearance of a ribbon presenting only its edge to the eye. The penal plate resembles that of *X. cheopis*, but is broader and its antero-dorsal angle is not so pointed. The paramere has a separate dorsal

process and its apical margin is slanting. The apical portion of the ejaculatory tube is bent downwards and is provided with two dorsal teeth and a strong ventral hook. Above this tube there is a U-shaped brown sclerite with its limbs hanging on either side of the tube. The lower ends of these limbs are serrated. ♀. The eighth tergite bears 11-16 bristles along the apical margin and 7-10 short ones on the inner side. There is an irregular vertical row of 8-10 bristles along its anterior margin and another irregular row of 6-9 bristles between it and the apical row. The head of the spermatheca is much smaller than the dilated basal portion of the tail. The lower greater half of the tail is pigmented. The ductus obturatorius opens behind the dilated portion of the ductus receptaculi seminis.

Distribution and Hosts.—This species has so far been recorded from Indo-China[1], Singapore[2], Burma, India, Ceylon, Mesopotamia, and the Arabian peninsula[3] and certain East African ports—Mombasa, Dar-es-Salaam—where it has been introduced recently. According to Jordan its record from Accra, Gold Coast by Evans[4] is based on wrong identification of specimens of *X. nubicus* (Rothschild) which closely resembles *X. astia.*

According to Hirst[5] its original home was Indo-China from where it has migrated into the low plains of India, but in my opinion it is predominantly a species of the Ceylonese Subregion and has spread along the coast of the Bay of Bengal to Burma and from there into other parts of the Indo-Chinese Subregion. It is found all over India but is absent in the hilly regions. It is evidently a species of the plains and flourishes well in warm and moist areas.

It may be noted here that the specimens recorded by Rothschild as *X. nesiotes* in *Rec. Ind. Mus.* VI, p. 43 (1911) belong to this species. I have examined about sixty lots of this species from the plains all over India.

Xenopsylla brasiliensis (Baker).

1904. *Pulex brasiliensis*, Baker, *Proc. U. S. Nat. Mus.* XXVII, pp. 379, 380.
1909. *Loemopsylla vigetus*, Rothschild, *Novitates Zoologicae*, XVI, p. 53, pl. viii, figs. 3, 4.
1909. *Xenopsylla brasiliensis*, *id. ibid.* p. 332.
1910. *Xenopsylla brasiliensis*, Rothschild, *Bull. Entom. Res.* I, p. 92, text-figs. 8, 10.
1911. *Xenopsylla brasiliensis*, Jordan and Rothschild, *Novitates Zoologicae*, XVIII, p. 65, text-fig. 4.
1914. *Xenopsylla brasiliensis*, Rothschild, *Bull. Entom. Res.* V, pp. 84, 85, text-figs. 1, 4.
1925. *Xenopsylla brasiliensis*, Sinton, *Ind. Journ. Med. Res.* XII, pp. 473, 474, pl. xxxvi, figs. 10, 13.
1926. *Xenopsylla brasiliensis*, Jordan, *III. Internat. Entom.-Kongress*, II, p. 611, pl. xviii, fig. 42 ; pl. xix, fig. 57.

Head.—There are 9-13 short and stout hairs along the posterior margin of the antennal groove of the male only and 10-12 bristles in the subapical row on the occiput in both the sexes.

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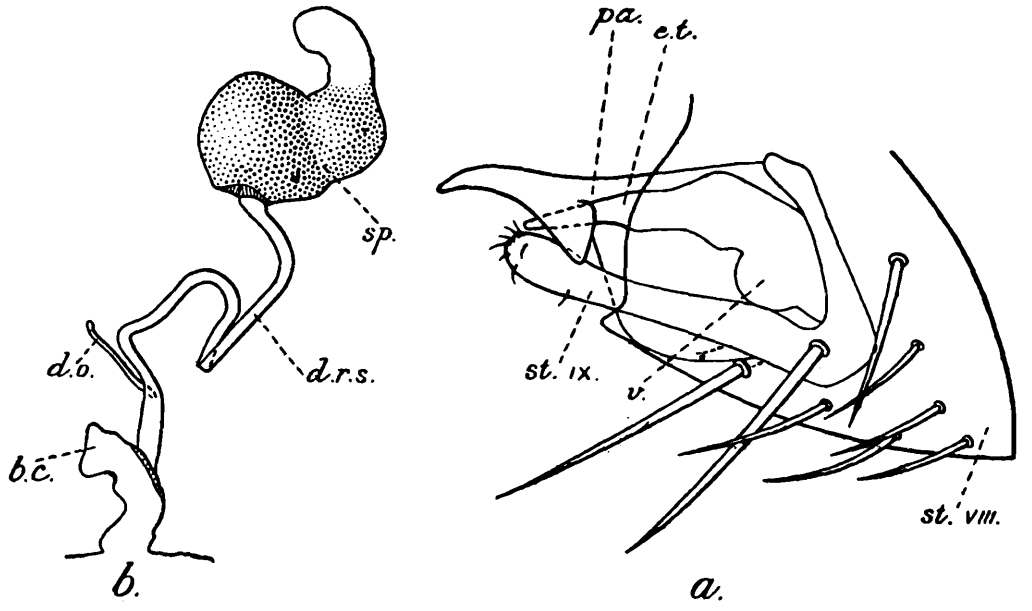
[1] *Vide* Hirst, *Ceylon Journ. Sci.* (*Sect. D.*) I, p. 340 (1927).
[2] Only a single specimen of this species has been recorded from Singapore and it is just possible that it might have been a recently imported specimen.
[3] *Vide* Hirst, *Ceylon Journ. Seci.* (*Sect. D.*) I, p. 162 (1926).
[4] Evans, *Ann. Trop. Med. Parasitol.* XVI, p. 449 (1922).
[5] Hirst, *Ceylon Journ. Sci.* (*Sect. D.*) I, p. 325 (1927).

Thorax.—There are 13-16 bristles on the pronotum, 12-14 bristles on the mesonotum and 10-13 bristles on the metanotum. The epimerum of the metathorax possesses 4-7 bristles in the first row and 4-6 in the second row.

Abdomen.—The first row on the first tergite has 4-7 bristles and the second 5 or 6 bristles. Tergites II-VI have each 13 or 14 bristles and the seventh tergite has 10-12 bristles. Sternite II has only 2 bristles in both sexes. Sternites III-VII in the male have each 4-6 bristles. In the female the numbers of bristles on the remaining sternites are as follows :—iii. 8-9 ; iv. 8-9 ; v. 7 or 8 ; vi. 7 ; vii. 10-14. The seventh sternite in the female possesses in addition to the postmedian row a row of 2-5 slender bristles in front of it. The antepygidial bristle is situated on a conical projection in the male, while it is submarginal in the female.

