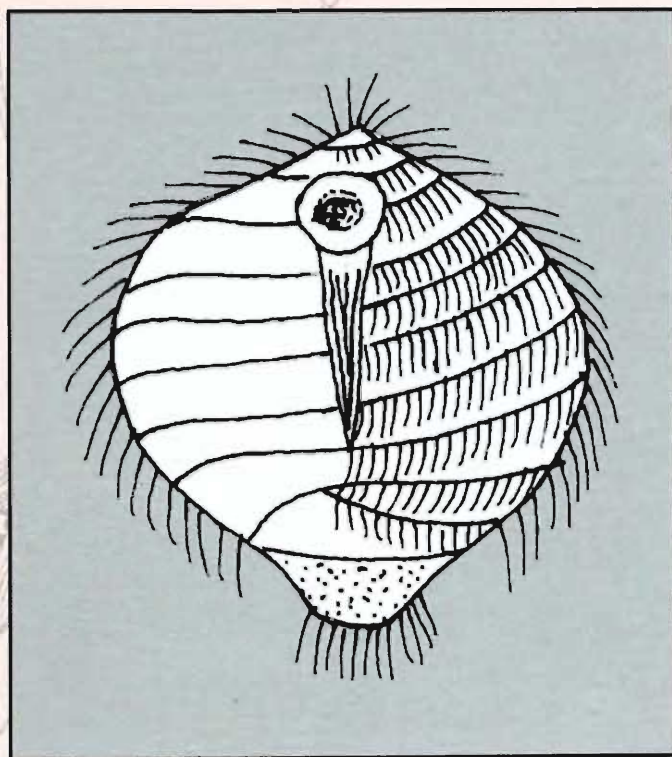


OCCASIONAL PAPER No. 262

**A MONOGRAPH OF
THE FLAGELLATE SYMBIOTES OF
INDIAN TERMITES WITH SPECIAL REFERENCE TO
THEIR HOST CORRELATION AND COEVOLUTION**

A. K. DAS



ZOOLOGICAL SURVEY OF INDIA

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Kolkata**

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INTRODUCTION

Termites are isopteran insects comprising of 9 families, namely, Mastotermitidae, Kalotermitidae, Termopsidae, Hodotermitidae, Rhinotermitidae, Stylotermitidae, Serritermitidae, Termitidae and Indotermitidae. Out of these, members of the first 7 families are known as lower termites which feed on sound wood or nearly sound wood (Cleveland, 1926). In addition, some members of Hodotermitidae may feed on grass and herbs (Kirby, 1941 a) and some of Kalotermitidae, Termopsidae and Rhinotermitidae can live on papers, cotton cellulose and a lignin cellulose complex (Cleveland, 1924, 1925 a, 1928). These lower termites invariably harbour enormously large number of flagellates in their guts, sometimes predominating over the real food in quantity. These gut inhabiting flagellates belong to 3 orders, viz., Oxymonadida, Trichomonadida and Hypermastigida and developed a true mutualistic relationship with their hosts (Cleveland, 1923, 1924, 1925 a,b,c, 1926, 1928). Cleveland (*op. cit*) experimentally showed that these termites can not survive without symbiotic flagellates even when they are given abundant supply of wood or any other form of cellulose as food since they lack cellulose splitting enzyme in their guts. As a result, lower termites can not digest food (wood) on their own. For nutrition they are to fully depend on thier gut inhabiting flagellates. Because, these flagellates are capable of digesting sound wood and other form of cellulose with the aid of the enzyme cellulase and thus prepare ready food for their hosts in the form of glucose. In turn, the flagellates get anaerobic and sheltered environment in the guts of their hosts as well as abundant food for survival.

On the other hand, members of the families Termitidae and Indotermitidae are known as higher termites. They feed on much degraded wood, for the digestion of which symbiotic flagellates are not essential. These termites have developed different mechanism for wood digestion (Honigberg, 1970). As studied by Cleveland (1923), Kirby (1927, 1932 b), Henderson (1941) and others many higher termites do not harbour any Protozoa in their guts. When Protozoa are present in these termites they are very scarce and do not ingest wood. Therefore, relationship between higher termites and their gut dwelling flagellates does not appear to be mutualistic.

There are about 525 species of lower termites known from the globe. Out of these, 210 species have been studied for their flagellate symbiotes. Two species of wood roaches, namely, *Cryptocercus punctulatus* and *Cryptocercus relictus* have also been studied for their flagellate symbiotes. As a result, 468 species of flagellates under 78 genera, 19 families and 3 orders have been recorded (Table 1) from the guts of lower termites and wood roaches. Amongst these, 429 species of flagellates have been recovered from the guts of lower termites and, 39 species and 2 varieties of flagellates from the guts of wood roaches (*vide* Yamin, 1979).

Table 1. Taxic diversity of flagellate symbiotes of termites and wood roaches

Order	Family	Subfamily	Genus	No. of Species
Oxymonadida (12 genera, 78 spp.)	Oxymonadidae (8 genera, 50 spp.)	Oxymonadinae (3 genera, 38 spp.)	<i>Barroella</i>	2
			<i>Microrhopalodina</i>	4
			<i>Oxymonas</i>	32
		Saccinobaculinae (5 genera, 12 spp.)	<i>Notila</i>	2
			<i>Opisthomitus</i>	2
			<i>Paranotila</i>	1
			<i>Saccinobaculus</i>	5
			<i>Sauromonas</i>	2
			<i>Dinenympha</i>	13
			<i>Pyrsonympha</i>	13
			<i>Streblomastix</i>	
	Pyrsonymphidae (3 genera, 27 spp.)		<i>Monocercomonoides</i>	1
	Monocercomonoididae (1 genus, 1sp.)			
Trichomonadida (30 genera, 186 spp.)	Devescoviniidae (16 genera, 123 Spp.)	Devescoviniinae (14 genera, 112 spp.)	<i>Achemon</i>	1
			<i>Astronympha</i>	1
			<i>Bullanympha</i>	1
			<i>Cauduceia</i>	8
			<i>Devescovina</i>	30
			<i>Evemonia</i>	3
			<i>Foaina</i>	30
			<i>Hyperdevescovina</i>	8
			<i>Kirbynia</i>	3
			<i>Metadevescovina</i>	22
			<i>Myxotricha</i>	1
			<i>Parajoenia</i>	1
			<i>Polymastigoides</i>	1
			<i>Pseudodevescovina</i>	2
			<i>Gigantomonas</i>	1
		Gigantomonadinae (2 genera, 11 spp.)	<i>Macrotrichomonas</i>	10

Table 1. Contd.

Order	Family	Subfamily	Genus	No. of Species
Hyperm- stigida (36 genera, 204 spp.)	Calonym- phidae (6 genera, 26 spp.)		<i>Calonympha</i>	5
			<i>Coronympha</i>	2
			<i>Diplonympha</i>	1
			<i>Metacoronympha</i>	1
			<i>Snyderella</i>	5
			<i>Stephanonympha</i>	12
	Monocerco- monadidae (3 genera, 17 spp.)	Monocerco- monadinae	<i>Hexamastix</i>	8
			<i>Monocercomonas</i>	3
			<i>Tricercomitus</i>	6
	Trichomona- didae (5 genera, 20 spp.)	Trichomona- dinae (1 genus, 7 spp.)	<i>Trichomonas</i>	7
		Trichomitop- siinae (2 genera, 6 spp.)	<i>Pseudotrypano- soma</i>	2
			<i>Trichomitopsis</i>	4
		Tritricho- monadinae (1 genus, 5 spp.)	<i>Tritrichomonas</i>	5
		Pentatricho- monoidinae (1 genus, 2 spp.)	<i>Pentatricho- monoides</i>	2
	Joeniidae (7 genera, 9 spp.)		<i>Joenia</i>	3
			<i>Joenoides</i>	1
			<i>Joenina</i>	1
			<i>Joenopsis</i>	1
			<i>Parajoenopsis</i>	1
			<i>Projoenia</i>	1
			<i>Cyclojoenia</i>	1
	Kofoidiidae (1 genus, 1 sp.)		<i>Kofoidea</i>	1
	Lophomona- didae (1 genus, 1 sp.)		<i>Prolophomonas</i>	1
	Rhizonymphidae (1 genus, 1 sp.)		<i>Rhizonympha</i>	1

Table 1. *Contd.*

Order	Family	Subfamily	Genus	No. of Species
	Holomastigotidae (2 genera, 38 spp.)		<i>Holomastigotoides</i>	37
			<i>Rostronympha</i>	1
	Spirotrichonymphidae (5 genera, 46 spp.)		<i>Microjoenia</i>	5
			<i>Spirotrichonympha</i>	31
			<i>Spirotrichonymphella</i>	2
			<i>Holomastigotes</i>	7
			<i>Micromastigotes</i>	1
			<i>Eucomonympha</i>	2
			<i>Pseudotriconympha</i>	17
	Hoplonymphidae (4 genera, 8 spp.)		<i>Barbulanympha</i>	4
			<i>Hoplonympha</i>	1
			<i>Rynchonympha</i>	1
			<i>Urinympha</i>	2
	Spirotrichosomidae (6 genera, 35 spp.)		<i>Apospirotrichonympha</i>	4
			<i>Bispirotrichonympha</i>	1
			<i>Colospirotrichonympha</i>	3
			<i>Leptospirotrichonympha</i>	13
			<i>Macrospirotrichonympha</i>	1
			<i>Spirotrichosoma</i>	13
	Staurojoenidae (2 genera, 5 spp.)		<i>Idionympha</i>	1
			<i>Staurojoenina</i>	4
	Teratonymphidae (1 genus, 1 sp.)		<i>Teranympha</i>	1
	Trichonymphidae (4 genera, 40 spp.)		<i>Protrichonympha</i>	1
			<i>Trichonympha</i>	36
			<i>Deltotrichonympha</i>	2
			<i>Koruga</i>	1
Total (in Nos.) 3	19		78	468

In India 99 species and 6 varieties of termite flagellates have been recorded so far (Table 3) from 19 species of termites including 4 unidentified termite species (Table 4). However, Indian works on this group deserve critical consideration because some works of De Mello and his collaborators (1919-1949) who are the major contributors in this field and recorded 44 species and 5 varieties of flagellate symbiotes from Indian termites (Table 2) have caused a great deal of taxonomic inconvenience in some of their publications as pointed out by Kirby on several occasions and by Cross (1946), Honigberg (1970), Emerson (1971) and Das (1974, 1983). Honigberg (*op. cit.*) commented that many of De Mello's descriptions are rather inadequate and it seems very likely that some organisms for which he proposed new names were assignable to known species. He also opined in a personal communication to the present author in 1979 that "as far as De Mello's contributions are concerned one could only wish that there were way to suppress them; unfortunately there are none." Owing to such taxonomic compulsions most of the species described by De Mello are retained as such in the present work. One of Uttangi's contributions (1959) in this field wherein he described a new species of *Trichonympha* from a rhinotermitid termite, *Heterotermes indicola* has also created confusion as discussed in details by Das (1983, 1990). Works of Narain (1956 a,b,c) also contain some error in identification of both flagellates and their termite hosts. This will be discussed elsewhere in this work. In view of these, it is quite evident that discrepancies in the taxonomic works of flagellate symbiotes of Indian termites are primarily due to error in identification of termite hosts as well as error in identification and inadequate description of flagellate symbiotes.

In this context, the purpose of the present monograph is to present a comprehensive taxonomic account of all the species of flagellate symbiotes of Indians termites recorded so far and to assess their current taxonomic status in the light of all available information and recent studies on this group. In addition, distribution and host correlation of the flagellate symbiotes are discussed in global perspective for analysing Indian works on this group and for enlightening their coevolution with the hosts.

HISTORICAL REVIEW

Lespes (1856) was the first to report the occurrence of "Infusoria" from the gut of lower termites belonging to *Leucotermes lucifugus*. But, it was Leidy (1877, 1881) who gave the first detailed description of them from the gut of *Termes flavipes* of North America. Initially he described three forms and placed them under three genera, *viz.*, *Trichonympha*, *Pyrsonympha* and *Dinenympha*. It is needed to mention here that both the above mentioned termite hosts are at present synonymised under *Reticulitermes lucifugus* and *Reticulitermes flavipes* respectively and all the above three flagellate genera described by Leidy (*op. cit.*) are still valid.

Only nine years after the last publication of Leidy, that is, in 1890 Simons published a brief account of two flagellates from the termites of Kolkata, India. But, in his description he neither mentioned generic and species names of those flagellates and

their host nor produced any illustration for them, which could have been sufficient for their identity. Nevertheless, this work is noteworthy as it constitutes the first report on flagellates from Asian termites. Subsequently Simons also studied some "Behar termites" which, as he stated, were not infected with Protozoa (*loc. cit.* Kirby, 1932a). In that work also he did not mention even the family or generic name of those termites. Then, after a long gap, Imms (1919) described two new species of flagellates, viz., *Trichomonas termites* and *Trichonympha pristina* from the termites *Archotermopsis wroughtoni* from India. Subsequently, after obtaining a living stock of this termite species from Imms, Cutler (1919, 1921) carried on further studies and redescribed these flagellates as *Ditrichomonas termitis* and *Pseudotrichonympha pristina* respectively. In addition, Cutler (1920) described a new genus *Joenopsis* to accommodate two new species, *J. polytricha* and *J. cephalotricha* and described another new species of the genus *Microjoenia*, viz, *M. axostylis*.

From 1919 to 1949 De Mello and his co-workers published a series of papers on flagellates of Indian termites, contributing 44 species and 5 varieties, out of which 41 species and 5 varieties were described as new to science. Several of these species are synonymised. Accordingly, a list of termite flagellates described by them along with the current valid name of each species is presented in Table 2.

Table 2. List of flagellate symbiotes of Indian termites described or recorded by De Mello and his collaborators

Sl. No.	Original Name	Current Name
1.	<i>Proboscidiella hoffmanni</i> De Mello & De Brito	<i>Microhopalodina hoffmanni</i> (De Mello & De Brito)
2.	<i>Pyrsonympha grasii</i> De Mello	<i>Holomastigotoides grassii</i> (De Mello)
3.	<i>Hexamastix indica</i> De Mello	As in original
4.	<i>Tricerocomitus divergens</i> Kirby	As in original
5.	<i>Tricerocomitus damasmorai</i> De Mello	As in original
6.	<i>Tricerocomitus sokheyi</i> De Mello	As in original
7.	<i>Devescovina cometoides</i> De Mello & De Brito	As in original
8.	<i>Devescovina damanensis</i> De Mello & De Brito	<i>Devescovina lemniscata</i> Kirby
9.	<i>Devescovina gyronoides</i> De Mello	As in original
10.	<i>Devescovina kirbyi</i> De Mello & De Brito	<i>Foaina nana</i> (partim) Kirby and <i>Foaina solita</i> (partim) Kirby
11.	<i>Strobilonympha pisciformis</i> De Mello & G. Monteiro	<i>Polymastigoides elongata</i> (Bernstein)
12.	<i>Strobilonympha schizophyla</i> De Mello & G. Monteiro	-do-
13.	<i>Strobilonympha serpentiformis</i> De Mello & G. Monteiro	-do-
14.	<i>Metastephanonympha perronciti</i> De Mello & De Brito	<i>Stephanonympha perronciti</i> (De Mello & De Brito)
15.	<i>Stephanonympha reenstiernai</i> De Mello	As in original
16.	<i>Trichomonas costulata</i> De Mello	As in original

Table 2. Contd.

Sl. No	Original Name	Current Name
17.	<i>Holomastigotoides cingulatum</i> var. <i>coimbatorensis</i> De Mello & De Mello	As in original
18.	<i>Holomastigotoides gigas</i> De Mello	As in original
19.	<i>Holomastigotoides globosus</i> De Mello	As in original
19a.	<i>Holomastigotoides globosus</i> var. <i>britoi</i> De Mello	As in original
20.	<i>Holomastigotoides hartmanni</i> var. <i>indica</i> De Mello	<i>Holomastigotoides hemigymnum</i> var. <i>indica</i> (De Mello)
20a.	<i>Holomastigotoides hartmanni</i> var. <i>katiawarensis</i> De Mello	<i>Holomastigotoides mirabile</i> var. <i>katiawarensis</i> (De Mello)
21.	<i>Holomastigotoides hemigymnum</i> Grassi	As in original
22.	<i>Holomastigotoides inexpectatus</i> De Mello	As in original
23.	<i>Holomastigotoides koidzumii</i> De Mello	As in original
24.	<i>Holomastigotoides mirabile</i> var. <i>margabhandui</i> De Mello & De Mello	As in original
25.	<i>Holomastigotoides ogivalis</i> De Mello	As in original
26.	<i>Holomastigotoides operculatum</i> De Mello	As in original
27.	<i>Holomastigotoides piriformis</i> De Mello	As in original
28.	<i>Holomastigotoides proboscifer</i> De Mello & De Mello	As in original
29.	<i>Holomastigotoides reniformis</i> De Mello	As in original
30.	<i>Holomastigotoides sphaeroidalis</i> De Mello	As in original
31.	<i>Leidya annandalei</i> De Mello	<i>Holomastigotoides hemigymnum</i> Grassi
32.	<i>Leidya campanula</i> De Mello	<i>Holomastigotoides campanula</i> (De Mello)
33.	<i>Leidya kempii</i> De Mello	<i>Holomastigotoides hemigymnum</i> var. <i>indica</i> (De Mello)
34.	<i>Leidya metchnikowi</i> De Mello	<i>Holomastigotoides grassii</i> (De Mello)
35.	<i>Spirotrichonympha coimbatorensis</i> De Mello	As in original
36.	<i>Spirotrichonympha elongata</i> Grassi	As in original
37.	<i>Spirotrichonympha leidyi</i> var. <i>leucotermes indicola</i> De Mello	<i>Spirotrichonympha leidyi</i> Koidzumi
37a.	<i>Spirotrichonympha leidyi</i> var. <i>damanensis</i> De Mello	As in original
38.	<i>Spirotrichonympha mirabilis</i> Grassi	As in original
38a.	<i>Spirotrichonympha mirabilis</i> var. <i>indica</i> De Mello	As in original
39.	<i>Spirotrichonympha ovoides</i> De Mello	As in original
40.	<i>Spirotrichonympha rotunda</i> De Mello	As in original
41.	<i>Pseudotrichonympha belari</i> De Mello	As in original
42.	<i>Pseudotrichonympha hertwigi</i> var. <i>simplex</i> De Mello	As in original
43.	<i>Pseudotrichonympha ramani</i> De Mello	As in original
43a.	<i>Pseudotrichonympha ramani</i> var. <i>seminuda</i> De Mello	As in original
44.	<i>Trichonympha fletcheri</i> De Mello	As in original

Kirby (1932a) examined some alcohol preserved specimens of *Anacanthotermes macrocephalus*, sent to him by Dr. Light from India. In the guts of those specimens Kirby (*op. cit.*) recorded *Trichonympha turkestanica* and observed some poorly preserved forms of *Holomastigotoides*, *Holomastigotes*, *Microspironympha* and *Stephanonympha* which could not be identified by him up to species level.

Karandikar and Vittal (1954) recorded 16 species of termite flagellates from two hosts, *Coptotermes heimi* and *Heterotermes malabaricus* collected from Karnataka and Maharashtra. These flagellates include 7 new species, viz., *Holomastigotoides dharwarensis*, *Holomastigotoides rayi*, *Spirotrichonympha karnataki*, *Spirotrichonympha froilanoi*, *Pseudotrichonympha cardiformis*, *Pseudotrichonympha pisciformis* and *Pseudotrichonympha subapicalis*. Chakravarty and Banerjee (1956) described 3 new species, viz., *Holomastigotoides bengalensis*, *Spirotrichonympha pyriformis* and *Pseudotrichonympha indica* from the guts of some undetermined species of *Heterotermes* collected in Kolkata, West Bengal.

From the gut contents of some unidentified termites of Lucknow, Uttar Pradesh Narain (1956 a, b) described two new species, *Holomastigotoides rostrata*, and *Holomastigotoides truncata*. These species are treated here as *nomen nudum* as detailed elsewhere in this work under the taxonomic account. Narain (1956 c) also recorded 5 species of hypermastigid flagellates from the gut of a higher termite species *Odontotermes assumuthi*. This work constitutes error in identification of both termites and flagellates as discussed in this communication under the subhead — distribution and host correlation dealt with later. Uttangi (1959) recorded a new species, *Trichonympha gujarathensis* from the gut of a rhinotermitid termite *Heterotermes indicola*. This is also quite improbable (*vide* Das, 1990). Uttangi and Joseph (1960) gave a list of 69 species of termite flagellates under 14 genera recorded from Indian termites. In that list they (*op. cit.*) included 10 species as new to science without incorporating their descriptions and/or illustration. Later Uttangi (1962) described 7 of them, viz., *Holomastigotoides elongata*, *Holomastigotoides magnus*, *Holomastigotoides melloi*, *Holomastigotoides ovalis*, *Holomastigotoides saccusiformis*, *Holomastigotoides turboformis* and *Holomastigotoides visnagarensis*. In view of this, the remaining 3 species, viz., *Pseudotrichonympha indica*, Uttangi 1960, *Spirotrichonympha heimi* Uttangi, 1960 and *Spirotrichonympha indicola* Uttangi, 1960 are treated here as *nomen nudum*.

Tiwari (1977, 1978, 1988, 1992) recorded 29 species of termite flagellates from Bihar, Uttar Pradesh, Uttaranchal and West Bengal. He (1997) also described a new species, *Spirotrichonympha bhadreshwarensis* from the termite *Coptotermes heimi*, collected from West Bengal. Mukherjee and Maiti (1988, 1989) studied flagellate symbiotes of *Reticulitermes tirapi* collected in Arunachal Pradesh and described 4 new species, viz., *Pyrsonympha rostrata*, *Pyrsonympha tirapi*, *Dinenympha mukundai* and *Dinenympha rayi*.

Last but not the least, Das and his co-workers (1972-2006) made detailed studies of flagellate symbiotes of 10 species of lower termites procured from West Bengal, Meghalaya, Tripura, Sikkim, Nagaland, Arunachal Pradesh, Andhra Pradesh and

Andaman islands and recorded 52 species including 10 new species, viz., *Oxymonas bengalensis*, *Oxymonas bosei*, *Devescovina steni*, *Stephanonympha minuta*, *Stephanonympha pyriformis*, *Holomastigotoides emersoni*, *Holomastigotoides hollandei*, *Spirotrichonympha roonwali*, *Holomastigotes indica* and *Trichonympha meghalayensis*.

MATERIAL AND METHODS

For the taxonomic study of flagellate symbiotes the present author has examined the gut contents of large number of lower termites, comprising of 10 species, viz., *Cryptotermes dudleyi*, *Cryptotermes havilandi*, *Neotermes andamanensis*, *Neotermes bosei*, *Glyptotermes caudomunitus*, *Coptotermes heimi*, *Coptotermes travians*, *Heterotermes indicola*, *Reticulitermes assamensis* and *Reticulitermes tirapi*. These hosts were collected from West Bengal, Meghalaya, Tripura, Sikkim, Nagaland, Arunachal Pradesh, Andhra Pradesh and Andaman islands. Collections of these termites were made from sound wood of living trees, dead branches, wood and logs, timber depots, ply wood, pitch boards and, books and papers dumped for a long time.

While exploring termite colonies, care was taken to procure different castes of termites, particularly workers for the collection of preponderant number of flagellate symbiotes and soldiers for identifying termite species. For the purpose of host identification few specimens of soldiers were preserved in tact in 70 per cent alcohol. All the termites studied by the present author were identified by the Scientists of the Zoological Survey of India.

For collecting flagellate symbiotes a portion of the termite colony with sufficient number of workers were brought to the laboratory in living condition and kept in a suitable container with its mouth covered with mulmul cloth so that air can pass through it. Care was taken to protect the colony from ants and other predators. Sometimes these termites were transferred to filter paper before being used for study.

For obtaining termite flagellats, the entire gut was removed carefully from the living host specimens preferably of worker caste and the gut contents were emptied on grease-free slides, containing a small drop of 0.5 per cent saline. For the study of internal structures of living flagellates 67 per cent Lock's solution was added to the fresh gut contents in which the flagellates remained active with natural shape and size for a longer period of time.

Identification of the flagellate species was primarily based on critical study of permanent stained smears on glass slides under compound microscope. For the preparation of such permanent slides, thin and uniform smears of the gut contents slightly diluted with 0.5 per cent saline were drawn on slides and allowed to semi-dry without killing the flagellates. Then these smears were fixed in Schaudinn's fluid, Carnoy's fluid, Flemming's fluid and acetoformol, then stained in Heidenhain's and Delafield's haematoxylin, dehydrated through upgradation of alcohol, then emerged in xylene and then mounted in DPX.

For the collection of flagellates from the termites preserved in alcohol, their entire guts were dissected and kept in running water until all the alcohol was washed out. Thin smears of the gut contents were then drawn on slides, made them semidry and dipped slowly in coplin jars containing 70 per cent alcohol. Then usual staining procedure in Heidenhain's and Delafield's haematoxylin was followed.

All the measurements were taken with the aid of an ocular micrometer and drawings were made with a camera lucida.

Diagnoses of the flagellate species which were not collected by the present author and whose type materials are not available with him for study are based on their original descriptions and illustrations. However, taxonomic assessment of those species has been made in light of updated study on this group.

While dealing with taxonomic account of each flagellate species, its first reference, some relevant references and all the references of Indian works are given. On several occasions, type host species and additional host species of flagellate symbiotes, as mentioned in earlier works, have been synonymised. In order to demonstrate those synonymy, current valid name of each host species is mentioned first, followed by its synonymy, if any, within bracket, prefixing an equal (=) sign. The abbreviation "loc." for mentioning the collection locality of the termite hosts is frequently used in this monograph.

Table 3. Checklist of flagellate symbiotes from Indian Termites

Order OXYMONADIDA Grassé, 1952	
Family OXYMONADIDAE Kirby, 1928	
Subfamily OXYMONADINAE Cleveland, 1934; Kirby, 1937 emend.	
Genus <i>Oxymonas</i> Janicki, 1915	
1. <i>Oxymonas bengalensis</i> Das, 1974	Type Host : <i>Cryptotermes havilandi</i> ; loc., West Bengal : India.
2. <i>Oxymonas bosei</i> . Das, 1974	Type host : <i>Neotermes bosei</i> ; loc., West Bengal : India. Other Indian hosts : <i>Cryptotermes havilandi</i> ; loc., Bihar and Nagaland : India; <i>Cryptotermes dudleyi</i> ; loc., Andhra Pradesh : India.
3. <i>Oxymonas grandis</i> Cleveland, 1935	Indian hosts : <i>Cryptotermes dudleyi</i> ; loc., Andhra Pradesh : India; <i>Cryptotermes havilandi</i> ; loc., Bihar and Nagaland : India; <i>Neotermes bosei</i> , loc., West Bengal : India.

Table 3. Contd.

4. *Oxymonas parvula* Kirby, 1926

Indian host : *Cryptotermes havilandi*; loc., West Bengal : India.

Genus *Microrhopalodina* Grassi and Foa, 1911

(= *Proboscidiella* Kofoid and Swezy, 1926)

5. *Microrhopalodina hoffmanni* (De Mello and De Mello, 1944) Cross, 1946

(= *Proboscidiella hoffmanni* De Mello and De Mello, 1944)

Type host : "Indian *Cryptotermes*" (exact locality not reported).

Family PYRSONYMPHIDAE Grassi, 1892

Genus *Dinenympha* Leidy, 1877

6. *Dinenympha exilis* Koidzumi, 1921

Indian host : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India.

7. *Dinenympha leidy* Koidzumi, 1921

Indian host : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India.

8. *Dinenympha mukundai* Mukherjee and Maiti, 1989

Type host : *Reticulitermes tirapi*; loc., Arunachal Pradesh : India.

9. *Dinenympha nobilis* Koidzumi, 1921

Indian hosts : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India; *Reticulitermes tirapi*; loc., Arunachal Pradesh : India.

10. *Dinenympha parva* Koidzumi, 1921

Indian host : *Reticulitermes assamensis*; loc., Meghalaya and Sikkim : India.

11. *Dinenympha porteri* Koidzumi, 1921

Indian host : *Reticulitermes assamensis*; loc., Meghalaya : India.

12. *Dinenympha rayi* Mukherjee and Maiti, 1989

Type host : *Reticulitermes tirapi*; loc., Arunachal Pradesh : India.

13. *Dinenympha rugosa* Koidzumi, 1921

Indian host : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India.

Table 3. Contd.

Genus *Pyrsonympha* Leidy, 187714. *Pyrsonympha grandis* Koidzumi, 1921

Indian hosts : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India; *Reticulitermes tirapi*; loc., Arunachal Pradesh : India.

15. *Pyrsonympha modesta* Koidzumi, 1921

Indian host : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India.

16. *Pyrsonympha rostrata* Mukherjee and Maiti, 1988

Type host : *Reticulitermes tirapi*; loc., Arunachal Pradesh : India.

17. *Pyrsonympha tirapi* Mukherjee and Maiti, 1988

Type host : *Reticulitermes tirapi*; loc., Arunachal Pradesh : India.

Order TRICHOMONADIDA Kirby, 1947

Family MONOCERCOMONADIDAE Kirby, 1944

Genus *Hexamastix* Alexeieff, 191218. *Hexamastix indica* De Mello, 1946

Type host : *Cryptotermes* sp.; loc., Goa : India.

Genus *Tricercomitus* Kirby, 193019. *Tricercomitus damasmorai* De Mello, 1946

Type host : *Cryptotermes* sp.; loc., Goa : India.

20. *Tricercomitus divergens* Kirby, 1930

(= *Pyrsonympha havilandi* Das, 1972)

Indian hosts : *Cryptotermes havilandi*; loc., West Bengal : India; *Cryptotermes* sp.; loc., Goa : India; *Neotermes andamanensis*; loc., South Andaman : India.

21. *Tricercomitus sokheyi* De Mello, 1942

Type host : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., Tamil Nadu : India.

Table 3. Contd.

Family DEVESCOVINIDAE Doflein, 1911

Subfamily DEVESCOVININAE Doflein, 1911 emend. Kirby, 1931

Genus *Caduceia* Franca, 191822. *Caduceia kalshoveni* Kirby, 1942

Indian hosts : *Neotermes andamanensis*; loc., South Andaman : India; *Neotermes bosei*; loc. Bihar : India.

Genus *Devescovina* Foa, 190523. *Devescovina arta* Kirby, 1941

Indian hosts : *Glyptotermes caudomunitus*; loc., Bihar and West Bengal : India; *Neotermes andamanensis*; loc.; South Andaman : India.

24. *Devescovina cometoides* De Mello and De Brito, 1929

Type host : *Kalotermes* sp.; loc., Daman : India

Other Indian host : *Glyptotermes caudomunitus*; loc., Bihar and West Bengal : India.

25. *Devescovina glabra* Grassi, 1917

Indian hosts : *Cryptotermes dudleyi*; loc., Andhra Pradesh and Tripura : India; *Cryptotermes havilandi*; loc., Nagaland and West Bengal : India.

26. *Devescovina gyrinoides* De Mello, 1946

Type host : *Cryptotermes* sp.; loc., Goa : India.

27. *Devescovina lemniscata* Kirby, 1926

(= *Devescovina damanensis* De Mello and De Mello, 1929)

Indian hosts : *Cryptotermes dudleyi*; loc., Andhra Pradesh and Tripura : India; *Cryptotermes havilandi*; loc., Bihar, Nagaland and West Bengal : India; *Kalotermes* sp.; loc., Daman : India.

28. *Devescovina parasoma* Kirby, 1941

Indian hosts : *Neotermes andamanensis*; loc., South Andaman : India; *Neotermes bosei*; loc., Uttaranchal : India.

29. *Devescovina steini* Das, 1974

Type host : *Cryptotermes havilandi*; loc., West Bengal : India.

Table 3. Contd.

Genus *Foaina* Janicki, 191530. *Foaina nana* (Kirby, 1926) Kirby, 1942

(= *Devescovina kirbyi* De Mello and De Brito, 1929 (*partim*))

Indian hosts : *Cryptotermes havilandi*; loc., West Bengal : India; *Cryptotermes* sp.; loc., Daman : India, (= *Coptotermes heimi sensu* De Mello and De Brito); *Neotermes andamanensis*; loc., South Andaman : India.

31. *Foaina reflexa* Kirby, 1942

Indian hosts : *Cryptotermes dudleyi*; loc., Andhra Pradesh and Tripura : India; *Cryptotermes havilandi*; loc., Nagaland and West Bengal : India; *Neotermes andamanensis*; South Andaman : India; *Neotermes bosei*; Bihar : India.

32. *Foaina solita* Kirby, 1942

(= *Devescovina kirbyi* De Mello and De Brito, 1929 (*partim*))

Indian hosts : *Cryptotermes dudleyi*; loc., Andhra Pradesh and Tripura : India; *Cryptotermes havilandi*; loc., Bihar, Nagaland and West Bengal : India; *Cryptotermes* sp.; loc., Daman : India.

Genus *Polymastigoides* Grassé and Hollande, 195133. *Polymastigoides elongata* (Bernstein, 1928) Grassé and Hollande, 1951

(= *Strobilonympha schizophyla* De Mello and Monteiro, 1942)

(= *Strobilonympha pisciformis* De Mello and Monteiro, 1942)

(= *Strobilonympha serpentiformis* De Mello and Monteiro, 1942)

Indian host : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., Tamil Nadu : India.

Subfamily GIGANTOMONADINAE Kirby, 1946

Genus *Macrotrichomonas* Grassi, 191734. *Macrotrichomonas pulchra* Grassi, 1917

Indian host : *Glyptotermes caudomunitus*; loc., Bihar : India.

Family CALONYMPHIDAE Grassi and Foa, 1911

Genus *Stephanonympha* Janicki, 1911

(= *Metastephanonympha* De Mello and De Brito, 1929)

35. *Stephanonympha minuta* Das and Choudhury, 1972

Type host : *Neotermes bosei*; loc., West Bengal : India.

Table 3. Contd.

Other Indian hosts : *Cryptotermes dudleyi*; loc., Andhra Pradesh : India; *Cryptotermes havilandi*; loc., Bihar and Nagaland : India.

36. *Stephanonympha perronciti* (De Mello and De Brito, 1929) Kirby, 1937
(= *Metastephanonympha perronciti* De Mello and De Brito, 1929)

Type host : *Cryptotermes* sp.; Daman : India (= *Coptotermes heimi sensu* De Mello and De Brito).

37. *Stephanonympha pyriformis* Das and Choudhury, 1972

Type host : *Cryptotermes havilandi*; loc., West Bengal and Nagaland : India.

Other Indian hosts : *Cryptotermes dudleyi*; loc., Andhra Pradesh and Tripura : India; *Neotermes bosei*; loc., West Bengal : India.

38. *Stephanonympha reenstiernai* De Mello, 1946

Type host : *Cryptotermes* sp.; loc., Goa : India.

39. *Stephanonympha silvestrii* Janicki, 1911
(= *Stephanonympha havilandi* Kirby, 1926)

Indian hosts : *Cryptotermes dudleyi*; loc., Andhra Pradesh and Tripura : India; *Cryptotermes havilandi*; loc., Bihar, Nagaland and West Bengal : India; *Neotermes andamanensis*, loc., South Andaman : India.

Family TRICHOMONADIDAE Chalmers and Pekkola, 1918

Subfamily TRICHOMONADINAE Chalmers and Pekkola, 1918
emend. Honigberg, 1963

Genus *Trichomonas* Donné, 1836

40. *Trichomonas costulata* De Mello, 1946

Type host : *Cryptotermes* sp; loc., Goa : India.

Subfamily TRICHOMITOPSIINAE Brugerolle, 1976

Genus *Trichomitopsis* Kofoid and Swezy, 1919
(= *Ditrichomonas* Cutler, 1919)

41. *Trichomitopsis termitis* (Imms in Cutler, 1919) Honigberg, 1963

(= *Ditrichomonas termitis* Imms in Cutler, 1919)

(= *Trichomonas termitis* Imms, 1919)

Type host : *Archotermopsis wroughtoni*; loc., India; (exact locality not mentioned).

Table 3. Contd.

Order HYPERMASTIGIDA Grassi and Foa, 1911

Suborder LOPHOMONADINA Light, 1927

Family JOENIIDAE Janicki, 1915

Genus *Joenopsis* Cutler, 192042. *Joenopsis polytricha* Cutler, 1920

Type host : *Archotermopsis wroughtoni*; loc., India; (exact locality not mentioned).

Genus *Parajoenopsis* Saleem, 195243. *Parajoenopsis cephalotricha* (Cutler, 1920) Saleem, 1952

(= *Joenopsis cephalotricha* Cutler, 1920)

Type host : *Archotermopsis wroughtoni*; loc., India; (exact locality not mentioned).

Suborder SPIROTRICHONYMPHINA Grassé, 1952

Family HOLOMASTIGOTIDAE Janicki, 1915

Genus *Holomastigotoides* Grassi and Foa, 1911**44. *Holomastigotoides bengalensis* Chakravarty and Banerjee, 1956

Type host : *Heterotermes indicola* (= *Heterotermes* sp. sensu Chakravarty and Banerjee, 1956) (see Das, 1976); loc. West Bengal : India.

Other hosts : *Coptotermes heimi*; loc., Andhra Pradesh, Bihar, Uttar Pradesh and West Bengal : India; *Coptotermes travians*; loc., Nagaland, Sikkim and Tripura : India.

45. *Holomastigotoides campanula* (De Mello, 1921) De Mello, 1927

(= *Leidya campanula* De Mello, 1921)

Type host : *Heterotermes indicola* (= *Leucotermes indicola*) ; loc., Diu, West Bengal : India.

Other hosts : *Coptotermes heimi*; loc., Andhra Pradesh, Bihar and Karnataka : India; *Coptotermes travians*; loc., Nagaland, Sikkim and Tripura : India; *Coptotermes* sp.; loc., Goa : India; *Heterotermes malabaricus*; loc., Karnataka : India.

46. *Holomastigotoides cingulatum* Bernstein, 1928 var. *coimbatorensis* De Mello and De Mello, 1942.

Type hosts (for the variety) : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., Tamil Nadu : India.

** Two species of *Holomastigotoides*, reported as new by Narain (1956 a,b), viz., *H. rostrata* and *H. truncata* are excluded from the checklist as elaborated elsewhere in this monograph.

Table 3. Contd.

47. *Holomastigotoides dharwarensis* Karandikar and Vittal, India 1954

Type hosts : *Coptotermes heimi*; loc., Karnataka : India; *Heterotermes malabaricus*; loc., Karnataka : India.

48. *Holomastigotoides elongata* Uttangi, 1962

Type host : *Coptotermes heimi*; loc., Maharashtra and Karnataka : India.

49. *Holomastigotoides emersoni* Das, 1976

Type host : *Coptotermes heimi*; loc., Andhra Pradesh, Bihar, West Bengal : India.

Other Indian host : *Coptotermes travians*; loc., Nagaland : India.

50. *Holomastigotoides gigas* De Mello, 1929

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Goa : India.

51. *Holomastigotoides globosus* De Mello, 1937

Type hosts : *Heterotermes* sp; loc., Diu : India; *Coptotermes* sp.; loc., Daman : India.

Other Indian hosts : *Coptotermes travians*; loc., Tripura : India; *Heterotermes indicola*; loc., West Bengal : India; *Heterotermes malabaricus*; loc., Karnataka : India.

51a. *Holomastigotoides globosus* De Mello, 1937 var. *britoi* De Mello, 1937

Type host : *Coptotermes* sp.; loc., Daman : India.

52. *Holomastigotoides grassii* (De Mello, 1919) Grassé and Hollande, 1963

Type host : *Heterotermes indicola* (= *Leucotermes indicola*) ; Daman : India.

Other Indian host : *Coptotermes* sp.; loc., Daman : India.

53. *Holomastigotoides hemigymnum* Grassi, 1917

(= *Leidya annandali* De Mello, 1919)

(= *Holomastigotoides annandalei* (De Mello) De Mello, 1929)

Indian hosts : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Daman, Goa : India; *Heterotermes malabaricus*, Karnataka : India.

53a. *Holomastigotoides hemigymnum* Grassi var. *indica* (De Mello, 1919) n. comb.

(= *Leidya kempi* De Mello, 1919)

(= *Holomastigotoides hartmanni* var. *indica* De Mello, 1928)

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Daman and Goa : India.

Table 3. Contd.

Other Indian hosts : *Coptotermes* sp.; loc., Daman : India; *Heterotermes malabaricus*; loc., Karnataka : India.

54. *Holomastigotoides hollandei* Das, 1976

Type host : *Heterotermes indicola*; loc., Bihar, West Bengal (type locality) : India.

Other Indian host : *Coptotermes travians*; loc., Nagaland : India.

55. *Holomastigotoides inexpectatus* De Mello, 1937

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Diu and Goa : India.

56. *Holomastigotoides koidzumii* De Mello, 1929

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Goa : India.

57. *Holomastigotoides magnus* Uttangi, 1962

Type host : *Heterotermes indicola*; loc., Gujarat (type locality), West Bengal : India.

Other Indian hosts : *Coptotermes heimi*; loc., Andhra Pradesh : India; *Coptotermes travians*, Nagaland, Sikkim and Tripura : India.

58. *Holomastigotoides melloi* Uttangi, 1962

Type host : *Heterotermes indicola*; loc., Gujarat : India.

59. *Holomastigotoides mirabile* Grassi, 1917

(= *Holomastigotoides hartmanni* Koidzumi, 1921)

Indian host : *Coptotermes heimi*; loc., West Bengal : India.

59a. *Holomastigotoides mirabile* Grassi, 1917 var. *katiawarensis* (De Mello, 1937) Das, 1983

(= *Holomastigotoides hartmanni* Koidzumi, 1921 var. *katiawarensis* De Mello, 1937)

Type hosts : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Goa : India; Undetermined termite; loc., Diu : India.

Other Indian hosts : *Heterotermes malabaricus*; loc., Karnataka : India; *Coptotermes heimi*; loc., Karnataka : India.

59b. *Holomastigotoides mirabile* Grassi, 1917 var. *margabhandui* De Mello and De Mello, 1942

Type host : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., Tamil Nadu : India.

Table 3. Contd.

60. *Holomastigotoides ogivalis* De Mello, 1937

Type host : *Coptotermes* sp.; loc., Daman : India.

Other Indian hosts : *Coptotermes heimi*; loc., Bihar, Karnataka, Uttar Pradesh and West Bengal : India; *Coptotermes travians*; loc., Nagaland, Sikkim and Tripura : India.

61. *Holomastigotoides operculatum* De Mello, 1949

Type host : Undetermined; loc., India (exact locality not mentioned).

62. *Holomastigotoides ovalis* Uttangi, 1962

Type host : *Heterotermes indicola*; loc., Bihar, Gujarat : India.

Other Indian hosts : *Coptotermes heimi*; loc., Andhra Pradesh : India; *Coptotermes travians*; loc., Nagaland and Tripura : India.

63. *Holomastigotoides piriformis* De Mello, 1937

Type hosts : *Coptotermes* sp.; loc., Daman : India; *Heterotermes indicola* (= *Leucotermes indicola*); loc., Diu and Goa : India.

64. *Holomastigotoides proboscifer* De Mello and De Mello, 1942

Type host : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., Tamil Nadu : India.

65. *Holomastigotoides rayi* Karandikar and Vittal, 1954

Type host : *Coptotermes heimi*; loc., Andhra Pradesh, Karnataka and West Bengal : India.

Other Indian hosts : *Coptotermes travians*; loc., Nagaland, Sikkim and Tripura : India; *Heterotermes indicola*; loc., Bihar : India.

66. *Holomastigotoides reniformis* De Mello, 1937

Type hosts : *Coptotermes* sp.; loc., Daman : India.

Other Indian hosts : *Coptotermes heimi*; loc., Andhra Pradesh, Bihar and West Bengal : India; *Coptotermes travians*; loc., Nagaland, Sikkim and Tripura : India.

67. *Holomastigotoides saccusiformis* Uttangi, 1962

Type host : *Heterotermes indicola*; loc., Gujarat : India.

68. *Holomastigotoides sphaeroidalis* De Mello, 1937

Type hosts : *Coptotermes* sp.; loc., Daman : India; *Heterotermes indicola* (= *Leucotermes indicola*); loc., Goa, West Bengal : India.

Table 3. Contd.

Other Indian hosts : *Coptotermes heimi*; loc., Andhra Pradesh, Bihar, Karnataka and Uttar Pradesh : India; *Coptotermes travians*; loc., Tripura, Sikkim, Nagaland : India; *Heterotermes malabaricus*; loc., Karnataka : India.

69. *Holomastigotoides turboformis* Uttangi, 1962

Type host : *Coptotermes heimi*; loc., Maharastra and Karnataka : India.

70. *Holomastigotoides visnagarensis* Uttangi, 1962

Type host : *Heterotermes indicola*; loc., Gujarat : India.

Family SPIROTRICHONYMPHIDAE Grassi, 1917

Genus *Microjoenia* Grassi, 1892

71. *Microjoenia axostylis* Cutter, 1920

Type host : *Archotermopsis wroughtoni*, India (exact locality not mentioned).

Genus *Spirotrichonympha* Grassi and Foa, 1911

72. *Spirotrichonympha bhadreshwarensis* Tiwari, 1977

Type host : *Coptotermes heimi*; loc., West Bengal and Bihar : India.

73. *Spirotrichonympha coimbatorensis* De Mello, 1941

Type host : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., Tamil Nadu : India.

74. *Spirotrichonympha elongata* Grassi, 1917

Indian hosts : *Coptotermes heimi*; loc., Karnataka : India; *Coptotermes* sp.; loc., Daman : India.

75. *Spirotrichonympha flagellata* (Grassi, 1892) Grassi and Foa, 1911

Indian hosts : *Coptotermes heimi*; loc., Karnataka and West Bengal : India : *Heterotermes indicola*; loc., Goa, West Bengal : India.

76. *Spirotrichonympha froilanoi* Karandikar and Vittal, 1954

Type hosts : *Coptotermes heimi*; loc., Andhra Pradesh, Karnataka (type locality), Uttar Pradesh and West Bengal : India; *Heterotermes malabaricus*; loc., Karnataka : India.

Other Indian hosts : *Coptotermes travians*; loc., Nagaland, Sikkim and Tripura : India; *Heterotermes indicola*; loc., Bihar, Tripura : India.

77. *Spirotrichonympha karnataki* Karandikar and Vittal, 1954

Type host : *Coptotermes heimi*; loc., Karnataka : India.

Table 3. Contd.

78. *Spirotrichonympha leidy* Koidzumi, 1921

Indian host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Daman : India.

78a. *Spirotrichonympha leidy* Koidzumi, 1921 var. *damanensis* De Mello, 1937

Type host : *Heterotermes indicola*; loc., Diu : India.

79. *Spirotrichonympha mirabilis* Grassi, 1917

Indian host : *Heterotermes indicola*; loc., Diu : India.

79a. *Spirotrichonympha mirabilis* Grassi, 1917 var. *indica* De Mello, 1937

Type host : *Heterotermes indicola*; loc., Diu : India.

80. *Spirotrichonympha ovoidea* De Mello, 1937

Type host : *Heterotermes indicola*; loc., Diu : India.

81. *Spirotrichonympha (Spironympha) porteri* (Koidzumi, 1917) Grassé, 1952

Indian hosts : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India; *Reticulitermes tirapi*; loc., Arunachal Pradesh : India.

82. *Spirotrichonympha pyriformis* Chakravarty and Banerjee, 1956

Type host : *Heterotermes indicola*; (= *Heterotermes* sp. sensu Chakravarty and Banerjee, 1956); loc., West Bengal : India.

83. *Spirotrichonympha roonwali* Das, 1976

Type host : *Coptotermes heimi*; loc., West Bengal (type locality), Bihar : India.

Other Indian host : *Coptotermes travians*; loc., Tripura : India.

84. *Spirotrichonympha rotunda* De Mello, 1927

Type host : *Heterotermes indicola* (= *Leucotermes indicola*) ; loc., Daman : India.

Genus *Holomastigotes* Grassi, 1892

85. *Holomastigotes indica* Das, Mandal, Tiwari and Sarkar, 1995

Type host : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India.

Suborder TRICHONYMPHINA Grassé, 1952

Family EUCOMONYMPHIDAE Cleveland, Hall, Sanders and Collier, 1934

Genus *Pseudotrichonympha* Grassi and Foa, 1911

86. *Pseudotrichonympha belari* De Mello, 1927

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Daman : India.

Table 3. Contd.

87. *Pseudotrichonympha cardiformis* Karandikar and Vittal, 1954

Type hosts : *Heterotermes malabaricus*; loc., Karnataka : India; *Coptotermes heimi*; loc., Andhra Pradesh, Karnataka, Uttar Pradesh and West Bengal : India.

Other Indian hosts : *Coptotermes travians*; loc., Nagaland, Sikkim, Tripura : India; *Heterotermis indicola*; loc., Bihar, West Bengal : India.

88. *Pseudotrichonympha hertwigi* (Hartmann, 1910) Grassi, 1917 var. *simplex* De Mello, 1937

Type host : *Coptotermes* sp.; loc., Daman : India.

89. *Pseudotrichonympha indica* Chakravarty and Banerjee, 1956

Type host : *Heterotermes indicola* (= *Heterotermes* sp. sensu Chakravarty and Banerjee, 1956); loc., West Bengal : India.

Other Indian hosts : *Coptotermes heimi*; loc., Andhra Pradesh, Bihar, Uttar Pradesh and West Bengal : India; *Coptotermes travians*; loc., Nagaland, Sikkim and Tripura : India.

90. *Pseudotrichonympha pisciformis* Karandikar and Vittal, 1954

Type hosts : *Heterotermes malabaricus*; loc., Karnataka : India; *Coptotermes heimi*; loc., Karnataka : India.

91. *Pseudotrichonympha ramani* De Mello, 1937

Type host : *Heterotermes* sp.; loc., Goa : India.

91a. *Pseudotrichonympha ramani* De Mello, 1937 var. *seminuda* De Mello, 1937

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., Goa : India.

92. *Pseudotrichonympha subapicalis* Karandikar and Vittal, 1954

Type hosts: *Heterotermes malabaricus*; loc., Karnataka : India; *Coptotermes heimi*; loc., Andhra Pradesh, Bihar, Karnataka, West Bengal : India.

Other Indian host : *Coptotermes travians*; loc., Nagaland, Sikkim and Tripura : India.

Family TERATONYMPHIDAE Koidzumi, 1921

Genus *Teranympha* Koidzumi, 1917

93. *Teranympha mirabilis* Koidzumi, 1917

Indian hosts : *Reticulitermes assamensis*; loc., Meghalaya, Nagaland and Sikkim : India; *Reticulitermes tirapi*; loc., Arunachal Pradesh : India.

Table 3. Contd.

Family TRICHONYMPHIDAE Kent, 1880	
Genus <i>Protrichonympha</i> Saleem, 1952	
94. <i>Protrichonympha pristina</i> (Imms, 1919) Saleem, 1952	
(= <i>Trichonympha pristina</i> Imms, 1919)	
(= <i>Pseudotrachonympha pristina</i> (Imms, 1919) Cutler, 1921)	
Type host : <i>Archotermopsis wroughtoni</i> ; loc., "Punjab" : India.	
Genus <i>Trichonympha</i> Leidy, 1877	
95. <i>Trichonympha agilis</i> Leidy, 1877	
Indian hosts : <i>Reticulitermes assamensis</i> ; loc., Meghalaya, Nagaland and Sikkim : India; <i>Reticulitermes tirapi</i> ; loc., Arunachal Pradesh : India.	
96. <i>Trichonympha fletcheri</i> De Mello, 1942	
Type host : <i>Anacanthotermes viarum</i> (= <i>Hodotermes viarum</i>); loc., Tamil Nadu : India.	
97. <i>Trichonympha gujarathensis</i> Uttangi, 1959	
Type host : <i>Heterotermes indicola</i> ; loc., Gujarat : India.	
98. <i>Trichonympha meghalayensis</i> Das, Tiwari, Mandal and Sarkar, 1995	
Type host : <i>Reticulitermes assamensis</i> ; loc., Meghalaya, Nagaland and Sikkim : India.	
99. <i>Trichonympha turkestanica</i> Bernstein 1928	
Indian host : <i>Anacanthotermes macrocephalus</i> (= <i>Hodotermes macrocephalus</i>); loc., India (exact locality nor recorded).	

Table 4. Host-symbiote List of Indian Termites

Sl. No.	Host species	Sl. No.	Species of flagellate symbiotes
1.	Family Kalotermitidae <i>Cryptotermes dudleyi</i>	1.	<i>Oxymonas bosei</i> Das
		2.	<i>Oxymonas grandis</i> Cleveland
		3.	<i>Devescovina glabra</i> Grassi
		4.	<i>Devescovina lemniscata</i> Kirby
		5.	<i>Foaina reflexa</i> Kirby
		6.	<i>Foaina solita</i> Kirby
		7.	<i>Stephanonympha minuta</i> Das and Choudhury

Table 4. Contd.

Sl. No.	Host species	Sl. No.	Species of flagellate symbiotes
2.	<i>Cryptotermes havilandi</i>	8.	<i>Stephanonympha pyriformis</i> Das and Choudhury
		9.	<i>Stephanonympha silvestrii</i> Janicki
		1.	<i>Oxymonas bengalensis</i> Das
		2.	<i>Oxymonas bosei</i> Das
		3.	<i>Oxymonas grandis</i> Cleveland
		4.	<i>Oxymonas parvula</i> Kirby
		5.	<i>Tricercomitus divergens</i> Kirby
		6.	<i>Devescovina glabra</i> Grassi
		7.	<i>Devescovina lemniscata</i> Kirby
		8.	<i>Devescovina steini</i> Das
		9.	<i>Foaina nana</i> (Kirby)
		10.	<i>Foaina reflexa</i> Kirby
		11.	<i>Foaina solita</i> Kirby
		12.	<i>Stephanonympha minuta</i> Das and Choudhury
		13.	<i>Stephanonympha pyriformis</i> Das and Choudhury
		14.	<i>Stephanonympha silvestrii</i> Janicki
3.	<i>Cryptotermes</i> sp.	1.	<i>Microrhopalodina hoffmanni</i> (De Mello & De Mello)
		2.	<i>Hexamastix indica</i> De Mello
		3.	<i>Tricercomitus damasmorai</i> De Mello
		4.	<i>Devescovina gyrinoides</i> De Mello
		5.	<i>Stephanonympha perronciti</i> (De Mello and De Brito)
		6.	<i>Stephanonympha reenstiernai</i> De Mello
		7.	<i>Trichomonas costulata</i> De Mello
4.	<i>Glyptotermes caudomunitus</i>	1.	<i>Devescovina arta</i> Kirby
		2.	<i>Devescovina cometoides</i> De Mello & De Brito
		3.	<i>Macrotrichomonas pulchra</i> Grassi
5.	<i>Kolotermes</i> sp.	1.	<i>Devescovina cometoides</i> De Mello & De Brito
		2.	<i>Foaina nana</i> (Kirby)
		3.	<i>Foaina solita</i> Kirby
6.	<i>Neotermes andamanensis</i>	1.	<i>Tricercomitus divergens</i> Kirby

Table 4. Contd.

Sl. No.	Host species	Sl. No.	Species of flagellate symbiotes
7.	<i>Neotermes bosei</i>	2.	<i>Devescovina arta</i> Kirby
		3.	<i>Devescovina parasoma</i> Kirby
		4.	<i>Foaina nana</i> (Kirby)
		5.	<i>Foaina reflexa</i> Kirby
		6.	<i>Cauduceia kalshoveni</i> Kirby
		7.	<i>Stephanonympha silvestrii</i> Janicki
		1.	<i>Oxymonas bosei</i> Das
		2.	<i>Oxymonas grandis</i> Cleveland
		3.	<i>Devescovina parasoma</i> Kirby
		4.	<i>Foaina reflexa</i> Kirby
		5.	<i>Caduceia kalshoveni</i> Kirby
		6.	<i>Stephanonympha pyriformis</i> Das & Choudhury
8.	Family Termopsidae <i>Archotermopsis wroughtoni</i>	1.	<i>Trichomitopsis termitis</i> (Imms in Cutler)
		2.	<i>Joenopsis polytricha</i> Cutler
		3.	<i>Parajoenopsis cephalotricha</i> (Cutler)
		4.	<i>Microjoenia axostylis</i> Cutler
		5.	<i>Protrichonympha pristina</i> (Imms)
9.	Family Hodotermitidae <i>Anacanthotermes macrocephalus</i>	1.	<i>Trichonympha turkestanica</i> Bernstein
10.	<i>Anacanthotermes viarum</i>	1.	<i>Tricercomitus sokheyi</i> De Mello
		2.	<i>Polymastigoides elongata</i> (Bernstein)
		3.	<i>Holomastigotoides cingulatum</i> var. <i>coimbatorensis</i> De Mello & De Mello
		4.	<i>Holomastigotoides mirabile</i> var. <i>margabhandui</i> De Mello & De Mello
		5.	<i>Holomastigotoides proboscifer</i> De Mello & De Mello
		6.	<i>Spirotrichonympha coimbatorensis</i> De Mello
		7.	<i>Trichonympha fletcheri</i> De Mello
11.	Family Rhinotermitidae <i>Coptotermes heimi</i>	1.	<i>Holomastigotoides bengalensis</i> Chakravarty & Banerjee
		2.	<i>Holomastigotoides campanula</i> (De Mello)
		3.	<i>Holomastigotoides dharwarensis</i> Karandikar & Vittal

Table 4. Contd.

Sl. No.	Host species	Sl. No.	Species of flagellate symbiotes
12.	<i>Coptotermes travians</i>	4.	<i>Holomastigotoides elongata</i> Uttangi
		5.	<i>Holomastigotoides emersoni</i> Das
		6.	<i>Holomastigotoides magnus</i> Uttangi
		7.	<i>Holomastigotoides mirabile</i> Grassi
		8.	<i>Holomastigotoides ogivalis</i> De Mello
		9.	<i>Holomastigotoides ovalis</i> Uttangi
		10.	<i>Holomastigotoides rayi</i> Karandikar & Vittal
		11.	<i>Holomastigotoides reniformis</i> De Mello
		12.	<i>Holomastigotoides sphaeroidalis</i> De Mello
		13.	<i>Holomastigotoides turboformis</i> Uttangi
		14.	<i>Holomastigotoides bhadreshwarensis</i> Tiwari
		15.	<i>Spirotrichonympha elongata</i> Grassi
		16.	<i>Spirotrichonympha flagellata</i> (Grassi)
		17.	<i>Spirotrichonympha froilanoi</i> Karndikar & Vittal
		18.	<i>Spirotrichonympha karnataki</i> Karandikar & Vittal
		19.	<i>Spirotrichonympha roonwali</i> Das
		20.	<i>Pseudotrichonympha cardiformis</i> Karandikar & Vittal
		21.	<i>Pseudotrichonympha indica</i> Chakravarty & Banerjee
		22.	<i>Pseudotrichonympha pisciformis</i> Karandikar & Vittal
		23.	<i>Pseudotrichonympha subapicalis</i> Karandikar & Vittal
		1.	<i>Holomastigotoides bengalensis</i> Chakravarty & Banerjee
		2.	<i>Holomastigotoides campanula</i> (De Mello)
		3.	<i>Holomastigotoides globosus</i> De Mello
		4.	<i>Holomastigotoides hollandei</i> Das
		5.	<i>Holomastigotoides magnus</i> Uttangi
		6.	<i>Holomastigotoides ogivalis</i> De Mello
		7.	<i>Holomastigotoides ovalis</i> Uttangi
		8.	<i>Holomastigotoides rayi</i> Karandikar & Vittal
		9.	<i>Holomastigotoides reniformis</i> De Mello
		10.	<i>Holomastigotoides sphaeroidalis</i> De Mello
		11.	<i>Spirotrichonympha froilanoi</i> Karandikar & Vittal

Table 4. Contd.

Sl. No.	Host species	Sl. No.	Species of flagellate symbiotes
13.	<i>Coptotermes</i> sp.	12.	<i>Spirotrichonympha roonwali</i> Das
		13.	<i>Pseudotrichonympha indica</i> Chakravarty & Banerjee
		14.	<i>Pseudotrichonympha subapicalis</i> Karandikar & Vittal
		1.	<i>Holomastigotoides campanula</i> (De Mello)
		2.	<i>Holomastigotoides globosus</i> De Mello
		2a.	<i>Holomastigotoides globosus</i> var. <i>britoi</i> De Mello
		3.	<i>Holomastigotoides grassii</i> (De Mello)
		4.	<i>Holomastigotoides hemigymnum</i> var. <i>Indica</i> (De Mello)
		5.	<i>Holomastigotoides ogivalis</i> De Mello
		6.	<i>Holomastigotoides piriformis</i> De Mello
14.	<i>Heterotermes indicola</i>	7.	<i>Holomastigotoides reniformis</i> De Mello
		8.	<i>Holomastigotoides sphaeroidalis</i> De Mello
		9.	<i>Spirotrichonympha elongata</i> Grassi
		10.	<i>Pseudotrichonympha hertwigi</i> var. <i>simplex</i> De Mello
		1.	<i>Holomastigotoides bengalensis</i> Chakravarty & Banerjee
		2.	<i>Holomastigotoides campanula</i> (De Mello)
		3.	<i>Holomastigotoides gigas</i> De Mello
		4.	<i>Holomastigotoides globosus</i> De Mello
		5.	<i>Holomastigotoides grassii</i> (De Mello)
		6.	<i>Holomastigotoides hemigymnum</i> Grassi
		6a.	<i>Holomastigotoides hemigymnum</i> var. <i>indica</i> (De Mello)
		7.	<i>Holomastigotoides hollandei</i> Das
		8.	<i>Holomastigotoides inexpectatus</i> De Mello
		9.	<i>Holomastigotoides koidzumii</i> De Mello
		10.	<i>Holomastigotoides magnus</i> Uttangi
		11.	<i>Holomastigotoides melloi</i> Uttangi
		12.	<i>Holomastigotoides mirabile</i> var. <i>katiawarensis</i> (De Mello)
		13.	<i>Holomastigotoides ovalis</i> Uttangi
		14.	<i>Holomastigotoides piriformis</i> De Mello

Table 4. Contd.

Sl. No.	Host species	Sl. No.	Species of flagellate symbiotes
15.	<i>Heterotermes malabaricus</i>	15.	<i>Holomastigotoides rayi</i> Karandikar & Vittal
		16.	<i>Holomastigotoides saccusiformis</i> Uttangi
		17.	<i>Holomastigotoides sphaeroidalis</i> De Mello
		18.	<i>Holomastigotoides visnagarensis</i> Uttangi
		19.	<i>Spirotrichonympha flagellata</i> (Grassi)
		20.	<i>Spirotrichonympha froilanoi</i> Karandikar & Vittal
		21.	<i>Spirotrichonympha leidy</i> Koidzumi
		21a.	<i>Spirotrichonympha leidy</i> var. <i>damanensis</i> De Mello
		22.	<i>Spirotrichonympha mirabilis</i> Grassi
		22a.	<i>Spirotrichonympha mirabilis</i> var. <i>indica</i> De Mello
		23.	<i>Spirotrichonympha ovoidea</i> De Mello
		24.	<i>Spirotrichonympha pyriformis</i> Chakravarty & Banerjee
		25.	<i>Spirotrichonympha rotunda</i> De Mello
		26.	<i>Pseudotrichonympha belari</i> De Mello
		27.	<i>Pseudotrichonympha indica</i> Chakravarty & Banerjee
		28.	<i>Pseudotrichonympha ramani</i> var. <i>seminuda</i> De Mello
		29.	<i>Trichonympha gujarathensis</i> Uttangi
		1.	<i>Holomastigotoides campanula</i> (De Mello)
		2.	<i>Holomastigotoides dharwarensis</i> Karandikar & Vittal
		3.	<i>Holomastigotoides globosus</i> De Mello
		4.	<i>Holomastigotoides hemigymnum</i> var. <i>indica</i> (De Mello)
		5.	<i>Holomastigotoides sphaeroidalis</i> De Mello
		6.	<i>Spirotrichonympha froilanoi</i> Karandikar & Vittal
		7.	<i>Pseudotrichonympha cardiformis</i> Karandikar & Vittal
		8.	<i>Pseudotrichonympha pisciformis</i> Karandikar & Vittal

Table 4. Contd.

Sl. No.	Host species	Sl. No.	Species of flagellate symbiotes
16.	<i>Heterotermes</i> sp*	9.	<i>Pseudotrichonympha subapicalis</i> Karandikar & Vittal
		1.	<i>Holomastigotoides bengalensis</i> Chakravarty & Banerjee
		2.	<i>Holomastigotoides globosus</i> De Mello
		3.	<i>Spirotrichonympha pyriformis</i> Chakravarty & Banerjee
		4.	<i>Pseudotrichonympha indica</i> Chakravarty & Banerjee
		5.	<i>Pseudotrichonympha ramani</i> De Mello
17.	<i>Reticulitermes assamensis</i>	1.	<i>Dinenympha exilis</i> Koidzumi
		2.	<i>Dinenympha leidy</i> Koidzumi
		3.	<i>Dinenympha nobilis</i> Koidzumi
		4.	<i>Dinenympha parva</i> Koidzumi
		5.	<i>Dinenympha rugosa</i> Koidzumi
		6.	<i>Pyrsonympha grandis</i> Koidzumi
		7.	<i>Pyrsonympha modesta</i> Koidzumi
		8.	<i>Spirotrichonympha</i> (<i>Spironympha</i>) <i>porteri</i> (Koidzumi)
		9.	<i>Holomastigotes indica</i> Das, Mandal, Tiwari & Sarkar
		10.	<i>Teranympha mirabilis</i> Koidzumi
		11.	<i>Trichonympha agilis</i> Leidy
		12.	<i>Trichonympha meghalayensis</i> Das, Mandal, Tiwari & Sarkar
18.	<i>Reticulitermes tirapi</i>	1.	<i>Dinenympha mukundai</i> Mukherjee & Maiti
		2.	<i>Dinenympha nobilis</i> Koidzumi
		3.	<i>Dinenympha rayi</i> Mukherjee & Maiti
		4.	<i>Pyrsonymphis grandis</i> Koidzumi
		5.	<i>Pyrsonympha rostrata</i> Mukherjee & Maiti
		6.	<i>Pyrsonympha tirapi</i> Mukherjee & Maiti
		7.	<i>Spirotrichonympha</i> (<i>Spironympha</i>) <i>porteri</i> (Koidzumi)
		8.	<i>Teranympha mirabilis</i> Koidzumi
		9.	<i>Trichonympha agilis</i> Leidy
19.	Undetermined termites	1.	<i>Holomastigotoides operculatum</i> De Mello

*Most probably this species belongs to *Heterotermes indicola* (vide Das, 1976)

SYSTEMATIC ACCOUNT

Order OXYMONADIDA Grassé, 1952

1952. Oxymonadida Grassé, *Traite de Zoologie*, Paris, vol. 1, fasc. 1 : 801.

Diagnosis : One or more karyomastigonts, each containing 4 flagella typically arranged in 2 pairs in motile stages; one or more flagella may be recurrent, adhering to the body surface for greater or lesser distance; kinetosome of flagellar pairs connected by paracrystalline structure ("preaxostyle"); axostyles one to many.

Key to the families of order Oxymonadida reported from Indian termites

1. Body of various shapes, never spirally twisted; 2 or 3 flagella arising from each blepharoplast; anterior organelle of attachment (rostellum) present; shape of axostyle varying from a slender ribbon to a scimitar or a stiletto Family OXYMONADIDAE
- Body club shaped or spindle shaped, usually twisted, body surface with 4-8 flagellar cords arranged length-wise or slightly spirally; rostellum absent; shape of axostyle varying from a cord to a band Family PYRSONYMPHIDAE

Family OXYMONADIDAE Kirby, 1928

1928. Oxymonadidae Kirby, *Quart. J. micr. Sci.*, **72** : 356.

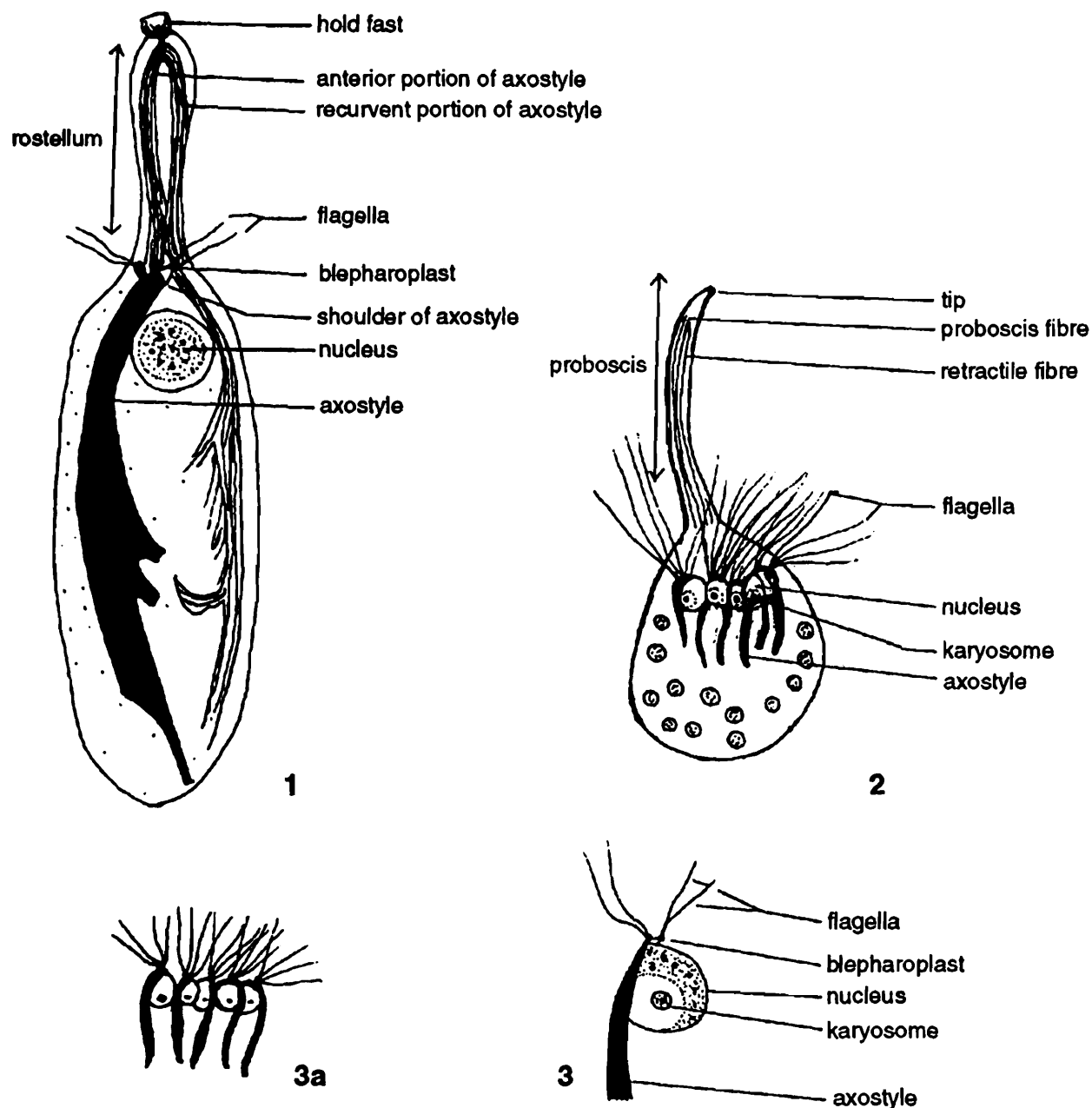
Diagnosis : Flagellates having an anterior organelle of attachment, the rostellum; each mastigont having two blepharoplasts, each of which giving rise to 2 or 3 flagella (excepting *Microrhopalodina multinucleata*), an axostyle and cytoplasmic rostellar filaments; nucleus containing a large karyosome and granular chromatin filling the remaining space; majority of species uninucleate but some are multinucleate.

Subfamily OXYMONADINAE Cleveland, 1934, emend. Kirby, 1937 (Figs. 1-3)

1934. Oxymonadinae Cleveland, *Mem. Amer. Acad. Arts Sci.*, **17** : 304.

1937. Oxymonadinae : Kirby, *Univ. Calif. Publ. Zool.*, **41** : 205.

Diagnosis : "Polymastigote flagellates" with one or many nuclei; nucleus containing a karyosome, halo and chromatin in a granular reticulum or in granules massed against nuclear membrane; blepharoplasts 2 in number and closely associated with the shoulder of axostyle; each blepharoplast giving rise to 2 flagella; rostellum situated anteriorly and appearing as a low mound or slender and lengthy, tubular or flattened; axostyle of varying length resembling a slender ribbon, a stiletto, a pennant or a scimitar; occurring in both motile and sessile stages in the gut of the termite family Kalotermitidae (except for 2 species of *Oxymonas*).



Figs. 1-3 : Semidiagrammatic representations of Indian genera of the subfamily Oxymonadinae, showing salient taxonomic features. **Fig. 1.** Genus *Oxymonas* Janicki; **Fig. 2.** Genus *Microrhopalodina* Grassi & Foa; **Fig. 3.** Showing locations of blepharoplast, flagella and axostyle in relation to each nucleus of *Microrhopalodina*; **Fig. 3a.** Showing polymerisation of nucleus and its associated organelles in *Microrhopalodina*

Key to the genera of the subfamily Oxymonadinae recorded from Indian termites

1. Predominantly uninucleate, occasionally binucleate, very rarely with 4-6 nuclei, axostyle usually single, resembling a slender stiletto, a pennant or a broad scimitar Genus *Oxymonas*
- Multinucleate, axostyles slender and many, number of which usually same as the number of nuclei Genus *Microrhopalodina*

Genus *Oxymonas* Janicki, 1915

1915. *Oxymonas* Janicki, Zeit. Wiss. Zool., 112 : 608.
 1926. *Oxymonas* emend. Kofoed and Swezy, Univ. Calif. Publ. Zool., 28 : 295.
 1945. *Metasaccinobaculus* de Frietas, Mem. Inst. Oswaldo Cruz., 43 : 349.
 1946. *Oxymonas* : Cross, Univ. Calif. Publ. Zool., 53 : 97.

