TAXONOMIC STUDIES ON SELECTED SPECIES OF COLLEMBOLA FROM NORTH-EAST INDIA

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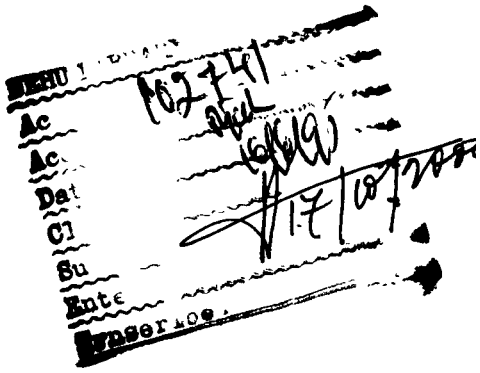

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This is to certify that the thesis entitled *"Taxonomic studies on selected species of Collembola from North-East India"*, submitted by Mr. Ranit Kumar Bhattacharjee for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong (India), embodies the record of original investigations carried out under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of Ph.D. degree. This work has not been submitted for any Degree of any other University.

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DEDICATED TO
MY
P·A·R·E·N·T·S

A C K N O W L E D G E M E N T

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FOREWORD

Collembola or Springtails are apterous, ametabolous insects primarily found in soils. It is interesting to note that the oldest known fossil record of insects is a Collembole Rhyniella praecursor that lived during mid Devonian period about 350 million years ago. These insects occur in diverse ecological habitatsviz. leaf litter , decaying vegetables, moss, bark of trees, mounds of ants and termites, and nest of rodents. They have even been reported from glaciers, snowclad mountains, caves and water surface. The adaptive plasticity of these insects have made them interesting material to the taxonomists for studying animal form and functions and on the other hand to the ecologists trying to study interactions and responses of animals to biotic and abiotic factors (Choudhuri, 1960,1963a,b; Roy, 1973,1974; Prabhoo, 1976). Physiologists attempted to relate insect hormones, pheromones (Verhoef,1984) and neuroendocrine system of Collembola to establish phylogeny (Tyszkiewiez, 1977). To an evolutionary biologist, Collembola, specially the cavernicolous forms have proved to be ideal material to study microgeographic evolution as the same species in different caves exhibits series of forms independent of each other from primitive to advanced type creating 'clines' within each cave system (Christiansen and Culver, 1968). Importance of Collembola to agricultural scientists is from the role they play in soil formation and litter decomposition or energy flow of soil

(Balaguer, 1982). Many forms e.g. Sminthurus viridis (Lucernae flea) have been found to be pests.

New species or new forms of Collembola are being described almost every day (over 6000 species now) from different parts of the world. However, many species described by earlier workers have later on turned out to be synonyms of some other species. Morphotaxonomists are thus handicapped and look for some perfectly nonadaptive criteria for species separation/identification. But as White (1973) has pointed out 'speciation is a slow and gradual process', and we must not forget that we are dealing with living entities, the basic requirement of which is of course plasticity - we wonder if perfect or stable characters do exist in a species. But surely everything is not closed and our problem of synonomy or homonomy can be resolved to some extent by interdisciplinary investigations like cytotaxonomy which collect chromosomal information within a given material and after due evaluation correlates these findings with morphotaxonomy. In course of time it has proved to be an additional tool in the repertory of taxonomists.

We have undertaken in our laboratory a survey of the Collembola fauna of North-East India specially the State of Meghalaya ("Abode of Clouds"), which with its rich evergreen forest and water resources, and a high relative humidity

is expected to harbour a rich and diverse fauna of springtails (Bhattacharjee, 1984,1985; Bhattacharjee and Chatterjee, 1989). In our pursuit we have made a combined approach of morpho- and cytotaxonomy and the results are described under two separate sections as follows:

Section A : Morphotaxonomic Study

This includes detailed notes on morphotaxonomic characters with illustrations, comparison of all related species, report of and key to new species and new records.

Section B : Cytotaxonomic Study

This section describes germ cell cytology of dominant species, karyotypes, meiotic behaviour and notes on sex chromosomes and accessory chromosomes. We have also attempted to suggest possible karyotype interrelationships among major families of Collembola. These findings have been correlated in a third section (Section C : Concluding Remarks) and a brief report has been made on the use of another additional tool viz. Scanning Electron Microscopy for elucidation of morphological characters.

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* Original not seen

[....] Translated version in English

SECTION A

MORPHOTAXONOMY

1 INTRODUCTION

Taxonomy is the science of classification endeavouring to reflect possible phylogenetic relationship and affinities among different living beings. Taxonomists provide descriptions which enable biologists to identify readily the specimens they may collect and in doing so they mainly depend on morphological characters even though internal anatomy, behaviour, physiology or cytology of the organisms might provide additional information to their identity. Characters on which classification of a particular animal group is based need not be similar and often controversies arise among "taxonomists" regarding the relative importance of some taxonomic character. A difference between two populations may be an absolute one with little or no overlapping between the two groups or it may be only a matter of average values (Smith, 1962). Taxonomic characters should serve double purposes, viz. a) indicate intraspecific similarities, and b) interspecific dissimilarities. The extent to which these similarities/dissimilarities are found in a species are somewhat dependent on their habitat. However, the 'unit of taxonomic grouping', i.e. 'species' have two attributes: 1) some degree of structural differences and 2) reproductive isolation, the latter being primary according to Mayr (1969). Thus structural differences (similarities/dissimilarities) are to be judged through reproductive isolation which acts

as a check to controversial visible and morphological indistinctiveness between individuals. Simpson (1929) opines that distinctive characters for species separation need not be great but must be a 'constant one', eg. colour of apex of coiled shell whether pink or white in ornate snail Liguus or plumage colour of some birds. It is quite clear from the foregoing statements that there is always an element of individual subjective judgement to regard what are "distinctive characters" for a particular species (Moody, 1964). Stebbins (1970) mentions the necessity to hold a "test of sympatry" for readily separable species as "they do not exchange genes with each other or do so to a limited extent" due to reproductive isolation. Since speciation is a slow and gradual process, different populations of the same species might differ in adaptive and visible characteristic but intergrade in intermediate environment giving rise to "races" and "subspecies". In any taxonomic studies observation of such "races" or subspecies" is quite common.

Combining various points mentioned earlier it can be summarized that all "species" must stand the "test of sympatry" and possess distinctive, constant but non-adaptive structural differences among themselves.

"Collembola" or springtails belong to the primitive wingless insects or "Apterygota". Rhyniella praecursor, a Collembola, that lived during middle Devonian period about 350 m. years ago is the oldest known fossil record of any insect (Moore et. al. 1952).

The order "Collembola" Lubbock, 1862 (GK. Coll = glue, embola = peg or wedge) is sometimes regarded as an intermediate between Insecta and Myriapoda. These are wingless microarthropods (maximum size varies around 5 mm) possessing entognathous mouth parts, simple eyes or ocelli, 4 to 6 segmented antennae, 6 segmented abdomen (might be fused giving almost a globular shape as in suborder Symphypleona), with 3 pairs of appendages viz. a ventral tube or collophore (on segment I), retinaculum (on segment III) and a furcula or spring organ (may be vestigeal, on segment IV/V). Distribution of Collembola is world wide in all zoogeographical realms with a possible northern subtropical primary origin somewhere in South Europe or Asia (Salmon, 1949).

Collembola represent one of the most abundant soil microarthropods ranging 5,000 to 50,000 per sq. meter. They inhabit diverse biotopes like soil, leaf litters decaying vegetables, moss and bark. They have also been reported from the nests of rodents (Hrivnak, 1983), mounds of ants and termites, surface of fresh or salt water

(Prabhoo, 1970, Christiansen and Bellinger, 1988), glaciers of snowclad mountains (Baijal, 1955a,b, 1958) and caves in various parts of the world (Christiansen, 1982; Yosii, 1988).

The various parameters used in Collembolan taxonomy are size and shape of the body, coloration or color patterns on the body, food habit, mouth parts, relative proportion of body segments, antennae and parts of furcula, number of eyes or ocelli, structure of claw, presence or absence of spring organ and clothing of head, body and appendages in the form of scales, scaly setae and setae with their various modifications including bothriotrichia, lasiotrichia, micro and macrochaetae (flexed, clavate, plain, ciliated or serrated types). Macrochaetal pattern on head, body and appendages of Collembola are very unique and species-specific in nature and are being recently used extensively not only for species separation but for phylogenetic studies (Yosii, 1961, 1962; Szepteki, 1967, 1979, Snider, 1967, Cassagnau, 1974, and most recently Andre, 1988). However, "chaetotaxy" has to be verified in the light of the phenotypic plasticity including ecomorphosis, cyclomorphosis and epitoky (Cassagnau, 1971; Fjellberg, 1976, 1977).

The order Collembola Lubbock, 1862, originally included only two families Papiriidae and Anuridae.

Börner (1901) divided Collembola (order) into two suborders Arthropleona and Symphypleona and in 1913 further sub divided Arthropleona into two sections viz. (a) Poduromorpha and (b) Entomobryomorpha including in all 11 families under the order Collembola (Brues et. al., 1954). This classification was followed by many taxonomists including Gisin (1960) and Gama, (1961, 1964.) Salmon (1964) regrouped Arthropleona into 3 suborders viz. Arthropleona, Neoarthropleona and Metaxypleona mainly basing on shape of head, body segments and mouth parts. According to recent classification (Cassagnau, 1981 and Bellinger, 1985) the order Collembola consists of 3 suborders viz. (a) Arthropleona with 2 sections (i) Poduromorpha including 4 families, (ii) Entomobryomorpha with 8 families; (b) Symphypleona including 7 families; and (c) Neelipleona with a single family Neelidae (Table I). Thus, the total number of families is 20 (Cassagnau, 1981, Bellinger, 1985) including 752 genera (Ellis and Bellinger, 1973, 1984) and over 6000 species. From India about 431 species have been reported so far, of which only 41 species (including the present work) come from North-Eastern India (Table II).

Review of literature on Collembolan systematics indicate description of a number of new species, genera, subfamilies and families along with some revisional works

upgrading earlier taxonomic placement. Some of the leading "springtail" taxonomists of the world with significant contributions to their credit are Imms (India, Burma and Ceylon Collembola, 1912), Stach (Poland Collembola in relation to world fauna, Isotomidae 1947, Sminthuridae 1956, Collembola of Afghanistan 1960, 1963, China 1964 and North Vietnam 1965), Salmon (Revision of Onychiuridae 1959 and Index to Collembola 1964), Yosii (Critical Study of genera Hypogastrura (1960, 1962), Lobella, Lepidocyrtus and Callyntrura in Collembola of Thailand, 1961a, Isotoma and allies 1963, Afghanistan 1966d, Himalaya and Khumbu Himal 1966e and 1971 and Cavernicolous forms of Japan 1964, 1967), Christiansen (Cave Collembola 1960, 1982), Gisin (Collembola of Europe, 1960), Murphy (British Collembola 1960), Gama (Collembola of Portugal 1961, 1964, and monograph of Isotomodes 1963), Nosek (Collembola of Czechoslovakia 1962), Choudhuri (Revision of Bagnall's Onychiuridae 1963c), Massoud (family Neanuridae and Neelidae 1967), Martynova (Collembola of Middle Asia and U.S.S.R. 1968), Richards (World distribution, Classification and Evolution of Sminthuridae 1968), Mitra (Revision of genera Salina and Callyntrura 1973a, 1974), Marimutt (Revision and World distribution of sub-family Orchesellinae 1976-1988), Lee (Collembola of Korea 1977, 1983), Cassagnau (Neanurid Collembola, 1982).

Furthermore, comparatively recent works of Gama (Phylogeny and Evolution of Xenylla and Pseudosinella of the world 1984, 1986 and 1988), Bellinger (A new family Coenaletidae 1985), Yosii (Paronellids of South East Asia, 1985 and Cave Collembola of South and Central America, 1988) and Christiansen and Bellinger (Marine littoral Collembola of North and Central America, 1988) are of great significance to Collembolan morphotaxonomy.

Systematics of Indian Collembola dates back to Ritter, (1911). Imms (1912) recorded 27 new species and 4 new genera viz. Heteromuricus, Dicranocentroides, Idomurus and Pseudocyphoderus from oriental region. Carpenter (1917, 1924) reported new genus Cyphoderopsis and a new species from Rotung, Arunachal Pradesh and 4 new species from Garo Hills. Bonet (1930) reported 4 new species from Bandra, Bombay. Handschin (1929) and Denis (1936, 1947), reported altogether about 40 species from South India.

Collembola of North-West Himalaya specially the "Nival forms" have been extensively studied by Baijal and Singh (1954), Baijal (1955a,b, 1958 and 1966), Singh et al. (1956) and Mani and Singh (1961a,b). Baijal (1955a,b, 1958) described 16 new species and 2 new genera viz. Himalanura and Salmonia from Gramphu and Lahul Spiti, Great Himalaya. However, Yosii (1966e) considers the former as

a subgenus under genus Entomobrya. Baijal (1966) gave a list of 137 species and mentioned that 75% of these species are endemic to India. Singh (1967, 1968) listed 31 species belonging to 19 genera under 6 families.

Salmon (1956) described 2 new genera viz. Spinanurida and Uchidanurida from Sikkim. Salmon (1957a) studied Paronellid Collembola from Assam, Nagaland and Manipur and described 2 new species Handschinphysa serrata and Pseudoparonellides bulbosa. From central Himalaya (=Tehri Gerwal, U.P.) Salmon (1957b) described a new species Pseudentomobrya lampreyi. In 1965 Salmon described a new genus and species of Prabhergia and recorded a new species of Paratullbergia from Kerala. In 1969 and 1970 Salmon described 5 new species (4 from Manipur and 1 from Assam) alongwith 2 new records from Manipur.

Yosii (1966d,e and 1971) mainly worked on the Collembola of India, Nepal Himalaya and Khumbu Himal. However, in 1966 , Yosii described a number of new species and new records of Collembola from West Bengal (Botanical garden, Calcutta), Punjab, Sikkim and Assam. In Collembola of Himalaya (Yosii, 1966e), 11 new records from India are mentioned alongwith a new species of Lobella from Assam. Yosii (1966b) described 16 new species from Malabar Hills and Lonavella (Bombay) and Nasik.

Mitra (1966a,b, 1967, 1973a, 1974, 1976a,b) and Mitra and Choudhuri (1973) reported 12 new species and 3 new genus viz. Pseudosalina Mitra and Choudhuri and Yosiia Mitra and Delamarerus Mitra from various parts of Uttar Pradesh (mainly Dehradun, U.P.), West Bengal, Haryana and Orissa. The new species described by Mitra (l.cit.) and Mitra and Choudhuri (l.cit.) belong to the genera Xenylla, Salina, Pseudosalina, Callyntrura and Lepidocyrtus . Mitra (1976c) also studied Collembola of Arunachal Pradesh and described a new Seira sp. viz., Seira arunachala.

Prabhoo (1967, 1970, 1971a,b,c and 1974) and Prabhoo and Haq (1974) investigated Collembolan fauna of Kerala, South India and reported 30 new species, a new genus Indoscopus and 17 new records including the first record of a marine Collembola, Oudomansia subcoerulea Denis from India.

Cassagnau (1980, 1981, 1982) described 2 new genera viz. Paleonura and Parvitnura from Himalaya. Prabhoo and Muraleedharan (1980) added a new species Tomocerus mitrai to South Indian Collembolan fauna. Collembola of Kumaun Himalaya have been studied by Sharma et al. (1984). Paliwal et.al. (1985) reported 3 new species of Lepidocyrtinus from Agra. Baijal and Verma (1986) described a new Sminthurides : S. antennata also from Agra.

Turning towards the taxonomic studies of North-Eastern Collembolan fauna, it can be noted that out of 7 states forming this zone almost no work has been done on "Springtail" fauna of Tripura and Mizoram. However Collembola of other 5 states are studied to some extent (Table II). Carpenter (1917,1924) studied Collembola from some parts of Arunachal (=Rotung), border of Arunachal and Assam (=Sadiya) and Meghalaya, Garo Hills (=Siju cave, at various depths). He discovered a new genus Cyphoderopsis (Type C. kepmi) from Rotung in Arunachal Pradesh (Carpenter 1917), along with another new species Protanura spinifera from Sadiya, Assam (other 4 new species, 3 Paronella (=Callyntrura) and 1 Lepidocyrtus were from Burma. From different depth of Siju Cave Carpenter (1924) reported 4 new species viz. Lepidocyrtus nagnificus, Lepidocyrtus exploratorius, Paronella brunnea and Cyphoderopsis gracilis.

Salmon (1957a) studied Paronellinae Collembola from Manipur, Assam and Nagaland and described 2 new species viz. Handschinphysa serrata Salmon,1957, from moss over stones at Kohima, Nagaland and Pseudoparonellides bulbosa Salmon 1957 from edge of a lake at Imphal, Manipur. He (Salmon, l. cit.) also reported Handschinphysa lineata (Parona, 1892) from Bisenpur, Manipur, Dicranocentroides fasciculatus (Imms, 1912) and Salina indica (Imms, 1912). However, Mitra (1973) considered this last species partly as

S. tricolour tricolour (Handschin, 1928). Salmon (l. cit.) also reported H. vestita (Handschin, 1925) from Kohima, Nagaland and H. longicornis (Oudemans, 1890) and Salina celebensis (Schaeffer, 1898) from Oating, Sibsagar, Assam.

Yosii (1966e) in his Collembola of Himalaya reported Cyphoderopsis ceylonica Yosii,1966 and a new species Lobella (s.str.) assamensis Yosii,1966 from Difu, Assam.

In 1969, Salmon reported 3 new species, i.e. Pronura indiana Salmon, 1969 from Sibsagar, Assam, Setogaster manipuri Salmon, 1969 from Moirang, Manipur and Rodanella plumosa Salmon,1969 from Imphal, Manipur. Salmon (1970) also described 2 new species from Manipur as Hypogastrura indovaria n.sp. and 2 new records Lepidocyrtus scaber Ritter, 1910 and Brachystomella surendrai Goto, 1961 from Imphal, Manipur.