Legs.—The comb on the hind coxa has 4-6 spinelets. On the inner side of the hind femur there is a row of 4-6 bristles, while there are 2 subapical ventral bristles on its outer side. The hind tibia has six notches including the apical one. The fifth tarsal segment in all legs of the female has 2 slender, unequal, ventral, subapical bristles ; but in the male the fifth segment of the fore and mid tarsus has 3 short and spiniform bristles and the fifth hind tarsal segment, as in the female, bears only 2 bristles. In other respects the legs are as in *X. cheopis.*



Text-fig. 8.—*Xenopsylla brasiliensis :* (*a*) ♂, lower portion of the terminal genital regments, × 188 ; (*b*) ♀, spermatheca, bursa copulatrix and associated structures, × 150.

b. c. bursa copulatrix ; *d. o.* ductus obturatorius ; *d. r. s.* ductus receptaculi seminis ; *e. t.* ejaculatory tube ; *pa.* paramere ; *sp.* spermatheca ; *st. viii., st. ix.* eighth and ninth sternites ; *v.* vesicle.

Modified Segments.—♂. The eighth sternite bears on each side a vertical row of 3 bristles along the anterior margin and 4 or 5 bristles along the ventral margin ; of these the distalmost is the largest and best developed ; there is in addition a strong bristle in between these two rows. The manubrium, which is short and slender, is shorter than the distance from its junction with the clasper to the tip of the longer process (P^{2}·) of the clasper. The outer process (P^{1}·) of the clasper is subcylindrical and bears 7 or 8 strong bristles on the dorsal side ; of these

the third from the base is the strongest, the fourth is the longest and is curved like a boomerang; the two distal bristles are very slender. The inner process (P^2) is narrower and longer than the outer and its distal end is curved upwards. The horizontal portion of sternite IX is club-shaped. Its tip is distinctly widened and rounded and its ventral surface has only a few hairs. The penal plate is as in *X. cheopis* but its proximal narrow portion passes gradually into the broad distal portion. The apical margin of the paramere is oblique and is provided with a big subtriangular dorsal process partially fused with the paramere. The apical portion of the ejaculatory tube, which bends downwards, is unarmed. ♀. The eighth tergite has 8-10 bristles along the apical margin and 6-9 short ones on the inner side. The lateral row contains 4-6 bristles and 2 or 3 bristles between it and the apical row. The anal stylet is comparatively longer than that in *X. cheopis* or *X. astia*. The head portion of the spermatheca is much larger than the base of the tail and only the swollen portion of the tail is pigmented. The ductus obturatorius is short and opens in front of the slightly dilated portion of the ductus receptaculi seminis.

Distribution and Hosts.—This species has, so far, been recorded from West, Central and South Africa, Comoro Islands and Mauritius [1] and the southern uplands of the Indian Peninsula, but is not found in the lowlands of the Madras Presidency. In the Punjab it has been recorded from Chiniot in the Jhang district, Karnal, Jullunder and Lyallpur: only a single specimen of this species has been recorded from each of the above mentioned places and Balipara Frontier Tract in Assam. These records are probably based upon recently and accidently introduced specimens of this species. It has been introduced into Brazil from where it was first described. One specimen of this species has been recorded from England.

I have examined specimens from the following places:—

Assam.—Balipara Frontier Tract (231/H6, ♂, off dog), Tezpur district.

Central Provinces.—Jubbulpore (357/H6, 226/H6, ♂s ♀s, off rat). Pachmarhi (227/H6, 280/H6, ♂s, off rat and 298/H6, ♀, off squirrel), Hoshangabad district.

Bombay Presidency.—Nasik (222/H6, 343/H6, ♂s♀s, off rat). Bombay (361/H6, ♂s ♀s, off rat). Belgaum (350/H6, ♂s ♀s, off rat).

Mysore State.—Mysore City (230/H6, ♂ ♀, off rat).

Xenopsylla hussaini, sp. nov.

Head.—The rostrum does not quite reach the tip of the fore coxa. There is a row of 22 short hairs along the hinder margin of the antennal groove. The subapical row of the occiput contains 13 bristles. The occipital groove is as deep as in *Xenopsylla astia* and its outline is almost similar.

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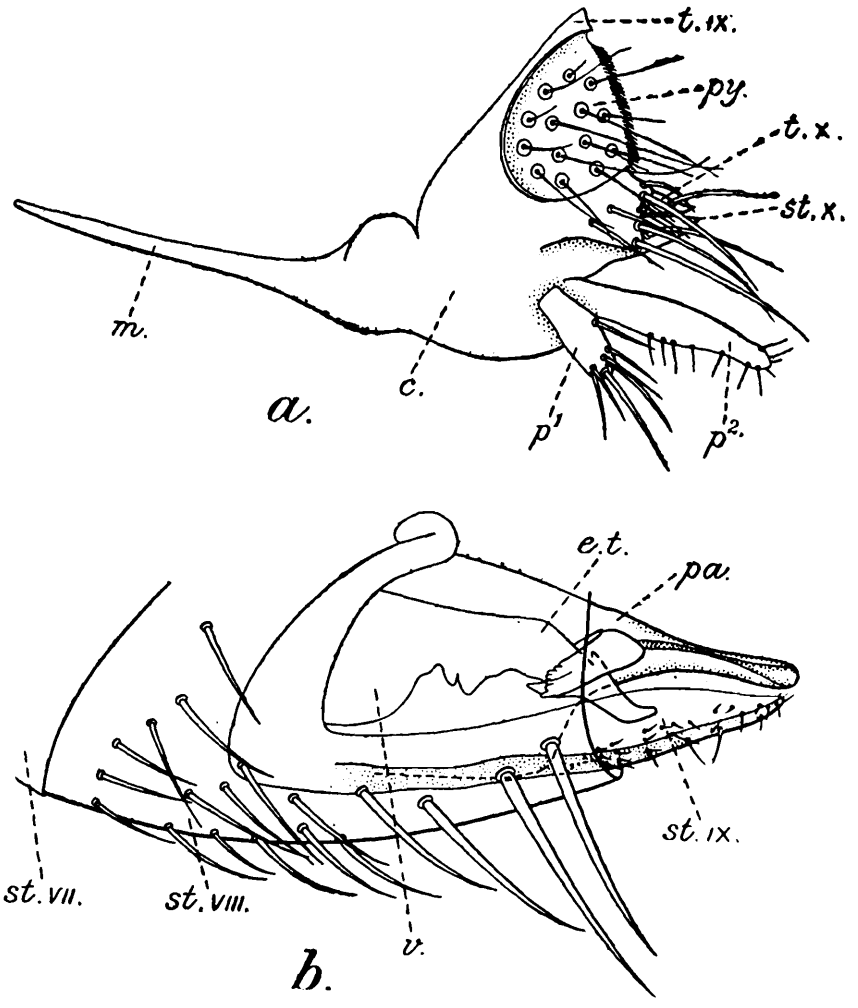
[1] *Vide* Hirst, *Ceylon Journ. Sci.* (*Sect. D.*) I, p. 283 (1927).

Thorax.—There are 16 bristles on the pronotum, 17 bristles on the mesonotum and 15 bristles on the metanotum. The metepimerum has 6 or 7 bristles in the first row and 5 in the second row.

Abdomen.—The two rows on the first tergite have each 8 bristles. The numbers of bristles on the other tergites are as follows :—ii. 17 ; iii. 18 ; iv. 16 ; v. 17 ; vi. 17 ; vii. 16. Sternite II has 2 bristles and sternites III—VII have each 11 bristles.