Diagnosis : Body spherical to elongate ellipsoidal, spindle-shaped, pear-shaped or top-shaped, usually uninucleate, sometimes binucleate, rarely with 4–6 nuclei; nucleus spherical to ellipsoidal or pyriform, with granular chromatin and a karyosome, surrounded by a halo; shape of axostyle resembling a slender stiletto, a pennant or a broad scimitar, with a faintly staining (with Heidenhain's haematoxylin) anterior prolongation terminating in the hold fast or its anlage; number of axostyle usually same as the number of nuclei; many species with a recurvent portion of axostyle extending backward from the hold fast into the body.

Remarks : As early as 1915 Janicki erected the genus *Oxymonas* with type species *Oxymonas granulosa*. Since then, a total of 30 species of *Oxymonas* (see Yamin, 1979) have been described from various termite hosts, all belonging to the family Kalotermitidae and 2 species from the wood roaches, belonging to *Cryptocercus*. Das (1974) was the first to record 4 species of *Oxymonas*, viz., *O. bengalensis*, *O. bosei*, *O. grandis* and *O. parvula* from the guts of Indian termites, *Cryptotermes havilandi* and *Neotermes bosei*. Out of these, the first two were new species. There is no additional species of *Oxymonas* known so far from India. However, in subsequent years, Tiwari and Ray (1981) and Das, et al. (2004, 2006a) reported *Oxymonas bosei* and *Oxymonas grandis* from Indian termites.

Key to the species of *Oxymonas* reported from Indian termites

1. Axostyle slender, resembling a stiletto in form, nucleus containing karyosome 2
 - Axostyle broad, resembling a scimitar in shape, nucleus without any karyosome during interkinetic period *O. grandis*
2. Body broadly ovoidal or subelliptical, position of karyosome central or slightly eccentric surrounded by a distinct halo 3
 - Body ovoidal, karyosome minute, chromatin granules fine and distributed throughout the nucleus, halo absent *O. parvula*
3. Body broadly ovoidal, axostyle extending slightly below nucleus; karyosome ovoid, surrounded by a distinct halo *O. bosei*
 - Body sub-elliptical with pointed posterior end; axostyle reaching up to posterior end of the body, karyosome round, surrounded by a distinct halo *O. bengalensis*

1. *Oxymonas bengalensis* Das, 1974
(Fig. 4)

1974. *Oxymonas bengalensis* Das, *Acta Protozoologica*, 12 : 336.

1983. *Oxymonas bengalensis* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 42.

1993. *Oxymonas bengalensis* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 484. *Zool. Surv. India*.

Type host : *Cryptotermes havilandi*; loc., India : West Bengal.

Diagnosis : Body generally sub-elliptical with pointed posterior end; length of rostellum greatly variable, may be shorter than or as long as or longer than that of the body; occasional bifurcation of axostyle also noted; axostyle stout and stiletto-shaped, broadest near its shoulder, gradually pointed to the posterior end of the body and ultimately enclosed within the cytoplasm; rostellum containing "non-staining" portion of axostyle, the recurvent portion of which not traceable; two blepharoplasts located near the shoulder of axostyle, each of which giving rise to 2 flagella; nucleus ovoid and located near the anterior end of the body, slightly below the blepharoplasts; nucleus containing chromatin granules just beneath the nuclear membrane and a round karyosome of 2.5 μm diameter surrounded by a distinct halo; endoplasm sometimes containing fragmented wood particles.



Fig. 4 : *Oxymonas bengalensis* Das

Morphometry (Table 5) :

Table 5. Mensural data of *Oxymonas bengalensis*

Characters	Range	Mean
Length of the body	42.5–98.6 μm	68 μm
Breadth of the body	15.3–17 μm	16.6 μm
Length of nucleus	5.1–6.8 μm	5.9 μm
Breadth of nucleus	3.4–4.2 μm	3.8 μm
Diameter of karyosome	–	2.5 μm

Remarks : Amongst all the species of *Oxymonas* Janicki reported so far, *O. bengalensis* resembles *O. projector* Kofoid and Swezy and *O. jouteli* Zelif in having stiletto shaped

axostyle and in the shape and position of karyosome. It resembles more with the former in body shape. But, it is quite distinct from the above two species by being larger in size (*O. projector* 12-40 μm long and *O. jouteli* 20.9 (13.3-30.7) μm long) and in having stout "staining" axostyle reaching up to posterior end of the body. In *O. projector* and *O. jouteli* "staining axostyle" is slender and projecting slightly or moderately beyond the posterior end of the body.

2. *Oxymonas bosei* Das, 1974

(Fig. 5)

1974. *Oxymonas bosei* Das, *Acta Protozoologica*, 12 : 337.

1981. *Oxymonas bosei* : Tiwar and Ray, *Bull. zool. Surv. India*, 4 : 161.

1983. *Oxymonas bosei* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 42.

1992. *Oxymonas bosei* : Tiwari, *Rec. zool. Surv. India*, 92 : 136.

1993. *Oxymonas bosei* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 485. *Zool. Surv. India*.

2004. *Oxymonas bosei* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 447. *Zool. Surv. India*.

2006a. *Oxymonas bosei* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 25. *Zool. Surv. India*

Type host : *Neotermes bosei*; loc., India : West Bengal.

Additional hosts : *Cryptotermes havilandi*; loc., India : Bihar and Nagaland; *Cryptotermes dudleyi*; loc., India : Andhra Pradesh.

Diagnosis : Body broadly ovoidal in shape with elongated anterior and broadly round posterior ends; length of rostellum considerably variable as in the preceding species depending perhaps on the attached and motile phase of the species; axostyle stiletto-shaped; its staining portion projecting backward slightly below the nucleus and its "non-staining" portion extending into the rostellum; blepharoplasts two in number and located near the shoulder of the axostyle; nucleus elliptical situated at the anterior part of the body near the base of the rostellum and containing numerous fine chromatin granules mostly concentrated to the peripheral zone of nucleus; an ovoid karyosome, 2 μm in diameter located

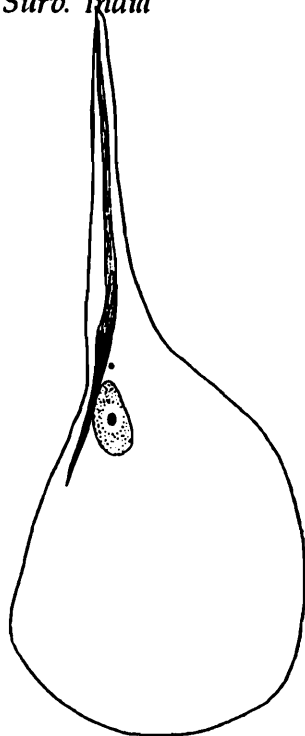


Fig. 5 : *Oxymonas bosei* Das

almost at the centre of the nucleus surrounded by a distinct halo; endoplasm occasionally containing fragments of wood particles.

Morphometry (Table 6) :

Table 6. Mensural data of *Oxymonas bosei*

Characters	Range	Mean
Length of the body	172 – 236.2 μm	204.6 μm
Breadth of the body	31 – 48.6 μm	38.2 μm
Length of nucleus	9 – 14.3 μm	11.9 μm
Breadth of nucleus	4.6 – 8 μm	5.1 μm
Diameter of karyosome	–	2 μm

Remarks : Morphometry in Table 6 is based on specimens of *Oxymonas bosei* collected from the type host and studied by Das (1974a). Subsequently this flagellate species was collected by Tiwari (1992) and Das *et al.* (2004, 2006a) from two additional hosts *Cryptotermes havilandi* and *Cryptotermes dudleyi*. These specimens being 150 (125–172) μm in length and 41.2 (34–45.5) μm in width from *Cr. havilandi* (Tiwari, 1992) and 182 (130–207) μm in length and 36 (30–43.2) μm in width from *C. dudleyi* (present study) are smaller than those from the type host, *N. bosei*.

The present species resembles *O. dimorpha* Connell, *O. barbouri* Zeliff and *O. pediculosa* Kofoid and Swezy in body shape and in having stiletto-shaped axostyle. But, *O. dimorpha* can be conveniently differentiated from *O. bosei* by its much broader size, round nucleus and axostyle, projecting slightly beyond the posterior end of the body. In *O. bosei* axostyle is much shorter in length, extends little beyond the nucleus, hangs free in the cytoplasm and never protrudes out of the posterior end of the body. The remaining two species, *O. barbouri* and *O. pediculosa* are considerably smaller in size and their axostyles also project beyond the posterior extremity of the body. Morphometric data and some relevant morphological features of the four species as referred above are presented in Table 7.

Table 7. Comparison of *O. bosei* Das with related species; all measurements are from specimens of type hosts of the concerned species

Characters	<i>O. dimorpha</i>	<i>O. barbouri</i>	<i>O. pediculosa</i>	<i>O. bosei</i>
Average body length	120 μm	16.1 μm	34 μm	204.6 μm
Average body width	100 μm	11 μm	21 μm	38.2 μm
Shape of nucleus	round	round or ovoid	spherical	elliptical
Shape of karyosome	round	oval	round	ovoid
Average dimension/ diameter of nucleus	7.7 μm	4 μm	7 μm	11.9 x 5.1 μm
Ratio of karyosome length to nuclear length (K/N)	1/3	2/5	1/3	2/5
Axostyle stiletto and projects out of the posterior end of the body	Resembles a <i>O. dimorpha</i>	As in <i>O. dimorpha</i>	As in stiletto, much shorter in length never projects out of the body	Resembles a

3. *Oxymonas grandis* Cleveland, 1935 (Fig. 6)

1935. *Oxymonas grandis* Cleveland, *Biol. Bull.*, **69** : 54.
 1974. *Oxymonas grandis* : Das, *Acta protozoologica*, **12** : 340.
 1981. *Oxymonas grandis* : Tiwari and Ray, *Bull. zool. Surv. India*, **14** : 161.
 1983. *Oxymonas grandis* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 42.
 1992. *Oxymonas grandis* : Tiwari, *Rec. zool. Surv. India*, **92** : 137.
 1993. *Oxymonas grandis* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, **3**(Part 12) : 485. *Zool. Surv. India*.
 2004. *Oxymonas grandis* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, **5**(Part 6) : 448. *Zool. Surv. India*.
 2006a. *Oxymonas grandis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, **12** : 25. *Zool. Surv. India*.

Type host : *Neotermes dalbergiae*, loc., Java : Kalshoven.

Additional hosts : *Neotermes bosei*; loc., India : West Bengal; *Neotermes dalbergiae*; loc., Java, Sumatra; *Neotermes tectonae*; loc., Java, Sumatra; *Cryptotermes dudleyi*; loc., India : Andhra Pradesh; *Cryptotermes havilandi*; loc., India : Bihar and Nagaland.

Diagnosis : Body ovoid to ellipsoid, sometimes irregular; rostellum varying in size, depending on motile or attaching phase of the species; axostyle broad, resembling a scimitar in shape; nucleus ovoid in shape and situated just posterior to the shoulder of the axostyle in the interkinetic period; chromatin in granular reticulum; karyosome totally absent; endoplasm finely granular, usually containing wood fragments.

Morphometry : Morphometry of Indian specimens of *Oxymonas grandis* collected by Das (1974a) and Tiwari (1992) is presented in Table 8 and compared with that of the specimens of Java and Sumatra, recorded by Cleveland (1935) and Cross (1946).

Table 8. Comparison of mensural data of *Oxymonas grandis* from different hosts; (measurements in μm)

Characters	From Indian termites		From termites of Java and Sumatra	
	<i>N. bosei</i>	<i>Cr. havilandi</i>	<i>N. dalbergiae</i> and <i>N. tectonae</i>	
	(Das, 1974)	(Tiwari, 1992)	Cleveland (1935)	Cross (1946)
Length of body	158.3 (78.7 – 266.2)	182.8 (87.5 – 224)	121 (76 – 183)	109 (41 – 241)
Breadth of body	30.7 (18.7 – 45)	43.2 (38.5 – 49)	52 (31 – 79)	36.4 (15.3 – 78.3)
Length of nucleus	12.1 (8.5-17)	20.1 (17.5-24.5)	21 (20-23)	16 (8.7 – 24.9)
Breadth of nucleus	5.9 (5.1-6.8)	14.8 (10.5-17.5)	-	12.6 (8-20.7)

Remarks : Table 8 reveals that dimensions of *Oxymonas grandis* are greatly variable and Indian specimens are quite larger than those of Java and Sumatra. Absence of karyosome

in nucleus during the interkinetic period is the characteristic feature of *O. grandis*. However, very small karyosome may be recognised during the reorganisation of nucleus, following division. It is to be noted here that in Indian specimens "staining portion" of axostyle extends little beyond the middle of the body. But, in specimens collected from Java including the type specimens this portion of axostyle extends up to the posterior end of the body and sometimes, slightly beyond it as observed by Cross (1946).



Fig. 6 : *Oxymonas grandis* Cleveland

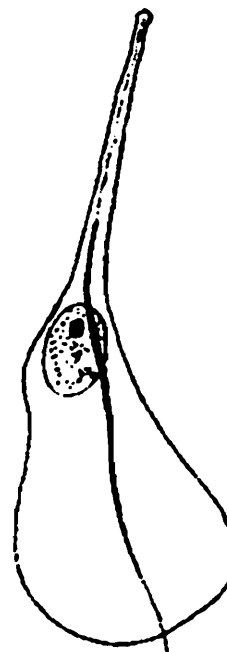


Fig. 7 : *Oxymonas parvula* Kirby

4. *Oxymonas parvula* Kirby, 1926 (Fig. 7)

1926. *Oxymonas parvula* Kirby, Univ. Calif. Publ. Zool., 29 : 116.

1974. *Oxymonas parvula* : Das, Acta Protozoologica, 12 : 329.

1983. *Oxymonas parvula* : Das, Proc. Symp. Host Environ. zool. Surv. India : 42.

1993. *Oxymonas parvula* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3(Part 12) : 485. Zool. Surv. India

Type host : *Cryptotermes domesticus* (= *Cryptotermes hermsi*); loc., Fanning Island.

Additional host : *Cryptotermes havilandi*; loc., India : West Bengal.

Diagnosis : Body ovoid or slender with round or truncated posterior end; rostellum minute or as long as body length; axostyle slender, projecting slightly or sometimes far beyond the posterior end of the body; nucleus oval or round; fine chromatin granules distributed throughout the nucleus; karyosome minute, spherical, not surrounded by halo; endoplasm containing fragments of wood.

Morphometry (Table 9) :

Table 9. Mensural data of *Oxymonas parvula* collected from Indian termites

Characters	Range	mean
Length of the body	23.8–45.9 μm	31.1 μm
Breadth of the body	3.4–8.5 μm	5.9 μm
Length of the nucleus	3–4.2 μm	3.6 μm
Breadth of the nucleus	1.7–2.5 μm	2.0 μm

Remarks : In the original description of Kirby (1926) as well as in the subsequent description by Cross (1946) morphometric data of *Oxymonas parvula*, except its length are lacking. Type specimens from the host *Cryptotermes domesticus* (= *Cryptotermes hermsi*) were considerably small, measuring only 5–13 μm in length. Table 9 shows that Indian specimens are much larger in size than the specimens described from the type host. Yet, the shape, nature of axostyle, minute karyosome and absence of halo, as observed in the specimens collected from the Indian termites are in conformity with Kirby's description of *O. parvula*.

Genus *Microrhopalodina* Grassi and Foa, 1911

(Fig.2)

1911. *Microrhopalodina* Grassi and Foa, *Rend. R. Accad. Lincei* (5), sem.1, 20 : 730.

1926. *Proboscidiella* Kofoid and Swezy, *Unif. Calif. Publ. Zool.*, 28 : 312.

Diagnosis : Multinucleate oxymonadinae; shape of the body varying from spheroidal to pyriform to irregular elongate; axostyle slender; number of axostyle usually equal to the number of nucleus; recurvent portion of the axostyle often much shorter, nucleus spherical to ovoid; chromatin in granular reticulum or massed against nuclear membrane; karyosome round or ovoid, surrounded by a halo; usually each nucleus in close association with shoulder of each axostyle.

5. *Microrhopalodina hoffmanni* (De Mello and De Mello, 1944) Cross, 1946

1944. *Proboscidiella hoffmanni* De Mello and De Mello, *An. Inst. Med. Trop.*, 1 : 211.

1946. *Microrhopalodina hoffmanni* (De Mello and De Mello) Cross, *Univ. Calif. Publ. Zool.*, 53 : 120.

1983. *Microrhopalodina hoffmanni* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 42.

Type host : "Indian *Cryptotermes*"

Diagnosis : Body spherical to ellipsoidal; length 12–54 μm with average 27 μm and width 11–56 μm with average 20 μm ; nucleus ovoid, 2–14 in number; chromatin in granular reticulum; karyosome round, ecentric and surrounded by a halo; anterior corona formation of nuclei irregular; number of axostyle not equaling number of nucleus; axostyle slender, deeply stained, extending full length of the body; recurvent portion of axostyle delicately stained.

Remarks : Cross (1946) dealt with *Microrhopalodina hoffmanni* in some details. He (*op. cit.*) derived the meridians in the measurements of body length and body width and, number of nucleus from the figures given by De Mello and De Mello (1946) during the description of this species under the name *Proboscidiella hoffmanni*. According to Cross (1946) *M. hoffmanni* resembles *M. inflata* since in both the species axostyles extend practically the full length of the body and nuclear corona irregular. Again, in having delicately stained anterior and recurvent portion of axostyle *M. hoffmanni* also resembles *M. multinucleata*.

Family PYRSONYMPHIDAE Grassi, 1892

1892. Pyrsonymphidae Grassi, *Rend. R. Accad. Lincei* (5), 20 : sem 1 : 726.

Diagnosis : "Polymastigote" flagellates with usually 4 flagella arising from each blepharoplast; a well developed axostyle stained deeply with Heidenhain's haematoxylin and delicately or not at all with Delafield's haematoxylin; parabasal bodies absent.

Remarks : Two genera under this family, namely, *Dinenympha* Leidy and *Pyrsonympha* Leidy have been reported so far from the guts of Indian termites. Incidentally, both the genera were established by Leidy (1877), with type species *Dinenympha gracilis* and *Pyrsonympha vertens* respectively from the termite host, *Termes flavipes* which has been synonymed at present under *Reticulitermes flavipes*.

Subsequently Grassi (1892) synonymed *Pyrsonympha vertens* (*proparte*) with *Dinenympha* Leidy. But, he neither stated anything regarding the taxonomic status of the remaining part of *Pyrsonympha* nor included it under the synonymy of the genus *Dinenympha*. In 1911 Grassi and Foa defined the family Dinenymphidae which contained only one genus *Dinenympha* under which *Pyrsonympha* Leidy and *Lophophora* Comes were synonymised. In 1921 Koidzumi treated both *Pyrsonympha* and *Dinenympha* as the subgenera of the genus *Pyrsonympha*. He retained the generic status of *Pyrsonympha* because "characters of this group are more typically and distinctly represented in *Pyrsonympha* than in *Dinenympha* and the former name stands prior to the latter in the original description of Leidy (1877)" Later, Cleveland *et al.* (1938a) retained the generic status of both *Pyrsonympha* and *Dinenympha*. The same is followed in the present work as both the taxa differ in body shape and arrangement of axial filament. As noted by Koidzumi (1921), whole body curled into a spiral in *Dinenympha* whereas in *Pyrsonympha* some forms may be twisted into a screw, but never curled as a whole.

Key to the genera of the family Pyrsonymphidae reported from Indian termites

1. Axostyle not hanging freely in the cytoplasm, usually adherent to the body wall to the greater part of its length and fixed at posterior tip of the body Genus *Dinenympha*

- Axostyle a narrow band, may be divided into two parts, hanging free in the cytoplasm and its posterior end free from body wall Genus *Pyrsonympha*

Genus *Dinenympha* Leidy, 1877

1877. *Dinenympha* Leidy, *Proc. Acad. Nat. Sci. Phila.*, 29 : 149.

1921. *Dinenympha* Leidy, emend. Koidzumi, *Parasitology*, 13 : 281.

Diagnosis : Body slender, usually assuming the shape of a club or elongated spindle or may be flattened and ribbon-shaped, showing more or less distinct edges at both sides; body sometimes twisted and spirally wound, showing 2-5 undulations; body surface may be smooth or ridged; axostyle not hanging freely in the cytoplasm, usually adherent to the body wall to the greater part of its length and fixed at posterior tip of the body or indistinct except at anterior end; flagellar cords 4-8 in number running partially with the longitudinal axis of the body, their distribution not uniform over entire body surface and limited to one-half of the surface or little more; each flagellar cord usually situated on a distinct ridge, making the outline of the body serrated.

Remarks : Eight species of *Dinenympha* have been reported so far from Indian termites. Key to those species is presented below for the convenience of identification.

Key to the species of *Dinenympha* reported from Indian termites

1. Body surface almost smooth, ridge on which flagellar cords situated indistinct 2
 - Body surface not smooth, ridge on which flagellar cords situated high and distinct 6
2. Axostyle indistinct 3
 - Axostyle distinct 5
3. Body lanceolate or club-shaped, its anterior portion usually bend back, free ends of flagellar cords not very long 4
 - Body lanceolate and fairly thick at posterior part, free ends of flagellar cords conspicuously long, almost half the length of the body *D. leidy*
4. Body club-shaped, gradually thickened towards posterior end, anterior portion of the body usually turned back, assuming commonly the shape of a hook *D. nobilis*
 - Body slender, its anterior portion often curved and bend back, body simply twisted or wound slightly in a spiral *D. parva*
5. Axostyle thick and distinct throughout its entire length, body usually lanceolate, occasionally club-shaped, covered thickly with filamentous appendages, diffusely distributed over almost the entire length *D. porteri*

- Axostyle distinct and thick, becoming slightly thinner at posterior portion, body long and slender, tapering gradually at extremities *D. exilis*
- 6. Body long, slender, flat and ribbon like, tapering abruptly at posterior end; axostyle slender and indistinct *D. rugosa*
- Body elongately club-shaped, axostyle distinct and slender 7
- 7. Axostyle a slender cord, sometimes bifurcated, its terminal end fixed either to lateral wall or to posterior extremity *D. mukundai*
- Axostyle a slender cord running distinctly throughout the entire length, protruding out of the body, free flagella uniting together, making a tail-like structure at posterior-most margin of the body *D. rayi*

6. *Dinenympha exilis* Koidzumi, 1921

(Fig. 8)

1921. *Dinenympha exilis* Koidzumi, *Parasitology*, 13 : 291.

1995. *Dinenympha exilis* : Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series*, 4(Part 10) : 85. *Zool. Surv. India*.

2003. *Dinenympha exilis* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 27. *Zool. Surv. India*.

2006a. *Dinenympha exilis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 26. *Zool. Surv. India*.

Type hosts : *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan; *Reticulitermes flavipes* (= *Leucotermes flavipes*); loc., Japan.

Additional host : *Reticulitermes assamensis*; loc., India : Nagaland, Meghalaya and Sikkim.

Diagnosis : Body long and slender, its greater portion having almost uniform thickness and then tapering gradually at extremities; length 50–110 μm with average 85.5 μm and width 4–10 μm with average 6.2 μm in the middle of the body; flagellar bands 8 in number; number of complete spiral turn of the whole body usually two or two and a half; however, in side view four or five undulations commonly visible; body surface almost smooth; ridge on which flagellar bands situated being indistinct; centropharoplast located at anterior tip; axostyle distinct and thick, becoming slightly thinner towards posterior end of the body; nucleus oval, 7–10 μm x 2–4.5 μm in dimensions, usually located at anterior end and connected with centropharoplast.

Remarks : Koidzumi (1921) described *Dinenympha exilis* from two termite hosts of Japan, viz., *Reticulitermes speratus* and *Reticulitermes flavipes*. The type materials collected by him were slightly smaller in dimensions than those of Indian specimens as shown in Table 10.

Table 10. Comparison of morphometric data of *D. exilis* from Indian host with those from type hosts

Characters	From <i>R. speratus</i> and <i>R. flavipes</i> (type hosts)	From <i>R. assamensis</i> (Indian host)
Length of the body	50–100 μm	85.5 (50–110) μm
Breadth of the body	4–8 μm	6.2 (4–10) μm
Ratio of body length : to body width (average)	12.5 : 1	13.7 : 1
Length of nucleus	–	8.2 (7–10) μm
Breadth of nucleus	–	3 (2–4.5) μm

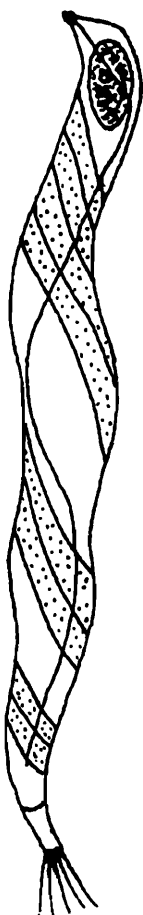


Fig. 8 : *Dinenympha exilis* Koidzumi

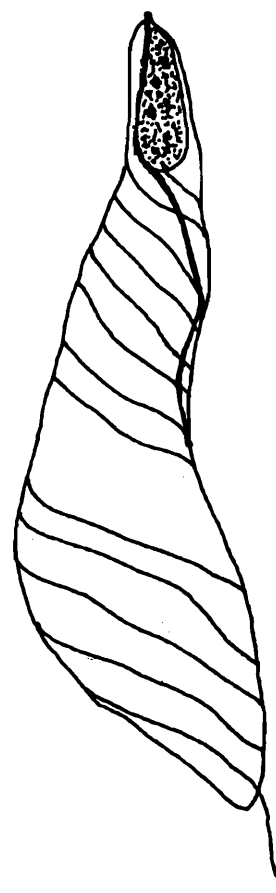


Fig. 9 : *Dinenympha leidyi* Koidzumi

7. *Dinenympha leidyi* Koidzumi, 1921
(Fig. 9)

1921. *Dinenympha leidyi* Koidzumi, *Parasitology*, 13 : 292.

1995. *Dinenympha leidyi* : Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series*, 4(Part 10) : 85. *Zool. Surv. India*.

2003. *Dinenympha leidy* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 27. *Zool. Surv. India*.

2006a. *Dinenympha leidy* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 26. *Zool. Surv. India*.

Type hosts : *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan; *Reticulitermes flavipes* (= *Leucotermes flavipes*); loc., Japan.

Additional host : *Reticulitermes assamensis*; loc., India : Meghalaya, Nagaland, Sikkim.

Diagnosis : Body lanceolate and fairly thick at anterior portion, length 32-65 μm with average 41 μm and width 10-18 μm with average 13 μm ; body surface smooth; ridges on which flagellar bands situated very indistinct and arranged regularly; axostyle very indistinct, visible at anterior region only, that too, after careful examination; free ends of flagellar bands considerably long, attaining about half the length of the body; nucleus spherical or oval, 3-6 μm in length, 2.5-5 μm in width, situated at the anterior extremity of the body.

Remarks : In Table 11, mensural data of Indian specimens of *Dinenympha leidy* are compared with those of type specimens. As in the previous species, *D. leidy* from Indian hosts are slightly larger in dimensions than that from type hosts.

Table 11. Comparison of morphometric data of *D. leidy* from Indian hosts with those from type hosts

Characters	From <i>R. speratus</i> and <i>R. flavipes</i> (type hosts)	From <i>R. assamensis</i> (Indian host)
Length of the body	25 – 50 μm	41 (32 – 65) μm
Breadth of the body	8 – 15 μm	13 (10 – 18) μm
Ratio of body length : to body width (average)	3.2 : 1	3 : 1
Length of nucleus	–	3-6 μm
Breadth of nucleus	–	2.5-5 μm

8. *Dinenympha mukundai* Mukherjee and Maiti, 1989 (Fig. 10)

1989. *Dineympha mukundai* Mukherjee and Maiti, *Arch. Protistenkd.*, 137 : 92.

2006b. *Dinenympha mukundai* : Das, Nandi and Chattopadhyaya, *Fauna of Arunachal Pradesh, State Fauna Series*, 13(Part 2) : 30. *Zool. Surv. India*.

Type host : *Reticulitermes tirapi*; loc., India : Arunachal Pradesh.

Diagnosis : Body "elongately club-shaped", anterior end narrower, sometimes bend back like a hook, posterior portion of the body gradually attaining maximum width and

posterior end broad or pointed; flagellar bands 8 in number, somewhat wavy, encircling the body in two and a half turn; bands highly ridged at anterior end above the nucleus but posterior portion of body surface somewhat smooth; axostyle distinct, resembling a slender cord of almost uniform thickness throughout its entire length, occasionally becoming thinner towards its posterior portion; terminal end of the axostyle either fixed to lateral wall or to posterior extremity; axostyle may also be folded or bifurcated; nucleus pyriform or elongated and located at the anterior end of the body.

Morphometry (Table 12) :

Table 12. Morphometric data of *Dinenympha mukundai* (as per original description)

Characters	Range	Mean
Length of body	22 – 60 μm	40.8 μm
Breadth of body	4.6 – 14.4 μm	8.5 μm
Ratio of body-length to body-width (average)	—	4.8 : 1
Length of nucleus	4 – 13.2 μm	7.8 μm
Breadth of nucleus	2.4 – 9.6 μm	5.1 μm

Remarks : In having club-shaped body with anterior portion turned back taking the shape of a hook, *Dinenympha mukundai* resembles *Dinenympha nobilis* and *Dinenympha parva* to a great extent. However, presence of distinct axostyle differentiates *D. mukundai* from the latter two species. Mukherjee and Maiti (1989) recorded some specimens of *D. mukundai* with anterior portion "broad, flat and folding inside" But their text-figures 3, 4 and 5 appear to have been drawn from the specimens which are folded in such a fashion that their narrow and hook-like portions are not visible.

In the original description of *D. mukundai* Mukherjee and Maiti (1989) have given morphometric data of larger forms (stated as "adult") and small forms (stated as "young") separately. These data are clumped together and presented in Table 12.

The type locality of *D. mukundai* being Arunachal Pradesh, India, this species has been included in the State Fauna of Arunachal Pradesh by Das *et al.* (2006b). The description of this species incorporated therein is based on original description by Mukherjee and Maiti (1989).

9. *Dinenympha nobilis* Koidzumi, 1921 (Fig. 11)

1921. *Dinenympha nobilis* Koidzumi, *Parasitology*, 13 : 292.

1995. *Dinenympha nobilis* : Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series*, 4(Part 10) : 85. *Zool. Surv. India*.

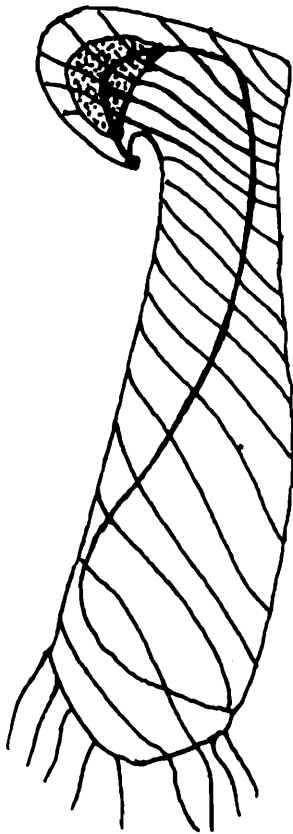


Fig. 10 : *Dinenympha mukumdai* Mukherjee & Maiti

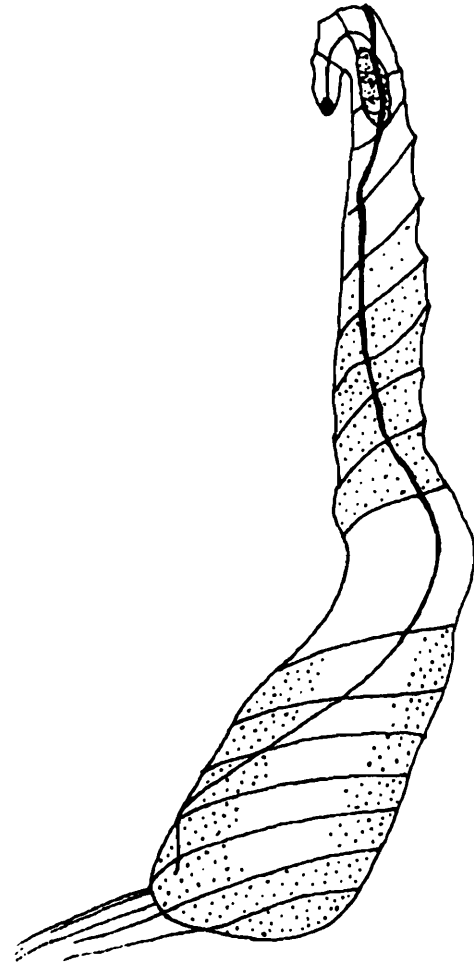


Fig. 11 : *Dinenympha nobilis* Koidzumi

2003. *Dinenympha nobilis* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 27. *Zool. Surv. India*
- 2006a. *Dinenympha nobilis* Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna series*, 12 : 27. *Zool. Surv. India*.
- 2006b. *Dinenympha nobilis* : Das, Nandi and Chattopadhyay, *Fauna of Arunachal Pradesh, State Fauna Series*, 13(Part 2) : 30. *Zool. Surv. India*.

Type host : *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan.

Additional hosts : *Reticulitermes assamensis*; loc., India : Meghalaya, Nagaland and Sikkim; *Reticulitermes tirapi*; loc., India : Arunachal Pradesh.

Diagnosis : Body club shaped, gradually thickened towards posterior end, evenly rounded at both ends; length 30-50 μm with average 38 μm and width 5-15 μm with average 12 μm ; body surface smooth, twisting of body slight; anterior portion of the body usually bend back assuming the shape of a hook; axostyle indistinct but fairly thick anteriorly, gradually becoming slender towards posterior end; nucleus round, 2-5 μm in diameter and located towards the anterior end of the body.

Morphometry : Mensural data of Indian specimens of *Dinenympha nobilis* are compared with those of its type specimens in Table 13.

Table 13. Comparison of morphometric data of Indian specimens of *D. nobilis* with those of its type specimens

Characters	Type specimens	Indian specimens
Length of the body	30–60 μm	38 (30–50) μm
Breadth of the body	5–10 μm	12 (5–15) μm
Ratio of body-length to body-width (average)	6 : 1	3.1 : 1
Diameter of nucleus	–	2-5 μm

Remarks : Table 13 reveals that specimens of *D. nobilis* from Indian termites are slightly shorter but considerably broader than type specimens. In type specimens axostyle is indistinct but thick at anterior part of the body, slender in the middle, making it almost invisible, then gradually becoming thicker posteriorly and more thickened at posterior end (Koidzumi, 1921). In Indian specimens of *D. nobilis* axostyle is somewhat different in shape – thicker at anterior end and gradually becoming slender towards its posterior part.

10. *Dinenympha parva* Koidzumi, 1921 (Fig. 12)

1921. *Dinenympha parva* Koidzumi, *Parasitology*, 13 : 294.

1995. *Dinenympha parva* : Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series*, 4(Part 10) : 86. *Zool. Surv. India*.

2003. *Dinenympha parva* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 27. *Zool. Surv. India*.

Type hosts : *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan; *Reticulitermes flavipes* (= *Leucotermes flavipes*); loc., Japan.

Additional host : *Reticulitermes assamensis*; loc., India : Meghalaya and Sikkim.

Diagnosis : Body slender, anterior portion curved or bent back, rest of the body almost straight, appearing simply twisted; in some forms body wound slightly in a spiral; length 18–44 μm with average 26 μm and width 4–6 μm with average 5 μm ; body surface almost smooth; ridge on which flagellar bands situated also very indistinct; axostyle very slender and indistinct; nucleus spherical, minute, 2–3 μm in diameter, located near the anterior end of the body.

Morphometry (Table 14) :

Table 14. Comparison of morphometric data of *D. parva* from Indian termites with those of type hosts

Characters	From <i>R. speratus</i> and <i>R. flavipes</i> (type hosts)	From <i>R. assamensis</i> (Indian termite)
Length of the body	20–25 μm	26 (18–44) μm
Breadth of the body	3–5 μm	5 (4–6) μm
Ratio of body length to body width (average)	5.6 : 1	5.2 : 1
Diameter of nucleus	–	2–3 μm

Remarks : Koidzumi (1921) commented that *Dinenympha parva* is the smallest member of *Dinenympha* as its type specimens, on average, are considerably smaller in comparison with its congeners. But during the present study some larger forms of *D. parva* having maximum length 44 μm have been collected from Indian termites. However, other characteristic features of Indian forms of *D. Parva* are quite in conformity with those described by Koidzumi (*op. cit.*)

11. *Dinenympha porteri* Koidzumi, 1921
(Fig. 13)

1921. *Dinenympha porteri* Koidzumi, *Parasitology*, 13 : 294.

Type host : *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan.



Fig. 12 : *Dinenympha parva* Koidzumi

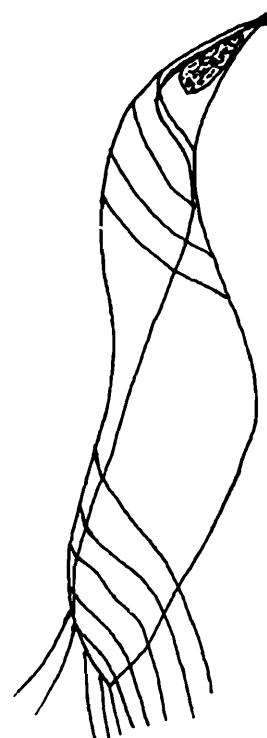


Fig. 13 : *Dinenympha porteri* Koidzumi

Additional host : *Reticulitermes assamensis*; loc., India : Meghalaya.

Diagnosis : Body usually lanceolate, occasionally club-shaped; its edges usually distinct, sometimes indistinct; length 28-75 μm with average 42 μm and width 6-10 μm with average 7.6 μm ; axostyle thick and distinct throughout its entire length; sometimes protruding out of the body; almost entire body covered with "filamentous appendages" densely at its posterior portion; nucleus elongately oval, 7-9 μm in length and 3-4 μm in width and located near the anterior end of the body.

Morphometry (Table 15) :

Table 15. Comparison of morphometric data of *Dinenympha porteri* of Indian forms with those of type specimens

Characters	From <i>R. speratus</i> (type host)	From <i>R. assamensis</i> (Indian host)
Length of the body	25 – 80 μm	42 (28 – 75) μm
Breadth of the body	6 – 10 μm	7.6 (6 – 10) μm
Ratio of body length to body width (average)	6.5 : 1	6 : 1
Length of nucleus	–	7 – 9 μm
Breadth of nucleus	–	3 – 4 μm

Remarks : Koidzumi (1921) recognised following 4 "types" of population of *Dinenympha porteri* primarily on the basis of "coat" of "filamentous appendages"

Type 1. Body lanceolate, no filamentous appendages present; 30-60 μm x 7-15 μm in dimensions.

Type 2. Shape and size as above, 12-14 filamentous appendages found at posterior end of the body.

Type 3. Body lanceolate or club-shaped, filamentous appendages covering the entire body, distributed diffusely and more densely at posterior portion, 25-80 μm x 6-10 μm in dimensions.

Type 4. Resembles Type 3, but body slightly smaller; filamentous appendages not distributed diffusely on body surface but arranged in 12-18 number of transverse rows.

While examining the permanent stained smears of the gut contents of *Reticulitermes assamensis* collected from Meghalaya and deposited in the National Collection of the Zoological Survey of India, Kolkata, *D. porteri* has been observed in sufficient number during the present study. These Indian forms quite resemble Type 3 of *D. porteri* described by Koidzumi (1921). In Table 15 dimensions of the type 3 of the type specimens are presented for comparing morphometric data of Indian population.

12. *Dinenympha rayi* Mukherjee and Maiti, 1989
(Fig. 14)

1989. *Dinenympha rayi* Mukherjee and Maiti, *Arch. Protistenkd.*, 137 : 93.

2006b. *Dinenympha rayi* : Das, Nandi and Chattopadhyay, *Fauna of Arunachal Pradesh, State Fauna Series*, 13(Part 2) : 30. *Zool. Surv. India*.

Type host : *Reticulitermes tirapi*; loc., India : Arunachal Pradesh.

Diagnosis : Body elongately club-shaped with gradually tapering anterior and round posterior ends; body slightly twisted near the middle; in some individuals anterior end of the body slightly bend back, assuming the shape of a hook; flagellar bands 8 in number and somewhat wavy, encircling the whole body in two turns; lateral edges of the bands highly ridged, making body surface rough; these flagellar bands terminating posteriorly as free flagella which unite together forming a "tail-like structure" at the posterior margin of the body; axostyle distinct, resembling a slender cord, slightly thickened at anterior portion and protruding out of the body extending up to the length of the free flagella at posterior end; nucleus round or oval and located at extreme anterior end.

Morphometry (Table 16) :

Table 16. Morphometric data of *D. rayi* (as per original description)

Characters	Range.	Mean
Length of the body	32.4 – 60 µm	48 µm
Breadth of the body	9.6 – 14 µm	12 µm
Ratio of body length to body width (average)	–	4 : 1
Length of nucleus	3.6 – 6 µm	4.8 µm
Breadth of nucleus	2.4 – 4.8 µm	3.4 µm

Remarks : In the original description of *Dinenympha rayi*, Mukherjee and Maiti (1989) presented the morphometric data of larger forms and small forms of this species separately. These data are clumped together and presented in Table 16. *D. rayi* in having high and distinct ridges resembles *D. rugosa* but it differs from the latter in body shape, nature of axostyle and presence of posteriormost free flagella which unite with the protruding part of axostyle.

Based on the original description of this species by Mukherjee and Maiti (1989), Das *et al.* (2005) incorporated it in the State Fauna of Arunachal Pradesh, published by the Zoological Survey of India as type locality of this species is in Arunachal Pradesh.

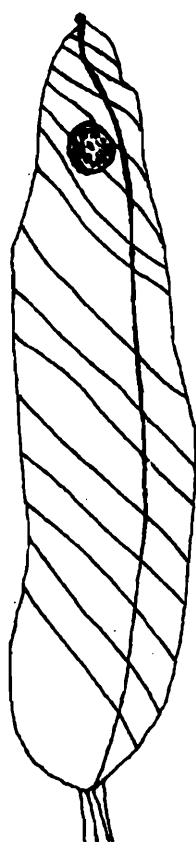


Fig. 14 : *Dinenympha rayi* Mukherjee & Maiti

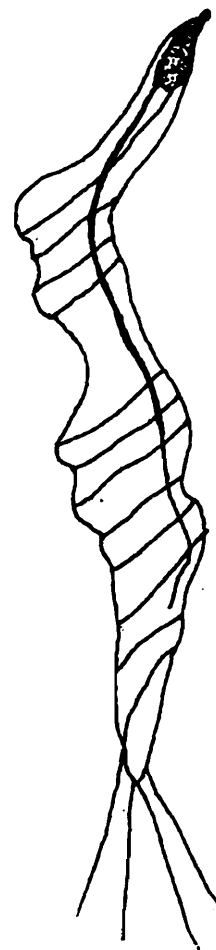


Fig. 15 : *Dinenympha rugosa* Koidzumi

13. *Dinenympha rugosa* Koidzumi, 1921
(Fig. 15)

1921. *Dinenympha rugosa* Koidzumi, *Parasitology*, 13 : 292.
1995. *Dinenympha rugosa* : Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series* 4(Part 10) : 86. *Zool. Surv. India*.
2003. *Dinenympha rugosa* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 28. *Zool Surv. India*.
- 2006a. *Dinenympha rugosa* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 27. *Zool. Surv. India*.

Type host : *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan.

Additional host : *Reticulitermes assamensis*; loc., India : Meghalaya, Nagaland and Sikkim.

Diagnosis : Body long and slender but flat and ribbon-like; its both sides distinctly edged, tapering more abruptly at posterior end; length 40-100 μm with average 78 μm , width 8-15 μm with average 12.5 μm ; provided with high and distinct ridges; course of flagellar cords considerably wavy; axostyle slender, slightly thicker than flagellar cords at the anterior part of the body and having almost same thickness as that of flagellar cords

at the posterior part of the body, making it hardly distinguishable from them; nucleus usually round, 7-10 μm in diameter and located near the middle of the body.

Morphometry (Table 17) :

Table 17. Comparison of morphometric data of *D. rugosa* of Indian forms with those of type specimens

Characters	From <i>R. speratus</i> (type host)	From <i>R. assamensis</i> (Indian host)
Length of the body	50 – 100 μm	78 (48 - 100) μm
Breadth of the body	8 – 16 μm	12.5 (8 - 15) μm
Ratio of body length to body width (average)	6.3 : 1	6.2 : 1
Diameter of nucleus	–	7 - 10 μm

Remarks : *Dinenympha rugosa* resembles *D. exilis* to a great extent in having long and slender body and almost similar length. But its flat and ribbon like body, comparatively much less length-breadth ratio, ridged body surface and indistinct axostyle clearly differentiate it from *D. exilis*. Table 17 shows that dimensions of type specimens and those of Indian forms are more or less similar. Other characteristic features of Indian forms of *D. rugosa* are also quite in conformity with those of the type specimens, described by Koidzumi (1921).

Genus *Pyrsonympha* Leidy, 1877

1877. *Pyrsonympha* Leidy, *Proc. Acad. Nat. Sci. Phila.*, 29 : 148.

Diagnosis : Body pyriform, club-shaped or fusiform, posterior end rounded, body surface with 4-8 flagellar cords, arranged length-wise or slightly spirally; blepharoplast at anterior tip, often with short process of attachment; axostyle a narrow band, may be divided into two parts, hanging free in endoplasm and its posterior end free from body wall; nucleus large, usually pyriform, located at the anterior part of the body.

Remarks : De Mello (1921) was the first to record *Pyrsonympha* from India and described *Pyrsonympha grassii* from the Indian termite, *Leucotermes indicola* whose current valid name is *Heterotermes indicola*. According to Kirby (1926) it is an erroneous identification. He (*op. cit.*) synonymised this flagellate species under *Holomastigotoides grassii*. Subsequently Das (1972) described another species of *Pyrsonympha*, viz., *P. havilandi* from India from the termite *Cryptotermes havilandi*. It also constitutes an erroneous identification and is reidentified as *Tricercomitus divergens* (see Das, 1983).

In recent years four valid species of *Pyrsonympha*, viz., *P. grandis*, *P. modesta*, *P. rostrata* and *P. tirapi* have been recorded from Indian termites. Out of these, the first two have

been recovered from the host, *Reticulitermes assamensis* by Das *et al.* (1995, 2003, 2004, 2006a,b) and the remaining two are new species, described by Mukherjee and Maiti (1988) from the host, *Reticulitermes tirapi*.

**Key to the species of *Pyrsonympha*
reported from Indian termites**

1. Flagellar cords 4 in number in adult forms, body elongated and club-shaped, anterior part of which forming a rostrum, lateral margins of the body appearing serrated ..
..... *P. rostrata*
- Flagellar cords 8 in number in adult forms 2
2. Body pear-shaped, often twisted with anterior end bend back, resembling a screw, flagellar ridges distinct in twisted forms *P. modesta*
- Body club-shaped, anterior end not bend back as above 3
3. Body club-shaped, almost straight or slightly curved, flagellar cords running backwards spirally and becoming free after reaching the posterior end, axostyle thicker at anterior end and becoming gradually thinner posteriorly *P. grandis*
- Body club-shaped and sub-straight, flagellar cords encircling the anterior third of the body into a single turn, then running almost straight and parallel to the body and freely emerging posteriorly like flagella *P. tirapi*

**14. *Pyrsonympha grandis* Koidzumi, 1921
(Fig. 16)**

1921. *Pyrsonympha grandis* Koidzumi, *Parasitology*, 13 : 281.
1995. *Pyrsonympha grandis* : Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series* 4(Part 10) : 87. *Zool. Surv. India*.
2003. *Pyrsonympha grandis* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*. 9(Part 5) : 27. *Zool. Surv. India*.
- 2006a. *Pyrsonympha grandis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 27. *Zool. Surv. India*.
- 2006b. *Pyrsonympha grandis* : Das, Nandi and Chattopadhyay, *Fauna of Arunachal Pradesh, State Fauna Series*, 13(Part 2) : 30. *Zool. Surv. India*.

Type host : *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan.

Additional hosts : *Reticulitermes assamensis*; loc., India : Meghalaya, Nagaland and Sikkim; *Reticulitermes tirapi*, loc., India : Arunachal Pradesh.

Diagnosis : Body club-shaped, almost straight or slightly curved, broader posteriorly, anterior end pointed and posterior end round; flagellar cords 4 in young and 8 in mature

forms, running backwards spirally around the surface of the body; these cords becoming free after reaching the posterior end; axostyle well developed, thick at anterior end, becoming gradually slender towards the posterior end, hanging free posteriorly in the endoplasm, without having any attachment with the body wall; nucleus large, usually triangular in shape, located at anterior end and closely connected with both axostyle and body wall.

Morphometry : Morphometric data of *Pyrsonympha grandis* collected from Indian termites are presented in Table 18 and compared with those from the type hosts of Japan.

Table 18. Comparison of morphometric data of *P. grandis* from different hosts; measurements in μm

Characters	From <i>R. speratus</i> (type host)	Indian hosts	
		<i>R. assamensis</i>	<i>R. tirapi</i>
Length of the body	40–150	70.4 (67.2–83.2)	72 (58.5–90)
Breadth of the body	19–40	21 (19–22)	27 (20–34)
Ratio of body length to body width (average)	3.1 : 1	3.3 : 1	2.6 : 1
Length of nucleus	–	15(14–16)	17.5(15–19)
Breadth of nucleus	–	6.5(5–7)	6 (4–7)

Remarks : *Pyrsonympha grandis* collected from different termite hosts shows some variability in dimensions and length-breadth ratio. But, characteristic features of Indian specimens from both the hosts, *R. assamensis* and *R. tirapi* are quite in conformity with those described by Koidzumi (1921) from Japan termites.

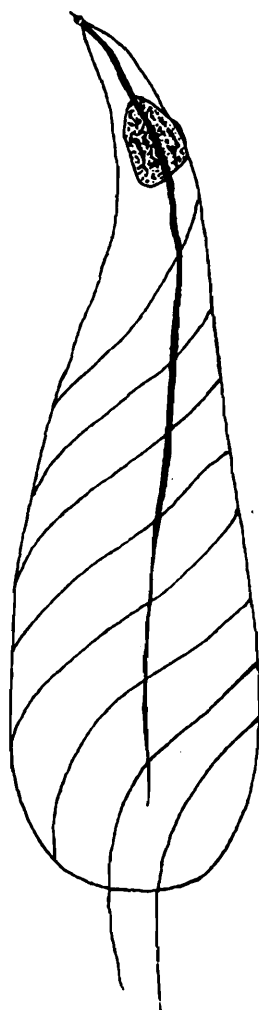
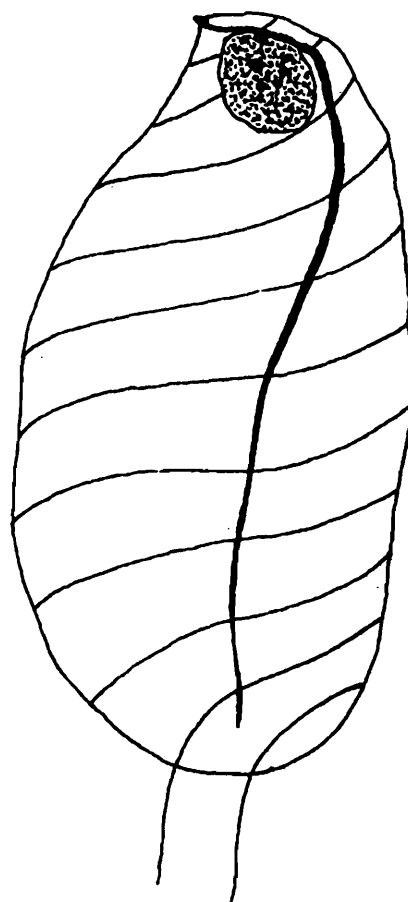
15. *Pyrsonympha modesta* Koidzumi, 1921 (Fig. 17)

1921. *Pyrsonympha modesta* Koidzumi, *Parasitology*, 13 : 289.
1995. *Pyrsonympha modesta* : Das, Mandal, Tiwari and Sarkar, *State Fauna Series, Fauna of Meghalaya*, 40(Part 10) : 87. *Zool. Surv. India*.
2003. *Pyrsonympha modesta* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 28. *Zool. Surv. India*.
- 2006a. *Pyrsonympha modesta* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 27. *Zool. Surv. India*.

Type host : *Reticulitermes lucifugus*; loc., Japan; *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan.

Additional host : *Reticulitermes assamensis*; loc., India : Meghalaya, Nagaland and Sikkim.

Diagnosis : Body usually pear-shaped with slightly pointed anterior end and, broad and round posterior end; length 40.7–59.3 μm with average 52.2 μm , width

Fig. 16 : *Pyrsonympha grandis* KoidzumiFig. 17 : *Pyrsonympha modesta* Koidzumi

24-37 μm with average 29 μm ; body often conspicuously twisted, with anterior end bend back resembling a screw; flagellar cords 8 in number in adult form and run almost straight; flagellar ridges on which flagellar cords situated appearing distinct in twisted forms; axostyle more slender than that of *Pyrsonympha grandis* and always single hanging freely in cytoplasm; nucleus oval or round, located at anterior end of the body.

Morphometry (Table 19) :

Table 19. Morphometric data of *P. modesta* from Indian termites

Characters	Range	Mean
Length of the body	40.7 – 59.3 μm	52.2 μm
Breadth of the body	24 – 37 μm	29 μm
Ratio of body-length to body-width (average)	–	1.7 : 1
Length of nucleus	9 – 12 μm	10.5 μm
Breadth of nucleus	7 – 8 μm	7.5 μm

Remarks : Koidzumi (1921) recorded the length of type specimens of *Pyrsonympha modesta* as 30-80 μm . He did not mention anything regarding the width and dimensions of nucleus of those specimens. So type specimens are considerably larger than Indian forms in maximum length. Koidzumi (*op. cit.*) observed both twisted and non-twisted forms of *P. modesta*. According to him, flagellar ridges appeared distinct in twisted forms and indistinct in non-twisted forms. In Indian specimens non-twisted forms of *P. modesta* are not recognised. As a matter of fact, its pear-shaped body with conspicuously screw-like twisted anterior end conveniently differentiates it from *P. grandis* and all other species of *Pyrsonympha*.

16. *Pyrsonympha rostrata* Mukherjee and Maiti, 1988
(Fig. 18)

1988. *Pyrsonympha rostrata* Mukherjee and Maiti, *Proc. Zool. Soc., Calcutta*, 38 : 41.

2006b. *Pyrsonympha rostrata* : Das, Nandi and Chattopadhyay, *Fauna of Arunachal Pradesh, State Fauna Series*, 13(Part 2) : 31. *Zool. Surv. India*

Type host : *Reticulitermes tirapi*; loc., India : Arunachal Pradesh

Diagnosis : Body elongated and club-shaped, anterior half gradually narrowing towards anterior end forming a rostrum; posterior half much broad with rounded posterior end; in some specimens anterior extremity bend slightly, giving the appearance of a hook; flagellar cords 4 in number, encircling the whole body with 3-4 complete turns; flagellar ridges almost indistinct; lateral margins of the body appearing serrated; axostyle resembling a slender cord, much thickened anteriorly and gradually becoming thinner posteriorly, hanging free in the cytoplasm, extending up to the middle of the body, sometimes beyond the middle, even occasionally up to posterior end; nucleus small and round and situated almost at or near the middle of the body, just nearly at the commencement of the rostrum.

Morphometry (Table 20) :

Table 20. Morphometric data of *P. rostrata* (as per original description)

Characters	Range	Mean
Length of the body	62.4 – 96 μm	79.8 μm
Breadth of the body	16.8 – 30 μm	21.8 μm
Ratio of body-length to – body-width (average)	–	3.6 : 1
Length of nucleus	4.8 – 8.4 μm	6.4 μm
Breadth of nucleus	2.4 – 8.4 μm	4.6 μm

Remarks : *Pyrsonympha rostrata* has not been recorded till date since its first description by Mukherjee and Maiti (1988). Since type locality of this species is in Arunachal Pradesh, Das *et al.* (2006b) included it in the State Fauna Series of Arunachal Pradesh published by the Zoological Survey of India. The diagnosis of *P. rostrata* given in the present communication is based on its original description (Mukherjee and Maiti, *op. cit.*).

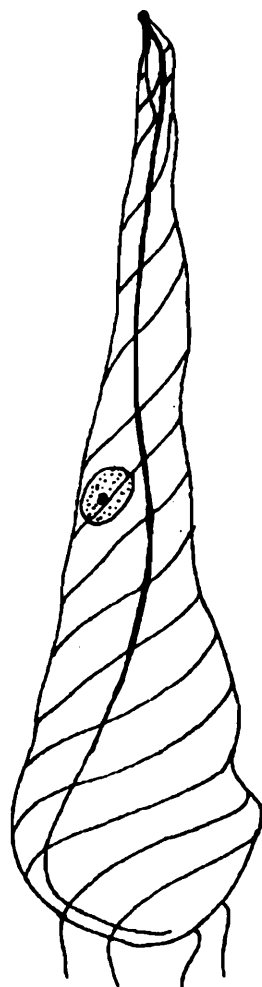


Fig. 18 : *Pyrrsonympha rostrata* Mukherjee & Maiti

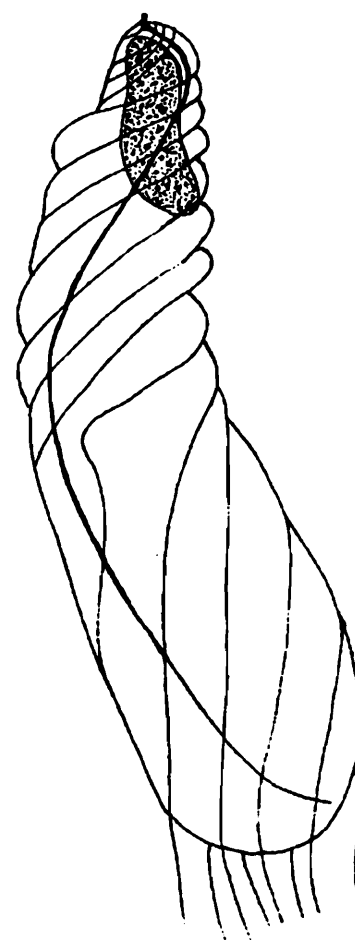


Fig. 19 : *Pyrrsonympha tirapi* Mukherjee & Maiti

17. *Pyrrsonympha tirapi* Mukherjee and Maiti, 1988
(Fig. 19)

1988. *Pyrrsonympha tirapi* Mukherjee and Maiti, *Proc. Zool. Soc., Calcutta*, 38 : 38.

2006b. *Pyrrsonympha tirapi* : Das, Nandi and Chattopadhyay, *Fauna of Arunachal Pradesh, State Fauna Series*, 13(Part 2) : 31. *Zool. Surv. India*.

Type host : *Reticulitermes tirapi*; loc., India : Arunachal Pradesh.

Diagnosis : Body club-shaped and sub-straight with pointed anterior end and considerably broader posterior end; flagellar cords 8 in number in adult forms, encircling the anterior third of the body, then running straight and parallel to the body emerging from posterior end of the body resembling free flagella; flagellar ridges distinct at anterior third of the body, but lateral margin appearing almost smooth posteriorly; axostyle resembling a narrow band of almost uniform thickness, originating from the centropharoplast at anterior end, running posteriorly through the middle of the body terminating at posterior sixth of the body and hanging freely in the endoplasm; nucleus large, spherical to kidney shaped, located near the anterior end of the body.

Morphometry (Table 21) :**Table 21.** Morphometric data of *P. tirapi* (as per original description)

Characters	Range	Mean
Length of the body	44.4 – 96 μm	68.1 μm
Breadth of the body	12 – 30 μm	17.6 μm
Ratio of body-length to body-width (average)	–	3.8 : 1
Length of nucleus	8.4 – 18 μm	12.5 μm
Breadth of nucleus	3.6 – 11 μm	6.6 μm

Remarks : Mukherjee and Maiti (1988) recorded the mensural data of both young and adult forms of *Pyrsonympha tirapi*. From length-breadth ratio it is quite evident that this species is slender in form. Das *et al.* (2006b) included this species in the State Fauna Series of Arunachal Pradesh, published by the Zoological Survey of India since type locality of the species is in Arunachal Pradesh. Diagnosis of this species given in the present communication is based on the original description of this species (Mukherjee and Maiti, *op. cit.*)

Order TRICHOMONADIDA Kirby, 1947

1947. Trichomonadida Kirby, 1947. *J. Parasitol.*, 33 : 215.

1963. Trichomonadida : Honigberg, *J. Protozool.*, 10 : 23.

Diagnosis : Typically 4-6 flagella, of which one flagellum recurrent per mastigont system; recurrent flagellum free or with proximal part or entire length adherent to the body surface; undulating membrane may or may not be present in association with adherent part of flagellum; mastigont associated with a nucleus, an axostyle and a parabasal body, although in some multinucleated forms nucleus may be dissociated from the complex; polymonad organisation in one family.

**Key to the families of the order TRICHOMONADIDA
reported from Indian termites**

1. Multinucleate, each nucleus associated with a blepharoplast, a parabasal body, an axostyle, a cresta and four flagella Family CALONYMPHIDAE
- Uninucleate, each nucleus associated with structures as above 2
2. With an undulating membrane and costa, 4 free anterior flagella, fifth flagellum along the outer margin of undulating membrane Family TRICHOMONADIDAE
- Without any undulating membrane 3

3. With cresta, three anterior flagella, one trailing flagellum generally adherent in part to the body surface Family DEVESCOVINIDAE
- Without any cresta or costa, 2-5 free anterior flagella; trailing flagellum free from surface or adherent Family MONOCERCOMONADIDAE

Family MONOCERCOMONADIDAE Kirby, 1944

1944. Monocercomonadidae Kirby, J. Morphol., 75 : 364.

Diagnosis : Recurrent flagellum generally adherent in part to the body surface, but sometimes free; no cresta or costa and no undulating membrane.

Key to the genera of the family MONOCERCOMONADIDAE recorded from Indian termites

1. Three to four flagella, of which one recurrent Genus *Tricercomitus*
- Six flagella, of which one recurrent Genus *Hexamastix*

Genus *Hexamastix* Alexeieff, 1912 (Fig. 20)

1912. *Hexamastix* Alexeieff, Zool. Anz., 39 : 679.

1926. *Hexamastix* : Grassi, Arch. Zool. Exp. Gen., 85 : 345.

1930. *Hexamastix* : Kirby, Univ. Calif. Publ. Zool., 33 : 416.

Diagnosis : Six flagella, of which one recurrent; axostyle often conspicuous; parabasal body bacilliform and prominent; no undulating membrane.

18. *Hexamastix indica* De Mello, 1946 (Figs. 21–22)

1946. *Hexamastix indica* De Mello, An. Inst. Med. trop., 3 : 42.

1983. *Hexamastix indica* : Das, Proc. Symp. Host Environ. Zool. Surv. India : 42.

Type host : *Cryptotermes* sp.; loc., India : Goa.

Diagnosis : Body oval, rather pyriform with posterior tip projecting at fine point; however, round forms (without any pointed tip) also present; oval forms 12 - 26 μm in length, 8 - 12 μm in width; protruding part 3 - 6 μm ; round forms 12 μm x 12 μm in dimensions; a cytostome present in the form of a narrow longitudinal split, bordering supralateral contour of the body; blepharoplast located at anterior end; trailing flagellum single, slightly thicker and longer than anterior flagella; axostyle more or less tubular, not continuing beyond the protruding part of the body, though a linear filament narrowing uniformly up to its distal tip; parabasal body pyriform or club-shaped, lying very close to the nucleus; nucleus oval or circular in shape, 2.5–5 μm in diameter.

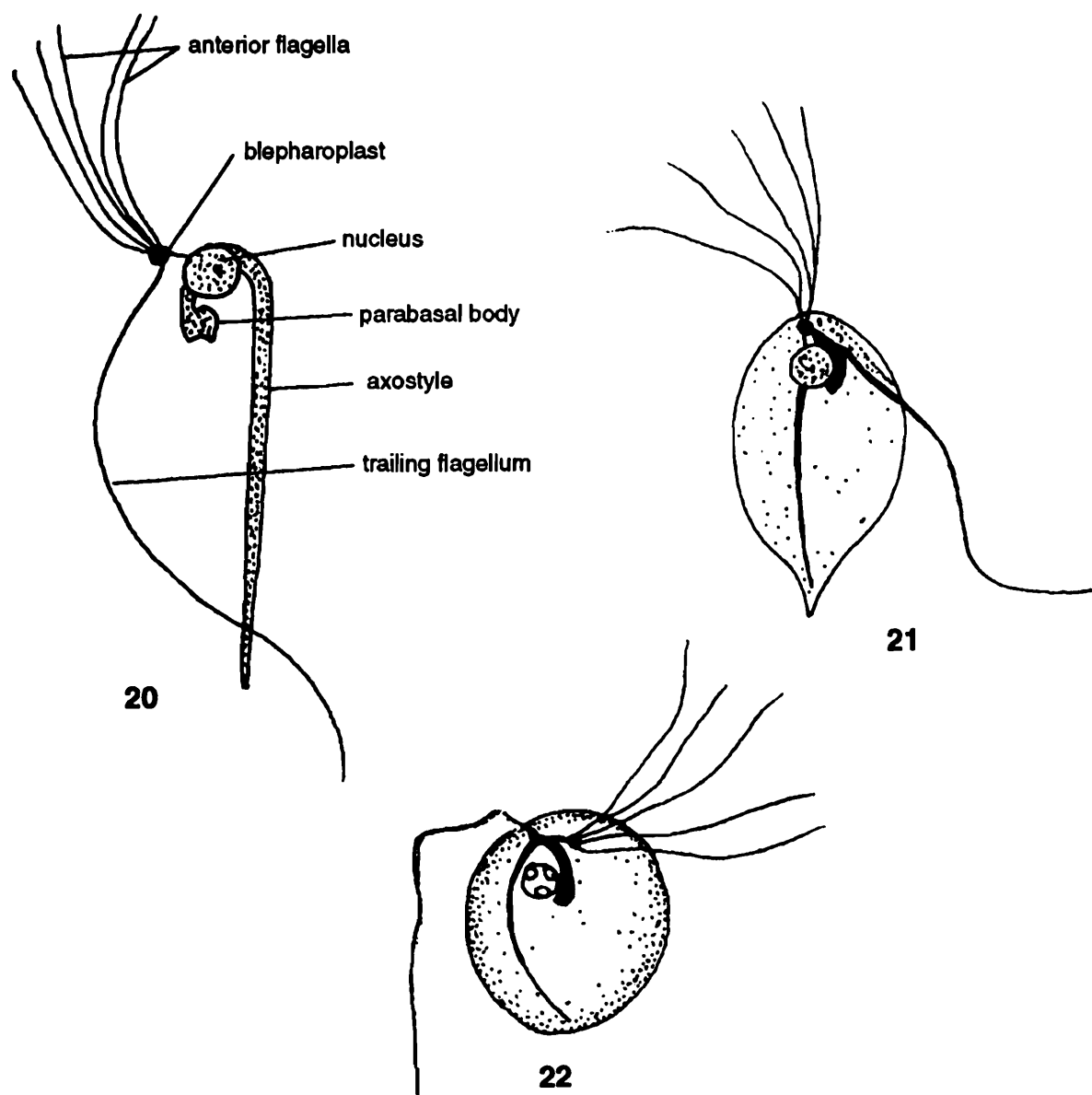


Fig. 20. Showing nucleus and its associated organelles in the genus *Hexamastix* Alexeieff;
Figs. 21-22 : Different forms of *Hexamastix indica* De Mello (Fig. 21. Oval form; Fig. 22. Round form)

Remarks : De Mello (1946) described *Hexamastix indica* from some unidentified species of *Cryptotermes* of India. Since then, no further record of this species has been made. Das (1983) incorporated this species in a checklist of termite flagellates of India, based on this record. The present diagnosis of *H. indica* is also based on its original description of De Mello (*op. cit.*)

Genus *Tricercomitus* Kriby, 1930
 (Fig. 23)

1930. *Tricercomitus* Kirby, Univ. Calif. Publ. Zool., 33 : 395.

Diagnosis : Small with three anterior flagella (two, after division in some cases) and one stout and very long recurrent flagellum, 2 to 10 times longer than anterior flagella; recurrent

flagellum adhering to the body surface until close to posterior end; a relatively large blepharoplast to which a parabasal body and a very slender axostyle attached; nucleus located nearer to anterior end; chromatin mostly collected into several relatively large peripheral granules; no endosome.

Key to the species of *Tricercomitus* reported from Indian termites

1. Body pyriform, 8-17 μm $\times$ 6-10 μm in dimensions, a parablepharoplastic bar emerging from blepharoplast *T. damasmorai*
- Body oval or roundish, parablepharoplastic bar absent 2
2. Body oval, often more rounded posteriorly, 3-8 μm $\times$ 2-5.5 μm in dimension, axostyle fine but very distinct *T. divergens*
- Body ovoid or roundish, 5-14 μm $\times$ 2.5 – 9 μm in dimensions, axostyle difficult to detect *T. sockeyi*

19. *Tricercomitus divergens* Kirby, 1930 (Figs. 24 – 27)

1930. *Tricercomitus divergens* Kirby, Univ. Calif. Publ. Zool., 33 : 403.

1983. *Tricercomitus divergens* : Das, Proc. Symp. Host Environ. Zool. Surv. India : 42.

1993. *Tricercomitus divergens* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3 (Part 12) : 486. Zool. Surv. India

Type host : *Marginitermes hubbardi* (= *Kaloterme hubbardi*); loc., California, Arizona.

Additional hosts : *Calcaritermes brevicollis*; *Calcaritermes emerginicolis*; *Cryptotermes brevis*; loc., Porto Rico; *Cryptotermes caviformis*; *Cryptotermes domesticus*; loc., Malaysia, (= *Cryptotermes breviarticulatus*; loc., Panama & = *Cryptotermes hermsi*; loc., Fanning Island); *Cryptotermes dudleyi*, loc., Canal zone; *Cryptotermes havilandi*; loc., India : West Bengal; *Cryptotermes longicollis*; *Cryptotermes piceatus*; loc., Hawaii; *Cryptotermes* sp. (= *Coptotermes heimi sensu De Mello*); loc., India : Goa; *Cryptotermes* sp. *sensu* Krishna (= *Kaloterme* sp. *sensu* Kirby); loc., Galapagos Island; *Glyptotermes angustus*; *Glyptotermes contracticornis*; *Incisitermes banksi*; *Incisitermes immigrans*; *Incisitermes marginipennis*; *Incisitermes minor*; *Incisitermes tobogae*; *Incisitermes* sp. (= *Kaloterme* sp. *sensu* Kirby); loc., Costa Rica; *Incisitermes* sp. (= *Kaloterme* sp. *sensu* Kirby); loc., Galapagos Island; *Kaloterme flavicollis*; *Neoterme andamanensis*; loc., India : South Andaman; *Neoterme connexus*; *Neoterme holmgreni*; *Paraneoterme simplicicornis*; *Rugiterme kirbyi*; *Rugiterme panamae*; *Rugiterme rugosus*.

Diagnosis : Oval in shape, but usually more rounded posteriorly; 3-8 μm in length, 2.5-5.5 μm in width; nucleus round, 2-2.5 μm in diameter and located near the anterior end of the body; recurrent flagellum usually very long but sometimes little shorter and stouter; axostyle fine but distinct, extending from blepharoplast to, and in some forms, beyond the posterior end of the body.

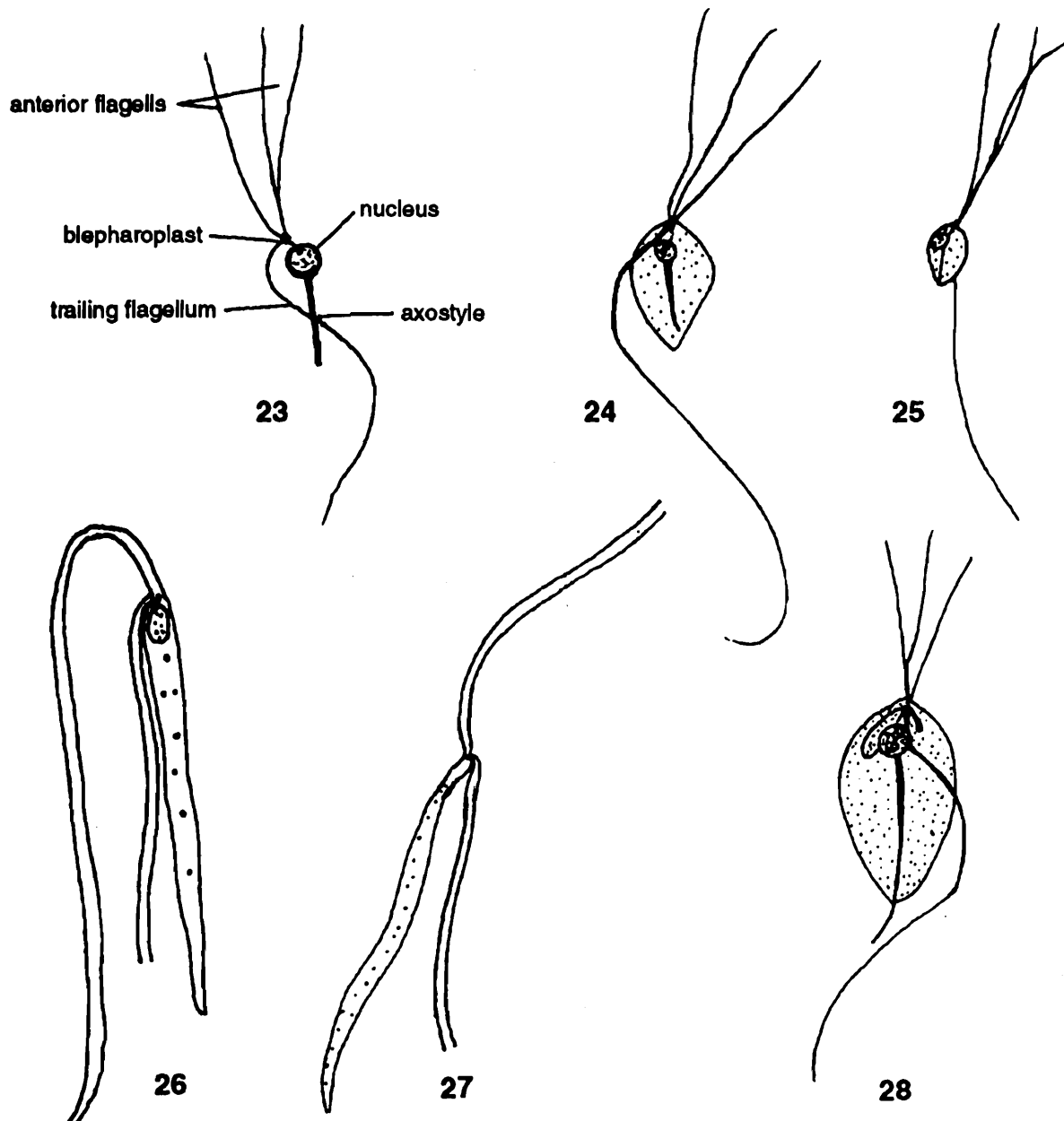


Fig. 23. Showing nucleus and its associated organelles in the genus *Tricercomitus* Kirby; **Figs. 24-27 :** Different forms of *Tricercomitus divergens* Kirby. (**Figs. 24-25** oval forms; **Figs. 26-27;** Greatly enlarged forms from recently moulted nymphs of termite host (after Kirby, 1930); **Fig. 28 :** *Tricercomitus damasmorai* De Mello

Remarks : *Tricercomitus divergens* is widely distributed and recovered from 29 species of lower termites as listed earlier. All these termites belong to Kalotermitidae.

