STUDIES ON INDIAN ECHIURIDS WITH SPECIAL REFERENCE TO *IKEDOSOMA PIROTANSIS* MENON AND DATTAGUPTA

By

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Supervisor's Note

The thesis entitled "Studies on Indian Echivide with special reference to *Ikedosoma pirotansis* Menon and Dattagupta is a piece of original work of Sri P. K. B. Menon.

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INTRODUCTION

Our knowledge about the Indian echiuroids is very limited. The earliest report of an echiuroid from India was that of Thurston (1895) who reported a species of Thalassema from the Gulf of Mannar. Shipley (1903), Annandale and Kemp (1915), Annandale (1922), Prashad and Awati (1929), and Prashad (1919a, 1919b, 1920, 1935) were mainly responsible for the description of a number of Indian echiuroids. There was a big gap in the study of Indian echiuroids since 1935. In recent years the study of echiuroids has been taken up in India by a group of workers with whom I am also associated. I had many opportunities of visiting the coasts of Gulf of Kutch, southern and western coasts of India, and Andaman and Nicobar Islands (Bay of Bengal). Echiurids and bonellids are occasionally found along the coasts of Gujerat (Gulf of Kutch) Portblair and Car Nicobar islands (Bay of Bengal) and Kerala (Arabian sea) . In Pak Bay and Gulf of Mannar they are, however, of less frequent occurrence. Some echiurids were reported from Chilka Lake (Orissa).

Attempts to suggest a phylogenetic classification of Echiuroidea have been made only recently (Bock, 1942; Fisher, 1946; Dawydoff, 1959). Still every worker in this field feels for a more satisfactory classification. The real difficulties facing the echiuroid taxonomist are the inadequate description of species. In recent years several new species have been added to this group and the available descriptions are so brief and sometimes so incomplete that it is difficult to ascertain the true relationship with any degree of certainity. It should be important at this stage to describe adequately the species available and to study their distribution and relationship. Such studies would evidently throw light on the evolutionary pattern of the group. With this object in mind, I have taken up the work on Indian echiuroids. In the course of the work I have discussed certain features in the anatomy of echiurids which would be useful in the classification of the group.

CHAPTER I

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1. General Introduction to Echiuroidea

Quartefages (1847) established the group Gephyrea (a bridge) in which he included Echiuroidea, Sipunculoidea and Priapuloidea. Sedgwick (1898) set up separate phyla each for Sipunculoidea and Priapuloidea but retained Echiuroidea as a class of Annelida. Hatschek (1880) and Lang (1888) regarded echiuroids as chaetopod annelids. It was only recently (Newby 1940) an independent status of a phylum was assigned to this group. Fisher (1946) also treated Echiuroidea as a distinct phylum. He writes "when numerous differences which appear in their development are considered, it seems improbable that the inclusion of the echiuroids with the annelids as a subphylum or class, is justified. It is probably more accurate to consider the Echiuroidea as forming a separate phylum, distinct from the phylum Annelida'. Marcus (1958) regarded Echiuroidea as degenerate forms derived from the Annelida.

The echiuroids are soft bodied animals, with a long or short proboscis. The proboscis may be short, spatula like, or long, ribbon shaped . One or two genera have only rudimentary proboscis. Most of the echiuroids have anterior ventral setae ~~while~~ Whereas two genera have additional anal circlets of setae . The body of echiuroids is covered by papillae. The proboscis leads into a mouth. The alimentary canal is highly coiled and the intestine is always accompanied by siphon . The segmental organs are nephridia which are more numerous in echiurids than bonellids . The nephridia are functional gonoducts and in many bonellids the males live in the nephridia of females. There is a pair of anal vesicles which open into the rectum. The shape and size vary in different members.

The echiuroids are generally burrowing forms; some of them live in soft mud, or in excavations of coral rocks . A few forms live at a depthof 4 to 6 feet under sand, mud or shingle in the littoral area. While they are generally littoral; a few echiuroids have been reported from deep sea. The echiuroids are found in tropical, temperate, arctic and antarctic regions, and Stephen (1941) suggested a 'bipolarity in the distribution of echiurids. So far only eleven genera of echiurids and 20 genera of bonellids are known . Collection of echiuroids is often very tedious and laborious and this perhaps is one of the reasons for their rarity.

2. Review of the Classification of Echiuroidea

Attempts to classify echiuroids were made only in the beginning of the century, though several genera of echiuroids were already known. Lankester (1883) made a comparative study of the genera *Hamingia*, *Bonellia* and *Thalassema*. Reitsch (1886) published a general survey of the group and he recognised five genera of echiuroids.

Delage and Herouard (1897) described seven echiuroidean genera. They are Echiurus (Guerin), Thalassema(Gaertner), Bonellia (Rolando), Hamingia (Danielssen and Koren), Saccosoma (Danielssen and Koren), Epithetosoma (Koren and Danielssen) and Sternaspis (Otto). Shipley (1899) mentioned five genera and thirty one species of echiuroids and dropped the genus Sternaspis and Epithetosoma from his list. Rietsch (1886) expressed that Sternaspis should be transferred to Polychaeta. Theel (1906) stated that Epithetosoma was most likely a nemertine. Bock (1920) established that Epithetosoma is a nemertine belonging to the genus Micrura of the family Lineidae. Up to 1920 there was hardly any attempt to arrange the different genera of echiuroids in a systematic way. Monro (1927) made an attempt to arrange the then existing genera of echiuroids into families and subfamilies. His scheme is given below:

Class Echiuroidea
  Family Echiuridae
    Subfamily Echiurinae Genus Echiurus, Guerin
    Subfamily Urechinae Genus Urechis, Seitz
    Subfamily Thalassematinae
      Genus Thalassema , Gaentner
      " Ikeda , Wharton
  Family Bonelliidae
    Subfamily Protobonelliinae
      Genus Protobonellia, Ikeda

Subfamily Bonelliinae

Genus Bonellia, Rolando

" Archibonellia, Fisher

" Pseudobonellia, Johnston & Tiegs

" Ikedella, gen. nov. for
Bonellia misakensis, Ikeda

Subfamily Hamingiinae

Genus Hamingia, Koren & Danielssen

Genus Acanthohamingia, Ikeda

Genus Sluiterina, gen. nov. for
Hamingia sibogae, Sluiter

Baltzer (1934) classified the echiuroids into three groups based on the nature of frontal lobe (proboscis). He recognized 8 genera.

I. With frontal lobes undivided.

Echiurus Guerin
Urechis Von Drasche
Thalassema Lamarck
Ochetostoma (Leuckart and Ruppell)
Listriolobus Spengel
Hamingia Koren and Danielssen

II. With bifid frontal lobe.

Bonellia Rolando

III. Without frontal lobe.

Saccosoma Koren and Danielssen

Since Baltzer many new echiuroids were discribed. Bock (1942) listed the following genera in addition to Baltzer's list of 1934.

Protobonellia Ikeda.
Acanthohamingia Ikeda.
Ikeda Wharton
Pseudobonellia Johnston and Tiegs
Archibonellia Fischer
Parabonellia Onoda
Arhynchite Sato
Ikedosoma Bock
Maxmulleria Bock

Bock (1942) had recognized 17 genera of echiuroids and suggested a new classification. He considered 'Echiuroidea' as a class under phylum Annelida. His scheme of Classification is as follows:

Order Echiuroinea nov.
  Family Echiuridae Baird.
      Genera *Echiurus* and *Urechis*
  Family Thalassematidae nov.
    Subfamily Ikedinae nov.
      Genus *Ikeda*
    Subfamily Thalassematinae nov.
      Genera *Thalassema*, *Ochetostoma*(incl. *Listriolobus*), *Ikedosoma* n.g. (for *Th. elegans* Ikeda) and *Arhynchite*.

Family Bonelliidae Baird.

Genera *Maxmulleria* n.g., *Acanthohamingia*,
Archibonellia, *Hamingia*,
Parabonellia, *Protobonellia*,
Pseudobonellia, *Bonellia*.

Order Saccosomatinea, nov.

Genus *Saccosoma* Kor. and Dan.

Order Poeobiinea, nov.

Family Poeobiidae Heath.

Genus *Poeobius* Heath.

Bock (1942) felt that the two orders Saccosomatinea and Poeobiinea should be considered as very aberrant annelids of somewhat doubtful relationship to the true echiurids. Fisher (1946) proposed a phylum Poeobiodea for *Poeobius* and thus removed it from Echiuroidea. He believed that *Poeobius* originated from a group common to the echiuroids and annelids. Heath (1930) considered this as a link between annelids and echiurids. Pickford (1947) reinvestigated the anatomy of *Poeobius* and found that this animal is only an aberrant polychaetous worm and that the acquisition of some of the echiuridan characters of *Poeobius* may have been the result of its descent from sedentary ancestor. Hartman (1955, 1961) Hyman (1959) and Dales (1962) regarded *Poeobius* as polychaete while Dawydoff (1959) placed *Poeobius* ' *incertae sedis* ' with in the Echiuroidea. Rothschild (1961) doubtfully placed *Poeobius* in the Polychaeta.

Berkeley and Berkeley (1960) committed Poeobius to Archiannellida. Robbins (1965) stated that Poeobius was certainly derived from a benthic form and arose from the archiannelid type quite early in the history of the Annelida. He writes "it is difficult to consider Poeobius a polychaete due to the absence of setae and external segmentation, however, it would be unwise to raise the species to class level. The solution seems to be a broader concept of "Polychaeta" to include the family Poeobiidae".

Fisher (1946) proposed a new scheme of classification. He considered Echiuroidea as a phylum (Newby 1940, Hyman 1940). His classification is as follow:

Phylum Echiuroidea

Class Echiurida, Body wall with innermost circular or oblique layer of muscles well developed; anal vesicles present; collateral intestine or siphon well developed; proboscis and anterior setae present in nearly all species.

Order Echiuroinea Bock, emended

A closed blood-vascular system; no specialization for intestine for anal respiration.

Family Bonelliidae

Genus Bonellia Rolando

" Bonelliopsis, n.g.

" Pseudobonellia Johnston and Tiegs

Genus *Archibonellia* Fischer

" *Parabonellia* Onoda

" *Eubonellia*, n.g.

" *Protobonellia* Ikeda

" *Maxmulleria* Bock

" *Hamingia* Danielssen and Koren

" *Nellobia*, n.g.

" *Acanthohamingia* Ikeda

Family Echiuridae (de Blainville, 1827, restricted)

Genus *Echiurus* Guerin-Meneville

" *Arhynchite* Sato

" *Thalassema* Lamarck

" *Anelassorhynchus* Annandale

" *Lissomyema*, n.g.

" *Listriolobus* Fischer

" *Ochetostoma* Leuckart and Ruppel

" *Ikedosoma* Bock

Order Xenopneusta , new order.

No vascular system, coelomic fluid being heavily charged with large blood corpuscles containing hemoglobin or hemoglobin plus hematin; intestine with terminal portion enlarged, thin-walled, to receive water from cloacal pump.

Family Urechidae Fisher and MacGinitie, 1928

Genus *Urechis* Seitz

Order Heteromyota, new order.

Longitudinal layer of body wall lying outside both the circular layer and inner oblique layer; nephridia excessively numerous, unpaired and with terminal nephrostome; proboscis excessively long.

Genus Ikeda Wharton

Class II Sactosomatida, Body wall with innermost circular layer missing or degenerated to a net of fibers; no anal vesicles; apparently no siphon; no proboscis and no setae.

Genus Sactosoma

Dawydoff (1959) adopted the following classification:

Class Echiuroidea

Family Echiuridae de Blainville

Genus Echiurus Seitz.

Family Thalassemidae S. Bock (pro parte).

Genus Thalassema Lamarck,

" Ochetostoma Leuckart and Ruppel

" Listriobolus Spengel,

" Ikedosoma Bock.

Family Bonelliidae Baird, (emend.)

In addition to Fisher's (1946) list the following species were included by Dawydoff under the family Bonelliidae.

Genus Prometor Fisher

" Amalosoma Fisher

" Austrobonellia Fisher

" Achaetobonellia Fisher

" Sluiterina Monro

" Acanthobonellia Fisher

" Tatjanellia Zenkewitch

" Vitjazema Zenkewitch

Genus *Jakobia* Zenkewitch

" *Alomasoma* Zenkewitch

Family Urechiidae

Genus *Urechis* Seitz

Family Ikedaidae nov (= Ikedinae S.Bock).

Genus *Ikeda* Wharton

INCERTAE SEDIS

Genus *Platylobostoma* Wesenberg Lund

Poebius Heath

Family Saccosomidae Danielssen and Koren

Genus *Saccosoma* Dan and Kor

Wesenberg Lund (1959a) considered *Platylobostoma* nearer to *Ochetostoma*.

Systematic accounts of echiurids were available in the works of Fischer (1892, 1896a, 1896b, 1925, 1926a , 1926b, 1928);Ikeda (1904, 1907, 1908, 1924) Sato (1935, 1939) Shipley (1898a and 1898b, 1899, 1903), Selenka (1885, 1899, 1902) Lanchester (1905a, 1905b), Prashad (1919a, 1919b, 1920 , 1935). Wesenberg Lund (1932, 1934, 1937, 1938, 1939, 1955, 1959), Fisher (1946, 1947 , 1949) , Stephen (1936, 1941 , 1960), Bock (1942) and Datta Gupta et al (1961, 1963, 1965).

Brief descriptions of echiurids are available in all the systematic accounts. Detailed anatomical works are available only for a few species. Anatomy of *Thalassema neptuni* was studied by Lankester (1881) Rietsch (1886) and Jameson (1899). ~~while~~ *Echiurus pallassi* was studied by Greef (1879) and Spengel (1880). Embelton (1900) described the structure and affinities of *Echiurus unicinctus* (= *Urechis unicinctus*). Many useful anatomical details were given by Fisher (1946) with regard to many echiurids in addition to a detailed account of *Urechis caupo* and its systematic position. Ikeda (1907) described the salient features of *Ikedosoma elegans* and *Ikeda taenioides*. Prashad (1919a) described in detail the anatomy of *Thalassema branchiorhynchus*. Awati (1936) and Awati and Desh Pande (1936) worked out the anatomy of the proboscis and alimentary canal of *Thalassema bombayensis* respectively.

3. Introduction to Indian Echiuroidea

Echiurids are fairly common along the Indian sea shore, but still the group as a whole did not receive much attention among the workers. This is mainly due to the difficulties in obtaining specimens, since most of them live buried either in sand or mud and it is more or less a chance to find a specimen during collection trips.

Thurston (1895) perhaps was the first to report an echiurid from Indian waters. He described a species of *Thalassema* Lamarck from Gulf of Mannar. The species was described as *Thalassema formolosum*. According to Prashad

(1920) this species was *Thalassema formosulum* Lampert, and the name in Thurston's work was regarded as a *lapsus calamni*'. Shipley (1903) described the following five species of echiurids from the Minikoi and Maldive islands.

Thalassema diaphanes Sluiter
Thalassema moebii Greef
Thalassema semoni Fischer
Thalassema vagrande Lampert
Thalassema erythrogrammon Leuckart and Ruppel

Annandale and Kemp (1915) described *Thalassema dendrorhynchus* and *Thalassema branchiorhynchus.* Prashad (1919a) in his accounts of echiurids collected from Talesap (Far east), Chandipore (Orissa) and Ross Islands (Anadamans) reported a new species *Thalassema kempi* besides *Thalassema dendrorhynchus* Ann and Kemp *Thalassema branchiorhynchus* Ann and Kemp and *Thalassema sabinum* Lanchester. *Thalassema microrhynchus* was reported from Chandipore bay (Prashad 1919b). *Thalassema hornelli* was described by Prashad (1920) from the Gulf of Mannar. Annandale (1922) proposed a new genus *Analassorhynchus* to accommodate *Thalassema dendrorhynchus*. The other species of the genus are *Thalassema branchiorhynchus*, *Thalassema sabinum* and *Thalassema microrhynchus* . Prashad and Awati (1929) described *Thalassema bombayensis* . Prashad's report (1935) on a collection of Indian echiurids of the genus *Thalassema* of the Indian museum mentioned four species viz. *Thalassema caudex* Lampert, *Thalassema diaphanes*

Sluiter, *Thalassema arkati* Prashad and *Thalassema marshali* Prashad. The latter two were new species. Datta Gupta and Menon (1961) have reported *Ochetostoma zanzibarense* Stephen and Robertson which was collected from the littoral zone of Pirotan island (Gulf of Kutch).Menon and Datta Gupta (1962) described *Ikedosoma pirotansis*, a new species from theGulf of Kutch. In an account of Indian echiurids from the Indian waters (Datta Gupta *et al* (1963) listed six species of echiurids viz. *Anelassorhynchus chaetifera* a new species, *Anelassorhynchus sabinum*, *Ochetostoma septemyotum*, a new species, *Ochetostoma formosulum*, *Ochetostoma zanzibarense* and *Ikedosoma pirotansis*. In a recent paper Datta Gupta and Menon (1965) reported *Listriolobus brevirostris* Chang, *Anelassorhynchus moebii* Greef and a new species of *Anelassorhynchus loborhynchus*.

Compared with the Indian echiurids the Indian bonellids are much less known. *Bonellia virdis* Rolando was reported by Shipley from Maldive islands (1903). During the survey of the littoral fauna of the Gulf of Kuch, Gideon et al. (1956) reported *Ikedella misakiensis*. Menon, et al.(1964) reported the following five species of bonellids belonging to 3 genera.

Bonellia minor Marion
Acanthobonellia miyajimai (Ikeda)
Acanthobonellia vulgaris Menon and Datta Gupta
Acanthobonellia rollandoe Menon and Datta Gupta
Ikedella misakiensis (Ikeda)

Jose (1964) described Acanthobonellia pirotanensis, from Gulf of Kutch.

Anatomy of Indian echiurids was not adequately studied. The detailed anatomy of an Indian echiurid is given by Prashad (1919a) who described the anatomy of Thalassema branchiorhynchus with comparative notes on other species of Thalassema collected by him. Awati and Deshpande (1936) studied the proboscis and alimentary canal of Thalassema bombayensis.

4. Historical review of the genera and species of echiurids reported from India.

Ikedosoma Bock 1942

Bock proposed the genus Ikedosoma with as type species Thalassema elegans Ikeda (Ikeda 1904). The generic distinction was the presence of large number of segmental organs. Fisher (1946) independent of Bock suggested that Thalassema elegans did not belong to the genus Thalassema. Fisher (1946) writes " the structure of the body wall closely approximates that of Ochetostoma but elegans is peculiar in having numerous nephridia in six or seven pairs of groups comprising one to three nephrida each. The internal opening present at base is provided with 2 relatively short spiral lobes. The dorsal blood vessel ends with the heart on the hind end of the pharynx and is therefore shorter than in typical Echiuridae. The neurointestinal vessel arises from the ventral median point of the ring sinus which surrounds the extreme hind end of pharynx. There is no interbasal muscle and no intestinal caecum". Fisher (1946) regarded *Thalassema gogoshimense* Ikeda congeneric with *T. elegans*. Bock (1942) did not refer to *T. gogoshimense* as a distinct species. According to Ikeda (1944) the latter shows an essential agreement with *T. elegans* , the only difference being that all the internal organs in *T. gogoshimense* are developed on a smaller scale in proportion to the smaller size of its body. In the females there are only 3 pairs of nephridia situated behind the setae while in the male there are six to eight groups arranged in pairs which are like those of *T. elegans*. Thus, if we accept that *T. gogoshimense* and *T. elegans* are congeneric , then there were known only two species of *Ikedosoma*. Recently Menon and Datta Gupta (1963) collected a number of specimens from Gulf of Kutch which they have described as a new species of *Ikedosoma* viz. *Ikedosoma pirotansis*.

Genus *Ikedosoma* Bock 1942

Ikedosoma pirotansis Menon and Datta Gupta

1961 *Ikedosoma pirotansis*, Menon and Datta Gupta, p.305

1963 *Ikedosoma pirotansis*, Datta Gupta et al, p. 62.

Listriolobus W. Fischer 1926

Spengel (1912) established the genus *Listriolobus* for *Thalassema erythrogrammon* of Sluiter (1883) and Wilson (1900). Spengel regarded *Thalassema mellita* Conn also related to Sluiter's and Wilson's specimens and proposed the generic name *Listriolobus*. William Fischer (1926) named Wilson's and Sluiter's specimens *Listriolobus bahamensis* and *Listriolobus billitonensis* respectively. According to Fisher (1946), this was the first association of *Listriolobus* with a species from which a type can be chosen and therefore *Listriolobus* Spengel 1912 was to be considered as 'nomen nudum'. However, Dawydoff (1959) associated Spengel with the genus *Listriolobus*. Bock (1942) regarded *Listriolobus* as a subgenus of *Ochetostoma*. *Thalassema mellita* Conn was made the type of a new genus *Lissomyemma* (Fisher 1946).

Listriolobus Fischer 1926

Listriolobus brevirostris Chen Y and Chen Chang Y

1958 *Listriolobus brevirostris*, Chen Y and Chen Chang Y p.276.
1965 *Listriolobus brevirostris*, Datta Gupta and Menon p. 193.

Anelassorhynchus Annandale 1922.

Annandale (1922) proposed the genus *Anelassorhynchus* to include *Thalassema branchiorhynchus* Ann and Kemp and *Thalassema dendrorhynchus* Ann and Kemp. In these two species the proboscis is short and the lateral margins of the proboscis have dendritic gill-like outgrowths. To this genus he also added *Thalassema sabinum* Lanchester and

Thalassema microrhynchus Prashad. *Anelassorhynchus* resembles *Thalassema* in having a continuous longitudinal layer of muscles in the body. It differs from *Thalassema* in having long spirally coiled lateral lips to the nephrostome.

Anelassorhynchus Annandale 1922.

Anelassorhynchus branchiorhynchus (Ann and Kemp)

1915 *Thalassema branchiorhynchus* Ann and Kemp,p.61
1919 *Thalassema branchiorhynchus*, Prashad p. 324.
1922 *Anelassorhynchus branchiorhynchus*, Annandale p.181.
1935 *Thalassema branchiorhynchus*, Prashad p. 399.
1946 *Anelassorhynchus branchiorhynchus* Fisher p. 22.
1949 *Anelassorhynchus branchiorhynchus* Fisher p. 481.
1963 *Anelassorhynchus branchiorhynchus* Datta et al.p.61.
1965 *Anelassorhynchus branchiorhynchus* Datta Gupta and Menon, pp. 195,199.

Anelassorhynchus dendrorhynchus (Ann and Kemp)

1915 *Thalassema dendrorhynchus* Ann and Kemp. p. 58
1919 *Thalassema dendrorhynchus*, Prashad, p. 324.
1922 *Anelassorhynchus dendrorhynchus*, Ann andale p. 148.
1946 *Anelassorhynchus dendrorhynchus*, Fisher, p. 22.
1949 *Anelassorhynchus dendrorhynchus*, Fisher p. 481.
1963 *Anelassorhynchus dendrorhynchus* Datta Gupta et al.p.61.
1965 *Anelassorhynchus dendrorhynchus* Datta Gupta and Menon, p. 199.

Anelassorhynchus microrhynchus Prashad

1919 *Thalassema microrhynchus*,Prashad, p. 42.
1922 *Anelassorhynchus microrhynchus*, Annandale p. 148.

Anelassorhynchus vegrandis (Lampert)

1883 *Thalassema vegrande* Lampert, p. 341.

1899 *Thalassema vegrande*, Shipley, p. 352.
1902 *Thalassema vegrande*, Shipley, p. 130.
1946 *Anelassorhynchus vegrandis*, Fisher p. 221.
1949 *Anelassorhynchus vegrandis*, Fisher p. 481.
1960 *Anelassorhynchus vegrandis*, Edmonds, p. 91.
1965 *Anelassorhynchus vegrandis*, Datta Gupta and Menon, p. 199.

Anelassorhynchus semoni (Fischer)

1896 *Thalassema semoni*, Fischer, p. 21- 28.
1902 *Thalassema semoni*, Shipley, p. 128.
1902 *Thalassema semoni*, Sluiter, p. 47.
1913 *Thalassema semoni*, Wharton, p. 247.
1946 *Anelassorhynchus semoni*, Fisher, p. 222.
1949 *Anelassorhynchus semoni* Fisher p. 481.
1959 *Thalassema semoni* Wesenberg Lund p. 216.
1965 *Anelassorhynchus semoni*, Datta Gupta and Menon, p. 199.

Anelassorhynchus chaetifera Datta Gupta and Menon.

1963 *Anelassorhynchus chaetifera* Datta Gupta et al, p. 61.
1965 *Anelassorhynchus chaetifera*, Datta Gupta and Menon, p. 199.

Anelassorhynchus loborhynchus Datta Gupta & Menon.

1965 *Anelassorhynchus loborhynchus*, Datta Gupta & Menon, p. 198.

Thalassema *Lamarck* 1816

The generic name *Thalassema* was first used by Lamarck. The original genus *Thalassema* was split up into *Ochetostoma*, *Listriolobus* and *Thalassema* by Spengel (1913). At present the genus has been restricted to a few species.

The following genera of echiuroids were once included under the genus *Thalassema*.

Ochetostoma Leuckart & Ruppel 1828
Ikeda Wharton 1913
Anelassorhynchus Annandale 1922
Listriolobus Fischer 1926
Arhynchite Sato 1937
Ikedosoma Bock 1942
Maxmulleria Bock 1942
Lissomyema Fisher 1946

The only species of *Thalassema* so far described from Indian Waters is *Thalassema* diaphanes Sluiter.

Thalassema Lamarck, 1816

Thalassema diaphanes Sluiter

1888	*Thalassema diaphanes* Sluiter, p. 244.
1899	*Thalassema diaphanes* Shipley, p. 366.
1902	*Thalassema diaphanes* Shipley, p. 128.
1913	*Thalassema diaphanes* Wharton, p. 262.
1935	*Thalassema diaphanes* Prashad, p. 41.
1959a	*Thalassema diaphanes* Wesenberg Lund, p. 214.
1959b	*Thalassema diaphanes* Wesenberg Lund, p. 199.

Genus *Ochetostoma* Leuckart & Ruppel

Spengel (1912) re-established the genus *Ochetostoma* of Leuckart & Ruppel and included in it *Thalassema* like forms with longitudinal muscle layer interrupted by fasicles of inner oblique muscles.

Ochetostoma Leuckart & Ruppel

Ochetostoma zanzibarense Stephen & Robertson

1952 *Ochetostoma zanzibarense* ,Stephen & Robertson,p.431.
1959 *Ochetostoma zanzibarense*, Wesenberg Lund, p. 69.
1961 *Ochetostoma zanzibarense*, Datta Gupta & Menon,p.829.
1963 *Ochetostoma zanzibarense* Datta Gupta et al., p.60.

Ochetostoma formosulum (Lampert)

1883 *Thalassema formosulum* Lampert, p. 339.
1899 *Thalassema formosulum*, Shipley, p. 348.
1895 *Thalassema formosulum*, Thurston, p. 116.
1902 *Thalassema formosulum*, Sluiter, p. 48.
1920 *Thalassema formosulum*, Prashad, p. 37.
1946 *Ochetostoma formolusum*, Fisher, p. 241.
1963 *Ochetostoma formosulum*, Datta Gupta et al. p. 57.

Ochetostoma hornelli (Prashad)

1920 *Thalassema hornelli*,Prashad, p. 36.
1946 *Ochetostoma hornelli* Fisher, p. 241.

Ochetostoma bombayensis (Prashad & Awati)

1929 *Thalassema bombayensis* , Prashad & Awati, p.259.
1936 *Thalassema bombayensis* ,Awati, p. 96.
1936 *Thalassema bombayensis*, Awati & Dashpande,p.68.
1946 *Ochetostoma bombayensis*, Fisher, p. 241.

Ochetostoma kempi (Prashad)

1919 *Thalassema kempi* Prashad, p. 336.
1935 *Thalassema kempi*, Prashad, p. 40 and 41.
1946 *Ochetostoma kempi*, Fisher, p. 241.

Ochetostoma arkati (Prashad)

1935 *Thalassema arkati* Prashad , p. 41.
1946 *Ochetostoma arkati*, Fisher, p. 241.
1959 *Ochetostoma arkati*, Wesenberg Lund, p. 203-204.

Ochetostoma septemyotum Datta Gupta & Menon

1963 Ochetostoma septemyotum, Datta Gupta & Menon, p.5

Ochetostoma erythrogrammon Leucart & Ruppel

1828 *Thalassema erythrogrammon* Leucart & Ruppel,p.78.
1862 *Thalassema* ~~*caudex*~~ erythrogrammon, Maxmuller, p. 16.
1879 *Thalassema* ~~*caudex*~~ erythrogrammon, Greef p. 147.
1886 *Thalassema caudex*, Rietsch, p. 195.
1881 *Thalassema erythrogrammon*, Drasche p. 69.
1883 *Thalassema caudex*, Zeitschr p. 340.
1890 *Thalassema caudex*, Sluiter p. 110.
1892 *Thalassema kokotoniensis*, Fischer p. 82.
1892 *Thalassema stulhmani* , Fischer, p.82.
1892 *Thalassema leptodermon*, Fischer, p. 84-85.
1895 *Thalassema kokotoniensis*, Fischer p. 20.
1895 *Thalassema stulhmani*, Fischer, p. 20.
1898 *Thalassema caudex*, Shipley, p. 472.
1899 *Thalassema kokotoniensis*, Shipley, p. 337.
1899 *Thalassema caudex* ,Shipley, p. 347.
1899 *Thalassema caudex*, Shipley, p. 346.
1902 *Thalassema kokotoniensis*, Sluiter p. 46.
1902 *Thalassema caudex* ,Sluiter p. 49.
1902 *Thalassema erythrogrammon*, Shipley p. 128.
1902 *Thalassema leptodermon*, Sluiter p. 47.
1903 *Thalassema leptodermon*, Augener p. 297.
1903 *Thalassema stuhlmanni*, Augener p. 371.
1904 *Thalassema kokotoniensis*, Ikeda p. 60.
1912 *Ochetostoma erythrogrammon*, Spengel p. 316
1913 *Thalassema caudex*, Wharton p. 263.
1913 *Thalassema griffni*, Wharton, p. 243.
1914 *Thalassema multilineatum* ,Fischer p. 78.
1914 *Thalassema kokotoniensis*, Fischer p. 1-28.
1914 *Thalassema stuhlmanni*, Fischer p. 1-28.
1924 *Thalassema palense*, Ikeda p. 39- 41.

1935 *Ochetostoma erythrogrammon*,Sato p. 324.
1935 *Thalassema caudex* Prashad p. 39.
1939 *Ochetostoma erythrogrammon*, Sato, p. 357-359.
1946 *Ochetostoma erythrogrammon*, Fisher p. 241.
Ochetostoma stuhlmanni,Fisher p. 241.
Ochetostoma leptodermon ,Fisher p. 241.
Ochetostoma caudex,Fisher p. 241.
Ochetostoma kokotonniensis,Fisher p. 241.
Ochetostoma griffini,Fisher p. 241.
1952 *Ochetostoma erythrogrammon*,Stephen p. 181-182.
1952 *Ochetostoma erythrogrammon*,Stephen & Robertson, p. 430- 431.
1959a *Ochetostoma erythrogrammon*,Wesenberg Lund, p. 69.
1959b *Ochetostoma erythrogrammon*,Wesenberg Lund p.202-203
1962a *Ochetostoma erythrogrammon* Chuang p. 80 to 85.
1962b *Ochetostoma erythrogrammon* Chung p. 86- 93.
1954 *Ochetostoma erythrogrammon*,Wesenberg Lund p. 383.