Legs.—The comb on the hind coxa has 6 or 7 spinelets. The hind femur has a row of 8 bristles on the inner side and 3 subapical ventral bristles on the outer side. The hind tibia shows 6 dorsal notches bearing stout bristles. There is a row of 9 bristles on its outer side and 3 bristles between this row and the dorsal margin. Otherwise the legs are as in the male of *Xenopsylla cheopis*.



TEXT-FIG. 9.—*Xenopsylla hussaini* ♂ : (*a*) upper portion of the terminal genital segments, × 150 ; (*b*) lower portion of the terminal genital segments, × 150.

c. clasper ; *e. t.* ejaculatory tube ; *m.* manubrium ; p^1. p^2. first and second processes of the clasper ; *pa.* paramere ; *py.* pygidium ; *st. vii., st. viii., st. ix., st. x.* seventh, eighth, ninth and tenth sternites ; *t. ix., t. x.* ninth and tenth tergites ; *v.* vesicle.

Modified Segments.—♂. The eighth sternite bears on each side a row of 10 bristles along the ventral margin ; of these the first and third from the distal end are almost equally strong. On the lateral surface there are 19 bristles. The manubrium is shorter than that of *X. astia* and is as long as the distance from its junction with the clasper to the longer process ($P^{2\cdot}$) of the clasper, which is longer than that of *X. astia*. The

horizontal portion of sternite IX is as in *X. astia*, but its lateral surfaces are more chitinised and not so transparent as in that species. The paramere is subtriangular and its apical portion forms a very long spout-like process which is longer than that of *X. nesiotes* (Jordan and Rothschild). The terminal portion of the ejaculatory tube first bends downwards and then becomes straight. It is provided with a dorsal tooth and a strong ventral hook. Above this tube is a brown U-shaped sclerite of almost the same form but comparatively longer than that of *X. astia*. The female of this species is unknown.

This species resembles *X. astia* in several characters, but the genitalia is quite different and resembles that of *X. nesiotes* (Jordan and Rothschild).

I have great pleasure in associating this species with the name of my friend Mr. M. A. Hussain, Entomologist to the Government of the Punjab, who presented to the Indian Museum the only specimen upon which the description of this species is based. The type-specimen (480/H6), which was collected from a field-rat—*Gerbillus indicus* (Hardwicke)—at Tundla in the Ambala district, is deposited in the Indian Museum.

Xenopsylla sewelli, sp. nov.

Head.—The rostrum extends up to the middle of the fore trochanter. The subapical row of the occiput contains 11 bristles.

Thorax.—There are 18 bristles on the pronotum, 16 bristles on the mesonotum and 15 bristles on the metanotum. The metepimerum has 6 bristles in the first row and 5 bristles in the second row.

Abdomen.—The first row on the first tergite has 6 bristles and the second row has 7 bristles. The numbers of bristles on the other tergites are as follows :—ii. 17 ; iii. 18 ; iv. 17 ; v. 16 ; vi. 17 ; vii. 15. Unlike other species of this genus there are 2 bristles below the stigmata on tergites II—VI. The bristles on the sternites are as follows :—ii. 2 ; iii. 13 ; iv. 16 ; v. 14 ; vi. 14 ; vii. 15. The seventh sternite has a row of 11[1] hair-like bristles in front of the post-median row.

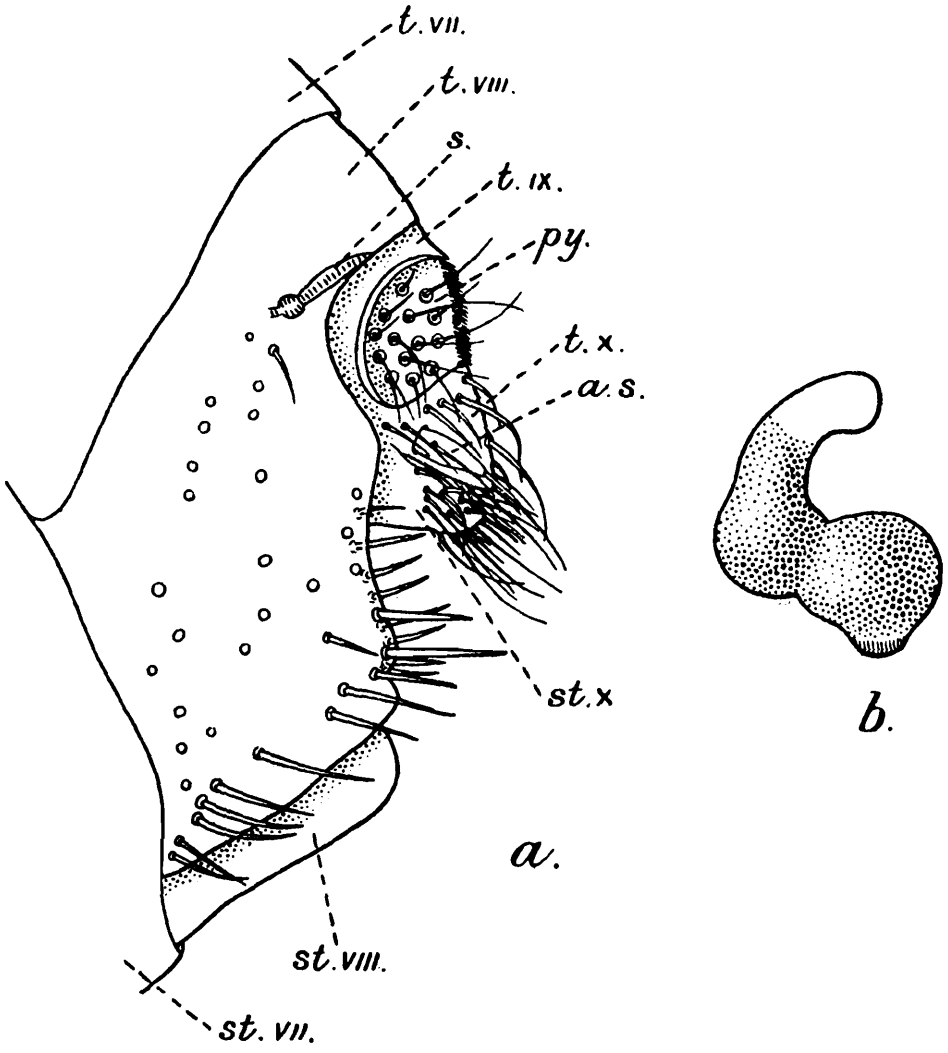
Legs.—The comb on the hind coxa and the arrangement of the bristles on the hind femur and on the hind tibia are similar to those of *X. hussaini*. The fifth tarsal segments of all legs are as in the female of *X. cheopis*.

Modified Segments.—♀. The eighth tergite has 14 bristles along the apical margin and 9 stout bristles on the inner side. There is an irregular vertical row of 10 bristles near its anterior margin and another irregular vertical row of 8 bristles in between the anterior and the apical rows. The head of the spermatheca is broader than the dilated portion of the tail whose proximal greater half is pigmented.