During the present study *T. divergens* has been collected from the guts of Indian termite, *Cryptotermes havilandi*. Das *et al.* (1987a) studied this species from a Malaysian termite, *Cryptotermes domesticus*.

Kirby (1930) observed some forms with shorter and stouter recurrent flagellum. But, all the Indian forms and Malaysian forms of *T. divergens* studied by the present author (Das, Misra and Tho, 1987) are found to possess very long recurrent flagellum as given

in its generic diagnosis. Kirby (1930) recorded the length of this species as 3-6 μm only and occasionally 9 μm and did not give any other mensural data. Kirby (*op. cit.*) also stated that sometimes in the recently molted nymphs of the termite hosts greatly elongated forms of *T. divergens* measuring 25-30 μm were also found (Figs. 26, 27).

Morphometry (Table 22) :

Mensural data of *T. divergens* recorded by Kirby (1930) are compared with those of specimens collected by the present author from Indian and Malaysian termites in Table 22.

Table 22. Comparison of morphometric data of *T. divergens* collected from type host with those of Indian and Malaysia forms

Characters	From type host, <i>M. hubbardi</i>	From Indian host <i>Cr. havilandi</i>	From Malaysian host <i>Cr. domesticus</i>
Length of the body	3-6 μm (occasionally 9 μm)	5.8 (3-8) μm	5-7 μm
Breadth of the body	—	3.5 (2.5-5.5) μm	3-5 μm
Ratio of body-length to body-width (average)	—	1.6 : 1	1.5 : 1
Diameter of nucleus	—	2.3 (2-2.5) μm	2-2.5 μm
Length of recurrent flagellum	—	14-20 μm	12-15 μm

De Mello (1946) recorded this species from India from the termite host *Coptotermes heimi*. His forms were elongated with anterior end roundish or projected forward "giving the appearance of the avicular forms of Duboscq and Grassi" (1924), trailing flagellum cercomonadic, slightly stouter and axostyle fairly visible. However, De Mello (*op. cit.*) did not record the dimension of his specimens.

Occurrence of *T. divergens* from a rhinotermitid termite, *Coptotermes heimi* (*loc. cit.* De Mello, 1946, p. 73) appears to be confusing. In every probability this host species is some kalotermitid termite. In one occasion De Mello (1953) himself stated that the host he had used for the study as *Coptotermes. heimi* was wrongly identified.

21. *Tricercomitus damasmorai* De Mello, 1946

(Fig. 28)

1946. *Tricercomitus damasmorai* De Mello, *An. Inst. Med. Trop.*, 3 : 48.

1983. *Tricercomitus damasmorai* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 42.

Type host : *Cryptotermes* sp.; *loc.*, India : Goa.

Diagnosis : Body pyriform, posterior end pointed or entirely round; length 8-17 μm with average 11.7 μm and width 6-10 μm with average 8.2 μm ; blepharoplast large appearing as a single unit and located near the anterior end of the body; anterior flagella 3 in number, very delicate often united in a bundle and diverging only at the tip; recurrent flagellum single, slightly thicker, lying very close to the body in cercomonadic forms, sometimes entirely free; axostyle thin, more or less distinct within the body in the form of a very narrow tubule, emerging from the blepharoplast and protruding out to a long distance from the posterior end of the body as a more or less sinuous thread; axostyle not protruding in some rounded forms; parabasal body claviform, emerging from the blepharoplast and located very close to the nucleus; parablepharoplastic bar 2-3 μm long, emerging from the blepharoplast; nucleus roundish or oval, 2-3 μm (occasionally 5 μm) in diameter, located near the blepharoplast; a series of chromatin granules scattered within the nucleus.

Remarks : De Mello (1946) described *Tricercomitus damasmorai* from the gut of some unidentified species of *Cryptotermes* from India. He observed an entirely "new structure" the "parablepharoplast" in the species. It is a strongly "siderophile rodlet" and such structure has not been described in any other species of *Tricercomitus*.

After its first description, *T. damasmorai* has not been collected so far. Based on De Mello's record, Das (1983) incorporated this species in the checklist of termite flagellates of India. The present diagnosis of *T. damasmorai* is also based on its original description.

21. *Tricercomitus sokheyi* De Mello, 1942

1942. *Tricercomitus sokheyi* De Mello, Arqu. Esc. Med. Cirug., Nova Goa, Ser. A. 18 : 268.

1983. *Tricercomitus sokheyi* : Das, Proc. Symp. Host Environ. zool. Surv. India : 42.

Type host : *Anacanthotermes viarum*; (= *Hodotermes viarum*); loc., India : Tamil Nadu (Coimbatore).

Diagnosis : Body ovoid or roundish, length 5-14 μm , width 2.5-9 μm ; anterior flagella 2 in number, recurrent flagellum single and slightly longer and thicker than anterior flagella, lying very close to the body in cercomonadic forms, but sometimes entirely free, just like the preceding species; parabasal body claviform starting from a special granule and connected with a blepharoplast by a fine rhizoplast; axostyle difficult to detect and not protruding out from the body.

Remarks : *Tricercomitus sokheyi* is the only species of *Tricercomitus* which was reported from the gut of host family Hodotermitidae. All the remaining species of this genus have been recorded from the termite family Kalotermitidae. Since the first description of this species by De Mello (1942b) it has not been reported till date. Das (1983) incorporated this species in the checklist of termite flagellates of India based on the above report. Diagnosis of *T. sokheyi* presented here is based on its original description by De Mello (1942).

Family DEVESCOVINIDAE Doflein, 1911

1911. Devescovicidae Doflein, *Lehrbuch der Protozoenkunde*, 3rd Edition, Jena, Fischer, p. 537.

1946. Devescovicidae emend. Kirby, *Univ. Calif. Publ. Zool.*, 53 : 190.

Diagnosis : Usually three anterior flagella and a trailing flagellum, an enlarged cresta located near the base of trailing flagellum; cresta becoming a large internal membrane in some species; trailing flagellum lightly adhering to the body surface along the edge of cresta; axostyle conspicuous; parabasal body of various forms; single nucleus at anterior end; no undulating membrane.

Key to the subfamilies of the family Devescovicidae reported from Indian termites

1. Cresta becoming a large internal membrane, in life history phase amoeboid form present subfamily GIGANTOMONADINAE
- Cresta a flattened, more or less elongated subtriangular structure, not becoming any internal membrane, in life history only flagellate phase but no amoeboid phase present Subfamily DEVESCOVININAE

Subfamily DEVESCOVININAE Doflein, 1911

1911. Devescovicinae Doflein, *Lehrbuch der Protozoenkunde*, 3rd edition, Jena, Fischer, p.537.

1931. Devescovicinae emend. Kirby, *Univ. Calif. Publ. Zool.*, 36 : 172.

Diagnosis : Flagellate phase, the only active phase with fully developed organelles; dividing with distribution of some organelles to daughter organelle.

Key to the genera of the subfamily Devescovicinae reported from Indian termites

1. Trailing flagellum slender or resembling a cord or ribbon and equal to or longer than the body 2
- Trailing flagellum slender and shorter than the body, parabasal body well developed and coiled round the axostyle in 2-20 turns Genus *Caduceia*
2. Trailing flagellum one to one and half times the body length 3
- Trailing flagellum more than two times the body length, cresta usually slender, parabasal body not coiled around the axostyle Genus *Foaina*
3. Body very slender, length-breadth ratio may be 12 : 1, an antero-lateral indentation making off the region of the papilla, trailing flagellum about the body length and as slender as anterior flagella Genus *Polymastigoides*

- Body elongated, usually pointed posteriorly, trailing flagellum usually longer than the body often about one and a half times, differing in diameter ranging from a slender cord to a broad ribbon genus *Devescovina*

Genus *Devescovina* Foa, 1905

(Fig. 29)

1905. *Devescovina* Foa, Atti. R. Accad. Lincei, (5), 14, sem 2 : 546.

1941. *Devescovina* : Kirby, Univ. Calif. Publ. Zool., 45 : 53.

Diagnosis : Body elongated, usually pointed posteriorly; three anterior flagella about the length of the body and one trailing flagellum differing in diameter in different species, ranging from a slender cord to a broad ribbon of about 3 μm width with filamentous anterior and terminal portions; parabasal body spiralled around the trunk of the axostyle or posterior part of nucleus half to five turns, rarely more; cresta small to moderate size, subtriangular in shape, with antero-medial edge shortest in most species; parabasal usually simple, without any branch or distal element; trunk of axostyle usually tapering to a filamentous posterior end, completely enclosed in cytoplasm, occasionally stouter most of its length and exceptionally projecting outside the posterior end of the body; nucleus ellipsoidal or ovoidal, longer diameter usually in the direction of the longitudinal axis of the body.

Remarks : De Mello and De Brito (1929b) were the first to record the genus *Devescovina* from Indian termites. They (*op. cit.*) described 3 species, *D. cometoides*, *D. damanensis* and *D. kirbyi* from the termite host, *Coptotermes heimi*. In a monograph of *Devescovina*, Kirby (1941a) retained the first species and synonymised the latter two under *D. lemniscata* and *Foaina nana* respectively. Simultaneously De Mello (1941) revised the family Devescovinidae and retained all his above species as valid, without consulting Kirby's above cited work. In his publication De Mello (*op. cit.*) stated that he had received a private letter from

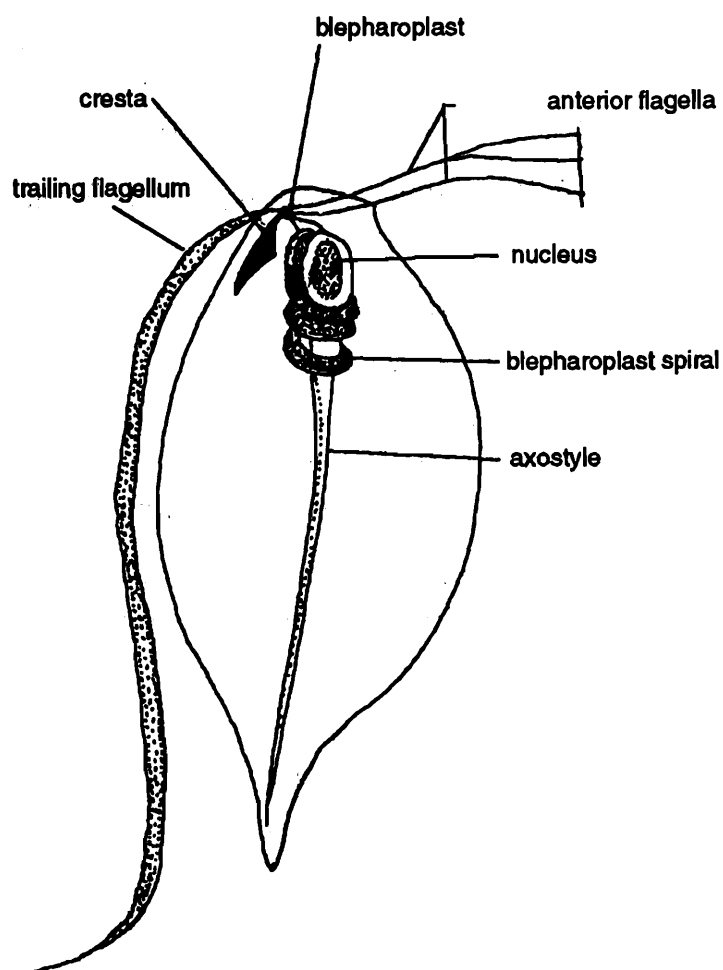


Fig. 29 : Genus *Devescovina* Foa (semidiagrammatic), showing its salient taxonomic features; anterior flagella and trailing flagellum partly shown

Kirby mentioning "*D. kirbyi* is rather a *Janickiella*" In a subsequent publication Das (1974b) retained Kirby's synonymy regarding Indian species of *Devescovina*, the reasons of which were discussed in details in that paper. Mention is to be made here that in De Mello's above work identification of termite host as *Coptotermes heimi* was not accurate as discussed by Kirby (1947) and Das (1974b). In every probability, this host belonged to some kalotermitid termite. De Mello (1953) also confessed that the host he had used for study was wrongly identified.

In 1946 De Mello described another species of *Devescovina*, viz., *D. gyrinoides* from the gut of *Cryptotermes* sp. Subsequently Das (1974b) recorded 3 species of *Devescovinas*, viz., *D. glabra*, *D. lemniscata* and *D. steini* from the host, *Cryptotermes havilandi*. Among these, the last one was a new species. During the present study *D. arta* and *D. parasoma* have been collected from *Glyptotermes caudomunitus* and *Neotermes andamanensis* respectively. In all, 7 species of *Devescovina* have been recorded from Indian termites.

**Key to the species of the genus *Devescovina*
reported from Indian termites**

1. Trailing flagellum resembling a stout cord or very narrow ribbon 2
 - Trailing flagellum resembling a broad ribbon 4
2. Cresta small (usually under 4 μ m), its antero-medial and postero-medial edges almost equal in length *D. cometoides*
 - Cresta longer (more than 4 μ m), its postero-medial edge longer than antero-medial 3
3. Trailing flagellum a moderately stout cord or a very narrow ribbon, parabasal body turned around the axostyle usually in one and a half turn, trunk of axostyle filamentous in its posterior part and generally enclosed in cytoplasm *D. glabra*
 - Trailing flagellum a very narrow ribbon, parabasal body usually turned around the axostyle in 3-4 turns, trunk of axostyle stouter in its posterior part often projecting from the cytostome *D. parasoma*
4. Cresta small (usually under 4 μ m), its antero-medial edge almost equal to its external edge, axostyle usually tapering to a slender filament *D. arta*
 - Cresta usually more than 5 μ m in length 5
5. Body ovoid usually with a tail-like appendage giving it "the appearance of a tadpole", parabasal body about half turn, axostyle stout, straight, sometime bent, and in most cases extruding outside the body *D. gyrinoides*
 - Body without having any tail-like appendage as above 6
6. Cresta 8-9 μ m in length, axostyle stout and straight, protruding from the posterior end of the body *D. steini*

- Cresta more than 10 μm , axostyle bent and enclosed within the cytoplasm
 *D. lemniscata*

22. *Devescovina arta* Kirby, 1941

(Fig. 30)

1941. *Devescovina arta* Kirby, Univ. Calif. Publ. Zool., 45 : 52.

Type host : *Glyptotermes angustus* (= *Glyptotermes barbouri*); loc., Panama.

Additional hosts : *Glyptotermes minutus*; loc., Sri Lanka; *Neotermes andamanensis*; loc., India : South Andaman; *Neotermes castaneus*; loc., Florida; *Glyptotermes caudomunitus*; loc., India : Bihar, West Bengal.

Diagnosis : Body elongated with pointed posterior end; anterior flagella slender, three in number, almost equal to the length of the body; trailing flagellum a broad ribbon and about one to one and a half times the body length; cresta small, 2.5 (2-3) μm in length; its antero-medial edge as long as its external edge; its postero-medial edge shortest, about 1 μm in length, parabasal turns 1-2 times (usually one and a half times) around the axostyle in close spiral tapering posteriorly to a blunt end; axostyle comparatively stout at anterior end, tapering to a slender filament, often curved or sinuous in its course through the cytoplasm, nucleus oval, usually lying very close to the blepharoplast.

Morphometry :

Morphometry of Indian population of *Devescovina arta* is presented in Table 23 and compared with that of type specimens.

Table 23. Comparison of morphometric data of *D. arta* of Indian population with those of type specimens (measurements in μm)

Characters	<i>G. angustus</i> (type host), Panama	Indian hosts	
		<i>G. caudomunitus</i>	<i>N. andamanensis</i>
Body length	42 (32-53)	40.5 (30.2-49.5)	35 (30-45.5)
Body width	8 (6-12)	8.5 (6-12)	8.5 (6-10)
Ratio of body length to body width (average)	5.2 : 1	4.7 : 1	4.1 : 1
Length of nucleus	4.4 (4-4.9)	4 (3.5-4.8)	4.5 (3.5-5)
Breadth of nucleus	3 (2.7-3.6)	2.9 (2.6-3.5)	2.5 (3-4.5)
Length of cresta	2.8 (2-3.3)	2.5 (2-3)	2.5 (2-4)
Length of trailing flagellum	-	40-45	37-51
No. of parabasal turns	1-2 turns (usually 1½)	1-2 turns (usually 1½)	1-2 turns (usually 1½)

Remarks : From Table 23 it is quite evident that the mensural data of Indian specimens of *D. arta* are well within the range of those of the type host. This species is considerably slender with body length about 4 to 5 times the body width. Kirby (1941a) observed some unusually large specimens, 50-73 μm in length, 10-20 μm in width and trailing flagellum 60-75 μm in length. Such large specimens were not observed in the guts of Indian termites.

The cresta of this species is comparatively small. Its shape is characteristic as its antero-medial edge is almost equal to its external edge and postero-medial edge is the shortest. But, in most other species of *Devescovina* antero-medial edge is the shortest of the three edges. However, in the shape of the cresta *D. arta* resembles *D. lepida*. But, the former differs from the latter, being considerably slender (length-breadth ratio of *D. arta* 4-5 : 1 whereas that of *D. lepida* in the type host 2.6 : 1). Parabasal body of both the species also considerably differs. Posterior end of the parabasal body of *D. arta* tapers to a blunt point and its longitudinal part slender. On the other hand, posterior end of the parabasal body of *D. lepida* is broad and rounded and its longitudinal part stout.

In characteristic features Indian specimens of *D. arta* closely resemble its type specimens as described by Kirby (1941a).

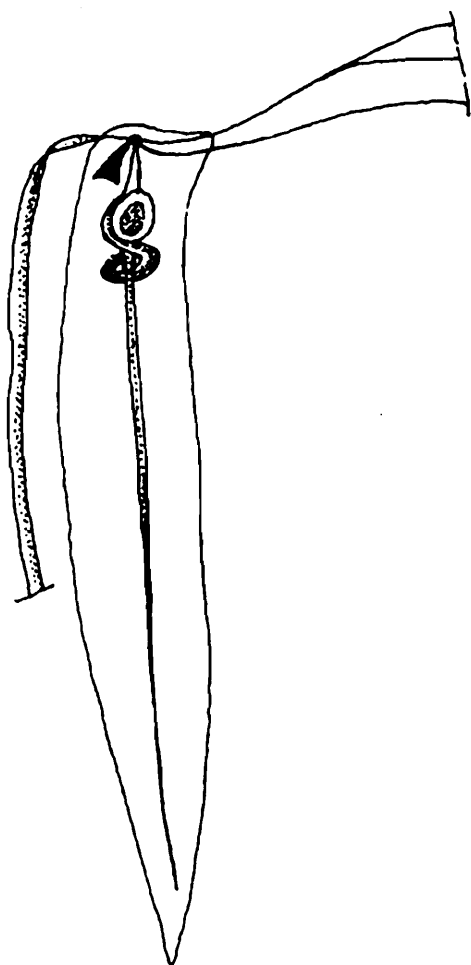


Fig. 30 : *Devescovina arta* Kirby; anterior flagella and trailing flagellum partly shown

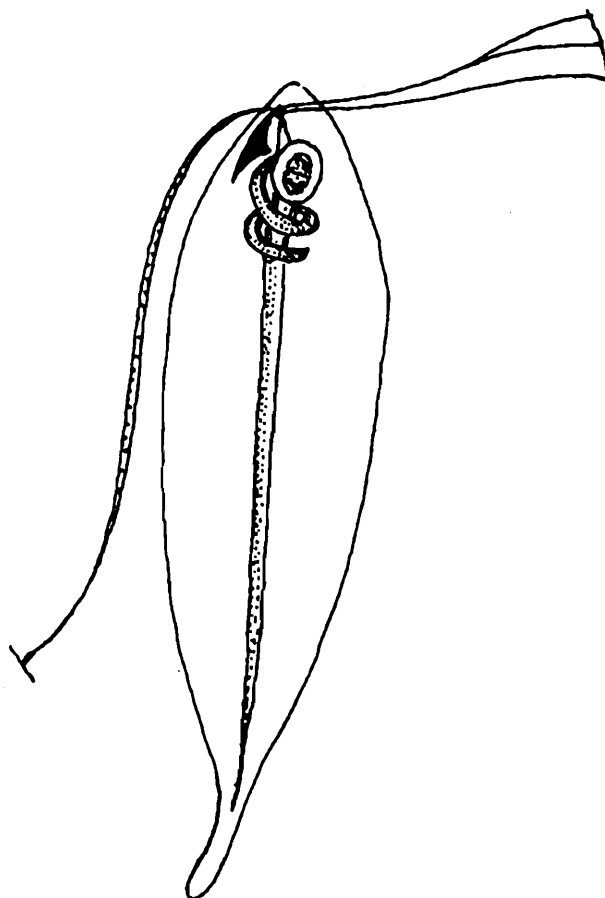


Fig. 31 : *Devescovina cometoides* De Mello & De Brito; anterior flagella and trailing flagellum partly shown

23. *Devescovina cometoides* De Mello and De Brito, 1929

(Fig. 31)

1929. *Devescovina cometoides* De Mello and De Brito, C. R. Soc. Biol., 101 : 394. (Name of the species mentioned only).
1929. *Devescovina cometoides* (partim,) : De Mello and De Brito, Arqu. ESc. Med. Cirug, Nôva Goa (A), fasc. 5 : 699.
1941. *Devescovina cometoides* : Kirby, Univ. Calif. Publ. Zool., 45 : 32.
1983. *Devescovina cometoides* : Das, Proc. Symp. Host Environ. zool. Surv. India : 42.

Type host : *Kaloterme*s sp., loc., India : Daman.

Additional hosts : *Cryptoterme*s *brevis*, loc., Brazil; *Cryptoterme*s *dudleyi*, loc., Java, Panama, Sri Lanka; *Cryptoterme*s sp., loc., Madagascar, Mauritius, Tanganyika territory; *Glyptoterme*s *caudomunitus*, loc., India : Bihar and West Bengal; *Glyptoterme*s *dilatatus*, loc., Sri Lanka; *Glyptoterme*s *conclavifrons* (= *Glyptoterme*s sp.); loc., Java; *Incisiterme*s *repandus* (= *Kaloterme*s *repandus*); loc., Figi Island.

Diagnosis : Body elongated with gradually pointed posterior end; in some specimens posterior part of the body tail-like; its length ranging from 30-52.7 μ m, width 8.3-15.5 μ m; anterior flagella slender, three in number, almost equal to the length of the body; trailing flagellum mostly resembling a stout cord and occasionally a very narrow band below 0.5 μ m in width and 45-65 μ m in length; cresta small, 2.5-3.9 μ m long, its antero-medial edge 1.5-2 μ m, almost equal to its postero-medial edge; parabasal body coiled closely around the axostyle in 1-2 turns, posterior part of which tapering to a blunt point; first turn of parabasal coiled around the trunk of the axostyle, not around the posterior end of the nucleus; axostyle stout at anterior end, gradually becoming slender towards posterior end and never extruding outside from the posterior end of the body; nucleus ovoidal, 4.8-7 μ m x 3.4-4.6 μ m in dimension, lying close to the blepharoplast.

Morphometry : Morphometric data of Indian specimens are presented in Table 24 and compared with those of the specimens reported from the termite hosts of outside countries.

Remarks : De Mello and De Brito (1929b) described *Devescovina cometoides* for the first time from the termite *Kaloterme*s sp., collected from Daman, India. They (*op. cit.*) recognised two forms : one is long and pisciform (their species B) and the other is stouter (their species A) and the dimension of the combined forms 30-100 μ m x 3-26 μ m. After critical examination of the type slides of De Mello and De Brito, Kirby (1941a) retained their first form as *D. cometoides* and but he identified the second form as *D. lemniscata* which has been dealt with later in this communication. Kirby (*op. cit.*) also presented the mensural data of the slender forms from original type slides of *D. lemniscata* (see Table 24).

D. cometoides has been collected from several termite hosts as mentioned above. All these host species belong to the family Kalotermitidae. During the present study this species has been collected from India from the host *Glyptoterme*s *caudomunitus*.

Table 24. Comparison of morphometric data of *D. cometoides* collected from different hosts; (measurements in μm)

Characters	From Indian hosts		From hosts of other countries		
	<i>Kalotermes</i> sp.* (Type host)	<i>Glyptotermes</i> <i>caudomunitus</i>	<i>Glyptotermes</i> <i>dilatatus</i>	<i>Incisitermes</i> <i>repundus</i>	<i>Cryptotermes</i> <i>dudleyi</i>
Body length	43(35-58)	41.2(30-52.7)	35(24-48)	49(39-61)	44(29-64)
Body width	9.5(6-17)	12.5(8.3-15.5)	10.5(7-14)	15(10-22)	14(11-21)
Ratio of body length to body width(average)	4.5:1	3.4:1	3.3:1	3.2:1	3.1:1
Length of nucleus	5-6	5.2(4.8-7)	4.5(3.8-4.8)	6.6(5.3-8)	4.7(4.2-5.6)
Breadth of nucleus	2.5-3.5	3.8(3.4-4.6)	2.7(2.2-3.3)	3.9(3.3-4.7)	3(2.4-3.7)
Length of cresta	3(2.5-3.5)	3(2.5-3.9)	3.2(2.5-3.6)	3.2(2.7-4)	3(2.5-3.7)
Length of trailing flagellum	60-70	45-65	—	60-70	—
No. of parabasal turns	1-2 turns	1-2 turns	1-2 turns	2(1¾ – 2¾)	1-2 turns

*Measurements taken from Kirby, (1941)

The Table 24 reveals that the specimens of *D. cometoides* from the type host are considerably slender having length-breadth ratio 4.5 whereas, in all other hosts it varies from 3.1-3.4. However, this species in having very small cresta (under 4 μm) with equal anteromedial and posteromedial edges is quite distinct from all other species of *Devescovina*.

24. *Devescovina glabra* Grassi, 1917
(Fig. 32)

1917. *Devescovina glabra* Grassi, *Mem. R. Accad. Lincei* (5) 12 : 54.
1941. *Devescovina glabra* : Kirby, *Univ. Calif. Publ. Zool.*, 45 : 39.
1974. *Devescovina glabra* : Das, *Arch. Protistenkd.*, 116 : 287.
1981. *Devescovina glabra* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 161.
1983. *Devescovina glabra* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 42.
1992. *Devescovina glabra* : Tiwari, *Rec. zool. Surv. India*, 92 : 138.
1993. *Devescovina glabra* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 487. *Zool. Surv. India*.
2000. *Devescovina glabra* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 37. *Zool. Surv. India*.
2004. *Devescovina glabra* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5 : 449. *Zool. Surv. India*.
- 2006a. *Devescovina glabra* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 28. *Zool. Surv. India*.

Type host : *Cryptotermes havilandi*; loc., Nigeria (type locality) and India : Nagaland, West Bengal.

Additional hosts : *Bifiditermes madagascariensis* (= *Glyptotermes* sp.); loc., Sumatra; *Cryptotermes dudleyi*; loc., India : Andhra Pradesh, Tripura; *Cryptotermes* sp.; loc., "East Africa", Java, Kenya, Madagascar, South Africa, "Tanganyika Territory", Zanzibar; *Glyptotermes caudomunitus*; loc., Java; *Glyptotermes kirbyi* (= *Glyptotermes* sp.); loc., Sumatra; *Neotermes europae* (= *Neotermes* sp. nov.); loc., Madagascar; *Neotermes meruensis*; loc., "East Africa"; *Neotermes zuluensis*; loc., South Africa.

Diagnosis : Body elongated with pointed posterior end; dimensions of Indian specimens from the hosts *Cryptotermes havilandi* and *Cr. dudleyi* 34–44.2 μm x 10.2–15.3 μm and 48–64 μm x 16–25 μm respectively; anterior flagella slender, three in number and almost equal to their body-length; trailing flagellum resembling a stout cord or a very narrow band, 51–60 μm in length; cresta 5.7–8 μm and its antero-medial edge 1.7–2 μm in Indian specimens; parabasal body usually turning one and a half times around the axostyle; axostyle straight or smoothly curved, its anterior part stout, while its posterior quarter filamentous, often sinuous, extending into the pointed end of the body or recurved in the

cytoplasm; nucleus oval, lying close to the blepharoplast; cytoplasm containing aggregate of deep staining granules around the axostyle lying at a short distance posterior to parabasal body (Fig. 32); in addition, bacteria also observed in few specimens.

Morphometry : Mensural data of *Devescovina glabra* collected from Indian termites are presented in Table 25 and compared with those collected from the type host in type locality (Nigeria) and some additional hosts of other countries.

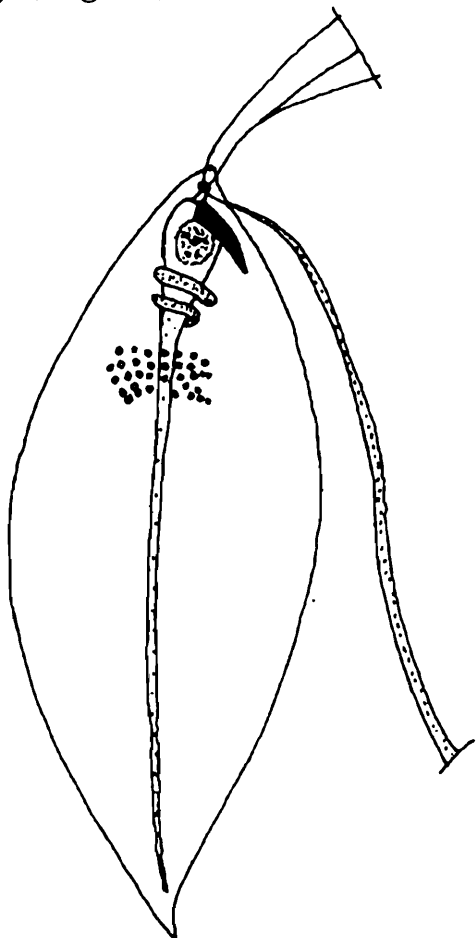


Fig. 32 : *Devescovina glabra* Grassi; anterior flagella and trailing flagellum partly shown

Remarks : The Table 25 shows that dimensions and other morphometric data of *D. glabra* from different hosts are quite variable. The same is also found in respect of Indian specimens collected from two different species of hosts, viz., *Cryptotermes havilandi* (same as the type host) and *Cr. dudleyi*. Number of parabasal turns also varies in different specimens and, is usually one and a half to two turns and occasionally 1 to 3 turns. However, the presence of deep staining granules or rods around the axostyle, lying moderately posterior to the parabasal body is one of the characteristics of this species. These granules are observed in all the Indian specimens of *D. glabra* studied by the present author. Moreover, in Indian specimens shape of cresta and axostyle with stout anterior part and filamentous or sinuous posterior part are quite in conformity with the type specimens of *D. glabra*, described by Kirby (1941a).

25. *Devescovina gyrinoides* De Mello, 1946 (Figs. 33-34)

1946. *Devescovina gyrinoides* De Mello, *An. Inst. Med. Trop.*, 3 : 30.

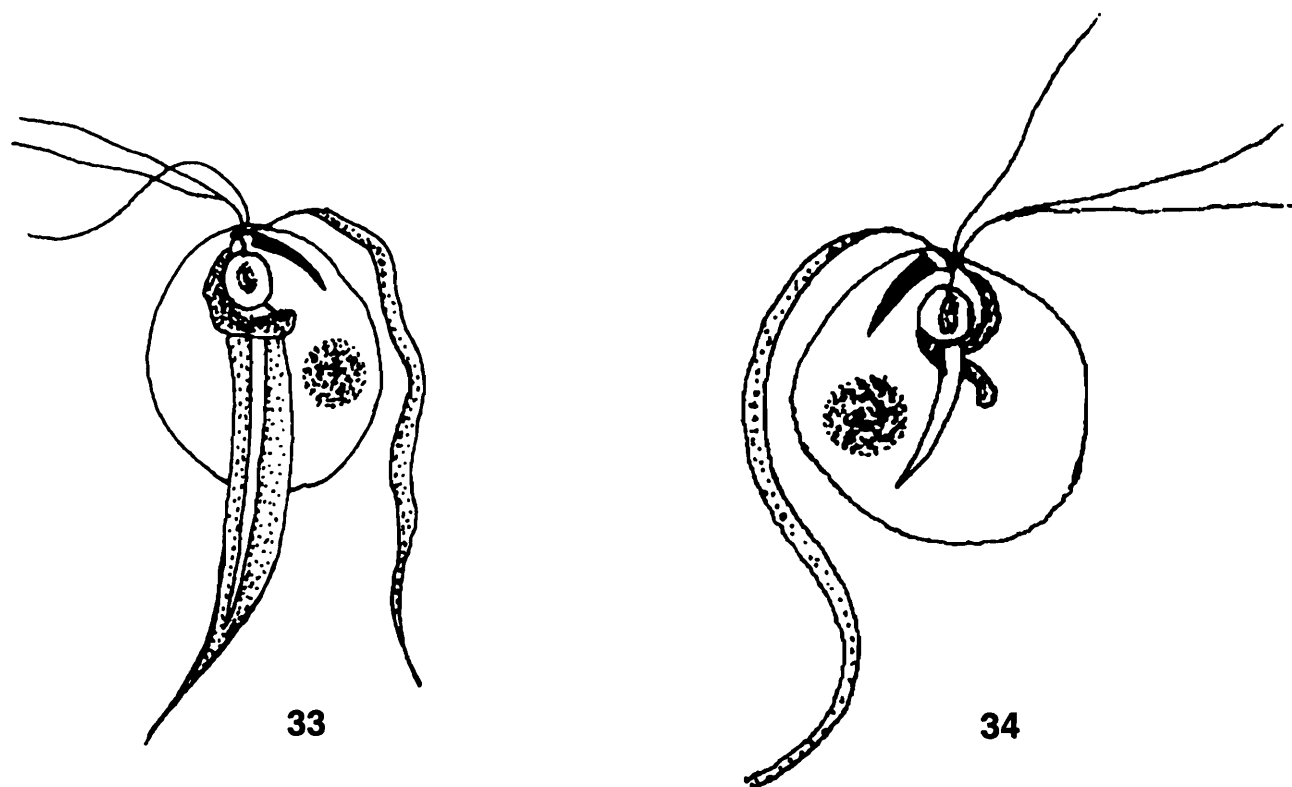
1983. *Devescovina gyrinoides* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 42.

Type host : *Cryptotermes* sp.; loc., India : Goa.

Diagnosis : Body ovoid and more or less round, in most of the cases with tail-like appendages, giving the specimens "tad pole like appearance" (Fig. 33); occasionally such tail may be absent (Fig. 34); anterior flagella slender, three in number, almost equal to body length; trailing flagellum ribbon-like with filamentous proximal and terminal portion; cresta sometimes "falciform but often reduced to a series of deeply stained granules

Table 25. Comparison of morphometric data of *Devescovina glabra*, collected from different hosts; (measurements in μm)

Characters	Indian hosts		Type host (in type locality) <i>Cr. havilandi</i>	Hosts of other countries	
	<i>Cr. havilandi</i>	<i>Cr. dudleyi</i>		<i>N. meruensis</i>	<i>B. madagascariensis</i>
Body length	38.1(34-44.2)	52(48-64)	44(27-58)	38(24-27)	39(27-48)
Body width	12.5(10.2-15.3)	19(16-25)	15(11-20)	9.5(7.5-12.5)	15.5(10-20)
Ratio of body length to body width (average)	2.8:1	2.7:1	2.9:1	4 :1	1.9 :1
Length of nucleus	4.4(3.4-5.1)	—	5.5(5-6)	4.5.(4-5)	5.8(5.1-6.8)
Breadth of nucleus	3.2(3-3.5)	—	4.4(3.5-4.5)	3(2.5-4)	4.3(3.4-5.1)
Length of cresta	5.9(5.7-6.2)	7.5(7.2-8)	7(6-8)	5(4.5-5.5)	6.7(5.5-7)
Length of trailing flagellum	56(51-60)	—	—	60-65	—
No. of parabasal turns	1½	2	1½-3	$\frac{7}{8}$ - 1½	1-2½



Figs. 33-34 : *Devescovina gyrinoides* De Mello. Fig. 33. "tailed forms"; Fig. 34. "round and nontailed form"

embedded in a more faint linear mass;" blepharoplast horse-shoe shaped and located adjacent to the nuclear membrane; parabasal body "S"-shaped, parabasal spiral lacking; axostyle slender and tubular in structure, straight or bent and in most of the cases extruding outside to a large distance from the posterior pole; "axostyle beyond the tail-like appendages continued by a very delicate flagellum like process, difficult to be detected"; nucleus ovoidal with strong nuclear membrane and chromatic mass.

In some forms body round or spherical, "tail" absent; axostyle neither protruding outside the body nor possessing any "flagellum like appendages" (Fig. 34).

Morphometry (Table 26) :

Table 26. Mensural data of *Devescovina gyrinoides*

Characters	Mean	Range
Length of the body	21 μ m	10-30 μ m
Breadth of the body	15.7 μ m	8-30 μ m
Ratio of body length to body width (without tail)	1.3 : 1	—
Tail like structure	15.5 μ m	8- 28 μ m
Diameter of nucleus	—	4-8 μ m
Length of trailing flagellum	—	30-35 μ m

Remarks : The present diagnosis and morphometric data of *Devescovina gyrinoides* are solely based on the original description of this species by De Mello (1946). This species has not been collected till date since its original description. According to De Mello (*op. cit.*) there is no parabasal spiral in *D. gyrinoides*. But, his Text-figure 1, No. 3 pertaining to this species in the said publication shows parabasal spiral of about half turn. Presence of tail-like appendage, faliciform cresta, often filled up with minute granules and parabasal with half turn appear to be the characteristic features of this species.

26. *Devescovina lemniscata* Kirby, 1926
(Figs. 35-48)

1926. *Devescovina lemniscata* Kirby, Univ. Calif. Publ. Zool., 29 : 103.
1929. *Devescovina damanensis* De Mello and De Brito, Arqu. Esc. Med. Cirug. Nova Goa (A) 5 : 699.
1941. *Devescovina lemniscata* : Kirby, Univ. Calif. Publ. Zool., 45 : 57.
1974. *Devescovina lemniscata* : Das, Arch. Protistenkd., 116 : 291.
1983. *Devescovina lemniscata* : Das, Proc. Symp. Host Environ. zool. Surv. India : 42.
1992. *Devescovina lemniscata* : Tiwari, Rec. zool. Surv. India, 92 : 139.
1993. *Devescovina lemniscata* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3 (Part 12) : 487. Zool. Surv. India.
2000. *Devescovina lemniscata* : Das, Tiwari and Sarkar, Fauna of Tripura, State Fauna Series, 7(Part 4) : 37. Zool. Surv. India.
2004. *Devescovina lemniscata* : Das, Tiwari, Nandi, Sarkar and Saha, Fauna of Andhra Pradesh, State Fauna Series, 5(Part 6) : 449. Zool. Surv. India.
- 2006a. *Devescovina glabra* : Das, Tiwari and Sarkar, Fauna of Nagaland, State Fauna Series, 12 : 28. Zool. Surv. India.

Type host : *Cryptotermes domesticus* (= *Cryptotermes hermsi*); loc., Fanning Island (type locality), Malaysia; (= *Cryptotermes breviarticulatus*); loc., Panama.

Additional hosts : *Cryptotermes brevis*; loc., Brazil; *Cryptotermes cyanocephalus*; loc., Java, Malaysia; *Cryptotermes dudleyi*; loc., Panama, India : Andhra Pradesh, Tripura; *Cryptotermes fautulus*; loc., Galapagos Island; *Cryptotermes havilandi*; loc., India : Bihar; Nagaland and West Bengal; *Cryptotermes queenslandis*; loc., Australia; *Cryptotermes* sp.; loc., Ecuador, Kenya, Madagascar, Mauritius, "Tanganyika territory"; *Kalotermes* sp.; loc., India : Daman; *Glyptotermes caudomunitus*; loc., Java; *Glyptotermes tuberculatus*; loc., Australia; *Neotermes insularis*; loc., Australia; *Neotermes larseni*; loc., Cocos Island; *Postelectrotermes castaneiceps*; loc., Madagascar; *Postelectrotermes longus*; loc., Madagascar; *Postelectrotermes* sp. (= *Neotermes* sp. nov.); loc., Madagascar.

Diagnosis : Body more or less pyriform with bluntly pointed posterior end; dimensions of the body quite variable (Table 27); anterior flagella slender, three in number, almost equal to the length of the body, trailing flagellum broad ribbon-like with filamentous

Table 27. Comparison of morphometric data of *Devescovina lemniscata* collected from different hosts (measurements in μm)

Characters	From : Indian termites		Type host <i>Cr. domesticus</i>	Other hosts of outside India		
	<i>Cr. havilandi</i>	<i>Cr. dudleyi</i>		<i>Cr. cyanocephalus</i>	<i>Cr. dudleyi</i>	<i>N. insularis</i>
Body length	58.6(51-71.4)	49(43.2-51.2)	35(21-50)	45.5(42-49)	42(28-63)	42(22-78)
Body width	19.8(11.9-22.1)	18.3(17.6-19.2)	12.5(9-17)	13.8(12.5-17.6)	16(10-24)	16(9-37)
Length-breadth ratio (average)	2.96 : 1	2.7 : 1	2.8 : 1	3.2 : 1	2.8 : 1	2.8 : 1
Length of nucleus	6.2(5.1-6.8)	—	6(5.5-7)	6(5.5-7)	5.2(5.5-7)	6(4.9-7.3)
Breadth of nucleus	3.2(3-3.4)	—	3.5 (3-4)	3.5-4	4.1(3.6-4.7)	5(3.9-5.7)
Length of cresta	12.4(11-12.7)	—	8(7-9)	8-9	8.7(7-10)	9(7-13)
Length of trailing flagellum	71.5 (61.2-83.2)	—	—	—	—	—
No. of parabasal turn	2-3 turns	1-4 turns	1-2 turns	1-1½ turns	—	1-3 turns

proximal and distal ends about one and a half times the length of the body; cresta long with broad proximal and pointed distal ends; parabasal body usually turns one to one and a half, sometimes 2-3 times and occasionally 4 times around the trunk of the axostyle; axostyle stout at anterior part, gradually becoming slender and filamentous towards posterior end, embedded within cytoplasm and never projecting outside the body; nucleus ellipsoidal, cytoplasm occasionally containing micro-organisms and wood particles.

Morphometry : Mensural data of *Devescovina lemniscata* collected from Indian termites are presented in Table 27 and compared with those from some other hosts.

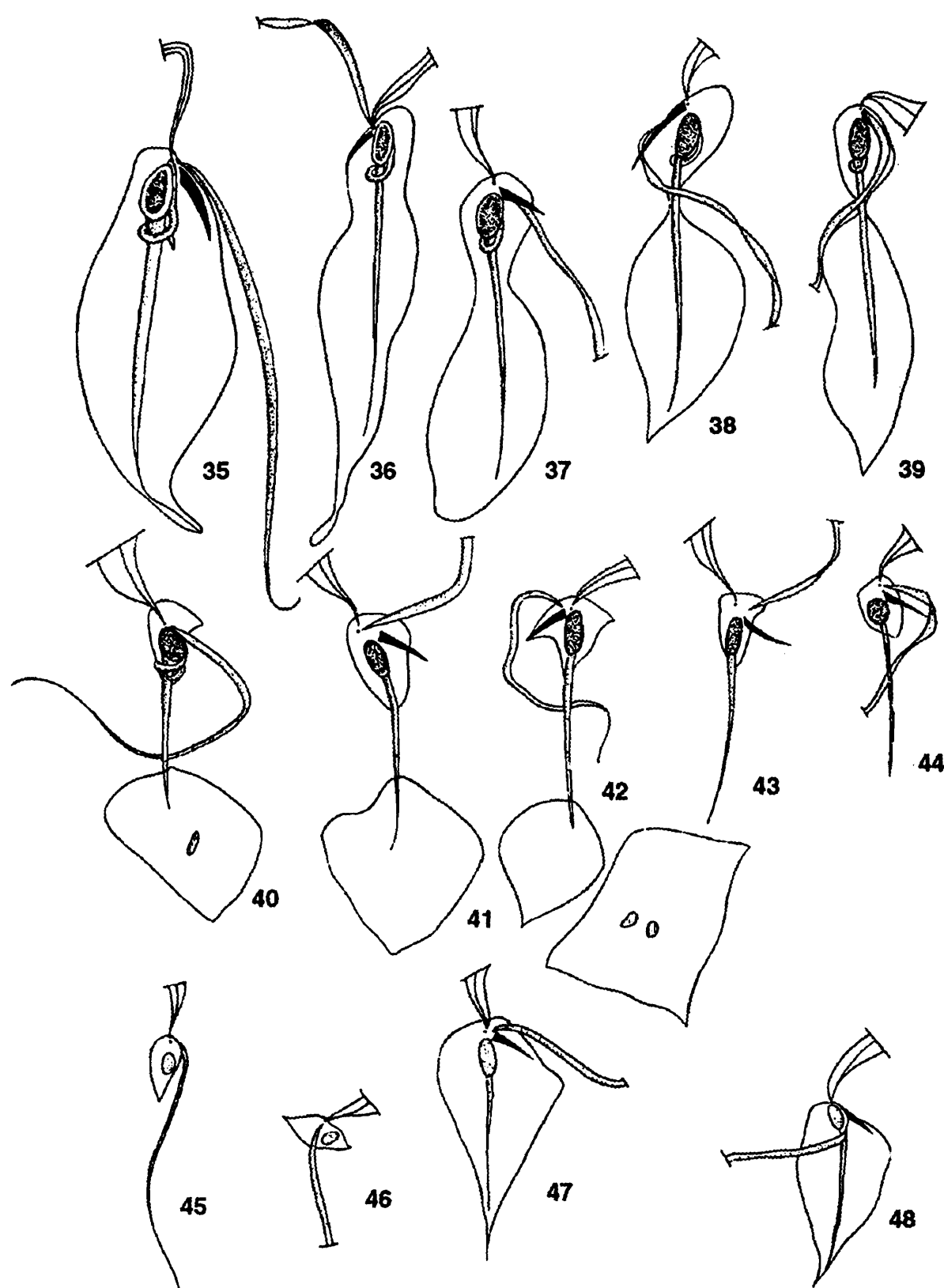
Remarks : In the original description of *Devescovina lemniscata* Kirby (1926) distinguished two forms – one is broad with included axostyle and the other is small with projecting axostyle. Subsequently, in his monographic work on *Devescovina* Kirby (1941a) stated that "broad form more closely represents the normal form of the flagellate" and the smaller form was abnormal owing to plasmotomy. Indian forms collected by Das (1974b) and Das *et al.* (2000-2006) from two hosts, *viz.*, *Cryptotermes havilandi* and *Cr. dudleyi* resemble the broad form of Kirby (*op. cit.*).

Specimens of *D. lemniscata*, recorded from the guts of different hosts are considerably variable in dimensions and in other morphometric data (Table 27). Its length-breadth ratio also ranges from 2.7 - 3.2, the maximum value of which was recorded by Das *et al.* (1986) after examining *D. lemniscata* from the host, *Cryptotermes cyanocephallus* from Malaysia. *D. lemniscata* has been recorded from the type host, *Cryptotermes domesticus* from Panama (Kirby, 1941a) and Malaysia (Das *et al.*, 1987) besides from the type locality in Fanning Island (Kirby, 1941a). The Table 28 shows that dimensions of this species are also variable in different localities, even when it is collected from the same host. The Table 28 also reveals that the specimens from the type locality are the smallest in dimensions.

Table 28. Comparison of morphometric data (in μm) of *Devescovina lemniscata* from the type host *Cryptotermes domesticus* recorded from different localities

Characters	From Fanning Island (type locality)	From Panama (as <i>Cr. breviarticulatus</i>)	From Malaysia
Body length	35 (21–51)	46 (36–61)	41 (30–54)
Body width	12.5 (9–17)	17 (9–25)	15.5 (9–19)
Body length-body width ratio (average)	2.8 : 1	2.7 : 1	2.7 : 1
Length of nucleus	6(5.5–7)	–	6 (5.5–6.5)
Breadth of nucleus	3.5 (3–4)	–	3–4

De Mello and De Brito (1929) described *Devescovina damanensis* from the gut of a rhinotermitid termite *Coptotermes heimi*. After examining the permanently stained material of De Mello and De Brito, Kirby (1941a) synonymised this species under *Devescovina*



Figs. 35-48 : *Devescovina lemniscata* Kirby. Fig. 35. Adult individual; Figs. 36-48. Different stages of cytoplasmic extrusion. Figs. 36-37. Showing appearance of constriction little below nucleus; Figs. 38-39. Constriction touching the trunk of the axostyle; Figs. 40-42. Extrusion of posterior part in progress; Fig. 43. Posterior cytoplasmic part extruded out leaving a separate anterior part; Fig. 44. Anterior part with mastigont; Figs. 45-46. Showing development of anterior portion; cresta and axostyle dissolved; Figs. 47-48. Forms with newly formed cresta and axostyle

lemniscata. Further to state that identification of this host species was most probably not correct. According to Kirby (1947) it was one of the *Kaloterme*s group. This was discussed in detail by Das (1974b). Specimens of De Mello and De Brito measured 32-67 μm in length with average 47 μm , 12-27 μm in width with average 20 μm and length-breadth ratio 2.3 : 1, as examined and recorded by Kirby (1941a).

During the course of studying the morphological features of *D. lemniscata* *in vivo* and also in permanently stained smears, collected from the guts of *Cryptotermes havilandi* from five different colonies in Kolkata (India) a phenomenon of cytoplasmic extrusion was recorded by the present author (see Das, 1974b).

Cytoplasmic extrusion : At the outset, a constriction appears little below the nucleus (Fig. 36). This constriction gradually deepens (Fig. 37) and ultimately touches the trunk of the axostyle (Figs. 38–39). Then, the anterior part of the organism with blepharoplast, nucleus, anterior flagella, trailing flagellum, cresta, axostyle and blepharoplast spirals begins to come out from the major portion of the body (Figs. 40–42). Gradually anterior portion of the body is completely separated from its posterior portion (Fig. 43). By that time a total detachment of blepharoplast spirals takes place. The remaining bulk of the posterior portion consisting of cytoplasmic mass is ultimately disintegrated (Fig. 43).

The detached anterior portion contains nucleus and mastigont only, surrounded by little amount of cytoplasmic mass. In the course of further development it loses the axostyle and its cresta is dissolved (Figs. 44 - 46). At this stage it assumes an elliptical and, sometimes a circular shape possessing a nucleus, blepharoplast, three anterior flagella and a trailing flagellum (Figs. 45 - 46). During the course of further development new cresta and axostyle appear from the vicinity of the blepharoplast. Subsequently the blepharoplast spiral appears within the organism (Figs. 47 - 48). In this way, the anterior portion develops as a full fledged organism with all the characteristic features of this species (Fig. 35).

Thus, during this process a major portion of the cytoplasmic mass is extruded from the posterior portion of the body and the remaining small anterior portion is developed as an adult organism as stated earlier. In a nutshell, during this process :

i) the parental flagella are retained in tact during the development of anterior portion of this flagellate, ii) axostyle and cresta are dissolved, iii) blepharoplast spiral is detached and thereafter (iv) the lost organelles are regenerated afresh.

It is really interesting to note that these developmental features are noted by Kirby (1944) during the normal binary fission of this species. But, the present phenomenon is not a case of binary fission as there is no trace of nuclear division and only one organism is developed (not two as in binary fission) after this process. It is simply some cytoplasmic extrusion of the major part of the organism as stated above, the significance of which is yet to be studied.

27. *Devescovina parasoma* Kirby, 1941
(Fig. 49)

1941. *Devescovina parasoma* Kirby, Univ. Calif. Publ. Zool., 45 : 46.

Type host : *Neotermes techtoni*; loc., Java, Sumatra.

Additional hosts : *Cryptotermes cyanocephalus*; loc., Malaysia; (= *Cryptotermes* sp.); loc., Java; *Cryptotermes* sp. nov.; loc., Java; *Cryptotermes* sp.; loc., Kenya; *Neotermes andamanensis*; loc., India : South Andaman; *Neotermes bosei*, loc., India : Uttaranchal; *Neotermes dalbergiae*, loc., Java; *Neotermes sonneratae*; loc., Java.

Diagnosis : Body ovoidal with blunt anterior and pointed posterior ends; anterior flagella slender, three in number and almost equal to the length of the body; trailing flagellum longer, about one and a half times the length of the body, resembling a narrow ribbon; cresta comparatively small, usually 5-6 μ m in length and its anteromedial edge 2-2.5 μ m; parabasal body usually coiling tightly 3-4 times around the axostyle; diameter of parabasal spirals diminishing posteriorly; trunk of the axostyle stout in both anterior and posterior portions; its posterior part never sinuous, sometimes projecting slightly beyond the posterior end of the body; nucleus ovoidal.

Morphometry : The morphometric data of *Devescovina parasoma* collected from Indian termites are presented in Table 29 and compared with those of the specimens, as recorded from other hosts from outside India.

Remarks : During the present study, the author has collected *Devescovina parasoma* from two species of Indian termites, viz., *Neotermes andamanensis* and *Neotermes bosei*. He also (see Das *et al.*, 1986) recorded this flagellale from a Malaysian termite, *Cryptotermes cynocephalus*. The distinctive features of this species are short cresta, narrow band shaped trailing flagellum and 3-4 tightly coiled parabasal spirals, the diameter of which diminishes posteriorly such that the diameter of the last spiral may be about half of the first one. Moreover, trunk of the axostyle is stout throughout never sinuous and occasionally protruding out to a short distance from the posterior end of the body.

Table 29 reveals that specimens collected from the host *Neotermes dalbergiae* are the smallest and those collected from *Cryptotermes cynocephalus* is the largest in dimensions. Kirby (1941a) observed 1½- 4 parabasal turns (usually 3-4 turns) in the specimens collected from the type host. In all the Indian specimens and those from Malaysian host, *Cryptotermes cynocephalus* the present author observed 3-4 parabasal turns.

28. *Devescovina steini* Das, 1974
(Fig. 50)

1974. *Devescovina steini* Das, Arch. Protistenkd., 116 : 286.

1983. *Devescovina steini* : Das, Proc. Symp. Host Environ. zool. Surv. India : 42.

1993. *Devescovina steini* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3(Part 12) : 488. Zool. Surv. India.

Table 29. Comparison of morphometric data of *Devescovina parasoma* collected from different hosts (measurements in μm)

Characters	From : Indian termites		Termites from outside India		
	<i>N. andamanensis</i>	<i>N. bosei</i>	<i>N. tectonae</i> (Type host)	<i>N. dalbergiae</i>	<i>Cr. cyanocephalus</i>
Body length	38 (32.5-47)	42.5 (36.5-58)	43 (24-60)	32 (25-42)	48 (41-65.5)
Body width	16 (14.5-18.5)	17.8 (15.3-25.8)	19 (11-27)	12 (9-19)	21.6 (19-32.5)
Leanth-breadth ratio (average)	2.3 : 1	2.4 : 1	2.3 : 1	2.5 : 1	2.2 : 1
Length of nucleus	4.5 (4-5)	4.5 (4-5.5)	5.6 (4.4-6.2)	4.3 (3.3-6.1)	5.4 (5-6)
Breadth of nucleus	4 (3.5-4.5)	4.2 (3.8-5.8)	4.6 (3.6-5.3)	3.6 (2.6-4.5)	4.5 (4-5.2)
Length of cresta	5.2 (5-5.6)	5.5 (5-6)	5.2 (4.4-6)	5.1 (4.4-5.5)	4.5 (4-5)
Length of trailing flagellum		50-62	54-70	-	- -
No. of parabasal turns	3-4 turns	3-4 turns	1½-4 turns usually 3-4 turns	-	3-4 turns

Type host : *Cryptotermes havilandi*; loc., India : West Bengal.

Diagnosis : Body ovoidal with broadly round posterior end; occasionally posterior end having some blunt projection; in suitably stained specimens blepharoplast group visible as a mass of moderate size near the edge of the body, anterior to cresta; anterior flagella slender, three in number, almost equal to the length of the body; trailing flagellum about one and a half the length of the body, resembling a broad ribbon with filamentous proximal and terminal ends; cresta comparatively long, 8.2-8.9 μm with broad proximal and bluntly pointed distal ends; parabasal turning 2 times around the trunk of the axostyle; axostyle stout and straight, never sinuous, gradually tapering towards posterior end and protruding out to a considerable distance from the posterior extremity of the body; nucleus ovoidal with well developed nuclear membrane; a clear space present between the chromatin mass and nuclear membrane; chromatin material dispersed in the form of irregularly arranged granules.

Morphometry : The mensural data of *Devescovina steini* is presented in Table 30.

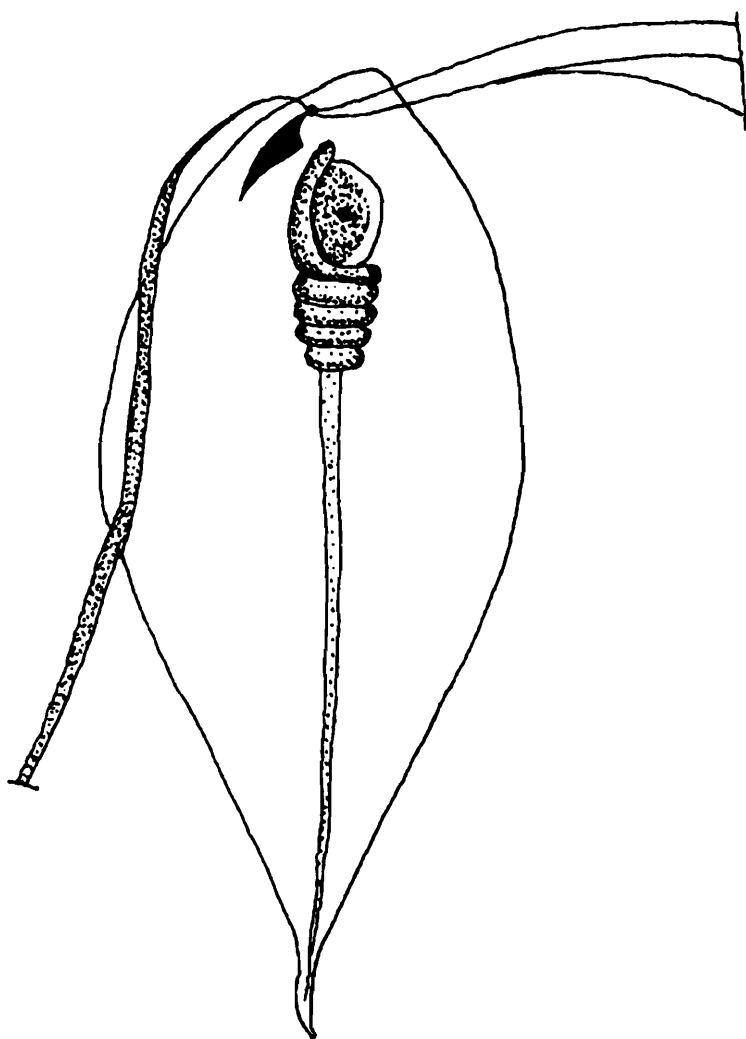


Fig. 49 : *Devescovina parasoma* Kirby; anterior flagella and trailing flagellum partly shown

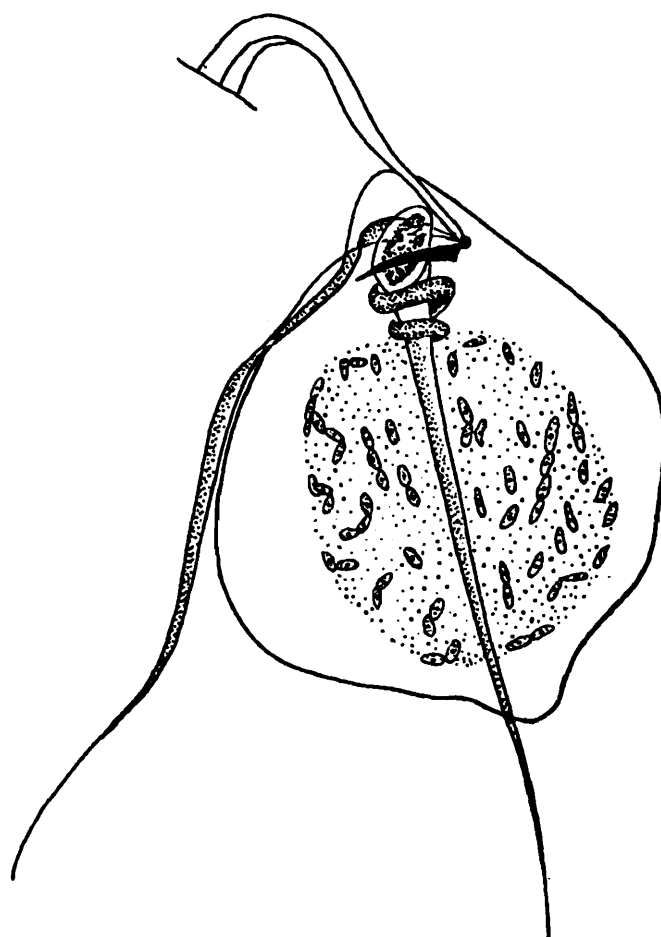


Fig. 50 : *Devescovina steini* Das; anterior flagella partly shown

Table 30. Morphometric data of *D. steini*

Characters	Range	Mean
Body length	33 – 44.2 μm	40.4 μm
Body width	18.7 – 25.5 μm	22.5 μm
Ratio of body length to body width (average)	-	1.8 : 1
Length of nucleus	5.1 - 5.9 μm	5.5 μm
Breadth of nucleus	3.4 - 4.2 μm	3.6 μm
Length of cresta	8.2 - 8.9 μm	8.5 μm
Length of trailing flagellum	42.5 - 54 μm	50.2 μm
No. of parabasal turns	2 turns	-

Remarks : Amongst all the species of *Devescovina* described so far *D. steini* resembles only *D. gyrinoides* to some extent in having ovoid body shape, ribbon like trailing flagellum and, stout and straight axostyle protruding out to a considerable distance (only in "tailed form" of *D. gyrinoides* De Mello) from the posterior end of the body. But, *D. gyrinoides* differs considerably from *D. steini* by possessing "a tail-like appendage which at first sight gives the animal the appearance of a tad pole" and 'S'-shaped parabasal without any spiral around the axostyle. Moreover, in the tailed form of *D. gyrinoides* axostyle protrudes out of the body as a "very delicate flagellum-like process."

Genus *Caduceia* Franca, 1918

1918. *Caduceia* Franca, *Bull. Soc. Port. Sci. Nat.*, 8 : 94.

1938. *Caduceia* : Kirby, *Univ. Calif. Publ. Zool.*, 43 : 2.

1942. *Caduceia* : Kirby, *Univ. Calif. Publ. Zool.*, 45 : 93.

Diagnosis : Body resembling a large and broad *Devescovina* in shape; anterior flagella slender, three in number and usually shorter than the body; trailing flagellum slender, cord like and also usually shorter than the body; cresta usually relatively short; parabasal body coiling around the axostyle loosely or tightly in 2-20 turns; trunk of axostyle tapering to a filamentous end posteriorly and enclosed within the cytoplasm; in preserved specimens posterior part of axostyle often curved forward within the cytoplasm; nucleus large, longer diameter usually on the longitudinal axis of the body with blepharoplast granules near the anterior continuation of the same axis; body with a dense aggregate of short adherent spirochaetes.

29. *Caduceia kalshoveni* Kirby, 1942 (Fig. 51)

1942. *Caduceia kalshoveni* Kirby, *Univ. Calif. Publ. Zool.*, 45 : 108.

1992. *Caduceia kalshoveni* : Tiwari, *Rec. zool. Surv. India*, 92 : 138.

Type host : *Neotermes dalbergiae*; loc., Java.

Additional hosts : *Neotermes andamanensis*; loc., India : South Andaman; *Neotermes bosei*; loc., India : Bihar.

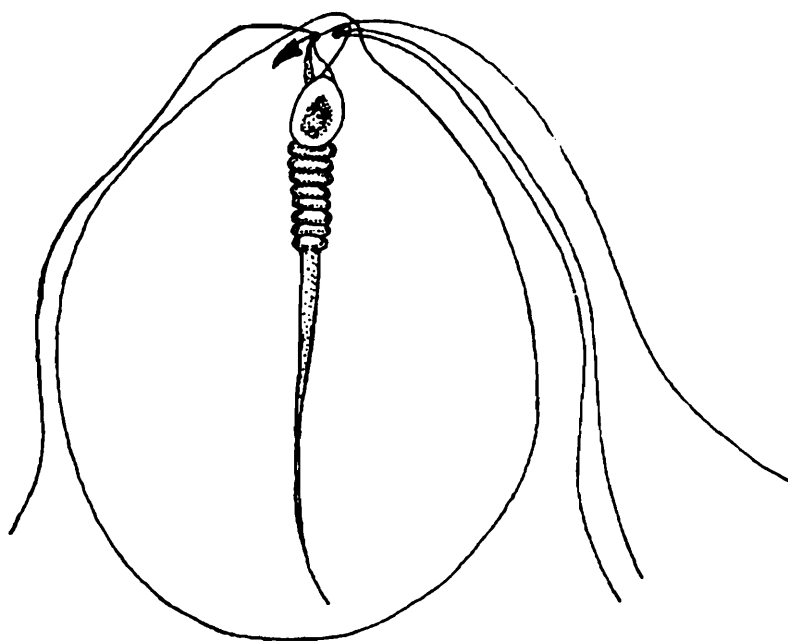


Fig. 51 : *Cauduceia kalshoveni* Kirby

Diagnosis : Body more or less oval with broad and round posterior end; anterior flagella slender, three in number and trailing flagellum resembling a slender cord; both anterior and trailing flagella shorter than the body length; cresta relatively very small, subtriangular and around 2 μm long; parabasal body coiled tightly around the axostyle; parabasal turns usually 5-14; chromatic shield absent; trunk of axostyle tapering posteriorly to a filamentous end and enclosed within the cytoplasm; nucleus oval; endoplasm containing numerous granules and ingested wood particles; small spirochaetes densely distributed on entire body surface.

Morphometry :

Morphometric data of *Cauduceia kalshoveni*, collected from Indian termites are incorporated in Table 31 and compared with those collected from the type host.

Table 31. Morphometric data of *C. kalshoveni* from different hosts (measurements in μm)

Characters	From Indian termites		Type host <i>N. dalbergiae</i>
	<i>N. bosei</i>	<i>N. andamanensis</i>	
Body length	42.6 (36-52.5)	76 (50-102)	88 (35-130)
Body width	30.9 (24-45)	53.4 (32-70.8)	58 (18-89)
Ratio of body length to body width (average)	1.3 : 1	1.4 : 1	1.5 : 1
Length of nucleus	7.3 (6.7-7.5)	8.5 (7-10.5)	9 (7-12)
Width of nucleus	5.8 (5.2-6)	5.5 (4.2-7.6)	5.5 (4.5-8)
Length of trailing flagellum	34.5-45	44-90	—
Length of cresta	2 μm	2 μm	1-2 μm
No. of parabasal turns	5-9 turns	9-14 turns	11-14 turns (average)

Remarks : Tiwari (1992) was the first to record *Caduceia kalshoveni* from Indian termites belonging to *Neotermes basei*. During the present investigation the present author collected this flagellate from another host species of India, viz, *Neotermes andamanensis*. Table 31 shows that specimens of *C. kalshoveni* from *Neotermes basei* are considerably smaller in dimensions than those from the type host as well as from the other Indian host, *N. andamanensis*.

While describing *C. kalshoveni*, Kirby (1942a) mentioned that he found numerous "unusually small specimens" on one slide. Their average dimensions were only 48 μm x 29 μm . But, they resembled the larger forms of this species in all respect. Therefore, it is evident that in body size Indian forms of *C. kalshoveni* collected from *N. basei* are quite at par with the small forms of this flagellate species reported by Kirby (1942a).

Genus *Foaina* Janicki, 1915
(Fig. 52)

1915. *Foaina* Janicki, *Zeitschr. Wiss. Zool.*, **92** : 615.
 1923. *Janickiella* Duboscq and Grassi, *C. R. Acad. Sci.*, **177** : 178.
 1926. *Paradevescovina* Kirby, *Univ. Calif. Publ. Zool.*, **29** : 114.
 1938. *Crucinympha* Kirby, *Quart. Jour. Micr. Sci.*, **81** : 9.
 1942. *Foaina* : Kirby, *Univ. Calif. Publ. Zool.*, **45** : 167.

Diagnosis : Size small to moderate; three slender anterior flagella about the length of the body; trailing flagellum usually exceeding twice the length of the body, resembling a stout cord or a ribbon; cresta usually very slender, sometimes very small (1.5 μm) and sometimes very long (29 μm), reaching to the posterior end of the body; parabasal body single, in some cases with one or more rami, ellipsoidal or bacilliform in structure curved around the nuclear membrane and never coiled around the axostyle; parabasal filament often extending free beyond the main substance; capitulum of axostyle usually a moderately expanded flat structure alongside the nucleus and extended into the papilla; trunk of axostyle a stout cord, straight or slightly curved, extending through the cytoplasm towards the posterior end of the body; a terminal cusp projecting from the

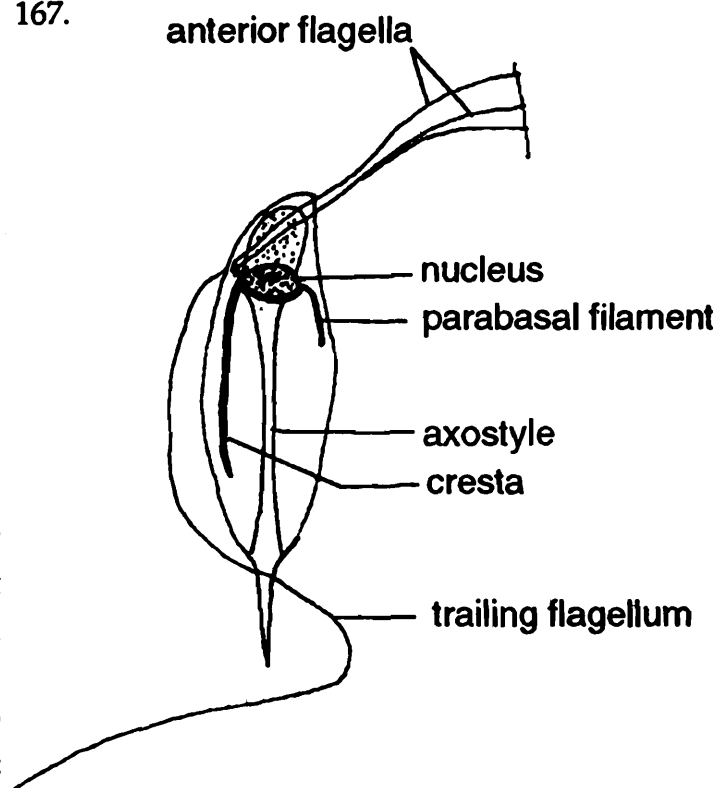


Fig. 52 : Genus *Foaina* Janicki (semi-diagrammatic), showing some salient taxonomic features; anterior flagella partly shown

body, tapering to a point and often prolonged in a filament; longer diameter of nucleus transverse or oblique.

Remarks : The genus *Foaina* was erected by Janicki (1915) to accommodate a species *F. gracilis*, collected from the host *Neotermes connexus* from Hawaii. Since then other 30 species of *Foaina* have been described from 97 species of termite hosts. Even then, initial works on this group of flagellates from India appear to be confusing as thoroughly discussed by Das (1974a). De Mello and De Brito (1929b) described *Devescovina kirbyi* from an Indian termite, wrongly identified as *Coptotermes heimi* (see De Mello, 1953, p. 66) which was collected from Daman, India. While writing up a monograph on the genus *Foaina* Kirby (1942b) examined this material sent to him by De Mello and commented that the description of *D. kirbyi* is nothing but an admixture of that of two species of *Foaina*, viz, *F. nana* and *F. solita*. Kirby (*op cit.*) also stated further that De Mello "doubtless" made most of his observations on the more abundant and larger *Foaina nana*. After a long gap Das (1977) recorded *F. reflexa* and *F. nana* from the Indian termite, *Cryptotermes havilandi* and dealt with all the three species of *Foaina* recorded so far from this country. Since then no further addition of any species of *Foaina* has been made from India.

Key to the species of genus *Foaina* reported from Indian termites

1. Parabasal body with U-shaped bend *F. reflexa*
- Parabasal body without such bend 2
2. Parabasal body with long free filament, a conspicuous "cytostome" like clear area usually visible anterior to the nucleus *F. nana*
- Parabasal body short, bacilliform and restricted to the dorsal side of the nucleus, conspicuous clear area anterior to the nucleus absent *F. solita*

30. *Foaina nana* (Kirby) Kirby, 1942 (Fig. 53)

1926. *Paradevescovina nana* Kirby, Univ. Calif. Publ. Zool., 29 : 114.
1929. *Devescovina kirbyi* De Mello and De Brito, Arqu. Esc. Med. Cirug. Nova Goa, Ser. A., fasc. 5 : 699.
1942. *Foaina nana* (Kirby) Kirby, Univ. Calif. Publ. Zool., 45 : 190.
1949. *Foaina nana* : Kirby, Univ. Calif. Publ. Zool., 45 : 366.
1977. *Foaina nana* : Das, Proc. zool. Soc., Calcutta, 30 : 63.
1983. *Foaina nana* : Das, Proc. Symp. Host Environ. zool. Surv. India : 43.
1993. *Foaina nana* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3(Part 12) : 488. Zool. Surv. India.