Mitra (1973,1974,1976c) reported Salina indica (Imms 1912) and Salina tricolour tricolour (Handschin, 1928) from Manipur, S. striata (Handschin, 1928) from Shillong, S. montana (Imms, 1912) [Salmon (1957) synonymised this species with S. indica from Assam] and described a new species Salina choudhuri Mitra,1973 from Cave Mousmai, K & J Hills, Meghalaya. He also recorded Callyntrura vestita from Shillong Peak, Umdiengpun and a forest near cave Mousmai, K & J Hills,

Meghalaya (Mitra 1974). From Arunachal Pradesh Mitra (1976c) described a new species Seira arunachala along with record of Homidia cingula, Salina yosii and a Lepidocyrtus sp. all from Wakro, Lohit district of Arunachal Pradesh.

Cassagnau (1980) reported a new genus of Neanurid Collembola viz. Assamanura besucheti Gen.et. sp.n. from Nongpoh (Khasi Hills), Songsak and Rongrengiri (Garo Hills), Meghalaya. MariMutt and Bhattacharjee (1980) described 2 new species of Dicranocentrus viz. D. fraternus and D. singularis from Shillong, Meghalaya. Bhattacharjee (1984,1985) reported 4 new species from Shillong, Meghalaya viz. Hypogastrura prabhooii, Isotoma (s.str.) jayasrae Cyphoderus sarojini and Troglopedetes rasendrans. He (Bhattacharjee, 1984) also recorded Folsomia candida var distincta and Isotoma (Desoria) trispinata from Shillong, Meghalaya.

For the unique climatic conditions and other physical factors, North-Eastern India is expected to harbour a rich and diverse Collembolan fauna. With a view to study the springtail fauna of the North-Eastern states, we have undertaken a systematic survey of the Collembolan fauna of this region (Mari Mutt and Bhattacharjee 1980, Bhattacharjee

1984, 1985). Detailed results of our findings are embodied in the present work incorporating morphotaxonomic investigations on 12 species belonging to 5 families including some new species and new records with comparison and key to the new species (Table II).

Table I

Principal families of Collembola (Sensu lato)

		Families
Suborder - Arthropleona	Section - Poduromorpha	*Poduridae*
		Hypogastruridae
		Onychiuridae
		Neanuridae
	Section - Entomobryomorpha	Isotomidae
		Oncopoduridae
		Tomoceridae
		Entomobryidae
		Cyphoderidae
		Paronellidae
		Microfalculidae
		Coenaletidae
Suborder - Symphypleona		Sminthurididae
		Spinothecidae
		Arrohopalitidae
		Katiannidae
		Bourletiellidae
		Dicyrtomidae
		Sminthuridae
Suborder - Neelipleona		Neelidae

Table II

List of Collembola reported from N.E. India

Sl. No.	Family	Species and Authority	Localities	References
1	2	3	4	5
1.	Hypogasturidae	*Hypogastrura indovaria* Salmon, 1970	Bisenpur, Manipur	Salmon (1970)
		**H. prabhooi* Bhattacharjee 1985	Botanical Garden, Shillong	Bhattacharjee (1985)
2.	Neanuridae	*Lobella assamensis* Yosii, 1966	Difu, Assam	Yosii (1966e)
		Pronura indiana Salmon, 1969	Sibsagar, Assam	Salmon (1969)
		Protanura spinifera Carpenter, 1917	Sadiya, Assam	Carpenter (1917)
		Brachystomella surendrai Goto, 1961	Imphal, Manipur	Salmon (1970)
		Assamanura besucheti Cassagnau, 1980	Nongpoh (Khasi Hills) Songsak (Garo Hills) Rongrengiri (Garo Hills)	Cassagnau (1980)

Table II continued

Table II continued

1	2	3	4	5
3.	Isotomidae	*Rodanella plumosa* Salmon, 1969	Imphal, Manipur	Salmon (1969)
		**Isotoma jayasrae* Bhattacharjee, 1984	Botanical Garden, Shillong	Bhattacharjee (1984
		**I.(Desoria)trispinata* MacGillivary, 1896	Botanical Garden, Shillong	Bhattacharjee (1984
		**Folsomia candida distincta* Bagnall, 1939	Botanical Garden, Shillong Peak, Shillong	Bhattacharjee (1984
4.	Entomobryidae	*Lepidocyrtus magnificus* Carpenter.1924	Siju Cave, Garo Hills	Carpenter (1924
		L.exploratorius Carpenter,1924	Siju Cave, Meghalaya,	Carpenter (1924)
		Lepidocyrtus sp.	Wakro, Lohit, Arunachal	Mitra (1976c)
		L. scaber Ritter,1910	Imphal, Manipur	Salmon (1970)
		Setogaster manipuri Salmon,1969	Moirang, Manipur	Salmon (1970)
		Homidia cingula (syn.*S. subscingula* Denis,1948	Wakro, Lohit Arunachal	Mitra (1976c)
		Seira arunachala Mitra,1976	Wakro, Lohit Arunachal	Mitra (1976c)
		**Dicranocentrus fraternus*	Crinoline falls, Shillong	
		**D. singularis*	Ka Mari Road, Shillong	
		**Sinella montana* Imms, 1912	Dohling House, Hopkinson Rd, Shillong	Present work
		**S. curviseta* Brook, 1882	Botanical Garden, Shillong.	Present work

Table II continued

1	2	3	4	5
5.	Paronellidae	*Paronella brunnea* Carpenter,1924	Siju Cave, Meghalaya	Carpenter (1924)
		Dicranocentroides fasciculatus Imms,1912	Bisenpur, Manipur	Salmon (1957)
		Pseudoparonellides bulbosa Salmon,1957	Edge of a lake, Imphal	Salmon (1957)
		Salina chouduri Mitra, 1973	Cave Mousmai, Meghalaya	Mitra (1973)
		S. indica Imms, 1912	Bisenpur, Manipur	Salmon (1957) Mitra (1973)
		S. celbenesis Schaeffer,1898	Oating, Sibsagar	Salmon (1957) as *S.tricolour* (see Mitra 1973)
		S. montana Imms,1912	Oating, Sibsagar	Salmon (1957) as *S.indica* (see Mitra 1973)
		**S. striata* Handschin, 1928	Bot.Garden,Shillong	Mitra (1973)
		S. tricolour tricolour Handschin, 1928	Bisenpur, Manipur	Salmon (1957) as *S.indica* (see Mitra 1973)
		S. yosii Salmon,1964	Wakro,Lohit, Arunachal	Mitra (1976c)
		Handschinphysa serrata Salmon, 1957	Bisenpur, Manipur	Salmon (1957)
		H. longicornis Oudemans, 1890	Bisenpur, Manipur and Sibsagar, Assam	Salmon (1957)
		Callyntrura (H) vestita Handschin, 1925	Bot.Garden, Shillong	Mitra (1974)

Table II continued

1	2	3	4	5
5.	Paronellidae (continued)	*Callyntrura(H) lineata (Parona 1892)	Forest near Cave Mousmai, K & J Hills Meghalaya	Mitra (1974)
			Bisenpur, Manipur	Salmon (1957)
		Cyphoderopsis kempi Carpenter 1917	Rotung, Arunachal Pradesh	Carpenter (1917)
		C. gracilis Carpenter 1924	Siju Cave, Garo Hills Meghalaya	Carpenter (1924)
		C. ceylonica Yosii 1966	Difu, Assam	Yosii (1966)
		**Troglopedetes rasendrans* Bhattacharjee 1985	Shillong Peak and Crinoline Falls area, Shillong, Meghalaya	Bhattacharjee (1985)
6.	Cyphoderidae	**Cyphoderus sarojini* Bhattacharjee 1985	Assam Rifles Road, Shillong, Meghalaya	Bhattacharjee (1985)

Note :

* Indicate Collembola detailed description of which are presented in this work

Additional data on localities of all described species are given under "Materials examined" in Observations.

2 MATERIALS AND METHODS

2.1 Materials and site of collection :

The materials forming the basis of this work were collected at different times of the year from 1974 upto 1988, from various localities of Assam, Meghalaya, Nagaland and Tripura states. These materials were obtained from diverse biotopes like soil, leaf litter, bark and moss and consisted of mature males and females as well as juveniles (Table 2A).

2.1.1 Materials :

In total 12 species belonging to 5 different families have been studied.

A. Family : Hypogastruridae

1. Hypogastrura prabhooii Bhattacharjee, 1985

B. Family : Isotomidae

1. Folsomia candida distincta Bagnall, 1939
2. Isotoma (Desoria) trispinata (Mac Gillivary, 1896).
3. Isotoma (S.str) jayasrae Bhattacharjee, 1984

C. Family : Entomobryidae

1. Sinella montana Imms, 1912.
2. Sinella curviseta Brook, 1882.
3. Dicranocentrus fraternus
4. Dicranocentrus singularis

D. Family : Cyphoderidae

1. Cyphoderus sarojini Bhattacharjee, 1985

E. Family : Paronellidae

1. Troglopedetes rasendrans Bhattacharjee, 1985
2. Callyntrura lineata (Parona, 1892)
3. Salina striata (Handschin, 1928)

2.1.2 Sites of collection :

The collection sites comprised of hilly terrain consisting of evergreen or deciduous broadleaf forests of Meghalaya and Nagaland and plains of Assam and Tripura. Most of the collections were made during day time in the morning hours or forenoon and on sunny days. However some specimens from Meghalaya were collected during monsoon months and rainy days. Sudden rain in dry months made outburst of Collemboles of various size groups. Soil in the hills and forest areas were rich in organic matter, acidic in nature while in plains they were loamy to clay loamy in texture. Minimum and maximum air temperature recorded during collection period were; Meghalaya : Shillong 03.9°C and 23.3°C, Nagaland : Kohima 18.0°C and 21.0°C, Assam : Silchar, Badarpur and Fulertol Lakhipur 18.0°C and 22.5°C and Tripura : Dharmanagar 19.5°C and 23.0°C. Average rainfall in the year of collection was Meghalaya 241.5 cm, Assam 201.0 cm, Nagaland 223.0 cm and Tripura 224.6 cm. Altitudinal variation ranged from near to sea

level 150 mt. (Silchar) upto 1,444.12 mt. (Kohima) and 1,496.0 mt. (Shillong). Latitude and longitude of collection sites were Shillong 23.0°N and 91.5°E, Kohima 25.5°N and 94.0°E, Silchar 24.5°N and 92.5°E. The vegetation consists mainly of Eucalyptus, various conifers viz. Pinus, Cryptomeria, Cupressus, Thuja; broad leaf plants viz. Ficus, Tictona, Quarcus spp.; flowering plants like Sympalocos sp, Vernoria sp, Neolicacae Arenga; herbs like Comelina, Acalypha, Mimosa and ferns like Pteris and Adiantum with undergrowth of grass and Lantana etc. Collection made at Lakhipur, Phulertol near Silchar (Assam) were on pineapple fields and tea gardens.

2.2 Collection

Since Collembola are not restricted to any particular habitat, methods of collection employed for them also differed. Four methods of collections were found most suitable for these microarthropods.

2.2.1 Extraction by Berlese-Tullgren funnel :

This method was extensively used for all kinds of leaf litters and soil samples. In this process soil or leaf litters were placed in a series of plastic funnels with iron net work of 2 mm. mesh size inside and an electric bulb of 60 watt or 100 watt at the top. Collembola were collected in glass bottles below containing 95% ethyl alcohol.

2.2.2 Hand picking :

In this method Collembola were picked up by a preservative moistened brush directly or after the springtails were immobilised by pouring a drop of 95% ethyl alcohol on them. For some less active individuals two small pieces of papers were brought gradually from either side closing in the Collembola, which invariably moved onto one of the papers - this process was then followed by their careful dropping in the preservative medium. This method was suitable for Isotoma, Troglopedetes and Cyphoderus.

2.2.3 Beating vegetation :

Beating of the vegetations and undergrowths of forests specially deciduous ones accompanied by spreading a white cloth below to collect the Collemboles was found suitable for some Entomobryid and Paronellid types occurring on foliages.

2.2.4 Aspirator method :

Smaller Collembola especially those below thick moss cushion or above stones were sucked into the collecting tube by aspiration (Singer, 1964). It was found convenient for some Hypogastrurid and Cyphoderid Collembola.

2.3 Fixation :

Collection of the material was followed by fixation and prevention of loss of pigmentation, by Gisin's fixative (1960) consisting of:

90% ethyl alcohol	750 ml
Ether	250 ml
Lactic acid	30 ml
Formalin (40%)	3 ml

When many specimens were available from various localities, locality with large number of intact or complete specimens was selected as type locality and a few of the maximum sized animals were studied through temporary and permanent preparations, one of which was regarded as holotype and others as paratypes, in case of a new finding. Some specimens were kept in the fixative for future studies and references.

2.4 Clearing :

The larger specimens were sorted out and when their number permitted a few were sacrificedfor detailed morphometrical analysis of the type. The specimens were 'cleared' in a clearing fluid like lactic acid. The heavily pigmented specimens were treated in a mixture of equal parts of 20% aqueous KOH and 100% glycerine (v/v). The specimen, specially

the head region (which is mostly pigmented heavily) after it has been placed in this mixture could be slowly warmed with constant observation to see whether the ocular area or other parts of the head or body had become depigmented so as to make observations of macrochaetae on those areas possible. Mitra (1972) used this method with great success in locating an accessory ocular structure called "extra ocular structure" or e.o.s. (Mitra 1972).

2.5 Mounting :

2.5.1 Temporary mounting medium :

Many taxonomic features required to be examined in a suitable temporary mountant. In the present work Gisin's (1960) temporary mounting medium was used with full satisfaction.

Gisin's temporary mountant (Gisin,1960)

Lactic acid	10 ml
Glycerine	2 ml
Formalin 40%	0.4 ml

Observation of specimens in temporary mounting medium : (Cavity slide method)

Taxonomic characters of collembola require their thorough and detailed examination under microscope. For this purpose orientation of the specimen was very important.

The best method for observation of "phanerotaxy" of collembola was found to be through "temporary cavity slides". Individuals kept in any of the temporary mounting media could be manipulated in the cavity of the cavity slide with the help of a fine brush and ultimately bringing it to the desired orientation by gently "rolling" the coverslip with the help of the brush (Andre 1988). Head of Collembola show a number of taxonomic features both dorsally and ventrally including mouth parts. For this purpose mounting of 'head' between two coverslips as suggested by Christiansen and Bellinger (1980) was found to be very useful. Body of the Collembola was mounted dorsal side up and tilted slightly by the coverslip to observe lateral setae on the abdomen. Furcula was pressed to the body ventrally (as it remains in its resting position) so that genital setae and genital orifice could be observed easily.

2.5.2 Permanent slide preparation :

Two methods were applied for preparation of permanent slides as no single method was found universal in application.

2.5.2.1 Polyvinyl alcohol or PVA method (Salmon 1951c, 1954) with some modification was used in many permanent preparations.

Components of PVA method :

PVA (Commercially available powder, dissolved in water; see below) = 10 c.c.

Lactic acid = 10 c.c.

Glycerine = 1 c.c.

To prepare PVA stock solution following procedure was followed (for 5 gms PVA in 30 ml H_2O).

1. Distilled water was added drop by drop on the PVA powder (5 gms) stirring continually in a glass beaker.
2. When all powder was wet - remaining water was added.
3. The "Paste" became "fluffy" and white due to occluded air.
4. The mixture was cleared by gently heating over a hot plate or water bath placing a watch glass over the beaker to prevent excess moisture from escaping outside.
5. 10 c.c. of lactic acid was now added, stirring vigorously by glass rod.
6. 1 c.c. of pure glycerine was added to the mixture.
7. The mixed solution was filtered and left for 24 hrs to mature.

This medium was colourless, crystal clear, viscous, oily substance. The specimens fresh or preserved placed between 2 drops of mountant on a slide and covered by coverslip. The prepared slides were kept for 2 days at 40°C.

2.5.2.2 Hoyer's medium :

Gum arabic	=	30 gm.
Chloral hydrate	=	200 gm.
Glycerine	=	20 gm.
Distilled water	=	50 c.c.

Preparation : Gum arabic was dissolved in distilled water, chloral hydrate was now added and kept for 1-2 days till all solids dissolved, glycerine was added and filtered through glass wool. Slides prepared in this mountant were kept at 53°C for 2 days and then examined or stored. The mountant has to be stored in bottle with glass stopper.

2.6 Camera lucida drawing and photomicrographs :

A Leitz Ortholux II with varioorthomax and Olympus wf 10x microscope with oilimmersion lens (100 x) along with built-in photographic accessory was used for the systematic study of the Collembola. Camera lucida was attached to a monocular microscope for morphological studies. Line or pencil drawings were made on drawing board. For various measurements an eye piece or ocular standardized by comparing

with stage micrometer (Nikken, Tokyo) was used. The scale accompanying the figures gives magnification and measurement of different structures.

2.7 Repository :

The types, paratypes and other specimens are provisionally kept in the Zoology Department of St. Anthony's College and author's collection except holotypes of D. singularis and D. fraternus which have been deposited to Illinois State Natural History (I.S.N.H.) museum, U.S.A. and some paratypes of these two species are with Dr. J.A. Mari Mutt, U.S.A. All other holotypes of various new species described herein will be deposited to the Zoological Survey of India (ZSI), Calcutta in due course of time.