This species is described from a single specimen (type-specimen, 481/H6) taken from *Gerbillus indicus* (Hardwicke) at Tundla in the Ambala district. The specimen came from the same lot as *X. hussaini*. At first I considered it to be the female of *X. hussaini*, but the shape of the spermatheca of this species is of the type of the *brasiliensis* subgroup of

[1] The places of insertion of the bristles are to be clearly seen though the bristles have dropped off in the type-specimen.

species, while *X. hussaini* undoubtedly belongs to the *cheopis* subgroup of species, and I have, therefore, no hesitation in considering the two



TEXT-FIG. 10.—*Xenopsylla sewelli* ♀: (*a*) terminal segments of the abdomen, × 106; (*b*) spermatheca, × 200.

a. s. anal stylet; *py.* pygidium; *s.* stigmata; *st. vii., st. viii., st. x.* seventh, eighth and tenth sternites; *t. vii., t. viii., t. ix., t. x.* seventh, eighth, ninth and tenth tergites.

specimens as distinct. The type-specimen is deposited in the Indian Museum.

Genus **Ctenocephalus** Kolenati.

1758. *Pulex* (*en partim*), Linnaeus, *Systema Naturae* (X. ed.), p. 614.
1859. *Ctenocephalus*, Kolenati, *Jahresh. Nat. Sect. Mähr. Schles. Ges.* 1858, p. 65.
1863. *Ctenocephalus*, Kolenati, *Horae Soc. Entom. Ross.* II, pp. 44, 45.
1880. *Pulex* (*en partim*), Taschenberg, *Die Flöhe*, p. 64.
1904. *Ctenocephalus* (*en partim*), Baker, *Proc. U. S. Nat. Mus.* XXVII, p. 384.
1904. *Ctenocephalus* (*en partim*), Tiraboschi, *Arch. Parasitol.* VIII, pp. 253, 254.
1907. *Ctenocephalus*, Tiraboschi, *Arch. Parasitol.* XI, p. 588.
1911. *Ctenocephalus*, Jordan and Rothschild, *Novitates Zoologicae*, XVIII, p. 66.
1915. *Ctenocephalus*, Rothschild, *Entom. Month. Mag.* (3) I, pp. 56, 91.
1925. *Ctenocephalus*, Fox, *Insects and Disease of Man*, p. 135.

In India this genus is represented by *C. canis* (Curtis), *C. felis* (Bouché) and *C. felis* subsp. *orientis* Jordan. These three forms are very closely related to one another, and the subspecies *orientis* is undoubtedly intermediate between *C. felis* and *C. canis*.

Key to the Indian species and subspecies of the genus *Ctenocephalus*.

I. Anteriormost genal spines much smaller than those behind; metepisternum usually with three or more bristles and metepimerum with 7-14 bristles in the first and 7-9 bristles in the second row; hind tibia with eight dorsal notches; male with moveable finger of clasper broadly rounded at the apex, its proximal three-fourths along ventral margin strongly chitinised and devoid of hairs; anal stylet of female one and a half times as long as broad .. .. *canis*.

II. Anteriormost genal spines nearly as strong as those behind; metepisternum usually with two bristles and metepimerum with 4-8 bristles in both rows; hind tibia with either six or seven dorsal notches; male with moveable finger of clasper somewhat pointed apically, its proximal half along ventral margin strongly chitinised and devoid of hairs; anal stylet of female nearly three times as long as broad.

A. Frons elongate and pointed at the anterior end; female without a row of short hairs behind antennal groove; hind tibia with six dorsal notches; manubrium not widened apically.. .. .. *felis* forma *typica*.

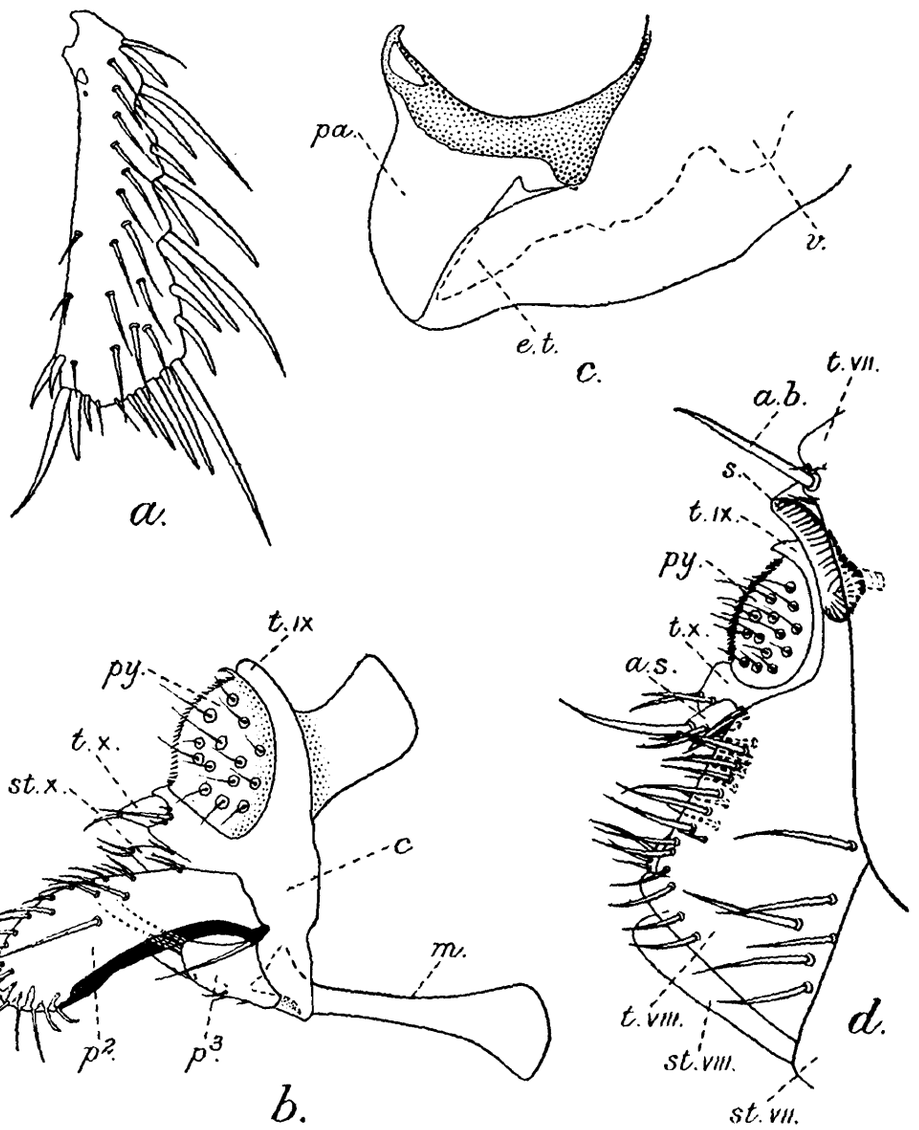
B. Frons short and broadly rounded anteriorly; female with a row of 1-8 short hairs behind antennal groove; hind tibia with seven dorsal notches; manubrium widened apically.. .. .. .. *felis* subsp. *orientis*.

Ctenocephalus canis (Curtis).