CHAPTER II

MATERIAL AND METHODS

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The material for the present investigation was obtained from various sources. *Ikedosoma pirotansis* was collected from the littoral zone of Pirotan island (Gulf of Kutch). About fifty three specimens were examined. *Listriolobus brevirostris* was obtained from Thavara (Kerala). Thirty five specimens were studied . Two specimens of *Ochetostoma formosulum* from the Gulf of Kutch, eighteen specimens of *Ochetostoma septemyotum* from Quilon (Kerala) as well as Veeraval, (Gujerat) one specimen of *Anelassorhynchus sabinum* from the Gulf of Kutch, one specimen of *Anelassorhynchus chaetifera* from the Gulf of Mannar (Madras) one specimen of *Anelassorhynchus loborhynchus* from Gomti creek (Gujerat) and two specimens of *Anelassorhynchus moebii* from Laccadives have been examined. Further, I had the opportunity of studying the following specimens. Two specimens of *Anelassorhynchus branchiorhynchus* from the museum of Zoological Survey Calcutta, one specimen of the same species from the museum of the Department of Fisheries Okha; one specimen each of *Ikedosoma gogoshimmense*, *Ochetostoma bombayensis*, *Ochetostoma erythrogrammon*, *Ochetostoma kempi*, *Ochetostoma caudex*, *Anelassorhynchus moebii* and *Urechis unicinctus* from the museum of the Zoological Survey, Calcutta and two specimens of Thalassema neptuni from the museum of the Zoology Department , Panjab University,Chandigarh.

The collections were made during the period between 1959 and 1965.

The living specimens were killed in strong formalin and later preserved in 5 % formalin or 70 % alcohol. For histological studies various tissues of Ikedosoma pirotansis were fixed in Zenker's and Bouin's fluids, and 10 % formalin. Sections were cut at 6 u to 8 u thick and were stained in Delafield's haematoxylin, iron haematoxylin, and Mallory's triple stain.

For the study of eggs both paraffin and gelatin sections of the nephridia containing the eggs were cut at 7 u and 10 u respectively. Gelatin sections were stained in Sudan black B (Baker 1949) Sudan III and IV (Kay and Whitehead 1941) and Nile blue sulphate (Cain 1947). Paraffin sections were stained in Delafield haematoxylin/ eosin and iron haematoxylin/ eosin techniques. Periodic acid (PAS) technique (Hotchkiss 1948) along with acetylation and KOH reversal was used to detect the carbohydrates (McManus and Cason, 1950). Bromphenol blue (HgBPB) technique (Maizia and others 1952) and alkaline fast green (Alfert and Geschwind 1953) techniques were employed for the detection of protein. Methyl green/

pyronin G technique (Jordan and Baker 1955) along with salivary ribonuclease (Bradbury, 1956) and trichloroacetic acid and perchloric acid (Pearse 1960) controls was performed for detection of nucleic acids.

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CHAPTER III

MORPHOLOGY OF *IKEDOSOMA PIROTANSIS*

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1. External Morphology

Ikedosoma pirotansis in the preserved state measures 26 to 96 cm in length including proboscis. The fresh specimen is bright red in colour while the proboscis is pale white, with dark spots on the dorsal surface. When these animals are taken out of their burrows and kept in sea water they gradually lose their characteristic colour and start disintegration. It was observed that some kind of pigment diffuses into the water from its body.

A brief description of the species is already published (Menon and Datta Gupta 1962) . The proboscis is ribbon shaped and can extend to a great length. The ventral side of the proboscis is slightly concave and there is a median groove running from the base of the proboscis to the tip. This groove is ciliated and leads into the buccal cavity. The lower surface of the proboscis is not ciliated. There are no papillae on the proboscis.

The body is covered over by papillae. In the anterior region the papillae are large and are compactly arranged. Around the setal region the papillae are arranged concentrically(Fig. 1). In the middle part of the body they are scattered and project prominently from the surface (Fig. 2). Around the cloaca the papillae are again large and crowded(Fig. 3). Ventrally one can see a faint line running from the anterior to the posterior end. This is the ventral nerve cord seen through the body wall. Posterior to the setae on either side of the ventral nerve cord are seen the nephridiopores . The nephridiopores vary from 8 to 20 pairs. These pores are placed on the summit of enlarged papillae on either side of the mid ventral nerve cord. Considerable variations were observed in the number and arrangement of nephridiopores. Most of the nephridiopores are situated symmetrically on either side of the nerve cord (Fig. 1 , Menon & Datta Gupta 1962). A few posterior nephridiopores , however, show a definite asymmetrical arrangement. The details of these segmental organs are discussed later.

Ikedosoma pirotansis resembles *Ikeda taenioides* and *Ikedosoma elegans* in its general shape, body proportions and long proboscis. All these three worms have the same type of habitat. Ikeda stated that *T. elegans* inhabits the same shallow and muddy ground as *T. taenioides*. It lives in deep vertically or somewhat obliquely sunk pits which may be 4 feet deep and is scarcely distinguishable from those of *T. taenioides* (Ikeda 1904). *I. pirotansis* lives almost under the same conditions and all the above three forms exhibit perhaps an interesting example of convergence in response to similar habitat. *I. elegans* protrudes out its proboscis probably only at night but I. pirotansis extends its proboscis during low tide irrespective of the time. The arrangement of the papillae is also similar in three forms. Ikedosoma gogoshimense which I have examined at the Zoological Survey Museum (India), however, does not resemble I. pirotansis. This specimen was collected by Prof. I. Ijimai. The preserved specimen is greyish white in colour. Body is covered over with small papillae which are minute anteriorly. Posteriorly the papillae are bigger in size. The body measures 72 mm. in length and the length of the proboscis is only 13 mm. Only three pairs of nephridiopores could be seen. The nephridia are no doubt of the Ikedosoma elegans type with lateral nephrostomes having coiled filaments. Anal vesicles are tubular with short stalked funnels. This species may be congeneric with Ikedosoma elegans. But I am convinced that there is very little in common with Ikedosoma pirotansis and Ikedosoma gogoshimmense.

Short descriptions of Indian echiuroids are available in the papers which are appended (Gideon et al. 1956 , Datta Gupta and Menon 1961, Menon and Datta Gupta 1962, Datta Gupta et al 1963, Menon et al 1964, Datta and Menon 1965).

2. The Integument

The body wall in echiurids consists of cuticle, epidermis, cutis, the three muscular layers and the parietal layer of coelomic epithelium.

Cuticle.- The cuticle in *Ikedosoma pirotansis* is a thin non cellular covering secreted by the epidermis and its relative thickness varies in the different regions. It is altogether absent in the ventral part of the proboscis where the epithelium is ciliated. The papillae have a thicker layer of cuticle than the depressions between them. Anteriorly in the setal region the cuticle is very thick (Photo. 1). The cuticles of *L. brevirostris*, *O. bombayensis*, and *O. septemyotum* resemble that of *I. pirotansis*. In *L. brevirostris* the lateral and ventral marginsof the proboscis are profusely ciliated where they are thrown up into a number of folds to form the characteristic gill like out-growths (Photos. 2 and 3). *O. bombayensis* and *O. septemyotum* also have gill like out growths. Embleton (1900) and Jameson (1899) observed a vacuolated layer of cuticle in *Urechis unicinctus* and *T. neptuni* respectively. The description of the cuticle of *A. branchiorhynchus* closely corresponds to that of *T. neptuni* (Prashad 1919a). Dahl (1958) described the cuticle of *E. echiurus* which is identical to that of *T. neptuni*.

Papillae.- The entire body of *I. pirotansis* is covered over by numerous papillae and they project out prominently from the surface. In *L. brevirostris* the papillae are smaller and less elevated while in *L. hexamyotus* the papillae are low, and conical with a central dark spot. They are arranged in transverse rows and are visible only under strong magnification (Fisher 1949). The papillae are transversely elongated in A. chaetifera. A. sabinum and A. moebii have very minute papillae, while in A. loborhynchus the body is covered over by numerous oval papillae, which are larger towards the posterior end (Datta Gupta et al 1962 , Datta Gupta and Menon 1963).In A. dendrorhynchus the papillae are most numerous towards the distal extremities where they are arranged in concentric rings emphasized by corresponding circular folds of integument where as in A. branchiorhynchus there are two kinds of papillae large and small, the large being the most numerous towards the distal extremities. Prashad (1919a) stated that in A. microrhynchus the papillae are arranged in definite rings at the two ends of the body. On the ventral surface of the body about the middle the adjacent papillae are united together to form a crescentic area. In A. abyssalis the papillae are numerous and according to Fisher (1949) they are almost flush with surface and are more translucent than the skin, so that they resemble "tiny grains of cooked tapioca". In A. porcellanus and A. adelaidense the papillae are flat (Edmonds 1960). The skin papillae of O. erythrogrammon are minute and are irregularly distributed and at both ends the papillae are larger, taller and crowded. In O. zanzibarense the papillae are rounded. Stephen (1952) stated that the papillae in *O. zanzibarense* are moderately large and crowded at the anterior end, small and scattered in the middle region and mostly large at the posterior end. In *O. arkati* these papillae are not numerous. They are rather, inconspicuous. The body papillae are minute in both *O. septemyotum* and *O. formosulum* (Datta Gupta et al 1962). The two specimens of *T. neptuni* that I have examined in course of this work the papillae are as a rule irregular in form. They are well developed posteriorly and are smallest about the middle of the body.

Epidermis

The epidermis of *Ikedosoma pirotansis* is made up of a single layer of columnar cells interspersed with numerous glandular cells of different shape and size and sensory cells. The supporting cells are typically columnar and they taper towards their bases and are produced into fine root like processes which merge with the subepidermal cutis layer. The nuclei are situated towards the base of the cell. In the body wall the cell boundaries are not sharply defined while in proboscis they are more clearly marked (Fig. 4). The epidermis shows differences in the different regions and this is largely due to the glandular elements. The epithelium of the proboscis in *L. brevirostris* is glandular and these glands are often seen in dense clusters (Photo.2 and Fig. 5). The cutis layer in the posterior region of the body attains enormous proportions to form a connective tissue cap (Fig. 6). *O. septemyotum* also has a similar connective tissue cap in the posterior region.

Four different types of glandular cells had been observed in the epidermis of *I. pirotansis*.

The Clear Cells.- These cells lie between the ordinary supporting cells and are more common in the proboscis than in the body wall (Fig. 4). They are modified columnar cells and contain hyaline protoplasm. These cells open to the cuticle by small openings. Jameson (1899) described similar cells in the epidermis of *T. neptuni*. Embleton (1900) also observed similar cells in *Urechis unicinctus* . Jameson (1899) regarded these clear cells to be identical with those found in the epidermis of male *Bonellia*(Spengel (1879). The integument of the *Acanthobonellia vulgaris* has no such clear cells (Dutta Gupta and Menon, 1964) . Menon and Sareen (1966) reported the presence of clear cells in a polychaete worm namely *Sabellaria clandestinus*. The frequent presence of an external opening indicates a glandular nature and it may even represent some stages in the development of the one of the several types of unicellular glands as suggested by Jameson (1899).

Pear Shaped Glands.- These gland cells occur singly or in clusters. They are numerous in the proboscis and the papillae of the body wall. They appear as dense clusters under the papillae and one could easily take it for a compound gland, Each gland cell is a pearshaped structure which opens to the cuticle through minute pores (Fig. 8). These cells show considerable variations in its extent and size. Their swollen basal part projects into the cutis . The secretory granules also differ in size which probably depends upon the state of elaboration of the secretions. These glandular cells aggregate themselves into groups of five to twenty cells. They do not open by a single duct as in compound glands, but open by as many ducts as there are gland cells. The unicellular nature of these glands are more or less masked by the clustering, but it is evident in the proboscis where these glands are not compactly packed (Fig. 4). Here one can demarcate the limits of the individual gland cell and its duct. Jameson (1899) described similar gland cells in T. neptuni where they open in irregular groups. These cells form the major part of the substance of the fleshy papillae of the skin. Spengel (1880) described only one type of integumentary gland cell in E. echiurus . Dahl (1957) however , mentions two types of gland cells, the granular gland cells and the bulb gland cells. The granular gland cells are pear shaped and are found in large numbers in papillae as well as on the ventral side of the proboscis. The bulb-gland cell is found in the central parts of the larger papillae. Urechis has unicellular glands which assume great proportions and might well be mistaken for compound glands (Embleton 1900). Prashad (1919) described in A. branchiorhynchus, elongated and flask shaped unicellular gland cells . Newby (1941) has described slime net glands in Urechis. In L. brevirostris these pear shaped glands are present but they are not clustered together in the body, as in I. pirotansis. They resemble the A. branchiorhynchus type of glands as described by Prashad (1919) . These glands are absent from the posterior region where a thick connective tissue cap is formed. However, these glands are numerous and occur in dense clusters in the ventral surface of the proboscis (Fig. 5). Similar gland cells were reported by Bhatia (1941) in the integument of Hirudinaria granulosa.

Compound Granular Glands.- The integument of the proboscis of I. pirotansis is having a peculiar type of glands embedded in the musculoconnective tissue. They are subepidermal and are more numerous on the dorsal side than the ventral (Figs. 4 and 9). They are oval in shape and contain large number of coarse granules of varying shape and size. These cells are more numerous on the distal extremity of the proboscis than the proximal region. They have a connective tissue covering and are held together by strands of connective tissue fibres. In a few sections, the granules have come out of these glands and are found to adhere on the surface of the epidermis.

This in all probability could be owing to rupture of the cells. Similar glands with coarse granules were described in the body wall of Phoronis (Marcus 1949) and Sabellaria clandestines (Menon and Sareem, 1966).

Basophilous glands.- These glands are common in the proximal region of the proboscis, and the contents take deep blue stain with haematoxylin (Fig. 10). The nuclei are situated towards the base of the cells. They open to the surface by small pores mounted on a special thickening of the cuticle. It may be mentioned that similar glands are common in the pharyngeal-epithelium.

Tubular glands.- These are found in the proboscis as well as in the body wall (Figs. 4 and 11). In the lateral margin of the proboscis these glands are aggregated together along with large number of pearshaped glands to form a lateral glandular ridge. Each gland cell is very long and narrow and extends into the cutis. In the body wall they are found only on the papillae. The contents of these glands are eosinophilous. The eosinophilous tubular glands show a striking similarity with the tubular glands described by Bhatia (1941) in Hirudinaria granulosa.

Cutis.- The cutis layer lies beneath the epidermis. The substance of the papillae is made up of cutis and the clusters of the closely packed unicellular glands. The cutis is of uniform thickness throughout in I. pirotansis .

In L. brevirostris the cutis is having more or less the same structure as that of I. pirotansis except that it is generally free from glandular cells (Fig. 6). Posteriorly, the connective tissue becomes very thick and forms a cap like structure (Fig. 7). Similar thickenings in the posterior region have been observed in O. septemyotum (Datta Gupta et al. 1963) and O. arkati (Prashad 1935). In other echiurids (Jameson 1899, Embleton 1900 , Prashad 1919, Dahl 1957) the cutis has got more or less the same structure but its dimensions may vary in the different forms.

Body Musculature

The body musculature lies beneath the cutis. The circular layer of muscles is the outermost followed by the longitudinals (Photo. 5). There is an inner layer of oblique muscles. The relative thickness of the muscles vary; they are thickest at the two extremeties. In L. brevirostris the longitudinal muscle bands are thickened along seven bands. In larger specimens these bands are well pronounced. The oblique muscles are continuous (Fig. 7 , Photo. 6). In O. bombayensis and O. septemyotum the oblique muscles are interrupted . Further a number of coelomic spaces were also observed in the body wall of O. bombayensis (Photo.7). In A. chaetifera the body musculature is similar to that of I. pirotansis. In all echiurids that I have examined the circular layer of muscles lies out side the longitudinal.

The arrangement of the dermal muscles in echiurids is considered to be taxonomically important. Shipley (1899) used dermal muscle layers and the number of segmental organs as the basis for the classification of Echiuroidea. Spengel (1912) re-established the old generic name Ochetostoma for T. erythrogrammon, in which the longitudinal muscles are in bands and the inner oblique muscles are interrupted . In Listriolobus the inner oblique muscles are continuous. Wharton (1913) came to the conclusion that it was not possible to maintain a genus Listriolobus as characterised by Spengel. Bock (1942) was also of the same opinion. Fisher (1946) created a new order Heteromyota to include I. taenioides characterised by the reversal of muscle layers. Prashad (1936) in A. branchiorhynchus described similar reversal in the arrangement of muscles.

Seta and Setal Musculature

The ventral setae are placed anterior to the first nephridiopore. In between the setae there is a prominent muscular cushion on either side of which are placed the setae (Photo. 1). Externally only the curved portion of the setae are visible. I have not come across any reference of such a muscle cushion in between the setae in other echiurids. The length of the setae is about 4.8 mm. The greater part of the setae is enclosed in the setigerous sac (Fig. 12).

The muscles of the ventral hooks are well developed. Anteriorly at the neck of the setae are inserted well developed transverse muscle bands. Posteriorly there is a strong interbasal muscle. There are a large number of radiating muscle strands emerging from the posterior part of the setae. Most of them are inserted on to the anterior body wall (Fig. 12). In *L. brevirostris* the intersetal muscle cushion is absent. The interbasal muscle is very thin. There are always one or two pairs of accessory setae in the setal sac.

Interbasal muscle is usually present in *Ochetostoma* species; *Ochetostoma australiense* does not have one. Among the specimens that I have examined an interbasal muscle is absent in *A. moebii* . *A chaetifera*, *A. loborhynchus* and *I. gogoshimmense* .

The setae in echiurids are generally limited to one pair situated in the anterior side just posterior to the mouth. *Urechis* and *Echiurus* have posterior circlets of setae besides the anterior pair. In *Urechis unicinctus* there is only a single circlet while in *Echiurus echiurus* there are two circlets of setae. The anterior setae of *A. chaetifera* are distinctly different from the rest of the *echiurids*; there are two conspicuous openings plugged with muscle pads. Minute spinelets are embedded in this pad. Similar modifications of setae are found in *Acanthobonellia* and *Acanthohamingia*. In the former (Menon et al. 1963) there are a number of spines embedded in a single or paired muscular cushion while in *A. chaetifera* the spines are fused to form a common base.

3. Coelom

The coelom in *I. pirotansis* is spacious and uninterrupted. This enables free movement of fluid in the body cavity. Mesenterial strands radiate from the alimentary canal to the body wall. At the neck region these radial strands are thick and emerge from the pharynx which could be seen in a transverse section as spaces more or less filled up by connective tissue and coelomic corpuscles.

Proboscis coelom.- At the junction of the proboscis and body the entire coelom is obliterated by connective tissue and muscle strands except for two lateral spaces which continue into the proboscis as the lateral coelomic channels. The lateral blood vessels of the proboscis is are located in these coelomic spaces (Photo. 4). They run all along the length of the proboscis to become confluent at the extreme tip. In *L. brevirostris* the general pattern of the coelom is essentially the same except in the proboscis where it forms a number of lacunae. The body coelom is continuous. At the region of the pharynx, the coelom is interrupted by the mesenterial strands as in *I. pirotansis.* In the proximal region of the proboscis the coelom remains as a spacious cavity confined to the ventral side (Photo.3). This cavity soon gets divided into a number of smaller lacunae by bridges of delicate connective tissue strands (Photo. 8). The lateral coelomic channels are distinguishable as two spaces enclosing the lateral blood vessels. This channel extends into the gill folds where it forms a net work of coelomic spaces (Photo.3). These spaces are absent in the proboscis of I. pirotansis (Photo.4). In O. bombayensis and O. septemyotum the proboscis has large number of lacunae and conforms to the Listriolobus type (Photos.9-10).

One can see two definite trends in echiurids as far as the disposition of coelom in the proboscis is concerned. L. brevirostris and I. pirotansis demonstrate these two trends. The Listriolobus (Photos. 2,3 and 8) type shows a large number of coelomic spaces in the proboscis and in this respect it is similar to Ochetostoma and Anelassorhynchus. O. erythrogrammon has a net work of very wide lacunae and the ventral transverse muscles are well developed. In O. bombayensis the author has observed a number of coelomic spaces in the proboscis (Photos.9 and 10). In A. branchiorhynchus, at the junction of the proboscis there are two large spaces which are in direct continuation of the body coelom. These spaces become divided into large number of small compartments. At the tip of the proboscis these smaller spaces again unite until at the end only a single space is seen (Prashad, 1919). Fisher (1946) stated that the modifications of the proboscis which exhibit a number of gradations in complexity are adaptations to an ecology in various ways abnormal, a parallel development being found in Ochetostoma arkati. In T. neptuni and Echiurus echiurus similar lacunae are found (Bock 1942). In Urechis unicinctus a large number of lacunae are discribed (Embleton 1900).

The second type as we find in Ikedosoma pirotansis (Photo. 4) has no lacunae in the proboscis and the coelom is confined only to the lateral coelomic channels enclosing the blood vessels. This condition closely approaches the Bonellidan proboscis (Bock 1942) . According to Bock this type of proboscis represents the most advanced stage in the echiuroidean organization.

It is rather difficult at this stage to discuss the evolutionary significance of the two types of proboscides structure. Prashad described T. sabinum, T. dendrorhynchus and T. branchiorhynchus representing a series in the development of gill like structures from mere indentations on the margins of the proboscis. The lacunae also show corresponding graduations in their complexities. These are much larger in A. branchiorhynchus than in A. dendrorhynchus. In L. brevirostris the lacunae are very extensive. Such spaces are reported in L. billitonensis and L. pelodes (Bock 1942). But the presence of lacunae in forms without gills, as in Thalassema, Echiurus and Urechis shows that the lacunar nature is a basic pattern in the majority of Echiurids, and the gradation in complexities of these spaces may be a secondary feature developed in association with the dendritic gill like out growths.

It seems that devalopment of gills are usually seen in forms which dwell in mud and with short proboscis incapable of great prolongation as in some species of Anelassorhynchus, Listriolobus and Ochetostoma.

Mesenteries.- Peritoneum invests all the internal organs like the alimentary canal, blood vessels, nephridia and the ventral nerve cord.

A definite ventral mesentery is running from the anterior to the posterior end. The ventral nerve cord and the vessel are held by this mesentery. This is attached to the alimentary canal only in the anterior and posterior regions.

The alimentary canal is fixed to the body wall by numerous mesenterial strands. The insertion of these strands are at various levels. Anteriorly, a fixing mesenterial strand holds the oesophageal loop firmly (Fig.13). The anal vesicles are attached to the body throughout by a number of strands. At the distal end, there is a prominent well developed strand which fastens the tip to the body wall.

A peculiar specialization in the mesentery is noticed in I. pirotansis. Anteriorly the presiphonal loop of the intestine is invested with a peritoneum. This peritoneum meets ventrally where it enlarges into sac like structures. These in their turn are attached to the ventral mesentery. This specialized mesenterial structure is an active proliferation centre for the chlorogogen cells. The chlorogogen cells are numerous and they appear as small vesicles attached to the mesentery (Photo. 11).

Chlorogogen cells.- The chlorogogen cells are well developed in relation to the main blood vessels, intestinal peritoneum and the mesenterial strands. In I. pirotansis there are special areas for the proliferation of these cells. Anteriorly in the presiphonal intestine, the peritoneum is very much folded to form sac like structures. From these peritoneal folding, chlorogogen cells proliferate in large numbers. Another equally important region for the proliferation of these cells are the peritoneal lining of the collateral intestine. These cells are more or less flask shaped, their distal ends are rounded with a tapering proximal end. They always contain one or two inclusions of different shape, some may be rod shaped and yet others may be spherical bodies. At the site of proliferation one can see cells in different stages of growth. A fully mature cell usually has more inclusions in it than an immature cell.

In L. brevirostris the chlorogogen cells are formed in association with the blood vessels and concentrations of these cells have not been observed in any specialized area as in *I. pirotansis* . I have examined carefully *I. pirotansis* and *L. brevirostris.* The association of chlorogogen cells with the blood vessels and the collateral intestine is a common feature in the two species.

In the presiphonal intestine of *I. pirotansis* as already stated, the peritoneal layer gets itself folded to a great extend. From these foldings chlorogogen cells bud off (Fig. 13). Fisher (1946) in *Thalassema steinbecki* described intestinal mesentries enclosing conspicuous subfusiform fleshy masses. He writes " Posterior to the region of the siphon, the mesenteries enclose, or hold, conspicuous yellowish-white masses, sometimes subfusiform or in irregular sheets, which remind one of the suet found in mammals. A squeeze reveals several sorts of cells, some of which may be immature sperms". The mesentarial folds in *I. pirotansis* ~~is~~ are probably of the same nature though they are presiphonal in position. Further no immature germ cells associated with ~~it~~ them have been observed. According to present findings these foldings seem to be very active centres of proliferation of chlorogogen cells at least in *I. pirotansis.*

Opinions differ as to the function of chlorogogen cells. There was no attempt to find out the functions of the chlorogogen cells in echiurids, although, there is some information about the probable functions of chlorogogen cells in annelids. The chlorogogen cells of earthworms have been credited with a nutritive function by Schneider (1896) and Liebman (1926). Willem and Mine (1900) concluded that chlorogogen cells absorb waste products from the coelomic fluid. Vacuoles may accumulate and these may discharge their fluid contents into the coelom, which are picked up by amoebocytes. Stephenson (1930) has reviewed the different views as to the function of chlorogogen cells. Cuenot (1898) Rosa (1903) Joseph (1909) Stolte (1922) Szuts (1920) and Willem and Mine (1900) attribute an excretory function for these cells in earthworms. Needham (1966) isolated the characterstic pigment of chorogogen cells and found it to be a flavin probably riboflavin. According to him the main function of chlorogogen tissue is excretion, though he did not rule out other functions such as storage and other hepatic functions. The chlorogogen cells of I. pirotansis may be homologus to similar cells found in oligochaetes. This is all the more evident, since in echiurids and oligochaetes, these cells are proliferated from the peritoneum covering similar organs such as intestine and blood vessels. They contain characteristic yellow pigment.

Coelomic inclusions.- The coelomic fluid contains large number of bodies, such as coelomic corpuscles, chlorogogen cells and germ cells.

The coelom is packed with round multicellular vesicles. They are found in different sizes which represent stages of growth (Fig. 14). The smallest one is in the shape of a ball with 3 to 4 nuclei embedded in the reticulate cytoplasm. As it grows, the number of nuclei becomes more. The wall of the vesicle is made up of a reticulate syncitial mass, which contains, in addition to nuclei, many other bodies. A slight pressure will break the vesicle and the reticulate nature of the vesicular wall becomes more evident (Figs. 15 and 16). The red corpuscles are round and they are found in large numbers. Each of them is having a nucleus and one or two vacuoles(Fig. 17). The amoebocytes are also common. There are three types of coelomocytes in *L. brevirostris*; the large eosinophilic corpuscles which are similar to the red corpuscles of *I. pirotansis*(Fig.18) the basophilic corpuscles and ameobocytes. The author had the opportunity of examining the corpuscles of *O.bombayensis*, *O. septemyotum* and *A. sabinum*. The corpuscles of *O. bombayensis* are similar to *L. brevirostris* except for the presence of multicellular coelomic vesicles in the former. The corpuscles of *A. sabinum* are petaloid in shape. The multicellular vesicles are absent. Clusters of basophilic cells are a common feature in both *A. sabinum* and *O. septemyotum*. The coelomic corpuscles paly a major role in the physiology of echiurids and in many cases it is an efficient substitute for an otherwise poorly developed vascular system. In Urechis in the absence of a vascular system the corpuscles play an important role in the respiratory exchanges (Fisher 1946). In I. pirotansis multinucleate coelomic vesicles are a characteristic feature. These vesicles start as a single cell, which gradually grows to form a large vesicle. Similar multinucleate vesicles were described by Cuenot (1900) in Golfingia vulgaris. The eosinophilic corpuscles in the different genera, which have been examined show characteristic differences in their shape and inclusions.

4. Alimentary Canal

Generally alimentary canal consists of foregut presiphonal intestine, siphonal intestine, postsiphonal intestine and a short rectum. It is attached to the body wall throughout by means of mesenterial strands. These strands are well developed in the pharyngeal and rectal regions (Figs. 13, 19 and 20).

The introductory part of the alimentary canal is distinguished as a buccal tube. The lateral edges of the proboscis proximally meet to form a groove which leads into the buccal tube. The proboscis epithelium is continued into this part and a section at this place shows no reversal of muscles, thus distinguishing this part clearly from the pharynx where a reversal of muscle layers takes place. This buccal tube is firmly attached to the body wall by a number of radial muscle strands which vary from 20 to 25. The radial strands are attached to the circular layer of muscles of the buccal tube. The muscles are smooth; the longitudinal muscles lie inside the circular and are located immediately beneath the epithelial folds. The epithelium is thrown into 12- 14 folds. These folds extend considerably into the lumen of the buccal tube. The cells are ciliated,columnar and are densely packed. Each cell is broader towards the free end and tapers towards the basal end. The nucleus is situated at about the middle of the cell. The epithelium is characterised by the presence of a large number of glands. These are more or less elongated oval glands with basophilous secretion and open in to the lumen by distinct pores. These glandular cells are very well comparable with the glands found in the epithelium of the proboscis (Fig.21).

The buccal tube merges into the pharynx. At this region the radial mesentries are only a few in number and the coelom is more spaceous. The pharynx is a wide tube 4 to 5 cms in length with muscular walls. This tube appears to be dorsoventrally flattened in most of the specimens. The wall of the pharynx is thick compared with the rest of the alimentary canal. The longitudinal muscles lies out side the circular layer. The epithelium of the pharynx and the buccal tube are similar in its glandular nature (Fig.22).

The oesophagus in its biginning is a coiled structure, and after making 2½ coils around a spindle muscle, becomes straight to make a long loop. Unlike the pharynx the oesophagus is very long. This is attached to the body wall by means of numerous short strands. The longitudinal muscles lie outside a thin circular layer of muscles. The cells are very narrow and long. The nuclei are situated at the base of the cells. The gland cells are interspersed in between the supporting cells. In cross-section the epithelium is seen as papillae like aggregations. The cells are compactly arranged in this papillae. In between these aggregations the cells are smaller (Fig. 23).

The prointestine is demarcated anteriorly from the oesophagus by the mesenteric fold and posteriorly by the ring sinus . It makes two loops before it is continued into the mid intestine. A cross-section of prointestine shows that the longitudinal muscles are internal to the circular layer. This arrangement of muscles is distinctly different from foregut where the longitudinal layer of muscles lies out side the circular. The epithelium is composed of the usual columnar type of supporting cells and large number of glandular cells. These gland cells are of different sizes. The epithelium shows the different stages of differentiation of a gland cell from the columnar cells. A columnar cell gradually becomes larger and accumulates a variety of cell inclusions. The free ends of these cells become broadly rounded and project out to the lumen prominently from the general surface of the epithelium. This enlarged part is then nipped off into the lumen leaving the remaining part intact (Fig. 24 and Photo. 11). The prointestine is post cardiac in <u>L. brevirostris</u> and characterised by the presence of a ciliated groove.

The region of transition between the pro-and mid- intestine is marked by the presence of the vascular sinus which receives the neuro-intestinal and gives off the dorsal vessel. The collateral intestine also emerges out at this point(Fig. 25 , Photo.12). This part of the intestine is a long and convoluted tube and often found to contain large amount of soft mud. The mid-intestine is accompanied by the collateral instestine. The collateral intestine is covered by a peritoneum. The peritoneal cells are columnar. Internal to the peritoneum there is a very thin layer of circular muscles. The longitudinal bands are arranged inside the circular layer. The epithelium is folded, columnar and glandular. A ciliated internal groove bordered by conspicuous folds on each side is a feature common to the mid-intestine and hind-intestine. The supporting cells of this groove are profusely ciliated, thus differentiating them from the ordinary intestinal cells. It is interesting to note that a muscular barrier is absent between the ventral groove and the collateral intestine and the former is separated from the latter only by means of a thin connective tissue layer. The collateral intestine and the mid intestine is enclosed by a common peritoneal sheath. On either side of the collateral intestine, there is a well marked groove running all along the mid intestine. This groove contains some sort of connective tissue with large number of spaces. The significance of this space is discussed later. The epithelium of the collateral intestine is columnar and non-ciliated. Gland cells are absent (Fig. 26).

The hind intestine is the longest part of the alimentary canal. The collateral intestine is absent but internally the ciliated groove is present. This groove abruptly ends at the rectum, where the ventral vessel also merges with the rectal wall. There is practically no difference in the epithelium of the mid intestine and hind intestine. The wall of the hind intestine is very thin and the faecal pellets are quite visible from outside. The muscular layer is composed mostly of circular fibres.