2.8 Descriptive terminology and abbreviations : (Pl I, Figs. 1-19)

Morphological structures considered in the Collembolan taxonomy largely depend on the type or group of species in question and to some extent on individual subjective judgement. Characters of great importance in one group may not be that important in another or even not at all considered. Variations in notations are however not

too many, as many terms are accepted by taxonomists in general. Regarding naming of various integumentary derivatives differences in the terminology are often confusing as same or similar structures have been named differently viz. some antennae IV sense organ has been differently named as Fossette subapicale (Bonet,1930) Sensilla subapical (Bonet,1945), Subapical grube (Yosii, 1956), Subapical groove (Yosii,1962), Organite subapical (Deharveng,1981). Recent studies of Andre (1988) on Phanerotaxy of Collembola may be regarded as an unique attempt to classify structures like sense setae (S.S.), rods, bulbs or cones of antennae and such other modified setae on the basis of their development or homology.

In the description of various species of Collembola in this work different abbreviations or notations used are adopted mainly from Yosii (1956,1960,1962), Gisin (1960), Salmon (1964), Gama (1964), Snider (1967), Szeptycki (1967 and 1979), Mitra (1973,1974) and Mari Mutt (1979). Dorso-ventrality of the spring organ or furcula is after Handschin (1925). Mitra's (1974) suggestion of imaginary subdivision of tergites into different zones of Paramedial area (e.g. Pa, Pb, Pc etc.), however is difficult to judge and hence as far as possible such sub-divisions have been mentioned, or otherwise total number of macrochaetae on different body segments are stated.

Various features of morphology, accepted as taxonomic characters, are discussed below with terminology in the brackets alongwith their relative importance in the Collembolan systematics. Diagrams or illustrations of different structural parts as referred to, will substantiate explanation of the terms used in this investigation.

2.8.1 Body length and ratios :

Body length of a species is measured in millimeters (m.m) excluding all appendages and furcula or spring organ. The measurement is taken from temporary preparations in fully extended specimens calculating total distance from the base of antennae upto tip of last abdominal segment. Relative length indices of antennae, thorax, abdomen or spring organ however do not give their actual measurements in the scale but indicate relative ratios of different parts. Body cover or cuticle is variously described in different species (fine/coarse, granulate, tuberculate or reticulate) as the case may be.

2.8.2 Coloration :

In most cases coloration is a reflection of the habitat of the animals and/often adaptive, therefore/not an important character in Collembolan taxonomy as in other groups of insects. However some species show unique color patterns by which these species might be readily

identified e.g. Isotoma jayasrae (PL I,Fig.2), Dicranocentrus singularis Mari Mutt and Bhattacharjee (Fig.PL VIII(1)), Salina striata (Handschin)(Fig.PL XI(9)) or Callyntrura(H.)vestita (Handschin). Yosii (1965) has noted coloration as the prime criteria in some species where interspecific chaetotaxic uniformity makes it unsuitable for taxonomic placement or species diagnosis.

2.8.3 Clothing :

Clothing of head and body alongwith different appendages are the most important parameters in taxonomy of Collemboles. Various experiments and observations on natural populations e.g. soil(epigean) and cave(cavernicolous) forms increasingly demonstrate nonadaptive nature of chaetotaxy (Massoud and Thibaud, 1973). Cephalic and trunk setal patterns of various species are so specific that even 12 different color forms were recorded in a single population of Callyntrura(H.) lineata by Mitra (1974), all showing uniformity in chaetotaxy. Cephalic chaetotaxy in this work is studied and described after Yosii (1956, 1960, 1962) and Gisin (1960). Trunk chaetotaxy study is based on the concept of Snider (1967) and Szeptycki (1967 and 1979) (PL I, Fig. 14). Cephalic chaetotaxy is described by subdividing head into different areas and abbreviating those terms followed by specific serial number for each seta starting from the

mid dorsal region and moving outwards towards the margin. In general a capital letter denotes a macrochaeta while a small letter a microchaeta viz. third macrochaeta on the dorsal region of head (D_3), 1st posterior ocularis macrochaeta, (PO_1) third to sixth subdorsal microchaetae (sd_{3-6}) and so on. Abbreviations of other cephalic regions are vertex (V), parietal (P), occipital (O), ocular or eyefield (OC), cervical (C) and genal (G). However any seta on the middle line of the head is denoted by a number (o) e.g. macrochaeta on the mid dorsal region of vertex (V_o) (PL I,Fig.12). It should be noted that in case the setae are microchaetae small letters for abbreviations are to be used e.g. p, o, oc, v etc. Mari Mutt (1979) followed Szeptycki (1973) in descriptive terminology for Dicranocentrus spp. of the world and designated cephalic setae in 4 groups, as antennal group, median-ocellar group, sutural group and posterior group of setae (A, M, S and P respectively) with notations like (Ps) post sutural, (Po) post ocular etc. This system is adapted here for two Dicranocentrus spp. described (PL VII, Figs.12,13; PL VIII, Figs.13,14). All abbreviations are followed by serial numbers of the setae.

Trunk chaetotaxy are described differently by Yosii (1960, 1962) and Snider (1967). Yosii (l.Cit) proposed three divisions (transversely) for each tergite as anterior

(a), medial (m) and posterior (p) while the principle of numbering remains the same i.e. beginning from mid dorsal line of the body viz. 3rd anterior seta of 1st abdominal segment (a_3 of Abd. I)(PL.II,Figs. 15 and 16). Special or sensory seta (seta sensualis or s.s.) is also designated in the same manner i.e. 5th posterior seta is the sensory seta of 4th abdominal segment (Abd.IV, P_5 is s.s.). However Snider (1967) and Mitra (1974) suggested longitudinal subdivisions of each tergite viz. medial (M or m), paramedial (P or p) and lateral (L or l) for macro and micro chaetae (PL.I, Fig. 14). Mitra (1974) advocated further subdivisions of paramedial in various zonations (Pa, Pb, Pc etc.), Macrochaetal formulae for different species are mentioned by number of setae on half of each tergite since the other half is supposed to be identical. In the Key to related species of Dicranocentrus setal formulae of main body segments are expressed. However, it is worth mentioning here that in all figures of chaetotaxy usually a solid dot or hollow circle expresses a single macrochaeta, while a small dot with a wavy line from it denotes a lasiotrichia. Apart from cephalic and trunk chaetotaxy setae on trochanter (trochanteral organ), ventral tube (vt.) and spring organ (furea) are also recorded. Setal pattern on the dens may be represented as outer (o), inner (i) and ventral (v) and

absence of setae by dots starting as usual from proximal or basal portion of den eg. 1 outer, 1 ventral and 1 inner setae (ovi) (Fig.PL.III,II) Folsomia candida distincta Bagnall). Scales on dens are also described in the same manner viz. outer, inner, dorsal or ventral. Many families or subfamilies of Collembola show characteristic type of setae or scales e.g. Paronellidae, Orchesellinae or Cyphoderidae, each of which has its unique type of scales by which it can be easily identified (Salmon, 1957, Mari Mutt, 1979). Setae on different parts of the body or appendages may be variously modified as long, plain, wavy, sensory hairs (bothriotrichia), long ciliated wavy sensory hairs (lasiotrichia). Setae may be with their apex bent and brush like (flexed setae) or swollen (clavate). Many flexed macrochaetae may form whorls on the distal border of head (collar) or proximal end of mesothorax in Entomobryids. Setae may be parallel sided and non-tapering (hairs) or modified into short, stout usually sharply pointed non flexible structures (spines) which again may be plain, ciliated or serrated (PL.I, Fig.3). Richards (1968) has based his classification of Sminthuridae of the world on four patterns of bothriotrichia separating the families. Various combinations of different types of setae are met with in Collembolans which are significant even at infra-generic levels. A thick ciliated seta (plumose seta)

on dens of the spring organ is an important character in Dicranocentrus species separation (PL.VII,Fig. 15). Number or distribution of scales on dentes are also species specific in the genus Cyphoderus (PL.IX,Fig. 3 and 4). In all descriptionsof clothing of setae or scales numbering is from proximal or basal towards distal or apical.

2.8.4 Head :

Head is variously described in different species as pear shaped, pro- , obliquely pro - or hypognathous (Salmon 1964). Antennae in Collembola is usually 4 segmented, however subdivision of 1st and 2nd segment often give rise to 6 segmented antennae as in subfamily Orchesellinae (Mari Mutt, 1979). Various segments of antenna are abbreviated as Ant. I, Ant. II, Ant. III and so on. Often last 2 segments possess short (verticilating) whorl like setal arrangement and in many cases segments specially the last 4 or 2 become modified (annulated). Many sensory setae located on antennae are described (rods, bulbs, cones) depending on their shape and size they may be apical or subapical. Special seta on the last or 4th antennal segment with truncated apex is found in some species (Pin or P seta) e.g. D. fraternus Mari Mutt and Bhattacharjee. Ratio of Antenna and head diagonal is given (Ant./Head) measuring antennae from its base to apex and diagonal line passing

through vertex of head. Labral setae are described indicating their number and separating them from prelabral setae by an oblique (/) sign (PL.I,Fig. 10). Description of these setae are followed from proximal towards distal or outer margin of labrum. Teeth on apex of mandible are expressed in number, while setae on labial basis or triangle are indicated by letters denoting anterior, posterior or lateral setae (A, M, or L) Mari Mutt and Bhattacharjee, 1980. Eyes or ocelli in Collembola are another important morphological feature of great importance in taxonomy. Number of ocelli is often considered to be diagnostic among various species. Eyes are denoted by capital letters (A, B, C, D, E, F, G, H) starting from the outer border of the ocular area (PL.II,Fig. 6 and 13). Often some of these ocelli may be reduced/denoted by small letters (g, h, etc.) due to regression and subsequent disappearance of formation. Occasionally above the ocular area and posterior to antennae some sensory structures of various shapes, sizes and formations are observed. These are called postantennal organ (PAO) which may be simple, single double outlined or a complex structure. Presence, absence and number of elements (in compound PAO) forming this structure or its shape or size (in simple PAO) are very characteristic as in genera Isotoma, Desoria, Hypogastrura etc. (PL.V,Fig.2 and 13; PL.II,Fig.7).

Posterior to ocular area some extra ocular structures (e.o.s.) are found in some genera of Paronellidae (Mitra, 1972).

2.8.5 Thorax :

Thorax in Collembolans consist of 3 segments denoted as 1st thoracic segment, 2nd thoracic segment and 3rd thoracic segment (Ths. I, II, III). Legs comprise of usual arthropodan subdivisions as coxa, trochanter, femur, tibiotarsus and claw. Claw consists of 2 portions, the claw proper (Unguis) and supporting structure (Unguiculus or empodial appendage.). Teeth on the claw or empodium are of great significance having constant feature in majority of species (PL.I,Fig.15). Inner, outer, basal (proximal), distal or lateral are some terms applied to teeth basing on their location. Setae on trochanter mostly form special arrangement (triangular, linear, quadriangular etc.) and may be spiny, thick and short. Teeth on the inner basal region of claw or outer border of unguiculus may be paired and wing like (winged teeth), which are characteristic of Sinella and Cyphoderus. A special seta (tenent hair) on the dorsal side of claw and tibio-tarsal border may be variously modified (truncate or clavate or pointed).

2.8.6 Abdomen :

Abdomen consists of 6 segments which are described as 1st abdominal segment, 2nd abdominal segment (Abd. I, Abd. II) etc. However, in many cases some posterior segments might be fused giving globular shape. Three important appendages are located on various segments of abdomen viz. ventral tube or collophore (Vt.) located on ventral side of 1st abdominal segment formed by union of its appendages and consists of a basal column and a pair of vesicles which often become quite long and tubular (PL.I,Fig.1). The cavity of ventral tube freely communicates with body cavity and contains uric acid and blood, the vesicles may be withdrawn by special muscles. It may be mentioned here that the name 'Collembola' was derived from this collophore. Setal distribution on ventral tube is analysed in three aspects viz. setae on its anterior region i.e. towards head end (ant. face of Vt.), on its posterior surface i.e. towards anal end (post. face of Vt.) and on sides (lateral flaps of Vt.) by numbers and stating their nature or type (PL.I,Fig.9). On many Collembolans a minute pair of appendages exists on the ventral aspect of 3rd abdominal segment (retinaculum, tenaculum or hamula), fused at the base (proximally) into a single piece (corpus) but free distally (ramii) (PL.I,Fig.4). This structure retains the spring organ when not used or in the resting

stage. Seta on the corpus may be one to many depending on the species and is/are designated by numbers, while ramii usually possess 4 teeth (barbs) each. By far the most important structure of a Collembola is its spring organ possessed by a vast majority of them. The name springtail is coined from this structure. However it should be noted that some possess only vestiges or reminent of such organ (furcal rest). The spring organ (furcula or furca) when released from hamula, the exterior muscles contract pulling it downwards and backwards striking the ground and thereby propelling the insect into the air to a sudden leap. 3 parts of furcula are a basal fused piece (manubrium or man. or m.), a middle paired structure (dentes or dens or d.) and a distal paired structure each unit of the pair corresponding to its den (mucrone or mucro or mu.). Furcula varies greatly in development and is of great importance in any phylogenetic studies. In Hypogastrura mucro is short (PL.II,Fig.10 and 11) while in Entomobrya and its allies it is mostly either a simple sickle shaped (falcate) or with 2 teeth (bidentate) with or without a spine like structure (basal spine)(PL.I,Fig.16). In Paronellidae mucro has developed into a strong structure with well developed teeth described according to their location taking contracted structure of furca to determine dorso-ventrality following Handschin (1925) and Mitra (1974). In this contracted or

natural condition (resting or when furcula is not in use) of furcula teeth are described as apical (ap.), anteapical (ante-ap), ventral (v.) and lateral (l.). Yosii (1959) however has accepted Deniss (1948) contention and described furcula or mucro in its extended state describing dorsal (d) teeth in place of ventral (v.) of previous concept and adding inner (i) and outer (o) teeth on an anterior-posterior sense (PL.I,Fig.16). In present work mostly Handschin's (1925) concept is followed. In some genera viz. Callyntrura (Handschinphysa) and Salina, some additional (bladder like) structure is observed at the den-mucro joint (bladder scale, scale appendages or lobe of dentes) which is an important taxonomic character in subgenera level (PL.XI,Fig.8,13 and 14). In some species last abdominal segment dorsally bear 1,2 or rarely more spine like structures (anal apine, an.sp.), location, size and shape of which are characteristic of a species. Genital opening in general in male is a cross or vertical slit like structure and in some surrounded by a whorl of papillated structures bearing specialised setae (papillate type of genital slit).—In females the slit is a transverse one with some special setae (genital setae)(PL.I,Fig.17).

Number and nature of genital setae are some additional taxonomic characters in some species of the family like Paronellidae and Entomobryidae.

Map of North Eastern States showing collection sites for various species

A. MEGHALAYA

1. Rongrengri
2. Tura
3. Songsak
4. Mawphlang
5. Shillong (Capital)
6. Happy Valley
7. Umtyngor
8. Mousmai (Cherrapunjee)
9. Jakrem
10. Siju
11. Umroi
12. Nongpoh

B. ASSAM

13. Dispur (capital)
14. Sadiya
15. Sibsagar
16. Diphu
17. Badarpur
18. Silchar

C. TRIPURA

19. Dharmanagar
20. Agartala (Capital)

D. MIZORAM

21. Aizawl (Capital)

E. MANIPUR

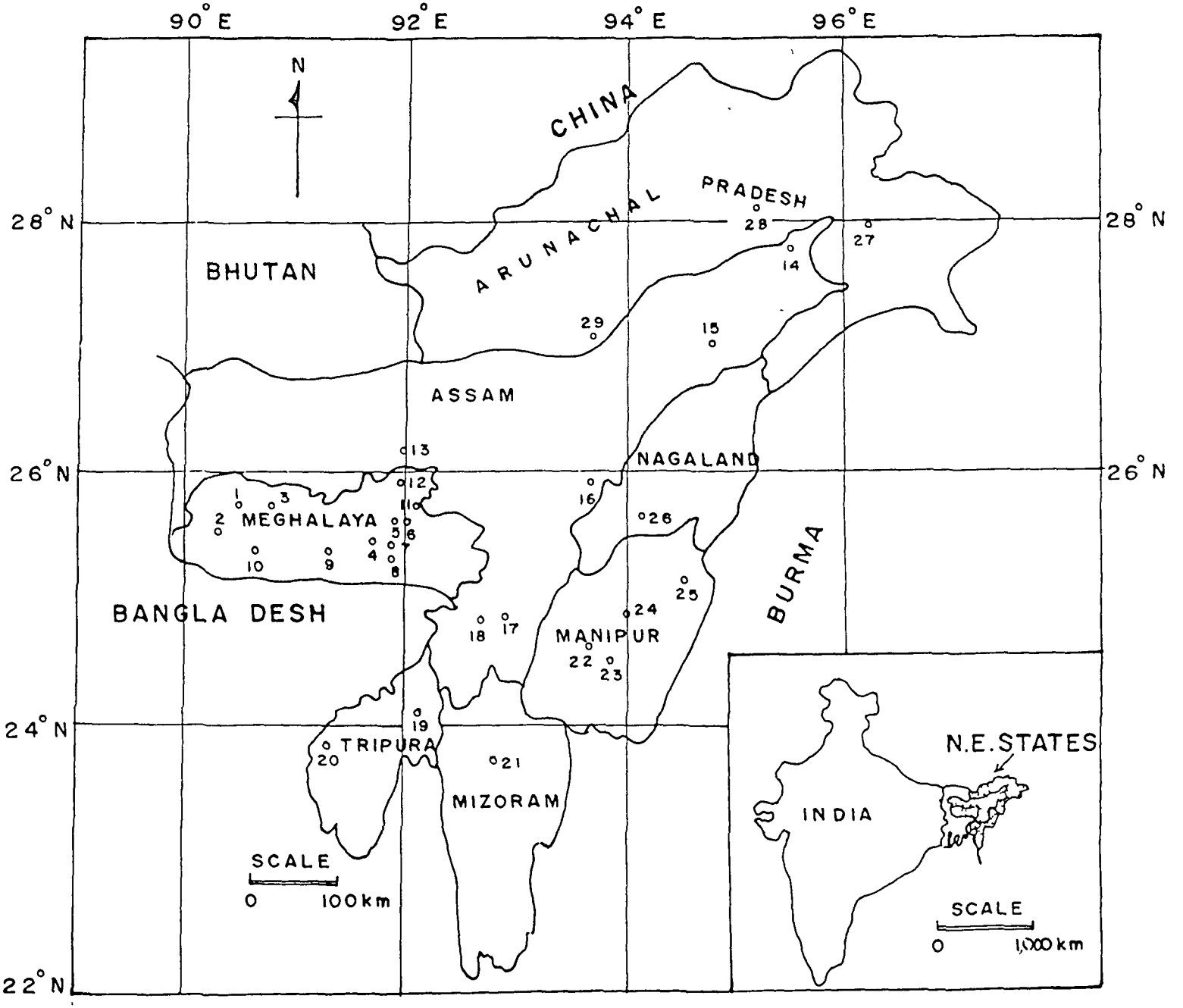
22. Bisenpur
23. Moirang
24. Imphal (capital)
25. Ukhrul

F. NAGALAND

26. Kohima (Capital)

G. ARUNACHAL PRADESH

27. Lohit
28. Rotung
29. Itanagar (Capital)



Map showing various collection sites.