1826. *Pulex canis*, Curtis, *Brit. Entom.* III, No. 114, figs. A-E, 8.
1832. *Pulex canis* (*en partim*), Dugès, *Ann. Sci. Nat.* XXVII, pp. 157-160, 163, pl. iv, figs. 2, 5, 7, 8.
1844. *Pulex canis*, Gervais in *Walckenaer's Histoire Naturelle des Insectes Aptères* III, p. 372.
1904. *Ctenocephalus serraticeps*, Tiraboschi, *Arch. Parasitol.* VIII, pp. 254-259.
1904. *Ctenocephalus canis* (*en partim*), Baker, *Proc. U. S. Nat. Mus.* XXVII, pp. 384, 385, 438.
1905. *Ctenocephalus canis* (*en partim*), Baker, *Proc. U. S. Nat. Mus.* XXIX, pp. 131, 145.
1907. *Ctenocephalus canis*, Tiraboschi, *Arch. Parasitol.* XI, pp. 591, 592, text-figs. 11A, 11A'.
1910. *Ctenocephalus canis*, Fox, in *The Rat and its Relation to the Public Health*, pp. 143, 144, pl. vi.
1911. *Ctenocephalus canis*, Jordan and Rothschild, *Novitates Zoologicae*, XVIII, p. 67.
1915. *Ctenocephalus canis*, Rothschild, *Entom. Month. Mag.* (3) I, pp. 56, 91, 92, pl. vii, figs. 4, 10.
1925. *Ctenocephalus canis*, Fox, *Insects and Disease of Man*, pp. 135, 136, text-fig. 63.

Head.—In both sexes the frons is broadly rounded at the anterior end and the perpendicular distance between the falx and the anterior oral corner is equal to the distance between the base of the posteriormost genal spine and the apex of the falx. The genal comb has 16 spines (rarely 14 or 15), the two anteriormost being about half as small as those behind. The labial palpi reach two-thirds to three-fourths the length of the fore coxa. The internal frontal tuber is comparatively short and its proximal half is near the anterior edge of the frons. The occiput has 2 bristles behind the antennal groove, one near the base and the other near the middle. In some cases there is a row of 2 bristles in the middle. The subapical row of the occiput has 10-12 bristles. The male has two or three rows, each consisting of about 8 short stout hairs behind the antennal groove; they are altogether absent in the female.

Thorax.—The pronotal comb contains 14-17 spines in the male and 16-18 in the female. The number of bristles in the row on the pronotum is 12-14, on the mesonotum 12-16 and on the metanotum 10-13. The mesothorax bears a single bristle (rarely 2 or more) on the episternum and 4-7 bristles on the epimerum. The metathorax has a single bristle (rarely 2 or more) on the sternum and 3-5 (rarely 2) on the episternum and two rows of 7-14 and 7-9 bristles on the epimerum. The bristles of the first row are not regularly arranged and in some specimens are seen to be arranged in two rows, thus making the number of rows on the metepimerum three.



TEXT-FIG. 11.—*Ctenocephalus canis:* (*a*) ♂, hind tarsus, × 82; (*b*) ♂, upper portion of the terminal genital segments, × 133; (*c*) ♂, terminal portion of the ejaculatory tube and paramere, × 240; (*d*) ♀, terminal segments of the abdomen, × 80.

a. b. antepygidial bristle; *a. s.* anal stylet; *c.* clasper; *e. t.* ejaculatory tube; *m.* manubrium; p^2. p^3. second and third processes of the clasper; *pa.* paramere; *py.* pygidium; *s.* stigmata; *st. vii., st. viii., st. x.* seventh, eighth and tenth sternites; *t. vii., t. viii., t. ix., t. x.* seventh, eighth, ninth and tenth tergites; *v.* vesicle.

Abdomen.—The two rows on the first tergite have each 4 (sometimes 5-7) bristles. Tergites II—V have each 11-15 bristles and tergites VI and VII have each 10-12 bristles. The second sternite has 2 bristles

and sternites III—VI have each 4-6 bristles. Sternite VII bears 4-8 bristles. The abdonimal stigmata are large in size.

Legs.—The fore coxa is strongly hairy and usually bears 30 stout bristles on the outer surface. The comb on the hind coxa has 8-11 spinelets. The fore femur has 6-11 bristles on the outer surface and 1 or 2 subapical ventral bristles. The hind femur bears a row of 7-13 bristles on the inner side and 3 (rarely 2 or 4) subapical ventral bristles on the outer side. There are 9-13 bristles on the outer surface of the hind tibia and it also possesses 8 dorsal notches including the apical one. The third, sixth and seventh usually possess each a single bristle. In some specimens there is an additional notch after the third notch from the proximal end. The fifth tarsal segment of all the legs has 2 ventral subapical bristles of unequal length.

Modified Segments.—♂. The eighth sternite bears a vertical row of 10-14 bristles and one or two rows of 2 bristles in front of the row. The clasper has a sole-shaped moveable finger (P^2·), beneath which there is a small triangular process (P^3·). The moveable finger is broadly rounded at the apex and its proximal three-fourths along the ventral margin, which is strongly chitinised, is devoid of hairs. The manubrium is straight and narrow at its origin, but is considerably widened at the apex to form a spatula-like structure. The apical margin of the paramere is slightly convex and is produced dorsally into a hook-like process. The apical portion of the ejaculatory tube, which is bent downwards, has only a backwardly directed dorsal tooth. ♀. The eighth tergite bears 8-12 bristles in the apical row, 2 or 3 bristles on the apical margin and 5-8 bristles on the inner side. There are 4-9 bristles sometimes arranged in two rows on the lateral surface. The anal stylet is nearly one and a half times as long as broad, and bears 2 strong apical bristles of unequal length. The head of the spermatheca is subrectangular in shape, and the two ducts are subequal in length; they open into a common broad duct before opening into the bursa copulatrix.

Distribution and Hosts.—This species has hitherto been confused with *C. felis* and its subspecies, and it is, therefore, very difficult to form a correct idea of its exact distribution. According to Rothschild it is found only in Europe, Africa and Asia. There are, however, records of its occurrence in other areas, but these appear to be based on wrongly identified specimens as the species is not indigenous in other continents. There is the possibility that it may have been introduced into these parts, but in such cases it would be confined only to certain trade centres and could not already have become widely distributed. According to Jordan [1] it has been introduced into South and East Africa where *C. felis strongylus* Jordan is the indigenous flea. In my opinion it is predominantly a flea of the Palaearctic Region and has spread with its main host—the dog—all over the world. It is a flea of cold regions and cannot flourish in hot climates. Its chief hosts are the dog and the cat, but it occasionally attacks other animals and man.

The previous records from India are mostly based on wrongly identified specimens of *C. felis* subsp. *orientis*. In this country it is only confined to the hilly regions and is very scarce in the plains. I have ex-

[1] Jordan, *Novitates Zoologicae*, XXXII, p. 98 (1925).

amined a fairly large number of specimens of the genus *Ctenocephalus* from all over India but only a few lots from places mentioned below belong to this species.

Madras Presidency.—Kodaikanal (454/H6, ♂s ♀s, host ?), Madura district.

United Provinces.—Muktesar (122/H6, ♂ ♀s, off fox and 121/H6, ♂ ♀s, off dog), Naini Tal district. Almora city (166/H0, ♂s ♀s, off dog). Chakrata (208/H6, ♂s ♀s, off dog), Dehra Dun district.

Punjab.—Hissar (462/H6, ♀, off wild boar). Sohawa (453/H6, ♂s ♀s, off dog), Jhelum district.