Type host : *Cryptotermes domesticus* (= *Cryptotermes hermsi*); loc., Fanning Island (type locality), also from Singapore and Malaysia.

Additional hosts : *Allotermes papillifer* (= *Procryptotermes* sp. nov.); loc., Madagascar; *Bifiditermes condonensis* (= *Kalotermes condonensis* var. *chryseus*); loc., Australia; *Bifiditermes madagascariensis* (= *Kalotermes* sp.); loc., Madagascar; *Calcaritermes brevicollis*; loc., Panama; *Calcaritermes emerginicollis*; loc., Costa Rica; *Calcaritermes nearcticus*; loc., Florida; *Calcaritermes nigriceps*; loc., British Guiana; *Calcaritermes snyderi* (= *Calcaritermes* sp. nov.); loc., El Salvador; *Cryptotermes brevis*; loc., Brazil; *Cryptotermes cubiceps*; loc., British Guiana; *Cryptotermes cynocephalus*; loc., Java, Malaysia; *Cryptotermes dudleyi*; loc., Panama; *Cryptotermes fatulus*; loc., Galapagos Islands; *Cryptotermes havilandi*; loc., India : West Bengal; *Cryptotermes* sp. (= "*Cryptotermes heimi*" of De Mello); loc., India : Daman; *Glyptotermes concavifrons* (= *Glyptotermes* sp. nov.); loc., Java; *Glyptotermes dialatus*, loc., Sri Lanka; *Glyptotermes kirbyi* (= *Glyptotermes taveuniensis*); loc., Fiji Island; *Incisitermes rapundus*; loc., Fiji Island; *Neotermes andamanensis*; loc., India : Andaman Islands; *Neotermes connexus*; loc., Hawaii; *Neotermes dalbergiae*; loc., Java; *Neotermes greeni*; loc., Sri Lanka; *Neotermes larseni*; loc., Coco Island; *Neotermes sonneratae*; loc., Java; *Neotermes tectonae*; loc., Java; *Rugitermes kirbyi*; loc., Costa Rica; *Rugitermes magninotus*; loc., British Guiana; *Rugitermes panamae*; loc., Panama; (*Glyptotermes* sp.); loc., Sumatra; *Rugitermes rugosus* (= *Procryptotermes* sp. nov.); loc., Reunion.

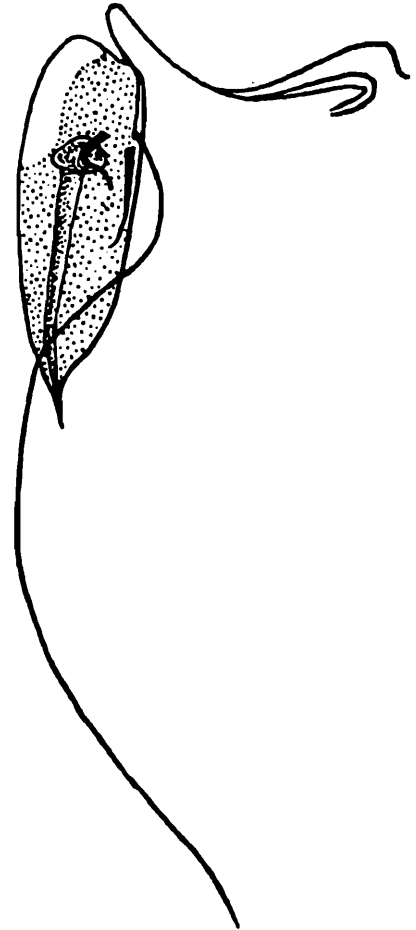


Fig. 53 : *Foaina nana* (Kirby)

Diagnosis : A small devescovinid; dimensions of this species from Indian termite, *Cryptotermes havilandi* 11.9-21.6 μm x 3.4-6.8 μm ; anterior flagella slender, three in number and equal to or slightly longer than the body length; trailing flagellum resembling a fairly stout cord, about 2.5 times the length of the body in Indian specimens; papilla large; when it extended the body coming to a rounded point anteriorly and when end of the papilla lateral, anterior end of the capitulum becoming oblique and antero-lateral to it a well marked clear area visible; cresta long and slender; parabasal body generally running over the dorsal side of the posterior portion of nucleus; sometimes a long free parabasal filament typically passing posteriorly to some distance at the periphery of the body; axostyle moderately stout and projecting out from the posterior end of the body, sometimes through enlarged cusp; nucleus oval but sometimes irregular.

Morphometry : Morphometric data of *Foaina nana* collected from the Indian termites are presented in Table 32 and compared with those from the type host and the other additional hosts of outside India.

Table 32. Comparison of morphometric data of *Foaina nana* collected from different hosts (measurements in μm)

Characters	Indian termites		Type host (Type locality) <i>Cr. domesticus</i>	Some additional hosts from outside India	
	<i>Cr. havilandi</i>	<i>N.andamanensis</i>		<i>Cr.dudleyi</i>	<i>Cr. cynocephalus</i>
Body length	16.9 (11.9-21.6)	17.5 (13-19.5)	12 (6-18)	17 (12-20)	13.5 (8.5-17.5)
Body width	5 (3.4-6.8)	8 (6-10.5)	6.5 (4.5-8.5)	7.5 (4-11)	7 (5-8.5)
Ratio of body length to body width (average)	3.3 : 1	2.1:1	1.8:1	2.2 :1	1.9 : 1
Length of nucleus	2.2 (1.7-2.5)	2.5 (2-3.5)	2-3	2-3.5	2-3
Breadth of nucleus	2 (1.5-2.4)	2 (1.5-3)	1.5-2	1.5-3	1.5-2
Length of cresta	6.8 (6.5-7)	8.5 (6-10)	8.5 (6.5-10.5)	10 (8-11)	-

Remarks : As mentioned earlier, *Devescovina kirbyi* De Mello and De Brito, *in part*, represents *Foaina nana*. The dimensions of *D. kirbyi* as recorded by De Mello and De Brito (1929b) are quite variable ranging from 7-55 μm in length without the projecting axostyle, 12-88 μm in length including the length of the projected axostyle and 3-16 μm in width. After examining these material, Kirby (1942b) pointed out that De Mello and De Brito (*op. cit*) included some measurements of the small *F. solita* and larger measurements were not made on normal *Foaina*.

F. nana has so far been recorded from 33 species of termite hosts under 8 genera from different countries. However, all these host species and genera belong to one termite family, Kalotermitidae. So this flagellate species shows wider distribution amongst kolotermitid termites only. *Foaina nana* collected from the guts of different hosts is quite variable in dimensions (Table 32). Even specimens collected from the type host, *Cryptotermites domesticus* from two different localities (Fanning Island and Malaysia) also display some variation in morphometry as shown in Table 33. Irrespective of its variability in mensural data some morphological features, such as enlarged capilla, free parabasal filaments and a wall marked clear area anterolateral to capilla (Fig. 53) make this species distinct from its other congeneric species.

Table 33. Comparison of morphometric data of *Foaina nana* from type host *Cr. domesticus* collected from different localities

Characters	From Fanning island (type locality) Kirby, 1942	From Malaysia Das <i>et al.</i> (1987)
Body length	12 (6-18) μm	14 (7-20) μm
Body width	6.5 (4.5-8.5) μm	7.5 (6-8.5 μm)
Ratio of body length to body width (average)	1.8 : 1	1.8 : 1
Length of nucleus	2 – 3 μm	2 – 3 μm
Breadth of nucleus	1.5 – 2 μm	1.5 μm

30. *Foaina reflexa* Kirby, 1942
(Figs. 54 - 55)

1942. *Foaina reflexa* Kirby, *Univ. Calif. Publ. Zool.*, 45 : 206.

1949. *Foaina reflexa* : Kirby, *Univ. Calif. Publ. Zool.*, 45 : 365.

1977. *Foaina reflexa* : Das, *Proc. zool. Soc, Calcutta*, 30 : 62.

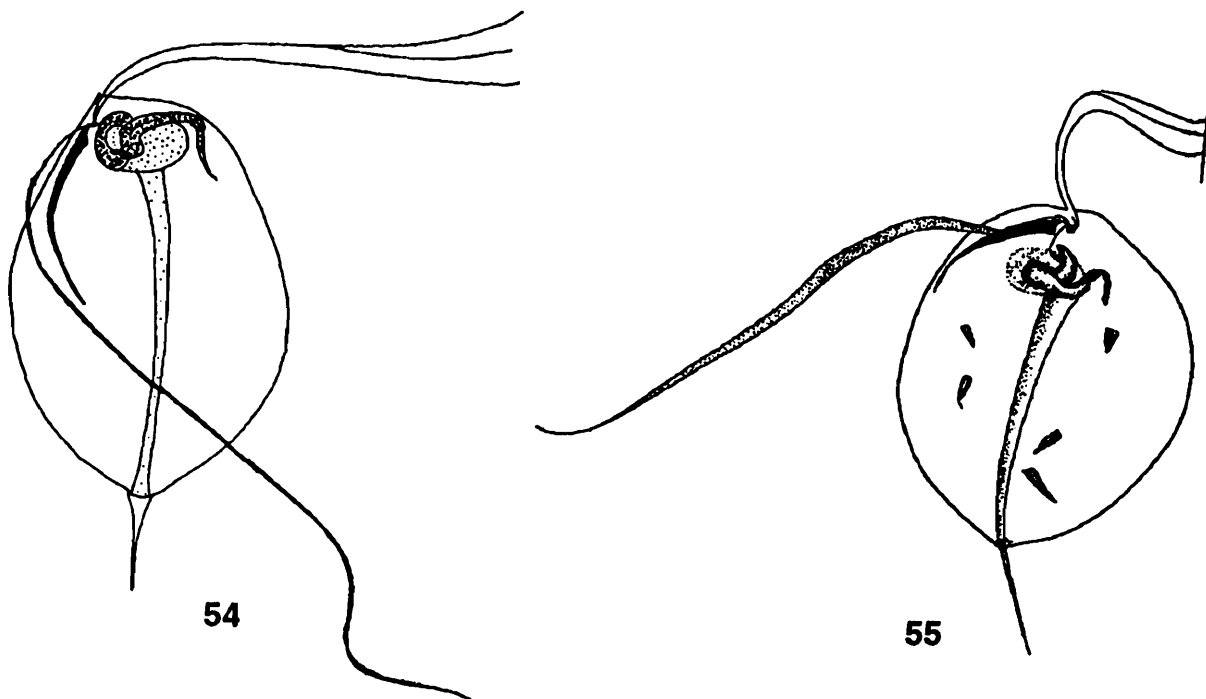
1983. *Foaina reflexa* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 43.

1992. *Foaina reflexa* : Tiwari, *Rec. zool. Surv. India*, 92 : 139.

1993. *Foaina feflexa* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series, 3(Part 12)* : 488. *Zool. Surv. India*.
2000. *Foaina reflexa* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series, 7(Part 4)* : 37. *Zool. Surv. India*.
2004. *Foaina reflexa* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series, 5(Part 6)* : 450. *Zool. Surv. India*.
- 2006a. *Foaina reflexa* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series 12* : 29. *Zool. Surv. India*.

Type host : *Proneotermes perezii* (= *Kalotermes perezii*); loc., Costa Rica.

Additional hosts : *Bifiditermes jeannelanus* (= *Kalotermes jeannelanus*); loc., East Africa; *Bifiditermes mutabae* (= *Kalotermes* sp. nov.); loc., East Africa, Swaziland; *Bifiditermes* sp. nov. (= *Kalotermes* sp.); loc., Transval; *Calcaritermes brevicollis*; loc., Panama; *Calcaritermes emerginicollis*; loc., Costa Rica; *Calcaritermes nearcticus*; loc., Florida; *Calcaritermes nigriceps*; loc., British Guiana; *Calcaritermes parvinoxus*; loc., Mexico; *Calcaritermes* sp. nov.; loc., El Salvador; *Cryptotermes brevis*; loc., Brazil; *Cryptotermes breviarticulatus*; loc., Panama; *Cryptotermes cavifrons*; loc., Florida; *Cryptotermes dudleyi*; loc., India : Andhra Pradesh, Tripura; *Cryptotermes havilandi*; loc., East Africa : Swaziland, India : Nagaland, West Bengal; *Cryptotermes longicollis*; loc., Panama; *Epicalotermes kempae* (= *Kalotermes* sp. nov.); loc., Kenya; *Epicalotermes mkuzii* (= *Kalotermes* sp. nov.); loc., South Africa : Transval; *Neotermes andamanensis*; loc., India : Andaman Islands; *Neotermes bosei*; loc., India : Bihar; *Neotermes castaneus*; loc., Florida; *Neotermes erythraeus*; loc., Eritrea; *Neotermes europae*; loc., Madagascar; *Neotermes holmgreni*; loc., Panama; *Neotermes meruensis*; loc., East Africa; *Neotermes zuluensis*; loc., East Africa : Swaziland; South Africa : Transval.



Figs. 54-55 : *Foaina reflexa* Kirby; in Fig. 55 Anterior flagella and trailing flagellum partly shown

Diagnosis : Body moderate to large in size, anterior flagella slender, three in number and equal to the length of the body; trailing flagellum usually resembling a stout cord and sometimes a narrow ribbon, exceeding to twice the body length; cresta long and narrow, its antero-medial edge about 1 μm or little more; parabasal body characteristic; part of the parabasal body near blepharoplast showing different shape of U-shaped bend; parabasal filament appearing clearly at the edge of parabasal, usually extending transversely across the body; the clear area, as observed by Kirby (1942), antero-lateral to the capitulum of the axostyle not traceable in Indian forms; axostyle stout, projecting out of the posterior end of the body to a considerable distance through moderately enlarged cusp; nucleus more or less round or oval.

Morphometry : Morphometric data of *Foaina reflexa* recorded from the different hosts of Indian termites are presented in Table 34 and compared with those collected from the type host.

Remarks : In his monographic account of the genus *Foaina*, Kirby (1942b) dealt with *F. reflexa* in details. So far, this species has been recorded from the guts of 26 species of termite hosts, of which 22 host species have been examined by Kirby (*op. cit.*).

Das (1977) was the first to report *F. reflexa* from India from the guts of *Cryptotermes havilandi*. Subsequently Tiwari (1992) and Das *et al.* (2000, 2004, 2006a) recorded this species from the hosts from the Indian termites *Neotermes bosei*, *Cryptotermes dudleyi* and *Cryptotermes havilandi* respectively. During the present study, the author has studied this species from *Neotermes andamanensis*, collected from Andaman islands.

Kirby (1942b) also studied *F. reflexa* from *Cryptotermes havilandi* from Swaziland in Africa. Majority of Kirby's specimens were about 35 μm in length and the smallest one was 19 μm . The Table 34 shows that Indian specimens of *F. reflexa* from *Cr. havilandi* being 25.5-42.5 μm in length are larger than those collected by Kirby (*op.cit.*) from the same host from different localities. The Table also reveals that Indian specimens of *F. reflexa* are larger than type specimens.

32. *Foaina solita* Kirby, 1942 (Fig. 56)

1942. *Foaina solita* Kirby, Univ. Calif. Publ. Zool., 45 : 182.

1949. *Foaina solita* : Kirby, Univ. Calif. Publ. Zool., 45 : 368.

1929. *Devescovina kribyi* De Mello and De Brito (*partim*), Esc. Med. Cirug. (Nova Goa) A (5) : 699.

1977. *Foaina solita* : Das, Proc. zool. Soc., Calcutta, 30 : 64.

1983. *Foaina solita* : Das, Proc. Symp. Host Environ. zool. Surv. India : 43.

1992. *Foaina solita* : Tiwari, Rec. zool. Surv. India, 92 : 140.

Table 34. Comparisom of morphometric data of *Foaina reflexa* from India hosts with those of type host; (all measurements in μm)

Characters	Indian hosts				Type host
	<i>Cr. havilandi</i>	<i>Cr. dudleyi</i>	<i>N. andamanensis</i>	<i>N. bosei</i>	<i>P. perezi</i>
Body length	31.3 (25.5-42.5)	24-43.5	30 (23-40)	33.6 (24-43.5)	24 (17-40)
Body width	22.8 (15.5-28)	16-31	21 (15-29)	24.4 (16-32)	12 (9-18)
Ratio of body length to body width (average)	1.4 : 1	1.4 : 1	1.4 : 1	1.3 : 1	2 : 1
Length of nucleus	5.7 (4.2 - 6.8)	-	5.5 (4-6)	5.4 (4.8-6.4)	3.2 (3-4)
Breadth of nucleus	4.5 (3.4-5.1)	-	4 (3.5-5.5)	4.2 (4-4.8)	2.4 (2-3)
Length of cresta	14 (13.5-15.3)	-	14.5 (12-16)	14.6 (13.6-16)	11-17

1993. *Foaina solita* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 489. *Zool. Surv. India*.
2000. *Foaina solita* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 38. *Zool. Surv. India*.
2004. *Foaina solita* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 450. *Zool. Surv. India*.
- 2006a. *Foaina solita* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 29. *Zool. Surv. India*.

Type host : *Cryptotermes dudleyi*; loc., Panama (type locality); India : Andhra Pradesh, Tripura.

Additional hosts : *Bifiditermes jeannelanus* (= *Kalotermes jeannelanus*); loc., East Africa; *Bifiditermes madagascariensis* (= *Kalotermes* sp.); loc., Madagascar; *Bifiditermes mutabae*; *Cryptotermes havilandi*; loc., India : Bihar, Nagaland, West Bengal; *Cryptotermes longicollis*; loc., Panama; *Cryptotermes queenslandis*; loc., Australia; *Cryptotermes* sp. nov.; loc., Madagascar, Mauritius; *Cryptotermes* sp. (= *Coptotermes heimi* of De Mello), loc., India : Daman; *Glyptotermes angustus*; loc., Panama; *Glyptotermes dilatatus*; loc., Sri Lanka; *Glyptotermes longisculus* (= *Glyptotermes* sp. nov.); loc., Belgium Congo; *Glyptotermes parki* (= *Glyptotermes* sp. nov.); loc., Ruanda Urundi; *Glyptotermes parvulus*; loc., Gold coast; *Glyptotermes tuberculatus*; loc., Australia; *Glyptotermes ueleensis* (= *Glyptoermes* sp. nov.); loc., Uganda; *Incisitermes repandus* (= *Kalotermes repandus*); loc., Figi Island; *Neotermes castaneus*; loc., Florida; *Neotermes connexus*; loc., Hawaii; *Neotermes greeni*; loc., Sri Lanka; *Neotermes holmgreni*; loc., Panama; *Neotermes sonneratae*; loc., Java; *Neotermes tectonae*; loc., Java; *Procryptotermes falcifer* (= *Procryptotermes* sp. nov.); *Rugitermes kirbyi*; loc., Costa Rica; *Rugitermes magninotus*; loc., British Guiana; *Rugitermes panamae*; loc., Panama.

Diagnosis : Small in size, anterior flagella slender, three in number, slightly larger than the body length; trailing flagellum a moderately stout cord, 2-5 times the length of the body; cresta narrow, 3.8-5 μ m in length; parabasal body bacilliform, almost equal to nucleus in length and restricted to dorsal side of nucleus; axostyle moderately stout with or without enlarged cusp; in many specimens 2-4 rings present surrounding the trunk of the axostyle, before projecting out of the posterior portion of the body; nucleus more or less rounded.

Morphometry : Mensural data of *Foaina solita* collected from Indian termites are presented in Table 35 and compared with those of type material.

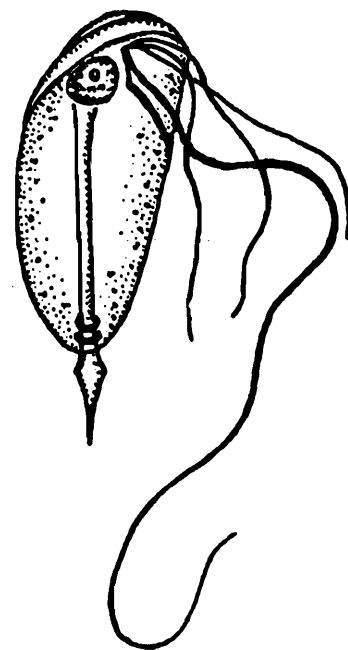


Fig. 56 : *Foaina solita* Kirby

Table 35. Comparison of morphometric data of Indian specimens of *Foaina solita* with those of type specimens; (measurement in μm)

Characters	Indian specimens		Type specimens
	<i>Cr. havilandi</i>	<i>Cr. dudleyi</i>	<i>Cr. dudleyi</i> (type locality) Panama
Body length	11.5 (8-16)	11.7 (8.2-17)	11.1 (7.6-17.7)
Body width	5.4 (3.2-8)	6.2 (3.2-8.5)	5.6 (3.2-9.2)
Ratio of body length to body width (average)	2.1 : 1	1.8 : 1	1.9 : 1
Length of nucleus	2-3	2.5-3.5	2-3
Breadth of nucleus	2-2.5	2-2.5	1.5-2.5
Length of trailing flagellum	23-40	30-45	35-50
Length of cresta	3.9 (3.5-4.8)	4.1 (3.8-5)	3.7 (3-4.5)

Remarks : As mentioned earlier, Kirby (1942b) ascertained that a part of the material of *Devescovina kirbyi* described by De Mello and De Brito (1929b) from Indian termites (incorrectly identified by De Mello as *Coptotermes heimi*) comprises of *Foaina solita* and the remaining part belongs to *Foaina nana*. *F. solita* has also been reported from *Cryptotermes dudleyi* by Dás *et al.* (2000, 2004, 2006a) from India.

The Table 35 reveals that mensural data of Indian specimens of *F. solita* are well within the range of those of type specimens. Kirby (1942, 1949) who examined this species from 25 species of termite hosts observed that *F. solita* was associated with *F. nana* in many of those hosts including the type host. In Indian termites such association was found only in *Cryptotermes havilandi* but not in the type host, *Cryptotermes dudleyi*, collected from India. Mention is to be made here that *F. solita* has so far been recorded from 28 species of termite hosts, all belonging to the family Kalotermitidae.

Foaina solita resembles *F. nana* to a great extent. But, long axial filament and characteristic "cystostome" like clear area at the anterior of nucleus and absence of bacilliform parabasal body conveniently differentiate *F. nana* from *F. solita*.

Genus *Polymastigoides* Grassé and Hollande, 1951

1951. *Polymastigoides* Grassé and Hollande, *Ann. Sci. Nat. Zool. Biol. Ser.* 11, 13 : 26.

Diagnosis : Body very slender, length-breadth ratio about 12 : 1; an antero-lateral indentation marking off the region of the papilla; anterior flagella slender, three in number and about the body-length; trailing flagellum also about the body length and as slender as anterior flagella; parabasal body short; cresta very small, flattened and thorn shaped; axostyle slender, not projecting out from the posterior end of the body; adherent "Fusiform" like organisms comparatively short and stout; numerous spirochaetes adherent to the surface.

Remarks : Bernstein (1928) described *Devescovina elongata* from the termite *Anacanthotermes murgabicus*. Kirby (1941a) recorded the same from another species of termite host, viz, *Anacanthotermes ochraceus*. Bernstein (*op. cit.*) did not describe any cresta. She (*op. cit.*) observed four flagella and did not differentiate one as a trailing flagellum. She also observed two basal granules of equal size side by side. Based on Bernstein's description Duboscq *et al.* (1937) synonymised *D. elongata* with *Polymastix lineata*. They (*op. cit.*) placed this species under *Polymastix* because of the absence of rostrum, the manner of implantation of flagella, the elongate form and manner of fixation of bacteria. According to Kirby (1949a) none of these characters are significant for the diagnosis of a genus. However, he (*op. cit.*) admitted that *D. elongata* possesses certain features which are not typical of *Devescovina*. So he suggested to define a new genus to accommodate this species on the basis of the differences in shape of the anterior end and a different type of rod on the surface. Subsequently Grassé and Hollande (1951) established the genus *Polymastigoides* and placed *D. elongata* under this genus as *P. elongata*.

33. *Polymastigotoides elongata* (Bernstein, 1928) Grassé and Hollande, 1951 (Fig. 57)

- 1951. *Polymastigoides elongata* (Bernstein) Grassé and Hollande, *Ann. Sci. Nat. Zool. Biol. Anim. Ser* 11, 13 : 26.
- 1928. *Devescovina elongata* Bernstein, *Arch. Protistenkd.*, 61 : 24.
- 1937. *Polymastix lineata* Duboscq, Grassi and Rose, *C. R. Accad. Sci.*, 205 : 574.
- 1943. *Polymastix lineatus* Duboscq, Grassi and Rose, *Arch. Zool. exp. gen.*, 82 : 405.
- 1942. *Strobilonympha schizophyla* De Mello and Monteiro, *Arqu. Esc. Med. Cirug. Nova Goa (A)* 18 : 1.
- 1942. *Strobilonympha pisciformis* De Mello and Monteiro, *Arqu. Esc. Med. Cirug. Nova Goa (A)* 18 : 1.
- 1942. *Strobilonympha serpentiformis* De Mello and Monteiro, *Arqu. Esc. Med. Cirug. Nova Goa (A)* 18 : 1.

Type hosts : *Anacanthotermes murgabicus*; loc., Turkestan.

Additional hosts : *Anacanthotermes ochraceus*; loc., Egypt; *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., India : Tamil Nadu.

Diagnosis : As for the genus *Polymastigoides*.

Remarks : De Mello and Monteiro (1942) established a new genus *Strobilonympha* and described three new species under this genus, viz., *S. schizophyla*, *S. pisciformis* and *S. serpentiformis* from the gut of an Indian termite *Anacanthotermes viarum*. They considered this genus as a hypermastigote, covered with flagella and stated that it was related to "*Teratonympha*" as they observed pseudometamerism in the above three species. Examining the illustrations of these three species, given by De Mello and Monteiro (1942), Kirby (1949a) was convinced that they actually got "polymastigote" flagellates, belonging to *Devescovina elongata* Bernstein, 1928 which was subsequently synonymised under

Polimastigoides elongata as discussed above. According to Kirby (*op. cit.*), the longitudinal "scales or spikes", the arrangement of which appeared to be pseudometamerism to De

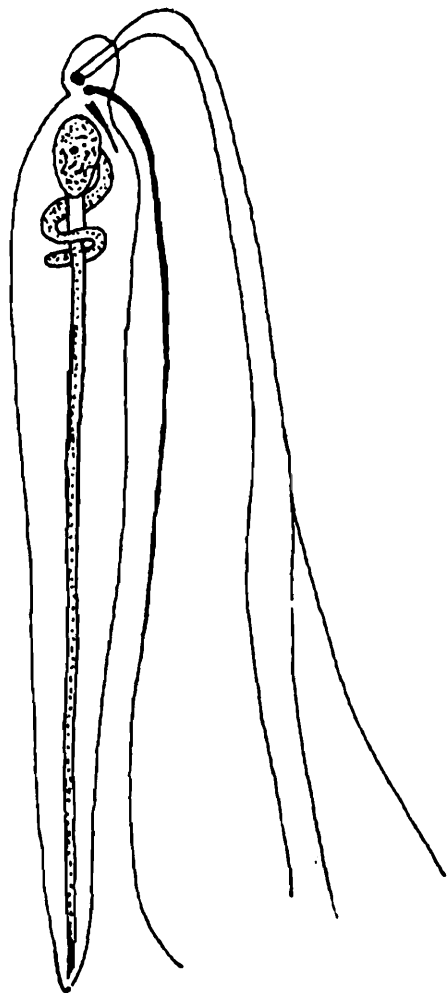


Fig. 57 : *Polymastigoides elongata* (Bernstein)

Mello and Monteiro (1942) were adherent micro-organisms. The dense fine coat of cilia over the whole body for which these flagellates were treated as hypermastigotes was an artefact. Kirby (1949a) further stated that De Mello and Monteiro (*op. cit.*) might have overlooked three anterior flagella and one recurrent flagellum as well as small cresta.

De Mello and Monteiro (1942) differentiated *S. schizophyla* and *S. pisciformis* on the basis of size differences and number of adherent spirochaetes. Kirby (1949a) opined that these differences are well within the range of a variation of a species. Further, according to him the structure of *S. serpentiformis* described by De Mello and Monteiro is not known in any flagellate and is "highly improbable." To quote Kirby (*op. cit.*), "it seems possible that parts of two separate flagellates were combined in supposed organisms of that species." In view of this, all the above three species of *Strobilonympha* were treated as one species by Kirby (1949a), following which these are synonymised under *Polymastigoides elongata*.

Subfamily GIGANTOMONADINAE Kirby, 1946

1946. Gigantomonadinae Kirby, *Univ. Calif. Publ. Zool.*, 53 : 193.

Diagnosis : Mastigont system of three anterior flagella, one trailing flagellum, axostyle and cresta within cytoplasm; cresta becoming a large internal membrane, trailing flagellum paralleling and insecurely adherent to the outer edge of cresta, but no undulating membrane; in life history phase a much enlarged and frequently binucleate amoeboid phase present, with reduced development of mastigont structures.

Genus *Macrotrichomonas* Grassi, 1917

1917. *Macrotrichomonas* Grassi, *Mem. R. Accad. Lincei*, 5(12) : 376.

1932. *Gigantomonas* Connell, *partim*, *Univ. Calif. Publ. Zool.*, 37 : 180 (not *Gigantomonas* Dogiel).

1938. *Macrotrichomonas* : Kirby, *Univ. Calif. Publ. Zool.*, 43 : 15.

1942. *Macrotrichomonas* : Kirby, *Univ. Calif. Publ. Zool.*, 45 : 111.

Diagnosis : Large devescovinid with three slender anterior flagella; trailing flagellum well developed, usually 1-1.5 times the length of the body, resembling a band in some species; cresta developed into a large intra-cytoplasmic membranous structure, extending from the nucleus to the periphery of the body; external edge of cresta more or less waved in undulatory folds; parabasal body coiled closely around the axostyle in 1-13 turns, branched in one species; capitulum moderately developed, often with arm; trunk of the axostyle stout anteriorly, tapering posterior but not reduced to filament nor extended in a filament; nucleus large, containing small chromatic granules, its longer axis longitudinal.

34. *Macrotrichomonas pulchra* Grassi, 1917
(Fig. 58)

1917. *Macrotrichomonas pulchra* Grassi, Mem. R. Accad. Lincei, 5(12) : 376.
 1932. *Gigantomonas pulchra* (Grassi) Connell, Univ. Calif. Publ. Zool., 37 : 180.
 1937. *Gigantomonas pulchra* : Grasse, C. R. Soc. Biol., 125 : 918.
 1938. *Macrotrichomonas pulchra* : Kirby, Univ. Calif. Publ. Zool., 43 : 16.
 1942. *Macrotrichomonas pulchra* : Kirby, Univ. Calif. Publ. Zool., 45 : 115.
 1992. *Macrotrichomonas pulchra* : Tiwari, Rec. zool. Surv. India, 92 : 141.

Type host : *Glyptotermes parvulus*; loc., Gold coast.

Additional hosts : *Glyptotermes caudomunitus*; loc., Inida : Bihar; *Glyptotermes brevicollis* (= *Glyptotermes dubius* / *perungustus*); loc., Australia; *Glyptotermes ceylonicus*; loc., Sri Lanka; *Glyptotermes contracticornis*; loc., Costa Rica; *Glyptotermes irridipennis*; loc., Australia; *Glyptotermes longuisculus* (= *Glyptotermes perungustus*); loc., Australia; *Glyptotermes magsaysayi* (= *Glyptotermes* sp. nov.); loc., Philippines; *Glyptotermes montanus*; loc., Java; *Glyptotermes neotuberculatus*; Australia; *Glyptotermes parki* (= *Glyptotermes* sp. nov.); loc., Belgium Congo, Ruanda Urundi; *Glyptotermes taveuniensis*; loc., Fiji Island; *Glyptotermes ueleensis* (= *Glyptotermes* sp. nov.); loc., Uganda.

Diagnosis : Body more or less elongate oval with bluntly pointed posterior end; anterior flagella slender, three in number, about the length of the body; trailing flagellum band-shaped, about 1.5 times the body length; cresta large, inner part uniformly dense, outer part undulated, postero-medial edge concave; paracrestal filament running along the antero-medial edge and extending further to a short distance; parabasal body coiled closely in 4-5 turns around the axostyle; capitulum of axostyle broadened ventrally by a suspensorial lamella; trunk of the axostyle tapering towards posterior end and protruding outside the body from the bluntly pointed end to a short distance; nucleus ellipsoidal, containing densely distributed chromatin granules; a clear space between nuclear membrane and chromatin granules present.

Morphometry : Morphometric data of Indian forms of *Macrotrichomonas pulchra* are presented in Table 36 and compared with those of specimens from the type host and the Sri Lankan host.

Table 36. Comparison of morphometric data of *Macrotrichomonas pulchra* from Indian termites with those from type host and a host from Sri Lanka; (measurements μm)

Characters	From Indian termites <i>G. caudomunitus</i>	Termites of outside India	
		Type host <i>G. parvulus</i>	Sri Lankan host <i>G. ceylonicus</i>
Body length	63.3 (57.6-73.6)	67 (44-91)	52 (37-66)
Body width	31.6 (22.8-33.6)	32 (21-41)	26 (19-39)
Ratio of body length to body width (average)	2 : 1	2 : 1	2 : 1
Length of nuclues	9.7 (8.8-10.4)	9.6	8.3 (7.4-9)
Breadth of nuclues	6.4 (6.1-7)	7.7	5.8 (5-6.4)
Length of cresta	42.2 (27.2-48)	—	21-28
Length of trailing flagellum	70-115	—	—
No. of parapasal turn	4-5 turns	4-5 turns occasionally 10	—

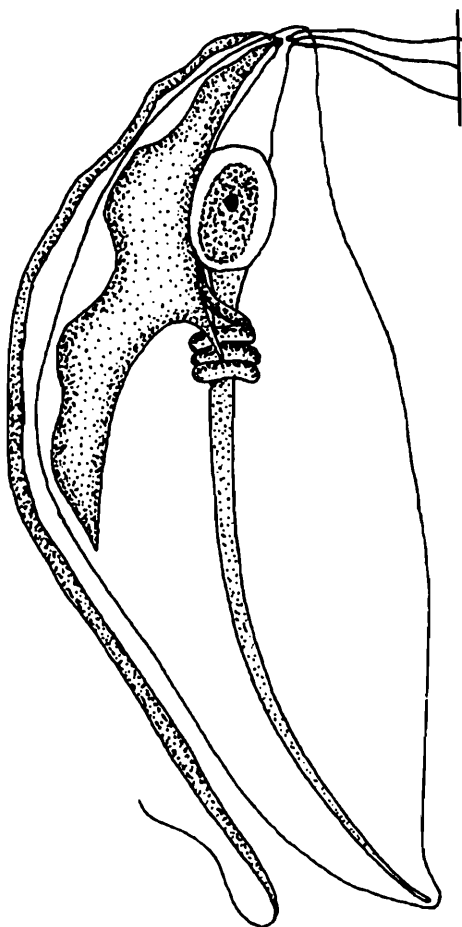


Fig. 58 : *Macrotrichomonas pulchra* Grassi; anterior flagella partly shown

Remarks : Considerably large cresta of *Macrotrichomonas* is comparable to that of the genus *Gigantomonas*. So Connell (1932) considered *Gigantomonas hercula* and *Macrotrichomonas pulchra* as congeneric under the genus *Gigantomonas*. After detailed study of both the genera, Kirby (1942a, 1946) retained the status of *Macrotrichomonas*. According to him there is an evolutionary distinctness between these two genera since all the species of *Macrotrichomonas* occurs in the termites of the family Kalotermitidae while *Gigantomonas* occurs in the termites, belonging to the family Hodotermitidae. Moreover, absence of parabasal body in *Gigantomonas* differentiates it further from *Macrotrichomonas*. However, both the genera are placed under the subfamily Gigantomonadinae by Kirby (1946) because they share some salient characteristic features as mentioned earlier under the diagnosis of this subfamily.

Macrotrichomonas pulchra has so far been reported from 13 species of termite hosts, all of which belong to the genus *Glyptotermes* under

the family Kalotermitidae. Presence of band-shaped trailing flagellum, well developed cresta with a rectangular shelf-like extension from the posterior part of the antero-medial edge and parabasal body without any branching make this species distinct from all its congeners. The Table 36 shows that Indian forms of *M. pulchra* are slightly smaller in dimensions than the type species but these are larger than the Sri Lankan forms.

Family CALOMYMPHIDAE Grassi and Foa, 1911

1911. Calonymphidae Grassi and Foa, *Rend. R. Accad. Lincei*, Ser. 1, sem. 1, 20 : 727.

Diagnosis : Trichomonadida with a permanent polymonad organisation, multinucleate, each nucleus associated with a mastigont (termed as karyomastigont), comprising of one or more blepharoplasts, a parabasal body, an axostyle or axial filament and flagella four in number (Fig. 59) ; in some forms nucleus may be dissociated from the mastigont system (termed as akaryomastigont).

Remarks : The first record of calonymphid flagellates from India was made by De Mello and De Brito (1929c) who erected a genus *Metastephanonympha* with the type species *M. perronciti* which was collected from the termite *Coptotermes heimi*. In 1946 De Mello described another species of calonymphid flagellate, viz., *Stephanonympha reenstiernai* from the termite *Cryptotermes* sp. from India. Subsequently Das and Choudhury (1972) described two new species of *Stephanonympha*, viz., *S. pyriformis* and *S. minuta* from the Indian termites *Cryptotermes havilandi* and *Neotermes bosei* respectively and recorded one known species, *S. silvestrii* from the former host.

According to De Mello and De Brito (1929c) the genus *Metastephanonympha*

possessed two flagella in each mastigont instead of four, found in all other calonymphid genera. But Kirby (1937) doubted the validity of this genus and considered it to be a synonym of the genus *Stephanonympha*. According to him "there is much reason to doubt the correctness of their (De Mello and De Brito's) statement. Probably all Calonymphidae have four flagella in a mastigont" However, De Mello and Uttangi (1950) reestablished this genus describing another species under this genus, viz, *M. karnataki* from an Indian millipede. The occurrence of calonymphid flagellates in the gut of millipedes is quite improbable and deserves further confirmation. Because, excluding the species of De Mello

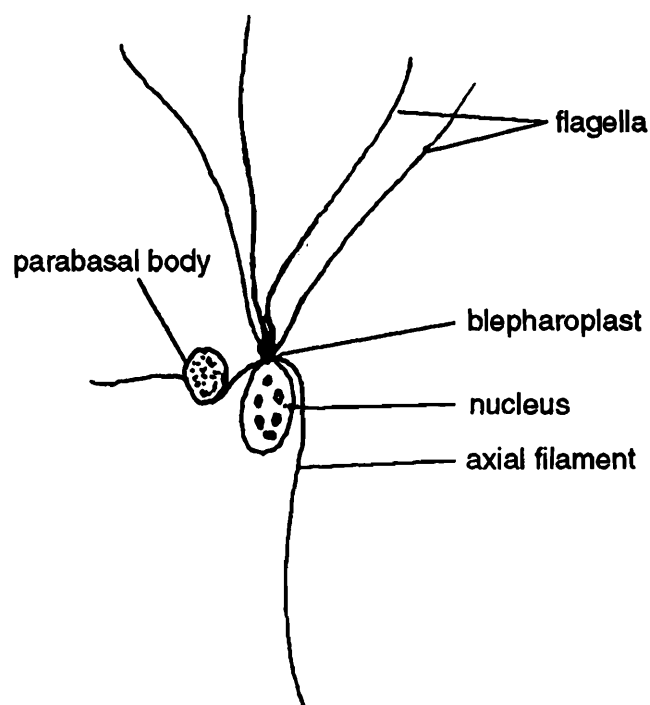


Fig. 59 : A typical karyomastigont of the family Calonymphidae

and De Brito (1929c) and De Mello and Uttangi (1950) referred above all the calonymphid flagellates recorded so far from the globe, comprising of 22 determined and 3 undetermined species under 6 genera are found to be restricted to the guts of 27 species of termites, belonging to the family Kalotermitidae only (see Yamein, 1978; Das *et al.* 1986). In view of above, synonymy of *Metastephanonympha* under the genus *Stephanonympha* is quite justified. The same is followed in the present work. Thus, under the family Calonymphidae only one valid genus *Stephanonympha* with five species have been reported so far from Indian termites.

Genus *Stephanonympha* Janicki, 1911

1911. *Stephanonympha* Janicki, *Biol. Central.*, 31 : 325.

1929. *Metastephanonympha* De Mello and De Brito, *C. R. Soc. Biol.*, 101 : 394.

1929. *Metastephanonympha* De Mello and De Brito, *Arqu. Esc. Med. Cirug Nova Goa (A)* 5 : 707.

Diagnosis : Body oval but plastic; a large number of nuclei arranged spirally in the anterior half of the body; each nucleus associated with a mastigont structure (= karyomastigont), comprising of four flagella, an axial filament, a blepharoplast and a parabasal apparatus; axial filaments anastomosing to form a conspicuous bundle extending to the posterior portion of the body.

Key to the species of the genus *Stephanonympha* reported from Indian termites

1. Each mastigont possessing a pair of parabasal granules and (?) two flagella; body small, oval with broadly round anterior and broad posterior end *S. perronciti*
- Each mastigont with one parabasal granule and four flagella 2
2. Number of nuclei 6-12, arranged in one concentric spiral *S. minuta*
- Number of nuclei many, arranged in more than one concentric spirals 3
3. Body pyriform with bluntly pointed posterior end, body size large, 75.3 (72.2-86.7) μm , nuclei many, arranged in 8-9 spirals *S. pyriformis*
- Body mostly oval or round, body size comparatively small, nuclei usually arranged in 2-6 spirals 4
4. Body ovoid, some forms very elongated and narrow and, 'cucumber like', 41(22-55) μm in length, nuclear spirals 3-6, occasionally 9; in some specimens disposition of nuclei very irregular *S. reenstiernai*
- Body oval or round, Indian forms 49.3 (45-56.3) μm , nuclei arranged in 2-3 spirals *S. silvestrii*

35. *Stephanonympha minuta* Das and Choudhury, 1972
(Fig. 60)

1972. *Stephanonympha minuta* Das and Choudhury, *Proc. zool. Soc., Calcutta*, 25 : 26.
1981. *Stephanonympha minuta* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 161.
1983. *Stephanonympha minuta* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 43.
1992. *Stephanonympha minuta* : Tiwari, *Rec. zool. Surv. India*, 92 : 141.
1993. *Stephanonympha minuta* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 489. *Zool. Surv. India*.
2004. *Stephanonympha minuta* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 451. *Zool. Surv. India*.
2006a. *Stephanonympha minuta* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 29. *Zool. Surv. India*.

Type host : *Neotermes basei*; loc., India : West Bengal.

Additional hosts : *Cryptotermes havilandi*; loc., India : Bihar, Nagaland; *Cryptotermes dudleyi*; loc., India : Andhra Pradesh.

Diagnosis : Body oval with broad anterior and bluntly pointed posterior ends; nuclei oval, 6-10 in number and set closely, forming a single spiral series near the anterior end of the body; each nucleus containing deeply stained granules and possessing a large spherical blepharoplast close to the anterior part of the nuclear membrane; a small spherical parabasal body located adjacent to the nucleus and connected with the blepharoplast by means of parabasal thread; from the posterior end of each blepharoplast an axial filament arising and running towards the posterior portion of the body; axial filaments ultimately uniting to form an axial bundle, reaching up to the posterior end of the body.

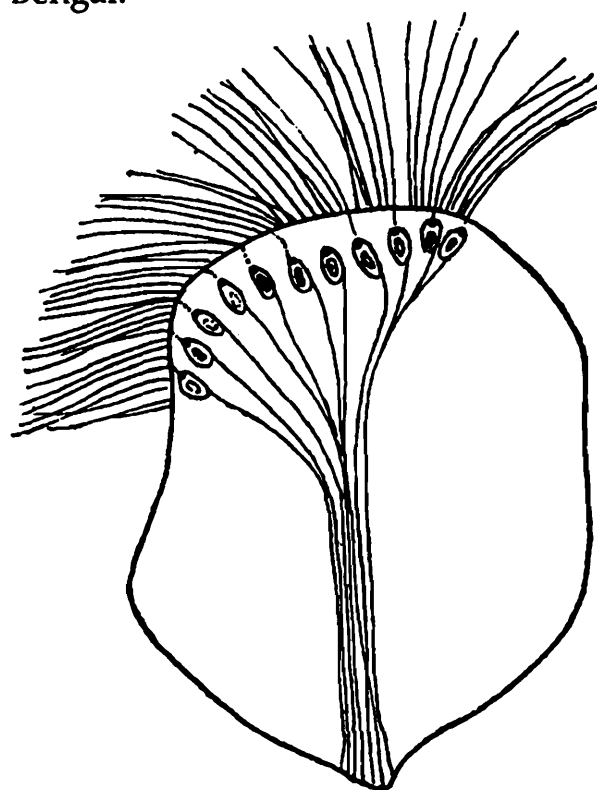


Fig. 60 : *Stephanonympha minuta* Das

Morphometry : Mensural data of *Stephanonympha minuta*, collected from different Indian hosts are presented in Table 37 for comparison.

Table 37. Mensural data of *Stephanonympha minuta* from different Indian hosts; (measurements in μm)

Characters	<i>N. bosei</i> (Type host)	<i>Cr. havilandi</i>	<i>Cr. dudleyi</i>
Body length	34 (28-36)	37.8 (36-40)	35.5 (30-38.5)
Body width	26.3 (20-29.7)	32 (30-36)	28 (24-31)
Ratio of body length to body-width(average)	1.3 : 1	1.1 : 1	1.2 : 1
Number of nuclei	6-10	8-12	6-12
Number of nuclear spiral	one	one	one

Remarks : *Stephanonympha minuta* is quite distinct from all other described species of *Stephanonympha* in having only 6-12 nuclei arranged in a single nuclear spiral at the anterior end of the body. Table 37 shows that specimens of *S. minuta* collected from both the host species of *Cryptotermes* are slightly larger and broader in dimensions than those collected from the type host, *Neotermes bosei*.

36. *Stephanonympha perronciti* (De Mello and De Brito, 1929) Kirby, 1937

1929. *Metastephanonympha perronciti* De Mello and De Birto, *Arqu. Esc. Med. Cirug Nova Goa (A)* 5 : 707.

1937. *Stephanonympha perronciti* (De Mello and De Brito) Kirby, *Univ. Calif. Publ. Zool.*, 41 : 202.

1983. *Stephanonympha perronciti* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 43.

Type host : *Cryptotermes* sp. (= *Coptotermes heimi* sensu De Mello and De Brito), India : Daman.

Diagnosis : Small oval forms with a thin flattened body, broadly rounded anterior end and rounded posterior end; variable number of nuclei, located at anterior end, attached with mastigont structures; each mastigont comprising of a pair of parabasal granules, a parabasal body, curved cresta, the rhizoplast and axostyle; two flagella (?) attached to each mastigont.

Remarks : De Mello and De Brito (1929c) described this species as *Metastephanonympha perronciti*. As elaborated earlier, Kirby (1937) synonymised this species under the genus *Stephanonympha*. According to Kirby (*op. cit.*) all calonymphid flagellates possess four flagella in each mastigont. So, presence of two flagella in each mastigont in this species was, according to him, not correct observation.

In every probability, host species of this flagellate was incorrectly identified as *Coptotermes heimi*. As all the calonymphid species occur only in the guts of the termite family Kalotermitidae, the above mentioned incorrectly identified host species was also a Kalotermitid termite. Considering the distribution of termites in the type locality (in Daman), it was most probably a species of *Cryptotermes* and probably *Cryptotermes havilandi*.

37. *Stephanonympha pyriformis* Das and Choudhury, 1972
(Fig. 61)

1972. *Stephanonympha pyriformis* Das and Choudhury, *Proc. Zool. Soc., Calcutta*, 25 : 27.
1981. *Stephanonympha pyriformis* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 161.
1983. *Stephanonympha pyriformis* Das : *Proc. Symp. Host Environ. zool. Surv. India* : 43.
1992. *Stephanonympha pyriformis* : Tiwari, *Rec. zool. Surv. India*, 92 : 142.
1993. *Stephanonympha pyriformis* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series* 3(Part 12) : 490. *Zool. Surv. India*.
2000. *Stephanonympha pyriformis* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 38. *Zool. Surv. India*.
2004. *Stephanonympha pyriformis* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 452. *Zool. Surv. India*.
- 2006a. *Stephanonympha pyriformis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 30. *Zool. Surv. India*.

Type host : *Cryptotermes havilandi*; loc., India : Nagaland and West Bengal (type locality).

Additional hosts : *Cryptotermes dudleyi*; loc., India : Andhra Pradesh, Tripura; *Neotermes bosei*; loc., India : West Bengal.

Diagnosis : Body pyriform with bluntly pointed posterior end; nuclei ovoid or a little elongated, numerous, feulgen-positive (Das and Choudhury, 1975) and embedded in a series in 8-9 concentric spirals, occupying almost one-third portion of the anterior end of the body; each nucleus possessing one small and one round blepharoplast at its anterior pole and more or less round parabasal body near its closest vicinity; four flagella emerging out of each blepharoplast; blepharoplast connecting parabasal body with a fibril as well as sending out one long axial filament over the nuclear membrane towards the posterior portion of the body; such axial filaments from different blepharoplasts uniting together forming an axial bundle; this axial bundle running through the middle of the body, reaching almost its posterior extremity; endoplasm containing fragments of wood particles and many PA-Schiff positive granular inclusions (Das and Choudhury, 1975).

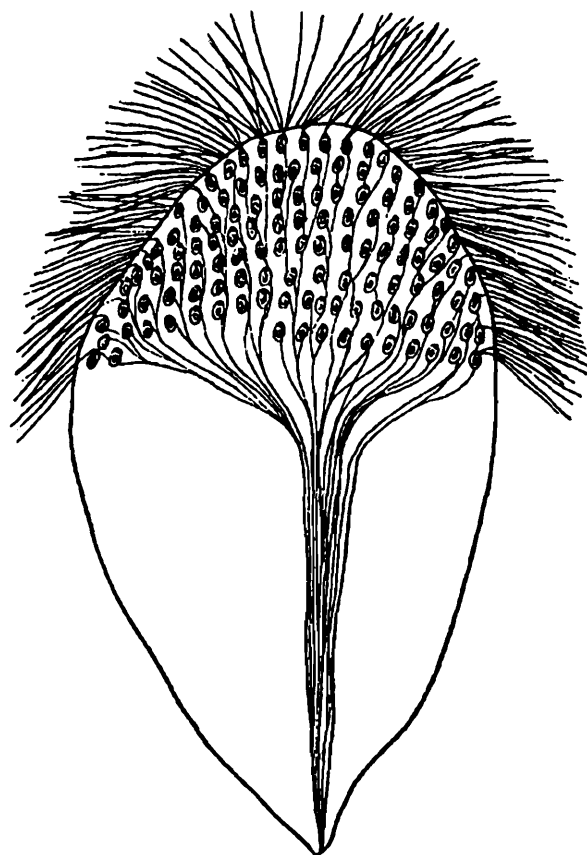


Fig. 61 : *Stephanonympha pyriformis* Das

Morphometry : Mensural data of the type specimens of *Stephanonympha pyriformis* are presented in Table 38 and compared with those of the specimens collected from *Cryptotermes dudleyi*.

Table 38. Comparison of morphometric data of *Stephanonympha pyriformis* from different Indian termites; (measurements in μm)

Characters	Type host <i>Cr. havilandi</i>	<i>Cr. dudleyi</i>
Body length	75.3 (70.2–86.7)	64 – 83.2
Body width	43.1 (38–47.5)	38 – 52.5
Ratio of body length to body width (average)	1.7 : 1	1.6 : 1
Number of nuclei	100 – 120	100 – 110
Number of nuclear spirals	8 – 9	8 – 9

Remarks : *Stephanonympha pyriformis* has been collected from three species of Indian termites as mentioned above. Out of these, morphometric data of this flagellate species collected from the host *Neotermes bosei* by Tiwari (1992) were not recorded. The Table 38 shows that the specimens of *S. pyriformis* collected from *Cr. havilandi* and *Cr. dudleyi* are almost similar in dimensions. Comparatively large body size, pyriform shape and presence of large number of nuclei in 8-9 concentric circles are the characteristic features of this species, by which *S. pyriformis* can be conveniently differentiated from its congeners.

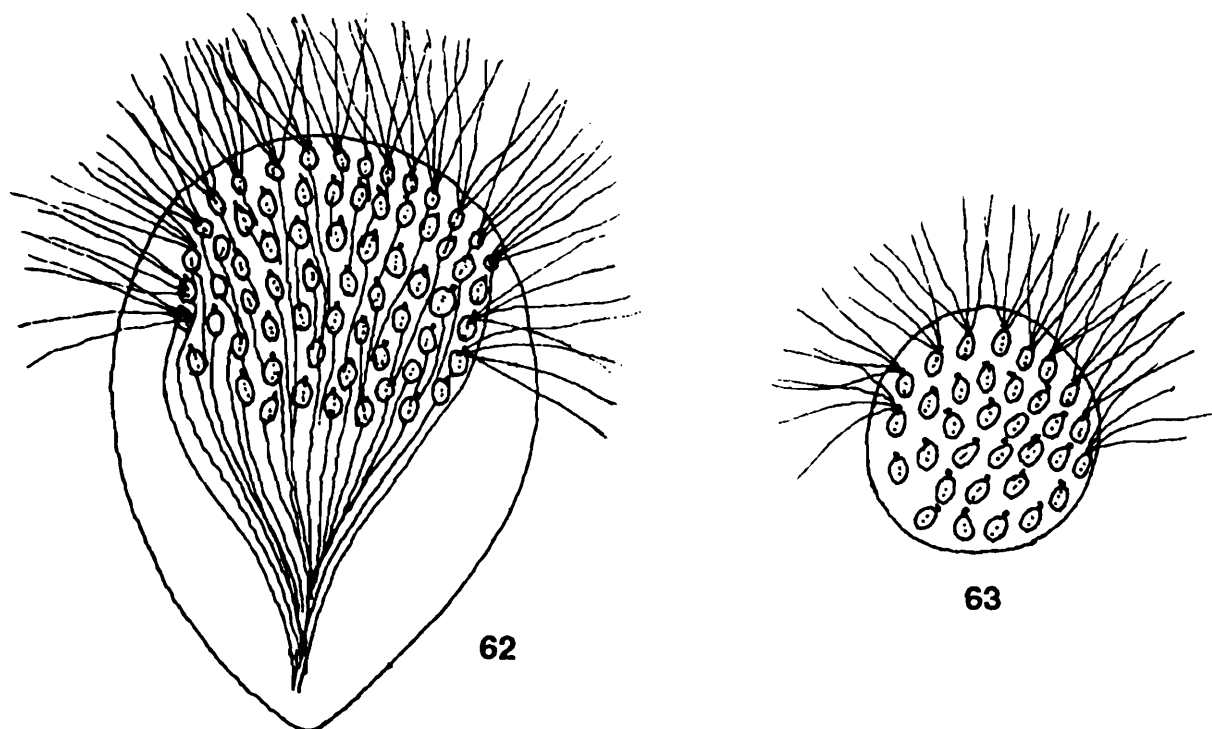
38. *Stephanonympha reenstiernai* De Mello, 1946 (Figs. 62-63)

1946. *Stephanonympha reenstiernai* De Mello, *An. Inst. Med. Trop.*, 3 : 37.

1983. *Stephanonympha reenstiernai* : Das, *Proc. Symp. Host Environ. Zool. Surv. India* : 43.

Type host : *Cryptotermes* sp.; loc., India : Goa.

Diagnosis : Most specimens ovoid with posterior pole pointed; some forms very elongated and narrow and more or less cucumber like; number of nuclei varying to a great extent from 40 to "countless"; number of nuclear spirals 3-9 (average 5-6); generally nuclei situated at the anterior pole and disposed in some more or less parallel rows but in many specimens disposition of nuclei very irregular; in some of them, specially in small spherical forms, the whole area filled up with nuclei (Fig. 63); each mastigont attached to a nucleus and composed of a nucleus, a parabasal body, an axial filament and four anterior flagella; nucleus ovoid, often with posterior end pointed, a conspicuous blepharoplast situated at its anterior end; axial filaments arising from the blepharoplast extending up to the posterior end of the body forming an axostylar bundle, uniting with other similar axial filaments.



Figs. 62-63 : *Stephanonympha reenstiernai* De Mello. Fig. 62. Typical form; Fig. 63 : Spherical form, appearing to be fully occupied by nuclei (after De Mello, 1946)

Morphometry : The morphometric data as recorded by De Mello (1946) are presented in Table 39.

Table 39. Morphometric data of type specimens of *Stephanonympha reenstiernai*

Characters	Morphometric data
Body length	41 (24 – 55) μm
Body width	28.1 (10 – 50) μm
Ratio of body length to body width (average)	1.4 : 1
Number of nuclei	40 to numerous
Number of nuclear spirals	3 – 9 (average 5-6)

Remarks : *Stephanonympha reenstiernai* has not been reported since its description by De Mello (1946). However, in a checklist of flagellate symbiotes of Indian termites Das (1983) incorporated this species, consulting the relevant literature. The diagnosis of this species presented in this paper is solely based on its original description.

While describing *S. renstrienai* De Mello (*op. cit.*) categorised large and small speherical forms with dimensions 52-55 μm x 48-50 μm and 28-32 μm x 22 μm respectively. However, total population of this species comprising spherical, ovoid and very elongated forms have dimensions 24-55 μm x 10-50 μm with average 41 μm x 28.1 μm as presented in Table 39.

39. *Stephanonympha silvestrii* Janicki, 1911
(Figs. 64-70)

1911. *Stephanonympha silvestrii* Janicki, *Biol. Central.* **31** : 325.
1917. *Stephanonympha silvestrii* var. *cryptotermes havilandi* Grassi, *M. R. Accad. Lincei* (5), **12** : 338.
1917. *Stephanonympha silvestrii* var. *neotermes erythraei* Grassi, *M. R. Accad. Lincei* (5), **12** : 338.
1926. *Stephanonympha havilandi* : Kirby, *Univ. Calif. Publ. Zool.*, **29** : 112.
1926. *Stephanonympha erythraei* : Kirby, *Univ. Calif. Publ. Zool.*, **29** : 112.
1954. *Stephanonympha havilandi* : De Mello, *Parasitol.*, **44** : 30.
1972. *Stephanonympha havilandi* : Das, *Proc. Zool. Soc., Calcutta*, **25** : 29.
1983. *Stephanonympha silvestrii* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 43.
1992. *Stephanonympha silvestrii* : Tiwari, *Rec. zool. Surv. India*, **92** : 142.
1993. *Stephanonympha silvestrii* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 490. *Zool. Surv. India*.
2000. *Stephanonympha silvestrii* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 7) : 38. *Zool. Surv. India*.
2004. *Stephanonympha silvestrii* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 542. *Zool. Surv. India*.
- 2006a. *Stephanonympha silvestrii* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, **12** : 30. *Zool. Surv. India*.

Type host : *Neotermes connexus*; loc., Honolulu.

Additional hosts : *Cryptotermes domesticus*; loc., Malaysia; *Cryptotermes dudleyi*; loc., India : Andhra Pradesh and Tripura; *Cryptotermes havilandi*; loc., India : Bihar, Nagaland, West Bengal; *Neotermes andamanensis*; loc., India : Andaman Island; *Neotermes erythraeus*; loc., Eritrea; *Neotermes insularis*; loc., Australia.

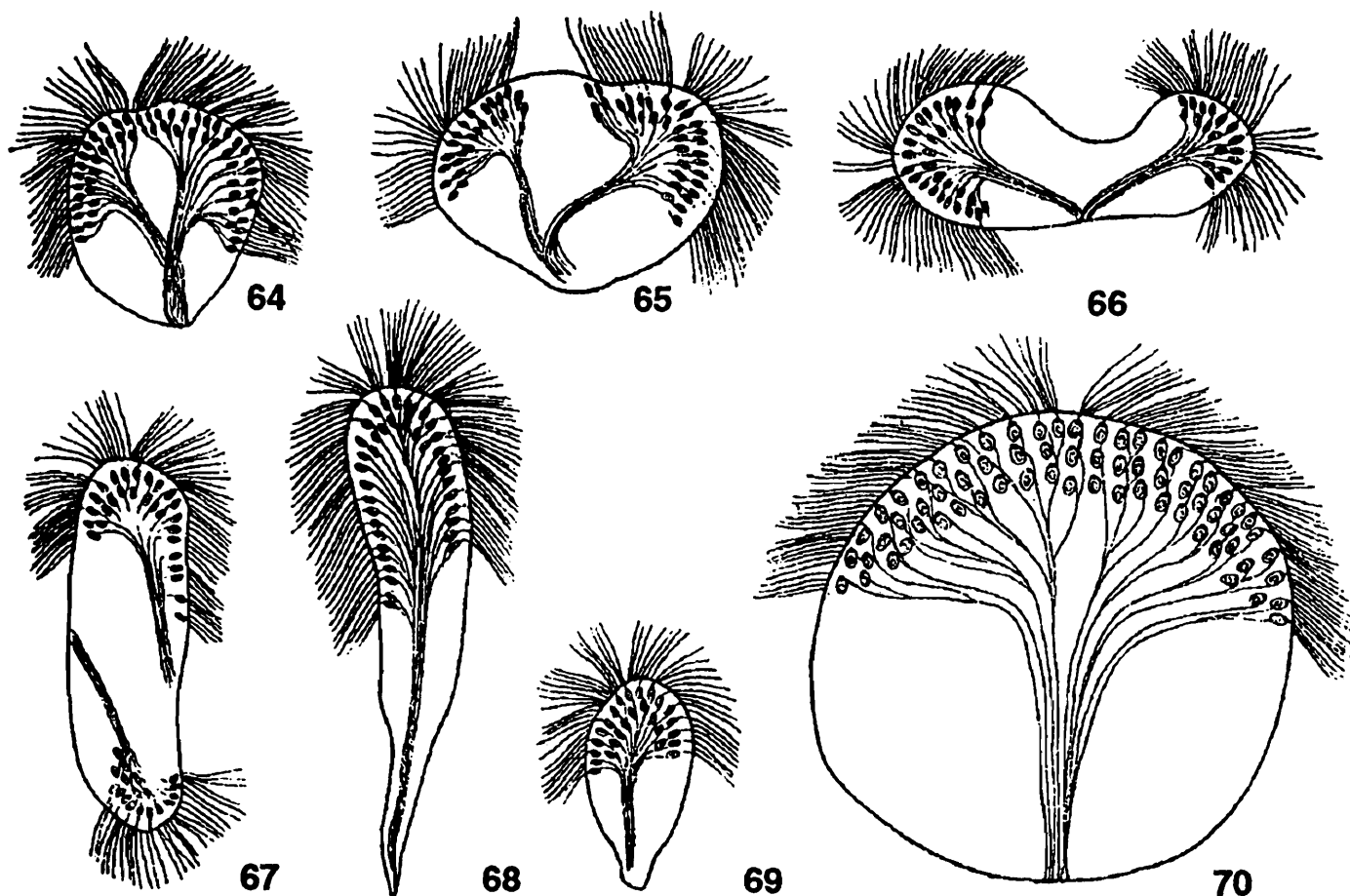
Diagnosis : Body oval or rounded; nuclei fusiform containing dense chromatin granules, separated by a clear space from nuclear membrane; number of nuclei in Indian forms varying from 65 to 100; these nuclei closely embedded in 2 or 3 spiral series, occupying the anterior portion of the body; as in other *Stephanonympha* species, each nucleus possessing one small and round blepharoplast from which 4 flagella arising; parabasal body smaller, axial filaments extending downwards from the blepharoplast towards the posterior part of the body, forming axial bundle; endoplasm containing fragments of wood particles.

Morphometry : Morphometric data of *Stephanonympha silvestrii* collected from different Indian termies are presented in Table 40.

Table 40. Comparison of morphometric data of *Stephanonympha silvestrii* from different Indian termites; (measurements in μm)

Characters	<i>Cr. havilandi</i>	<i>Cr. dudleyi</i>	<i>N. andamanensis</i>
Body length	49.3 (45-56.3)	65 (48-80)	78 (67-85)
Body width	33.7 (31.5-41.2)	50 (36-68)	55 (42-70)
Ratio of body length to body width (average)	1.4 : 1	1.3 : 1	1.4 : 1
Number of nuclei	65-100	60-100	60-100
Number of nuclear spirals	2-3	2-3	2-3

Remarks : Janicki (1911) described *Stephanonympha silvestrii* from the host *Neotermes connexus* and categorised two forms, viz., *minor* and *major*. The former was 69 μm in length with 100 nuclei, arranged in 2-4 spiral series and the latter was 136 μm in length with 150 nuclei embedded in 3 spiral series.



Figs. 64-70 : *Stephanonympha silvestrii* Janicki, showing its binary fission. Figs. 64-67. Different stages of binary fission; Fig. 68. Form with slender posterior portion (just after fission); Fig. 69. Form with blunt posterior portion; Fig. 70. Adult individual

Grassi (1917) described two varieties of *S. silvestrii* from termites, one from *Cryptotermes havilandi* and the other from *Neotermes erythraeus* and named them *Stephanonympha silvestrii* var. *cryptotermes havilandi* and *S. silvestrii* var. *neotermes erythrei* respectively. The former was 65 µm in length, having small parabasal bodies of irregular outline and 4 circular series of nuclei while the latter possessed dense plasma close above the nucleus in place of definite parabasal body. But, its body size, number of nuclear spiral or other details were not given in the descriptions or figures. Kirby (1926) changed the clumsy quadrinomials of these two varieties as two species, viz. *Stephanonympha havilandi* and *S. erythrei*. Accordingly, Das and Choudhury (1972) reported *S. havilandi* from West Bengal. Since *S. havilandi* and *S. erythrei* are identical with *S. silvestrii* in all morphological characters except in dimensions Grassé (1952) rightly synonymised all the above taxa under *Stephanonympha silvestrii*. This species was first reported from India by Das and Choudhury (1972) under the name *S. havilandi*. Afterwards, Das (1983) and Das *et al.* (1993, 2000, 2004, 2006a) dealt with this species as *S. silvestrii* following Grassé (1952). Table 40 shows that amongst the Indian forms of *S. silvestrii* from *Cryptotermes havilandi* are the smallest in dimensions.

Binary fission of *S. silvestrii* : In the resting stage of this species nuclei contain deeply stained chromatin mass, shrunk back from the nuclear membrane. Prior to fission, the chromatin becomes more dispersed and fills up the whole space within the nuclear membrane. The nuclei with their mastigont ultimately become separated into two groups and then axial bundle also bifurcates (Figs 64, 65). The organism gradually assumes the elongated shape and each set of nuclei occupies each pole after which cytosomal division takes place resulting in two daughter individuals (Figs 66, 67). Each daughter individual is much elongated with a tail-like posterior end (Fig. 68) The tail like structure is lost in the course of further development (Fig. 69). Gradually the individual becomes more or less round in its adult stage. (Fig. 70).

Family TRICHOMONADIDAE Chalmers and Pekkola, 1918

1918. Trichomonadidae Chalmers and Pekkola, *Ann. Trop. Med. Parasitol.*, 11 : 251.

1947. Trichomonadidae emend. Kirby, *J. Parasitol.*, 33 : 226.

Diagnosis : Anterior flagella variable in number, undulating membrane bordered by recurrent flagellum; axostyle often conspicuous and protruded from the posterior end; costa present.

Key to the subfamilies of the family Trichomonadidae recorded from Indian termites

1. Three to five anterior flagella, costa slender, capitulum of axostyle continuing anteriorly into typical pelta, trunk of axostyle resembling a hyaline rod, not tube like in appearance, nor with bulbous terminal segment Subfamily TRICHOMONADINAE
- Four anterior flagella, costa stout, capitulum of axostyle not continuing anteriorly into typical pelta, trunk of axostyle tube like in appearance with bulbous terminal segment Subfamily TRICHOMITOPSIINAE

Subfamily TRICHOMONADINAE Chalmers and Pekkola, 1918

1918. Trichomonadinae Chalmers and Pekkola, *Ann. Trop. Med. Parasitol.*, 11 : 251.

1963. Trichomonadinae emend. Honigberg, *J. Protozool.*, 10 : 40.

Diagnosis : Three to five anterior flagella, proximal part or anterior recurrent flagellum incorporated along accessory filament into margin of the undulating membrane; membrane varying in length and degree of development; costa usually slender; capitulum of axostyle of varying complexity, continuing anteriorly into typical pelta; trunk of axostyle resembling a hyaline rod, usually slender or of moderate diameter and not tube like in appearance; projecting for some distance from posterior body surface with terminal segment of projecting part tapering to a point.

Genus *Trichomonas* Donné, 1836

1836. *Trichomonas* Donné, *C. R. Acad. Sci. Paris*, 3 : 385.

Diagnosis : Pyriform; typically with four anterior flagella, fifth flagellum lying along the outer margin of the undulating membrane; a costa at the base of the membrane; axostyle often protruding beyond the posterior end of the body.

40. *Trichomonas costulata* De Mello, 1946 (Fig. 71)

1946. *Trichomonas costulata* De Mello, *An. Inst. Med. Trop.*, 3 : 69.

1983. *Trichomonas costulata* : Das, *Proc. Synp. Host Environ. zool. Surv. India* : 43.

Type host : *Cryptotermes* sp.; loc., India : Goa.

Additional host : *Cryptotermes havilandi*; loc., Brazil.

Diagnosis : Body more or less oval or pyriform; some forms very elongated or irregularly shaped; blepharoplast located at the anterior tip; anterior flagella four in number and very slender; a costa starting from the blepharoplast extending up to the posterior part of the body; an irregularly folded undulating membrane attached to the costa and trailing flagellum lying along the border of this membrane and ending as a thin and short free filament beyond the membrane; parabasal body sacciform or cordiform; a "costula" (a strongly siderophil bar) more or less bacilliform, sometimes curved and often short, connected with the blepharoplast; axostyle thin and tubular and, sometimes almost indistinct, generally protruding beyond the posterior end of the body; nucleus round or oval, occupying almost middle of the body; chromatin granules present on the periphery of the nuclear membrane forming a conspicuous ring.

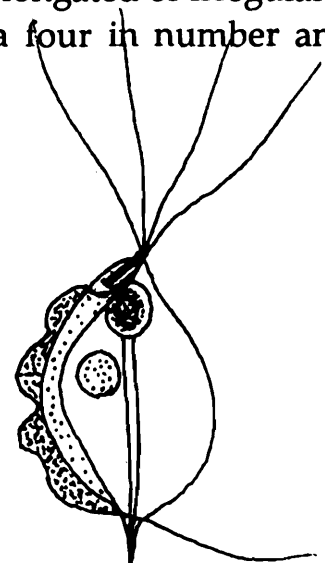


Fig. 71 : *Trichomonas costulata*
De Mello

Morphometry : De Mello (1946) recorded only the dimensions of the body and length of nucleus of *Trichomonas costulata* as 13-25 μm $\times$ 7-14 μm and 2-3.5 μm respectively. No further morphometric data of this species are available.

Remarks : De Mello (1946) described *T. costulata* from the Indian termite, *Cryptotermes* sp. and subsequently recorded this species from the termite *Cryptotermes havilandi* from Brazil. According to him, presence of an "unique structure" costula makes *T. costulata* distinct because this structure is not found in any other species of *Trichomonas*.

Subfamily TRICHOMITOPSIINAE Brugerolle, 1976

1996-97. Trichomitopsiinae Brugerolle, *Ann. Stat. Biol. Basse-en-Chandesse*, No. 10 : 38.

Diagnosis : Four equal or subequal anterior flagella; proximal part or entire recurrent flagellum incorporated along usually two accessory filaments into margin of well developed undulating membrane, extending for entire length of the body; costa stout, capitulum of axostyle spatulate, not continuing anteriorly into typical pelta; trunk of axostyle of large diameter, tube-like in appearance; terminal segment of trunk enlarged into pointed bulbular expansion.

Genus *Trichomitopsis* Kofoid and Swezy, 1919

(Fig. 72)

1919. *Trichomitopsis* Kofoid and Swezy, *Univ. Calif. Publ. Zool.*, 20 : 36.

1919. *Ditrichomonas* Cutler, *Quart. J. micr. Sci.*, 63 : 555.

1963. *Trichomitopsis* : Honigberg, *J. Protozool.*, 10 : 53.

Diagnosis : Four anterior flagella; recurrent flagellum continuing usually for a short distance beyond the well developed undulating membrane as free posterior flagellum; costa stout; capitulum of axostyle large and flattened; trunk of axostyle stout, tube-like in appearance with terminal segment often expanded into pointed bulbous enlargement near the site of its emergence from posterior body surface; typically no periaxostylar rings; parabasal body often quite long, band-, rod- or sausage-shaped, associated with filament.

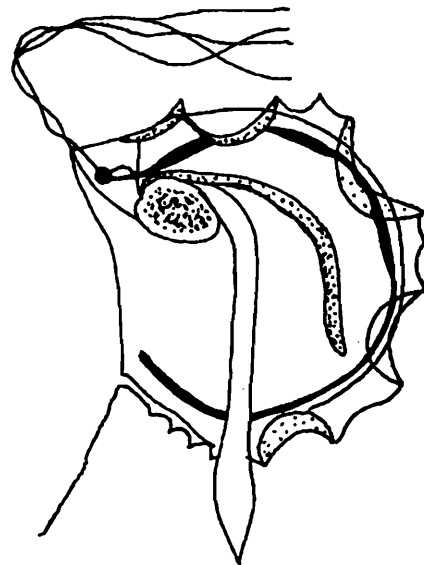


Fig. 72 : Genus *Trichomitopsis* Kofoid and Swezy

41. *Trichomitopsis termitis* (Imms in Cutler, 1919) Honigberg, 1963

1919. *Trichomonas termitis* Imms, *Phil. Trans. Roy. Soc. London*, B 209 : 132.

1919. *Ditrichomonas termitis* Imms in Cutler, *Quart. J. micr. Sci.*, 63 : 555.

1963. *Trichomitopsis termitis* (Imms in Cutler) Honigberg, J. Protozool., 10 : 53.

1983. *Trichomitopsis termitis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 43.

Type host : *Archotermopsis wroughtoni*; loc., India.

Diagnosis : Length 30-83 μm with average 64 μm and width 15-64 μm with average 38 μm ; undulating membrane thrown into 11-17 undulations in stained preparations; anterior flagella two in number, relatively short but stout and of equal length; third flagellum (recurrent flagellum) adherent along the outer margin of the undulating membrane; a cytostome present at "far forward"; axostyle distinct; a thick chromatic "basal" rod, 2 μm in thickness present, extending near to cytostome to the posterior end of the body, where it usually curving somewhat inwards.