Table IIA

Morphotaxonomic Studies

Species	Biotope	Localities (Ref. Map)
HYPOGASTRURIDAE		
Hypogastrura (s.str.) prabhooi nsp.	Moss	5, Jammu
ISOTOMIDAE		
Folsomia candida distincta (Bag)	Deeper soil	5
Isotoma (s.str.) jayasrae n.sp.	Moss	5,11, Jammu
I(Desoria) trispinata (MacGill)	Moss, litter	5
ENTOMOBRYIDAE		
Sinella (s.str.) montana Imms	Soil, sand rotting wood	5
S. curviseta Brook	Soil, sand coconut shell	5
Dicranocentrus fraternus	Litter	5,26
D. singularis	Litter,moss	5,26
PARONELLIDAE		
Callyntrura(H.) lineata (Parona)	Litter,bark	5,9
Salina striata Handschin	Litter,bark	4,5,9, 19,26
Troglopedetes rasendrans n.sp.	Mineral layer on rock	5
CYPHODERIDAE		
Cyphoderus sarojini n.sp.	Mineral layer on rock	5

Plate I : Figs. 1-19 *Morphology of Collembola*

(1) Habitus (*Isotoma jayasrae* n.sp.) and different structural parts with abbreviations.

(2) Coloration (*Isotoma jayasrae* n.sp) clothing not shown.

(3) Spine (sp.) Flexed macrochaeta (F.), Plumose seta(P) and lasiotrichia (l).

(4) tenaculum or retinaculum

(5) antenna IV sense organs,

(6) anterior ocelli and PAO (Postantennal organ)

(7) Trochanteral organ with modified microchaetae

(8) apex of mandible showing teeth

(9) Ventral tube or collophore, Ant. = anterior face, and lateral faces with specific clothing of small and medium sized setae,

(10) Prelabral and labral chaetotaxy,

(11) a typical trunk scale of *Dicranocentrus* sp.,

(12) Cephalic chaetotaxy showing various notations, Ocelli and PAO in *Hypogastrura prabhooii* n.sp.,

(13) thorax II chaetotaxy and sense setae (s.s.) in *H. prabhooii* n.sp.

(14) trunk chaetotaxy of *Callyntrura (H.) lineata* following Snider's (1967) concept of body divisions and notations of macrochaetae; M = medial, P =

paramedial (subdivided into Pa, Pb, Pc etc) and L = lateral macrochaetae and lasiotrichia (L),

(15) metathoracic claw with Unguis having winglike teeth (w) and Unguiculus or empodium with outer teeth, plumose seta (P) and specialised seta "tenent hair" with clavate apex in *Sinella montana* Imms.

(16) a,b,c and d: Various types and views of mucro, a = bidentate with basal spine (b:sp), b = quadridentate mucro (*Isotoma jayasrae* n.sp.) c = mucro of *Callyntrura (H.) lineata* and d = dorsal view, explaining Denis's (1948) concept,

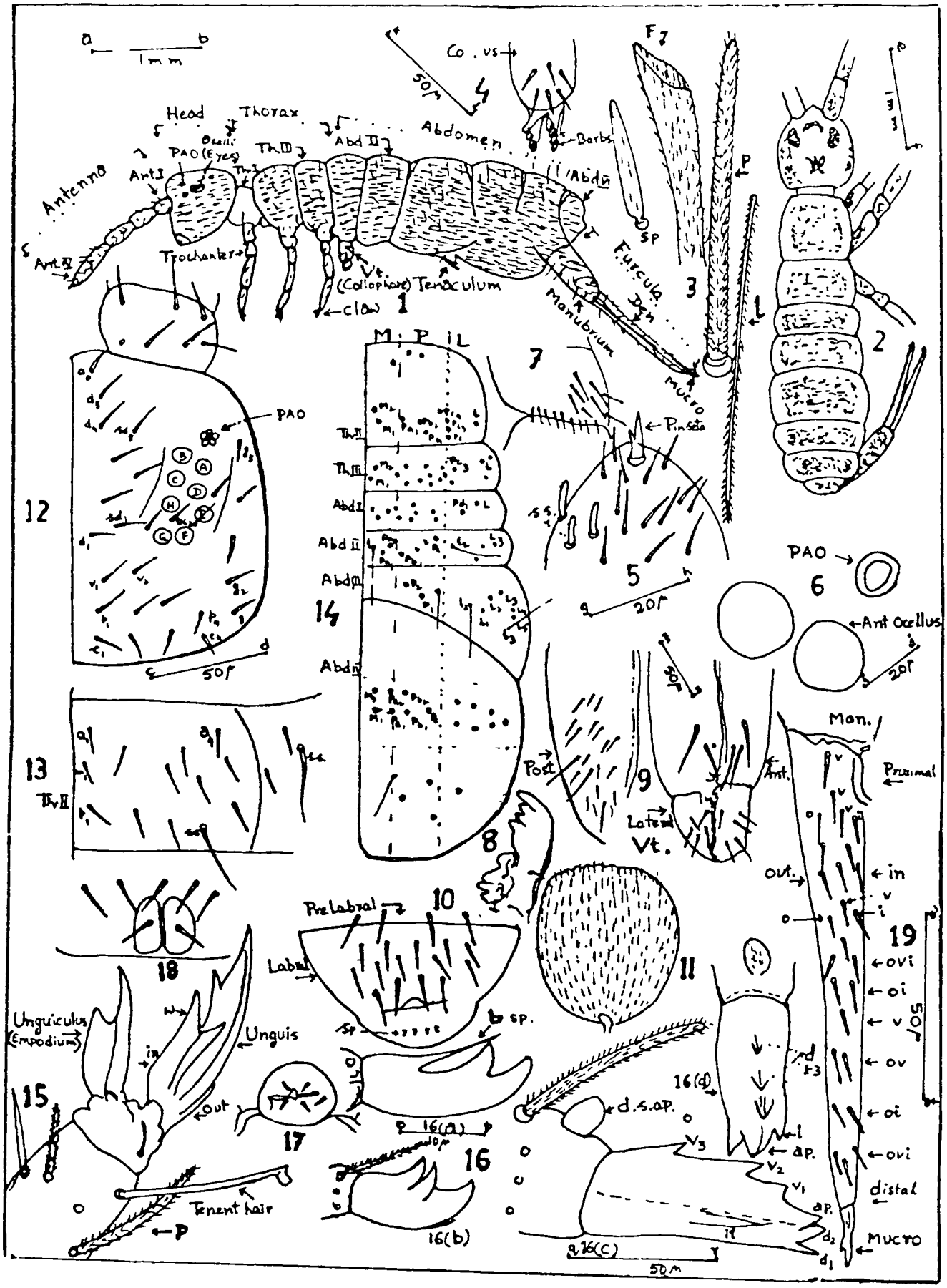
(17) female genital slit with associated setae, *H. prabhooii* n.sp.

(18) male genital slit with associated setae *I. (Desoria) trispinata* MacGill.

(19) Setal distribution on den in *Folsomia candida distincta* Bagnall.

Scales (a-b) Figs. I,II : (c-d) Figs. 7,8,12,13,18; (e-f) Fig.2; (g-h) Figs. 3(f), 5,10,15,16(b); (i-j) Figs. 3(l), 6; (k-l) Figs. 4,17; (m-n) Fig. 9; (o-p) Figs. 3 (p), 16(a); (q-r) Fig. 16 (c); (s-t) Fig. 19.

PLATE I


Head
Thorax
Abdomen
Antenna
Ant I
Ant II
PAO (Eyes)
Ocelli
Th II
Th III
Abd II
Abd IV
Trochanter
Vt. (Collophore)
Tenaculum
claw
Barbs
Co. vs
Fj
SP
Furcula
Dens
Manubrium
Mucro
P
L
M
Prostia
PAO
Ant Ocellus
Mon.
Proximal
Post
Ant.
Lateral
Vt.
Prelabral
Labral
Labium
sp.
Unguiculus (Empodium)
Unguis
in
out
Tenent hair
d.s.ap.
ap.
distal
ovi
oi
v
ov
50μ
20μ
1mm

3 OBSERVATIONS

Order - Collembola Lubbock, 1862
Suborder - Arthropleona Borner, 1901
Family - Hypogastruridae Borner, 1913
Genus - Hypogastrura Bourlet, 1839
Subgenus - Hypogastrura Goto, 1960

3.1 Hypogastrura (S.Str.) prabhooii, n.sp. (Plate II, Figs. 1-18)

3.1.1 Habitus and Integument :

Habitus typical of the genus (Fig.1), length excluding appendages upto 0.72 mm. Integument with coarse and fine granules on the body and head. On the dorsal side of den and claw basis it is finely granular. Abd. V median area not well defined and with a few large skin granules.

3.1.2 Coloration :

Dorsally bluish black on all segments of the body, head, antennae and ocular field. Dark blue black longitudinal bands extend from abdomen anteriorly and concentrate in the 'area verticalis' on the head. These bands enclose a light orange pigmented area on the mid dorsal line of Abd. II and III. Ventral tube, tenaculum and furca upto mucronal base with little pigmentation.

3.1.3 Clothing :

Head and body covered with small sized simple smooth setae (except s.s.), which are not much differentiated. Setal covering of antennae, legs and anogenital segment

slightly longer. Sense organs of Ant. III with 2 small rods in a faint groove guarded by 2 sensory setae (Fig. 2). Ant. IV with a single sub-apical bulb in a pit and with 7-8 well developed stout sensory rods (Fig. 2). Ant. I without 'p' seta . Ventrally antennae with some small setae. No eversible sac is present between Ants. III and IV. Body with smooth, simple, subequal setae. Many setae present around anal aperture (Fig. 17), Setae around genital slit not differentiated (Fig. 14). In thorax II and III p_4 in "sese seta", m_2 absent. Abd. I-III have 2 rows of setae and in all specimens examined show a quartet of setae in specific arrangement, p_3 may be absent sometimes, p_1 and p_2 subequal, p_5 is s.s. Abd. IV with 3 rows of setae, p_4 is s.s., p_1 and p_2 subequal. In Abd. V p_2 is s.s. and in Abd. VI p_0 is present, setae are longer than the rest of the body setae (Fig. 16).

3.1.4 Head :

Head without cephalic spines, a_o present, v_1 and v_2 subequal (Fig. 13). Head/antenna - 1:1. Relative length index of Ant. I:II:III:IV = 15:20:22:32. Apex of maxilla with 3 apical teeth and one fringed lamella in a finger like process (Fig. 5). Mandible apically with 1+3+1=5 teeth, the last slightly smaller and tending to be a round bump. The apical tooth is slightly broad and bent inwards (Fig. 4).

Labrum with 4/5, 5,4 setae and labral margin with 4 round, subequal tubercles (Fig. 3). Ocelli 8+8, all subequal. PAO is composed of 4 subequal elements (of which the anterior one is slightly elongated) around a central boss. PAO is slightly smaller in diameter than the anterior ocellus (Fig. 7). No accessory tubercles present.

3.1.5 Thorax :

Legs all similar (Fig. 8), with unguis without lateral teeth but a fine inner tooth at about 2/3 down from the base of claw. Unguiculus about half as long as the unguis, setaceous with broad inner lamella. Tenent hair 1,1,1, apically blunt, slightly longer than the unguis.

3.1.6 Abdomen :

Ventral tube anteriorly with 4+4 setae. Tenaculum with 4 barbs in rami (Fig. 9). Furcula small, well developed, reaching the posterior border of abdomen II. Relative length index of manubrium : den : mucro = 20 : 14 : 4. Manubrium with ca. 26 setae dorsally (Fig. 18). Den with 7 setae dorsally, basal seta longest (Fig. 18). Mucro spoon shaped, apically rounded with inner side thickened and a fine but clear outer lamella (Fig. 10 and 11). Anal spines straight and small, placed slightly anteriorly (Fig. 12). Anal papillae separated from each other at the base by about 2 granules. Anal spine : anal papilla : mucro = 1 : 1 : 3.

3.1.7 Material examined : Holotype : ♀, slide; India : Meghalaya, Shillong Peak, 1960.78 m.el, from rotting pine seeds, 4ii 1975 Coll. R.K. Bhattacharjee.

Paratypes : India, Meghalaya, Shillong, Botanical Garden, 1496.00 m.el: pine seeds and leaf litter 9 IX 1974, 18 exs; rotting seeds of pine and rotten Arenga tree 10 X 1974 11 exs; Shillong Peak, rotting pine seeds, 23i 1975, 8 exs; same locality on 4 XI 1975, 15 exs, collected by R.K. Bhattacharjee, Jammu and Kashmir, Katra (Jammu) side of a hill towards Baishna Devi temple, leaf litters, 13 X 1987, 3 exs, Coll, J. Bhattacharjee.

3.1.8 Distribution : - India : Meghalaya (Shillong); J & K State (Katra).

3.1.9 Comparison :

Altogether 9 species of Hypogastura have been reported from India and Nepal by earlier authors of which only 3 species belonging to Hypogastrura (S.Str.) subgenus seem to be related to the present species and these are included in the key. However, the new species can be sorted out easily from these 6 species as well basing on the characters like absence of an eversible sac on Ant. III, as seen in H. armata (Nicolet, 1841) Imms, 1912, Handschin, 1929, Denis, 1936, Roonwal, 1951 and Mani et al., 1955 : South India and N.W. Himalaya; H. communis (Folsom, 1898),

Denis, 1936; Mani et.al., 1955, Yosii, 1960 and Prabhoo, 1971 : N.W. Himalaya and South India; H. indica (Salmon, 1956); Sikkim and from H. indovaria Salmon, 1970 : Sikkim, or by its different relative length index of antennae and smaller body setae compared to H. narkandae (Baijal 1955) : Sutlej valley, or by possession of analspines, more setae on dentes and dentate unguis unlike H. sonapani Baijal, 1958 : Sonapani Glacier, Great Himalaya.

The new species resembles Hypogastrura (S.Str.) nepalica Yosii (1966a) from Maedane Karka, Nepal in having the ventral tube with 4+4 setae, anteriorly placed analspines/manubrium and dorsally with ca. 26 setae. It differs from H. nepalica in possessing a single apical bulb on Ant. IV, labral margin bearing 4 subequal tubercles and s.s. in Abds. IV and V being p_4 and p_2 respectively.

Hypogastrura (S.Str.) prabhooii n.sp. is similar to H. (S.Str.) himalayana Yosii, 1971; Khumbu Himal, in having 1,1,1 tenent hairs, but differs in number of PAO elements, by the setae of the ventral tube, absence of paired lateral teeth of the unguis and by having different mucro and 3 rows of setae on Abd. IV.

In color pattern the new species resembles endemic species H. reticulata (Borner, 1909; Yosii, 1960) of Japan, but the presence of m_3 on Th. III, the separated anal papillae, the spoon shaped mucro and den with more setae will distinguish the new species easily. The new species differs from H. copiosa (Folsom, 1916) in having 2+2 setae on "area verticalis", Abds. I-III with 2 rows of setae and s.s. on Abd. IV and Abd. V being p_4 and p_2 respectively.

3.1.10 Key to related species of Hypogastrura (S.Str.) from India and Nepal

1 Tenent hair on tibiotarsus, 1,1,1 2

- Tenent hair on tibiotarsus more than 1,1,1 ... . H. (S.Str.) distincta (Axelson, 1902) Yosii, 1971 Nepal.

2 Ventral tube anteriorly with less than 6 + 6 setae (usually 4+4), no lateral teeth in unguis 3

- Ventral tube with 6 + 6 setae, unguis with a pair of lateral teeth --- H. (S.Str.) himalayana Yosii, 1971; Khumbu Himal.

3. Antenna IV with 3 large subapical bulbs, distal margin of labrum without tubercles ... H. (S.Str. nepalica Yosii, 1966; Maedane Karka, Nepal.

- Antenna IV with single subapical bulb, distal margin of labrum with 4 round tubercles ... H. (S.Str.) prabhooii, n.sp.: Shillong, Meghalaya.

Comments : According to Yosii (1960), H. reticulata is endemic to Japan. Dr. P.F. Bellinger of California State University in a personal letter suggests that this species might be included in the subdivision of group "Packardi" of Hypogastrura (S.Str.) tentatively modified after Yosii by Christiansen and Bellinger (Pers.Comm. 1978).

3.1.11 Etymology :

This new species is most respectfully dedicated to Late Dr. N.R. Prabhoo, Reader in Zoology, Kerala University.

Family - Isotomidae Borner, 1913

Sub-family- Proisotominae Stach, 1947

Genus - Folsomia Willem, 1902

3.2 Folsomia candida var distincta (Bagnall, 1939) (Plate III, Figs. 1-13)

Folsomia distincta Bagnall, 1939, Ent. Mon. Mag. 75 : 27; Folsomia candida var distincta Gisin, 1960, Mu. D'Hist. Nat. Geneve : 184; Folsomia candida Willem 1902, Ann. Soc. ent. Belg. 46:280.