Ctenocephalus felis (Bouché).

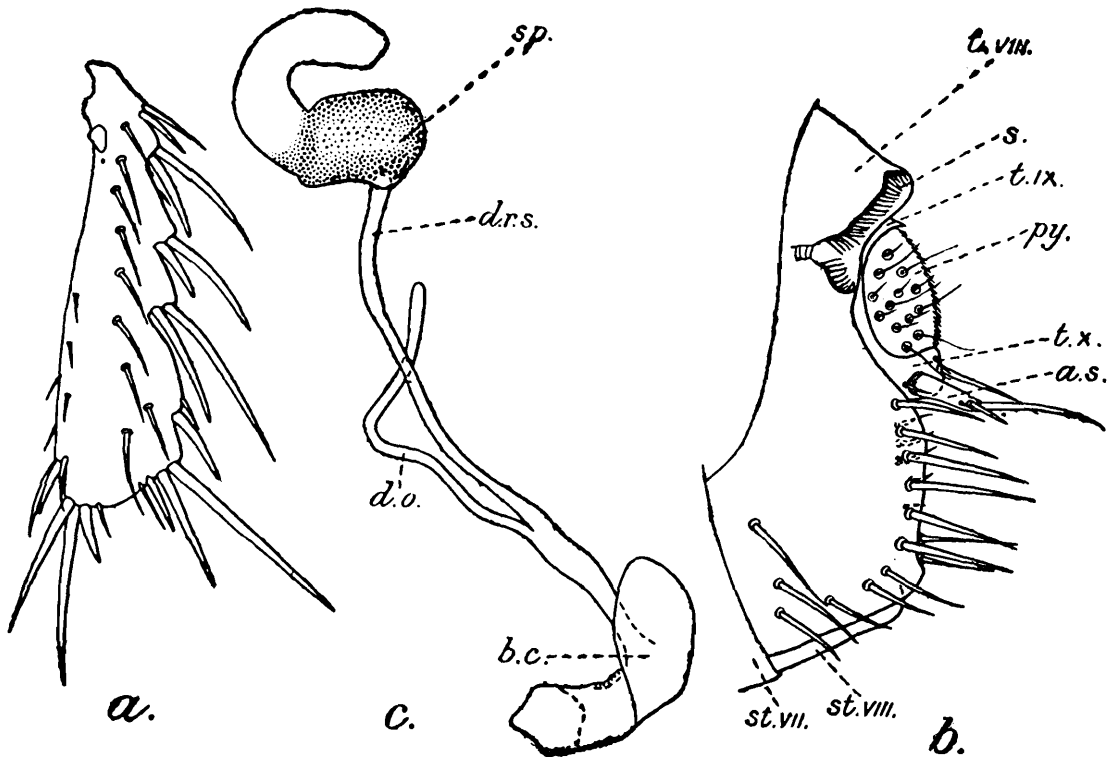
1832. *Pulex canis* (*en partim*), Dugès, *Ann. Sci. Nat.* XXVII, pp. 157-160, 163, pl. iv, figs. 2, 5, 7, 8.
1835. *Pulex felis*, Bouché, *Nova Acta Physico-Medica Acad. Caes. Leop. Carol.* XVII, pp. 505, 506.
1896. *Pulex serraticeps* (*en partim*), Howard, *Bull. U. S. Dept. Agric., Divis. Entom.* (n. s.) No. 4, pp. 24-31, text-figs. 5, 6.
1896. *Pulex serraticeps* (*en partim*), Osborn, *Bull. U. S. Dept. Agric., Divis. Entom.* (n. s.) No. 5, pp. 150-152, text-fig. 83.
1905. *Pulex felis*, Liston, *Journ. Bombay Nat. Hist. Soc.* XVI, p. 264, pl. A, 1 fig. ; pl. B, 1 fig.
1905. *Ctenocephalus canis* var. *felis*, Baker, *Proc. U. S. Nat. Mus.* XXIX, p. 131.
1907. *Ctenocephalus felis*, Tiraboschi, *Arch. Parasitol.* XI, pp. 592, 593, text-figs. 11B, 11B′.
1911. *Ctenocephalus felis*, Jordan and Rothschild, *Novitates Zoologicae*, XVIII, pp. 67, 68.
1915. *Ctenocephalus felis*, Rothschild, *Entom. Month. Mag.* (3) I, pp. 56, 57, 92, 93, pl. vii, figs. 5, 11.

Head.—The frons is longer and more pointed at the anterior end than in *C. canis*, especially so in the female. The two bristles on the frons are weaker than those in *C. canis*, especially the one at the anterior oral corner. The genal comb has 16 spines (rarely 15) ; the two anteriormost and the one situated at the apex of the genal lobe are longer and stronger than those in *C. canis* : the former are approximately as strong as those behind them. The internal frontal tuber is longer than that in *C. canis*. The occiput has only 2 bristles behind the antennal groove and its subapical row consists of 10 bristles (rarely 8 or 9). The male has two rows, each consisting of 8 short and stout hairs behind the antennal groove, while they are absent in the female.

Thorax.—The pronotal comb contains 14-17 spines in the male and 15-18 spines in the female. The number of bristles in the row on the pronotum is 10-13, on the mesonotum 11-13 and on the metanotum 9-12 (generally 10). The mesothorax bears a single bristle on the episternum and 4 bristles on the epimerum. The metathorax has one bristle on the sternum and 2 (rarely 3) on the episternum and two rows of 4-7 and 5-8 bristles on the epimerum.

Abdomen.—The first row on the first tergite has 2-4 bristles (rarely 5 or 6) and the second row has 4 bristles (rarely 5 or 6). Tergites II—VI have each 10 or 11 (rarely 12 or 13) bristles and tergite VII possesses 10 (sometimes 8 or 9) bristles. Sternite II possesses only 2 bristles, while sternites III—VII have each 2-4 bristles (always 4 in ♀). The stigmata are much smaller than in *C. canis*.

Legs.—The fore coxa is less hairy than in *C. canis* and bears about 20 comparatively less stout bristles on the outer surface. The comb of the hind coxa has 6-12 spinelets. The fore femur has 3-7 bristles on the outside and a single subapical ventral bristle. The hind femur has 6-9 bristles on the inner side and 2 subapical ventral bristles on the outer side. There are 7-11 bristles on the outer side of the hind-tibia : it also bears 6 dorsal notches including the apical one, of these only the fifth notch has a single bristle. The mid tarsus is more slender than that in *C. canis*, especially its second segment.



TEXT-FIG. 12.—*Ctenocephalus felis* ♀ : (*a*) hind tarsus, × 82 ; (*b*) terminal segments of the abdomen, × 82 ; (*c*) spermatheca, bursa copulatrix and associated structures, × 150.

a. s. anal stylet ; *b. c.* bursa copulatrix ; *d. o.* ductus obturatorius ; *d. r. s.* ductus receptaculi seminis ; *py.* pygidium ; *s.* stigmata ; *sp.* spermatheca ; *st. vii., st. viii.*, seventh and eighth sternites ; *t. viii., t. ix., t. x.* eighth, ninth and tenth tergites.