Remarks : The present diagnosis of *Trichomitopsis termitis* is based on Cutler (1919) who treated it as *Ditrichomonas termitis* because, he observed two anterior flagella in this flagellate.

Mention is to be made here that Cutler (1919) described a new genus *Ditrichomonas* from the termite *Archotermopsis wroughtoni* and put *D. termites* under this genus because, as Honigberg (1963) presumed, Cutler was possibly aware of Imm's work and influenced by Imm's original figure of this species with two flagella. Honigberg (*op. cit.*) pointed out that Imm's species from *Archotermopsis wroughtoni* under the name *Trichomonas termitis* was published several months after the publication of Cutler's paper. In view of above, authorship of this species is required to be stated as "Imms in Cutler" according to the provision of the International code of Zoological Nomenclature as mentioned by Honigberg (1963).

Honigberg (1963) made in-depth analysis of the genus *Ditrichomonas* and its type species *D. termitis*. He stated that as per recent studies no flagellates in the order Trichomonadida are found to possess two flagella with possible exception of *Tricercomitus*. Cleveland *et al.* (1934) also reported that the flagellate described by Cutler (1919) as *Ditrichomonas termitis* had four flagella not two as Cutler and other writers had supposed. According to Cleveland (*op. cit.*) this flagellate species is similar to and possibly identical with *Trichomonas termopsidis*. Based on these observations and analysis, Honigberg (1963) synonymised the genus *Ditrichomonas* Cutler under the genus *Trichomitopsis* Kofoid and Swezy and placed *D. termitis* (Imms in Cutler) under *Trichomitopsis termitis*.

Order HYPERMASTIGIDA Grassi and Foa, 1911

1911. Hypermastigida Grassi and Foa, Rend. R. Accad. Lincei, Ser. 5, sem 1, 20 : 727.

Diagnosis : Mastigont system with numerous flagella and multiple Janicki-type parabasal apparatus; flagella bearing kinetosomes distributed in complete or partial circle in plate or plates, or in longitudinal or spiral rows meeting in a centralised structure; nucleus single per cell.

**Key to the suborders of the order HYPERMASTIGIDA
reported from Indian termites**

1. Numerous flagella separate or in bundles, arranged in spiral or broken circle at one end of the cytostome; neuromotor system integrated to the nucleus by an endoskeleton Suborder LOPHOMONADINA
- Numerous flagella arranged in longitudinal rows or in dextrotropic or leiotropic spirals, no endoskeleton as above 2
2. Flagellar bands originating at anterior end and reaching the posterior end of the body in dextrotropic spiral, no rostral tube at anterior end Suborder SPIROTRICHONYMPHINA
- Flagella arranged in longitudinal rows or in leiotropic spiral, not originating at anterior end as above, rostral tube at anterior end Suborder TRICHONYMPHINA

Suborder LOPHOMONADINA Light, 1927

1927. Lophomonadina Light, *Univ. Calif. Publ. Zool.*, 29 : 486.

Diagnosis : Numerous flagella separate or in bundles (loricula), arranged in a spiral or broken circle at one end of the cytostome; neuromotor system integrated to the nucleus by a endoskeleton from which supporting filament projecting posteriorly into the cytostome; typically all old structures reabsorbed in division and daughter organelles formed *de novo*.

Family JOENIIDAE Janicki, 1915

1915. Joeniidae Janicki, *Zeit. Wiss. Zool.*, 112 : 644.

Diagnosis : Lophomonadids having a horse-shoe shaped supporting body with basal granules from which flagella arising and arranged in a tuft near the anterior end of the body; several striations radiating from the supporting body.

Key to the genera of the family JOENIIDAE recorded from Indian termites

1. Presence of parabasal apparatus and oblique groove in the body, striations from the supporting body with basal granules extending anterior two-third of the body, body flagella arranged in longitudinal rows Genus *Joenopsis*
- Parabasal apparatus and oblique groove as above absent, striations from the supporting body short and devoid of basal granules and not extending beyond the anterior one-third of the body, body flagella absent Genus *Parajoenopsis*

Genus *Joenopsis* Cutler, 1920

1920. *Joenopsis* Cutler, Quart. J. micr. Sci., 64 : 383.

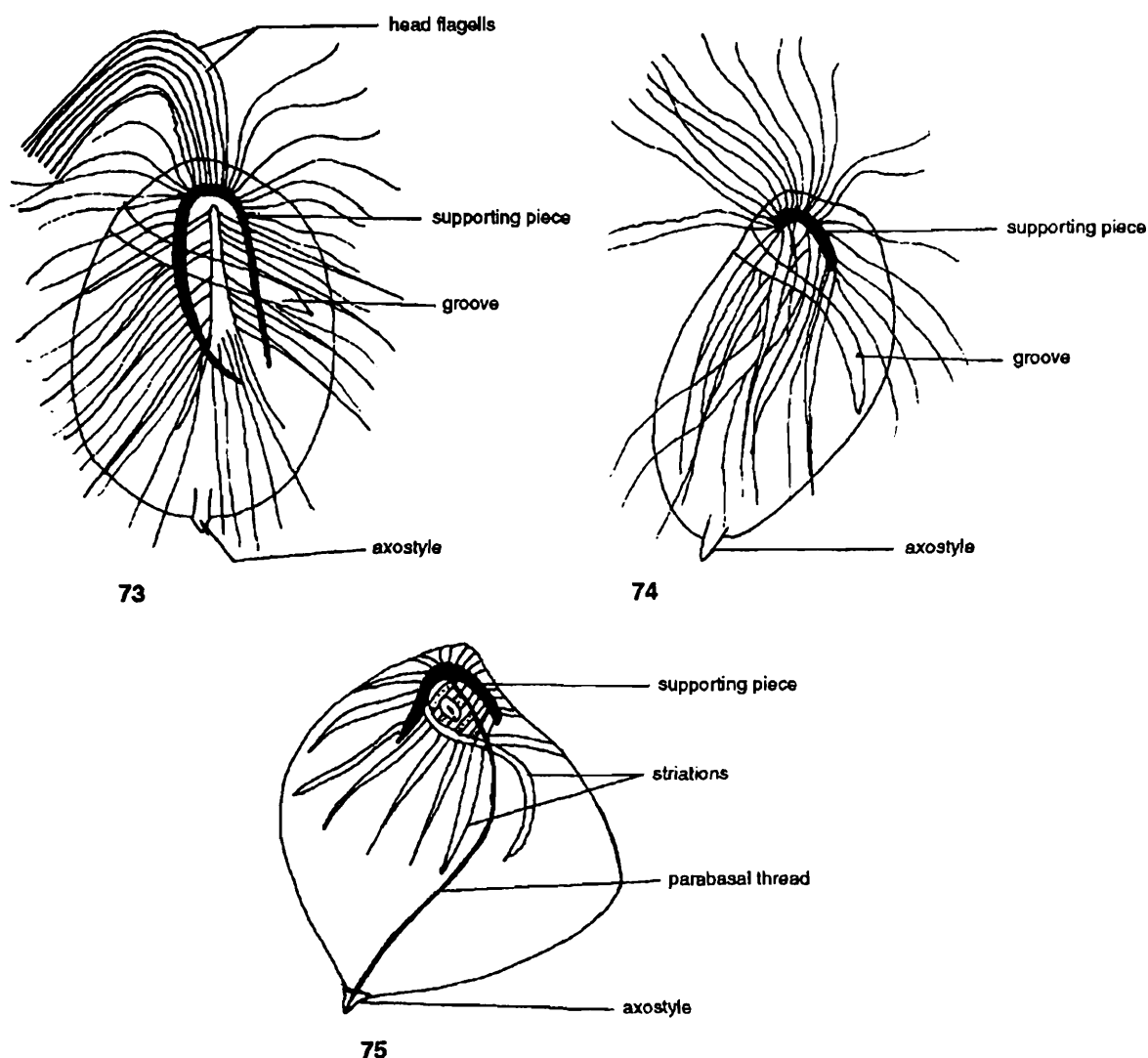
Diagnosis : A parabasal apparatus and oblique groove present, body flagella arranged in longitudinal rows; horse-shoe shaped supporting body in front of nucleus; a tuft of flagella in the head region; striations from the supporting body with basal granules and extending anterior third of the body; homogenous mass of protoplasm in the anterior region of the body.

42. *Joenopsis polytricha* Cutler, 1920
(Figs. 73-75)

1920. *Joenopsis polytricha* Cutler, Quart. J. micr. Sci., 64 : 385.

1983. *Joenopsis polytricha* : Das, Proc. Symp. Host Environ. Zool. Surv. India : 44.

Type host : *Archotermopsis wroughtoni*; loc., India.



Figs. 73-75 : *Joenopsis polytricha* Cutler (after Cutler, 1919). Fig. 73. Drawn from living specimen; Fig. 74. Living specimen (side view); Fig. 75. Drawn from stained preparation

Diagnosis : Size large, average dimensions $112\ \mu\text{m} \times 63.3\ \mu\text{m}$, body divided into two regions by a groove somewhat obliquely round the body, demarcating smaller anterior part from the larger posterior one; no cytostome present; a horse-shoe shaped supporting body present at the anterior end with numerous basal granules from each of which arising a flagellum; whole complex of flagella arranged in a tuft in the head region, forming a whip-like locomotary apparatus; anterior two-third of the body traversed by striations, arranged in a right or left handed series taking origin from the supporting body; these striations representing the edges of the raised area of body surface with basal granules from each of which arising a body flagella; body flagella arranged in longitudinal rows; a well developed axostyle and two parabasal threads arising from the supporting body; numerous parabasal bodies developed on parabasal threads; nucleus large, $10\text{-}16\ \mu\text{m}$ in diameter and located between the two arms of the supporting body; irregular chromatin granules embedded in nucleoplasm; a clear space present between chromatin and nuclear membrane.

Remarks : In the original description of *Joenopsis polytricha* Cutler (1920) provided only the average dimension and diameter of nucleus of this species as mentioned earlier. The present diagnosis of this species is based on Cutler's description (1920) and text figures of this species. Mention is to made here that this flagellate species has not been recorded till date since its original description by Cutler (*op. cit.*). Based on this description Das (1983) included *J. polytricha* in the checklist of flagellate symbiotes of Indian termites.

Genus *Parajoenopsis* Saleem, 1952

1952. *Parajoenopsis* Saleem, *Proc. Pakistan Sci. Conf.*, 4 : 65.

1955. *Parajoenopsis* : Saleem, *Biologia* (Lahore), 1 : 37.

Diagnosis : Body pyriform with a tuft of flagella at the head region; oblique groove and parabasal body absent; horse-shoe shaped supporting body in front of the nucleus; striations from supporting body short, not extending beyond the anterior third of the body and devoid of basal granules; consequently no body flagella; homogeneous mass of protoplasm in the anterior region of the body.

43. *Parajoenopsis cephalotricha* (Cutler, 1920) Saleem, 1952 (Fig. 76)

1920. *Jeonopsis cephalotricha* Cutler, *Quart. J. micr. Sci.*, 64 : 400.

1952. *Parajoenopsis cephalotricha* (Cutler) Saleem, *Proc. Pakistan Sci. Conf.*, 4 : 65.

1955. *Parajoenopsis cephalotricha* : Saleem, *Biologia* (Lahore), 1 : 37.

1983. *Parajoenopsis cephalotricha* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.

Type host : *Archotermopsis wroughtoni*; loc., India (type locality), Pakistan.

Diagnosis : Body pyriform, anterior end more broadly rounded than the posterior end; a tuft of flagella present at head region; oblique groove absent; a horse-shoe shaped supporting body present near the anterior end of the body with numerous basal granules, from each of which arising a flagellum; striations radiating from the supporting body short, not extending beyond the anterior third of the body, not arranged in right and left handed series and devoid of basal granules; consequently no body flagella present; parabasal bodies and threads not developed but an axostyle taking its origin from the supporting body, protruding through the posterior end of the body; posterior end of axostyle pointed; nucleus broadly oval and located between the limbs of the supporting body; nuclear membrane distinct and chromatic mass lying in the centre of nucleus.

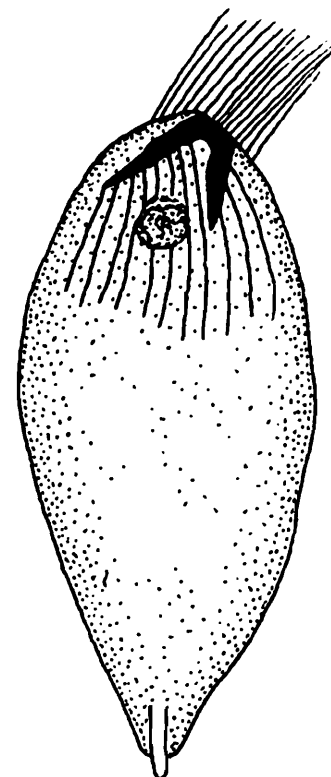


Fig. 76 : *Parajoenopsis cephalotricha* (Cutler)

Morphometry : Morphometric data of *Parajoenopsis cephalotricha* collected by different workers from the host, *Archotermopsis wroughtoni* are presented in Table 41.

Table 41. Morphometric comparison of different populations of *Parajoenopsis cephalotricha*

Characters	Host : <i>Archotermopsis wroughtoni</i>	
	by Cutler (1920)	by Saleem (1952)
Body length	87 (85-90) μm	55.1 (46-75) μm
Body width	51 (45-60) μm	28.1 (26-40) μm
Ratio of body length to body width (average)	1.6 : 1	1.8 : 1
Diameter of nucleus	5.7 μm	5.6 (4-8) μm

Remarks : Cutler (1920) established the genus *Joenopsis* and included two species under it, viz., *J. polytricha* and *J. cephalotricha*, collected from the termite host, *Archotermopsis wroughtoni*. Subsequently Saleem (1952) studied Cutler's *J. cephalotricha* from the same termite host and placed this species under his newly erected genus *Parajoenopsis*.

Parajoenopsis resembles *Joenopsis* in having a horse-shoe shaped supporting body, a tuft of flagella at the head region and homogeneous protoplasmic mass near the anterior region of the body. But it lacks three main characteristic features of *Joenopsis*, namely, parabasal apparatus, oblique groove of the body and body flagella arranged in longitudinal rows.

Suborder SPIROTRICHONYMPHINA Grassé, 1952

1952. Spirotrichonymphina Grassé, *Traite de Zoologie*, Paris, Vol. 1, Fasc.1 : 916.

Diagnosis : Pyriform or elongate pyriform; various number of dextrotropic spiral rows of flagella originating at anterior end and reaching posterior end of the body.

Key to the families of the suborder SPIROTRICHONYMPHINA reported from Indian termites

1. Spiral flagellar bands originating from a common point near the anterior end of the body, nucleus usually anchored to the rostrum by a nuclear sleeve Family SPIROTRICHONYMPHIDAE
- Spiral flagellar bands originating at anterior end but not originating from a common point; nuclear sleeve as above not present; nucleus usually surrounded by a mass of dense cytoplasm Family HOLOMASTIGOTIDAE

Family HOLOMASTIGOTIDAE Janicki, 1915

1915. Holomastigotidae Janicki, *Zeit. Wiss. Zool.*, **112** : 644.

Diagnosis : Spiral rows of flagella usually 12-40 in number originating at anterior end and reaching the posterior end of the body; a mass of dense cytoplasm usually surrounding ovoid nucleus near anterior end of the body.

Genus *Holomastigotoides* Grassi and Foa, 1911

1911. *Holomastigotoides* Grassi and Foa, *Rend. R. Accad. Lincei* (5), ser. 1, **20** : 729.

Diagnosis : Large and mostly pyriform in shape; flagella arranged in spiral rows dextrotropically from anterior to posterior end of the body; nucleus ovoid, usually located near the anterior end and surrounded by a mass of dense cytoplasm and without any tubular centro-blepharoplast; axostyle with multiple fibres, sometimes difficult to detect; spiral dextrotropic band provided with flagella.

So far 27 species of *Holomastigotoides* have been described from India (Table 3). In addition to these, Narain (1956 a,b) described two new species of *Holomastigotoides*, viz., *H. rostrata* and *H. truncata* from the guts of some unidentified termites of Lucknow, India. But both these species are treated here as *nomen nudum* because : i) these species were published as abstracts and never published as full papers; ii) description of these species did not reveal any distinctive feature for species identification and iii) no illustration was provided for these species. As such, these two species are not included in the checklist of symbiotic flagellates of Indian termites in the present communication nor in the following key to the Indian species of *Holomastigotoides*. Therefore taxonomic account of these species is also not provided in this monograph. The following key to the species of *Holomastigotoides* also excludes *H. cingulatum* as this species is very inadequately described. This aspect has been dealt with in the present monograph in details during its taxonomic account.

Key to the species of the genus *Holomastigotoides* reported from Indian termites

1. Prenuclear zone present 2
 - Prenuclear zone absent 18
2. Posterior portion glabrous 3
 - Posterior portion not glabrous 8
3. Posterior end of the body provided with "steriocilia" or longer flagella 4
 - Posterior end of the body without any flagella 6
4. Axostyle extending upto posterior three-fourth of the body or more 5
 - Axostyle not distinct, body shape elongated, oval or elliptical, slightly narrowed at anterior end; shorter flagella covering the whole body in dextrotropic rows, while "steriocilia" covering the posterior portion of the body *H. mirabile*
5. Body oval to elliptical, shorter flagella covering the major portion of the body in dextrotropic rows excepting very small posterior portion; that posterior portion without any flagella; posterior extremity provided with longer flagella *H. bengalensis*
 - Body oval, shorter flagella covering the whole body in dextrotropic rows leaving about one-fifth posterior glabrous portion, occupying by dense "steriocilia" *H. rayi*
6. Body pear shaped, axostyle small but distinct, a small (about one-seventh the body length) posterior portion of the body glabrous without any flagella *H. melloi*
 - Body ovoid, axostyle long extending up to the middle of the body 7
7. Body somewhat ovoidal, anterior end slightly conical, posterior end obtuse and finger-like, posterior one-fourth of the body glabrous and without any flagella *H. hemigymnum*
 - Body large and ovoidal, both anterior and posterior ends broadly round, glabrous portion of the body as above *H. magnus*
8. Steriocilia present 9
 - Steriocilia absent 11
9. Oval or elliptical in shape, with a large elliptic operculum at anterior end of the body *H. operculatum*
 - Body spheroidal, round or globose without having any operculum at anterior end of the body 10
10. Body typically spheroidal, covered with flagella all round the body in dextrotropic

- rows, except for a very small area on the posterior surface, long steriocilia present in that part of posterior surface *H. dharwarensis*
- Body somewhat rounded or globose, covered with flagella in dextrotropic rows excepting about one-fifth of the posterior portion of the body, short steriocilia covering that region *H. visnagarensis*
11. Axostyle present 12
- Axostyle absent, body large and elongate, single type of long flagella found all over body *H. elongata*
12. Axostyle well developed 13
- Axostyle faintly developed 16
13. Anterior end of the body with finger-like elevation 14
- Anterior end of the body round without any finger-like elevation as above 15
14. Body round with finger like projection at anterior end, flagella of two types, longer flagella restricted to posterior extremity of the body *H. hollandei*
- Body resembling an inverted cup with blunt finger like elevation, flagella of two types, longer flagella covering the posterior surface of the body *H. ogivalis*
15. Reniform in shape, axostyle distinct and short *H. reniformis*
- Almost spherical in shape, axostyle well developed and comparatively long *H. sphaeroidalis*
16. Flagella of one type 17
- Flagella of two types, longer ones restricted to posterior extremity of the body; body club-shaped *H. emersoni*
17. Body bottle shaped, anterior end resembling a truncate cone, 50-90 μm x 30-60 μm in dimension *H. koidzumii*
- Anterior end of the body cone-shaped, posterior end round, 70-190 μm x 50-135 μm in dimension *H. grassii*
18. Axostyle present 19
- Axostyle absent, body oval or egg-shaped, flagella of two types, non-flagellar posterior glabrous portion with short steriocilia *H. ovalis*
19. Axostyle well developed 20
- Axostyle faintly developed 24

20. A characteristic proboscis-like structure at anterior end of the body and one small siderophilic ring present *H. proboscifer*
- Proboscis like structure as above lacking 21
21. Body resembling a bell jar, flagella of two types *H. campanula*
- Body of different shape, flagella of one type 22
22. Body balloon-shaped, posterior fifth of the body glabrous without any steriocilia ..
..... *H. saccusiformis*
- Body of different shape, whole of the body covered with flagella without having any glabrous portion 23
23. Body large, elongate, more or less cylindrical, dimension of the body 105-305 μm x 60-150 μm *H. gigas*
- Body typically oval, maximum dimension of the body recorded 140 μm x 90 μm ...
..... *H. globosus*
24. Body round with a narrow blunt finger-like projection at anterior end, one-third of the posterior portion of the body glabrous without having any steriocilia
..... *H. turboformis*
- Body of different shape and without having any glabrous portion 25
25. Body pyriform, anterior pole broadly round and posterior pole pointed
..... *H. piriformis*.
- Body elongate and vermiform, both anterior and posterior ends of the body irregularly round *H. inexpectatus*

44. *Holomastigotoides bengalensis* Chakravarty and Banerjee, 1956 (Fig. 77)

1956. *Holomastigotoides bengalensis* Chakravarty and Banerjee, *Proc. Zool. Soc., Calcutta*, 9 : 36.
1976. *Holomastigotoides bengalensis* : Das, *Acta Protozool.*, 15 : 113.
1978. *Holomastigotoides bengalensis* : Tiwari, *Bull. zool. Surv. India*, 1 : 311.
1981. *Holomastigotoides bengalensis* : Tiwari and Ray, *Bull., zool. Surv. India*, 4 : 161.
1983. *Holomastigotoides bengalensis* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 43.
1988. *Holomastigotoides bengalensis* : Tiwari, *Rec. zool. Surv. India*, 85 : 218.
1992. *Holomastigotoides bengalensis* : Tiwari, *Rec. zool. Surv. India*, 92 : 143.
1993. *Holomastigotoides bengalensis* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 492. *Zool. Surv. India*.

2000. *Holomastigotoides bengalensis* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 39. *Zool. Surv. India*.
2003. *Holomastigotoides bengalensis* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 29. *Zool. Surv. India*.
2004. *Holomastigotoides bengalensis* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna of Series*, 5(Part 6) : 453. *Zool. Surv. India*.
- 2006a. *Holomastigotoides bengalensis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 31. *Zool. Surv. India*.

Type host : *Heterotermes indicola* (= *Heterotermes* sp. *sensu* Chakravarty and Banerjee, 1956); loc., India : West Bengal.

Additional hosts : *Coptotermes heimi*; loc., India : Andhra Pradesh, Bihar, Uttar Pradesh and West Bengal; *Coptotermes travians*; loc., India : Nagaland, Sikkim and Tripura.

Diagnosis : Body more or less oval, sometimes elliptical in shape, anterior end bluntly pointed resembling a nipple and posterior end rounded; flagella of two types, the shorter ones covering the major portion of the body in dextrotropic manner leaving a posterior glabrous portion without having any flagellar band; longer flagella occupying the posterior extremity of the body; nucleus more or less spherical or oval and situated near the anterior pole of the body; in a stained preparation prenuclear zone represented by a densely granulated conical area over the nucleus; axostyle well developed and fibrous running almost straight from the postnuclear zone to very near the posterior extremity of the body.

Morphometry : The morphometric data of *Holomastigotoides bengalensis* from its type host is presented in Table 42 and compared with those from the additional hosts.

Table 42. Comparison of morphometric data of *Holomastigotodes bengalensis* from different hosts, (measurement in μm)

Characters	Type hosts		Additional hosts	
	<i>Heterotermes</i> sp.	<i>H. indicola</i>	<i>C. heimi</i>	<i>C. travians</i>
Body length	81.9 (27.8–135)	95.4 (83.3–107.1)	67.3–105.2	67.6–105
Body width	53.2 (21.4–87.5)	57 (47.6–66.3)	41.2–70.5)	41.2–70.5
Ratio of body length to body width (average)	1.5 : 1	1.6 : 1	1.5 : 1	1.5 : 1
Length of nucleus	–	12.9 (12.7–13.6)	–	–
Breadth of nucleus	–	12.5 (11.6–13.4)	–	–
Length of shorter flagella		–	8–9	—
Length of longer flagella	–	11–12	–	–

The table 42 reveals that the specimens of *H. bengalensis* collected from the type hosts are slightly larger than those collected from the additional hosts. But salient morphological features of all these specimens are quite identical with those of the type specimens of *H. bengalensis* and their length-breadth ratio is also almost identical.

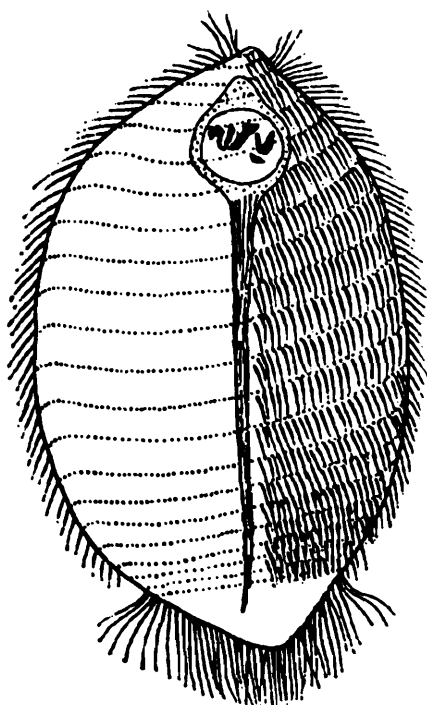


Fig. 77 : *Holomastigotoides bengalensis* Chakravarty and Banerjee; arrangement of flagella partly shown

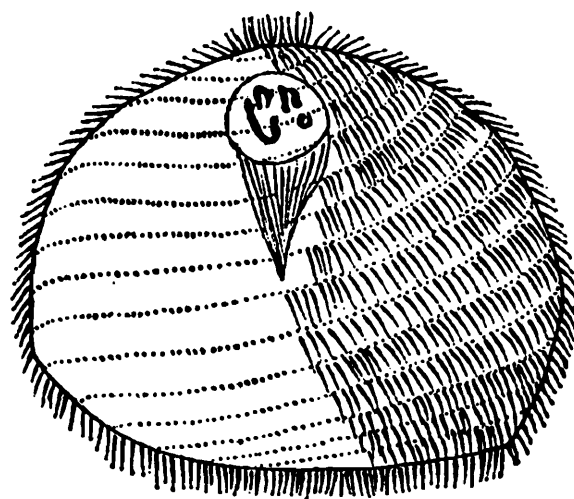


Fig. 78 : *Holomastigotoides campanula* (De Mello); arrangement of flagella partly shown

45. *Holomastigotoides campanula* (De Mello, 1921) De Mello, 1927 (Fig. 78)

- 1921. *Leidya campanula* De Mello, *Arqu. Indo-Port. Med. Hist. Nat.*, 1 : 179.
- 1927. *Holomastigotoides campanula* De Mello, *Trans. 7th Congr. East Assoc. Trop. Med.*, 2 : 591.
- 1928. *Holomastigotoides campanula* ; De Mello, *Arqu. Esc. Med. Cirug. Nova Goa, Ser. A.* 3 : 250.
- 1937. *Holomastigotoides campanula* : De Mello, *C. R. Congr. Inst. Zool. Lisb.*, 1935, 2 : 1334, 1339.
- 1954. *Holomastigotoides campunula* : Karandikar and Vittal, *J. Univ. Bombay*, 23B : 12.
- 1976. *Holomastigotoides campanula* : Das, *Acta Protozool.*, 15 : 105.
- 1983. *Holomastigotoides campanula* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 43.
- 1992. *Holomastigotoides campanula* : Tiwari, *Rec. zool. Surv. India*, 92 : 143.
- 1993. *Holomastigotoides campanula* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series 3(Part 12)* : 492. *Zool. Surv. India*.
- 2000. *Holomastigotoides campanula* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series, 7(Part 4)* : 39. *Zool. Surv. India*.

2003. *Holomastigotoides campanula* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 29. *Zool. Surv. India*.
2004. *Holomastigotoides campanula*, Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 454. *Zool. Surv. India*.
- 2006a. *Holomastigotoides campanula*, Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 31. *Zool. Surv. India*.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Diu (type locality), West Bengal.

Additional hosts : *Heterotermes malabaricus*; loc., India : Karnataka; *Coptotermes heimi*; loc., India : Andhra Pradesh, Bihar, Karnataka; *Coptotermes travians*; loc., India : Nagaland, Sikkim, Tripura; *Coptotermes* sp; loc., India : Goa.

Diagnosis : Body resembling a bell jar without any apical knob; its anterior end usually broadly convex and posterior end usually flat; flagella of two types; shorter flagella arranged in dextrotropic rows all over the body and longer flagella restricted to the posterior extremity of the body; nucleus more or less oval and located near the anterior pole of the body; prenuclear zone absent; axostyle distinct but usually short in length.

Morphometry : Mensural data of *Holomastigotoides campanula* recorded by De Mello (1927) during its original description from the type host, *Heterotermes indicola* is presented in Table 43 and compared with those collected from the type host of different locality as well as from other hosts.

Table 43. Morphometry of *H. campanula* collected from different hosts; all measurements in μm .

Characters	Type host, <i>H. indicola</i>		Additional hosts		
	Diu	West Bengal	<i>H. malabaricus</i> *	<i>C. heimi</i>	<i>C. travians</i>
Body length	70(37.5-118)	52.6(42.5-69.1)	120	73.9(36.8-105)	58.4(36.8-80)
Body width	76(62-100)	64.9(56.1-73.7)	100	62.4(35.2-80)	73.5(42-105)
Ratio of body-length to body width (average)	0.9 : 1	0.8 : 1	1.2 : 1	1.1 : 1	0.8 : 1
Length of nucleus	—	13.1	—	7.6(4.8-9.6)	—
Breadth of nucleus	—	10.2	—	7.2(6.4-8)	—
Length of shorter flagella	—	5-7	6-8	—	—
Length of longer flagella	—	9-10	14-16	—	—

*Measural data of combined forms of *H. campanula*, collected from the two hosts *H. malabaricus* and *C. heimi* recorded by Karandikar and Vittal (1954).

Remarks : *Holomastigotoides campanula* can be conveniently identified by its unique body shape and axostyle and by the absence of prenuclear zone. Table 43 shows that

specimens collected from West Bengal from the type host, *H. indicola* are the smallest and those reported from Karnataka from the host *H. malabaricus* is the largest. In some forms (from the type host, *H. indicola* and from *C. travians*) width is more than length but in other (from the hosts *H. malabaricus* and *C. heimi*) it is just the reverse. However, all the forms possessed characteristic bell jar like shape of *H. campanula*.

**46. *Holomastigotoides cingulatum* Bernstein, 1928 var. *coimbatorensis*
De Mello and De Mello, 1942
(Fig. 79)**

1928. *Holomastigotoides cingulatum* Bernstein, Arch. Protistenkd., 61 : 17.
1942. *Holomastigotoides cingulatum* Bernstein var. *cingulatum* De Mello and De Mello, Arqu. Esc. Med. Cirug. Nova Goa, Ser A, 18 : 145.
1983. *Holomastigotoides cingulatum* var. *coimbatorensis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 43.

Type host : *Anacanthotermes murgabicus*; loc., Turkestan.

Type host (for the variety) : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., India : Tamil Nadu (Coimbatore).

Diagnosis : See remarks below.

Remarks : *Holomastigotoides cingulatum* is very inadequately described by Bernstein (1928), due to which diagnosis of this species could not be included in this communication. However, from its text-figure given by Bernstein (*op. cit.*) (Fig. 79) it is quite evident that this species possesses large number of spiral flagellar bands (around 50 in number) originating from the anterior end of the body, leaving about one-eighth of its total body length at the posterior end as glabrous. In the said figure neither axostyle nor prenuclear zone is shown.

De Mello and De Mello (1942) studied *Anacanthotermes* (= *Hodotermes*) *viarum* from Coimbatore, India for its flagellate symbiotes and recorded *H. cingulatum* from the gut contents of that termite host. They (*op. cit.*) established a new variety of this species and named it as *H. cingulatum* var. *coimbatorensis*. The concerned literature of this variety could not be procured by the present author inspite of his earnest endeavour. For this reason, the diagnosis of this variety could not be given. However, an illustration of *H. cingulatum* after Bernstein (1928) (Fig. 79) is included here for the convenience of future study of this species.

H. cingulatum has not been recorded by any worker since its description by De Mello and De Mello (1942). However, Das (1983) included this species and the variety in the checklist of flagellate symbiotes of Indian termites, based on above record.

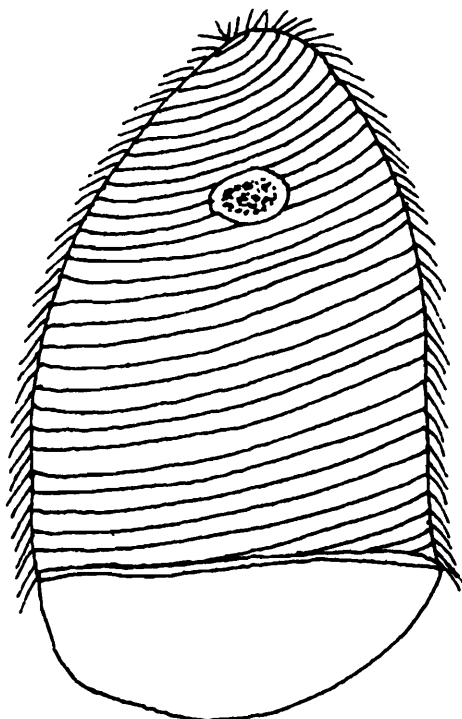


Fig. 79 : *Holomastigotoides cingulatum* Bernstein

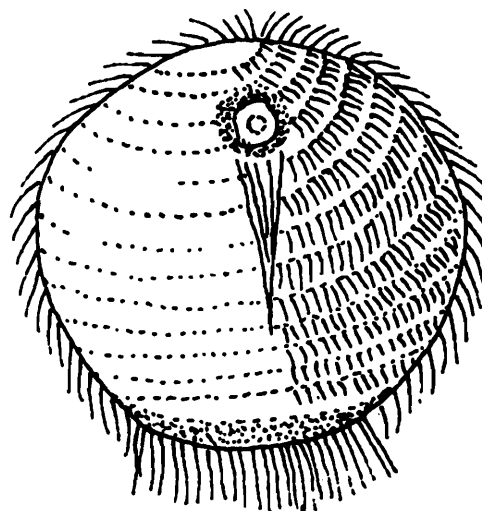


Fig. 80 : *Holomastigotoides dharwarensis* Karandikar & Vittal; arrangement of flagella partly shown

47. *Holomastigotoides dharwarensis* Karandikar and Vittal, 1954
(Fig. 80)

1954. *Holomastigotoides dharwarensis* Karandikar and Vittal, J. Univ. Bombay, 23B : 17.

1983. *Holomastigotoides dharwarensis* : Das, Proc. Symp. Host Environ. zool Surv. India : 43.

Type hosts : *Heterotermes malabaricus*; loc., India : Karnataka; *Coptotermes heimi*; loc., India : Karnataka.

Diagnosis : Typically spheroidal in shape, resembling *Holomastigotoides sphaeroidalis* (dealt with elsewhere); flagella of two types; shorter flagella arranged in dextrotropic rows covering all over the body while longer steriociia restricted to its posterior end; nucleus rounded and often surrounded anteriorly by a faintly differentiated endoplasmic prenuclear zone; an indistinct fibrous axostyle extending from the nucleus towards the posterior direction up to around the middle of the body.

Morphometry (Table 44) :

Table 44. Mensural data of *Holomastigotoides dharwarensis*

Characters	From original description
Diameter of the body	80 μ m
Dimensions of nucleus	not given
Length of shorter flagella	8 – 10 μ m
Length of longer flagella (steriociia)	16 – 18 μ m

Remarks : Karandikar and Vittal (1954) described *Holomastigotoides dharwarensis* from two species of termite hosts, mentioned above which were collected from Dharwar in Karnataka, India. This flagellate species being typically spheroidal in shape quite resembles *Holomastigotoides sphaeroidalis* described by De Mello (1937) from *Coptotermes* sp., collected from Daman, India. However, *H. dharwarensis* in having a distinctive bunch of longer stereocilia on its posterior surface can be conveniently differentiated from *H. sphaeroidalis* which does not possess any stereocilia.

48. *Holomastigotoides elongata* Uttangi, 1962
(Fig. 81)

1962. *Holomastigotoides elongata* Uttangi, J. Karnatak Univ. Sci., 7 : 190.

1983. *Holomastigotoides elongata* : Das, Proc. Symp. Host Environ. zool Surv. India : 43.

Type host : *Coptotermes heimi*; loc., India : Karnataka and Maharashtra (Mumbai).

Diagnosis : Body large, elongate, slender and cylindrical; anterior end of the body tapering to a narrow conical blunt point forming an apical pit; the middle of two sides of the body nearly parallel and posterior end broadly rounded; flagella of single type, long, covering the whole body in dextrotropic rows without leaving any glabrous region of the body; stereocilia absent; nucleus large and oval, located near anterior pole of the body; prenuclear zone of endoplasm well differentiated into a densely granulated conical area over the nucleus; axostyle absent.

Morphometry (Table 45) :

Table 45. Morphometric data of *Holomastigotoides elongata*

Characters	From original description
Length of the body	165 µm
Breadth of the body	50 µm
Ratio of body length to body width	3.3 : 1
Length of nucleus	15 µm
Breadth of nucleus	10 µm
Length of flagella	20 µm

Remarks : In the original description of *Holomastigotoides elongata* Uttangi (1962) recorded only its average mensural data. He designated this species as new to science because of its characteristic elongated, slender and cylindrical body shape and absence of axostyle. In *Holomastigotoides* absence axostyle is noteworthy. It deserves further examination to verify whether this species possessed very indistinct axostyle which was very difficult to observe.

Mention is to be made here that *H. elongata* with its considerably larger flagella closely resembles the text-figure of "intiero" individual of *H. mirabile* given by Grassi (1917). But in *H. elongata* there is no glabrous region, steriocilia and axostyle, whereas these are present in the above mentioned text-figure of *H. mirabile*.

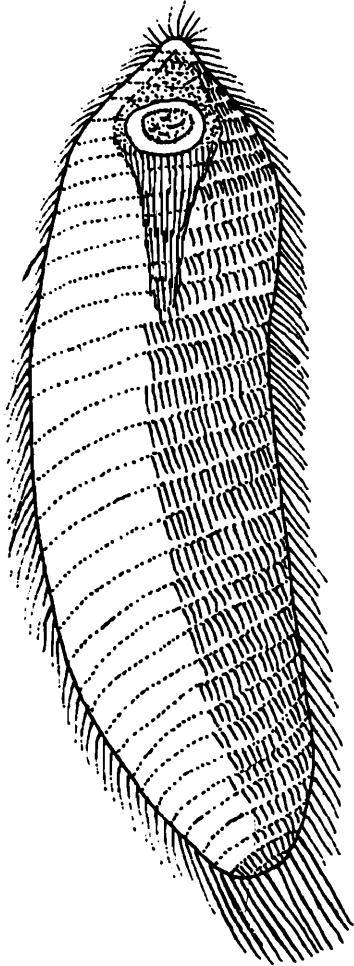


Fig. 81 : *Holomastigotoides elongata* Uttangi; arrangement of flagella partly shown

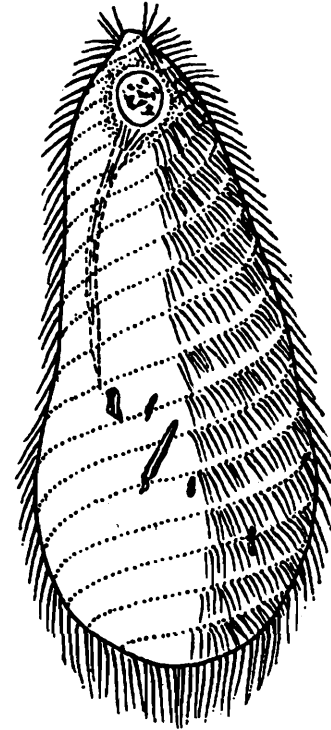


Fig. 82 : *Holomastigotoides emersoni* Das; arrangement of flagella partly shown

49. *Holomastigotoides emersoni* Das, 1976
(Fig. 82)

- 1976. *Holomastigotoides emersoni* Das, *Acta Protozool.*, 15 : 105.
- 1981. *Holomastigotoides emersoni* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 161.
- 1983. *Holomastigotoides emersoni* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 43.
- 1992. *Holomastigotoides emersoni* : Tiwari, *Rec. zool. Surv. India*, 92 : 144.
- 1993. *Holomastigotoides emersoni* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 493. *Zool. Surv. India*.
- 2004. *Holomastigotoides emersoni* : Das, Tiwari Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 454. *Zool. Surv. India*.

2006a. *Holomastigotoides emersoni* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 31. *Zool. Surv. India*.

Type host : *Coptotermes heimi*; loc., India : West Bengal (type locality), Andhra Pradesh, Bihar; *Coptotermes travians*; loc., India : Nagaland.

Diagnosis : Body club-shaped having maximum width near the posterior half of the body; anterior end of the body considerably elevated forming a nipple like structure while posterior end broadly round; flagella of two types; shorter flagella covering the whole body in dextrotropic rows while longer flagella restricted to the posterior extremity of the body; nucleus round and located near the anterior pole of the body; a dense and homogeneous prenuclear zone distinctly visible; axostyle ill developed and indistinct, extending almost up to the middle of the body.

Morphometry (Table 46) :

Table 46. Mensural data of *Holomastigotoides emersoni*

Characters	From original description	
	Range	Mean
Length of the body	76.5-110.4 μm	97 μm
Breadth of the body	28.9-47.6 μm	40.5 μm
Ratio of body length to body width (average)	—	2.2
Length of nucleus	6.8-10.2 μm	8 μm
Breadth of nucleus	6.2-10.2 μm	7.5 μm
Length of shorter flagella	6-7.5 μm	7 μm
Length of longer flagella	10-15 μm	12 μm

Remarks : *Holomastigotoides emersoni* was first described by Das (1976) from *Coptotermes heimi*, collected from West Bengal. Subsequently several workers, namely, Tiwari (1981, 1992) and Das *et al.* (2004) recorded this flagellate from the type host from Bihar, Andhra Pradesh and West Bengal. Later, Das *et al.* (2006a) recorded this flagellate from another host species, *Coptotermes travians* from Nagaland.

50. *Holomastigotoides gigas* De Mello, 1929 (Fig. 83)

1929. *Holomastigotoides gigas* De Mello, *Trans 7th Congr. Far East Assoc. Trop. Med.*, 1927, 2 : 592.

1963. *Holomastigotoides gigas* : Grassé and Hollande, *Ann. Sci. Nat. zool. Biol. Anim* (12) 5 : 759.

1983. *Holomastigotoides gigas* : Das, *Proc. Symp. Host Environ. Zool. Surv. India* : 43.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Goa.

Diagnosis : Body considerably large, elongate and more or less cylindrical and anterior pole rounded; flagella of one type and long, covering the body in dextrotropic rows;

nucleus round; prenuclear zone absent; axostyle fibrous and well developed, extending posteriorly beyond the middle of the body.

Morphometry (Table 47) :

Table 47. Mensural data of *Holomastigotoides gigas*

Characters	From original description
Length of the body	150 – 305 μm
Breadth of the body	60 – 150 μm
Ratio of body length to body width (average)	2.1 : 1
Length of nucleus	20 – 24 μm
Breadth of nucleus	—
Length of flagella	15 – 18 μm

Remarks : Since the original description of *Holomastigotoides gigas* by De Mello (1929), this species has not been recorded by any subsequent worker. The diagnostic features and mensural data presented here are taken from the original description and text figure of this species given by De Mello (*op. cit.*).

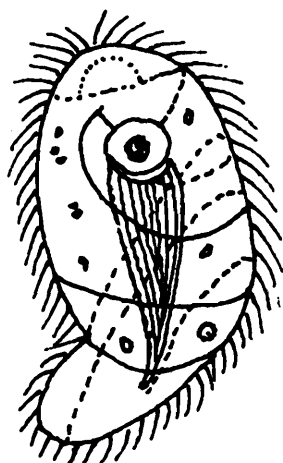


Fig. 83 : *Holomastigotoides gigas* De Mello

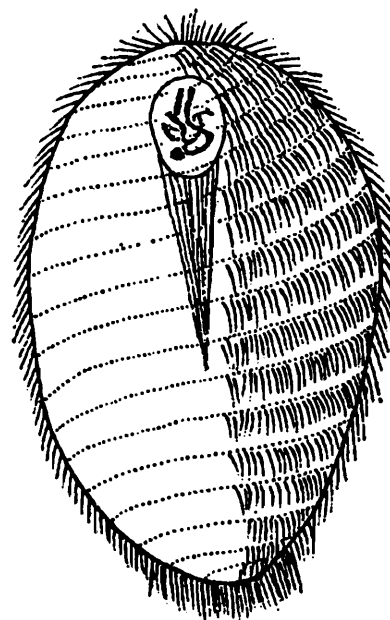


Fig. 84 : *Holomastigotoides globosus* De Mello

51. *Holomastigotoides globosus* De Mello, 1937
(Fig. 84)

1937. *Holomastigotoides globosus* De Mello, C. R. XII. Congr. Inst. Zool. Lisb., 1935, 2 : 1370.

1954. *Holomastigotoides globosus* : Karandikar and Vittal, J. Univ. Bombay, 23B : 15.

1976. *Holomastigotoides globosus* : Das, Acta Protozool., 15 : 109.

1983. *Holomastigotoides globosus* : Das, Proc. Symp. Host Environ. zool. Surv. India : 43.
1993. *Holomastigotoides globosus* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series 3(Part 12) : 493. Zool. Surv. India.
2000. *Holomastigotoides globosus* : Das, Tiwari and Sarkar, Fauna of Tripura, State Fauna Series, 7(Part 4) : 40. Zool. Surv. India.

Type hosts : *Heterotermes* sp.; loc., India : Diu (type locality); *Coptotermes* sp.; loc., India : Daman.

Additional hosts : *Coptotermes travians*; loc., India : Tripura; *Heterotermes indicola*; loc., India : West Bengal; *Heterotermes malabaricus*; loc., India : Karnataka.

Diagnosis : Typically oval in shape, flagella of one type, covering the whole body in dextrotropic rows; nucleus ovoidal, rarely round, located near the anterior end of the body; prenuclear zone absent; axostyle moderately developed, reaching almost the middle of the body.

Morphometry : Mensural data of *Holomastigotoides globosus* recorded from the type hosts and different other species of hosts are presented in Table 48 for comparison.

Table 48. Comparative morphometry of *H. globosus* recovered from different hosts (measurements in μm)

Characters	Type hosts		Additional hosts		
	<i>Heterotermes</i> sp.	<i>Coptotermes</i> sp.	<i>H. indicola</i>	<i>H. malabaricus</i>	<i>C. travians</i>
Body length	76.8(65-90)	69.4 (35-100)	105.2 (90.5-124.1)	140	49-94.5
Body width	60.3(45-75)	54.4 (35-80)	65.4 (56.1-81.6)	90	35-56
Ratio of body length to body width (average)	1.2 : 1	1.2 : 1	1.6 : 1	1.5 : 1	1.5 : 1
Length of nucleus	—	—	12 (10.5-15.3)	—	—
Breadth of nucleus	—	—	9.7 (8.5-11)	—	—
Length of flagella	—	—	5-8	8-10	—

Remarks : From the Table 48 it is quite evident that average dimension of *H. globosus* recovered from the hosts *H. indicola* and *H. malabaricus* are comparatively large than that recovered from the type hosts as well as *C. travians*.

51a. *Holomastigotoides globosus* De Mello, 1937 var. *britoi* De Mello, 1937 (Fig. 85)

1937. *Holomastigotoides globosus* De Mello var. *britoi* De Mello, C. R. XII. Congr. Inst. Zool. Lisb., 1935, 2 : 1371.
1983. *Holomastigotoides globosus* var *britoi* : Das, Proc. Symp. Host Environ. zool Surv. India : 43.

Type hosts : *Coptotermes* sp.; loc., India : Daman.

Diagnosis : Resembles *Holomastigotoides globosus* in all respect except the presence of "steriocilia" on the posterior extremity of the body.

Remarks : While describing *Holomastigotoides globosus* from Indian termites De Mello (1937) collected a population of *H. globosus* which possessed two types of flagella (instead of one type of flagella). The longer ones were "steriocilia", restricted to the posterior extremity of the body. Based on this characteristic feature he erected a new variety of *H. globosus* and named it *H. globosus* var. *britoi*. De Mello (1937) recorded the dimensions of this new variety as 70 μm x 50 μm .

52. *Holomastigotoides grassii* (De Mello, 1919) Grassé and Hollande, 1963

1919. *Pyrsonympha grassii* De Mello, *Biol. Agric.*, 1 : 140.

1921. *Pyrsonympha grassii* De Mello, *Arqu. Indo-Portugaise Med. Hist. Nat.*, 1 : 75-189.

1919. *Leidyia metchnikowi* De Mello, *J. Proc. Asiatic Soc. n.s., Bengal*, 15 : cl-cli.

1929. *Holomastigotoides metchnikowi* (De Mello) De Mello, *Trans. Far East Assoc. Trop. Med.*, 2, 1927 : 582-598.

1937. *Holomastigotoides metchnikowi* : De Mello, *Congr. Zool. Lisb.*, 1935 : 1371.

1963. *Holomastigotoides grassii* (De Mello) Grassé and Hollande, *Ann. Sci. Nat. Zool. Biol. Anim.* (12) 5 : 759.

1983. *Holomastigotoides grassii* : Das, *Proc. Symp. Host Environ.* ~~Zool.~~ *Surv. India* : 43.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Daman.

Additional Host : *Coptotermes* sp.; loc., India : Daman.

Diagnosis : Anterior pole cone-shaped, posterior pole broadly round; flagella covering the whole body in dextrotropic spiral bands; axostyle fibrous and indistinct; prenuclear zone compact.

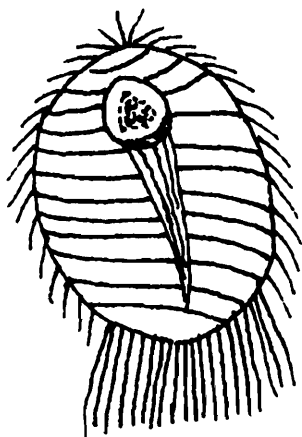


Fig. 85 : *Holomastigotoides globosus* var. *britoi* De Mello

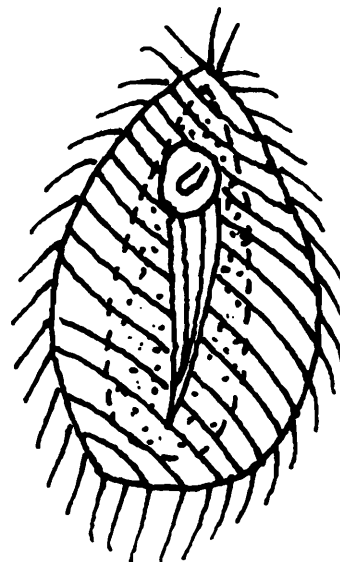


Fig. 86 : *Holomastigotoides grassii* (De Mello)

*Morphometry (Table 49) :***Table 49.** Morphometric data of *Holomastigotoides grassii* (after De Mello, 1927, 1937)

Characters	Type host <i>H. indicola</i>	Additional host <i>Coptotermes</i> sp.
Length of the body	130 (70-190) μm	83.7(63-133) μm
Breadth of the body	92.5 (50-135) μm	63.6 (40-90) μm
Ratio of body length to body breadth (average)	1.4 : 1	1.3 : 1
Length of nuclueus	15 – 24 μm	–
Length of flagella	15 – 20 μm	

Remarks : In 1919 De Mello described a species under the name *Pyrsonympha grassii*, collected from the termite, *Heterotermes* (= *Leucotermes*) *indicola* from Daman, India. In a subsequent publication De Mello (1919b) himself synonymised it under *Leidya metchnikowi*. Later, De Mello (1929, 1937) placed it under *Holomastigotoides metchnikowi*. Then Grassé and Hollande (1963) put it under *Holomastigotoides grassii* as a new combination.

Holomastigotoides grassii has never been recorded by any worker since its description by De Mello as mentioned above. However, Das (1983) kept this species in the checklist of flagellate symbiotes of India, based on De Mello (1919b, 1929, 1937) and, Grassé and Hollande (1963). Diagnostic characters of this species, as given above, are solely based on De Mello (1929, 1937). In his text-figure of *H. grassii* (as *H. metchnikowi*) some additional morphological features are observed, such as, nucleus more or less oval and located near the anterior pole and flagella of one type without having any 'steriocilia'.

53. *Holomastigotoides hemigymnum* Grassi, 1917
(Fig. 87)

1917. *Holomastigotoides hemigymnum* Grassi, *Mem. R. Accad. Lincei*, (5) 12 : 334.
1919. *Leidya annandalei* De Mello, *J. Proc. Asiatic Soc. Bengal*, n.s. 15 : cl.
1919. *Leidya annandalei* De Mello, *Bol. Agric.*, 1 : 137.
1929. *Holomastigotoides annandalei* (De Mello) De Mello, *Trans. VII Congr. Brit. India*, 1927, 2 : 590.
1937. *Holomastigotoides annandalei* : De Mello, *C. R. XII Congr. Inst. Zool. Lisb.*, 1935, 2 : 1373.
1954. *Holomastigotoides hemigymnum* : Karandikar and Vittal, *J. Univ. Bombay*, 23B : 11.
1963. *Holomastigotoides hemigymnum* : Grassé and Hollande, *Ann. Sci. Nat. Zool. Biol. Anim.*, ser. 12 : 750–792.
1983. *Holomastigotoides hemigymnum* : Das, *Proc. Symp. Host Environ. Zool. Surv. India* : 43.

Type host : *Coptotermes sjostedti*; loc., France.

Additional hosts : *Coptotermes lacteus*; loc., Australia; *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Daman and Goa; *Heterotermes malabaricus*; loc., India : Karnataka.

Diagnosis : Body somewhat ovoidal in form; anterior end slightly conical, posterior end somewhat broadly rounded; one type of flagella covering the body in dextrotropic rows excepting one third to one-fourth of the posterior end of the body, making this portion glabrous without having any flagella; nucleus more or less oval, located anteriorly; prenuclear zone distinct, having a conical appearance; axostyle long, fibrous and faintly visible, running straight posteriorly.

Morphometry : Various mensural data of Indian specimens of *Holomastigotoides hemigymnum* recorded by De Mello (1929) (under the name *H. annandalei*) and, Karandikar and Vittal are presented in Table 50.

Table 50. Morphometric data of *Holomastigotoides hemigymnum* from different hosts

Characters	<i>H. indicola</i> (De Mello, 1929)	<i>H. malabaricus</i> (Karandikar & Vittal, 1954)
Length of the body	120 (70–170) μm	100 μm
Breadth of the body	92.5 (40–145) μm	65 μm
Ratio of body length to body breadth (average)	1.3 : 1	1.5 : 1
Length of nucluuus	15–20 μm	–
Length of flagella	12–18 μm	8–10 μm

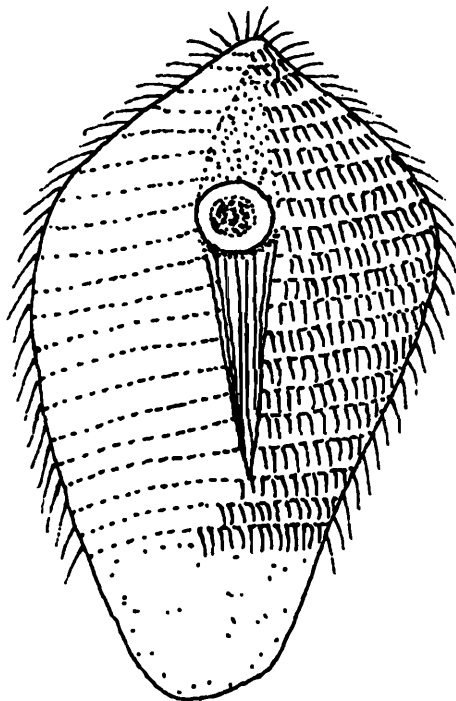


Fig. 87 : *Holomastigotoides hemigymnum* Grassi; arrangement of flagella partly shown

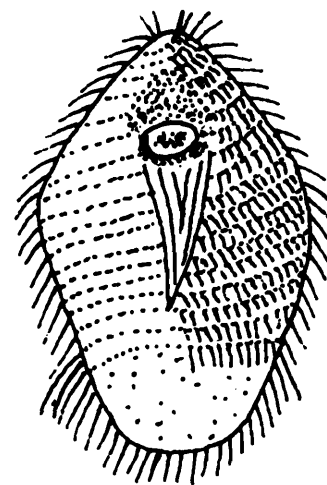


Fig. 88 : *Holomastigotoides hemigymnum* var. *indica* (De Mello)

Remarks : De Mello (1919a,b) was the first to record *Holomastigotoides hemigymnum* from India under the name *Leidya annandalei* and subsequently (in 1929) as *Holomastigotoides annandalei*. Morphometric data of his specimens are presented in Table 50. De Mello (1937) recorded two smaller specimens of *H. annandalei* with dimensions 55 μm x 40 μm and 60 μm x 40 μm . Mention is to be made here that Grassé and Hollande (1963) synonymised *H. annandalei* under *H. hemigymnum*.

53a. *Holomastigotoides hemigymnum* Grassi, 1917 var. *indica* (De Mello) n. comb. (Fig. 88)

1919. *Leidya kemp*i De Mello, J. Proc. Asiatic Soc. n.s. 15 : cl.
 1919. *Leidya kemp*i : De Mello, Biol. Agric., 1 : 37.
 1928. *Holomastigotoides hartmanni* var. *indica* De Mello, Arqu. Esc. Med. Cirug. Nova Goa, Ser A 3 : 20.
 1929. *Holomastigotoides hartmanni* var. *indica* : De Mello, Trans VII Congr. Far East Assoc. Trop. Med., 2, 1927 : 582-598.
 1954. *Holomastigotoides hartmanni* var. *indica* : Karandikar and Vittal, J. Univ. Bombay, 23B : 13.
 1963. *Holomastigotoides hemigymnum* : Grassé and Hollande, Ann. Sci. Nat. Zool. Biol. Anim., Ser 12 : 750-792.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Daman and Goa.

Additional hosts : *Heterotermes malabaricus*; loc., India : Karnataka; *Coptotermes* sp.; loc., India : Daman.

Diagnosis : Body ovoid in form, anterior end bluntly conical, posterior end relatively wide and rounded; body with two types of flagella, shorter flagella covering the major portion of the body in dextrotropic rows excepting the posterior one-fourth; steriocilia thickly set and covering the posterior fourth of the body distally, leaving proximally some glabrous area without having any flagella; nucleus slightly oval, prenuclear zone broadly conical and distinct; a long and fibrous axostyle running straight from post-nuclear part to about posterior two-third of the body.

Morphometry : Mensural data of *Holomastigotoides hemigymnum* variety *indica*, collected from different Indian hosts and under different names by De Mello (1929) as well as by Karandikar and Vittal (1954) are presented in Table 51.

Table 51. Morphometric data of *Holomastigotoides hemigymnum* var. *indica*

Characters	De Mello (1929) under the names		Karandikar & Vittal(1954) under the name
	<i>H. hartmanni</i> var. <i>indica</i>	<i>H. kemp</i> i	<i>H. hartmanni</i> var. <i>indica</i>
Length of the body	70 (50 – 90) μm	80 (60 – 100) μm	125 μm
Breadth of the body	45 (30 – 60) μm	45 (30 – 60) μm	75 μm
Ratio of body length to body breadth (average)	1.5 : 1	1.6 : 1	1.6 : 1
Length of nucleus	10 – 15 μm	12 – 15 μm	–
Length of shorter flagella	10 – 18 μm	10 – 15 μm	8 – 10 μm

Remarks : De Mello (1919) described a new species *Leidya kemp*i from the Indian termite *Heterotermes* (= *Leucotermes*) *indicola*. Afterwards, he (1929) described a new variety, *Holomastigotoides hartmanni* var. *indica* from the same termite host. Later, Karandikar and Vittal (1954) recorded this variety from another species of termites of India, viz., *Heterotermes malabaricus*. Subsequently Grassé and Hollande (1963) synonymised both *L. kemp*i and *H. hartmanni* var *indica* under *Holomastigotoides hemigymnum*. But this variety *indica* differs from its typical species *Holomastigotoides hemigymnum* in having two types of flagella (*vs.* one type of flagella in typical species). The longer ones are steriocilia which are thickly set distally covering about posterior one fourth of the body. Since there is sufficient morphological distinctness between the typical species and its variety, as mentioned earlier, *H. hertmanni* var. *indica* is retained here as *H. hemigymnum* var. *indica* as a new combination.

54. *Holomastigotoides hollandei* Das, 1976

(Fig. 89)

1976. *Holomastigotoides hollandei* Das, *Acta Protozool.*, 15 : 103.
1981. *Holomastigotoides hollandei* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 181.
1983. *Holomastigotoides hallandei* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 43.
1992. *Holomastigotoides hollandei* : Tiwari, *Rec. zool. Surv. India*, 92 : 144.
1993. *Holomastigotoides hollandei* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series* 3(Part 12) : 493. *Zool. Surv. India*
- 2006a. *Holomastigotoides hollandei* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 32. *Zool. Surv. India*.

Type host : *Heterotermes indicola*; loc., India : West Bengal (type locality) and Bihar.

Additional host : *Coptotermes travians*; loc., India : Nagaland.

Diagnosis : Body more or less round in shape with finger like projection at the anterior end, sometimes bearing an apical pit; flagella of two types, shorter flagella covering the whole body in dextrotropic rows; longer flagella studded at the posterior extremity of the body; nucleus ovoidal in shape, situated at the anterior end of the body; a conspicuous prenuclear zone in the form of a dense homogeneous irregular mass visible in stained preparation; axostyle fibrillar and well developed reaching obliquely almost the posterior part of the body.

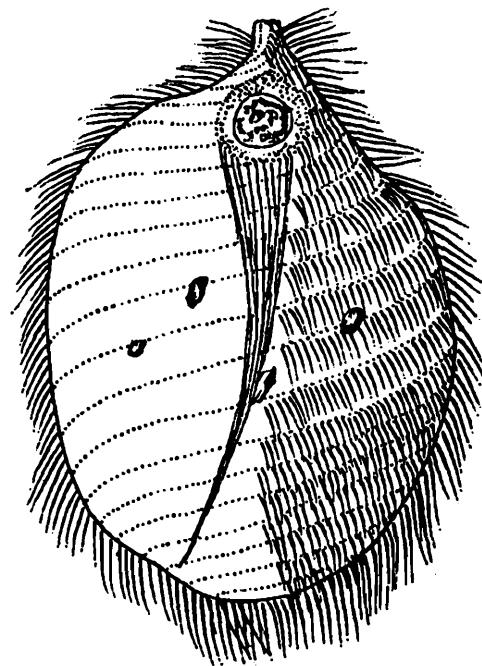


Fig. 89 : *Holomastigotoides hollandei* Das; arrangement of flagella partly shown

Morphometry : Morphometric data of *Holomastigotoides hollandei* recorded by Das (1976) from the host, *Heterotermes indicola* is presented in Table 52 and compared with those recorded by Tiwari (1992) from the same host, but from different locality.

Table 52. Mensural data of *Holomastigotoides hollandei* (measurements in μm)

Characters	Host : <i>Heterotermes indicola</i>	
	from West Bengal Das (1976)	from Bihar Tiwari (1992)
Body length	71 (45.9-96)	70.9 (55-76.8)
Body width	51.4 (30.6-73.1)	57.1 (50.2-64)
Ratio of body length to body width (average)	1.4 : 1	1.2 : 1
Length of nucluus	13.3 (10.1-14.4)	8 (6.8-10.4)
Breadth of nucleus	9.5 (6.8-11.9)	7 (6-9.6)
Length of shorter flagulla	12 (8.5-15)	—
Length of longer flagella	21.5 (17-25.5)	—

Remarks : Specimens of *Holomastigotoides hollandei* recorded by Tiwari (1992) quite resemble its type specimens, described by Das (1976). Dimensions of both populations collected from the type host from West Bengal and Bihar are also more or less similar in morphometry as evident in Table 52.

55. *Holomastigotoides inexpectatus* De Mello, 1937 (Fig. 90)

1937. *Holomastigotoides inexpectatus* De Mello, C. R. XII Congr. Inst. Zool. Lisb., 1935, 2 : 1372.

1983. *Holomastigotoides inexpectatus* : Das, Proc. Symp. Host Environ. zool. Surv. India : 43.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Diu and Goa.

Diagnosis : Body elongate and vermiform, both anterior and posterior ends of the body irregularly round; flagella of one type, covering whole of the body in dextrotropic rows; fibrillar axostyle not visible and prenuclear zone absent.

Morphometry : While describing *Holomastigotoides inexpectatus* De Mello (1937) recorded the dimensions of three specimens only as $128\ \mu\text{m} \times 58\ \mu\text{m}$, $132\ \mu\text{m} \times 47\ \mu\text{m}$ and $118\ \mu\text{m} \times 57\ \mu\text{m}$. No other morphometric data of this species is available.

Remarks : Diagnostic characters of *H. inexpectatus* given above are taken from the original description of this species by De Mello (1937) because it has not been recorded by any worker since its first description. However, Das (1983) incorporated this species in the checklist of flagellate symbiotes of Indian termites based on published record as above. *H. inexpectatus* is insufficiently described. The text-figure of this species published by De Mello (*op. cit.*) (Fig. 90) reveals that nucleus is roundish and located near the anterior pole of the body without having any prenuclear zone.

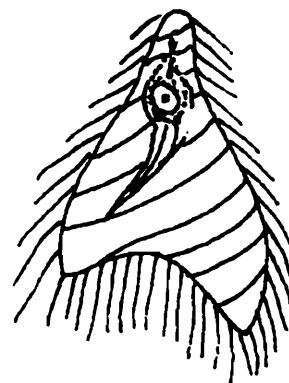
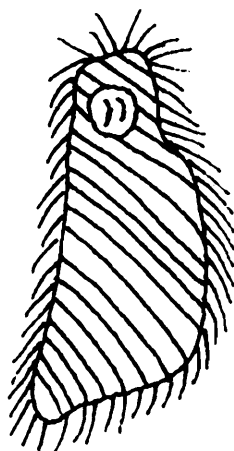


Fig. 90 : *Holomastigotoides inexpectatus* De Mello Fig. 91 : *Holomastigotoides koidzumii* De Mello

56. *Holomastigotoides koidzumii* De Mello, 1929

(Fig. 91)

1929. *Holomastigotoides koidzumii* De Mello, Trans. VII Congr. Far East Assoc. Trop. Med., 1927, 2 : 591.

1983. *Holomastigotoides koidzumii* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Goa.

Diagnosis : Body bottle shaped ('forme en bouteille très caractéristique'), anterior end resembling a truncate cone; body covered by flagella in dextrotropic rows; pre-nuclear zone distinct.

Morphometry (Table 53) :

Table 53. Mensural data of *Holomastigotoides koidzumii*

Characters	From original description
Length of the body	70 (50-90) μm
Breadth of the body	45 (30-60) μm
Ratio of body length to body width (average)	1.5 : 1
Length of nucleus	10-15 μm
Length of flagella	10-18 μm

Remarks : *Holomastigotoides koidzumii* has not been reported by any worker since its first description by De Mello (1929). Das (1983) included this species in the checklist of flagellate symbiotes of Indian termites based on the above published record. The diagnosis of this species given here is taken from De Mello (*op. cit.*). This species is very insufficiently

described. Text figure of *H. koidzumii* given by De Mello (*op. cit*) reveals that its body is oval with slightly conical anterior end and broadly rounded posterior end; flagella of one type covering the body in dextrotropic rows; fibrillar axostyle moderately developed; nucleus more or less round, located near the anterior pole of the body with distinct prenuclear zone.

57. *Holomastigotoides magnus* Uttangi, 1962
(Fig. 92)

1962. *Holomastigotoides magnus* Uttangi, J. Karnataka Univ. Sci., 1 : 188.
1976. *Holomastigotoides magnus* : Das, Acta Protozool., 15 : 114.
1983. *Holomastigotoides magnus* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.
1993. *Holomastigotoides magnus* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3(Part 12) : 494. Zool. Surv. India.
2000. *Holomastigotoides magnus* : Das, Tiwari and Sarkar, Fauna of Tripura, State Fauna Series, 7(Part 4) : 40. Zool. Surv. India.
2003. *Holomastigotoides magnus* : Das, Tiwari and Sarkar, Fauna of Sikkim, State Fauna Series, 9(Part 5) : 30. Zool. Surv. India.
2004. *Holomastigotoides magnus* : Das, Tiwari, Nandi, Sarkar and Saha, Fauna of Andhra Pradesh, State Fauna Series, 5(Part 6) : 455. Zool. Surv. India.
2004. *Holomastigotoides magnus* : Das, Fauna of Gujarat, State Fauna Series, 8(Part 2) : 422. Zool. Surv. India.
- 2006a. *Holomastigotoides magnus* : Das, Tiwari and Sarkar, Fauna of Nagaland, State Fauna Series, 12 : 32. Zool. Surv. India.

Type host : *Heterotermes indicola*; loc., India : Gujarat (type locality) and West Bengal.

Additional hosts : *Coptotermes heimi*; loc., India : Andhra Pradesh; *Coptotermes travians*; loc., India : Nagaland, Sikkim and Tripura.

Diagnosis : Body large and ovoidal; both anterior and posterior ends broadly round; flagella of one type, covering the major portion of the body in dextrotropic rows, leaving a posterior glabrous portion without any flagella, measuring about one-fifth the body length; nucleus round and situated near the anterior end of the body; prenuclear zone clearly visible in stained preparation as a narrow strip; axostyle fibrous and moderately developed, running posteriorly beyond the middle of the body.

Morphometry : Mensural data of *Holomastigotoides magnus* collected from the type host are presented in Table 54 and compared with those procured from the other hosts.

Table 54. Morphometric data of *Holomastigotoides magnus* from different hosts (measurements in μm)

Characters	Type host, <i>H. indicola</i>		Other hosts	
	Gujarat	West Bengal	<i>C. heimi</i> (Andhra Pradesh)	<i>C. travians</i> (Tripura)
Body length	165	125.1 (100.3-170)	100.3-17	176.3-220
Body width	110	87.7 (74.8-102)	74.8-102	94.3-114.8
Ratio of body length to body width (average)	1.5 : 1	1.4 : 1	1.5 : 1	1.8 : 1
Diameter of nucleus	15-20	15.3 (13.6-17)	—	—
Length of flagella	—	25.5	—	—
Length of glabrous portion of the body	about one-fifth of body length	about one fifth of body length	—	—

Remarks : Uttangi (1962) described *H. magnus* from the gut of *Heterotermes indicola* collected from Gujarat. Das (1976) also recorded this species from the type host, collected from West Bengal. Subsequently Das *et al.* (2000, 2003, 2004, 2006a) recorded this flagellate from two other host species, namely, *Coptotermes travians* and *Coptotermes heimi*, collected from Tripura and Andhra Pradesh respectively.

Large ovoidal body shape, one type of flagella and characteristic glabrous non-flagellated portion of the body make *H. magnus* distinct from all its congeners. From Table 54 it is quite evident that specimens of *H. magnus* collected from the host *C. travians* were the largest, compared to those collected from other hosts.

58. *Holomastigotoides melloi* Uttangi, 1962
(Fig. 93)

1962. *Holomastigotoides melloi* Uttangi, J. Karnataka Univ. Sci., 7 : 187.

1983. *Holomastigotoides melloi* : Das, Proc. Symp. Host Environ., zool. Surv. India : 44.

2004. *Holomastigotoides melloi* : Das, Fauna of Gujarat, State Fauna Series, 8(Part 2) : 422. Zool. Surv. India.

Type host : *Heterotermes indicola*; loc., India : Gujarat.

Diagnosis : Body somewhat pear-shaped or pyriform; anterior end of the body protruding into finger like projection; flagella of one type and small, covering the whole body in

dextrotropic rows leaving a glabrous portion without having any steriocilia; glabrous portion measuring about one-seventh the total length of the body; nucleus oval and located near the anterior end of the body; prenuclear zone distinct in stained preparations forming a densely granulated cap-like area over the nucleus; axostyle fibrillar, conical, small but distinct, never extending beyond the middle of the body.

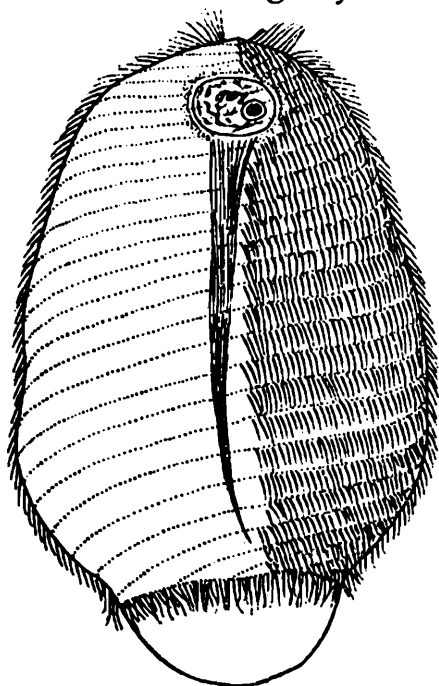


Fig. 92 : *Holomastigotoides magnus* Uttangi; arrangement of flagella partly shown

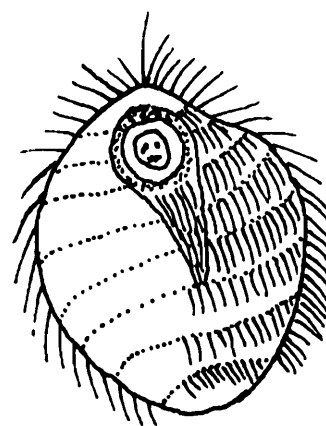


Fig. 93 : *Holomastigotoides melloi* Uttangi; flagellar arrangement partly shown

Morphometry (Table 55) :

Table 55. Mensural data of *Holomastigotoides melloi*

Characters	From <i>H. indicola</i> (De Mello, 1962)
Length of the body	40-45 μm
Width of the body	30-35 μm
Ratio of body length to body width (average)	1.3 : 1
Diameter of nucleus	7.5 μm
Length of flagella	6 μm

Remarks : *Holomastigotoides melloi* has not been recorded by any worker since its first description by Uttangi (1962). Das (1983, 2004) included this species in the checklist of flagellate symbiotes of Indian termites and in the State Fauna of Gujarat, based on published account by De Mello (1962). Diagnosis of *H. melloi* given above is solely based on its original description (Uttangi, *op. cit.*). The Table 55 reveals that this species is very small in dimensions.