3.2.1 Body length : 1.3 mm.

3.2.2 Coloration : Pale yellow throughout.

3.2.3 Clothing :

Ant. IV with apical cone and subapical sense bulbs with guard setae in a groove and ca. 10 typical sensory setae (Fig. 1) Ant. III with a pair of straight small rods in a groove accompanied by a pair of blunt setae situated slightly behind (Fig. 2). Setae on manubrium moderately long, simple.

3.2.4 Head :

Ant./head = 8/7. Relative length index of Ants. I: II:III:IV = 3:6:5:11, eyes absent. PAO (Fig. 3) broadly elliptical (on one example one side PAO is notched, other

side being elliptical as usual), double outlined. PAO/base of Ant. I = 7:10. Labrum low with 4/5, 5.4 setae, margin without structures and distal 2 rows with papillae (Fig. 13). There is a transverse cuticular fold near the distal margin of labrum. Maxillae (Fig. 4) with fingerlike lamellae and mandible (Fig. 5) apically with 4 teeth and well developed molar plate.

3.2.5 Thorax :

Unguis and unguiculus slender (Fig. 6) untoothed, without tenent hair. Relative length index of Ths. I:II:III = 3:6:5 and unguis:unguiculus = 11:6.

3.2.6 Abdomen :

Ventral tube anteriorly without setae, posteriorly with ca. 6 setae and laterally with 7 setae in each flap (Fig. 8) Rami tenaculi quadridentate, corpus with a single stout seta (Fig. 7). Furca short, attaining the distal end of the abdomen I. Relative length indices of Abds, I:II: III:IV-VI = 4:5:5:10 and of manubrium : den : mucro = 14:20:3. Manubrium anteriorly with 9+9 = 18 setae arranged as 1,1,2,2,2,1 (Fig. 9), the last or distal setae is longest, all/other setae are simple and moderately long. Posteriorly manubrium with 27-28 setae, feeble in nature (Fig. 10), median sclerosis is absent. Den anteriorly with ca. 26 setae arranged as v, v, ovi, oi, ovi, ovi, ovi, oi, v, ov, oi, ovi = 26 (Fig. 11a,b). Posteriorly den has 6 setae

arranged as 1,1,1 ... 1,1,1 = 6. Mucro short, bidentate with subequal apical and anteapical tooth (Fig. 12).

3.2.7 Materials examined : Shillong:Botanical Garden: from soil and leaf litter, 16 X 1974, 4 exs; from leaf litter, 31 XII 1974, 5 exs, Shillong Peak area, leaf litter and soil, 4 ii 1975, 4 exs. All examples were collected by R.K. Bhattacharjee.

3.2.8 Distribution :

Folsomia candida (S.Str.) Willem, 1902 has been recorded from Europe, USSR, Czechoslovakia, Japan and Nepal. Folsomia candida var distincta Bagnall, 1939 was recorded from Britain, Switzerland, France, Spain and now from India (nov.).

3.2.9 Comparison :

The unique features of this subspecies (var. distincta) are :

a) Antenna IV is more than twice of antenna III.

b) Claw without tooth.

c) Fewer setae on the manubrium in the adult.

d) PAO is less than the breadth of antenna I.

Apart from these characters, setae on the ventral tube and ventral setae of dentes are also characteristic of the subspecies. Yosii (1966) reported Folsomia candida from Jumbesi, Nepal, however, he (Yosii, 1966) holds that these

specimens were badly damaged and exact morphological studies were difficult to make. However, Yosii (1971) recorded this species from Khumbu Himal Nepal. There is no record of Folsomia candida var distincta from India and as such this is a new record for India.

Family - Isotomidae Borner, 1913

Subfamily - Isotominae Schaeffer, 1896

Genus - Isotoma Bourlet, 1839.

3.3 Isotoma (Desoria) trispinata MacGillivary, 1896 (Plate IV, Figs. 1-10)

Isotoma trispinata MacGillvary, 1896, Cand. Entom, 28:51, Desoria trispinata Yosii, 1966, J. Coll. Arts and Science; Chiba Univ. 4(4): 504-505.

Isotoma (Desoria) trispinata Yosii 1971, Bd.4 Lg 1, S.80:80-130, Innsbruck-Munchen, 1971.

3.3.1 Body length : upto 1.5 mm

3.3.2 Coloration :

Bluish-black pigments on dirty yellow ground color. Ocellar field black. Base of antennae, dorsal side of head, ventral tube, manubrium and legs colored with bluish-black pigments. Two longitudinal stripes of black pigments interrupted only on the inter-segmental area, extend from thorax II to abdomen V.

3.3.3 Clothing :

All antennal segments bear simple setae, manubrium ventrally with many simple setae arranged in a triangle, distal manubrial setae long but not modified into spines (Fig. 9). All body setae are plain and short arranged in transverse rows in the middle of each segment.

3.3.4 Head :

Head/antennae = 13/19. Relative length index of Ants. I:II:III:IV = 8:10:15:24. Eyes 8+8 forming 2(5+3) groups, all subequal (Fig. 1). PAO broadly oval, double lined, placed in front of anterior eye and slightly larger than the latter. Sense organ of Ant. IV (Fig. 2) is a small apical dome with a subapical conical process and a small knob in a pit slightly behind the conical process. Labrum (Fig. 3) with 4/5, 5,4 setae, the distal row socketed, margin with 4 very small spinules. Beginning of the ventral groove in the head with characteristic fold of integument bearing 5+5 setae.

3.3.5 Thorax :

Claw (Fig. 4) broad, without tooth. Unguiculus almost half of unguis, with broad triangular inner lamella, apically pointed, the outer lamella more or less straight. Tenent hair absent. Relative length index of Ths. I:II:III = 6:34:36.

3.3.6 Abdomen :

Ventral tube with 4 + 4 setae on the anterior face (Fig. 6) and 3 + 3 setae on the posterior face in longitudinal rows (Fig. 7). Lateral flaps of ventral tube with 3 + 3 setae (Fig. 6). Tenacula with 4 barbs in ramii and corpus with 6 setae (Fig. 5). Relative length index of Abds. I-VI = 18:32:35:35:14:11. Manubrium ventrally with

many simple setae in a triangle, marginal thickening with 1 + 1 process, distal setae are not spiny (Fig. 9). Den annulated, dorsally with a distal unannulated portion. Den anteriorly possesses 3 setae and some 6 + 6 lateral setae alongwith small ventral setae arranged in 3 longitudinal rows. Relative length index of manubrium : den : mucro = 30 : 65 :5. Mucro tridentate (Fig. 10) apical tooth is elongate and slightly bigger than the subapical, the third tooth is lateral, spine like and smaller than apical tooth. Female genital opening as in Fig. 8, having a few small setae specifically arranged.

3.3.7 Materials examined : India : Meghalaya : Shillong : Botanical Garden - from rotting pineseeds on soil 9 IX 1974, 21 exs; decayed leaves 16 X 1974, 7 exs; Shillong-peak, leaf litter 12 X 1974, 15 exs. All examples were collected by R.K. Bhattacharjee.

3.3.8 Distribution :

USA, Europe, Japan, Formosa (Taipai), Nepal (Khumbu Himal), India (Sikkim, Gangtok, previously by Yosii, 1966 and now from Shillong, Meghalaya).

3.3.9 Comparison :

These examples are similar to the Japanese forms of Isotoma (Desoria) trispinata described from Japan, Nepal and

Hhumbu Himal by Yosii (1966 and 1971) with minor differences of possessing 1 + 1 marginal thickening of manubrium and 7 setae on corpus.

Fjellberg (1977) in a personal letter wrote to me that these specimens show close resemblance in their maxillae with his "Notabilis" group. Significant morphological features of this species are the position of PAO directly above the eyes and all ocelli in the eye field are almost equal in size.

3.4 *Isotoma* (S. Str.) *jayasrae* n.sp. (Plate IV, Figs. 11-18)

3.4.1 Body length upto 3.8 mm.

3.4.2 Coloration :

Ground colour brownish yellow. Immature specimens less colored (upto 2.4 mm) and mature specimens are usually either deep black or blue-black colored throughout dorsal part of head, trunk, antennae, eye field, legs and manubrium. Intersegmental areas colorless, ventral side of the body pale. A deep black spot in the "vertical field" is noted in all examples. Lateral part of head with less pigmentation.

3.4.3 Clothing :

Ant. III sense organs are 2 pairs of almost straight rods with a few longer curved sense setae, slightly modified than the usual ones (Fig. 12). Setae on the ventral tube subequal and on manubrium and den dorsal setae are ciliated. Ventral side of den with many small setae. All body setae are brownish, larger ones are serrated, smaller ones are either ciliated or smooth. Male genital opening is surrounded by a ring of many short setae, central cone with 2+2 subequal setae. Anterior to the genital opening there are 8 medium length setae.

3.4.4 Head :

Ant./head = 5/3. Relative length index of Ants. I:II: III:IV = 6:19:18:25. Ant. IV subapically with a conical process (Fig. 11). PAO oval (Fig. 13) double lined and 2/3 in diameter of the anterior eye. Eyes 8+8, subequal, 'h' is smaller than others. Apex of mandible with 4 teeth. Labrum with 4/5, 5,4 setae; margin narrow with 2+2 unequal round tubercles, the outer two are larger than the rest.

3.4.5 Thorax :

Claw (Fig. 14), unguiculus half as long as unguis, both well-developed. Unguis with 2,2,2 inner teeth, the proximal inner tooth is slightly larger than the distal; a pair of prominent outer lateral teeth and a slight long seta in the place of tenent hair. The inner border of the unguis with 'transverse striae' as in Isotoma viridis group. Unguiculus acutely lanceolate with a prominent inner tooth. Relative length indices of Th. II : Th. III = 35 : 31 and of femur : tibiotarsus = 20 : 23.

3.4.6 Abdomen :

Ventral tube anterior face with ca. 25 pairs of subequal setae (Fig. 18), posterior face with ca. 46 setae, distal pair longer than the rest. Lateral flaps of ventral tube with ca. 60 setae each. In lighter or immature form setae on ventral tube are less in number. Rami tenaculi

quadridentate, corpus with ca. 35 subequal setae (Fig. 17). Relative length index of Abds. I:II:III:IV:V:VI = 22:25:36: 29:15:13. Abd. III slightly bigger than Abd. IV. Relative length index of manubrium:den:mucro = 30:70:3. Manubrium dorsally hirsute with 3+3 longer and ciliated setae and ventrally with many setae arranged in a triangular field, distal setae are spiniform and intensely brownish in colour. Marginal thickening of manubrium, brownish with 2+2 anisomorphous teeth (Fig. 15). Inner lateral setae of the den are considerably feathered, while the outer lateral setae are ciliated. Dental base dorsally with 2 long and many medium setae. Ventrally den with many small setae. Mucro (Fig. 16) always with 4 teeth, apical and anteapical subequal the 3rd is lateral and 4th is very small, ventral in position.

3.4.7 Materials examined : Holotype : ♀, (slide), India : Meghalaya : Shillong : Botanical Garden : leaf litter and moss 16 X 1979, Coll. Smt. Jayasree Bhattacharjee.

Paratypes : India : Meghalaya : Shillong : Botanical Garden, leaf litter and moss 16 X 1979 coll. Jayasree Bhattacharjee 19 exs; same data 3ii 1980 Coll. R.K. Bhattacharjee, 5 exs; Umroi - from moss 24 XI 1984, Coll. R.K. Bhattacharjee, 5 exs. J & K State : Katra (Jammu) side of a hill towards BaisnaDevi temple, leaf litter, 13 X 1987, 5 exs. Coll : Jayasree Bhattacharjee.

3.4.8 Distribution :

India, Meghalaya (Shillong and Umroi), J & K State Jammu (Katra, Baisna Devi Hills).

3.4.9 Comparison :

This new species is unique in combining features like number of seate on the corpus, 2 long setae on dorsal dental base, 2+2 anisomorphous teeth on the marginal thickening of manubrium and smaller oval PAO compared to other species of Isotoma viridis group. In coloration and nature of PAO, it is similar to I. virgata Yosii, 1963, but the latter has more setae on corpus, unispinose marginal thickening of manubrium and different furcal ratio. In the shape of mucro, claw and labral margin it (the new species) is very close to I. pinnata (Borner, 1909) but differs in color pattern, marginal thickening of manubrium, shape and size of PAO and setae on Vt. and tenaculum. The new species with its 2+2 anisomorphous marginal thickening resembles I. nishihirai Yosii, 1965, but can be readily separated from the latter by size of PAO, setae on Vt. and corpus and in absence of purple transverse band along the proximal part of each tergites from Th. III to Abd. V.

The new species differs from I. viridis, Bourlet, 1839 in not having mid dorsal longitudinal pigmented streak on body. Species separation of Isotoma genus might be based on number and nature of setae along inner and outer dorsal side of dentes (Borner, 1909, Stach, 1947) or number of marginal thickening on ventral side of manubrium and Ant. III sense organs (Yosii, 1963). Isotoma Jayasrae n.sp. can be easily separated from I. anglicana (Lubbock 1862) by its anismorphous teeth of marginal thickening of manubrium and 2 long setae along with many medium sized setae on the dental base. I. siva Imms, 1912 (Badrinath, Himalaya) = Mani et.al. N.W. Himalaya having characters like 6+6 eyes, absence of PAO and bidentate mucro needs further study for proper taxonomic determination. I. sarukundensis Baijal, 1955 with toothless claw, tridentate mucro possibly belong to I.(Desoria) group.

3.4.10 Key to related species of Isotoma genus

1 Ventral marginal manubrial thickening unispinose... 2

\- Ventral marginal manubrial thickening bispinose.. 5

2 Ant. III organ with more than 4 accessory sense setae ..... I. decorata Brown, 1926.

Syn I. spinicauda Bonet 1930
sensu Yosii 1963, 1971, Afghanistan, Nepal

\- Ant. III organ with less than 4 accessory sense setae 3

3 Ventral tube with characteristic 5 digital processes upon apical lobe ..... I. diverticula Yosii, 1966 (Nepal)

- Ventral tube without any digital process 4

4 Mid ventral manubrial setae short, thick and striated, violet black pigments on body in three broken longitudinal lines ..... I. pinnata Borner, 1909; sensu Yosii, 1963, Japan.

- Mid ventral manubrial setae short thick and smooth, distal dorsal manubrial setae feathery. Heavy black pigments on middle of Th. III, Abd. I, Abd. II and Abd. III ..... I. virgata Yosii, 1963, Hindukush.

5 Ventral marginal manubrial thickenings subequal .... I. anglicana Lubbock, 1862, England.

- Ventral marginal manubrial thickenings anisomorphous 6

6 PAO is almost round and as large as anterior ocellus, Ant. III = Ant. IV .... I. nishihirai Yosii, 1965

- PAO is oval and 2/3 in diameter of anterior ocellus ..... I. jayasrae, n.sp. North-East Indi

3.4.11 Etymology :

This new species is named after its collector Smt. Jayasree Bhattacharjee.

Family - Entomobryidae Tomosvary, 1882

Subfamily - Entomobryinae Schaeffer, 1896

Genus - Sinella Brook, 1882

3.5 Sinella (S.Str.) montana Imms, 1912 (Plate V, Figs. 1-10)

Sinella montana Imms, 1912, Proc. Zool. Soc. London 1912 : 80-125. Syn.S. (S.Str.) submontana Stach, 1960, Acta. Zool. Cracoviensia 5 : 526. (New Synonomy).

3.5.1 Body length upto 1.8 mm (excluding appendages)

3.5.2 Coloration :

White in life, pale yellow in preserved condition along with slightly diffused orange pigments on the body.

3.5.3 Clothing :

Body covered with ciliated setae. Flexed macrochaetae are present throughout the body specially a group of macrochaetae are found on the anterior border of mesonotum (Fig. 5). Lasiotrichia without accessory setae are distributed in 2,3,2 arrangement on Abd. II, Abd. III and Abd. IV. Mid and hind tibiotarsus with a thick blunt ciliated 'P' seta on the unguicular side. There are 6 sooth setae on tibio-tarsus. Distribution of macrochaetae on head and body are characteristic as illustrated in the Figs. 8 and 9. Manubrium and dentes only with ciliated setae.

3.5.4 Head :

Head with narrow elongated distal portion. Ant./head diagonal = 39/12. Relative length index on Ant. I : II : III : IV = 10 : 19 : 20 : 31 . Antennae not annulated. Ant. IV without subapical sense organs and Ant. III with 2 small rods in a groove distally. Eyes absent. Labrum with 4/5, 5, 4 setae, all setae smooth (Fig. 1). Labral margin with 2+2 unequal tubercles, median intrusion of the smooth area of labrum round and broad.

3.5.5 Thorax :

Relative length index of different parts of leg- viz. trochanter : femur : tibio-tarsus : claw = 8 : 24 : 37 : 4, and Th. II and Th. III = 30 : 22. Claw with both unguis and unguiculus toothed. Unguis with paired inner middle winged teeth, one of which is broad and large, a distal unpaired small tooth and a small outer dorsal tooth (Figs. 2,3,4). Tenent hair 1,1,1, feeble but distinctly truncated at the apex. Tibiotarsus with single row of 6 smooth spiny setae.

3.5.6 Abdomen :

Ventral tube on the anterior face with 3+3 large, ciliated setae alongwith some smaller setae. Lateral flaps with ca. 7 setae each (Fig. 7). Tenaculum with 4 barbs in rami and corpus with a median stout seta. Relative length index of Abds. III and IV = 15:40. Furcula well developed. Manubrium dorsally only with ciliated setae. Relative length

index of manubrium : den : mucro = 62 : 78 : 3. Dentes annulated dorsally, distal unannulated portion of den is small. Mucro falcate, elongate with a long basal spine reaching to the tip of mucro (Fig. 10).