The rectum is a short tube and is externally marked off by the termination of the ciliated groove. The anal vesicles open in to it ventrolaterally. The rectal wall is muscular and is firmly attached to the body wall by a number of radial mesenteries (Figs.27 and 28). In L. brevirostris and O. septemyotum, the author has observed rectal ceaca. The ciliated groove abruptly ends at the rectal caecum.

The alimentary canal in echiurids is generally long and convoluted forming several loops. Spengel (1879) stated that the total length of alimentary canal in *Echiurus echiurus* is up to ten times that of the body while *E. abyssalis* had a comparatively short digestive tract with few convolutions which is a rare exception. (Skorikov (1901). Ikeda (1907) described the alimentary canal of *Ikedosoma elegans*. Jameson (1899) and Rietsch (1886) gave a fairly detailed account of the alimentary canal of *Thalassema*. Information about the alimentary canal of *A. branchiorhynchus* (Prashad 1919), *O. bombayensis* (Awati and Deshpande 1966) and many other species of echiurids (Fisher 1946, 1947, 1949) clearly indicate that the digestive tract in echiurids are generally very long and coiled and that they have certain constant and common features.

In the past there had been considerable amount of confusion in the terminology of the different regions of the alimentary canal. According to Bock (1942) it is possible to make out three clearly differentiated regions in the gut ; (1) the ectodermal foregut, where the longitudinal muscles lie out side the circular layer ,(2) the endodermal intestine, where the positions of the muscles are reversed and a (3) terminal rectum, which is again ectodermal having similar disposition of muscles as that of foregut. Fisher (1946) however, stated that echiuroids do not have a proctodaeum. This way of distinction of the different regions of the gut is morphologically sound, but unfortunately most of the early descriptions of the alimentary canal are not based on this character, and different authors distinguished various regions in the gut of echiurids without any strong morphological basis. Bock (1942) brought out the various terms used by different authors from time to time and according to him the various terms employed by Ikeda, Wharton and others, to designate the different parts of the alimentary canal do not always have the same meaning as those employed by Jameson or Embleton. To avoid this difficulty, it is absolutely necessary to rely on some important morphological character to distinguish the different parts of the gut. The present studies on I. pirotansis have led the author to believe that the reversal of the muscle layer is a dependable character at least to demarcate the foregut from the intestine. The rectum could be demarcated from the intestine by the absence of ciliated groove. A reversal of muscle is not noticed in the rectum. Bock (1942) stated that there is a reversal of muscle layers in the rectum in Maxmulleria.

Ikeda (1904) described the alimentary canal of Ikedosoma elegans and recognized three parts viz. the pharynx, the oesophagus and the intestine. The pharynx is a muscular tube, 4-3 cm. long and in the empty state about

5 cm. wide. The posterior end of it is marked by the presence of the heart, situated on the dorsal side. The oesophagus is a narrow tube measuring 25.30 cm. in length... The intestine forms by far the largest part of the alimentary canal. The transition of the oesophagus into the intestine is externally marked by the point of origin of the collateral intestine. The collateral intestine is a moderately wide tube , accompanying the intestine for a length of about 80 cm. The posterior part of the intestine exhibits the siphonal groove which terminates behind in front of the rectum.

A comparison of the alimentary canal of I. elegans and I. pirotansis is useful in ascertaining the relationships of the two. The most outstanding feature is the position of the heart, which is situated between the pharynx and oesophagus in I. elegans, but in I. pirotansis the heart is located between the prointestine and mid-intestine or in other words, the heart in I. elegans embraces the ectodermal foregut while in I. pirotansis it envelops the endodermal intestine. It must be recalled that Ikeda did not distinguish a prointestine in I. elegans anterior to the siphon. On the other hand, in Ikeda taenioides Ikeda described a midgut immediately behind the crop. According to Bock (1942) this midgut anterior to the origin of the collateral intestine and heart, in I. taenioides may be homologus to the prointestine. The present author also feels that the so called midgut of I. taenioides corresponds to the prointestine. Further, the position of the heart is also the same in I. taenioides and I. pirotansis. The presence of a precardiac prointestine without a ciliated groove in both I. taenioides and I. pirotansis is not merely a coincidence.

The foregut in Echiurids is usually demarcated into different regions such as pharynx, oesophagus and crop or gizzard (Fisher 1946 , 1947 ; Ikeda 1904; Prashad 1935). But in a few forms like Ikeda taenioides and Ikedosoma pirotansis, the foregut could be distinguished only into two regions; the pharynx and oesophagus. In Ikedosoma elegans also no distinct gizzard was observed (Ikeda 1904). In all these three forms the oesophagus is very long.

The position of the ring vessel or ring sinus is also an important land mark to distinguish the foregut from midgut, since in most echiurids, the ring sinus is situated between the foregut and midgut. Ikedosoma elegans alone has the ring sinus situated at the extreme hind end of the pharynx; while in Ikedosoma pirotansis , Ikeda taenioides, Arhynchite inamoenus and A. californicus, the ring sinus is situated between pro and mid intestine. The prointestine which is posterior to the ring sinus, may be called postcardiac prointestine as in Ochetostoma and Listriolobus ; when it is anterior to the ring sinus, it may be called precardiac prointestine as in Ikeda taenioides, Ikedosoma pirotansis and in a few species of Arhynchite.

It is an interesting coincidence that a ciliated groove is absent in the prointestine when it is precardiac, and present when the prointestine is postcardiac. This fact is well established by examining the available descriptions. In L. brevirostris the ring vessel is between the foregut and prointestine and the latter has got a well developed ciliated groove. There are well marked ciliated grooves in Thalassema, Echiurus, Ochetostoma, Listriolobus, Anelassorhynchus and Lissomyemma; all of them have postcardiac prointestine. Ikeda taenioides, Ikedosoma pirotansis, and two species of Arhynchite do not have any ciliated groove in the prointestine, and the prointestine is precardiac in all these forms.

The collateral intestine is a feature met with in all echiurids and bonellids. As indicated above it begins as a ciliated groove in a majority of echiurids, while in I. pirotansis it emerges out from the distal end of the prointestine. The collateral intestine is closely adhering to the ventral ciliated groove separated only by means of a thin connective tissue. The cells bordering this groove are profusely ciliated, while rest of the intestinal epithelium is non ciliated. Jameson (1899) did not see cilia in the intestinal epithelium except in the ventral groove, but he thought it may be due to defective state of preservation. My observation confirms that the intestinal epithelium is non ciliated except for a short strip in the ventral groove. In Maxmulleria, Bock (1942) stated that the supporting cells of the glyphe carry densely arranged short cilia, thus contrasting with the ordinary intestinal epithelium. Robbins (1965) described a ciliated groove in Poebius. According to him faecal pellets are propelled through the intestine to the anus by the ciliary action of the groove as well as by peristaltic movements of the gut wall. The removal of excess of water is directly related to the process of pellet formation and it is possible that the excess of water is removed through the collateral intestine. Awati and Deshpande (1936) attributed a respiratory function for the tube, though by collateral intestine they meant the siphon as well as the mid intestine. Bock (1942) also thought that this may be an adaptation connected with respiratory and not directly a digestive function.

5. Blood Vascular System

There is a closed blood vascular system as in other echiurids. The blood vascular system in I. pirotensis is constituted by a system of blood vessels and sinuses. The main blood vessels are the dorsal, ventral and neurointestinal. The sinuses are the ring sinus and a pair of ventrolateral sinus (Figs. 29 and 30).

Dorsal Vessel.- The dorsal vessel is limited only to the anterior region of the animal. It emerges from the ring sinus or heart situated at the junction of the pro-intestine and mid-intestine. This vessel in I. pirotansis is very long. Posteriorly the dorsal vessel lies ventral to the oesophagus, but it emerges dorsally in the anterior region. It is a very prominent vessel on the dorsal side of the pharynx (Fig. 13). Anteriorly the dorsal vessel enters the proboscis and runs as a median vessel all through the length of the proboscis, and is firmly embedded in the musculoconnective tissue of the proboscis (Photo.4).

The dorsal vessel has a covering of a peritoneal layer. Internal to this is a layer of muscle which is composed mainly of circular fibres. The blood vessel is lined internally by a flattened epithelium. This epithelium shows different stages of the formation of corpuscles. In L. brevirostris the dorsal vessel emerges from the ring vessel and runs to some distance closely adhering to the oesophagus as a swollen vessel. Anteriorly it enters the proboscis as the median vessel of the proboscis. The dorsal vessel in this case is extremely short (Dutta Gupta and Menon 1965).

Ventral Vessel.- The ventral vessel runs along the nerve cord. Posteriorly the ventral vessel does not extend to the end of the nerve cord, but takes an upward bent to merge imperceptibly on the rectal wall at the region where the ciliated groove terminates. Anteriorly, at the level of the interbasal muscle, the ventral vessel divides into two, one lying below the interbasal and the other above the interbasal muscle. The vessel lying above the interbasal muscle can be called as an " accessory ventral vessel". Both these vessels continue forward, almost parallel to each other. At the neck region the ventral vessel bifurcates; one of these branches reunites with "the accessory ventral vessel" and the other continues forward as the right lateral proboscis vessels. The left lateral proboscis vessels takes its origin from the ring formed by the ventral accessory vessel and the ventral vessel (Fig. 30). It is interesting to note that the accessory ventral vessel is wider and more prominent than the ventral vessel. The lateral proboscis vessels are lodged in the coelomic spaces.

The neurointestinal arises from the ventral vessel and runs posteriorly to some distance along with the dorsal vessel. It bifurcates before it opens into the ring sinus. In _L. brevirostris_ the neurointestinal emerges out as a single vessel, but divides into two, one of them lying below, and the other above the interbasal muscle. These two branches meet and continue as the neurointestinal vessel which opens into the ring sinus (Fig. 32). The ventral vessel at the base of the proboscis divides into two to form the lateral proboscis vessels (Datta Gupta and Menon 1965). In other echiurids (Datta et al. 1961 ; Datta Gupta and Menon 1965) the blood vascular system is more or less built in the same plan as in Listriolobus .

Ring Sinus:- The ring sinus is situated at the junction of the prointestine and mid-intestine. The collateral intestine also emerges out from this place. The two vessels that communicate with this sac are the dorsal and the neurointestinal (Fig. 25). Posteriorly, the spacious ring sinus, soon becomes moreor less obliterated by the close apposition of the peritoneum with the wall of the intestine. Still a clear perintestinal sinus could be observed in the mid-intestine (Photo. 13). On either side of the collateral intestine, there is a conspicuous longitudinal groove. This is called the ventrolateral sinus . This sinus communicates with perintestinal sinus anteriorly. The ventrolateral sinus is not an empty space but contains connective tissue net work with lacunae (Fig.26). The ring sinus in L. brevirostris is situated in between the foregut and prointestine. The sinus is very spacious.

The lateral and the median vessels of proboscis show identical histological peculiarities. Externally the vessels are covered by a folded epithelium. This epithelium resembles the peritoneal lining of the alimentary canal. Internal to this, there is a layer formed by circular muscle fibres and connective tissue. The lumen of the vessel is lined by an endothelium. The dorsal, the ventral and the neuro-intestinals also have a peritoneal covering. This covering is thrown into a large number of folds. These folds vary in their extent in the different parts of the vessels. The neurointestinal vessel is covered over by a thick layer of cells. Similar thickenings of the neurointestinal vessel have been observed in O. septemyotum. The ring sinus is lined by cuboidal epithelium and there is no indication of any muscle fibres.

Our knowledge about the blood vascular system of the echiurids is confined only to the main blood vessels. Greef (1879) described an open vascular system in E. pallasi. Spengel (1880) and Rietsch (1886) described the blood system of Thalassema neptuni. According to Greef, the two branches of the neurointestinal anastomosis do not form a simple ring but open into a peri-intestinal sinus. Jameson (1899) did not observe any sinus but a definite ring vessel in T. neptuni. Brief descriptions of the vascular system are available from the works of Baltzer (1917) Ikeda (1907) , Prashad (1919) , Fisher (1946) and Datta Gupta and Menon (1965). Unique among echiurids is Urechis where a vascular system is completely absent (Embleton 1900).

The vascular system in echiurids is built upon a definite plan and the variations are mainly observed in details. It generally consists of a dorsal, a ventral and a neurointestinal vessel. A ring sinus around the intestine communicates with the dorsal and neurointestinal.

In the proboscis there are three vessels : two lateral longitudinal vessels and a median dorsal vessel.

The position of the ring sinus in echiurids apparently vary in different forms. The ring sinus is situated dorsally on the hind end of pharynx in *Ikedosoma elegans.* According to Ikeda this anterior position of the heart constituted one of the peculiarities of this species. In *Ikeda taenioides* the ring sinus is situated between 'midgut' (prointestine) and intestine proper. *Ikedosoma pirotansis* and *Ikeda taenioides* are having identical conditions. In both the dorsal vessel has become very long due to the shifting of the ring sinus posteriorly. In *Arhynchite* spp. the presiphonal intestine is very long, but there is no indication of a ring sinus except in *Arhynchite pugettensis* (Fisher 1949). In *Arhynchite* the relation between the dorsal and neurointestinal is similar to that of *Bonellia* (Fisher, 1946).

Three positions of the ring sinus could be distinguished in echiurids.

1. Anterior position of the ring sinus between pharynx and oesophagus as described by Ikeda in *Ikedosoma elegans* .
2. Position of the ring sinus between foregut and midgut as in the majority of echiurids (Figs.31 and 32).
3. Position of the ring sinus between prointestine

and mid-intestine as in *Ikeda taenioides*, *Ikedosoma pirotansis* and *Arhynchite inamoenus* (Figs. 29).

These three conditions could be considered in elucidating the relationship of echiurids. Apart from the position of the heart, there are certain variations reported as to the nature of the heart. Two types of structures are described (1) a ring sinus and (2) a ring vessel. In *Thalassema neptuni*, Jameson (1899) described a clear ring vessel. But in most echiurids a ring sinus is described.

A number of variations are reported in the neurointestinal and other vessels which emerge from the ventral vessel. In most echiurids the ventral vessel bifurcates at the base of the proboscis and continuesin the proboscis as lateral proboscis vessel. Most workers have described a neuro-intestinal emerging from the ventral vessel which forms a loop around the interbasal muscle before it joins the ring sinus. In *Listriolobus brevirostris* the ventral vessel gives rise to a branch which soon bifurcates, of which one lies below, and the other above the interbasal muscle (Datta Gupta and Menon, 1965). These meet again to continue as the neurointestinal. Prashad (1919) described the neuro-intestinal vessel in *A. branchiorhynchus* forming a ring around the oesophagus; he called it the 'muscle ring' after spengel . Jameson (1890) in T.neptuni stated that the two limbs of the 'muscle ring' generally open separately into the ventral vessel, but some times unite first into a single vessel. In Echiurus echiurus alaskanus Fisher (1946) observed that the neurointestinal connective results from the branching of the dorsal vessel at the biginning of intestine by which the neurointestinal ring is formed. He further stated that this connective branches again to form the muscle ring before merging broadly with the ventral vessel. In Ochetostoma edax (Fisher, 1946) a branch of the ventral vessel forms a loop around the interbasal muscle and continues as paired neurointestinal. In L. pelodes the neurointestinal makes a loop around the interbasal muscles. Thus in a majority of echiurids the neurointestinal makes a loop around the interbasal muscle before it drains in to ring vessel.

In A. moebi the neurointestinal emerges as paired tubes from the ventral vessel and opens separately in the ring sinus. In A. loborhynchus, the neurointestinal emerges as a single vessel and open separately in the ring sinus. In these two forms interbasal muscles are absent (Datta Gupta and Menon, 1965). The only information about Ikedosoma elegans is that the neurointestinal arises from the ventral median point of the ring sinus which surrounds the extreme hind end of pharynx. However, an interbasal muscle is absent in Ikedosoma elegans. The exceptions to this general rule are afforded by Anelassorhynchus abyssalis, Fisher (1946), Listriolobus hexamyotus (Fisher 1949), Arhynchite inamoenus and Ikedosoma pirotansis. In A. abyssalis the vascular system is characterised by the "absence of any relation with the interbasal muscle of setae and the absence of a direct well marked ring vessel". In I. pirotansis the neuro-intestinal takes its origin far behind the interbasal muscle. In Arhynchite the neurointestinal has a paired origin but does not form a loop around the interbasal muscle.

Thus in a majority of echiurids the neurointestinal is associated with the interbasal muscle, and in a few genera, the neurointestinal does not take part in the formation of the interbasal loop. Further, the neurointestinal takes its origin by a paired vessel which unites together to form the muscle ring, while in a few forms The neurointestinal takes its origin by a single vessel.

The association of neurointestinal with the interbasal muscle is probably a characteristic feature of echiurids since it is found in a majority of them. The deviation from the normal pattern as in Ikedosoma pirotansis, Ikeda taenioides, Arhynchite inamoenus, Anelassorhynchus abyssalis and Listriolobus hexamyotus must be considered as interesting exceptions. However, in Arhynchite arhynchite (Ikeda), the neurointestinal does take part in the formation of the interbasal loop. These instances show that the neurointestinal and its use in taxonomy would very well be considered but for the exceptions stated above.

The ventral vessel in I. *pirotansis* gives rise to an accessory vessel lying above the interbasal muscle. After a short distance this vessel rejoins the ventral vessel at the base of the proboscis and from this junction is given off one of the lateral proboscis vessels (Fig.30). Such accessory ventral vessel are not observed in echiurids other than I. *pirotansis* though they are usually present in bonellids. Ikeda (1905) described a similar vessel in *Protobonellia mitsukuri*. In *Bonellia virdis* such an accessory vessel is present (Fisher 1946). Jose (1964), however, did not observe an accessory vessel in *Acanthobonellia pirotansis*.

The presence of an accessory ventral vessel probably adds to the efficiency of the circulation in the anterior region. The proboscis of I. *pirotansis* is very long and is capable of great elongation. When the proboscis contracts, there will be a great rush of blood through the lateral vessels. It is possible a major part of this blood is drained to the ventral side through this accessory vessel. Of course, a part of the aerated blood always goes to the ventral vessel directly from the lateral proboscis vessel. The superimposition of an additional vessel increases the drainage capacity at this region, where the rush of blood is great due to frequent contraction and expansion of the proboscis.

The ventral vessel in all echiurids run along the ventral nerve cord, and posteriorly merge with either the rectal caecum or the rectal wall. In *I. pirotansis* the ventral vessel gives rise to 3 vessels to the rectal wall. In *L. brevirostris* there is a prominent rectal caecum to which extends the ventral blood vessel. The same condition prevails in *O. edax*, *O. octomyotum* and *T. steinbecki* (Fisher, 1946). In *A. branchiorhynchus* (Prashad 1913) the ventral vessel ends blindly at the posterior end.

The ring sinus in *I. pirotansis* is probably not a propulsive organ. It is more likely a reservoir which collects the blood from various sources. The muscular dorsal vessel probably propels the blood forward to the proboscis. The lateral proboscis vessels are contractile since they are provided with muscles.

Embleton (1899) stated that there may be some corelation between the development of the blood vascular system and the proboscis. According to him, in the adult it functions less as a circulatory system than as a hydraulic apparatus for expanding the proboscis. The complete absence of a vascular system in *Urechis unicinctus* is correlated with extreme reduction of the proboscis. Bock (1942) also was of the same opinion. Prashad (1919) described a number of *Anelassorhynchus* species with proboscides provided with dendritic gill-like outgrowths. He believed that the proboscis in A. branchiorhynchus and other related species is respiratory in function. Embleton (1900) ,however, was doubtful as to whether so important a function as that of respiration could be assigned to a structure which is likely to be thrown out completely at the slightest provocation. He regarded the vascular system of echiurids to be essentially a hydraulic apparatus and compared this system with tentacular system of Sipunculoidea. In sipunculoids the tentacular system acts as compensation sacs for the tentacles, receiving the fluid from the latter when they contract and sending it to the tentacles when they expand. Thus the whole system is subservient to the tentacles. No communication of this system with the coelom was observed though the coelomocytes are found in them. It is not clear how the coelomocytes penetrate into the sacs. At present there seems to be no evidence to homologise the tentacular system to the vascular system of echiurids. The echiurids, on the other hand have a vascular system as in annelids but profoundly modified. Bock (1942) even tried to compare the neuro-intestinal complex to one of the commissural vessels of annelids. The vascular system is better developed in the anterior region and is made in such a way that a large amount of blood is always propelled to the proboscis. The propulsion of the blood into the proboscis expands this organ. Simultaneously, the coelomic fluid also rushes to the lateral coelomic spaces of the proboscis. The coelomic fluid is probably aerated in the proboscis. The blood vessel which lies in the coelom is immediately in contact with the coelomic fluid. The blood is probably aerated by the coelomic fluid. The blood flows into the proboscis through the dorsal vessel and returns into the ventral through the lateral vessels of the proboscis. If the circulation is controlled by the expansion and contraction of the proboscis then, there should be a back and forth movement of blood in all the vessels but in echiurids the blood flows forward in the dorsal vessel while in the ventral vessel it is reverse. Thus, it is highly improbable that the vascular system in echiurids functions in the same way as the compensation sac of the sipunculoids. There is no doubt it may assist in the working of the proboscis but at the same time it may have other functions. The ventral vessel is extending from the anterior to the posterior side and the blood is always flowing back. The course of circulation in echiurids has not been properly explained. Prashad writes (1909 p. 333) 'the course of the blood in this system cannot be definitely understood with the present state of our knowledge of these forms". It is generally believed that blood flows from ring sinus to the dorsal vessel. From the dorsal vessel it flows into the lateral proboscis vessel which drains into the ventral. From the ventral vessel a part of the blood is drawn into the ring sinus through neurointestinal thus completing a circuit anteriorly. But the course of blood flowing back through ventral vessel is not clearly understood. I am not aware of an answer to this point of circulatory system. My studies on I. pirotansis reveal that there is a peri-intestinal sinus around the alimentary canal in the anterior region of the intestine. This peri-intestinal sinus or ring sinus is obliterated to a great extent posteriorly except for two ventral sinuses in the wall of the intestine. This ventral sinus runs on either side of the collateral intestine and is in communication with the ring sinus anteriorly. It is relevent to recall that a ciliated groove or siphon always start from the region of the ring sinus. In I. pirotansis the ventral vessel divides into three or four branches before it merges with the rectal wall. It is possible that the blood flowing through the ventral vessel finds its way back to the ring sinus through the system of sinuses which lie on either side of the siphon. I am not sure that this is the state in other echiurids. There are occasional references to the presence of peri-intestinal sinus in echiurids. Reitsch (1886) described a peri-intestinal sinus in Thalassema neptuni and Jameson (1899) described, "traces of sinus in the intestine proper behind the preintestinal constriction and consequently behind the blood vascular ring.

6. Nervous System

The nervous system of I. pirotansis has the same arrangement as found in other echiurids. It consists of a ventral nerve cord (Fig.50) running from the anterior region to the posterior end. The ventral vessel also adheres to it. Large number of lateral nerves are given off from the ventral nerve cord to the body wall. These nerves do not show any segmental arrangement, but are given off at irregular intervals. Ganglionic swellings are entirely absent (Fig. 33).

The ventral nerve cord bifurcates at the region of the junction of the proboscis (Figs. 34 and 35) and body. This part of the nerve cord is thicker as compared to the rest of the cord. The two 'peripharyngeal' nerves enter the proboscis and continue as the lateral nerves of the proboscis. These two nerves meet at the anterior end to form the 'peripharyngeal ring'.

The ventral nerve cord appears to be single, but in sections there is a conspicuous dorsal groove. The nerve cells are found more towards the ventro-lateral region. The detailed histology of the nerves could not be made, since tissues were not fixed for neurological studies. In the proboscis the lateral nerve cord gives rise to transverse branches which innervate the margin of the proboscis. Along the lateral margins of the proboscis are observed a number of sensory cells. These cells are very similar to those observed in the prostomium of earthworms (Menon and Sudarshan 1966 unpublished).

Prashad (1919) considered the proboscis as an elongated prostomium. He stated that the supra-oesophageal ganglion of the earth worm is further shifted far forward in the echiurids and the two lateral nerves are the very much elongated circum oesophageal connectives while the triangular area from which the nerves arise is the sub oesophageal ganglion. Embleton (1900) described in some detail the nervous system of *Urechis unicinctus*. He described a 'central canal' in the ventral nerve and compared with the giant fibres of the earthworm. Greef (1879) also had referred to this central canal in *Echiurus echiurus*. The gross morphology of the nervous system is almost identical in different echiurids. The main nerves are accompanied throughout their length by blood vessels, the ventral nerve cord by the ventral vessel and the lateral nerve cord by the proboscideal lateral vessels.

7. Segmental Organs

The segmental organs of echiurids are the anterior nephridia, which act as gonoducts and the anal vesicles, which are mainly excretory in function. The anterior segmental organs of *I. pirotansis* are constituted by 8 to 20 pairs of nephridia (Fig. 13). They are arranged on either side of the nerve cord and open externally by nephridiopores situated on either side of the mid - ventral line of the body. All the nephridia are post setal in position and the last pair of the series is situated at the level of the ring sinus. Internally a single nephridium communicates with the coelom by an apical ciliated funnel.

The lips of the funnel are petaloid (Fig. 36). Each organ represents a long necked flask with a terminal opening. The length of nephridia may vary from 4-6 mms. Three regions could be distinguished, a short nephridial duct, which opens out by nephridiopores, a sac like middle region and an apical funnel. The sac-like middle region is usually filled with eggs (Photo. 16). The first pair of nephridia is usually undisturbed. Some of the posterior members of the segmental series show a definite tendency towards an asymmetrical arrangement. This asymmetry is expressed in two ways :(a) Two nephridia may be present on the right side, while on the left side on the corresponding place, there may be only one organ (b) one nephridium may be present on the right side, while on the left side there may be none or vice versa (Table I). I have examined a number of specimens and found the total number of nephridia on the right and left side are not always equal. As a rule the number of nephridia is more in larger specimens than in the smaller. It is obvious that new nephridia are added during the growth of the animal. The nephridiopores are very prominent externally and open on the summit of well pronounced body papilla.

The funnel of the nephridium is more or less flower shaped and it leads to the neck. The neck of the nephridia is thicker than the sac. Externally there is a layer of peritoneum . The cells are columnar. Beneath the epidermis there are two layers of muscles (Figs.37 and 38). The nephridial duct is very short and muscular. Internally

Table I

The table showing the arrangement of nephridia

	Specimen 1 length 11 cms		Specimen 2 length 16 cm.		Specimen 3 length 36 cm.		Specimen 4 length 45 cm.	
	L	R	L	R	L	R	L	R
I	1	0	1	1	1	1	1	1
II	1	2	2	1	1	1	1	1
III	2	1	1	1	1	2	1	0
IV	0	1	1	1	1	1	1	1
V	1	1	1	0	1	2	2	1
VI	0	1	1	2	1	1	0	1
VII	2	2	0	1	1	1	1	2
VIII			1	1	1	1	1	1
IX			1	0	1	1	1	0
X			1	1	1	1	1	1
XI			0	1	1	1	1	1
XII					1	1	0	1
XIII					1	1	1	2
XIV					1	1	1	1
XV					1	0	1	2
XVI					0	1	0	1
XVII					1	0	1	1
XVIII					1	0	1	0
XIX					0	2	1	1
XX					1	0	1	1
XXI					1	0	1	0
XXII							1	0
XXIII							0	0
Total	7	8	11	10	19	19	20	20

there is a layer of folded epithelial cells. The cells are columnar. Immediately beneath the epidermis is a circular layer of muscles. The longitudinal muscle lies out side the circular (Fig. 39). The muscle layers of the nephridial duct are very similar to the male sac in *Acanthobonellia vulgaris* in which this structure is formed as an invagination of the body wall. The circular layer of muscles ~~are~~ is more pronounced than the longitudinal. The sac is thin walled.

The anterior nephridia of other Indian echiurids are basically different from *I. pirotansis*. In *L. brevirostris* there are only two pairs of segmental organs. They are long and tubular organs extending upto 1/3 the length of the body. It is always filled with genital products (Fig. 40). The distal end of the nephridium is blind and the nephrostome is situated at the base of the organ. In *O. formosulum*, the nephridia are two pairs with coiled lips attached to the lateral nephrostome. The nephridia in *O. septemyotum* are similar to *O. formosulum*. In *A. sabinum* and *A. chaetifera* there are two pairs of nephridia with coiled lips (Datta Gupta et al. 1963). *A. loborhynchus* has five nephridia , three on the right and two on the left (Datta Gupta and Menon 1965). In all these forms the lateral lips of the nephrostome are drawn into a pair of long or short spirally coiled filaments. These are intricately intertwined and are very conspicuous structures in the coelomic cavity. They ramify enormously and are in contact with all the organs in the coelom. The coiled filaments collect the eggs floating in the coelom and direct them towards the nephrostome. The eggs travel along the ciliated groove of the filaments. The mechanism of picking up the germ cells is not understood. In Ikedosma gogshimense, there are only three pairs of long tubular nephridia situated behind the setae. The nephrostomes are at the base forwarded with spirally coiled lips.

The anal vesicles are a pair of thin walled sac each one projecting from the lateral walls of the rectum. They are long and measure about 5 to 8 cms. The surface of the sac is beset with large number of slender tubules with a ciliated funnel at the tip. These tubules open into the vesicle . The vesicle itself is closely held to the body wall throughout by means of short mesentrial strands. Most of the tubules open directly into the vesicle (Fig. 20). A few tubules undergo secondary branching (Fig.41). The long tubules arising from the distal part of the vesicle give rise to five or six secondary branches. The tubules which directly open into the central canal may be called the primary tubules (Photo. 14). Branching tubules in the anal vesicle were not observed in other echiurids, though it is the usual condition in bonellids (Menon et al. 1964). Externally the vesicle has a covering of circular muscles. The longitudinal fibres are arranged in groups internal to the circular layer. The epithelial layer is formed by tall columnar cells which are more or less irregularly arranged (Fig. 42). The cells are granular . The ciliated funnel of the tubule has essentially the same structure as that of the terminal funnel of the nephridia except that these are smaller and numerous . The funnel is lined by tall ciliated columnar cells (Fig.43). The tubules have a delicate lining of circular muscle fibres. Internally they are lined by columnar cells(Fig. 44). The anal vesicles of L. breviorstris are in the form of two elongated sacs. These sacs are broad at the base and distally taper into a fine filament. Only sessile funnels are found which are comparatively few in number (Datta Gupta and Menon 1965).

The segmental organs of echiurids are usually one or more pairs of anterior nephridia and a pair of posterior anal vesicles. The number, disposition and morphology of these segmental organs vary in different genera, and are the most important reliable characters in elucidating the relationship of the different genera of echiurids. The anterior nephridia are usually situated behind the ventral setae. But in many species of Ochetostoma and Anelassorhynchus a pair or more is found presetally. In most of the genera the presetal pair is absent. The number of nephridia also varies within a genus. They are two to three pairs in Echiurus, Urechis, Thalassema, Anelassorhynchus , Listriolobus and Lissomyemma (Jameson, 1899, Embleton, 1900, Prashad, 1919 a and 1919b, 1920, 1935, Fisher, 1946, Datta Gupta et al. 1963, Datta Gupta and Menon, 1965). An increased number of these organs was reported in some species of Ochetostoma, (Stephen and Robertson, 1952, Prashad, 1929, Datta Gupta and Menon, 1961), Ikedosoma (Ikeda 1907) ; Menon and Datta Gupta, 1962) and Ikeda (Ikeda, 1907). In O. zanzibarense there are seven pairs of nephridia while in O. hornelli there are five pairs. In I. elegans the segmental organs present some very remarkable points, though taken singly they are of the ordinary type of structure. Each organ represents a conspicuous sac of an elongate shape tapering towards the inner end. The internal opening present at the base is provided with two relatively short spiral lobes. Numerically the nephridia are far less in number in I. elegans as compared with Ikeda taenioides and Ikedosoma pirotansis. Moreover, the number varies with individuals and occasionally also with sex. In I. elegans it ranges from 13-27 arranged in six or seven groups. From Ikeda's table showing the arrangement of nephridia, it is clear that they are in six or seven groups in each side, a group some times containing one, two or three nephridia. In a single female specimen Ikeda reported seven nephridia on the right and six on the left side making a total of thirteen. As mentioned above in Ochetostoma zanzibarense there are up to 14 nephridia arranged in seven pairs. The significant difference of I. elegans from O. zanzibarense is that in the former there is a tendency to develop supernumerary pairs of nephridia which leads to the formation of groups of nephridia per segment, which varies individually. Thus in the female specimen, there is hardly any grouping, though it shows an asymmetry in the arrangement. Such asymmetry is not unknown in other echiurids. Unpaired nephridia have been found earlier in *Thalassema neptuni* (Stewart, 1900). In *A. loborhynchus* there are altogether 5 nephridia of which 3 are on the left side and 2 on the right (Datta Gupta and Menon 1965). Basically *I. elegans* and *O. zanzibarense* have the same plan i.e. 7 groups or pairs of nephridia. Moreover, the nephridia are typically of the echiurid type in which the lateral lips of nephrostome are extended to form long spirally coiled filaments. This condition is in fact found in all echiurids except *I. pirotansis* and *Ikeda taenioides*.