59. *Holomastigotoides mirabile* Grassi, 1917
(Fig. 94)

1917. *Holomastigotoides mirabile* Grassi, Mem. R. Accad. Lincei, (5) 12 : 334, 373.
1921. *Holomastigotoides hartmanni* Koidzumi, Parasitol., 13 : 271.
1963. *Holomastigotoides mirabile* : Grassé and Hollande, Ann. Sci. Nat. Zool. Biol. Anim., (12) 5 : 758.
1978. *Holomastigotoides hartmanni* : Tiwari, Bull. zool. Surv. India, 1 : 312.
1983. *Holomastigotoides mirabile* : Das, Proc. Symp. Host Environ. Zool. Surv. India : 44.
1993. *Holomastigotoides mirabile* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3(Part 12) : 493. Zool. Surv. India.

Type host : *Coptotermes sjostedti*; loc., France.

Additional hosts : *Coptotermes acinaciformis*; loc., France; *Coptotermes formosanus*; loc., Japan; *Coptotermes heimi*; loc., India : West Bengal; *Prorhinotermes flavus*; loc., Australia.

Diagnosis : Shape variable; elongated to oval or elliptical, slightly narrowed at anterior end; flagella of two types, shorter flagella covering the whole body in dextrotropic rows leaving a small glabrous portion; longer flagella, the steriocilia covering the posterior portion of the body; nucleus oval, its larger axis horizontal, located at anterior region of the body; distinct prenuclear zone present in stained preparation; axostyle not always distinct.

Morphometry : See remarks below.

Remarks : Grassi (1917) was the first to report *Holomastigotoides mirabile* as new to science but he did not provide any description of this species. However, he incorporated 16 illustrations of this species in the said publication. These illustrations are good enough for the identification of the said species. Mainly based on these illustrations Grassé and Hollande (1963) synonymised *Holomastigotoides hartmanni* Koizumi under *H. mirabile* Grassi.

Koidzumi's forms (as *H. hartmanni*) were commonly oval or elliptical with slight narrow anterior end, measuring 50-140 μm (rarely 170 μm) in length and 30-80 μm (sometimes 100 μm) in width, having a small glabrous area (about one-ninth the total length of the body) at the posterior end and an oval nucleus, 20-26 μm x 10-15 μm in dimension. In the above publication (Koidzumi, 1921) nothing is mentioned regarding axostyle. It was also not shown in his diagram of the species.

Only record of *H. mirabile* from India was made by Tiwari (1978), that too, under the name *H. hartmanni* which was collected from the gut of *Coptotermes heimi*. His forms quite resemble those of Koidzumi and measured 93.7-175.5 μm with an average 110.6 μm in length and 63.7-86.2 μm in breadth with an average 75 μm . Dimensions of nucleus of these forms were 15.9 μm x 11.9 μm . Based on this record, Das (1983, 1993) included this species in the checklist of flagellate symbiotes of Indian termite as well as in the State Fauna of West Bengal published by the Zoological Survey of India.

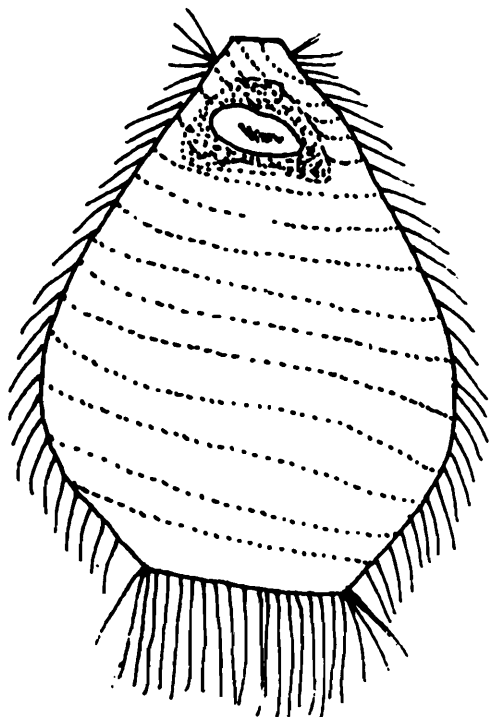


Fig. 94 : *Holomastigotoides mirabile* Grassi

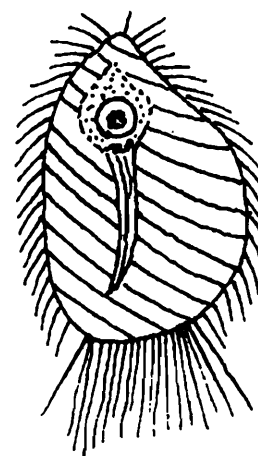


Fig. 95 : *Holomastigotoides mirabile* var. *katiawarensis* (De Mello)

**59a. *Holomastigotoides mirabile* Grassi, 1917 var. *katiawarensis*
(De Mello, 1937) Das, 1983
(Fig. 95)**

1937. *Holomastigotoides hartmanni* var. *katiawarensis* De Mello, C. R. XII Congr. Int. Zool. Lisb., 1935, 2 : 1372.
1954. *Holomastigotoides hartmanni katiawarensis* : Karandikar and Vittal, J. Univ. Bombay, 23 B : 16.
1983. *Holomastigotoides mirabile katiawarensis* (De Mello) Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type hosts : Undetermined; loc., India : Diu ; *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Goa.

Additional hosts : *Heterotermes malabaricus*; loc., India : Karnataka; *Coptotermes heimi*; loc., India : Karnataka.

Diagnosis : Body ovoidal in form, anterior end widely or narrowly conical; flagella of two types; shorter flagella running in dextrotropic rows all over the body except for a small area at the posterior end; posterior extremity of the body covered with long steriocytes; nucleus round, pre-nuclear zone distinct; axostyle fibrous and in some cases very distinct.

Morphometry : Mensural data of only length and width of *Holomastigotoides mirabile katiawarensis* were recorded from different hosts as shown in Table 56.

Table 56. Morphometric data of *H. mirabile katiawarensis*

Characters	De Mello (1937)		Karandikar & Vittal (1954) <i>H. malabaricus</i> & <i>C. heimi</i>
	undetermined host	<i>H. indicola</i>	
Body length	57.3 (48-68) μm	93.5 (75-129) μm	150 μm
Body width	36.3 (29-42) μm	48.1 (42-63) μm	80 μm
Ratio of body length to body width (average)	1.6 : 1	1.9 : 1	1.8 : 1

Remarks : Variety *katiawarensis* mainly differs from its typical species *H. mirabile* in shape of the body and distribution of steriocilia. Table 56 shows that specimens of the variety collected by Karandikar and Vittal (1954) are considerably larger than those collected by De Mello (1937).

59b. *Holomastigotoides mirabile* Grassi, 1917 var. *margabhandui*
De Mello and De Mello, 1942

1942. *Holomastigotoides mirabile* var. *margabhandui* De Mello and De Mello, *Arqu. Esc. Med. Cirug. Nova Goa (A)*, 18 : 146.

1983. *Holomastigotoides mirabile* var. *margabhandui* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.

Type host : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., India : Tamil Nādu.

Diagnosis : Not available.

Remarks : *H. mirabile* var. *margabhandui* was described by De Mello and De Mello (1942) from the gut of a hodotermitid termite *Anacanthotermes* (= *Hodotermes*) *viarum* from Coimbatore (Tamil Nadu), India. The concerned literature could not be collected by the present author. So its diagnosis could not be incorporated here.

60. *Holomastigotoides ogivalis* De Mello, 1937
(Fig. 96)

1937. *Holomastigotoides ogivalis* De Mello, C. R. XII Congr. Int. Zool. Lisb., 1935, 2 : 1373.

1954. *Holomastigotoides ogivalis* : Karandikar and Vittal, *J. Univ. Bombay*, 23B : 14.

1976. *Holomastigotoides ogivalis* : Das, *Acta Protozool.*, 15 : 106.

1978. *Holomastigotoides ogivalis* : Tiwari, *Bull. zool. Surv. India*, 1 : 32.

1981. *Holomastigotoides ogivalis* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 161.

1983. *Holomastigotoides ogivalis* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.

1988. *Holomastigotoides ogivalis* : Tiwari, *Rec. zool. Surv. India*, 85 : 218.

1992. *Holomastigotoides ogivalis* : Tiwari, *Rec. zool. Surv. India*, 92 : 146.

1993. *Holomastigotoides ogivalis* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 494. *Zool. Surv. India*.
2000. *Holomastigotoides ogivalis* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 40. *Zool. Surv. India*.
2003. *Holomastigotoides ogivalis* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 30. *Zool. Surv. India*.
- 2006a. *Holomastigotoides ogivalis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 32. *Zool. Surv. India*.

Type host : *Coptotermes* sp.; loc., India : Daman.

Additional hosts : *Coptotermes heimi*; loc., India : Bihar, Karnataka, Uttar Pradesh, West Bengal; *Coptotermes travians*; loc., India : Nagaland, Sikkim, Tripura.

Diagnosis : Body resembling an inverted cup with a blunt finger like elevation at the anterior end; flagella of two types; shorter flagella covering the whole body in dextrotropic rows; longer flagella (not steriociia) thickly set at the posterior extremity of the body; nucleus oval, located near the anterior end; crescent shaped prenuclear zone of differentiated cytoplasm clearly visible in stained preparation; axostyle distinct, extending posteriorly from the nucleus.

Morphometry : Mensural data of *Holomastigotoides ogivalis* collected from different hosts are presented in Table 57.

Table 57. Comparative morphometric data of *Holomastigotoides ogivalis* (all measurements in μm)

Characters	From <i>Coptotertmes heimi</i>			<i>C. travians</i> Tripura
	West Bengal	Bihar	Karnataka	
Body length	82.3 (71.4–91.8)	80.7 (60.5–94)	90	60.5–94
Body width	55.7 (34–74.8)	48.3 (40.5–56.2)	80	40.5–63
Ratio of body length to body width (average)	1.4 : 1	1.6 : 1	1.1 : 1	1.4 : 1
Length of nucleus	11.8(10.2–12.7)	11.6(8.2–12.7)	–	–
Breadth of nucleus	8(6.1–9.5)	9(6.1–9.5)	–	–
Length of shorter flagella	6–7	–	6–8	–
Length of longer flagella	9–10	–	10–12	–

Ramarks : De Mello (1937) described *Holomastigotoides ogivalis* from the host *Coptotermes* sp., collected from Daman, India and recorded the dimensions of two specimens only as $44\ \mu\text{m} \times 99\ \mu\text{m}$ and $49\ \mu\text{m} \times 44\ \mu\text{m}$. Subsequently *H. ogivalis* was recorded from two hosts, viz., *C. heimi* and *C. travians*, morphometry of which is shown in Table 57. The Table reveals that breadth of this species and consequently its length-breadth ratio is considerably variable. However, characteristic body shape of *H. ogivalis* as stated in its diagnosis, makes it distinct from all its congeners.

61. *Holomastigotoides operculatum* De Mello, 1949
(Fig. 97)

1949. *Holomastigotoides operculatum* De Mello, *An. Inst. Med. Trop.*, 6 : 71.

1983. *Holomastigotoides operculatum* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.

Type host : Undetermined; loc., India (exact locality not mentioned).

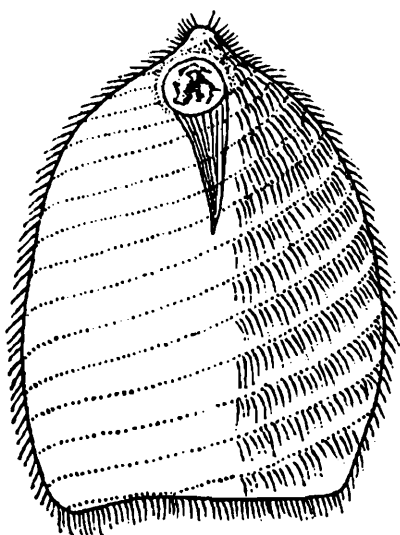


Fig. 96 : *Holomastigotoides ogivalis* De Mello;
flagellar arrangement partly shown.

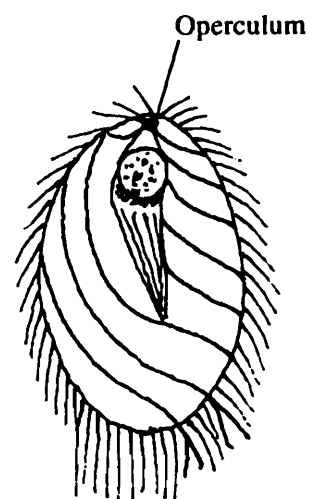


Fig. 97 : *Holomastigotoides operculatum*
De Mello

Diagnosis : Body mostly oval or elliptical, rarely spherical; a conspicuous, large, elliptical siderophil operculum present at anterior end; spiral bands originating from the operculum and covering the whole body "sometimes protruding beyond it as small lanceolated appendages provided with two (?) flagella"; numerous flagella distributed throughout the flagellar bands and periphery of the whole body, giving rise to longer steriocilia at the posterior end; nucleus more or less round and located very closely near the anterior pole; a small prenuclear zone of differentiated endoplasm visible in stained preparation; axostyle fibrous, faintly visible and connected with a "basal rod"

Morphometry : De Mello (1949) recorded the body dimensions and diameter of nucleus of eight specimens, based on which morphometry of *Holomastigotoides operculatum* is presented in Table 58.

Table 58. Mensural data of *H. operculatum* (after De Mello, 1949)

Characters	From undetermined species of termites
Length of the body	128.7 (80-160) μm
Breadth of the body	74.5 (60-85) μm
Ratio of body length to body width (average)	1.7 : 1
Diameter of nuclues	8 – 10 μm

Remarks : *Holomastigotoides operculatum* has not been recorded by any worker since its first description by De Mello (1949). Das (1983) included this species in the checklist of flagellate symbiotes of Indian termites based on De Mello's above published report. Diagnosis of this species given above is also based on De Mello (*op. cit.*). Presence of a large and conspicuous operculum at the anterior end of the body of the species is the unique characteristic feature by which *H. operculatum* can be differentiated from all its congeners.

62. *Holomastigotoides ovalis* Uttangi, 1962
(Fig. 98)

1962. *Holomastigotoides ovalis* Uttangi, J. Karnatak Univ. Sci, 7 : 185.
1983. *Holomastigotoides ovalis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.
1992. *Holomastigotoides ovalis* : Tiwari, Rec. zool. Surv. India, 92 : 146.
2000. *Holomastigotoides ovalis* : Das, Tiwari and Sarkar, Fauna of Tripura, State Fauna Series, 7(Part 4) : 40. Zool. Surv. India.
2004. *Holomastigotoides ovalis* : Das, Tiwari, Nandi, Sarkar and Saha, Fauna of Andhra Pradesh, State Fauna Series, 5(Part 6) : 455. Zool. Surv. India.
2004. *Holomastigotoides ovalis* : Das, Fauna of Gujarat, State Fauna Series, 8(Part 2) : 422. Zool. Surv. India.
- 2006a. *Holomastigotoides ovalis* : Das, Tiwari and Sarkar, Fauna of Nagaland, State Fauna Series, 12 : 32. Zool. Surv. India.

Type host : *Heterotermes indicola*; loc., India : Karnataka (type locality), Bihar.

Additional hosts : *Coptotermes heimi*; loc., India : Andhra Pradesh; *Coptotermes travians*; loc., India: Nagaland, Tripura.

Diagnosis : Body oval or somewhat egg shaped; anterior end narrowly rounded and the posterior end broadly rounded; flagella of two types; longer flagella covering the body in dextrotropic rows, leaving some non-flagellar glabrous region; shorter flagella (steriocilia) present on some portion of the glabrous non-flagellar area at the posterior end; nucleus oval, located near the anterior pole; prenuclear zone of endoplasm and axostyle absent.

Morphometry (Table 59)

Table 59. Mensural data of *Holomastigotoides ovalis* form different hosts

Characters	Type host		Additional hosts	
	<i>Heterotermes indicola</i> (Karnataka)	(Bihar)	<i>C. heimi</i> (Andhra Pradesh)	<i>C. travians</i> (Tripura)
Length of the body	80 µm	102 µm	105 µm	102 µm
Breadth of the body	50 µm	63 µm	68 µm	63 µm

Table 59. *Contd.*

Characters	Type host		Additional hosts	
	<i>Heterotermes indicola</i> (Karnataka)	(Bihar)	<i>C. heimi</i> (Andhra Pradesh)	<i>C. travians</i> (Tripura)
Ratio of body length to body width (average)	1.6 : 1	1.6 : 1	1.5 : 1	1.6 : 1
Length of nucleus	8 µm	8.2 µm	—	—
Breadth of nucleus	7 µm	6.5 µm	—	—
Length of longer flagella	15 µm	—	—	—
Length of shorter flagella	5 µm	—	—	—

Remarks : Uttangi (1962) described *Holomastigotoides ovalis* from *Heterotermes indicola* from Karnataka. Tiwari (1992) also collected this species from the same host from Bihar. Subsequently Das (1974) and Das *et al.* (2000, 2004, 2006a) recorded this species from Gujarat, Tripura Nagaland and Andhra Pradesh from the host *Coptotermes travians* and *C. heimi* respectively. Table 59 reveals that type specimens (from Karnataka) is the smallest in dimension. However, average length-breadth ratio of *H. ovalis* collected from different hosts is almost same.

63. *Holomastigotoides piriformis* De Mello, 1937
(Fig. 99)

1937. *Holomastigotoides piriformis* De Mello, C. R. XII Congr. Int. Zool., Lisbon, 1935, 2 : 1371.

1983. *Holomastigotoides piriformis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type hosts : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Diu, Goa; *Coptotermes* sp.; loc., India : Daman.

Diagnosis : Body pyriform in shape, anterior pole broadly round and posterior pole pointed; flagella of one type, covering the whole body in dextrotropic rows; axostyle fibrous and faintly visible.

Morphometry : Vide remarks below.

Remarks : Description of *Holomastigotoides piriformis* is very insufficient. Its illustration given by De Mello (1937) (Fig. 99) reveals that nucleus was more or less round and located near the anterior pole of the body; prenuclear zone of differentiated endoplasm is absent.

H. piriformis is never recorded by any worker since its first description. However, Das (1983) included this species in the checklist of flagellate symbiotes of Indian termites on the basis of its original description.

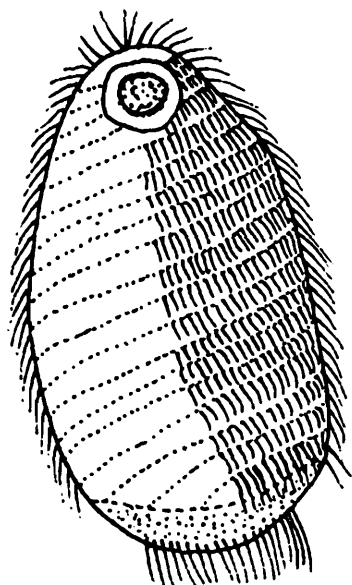


Fig. 98 : *Holomastigotoides ovalis* Uttangi; flagellar arrangement partly shown.

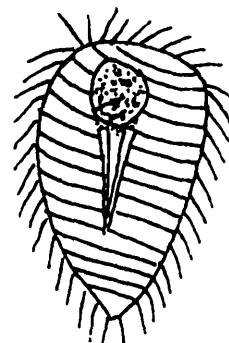


Fig. 99 : *Holomastigotoides piriformis* De Mello

While describing this species, De Mello (1937) recorded the dimensions of 24 specimens (not 23 specimens as mentioned in his paper) — 3 from the host, *Heterotermes indicola* and 21 from *Coptotermes* sp. The specimens from the former host were having the length 75-85 μm with average 80 μm , width 40-65 μm with average 52.3 μm and length breadth ratio 1.5 : 1. On the other hand, specimens from *Coptotermes* sp. measured 50-150 μm in length with average 86.1 μm and width 31-75 μm with average 48.9 μm and length breadth ration 1.7 : 1.

64. *Holomastigotoides proboscifer* De Mello and De Mello, 1942

1942. *Holomastigotoides proboscifer* De Mello and De Mello, *Arqu. Esc. Med. Cirug. Nova Goa* (A), 18 : 147.

1983. *Holomastigotoides proboscifer*, Das : *Proc. Symp. Host Environ. zool. Surv. India* : 44.

Type host : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., India : Tamil Nadu.

Diagnosis : A characteristic probosis-like structure present (hence the specific name); a small siderophyl ring also present, from which originating the spiral dextrotropic flagellar bands; prenuclear zone not present.

Remarks : *Holomastigotoides proboscifer* was described by De Mello and De Mello (1942) from a hodotermitid termite, *Anacanthotermes* (= *Hodotermes*) *viarum*, collected from Coimbatore in Tamil Nadu. Since then no further record of this species could be made by any worker. This species was included in the checklist of flagellate symbiotes of Indian termites by Das (1983), based on above record.

Literature pertaining to the original description of *H. proboscifer* was not available to the present author. The above diagnosis was given, consulting a publication of De Mello (1949) in which another new species of *Holomastigotoides*, namely, *H. operculatum* was described.

65. *Holomastigotoides rayi* Karandikar and Vittal, 1954
(Fig. 100)

1954. *Holomastigotoides rayi* Karandikar and Vittal, *J. Univ. Bombay*, **23 B** : 18.
1976. *Holomastigotoides rayi* : Das : *Acta Protozool.*, **15** : 112.
1983. *Holomastigotoides rayi* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.
1992. *Holomastigotoides rayi* : Tiwari, *Rec. zool. Surv. India*, **92** : 147.
1993. *Holomastigotoides rayi* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, **3**(Part 12) : 495. *Zool. Surv. India*.
2000. *Holomastigotoides rayi* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, **7**(Part 4) : 40. *Zool. Surv. India*.
2003. *Holomastigotoides rayi* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, **9**(Part 5) : 30. *Zool. Surv. India*.
2004. *Holomastigotoides rayi* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, **5**(Part 6) : 455. *Zool. Surv. India*.
- 2006a. *Holomastigotoides rayi* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, **12** : 33. *Zool. Surv. India*.

Type host : *Coptotermes heimi*; loc., India : Andhra Pradesh, Karnataka (type locality), West Bengal.

Additional hosts : *Coptotermes travians*; loc., India : Nagaland, Sikkim, Tripura; *Heterotermes indicola*; loc., India : Bihar.

Diagnosis : Body oval in shape, sometimes with an apical pit at anterior end; flagella of two types; shorter flagella covering the body in regular dextrotropic rows, leaving about one-fifth of the posterior part of the body without having any dextrotropic spiral; this posterior part of the body occupied by densely but irregularly distributed longer flagella which are not steriociia; nucleus ovoidal in shape and located near the anterior pole of the body; prenuclear zone distinct in stained preparation; axostyle fibrous and faintly visible, extending up to about anterior three-fourth of the body.

Morphometry : A comparative morphometric data of *Holomastigotoides rayi* collected from different hosts and localities are presented in Table 60.

Table 60. Comparative mensural data of *Holomastigotoides rayi* collected from different hosts; (measurements in μm)

Characters	Type host <i>C. heimi</i>		Additional hosts	
	Karnataka	West Bengal	<i>H. indicola</i> Bihar	<i>C. travians</i> Tripura
Body length	200	104.1 (88.4-125.8)	84.9 (77-90.2)	83.6 (77-90.2)
Body width	125	66.3 (61.2-70.5)	49 (41.5-52.5)	47 (41.5-52.5)
Ratio of body length to body width (average)	1.6 : 1	1.5 : 1	1.7 : 1	1.7 : 1
Length of nucleus	–	12.7 (11.9-13.6)	11.6 (10.5-12.3)	
Breadth of nuclues	–	10.2 (9.3-11.5)	9.1 (8.2-10.5)	
Length of shorter flagella	12-16	10	–	
Length of longer flagella	slightly longer	14-15	–	

Remarks : Karandikar and Vittal (1954) described *Holomastigotoides rayi* from *Coptotermes heimi* collected from Karnataka and recorded only the average dimensions of this species. Later on Das (1976) and Das *et al.* (2004) collected it from the same host from West Bengal and Andhra Pradesh respectively. Das *et al.* (2000, 2003, 2006a) collected *H. rayi* from another termite host, *Coptotermes travians* from Tripura, Sikkim and Nagaland. Tiwari (1992) also recorded this species from the host *Heterotermes indicola* collected from Bihar.

The Table 60 clearly reveals that the specimes collected from *H. indicola* were smaller than those collected from the type host, *C. heimi*. The type specimens collected in Karnataka are the largest.

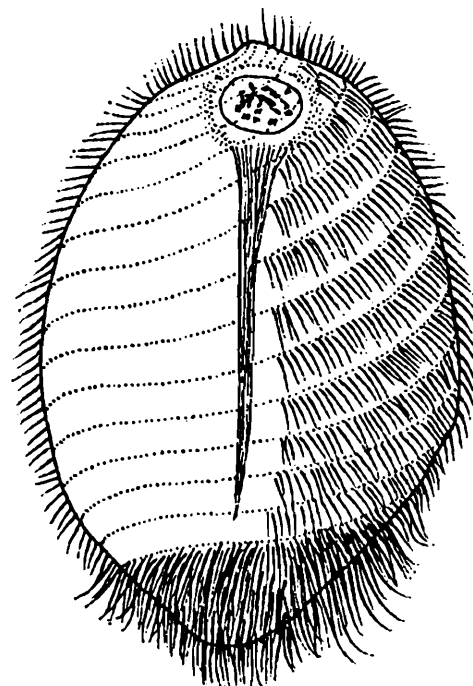


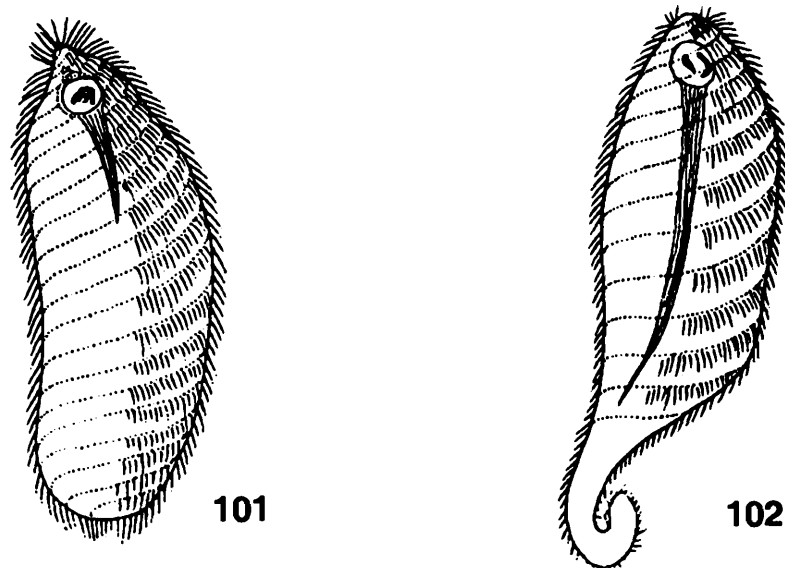
Fig. 100 : *Holomastigotoides rayi* Karandikar and Vittal; flagellar arrangement partly shown

66. *Holomastigotoides reniformis* De Mello, 1937
(Figs. 101–102)

1937. *Holomastigotoides reniformis* De Mello, C. R. XII Congr. Int. Zool. Lisb., 2 : 1373.

1983. *Holomastigotoides reniformis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.
1992. *Holomastigotoides reniformis* : Tiwari, Rec. zool. Surv. India, 92 : 147.
2000. *Holomastigotoides reniformis* : Das, Tiwari and Sarkar, Fauna of Tripura, State Fauna Series, 7(Part 4) : 41. Zool. Surv. India.
2003. *Holomastigotoides reniformis* : Das, Tiwari and Sarkar, Fauna of Sikkim, State Fauna Series, 9(Part 5) : 30. Zool. Surv. India.
2004. *Holomastigotoides reniformis* : Das, Tiwari, Nandi, Sarkar and Saha, Fauna of Andhra Pradesh, State Fauna Series, 5(Part 6) : 456. Zool. Surv. India.
- 2006a. *Holomastigotoides reniformis* : Das, Tiwari and Sarkar, Fauna of Nagaland, State Fauna Series, 12 : 33. Zool. Surv. India.

Type host : *Coptotermes* sp.; loc., India : Daman.



Figs. 101-102 : *Holomastigotoides reniformis* De Mello; flagellar arrangement partly shown, Fig. 101. Typical form; Fig. 102. Tailed form

Additional hosts : *Coptotermes heimi*; loc., India : Andhra Pradesh, Bihar, West Bengal; *Coptotermes travians*; loc., India : Nagaland, Sikkim, Tripura.

Diagnosis : Body elongated, cylindrical with bluntly pointed anterior and rounded posterior ends; some specimens "reniform" in shape as described by De Mello (1937) (Fig. 101); some forms, just after binary fission, having tail like posterior end (Fig. 102); body covered with one type of flagella in dextrotropic rows; its ectosarc as well as the posterior extremity of the body also covered with same type of flagella; nucleus round and anteriorly located; prenuclear zone granular and distinctly conical; axostyle fibrous and short, but in forms, just after binary fission, axostyle considerably long.

Morphometry : Mensural data of *Holomastigotoides reniformis*, collected from different hosts are presented in Table 61.

Table 61. Comparative morphometric data of *H. reniformis* collected from different hosts; measurements in μm

Characters	Type host <i>Coptotermes</i> sp. (Daman)	Additional hosts	
		<i>C. heimi</i> (West Bengal)	<i>C. travians</i> (Tripura)
Body length	66 (45-95)	124.3 (101-138.7)	102
Body width	31.1 (17-57)	41 (33.7-49.4)	36
Ratio of body length to body width (average)	2.1 : 1	3 : 1	2.8 : 1
Length of nucleus	—	5 – 6	—
Breadth of nucleus	—	5 – 5.5	—
Length of flagella	—	8 – 9	—

Remarks : De Mello (1937) described *Holomastigotoides reniformis* from the gut of an undetermined species of termite host, *Coptotermes* sp. which was collected from Daman, India. He (*op. cit.*) recorded the dimension of 7 specimens only, the range and average of which were presented in Table 61. Das (1972b), Das *et al.* (2004) and Tiwari (1992) collected this species from *Coptotermes heimi* from West Bengal, Andhra Pradesh and Bihar respectively. *H. reniformis* was also collected from another host, *C. travians* by Das *et al.* (2000, 2003, 2006a) from Tripura, Sikkim and Nagaland.

The Table 61 clearly shows that specimens collected from *C. heimi* were considerably larger in dimensions than type specimens and their length-breadth ratio was considerably variable. Tiwari (1992) recorded the average dimensions of his specimens of *H. reniformis* collected from Bihar from *C. heimi* as follows : length 110.2 μm , width 36 μm , length-breadth ratio 3 : 1 and length of nucleus 4.2 μm .

67. *Holomastigotoides saccusiformis* Uttangi, 1962
(Fig. 103)

1962. *Holomastigotoides saccusiformis* Uttangi, J. Karnatak Univ. Sci., 7 : 194.

1983. *Holomastigotoides saccusiformis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

2004. *Holomastigotoides saccusiformis* : Das, Fauna of Gujarat, State Fauna Series, 8(Part 2) : 422. Zool. Surv. India.

Type host : *Heterotermes indicola*; loc., India : Gujarat.

Diagnosis : Body "typically balloon-shaped", anteriorly wide and posteriorly tapering to a bluntly rounded end; flagella of one type and short in length; flagellar rows originating from an apical pit at anterior end and covering the whole body dextrorotically leaving posterior fifth of the body as glabrous and without any steriocytes over it; nucleus spherical and located near the anterior pole; prenuclear zone absent; axostyle fibrous and cord-like, extending posteriorly beyond the middle of the body.

Morphometry : While describing *Holomastigotoides saccusiformis*, Uttangi (1962) recorded some average mensural data of his type specimens. These are presented in Table 62.

Table 62. Morphometric data of *Holomastigotoides saccusiformis*

Characters	Type specimens
Length of the body	115 μm
Breadth of the body	70 μm
Ratio of body length to body width (average)	1.6 : 1
Diameter of nuclues	15 μm
Length of flagella	8-8 μm

Remarks : *Holomastigotoides saccusiformis* has not been collected by any worker since its first description by Uttangi (1962). Das (1983, 2004) incorporated this species in the checklist of flagellate symbiotes of Indian termites as well as in the State Fauna (Protozoa) of Gujarat published by the Zoological Survey of India, based on its original description (De Mello, 1962). Diagnosis of *H. saccusiformis* incorporated here is solely based on the above description.

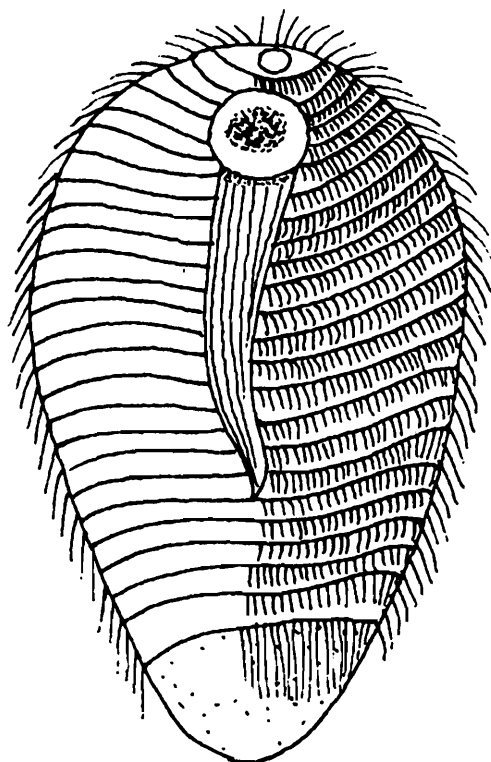


Fig. 103 : *Holomastigotoides saccusiformis* Uttangi; flagellar arrangement partly shown

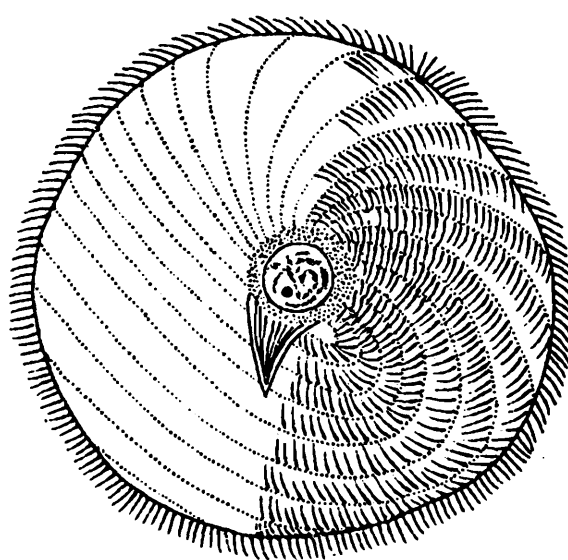


Fig. 104 : *Holomastigotoides sphaeroidalis* De Mello; flagellar arrangement partly shown

68. *Holomastigotoides sphaeroidalis* De Mello, 1937
(Fig. 104)

1937. *Holomastigotoides sphaeroidalis* De Mello, C. R. XII Congr. Int. Zool. Lisb., 1935, 2 : 1373.
1954. *Holomastigotoides sphaeroidalis* : Karandikar and Vittal, J. Univ. Bombay, 23B : 15.
1976. *Holomastigotoides sphaeroidalis* : Das, Acta Protozool., 15 : 109.
1983. *Holomastigotoides sphaeroidalis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.
1988. *Holomastigotoides sphaeroidalis* : Tiwari, Rec. zool. Surv. India, 85 : 219.
1992. *Holomastigotoides sphaeroidalis* : Tiwari, Rec. zool. Surv. India, 92 : 147.
1993. *Holomastigotoides sphaeroidalis* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3(Part 12) : 495. Zool. Surv. India.
2000. *Holomastigotoides sphaeroidalis*, Das, Tiwari and Sarkar, Fauna of Tripura, State Fauna Series, 7(Part 4) : 41. Zool. Surv. India.
2003. *Holomastigotoides sphaeroidalis* : Das, Tiwari and Sarkar, Fauna of Sikkim, State Fauna Series, 9(Part 5) : 31. Zool. Surv. India.
2004. *Holomastigotoides sphaeroidalis* : Das, Tiwari, Nandi, Sarkar and Saha, Fauna of Andhra Pradesh, State Fauna Series, 5(Part 6) : 456. Zool. Surv. India.
- 2006a. *Holomastigotoides sphaeroidalis* : Das, Tiwari and Sarkar, Fauna of Nagaland, State Fauna Series, 12 : 33. Zool. Surv. India.

Type host : *Coptotermes* sp.; loc., India : Daman; *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Goa, West Bengal.

Additional hosts : *Coptotermes heimi*; loc., India : Andhra Pradesh, Bihar, Karnataka, Uttar Pradesh; *Coptotermes travians*; loc., India : Nagaland, Sikkim, Tripura; *Heterotermes malabaricus*; loc., India : Karnataka; *Heterotermes tenuis*; loc., Brazil.

Diagnosis : Body almost spherical in shape as implied by the species name; flagella of one type covering the whole body in dextrotropic spirals; nucleus circular in shape and located very near a point at the anterior end from which flagellar bands seem to be diverging out; prenuclear zone distinct in forms studied by Das (1976), Das *et al.* (2000, 2003, 2004, 2006a) and Tiwari (1988, 1992) but this prenuclear zone not visible in forms recorded by De Mello (1937) and, Karandikar and Vittal (1954); axostyle fibrous and well developed.

Morphometry : Das (1976) studied this species in details. The following mensural data (Table 63) are based on his specimens.

Table 63. Morphometric data of *H. sphaeroidalis* collected from *C. heimi* from West Bengal

Characters	Range	Mean
Diameter of the body	67.5–86.2 μm	76.8 μm
Diameter of nucleus	7.5–9.4 μm	7.8 μm
Ratio of body diameter of the body to the diameter of nucleus (average)	–	9.9 : 1
Length of flagella	9–11 μm	–

Ramarks : While describing *Holomastigotoides sphaeroidalis* De Mello (1937) recorded the dimensions of three specimens only as 41 μm x 39 μm , 43 μm x 41 μm and 49 μm x 47 μm , revealing that these were almost spherical. All subsequent workers like Karandikar and Vittal (1954), Das *et al.* (2000, 2003-2006a) and Tiwari (1988, 1992) recorded this species as spherical. In fact, its characteristic body shape, and disposition of flagellar bands from the anterior pole with one type of flagella make it distinct from all its congeners. However, dimension of this species as recorded by various workers from different hosts and localities are considerably variable as shown in Table 64.

Table 64. Comparison of some mensural data of *H. sphaeroidalis* collected from different hosts and localities (measurements in μm)

Characters	<i>Coptotermes heimi</i>			<i>C. travians</i>	<i>H. indicola</i>
	Bihar (Tiwari, 1992)	Karnataka (Karandikar Vittal, 1954)	U.P. (Tiwari, 1988)	Tripura (Das <i>et.al.</i> , 2000)	West Bengal (Das, 1976)
Diameter of the body	31.8	100	21.8 (14.4-32)	31.5-52	76.8 (67.5-86.2)

Table 64 reveals that specimens of *H. sphaeroidalis* collected by Kar ndikar and Vittal (1954) were the largest and those collected by Tiwari (1988) were the smallest in dimensions. It appears that some juvenile specimens of the species might have been measured and included in the morphometric data by Tiwari (*op. cit.*).

69. *Holomastigotoides turboformis* Uttangi, 1962 (Fig. 105)

1962. *Holomastigotoides turboformis* Uttangi, J. Karnataka Univ. Sci., 7 : 192.

1983. *Holomastigotoides turboformis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type host : *Coptotermes heimi*; loc., India : Maharastra and Karnataka.

Diagnosis : Shape of the body rounded as in *Holomastigotoides sphaeroidalis*, but its anterior pole protruding into a narrow blunt finger-like projection with an apical pit, its

posterior end glabrous and broadly rounded, thus making the body shape "top" like (implying the species name); flagella of two types; the longer flagella arranged in dextrorotary rows, covering about two-third of the anterior region of the body leaving about posterior one-third nonflagellar area; some posteriormost part of this non-flagellar glabrous area covered with short steriocilia; nucleus spherical, located near the anterior pole; prenuclear zone lacking; axostyle fibrous and conical, extending beyond the middle of the body.

Morphometry : Mensural data of *Holomastigotoides turboformis* of the type specimens are presented in Table 65.

Table 65. Morphometric data of *H. turboformis*

Characters	From <i>C. heimi</i>
Length of the body	50 μ m
Breadth of the body	45 μ m
Ratio of body length to body width (average)	1.1 : 1
Diameter of nucleus	5 μ m
Length of longer flagella	10 μ m
Length of shorter flagella	5 μ m

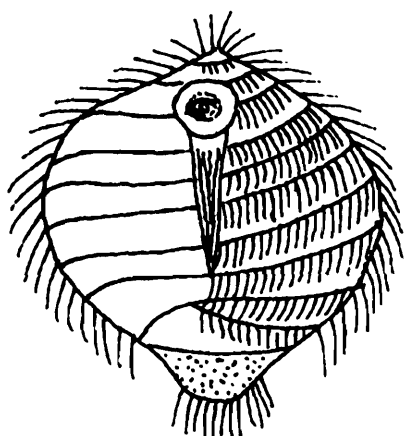


Fig. 105 : *Holomastigotoides turboformis* Uttangi; flagellar arrangement partly shown

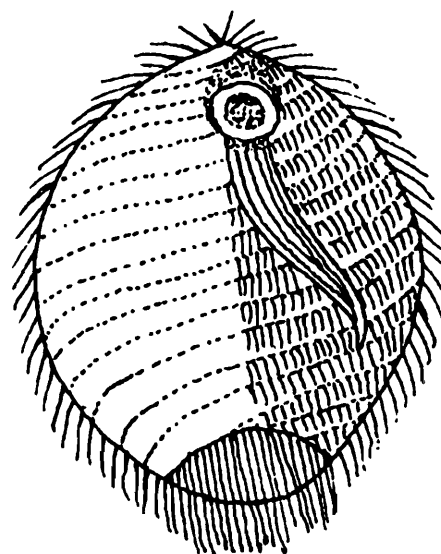


Fig. 106 : *Holomastigotoides visnagarensis* Uttangi; flagellar arrangement partly shown

Remarks : *Holomastigotoides turboformis* has not been reported by any worker since its first description by Uttangi (1962). Das (1983) included *H. turboformis* in the checklist of flagellate symbiotes of Indian termites on the basis of its first description. The diagnosis of this species incorporated here is solely based on that publication.

70. *Holomastigotoides visnagarensis* Uttangi, 1962
(Fig. 106)

1962. *Holomastigotoides visnagarensis* Uttangi, J. Karnataka Univ. Sci., 7 : 183.
 1983. *Holomastigotoides visnagarensis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.
 2004. *Holomastigotoides visnagarensis* : Das, Fauna of Gujarat, State Fauna Series, 8(Part 2) : 422. Zool. Surv. India.

Type host : *Heterotermes indicola*; loc., India : Gujarat.

Diagnosis : Body somewhat rounded or globose; anterior end of the body rounded and not protruded; a small apical pit found in some individuals; posterior end variable in form – narrowed, broadly rounded or sometimes flat; flagella of two types; longer flagella covering the whole body in dextrotropic rows leaving about one-fifth of the posterior end; the non-flagellated area covered with short steriocilia; nucleus oval in shape and located near the anterior pole; an indistinct cap-like prenuclear zone visible; axostyle fibrous, conical and cord-like, indistinct in some individuals and extending beyond the middle of the body.

Morphometry (Table 66) :

Table 66. Mensural data of *Holomastigotoides visnagarensis*

Characters	Type specimens (Uttangi, 1962)
Length of the body	67-70 μm
Breadth of the body	50-60 μm
Ratio of body length to body width (average)	1.2 : 1
Length of nuclues	10 μm
Breadth of nucleus	15 μm
Length of longer flagella	11 μm
Length of shorter flagella	4-5 μm

Remarks : Since first description of *H. visnagarensis* by Uttangi (1962) this species has not been collected by any worker. Das (1983, 2004) incorporated this species in the checklist of flagellate symbiotes of Indian termites as well as in the State Fauna of Gujarat (Protozoa) based on the above published account. The diagnosis of *H. visnagarensis* given above is taken from its original description.

Family SPIROTRICHONYMPHIDAE Grassi, 1917

1917. Spirotrichonymphidae Grassi, Mem. R. Accad. Lincei, Ser 5, 12 : 333.
 1958. Spirotrichonymphidae (emend.) Cleveland and Day, Arch. Protistenkd., 103 : 5.

Diagnosis : Spiral bands arising from a common point or from a series or ring near the anterior end of the body; flagella arising from bands adhering or lining up closely in rows, reaching the surface of the body; nucleus anchored to a rostrum by a nuclear sleeve; axostyles may be long, slender and separate or joining to form clearly adhering bundle which may or may not protrude posteriorly beyond the surface of the body.

**Key to the genera of the family SPIROTRICHONYMPHIDAE
reported from Indian termites**

1. Flagella arising from a series or ring of parabasal bodies, axostyle stout often projecting to a point outside the posterior end of the body Genus *Microjoenia*
- Flagella arising from spiral bands, axostyle distinct, indistinct or absent and may or may not projecting beyond the posterior surface of the body 2
2. Body spindle-shaped, nucleus located very close to the rostrum embedding in a mass of dense cytoplasm, flagella arising from spiral bands forming fasciculi after reaching the surface of the body Genus *Holomastigotes*
- Body of various shapes, nucleus considerably away from rostrum and appearing to be suspended in a mass of conical cytoplasm, flagella not forming fasciculi as above Genus *Spirotrichonympha*

Genus *Microjoenia* Grassi, 1892

1892. *Microjoenia* Grassi, *Rend. R. Accad. Lincei*, ser. 1, 1 : 36.

1930. *Torquenympha* Brown, *Univ. Calif. Publ. Zool.*, 36 : 69.

Diagnosis : Small, pyriform, anterior end thick and flattened; at anterior end flagella arranged in longitudinal rows, arising from a series or ring of parabasal bodies; axostyle stout often projecting out side the body to a point.

**71. *Microjoenia axostylis* Cutler, 1920
(Figs. 107–108)**

1920. *Microjoenia axostylis* Cutler, *Quart. J. micr. Sci.*, 64 : 406.

1983. *Microjoenia axostylis* : Das, *Proc. symp. Host Environ. zool. Surv. India* : 44.

Type host : *Archotermopsis wroughtoni*; loc., India (exact locality not mentioned).

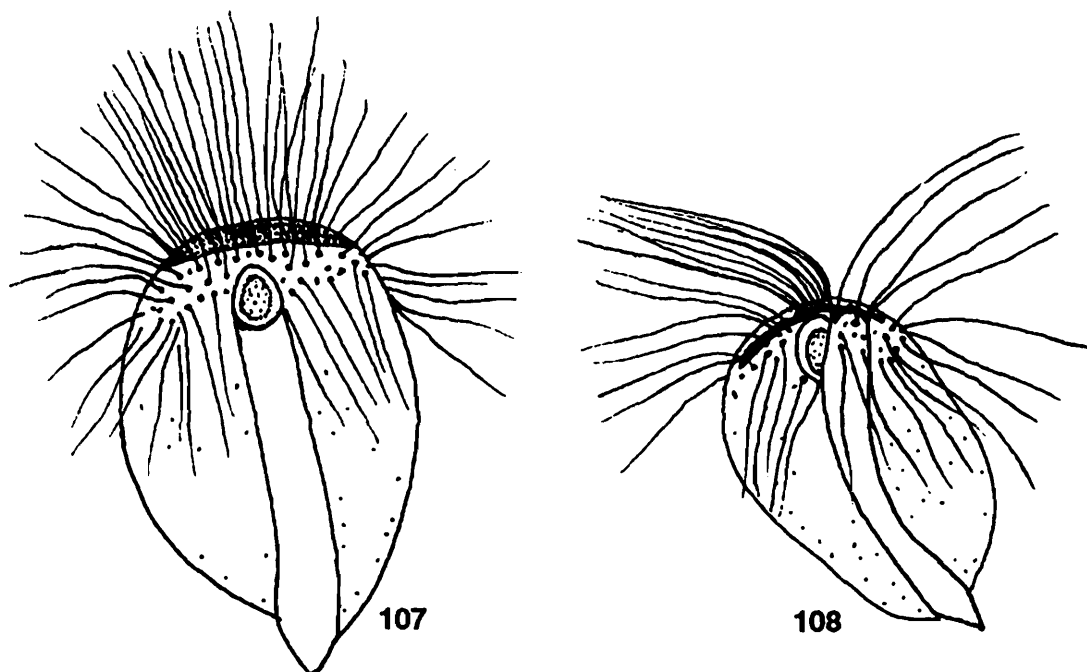
Diagnosis : Body surface smooth without any striation; anterior end of the body much thickened and, flattened and not raised into a papilla; a tuft of flagella arising at anterior end of the body forming a series of granules arranged in two or three longitudinal rows; axostyle large and very wide relative to its body width, arising from the anterior end of the body, passing ventral to the nucleus and piercing the posterior end of the body, forming a pointed tip.

Morphometry : While describing *Microjoenia axostylis*, Cutler (1920) recorded only the mensural data of length and width of his type specimens and width of their axostyle. These are presented in Table 67.

Table 67. Mensural data of type specimens of *Microjoenia axostylis*

Characters	Range	Mean
Length of the body	16.16-30 μm	23.5 μm
Width of the body	12.1 -25 μm	18.5 μm
Ratio of body length to body width (average)	—	1.2 : 1
Ratio of width of the body to the width of axostyle (average)	—	3.9 : 1

Remarks : *Microjoenia axostylis* has not yet been reported by any worker since its first description by Cutler (1920). The diagnosis of this species given above is solely based on Cutler's description. According to Cutler (*op. cit.*) its axostyle is characteristic because its "most noticeable feature is the width" which is "enormous" relative to its body width (Table 67).

Figs. 107-108 : *Microjoenia axostylis* Cutler

The text-figures of *M. axostylis* clearly reveal that its body is pyriform with broadly rounded anterior end and narrowly rounded posterior end; nucleus more or less round and located near the anterior pole of the body. Very long flagella are distributed in three spiral rows near the anterior end only. Rest of the body is non-flagellar. No such spiral rows of flagella are present as in the other genera, *viz.* *Spirotrichonympha* and *Holomastigotes* under the family Spirotrichonymphidae. Broad axostyle emerges out of the posterior end of the body to a short distance, forming a pointed tip.

Genus *Spirotrichonympha* Grassi and Foa, 1911

1911. *Spirotrichonympha* Grassi and Foa, *Rend. R. Accad. Lincei*, Ser. 5, Sem. 1, 20 : 727.

1958. *Spirotrichonympha* emend. Cleveland and Day, *Arch. Protistenkd.*, 103 : 5.

Diagnosis : Body elongate, pyriform; flagella deeply embedded in cytoplasm in anterior region of the body, arising from flagellar bands; nucleus considerably away from the rostrum and appearing to be suspended in a mass of dense conical-shaped cytoplasm, whole base indistinct.

Key to the species of the genus *Spirotrichonympha* recorded from Indian termites

A total of 13 species of *Spirotrichonympha* have so far been reported from the guts of Indian termites (Table 3). Out of these, description or diagnostic feature of one species, viz., *Spirotrichonympha coimbatorensis* is not available to the present author. As such, key to the remaining 12 species of *Spirotrichonympha* has been provided below.

1. Axostyle absent 2
- Axostyle present 4
2. Body cone-shaped, anterior end of the body slightly convex, average dimensions 32.5 μm x 19 μm *S. leidy*
- Body pear shaped, anterior end of the body terminating to a point 3
3. Body pyriform, average dimensions 30 μm x 15.4 μm , nucleus with 5 chromosomes *S. pyriformis*
- Body pyriform, average dimensions 50.4 μm x 27.3 μm , nucleus with 6 chromosomes *S. bhadreshwarensis*
4. Axostyle distinct 5
- Axostyle indistinct 8
5. Body cone-shaped, anterior portion narrowed to a blunt point, posterior surface broadest and with bunch of very long flagella, resembling a tuft of hair emerging from a brush *S. froilanoi*
- Body of different shapes, posterior surface without having such brush like long flagella 6
6. Body elongated, swollen at middle, pointed at both ends, average dimensions 28 μm x 16.8 μm *S. elongata*
- Body pyriform, fusiform or ovoid 7
7. Body pyriform with finger like projection at anterior end with hyaline cap, posterior end broad and drawn out into a cone at its middle, axostyle thin and fibrous, extending posteriorly beyond the middle of the body *S. roonwali*

- Body commonly fusiform, sometimes pyriform or ovoid, anterior end cone-shaped, posterior end rounded, sometimes prolonged into a finger like process, axostyle rod-like structure, extending up to posterior end of the body *S. porteri*
- 8. Body ovoidal in shape 9
- Body elongate or cone-shaped 11
- 9. Both anterior and posterior poles broadly round, large flagella covering the major portion of the body in dextrotropic spiral rows; some posterior portion of the body without any flagella *S. ovoidea*
- Anterior pole with finger-like elevation and posterior pole broadly rounded 10
- 10. Average dimensions 16 μm x 10.1 μm , short flagella covering the whole body in dextrotropic spiral rows; longer flagella thickly studded at posterior end of the body *S. mirabile*
- Average dimensions 12 μm x 10 μm , flagella of one type and covering the whole body *S. rotunda*
- 11. Body elongated, swollen at the middle of the body and tapering at both ends, flagella of one type covering the whole body in dextrotropic spirals *S. elongata*
- Body cone-shaped, carrying a small hyaline operculum at anterior end, posterior surface of the body without any flagella *S. karnataki*

72. *Spirotrichonympha bhadreshwarensis* Tiwari, 1977

(Fig. 109)

1977. *Spirotrichonympha bhadreshwarensis* Tiwari, Curr. Sci., 46 : 232.

1983. *Spirotrichonympha bhadreshwarensis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

1992. *Spirotrichonympha bhadreshwarensis* : Tiwari, Rec. zool. Surv. India, 92 : 149.

1993. *Spirotrichonympha bhadreshwarensis* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3(Part 12) : 496. Zool. Surv. India.

Type host : *Coptotermes heimi*; loc., India : Bihar, West Bengal (type locality).

Diagnosis : Body more or less pear-shaped with pointed anterior end and its slightly compressed posterior end; a short tubule originating at the anterior end of the body and not reaching up to the nucleus; dextrotropically arranged spiral flagellar bands numbering 19-22 in adult forms; a small part of the posterior end of the body without any spiral flagellar band; nucleus spherical, located at the anterior third of the body, containing scattered chromatin granules and six chromosomes; axostyle not found.

Morphometry (Table 68) :**Table 68.** Mensural data of *S. bhadreshwarensis* (from type specimess)

Characters	Range	Mean
Length of the body	22.5-67.5 μm	50.4 μm
Breadth of the body	18-34.5 μm	27.3 μm
Ratio of body length to body width (average)		1.8 : 1
Diameter of nucleus	4.5-7.5 μm	6 μm
Length of flagella	7.5-19.5 μm	—

Remarks : Table 68 shows that length and width of *Spirotrichonympha bhadreshwarensis* are considerably variable. This is due to lumping the mensural data of both adult and young forms of this species by Tiwari (1977).

S. bhadreshwarensis closely resembles *S. pyriformis*, described by Chakravarty and Banerjee (1956) in shape of the body, location and shape of nucleus and in absence of axostyle. Moreover in both the species a small portion of the posterior end of the body is not having any flagellar spiral. Tiwari (1977) differentiated the former from the latter by number of chromosomes only. According to him (*op. cit.*), nucleus of *S. bhadreshwarensis* contained 6 chromosomes while that of *S. pyriformis* was having 5 chromosomes. Such difference in chromosomal number (particularly when specimens were stained in Heidenhain's haematoxylin) in ascertaining the taxonomic status of closely related flagellate species appears to be insufficient for the purpose.

73. *Spirotrichonympha coimbatorensis* De Mello, 1941

1941. *Spirotrichonympha coimbatorensis* De Mello, *Arqu. Esc. Med. Cirug Nova Goa*, ser A, 15 : 334.

1983. *Spirotrichonympha coimbatorensis* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.

Type host : *Anacanthotermes viarum* (= *Hodotermes viarum*); loc., India : Tamil Nadu.

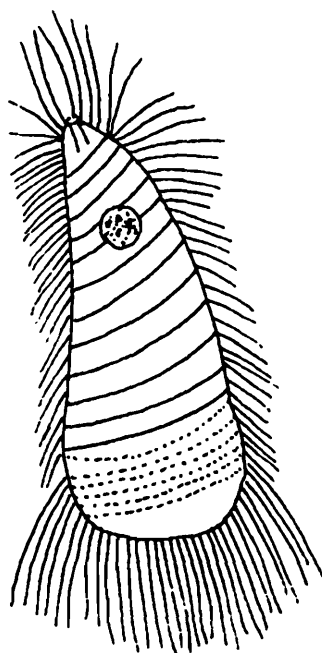
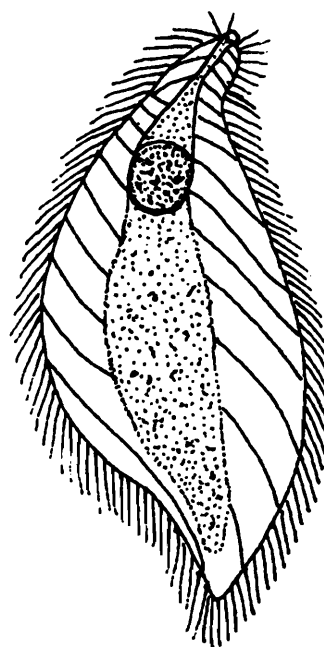
Diagnosis : See remarks.

Remarks : *Spirotrichonympha coimbatorensis* has never been reported since its first description by De Mello (1941c). Das (1983) included it in the checklist of flagellate symbiotes of Indian termites solely based on its above published report. The present worker could not collect De Mello's above publication inspite of his incessant endeavour. As such, diagnosis of *S. coimbatorensis* could not be included here. Accordingly, it is also excluded from the key to the species of the genus *Spirotrichonympha*, recorded from Indian termites.

74. *Spirotrichonympha elongata* Grassi, 1917
(Fig. 110)

1917. *Spirotrichonympha elongata* Grassi, *Mem. R. Accad. Lincei*, ser. 5, 12 : 334.

1937. *Spirotrichonympha elongata* : De Mello, *C. R. XII Congr. Int. Zool.*, Lisbon, 1935, 2 : 1377.

Fig. 109 : *Spirotrichonympha bhadreshwarensis* TiwariFig. 110 : *Spirotrichonympha elongata* Grassi

1954. *Spirotrichonympha elongata* : Karandikar and Vittal, J. Univ. Bombay, 23 B : 22.

1983. *Spirotrichonympha elongata* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type host : *Schedorhinotermes intermidus*; loc., Australia.

Additional hosts : *Coptotermes* sp.; loc., India : Daman; *Coptotermes heimi*; loc., India : Karnataka.

Diagnosis : Body elongated and swollen in the mid region of the body and tapering at both ends, which may sometimes curve slightly in opposite directions; flagella of one type covering the whole body in dextrotropic spiral bands; nucleus round or oval located near the anterior one-third of the body; prenuclear zone distinct and axostyle indistinct.

Morphometry : Mensural data of only length and breadth of Indian forms of *Holomastigotoides elongata* are available. These are presented in Table 69. Mention is to be made here that De Mello (1937) provided the measurements of only 5 specimens and, Karandikar and Vittal (1954) recorded only the average dimensions of this species.

Table 69. Morphometric data of Indian specimens of *Holomastigotoides elongata* provided by different workers

Characters	<i>Coptotermes</i> sp. from Daman (De Mello, 1937)	<i>C. heimi</i> from Karnataka (Karandikar & Vittal, 1954)
Body length	28 (22–38) μm	80 μm
Body width	16.8 (10–22) μm	35 μm
Ratio of body length to body width (average)	1.6 : 1	2.1 : 1

Remarks : De Mello (1937) was the first to report *Holomastigotoides elongata* from the guts of Indian termites, belonging to an undetermined species of *Coptotermes*. Later, Karandikar and Vittal (1954) collected this flagellate species from the Indian termite, *Coptotermes heimi* from Karnataka, India. Das (1983) included *H. elongata* in the checklist of flagellate symbiotes of Indian termites based on the above published works. The Table 69 shows that De Mello's (1937) specimens of *H. elongata* were considerably smaller than those collected by Karandikar and Vittal (1954) who recorded only the average dimensions of the body. In Karandikar and Vittal's forms (*op. cit.*) axostyle was indistinct at its proximal part but it protruded visibly beyond the posterior end of the body. Such visibly protruding axostyle in *S. elongata* has not shown in text-figures of this species by Grassi (1917) and De Mello (1937).

75. *Spirotrichonympha flagellata* (Grassi, 1892) Grassi and Foa, 1911
(Fig. 111)

1892. *Pyrsonympha flagellata* Grassi, *Rend. R. Accad. Lincei*, sem. 1, 1 : 36.
1911. *Spirotrichonympha flagellata* (Grassi) Grassi and Foa, *Rend. R. Accad. Lincei*, Ser 5, sem 1 : 20 : 719.
1919. *Leidya metchnikowi sensu* De Mello, *Biol. Agric.*, 1 : 131.
1928. *Spirotrichonympha flagellata* : De Mello, *Arqu. Med. Cirug., Nova Goa*, Ser A, 3 : 239.
1930. *Spirotrichonympha flagellata* : Brown, *Arch. Prolistenkd.*, 70 : 520.
1954. *Spirotrichonympha flagellata* : Karandikar and Vittal, *J. Univ. Bombay*, 23B : 19.
- 1972b. *Spirotrichonympha flagellata* : Das, *Ph. D (Science) thesis* (unpublished), University of Calcutta, India.
1983. *Spirotrichonympha flagellata* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.

Type host : *Reticulitermes lucifugus*; loc., Europe.

Additional hosts : *Coptotermes acinaciformis*; *Coptotermes heimi*; loc., India : Karnataka, West Bengal; *Coptotermes lacteus*; loc., Australia; *Heterotermes indicola*; loc., India : Goa; *Prorhinotermes flavus*; loc., Sri Lanka; *Reticulitermes flavipes*; *Reticulitermes hesperus*; *Reticulitermes tibialis*; *Reticulitermes virginicus*; *Schedorhinotermes intermedius*; loc., Australia.

Diagnosis : Body elongated, drawn out anteriorly into a very slender, slightly curved tube like rostrum; posterior end of the body rounded; flagellar bands four in number, turning round the body dextrorotically, bearing one type of long flagella, covering the whole body including the posterior extremity; nucleus round, located near the anterior third of the body; endoplasm in the prenuclear zone differentiated into an elongated thickened mass; axostyle fibrous and distinct, sometimes protruding out of the posterior extremity of the body.

Morphometry (Table 70) :Table 70. Mensural data of Indian forms of *Spirotrichonympha flagellata* (measurements in μm)

Characters	From <i>Coptotermes heimi</i>	
	Das, 1972 (West Bengal)	Karandikar & Vittal, 1954 (Karnataka)
Length of the body	55.4 (40.8–73.1)	70
Breadth of the body	29 (22.1–37.4)	30
Ratio of body length to body width (average)	1.9 : 1	2.3 : 1
Diameter of nucleus	6 (5.1–6.8)	–
Length of flagella	16–17	25

Remarks : Karandikar and Vittal (1954) were the first to record *Spirotrichonympha flagellata* from Indian termite, *Coptotermes heimi*, collected from Karnataka. Das (1972b) also collected this species from the same host from West Bengal. Morphometric data of *S. flagellata* collected from different localities of India, viz., Karnataka and West Bengal are compared in Table 70. The Table shows that average length of Karandikar and Vittal's specimens of *S. flagellata* are considerably larger than those collected by Das (*op. cit.*). Mention is to be made here that the posterior end of Karandikar and Vittal's forms was devoid of flagella but Das (*op. cit.*) observed thick set of longer flagella at the posterior end and posterior extremity of the body in his specimens of *S. flagellata* (Fig. 111).

76. *Spirotrichonympha froilanoi* Karandikar and Vittal, 1954
(Figs. 112-113)

1954. *Spirotrichonympha froilanoi* Karandikar and Vittal, *J. Univ. Bombay*, **23B** : 20.
1976. *Spirotrichonympha froilanoi* : Das, *Acta Protozool.*, **15** : 117.
1981. *Spirotrichonympha froilanoi* : Tiwari and Ray, *Bull. zool. Surv. India*, **4** : 161.
1983. *Spirotrichonympha froilanoi* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.
1988. *Spirotrichonympha froilanoi* : Tiwari, *Rec. zool. Surv. India*, **85** : 220.
1992. *Spirotrichonympha froilanoi* : Tiwari, *Rec. zool. Surv. India* : **92** : 149.
1993. *Spirotrichonympha froilanoi* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series* 3(Part 12) : 496. *Zool. Surv. India*.
2000. *Spirotrichonympha froilanoi* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 41. *Zool. Surv. India*.
2003. *Spirotrichonympha froilanoi* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna series*, 9(Part 5) : 32. *Zool. Surv. India*.

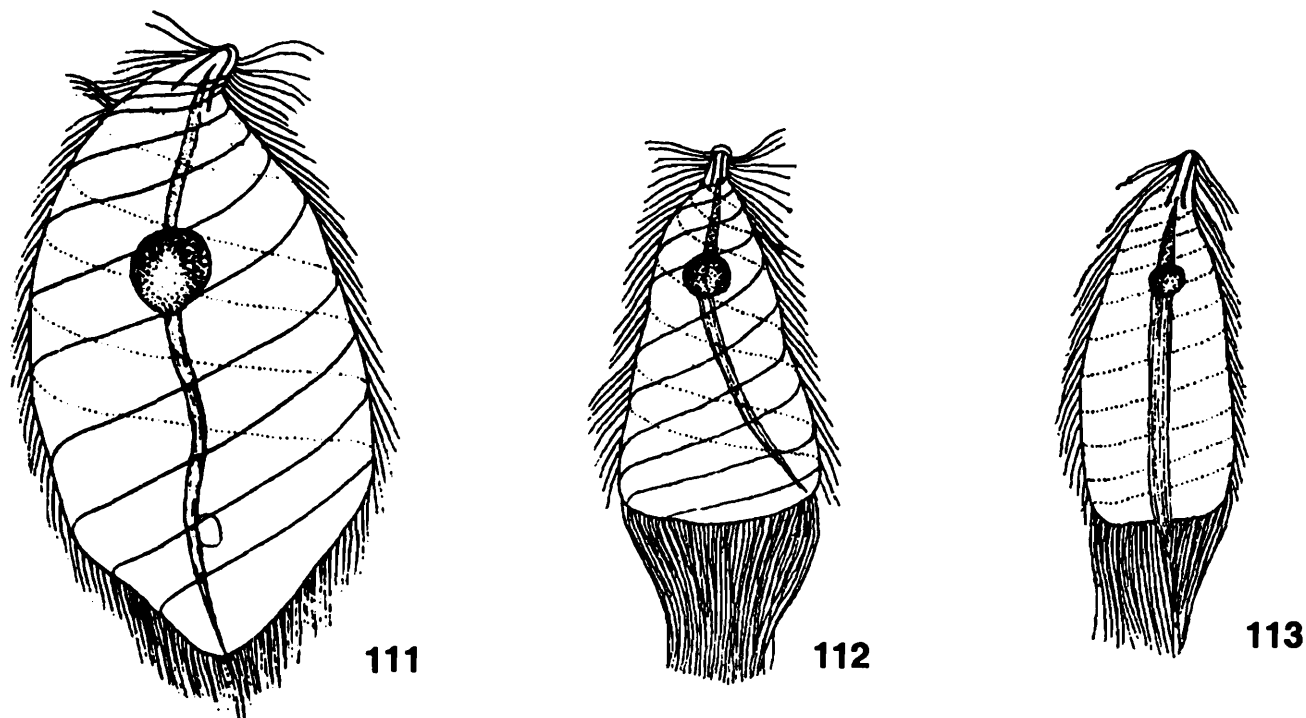


Fig. 111 : *Spirotrichonympha flagellata* (Grassi); **Figs. 112-113 :** *Spirotrichonympha froilanoi* Karandikar & Vittal. **Fig. 112.** Axostyle extending upto posterior end of the body; **Fig. 113.** Axostyle protruding outside the body

2004. *Spirotrichonympha froilanoi* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 457. *Zool. Surv. India*.

2006a. *Spirotrichonympha froilanoi* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series* 12 : 34. *Zool. Surv. India*.

Type hosts : *Coptotermes heimi*; loc., India : Andhra Pradesh, Karnataka (type locality), Uttar Pradesh and West Bengal; *Heterotermes malabaricus*; loc., India : Karnataka.

Additional hosts : *Coptotermes travians*; loc., India : Sikkim and Tripura; *Heterotermes indicola*; loc., India : Tripura, Bihar.

Diagnosis : Body cone-shaped, its anterior portion narrowed to a blunt end, posterior surface broadest and usually depressed; four flagellar bands originating from centrophepharoplast and covering the body dextrorotically; centrophepharoplast covered by a hyaline operculum; flagella of two types, shorter flagella covering the entire body dextrorotically, excepting posterior surface which studded with a thick bunch of very long flagella, resembling a tuft of hair emerging out from a brush; nucleus round and situated near the anterior third of the body; prenuclear zone of endoplasm carrying a thin fibre-like rhizoplast, attached anteriorly to blepharoplast and posteriorly to nuclear endoplasm; axostyle cord-like and very distinct, extending obliquely towards the posterior end of the body but usually not protruding outside the body, however, in rare cases axostyle protruding prominently to a shorter length through the posterior end of the body.

Morphometry (Table 71) :**Table 71.** Mensural data of *Spirotrichonympha froilanoi* collected from different hosts (measurements in μm)

Characters	From type host, <i>Coptotermes heimi</i>		<i>H. indicola</i>
	Type specimens (Karandikar & Vittal 1954)	From West Bengal (Das, 1976)	From Bihar (Tiwari, 1992)
Body length	50	29(20.4–42.5)	32.5(19.2–51.2)
Body width	25	16.8(11.9–27.2)	22.1(14.4–33.6)
Ratio of body length to body width (average)	2:1	1.7 : 1	1.4 : 1
Length of nucleus	–	4.5(3.4–5.1)	4.8(3.2–6.4)
Breadth of nucleus	–	4.2(3–4.6)	4.4(2.4–5.6)
Length of shorter flagella	–	15	9–10
Length of longer flagella	–	25	15–20

Remarks : The first description of *Spirotrichonympha froilanoi* was given by Karandikar and Vittal (1954) who collected this species from two species of termite hosts, viz., *Coptotermes heimi* and *Heterotermes indicola*, both collected from Dharwar in Karnataka. Subsequently Das (1976) made a detailed study of this flagellate from West Bengal from one of the type hosts, *C. heimi*. Tiwari (1992) recorded *S. froilanoi* from another host species, *Heterotermes indicola* from Bihar. In subsequent years Das *et al.* (2000, 2003, 2006a) studied this flagellate from the host, *Coptotermes travians* some North-eastern states of India, viz, Nagaland, Sikkim and Tripura. Table 71 reveals that average dimension and length of flagella of type specimens are considerably larger than those collected subsequently by different workers. Mention is to be made here that Das *et al.* (2000) recorded the dimension of the specimens of *S. froilanoi* from the host, *C. travians* collected from Tripura as 19.2 – 51.1 μm $\times$ 14.4 – 33.6 μm with average length breadth ratio 1.4 : 1.

For the diagnosis of *S. froilanoi*, Karandikar and Vittal (1954) stressed on the characteristic feature like "presence of conspicuously long flagella spreading out from the posterior surface in a brush like manner." This feature was non-exceptionally present in this species studied by all subsequent workers.

77. *Spirotrichonympha karnataki* Karandikar and Vittal, 1954
(Fig. 114)

1954. *Spirotrichonympha karnataki* Karandikar and Vittal, J. Univ. Bombay, 23 B : 21.

1983. *Spirotrichonympha karnataki* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type host : *Coptotermes heimi*; loc., India : Karnataka.

Diagnosis : Body form and dimension quite similar to those of *S. froilanoi* detailed earlier; anterior conical end of *S. karnataki* carrying a tiny and hyaline operculum, below

which a blepharoplast located; body covered by one type of flagella of about 12 μm length, running spirally round the body in dextrotropic rows; posterior surface of the body usually flat and devoid of thick bunch of very long brugh-like flagella; nucleus more or less round, generally located in the anterior region of the body and "often found to be a little off the median line."; prenuclear zone of endoplasm containing a central rhizoplast thread; axostyle fibrous and not distinct in the body region but protruding prominently to "a shorter or greater length through the posterior surface of the body in the form of a loosely wound cord of fibres"

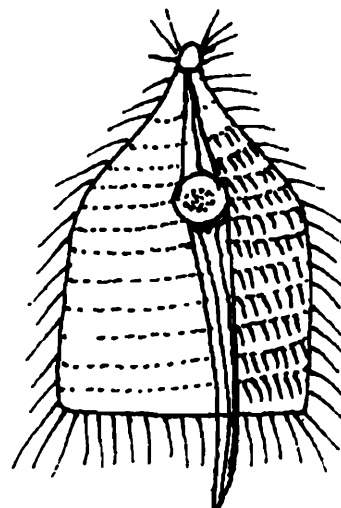


Fig. 114 : *Spirotrichonympha karnataki*
Karandikar & Vittal

Morphometry : Body dimensions same as those of *S. froilanoi*.

Remarks : *Spirotrichonympha karnataki* has not yet been recorded by any worker since its first description by Karandikar and Vittal (1954). However, Das (1989) included this species in the checklist of flagellate symbiotes of Indian termites based on above published record. *S. karnataki* closely resembles *S. froilanoi* in body shape, dimensions and other essential characters. Karandikar and Vittal (1954) emphasised on two characteristic diagnostic features of *S. karnataki*, namely, (i) posterior surface of the body devoid of thick bunch of very long brush-like flagella and (ii) axostyle always protruding outside the body to a short or long distance. According to them (*op. cit.*), the second character is an "outstanding feature which distinguishes *S. karnataki* from *S. froilanoi*" As stated earlier, Das (1976) observed protruding axostyle in few specimens of *S. froilanoi* also. So, the range of differences between *S. karnataki* and *S. froilanoi* seems to be considerably narrow and their diagnosis is solely dependent on the presence or absence of very long brush-like flagella on the posterior surface of the body.