Modified Segments.—♂. The eighth sternite bears a vertical row of 6 bristles and 2 bristles are present in front of the row. The moveable finger ($P^{2'}$) is somewhat pointed at the distal end; its greater proximal half along the ventral margin, which is strongly chitinised, is devoid of hairs. The breadth of the manubrium is practically uniform throughout. The dorsal tooth on the ejaculatory tube is either absent or poorly indicated. ♀. The eighth tergite bears 7-10 bristles in the apical row, 2 (rarely 3) bristles on the apical margin and 4 or 5 bristles on the inner side. There are 3 or 4 bristles in the lateral row. The anal stylet is about three times as long as broad. The spermatheca and bursa copulatrix are as in *C. canis*, but the ductus obturatorius and the ductus receptaculi seminis are longer than in that species.

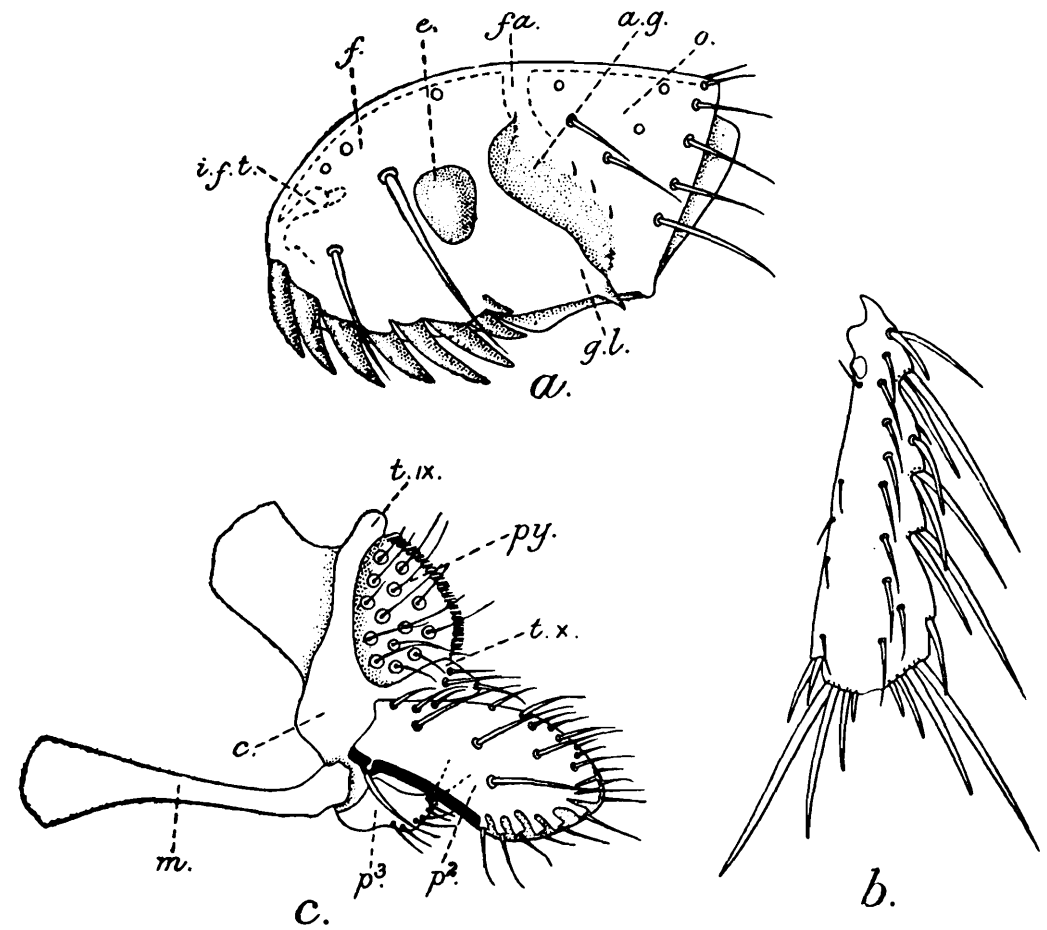
Distribution and Hosts.—This species is cosmopolitan in its distribution and appears to be the most widely distributed flea. It is found in all climes but flourishes best in tropical countries. Its chief host is the cat, but it is also found on other carnivores and occasionally attacks man and rodents. It is found all over India but appears to be less

common than its subspecies *orientis*. I have examined about one hundred lots from places all over India, Burma and the Andamans.

Subsp. **orientis** Jordan.

1925. *Ctenocephalus felis orientis*, Jordan, *Novitates Zoologicae*, XXXII, p. 99.

This subspecies is intermediate between *C. canis* and *C. felis* as it possesses certain characters in common with *C. canis* and others with *C. felis*. It differs from the typical form in the following points. The frons is more broadly rounded ; it is nearly as short and rounded as in *C. canis*. The anteriormost genal spines and the one at the apex of the genal lobe are as strong as in the *forma typica*. The female has a row of 1-8 short stout hairs behind the antennal groove. The abdominal stigmata are larger in size than those in the typical form, but not so large as in *C. canis*. The hind tibia possesses seven dorsal notches including the apical one and the third and sixth notches only bear each a bristle.



TEXT-FIG. 13.—*Ctenocephalus felis* subsp. *orientis* : (*a*) ♀, head, × 82 ; (*b*) ♂, hind tarsus, × 82 ; (*c*) ♂, upper portion of the terminal genital segments, × 133.

a. g. antennal groove ; *c.* clasper ; *e.* eye ; *f.* frons ; *fa.* falx ; *g. l.* genal lobe ; *i. f. t.* internal frontal tuber ; *m.* manubrium ; *o.* occiput ; p^2., p^3. second and third processes of the clasper ; *py.* pygidium ; *t. ix.*, *t. x.* ninth and tenth tergites.

Modified Segments.—♂. The eighth sternite bears a vertical row of 8 bristles (rarely 6 or 7) with 1 or 2 bristles in front of the row. The manubrium is widened at its apex into a spatula-like structure as in *C. canis*. ♀. The eighth tergite bears 7-11 bristles in the apical row and 4-7 bristles on the inner side. There are 3 (sometimes 4) bristles

in the lateral row. The spermatheca, bursa copulatrix and associated structures are more like those of *C. canis* than of *C. felis*.

Distribution and Hosts.—This subspecies has been recorded from the Admiralty Islands and Rook Island of the Bismarck Archipelago, the Philippine Islands, Sumatra, Pulo Bali (off west coast of Sumatra), Malay Peninsula, Burma, India and Ceylon. In India it appears to be the commonest flea of the genus *Ctenocephalus* and replaces *C. canis*. Its chief hosts are the dog, the goat and cattle, but it is sometimes found on the cat, sheep, the rat and the squirrel.

I have examined about 160 lots from all over India, Burma and the Andamans.

A NEW SPECIES OF BRANCHIOPOD FROM SOUTHERN INDIA.