Wharton (1913) established the genus *Ikeda* for *T. taenioides* because it has a peculiar type of simple tube like gonoduct unknown till recently in other echiurids. They were found in incredible numbers in the above mentioned species. Bock (1942) considered the presence of simple tube like gonoducts with apical ciliated funnels as an atavistic feature in the highly specialised *I. taenioides* . Ikeda (1907) suggested that the pairwise or pseudopair-wise arrangement of nephridia in other echiurids might have been derived from the condition obtaining in *Ikeda taenioides* in which the organs in question occur crowded together without apparent order. He further considered that *I. elegans* represented an intermediate stage between *I. taenioides* and other echiurids with respect to the number and mode of arrangement of segmental organs. Goodrich (1945) stated that in *I. taenioides* each organ has a simple tubular canal ending in a wide open canal. That these gonoducts are not simply metanephridia can hardly be doubted; on the other hand it is highly probable that they are nephromixia possibly strictly homologous with the mixonephridia in Polychaeta. Baltzer (1926) recorded that in *Bonellia* the funnel develops as an outgrowth of the coelomic epithelium. This fact is considered as strong evidence that it is a coelomostome".

The discovery of simple tube like nephridia in *I. pirotansis* has brought in new facts as to the possible evolutionary trends in the anterior nephridia. It must be stated here that in *I. pirotansis* there are about 8 to 20 pairs of simple tube-like nephridia with apical funnels, and that there is no tendency of overcrowding as in *I.taenioides*. Thus, it represents a much more simple condition than in *I. taenioides*. At the same time there is no doubt, that in both these forms these organs are of the same type, though in *I. taenioides* these organs are in large numbers, two hundred or more. The multiplication of the segmental organs as we find in *I. elegans* and *I. taenioides* may not indicate any immediate relationship between the two and the former may not represent a stage in between *I. taenioides* and other echiurids as claimed by Ikeda (1907). This is evident, because the segmental organs in these two genera are fundamentally of different types. On the other hand it is more probable that the supernumerary number of segmental organs of I. taenioides is derived from some form like I. pirotansis in which they occur in pairs. The development of many nephridia in a segment is not unusual in annelids. Goodrich (1945) made the following statement in connection with the meronephridia of Oligochaeta; "there can be little doubt that the condition with many nephridia per segment has been secondarily derived from an original distribution of only one pair of metanephridia in every segment as in other oligochaeta". Probably a multiplication of the nephridia has taken place in various families and genera independently and perhaps not always in exactly the same way. But it may at once be stated that multiplication is by growth, some sort of budding and subdivision of the primary paired nephridia either in embryonic or in latter stages. A similar process might have taken place in echiurids, along two parallel lines one culminating into the I. elegans condition, while the other attaining the I. taenioides condition. The pair-wise arrangement of the nephridia in the female specimen of I. elegans is not very different from Ochetostoma zanzibarense . In Ikedosoma gogoshimense there are only three pairsof nephridia reminding the Ochetostoma pattern. Ikeda taenioides condition can be derived from some form similar to Ikedosoma pirotansis with simple tube-like gonoducts.

It is a feature without exception that whenever the nephrostome is at the base, the lateral lips of the nephrostome are unequal or they are elongated to form long filaments. Bock (1942) considered the Ochetostoma pattern with lash-like filaments or lobes representing a primitive feature from which the Thalassema conditions could be derived. He further claimed that with a diminished number of segmental organs the size of the egg seems to increase and the spirally coiled filaments tend to disappear. In L. brevirostris the eggs are very small and numerous and their filaments are very long and form a labrynthine net work entangling all the organs in the coelom. It is presumable that the eggs are gathered by these filaments and directed to the nephridia, where they are stored. The reduction of the number of nephridia may have only a remote relationship with the size of eggs, because in I. pirotansis the eggs are larger than L. brevirostris or Ochetostoma species.

Anal vesicles are the excretory organs. There is considerable controversy as to the homology of this structure. Goodrich (1945) based on the observations of Hatschek (1880) Salensky (1905) and Baltzer (1917) concluded that part of the anal sac is coelomesoblastic in origin and the apical funnel develops as an outgrowth of the coelomic epithelium. Goodrich (1945) stated that the anal sacs are of the same nature as the gonoducts either coelomoducts or nephromixia. According to Goodrich, Baltzer's (1917) view that the anal vesicle represents neither the metanephridium nor the gonoduct of the female seems hardly justified. The anal vesicles of I. pirotansis is more akin to the Maxmulleria type where these organs project like two thin walled sacs form the lateral sides of the rectum and are richly beset with densely aggregated tubules. Bock (1942) in Maxmulleria reported branching of the tubules. In the anterior half of the anal vesicles of I. pirotansis similar branching of the tubules are observed. Herdman (1897) said that the tubules are never branched in Maxmulleria. Branching tubules are a characteristic feature of the anal vesicles of bonnelids. Thus the anal vesicles of I. pirotansis deviate considerably from I. elegans and other echiurids. In I. elegans the anal vesicles are long and conspicuous tubular organs provided with short stalked funnels.

8. Reproductive Organs

The description of the reproductive system is based only on the females since I have not come across a male specimen inspite of vigilant search. About fifty specimens were examined during the last four years. It is just possible that the males may look quite different from the females as in some bonellids. But an examination of the coelomic fluid, nephridia, and pharynx, did not yield any clue.

The ovaries are not of definite form and the oocytes are proliferated from the peritoneal lining of the posterior region of the ventral nerve cord(Photo. 15). The coelomic fluid contains large number of egg cells. In the earlier stages the peritoneal cells at the proliferation centre are small containing rounded nuclei. The destined egg cell grows in size at the expense of the surrounding peritoneal cells. When the egg has attained about 40- 43 μ diameter it gets detached from the mesentery and floats freely in the coelomic fluid with the characteristic cap of nurse cells (Fig. 45). The nurse cells are columnar and are arranged radially, converging to the centre. In the immature eggs the nurse cells are larger, but they start dwindling with the growth of eggs. The growing egg receives its nourishment from the nurse cells by a prominent tubular outgrowth of the egg which penetrates into a vesicle to which the nurse cells drain their contents (Figs. 46, 47, 48). The eggs with detached cap of cells floating in the coelom measured 300 μ to 450 μ. The floating eggs in the coelom are collected by the ciliated funnels and are conducted to the nephridial sac through the neck of the nephridia. The eggs which are stored in the nephridia vary in size (Photo. 16). Each egg is provided with a thin egg membrane. The eggs collected from the body fluid and the nephridia showed considerable shrinkage of their membrane during dehydration. An egg is provided with a rounded germinal vesicle of about 70 μ in diameter. There is a circumnuclear zone (yolk-nucleus in other oocytes) of about 29 µ thickness(Photos. 17 , 18). This circumnuclear zone is intensely fuchsinophil; eosinophil and pyroninophil (negative after ribonuclease control) trichloroacetic acid and perchloric acid and positive to Hg-BPB and PAS (negative after acetylation and positive after KOH reversal) and slightly positive to Sudan black B. The above reactions reveal the presence of proteins, RNA, carbohydrates and some lipids in the circumnuclear zone (Fig. 48).

The cytoplasm of a ripe egg obtained from the nephridia is full of yolk globules both of fatty and proteinous nature. The largest fatty yolk globule observed measures about 25 µ. They are intensely positive to Sudan black B, Sudan III and IV and colour pink in Nile blue sulphate. This reveals the presence of triglycerides in the fatty yolk globules (Fig. 49).

The protein yolk globules remain small in size than the fatty yolk globules. These globules are intensely stained in Delafield haematoxylin and are intensely positive to Hg-BPB, alkaline fast green and PAS (negative after-acetylation and positive after KOH reversal) . They are intensely pyroninophil (negative after salivary ribonuclease, trichloroacetic acid and perchloric acid treatments).

The above reactions reveal the presence of basic proteins, carbohydrates and RNA in the protein yolk globules.

In addition to fatty and protein yolk globules there are present granules amongst the fatty and protein yolk globules. These granules show intense reaction for RNA, carbohydrates and basic proteins (Fig. 49).

Coelomic fluid of L. brevirostris, T. neptuni, O. septemyotum and Acanthobonellia vulgaris were also examined. The cap of nurse cells was found to be absent in L. brevirostris (Fig. 50) and T. neptuni, while it was present in Acanthobonellia vulgaris (Fig. 52) . The nurse cells of A. vulgaris are larger in number than in I. pirotansis. The eggs are attached to the cap of nurse cells by a prominent tubular outgrowth as in I. pirotansis. In Maxmulleria on the other hand the eggs are devoid of the cap of nurse cells and according to Bock the presence of nurse cells is one of the characteristic features in Bonellids. The present study shows that nurse cells may be present in echiurids as well as bonellids. The oocytes of L. brevirostris are proliferated from the peritoneal lining along the ventral nerve cord, and there is no localised area as seen in I. pirotansis. The eggs are much smaller than the eggs of I. pirotansis (Figs. 50 , 51). The eggs measured 250 µ to 350 µ. The fully formed eggs were stored in the sac like nephridia. In O. septemyotum the eggs are provided with nurse cells (Fig. 53). In T. neptuni groups of oocytes of varying sizes are found floating in the coelom. They are most likely detached from the centre of proliferation. Each cluster contains 7-15 oocytes.

Bock (1942) stressed that with a diminished number of segmental organs, the size of eggs seems to increase. He cited the following examples. *T. billitonense* (3 pairs) the eggs measure 120 µ, *T. mellita* (3 pairs) 80 µ; in *Urechis caupo* (3 pairs) 115-180 µ; *T. neptuni* (2 pairs) 150 µ; *M. gigas* (one pair) 0.40 mm; *B. viridis* (one) 0.45 mm; *Protobonellia ijimai* (one) 0.45 mm; *Hamingia arctica* (one) 800 µ; *Urechis chilensis* (3 pairs) 150 µ; *E. echiurus* (2 pairs) 270 µ. These observations are no doubt suggestive but in *I. pirotansis* with 20 or more segmental organs the eggs are as large as 450 µ or more. It is not always true that the eggs become smaller when the segmental organs are more in number. However, there appears to be a correlation between the spiral lips of the nephrostome and size of eggs.

CHAPTER IV

SYSTEMATIC POSITION AND INTER-RELATIONSHIPS OF *I. PIROTANSIS*

CHAPTER IV

SYSTEMATIC POSITION AND INTER-RELATIONSHIPS OF IKEDOSOMA PIROTANSIS

Ikedosoma pirotansis was first described by Menon and Datta Gupta (1962). Subsequent studies on these animals revealed that they exhibit a large number of interesting features, and that they diverge in a large way from I. elegans. Further,it was felt that Ikedosoma pirotansis,cannot be included under the genus Ikedosoma. This genus was created by Bock to rehabilitate T. elegans in which the nephridia were arranged in groups. I consider that I. elegans is related more to Ochetostoma than any other genera of echiurids,in a number of ways. The body wall is distinctly of the Ochetostoma type. The longitudinal muscles are gathered into ten bundles. Ikeda (1904) writes " All the longitudinal lines visible on the outside excepting the one which runs in the mid ventral line and is superposed by the nerve cord,appear on the inner surface of the body wall as slightly elevated, narrow ridges or thickenings of the longitudinal layer. In the ten zones separated from one another by the above lines,the circular muscle fibres form more or less regularly arranged transverse bundles". This description is strongly suggestive of its similarity with Ochetostoma where an identical condition exists. The anterior nephridia also resemble the Ochetostoma type. They are provided with 7 pairs or paired groups of nephridia. These nephridia are provided with lateral lips.

Asymmetry in the arrangement of the nephridia is not a rare feature and, the supernumerary number (in this case 27) could be derived by secondary splitting .

The following characteristics of *I. pirotansis* distinguish it from all other known echiurids:

1. The longitudinal muscles are continuous and do not form bundles. As stated above, in this respect, it is different from, *Ochetostoma* and *Ikedosoma elegans*. The echiurids which have continuous muscle layers are *Echiurus* , *Thalassema*, *Anelassorhynchus*, *Arhynchite* and *Urechis*.

2. Nephridia have apical funnels. The only other echiurid to have this condition is *Ikeda taenioides*.

3. The nephridia are 8-20 pairs, not arranged in groups. In this respect it does not resemble *I. elegans* or *I. taenioides*.

4. The heart is situated between the prointestine and midintestine, as in *Ikeda taenioides*. In *Ikedosoma elegans* the heart is situated more anteriorly.

5. The anal vesicles are provided with long stalked funnels which show branching. No known echiurids have this condition.

6. An interbasal muscle is present. It is absent in *I. elegans*.

7. A prominent muscle plug is present between the setae . This structure is absent in *I. elegans* and in other echiurids.

A comparison of *I. pirotansis* and *I. taenioides* reveals some interesting features. In the latter the body wall is of *Ochetostoma* type though of a reverse order and the nephridia are of *I. pirotansis* type though they are incredibly large in number. On the other hand these two forms resemble in the nature of simple tube-like nephridia with apical funnels and the position of the heart between the prointestine and midintestine. Gizzard is absent in both. Thus, these two forms are related to a large measure but not close enough to justify the transfer of *Ikedosoma pirotansis* to the genus *Ikeda*.

On the basis of these considerations I propose a new genus *Polynephrosoma* as *I. pirotansis* as the type. The species should be named as *Polynephrosoma pirotansis*. This new genus is more closely related to *Ikeda* among echiurids and to *Maxmullaria* among bonellids.

Polynephrosoma Genus novo.

1. Longitudinal muscles continuous.
2. Proboscis very long and ribbon-like without lacunae.
3. Nephridia 8 - 20 pairs with apical funnels.
4. Anal glands sac-like provided with numerous slender tubules with apical funnels. The tubules show secondary branching.
5. The heart is situated between the prointestine and midintestine. The prointestine is without the ciliated groove.
6. Presence of an accessory ventral vessel.

7. Neurointestinal does not form a loop around the interbasal muscles.
8. Interbasal nuscle is present.
9. A prominent muscle plug is present in between the setae.

Type species <u>Polynephrosoma</u> <u>pirotansis</u> (Menon and Datta Gupta)

There is no doubt that <u>Polynephrosoma</u> <u>pirotansis</u> is allied to <u>I</u>. <u>taenioides</u> but the main point of difference is the disposition of the circular and longitudinal muscles. In <u>I</u>. <u>taenioides</u> the longitudinal muscles are gathered into five bundles and lie out side the circular muscle while in <u>Polynephrosoma</u>, the longitudinal muscle layer is inside the circular and is continuous. Fisher (1946) stressed great importance to this character and instituted an order Hetero-myota to include <u>I</u>. <u>taenioides</u> while Bock (1942) did not seem to consider this point while creating a new sub-family Ikedinae for <u>I</u>. <u>taenioides</u>. In his classification Bock clearly mentions that in Saccosomatinae "body musculature has reverse order of the layers of muscles in comparison with true echiuroids", thereby implying that all echiurids have longitudinal muscle layer inside the circular layer of muscles. It is highly improbable that Bock (1942) has over looked such an obvious character which he regarded important with reference to Saccosomatinae. It seems Fisher (1946) in creating Heteromyota has also over looked a previous reference. Prashad (1919) stated that the muscular layers in

Anelassorhynchus branchiorhynchus are well developed and consist of an outer one of longitudinal, a middle one of circular and an inner most of oblique layer. In this context Heteromyota based on the reversal of muscle layers has to accommodate *A. branchiorhynchus* together with *I. taenioides*, two forms so divergent in structure and habitat . During the course of the present study such a reversal of muscle layer in closely allied species such as *A. sabinum* and *A. chaetifera* has not been observed. It is, therefore, felt that the creation of a new order Heteromyota on the basis of reversal of body wall muscles needs further probe. Another important difference is the presence of numerous nephridia in *Ikeda taenioides*.

Polynephrosoma is related to *Thalassema*, *Anelassorhynchus* and *Arhynchite* in having a continuous layer of longitudinal muscles. Further, it shares with *Arhynchite* a long presiphonal prointestine which in a majority of *Arhynchite* species is without ciliated groove. *Polynephrosoma* has very little in common with *Ochetostoma* and other related genera. It, however, shows certain features in common with bonellids. The presence of ventral accessory vessel as in Protobonellia, the presence of branched and stalked funnels in the anal vesicles as in *Maxmullaria* and *Prometor* , and the presence of terminal nephrostome as in the case of *Bonelliopsis* and *Eubonellia* are some of the more important bonellidan characters of

Polynephrosoma pirotansis . If stalked funnels of the anal vesicle should be one of the criteria to distinguish a bonellid from echiurid, then *Polynephrosoma pirotansis* has unmistakable affinities towards bonellids. Bonellids are having sexual dimorphism. Since no male has been found in *Polynephrosoma pirotansis* , it is difficult at this stage to comment on sexual dimorphism. It may be mentioned that in *Maxmullaria* and *Prometor*, the males are still not known.

CHAPTER V

TAXONOMIC CONSIDERATIONS AND CLASSIFICATION

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(1). Taxonomic considerations

Fisher (1946) stated that systematics of Echiuroidea presents certain problems which are inherent to the group. According to him the principal difficulty is the lack of structures having a permanent form. Further, a character which seems to be important in one genus is relatively unimportant in other genera. Thus a long presiphonal gut may serve as a generic character in *Arhynchite* but this character is practically of not much use in *Thalassema* in which the presiphonal intestine may be short or long in the different species.

The echiurids are traditionally divided into two groups based on the presence or absence of posterior setae. It was conventional to group *Echiurus* and *Urechis* together since in both, the perianal setae are present. The presence of posterior setae in both these genera was considered to be a character indicating close affinity. It is well known that *Urechis* is a highly specialised echiurid. Retention of posterior setae in these two genera is probably only one of the landmarks of the Annelidan ancestry of echiurids. In most echiurids, the descriptions of anterior setae are more or less the same that they can hardly be used as a discriminating character. Chen and Cheng (1958), considered the length of setae as one of the specific characters to distinguish between *Arhynchite rugosum* and *Arhynchite inamoenus*. But the available data in this field shows that the length of the setae is a very variable character even within the species. Apparently microscopic examination of setae of different echiurids reveal that the setae show differences and the usefulness of this character in echiurid taxonomy is being examined (personal communication from Mr. Joseph Mathew , Deptt. of Zoology, B.I.T.S., Pilani).

The pigmentation of certain echiurids was ~~were~~ considered to have taxonomic significance. The colours are lost in preservatives and the specimens which are likely to be encountered by a systematist are preserved ones. Edmonds (1960), distinguished, two species of *A. porcellus* and *A. adelaidensis* only by their ~~its~~ colour, the former was sandy grey in life whereas, ~~while~~ the latter was deep green. ~~in life~~. *Polynephrosoma* is scarlet red in colour but lo~~s~~ses this colour within half an hour after preservation. Hence the colour may be a reliable taxonomic criterion, provided fresh specimens are examined.

The proboscis was considered an important taxonomic character of echiurids. Annandale (1922) proposed the genus *Anelassorhynchus* based on the structural modification of the proboscis. But now it is known that similar modifications are not uncommon in species of *Ochetostoma* and *Listriolobus*. The genus *Arhynchite* was established on the basis of the absence of proboscis although Fischer (1949) described a species of *Arhynchite* with proboscis. Edmonds (1960) reported *Arhynchite hiscocki* with proboscis from Australia. The presence of a long or a short proboscis is some-time used as a specific character. It should be remembered that the proboscis is a highly contractile organ and the relative length of proboscis depends upon the state of contraction at the time of preservation. The distal tip of the proboscis may be bilobed as in A. loborhynchus. Proboscis can be deciduous or nondeciduous. Anatomically, two distinct types of proboscis are found in echiurids; one with large number of lacunae and the other without them. The former condition prevails in the majority of echiurids ~~while~~ whereas, the latter is examplified by Polynephrosoma piretansis.

The size and arrangement of body papillae in certain echiurids were used to discriminate between species. In Echiurus echiurus, the small papillae are arranged in regular rows ~~while~~ whereas in Echiurus antarticus, they are not arranged in regular rows. According to Stephen (1941), these papillae are really arranged in rows in Echiurus antarticus. Wesenburg Lund (1955), confirmed Stephen's observations. The review of the literature (vide supra) shows that the distribution and the size of the papillae could not be used successfully at the interspecific or the intergeneric level.

The arrangement and disposition of longitudinal muscles are of some definite use in echiurid taxonomy. Spengel divided the old Thalassema group into three genera namely Thalassema, Ochetostoma and Listriolobus based on the nature of body muscles. This division though did not get universal approval among specialists, is still very much in vogue. My studies confirm that *Listriolobus* could be easily distinguished from *Ochetostoma* by the nature of the longitudinal muscles. The number of longitudinal muscle bands in *Ochetostoma* is extensively used as a specific character. In the past a minor variation in the number of muscle bands was considered taxonomically important with the result, many new species were described with varying number of muscle bands. For example, the following six species of *Ochetostoma* were distinguished solely on the basis of the number of longitudinal muscle bands.

O. erythrogrammon	14 muscle bands
O. stuhlmanni	15 or 16 "
O. leptodermon	15 or 17 "
O. caudex	16 or 18 "
O. kokotoniense	17 or 18 "
O. griffini	17 or 18 "

Sato (1939), rightly suggested that all these species should be considered as *Ochetostoma erythrogrammon*. Numerical variation of the muscle bands alone does not qualify the individual species mentioned above, particularly when the number of bands intergrade in the different species.

Two types of nephridia are known in echiurids. Nephridia with lateral funnels are found in most of the echiurids ~~while~~ whereas, nephridia with terminal funnels are found only in two species namely Ikeda taenioides and Polynephrosoma pirotansis. The structural modification of lateral nephrostome could be used to distinguish different genera. Anelassorhynchus has spirally coiled lateral lips and in Thalassema, the lateral lips are not produced into spirals. Lisomyemma has leaf like lobes in the lateral nephrostome and could be easily distinguished from Listriolobus which has long spirally coiled lips. The number and position of the nephridia are also widely used in echiurid taxonomy. Fisher (1946) used this character in his key for the identification of some of Ochetostoma species. Number of these organs and their position in relation to setae ~~was~~ were used in distinguishing the different species of Anelassorhynchus (Datta Gupta and Menon 1965).

The anal vesicles in echiurids exhibit very little variation. This organ is generally sac-like with short stalked funnels. The only exception to this rule is found in Polynephrosoma pirotansis in which the anal vesicle is provided with tubular funnels showing secondary branching.

Structural variations of the alimentary canal ~~has~~ have some bearing on echiurid classification. Fisher (1949), stated that the nephrosotome and the very long presiphonal segments of the intestine separate the genus Arhynchite from Thalassema. According to Wesenburg Lund (1959), the essential discriminating features of T. Steinbecki and

T. philostracum are to be found in the alimentary canal; the latter has a longer foregut and presiphonal intestine. T. hartmani (Fisher, 1947), has a very long presiphonal intestine. These are not very precise to be used as specific characters. The position of the prointestine on the other hand in relation to the ring sinus, is perhaps a useful character. There are a number of echiurids in which the prointestine is precardiac ~~whilst~~ whereas, in others, the prointestine is postcardiac. The presence or absence of ciliated groove in the prointestine could also be considered. No attempt has h~~e~~itherto been made to evaluate the taxonomic significance of these characters. It is well known that a ciliated groove is usually present in most echiurids in the prointestine though, in a few, it may be absent. The presence or absence of ciliated grooves is conditioned by two facts.

1. A ciliated groove is usually absent when there is no ring sinus as in some Arhynchite species.

2. A ciliated groove is absent when the prointestine is precardiac. On the other hand, a ciliated groove is always present when the prointestine is postcardiac.

The position of the heart and the length of the dorsal vessel ~~is~~ are used as a distinguishing character of I. elegans. In ~~the latter~~ this form, , the heart is situated between the pharynx and intestine. In other echiurids, the heart is placed either in between the foregut and midgut or between prointestine and midintestine (vide supra).

Very little is known about the presence or absence of intestinal caeca in different species. *A. inamoenus* is distinguished from *A. rugosum* by the absence of intestinal caecum in the latter. Many *Listriolobus* species have intestinal caecum. More data are ~~is~~ required to assess the taxonomic value of this character.

The coelomic corpuscles were found to be different in shape and size in *Ochetostoma formosulum*, *Anelassorhynchus*, *Listriolobus* and *Ikedosoma* (= *Polynephrosoma*). The usefulness of this character in echiurid taxonomy stresses need for further trials.

The developing egg cells in the coelom may or may not have a cap of nurse cells. Nurse cells are found to be present in *Ochetostoma* species and *Polynephrosoma* Whereas, ~~while~~ in *Listriolobus* and *Thalassema*, the nurse cells are absent. Further data are required to find out the taxonomic significance of such nurse cells.

The body musculature, presence or absence of post setal segmental organs, the position of the ciliated funnel, the presence or absence of ciliated groove~~s~~ in the pro-intestine, position of the heart in relation to the different regions of the alimentary canal, the anatomy of the proboscis, the coelomic corpuscles and the female germ cells seem to be the more important characters in echiurid taxonomy.

(2). Classification

Monro (1927) was one of the earliest to arrange all the known echiuroids in a systematic way. Among the modern classifications, Bock (1942), Fisher (1946) and Dawydoff (1959) deserve special consideration. A review of the literature and the present studies reveal that the existing classifications of echiurids require readjustments.

I suggest below the following scheme incorporating some of the salient features of Bock's and Dawydoff's classification.

Phylum Echiuroidea Newby 1940

Class Echiurida

Family 1. Echiuridae Baird 1868, amended. *Echiurus*.
with two rows of posterior setae proboscis not bifid. Anal glands with sessile fennels. Two pairs of gonoducts. Gizzard present.
... *Echiurus*.

Family 2. Urechidae Dawydoff.
with one row of posterior setae. Proboscis reduced and fold-like. Vascular system absent. Anal respiration. ... *Urechis*.

Family 3. Thalassematidae Bock, emended.
Nephridia with lateral nephrostome. One to seven pairs or paired groups of anterior nephridia.

Sub-family 1. Ochetostomatinae novo.

Longitudinal muscles in bands. The lateral lips of the basal nephrostome produced into long or short spiral lobes. Proboscis is provided with well developed coelomic spaces. ... <u>Ochetostoma</u> ,
<u>Listriolobus</u>,
<u>Ikedosoma</u>,
<u>Lissomyemma</u>,
<u>Platylobostoma</u>

Sub-family 2. Thalassematinae novo.

Longitudinal muscle is continuous.
... <u>Thalassema</u>,
<u>Anelassorhynchus</u>,
<u>Arhynchite</u>

Family 4. Ikedaidae Dawydoff, Ik

Nephridia in large numbers with terminal nephrostomes. Proboscis very long. Dorsal vessel long, heart situated between prointestine and midintestine. Gi$\overset{z}{k}$zard absent. ... <u>Ikeda</u>,
<u>Polynephrosoma</u>

Family 5. Bonellidae

Setae one pair, absent or numerous. Proboscis truncate, or bifid. Nephridia one or two with laterial or terminal nephrostomes. Anal vesicles undivided or branched usually with stalked funnels. Longitudinal muscle layer continuous. Sexual dimorphism is present.

Key to the Families and Subfamilies of Class Echiurida (excluding Family Bonellidae)

1. With posterior setae (2)
   Without posterior setae (3)
2. With two rows of posterior setae Echiuridae
   With one row of posterior setae -Urechidae
3. Nephridia with terminal funnels- Ikedaidae
   Nephridia with lateral funnels- Thalassematidae(4)
4. Longitudinal muscles in bands- Ochetostomatinae
   Longitudinal muscles continuous- Thalassematinae

Synopsis of genera of Echiurida

Fisher's key (1946) of the genera of echiurids is slightly modified to accommodate *Polynephrosoma*, *Urechis* *Ikeda* and *Platylobostoma*.

1. Posterior setae present (2)
   Posterior setae absent (3)
2. Two rows of Posterior setae- *Echiurus* Guerin Meneville
   One row of posterior setae- *Urechis* Seitz
3. Proboscis present (4)
   Proboscis absent-instead two ventral lobes bordering the mouth. *Platylobostoma* W.lund
4. Nephridia with terminal funnels (5)
   Nephridia with lateral funnels (6)
5. Longitudinal muscle bands present)
   Nephridia in clusters) Ikeda Wharton

	Longitudinal muscles continuous Nephridia 8-21 pairs	*Polynephrosoma* novo.
6.	Nephridia with or without spiral lobes	(7)
	Nephridia with leaf like lobes	*Lissomyemma* Fisher
7.	Longitudinal muscles in bands	(8)
	Longitudinal muscles continuous	(10)
8.	Longitudinal muscles interrupted by oblique muscles	(9)
	Longitudinal muscles not interrupted by oblique muscles	*Listriolobus* Fischer
9.	Nephridia groups of 7-14 - vascular ring vessel at posterior end of pharynx	*Ikedosoma* Bock
	Nephridia 2-7 pairs. Ring vessel in between foregut and intestine	*Ochetostoma* Lueckart & Ruppell
10.	Nephridia without spiraly coiled lips	(11)
	Nephridia with spiraly coiled lips	*Anelassorhynchus* Annandale
11.	Nephrostome with conspicuous flap like lips Presiphonal intestine long	*Arhynchite* Sato
	Nephrostome with inconspicuous lips Presiphonal intestine short with ciliated groove	*Thalassema* Lankester

The above classification is in general agreement with that of Bock (1942) and of Dawydoff (1959). The main point of departure is that in the present scheme Echiuridea is considered as a phylum. Bock (1942) regarded *Urechis* as a genus of the family Echiuridae. He seemed to have stressed upon the importance of the perianal setae and thus bracketed both *Urechis* and *Echiurus* in the family Echiuridae. But the structural peculiarities of *Urechis* are so striking (Fisher 1946, Embleton 1900, MacGinitie 1938) that it is more realistic to put them in two separate families. Accordingly, family Urechidae of Dawydoff is maintained, thus keeping *Echiurus* in a separate family Echiuridae. Monro (1927) kept *Urechis* in a subfamily Urechinae. Fisher (1946) created a new order Xenopneusta to include *Urechis*. The main deviation of *Urechis* from the normal pattern is the the complete absence of vascular system, which shows the extreme aberrant nature of the species; creation of a new order Xenopneusta does not seem to be appropriate.

In the proposed scheme, family Ikedaidae would include all the forms which are having a terminal nephrostome. Bock (1942) in fact has accepted this in principle by creating a new subfamily Ikedinae to include *Ikeda taenioides*, the only known echiurid at that time with terminal nephrostome and supernumerary number of nephridia. Dawydoff (1959) recognized family Ikedaidae to include *I. taenioides*. The place of *Polynephrosoma pirotansis* with terminal nephrostome would be in the family Ikedaidae. In this connection I may mention that Fisher (1946) had created Heteromyota to include *Ikeda taenioides*. The practical difficulties in creating the order Heteromyota ~~is~~ are evident (vide supra).

Bock's (1942) Thalassematidae contained both Ikedinae and Thalassematinae. In the proposed scheme Thalassematinae of Bock is raised to a family level and is further divided into two subfamilies. The two subfamilies are Ochetostomatinae and Thalassematinae - the former includes all those forms in which the longitudinal muscles are in bands, ~~while~~ whereas the latter includes Thalassema- like forms with continuous longitudinal muscles. Further, the anterior nephridia in the former are having spirally coiled lips attached to the nephrostome ~~while~~ whereas, in the latter, the lateral lips of the nephrostome may or may not prolong into long spiral bands.