78. *Spirotrichonympha leidy* Koidzumi, 1921 (Figs. 115-116)

- 1921. *Spirotrichonympha leidy*, Koidzumi, *Parasitologys*, 13 : 275.
- 1927. *Spirotrichonympha leidy* var. *leucotermes indicolae* De Mello, *Trans. VII Congr. Far East Trop. Med.*, 2 : 594.
- 1928. *Spirotrichonympha leidy* var. *leucotermes indicolae* : De Mello, *Arqu. Esc. Med. Cirug, Nova Goa (A)* 3 : 260.
- 1937. *Spirotrichonympha leidy* var. *leucotermes indicolae* : De Mello, *C. R. XII Congr. Inst. Zool. Lisobon*, 1935, 2 : 1354.
- 1983. *Spirotrichonympha leidy* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.

Type host : *Coptotermes formosanus*; loc., Japan.

Additional host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Daman.

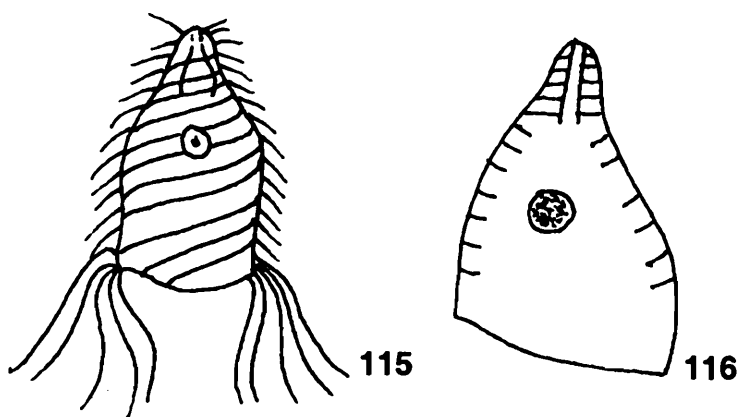
Diagnosis : Body cone-shaped posterior or basal part of which slightly convex; flagella fairly long running backwards spirally round the body in dextrotropic rows; flagellar rows 10-20 in number; nucleus oval and located near the middle region of the body.

Morphometry (Table 72) :

Table 72. Mensural data of *Spirotrichonympha leidy* from the type host

Characters	From <i>C. formosanus</i> (type host)
Length of the body	15–50 μ m
Breadth of the body	8–30 μ m
Ratio of body length to body width (average)	1.7 : 1
Length of flagella	10–16 μ m

Remarks : *Spirotrichonympha leidy* was described by Koidzumi (1921) from the host, *Coptotermes formosanus* from Japan. The description of this flagellate species is very insufficient. His illustrations show that in this species axostyle is lacking and posterior extremity of the body is completely devoid of any flagella.



Figs. 115-116 : *Spirotrichonympha leidy* Koidzumi

De Mello (1927) collected some flagellates from *Heterotermes* (= *Leucotermes*) *indicola* from Daman, India, which resembled *S. leidy* Koidzumi but differs from it in having anteriorly located nucleus. On that basis he (*op. cit.*) erected a new variety of this species and named it *S. leidy* var. *leucotermes indicolae*. Location of nucleus may be quite variable in different specimens. As such, this characteristic feature is too insufficient to create a new taxon, even a variety.

Moreover, such clumsy quadrunominal variety is no more valid at present. Therefore, *S. leidy* var. *leucotermes indicolae* is synonymised under *S. leidy*.

78a. *Spirotrichonympha leidy* var. *damanensis* De Mello, 1937
(Fig. 117)

1937. *Spirotrichonympha leidy* var. *damanensis* De Mello, C. R. XII Congr. Int. Zool. Lisbon, 1935, 2 : 1377.

1983. *Spirotrichonympha leidy* var. *damanensis* : Das, Proc. Symp. Host Environ. zool. Surv., India : 44.

Type host : *Heterotermes indicola*; loc., India : Diu.

Diagnosis and morphometry : See remarks.

Remarks : De Mello's (1937) flagellates from the host, *Heterotermes indicola* resemble *Spirotrichonympha leidy* to a great extent but they differ from the latter in having dense flagella at the posterior extremity of the body, for which he (*op. cit*) erected a new variety of this species and named it as *S. leidy damanensis*. He recorded the dimensions of three specimens of this variety as 25 μm x 12 μm , 10 μm x 8 μm and 14 μm x 12 μm with an average 16.3 μm x 10.6 μm . This reveals that De Mello's forms are quite smaller than Koidzumi's forms of *S. leidy*.

79. *Spirotrichonympha mirabilis* Grassi, 1917
(Fig. 118)

1917. *Spirotrichonympha mirabilis* Grassi, Mem. R. Accad. Lincei, (5) 12 : 333.

1937. *Spirotrichonympha mirabilis* : De Mello, C. R. XII Congr. Int. Zool. Lisb., 1935, 2 : 1376.

1983. *Spirotrichonympha mirabilis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type host : *Porotermes adamsoni*; loc., Australia.

Additional host : *Heterotermes indicola*; loc., India : Diu.

Diagnosis : Body ovoid, anterior pole pointed, fusiform with a rostrum; posterior pole broadly rounded; flagella of one type covering the whole body in dextrotropic rows; however, flagella of posterior extremity slightly longer; nucleus round, located near the anterior third of the body; endoplasmic prenuclear zone dense, conical and distinct; axostyle indistinct.

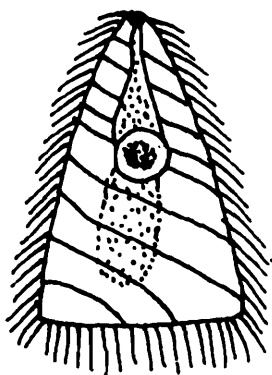


Fig. 117 : *Spirotrichonympha leidy* var. *damanensis* De Mello

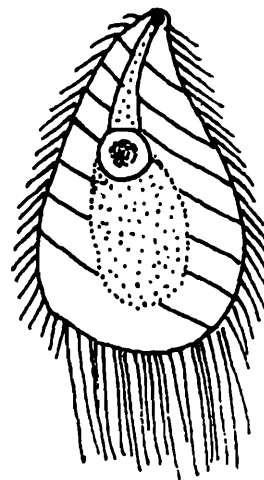


Fig. 118 : *Spirotrichonympha mirabilis* Grassi

Morphometry : De Mello (1937) recorded the dimensions of 7 specimens of *Spirotrichonympha mirabilis* in his account ranging from 12-25 μm in length with average 15.7 μm and 6-13 μm in width with average 10.1 μm . No other mensural data of this species from Indian termites are available.

Remarks : Diagnostic characters of *Spirotrichonympha mirabilis* is based on its description by De Mello's (1937). No further record of this species has been made from Indian termites.

However, Das (1983) included this species in the checklist of symbiotic flagellates of Indian termites based on above publication.

79a. *Spirotrichonympha mirabilis* Grassi, 1917 var *indica* De Mello, 1937
(Fig. 119)

1937. *Spirotrichonympha mirabilis* var. *indica* De Mello, C. R. XII Congr. Int. Zool. Lisb., 1935, 2 : 1377.

1983. *Spirotrichonympha mirabilis* var. *indica* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type host : *Heterotermes indicola*; loc., India : Diu.

Diagnosis : Closely resembles *Spirotrichonympha mirabilis* in morphological features; but its posteriormost portion of the body without any flagella.

Morphometry : De Mello (1937) recorded the dimensions of 15 specimens of *S. mirabilis* var. *indica* whose length ranging from 17 μm to 38 μm with an average 25.3 μm and width from 12 μm to 25 μm with an average 15.7 μm . No other morphometric data of this variety is available.

Remarks : De Mello (1937) collected *Spirotrichonympha mirabilis* from the Indian termite, *Heterotermes indicola* from Diu. Along with this flagellate species some forms were also collected which greatly resemble *S. mirabilis* but they distinctly differ from the typical species as their posteriormost region is completely devoid of any flagella. Based on this characteristic feature De Mello (1937) created a new variety *indica* under the species *S. mirabilis*.

80. *Spirotrichonympha ovoidea* De Mello, 1937
(Fig. 120)

1937. *Spirotrichonympha ovoidea* De Mello, C. R. XII Congr. Int. Zool. Lisb., 1935, 2 : 1376.

1983. *Spirotrichonympha ovoidea* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

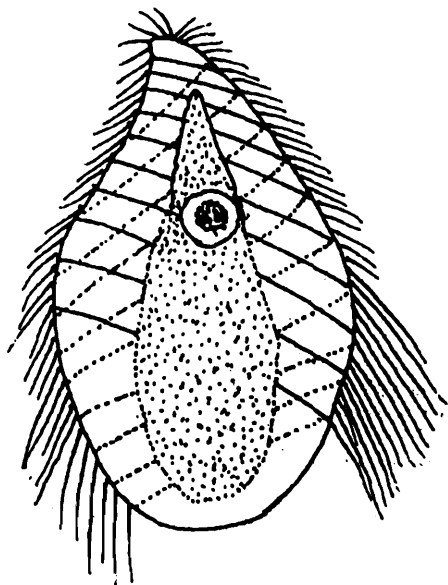


Fig. 119 : *Spirotrichonympha mirabilis* var. *indica* De Mello

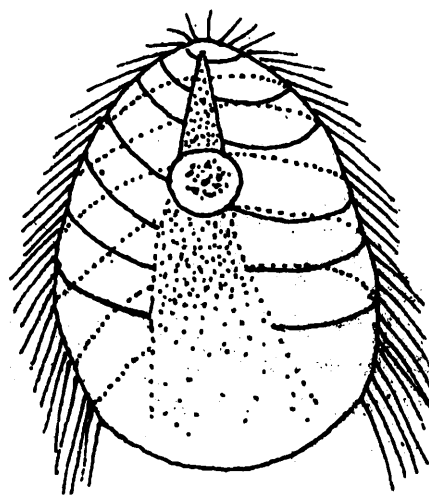


Fig. 120 : *Spirotrichonympha ovoidea* De Mello

Type host : *Heterotermes indicola*; loc., India : Diu.

Diagnosis : Body ovoid, both anterior and posterior poles rounded, but posterior pole more broadly round; large flagella covering the body in dextrotropic rows, excepting some posterior portion of the body, which devoid of any flagella; nucleus round and located near the anterior third of the body, prenuclear zone of dense endoplasm conical in shape; axostyle indistinct.

Morphometry : De Mello (1937) recorded the dimensions of 24 specimens of *Spirotrichonympha ovoidea* whose length ranges from 11 μm to 25 μm with an average 17.6 μm and width from 6 μm to 20 μm with an average 12.8 μm . No other morphometric data of this species was recorded.

Remarks : Description of *S. ovoidea* given by De Mello (1937) is insufficient for its identification. In view of this, diagnosis of this species incorporated here is mostly based on De Mello's text figure. This species has not been recorded by any worker since its first description (De Mello, *op.cit.*). However, Das (1983) included this species in the checklist of flagellate symbiotes of Indian termites based on the above publication.

81. *Spirotrichonympha (Spironympha) porteri* (Koidzumi, 1917) Grassé, 1952 (Fig. 121)

- 1917. *Spirotrichonympha porteri* Koidzumi, *Ann. Rep. Inst. Sci. Govt. Formosa*, 6 : 93.
- 1921. *Microspironympha porteri* Koidzumi, *Parasitology*, 13 : 268.
- 1928. *Microspironympha porteri* : Bernstein, *Arch. Protistenkd.*, 61 : 9-37.
- 1931. *Spironympha porteri*: Brown, *J. Morph. Physiol.*, 51 : 291.
- 1952. *Spirotrichonympha (Spironympha) porteri* (Koidzumi) Grassé, *Traite de Zoologie*, Paris, Vol 1., fasc 1 : 925.
- 1995. *Spirotrichonympha porteri*: Das, Mandal and Nandi., *Fauna of Meghalaya, State Fauna Series*, 5(Part 10) : 89. *Zool. Surv. India*.
- 2003. *Spirotrichonympha porteri* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 32. *Zool. Surv. India*.
- 2006a. *Spirotrichonympha porteri* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 34. *Zool. Surv. India*.
- 2006b. *Spirotrichonympha porteri* : Das, Nandi and Chattopadhyay, *Fauna of Arunachal Pradesh, State Fauna Series*, 13(Part 2) : 31. *Zool. Surv. India*.

Type host : *Reticulitermes flaviceps* (= *Leucotermes flaviceps*); loc., Japan.

Additional hosts : *Anacanthotermes murgabicus*; *Anacanthotermes ochraceus*; *Reticulitermes assamensis*; loc., India : Meghalaya, Nagaland and Sikkim; *Reticulitermes tirapi*; loc., India : Arunachal Pradesh.

Diagnosis : Shape of the body variable, commonly fusiform, sometimes pyriform or ovoid; anterior end of the body cone-shaped, posterior end rounded in some forms, prolonged and pointed in others or drawn out into a finger-like process in some other; flagella of one type, arranged in 6-8 flagellar bands and turning round the body spirally

towards the posterior portion dextrotopically but never reaching the posterior end of the body; flagella shorter at anterior portion but considerably longer posteriorly; hinder portion of the body free from any flagella; nucleus oval or round, situated at about anterior third of the body; nucleus not suspended freely in the cytoplasm but connected with anterior tip of the body by means of a rostral tube of uniform thickness; a rod-like tubular axostyle extending from the posterior portion of nucleus up to the posterior end of the body including its prolongation.

Morphometry (Table 73) :

Table 73. Comparison of mensural data of *Spirotrichonympha porteri* from different hosts (measurements in μm); (CF : combined forms; PF : pyriform forms; SF : Spindle shaped forms)

Characters	Type host : <i>R. flavipes</i> (Japan)	Addl host : <i>R. tirapi</i> (India)
Body length	SF : 20-55; PF : 20-40	CF : 32(18-50)
Body width	SF : 10-30; PF : 18-30	CF : 16.2 (12-30)
Ratio of body length to body width (average)	SF : 1.8 : 1 PF : 1.5 : 1	CF : 1.9 : 1
Length of nucleus	—	CF : 3.5(3-4.8)
Breadth of nucleus	—	CF : 3(2.5-4)

Remarks : Koidzumi (1917) described *Spirotrichonympha porteri* for the first time from the gut of *Reticulitermes flavipes* which was collected from Japan. Subsequently he (1921) erected a new genus *Microspironympha* and transferred *Spirotrichonympha porteri* under it as *Microspironympha porteri*. In 1952 Grassé synonymised the genus *Microspironympha* under the genus *Spirotrichonympha* and subgenus *Spirotrichonympha*. As such, the present status of this species is *Spirotrichonympha (Spirotrichonympha) porteri*.

Koidzumi (1921) recognised two forms of *S. porteri*, viz., spindle-shaped forms and pyriform forms and recorded dimensions of both forms separately (Table 73). In recent years Das *et al.* (1995, 2003, 2006a, b) studied this species and observed its variable shape. But sharp distinction of any form as above or otherwise was not plausible. Therefore, mensural data of combined forms were recorded by them, as presented in Table 73. The Table reveals that dimensions of Indian forms are well within the range of type specimens.

82. *Spirotrichonympha pyriformis* Chakravarty and Banerjee, 1956 (Fig. 122)

1956. *Spirotrichonympha pyriformis* Chakravarty and Banerjee, *Proc. Zool. Soc., Calcutta*, 9 : 40.
 1976. *Spirotrichonympha pyriformis* : Das, *Acta Protozool.*, 15 : 119.
 1981. *Spirotrichonympha pyriformis* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 161.
 1983. *Spirotrichonympha pyriformis* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.
 1993. *Spirotrichonympha pyriformis* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series*, 3(Part 12) : 497. *Zool. Surv. India*.

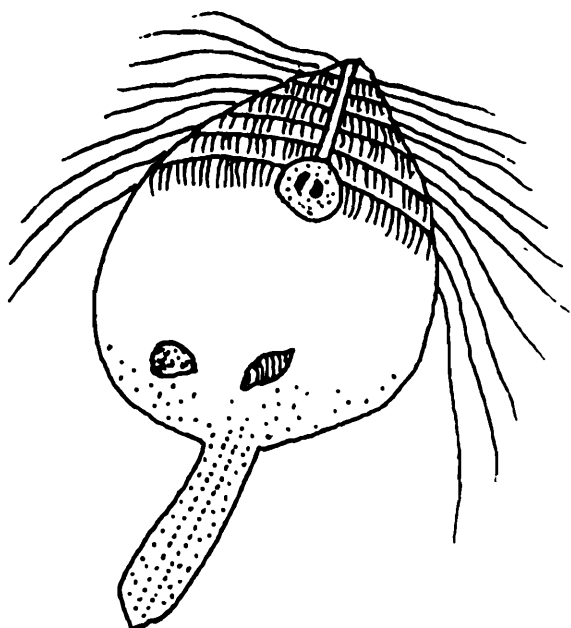


Fig. 121 : *Spirotrichonympha (Spironympha) porteri*
(Kodzumi)

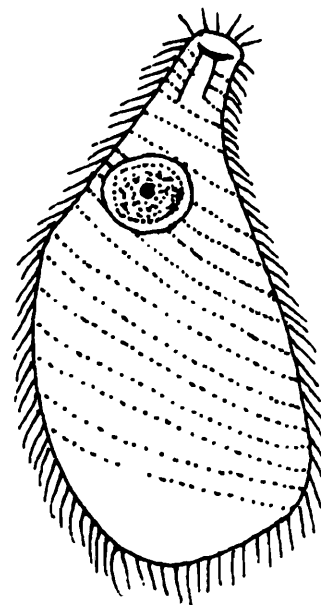


Fig. 122 : *Spirotrichonympha pyriformis*
Chakravarty & Banerjee

Type host : Heterotermes indicola; loc., India : West Bengal (= *Heterotermes* sp. sensu Chakravarty and Banerjee)

Diagnosis : Body pear-shaped with anterior end terminating to a point; tubule originating from the anterior end and not extending up to nucleus; flagellar spirals 20-24 in number; a part of the body at posterior end without any flagellar spiral; nucleus spherical located near the anterior third of the body; axostyle not detected.

Morphometry (Table 74) :

Table 74. Mensural data of *Spirotrichonympha pyriformis*

Characters	From : <i>Heterotermes indicola</i>	
	Range	Mean
Length of the body	10.7–55.6 μm	30 μm
Breadth of the body	8.5–29.5 μm	15.4 μm
Ratio of body length to body width (average)	–	1.9 : 1
Length of nucleus	5.3–8.5 μm	7 μm
Breadth of nucleus	5.3–8.5 μm	7 μm

Remarks : Das (1976) studied the flagellate symbiotes of *Heterotermes indicola* from the type locality (Kolkata, West Bengal) of *Spirotrichonympha pyriformis* in details. But he could not collect this flagellate species from this type host. The diagnostic characters and mensural data of *S. pyriformis* presented here are taken from the original description of this species by Chakravarty and Banerjee (1956). Dimensions of this species show very wide range of variation. In every probability, such variation in *S. pyriformis* is due to inclusion of many young forms during the measurements of dimensions of this species.

83. *Spirotrichonympha roonwali* Das, 1976

(Fig. 123)

1976. *Spirotrichonympha roonwali* Das, *Acta Protozool.*, 15 : 116.
1981. *Spirotrichonympha roonwali* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 161.
1983. *Spirotrichonympha roonwali* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 44.
1992. *Spirotrichonympha roonwali* : Tiwari, *Rec. zool. Surv. India*, 92 : 150.
1993. *Spirotrichonympha roonwali* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series* 3(Part 12) : 497. *Zool. Surv. India*.
2000. *Spirotrichonympha roonwali* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 42. *Zool. Surv. India*.

Type host : *Coptotermes heimi*; loc., India : Bihar, West bengal.

Additional host : *Coptotermes travians*; loc., India : Tripura.

Diagnosis : Body pyriform in shape with a finger-like projection at anterior end, bearing a hyaline cap or operculum; posterior end broad and drawn out into a cone at the middle of the posterior extremity; the greatest width of the body near its posterior end; flagella of one type, distributed on spirally arranged flagellar bands; four such bands arising from the base of a centroblepharoplast, situated at the tip of the body; these flagellar bands turned round the body dextrotropically reaching almost up to the posterior end, which also covered with flagella; nucleus more or less round; prenuclear endoplasmic mass dense and conical; axostyle thin and fibrous, extending beyond the middle of the body but not reaching the posterior extremity.

Morphometry (Table 75) :

Table 75. Comparative morphometric data of *Spirotrichonympha roonwali* from different hosts and localities (measurements in μm)

Characters	From Type host : <i>C. heimi</i>		From <i>C. travians</i> Tripura (Das <i>et al.</i> , 2000)
	West Bengal (Das, 1976)	Bihar (Tiwari, 1992)	
Body length	39 (35-42)	38.4 (32-48)	30-40
Body width	20.4 (18-22.4)	21.2 (17.6-27.2)	18-22
Ratio of body length to body width (average)	1.9 : 1	1.8 : 1	1.7 : 1
Length of nucleus	5.1 (4.8-5.7)	5 (4.8-5.6)	—
Breadth of nucleus	4.5 (4.2-5)	3.6 (3.2-4.6)	—
Length of flagella	13-16	—	—

Remarks : Pyriform body shape, well developed beak-like operculum at anterior end, widened posterior end drawn out into a cone at the middle of the posterior extremity and an indistinct axostyle, extending upto the middle of the body are the characteristic features by which *Spirotrichonympha roonwali* can be differentiated from all its congeners. Table 75 reveals that *S. roonwali* from *C. travians* is smaller in dimensions than that collected from the type host, *C. heimi*.

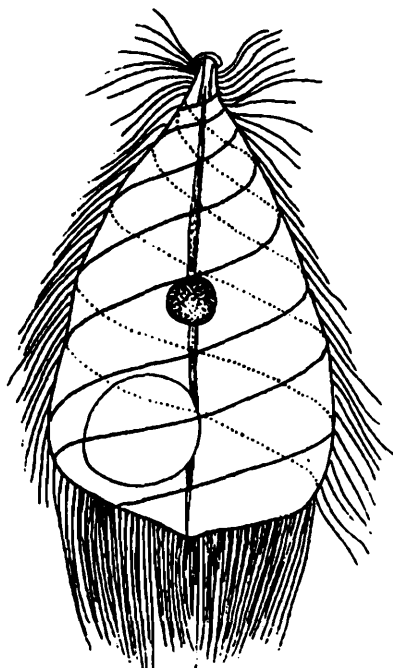


Fig. 123 : *Spirotrichonympha roonwali* Das

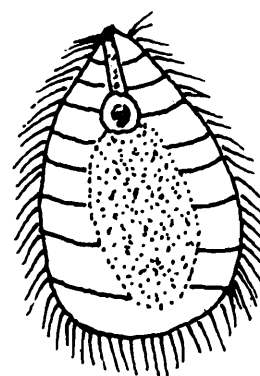


Fig. 124 : *Spirotrichonympha rotunda* De Mello

84. *Spirotrichonympha rotunda* De Mello, 1927 (Fig. 124)

1927. *Spirotrichonympha rotunda* De Mello, Trans. VIII Congr. Far East Assoc. Trop. Med., 2 : 595.
 1928. *Spirotrichonympha rotunda* : De Mello, Arqu. Esc. Med. Cirug. Nova Goa (A) 3 : 260.
 1937. *Spirotrichonympha rotunda* : De Mello, C. R. XII Congr. Int. Zool. Lisp., 1935, 2 : 1377.
 1983. *Spirotrichonympha rotunda* : Das, Proc. Symp. Host Environ. zool. Surv. India : 44.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Daman.

Diagnosis : Body ovoidal in shape with a finger like elevation at anterior end; posterior end broadly rounded; flagella of one type arranged in spiral flagellar bands, covering the body dextrorotically up to the posterior end of the body; nucleus more or less round, located near the anterior end of the body; rostral tube distinct, prenuclear zone of endoplasmic mass dense and conical; axostyle indistinct.

Morphometry : While describing *Spirotrichonympha rotunda* De Mello (1927) recorded the dimensions of three specimens as 10 μm $\times$ 10 μm , 12 μm $\times$ 11 μm and 14 μm $\times$ 10 μm . No other mensural data of this species are available.

Remarks : Description of *S. rotunda* given by De Mello (1927, 1937) is very insufficient for identifying this species. But illustrations included by him during those publications reveal several characteristic features, basing on which present diagnosis of *S. rotunda* is given. Morphometric data given above show that this species is very small in dimensions and therefore, may include immature forms of some other species of *Spirotrichonympha*.

Genus *Holomastigotes* Grassi, 1892

1892. *Holomastigotes* Grassi, *Rend. R. Accad. Lincei*, sem 1, 1 : 36.

Diagnosis : Body spindle-shaped, a few spiral flagellar bands arising from a common point near anterior end of the body and reaching up to posterior end; flagella arising from the bands lining up closely in rows and forming fasciculi after reaching the surface of the body; nucleus located very close to the rostrum, embedding in a mass of dense protoplasm.

Remarks : Koidzumi (1921) recorded the characteristic features of *Holomastigotes* as follows :

Body spindle shaped, body surface spirally ridged and flagella arising in the groove behind the ridge. He (*op. cit.*) placed this genus under the family Holomastigotidae. This systematic status was followed by many subsequent Protozoologists including Kudo (1966). However, Kudo (*op. cit.*) did not mention the occurrence of any spiral ridge in the diagnostic feature of *Holomastigotes*. At present, some workers treat this genus as *incertae sedes* (see Yamini, 1979). This may be due to its ambiguously stated taxonomic features.

Das *et al.* (1995, 2003, 2006a) collected some representatives of the genus *Holomastigotes* from the Indian termites, *Reticulitermes assamensis*. After critical examination they placed this genus under the family Spirotrichonymphidae. Because this genus possesses few spiral bands (4 or 8 pairs), arising from a common point near anterior end of the body and a nucleus anchored to the rostrum by a nuclear sleeve as noted by Cleveland and Day (1958).

85. *Holomastigotes indica* Das, Mandal, Tiwari and Sarkar, 1995 (Fig. 125)

1995. *Holomastigotes indica* Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series*, 4(Part 10) : 88. *Zool. Surv. India*.

2003. *Holomastigotes indica* : Das, Tiwari and Sarkar, *State Fauna Series, Fauna of Sikkim*, 9(Part 5) : 31. *Zool. Surv. India*.

2006a. *Holomastigotes indica* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 34. *Zool. Surv. India*.

Type host : *Reticulitermes assamensis*; loc., India : Meghalaya, Nagaland, Sikkim.

Diagnosis : Body more or less spindle shaped with bluntly pointed anterior and slightly rounded posterior ends; anterior end with well marked rostrum; flagellar

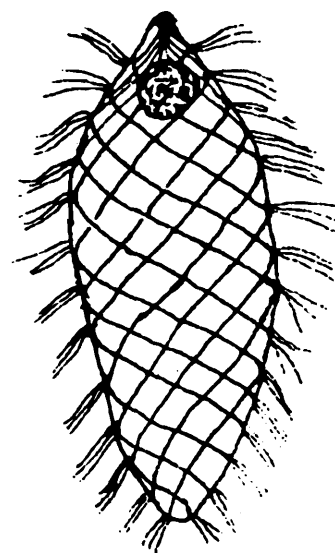


Fig. 125 : *Holomastigotes indica* Das, Mandal, Tiwari & Sarkar

bands 8 in number, arising from a common point near anterior end of the body; these bands spiralling slightly in rostrum but prominently in body portion reaching upto the posterior end of the body; flagella arising from bands lining up closely in rows, reaching the surface of the body and forming fasciculi; nucleus oval, situated very close to the rostrum and embedded in a mass of dense endoplasm, axostyle absent; endoplasm containing small fragments of ingested wooden particles.

Morphometry (Table 76) :

Table 76. Mensural data of *Holomastigotes indica*

Characters	Type host : <i>R. assamensis</i>	
	Range	Mean
Length of the body	43.2–65.5 μm	51.7 μm
Breadth of the body	12.8–25.6 μm	20.4 μm
Ratio of body length to body width (average)	–	2.5 : 1
Length of nucleus	3.6–9.6 μm	7.7 μm
Breadth of nucleus	3–6.2 μm	5.8 μm

Remarks : Das *et al.* (1995) described this species from the gut of an Indian termite, *Reticulitermes assamensis* which was collected from Meghalaya. Subsequently, this species was collected from the same host by Das *et al.* (2003, 2006a) from two different states of North East India, *viz.*, Sikkim and Nagaland.

Earlier, only one species of *Holomastigotes*, *viz.*, *H. elongatum* was described from three species of *Reticulitermes*, *viz.*, *R. hesperus*, *R. lucifugus* and *R. speratus* by Grassi (1892) and Koidzumi (1921). *H. elongatum* differs considerably from *H. indica* in several morphological and morphometric features as shown in Table 77.

Table 77. Morphological and morphometric comparison between *H. indica* and *H. elongatum*

Characters	<i>H. indica</i>	<i>H. elongatum</i>
Body shape	Spindle-shaped with bluntly pointed anterior and rounded posterior end	Fusiform or lanceolate
Rostrum	Very prominent	Not so prominent
Body length	43.2–65.5 μm	15–45 μm
Body width	12.8–25.6 μm	10–15 μm
Host	<i>R. assamensis</i>	<i>R. hesperus</i> , <i>R. lucifugus</i> , <i>R. speratus</i>
Distribution	India	Europe, America, Japan

Suborder TRICHONYMPHINA Grassé, 1952

1952. Trichonymphina Grassé, In : *Traite de Zoologie*, Vol. 1, Fasc. 1 : 862.

Diagnosis : Numerous flagella arranged in longitudinal rows or in leiotropic spiral; in one family (Teratonymphidae) flagella distributed in non-continuous spiral bands; rostral tube present.

Key to the families of the suborder TRICHONYMPHINA reported from Indian termites

1. Body regularly ridged giving it a segmented appearance, each ridge encircled by noncontinuous flagellar band; no connection between bands
..... Family TERATONYMPHIDAE
- No such ridge or such segmented appearance present, flagella covering the body in longitudinal rows 2
2. Body divisible into three regions : rostrum, flagella bearing region behind rostrum and non-flagellar posterior region; grouping of parabasal bodies around nucleus ...
..... family TRICHONYMPHIDAE.
- Body with rostral region and flagella bearing region, non-flagellar region as above lacking; only a very small portion at posterior end may be non-flagellar, no grouping of parabasal bodies around nucleus Family EUCOMONYMPHIDAE

Family EUCOMONYMPHIDAE Cleveland, Hall, Sanders and Collier, 1934

1934. Eucomonymphidae Cleveland, Hall, Sanders and Collier, *Mem. Amer. Acad. Arts Sci.*, 17 : 271.

Diagnosis : Entire body covered with flagella leaving a very small glabrous portion at posterior end; flagella arising from basal granules and arranged in rows; flagellar rows except for slight spiralling; parallel with the long axis of the body; rostral tube considerably broader than in Trichonymphidae; no grouping of parabasal bodies around nucleus.

Remarks : Only one genus under this family, viz., *Pseudotrichonympha* has been reported so far from the guts of Indian termites.

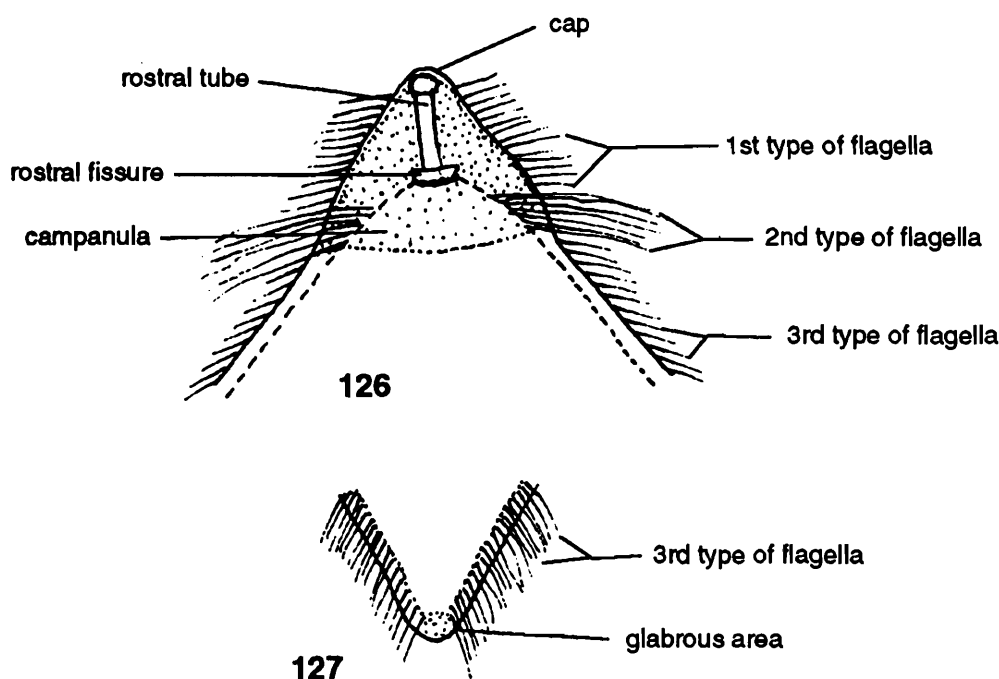
Genus *Pseudotrichonympha* Grassi and Foa, 1911 (Figs. 126-127)

1911. *Pseudotrichonympha* Grassi and Foa, *Rend. R. Accad. Lincei* (5), Sem 1., 20 : 729.

1959. *Pseudotrichonympha* : Vittal, *J. Zool. Soc. India*, 11 : 50.

Diagnosis : Anterior portion of the body possessing a campanula, covered by an apical cap; a distinct rostral tube present; anterior part of the body differentiated into ecto and

endoplasm; cytoplasm further differentiated into a narrow outer and inner layer; campanular surface covered by three types of flagella, distinguishable from one another in location and in length (Fig. 126); first type of flagella shortest in length, immobile and strictly confined to the rostral tube; second type of flagella longest and arranged below the first type in a thick circular band, third type of flagella also shorter in length, arranged below the second type in longitudinal rows covering the whole body mostly in leiotropic manner, leaving a very short glabrous posterior end (Fig. 127).



Figs. 126-127 : Genus *Pseudotriconympha* Grassi & Foa (diagrammatic). **Fig. 126.** Anterior region; **Fig. 127.** Posterior region

Key to the species of the genus *Pseudotriconympha* reported from Indian termites

1. Campanula super-imposed with a free posterior margin *P. belari*
- Campanula not super-imposed but continuous with ectoplasmic wall of the body 2
2. Campanula containing some "bottle shaped structure" in the vicinity of rostral tube *P. ramani*
- Campanula without any bottle-shaped structure as above 3
3. Campanula medially placed 4
- Campanula not medially placed 6
4. Body heart-shaped with sphaerita-like microorganisms in the endoplasm *P. cardiformis*
- Body elongated and truncated at both ends 5

5. Very large in dimensions, 330-750 μm x 40-60 μm , nucleus located anteriorly with large karyosome *P. hertwigi*
- Not so large as above, dimensions 220-300 μm x 38-55 μm , nucleus located little above the middle of the body containing scattered chromatin granules *P. indica*
6. Campanula distinctly subapical *P. subapicalis*
- Campanula disposed obliquely on one side of the body *P. pisciformis*

86. *Pseudotriconympha belari* De Mello, 1927

(Fig. 128)

1927. *Pseudotriconympha belari* De Mello, Arqu. Esc. Med. Cirug. Nova Goa (A), 1 : 3.
1929. *Pseudotriconympha belari* : De Mello, Trans. VII Congr. Brit. India, 1927, 2 : 583.
1919. *Triconympha agilis sensu* De Mello, Proc. Asiat. Soc. n.s. 15 : cl.
1924. *Holomastigotoides hertwigi sensu* Guimaraes and Andrade, Rev. Med. Angola, 4 : 495.
1983. *Pseudotriconympha belari* : Das, Proc. Symp. Host Environ. zool. Surv. India : 45.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Daman.

Diagnosis : Body shape variable but usually fusiform, greater width being near the middle of the body; anterior end of the body with campanula, rostral tube and apical cap; campanula of variable shape and "superimposed with a free posterior margin" (as shown in original illustration of De Mello, 1927) (Fig. 128) ; flagella of three types of which second type arranged below the first type of flagella in a circular band and longest, possessing "fan-shaped myonemes"; nucleus located near the middle of the body.

Morphometry (Table 78) :

Table 78. Mensural data of *Pseudotriconympha belari* (after De Mello, 1927)

Characters	From <i>H. indicola</i>
Length of the body	180-561 μm
Breadth of the body	60-220 μm
Ratio of body length to body width (average)	2.6 : 1
Length of nuclues	—
Breadth of nucleus	—
Length of 1st type of flagella	20-22 μm
Length of 2nd type of flagella	44-50 μm
Length of 3rd type of flagella	8-22 μm

Remarks : *Pseudotrichonympha belari* has not been collected by any worker since its original description by De Mello (1927). In one of his subsequent publication De Mello (1929) included some illustrations of this species. Das (1983) incorporated *P. belari* in the checklist of flagellate symbiotes of Indian termites based on De Mello's publications referred above. Campanula which is described as superimposed with a free posterior margin is the characteristic feature of this species. It needs mention here that campanula presumed as superimposed appears to be very unusual and perhaps the result of some incorrect observation. Range of variation in length and breadth of the body (Table 78) is considerably variable. In every probability mensural data of large number of immature forms of *Pseudotrichonympha* were added with mature forms for yielding such result. It may be mentioned here that it is too difficult to identify any species from its immature forms.

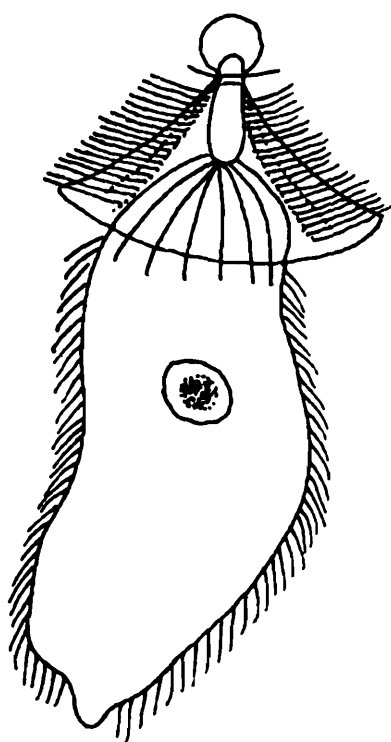


Fig. 128 : *Pseudotrichonympha belari*
De Mello

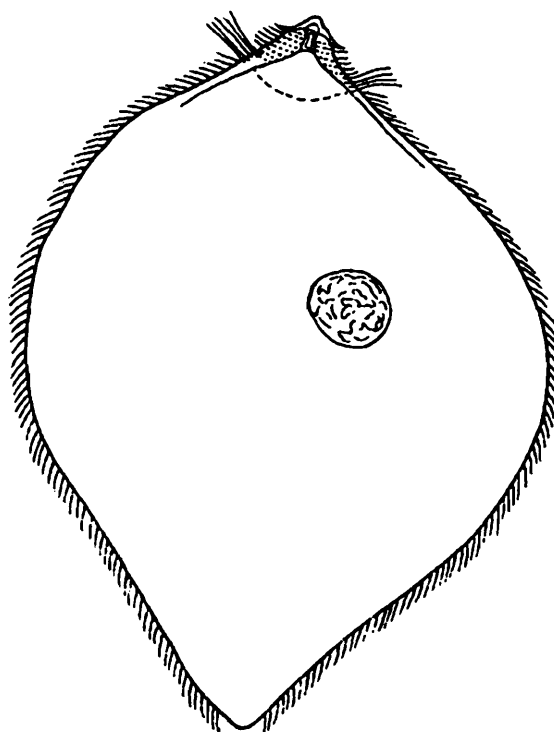


Fig. 129 : *Pseudotrichonympha cardiformis*
Karandikar & Vittal

87. *Pseudotrichonympha cardiformis* Karandikar and Vittal, 1954
(Fig. 129)

- 1954. *Pseudotrichonympha cardiformis* Karandikar and Vittal, *J. Univ. Bombay*, 23 B : 1.
- 1976. *Pseudotrichonympha cardiformis* : Das, *Acta Protozool.*, 15 : 119.
- 1978. *Pseudotrichonympha cardiformis* : Tiwari, *Bull. zool. Surv. India*, 4 : 161.
- 1983. *Pseudotrichonympha cardiformis* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 45.
- 1988. *Pseudotrichonympha cardiformis* : Tiwari, *Rec. zool. Surv. India*, 85 : 222.
- 1992. *Pseudotrichonympha cardiformis* : Tiwari, *Rec. zool. Surv. India*, 92 : 150.

1993. *Pseudotrichonympha cardiformis* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series* 3(Part 12) : 497. *Zool. Surv. India*.
2000. *Pseudotrichonympha cardiformis* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 42. *Zool. Surv. India*.
2003. *Pseudotrichonympha cardiformis* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 32. *Zool. Surv. India*.
2004. *Pseudotrichonympha cardiformis* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 458. *Zool. Surv. India*.
- 2006a. *Pseudotrichonympha cardiformis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 35. *Zool. Surv. India*.

Type hosts : *Heterotermes malabaricus*; loc., India : Karnataka (type locality) ; *Coptotermes heimi*; loc., India : Andhra Pradesh, Karnataka (type locality); Uttar Pradesh, West Bengal.

Additional hosts : *Coptotermes travians*; loc., India : Nagaland, Sikkim, Tripura; *Heterotermes indicola*; loc., India : Bihar, West Bengal.

Diagnosis : Body commonly heart-shaped, sometimes sac like or conical and divisible into campanula at anterior end of the body and body proper at its posterior; campanular periphery continuous with body ectoplasm (not free and superimposed on body); rostral tube located at the central portion of campanula, closed at the bottom and enlarged anteriorly into a hollow thin-walled bulb-like structure, covered apically by a thin helmet-shaped cap; campanular structure covered by three types of flagella distinguishable by their length and location; first type of flagella shortest and immobile and, confined to rostral tube; second type of flagella longest and extremely mobile, arranged below the first type in a thick circular band; third type of flagella little longer than the first type arranged in longitudinal rows in leiotropic manner and covering the part of campanula and the rest of the body excepting a short glabrous posterior extremity; nucleus spherical and located generally above the middle region of the body; endoplasm distinguishable into two zones, anterior one finely granular and posterior one containing large granules.

Morphometry (Table 79) :

Table 79. Comparison of morphometric data of *Pseudotrichonympha cardiformis* from different hosts (measurements in μm); (a : *Coptotermes heimi*; b : *Heterotermes malabaricus*)

Characters	Type specimens <i>H. malabaricus</i> & <i>H. heimi</i> (Karnataka)	Subsequent works		
		<i>C. heimi</i> (West Bengal)	<i>C. travians</i> (Tripura)	<i>H. indicola</i> (Bihar)
Body length	125–220	239 (213.7–352.2)	105–181	118.1 (105–181.2)
Body width	100–130	131.2 (82.5–247.5)	82.2–130.3	91.8 (82.2–130.3)
Ratio of body length to body width (average)	1.5 : 1	1.8 : 1	1.3 : 1	1.2 : 1

Table 79. Contd.

Characters	Type specimens <i>H. malabaricus</i> & <i>H. heimi</i> (Karnataka)	Subsequent works		
		<i>C. heimi</i> (West Bengal)	<i>C. travians</i> (Tripura)	<i>H. indicola</i> (Bihar)
Length of nucleus	15-27 ^a ; 14-18 ^b	25.6 (22.5-37.5)		25.6 (22.5-37.5)
Breadth of nucleus	15-27 ^a ; 14-18 ^b	25.5 (20-33.7)	-	25.6 (20-33.3)
Length of campanula	28-35 ^a ; 24-35 ^b	18.4 (16.8-22.5)	-	18 (14-18.6)
Campanula in maximum width	40-50 ^a ; 28-36 ^b	40.6 (37.5-45)	-	-
Length of rostrum	7-10 ^a ; 11-18 ^b	7.5	-	-
Height of apical cap	3-5	3	-	-
Length of 1st type of flagella	6-8	5-7	-	6-8
Length of 2nd type of flagella	18-20	17-18	-	17-20
Length of 3rd type of flagella	12-14	9-10	-	8-13.5

Remarks : Karandikar and Vittal (1954) described *Pseudotriconympha cardiformis* from two termite hosts of Karnataka, viz, *Coptotermes heimi* and *Heterotermes malabaricus*. Das (1976) also collected *P. cardiformis* from West Bengal from the host, *Coptoterems heimi*. Subsequently this species was collected from two other termite hosts, viz., *Heterotermes indicola* by Tiwari (1992) and *Coptotermes travians* by Das *et al.* (2000, 2003, 2006a). A comparative mensural data of *P. cardiformis*, collected from those hosts are presented in Table 79. The Table reveals that this species collected from *C. heimi* from West Bengal (Das, 1976) is considerably bigger in dimensions, whereas that from the hosts *C. travians* and *H. indicola* are the smallest. However, typical heart-shaped body of this species conveniently differentiates it from all its congeners.

88. *Pseudotriconympha hertwigi* (Hertmann, 1910) Grassi, 1917
var. *simplex* De Mello, 1937
 (Fig. 130)

1910. *Trichonympha hertwigi* Hartmann (*partim*) (male), *Festschrift zum Geburtstage R. Hertwig*, p. 359.
 1917. *Pseudotriconympha hertwigi* Grassi, *Mem. R. Accad. Lincei, Ser. 5, 12* : 333.
 1937. *Pseudotriconympha hertwigi* var. *simplex* De Mello, *C. R. XII Cong. Int. Zool.*, 1935, 2 : 1365.
 1983. *Pseudotriconympha hertwigi* var. *simplex* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 45.

Type hosts : *Cryptotermes* sp.; loc., India : Daman.

Diagnosis : A comparatively large *Pseudotriconympha*; its maximum length recorded as 410 µm; pisciform in shape; in general structure it resembles *Pseudotriconympha belari*

with three types of flagella; its campanula continuous with its posterior ectosarc (not superimposed as in *P. belari*), fully covered with flagella without having any glabrous posterior end; nucleus more or less round, located below the middle of the body.

Morphometry : De Mello (1937) provided the mensural data of length and breadth only of 33 specimens of *Pseudotriconympha hertwigi* var. *simplex*. Its length varies from 110 μm to 410 μm with average 197.6 μm , width 13 μm to 94 μm with average 55.9 μm and its average length-breadth ration 3.5 : 1. No other morphometric data of this variety is available.

Remarks : De Mello (1937) stated that his newly erected variety *simplex* almost resembles its typical species *Pseudotriconympha hertwigi* in its anterior part. But it differs from *P. hertwigi* and its varieties *major* and *minor* in lacking posterior glabrous zone.

P. hertwigi as well as its var. *simplex* were not collected by any worker since De Mello's publication in 1937. Present diagnosis has been given solely based on De Mello (1937). Das (1983) included this variety in the checklist of flagellale symbiotes of Indian termites based on above publication. It is needed to mention here that absence of glabrous portion at the posteriormost end of *Pseudotriconympha* is very unusual and deserves further study.

89. *Pseudotriconympha indica* Chakravarty and Banerjee, 1956 (Fig. 131)

1956. *Pseudotriconympha indica* Chakravarty and Banerjee, *Proc. Zool. Soc., Calcutta*, 9 : 42.

1976. *Pseudotriconympha indica* : Das, *Acta Protozool.*, 15 : 121.

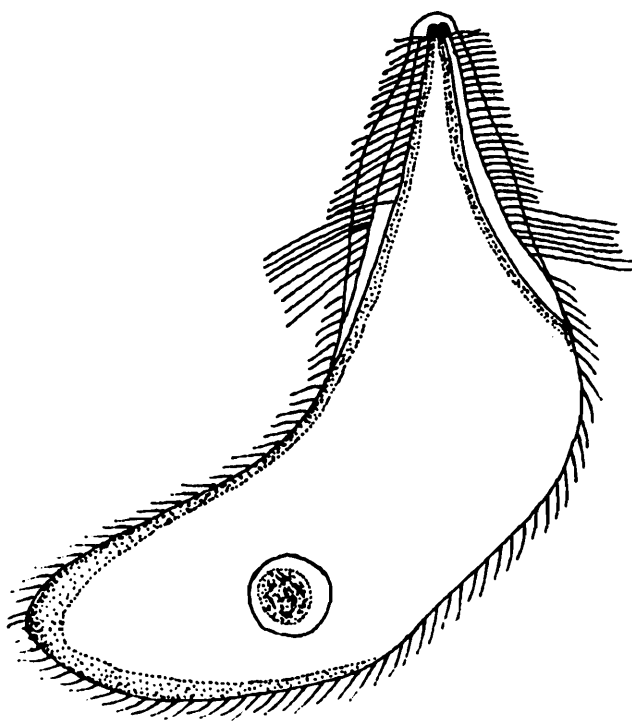


Fig. 130 : *Pseudotriconympha hertwigi* var. *simplex*
De Mello

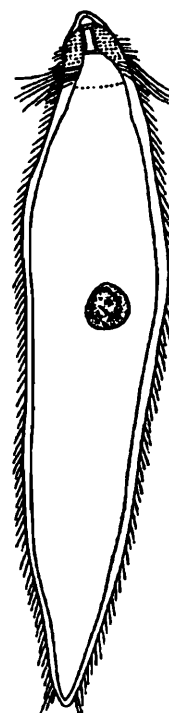


Fig. 131 : *Pseudotriconympha indica*
Chakravarty & Banerjee

1981. *Pseudotrichonympha indica* : Tiwari and Ray, *Bull. zool. Surv. India*, 4 : 161.
1983. *Pseudotrichonympha indica* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 45.
1988. *Pseudotrichonympha indica* : Tiwari, *Rec. zool. Surv. India*, 85 : 222.
1992. *Pseudotrichonympha indica* : Tiwari, *Rec. zool. Surv. India*, 92 : 151.
1993. *Pseudotrichonympha indica* : Das, Mandal and Nandi, *Fauna of West Bengal, State Fauna Series* 3(Part 12) : 498. *Zool. Surv. India*.
2000. *Pseudotrichonympha indica* : Das, Tiwari and Sarkar, *Fauna of Tripura, State Fauna Series*, 7(Part 4) : 42. *Zool. Surv. India*.
2003. *Pseudotrichonympha indica* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 33. *Zool. Surv. India*.
2004. *Pseudotrichonympha indica* : Das, Tiwari, Nandi, Sarkar and Saha, *Fauna of Andhra Pradesh, State Fauna Series*, 5(Part 6) : 458. *Zool. Surv. India*.
- 2006a. *Pseudotrichonympha indica* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 35. *Zool. Surv. India*.

Type host : *Heterotermes indicola*; (= *Heterotermes* sp. sensu Chakravarty & Banerjee, 1956); loc., India : West Bengal.

Additional hosts : *Coptotermes heimi*; loc., India : Andhra Pradesh, Bihar, Uttar Pradesh, West Bengal; *Coptotermes travians*; loc., India : Nagaland, Sikkim and Tripura.

Diagnosis : Body much elongated with its broadest part being almost near its middle; campanular region very short in comparison to body length; rostral tube short, bearing an apical cap as in *P. cardiformis*; flagella of three types, distribution of which also similar to that of *P. cardiformis*; nucleus more or less circular, containing scattered chromatin granules located near the middle of the body and occasionally near its posterior region; endoplasm granular, sometimes containing fragments of wood.

Morphometry (Table 80) :

Table 80. Comparison of morphometric data of *Pseudotrichonympha indica* from different hosts (measurements in μm)

Characters	Original description <i>Heterotermes</i> sp. (Chakravarty & Banerjee, 1956)	Subsequent records	
		<i>H. indicola</i> & <i>C. heimi</i> (Das, 1976)	<i>C. travians</i> (Das et al., 2000)
Body length	220–300	193.8 (165–221.2)	217–301
Body width	38–55	38.2 (22.5–52.5)	42–55
Ratio of body length to body width (average)	5.5 : 1	5 : 1	5.3 : 1

Table 80. *Contd.*

Characters	Original description <i>Heterotermes</i> sp. (Chakravarty & Banerjee 1956)	Subsequent records	
		<i>H. indicola</i> & <i>C. heimi</i> (Das, 1976)	<i>C. travians</i> (Das <i>et al.</i> , 2000)
Length of nucleus	10.2–11.4	15.1 (10.2–18.7)	—
Breadth of nucleus	10.2–11.4	13.5 (10.2–15)	—
Length of campanula	—	16.6 (16.3–17)	—
Campanula in maximum width	—	12 (9.3–14)	—
Length of rostrum	—	6–6.5	—
Height of apical cap	—	3.2	—
Length of 1st type of flagella	—	5–6	—
Length of 2nd type of flagella	—	—	11–12 —
Length of 3rd type of flagella	—	7–8	—

Remarks : Chakravarty and Banerjee (1956) described *Pseudotrichonympha indica* from an undetermined species of *Heterotermes* sp, collected from Kolkata, West Bengal. Das (1976) studied this flagellate species in details from two species of termite hosts, *viz.*, *H. indicola* and *C. heimi* collected from the type locality. Subsequently Das *et al.* (2000, 2003, 2006a) recovered it from another host *C. travians*. Morphometric data of the specimens of *P. indica* collected by Das (1976) and Das *et al.* (2000) are presented in Table 80 and compared with those of the type specimens (Chakravarty and Banerjee, 1956). The Table reveals that specimens collected by Das (1976) are the smallest in dimension and type specimens are most slender having length-breadth ratio 5.5 : 1.

90. *Pseudotrichonympha pisciformis* Karandikar and Vittal, 1954
(Fig. 132)

1954. *Pseudotrichonympha pisciformis* Karandikar and Vittal, *J. Univ. Bombay*, 23B : 6.

1983. *Pseudotrichonympha pisciformis* : Das, *Proc. Symp. Host Environ. zool Surv. India* : 45.

Type hosts : *Heterotermes malabaricus*; loc., India : Karnataka; *Coptotermes heimi*; loc., India : Karnataka.

Diagnosis : Body somewhat fusiform tapering posteriorly to a lengthened tip, resembling a tail; its anterior end relatively blunt and maximum width lying usually midway between anterior one-third and posterior two-third of the body; campanula disposed

obliquely on one side of the median axis and continuous with the cytoplasmic wall of the body; flagella of three types as in *P. cardiformis*; however, in obliquely placed campanula the flagellar band of second type of flagella forming a girdle "exposed fully to one side of the anterior end like a girland hanging round the neck obliquely on the chest; flagellar band almost apical at the upper end but running subapically at lower end along one side of the anterior region"; rostral tube closed at the bottom and bulb-like at anterior end bearing an apical cap; body covered with third type of flagella arranged in rows in leiotropic direction; nucleus more or less round and usually located at the anterior region of the body; endoplasm often filled with a few deeply stained globular masses.

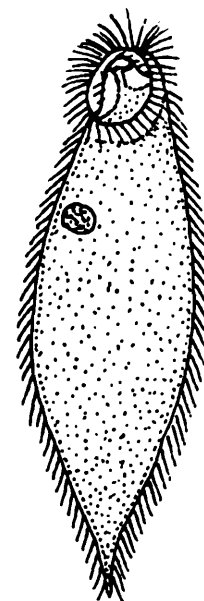


Fig. 132 : *Pseudotrichonympha pisciformis*
Karandikar & Vittal

Morphometry (Table 81) :

Table 81. Morphometric data of *P. pisciformis* (a. from *H. malabaricus*; b. from *C. heimi*)

Characters	From original description (Karandikar & Vittal, 1954)
Length of the body	100–230 μm
Breadth of the body	35–75 μm
Ratio of body length to body width (average)	3 : 1
Length of nucleus	–
Breadth of nucleus	–
Length of campanula	20–35 μm
Campanula in maximum width	30–35 μm
Length of rostrum	10–14 μm^a ; 7–10 μm^b
Height of apical cap	–
Length of 1st type of flagella	6–8 μm
Length of 2nd type of flagella	14–16 μm
Length of 3rd type of flagella	8–14 μm

Remarks : *Pseudotrichonympha pisciformis* has not been recorded by any worker since its description by Karandikar and Vittal (1954). However, Das (1983) included this species in the checklist of flagellate symbiotes of Indian termites, based on its original description. The species name "*pisciformis*" was assigned by its authors because of its fish-like fusiform body along with a "long posterior tail". The diagnostic features and mensural data of this species presented here are based on its original description.

91. *Pseudotrichonympha ramani* De Mello, 1937
(Fig. 133)

1937. *Pseudotrichonympha ramani* De Mello, C. R. XII Congr. Int. Zool. 1935, 2 : 1360.

1983. *Pseudotrichonympha ramani* : Das, Proc. Symp. Host Environ. zool Surv. India : 45.

Type hosts : *Heterotermes* sp.; loc., India : Goa.

Diagnosis : Body "amphiform" in shape, its maximum length 210 μm and maximum width 132 μm ; possessing three types of flagella; second type of flagella longest and prominent, forming a fasciculi and more or less recurved outside the campanula; characteristic bottle-shaped structures present below the rostral cap; fan-shaped myonemes located below centroblepharoplast; nucleus spherical, located below the middle of the body.

Morphometry : While describing *Pseudotrichonympha ramani*, De Mello (1937) incorporated the mensural data of length and breadth of 23 specimens. This data reveal that *P. ramani* ranges from 100 to 210 μm in length with average 164.2 μm and breadth 80–132 μm with an average 106.4 μm and average length-breadth ratio 1.5 : 1. No other morphometric data of this species is available.

Remarks : According to De Mello (1937), presence of bottle-shaped structure below the centroblepharoplast is unique in *P. ramani*. Such structure is not found in any of its congeners. *P. ramani* has never been reported since its first description by De Mello (*op. cit.*). Das (1983) incorporated this species in the checklist of flagellate symbiotes of India, based on above publication. Diagnostic features of *P. ramani* given above is also solely based on above publication.

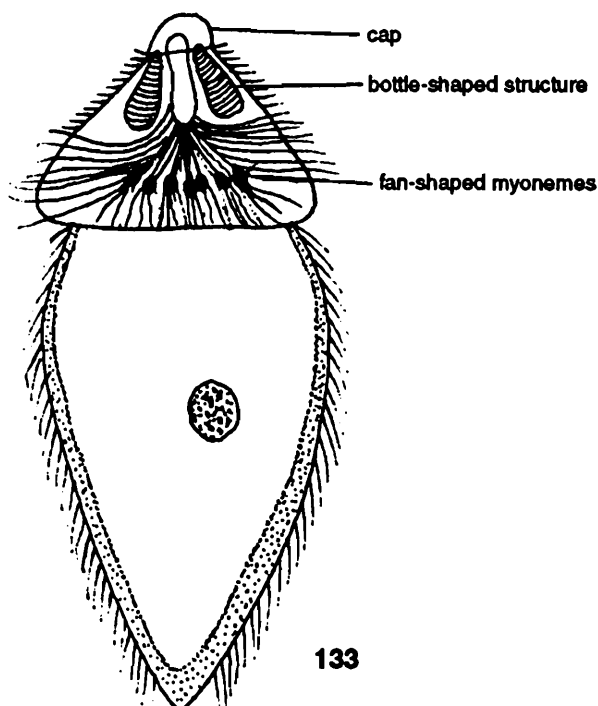


Fig. 133 : *Pseudotrichonympha ramani* De Mello

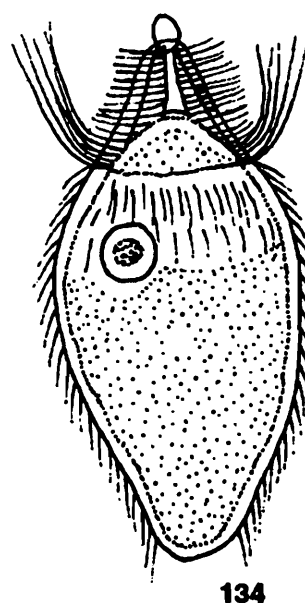


Fig. 134 : *Pseudotrichonympha ramani* var. *seminuda* De Mello

**91a. *Pseudotrichonympha ramani* De Mello, 1937 var. *seminuda* De Mello, 1937
(Fig. 134)**

1937. *Pseudotrichonympha ramani* De Mello var. *seminuda* : De Mello, C. R. XII Congr. Int. zool., 1935, 2 : 1963.

1983. *Pseudotrichonympha ramani* var. *seminuda* : Das, Proc. Symp Host Environ. zool. Surv. India : 45.

Type host : *Heterotermes indicola* (= *Leucotermes indicola*); loc., India : Goa.

Diagnosis : Greatly resembling its typical species, *Pseudotrichonympha ramani*; but differing from it in having pisciform body shape, less prominent bottle-like structure, second type of flagella excessively large and their curling up fasciculi reaching the level of the rostral cap; one-fifth of the body without having any endoplasmic inclusions but posterior four-fifth stuffed with such inclusions.

Morphometry : No mensural data of *Pseudotrichonympha ramani* var *seminuda* was provided by De Mello (1937) while he described this variety. He only mentioned the length of second type of flagella as 21 μ m.

Remarks : *P. ramani* var *seminuda* has not been reported since its first description by De Mello (1937). Therefore, diagnosis of this variety given above is based on above description. Das (1983) also included this variety in the checklist of flagellate symbiotes of Indian termites consulting the above publication.

**92. *Pseudotrichonympha subapicalis* Karandikar and Vittal, 1954
(Fig. 135)**

1954. *Pseudotrichonympha subapicalis* Karandikar and Vittal, J. Univ. Bombay, 23B : 8.

1978. *Pseudotrichonympha subapicalis* : Tiwari, Bull. zool. Surv. India, 1 : 313.

1983. *Pseudotrichonympha subapicalis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 45.

1992. *Pseudotrichonympha subapicalis* : Tiwari, Rec. zool. Surv. India, 92 : 151.

1993. *Pseudotrichonympha subapicalis* : Das, Mandal and Nandi, Fauna of West Bengal, State Fauna Series, 3(Part 12) : 498. Zool. Surv. India.

2000. *Pseudotrichonympha subapicalis* : Das, Tiwari and Sarkar, Fauna of Tripura, State Fauna Series 7(Part 4) : 43. Zool. Surv. India.

2003. *Pseudotrichonympha subapicalis* : Das, Tiwari and Sarkar, Fauna of Sikkim, State Fauna Series 9(Part 5) : 33. Zool. Surv. India.

2004. *Pseudotrichonympha subapicalis* : Das, Tiwari, Nandi, Sarkar and Saha, State Fauna of Andhra Pradesh, Fauna Series, 5(Part 6) : 459. Zool. Surv. India.

2006a. *Pseudotrichonympha subapicalis* : Das, Tiwari and Sarkar, Fauna of Nagaland, State Fauna Series 12 : 35. Zool. Surv. India.

Type hosts : *Heterotermes malabaricus*; loc., India: Karnataka; *Coptotermes heimi*; loc., India : Andhra Pradesh, Bihar, Karnataka (type locality), West Bengal.

Additional hosts : *Coptotermes travians*; loc., India : Nagaland, Sikkim, Tripura.

Diagnosis : Body generally rounded and swollen anteriorly just below the campanula and then gradually tapering posteriorly to a blunt end; campanula subapical in position and located at one side of the anterior portion of the body at right angles to the same; in most permanent preparations campanular region visible in the form of two or three circular areas (Fig. 135) because campanula rarely fixed in its longitudinal axis; outer circle very indistinct, representing the peripheral margin of the campanula; middle circle very prominent and the inner circle in the form of a disc with tiny aperture in the centre; the disc representing the fixed upper margin of the rostral tube and tiny aperture corresponding to its lumen; rostral tube, terminal bulb and apical cap may be observed in specimens *in situ* and in very few permanent preparations; flagella of three types; first type of flagella occupying the first circle, the second type of flagella arranged in the middle circle and the third type of flagella covering the body proper in slightly leiotropic direction except a very short posteriormost glabrous end; nucleus oval and situated above the middle of the body; endoplasm granular containing microorganisms and fragments of wood.

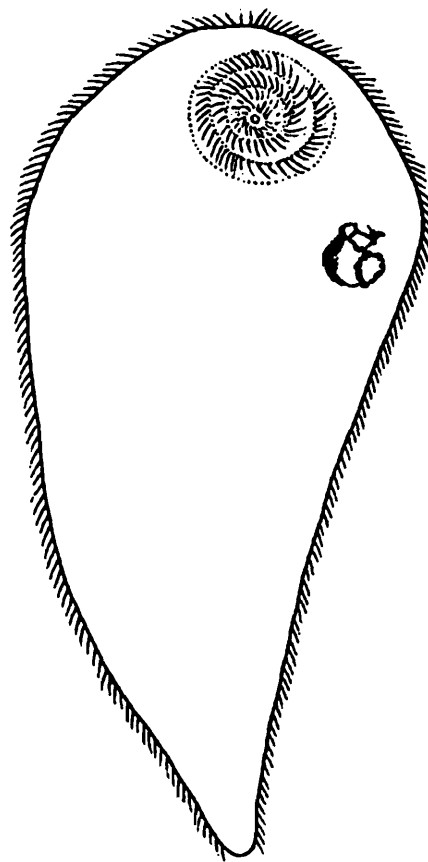


Fig. 135 : *Pseudotrichonympha subapicalis*
Karandikar & Vittal

Morphometry (Table 82) :

Table 82. Comparative morphometry of *Pseudotrichonympha subapicalis* collected from different hosts (measurements in μm); (a : from *C. heimi*; b : from *H. malabaricus*)

Characters	Original description <i>C. heimi</i> & <i>H. malabaricus</i> (Karandikar & Vittal, 1954)	Subsequent records	
		<i>C. heimi</i> Das (present study)	<i>C. travians</i> Das <i>et al.</i> (2000)
Length of the body	200–300	215 (180–243.7)	180.5–200
Breadth of the body	100–210	77.7 (71–85.2)	65–80
Ratio of body length to body width (average)	1.6 : 1	2.5 : 1	2.7 : 1
Length of nucleus	15–25	18 (15–20.6)	–

Table 82. Contd.

Characters	Original description <i>C. heimi</i> & <i>H. malabaricus</i> (Karandikar & Vittal, 1954)	Subsequent records	
		<i>C. heimi</i> Das (present study)	<i>C. travians</i> Das <i>et al.</i> (2000)
Breadth of nucleus	15-25	14.5 (11.2–16)	–
Length of campanula	–	18.7	–
Campanula in maximum width	–	26.2	–
Length of rostrum	7-10 ^a ; 11-16 ^b	7	–
Height of apical cap	–	3.8	–
Length of 1st type of flagella	–	7–8	–
Length of 2nd type of flagella	–	18-19	–
Length of 3rd type of flagella	8	–	–

Remarks : Unlike apically placed campanula of *P. cardiformis* and obliquely placed campanula of *P. pisciformis*, campanula of *P. subapicalis* is distinctly subapical. In original description of *P. subapicalis* Karandikar and Vittal (1954) stated that "campanula region of this species can not be seen in its longitudinal axis in permanent preparation." That is why they could not take the measurements of the maximum width of campanula and height of apical cap. But the present author could fix few specimens and make their permanent preparation with great difficulty arresting the campanula in its longitudinal axis and there by he could get mensural data of various parts of the body as presented in Table 82.

Family TERATONYMPHIDAE Koidzumi, 1921

1921. Teratonymphidae Koidzumi, *Parasitology*, 13 : 303.

Diagnosis : Large hypermastigids; anterior end of the body highly differentiated having a rostral tube; body regularly ridged transversely giving it a segmented appearance; each ridge encircled by a flagellar band; no connection present between these bands; single vesicular nucleus enclosed in a nuclear sac fixed to the body wall and base of the head lying at the first apparent segment of the body; characteristic nucleus-supporting strands 14-16 in number, lying just outside the nuclear sleeve and adhering to it from the base of the rostrum to mid-portion of the nucleus.

Remarks : This family is monotypic having only one genus *Teranympha* Koidzumi.

Genus *Teranympha* Koidzumi, 1917

1917. *Teranympha* Koidzumi, An. Rep. Inst. Sci., Govt. Formosa, 6 : 93.
 1916. *Metameronympha* Koidzumi, An. Rep. Inst. Sci., Govt. Formosa, 5 : 63.
 1916. *Cyclonympha* Dogiel, Zh. Microbiol., 4 : 47.
 1921. *Teratonympha* Koidzumi, Parasitology, 13 : 260.
 1938. *Teranympha* : Cleveland, Arch. Protistenkd., 91 : 442.

Diagnosis : As for the family Teratonymphidae.

Remarks : In a paper published in Japanese, Koidzumi (1917) erected a genus of termite flagellates and named it as *Teranympha*. In his subsequent paper published in English in 1921 he corrected this generic name as *Teratonympha*. Such correction is not acceptable in the International Code of Zoological Nomenclature. Therefore, *Teranympha* remains the current valid name. Koidzumi (1916) and Dogiel (1916) established the genera *Metameronympha* and *Cyclonympha* respectively. Both the genera have been synonymised under *Teranympha* (see Cleveland., 1938a).

Cleveland (1938a) presented a detail morphological account and taxonomic status of the genus *Teranympha* which differs markedly from all known hypermastigids by its segmented appearance and in having 16-24 incontinous spiral bands without any connection among them. Moreover, presence of 14-16 nucleus-supporting strands are also characteristic for this genus.

The genus *Teranympha* is also monotypic having a single species *Teranympha mirabilis*. This species has so far been reported from the termite hosts belonging to the genus *Reticulitermes*.

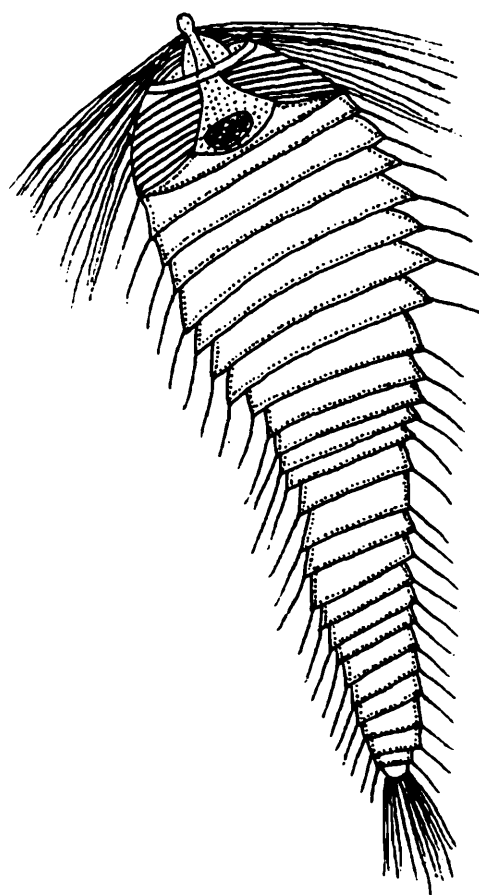


Fig. 136 : *Teranympha mirabilis* Koidzumi

93. *Teranympha mirabilis* Koidzumi, 1917

(Fig. 136)

1917. *Teranympha mirabilis* Koidzumi, Ann. Rep. Inst. Sci., Govt. Formosa, 6 : 93.
 1916. *Metameronympha monstrosa* Koidzumi, Ann. Rep. Inst. Sci. Govt. Formosa, 5 : 79.

1916. *Cyclonympha strobila* Dogiel, Zh. Microbiol., 4 : 47.
1921. *Teratonympha mirabilis* Koidzumi, Parasitology, 13 : 261.
1921. *Teratonympha mirabilis* var. *formosana* Koidzumi, Parasitology, 13 : 267.
1995. *Teranympha mirabilis* : Das, Mandal, Tiwari and Sarkar, Fauna of Meghalaya, State Fauna Series, 4(Part 10) : 90. Zool. Surv. India.
2003. *Teranympha mirabilis* : Das, Tiwari and Sarkar, Fauna of Sikkim, State Fauna Series, 9(Part 5) : 33. Zool. Surv. India.
- 2006a. *Teranympha mirabilis* : Das, Tiwari and Sarkar, Fauna of Nagaland, State Fauna Series, 12 : 36. Zool. Surv. India.
- 2006b. *Teranympha mirabilis* : Das, Nandi and Chattopadhyay, Fauna of Arunachal Pradesh, State Fauna Series, 13(Part 2) : 32. Zool. Surv. India.

Type host : *Reticulitermes speratus* (= *Leucotermes speratus*); loc., Japan.

Additional hosts : *Reticulitermes assamensis*; loc., India : Meghalaya, Sikkim and Nagaland; *Reticulitermes tirapi*; loc., India : Arunachal Pradesh.

Diagnosis : Body large, usually club-shaped, divided into rostral and post-rostral regions; body widest at about one-fourth distance from anterior end, then tapering gradually towards the posterior end; rostrum not covered with any apical cap; rostral flagella lying at the periphery of the rostral tube and encircling the rostrum; post-rostral region of the body provided with more or less prominent and sharp transverse ridges giving the body a segmented appearance; number of ridges varying from 16-30, sometimes more; flagella shortest anteriorly and longest posteriorly; body encircled with 16-24 flagellar bands without having any connection amongst them; nucleus single, oval, located at anterior end near the first flagellar band and lying in nuclear sleeve having characteristic nucleus supporting strands as detailed in its family diagnosis.

Morphometry (Table 83) :

Table 83. Comparative morphometric data of *Teranympha mirabilis* as recorded by different workers (measurements in μm)

Characters	Koidzumi (1921)	Cleveland (1938)	Indian specimens	
			<i>R. assamensis</i> (present study)	<i>R. tirapi</i> (present study)
Body length	200-250, also 300	136 (90-275)	142 (102-233)	156 (130-180)
Body width	40-50	74 (31-158)	41.2 (38-70)	51 (45-68)
Ratio of body length to body width (average)	5 : 1	1.7 : 1	2.8 : 1	3 : 1

Table 83. *Contd.*

Characters	Koidzumi (1921)	Cleveland (1938)	Indian specimens	
			<i>R. assamensis</i> (present study)	<i>R. tirapi</i> (present study)
Diameter of nucleus	10	20 (16-24)	9.2-13.5	8-12
Number of segments	18-30	—	16-30	15-25
Length of longer flagella	20-25	20	18-20	18-20

Remarks : Specimens of *Teranympha mirabilis* collected by various workers from different localities exhibit considerable variability in morphometry, particularly in body dimensions and length-breadth ratio (Table 83). Yet, all of them possessed characteristic body shape with segmented appearance, unconnected flagellar bands and nucleus with characteristic nucleus supporting strands.