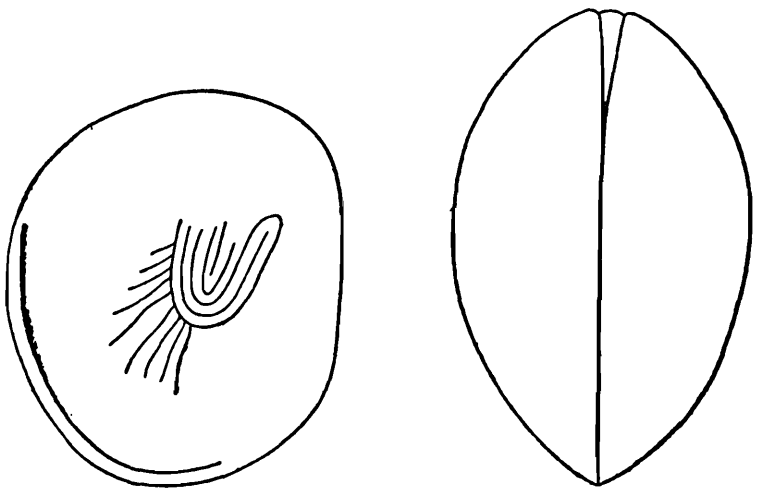
By ROBERT GURNEY.

(Plate I.)

Limnetis (Lynceus) denticulatus, n. sp.

Male.—Shell in side view oval, length 3 mm., height 2·3 mm., the greatest height in the middle. Posterior margin very slightly narrowed. In dorsal view relatively narrow—length 162, width 100. The edge of the shell, in the posterior region, is fringed with a row of small teeth. These are stronger on the right than on the left valve. Rostrum broad, with truncate apex, the median keel very prominent, and rounded in side view. The apex is a flattened or slightly concave triangular area. Ridge of fornix ending at the posterior angles of this area, which are consequently rather prominent.

Prehensile legs symmetrical, or nearly so. Hand (joint 5) much longer than broad (54 : 36), tapering distally, the inner margin bearing a row of strong short spines and a number of setae. The outer edge is roughened, with many small tubercles. These tubercles are more numerous on the right than on the left leg. Terminal claw long, curved and not dilated.



a. *b.*

Limnetis (*Lynceus*) *denticulatus*, n. sp.
a. Outline of shell, male.
b. Outline of shell, male, dorsal view.

Female.—Shell of same shape and size as male.

Anterior end of rostrum very broad, with a slightly upturned flattened area at the end, the edges of which are strongly toothed. Median ridge reaching to the edge of the flattened area. The " lamina abdominalis " consists of a membranous plate with three finger-like processes, folded downwards and outwards, and two long curved processes turned forwards near the middle line.

Locality.—Ammayanayakanur (Kodaikanal Road Station), Madura District. Collected by Dr. F. H. Gravely, June 9th, 1929, in temporary shallow pools on low lying ground just across the road from Kodaikanal Road Station.

Types in the Indian Museum, Calcutta.

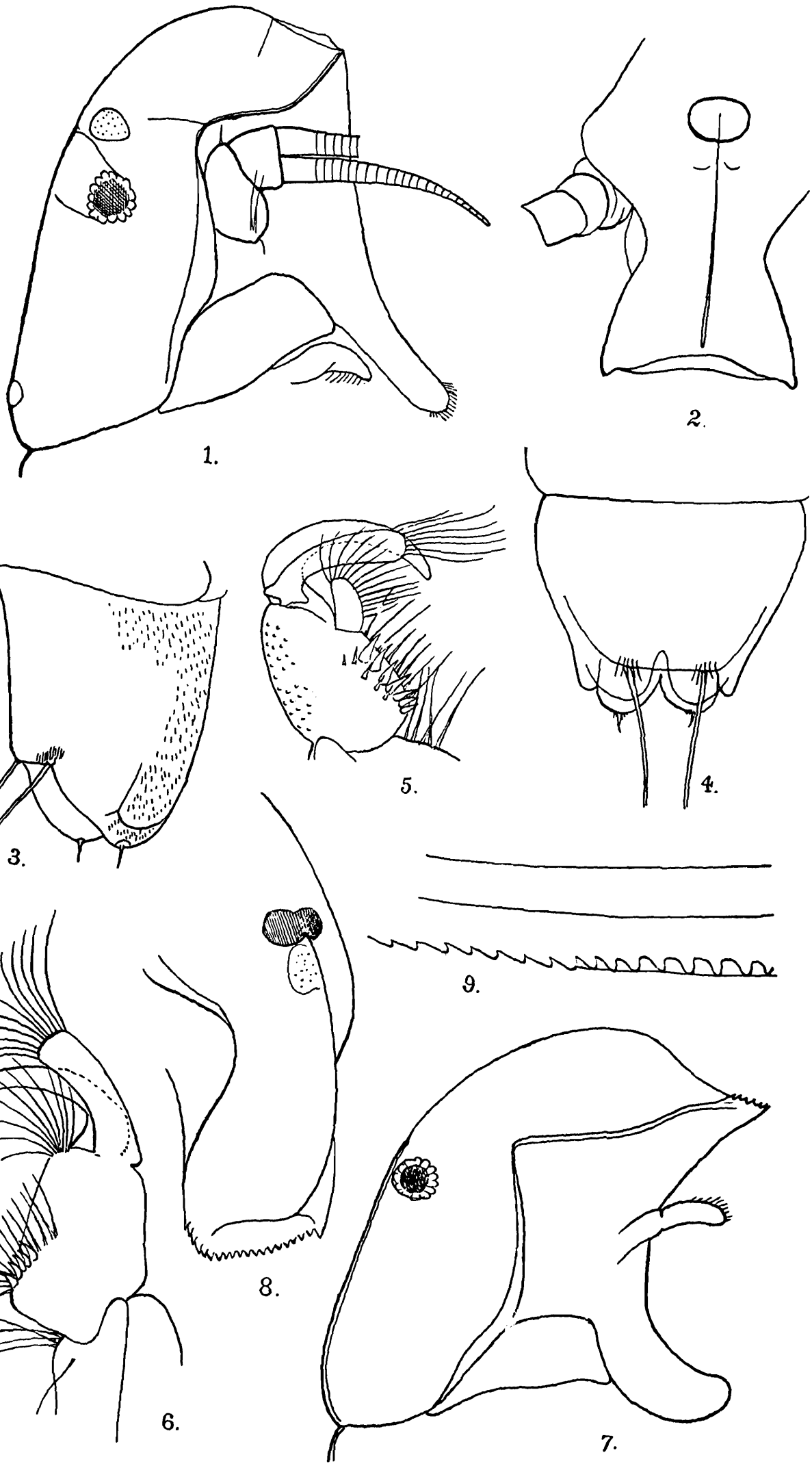
The only species of this genus hitherto described from India is *L. indicus* Daday from the Himalayas. The differences between the two species are small, but the southern form is readily distinguished by the denticulated rostrum of the female. There are also small differences in the prehensile legs of the male and in the shape of its rostrum.

MGIPC—M—III-8-14—24-3-30—500.

EXPLANATION OF PLATE I.

Limnetis (Lynceus) denticulatus, n. sp.

FIG. 1.—Head of male.
,, 2.—Head of male, anterior view.
,, 3.—Posterior abdomen of male, lateral view.
,, 4.—Posterior abdomen of male, dorsal view.
,, 5.—Right leg of male.
,, 6.—Left leg of male.
,, 7.—Head of male, side view.
,, 8.—Head of male, oblique view.
,, 9.—Edge of shell.



Limnetis (Lynceus) denticulatus, n. sp.