There is difference of opinion among workers in this field as to the practical utility of recognising the genus Anelassorhynchus. Annandale (1922) separated this group of estuarine species together with T. sabinum from Siam into a distinct genus for which he proposed the name Anelanssorhynchus. Anatomically these forms do not differ in any respect from the other marine species of the genus Thalassema Lamarck. Prashad and Awati (1929) stated "it is very doubtful whether the slight differences in the structure, function and physiology of the proboscis" are enough for separating them into a distinct genus." Bock (1942) was also of the same opinion. Fisher (1946), though recognized the genus Anelassorhynchus in his key, ~~however,~~ made the following comments : "It may not be of any practical value to recognise this group". But recent workers appear to have reconciled to the genus *Anelassorhynchus* (Fisher, 1946; Edmonds, 1960; Datta Gupta et al, 1963; W.Land 1939; Datta Gupta & Menon, 1965). The distinction is based on the nature of nephrostome which has spirally coiled lips in *Anelassorhynchus* species. The structure of the proboscis is possibly an instance of convergence, since other genera like *Ochetostoma* and *Listriolobus* also show the same modifications. Curiously enough, *Anelassorhynchus* species are mostly estuarine ~~while~~ whereas, *Thalassema* species are generally marine.

Similarly, opinions differ as to the genera *Listriolobus* and *Lissomyemma*. Fisher (1946) proposed the genus *Lissomyemma* for *T. mellita* Conn. Spengel (1912) established the old generic name *Ochetostoma* for *T. erythrogrammon* and recognized another genus *Listriolobus*. It was W. Fischer who associated the generic name *Listriolobus* to describe *T. bahamensis* and *T. billitonensis*. Later 3 more species were added to this group. As discussed elsewhere, Wharton (1913) and Bock (1942) did not seem to distinguish *Listriolobus* from *Ochetostoma*. My studies on the two species, namely *L. brevirostris* and *O. bombayensis*, show that the oblique muscles do not form fascicles in the former.

The genus *Arhynchite* was proposed by Sato to include *Thalassema arhynchite* which was characterized by the absence of proboscis. But Fisher (1946) described two species of Arhynchite with proboscis. He stated that the discovery of a proboscis in the two species need not invalidate the genus. The flap-like nephrostome and the long presiphonal segment of the intestine separate the group from Thalassema. In T. philostracum the nephrostome is fan-shaped ~~while~~ whereas T. hartmani has a very long presiphonal intestine as in Arhynchite. In this context, it is extremely difficult to find out the trenchent character that distinguishes Thalassema from Arhynchite. There is no doubt that these two genera are interrelated.

Platylobostoma is obviously related to Ochetostoma. Wesenberg-Lund (1959) compared Platylobostoma glaucum with Ochetostoma atlantidei. She writes "The main reason for not regarding the present specimen as identical with P. glaucum is, of course, the presence of a well developed proboscis." This organ was missing in Platylobostoma but replaced by two flabby lobes ventral to the mouth". The proximal lobes of O. atlantedi described here decidedly belong to the proboscis and likely to be lost together with it. On the other hand, in Platylobostoma the lobes in all probability belong to the trunk.

In conclusion, Polynephrosoma shows features common to bonellids and echiurids. The presence of a number of segmental organs is a typical echiurid character, whereas in bonellids these organs have under-gone extreme reduction, being single in many, with one pair in _Archibonellia_ _Pseudobonellia_, _Hamingia_ etc. (Bock 1942). In the nature of the vascular system, the reproductive organs and anal vesicles, it has strong affinities towards bonellids especially to _Maxmulleria_ and _Prometor_.

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SUMMARY

SUMMARY

The different systems of classification of echiuroids are reviewed. A review of the work on Indian echiuroids with a synonomic bibliography of the Indian species of echiurids are also given.

The morphology of *I. pirotansis* is described and compared with other Indian echiurids.

The integument of *I. pirotansis* is glandular. The presence of compound granular glands in the proboscis and eosinophilous tubular glands in the body wall as well as proboscis is peculiar to *I. pirotansis*. The longitudinal muscle is continuous and lies inside the outer circular layer of muscles. The body wall of *I. pirotansis* is compared with other echiurids and its taxonomic significance is discussed. A prominent muscle plug is observed in between the setae.

The coelom is spacious and uninterrupted. It extends into the proboscis as lateral proboscis coelom. In other Indian echiurids, the proboscides have a number of coelomic spaces which form very extensive cavities. The usefulness of this character is discussed in elucidating the relationship of different genera of echiurids. Different types of coelomic corpuscles are found in *I. pirotansis*. Giant multicellular corpuscles are found in large numbers. A well developed 'suet' like formation of the peritonium in the prointestine shows proliferation of

chlorogogen cells. This structure is peculiar to I. pirotansis among Indian echiurids. However, this structure is comparable to the mesentrial bodies found in T. steinbecki (Fisher 1942).

The alimentary canal is divided into 3 regions, the foregut, mid gut and rectum. A buccal chamber leads into the pharynx. The foregut is distinguished from the midgut by the position of the longitudinal muscle which lies out side the circular in the foregut. Only two regions of foregut could be seen viz. pharynx and a long oesophagus. The midgut has three regions. A precardiac prointestine, a siphonal intestine, and a post siphonal intestine with a ciliated groove. The presence of a prointestine without a ciliated groove is a unique feature of I. pirontansis among Indian echiurids. In all other Indian forms the prointestine is postcardiac and has a prominent ciliated groove. Rectum is a small tube characterised by the absence of the ciliated groove. It could be distinguished from the intestine by the absence of ciliated groove.

The histology of the various regions has also been studied. The epithelium of the foregut and midgut is glandular. The siphon or collateral intestine is lined by columnar epithelium. This is attached to the intestine by means of connective tissue.

The alimentary canal of I. pirotansis is compared with other echiurids.

The vascular system of Ikedosoma pirotansis is peculiar in having a ventral accessory vessel, a long neurointestinal, a long dorsal vessel and a pair of ventrolateral sinuses which communicate with the heart or the peri-intestinal ring sinus. The ventral vessel merges with the rectal wall posteriorly and it is proposed that the blood is collected by the ventrolateral sinuses which ultimately are in communication with the peri-intestinal ring sinusus. The vascular system of Ikedosoma pirotansis is compared with other echiurids as well as the tentacular system of sipunculoids. It is suggested that the position of the ring sinus in echiurids may have some systematic significance. The presence of a prointestine with or without a ciliated groove is correlated with the position of the ring sinus.

The nervous system shows no departure from the usual echiurid pattern.

The segmental organs are 8 to 20 pairs with terminal nephrostomes. This type of terminal nephrostome is not found in any other Indian echiurid. The only other echiurid to have this condition is I. taenioides . The morphology of this organ is described. Further a comparison of segmental organs of other echiurids are also given. The role of anterior nephridia in echiurid systematics is discussed. In other Indian echiurids the nephrostomes are lateral and they are provided with spirally coiled lips.

The anal vesicles of _I. pirotansis_ are unique which show long stalked funnels. These long stalked funnels show secondary branching. No other echiurid has this condition. This type of anal vesicle is usually expected only in bonellids. The anal vesicle of _I. pirotansis_ is compared with that of _Maxmullaria_.

A male worm has not yet been found. The ovarian cells are proliferated from the mesentry attached to the ventral nerve cord towards the posterior region. The growing eggs have a cap of nurse cells. The histological structure of the egg is studied. There is a conspicuous circumnuclear zone. The chemical components of the various regions of the egg is determined by various techniques. The circumnuclear zone reveals the presence of proteins, RNA, carbohydrates and some lipids. The cytoplasm contains yolk globules of fatty and proteinous nature. The protein yolk globules are smaller than the fatty globules. In addition to this there are granules basic proteins. There seem to be a correlation between the spiral lips of the nephrostome and size of the eggs.

The systematic position and interrelationship of _Ikedosoma pirotansis_ are described.

A new genus Polynephrosoma is proposed for Ikedosoma pirotansis . Polynephrosoma has strong affinities towards Ikeda taenioides . The systematic position and the interrelationship of Polynephrosoma pirotansis are discussed.

The importance of a number of characters in echiurid taxonomy is discussed . The body musculature, presence or absence of post-setal segmental organs , the position of the ciliated funnel, the presence or absence of ciliated groove in the prointestine, position of the heart in relation to the different regions of the alimentary canal, the anatomy of the proboscis , the coelomic corpuscles and the female germ cells seem to be the more important characters in echiurid taxonomy.

A scheme of classification incorporating some of the salient features of Bock's (1942) and Dawydoff's (1959) classification is suggested.

A synopsis of the families, subfamilies and the genera of echiurids is also given. The merits and demerits of the existing classification are discussed.

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REFERENCES

REFERENCES

Alfert, M., and Geschwind, I.I., 1953. A selective staining method for the basic proteins of cell nuclei. Proc. Nat. Acad. Sci. Wash., 39, 991.

Annandale, N., 1922. The marine element in the fauna of the Ganges. Bijdr. Dierk., pt. 22, Feest-nummer 70 Geboor edag van Dr. Max Weber, pp. 143-154.

Annandale, N. and Kemp, S., 1915. Fauna of the Chilka Lake. The Echiuroidea of the lake and of the Gangetic Delta. Mem. Indian Mus., Vol. 5, No.1 , pp.55-63.

Awati, P.R., 1936. Proboscis of Thalassema bombayensis . J. Univ. Bombay, Vol.4, p. 96.

Awati, P.R. and Deshpande, D.S., 1936. The alimentary canal of Thalassema bombayensis . J. Univ. Bombay, Vol.4, p. 68.

Baird, W., 1868. Monograph of the species of worms belonging to the subclass Gephyrea; with a notice of such species as are contained in the collection of the British Museum. Proc. Zool. Soc. London, 1868, pp. 76- 114.

Baltzer, F., 1917. Monographie der Echiuriden des Golfes von Neapel, Vol.34, p. 230.

Baltzer, E., 1934. Echiurida, In Kukenthal and Krumbach Handbuch der Zoologie, Berlin, Bd. 2: 2, pp. 62-168.

Baker, J.R., 1949. Further remarks on the Golgi element. Quart. J. micr. Sci., 90, p. 293.

Berkeley, E. and Berkely, C., 1960. Some further records of pelagic polychaeta from the Northeast Pacific north of latitude 40° N and east of longitude 175° W, together with records of Siphonophora, Mollusca, and Tunicata from the same region. Canad. J. Zool. 38: pp. 787- 799.

Blainville, H.M.D., 1827. Dictionnaire des Sciences naturelles, Vers, vol. 49.

Bock, S., 1920. Epithetosoma not a Gephyrean but an indeterminable Heteronemertine. Bergens Museums Aarbog 1920-21 , Naturvidensk. Raekke, Nr. 9.

Bock, S., 1942. On the structure and affinities of "Thalassema" lankesteri Herdman and the classification of the group Echiuroidea. Goteborgs Vet. Samh. Handl., ser. B., vol. 3, No.6, pp. 94.

Bradbury, S., 1956a. Human Saliva as a convenient source of ribonuclease. Quart. J. micr. Sci., 97, p.323.

Cain, A.J., 1947. The use of Nile blue in the examination of lipoids. Quart. J. micr.Sci., 88, p. 383.

Chamberlin, R.V., 1920. The Gephyrea collected by the Canadian Arctic Ex-pedition, 1913-19. Rep. Canad. Arctic Exped., Vol. 9.

Chen, Y. and Cheng chang, Y. , 1958. Notes on some Gephyrea of China with description of four new species. Acta Zoologica Sinica Vol.10, No.3, pp.273-278.

Chuang, S.H., 1962a. Feeding mechanism of the echiuroid, Ochetostoma erythrogrammon Leuckart & Rueppell. Biol. Bull., Vol. 123, No.1, pp.80-85.

Chuang, S.H., 1962b. Sites of oxygen uptake in Ochetostoma erythrogrammon Leuckart & Rueppell. Biol. Bull. vol. 123, No.1, pp. 86- 93.

Conn, H.W.1886. Life history of Thalassema mellita. Stud. Biol. Lab. Johns Hopk. Univers., vol.3, No.7, pp. 351-401.

Cuenot, L., 1898. Etudes physiologiques sur les oligochetes. Arch. Biol., 15.

Cuenot, M.L., 1902. Contrib. a la faune due bassin d' Archachon: Echiuriens et Sipunculiens. Bull. Soc. scient. d' Archachon.

Dahl E. 1957. The integument of *Echiurus echiurus* Kungl. Fysiografbka sallskapets i Lund Forhandlon gar vol. 28 No.5, 1958. pp. 33-44.

Dales, R.P., 1952. The development and structure of the anterior region of the body in the Sabellariidae, with special reference to *Phragmatopoma californica*. Quart. J. micr. Sci. 93:435- 452.

Dales, R.P., 1962. The polychaete stomodeum and the interrelationships of the families of Polychaeta. Proc. Zool. Soc. Lond. 139, pp. 289-326.

Danielssen, D.C., and Koren, J., 1881. Den Norske Nordhavs-Expedition (1876-1878). Gephyres, Zoologie, pp. 60.

Datta Gupta, A.K. and Menon, P.K.B., 1961. Occurrence of the Echiuroid *Ochetostoma zanzibarense* Stephen in the Gulf of Kutch. J. Bombay nat. Hist. Soc. 58(3), pp. 829-830.

Datta Gupta, A.K., P.K.B. Menon and Johnson, P., 1963. Echiurids from Indian waters with the description of two new species. Ann. Mag. Nat. Hist. Ser.13, 6, pp. 57-63.

Datta Gupta, A.K., 1963. Indian Echiuroidea. Presidential address Raj. Ac. Sci.

Datta Gupta , A.K. and Menon, P.K.B., 1964. Morphology and histology of the males of *Acamthobonellia*. Proc. Royal Society (Edin.). Vol. 68, pp. 267- 276.

Datta Gupta, A.K., and Menon, P.K.B. 1965. Additions to Indian Echiurid Fauna. Ann. Mag. Nat. Hist. Ser. 13, vol.8, pp. 193- 200.

Dawydoff , C. ,1959. In Grasse's Traite' de Zoologie. Tome V pp. 855- 907.

Delage, Y. and Herouard, E., 1897. Traite' de Zoologie concrete', Vol. V, Les Vermidiens. pp. 26-46.

Edmonds, S.J., 1960. Some Australian Echiuroids (Echiuroidea) Trans. Roy. Soc. S. Aust. Vol. 83, pp. 89-98.

Embleton, A.H., 1900. On the structure and affinities of *Echiurus unicinctus.* Trans. Linnean . Soc. London, Ser. 2, (Zool.), Vol.8, pp.77-97.

Fischer, W., 1892. Uebersicht der von Herrn Dr. F. Stuhlmann auf Sansibar und an der gegenuberliegenden Festlandes- Kuste gesammelten Gephyreen. Jahrb. wiss. Anst. Hamburg, Band 9, p. 11.

Fischer, W., 1896a. Gephyreen Ergeb. Hamburg Magelhaen. Sammelreise, p. 75.

Fischer, W., 1896b. Gephyreen, in Semon's Zool. Forschungsreise in Australien and dem Malayischen- Archipel, Band 5, p. 3.

Fischer, W., 1919. Gephyreen der Sudwestkuste Australiens. Zool. Anz., Vol. 50, pp. 283- 285.

Fischer, W., 1925 . Echiuridae, Sipunculidae, Priapulidae. Die Tierwelt des Nordund Ostsee. Lief I.Teilvid: pp. 1- 55.

Fischer, W., 1926a. Sipunculiden und Echiuriden der Hamburger Sudsee- Expedition 1908-1909. Mitt. Zool. Staatsinst. und zool. Mus. Hamburg, vol. 42, pp. 109- 117.

Fischer, W. 1926b. Sipunculoidea und Echiuroidea. Die Fauna Sudwest-Australiens, vol. 5, pp. 199- 214.

Fischer, W., 1928. Die Sipunculiden, Priapuliden and Echiuriden der Arktis, Fauna Arctica (Romer and Schaudinn), Band 5, p. 451.

Fisher, W.K. and MacGinitie, G.E., 1928 . A new echiuroid worm from California. Ann. Mag. Nat. Hist. Ser.10, vol. 1, pp. 199- 204.

Fisher, W.K., 1946. Echiuroid worms of the North Pacific Ocean. Proc. U.S. Nat. Mus. 96, pp. 215-292.

Fisher, W.K., 1947. New Genera and Species of Echiuroids and Sipunculoid worms. Proceedings to the United States National Museum Vol. 97, pp. 351- 372.

Fisher, W.K., 1948a. A new echiuroid worm from the Hawaiin Islands and a key to the genera of the Echiuridae. Pacific science, 2(4) pp. 274- 277.

Fisher, W.K., 1948b. A review of the Bonellidae (Echiuroidea). Ann. Mag. nat. Hist., Ser. II, Vol. 14, pp.852-860.

Fisher, W.K., 1949. Additions to the Echiuroids. Fauna of the North Pacific ocean . Proc. U.S. Nat. Mus. vol. 99, pp. 479- 497.

Gideon, P.W., Menon, P.K.B., Rao, S.R.V. and Jose, K.V., 1957. On the occurrence of *Ikadella misakiensis* from Indian waters. J.B.N.H.S. vol. 54(1) , pp. 201- 202.

Gideon, P.W., Menon, P.K.B., Rao, S.R.V. and Jose, K.V., 1957. A preliminary survey of the marine fauna of the Gulf of Kutch Part I. J.B.N.H.S. vol. 54(3), pp. 690- 706.

Goodrich, E.S., 1945. The study of Nephridia and Genital Ducts since 1895. Quarterly Journal of Microscopical Science. Vol. 86, pp. 113- 392.

Gravely, F.H., and Prashad, B. , 1919. A note on the Marine Invertebrate Fauna of Chandipore, Orissa, with notes on Echiuroids. Rec. Ind. Mus. vol. 16, pp.

Greef, R., 1879. Die Echiuren (Gephyrea armata). Nova Acta K. Leopold Carol. drulsch. Akad. Naturf. vol. 41, p. 172.

Hartman, O., 1955. Endemism in the north Pacific Ocean, with emphasis on the distribution of marine annelids, and descriptions of new or little known species. Essays in the Natural Sciences in honour of Captain Allan Hancock. 39-60 . Los Angeles: University of Southern California Press.

Hartman, O., 1961. Polychaetous annelids from California. Allan Hancock Pacif. Exped. vol. 25, pp.1-130.

Hatschek, B., 1880. Ueber Entwickelungsgeschichte von Echiurus und die systematische . Stellung der Echiuridae (Gephyrei chaetiferi). Arb. Zool. Stat. Triest, vol. 3, pp. 45- 79.

Heath, H., 1930. A connecting link between the Annelida and the Echiuroidea (Gephyrea armata). Journ. Morph., vol. 49, pp. 223- 246.

Herdman, W.A. ,1897. Note on a new British echiuroid gephyrean, with remarks on the genera *Thalassema* and *Hamingia.* Quart. Jour. Micr. Sci., new ser., vol. 40, pp. 367- 384.

Horst, R., 1881. Die Gephyrea gesammelt wahrend der zwei ersten Fahrten des Willem Barents. 1, Echiuria. Niederl. Arch. fur zool., Suppl. vol. 1,

Hotchkiss, R.D., 1948. A microchemical reaction resulting in the staining of Polysaccharide structures in fixed tissue preparations. Arch. Biochem., 16,131. (Quoted from Pearse, 1960).

Hyman, L.H., 1940. The invertebrates: Protozoa through Ctenophora, vol. 1, New York McGraw Hill Book Co.

Hyman, L.H., 1959. The invertebrates, vol. 5, New York: McGraw Hill Book Co.

Ikeda, I., 1904. The Gephyrea of Japan. Jour. Coll. Sci. Imp. Univ. Tokyo, vol. 20, pp. 1-87.

Ikeda, I., 1907. On three new and remarkable species of echiuroids. Jour. Coll. Sci. Imp. Univ. Tokyo, vol. 21, pp. 1-64.

Ikeda, I., 1908a. Note on a new deep sea echiuroid, *Protobonellia mitsukurii*, nov. g.et nov. p. Annotationes Zoologicae Japonenses, vol.6, pp. 259- 265.

Ikeda, I., 1910. Notes on a deep- sea echiuroid, Acanthohamingia shiplei (n.g. et n. sp.), with remarks on the species Hamingia ijimai Ikeda, Quart. Journ. Micr. Sci. new ser., vol. 56, pp. 135- 147.

Ikeda, I.,1924. Further notes on the Gephyrea of Japan with descriptions of some new species from the Marshall, Caroline, and Palau Islands. Jap. Journ. Zool., vol. 1, pp. 23- 44.

Ikeda, I., 1928. On a new echiuroid (Hamingia ijimai)from the Sagami Bay. Annotationes Zoologicae Japonenses, vol. 8, pp. 61- 68.

Jameson, H.L., 1899. Contributions to the anatomy and histology of Thalassema neptuni Gaertner. Zool. Jahrb., Abt., Anat., vol. 12, pp. 535- 566.

Johnston, T.H. and Tiegs, O.W., 1919. Pseudobonellia, a new echiuroid genus from the Great Barrier Reef. Proc. Linn. Soc. New South Wales, vol. 44, pp.213-230.

Jordan, B.M., and Baker, J.R., 1955. A simple pyronin/ methyl green technique. Quart. J. micr. Sci., 96, p. 177.

Jose, K.V., 1964. The morphology of Acanthobonellia pirotanensis N. Sp. a Bonellid from the Gulf of Kutch, India. J. Morph. v. 115, pp. 53- 68.

Joseph, H., 1909. Die Amoebocyten von Lumbricus. Arb. Zool. Inst. Univ. Wien, 18. (As quoted by Stephenson J., 1930).

Kay, W.W. and Whitehead, R., 1941. The role of impurities and mixtures of isomers in the staining of fat by commercial sudans. J. Path. Bact., vol. 53, p.279. (Quoted from Pearse, 1960).

Koren, J. and Danielssen, D.C. 1877. Contribution to the natural history of the Norwegian Gephyrea. Fauna littoralis Norvegiae. Hefte 3, 111- 155.

Lamarck, J.B., 1801. Systeme des animaux sans vertebres, 432, pp.

Lamarck, J.B., 1816. Histoire naturelle des animaux sans vertebres, vol. 3, p. 65.

Lampert, K., 1883. Uber einige neus Thalassemen. Zeitschr. wiss. Zool., vol. 39, pp. 334- 342.

Lanchester, W.F., 1905a. On the sipunculids and echiurids collected during the Skeat Expedition to the Malay Peninsula. Proc. Zool. Soc. London, 1905, pp. 35- 41.

Lanchester, W.F., 1905b. The marine fauna of Zansibar and British East Africa (Cyril Cross-land). Gephyrea. Ibid., pp. 28- 35.

Lang, 1888. Lehrbuch der vergleichenden Anatomic.

Lankester, Edwin Ray, 1881. On Thalassema neptuni Gaertner. Zool. Anz., vol. 4, p. 350.

Lankester, 1883. On specimens of the Gephyrean Hamingia arctica Kor. and Dan. from the Hardanger Fjord. Ann. Nat. Hist. vol. 5, 11, pp. 37- 43.

Leigh-Sharpe, W.H. 1928. Thalassema neptuni, Gaertner- a British echiuroid. Ann. Mag. Nat. Hist., ser. 10, vol. 2, pp. 499- 504.

Leuckart, F.G., and Ruppell, W.R.E. ,1828. Neue wirbellosen Tiere des Roten Meeres. Atlas zu der Reise im nordlichen Africa, Abt. Zool. pp. 7-8.

Liebmann, E., 1926. Untersuchungen uber das chloragogen der Lumbriciden. Zool. Anz., 69.

MacGinitie, G.E., 1935a. Normal functioning and experimental behaviour of the egg and sperm collectors of the echiuroid, Urechis caupo. Journ. Exp. Zool.,vol.70. pp. 341- 355.

Newby, W.W., 1940. The embryology of the echiuroid worm *Urechis caupo*. Mem. Amer. Philos. Soc., vol.16, pp. 219.

Newby, W.W., 1941. The development and structure of the slime-net glands of *Urechis*. Journ. Morph., vol. 69, pp. 303- 316.

Onoda, K., 1934. On *Pseudobonellia*, a new genus of the bonellian echiuroids. Annotationes Zoologicae Japonenses, vol. 14, pp. 413-420.

Onoda, K., 1935. *Parabonellia* (nom. nov.) *misakiensis* (Ikeda), correction of my paper on *Pseudobonellia*. Annotationes Zoologicae Japonenses, vol. 15, p. 141.

Pearse, A.G.E. ,1960. Histochemistry Theoretical and Applied , London (Churchill).

Pickford, G.E., 1947. Histological and histochemical observations upon an aberrant annelid *Poecbius meseres* Health. J. Morph. 80, pp. 287-319.

Prashad, B., 1919a. Zoological results of a tour in the Far East. Echiuroids from brackish water with the description of a new species from the Andamans. Mem. Asiatic Soc. Bengal, vol. 6, pp. 323- 338.

Prashad, B., 1919b. Notes on echiuroids from Chandipore, Orissa. Rec. Indian Mus., 16, 399- 402.

Prashad, B., 1920. On a new species of *Thalassema* from the Gulf of Manaar with notes on Thurston's species *T. formulosum*. Rec. Indian Mus., 19, pp.35-37.

Prashad, B., and Awati, P.R., 1929. On a new species of the genus *Thalassema* from Bombay. Rec. Indian Mus., 31, pp. 259- 261.

Prashad, B., 1935. On a collection of echiuroids of the genus *Thalassema* Lamarck in the Indian Museum,Calcutta. Rec. Indian Mus., 37, pp. 39-43.

Quartefages, J.L.A., 1847. Memiore sur Pechine de Gaertner. Ann. Sci. Natur. , Zool. ser. 3, p. 7.

Quatrefages, J.L.A., 1865. Histoire naturelle des anneles marins et d' eau douce, 2, pp. 591-599.

Remane, A., 1933. Echiuridae. In Handworterbuch der Naturwissenschaften. 3, pp. 1-6.

Rietsch, M., 1886. Etude sur les Gephyriens armes on Echiuriens. Rec. Zool. Suisse, 3, pp.313-515.

Robbins, D.E., 1965. The biology and morphology of the pelagic annelid Poeobius meseres Heath . Zool. 146, pp. 197- 212.

Rosa, D., 1930a. Le Valvole nei Vasi dei Lombrichi. Arch. Zool. Napoli, 1.

Rosa, D., 1903b. Nefridii di Rotifera in giovani Lambrichi. Boll. Mus. Zool. Anat. Camp. Torino, 17.

Rothschild, Lord, 1961. A classification of living animals. New York: John Wiley and Sons, Inc.

Salensky, W., 1905. 'Morphog. Studien an Wurmern", Mem. Acad. I. Sci. St. Petersb., 16.

Sato, H., 1931. Report of the biological survey of Mutsu Bay. 20, Echiuroidea. Sci. Rep. Tohoku Imp. Univ., ser. 4, 6, pp. 171- 184.

Sato, H., 1934. Report on the Sipunculoidea, Echiuroidea and Priapuloidea collected by the Soyo Maru Expedition of 1922-1930. Sci. Rep. Tohoku Imp. Univ., ser. 4,9,pp.1-32.

Sato, H., 1935. Sipunculoidea and Echiuroidea of the West Caroline Islands. Sci. Rep. Tohoku Imp. Univ., ser. 4, 10, pp. 299- 329.

Sato, H., 1937. Echiuroidea, Sipunculoidea and Priapuloidea obtained in northeast Honshu, Japan. Saito Ho-on Kai Mus. Res. Bull., 12, pp. 137- 176.

Sato, H., 1939. Studies on the Echiuroidea, Sipunculoidea and Priapuloidea of Japan. Sci. Rep. Tohoku Imp. Univ., ser. 4, 14, pp. 339- 460.

Schneider, G., 1896. Uber phagocytare Organs und Chloragogenzellen der Oligochaten. Z. wiss. Zool., 61.

Sedgwick, 1898. Students Text Book of Zoology.

Seitz, P., 1907. Der Bau von *Echiurus chilensis* (*Urechis* n.g., *chilensis*). Zool. Jahrb., Abt. Anat.,24, pp. 323- 356.

Selenka, E., 1885. Report of the Gephyrea collected during the voyage of H.M.S. Challenger. Report of sc. results of the explor. voyage of H.M.S. Challenger, vol.13, pp. 1-24.

Selenka, E., 1899. On a collection of Echiurids from the Loyalty Islands, New Britain and China straits, with an attempt to revise the group and to determine its geographical range. Willey's Zool. Results, 335. Cambridge.

Selenka, E., 1902. Die Sipunculiden und Echiuriden der Siboga- Expedition, Siboga- Expeditie. Monogr.

Shipley, E.A., 1898a. A report on the Sipunculoidea collected by Dr. Willey, Proceed. Zool. Soc. London. 151.

Shipley, E.A., 1898b. A report on the Gephyrean worms coll. by Mr. Stanley Gardiner at Rotuma and Funafuti. Proc. Zool.Soc. London

Shipley, E.A., 1899. On a collection of echiuroids from the Loyalty Islands. Willey's Zoological Results, 335- 356. (Review of nominal species of Echiuroidea).

Shipley, E.A., 1903. The Fauna and Geography of the Maldive and Laccadive Archipelagoes. Echiuroidea . pp. 127- 130.

Skorikov, A.S., 1901. Uber die Gattung Hamangia Kor. et. Dan (Bonelliidae). Zool.Anz., vol. 24, pp. 158- 160.

Skorikov, A.S., 1909. Subfam. Echiurini nov. (Gephyrea armata). Ann. Mus. Zool. Acad. Imp.Sci. St. Petersbourg, 14, pp. 77- 102.

Sluiter, C.P., 1884. Beitraege zuder Kenntnis der Gephyreen aus dem Malayschen Archipel, Mitt. Nat. Tijdschr. Nederi- Indie., vol. 43, pp. 26- 88.

Southern , R., 1913. Gephyrea of the Coasts of Ireland. Fisheries, Ireland, Sci. Invest., III(1913), pp. 1-46.

Spengel, J.W., 1879a. Uber die Organization des Echiurus Pallasii. Zool. Anz., vol. 2, pp. 542-547.

Spengel, J.W., 1879b. Beitrage zur Kenntniss der Gephyreen I. Die Eibildung, die Entwicklung und das Mannchen der Bonellia. Mitt. Zool. Stat. Neapel., 1, p. 357.

Spengel, J.W., 1880. Beitrage zur Kenntniss der Gephyreen II. Die Organization des Echiurus Pallasii. Zeits. wiss. Zool., 34, pp. 458- 538.

Spengel, J.W., 1912a. Idem., III: Zum Bau des Kopflappens der armaten Gephyreen. Zeitschr. wiss. zool., 101, pp. 342- 385.

Spengel, J.W., 1912b. Idem., IV: Revision der Gattung Echiurus. Zool. Jahrb., Abt. Syst., 33, pp.173-212.

Spengel, J.W., 1912c. Uber den Hautmuskelchlauch gewisser Thalassema Arten und Seine Bedeutung, fur die Systematik dieser Tiere. Verh. Deutsch. Zool. Ges., 22, pp. 309- 317.

Stephen, A.C., 1934. The Echiuridae, Sipunculidae and Priapulidae of Scottish andadjacent waters. Proc. Roy Phys. Soc. Edinburgh, 22(4),159- 185.

Stephen, A.C., 1941. The Echiuridae, Sipunculidae and Priapulidae collected by the ships of the discovery committee during the years 1926-1937. Discovery Reports 21 , pp. 237- 260.

Stephen, A.C., Robertson, J.D., 1952. A Preliminary Report on the Echiuridae and Sipunculidae of Zanzibar. Proc. Roy. Soc. Edinburgh Section B(Biology) 64, pp. 426- 444.

Stephen, A.C., 1960a. A synopsis of the Echiuroidea, Sipunculoidea and Priapaloidea of British waters. Synopsis of the British Fauna Linnear socity of London No.12, pp. 1-27.