Family TRICHONYMPHIDAE Kent, 1880

1980. Trichonymphidae Kent, *A manual of Infusoria*, London, David Bogue, Vol. 2 : 551.

Diagnosis : Body divisible into three regions : rostrum, flagella bearing region behind the rostrum and nonflagellated posterior region; rostrum separated by a fissure; campanular area lacking; flagella covering the body in longitudinal rows.

Key to the genera of the family Trichonymphidae reported from Indian termites

1. Rostrum simple, without apical cap, anterior part of the body not differentiated into inner and outer layer of cytoplasm, a bundle of protoplasmic threads running from the nucleus towards the posterior end of the body Genus *Protrichonympha*
- Rostrum with anterior cap, anterior part of the body differentiated into inner and outer layer of cytoplasm; parabasal apparatus composed of numerous cords located at anterior region, bundle of post-nuclear protoplasmic threads as above lacking ...
..... Genus *Trichonympha*

Genus *Protrichonympha* Saleem, 1952

1952. *Protrichonympha* Saleem, *Proc. Pakistan Sci. Conf.*, 4 : 45.

1955. *Protrichonympha* : Saleem, *Biologia*, 1 : 35.

Diagnosis : Rostrum simple and devoid of apical cap; no deeply stained cytoplasmic sheath round the rostrum; anterior part of the body not differentiated into inner and outer layers of ectoplasm; posterior tip of the body without flagella; two wavy protoplasmic threads joining the nucleus with rostrum; a bundle of protoplasmic threads (the axostyle) running from nucleus towards the posterior end of the body.

Remarks : It is a monotypic genus with one species, viz., *Protrichonympha pristina*.

94. *Protrichonympha pristina* (Imms, 1919) Saleem, 1952
(Figs. 137-138)

1919. *Trichonympha pristina* Imms, *Phil. Trans. Roy. Soc. London (B)*, 209 : 130.

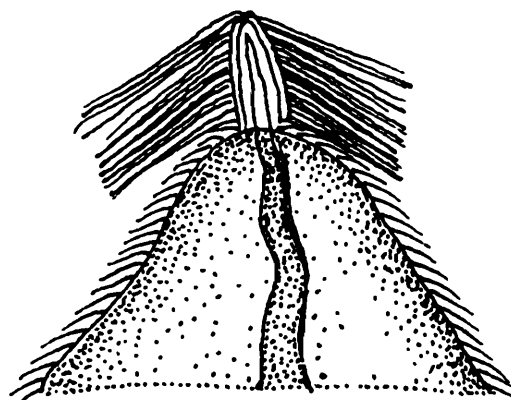
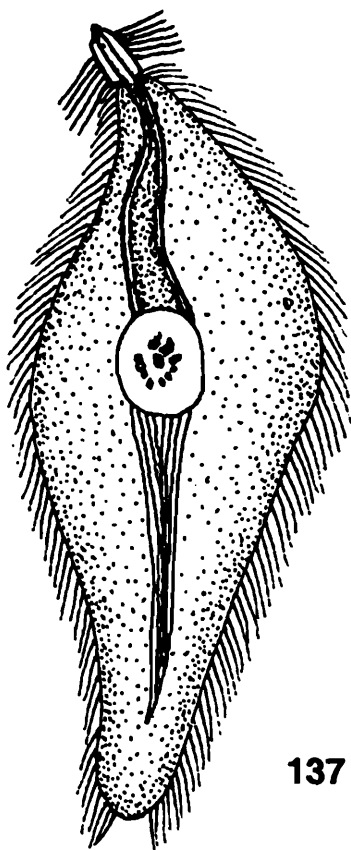
1921. *Pseudotriconympha pristina* Cutler, *Quart. J. Micr. Sci.*, 65 : 247.

1952. *Protrichonympha pristina* Saleem, *Proc. Pakistan Sci. Conf.*, 4 : 45.

1955. *Protrichonympha pristina* : Saleem, *Biologia*, 1 : 5.

Type host : *Archotermopsis wroughtoni*; loc., India : North-Western Himalaya ("Punjab"); also in Pakistan.

Diagnosis : General shape of the body spindle-shaped but sometimes oval; anterior end of the body modified into a rostrum and separated from the body proper by a notch; rostrum without any apical cap; whole of the body covered with flagella, excepting the very short posterior region; flagella of the rostrum slightly longer than the body flagella; flagellar bands running longitudinally over the surface of the body; nucleus ovoid and rounded and situated a little anterior to the centre of the body; two thread-like and wavy protoplasmic structures coming out of the rostrum and joining the nucleus; "a bundle of protoplasmic threads" (the axostyle) attached to the posterior side of the nucleus, gradually tapering and extending up to the posterior end of the body.



Figs. 137-138 : *Protrichonympha pristina* (Imms). **Fig. 137.** Entire individual; **Fig. 138.** Anterior third (after Saleem, 1955)

Morphometry (Table 84) :

Table 84. Mensural data of *Protrichonympha pristina*

Characters	From <i>Archotermopsis wroughtoni</i>
Length of the body	151.3 (116.6–208.2) μm
Width of the body	54.6 (33.3–83.3) μm
Ratio of body length to body width (average)	2.7 : 1
Length of nucleus	21.7 (16–24) μm
Breadth of the nucleus	17.6 (16–20) μm
Length of rostral flagella	8–20 μm
Length of body flagella	8–16 μm

Remarks : Imms (1919) was the first to describe this species under the name *Trichonympha pristina* from the termite, *Archotermopsis wroughtoni* from North-Western Himalaya. After obtaining a live stock of this termite host from Imms, Cutler (1919, 1921) made detailed studies of its gut dwelling flagellates and placed *Trichonympha pristina* under *Pseudotriconympha pristina*. Subsequently Saleem (1952, 1955) also examined this flagellate species from the same termite host and created a new genus *Protrichonympha* to accommodate this flagellate species under it. The genus *Protrichonympha* differs from the genus *Trichonympha* in having rostrum without any apical cap and ectoplasmic sheath around it. Moreover, it lacks parabasal apparatus and, instead, possesses two wavy protoplasmic threads in a prenuclear region and a bundle of protoplasmic threads (axostyle) in the post-nuclear region. Illustrations provided by Saleem (1955) show that length and distribution of its body flagella, leaving a very short glabrous portion at the posterior most region of the body resemble those of *Pseudotriconympha*. But, characteristic wavy protoplasmic threads in the prenuclear region and the axostyle in the postnuclear region clearly differentiate the genus *Protrichonympha* from the genus *Pseudotriconympha*.

Genus *Trichonympha* Leidy, 1877

1877. *Trichonympha* Leidy, Proc. Acad. Nat. Sci. Phila., 29 : 147.
 1910. *Gymnonympha* Dobell, Spol. Zeylan., 7 : 80.
 1919. *Leidyopsis* Kofoid and Swezy, Univ. Calif. Publ. Zool., 20, 99.
 1891. ?*Leidyonella* Frenzel, Arch. Mikroskop. Anat., 38 : 302.
 1932. *Trichonympha* : Kirby, Univ. Calif. Publ. Zool., 37 : 441.

Diagnosis : Relatively large hypermastigote flagellates; body divisible into three regions : rostrum with anterior cap, flagella bearing region behind the rostrum and nonflagellated

posterior region; first two regions excepting the apical cap covered with flagella in longitudinal rows; flagellated region varying in extent from less than a third to more than two thirds in body length; flagella arising at the posterior limit of the flagellated region longest, extending beyond the end of the body; rostrum separated by a fissure extending inward to rostral tube; blepharoplast a hemispherical granule at anterior end of the rostral tube in the base of cap; parabasal apparatus composed of numerous cords in endoplasm of anterior region often touching or forming basket around nucleus, sometimes free from it; nucleus single and located near the region between flagellated and nonflagellated parts of the body.

Key to the species of *Trichonympha* recorded from Indian termites

1. Prenuclear zone with a collar and granular sac *T. fletcheri*
- Prenuclear zone without any collar and granular sac 2
2. Parabasal apparatus not visible or described 3
- Characteristic parabasal apparatus present 4
3. Parabasal apparatus not visible, body typically sac-like, rostrum small, length in centre 5 μm , length of the body 70–80 μm *T. gujarathensis*
- Parabasal apparatus not described, body more or less slender, rostrum large, length in centre 13–15 μm , length of the body 120–264 μm *T. turkestanica*
4. Body spindle shaped, parabasal cords slender embracing the posterior part of nucleus, occasionally extending below nucleus, flagellated region one-third to half the length of the body *T. agilis*
- Body elongated, truncated posteriorly, a notch visible just below the flagellated region of the body, slender parabasal cords extending up to or above nucleus, flagellated region less than one-third the length of the body *T. meghalayensis*

95. *Trichonympha agilis* Leidy, 1877 (Figs. 139-140)

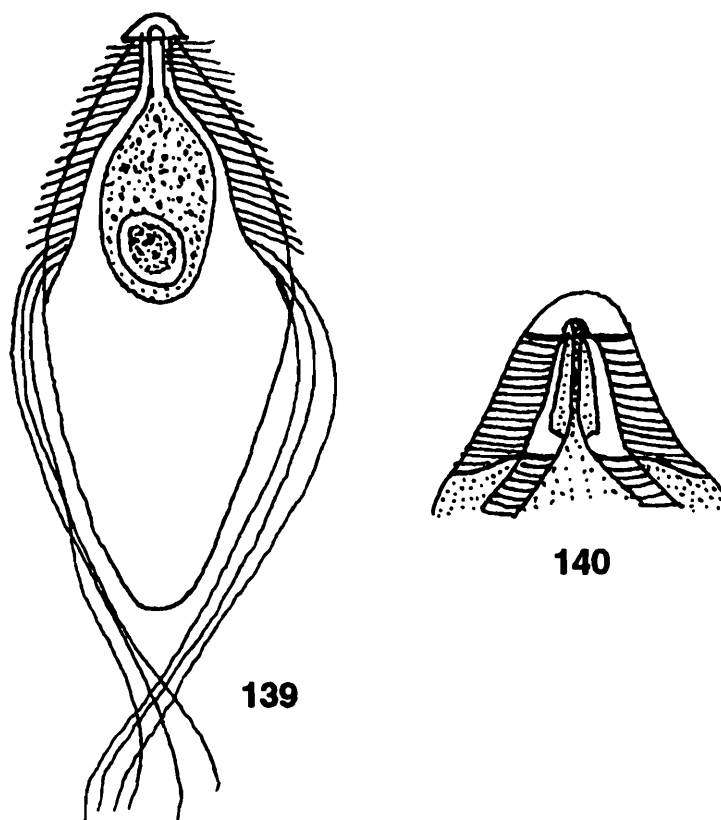
1877. *Trichonympha agilis* Leidy, *Proc. Acad. Nat. Sci.*, 29 : 147.
1916. *Trichonympha agilis* var. *formosana* Koidzumi, *Ann. Rep. Inst. Sci. Govt. Formosa*, 5 : 77.
1916. *Trichonympha agilis* var. *japonica* Koidzumi, *Ann. Rep. Inst. Sci. Govt. Formosa*, 5 : 69.
1930. *Trichonympha serbica* Georgevitch, *C. R. Soc. Biol.*, 1 : 326.
1932. *Trichonympha agilis* : Kirby, *Univ. Calif. Publ. Zool.*, 37 : 406.
1995. *Trichonympha agilis* : Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series*, 4(Part 10) : 91. *Zool. Surv. India*.

2003. *Trichonympha agilis* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series, 9(Part 5) : 34. Zool. Surv. India.*
- 2006a. *Trichonympha agilis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series, 12 : 36. Zool. Surv. India.*
- 2006b. *Trichonympha agilis* : Das, Nandi and Chattopadhyay, *Fauna of Arunachal Pradesh, State Fauna Series, 13(Part 2) : 32. Zool. Surv. India.*

Type host : *Reticulitermes flavipes* (= *Termes flavipes*).

Additional hosts : *Reticulitermes assamensis*; loc., India : Meghalaya, Nagaland, Sikkim; *Reticulitermes fukienensis*; *Reticulitermes hesperus*; *Reticulitermes lucifugus*; *Reticulitermes lucifugus* var. *santonensis*; *Reticulitermes speratus*; *Reticulitermes tibialis*; *Reticulitermes tirapi*; loc., India : Arunachal Pradesh; *Reticulitermes virginicus*.

Diagnosis : Body more or less spindle-shaped or oval; flagellated region occupying about one-third to half the length of the body; flagella on rostrum mostly uniform in length and those beyond the rostrum gradually increasing in length to longest ones extending in a twisted fasciculus with divergent ends beyond the end of the body; peripheral granules absent; parabasal apparatus bowl-shaped comprising of numerous slender separate cords embracing the posterior part of nucleus and occasionally extending beyond nucleus; nucleus spheroidal or ellipsoidal, situated near or just beyond the posterior end of flagellated zone of the body.



Figs. 139-140 : *Trichonympha agilis* Leidy. **Fig. 139** : Entire individual; **Fig. 140** : Anterior region, showing rostrum

Morphometry (Table 85) :**Table 85.** Mensural data of *Trichonympha agilis*

Characters	Specimens from outside India (Kirby, 1932)	Indian specimens Das (1995) and present study
Length of the body	76 (55–115) μm	75 (40–110) μm
Breadth of the body	32 (22–45) μm	31 (20–46) μm
Ratio of body length to body width (average)	2.4 : 1	2.4 : 1
Length of nucleus	10 – 14 μm	8 – 12 μm
Breadth of nucleus	10 – 14 μm	8 – 12 μm
Rostrum : length in centre	9.5 – 12 μm	10 – 12 μm
Ratio of flagellated-non- flagellated region (average)	0.64 : 1	0.66 : 1

Remarks : As early as 1877 *Trichonympha agilis* was described by Leidy from the gut of *Reticulitermes flavipes*. Since then, this flagellate species has been recovered from eight additional species of termite hosts, all belonging to the genus *Reticulitermes*. Kirby (1932) studied *T. agilis* in details and recorded the mensural data of this species as presented in Table 85. Das *et al.* (1995) were the first to record *T. agilis* from Indian termites belonging to *Reticulitermes assamensis* collected from Meghalaya. Morphometry of these Indian specimens came very close to that of Kirby's forms as evident in Table 85. Das *et al.* (2006b) also collected this species from another host from India, *viz.*, *Reticulitermes tirapi*. Specimens collected from this host were slightly larger in dimensions, 79 (60 – 118) μm $\times$ 36 (27 – 50) μm and their average length-breadth ratio was 2.1 : 1. But they exhibited all the salient features of *T. agilis* including characteristic blepharoplasts.

96. *Trichonympha fletcheri* De Mello, 1942

1942. *Trichonympha fletcheri* De Mello, *Arqu. Esc. Med. Cirug. Nova Goa (A)* : 5 : 295.

1944. *Trichonympha fletcheri* : Kirby, *Univ. Calif. Publ. Zool.*, 49 : 194.

1983. *Trichonympha fletcheri* : Das, *Proc. Symp. Host Environ. zool. Surv. India* : 45.

Type host : *Anacanthotermes viarum* (= *Hodotermes viarum*), loc., India : Tamil Nadu.

Remarks : Diagnosis and morphometric data of *Trichonympha fletcheri* could not be included here because De Mello's publication (1942) concerning the description of this species is not available to the author. This species has not been collected by any worker since its original description by De Mello. In one of his publications Kirby (1944) mentioned

the name of this species referring De Mello's above work but he also did not provide diagnostic characters of this species. Das (1983) included *T. fletcheri* in the checklist of flagellate symbiotes of India consulting Kirby's above mentioned publication.

97. *Trichonympha gujarathensis* Uttangi, 1959
(Fig. 141)

1959. *Trichonympha gujarathensis* Uttangi, J. Karnatak Univ. Sci., 4 : 101.

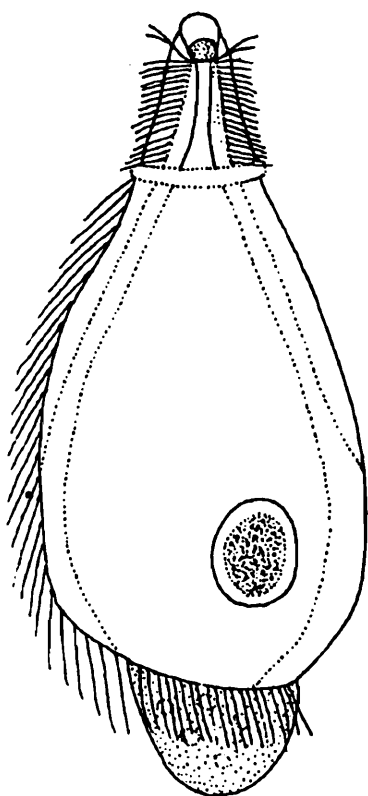
1983. *Trichonympha gujarathensis* : Das, Proc. Symp. Host Environ. zool. Surv. India : 45.

2004. *Trichonympha gujarathensis* : Das, Fauna of Gujara, State Fauna Series, 8(Part 2) : 423. Zool. Surv. India.

Type host : *Heterotermes indicola*; loc., India : Gujarat.

Diagnosis : Body "typically sac-like"; body divisible into rostral region, middle flagellated region and posterior non-flagellated glabrous area, no distinct campanular zone; rostral fissure distinctly visible at the junction of the rostral region and body; parabasal apparatus not visible; nucleus located towards the posterior end of the body.

Morphometry : Uttangi (1942) provided the mensural data of *Trichonympha gujarathensis* as follows : length 70–80 μm ; maximum width 30 μm ; width of glabrous region 20 μm ; rostral tube 8–10 μm and height of cap 3–4 μm .



Remarks : Taxonomic status of *Trichonympha gujarathensis* is quite uncertain. Uttangi (1959) accommodated this species under the genus *Trichonympha* mainly due to presence of rostral fissure and in absence of distinct campanular region. But, in this species parabasal apparatus which is very characteristic in *Trichonympha* (Kirby, 1932) is absent. Moreover, location of nucleus near the posterior end of the body is not the characteristic features of *Trichonympha*. Further to add that occurrence of *Trichonympha* in a rhinotermitid termites *Heterotermes indicola* is very doubtful and appears to be the result of incorrect identification as discussed by Das (1983) and further elaborated elsewhere in this communication.

Mention is to be made here that *T. gujarathensis* has not been collected till date since its first description by Uttangi (1959). Based on Uttangi's above publication Das (1983, 2004) incorporated this species in the checklist of flagellate symbiotes of Indian termites and in Gujarat State Fauna, published by ZSI.

Fig. 141 : *Trichonympha gujarathensis* Uttangi (after Uttangi, 1959); body flagella partly shown

98. *Trichonympha meghalayensis* Das, Mandal, Tiwari and Sarkar, 1995
(Fig. 142)

1995. *Trichonympha meghalayensis* Das, Mandal, Tiwari and Sarkar, *Fauna of Meghalaya, State Fauna Series*, 4(Part 10) : 91. *Zool. Surv. India*.
2003. *Trichonympha meghalayensis* : Das, Tiwari and Sarkar, *Fauna of Sikkim, State Fauna Series*, 9(Part 5) : 34. *Zool. Surv. India*.
- 2006a. *Trichonympha meghalayensis* : Das, Tiwari and Sarkar, *Fauna of Nagaland, State Fauna Series*, 12 : 37. *Zool. Surv. India*.

Type host : *Reticulitermes assamensis*; loc., India : Meghalaya (type locality), Nagaland and Sikkim.

Diagnosis : Body more or less elongated with truncated posterior end; usually a notch visible just behind the flagellated zone of the body; flagella of uniform length on the rostrum excepting just posterior to the apical cap where few shorter flagella present; posterior to rostrum, flagella increasing in length and those arising at the posterior limit of the flagellated region being the longest, sometimes extending beyond the posterior end of the body; flagellated zone occupying less than one-third the length of the body; parabasal apparatus distinct forming a bowl-shaped structure within which nucleus located; parabasal cords slender and numerous, extending up to or above nucleus; nucleus ovoidal, located near the posterior end of flagellated zone.

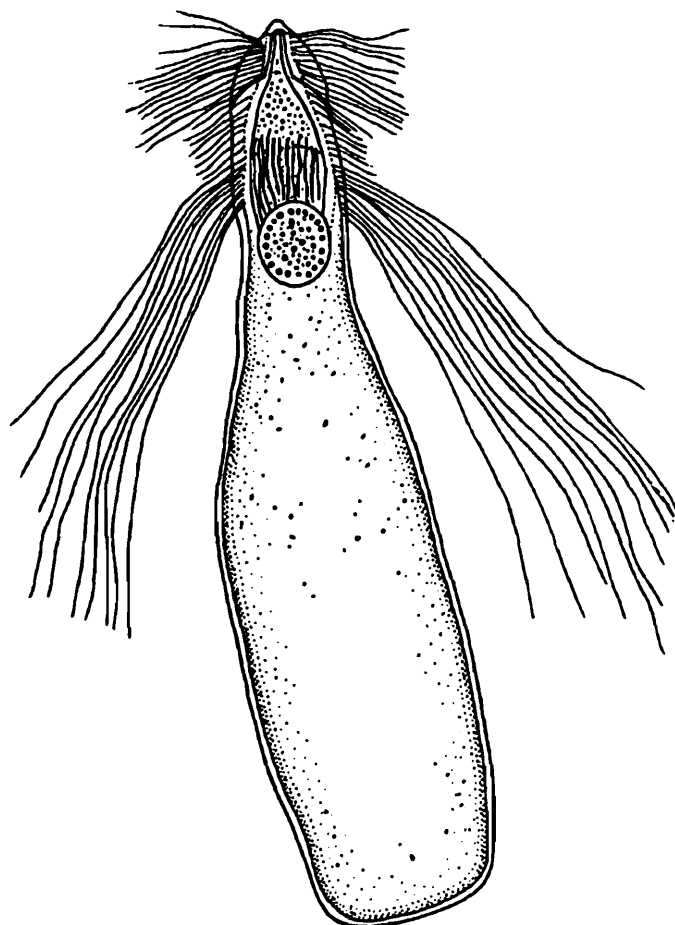


Fig. 142 : *Trichonympha meghalayensis* Das, Mandal, Tiwari & Sarkar

Morphometry (Table 86) :

Table 86. Mensural data of *Trichonympha meghalayensis*

Characters	From <i>R. assamensis</i> (Das <i>et al.</i> , 1995)
Length of the body	133.8 (98.1–148.7) μm
Breadth of the body	45.2 (29.6–59.2) μm
Ratio of body length to body width (average)	3 : 1

Table 86. Contd.

Characters	From <i>R. assamensis</i> (Das <i>et al.</i> , 1995)
Length of nucleus	12.6 (8.1 – 14.8) μm
Breadth of the nucleus	9.2 (7.2 – 12.9) μm
Rostrum : length in centre	7 – 7.5 μm
Ratio of flagellated non-flagellated region (average)	less than 0.66 : 1

Remarks : Das *et al.* (1995) described *Trichonympha meghalayensis* from the host *Reticulitermes assamensis* collected from Meghalaya. Later Das *et al.* (2003, 2006a) recovered this species from Sikkim and Nagaland, from the same host. Characteristic features of *T. meghalayensis*, such as, elongated body with truncated posterior end, presence of a notch just behind its flagellated zone, bowl-shaped parabasal body with parabasal cords not extending posterior end of nucleus and relatively short flagellated zone make it quite distinct from all the other species of *Trichonympha*.

99. *Trichonympha turkestanica* Bernstein, 1928
(Fig. 143)

1928. *Trichonympha turkestanica* Bernstein, *Arch. Protistenkd.*, 61 : 11.
 1932. *Trichonympha turkestanica* : Kirby, *Univ. Calif. Publ. Zool.*, 37 : 338.
 1937. *Trichonympha numidica* Duboscq, Grassé and Rose, *C. R. Acad. Sci. Paris*, 205 : 575.
 1944. *Trichonympha turkestanica* : Kirby, *Univ. Calif. Publ. Zool.*, 49.
 1960. *Trichonympha turkestanica* : Cleveland, *J. Protozool.*, 7 : 327.

Type host : *Anacanthotermes murgabicus*
(= *Hodotermes murgabicus*); loc., Turkestan.

Additional hosts : *Anacanthotermes macrocephalus*
(= *Hodotermes macrocephalus*); loc., India;
Anacanthotermes viarum (= *Hodotermes viarum*); loc., India.

Diagnosis : Body rather slender having average length-breadth ratio 2.6 : 1; flagella of rostrum and body equal in length; long flagella arising posteriorly; ratio of flagellated and nonflagellated region equal; parabasal apparatus unknown; nucleus situated at the middle of the body;

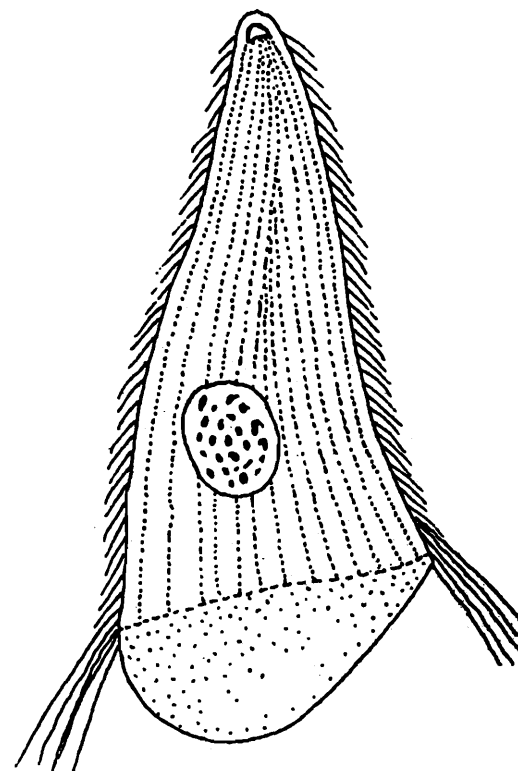


Fig. 143 : *Trichonympha turkestanica*
Bernstein

prenuclear endoplasmic inclusions small, numerous and spherical, stainable with iron-haematoxylin.

Morphometry (87) :

Table 87. Mensural data of *Trichonympha turkestanica*

Characters	<i>A. macrocephalus</i> (Kirby, 1932)	<i>A. murgabicus</i> (Bernstein, 1928)
Length of the body	192 (120–264) μm	140–250 μm
Breadth of the body	72 (43–115) μm	–
Ratio of body length to body width (average)	2.6 : 1	–
Rostrum : length in centre	13–15 μm	–
Ratio of flagellated and nonflagellated region (average)	1 : 1	–

Remarks : Bernstein (1928) described *Trichonympha turkestanica* from the termite host, *Anacanthotermes murgabicus*. He did not provide any mensural data of this species except its length as shown in Table 87. Kirby (1932) collected this flagellate species from some alcohol preserved specimens of India, belonging to *Anacanthotermes macrocephalus*, sent to him by Dr. Light (*vide* Kirby, *op. cit.*) and recorded the morphometry of its dimensions and other features as presented in Table 87. He also recorded the diameter at base cap as 11 μm and diameter at base collar as 22–24 μm .

Mention is to be made here that De Mello (1920a, 1920c) reported *Trichonympha agilis* from the host, *Anacanthotermes viarum* (= *Hodotermes viarum*), measuring 110–170 μm in length. According to Kirby (1932) De Mello's *Trichonympha* was considerably longer than *T. agilis* and fell within the range of *T. turkestanica*. Kirby (*op. cit.*) further stated that De Mello's species might have been similar to, if not identical with *T. turkestanica*. Till date *T. agilis* has been recovered only from the termite genus *Reticulitermes* and *T. turkestanica* from the termite genus *Anacanthotermes* (*vide* Yamin, 1979). These records firmly substantiate the above view of Kirby.

DISTRIBUTION AND HOST CORRELATION

It is now well established that in the guts of lower termites and wood roach, *Cryptocercus* presence of very large number of flagellates is obligatory. These flagellates help in digesting wood particles (cellulose) for their hosts with the aid of the enzyme cellulase present in them. This enzyme hydrolyses cellulose to cellobiose then, with the help of cellobiase to glucose which becomes ready food for their hosts. These hosts, in turn, offer shelter to the flagellates in complete anaerobic environment and ensure their food supply (Cleveland *et al.*, 1934). In the context of such true mutualism it is very important to analyse the distribution of these flagellates for assessing the degree of their host specificity.

As stated earlier, flagellate symbiotes of termites and wood roaches comprise of three orders, viz., Oxymonadida, Trichomonadida and Hypermastigida. Oxymonadida contains three families, Oxymonadidae, Pyrsonymphidae and Monocercomonoididae. The distribution of oxymonadid flagellates is presented in Table 88. The Table shows that all the three genera of the subfamily Oxymonadinae, viz., *Oxymonas*, *Barroella* and *Microrhopalodina* are exclusively found among the members of the termite family Kalotermitidae, excepting two species of *Oxymonas*, viz., *O. doroaxostylus* and *O. nana* which occur in wood roach *Cryptocercus*. On the other hand, the subfamily Saccinobaculinae is confined to the wood roaches excepting its two genera, *Opisthomitus* and *Sauromonas*. Interestingly, these two flagellate genera are distributed in Kalotermitidae only. The family Pyrsonymphidae comprises of three genera, viz., *Pyrsonympha*, *Dinenympha* and *Streblomastix*. Out of these, the first two genera with 13 species each are restricted to one termite genus *Reticulitermes*, belonging to the family Rhinotermitidae. While the third genus *Streblomastix* is monotypic and inhabits another lower termite family Termopsidae. However, oxymonadids belonging to the family Monocercomonoididae are widely distributed. Only one species of this family is found in wood roach and the remaining species in other invertebrates and vertebrates but none of them in lower termites.

Table 88. Distribution of oxymonadid flagellates (order Oxymonadida)

Family	Subfamily	Distribution
Oxymonadidae (8 genera, 50 species)	Oxymonadinae (3 genera, 38 species)	Lower termites (Kalotermitidae), except 2 spp., viz, <i>Oxymonas nana</i> and <i>O. doroaxostylus</i> , which occur in wood roach, <i>Cryptocercus</i>
	Saccinobaculinae (5 genera, 12 species)	Lower termites and wood roach; 3 genera, viz., <i>Notila</i> (2 spp.), <i>Paranotila</i> (1sp.) and <i>Saccinobaculus</i> (5 spp.) in wood roach and 2 genera, viz, <i>Sauromonas</i> (2 spp.) and <i>Opisthomitus</i> (2 spp.) in lower termites (Kalotermitidae)
Pyrsonymphidae (3 genera, 27 species)	—	Lower termites; 2 genera, viz., <i>Pyrsonympha</i> (13 spp.) and <i>Dinenympha</i> (13 spp.) in termite genus <i>Reticulitermes</i> (Rhinotermitidae) and one genus <i>Streblomastix</i> (1sp.) in termite <i>Zootermopsis</i> (Termopsidae)
Monocercomonoididae	—	One species, <i>Monocercomonoides globosus</i> in wood roach, none in lower termites and several species in other invertebrates and vertebrates

Distributional data of Oxymonadidae also reveal that out of 8 genera of this family 7 genera, viz, *Barroella*, *Microrhopalodina*, *Notila*, *Opisthomitus*, *Paranotila*, *Saccinobaculus* and *Sauromonas* (with 18 species) are found exclusively in a single host species. The remaining genus of this family, viz., *Oxymonas* is also mostly confined to a single species of host, because out of its 32 species only 8 species occur in 2-4 species of termite hosts while 24 species are found in single hosts species.

Order Trichomonadida includes 4 families, viz., Devescovichidae, Calonymphidae, Monocercomonadidae and Trichomonadidae, distribution of which is presented in Table 89.

Table 89. Distribution of trichomonadid flagellate (order Trichomonadida)

Family	Subfamily	Distribution
Devescovichidae (16 genera, 123 species)	Devescovichinae (14 genera, 112 species)	Lower termites; 9 genera in Kalotermitidae, 2 genera in Hodotermitidae, 1 genus in Mastotermitidae, 1 genus in both Kalotermitidae and Hodotermitidae and 1 genus in both Kalotermitidae and Mastotermitidae
	Gigantomonadinae (2 genera, 11 species)	Lower termites; 1 genus each in Kalotermitidae and Hodotermitidae
Calonymphidae (6 genera, 26 species)	—	Lower termites (Kalotermitidae)
Monocercomonadidae (3 genera, 17 species in lower termites)	Monocercomonadinae (3 genera, 17 species)	Lower termites (Kalotermitidae, Termopsidae, Hodotermitidae and one unidentified species of Rhinotermitidae); also in other invertebrates and vertebrates.
Trichomonadidae (5 genera, 20 species in lower termites)	Trichomonadinae (1 genus, 7 species)	Lower termites (Kalotermitidae, Hodotermitidae and Rhinotermitidae), also in vertebrates
	Trichomitopsiinae (2 genera, 6 species)	Lower termites (Kalotermitidae and Termopsidae)
	Tritrichomonadinae (1 genus, 5 species)	Lower termites (Kalotermitidae and Hodotermitidae); also in vertebrates
	Pentatrachomonadinae (1 genus, 2 species)	Lower termites (Kalotermitidae), also in vertebrates.

Family Devescovinidae consists of two subfamilies, Devescovininae and Gigantomonadinae. Devescovininae includes 14 genera, out of which 9 genera, viz., *Achemon*, *Astronympha*, *Bullanympa*, *Caduceia*, *Devescovina*, *Evemonia*, *Foaina*, *Hyperdevescovina* and *Parajoenia* with 83 species occur exclusively in Kalotermitidae. In addition, 21 out of 22 species of the genus *Metadevescovina* also occur in Kalotermitidae and the remaining species, viz., *Metadevescovina extranea* is found in Mastotermitidae. Out of the remaining 4 genera of Devescovininae, *Kirbynthia* (3 spp) and *Polymastigotoides* (1 sp) are found in Hodotermitidae, *Myxotricha* (1 sp) in Mastotermitidae and *Pseudodevescovina* in both Kalotermitidae and Hodotermitidae. The subfamily Gigantomonadinae contains 2 genera, *Gigantomonas* and *Macrotrichomonas*. The former is monotypic and distributed in Hodotermitidae and the latter with 10 species inhabits the guts of Kalotermitidae. From above, it is quite evident that amongst 123 species of the family Devescovinidae 115 species are restricted to Kalotermitidae leaving only 8 species of this flagellate group, of which 2 species occur in Mastotermitidae and 6 species in Hodotermitidae.

As far as species-wise host specificity of these devescovinids, there are contrasting situations. For example, *Foaina* includes 30 species, of which 16 are known from single host while 14 species have been recovered from 2 to 33 species of hosts. To mention a few, *Foaina nana*, *Foaina solita* and *Foaina reflexa* have been recorded from 33, 28 and 26 species of termite hosts under 1 to 8 genera. The same is also true for another wide-spread genus *Devescovina* which contains 30 species. Amongst these, 17 species are confined to a single host and the remaining ones from 2 to 17 species of hosts under 2 to 5 genera. Further to add that 4 monotypic genera of Devescovinidae, viz, *Achemon*, *Bullanympa*, *Myxotricha* and *Parajoenia* and all the species of the genera *Evemonia*, *Pseudodevescovina* and *Hyperdevescova* are also known so far from single host species.

Family Calonymphidae which appears to have been derived from the family Devescovinidae by polymerisation of mastigont structure (Fig. 144) is confined exclusively to the guts of Kalotermitidae. To the contrary, families Trichomonadidae and Monocercomonadidae are widely distributed. They inhabit not only in the guts of lower termites of the families Termopsidae, Kalotermitidae, Hodotermitidae and Rhinotermitidae but also in higher termites as well as in other invertebrates and vertebrates. Degree of host specificity of these flagellats also varies to a great extent as in previous cases. For example, the monocercomonadid flagellate, *Tricercomitus divergens* has been recorded from 28 host species under 9 genera and *Tricercomitus termopsides* from 4 species under 2 genera of Kalotermitidae. At the same time, 5 species of *Tricercomitus* are known only from a single host species. This is very important to note here that no flagellates of the order Trichomonadida occur in wood roach, *Cryptocercus*.

Order Hypermastigida is very much diverse and widely distributed. Excepting two species of *Lophomonas*, viz., *Lophomonas striata* and *Lophomonas blattarum* which are found in the guts of cockroaches, all other species of hypermastigid flagellates are confined to lower termites and the wood roach, *Cryptocercus* as shown in Table 90.

The Table 90 reveals that out of 12 families of Hypermastigida 6 families, *viz.*, Joeniidae, Kofoidiidae, Rhizonymphidae, Holomastigotidae, Spirotrichonymphidae and Teratonymphidae are restricted to lower termites, one family Lophomonadidae to the wood roach, *Cryptocercus* and cockroach and the remaining 5 families, *viz.*,

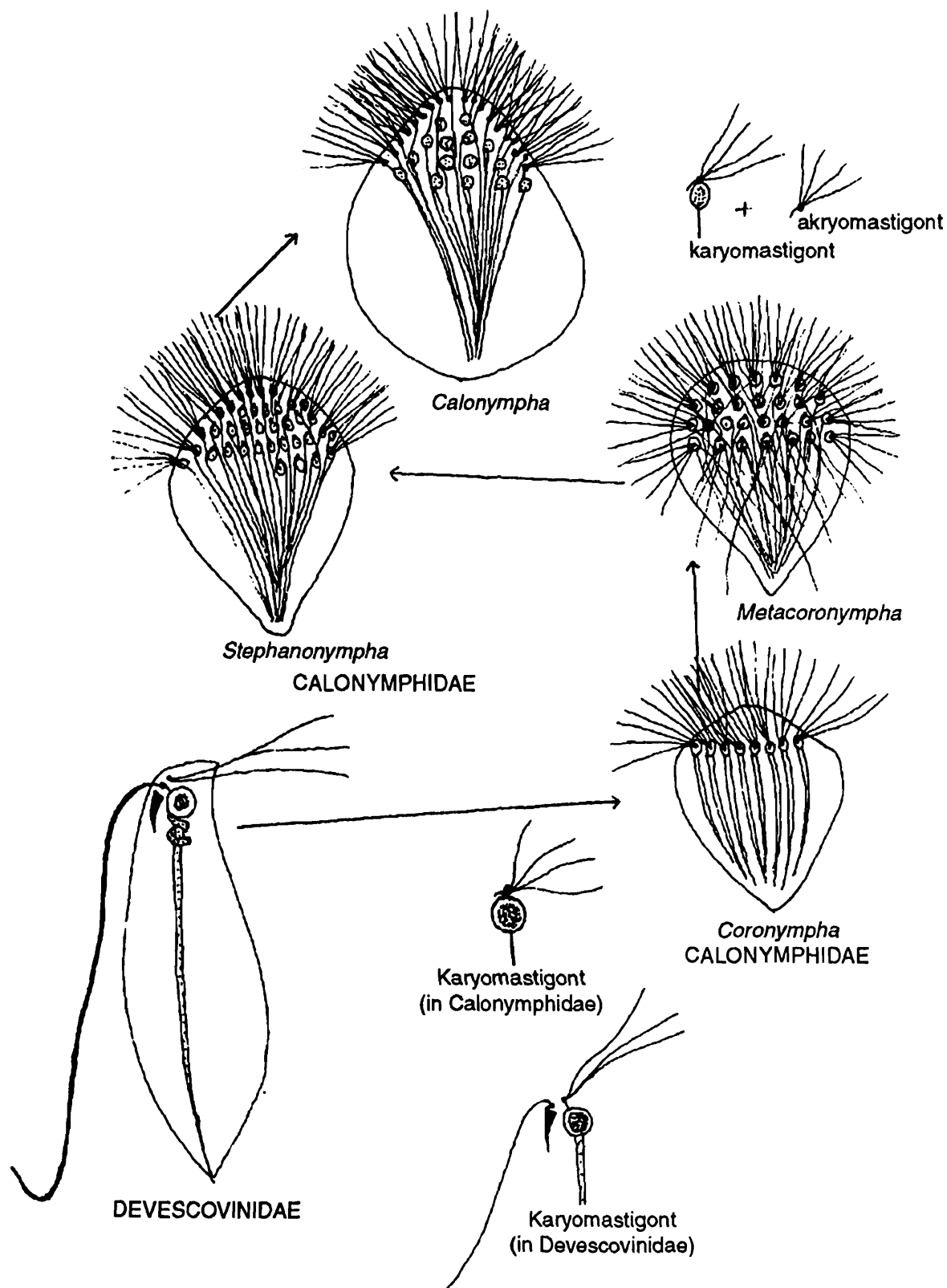


Fig.144 : Showing structural relationships amongst some genera in the family Calonymphidae and its suggested origin from the family Devescovichidae through polymerisation of mastigont structure

Eucomonymphidae, Hoplonymphidae, Spirotrichosomidae, Staurojoenidae and Trichonymphidae all belonging to the suborder Trichonymphina are distributed both in lower termites and wood roach.

Table 90. Distribution of hypermastigid flagellates (order Hypermastigida)

Suborder	Family	Distribution
Lophomonadina	Joeniidae (7 genera, 9 species)	Lower termites (Kalotermitidae, Termopsidae and Hodotermitidae)
	Kofoidiidae (1 genus, 1 species)	Lower termites (Kalotermitidae)
	Lophomonadidae (1 genus, 1 species in wood roach)	Genus <i>Prolophomonas</i> (with 1 species) in wood roach and genus <i>Lophomonas</i> (with 2 species) in cockroach
Spirotrichonymphina	Rhizonymphidae (1 genus, 1 species)	Lower termites (Hodotermitidae)
	Holomastigotidae (2 genera, 38 species)	Lower termites (Rhinotermitidae and Hodotermitidae)
	Spirotrichonymphidae (5 genera, 46 speceis)	Lower termites (Kalotermitidae, Termopsidae, Hodotermitidae and Rhinotermitidae)
Trichonymphina	Eucomonymphidae (2 genera, 19 species)	Genus <i>Eucomonympha</i> (with 2 spp) in wood roach and Genus <i>Pseudotrichonympha</i> (with 17 spp) in lower termites (Rhinotermitidae)
	Hoplonymphidae (4 genera, 8 species)	Genus <i>Hoplonympha</i> (with 1 sp) in lower termites (Kalotermitidae); 3 genera, viz., <i>Barbulanympha</i> (with 4 spp), <i>Rhynchonympha</i> (with 1sp.) and <i>Urinympha</i> (with 2 spp) in wood roach.
	Spirotrichosomidae (6 genera, 35 spp)	Genera <i>Bispironympha</i> (with 1sp), <i>Macrospironympha</i> (with 1sp) and part of <i>Leptospironympha</i> (6 out of 13 spp) in wood roach. Genera <i>Aspironympha</i> (with 4 spp), <i>Calospironympha</i> (with 3 spp), <i>Spirotrichosoma</i> (with 13 spp) and part of <i>Leptospironympha</i> (7 out of 13 spp) in lower termites (Termopsidae).

Table 90. Contd.

Suborder	Family	Distribution
	Staurojoenidae (2 genera, 5 species)	Genus <i>Staurojoenina</i> (4 spp) in lower termites (Kalotermitidae) and genus <i>Idionympha</i> (1sp) in wood roach
	Teratonymphidae (1 genus, 1 species)	Lower termites (in one genus, viz., <i>Reticulitermes</i> , of family Rhinotermitidae)
	Trichonymphidae (4 genera, 39 species)	Genera <i>Deltotrichonympha</i> (2 spp), <i>Koruga</i> (1sp), <i>Protrichonympha</i> (1sp) and part of <i>Trichonympha</i> (26 out of 36 spp) in lower termites (Kalotermitidae, Termopsidae, Hodotermitidae and Rhinotermitidae) Part of genus <i>Trichonympha</i> (10 out of 36 spp) in wood roach

Distributional data of flagellate symbiotes presented above reveal that their host specificity is not rigid. Rather, study of more and more termite hosts shows wider distribution of many flagellate species in different hosts. Nevertheless, it is also evident that distribution of flagellate symbiotes is not random. Several groups of these flagellates are found to be confined to some particular family and even in particular genus of termite hosts as shown in Tables 88 – 90. Few examples can also be cited in support of this. Bernstein (1928) described *Devescovina elongata* and *Stephanonympha dogieli* and, Kirby (1942) described *Foaina pectinata* from a hodotermitid genus *Anacanthotermes*. In a subsequent study Grassé and Hollande (1952) synonymised these species under *Polymastigoides elongata*, *Kirbynia dogieli* and *Kirbynia pectinata* respectively. This confirms that the genera *Devescovina*, *Foaina* and *Stephanonympha* occur only in Kalotermitidae not in any other termite family. Sometimes, assemblage of some flagellate species may aid in identifying their hosts. That is why, after a detailed study Kirby (1926) remarked "Dogiel (1917) describes *Calonympha strobila* from *Coptotermes* sp. of Japan. He also records *Dinenympha gracilis*, *Pyrsonympha vertens* and *Holomastigotes* sp. from this termite. Doubtless, he had *Reticulitermes* sp. probably *R. speratus*" From this statement it is evident that Kirby (*op. cit.*) was "doubtless" in identifying the host upto its generic level and could reach ultimately up to its species level by analysing the assemblage of flagellate species in the gut of termite host, mentioned above. It is worth mentioning here that identification of termite host from the assemblage of their flagellate symbiotes and *vice versa* may be possible only when accurate identification of these flagellates or their hosts is available.

Analysis of distributional data of flagellate symbiotes known so far from the globe clearly reveals several discrepancies in the taxonomic works of termite flagellates from India. De Mello and De Brito (1929b) described 3 species of *Devescovina*, viz. *D. cometoides*, *D. damanensis* (now synonymised under *D. lemniscata*) and *D. kirbyi* (now synonymised under *Foaina nana*) from a rhinotermitid termite, *Coptotermes heimi*. They (*op. cit.*) described a calonymphid flagellate, *Metastephanonympha perronciti* (now synonymised under *Stephanonympha perronciti*) from the same host. Occurrence of devescovinid and calonymphid flagellates in the gut of the above rhinotermitid host needs critical consideration because these groups of flagellates are exclusively restricted to kalotermitid termites as already discussed in details. The present author has examined the gut contents of large number of *Coptotermes heimi* and *Coptotermes travians*, collected from West Bengal, several states of North-east India, Sikkim, Andhra Pradesh and Andaman islands. But, he and several other Indian workers (Karandikar and Vittal, 1954; Uttangi, 1959 and Tiwari, 1988, 1992) had not observed any devescovinid or/and calonymphid flagellates in the gut of any *Coptotermes* sp. In light of above, it can be safely inferred that the above host species of De Mello and De Brito were wrongly identified and belonged to some kalotermitid termite (not rhinotermitid termite). This was also confessed by De Mello (1953) in one occasion.

Narain (1956 c) recorded 5 species of hypermastigid flagellates, viz., *Holomastigotoides hartmanni*, *Holomastigotes elongatum*, *Rhynchonympha tarda*, *Rostronympha magna* and *Microspironympha ovalis* from the gut of a higher termite, *Odontotermes assmuthi*, belonging to the family Termitidae. This work doubtless involves error in identification of both termite host and its flagellates. Because, occurrence of so many species of hypermastigids in large number in the gut of a higher termite is quite contrary to all the earlier findings as evident from the distributional data of this flagellate group presented earlier (Table 90). Moreover, presence of *Rhynchonympha tarda* in the guts of termites, that too, in higher termites is absolutely improbable because, this flagellate species is strictly confined to the wood roach, *Cryptocercus punctulatus*. Detailed studies of flagellate symbiotes throughout the globe also reveal that there is no flagellate species common to both termites and wood roach (see Yamin, 1979).

One of the Uttangi's contributions (1959) in this field wherein he recorded *Trichonympha gujarathensis* from the rhinotermitid termite, *Heterotermes indicola* needs scrutiny. So far 36 species of *Trichonympha* were reported from termites, including Uttangi's above *Trichonympha*. Kirby (1932a, 1937, 1949) made a detailed study and published a monographic account on the genus *Trichonympha*. His works and all subsequent studies reveal that except from the genus *Reticulitermes* which is unique as regard its flagellate symbiotes no other genus of Rhinotermitidae is found to harbour *Trichonympha*. On the other hand, the related genus *Pseudotrichonympha* is very common in *Heterotermes* as well as in other genera of Rhinotermitidae, excepting *Reticulitermes*. Thus, it is quite evident that in the present case identification of the host or the flagellate species was erroneous.

COEVOLUTION

The gut inhabiting flagellates of lower termites and the wingless wood roach, *Cryptocercus* are outstanding material for studying coevolution between them and their hosts because :

- i) These flagellates bear true symbiotic relationship with their hosts,
- ii) their transmission from one host species to another follows phylatic lines as discussed later,
- iii) their association with the hosts is not random as already discussed in details and
- iv) circumstances under which this host symbiote association has developed are very much favourable for consideration of their concomitant phylogeny.

Transmission of symbiotes

In termites transmission of flagellates from host to host in the same termite colony is effected only by the anal feeding of termites. Young termites and nymphs of various age lick off anal excreta containing flagellates and get them in their gut. However, at the time of each moult excepting at the time of the last one all or most of their gut flagellates die and are eliminated together with the old intima of their gut. As soon as the moult is completed nymphs regain their flagellates by proctodeal feeding from non-moulting nymphs. The situation is different during the final moult when imago is released (Grassé and Noirot, 1959). Flagellate population becomes greatly reduced in the final nymph about to moult, retaining only a representative sample of the whole set of flagellate species within the sac-like intima. These flagellates are subsequently released into the gut of the imago on rupture of this intima.

But, mode of transmission of flagellates in *Cryptocercus* is different from that in lower termites. At the time of moult, *Cryptocercus* releases the hormone ecdysone which initiates sexual reproduction of their flagellates. During the process of sexual reproduction these flagellates produce cysts and pseudocysts which are discharged into external medium at the time of moulting of their hosts (Cleveland *et al.*, 1934). The young roaches hatched from eggs become infected with the flagellates by devouring the cysts with wood particles. From above it is evident that in *Cryptocercus* transmission of flagellates usually occur at the time of moulting whereas in lower termites it may occur by means of anal droplets between moults and after the final moult.

Uniform assemblage of symbiotes in host species

It has already been discussed in details that all the species of termite flagellates are not host specific. Many of them are distributed in several host genera and species. But, detailed studies of Kirby (1947) revealed that each species of lower termites possesses an uniform assemblage of symbiotic flagellates irrespective of their geographic isolation and zoogeographic associations (Kirby, 1937). However, in some cases members of a particular

colony of termites may lack one or two species of flagellates (Kirby, 1947) due to the reason that the parental pair of termites which formed that colony had missed that/those species at the time of their final moult and they could not get sufficient time to regain those flagellates from other non-moulting nymphs through proctodeal feeding. Because, these parental pair left that colony immediately after their release as winged imago. Such occurrence and distribution of flagellate symbiotes are very important for explaining their evolutionary pathways in guts of lower termites.

Possibility of cross transmission of flagellates between inter-host termite species

Under experimental conditions flagellates can be transferred from one termite host species to another provided those hosts are systematically related (Dropkin 1941, 1946). But, in nature such cross transmission is quite improbable because of the distribution pattern and of the mechanism of transfer among the termites within a colony and from one colony to another. Further, if such cross infection occurs at all it must occur during the last nymphal stage so that flagellates such acquired will be of significance in the faunal assemblage in a new colony, since flagellates present in earlier stages are lost at the time of moult. In view of this, possibility of such cross infection of flagellates in the final nymph and their survival through the winged imago is very remote. If it occurs, the possibility is further remote that the infected imago would be one which established a new colony and transmitted those flagellates to the offspring of the pair. Even then, if such cross infection occurs crossing all the above mentioned barriers it will not disturb the phylogentic pattern because it may occur only between nearly related termites. It is, therefore, quite probable that the lower termites could acquire flagellates from other termites only in the line of descent. That is why the symbiotes are favourably used as indicators of the phylogeny of termites. Moreover, concomitant studies of symbiotes and their hosts provide a sound basis for studying their phylogeny.

Evolutionary pathways of flagellates of termites and roaches

Based on taxonomic information Cleveland *et al.* (1934) inferred that systematic similarity between flagellate symbiotes of lower termites and the wingless wood roach, *Cryptocercus* is a mere reflection of phylogentic relation of their hosts. This view is now well established through subsequent taxonomic works on these flagellates.

Most entomologists maintain that Isoptera (termites) descended directly from the stem of Blattellidae (roaches) in the late Palaeozoic or early Mesozoic (Emerson, 1955, 1971). A detailed comparison of the morphology of the most primitive representatives of orders Isoptera and Blattellidae, viz., *Mastotermes darwiniensis* and *Cryptocercus punctulatus* respectively reveals that they are similar in organisation (Mc. Kittrick, 1965 and Krishna, 1970) and possess similar symbiotic bacteria in their guts (Grassé and Noirot, 1959). Immunological studies of the intestinal contents of the roach, *Cryptocercus punctulatus* and the termite *Zootermopsis nevadensis* also show a number of similar antigens (Albin and Ritter, 1976). Moreover, both lower termites and *Cryptocercus* harbour preponderant number of closely related flagellates in their guts. All these findings lead to the inference that the

contemporary relict roaches, *Cryptocercus* are the surviving representatives of the stem of Blattoidea from which termites diverged and that their common ancestors, the blattoids are the primary host of these flagellates so also their direct descendent *Cryptocercus*. On the other hand, lower termites acquired these flagellates only secondarily. Under the circumstances the systematic resemblance between the flagellates of *Cryptocercus* and lower termites may be regarded as a consequence of parallel evolution of the hosts and their symbiotes. Therefore, it is of great interest to trace whether parallel evolution between the hosts and their symbiotes are retained in the course of subsequent separate evolution of flagellates in lower termites as well as in *Cryptocercus*. Das (1990) dealt with this aspect in details by analysing phylogenetic scheme of *Cryptocercus* and lower termites and, distribution of a hypermastigid flagellate *Trichonympha* along different branches of that scheme.

The genus *Trichonympha* was chosen for this purpose primarily in view of the fact that :

i) This genus is common to symbiotic fauna of both termites and roaches and is widespread among its hosts.

ii) This genus includes 35 species (excluding the doubtful record of *Trichonympha* by Uttangi, 1959 from the host *Heterotermes*), of which 10 species occur in all the living species of the wood roach *Cryptocercus* studied so far and 25 species occur in all the families of lower termites with the exception of Mastotermitidae. The family Mastotermitidae has only one living species, *Mastotermes darwiniensis* with very restricted distribution in Australia only. Absence of *Trichonympha* in Mastotermitidae can be explained by considering that *Trichonympha* might have been present in the extinct genera of the above termite family but it became accidentally absent from the parental pair of the ancestral form of the only surviving genus *Mastotermes* during the course of evolution.

3. The difference between the *Trichonympha* species is very distinct.

Table 91. Comparison of *Trichonympha* spp. as well as other symbiotic flagellates occurring in different species of wood roaches, *Cryptocercus* spp. (after Bobyleva, 1979, Yamin, 1979)

<i>Cryptocercus punctulatus</i> (Appalachian and Pacific area)	<i>Cryptocercus relictus</i> (Soviet Far East)
Order Hypermastigida <i>Trichonympha acuta</i> , <i>T. algoa</i> , <i>T. chula</i> , <i>T. grandis</i> , <i>T. lata</i> , <i>T. okolona</i> , <i>T. parva</i> <i>Urinympha talea</i> <i>Barbulanympha clevelandi</i> , <i>B. estaboga</i> , <i>B. laurabuda</i> , <i>B. ufuala</i> , <i>B. wenyoni</i> <i>Uconympha imla</i>	 <i>Trichonympha lutea</i> , <i>T. major</i> . <i>T. ussuriensis</i> <i>Urinympha cirrata</i> <i>Barbulanympha cryptocerci</i> <i>Bispironympha unica</i> , <i>Uconympha nana</i>

Table 91. Contd.

<i>Cryptocercus punctulatus</i> (Applachian and Pacific area)	<i>Cryptocercus relictus</i> (Soviet Far East)
<i>Leptospironympha eupora</i> , <i>L. rudis</i> , <i>L. wachula</i>	<i>Leptospironympha lepida</i> , <i>L. popularis</i> , <i>L. variabilis</i>
<i>Idionympha perissa</i>	—
<i>Macrospironympha xylopletha</i>	—
<i>Prolophomonas tocopola</i>	—
<i>Rhynoconympha tarda</i>	—
Order Oxymonadida	
<i>Notila proteus</i>	<i>Notila proteus ussuriensis</i>
<i>Oxymonas nana</i> , <i>O. doroaxostylus</i>	<i>Oxymonas nana ussuriensis</i>
<i>Saccinobaculus ambloaxostylus</i> , <i>S. lata</i>	<i>Saccinobaculus gloriosus</i> , <i>S. scabiosus</i> , <i>S. spatiatius</i>
<i>Paranotila lata</i>	—
<i>Monocercomonoides globus</i>	—

Table 91 shows that distribution of *Trichonympha* is strictly host specific in both the living species of wood roaches. It also reveals that *Trichonympha* which inhabited the gut of Tertiary *Cryptocercus* diverged strictly in parallel to the speciation of their hosts. In other words, a distinct parallel evolution of Tertiary *Cryptocercus* and their *Trichonympha* species has taken place.

On the other hand, after analysing the distribution of *Trichonympha* species in accordance with the phylogram of termites drawn by Krishna (1970) (Fig.145) two stages of their combined evolution can be clearly demarcated. During the first stage when termites differentiated from Palaeozoic roaches and diverged into families in early Mesozoic, parallel evolution of termites and their *Trichonympha* species occurred. This evolutionary parallelism was discontinued at the second stage of their evolution when phylogenetic differentiation of termites into subfamilies and genera took place in late Cretaceous (Emerson, 1955, 1971 and Krishna, 1970).

This view can be further substantiated by analysing the distribution of 25 species of *Trichonympha* in lower termites (Yamin, 1979; Das *et al.*, 1995). It reveals that host specificity of *Trichonympha* species is restricted to its host genera but not to its host species, excepting three, viz., *T. chattoni*, *T. corbula* and *T. zeylanica* which are found to inhabit more than one host genus. Such distribution of *Trichonympha* may be explained by considering that when a single species of this genus inhabits a number of related genera of termites (e. g., *T. chattoni* occurs in the host genera *Glyptotermes*, *Incisitermes* and *Rugitermes*) it must have been present in the gut of common ancestors of those genera. But, when a *Trichonympha*

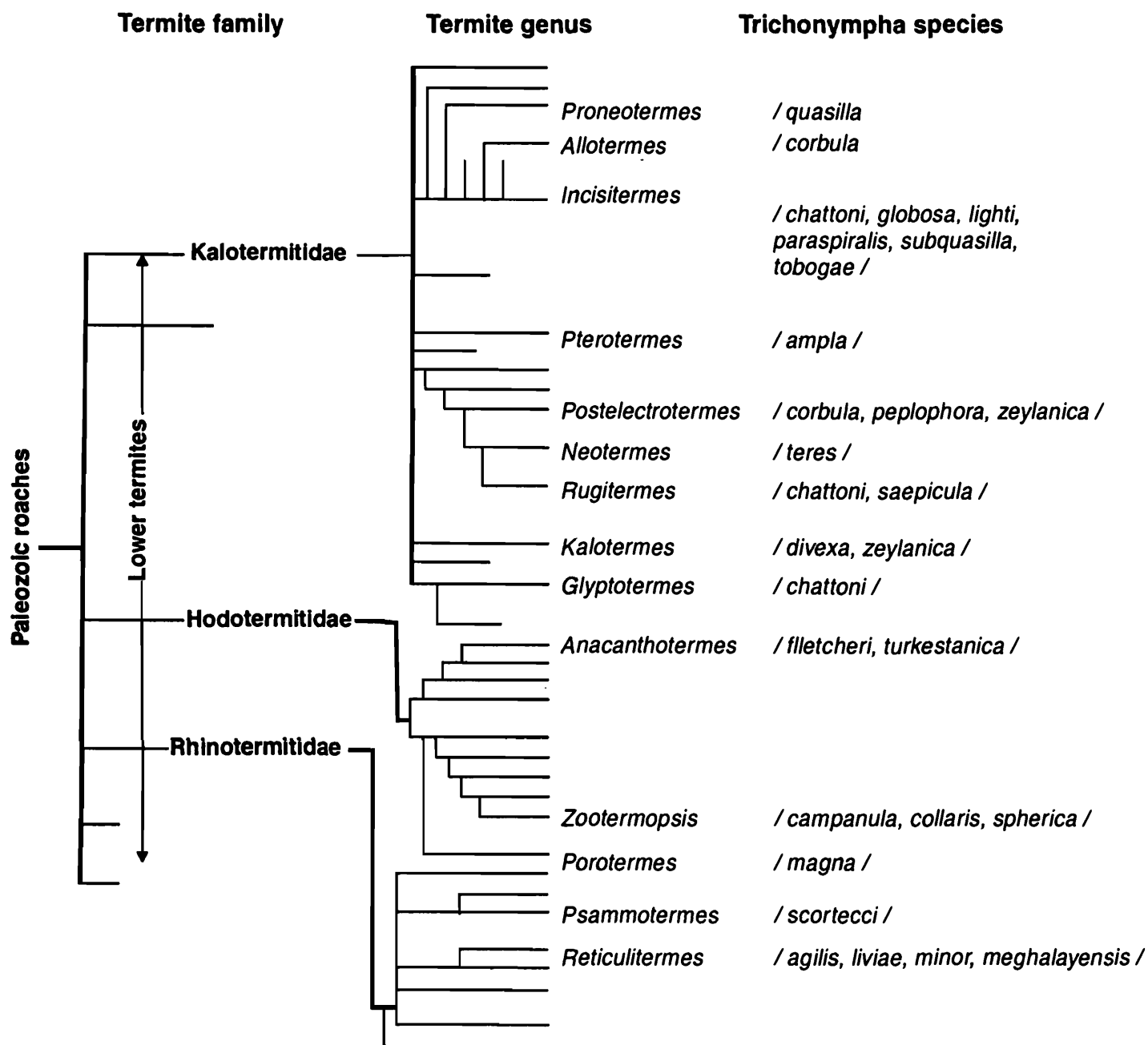


Fig. 145 : Phylogram of lower termites (as per Krishna, 1970) containing only the families and the genera, inhabited by *Trichonympha* species

species is apparently specific to one host genus (see Fig. 145) it must have been present in the ancestral form of that genus before it is differentiated to various host species. Several other genera of hypermastigids also, e. g., *Holomastigotoides*, *Leptospironympha*, *Pseudotrichonympha* and *Spirotrichonympha* provide examples of reciprocal flagellate-host phylogeny in roaches and lower termites.

Amongst oxymonadid flagellates the family Oxymonadidae occur in the host families Cryptocercidae and Kalotermitidae and those of the family Pyrsonymphidae are confined to one host genus *Reticulitermes* of the family Rhinotermitidae and another host genus *Zootermopsis* of the family Termopsidae. Absence oxymonodid flagellates from other genera of the families Rhinotermitidae and Termopsidae as well as from other families of lower

termites excepting above two families may perhaps be the result of extinction of the species and genera of both flagellates and ancestral termites (Emerson, 1971).

The trichomonadid flagellates, more particularly the family Devescovichidae inhabit all the genera of Kalotermitidae, 4 out of 6 genera of Hodotermitidae studied so far and the only living species of the family Mastotermitidae. Thus, they also exhibit reciprocal phylogeny in the genera of the aforesaid families of lower termites. Interestingly, these flagellates are not found in Rhinotermitidae and Cryptocercidae. Therefore, it is quite probable that these flagellates occurred in ancestral termites which diverged from roaches and subsequently became extinct in Rhinotermitidae in the course of their evolution.

Flagellates of woodroach, *Cryptocercus* undergo sexual reproduction. But termite flagellates have lost the ancestral ability to produce sexually. It is well known that sexual recombination is more effective as a cause of speciation than asexual reproduction because the former is the source of genetic variation. Therefore, loss of sexual reproduction in the life cycle of termite flagellates may be treated as an important factor for their restricted evolutionary change as traced in the genus *Trichonympha*. Since 429 species of flagellates have been reported so far from 210 species of lower termites and many more species of flagellates are expected to be collected from the remaining host species it can perhaps be safely inferred that loss of sexuality in termite flagellates has a limited effect on the systematic differentiation *vis-a-vis* evolution. On the other hand, polymerisation (Kirby, 1949) and in limited case polyploidy (Cleveland and Day, 1958) are related to the systematic differentiation of asexually reproducing termite flagellates.

In Trichomonadida the family Calonymphidae appears clearly to have evolved from the family Devescovichidae through polymerisation of mastigont structure (Fig. 144). Polymerisation of mastigont system has also taken place in Oxymonadida, more particularly in one of its subfamily Oxymonadinae in ways comparable to that in Calonymphidae although the former is not related to the latter. In Oxymonadinae genus *Oxymonas* is monomonad whereas genera *Microrhopolodina* and *Barroella* are polymoned. In the former, there is a circle of nucleated mastigont (Figs. 1-2) (as in the genus *Stepheononympha* in Calonymphidae) and in the latter nucleus become separated spatially from mastigont structures (as in the genus *Snyderella* in Calonymphidae).

In termite inhabiting Hypermastigida polymerisation has also occurred but not in the same manner as found in the families Oxymonadidae and Calonymphidae. In both these families mastigonts, each of which possesses 2 to 4 flagella, an axostyle and a parabasal body associated with a nucleus have been duplicated as unit. On the other hand in hypermastigids number of nucleus normally remains single even after polymerisation but there has been an increase in the number of individual organelles (Fig. 146) associated with the spindle pole at division (Kirby, 1949). In one genus of hypermastigids, *viz.*, *Spirotrichosoma* which occurs in the gut of the termite *Stolotermes ruficeps* polyploid series of species have been reported by Cleveland and Day (1958).

From the foregoing discussion it is quite evident that distinct parallelism in the evolution of hosts and their symbiotes occurred throughout the evolutionary period of the wood

roach *Cryptocercus*. But, in termites such evolutionary parallelism occurred only up to their differentiation in family level. This was gradually discontinued when they started differentiating into subfamilies and genera as evident in Fig. 145. The prime factors for this "evolutionary inertness" may be that i) the environment in which these flagellates live

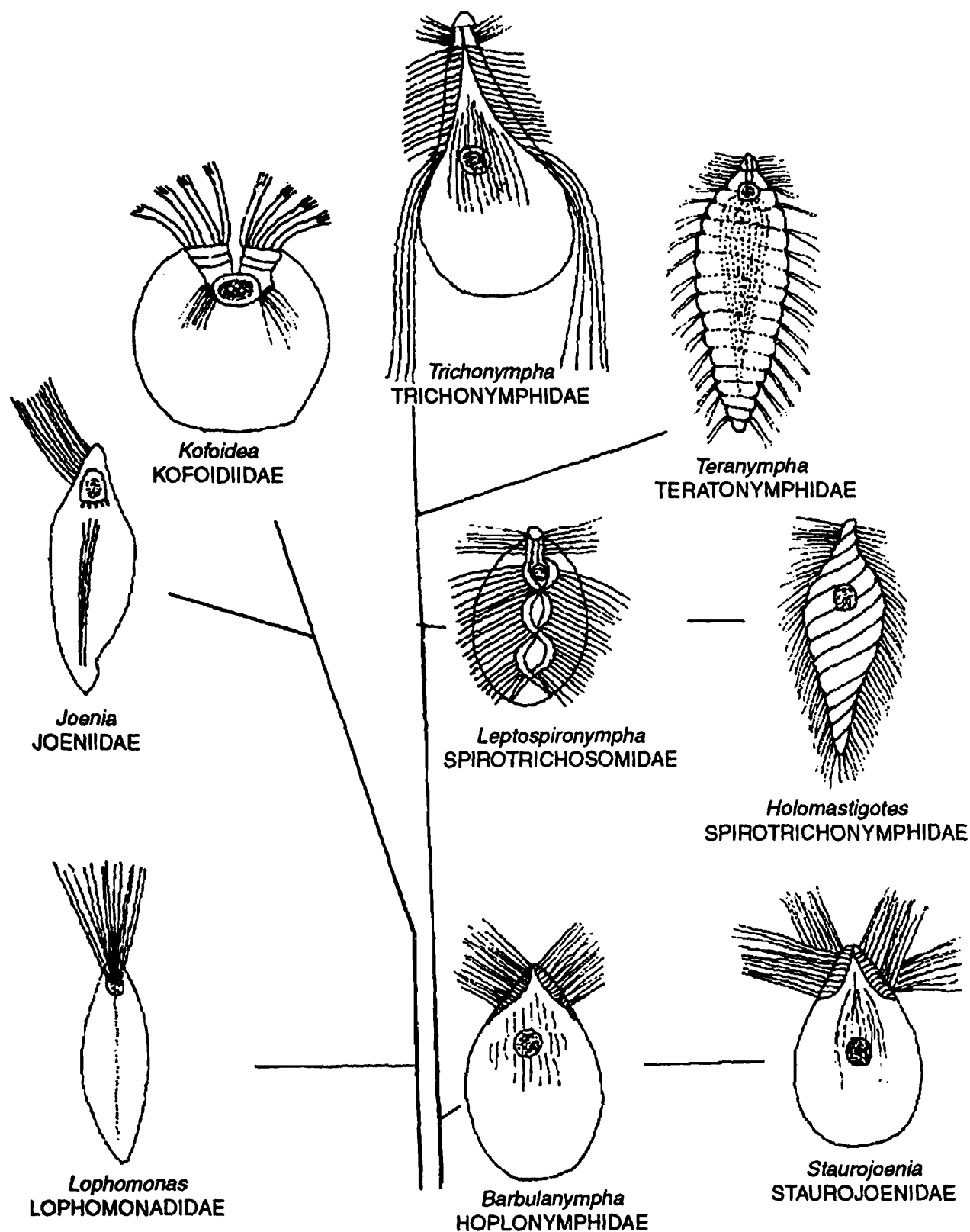


Fig. 146 : Showing structural relationships amongst some families in the order Hypermastigida (after Kirby, 1949)

is closely comparable from host to host and that ii) they have been living in extremely sheltered anaerobic intestinal environment for an estimated 200 million years or more without any necessity to search for food or face any predator. Moreover, their termite hosts have also evolved buffer against the environmental change through social behaviour which controls the homeostatic physical and biotic factors of their nests. Therefore, there seemed to be no factor of different nature in the environment that could be supposed to act selectively on flagellates. As a probable result, genera and species of flagellate symbiotes have remained stable for a very long period.

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SUMMARY

Innumerable flagellates of diversified taxonomic groups are invariably present in the guts of lower termites (*i.e.*, termites of the families Mastotermitidae, Kalotermitidae, Termopsidae, Hodotermitidae, Rhinotermitidae, Stylotermitidae and Serritermitidae) as they bear a true symbiotic relationship with their hosts. These flagellates help in digesting wood particles (cellulose) for their termite hosts and the hosts, in turn, offer shelter to these flagellates in complete anaerobic condition inside their gut and ensure their food supply. Keeping such host-symbiote relationship under consideration, 210 species of lower termites have been studied throughout the globe for their gut dwelling flagellates and 429 species of these symbiotes have been collected. From the two species of wood roaches belonging to the genus *Cryptocercus*, 29 species of flagellate symbiotes have also been recovered.

Till date, 99 species and 6 varieties of flagellate symbiotes under 24 genera, 12 families and 3 orders have been recorded from India from 19 species of termite hosts, belonging to the families Kalotermitidae, Termopsidae, Hodotermitidae and Rhinotermitidae. The present monograph deals with a comprehensive taxonomic account of all these flagellate species and assesses their current taxonomic status in light of all available information and current studies on this group. While dealing with the taxonomic account of each species, its synonymy, references of all Indian works as well as other most relevant works, type host with type locality and all additional hosts known so far from the globe have been incorporated. Scientific name of the host as used by the author of each species along with its current valid name, if needed, has also been given. Current valid names of each additional hosts have also been included for the convenience of future workers of these flagellates. Diagnostic characters and first reference of all the orders, suborders, families,

subfamilies, genera and species of the termite flagellates of India as well as their keys are given for the aid in their identification.

In the present monograph, distribution and host correlation of these flagellates are also discussed at length in the global perspective :

- i) to find out host specificity of these flagellates, if any;
- ii) to analyse Indian works on this group for assessing discrepancies, if any and
- iii) to elaborate their coevolution with the hosts.

In the present work it is made ample clear that host specificity of these flagellates is not rigid but, at the same time, their distribution is not random. Several groups of flagellates, for example, families Oxymonadidae, Devescovinidae and Calonymphidae are found to be confined to some particular families of termites. Certain other groups, for example, genera *Dinenympha* and *Pyrsonympha* are restricted to a particular host genus, *Reticulitermes* (family Rhinotermitidae). There are also some flagellate groups like some hypermastigid genus, e.g., *Trichonympha* and some trichomonadid genus, e. g., *Trichomonas* which are not only widely distributed in different families of termites but also in other invertebrates.

Analysis of distributional data of termite flagellates of the world reveals several discrepancies in some taxonomic works of flagellate symbiotes of Indian termites. These are primarily due to (i) incorrect identification of termite hosts, (ii) incorrect identification and inadequate description of flagellate symbiotes and (iii) lack of proper understanding regarding host-symbiote assemblage. Analysing some works of De Mello and his associates (1919–1949), Narain (1956a,b,c) and Uttangi (1959) all the above aspects have been discussed in details with probable inferences.

Coevolution of flagellate symbiotes and their hosts has also been dealt with in the present work by analysing relevant taxonomic, palaeontological and immunological works as well as host-symbiote assemblage and mode of flagellate transmission in termites and wood roaches. Analysis of the probable pathway of this coevolution reveals a distinct parallelism in the evolution of hosts and their symbiotes throughout the evolutionary period of wood roach, *Cryptocercus*. Such parallelism was followed by termites and their symbiotes also only up to the differentiation in the family level of the hosts. But, this parallelism was gradually discontinued when termites started differentiating into subfamilies and genera as shown in a phylogram. The prime factor for discontinuation of such parallelism is probably an "evolutionary inertness" of these flagellates. Such situation might have arisen as these flagellates have been living in an uniform and sheltered anaerobic intestinal environment in their hosts for an estimated 200 million years or more without any necessity to search for food or face predators. Add to this, their termite hosts have also evolved buffer against the environmental change through their social behaviour that controls the homeostatic physical and biotic factors of their nests. Consequently, there seemed to be no factor of different nature in the environment which could act selectively on flagellates. Probably for this reason, genera and species of the flagellate symbiotes have remained stable for a very long period.

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