3.5.7 Material examined : India : Meghalaya : Shillong : Dohling House, water soaked coconut shell, 8 IX 1974, 78 exs. and rotting wood 12 IX 1974, 83 exs. All examples were collected by R.K. Bhattacharjee.

3.5.8 Distribution :

Afganisthan, Nepal and India (N.W. Himalaya, South India, West Bengal and now from Shillong, Meghalaya).

3.5.9 Comparison :

These specimens of Sinella from Shillong due to absence of smooth setae on manubrium and more setae on Vt. are to be placed under S. (Sinella) group and are similar to Sinella coeca Schott, 1896 sensu Gisin, 1960 and Yosii, 1971, but differs in head/Ant. ratio, in having well developed outer tooth on the unguis and in possessing only ciliated setae (instead of smooth ones of the cited species) on the dorsal side of manubrium. Yosii (1971) while describing S. hoefti Schaeffer, 1901, from Khumbu Himal synonomized it with S. montana Imms, 1912, and noted that in S. hoefti Schaffer, 1901 labral margin has a transverse fold but no granules or spinules and ventral tube on its anterior face

possess 2+2 large alongwith 7+7 feeble setae. However, all the specimens examined in this investigation possess labral margin bearing 2+2 unequal tubercles and Vt. with 3+3 large ciliated setae alongwith smaller setae on anterior face. Yosii (1971) further opined that S. coeca Schott, 1896 is "species inquirenda" and therefore Khumbu Himal examples of Sinella are to be placed in S. (S.Str.) hoefti, Schaffer, 1901. However, it is evident from afore mentioned differences between S. hoefti and present examples of Sinella that these latter specimens are somewhat different. Differences between S. hoefti Schaffer and S. montana Imms invalidate Yosii's (1971) contention to synonymize latter with former species.

S. montana Imms, 1912 from Badrinath, Garwal Himalaya, also differs from the examples from Shillong in "claw character" in presence of 2 inner distal teeth and in absence of tenent hair. But present investigator is of the opinion that these characters are possibly due to geographic variations in these populations and are not sufficient to warrant species separation, and hence all these specimens are considered to be of Sinella montana Imms, 1912. Stach (1964) also while examining S. coeca from China disregarded distal inner tooth on unguis of S. montana. Stach (1960) reported a new species viz. Sinella submontana n.sp. from Kabul, Afghanistan, which also differs from the specimens obtained from Shillong due to smaller size of the outer

teeth of unguiculus, absence of clear tubercles on labral margin and in having an additional inner distal fine tooth on the unguis. However these differences are not sufficient to give a new species status to S. submontana Stach,1960. Considering all aspects of comparison between Shillong examples of Sinella and other reported species of Sinella, placement of these examples in the species Sinella (S.Str.) montana (Imms,1912) is favoured and S. submontana Stach, 1960 is synonymized with it for the first time. Unfortunately chaetotaxy of Sinella species were not considered in details by earlier authors and therefore no detailed study of various species or species complex is possible at this stage.

3.6 Sinella (S. Str.) curviseta Brook, 1882 (Plate VI, Figs. 1-10b)

Sinella curviseta Brook, 1882 Journ. Linn. Soc. Lond. (Zool) 16 : 541-45.

3.6.1 Body length upto 1.6 mm, excluding appendages.

3.6.2 Coloration :

White in life, pale yellow in preserved condition. Diffused orange pigments are present on the body.

3.6.3 Clothing :

Body covered with ciliated setae. Flexed macrochaetae are distributed throughout the body in specific arrangement (Fig. 9). Macrochaetae on the head region are also characteristic. Lasiotrichia are present on Abds. II: III:IV as 2:3:2 respectively. A group of flexed macrochaetae are present on the anterior border of mesonotum.

3.6.4 Head :

Head/antenna = 11/25. Relative length index of Ants. I:II:III:IV = 7:14:13:24. Antennae not annulated. Ant. IV without any subapical organ. Ant. III sense organs are a pair of small rods near the distal end (Fig. 1). Eyes 2+2 (Fig. 8) subequal, deeply black pigmented round or irregular in shape and separated from each other. Labrum with 4/5, 5,4 smooth setae, distal margin of labrum with

2+2 unequal tubercles median intrusion of the smooth area of labrum is round and slightly narrow (Fig. 2).

3.6.5 Thorax :

Mid and hind tibiotarsus with a thick blunt ciliated seta, 'P' seta on the unguicular side. Some 8 smooth setae are present between this 'P' seta and distal end of the tibiotarsus. These setae are medium in length and smooth in nature. Trochanteral organ consists of smooth ca. 23 slender setae (Fig. 5), inner setae being slightly spiny. Claw with a pair of inner middle wing like teeth, one of which is broader than the other (Figs. 4a,b). A small unpaired inner distal tooth is present above these winged teeth. External basal tooth of claw is very small. Unguiculus lanceolate without tooth. Tenent hair feeble, setaceous.

3.6.6 Abdomen :

Ventral tube anteriorly on each side with 2 large ciliated setae along with 5 smaller setae (Fig. 7). Lateral flaps of Vt. with ca. 7 smooth setae each and the posterior face with 7+7 setae, distal ones being longer than the rest (Fig. 6). Tenaculum with 4 barbs on rami and corpus with a single median stout seta (Fig. 3). Manubrium dorsally with ciliated setae. Furca well developed. Relative length index of manubrium : den : mucro = 96 : 120 : 5. Den dorsally

crenulated almost upto the base of mucro, uncrenulated portion = 2x mucro. Mucro elongate with 2 subequal teeth and a basal spine reaching upto the tip of ante-apical tooth (Figs. 10a,b). A ciliated seta over reach the mucro.

3.6.7 Materials examined : India : Meghalaya : Shillong : Dohling house : sand particles below and nearby area of a water tap 12 IX 1974, 50 exs. Botanical Garden water soaked coconut shell 8 IX 1974, 43 exs. and on 12 IX 1974, 61 exs. Leaf litter mixed up with soil 20 X 1974, 6 exs; house, below somewhat rusted oil tin with very little water inside, 11 II 1975, 23 exs; house below watersoaked rotting wood 15 IX 1975, 83 exs. All these materials were collected by R.K. Bhattacharjee.

3.6.8 Distribution :

Holarctic, Europe, U.S.A., Japan, U.S.S.R., India (Punjab, Sikkim, Kerala and now Meghalaya, Shillong).

3.6.9 Comparison :

These examples coincide very well with Sinella (S.Str.) curviseta Brook,1882 described by Gisin (1960) and Yosii (1971). However, specimens at hand differ from the cited species in not having any reddish brown pigments on the head, tergite, leg or manubrium. Considering these

differences in pigmentation to be insignificant for species separation all Shillong examples are placed under S.(S.Str.) curviseta Brook.

Family - Entomobryidae Tomosvary, 1882 (as tribe)

Subfamily - Orchesellinae Borner, 1906

Genus - Dicranocentrus Schott, 1893

3.7 Dicranocentrus fraternus . . (Plate VII, Figs. 1-16b)

3.7.1 Body length (excluding appendages) upto 4.2 mm.

3.7.2 Coloration :

Blue black pigments diffused on Ant. I and II while Ant. III and IV completely bluish violet in colour. Ocellar field, antennal base, coxae and tibiotarsus of all legs, femur of hind leg and base of the claw slightly pigmented. Thorax II to Abd. I with broken longitudinal patches of blue and violet pigmentation. There is a characteristic blue black marking on the interocular field.

3.7.3 Clothing :

Head and body covered with oval or round brownish scales, larger scales are slightly denticulate in the distal margin (Fig. 9a). Scales on the antennae extend upto Ant. III. Legs upto tibiotarsus and ventral tube, manubrium and den are also covered with slightly narrowed brownish scales. Annulated segments of antennae with small 'verticillating setae' only (Fig. 1a,1b). Manubrium dorsally with many plumose setae and ventrally with elongate

scales. Dentes dorsally with some 1+1 well developed blunt brownish conspicuously straight ciliated setae (Fig. 15). Dentes without any spines. Setae on the ventral side of head ciliated. Larger body setae are flexed at the apex and ciliated. Distribution of macrochaetae as in Figs. 12 and 13.

3.7.4 Head :

Antennae 6 segmented. Ant. I and II subdivided; segments Vth and VIth annulated (Fig. 1(b)). Relative length index of Ants. I:II:III:IV:V:VI = 6:21:11:26:68:61, (in one example (4.0 mm) antennae 5 segmented, Ant. ratio = 10:32:16:36:109). Head/Ant. = 1/4. Eyes 8+8, 'g' is the smallest. Labrum with 4/5, 5,4 setae, prelabral setae simple. Margin of labrum with 2+2 papillated spinules (Fig. 4). Labral papillae rounded. Macrochaetae on head are illustrated by Fig. 12, S_2 absent. Ant. VI with Pin seta (Fig. 1(a)). Setae of anterior row of labial triangle smooth but posterior row ciliated. There are about 9-10 setae on the ocellar field of this species. Apex of mandible with 3 teeth (Fig. 2) maxilla with 10/11 fine teeth (Fig. 3). Ant. III sense organs as in Fig. 5.

3.7.5 Thorax :

Tibiotarsus without smooth setae except a seta opposite the tenent hair of metathoracic leg. Unguis with a pair of

prominent inner teeth away from the claw base and 2 very small unpaired inner distal teeth and a pair of outer lateral teeth (Fig. 7). Unguiculus lanceolate with a small outer basal tooth. Tenent hair long with enflated distal portion. Pretarsal setae present. Body macrochaetae are illustrated in the Fig. 13, some specimens show irregularities in the macrochaetae of Th. II and Abd. IV. Trochanteral organ with ca. 45 setae, many of which are spine like.

3.7.6 Abdomen :

Ventral tube multi-setaceous, scaly, distal anterior ones are 3+3, ciliated and longer than the rest (Fig. 10). Rami of tenaculum with 4 teeth and corpus bears a median seta (Fig. 6). Furca well developed. Manubrium dorsally with many ciliated setae and ventrally with elongated scales. Dentes dorsally with 1+1 well developed "plumose setae" on the proximal portion (Fig. 15). Dentes without spines. Uncrenulated portion of the dentes are about 4 times the length of mucro. Relative length index of manubrium : den : mucro = 44 : 63 :2. Mucro bidentate with a basal spine (Fig. 16a). However, some specimens with broken spine are also found in the same population along with normal specimens (Fig. 16(b)).

3.7.7 Material examined : Holotype : India : Meghalaya : Shillong Crinoline falls, soil and leaf litter 18 X 1974 Coll: R.K. Bhattacharjee, deposited at Illinois Natural History Survey, Urbana, Illinois, U.S.A.

Paratypes : India, Meghalaya, Shillong, same data as holotype 30 exs; Shillong Peak, 1960 m. m.el; broad leaf litter forest 31 X 1974, 41 exs; same data 28i 1975, 54 exs; same data 3ii 1975, 60 exs; same data 4ii 1975; 40 exs; Boyce Road leaf litter and slope of a hill 29i 1975, 19 exs. Nagaland, Kohima, deciduous forest litter 11 IV 76 5 exs. All paratypes were collected by R.K. Bhattacharjee.

3.7.8 Distribution : India : Meghalaya (Shillong), Nagaland (Kohima).

3.7.9 Comparison :

This species is unique in its macrochaetal arrangement on the head and body apart from coloration and claw character. Absence of dental spines along with 1+1 conspicuous plumose setae on the dorsal portion of dentes are also significant for species separation. The specimens obtained from different collection sites can be separated into 2 forms one of which is darker with blue black pigments on the sides of the body and ocellar field the other being comparatively lighter form. However, no chaetotaxic differences could be recorded and both these forms occurred sympatrically.

This new species resembles Dicranocentrus indicus Bonet, 1930, in absence of dental spines and presence of strong proximal dorsal dental plumose setae. However, difference between the new species and D. indicus are significant to separate these species viz. chaetal pattern on the body of new species (Th. III to Abd. III = 10,4,3,4 and D. indicus sensu Yosii, 1964 (Th. III to Abd. III = 9,3,2,2), coloration, distal unpaired tooth of unguis, fine outer tooth of unguiculus and labral margin. D. indicus sensu Bonet, 1930 and D. indicus sensu Yosii, 1964 are probably different species since these 2 species differ in their character of claw, presence of "eversible sac" or vesicle of Abd. V and VI and antennae and dental chaetotaxy. The new species is also similar to the Nepalese D. janetscheki Yosii, 1971 and D. nepalensis Mari Mutt, 1980 but can be separated from the former by the chaetotaxy of Th. II and Abd. II and from the latter by color pattern and chaetotaxy of Th. III to Abd. II. Furthermore 1 outer cervical and 2 postocular macrochaetae on the head are absent in D. nepalensis Mari Mutt, 1980. A key to separate the new species from other Dicranocentrus described from India and Nepal is given after the next species D. singularis n.sp. D. fraternus n.sp. also differs from D. thaicus Yosii 1961 and D. fasciatus Yosii, 1961 (both from Thailand) in having different chaetotaxic formulae.

3.7.10 Etymology :

This new species is named as D. fraternus n.sp. indicating similarities between the new species and Nepalese species D. janetscheki Yosii, 1971 on one hand and with D. nepalensis Mari Mutt, 1980 on the other hand.

3.8 Dicranocentrus singularis . . . . (Plate VIII, Figs. 1-15)

3.8.1 Body length upto 2.3 mm, excluding appendages.

3.8.2 Coloration :

Blue black pigments in the form of transverse bands totally covering thorax II to abdomen II, pigments extending towards coxae. Abd. III to Abd. VI with pigments mostly restricted in the form of scattered patches on the middle of the segments. Antennae and legs with blue pigments (Fig. 1).

3.8.3 Clothing :

Head and body covered with oval or round brownish to bluish scales on areas intensely coloured, larger body scales are slightly denticulate in the distal margin (Fig. 10b). Scales on the antennae extend upto Ant. III. Legs, manubrium and den with elongate scales. Ant. V and VI annulated with 'verticillating shortsetae' only. Compared to previous species this species has less number of macrochaetae on the body (Figs. 13 and 14), ventral tube and trochanter.

3.8.4 Head :

Head macrochaetae as in Fig. 13. Ant V and VI subequal in length, annulated. Relative length index of Ants. I:II: III:IV:V:VI = 7:18:12:23:41:43. Ant. VI with 'Pinseta'.

Sense organs of Ant. III with 5 slightly curved sense rods (Fig. 2). Head without S_0-S_2 and S_4 macrochaetae. Labral papillae rounded with spinelike process (Figs. 5 and 6). Labral setae 5,5,4 all smooth and not bifurcated. Labial triangle in the posterior row with 1 smooth and 3 ciliated setae while the anterior row with 3 smooth setae (Fig. 4). Most setae on the ventral side of head except those immediately next to labial triangle are ciliated. Eyes 8+8, 'g' and 'h' smaller (Fig. 13).

3.8.5 Thorax :

Tibiotarsus without smooth setae. Unguis with a pair of small, very basal inner teeth alongwith 2 small distal unpaired teeth (Figs. 11 and 12). Inner margin of unguiculus of fore and mid claw notched at the middle but on hind claw it is lanceolate. Tenent hair long but apex not so truncated. Outer margin of the unguiculus with a very small tooth (Figs. 11 and 12). Trochanter well developed with setae on both sides (Fig. 9).

3.8.6 Abdomen :

Ventral tube with 1+1 longer ciliated setae on the anterior face alongwith many smaller setae (Fig. 8). Tenaculum with 4 teeth on rami and corpus with a median seta (Fig. 7). Relative length index of manubrium : den : mucro = 96 : 184 : 5. Manubrium dorsally with a double

row of conspicuous erect smooth setae. No modified or plumose upright setae on the dorsal portion of dentes. Dentes without spines. Mucro bidentate with a basal spine (Fig. 15). Larger body setae of this species are with flexed apex and ciliated.

3.8.7 Materials examined : Holotypes : India : Meghalaya : Shillong, Ka Mari Road, from moss over pillars on the side of a road on a hill 30 X 1974 Coll. R.K. Bhattacharjee, deposited at Illinois Natural History Survey, U.S.A.

Paratypes : Meghalaya, Shillong same data as holotype 34 exs; St. Edmund's College steps near B.T. Hostel moss over steps on the sides of a hill 12 XI 1974, 18 exs; Boyce Road from moss and fern roots on sides of a hill 20 X 1974, 8 exs. Nagaland, Kohima, forest (Pullebaze hills) litter 11 IV 1976, 3 exs. All paratypes were collected by R.K. Bhattacharjee.

3.8.8 Distribution : India : Meghalaya (Shillong). Nagaland (Kohima).

3.8.9 Comparison :

This species is unique among Indian and Nepalese specimens of Dicranocentrus in its reduced cephalic and trunk macrochaetae and notched unguiculus of fore and mid claw alongwith characteristic dark blue black coloration on body. The absence of upper inner pair of macrochaetae of

Th. II and chaetotaxy of Abd. IV are also significant for species separation. Furthermore D. singularis n.sp. differs from D. fraternus in possessing 1+1 long ciliated setae on the anterior face of ventral tube and less number of setae on the trochanteral organ. D. singularis n.sp. differs from D. indicus in characters like chaetotaxy, coloration, notched inner margin of unguiculus and labral margin.

3.8.10 Etymology :

This species is named in consideration of the unique features like color pattern and reduction of macrochaetae in general on the head and body which single out this species from its closest allies.