Stephen,A.C. ,1960. Echiuroidea and Sipunculoidea from Senegal, West Africa. Extrait d' Afrique Noire Tome 22, serie A, 2, pp. 512- 520.

Stephenson, J., 1930. The Oligochaeta.

Stewart, F.H., 1900. Note on a Variation in the number of Genital Pouches in <u>Thalassema neptuni</u> Gaertner. Ann. Mag. Nat. Hist. (7), 6, pp 218.

Stolte, H., 1922. Experimentelle Untersuchungen uber die ungeschlechtliche Fortpflanzung der Naiden. Zool. Jahrb., Allg. Zool. u. Physiol., 39.

Studer, Th., 1879. Thalassema verrucosa, sp. nov. Arch. f. Naturg., 45, p. 124.

Szuts, A. von., 1920. Degenerationserscheinungen in den Borstenbildungszellen,Chloragogenzellen und Samentaschenepithelzellen der Lumbricoiden. Arch. Zellforsch., 15.

Theel, H., 1905. Northern and Arctic Invertebrates in the collection of the Swedish State Museum (Biksmuseum). K. Svenska vetensk Akad. Handl., 39, No.1, pp. 3- 130.

Theel, H., 1906. Northern and Arctic Invertebrates. II. Priapulids, Echiurids, etc. Kungl. Svenska Vet. Akad. Handl., 90.

Thurston, 1895. Bull. Madras Mus. 111, p. 116.

Vejdovsky, F., 1878. Uber die Eibildung und die Mannchen von Bonellia viridis. Zeit. wiss. Zool., 30, 487. Review of same, Rev. Int., 1, 722 and Arch. Z. exper. 6, p. 46.

Wharton, L.D., 1913. A description of some Philippine Thalassemae with a revision of the genus. Phil. Jour. Sci., Soc. pp. 243- 270.

Wesenberg-Lund, E., 1932. The Godthaab Expedition 1928. Gephyrea. Medd. Gronland, 79, 1.

Wesenberg-Lund, E. 1934. Gephyreans and Annelids. Medd. Gronland, 104, p. 14.

Wesenberg Lund, E., 1937. Gephyrea The Zool. of Iceland, Copenhagen and Reykjavik, II, pp. 1-16.

Wesenberg Lund, E., 1938. Norwegian Gephyrea from the Collections of the Zoological Museum of Trondheim. Det Kgl. norske Vidensk. Selsk. Forhandl. 11, 7.

Wesenberg Lund, E., 1939. Gephyreans from Swedish waters in the Museum of Natural History of Gothenberg. Meddelanden Fran Goteborgs Musei Zoologiska Advelning. 80(Goteborgs Kungl. Vetenskaks och vitterhets Samhalles Handlingar. Femate Foljden. ser. B. 6, pp. 3-35.

Wesenberg Lund, E., 1954. Priapuloidea, Sipunculidea and Echiuroidea. Bull. Inst.Royal des Sci. natur. de Belgique, 30, pp. 1-18.

Wesenberg Lund, E., 1955. Gephyrea from Chile. Reports of the Lund University Chile Expedition 1948- 1949. Lund Universitets Arsskrift. N.F. Avel. 2. Bd. 51, Nr. 10. Kungl. Fysiografiska sallskapets Handlinger and Reykjavik, N.F. Bd. 66. Nr. 10.

Wesenberg Lund, E., 1957a. Sipunculoidea and Echiuroidea from West Africa together with a bibliography on Gephyrea after 1920. Inst. Royal des Sci. nat. Belgique, 33, pp. 1-24.

Wesenberg Lund,E., 1957b. Sipunculoidea and Echiuroidea from the Red Sea. Contributions to the knowledge of the Red Sea, No.3, Haifa, pp. 1-15.

Wesenberg Lund, E., 1959a. West African Sipunculoidea and Echiuroidea. Atlantide report No.5, pp. 177-210.

Wesenberg Lund, E., 1959b. Sipunculoidea and Echiuroidea from Mauritius. Vidensk. Medd. f. Dansk Naturhist. Foren.

Willem, V. and Minne, A. ,1900. Recherches sur I' excretion chez qualques Annelides. Mem. Acad. Roy. Belg., 58.

Wilson, C.B., 1900. Our North American echiurids. Biol. Bull., 1, pp. 163- 178.

LIST OF PUBLICATIONS

LIST OF PUBLICATION

Echiuroids and Annelids

Gideon, P.W., Menon, P.K.B., Rao S.R.V. and Jose, K.V. 1957. On the occurrence of *Ikadella misakiensis* from Indian waters. J.B.N.H.S. Vol. 54(1), pp. 201-202.

Gideon, P.W., Menon, P.K.B., Rao, S.R.V. and Jose, K.V., 1957. A preliminary survey of the marine fauna of the Gulf of Kutch Part I. J.B.N.H.S., vol. 54(3), pp. 690-706.

* Datta Gupta, A.K. and Menon, P.K.B. 1961. Occurrence of the Echiuroid *Ochetostoma zanzibarense* Stephen in the Gulf of Kutch. J.B.N.H.S., vol. 58(3), pp. 829-830.

* Menon, P.K.B. and Datta Gupta, A.K., 1962. On a New Species of Ikedosoma (Echiurida). Ann. Mag. Nat. Hist. Ser. 13, vol. 5, pp. (Reprints attached).

* Datta Gupta, A.K., P.K.B. Menon and Johnson, P., 1963. Echiurids from Indian waters with the description of two new species. Ann. Mag. Nat. Hist. Ser. 13, vol. 57, pp. 57-63.

* Menon, P.K.B., Datta Gupta, A.K. and Johnson, P. 1964. Report on Bonnelids collected from Indian waters with the description of two new species. Ann. Mag. Nat. Hist. Ser. 13, vol. 7, pp. 49-57.

* Datta Gupta, A.K. and Menon, P.K.B., 1964. Morphology and histology of the males of Acamthobonellia . Proc. Royal Society (Edin.) .Vol. 68, pp. 267-276.

* Datta Gupta, A.K., and Menon P.K.B. 1965. Additions to Indian Echiurid Fauna. Ann. Mag. Nat. Hist. Ser. 13, vol. 8, pp. 193- 200.

* Menon, P.K.B., and Sareen, M.L., 1966. Morphology of *Sabellaria clandestinus* (Sabellaridae: Polychaeta). Res. Bull.(N.S.) Panjab Univ. vol. 17, pp.129-137.

* Menon, P.K.B., and Sareen, M.L. and Suraj ,P. Sharma,1965. Occurrence of *Stylarioides parmatus* Grube from the Gulf of Kutch. Res. Bull.(N.S.) Panjab Univ.vol.16, pp. 263-264.

Menon, P.K.B. and Sareen, M.L. 1966. A new species of *Sabellaria* (Polychaeta) from India . Zool. Anz. (in press).

Others

Menon, P.K.B. 1952. Studies on Rajasthan Acrididae 1. Feeding and Breeding Habits of *Poecilocerus pictus* Fabr. Studies (Biological Sciences & Medicine) University of Rajputana. pp. 91-99.

Menon, P.K.B. and Rao, S.R.V. 1956. The 'Apical Cell' in Insects. Science and Culture ,vol. 32, pp. 341-342.

Mathur, S.N., Menon, P.K.B., and Rao , S.R.V. 1956. Insect Fauna of Pilani. Proc. Raj. Acad. Sci. vol.6, pp. 22- 23.

Datta Gupta, A.K., Menon, P.K.B. and Nair C.K.G. and Dass, C.R. 1961. Proc. Raj. Acad. Sci. vol. 8 (1 & 2): pp. 129- 134.

Menon, P.K.B. , Datta Gupta, A.K. and Dass, Gupta. 1961. On the Marine Fauna of the Gulf of Kutch. Part II. J.B.N.H.S. 61(2)

* Datta Gupta, A.K., Raj Tilak and P.K.B. Menon 1963. Intraspecific variation in Heteropneustes fossilis Bloch (Heteropneustidae : Siluroidea). Anat. Anz. Bd. 112 , S. 129- 134.

Menon, P.K.B. and Sareen, M.L. 1967. Occurrence of Pontodrilus bermudensis Beddard (Oligochaeta: Megascolecidae) in the Gulf of Kutch. Res. Bull. (N.S.) ,Vol. 18, (in press).

Menon, P.K.B. and Sareen, M.L. and Tandon, K.K. 1967. On the marine Fauna of Goa. A preliminary survey part I. Pelecypods. Res. Bull. (N.S.), Vol. 18, (in press).

Tandon, K.K. , Menon, P.K.B. and Sareen, M.L. 1967. On the marine Fauna of Goa. A preliminary survey part II. Fishes. Res. Bull. (N.S.), vol. 18,(in press)

Menon, P.K.B., Sareen, M.L. and Tandon, K.K. 1967. On the marine Fauna of Goa. A preliminary survey part III. Gastropods. Res. Bull.(N.S.),Vol. 18, (in press).

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* Reprints attached .

EXPLANATION OF FIGURES

EXPLANATION OF FIGURES

PLATE I

Fig. 1. Anterior region of Ikedosoma pirotansis .
PRB. Proboscis , M- Mouth, MC- Muscle cushion,
SET- Setae , PAP- Papillae

Fig. 2. Middle region of Ikedosoma pirotansis
PAP- Papillae , IPS- Interpapillar spaces.

Fig. 3. Posterior region of Ikedosoma pirotansis
PAP- Papillae, CLO- Cloaca .

Fig. 4. Transverse section of the proboscis of Ikedosoma pirotansis (From the dorsal side).
CU- Cubicle , EP- epidermis, CLC- Clear cells,
PGL- pear shaped gland cells, N- Nucleus,
LM- Longitudinal muscles, CGL- Compound granular
glands, TGL- Tubular gland cells.

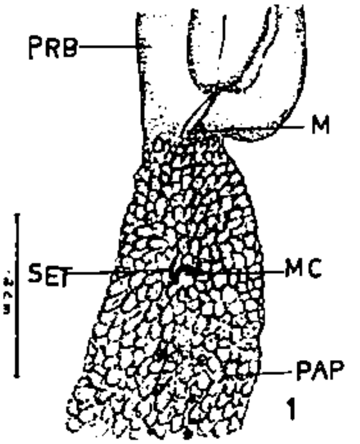
Fig. 5. Transverse section of the proboscis of Listriolobus brevirostris (from the ventral side)
CL- Cilia , N- Nucleus, PGL- pear shaped glands,
CT- Connective tissue.

Fig. 6. Transverse section of the body wall of Listriolobus brevirostris .
CU- Cuticle, CT- Connective tissue, CM- Circular
layer of muscles, LM- Longitudinal muscles,
ICM- Inner circular layer of muscles, VN- Ventral
nerve cord.

Fig. 7. Transverse section through the posterior region of Listriolobus brevirostris.
CU- Cuticle, EP- Epidermis, CTC- Connective tissue ,
CT- Connective tissue nucleus.

Fig. 8. A pear shaped gland cell
Fig. 9. A compound granular gland cell
Fig.10. A basophilous gland cell
Fig.11. A tubular gland cell
} from the integument of Ikedosoma pirotansis

GR- Granules , CT- Connective tissue , N- Nucleus



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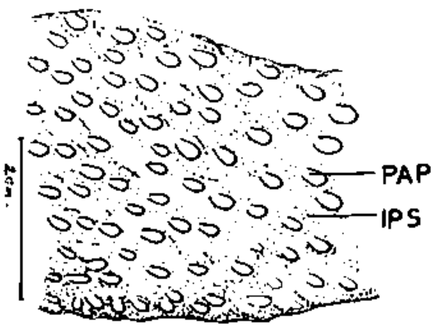

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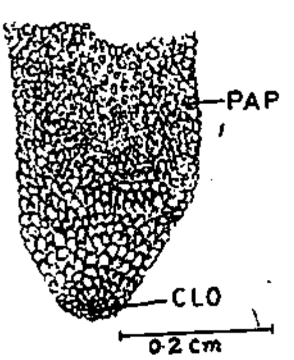

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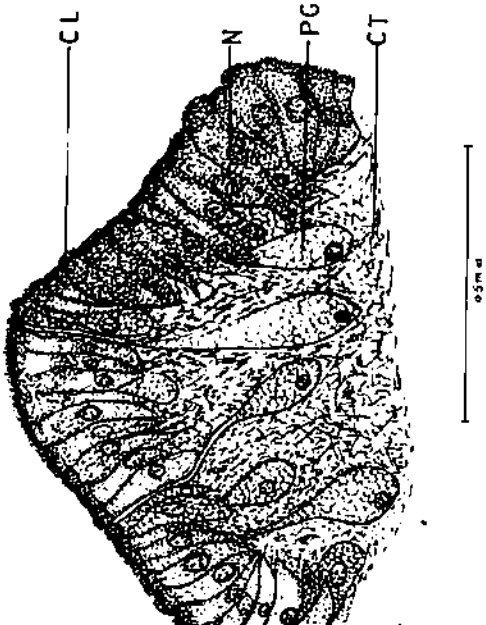

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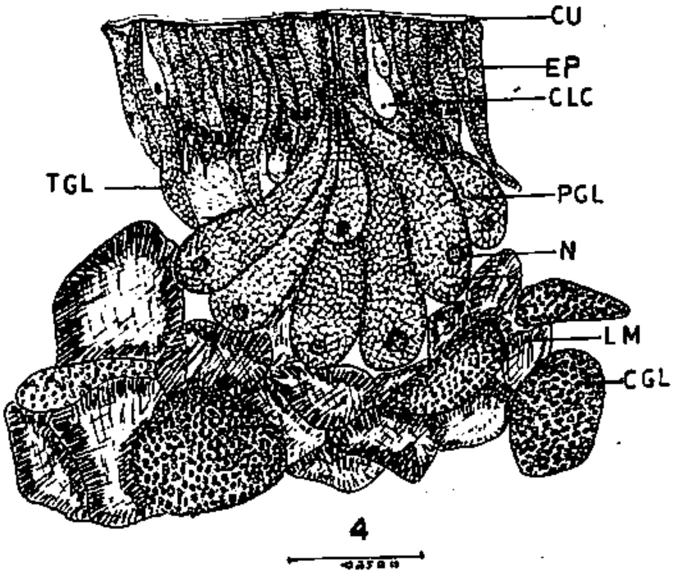

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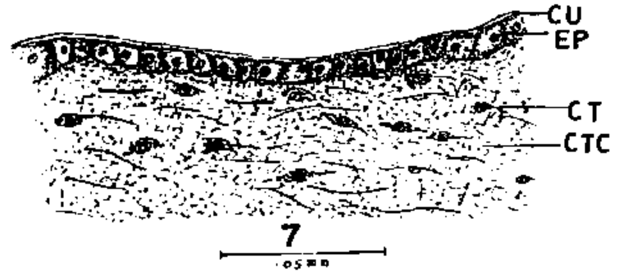

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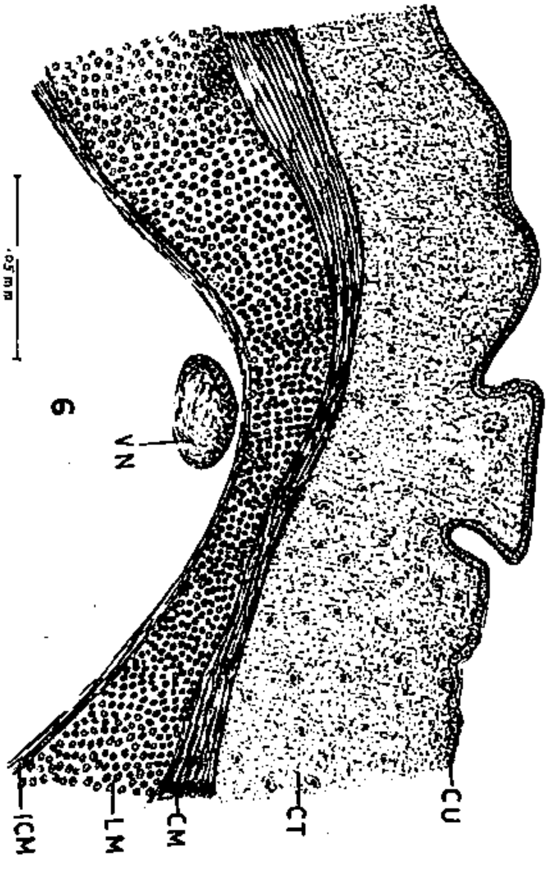

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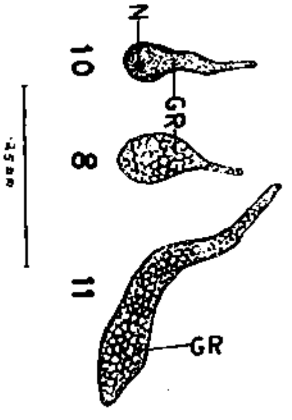

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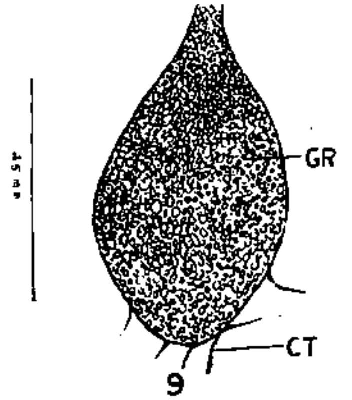

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PLATE -2

Fig. 12. Diagram of the setae and the setal musculature of Ikedosoma pirotansis

TM- Transverse muscle, SET- Seta, REM- Retractor muscle, VA- Ventral accessory vessel, IBM- Interbasal muscle, VN- Ventral nerve cord.

Fig. 13. Diagram showing the internal organs of Ikedosoma pirotansis (anterior region)

PH- Pharynx, OE- Oesophagus, SM- Spindle muscle NE- Nephridium , PRI- Prointestine, ME- Mesenterial body, VV- Ventral vessel, VN- Ventral nerve cord, DV- Dorsal vessel, NI- Neurointestinal vessel. RS- Ring sinus , COL- Collateral intestine, MI- Midintestine.

Fig. 14. Multinucleate giant coelomic corpuscles from the coelomic fluid of Ikedosoma pirotansis

A,B,C,D,E,F - showing different stages in the growth of the corpuscle.

Fig. 15. A giant corpuscle showing the reticulate nature of the wall

RCY- Reticulate cytoplasm

Fig. 16. A portion of the reticulate wall under oil immersion

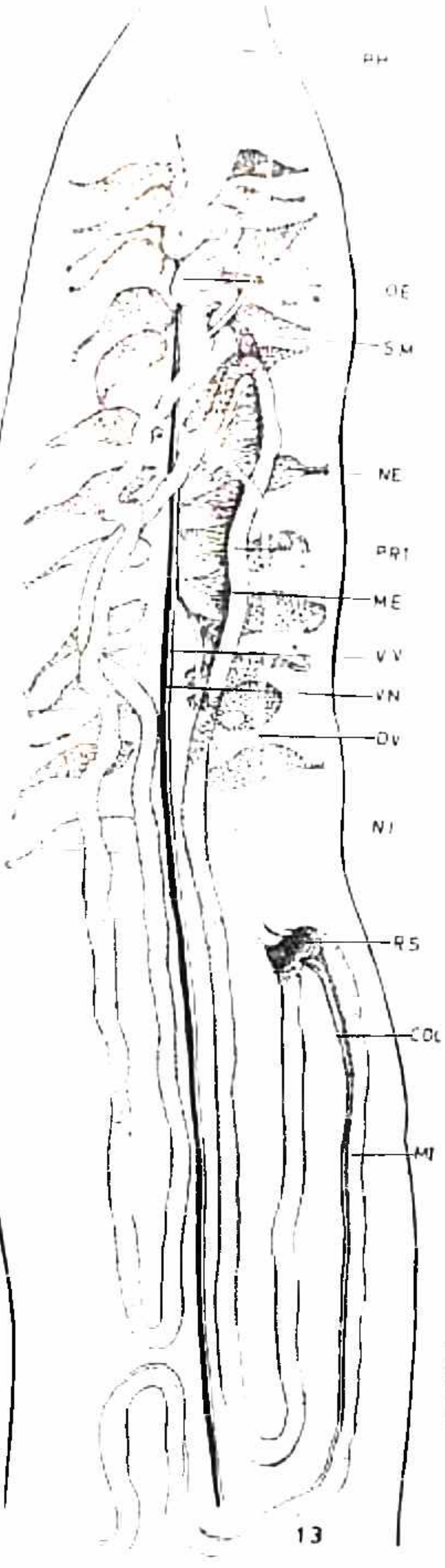
N- Nucleus, CI- Inclusions , CY- Cytoplasm

Fig. 17. Eosinophilous corpuscles of Ikedosoma pirotansis

CI- Inclusions , N- Nucleus,

Fig. 18. Coelomic corpuscles of Listriolobus brevirostris

BC- Basophilic corpuscles, EC- Eosinophilic corpuscles, N- nucleus



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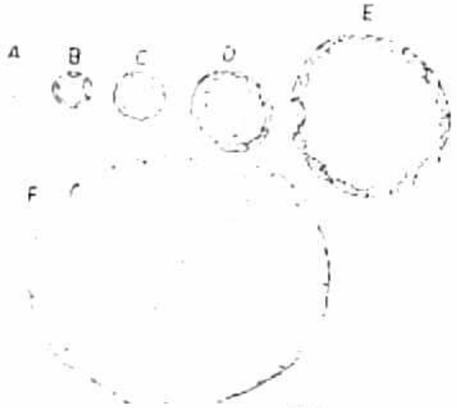

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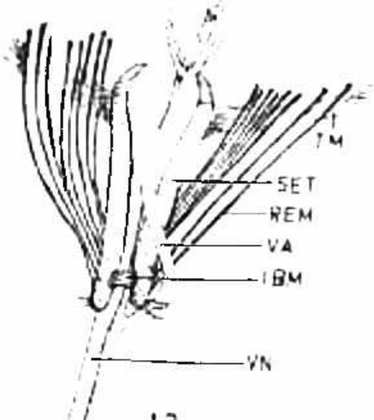

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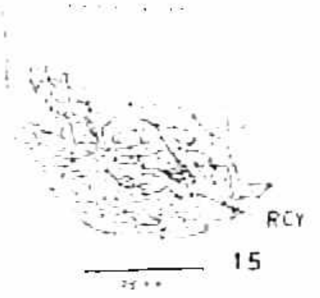

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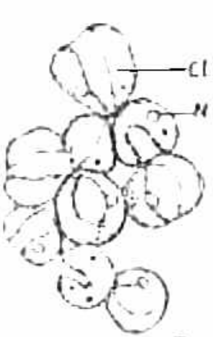

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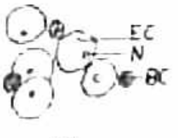

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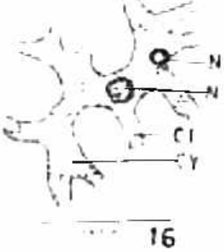

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PLATE - 3

Fig. 19. A part of the alimentary canal of Ikedosoma pirotansis showing the siphonal caecum and other structures

DV. Dorsal vessel, MI. Midintestine, PRI. Prointestine, CAE. Siphonal caecum, COL. Collateral intestine, NI. Neurointestinal,

Fig. 20. Diagram showing the internal organs of Ikedosoma pirotansis (Ventrolateral incision)

HI. Hind intestine, SG. Siphonal groove, VV. Ventral vessel, VB. Branches of the ventral vessel, VM. Ventral mesentery, VN. Ventral nerve cord, AV. Anal vesicle, RE. Rectum

Fig.21. Transverse section passing through the buccal chamber of Ikedosoma pirotansis

E. Epithelium, GL. Gland cell, LM. Longitudinal muscles,

Fig. 22. Transverse section of the pharynx of Ikedosoma pirotansis

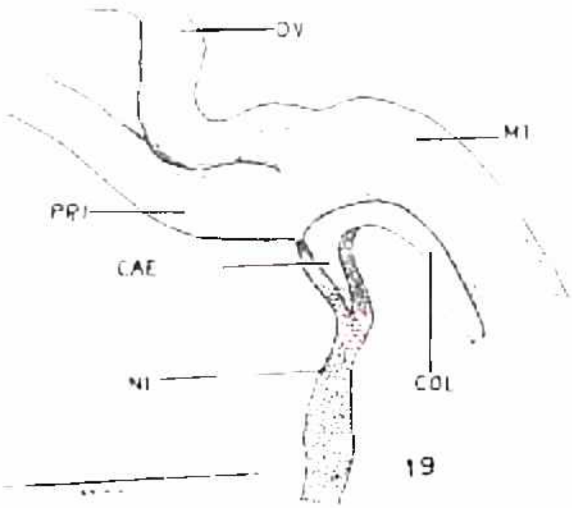
E. Epithelium, GL. Gland cells, CM. Circular layer of muscles, LM. Longitudinal layer of muscles.

Fig. 23. Transverse section passing through the oesophagus of Ikedosoma pirotansis

E. Epithelium (nonciliated), CM. Circular layer of muscles, LM. Longitudinal muscles

Fig. 24. Transverse section passing through the prointestine of Ikedosoma pirotansis

E. Epithelium, S. Secretions, N. Nucleus LM. Longitudinal muscles, CM. Circular layer of muscles .



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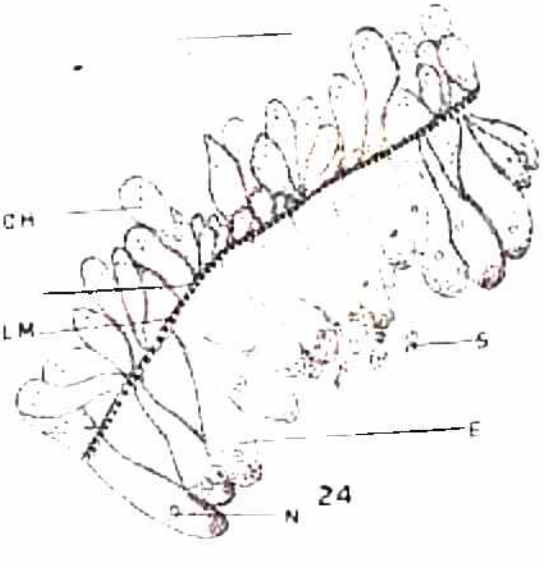

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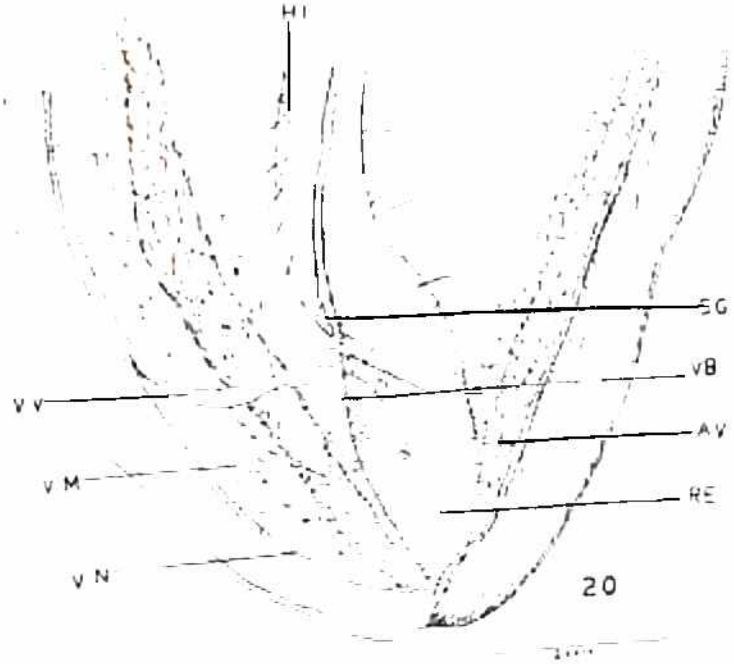

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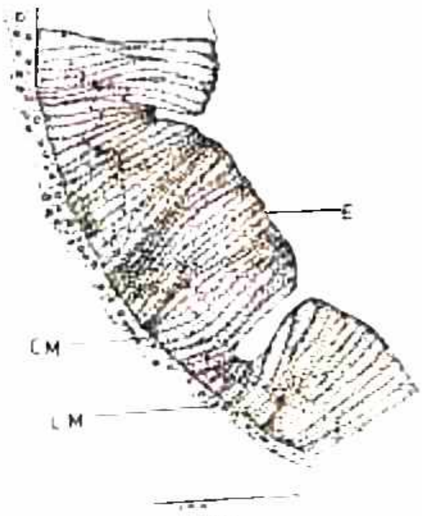

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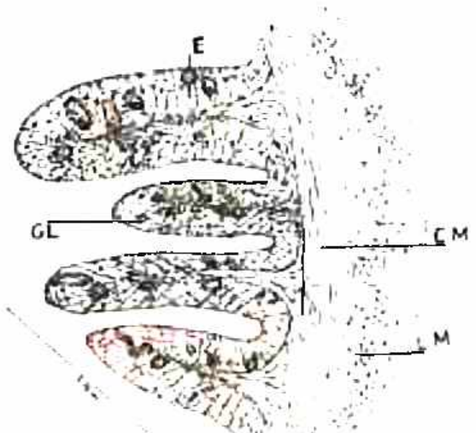

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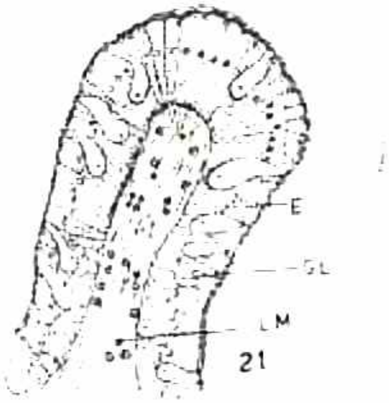

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PLATE- 4

Fig. 25. Transverse section passing through the junction of prointestine and midintestine of *Ikedosoma pirotansis*

RS- Ring sinus, DV- Dorsal vessel, CO- Collateral intestine.

Fig. 26. Transverse section passing through the midintestine along with collateral intestine of *Ikedosoma pirotansis*

LM- Longitudinal muscles, CH- Chlorogogen cells, CO- Epithilium of the collateral intestine, CG- Ciliated groove, VL- Ventrolateral sinus

Fig. 27. Transverse section passing through the rectum of *Ikedosoma pirotansis*

M- Mesenterial strands, LM- Longitudinal layer of muscles, CM- Circular layer muscles, E- Epithelium P- Peritoneal covering.

Fig. 28. Transverse section of the rectum (a portion magnified showing the position of the longitudinal muscle layer)

E- Epithelium, LM- Longitudinal layer of muscles, CM- Circular layer of muscles, P- Peritoneal covering.

Fig. 29. Diagram of the blood vessels of *Ikedosoma pirotansis*

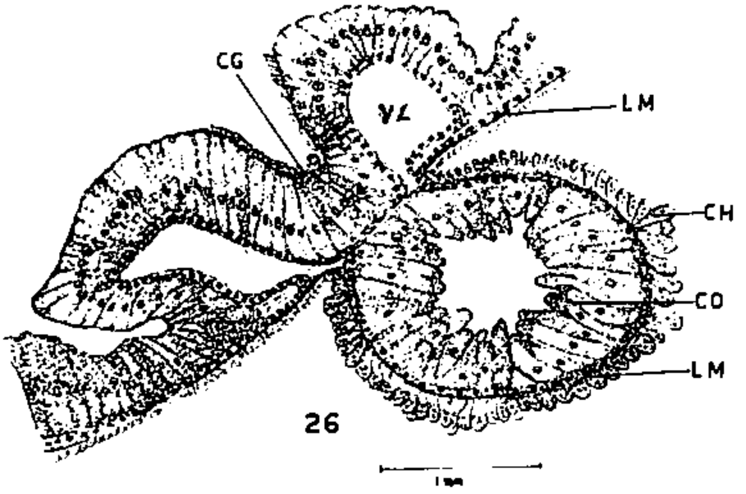
PH- Pharynx, AV- Accessory ventral vessel, OE- Oesophagus. DV- Dorsal vessel, MB- Mesenterial body, VN- Ventral nerve cord, NI- Neurointestinal , VV- Ventral vessel , RS- Ring sinus, CO- Collateral intestine, MI- Midintestine.

Fig. 30. Diagram of the blood vessels of the anterior region of *Ikedosoma pirotansis*

LV- Lateral proboscis vessel , LN- Lateral nerve cord, VV- Ventral vessel, VA, Ventral accessory vessel, VN- Ventral nerve cord,

Fig. 31. Diagram of the blood vessels of *Anelassorhynchus moebi*

DV- Dorsal vessel, PH- Pharynx, VV- Ventral vessel, OE- Oesophagus, NI- Neurointestinal , G- Gizzard, RS- Ring sinus, MI- Midintestine.



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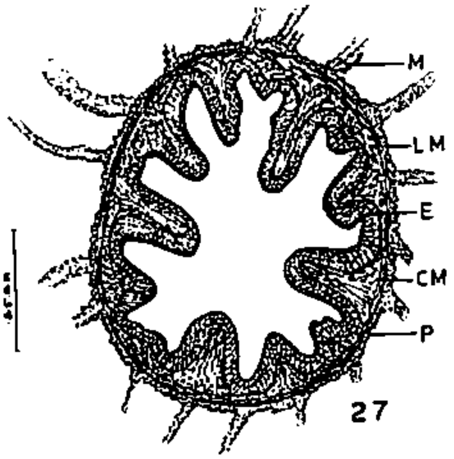

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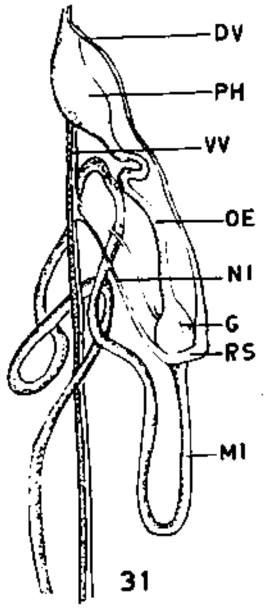

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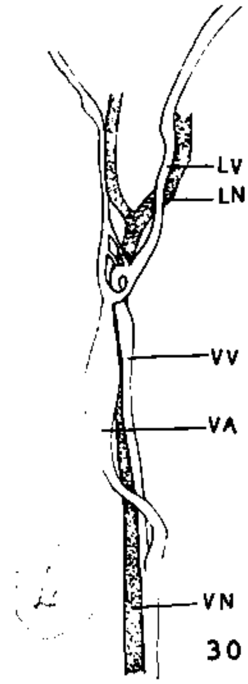

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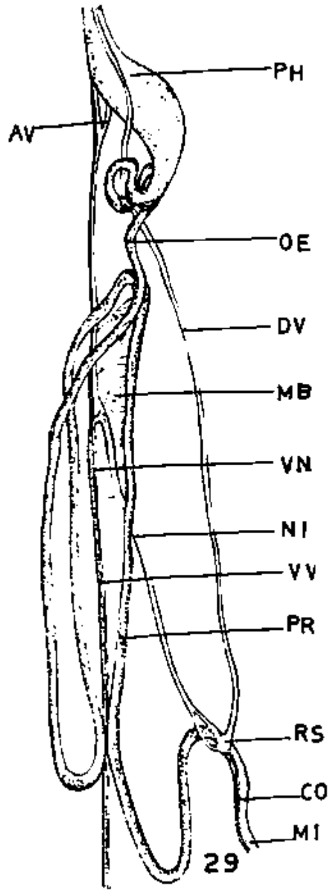

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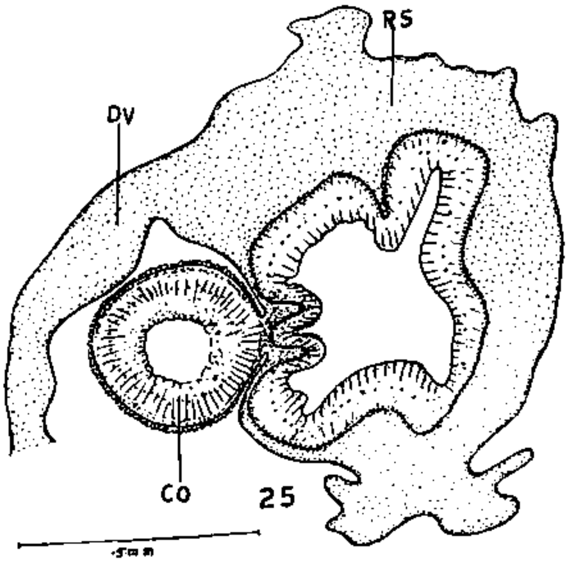

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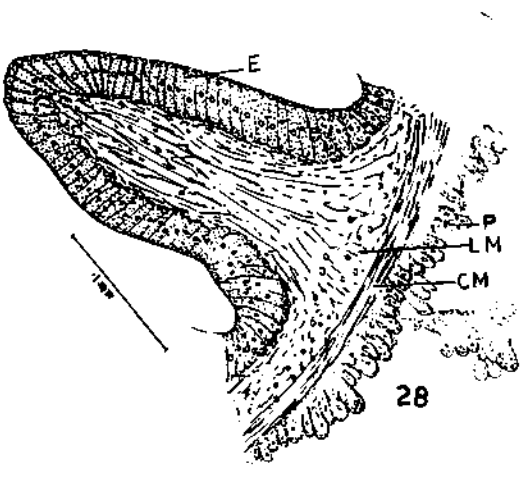

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PLATE - 5

Fig. 32. Diagram of the blood vessels of *Listriolobus brevirostris*.

PH- Pharynx, DV- Dorsal vessel, VN- Ventral nerve cord, IB- Interbasal muscle, OE- Oesophagus, VV- Ventral vessel, NI- Neurointestinal vessel, G- Gizzard, RS- Ring sinus, CG- Ciliated groove, PRI- Prointestine.

Fig. 33. Plan of the nervous system of *Ikedosoma pirotansis*. (Diagrammatic)

CN- Commissure, LV- Lateral proboscis nerve, MV- Median vessel of the proboscis, LN- Lateral nerve, IB- Interbasal nerve, AV- Accessory ventral vessel, VV- Ventral vessel, VN- Ventral nerve cord.

Fig. 34. Transverse section passing through the anterior region of *Ikedosoma pirotansis* just posterior to the bifurcation of the ventral nerve cord. The ventral vessel is already bifurcated.

EP- Epidermis, CUT- Cutis, PAP- Papillae, CM- Circular layer of muscles, LM- Longitudinal layer of muscles, VN- Ventral nerve cord, ICM- Inner circular layer of muscles, LV- Lateral vessels.

Fig. 35. Transverse section passing through the anterior region of *Ikedosoma pirotansis* showing the bifurcation of the ventral nerve cord.

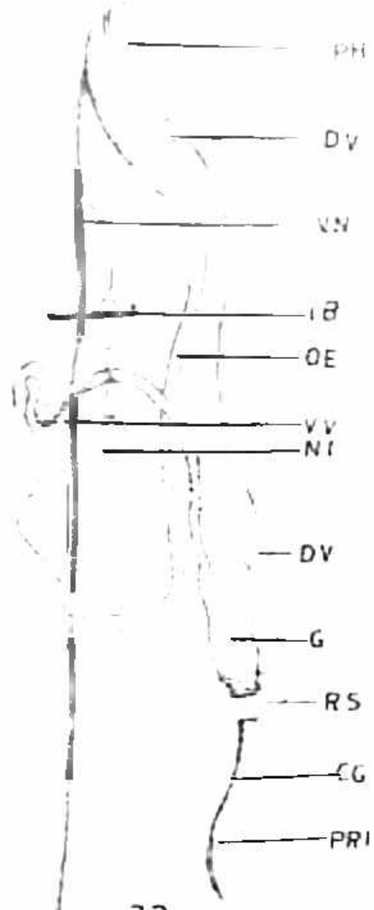
EP- Epidermis, LN- Lateral nerve cord, LM- Longitudinal layer of muscles, CM- Circular layer of muscles.

Fig. 36. Distal part of the nephridiumof *Ikedosoma pirotansis* showing the terminal nephrostome.

CF- Ciliated funnel, NE- Neck of the nephridium, EG- Egg, NESA- Nephridial sac.

Fig. 37. Transverse section of the neck of the nephridium of *Ikedosoma pirotansis*

P- Peritoneal layer, CM- Circular layer of muscles, LM- Longitudinal layer of muscles, E- Epithelium.



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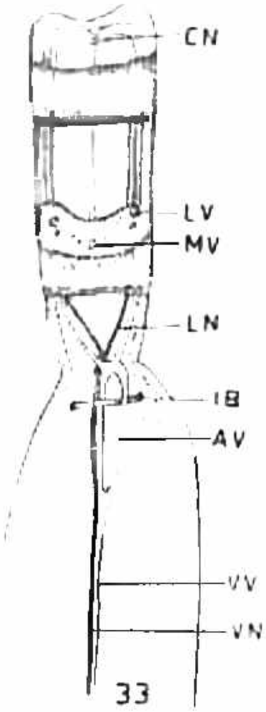

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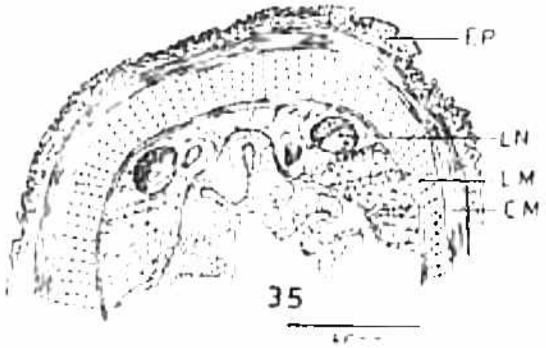

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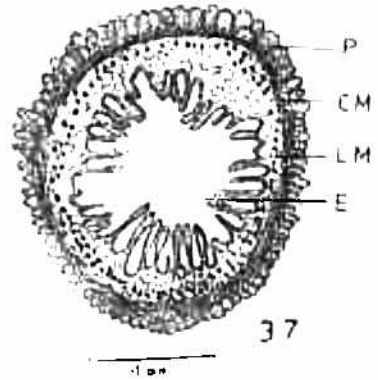

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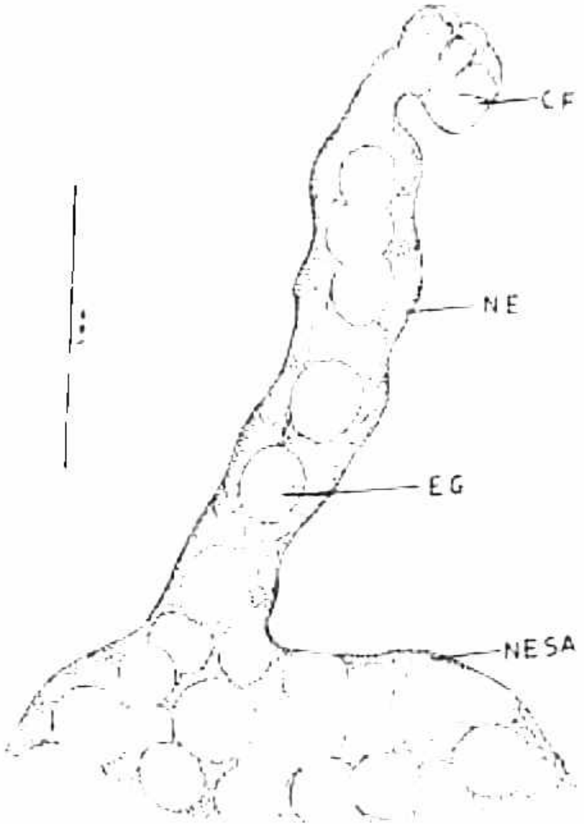

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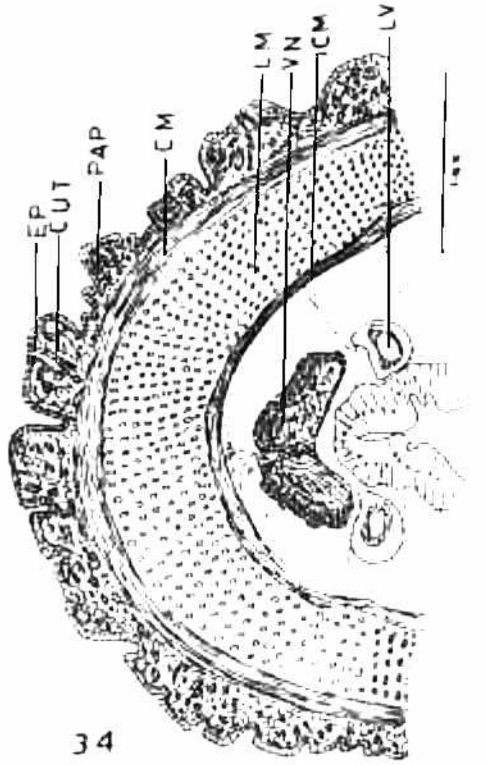

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PLATE -6

Fig. 38. Transverse section passing through the neck of nephridium (a portion magnified)

P. Peritoneal covering , CM. Circular layer of muscles, LM. Longitudinal layer of muscles, E. Epithelium.

Fig. 39. Longitudinal section of the nephridium showing the nephridiopore and nephridial duct.

EP. Epidermis, CM. Circular layer of muscles, LM. Longitudinal layer of muscles, NP. Nephridiopore, ND. Nephridial duct, PAP. Papillae, ICM. Inner circular layer of muscles.

Fig. 40. Nephridium of Listriolobus brevirostris.

LCF. Lateral nephrostome , SF. Spirally coiled filaments, NE. Body of the nephridium, EG. Egg.

Fig. 41. A few stalked funnels from the anal vesicle of Ikedosoma pirotansis showing the secondary branching .

CF. Ciliated funnel, ST. Secondary tubules, PT. Primary tubule .

Fig. 42. Transverse section passing through the anal vesicle of Ikedosoma pirotansis .

~~EM~~ E. Epithelium, LM. Longitudinal layer of muscles, CM. Circular layer of muscles.

Fig. 43. Longitudinal section of the ciliated funnel (anal vesicle)

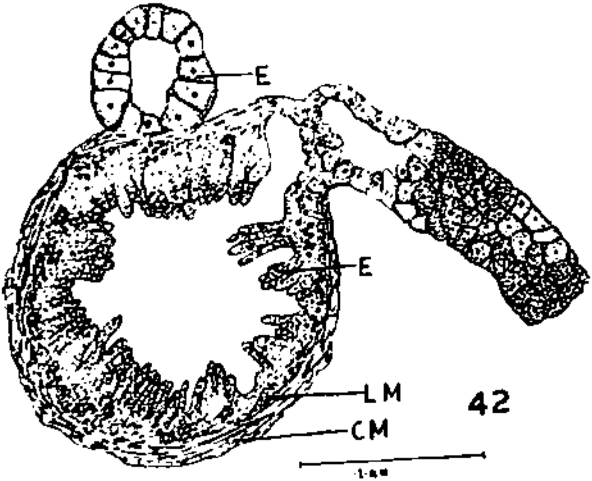
CC. Coelomic corpuscles, AVF. Funnel of the anal vesicle , E. Epithelium, L. Lumen of the tubule,

Fig. 44. Transverse section of a tubule (anal vesicle).

LU - Lumen , EP. Epithelium, N. Nucleus

Fig. 45. An egg cell of Ikedosoma pirotansis detached from the proliferation centre of germ cells.

NC. Nurse cells , N. Nucleus, EG. Egg.



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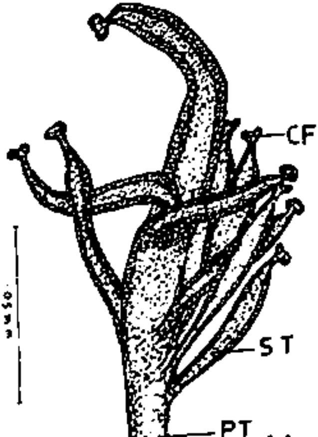

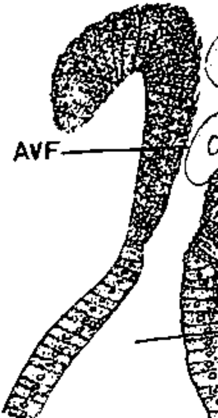

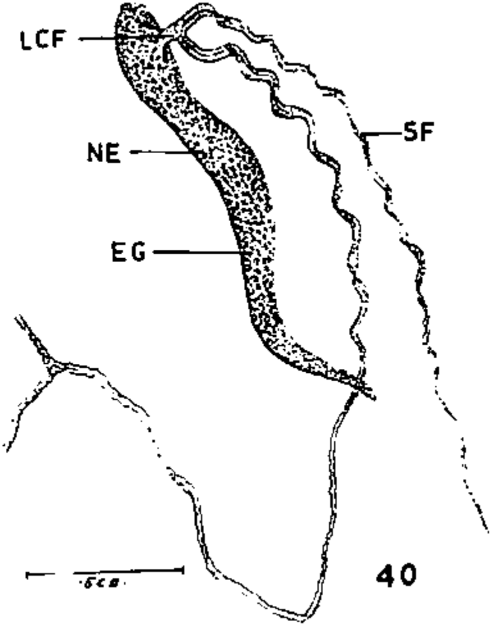

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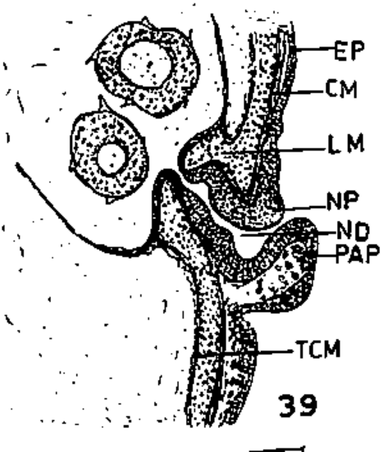

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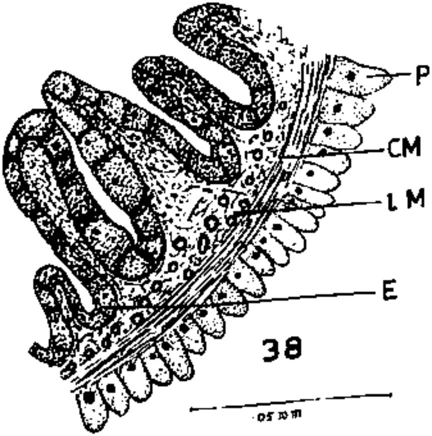

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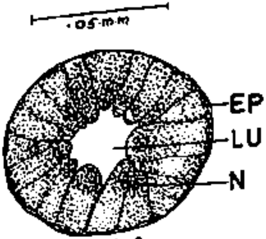

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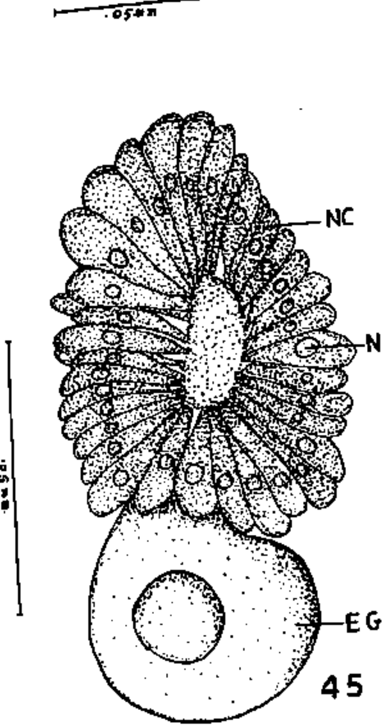

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PLATE -7

Fig. 46. Section of an egg with the cap of nurse cells.

NC- Nurse cells, N- Nucleus, NT- Nutrition tube, EG- Egg.

Fig. 47. An egg cells from the coelomic fluid showing the nurse cells.

N- Nucleus, NC- Nurse cells, NT- Nutrition tube, EG- Egg.

Fig. 48. Transverse section of an egg.

N- Nucleus, CNZ- Circum nuclear zone, PY- Protein yolk globules, FY- Fatty yolk globules, EM- Egg membrane.

Fig. 49. Transverse section of an egg with the nurse cells showing the distribution of fatty and protein yolk globules.

NC- Nurse cells, N- Nucleus, NT- Nutrition tube, PY- Protein yolk globules, FY- Fatty yolk globules.

Fig. 50. An egg of *Listriolobus brevirostris*.

N- Nucleus, CY- Cytoplasm.

Fig. 51. An egg of *Ikedosoma pirotansis*.

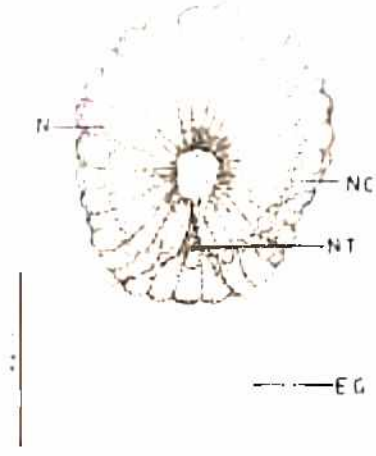
N- Nucleus, CY- Cytoplasm.

Fig. 52. An egg from the coelomic fluid of *Acanthobonellia vulgaris*.

NC- Nurse cells , N- Nucleus, NS- Nucleolus , FC- Follicular cells,

Fig. 53. A few egg cells from the coelomic fluid of *Ochetostoma septemyotum* .

A, B, C, D, E- Different stages of growth.



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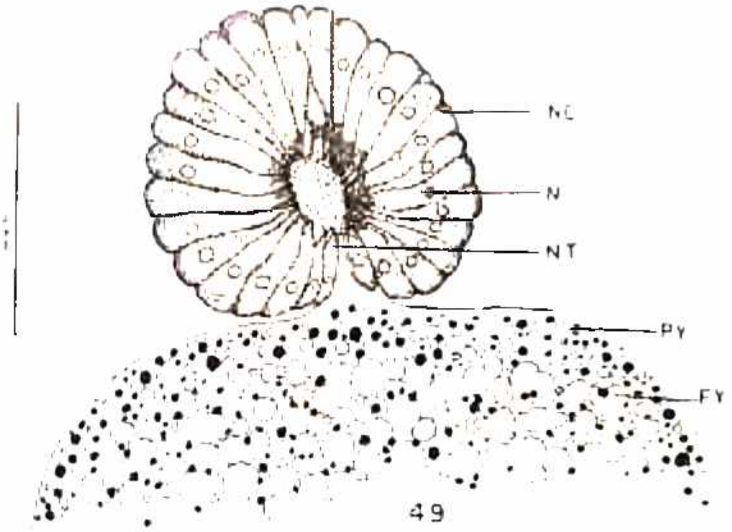

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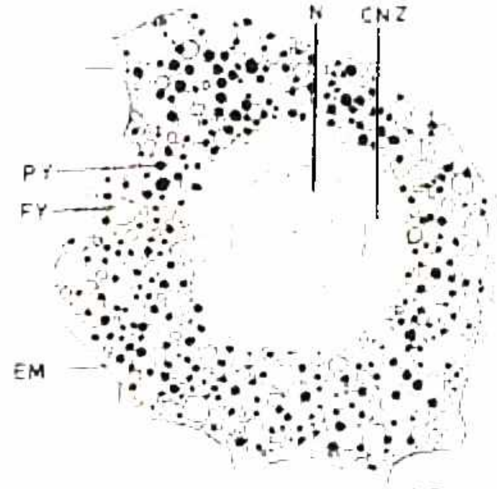

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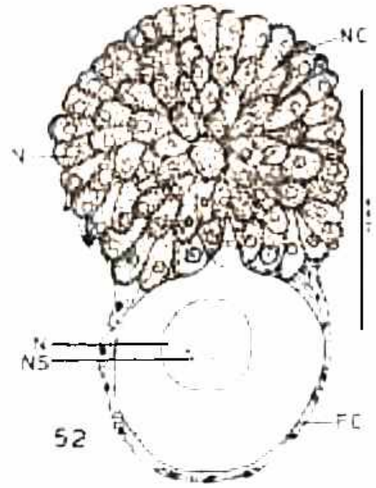

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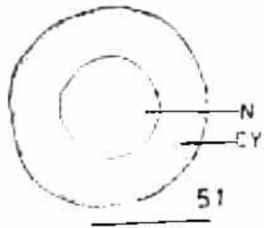

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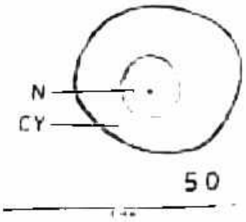

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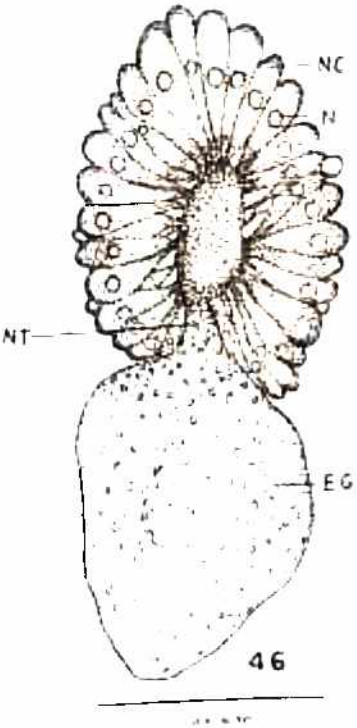

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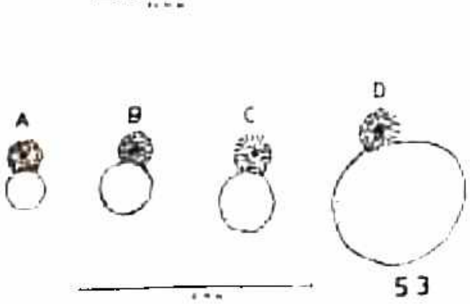

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EXPLANATION OF THE PHOTOMICROGRAPHS

Photomicrograph I. Transverse section of the setal region showing the characteristic muscle cushion between the setae (x 32).

MC- Muscle cushion , SET- Seta, VN- Ventral nerve cord , VV- ventral vessel.

Photomicrograph 2. Transverse section of the proboscis of *Listriolobus brevirostris* showing the gills (x 80).

C- Coelomic cavities, G- gills.

1

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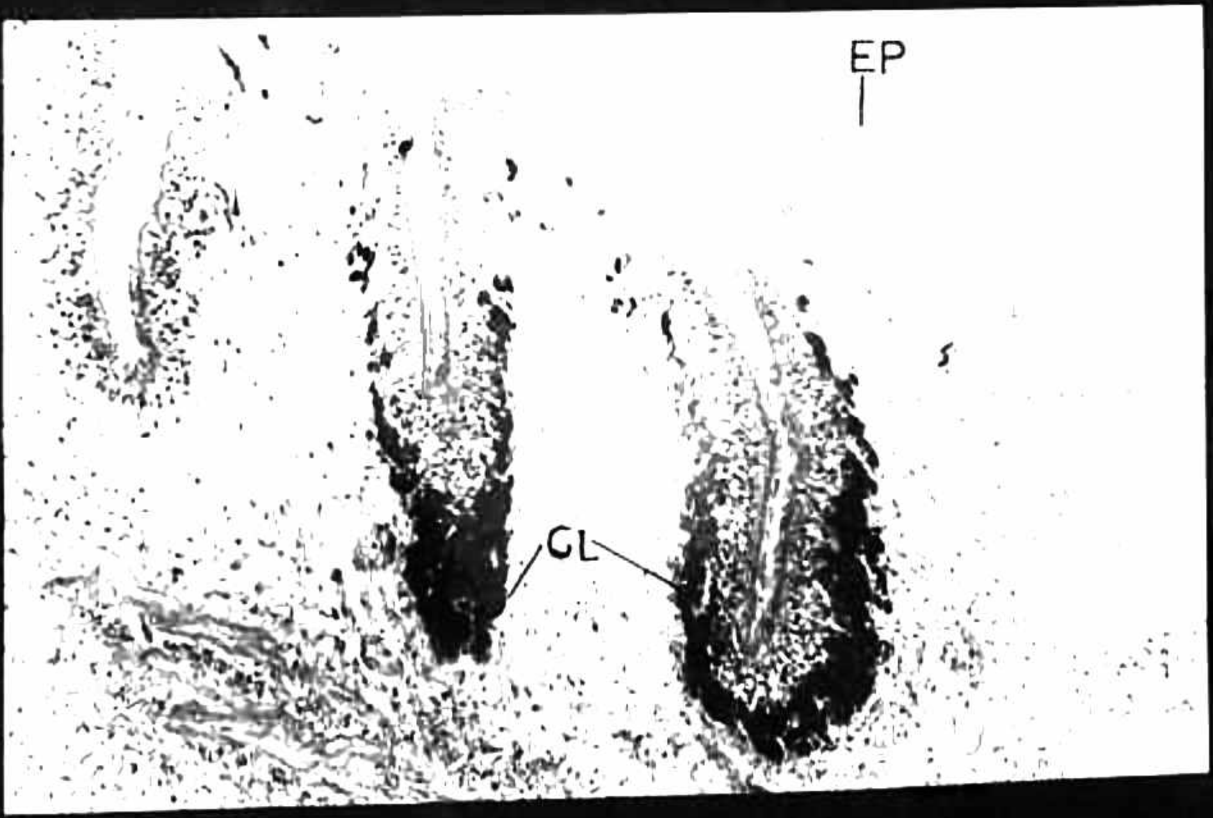
Photomicrograph 3. Transverse section of the proboscis of Listriolobus brevirostris showing the dense clusters of glands.

EP. Epidermis, GL. Gland cells.

Photomicrograph 4. Transverse section of the proboscis of Ikedosoma pirotansis . The coelomic spaces are absent except for the lateral coelomic channels (x 90).