3.8.11 Key to related Indian and Nepalese Dicranocentrus sp

1 Dental spines present 2

- Dental spines absent 4

2 Abdomen 6th characteristically elongated, its length approaching that of abdomen 4th.....

- ..... cercifer Imms, 1912 (South India)

- Abdomen 6th not particularly elongated, never as long as abdomen 5th 3

3 Both inner and outer margin of dentes with spines ..... spinosus Prabhoo, 1971 (South India)

- only inner margin of dentes bears spines .....

sundanensis Schoot, 1925

(North Sarawark and also from Malaya, Borneo and IndoChina by later workers)

4 Abdomen I with 2 macrochaetae per side, cephalic and rest of the body macrochaetae reduced .....

singularis n.sp.
(North-East India)

- Abdomen I with 3 or 4 or 6 macrochaetae per side, cephalic and rest of the body macrochaetae not reduced 5

5 Abdomen I with 6 macrochaetae per side 6

Abdomen I with either 3 or 4 macrochaetae perside. 7

6 Head and body with more than usual number of macrochaetae (27 and 65 setae respectively on each side) Unguis without inner tooth, Abd. II and III with 4 and 4 macrochaetae on each side..... pilosus Mari Mutt, 1980 (Nepal). Head and body with normal number of macrochaetae, Abds. II and III with 2 and 3 setae per side ..... thaicus Yosii, 1961 (Thailand).

7 Abdomen I with 3 macrochaetae per side 8

Abdomen I with 4 macrochaetae per side 9

8 Unguiculus without tooth, adult females with elongated upper anal flap bearing eversible sacs, body setae from Th. II to Abd. III = 11,9,3,2,2 ... *indicus* Bonet, 1930. (Sensu Yosii, 1966) (Sikkim, India (Bombay)) and Nepal.

Unguiculus with tooth, adult females without elongated upper anal flap or eversible sacs, dentes without 'plumose' seta, body setae from Th. II to Abd. III = 11,9,3,2,4 ..... *nepalensis* Mari Mutt, 1980 (Nepal).

9 Proximal portion of dentes with 1 upright blunt plumose seta each, pigments on the body do not form distinct bands, body setae from Th. II to Abd. III = 11,10,4,3,4 ..... *fraternus* n.sp. (North-east India)

Pigments on the body form distinct bands 10

10 Den with 1 upright "plumose seta" at the poximal dorsal portion, bands of pigments with specific patterns on Th. III and Abd. I, body setae from Th. II to Abd. III = 9.10,4.2.3 ..... *janetscheki* Yosii, 1971 (Nepal)

Den without any upright "plumose seta" transverse bands of purplish pigments on Th. III, Abd. III and distal part of Abd. IV, Abds. I and II with narrow median pigmented stripe, body setae from Th. II to Abd. III = 10,9,4,4,5 ..... *fasciatus* Yosii, 1961 (Thailand)

Family - Cyphoderidae Borner, 1913 (as subfamily)

Subfamily - Cyphoderinae Borner, 1906 (as a tribe)

Genus - Cyphoderus Nicolet, 1847.

3.9 Cyphoderus sarojini n.sp. (Plate IX, Figs. 1-11)

3.9.1 Habitus typical of the genus (Fig. 9). Body length excluding appendages = 1.1 mm.

3.9.2 Coloration :

Totally white in preserved condition, pale yellow in living state.

3.9.3 Clothing :

Antennae with many sensory setae, slender and curving, scattered among ciliated setae. Body setae small and plain without flexed or large setae. Scales on the body are mostly hyaline (Fig. 10).

3.9.4 Head :

Ant/head = 5.3, Relative length index of Ants. I:II: III:IV = 13:34:23:50. Antennae not annulated. Ant. IV without apical bulb. Sensory setae of antennae with curved rod like setae alongwith many ciliated setae. Mandible normal, labrum with 4/5, 5,4 setae, pre-labral setae smooth. Labral margin without tubercles or granules and distal smooth

portion of labrum not intruded, but with a narrow groove in the middle (Fig. 8). Outer most setae on either side on the middle row of labrum slightly thinner than the rest. Labial triangle with 8 smooth setae. Eyes and eye pigments absent.

3.9.5 Thorax :

Relative length index of Ths. II and III = 11/7. Unguis (Figs. 5,6) stout with 2 unequal, proximal inner teeth, the anterior one of which is thick and spiny. Posterior tooth of this pair is not sharply marked and almost like a ridge. Tenent hair 1,1,1 curved at the tip, subequal to unguiculus in length. No inner or outer distal teeth present on unguis. Unguiculus lanceolate with a broad outer tooth. Trochanteral organ is well represented with ca. 12 setae in 'L' arrangement (Fig. 1), setae on tochanter are small and plain. Relative length index of trochanter : femur : tibiotarsus : claw = 22 : 46 : 76 : 10.

3.9.6 Abdomen :

Ventral tube elongate with 2+2 slender ciliated setae on the anterior face and ca. 7 (2+2,1,1+1) slender setae on the posterior face (Fig. 2). The lateral flaps of Vt. with 3 small setae each (Fig. 2a). Tenaculum with 4 barbs and corpus with a single seta. Relative length index of Abd. III and IV = 1/4. Relative length index of manubrium : den : mucro = 70 : 49 : 26. Manubrium ventrally

with scales and dorsally with many ciliated setae. Dentes (Figs. 3a,b and 4) with 6 outer and 5 inner subequal finged scales. On the basal lobe of dentes there are 1 smooth and 3 ciliated setae in transverse rows. There are 3 ciliated setae and 1 small almost plain seta dorsally arranged on the middle longitudinal line between the outer and inner rows of scaly setae (Fig. 3a). Mucro relatively longer than in other species and with almost straight apical and slightly curved anteapical tooth (Figs. 7a,b). The margins joining anteapical to the base of mucro are smooth.

3.9.7 Materials examined : Holotype : India : Meghalaya : Shillong : Assam Rifles Road from the side of a hill opposite a stream along with loose stones 31 X 1974 Coll. R.K. Bhattacharjee.

Paratypes : India : Meghalaya : Shillong, Dohling House Compound, Hopkinson Road in loose stone chips blocked by rotten logs, 12 X 1983, 10 exs; from same locality and data as holotype, 5 exs. All paratypes were collected by R.K. Bhattacharjee.

3.9.8 Distribution : India : Meghalaya : Shillong.

3.9.9 Comparison :

This new species is similar to Cyphoderus albinus (Nicolet, 1842) syn. Cyphoderus rubiae Baijal, 1955 (Yosii, 1966b) by its bidentate mucro and claw with 2 unequal inner

teeth. However, the new species differs from C. albinus by having broad apical and comparatively smaller anteapical teeth of the mucro, by somewhat broad posterior, inner tooth on the claw (Gisin 1960; Nosek, 1962), by not having the median intrusion of the labral margin and by the different number of trochanteral setae. The new species differs from C. javanus Borner, 1906 (Syn. C. assimilis Borner 1906, sensu Handschin, 1929; Yosii, 1966) in that it lacks the inner distal tooth of the claw and the median intrusion of the smooth area of the labrum. Further, the lateral flaps of the ventral tube have 3 instead of 2 setae each, the basal lobe of den has 1 smooth and 3 instead of 2 ciliated setae and dorsally den has 3 feathery and 1 smooth setae unlike C. javanus. From the diagram (Fig. 1 and 2) given by Prabhoo, 1971a, his C. javanus from Kerala, better be placed in C. albinus Nic. C. dubious Borner, 1913 from Central India has longer mucro with slightly arcuate subequal teeth compared C. sarojini n.sp.

Cyphoderus simulans Imms, 1912 (Syn. C. assimilis Handschin, 1929) differs from the new species in having a longer claw with 1 basal and 2 small distal teeth on unguis. C. asiaticus Yosii, 1959 has much more straight mucro with 4 teeth.

It is worth mentioning here that most of the members of the family Cyphoderidae are well known myrmecophiles or

termitophiles (Murphy and Yosii, 1987). However, some species like the present one are commonly collected in the leaf litter, soil or sand granules. Delamare Debouteville (1948) revised the taxonomy of the family and discussed the ecology and ethnology of its species.

3.9.10 Etymology :

The new species is respectfully dedicated to my mother Late Sarojini Bhattacharjee.

3.9.11 Key to related species of Cyphoderus

1 Mucro bidentate 2

Mucro quadridentate ..... C. asiaticus Yosii, 1959 (Singapore)

2 Unguis with 1 prominent spine like and another almost obscure inner tooth ..... C. albinus (Nic, 1842) (Nepal, India) Syn. C. rubiae Baijal, 1955 Syn. nov. (Himalaya)

Unguis with more than one prominent inner teeth 3

3 Inner teeth of Unguis are unequal and two in number, median intrusion of the labral margin absent ..... C. sarojini n.sp. (North-East India).

Inner teeth of Unguis unequal and three in number, labral margin with median intrusion 4

4 Claw longer than in other spp., Unguis with 1 basal and 2 distal inner teeth, dentes with 6 outer and 6 inner scales each ..... C. simulans Imms, 1912 syn. C. assimilis (Lower Burma) Handschin, 1929, South India, Roonwal 1951, Himalaya

Unguis with 2 basal and 1 distal fine inner teeth, dentes with 6 outer and 5 inner scales each

..... C. javanus Borner, 1906

(Java, Thailand, India, Pakistan, Japan)

Family - Paronellidae Börner, 191[illegible] (as Subfamily)

Subfamily - Troglopedetinae Börner, 1913

Genus - Troglopedetes Absolon, 1907

3.10 Troglopedetes rasendrans n.sp. (Plate X, Figs. 1-14)

3.10.1 Habitus Cyphoderus like, typical for the genus (Fig. 14). Body length upto 1.2 mm excluding appendages.

3.10.2 Coloration : light pink in life but white in alcohol.

3.10.3 Clothing :

Ant. I and II with scales dorsally. All body segments hirsute with short ciliated setae and many round finely hyaline scales. Ant. IV with many blunt short slightly curved setae scattered almost throughout its length. Manubrium and dentes dorsally with ciliated setae but laterally and ventrally with scales. Dentes with spines alongwith setae on the dorsal side. No macrochaetae on antennae, legs or furcula. Ventral side of the head, manubrium and dentes with elongated ribbed scales. S.S. on Abds. III and IV are 2 and 3 respectively.

3.10.4 Head :

Ants. I and II with scales on the dorsal side. Ant. IV not subdivided and with an apical end bulb (Fig. 2 and 14). Head diagonal : antenna = 3 : 5. Relative length index of antennae I:II:III:IV = 6:13:9:21. Mandible and maxilla normal (Fig. 12) Labrum (Fig. 1) with 4/5, 5,4 setae, prelabral setae lightly ciliated. Labral margin with 2+2 unequal tubercles. No median intrusion present. Eyes, eye pigments and post antennal organ absent.

3.10.5 Thorax :

Relative length index of Ths. II:III = 11:8. Claw: unguis with a paired winglike inner basal teeth (Fig. 8 and 9). A well-developed inner tooth is placed above the winged teeth. Relative length index of trochanter; femur; tibiotarsus of hing leg : claw = 11:20:32:5. Unguiculus lanceolate, tenent hair short 1,1,1 in number, slightly knobed at the apex (Fig. 9). Legs without scales. Trochanteral organ consisting of ca. 18 setae of various lengths in a 'L' arrangement (Fig. 11).

3.10.6 Abdomen :

Ventral tube anteriorly with 3+3 long setae as 1+1, 2+2, posterior face with ca. 21 setae of various lengths and lateral flaps with 7 setae each (Fig. 13). Tenaculum

with 4 barbs on rami (Fig. 10), corpus with 1 long seta. Relative length index of Abds. I-IV = 12:6:8:28. Abd. IV is 3.5 times of abdomen III. Relative length index of manubrium:den:mucro = 30:19:6, den is therefore slightly more than three times of the mucro. Manubrium and dentes dorsally with ciliated setae but ventrally with scales. Dentes dorsally with ciliated setae (Fig. 6) and inner spines (Fig. 4) and outer ca. 9 strongly ciliated elongated spiny setae, the distal inner spines are slightly longer (Fig. 7). Mucro long with a blunt apical, a small anteapical and 1 small and 1 large proximal dorsal teeth on the outer margin that connects the anteapical tooth with the mucronal base (Fig. 5). No dental scale like appendage is present. "Setae sensualis" in abdomen II and III are 2 and 3 respectively.

3.10.7 Materials examined : Holotype : India : Meghalaya : Shillong Peak 1960.78 m.el. below thick layer of moss above stones on the side of a hill 24 X 1974, Coll : R.K. Bhattacharje

Paratypes : Same locality and data as the holotype, 4 exs; Boyce road from stone chips, below moss cushion on the side of a hill 20 X 1974, 5 exs; Elephant falls area, Upper Shillong, soil and leaf litter, 4 exs; Hopkinson Road, Dohling house compound (along with Cyphoderus sarojini (n.sp.) on the stone chips 12 X 1983, Crinoline falls area below moss cushions 15 IX 1974, 5 exs.

All paratypes were collected by R.K. Bhattacharjee from various parts of Shillong.

3.10.8 Distribution : India, Meghalaya : Shillong.

3.10.9 Comparison :

This species differs from Cyphoderopsis ceylonica (Yosii, 1966d) in the number and nature of setae on the posterior face of the ventral tube, the den : mucro ratio, the labral margin and by having less (2 instead of 4) teeth on the proximal dorsal side of the mucro. It differs from Cyphoderopsis kempi Carpenter, 1917 in lacking "dental scale like appendage", lacking serrations on the proximal dorsal teeth of the mucro and in having a double proximal dorsal teeth instead of a single tooth. The new species differs from Troglopedetes cavernicola Delamare, 1944 in not having any sub-division of Ant. IV in the absence of distal dental scale appendage and lanceolate unguiculus. In having 2 teeth on the proximal dorsal side of the mucro the new species is similar to Cyphoderopsis sexocellata Yosii, 1966d, however the latter species has 3+3 eyes. The present species differs from Cyphoderopsis gracilis Carpenter, 1924 (possibly a syn. of T. pallidus Absolon, 1907) in having comparatively shorter antennae, longer mucro and dentate unguis. The new species differs from T. vandeli Cassagnau et Delamare, 1955 (Lebanon) by its undivided Ant.

3.10.10 Comments :

The genus Troglopedetes has usually only 1 row of dental spines whereas genus Cyphoderopsis has 2 rows of dental spines. According to Salmon (1964) this difference is insufficient to separate the two genera. Yosii (1978 Pers.Comm.) holds that these divisions are provisional and Bellinger (1978 Pers. Comm.) suggests that the presence of a "dental scale like appendage" of Cyphoderopsis may justify the separation of Cyphoderopsis from Troglopedetes. Considering all the above opinions I have included this new species in Troglopedetes genus. It is worth mentioning here that basing on the contentions of Salmon and Bellinger, most of the described species of Cyphoderopsis have to be brought under genus Troglopedetes and the former then remains monotypic as Cyphoderopsis kempi Carpenter, 1917.

3.10.11 Etymology :

This new species is dedicated to my father Late Dr. Rasendra Nath Bhattacharjee.

3.10.12 Key to the genera Cyphoderopsis and Troglopedetes

Dental scale appendage present, dentes with double rows of spines, eyes usually absent ..... Cyphoderopsis

Type species : C. kempi, Carpenter, 1917

Rotung, Arunachal Pradesh, India.

Dental scale appendage absent, dentes with single row of spines, eyes present or absent .... Troglopedetes

Type species : T. pallidus Absolon, 1907
Austria

Key to related species of Troglopedetes Absolon, 1907.

1 Eyes present 2

Eyes absent 3

2 Eyes 3+3 in number, mucro with 4 (sp. from Bombay), 5 (sp. from Formosa) or 6 (sp. from Kerala) teeth; labral margin without structures; Vt. ant. 4+4 and post. with 20 setae ..... T. sexocellata (Yosii, 1966d)
India (Bombay, Kerala), Formosa.

Eyes 5+5 in number, mucro with 5 teeth.
..... T. decemoculata (Prabhoo, 1971a)
India (Kerala)

3 Both unguis and unguiculus without tooth.
.... T. pallidus Absolon, 1907 (Austria)
Syn. C. gracilis Carpenter, 1924.
India (Meghalaya : Siju caves).

Unguis always with teeth 4

4 Unguis with an unpaired inner tooth above the winged teeth 5

mucro with 6 teeth (i.e. 1 apical, 1 anteapical and 4 dorsal). Vt. ant. 3 + 3 and post. 15 setae
T. ceylonica (Yosii, 1966) Ceylon; India (Assam)

5 Antennae IV subdivided 6

Antennae IV not subdivided .... T. rasendrans. n.sp. India (Meghalaya, Shillong).

6 Unpaired inner tooth of claw in the distal half of the inner border of Unguis .... T. cavernicola Delam : 1944 (Portugal) Gisin, 1960.

Unpaired inner tooth in the middle or innerhalf of the unguis ..... T. vandeli Cass. and Delam:, 1955 (Lebanon) Gisin, 1960.

Family	-	Paronellidae Börner,1913 (as subfamily)
Subfamily	-	Paronellinae Börner, 1913
Genus	-	Callyntrura Börner, 1906
Subgenus	-	Handschinphysa Paclt, 1945

3.11 Callyntrura (Handschinphysa) lineata (Parona, 1892) (Plate XI, Figs. 1-8)

Entomobrya lineata Parona 1892, Atti.Soc.Ital. Milano, 34 : 132-135; Syn. Paronella borneri Imms, 1912, Proc. Zool.Soc. London : 80-125, P. tarsata Imms 1912, ibid.

3.11.1 Body length excluding appendages upto 3.25 mm.

3.11.2 Coloration :

Body color pale yellow with blue-black pigment patch in between the antennal base, ocular area continuing towards dorsolateral surface of head, lateral margin of Ths. II and III. Abds. I - III with blue-black pigments on the sides. Abd. IV with 8 radiating streaks or strands of purple to blue-black pigments concentrating towards a blotch or patch almost at the middle of the segment (Fig. 1). Abds. V and VI with pigmented spots on the sides distally. Legs marked by narrow transverse bands of deep blue pigments on femur (=2) and tibiotarsus (=2) distally (Fig. 2). Two different color forms are observed in the population viz. (i) less colored having pigments restricted only on the sides of the body and with two faint spots on Abds. IV and V and

(ii) more colored with purple to blue-black pigments as described above.