LC. Lateral coelomic channel, LV. Lateral proboscis vessel, LN. Lateral nerve cord, MV. Median proboscis vessel.



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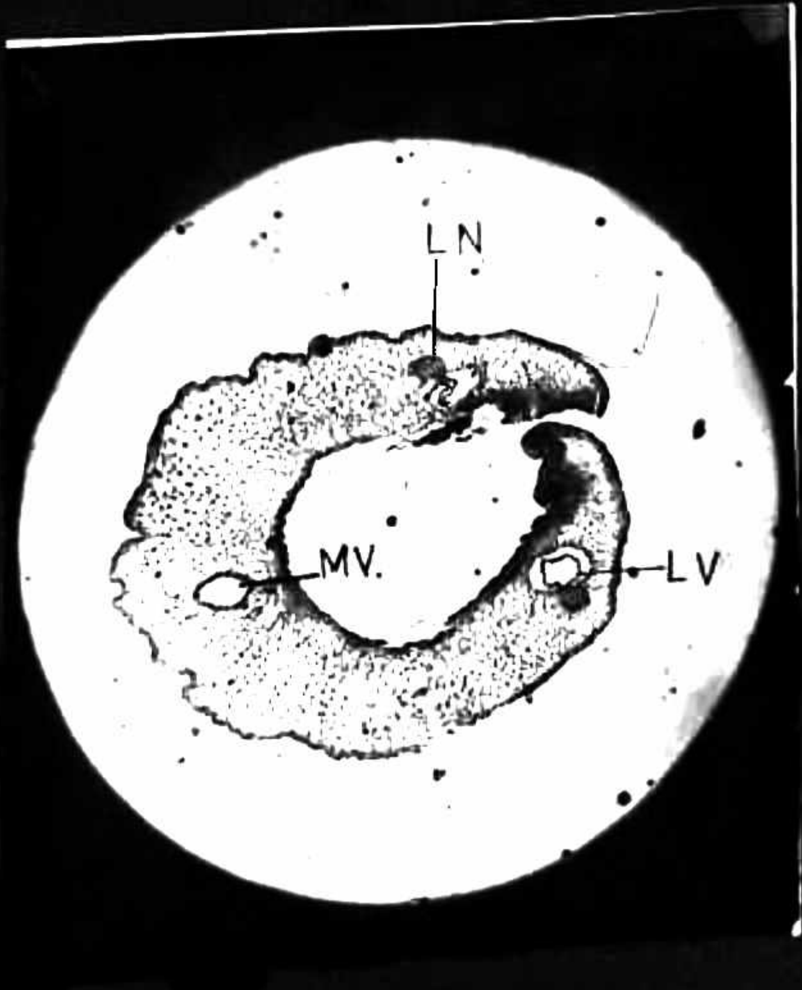

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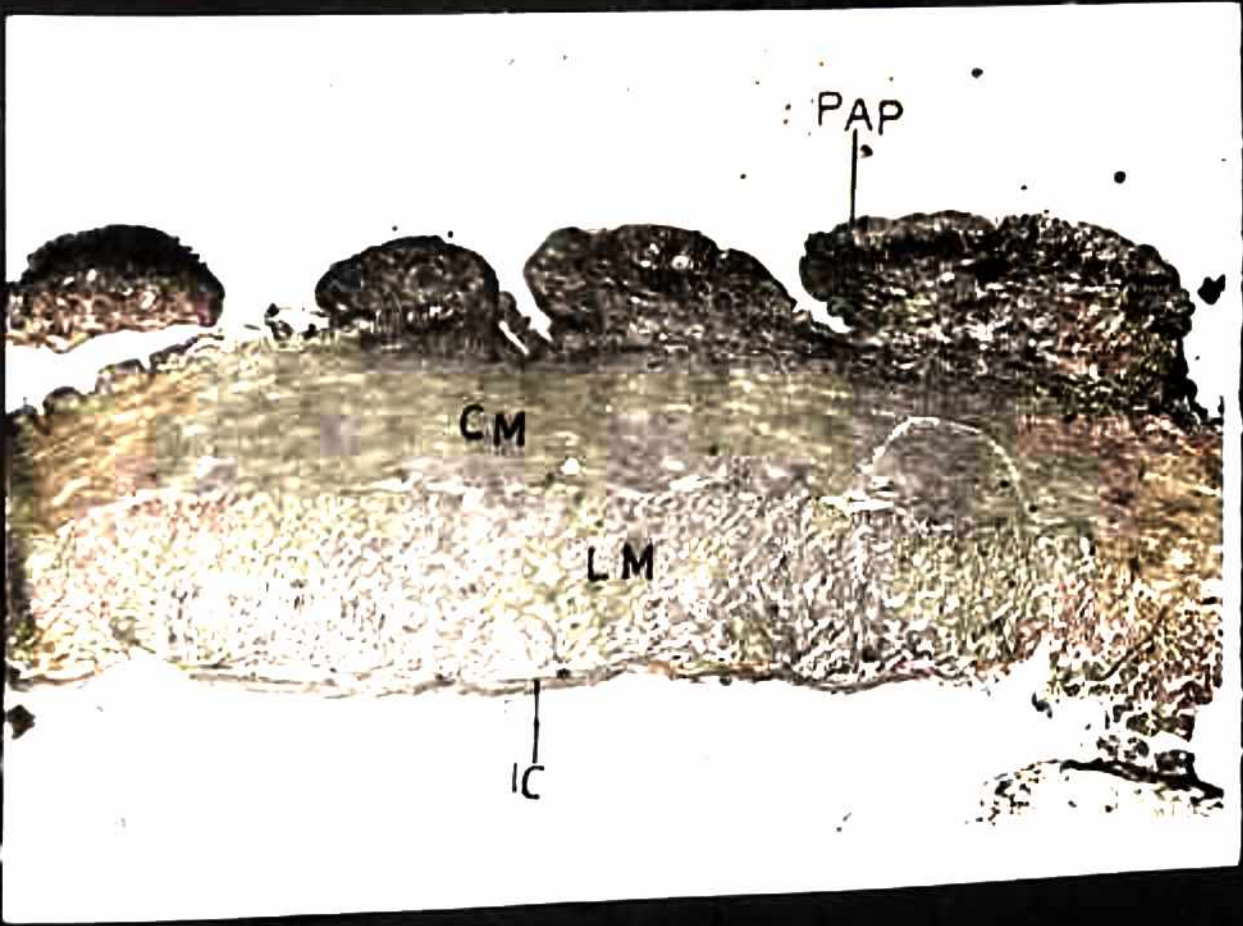
Photomicrograph 5. Transverse section of the integument of <u>Ikedosoma</u> <u>pirotansis</u> x 180).

PAP- Papillae, CM- Circular layer of muscles, LM- Longitudinal layer of muscles, IC- Inner circular layer of muscles.

Photomicrograph 6. Transverse sections of the integument of <u>Listriolobus</u> <u>brevirostris</u> showing the thickening of the longitudinal muscle to form longitudinal bands. The inner circular layer of muscles. is also continuous (x 80).

EP- Epidermis, CM- Circular layer of muscles, LM- Longitudinal layer of muscles, IC- Inner circular layer of muscles.



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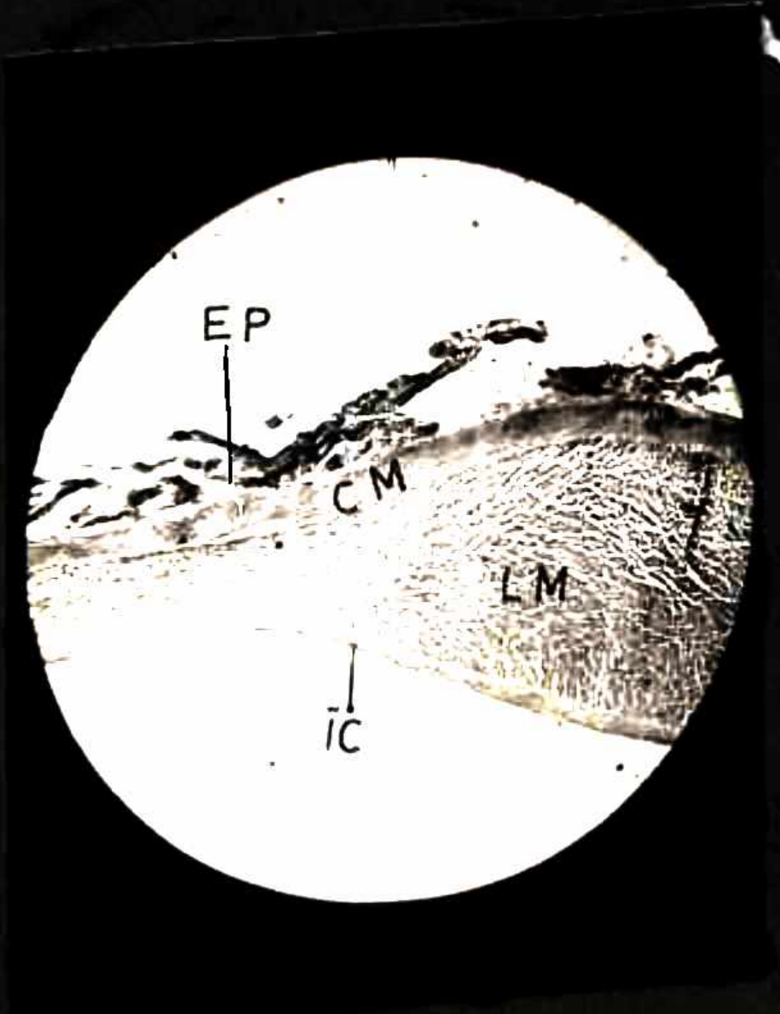

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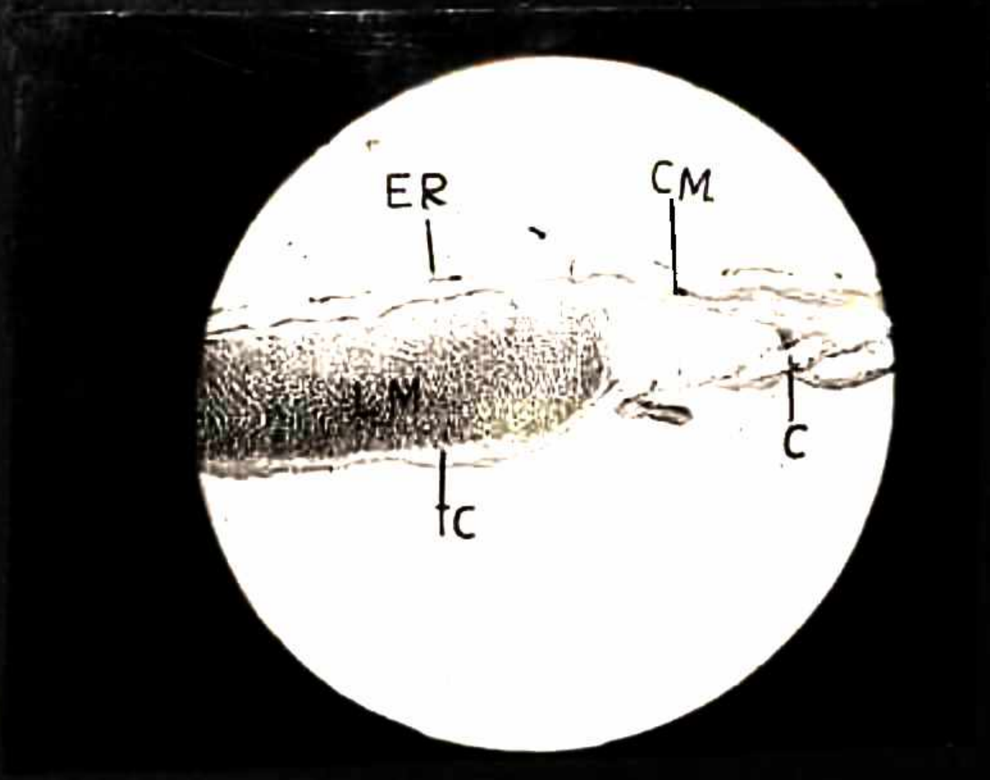
Photomicrograph 7. Transverse section of the integument of *Ochetostoma bombayensis* showing the one of the muscle bands clearly demarcated (x 80).

EP- Epidermis, CM- Circular layer of muscles, LM- Longitudinal layer of muscles, IC- Inner circular layer of muscles, C- Coelomic spaces in the body wall.

Photomicrograph 8. Transverse section of the proboscis of *Listriolobus brevirostris* passing through the distal end showing the coelomic spaces (x 160).

C- Coelomic spaces, GL- Glands.



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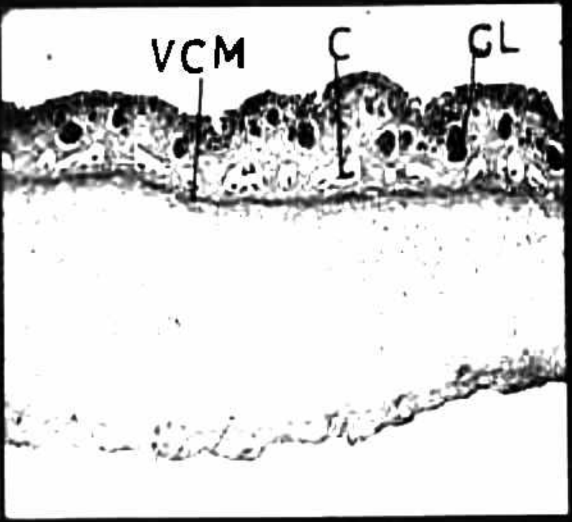
Photomicrograph 9. Transverse section of the proboscis of *Ochetostoma bombayensis* passing through the anterior end. (x 90).

VCM- Ventral circular layer of muscles, C- Coelomic spaces, GL- Gland cells.

Photomicrograph 10. Transverse section of the proboscis of *Ochetostoma bombayensis* passing through the middle region. (x45).

VCM- Ventral circular layer of muscles, C- Coelomic spaces, GL- Gland cells.



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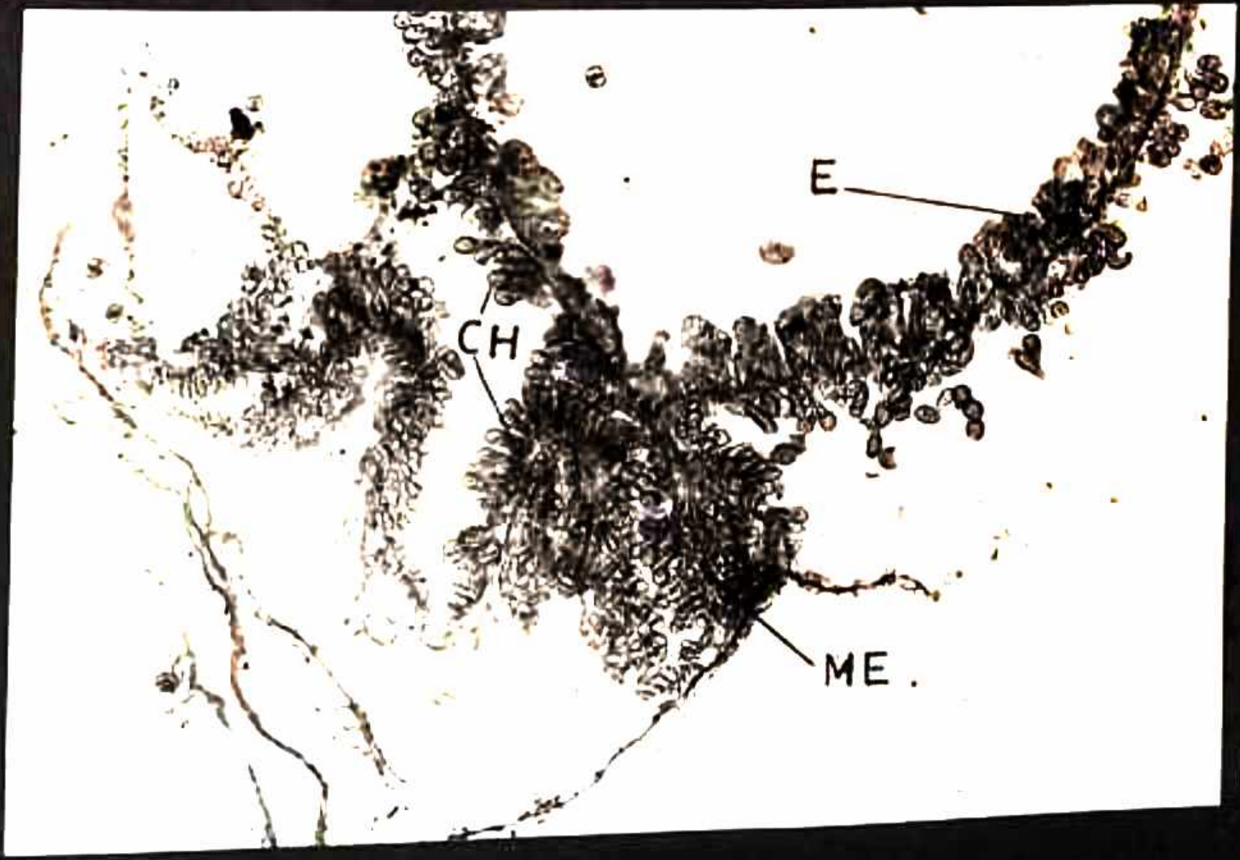
Photomicrograph 11. Transverse section of the prointestine of <u>Ikedosoma pirotansis</u> showing the suet like mesenterial bodies (x 180).

ME- Mesenterial body , CH- Chlorogogen cells , E- Epithelium.

Photomicrograph 12. Transverse section of the alimentary canal of <u>Ikedosoma pirotansis</u> passing through ring sinus. (x 80)

Col- Collateral intestine, RS- Ring sinus.



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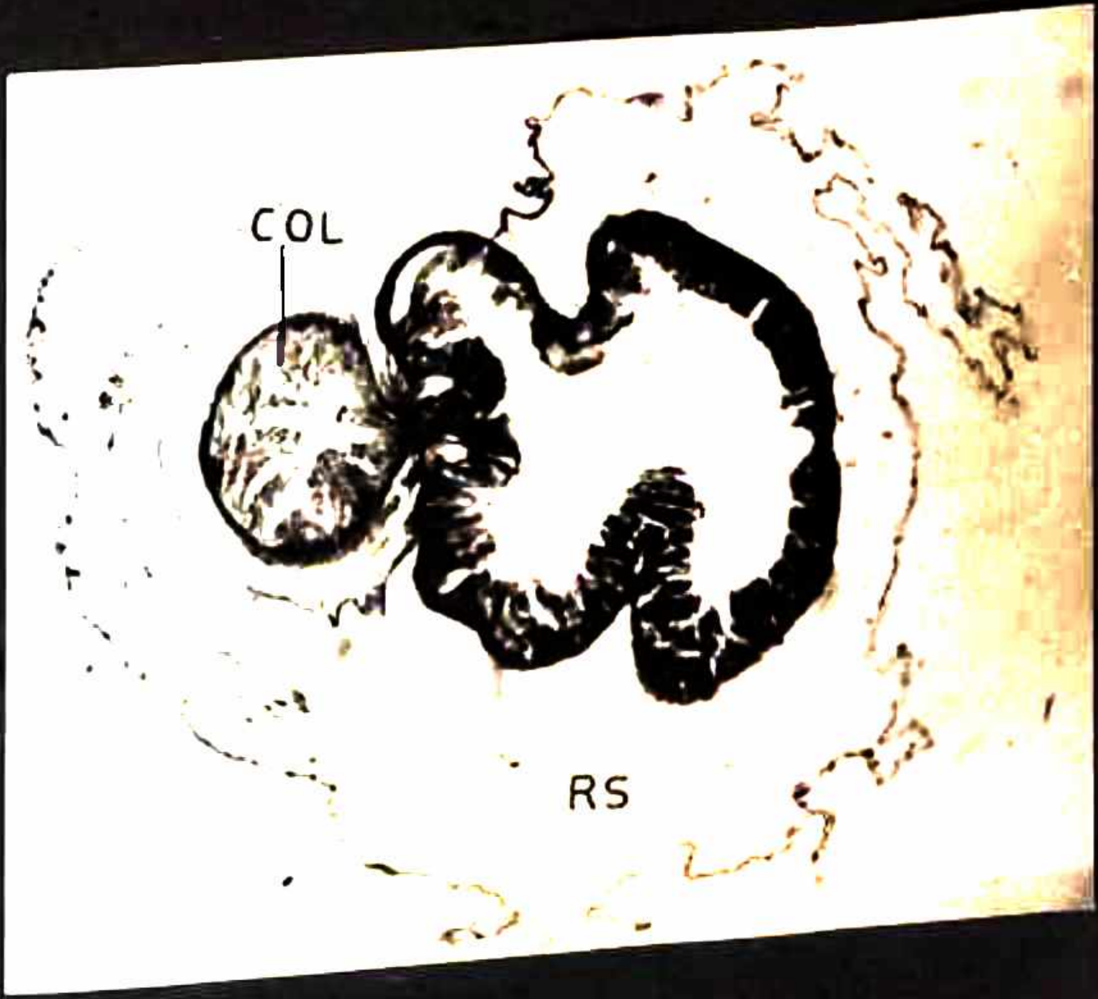

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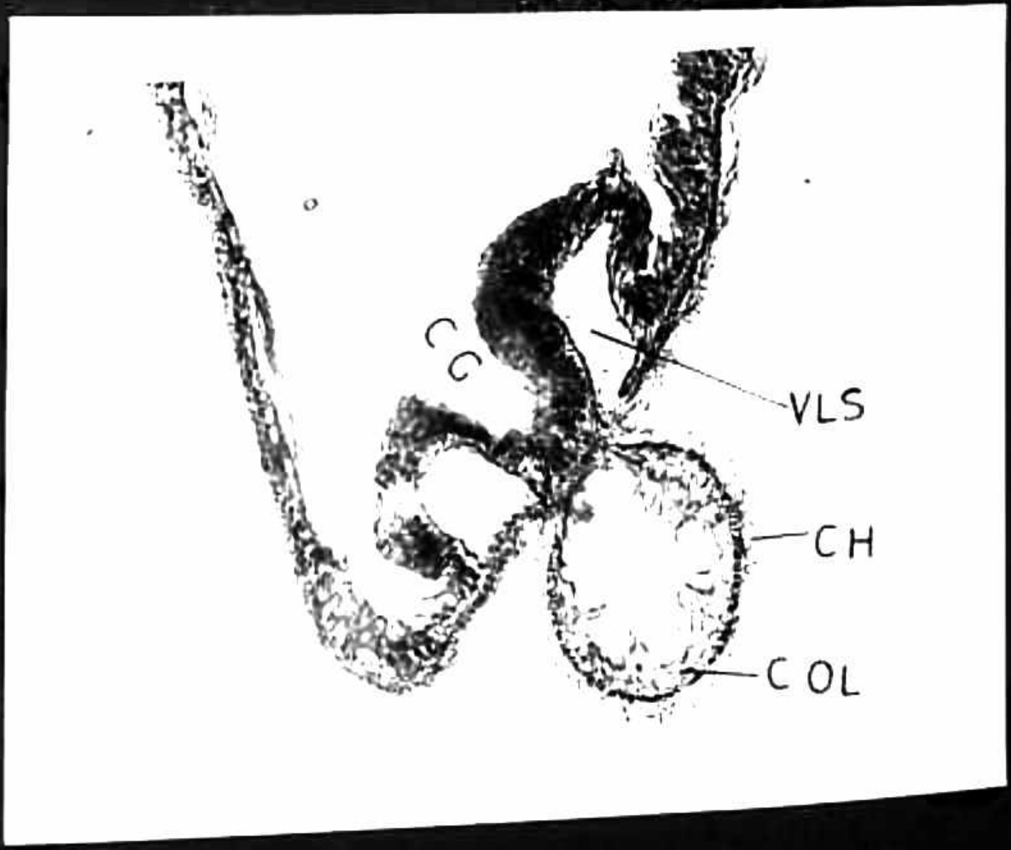
Photomicrograph 13. Transverse section of the mid intestine of *Ikedosoma pirotensis*. (x 180).

CG. Ciliated groove , VLS. Ventro lateral sinus, CH. Chlorogogen cells, COL. Collateral intestine.

Photomicrograph 14. Transverse section of the anal vesicle of *Ikedosoma pirotensis* (x 180).

PT. Primary tubule , CF. Ciliated funnel, CV. Central vesicle.



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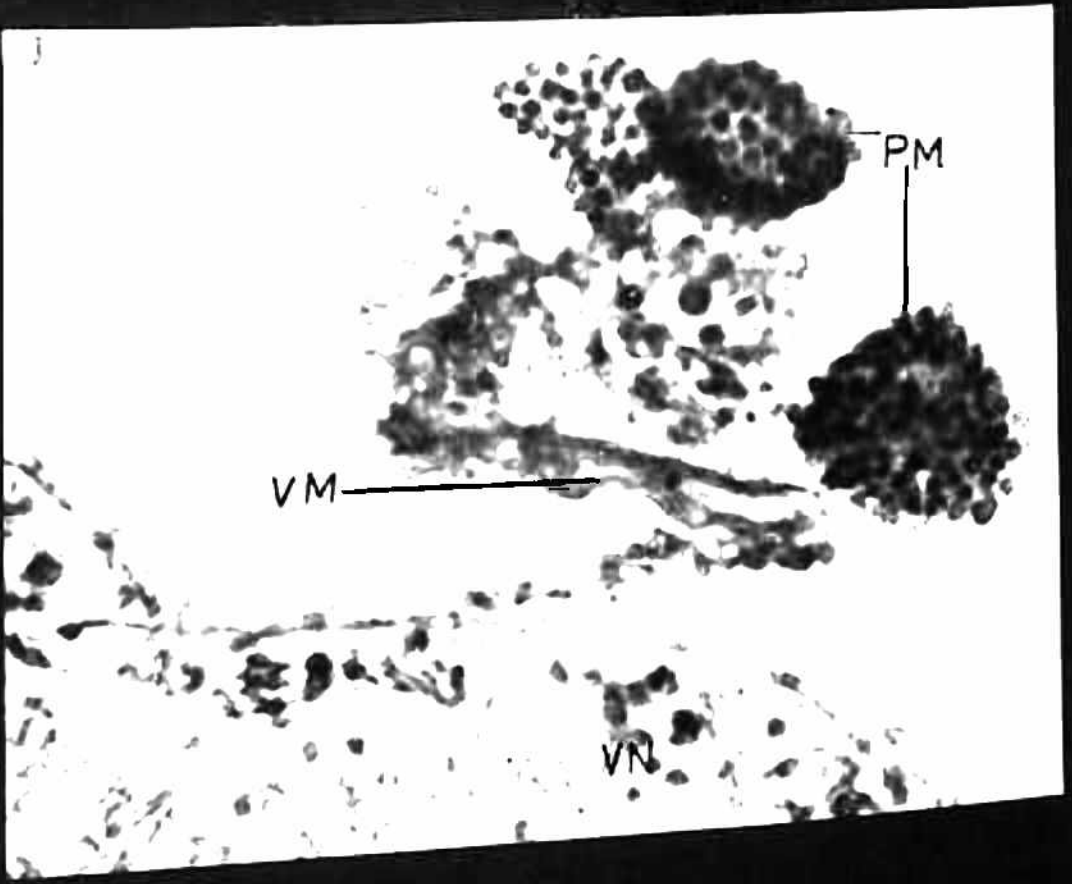
Photomicrograph 15. Transverse section through the ventral nerve cord and ventral mesentery (posterior region) showing the proliferation of egg cells (x 880).

PM. Primordial egg cells, VM. Ventral mesentery, VN. Ventral nerve cord.

Photomicrograph 16. Transverse section of egg sec.(x 75).

EG. Egg, ES. Egg sec.



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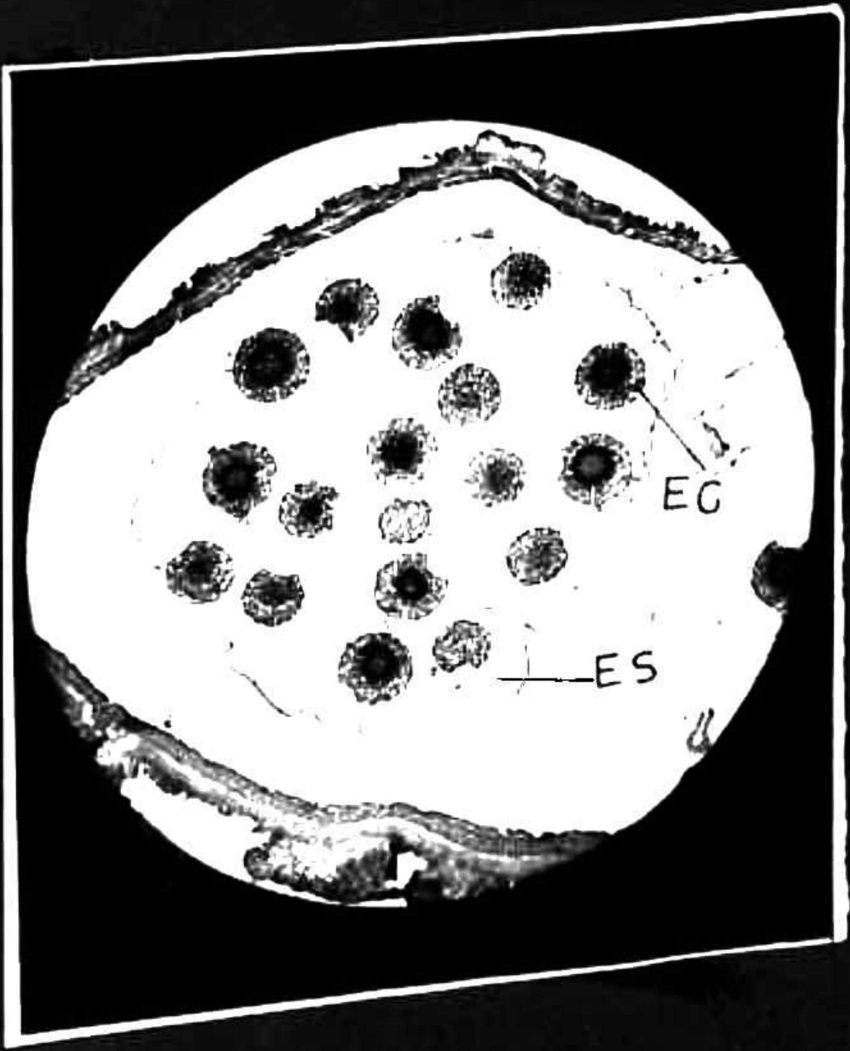

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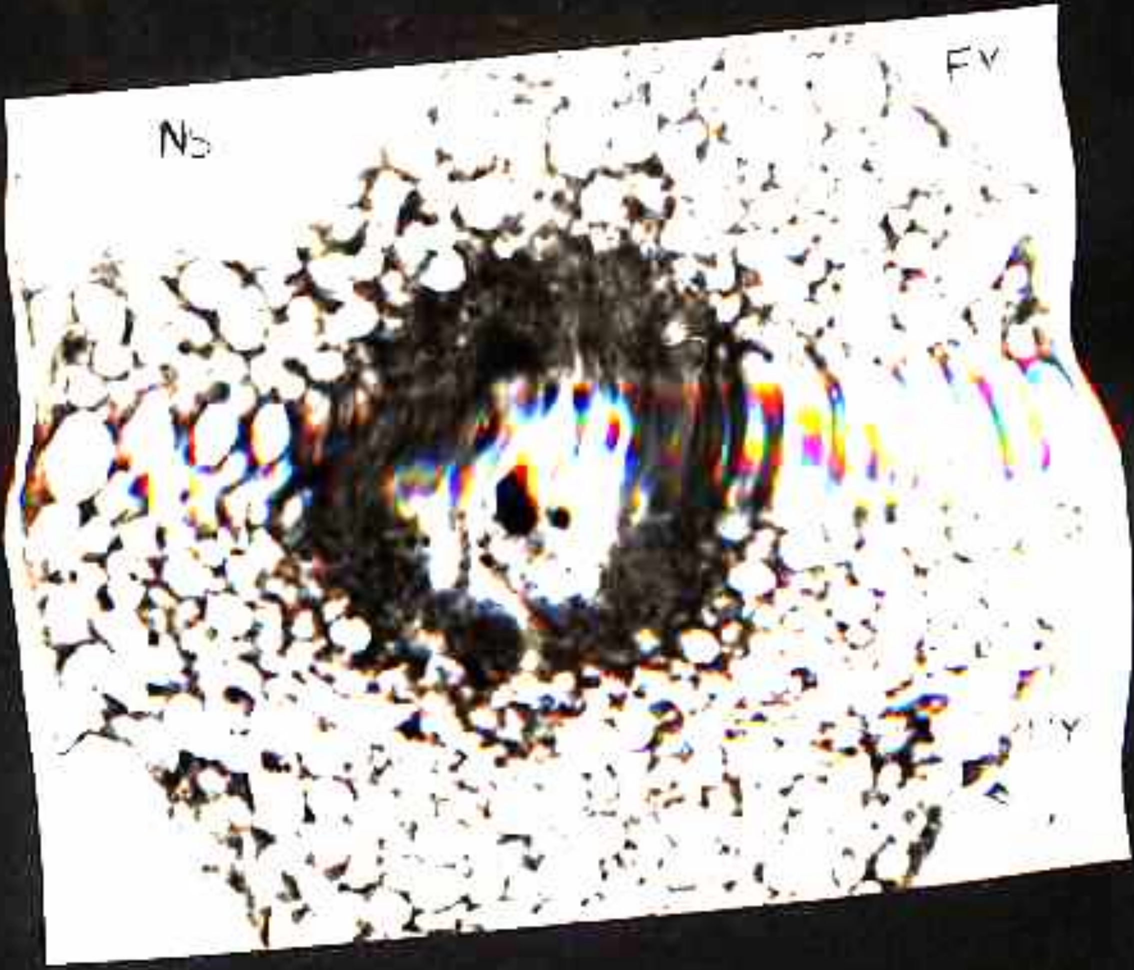
Photomicrograph 17. Transverse section of an egg
(Iron haematoxylin preparation)
x 720.

FY. Fatty yolk globules, CNZ. Circum nuclear zone, PY. Protein yolk globules, NS. Nucleolus.

Photomicrograph 18. Formaldehyde-calcium/Sudan black B.
x 280.

The whole cell looks black due to sudanophilia seen under the lower power. The large compound yolk globules in the ooplasm, and the germinal vesicle remain sudanophobic .

GV. Germinal vesicle , CY. Compound yolk globules.



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