3.11.3 Clothing :

Head, body and appendages clothed with typical lanceolate paronellid scales and setae. Ants. I and II with scales and microchaetae while Ants. III and IV with short ciliated setae only. Body setae are large macrochaetae, flexed or obliquely truncated and ciliated with specific arrangement (Fig. 7). Antennae and legs in addition to short setae also possess some darker stiff ciliated macrochaetae of varied shape and size. Scales are elongate lanceolate or pointed apically and tapering towards the base. The striations on the scales are very prominent and usually ranged from 10-15 longitudinal rows. Abd. IV possesses a pair of lasiotrichia (Fig. 7). In addition to setae and scales head also possesses 4+4 frontal spines. Cephalic chaetotaxy is characteristic of the species (Fig. 6). Macrochaetae on the middle of vertex area form a trapezoid like structure with V_o being below the line joining $V_1 - V_1$, total number of macrochaetae on the vertex being 13 (=6+1+6), each side having $V_1 - V_6$ and in the middle a V_o (Fig. 6). The subdorsal micro and macrochaetae are of various sizes of which 5 below the antennal basis are prominent. Trunk chaetotaxy : Thorax II with 13 macrochaetae

(excluding setae on anterior border) while Th. III to Abd. IV have 18-19, 11,10,9 and 31 (16 mid. and 15 post.) macrochaetae respectively (Fig. 7). Apart from scales, setae and lasiotrichia there is a dental scale appendage or bladder scale towards the mucronal end of each den (Fig. 8).

3.11.4 Head :

Pearshaped, with 4+4 frontal spines. Antennae slightly longer than the body. Head/Ant. I = 7/6. Apex of Ant. IV with a sense bulb and ca. 8 "sense setae". Eyes '8+8, ocelli sub equal, g and h being somewhat smaller than the rest (Fig. 6). Labrum with 4/5, 5,4 setae, prelabral setae ciliated, rest smooth; margin with 4 irregular tubercles. Relative length index of Ants. I:II:III:IV = 15:16:10:26.

3.11.5 Thorax :

Thorax II is 2 $\frac{1}{2}$ times of Th. III. Trochanteral organ with ca. 62 setae arranged in a quadriangle.

Claw : Unguis long apically curved with paired inner and two distal unpaired inner teeth. A pair of well developed external basolateral teeth are found on the unguis (Fig. 4). Unguiculus lanceolate in larger specimens while slightly notched or truncate towards the middle in relatively smaller (2.0 mm) specimen (Fig. 4). Tenent hair long, well

developed and clavate. Tibiotarsal lobe near the origin of tenent hair well developed.

3.11.6 Abdomen :

Relative length index of Abds. I - VI = 10:20:8: 122:10:4. Retinaculum with 4 barbs in rami and corpus with a long curved smooth seta. Ventral tube long with 8 ciliated macrochaetae and many smooth setae on the anterior face and many microchaetae on the posterior face. Manubrium long, slightly tapering distally. Man : den = 11 : 15. Mucro with 7 teeth (1 apical, 2 dorsal, 3 ventral and 1 lateral)(Fig. 8). A prominent scale appendage on the mucronal end of the dentes. Male genital area papillate type, each papilla having an apical seta. Dentes on anterior face with long plumose seta on each side.

3.11.7 Materials examined : India : Meghalaya : Shillong : Botanical Garden leaf litter-flowering plants and shrubs viz. Vernoria sp., Sympalcos sp., Neolicacae sp. 18 X 1974, 15 exs., Elephant falls area deciduous forest litter 24 X 1974, 37 exs.; Jakrem (Near Hotspring) litter, 11 XII 1978, 9 exs. All examples were collected by R.K. Bhattacharjee.

3.11.8 Distribution :

Mainly in the Oriental, Indo-China regions, Burma and Japan. In India from Uttar Pradesh, Manipur, Sikkim, South India and Shillong, Meghalaya (new record).

3.11.9 Comparison :

Color variation in C.(H.) lineata have been pointed out by Imms (1912), Yosii (1961) and Stach (1966). The use of color variations in species separation occassionally resulted in a number of synonyms of same species. In the population of this species at Shillong, 2 forms are available viz. one with less coloration and other more intensely colored. However the chaetotaxy of both these forms are strikingly similar. Mitra (1974) has noted chaetotaxic uniformity in a variety of specimens from 50 different localities he examined. Generally males have intense pigmentation while females are less colored (Mitra 1974). Yosii (1961) made a review of all different species of the genus Callyntrura described from Asia. However, he (Yosii, l.cit.) has noted that morphological details of many species are unknown so that pattern of the body color was the main distimguishing feature of the different species. Callyntrura (H.) semilineata Yosii, 1961 from Thailand show Abd. IV with narrow transverse stripes at about the middle and longitudinal stripes divided into 4 narrow linear stripes on the anterior half of the segment (i.e. Abd. IV). The longitudinal stripes make this species a close relative of C.(H.) lineata. However in the C.(H.) semilineata longitudinal stripes do not extend to the posterior border of the Abd. IV. Furthermore purple bands on each tibiotarsus, femur and coxa are also characteristic features of this species

However, diagram illustrating body macrochaetae of C.(H.) semilineata Yosii, 1961 is totally different from C.(H.) lineata (Parona, 1892). It is interesting to note that coloration of Callyntrura (H.) lineata (Parona, 1892) population from Shillong, Meghalaya show striking similarities with the color pattern of C.(H.) semilineata Yosii, 1961. However, cephalic and trunk macrochaetal pattern of the specimens from Shillong show close resemblance to the setal distribution of C.(H.) vestita (Handschin, 1925) sensu Mitra, 1974 except absence of Pc_2 in Abd. III. The claw of specimens at hand also show similarities with C.(H.) lineata (Parona, 1892). Color pattern of some of the forms of C. lineata as depicted by Schott (1903), Handschin (1925, 1928), Denis (1948), Yosii (1956) and Salmon (1957) indicate longitudinal blueblack strands on the Abd. IV. Basing on these linear patterns (which are so unique in this species) and claw character all specimens are placed under the species Callyntrura (H.) lineata (Parona, 1892).

It is worth mentioning here that some C.(H.) vestita (Hand.) described by Salmon (1957) from Sikkim and Nagaland, India; resemble more closely C.(H.) lineata (Parona) in their coloration, but can be sorted out easily by position and number of teeth on the unguis and moreover some specimens of Callyntrura (H.) vestita (Handschin, 1925) with their

typical coloration had been reported from Botanical garden and Umdiengpun of Shillong by Mitra, 1974 (Plate I,C page 411) the same localities from which present specimens of C. lineata are obtained. Yosii (1965) observed that C. (H.) taiwanica Yosii, 1965 and C.(H.) microphysarum Yosii, 1965 (both species from Taiwan) show similar chaetal arrangement although they differ strikingly in color patterns. Similar features might be found in Shillong population of C.(H.) lineata and C.(H.) vestita, both showing general uniformity in macrochaetal pattern but differing in claw structure and color patterns. However, from above arguments placement of specimens at hand in C.(H.) lineata seem justified.

Genus - Salina MacGillivary, 1894

3.12 Salina striata (Handschin, 1928) (Plate XI, Figs. 9-14)

Cremastocephalus striatus : Handschin, 1928, Treubia 10 : 245-270, Salina striata : Handschin, 1929, Rev. Suisse Zool. 36 : 229-262; Salina striatella Yosii, 1961, Nat. and Life in South East Asia 1 : 171-200.

3.12.1 Body length excluding appendages 2.65 mm.

3.12.2 Coloration :

Ground color, light yellow or pale white in preserved condition. Head, interocular field with diffused black pigments which extend to the sides of antennae. Ant. IV totally bluish pigmented. Ants. I - III laterally with purple or blue pigments. Cervix on each side with a darker blue patch behind the ocular area. Thorax II and III laterally with dark blueblack pigments. There are 2 longitudinal interrupted bands one on each side of thorax II to Abd. VI of brown to blueblack pigments. Abd. I also with blue pigments on the sides as Ths. II and III (Fig. 9). There are 2 fine longitudinal stripes of brown pigments on the middle portion of Abd. II which are very characteristic for this species. On Abd. III on each side there are 2 spots of blueblack pigments. Abd. IV with paired patches of blue pigments

anteriorly, orange and brown medially and 2 black and brown patches posteriorly. Abds. V and VI also with pigmented spots on the sides. Legs tibiotarsus pigmented, femur only distally with bluish pigmented patch. Trochanter diffused blue. Femur and tibiotarsus both with ring of blue pigments. Furcula yellowish or white.

3.12.3 Clothing :

Clothed with short ciliated setae and large flexed macrochaetae in specific arrangement (Fig. 12). Short simple or ciliated setae cover antennae, while ciliated setae occur on legs and furcula. Lasiotrichia on Abds. II - IV as 2,3,2 respectively. Cephalic chaetotaxy : typical of the "celebensis" group with a quadriangle of 4 macrochaetae on the vertex. There are 2+2 occipital and 3+3 cervical macrochaetae. Trunk chaetotaxy : Ths. II, III and Abds. I - II as 12 (excluding anterior macrochaetae), 12,5,4.

3.12.4 Head :

Pearshaped in outline with 1+1 frontal spines. Eyes 8+8, g and h smaller. Antennae 4 segmented. Relative length index of Ants. I : II : III : IV = 8 : 11 : 9 :14. Ant. IV apically with an end-bulb and 6 sense setae. Ants. III and IV faintly annulated and in some specimens longer than usual ratio mentioned above.

3.12.5 Thorax :

Relative length index of Ths. II and III = 31 : 19. Legs; unguis with a pair of prominent outer lateral teeth, a pair of inner basal teeth and a single distal unpaired inner tooth. Unguiculus trucate, about 2/3 of the unguis in length, with narrow outer and broad inner lamella abruptly ending in a truncated position (Fig. 10). A single very thick and finely ciliated clavate tenent hair present, opposite to which on the unguicular side there is a distinct tibiotarsal lobe or swelling. Trochanteral organ with ca. 49 spines of various sizes (Fig. 11).

3.12.6 Abdomen :

Relative length index of Abds. I - VI = 7:14:3:30:6:3. Retinaculum with 4 barbs on rami and corpus with a median seta. Ventral tube anteriorly with 4+4 macrochaetae and ca. 9+9 small setae while on the posterior face with microchaetae only. Relative length index of man : den : mucro = 8 : 9 : 4. The apex of dens with a short scale appendage (slightly smaller than the length of mucro) in the form of a lobe like swelling with faint striations. Mucro small, broad and with prominent fingerlike three teeth, outer one of which is slightly longer than the rest. The mucronal end of dentes with some moderately long ciliated setae.

3.12.7 Materials examined : India : Meghalaya : Shillong : Elephant falls area deciduous forest litter 24 X 1974, exs; Zakrem (hotspring area) 50 Km. from Shillong, West Khasi Hills, litter 11 XII 1978, 15 exs; Mawphlang (Sacred forest) deciduous forest litter 15 X 1975, 27 exs; Nagaland : Kohima : Pullebaze Hills area (near Sc. Coll.) litter and soil 11 IV 1976, 19 exs - all expls. Coll : R.K. Bhattacharjee. Tripura : Dharmanagar (Riverside) soil litter 26 X 1988, 5 exs. Coll : B. Dey.

3.12.8 Distribution :

India (Nilgiri Hills - South India, Uttar Pradesh, Assam , Meghalaya (Shillong, Zakrem and Mawphlang), Nagaland (Kohima) and Tripura (Dharmanagar), North Vietnam and Java. New records for Nagaland and Tripura.

3.12.9 Comparison :

In coloration this species is very close to S. tricolor tricolor (Handschin, 1928). However, in macrochaetal pattern and claw character the specimens at hand coincide with S. striata (Handschin, 1928) almost in all details. Abd. II in the middle with 2 small parallel longitudinal brown coloured stripes on these specimens where as in S. striata both Abds. I and II possess middle paired patches. It is quite possible that colored patches of Abd. I have not yet been formed (considering slightly smaller size of the specimens at hand). Similarly in the Abd. IV

middle paired patches are not united to form blotch as depicted by Mitra (1973). Mitra (1973) has mentioned resemblances of colour pattern of S. tricolor and S. striata (Handschin). Salmon (1957) described Salina indica (Imms, 1912) and considered S. striata (Handschin) a synonym of S. indica (Imms). However from short and broad mucro, subequal dental scale appendage and reduced number of macrochaetae on the body this synonym seems invalid. Salmon in the same paper (l. cit.) reported Salina celebensis (Schaffer, 1898) from Oating, Sibsagar, Assam, majority of which are possibly S. striata (Handschin) as indicated by their broad and short mucro.

Plate II Figs. 1-18 : *Hypogastrura (s.str.) prabhooii* n.sp.

Habitus (2) Ant. III and Ant. IV sense organs (3) Labral margin (4) mandible (5) maxilla (6) eyes and PAO (7) anterior ocelli and PAO (8) Metathoracic claw (9) retinaculum (10) mucro (11) mucro (Dorsal view) (12) Abd. VI and anal spine (side view) (13) cephalic chaetotaxy (14) genital slit and associated setae (15 and 16) thorax II and Abd. III - Abd. VI chaetotaxy (Half portion) (17) microchaetae on the anal segment (ventral) (18) manubrium, den and mucro with setal distribution (dorsal).

Scales : (a-b) Fig 1; (c-d) Figs. 2,5,6,13,14,15,16,18; (e-f) Figs. 4,7,9,11,12,17; (g-h) Figs. 3,10; (i-j) Fig.8.

PLATE II

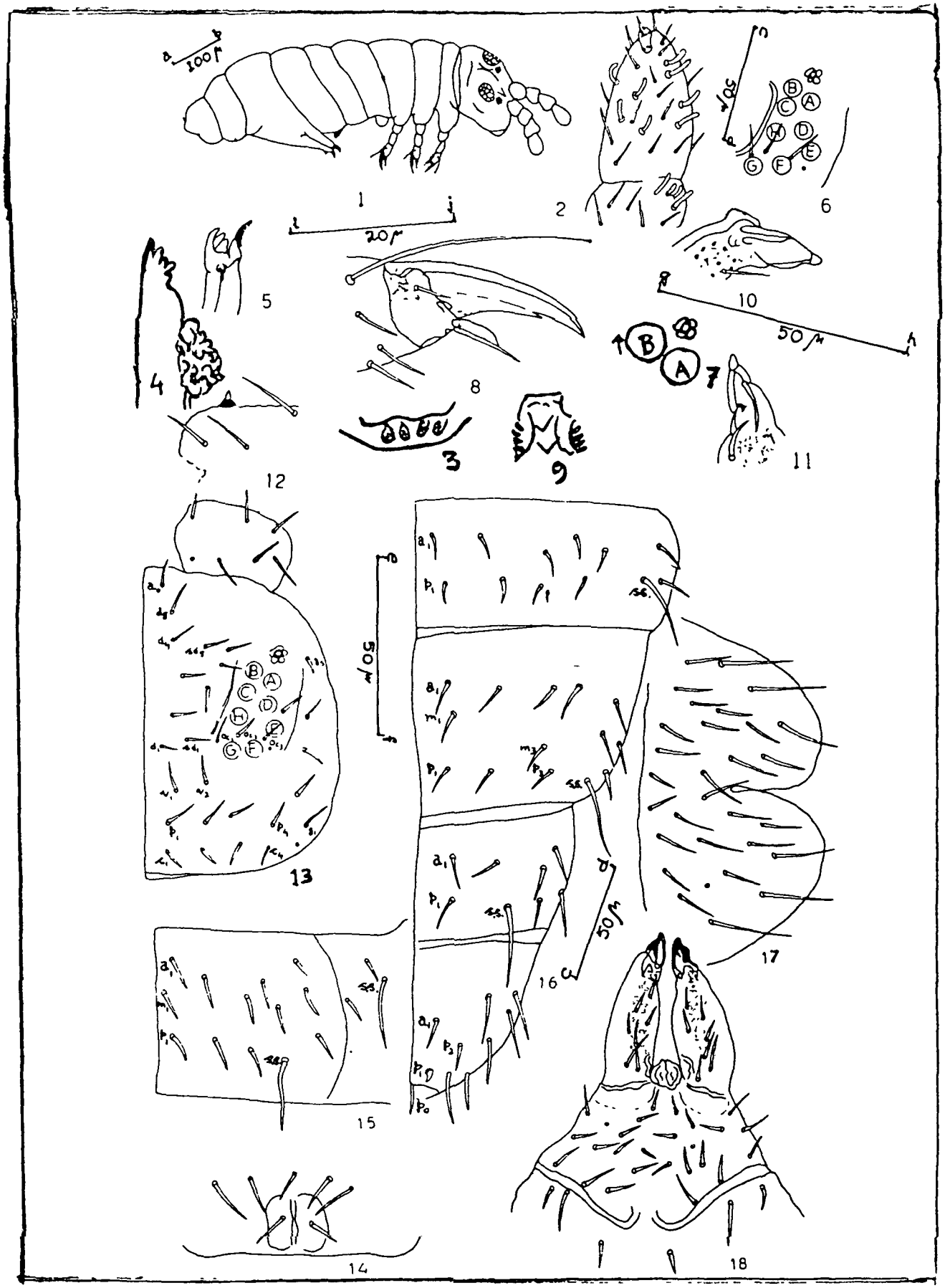


Plate III : Figs. 1-13 : *Folsomia candida distincta* Bagnall:

(1) Ant. IV sense organs (2) Ant. III sense organs (3) PAO and adjacent setae (4) apex of maxilla (5) apex of mandible (6) claw (7) retinaculum (8) ventral tube, Postero-lateral flaps (9) manubrium (anterior) (10) Manubrium (posterior) (11a and b) den and mucro (ventral) (12) mucro (13) labrum.

Scales : (a-b) Figs. 3,7,11; (c-d) Figs. 1,4,5,6,8-10,12,13; (e-f) Fig. 2.

PLATE III

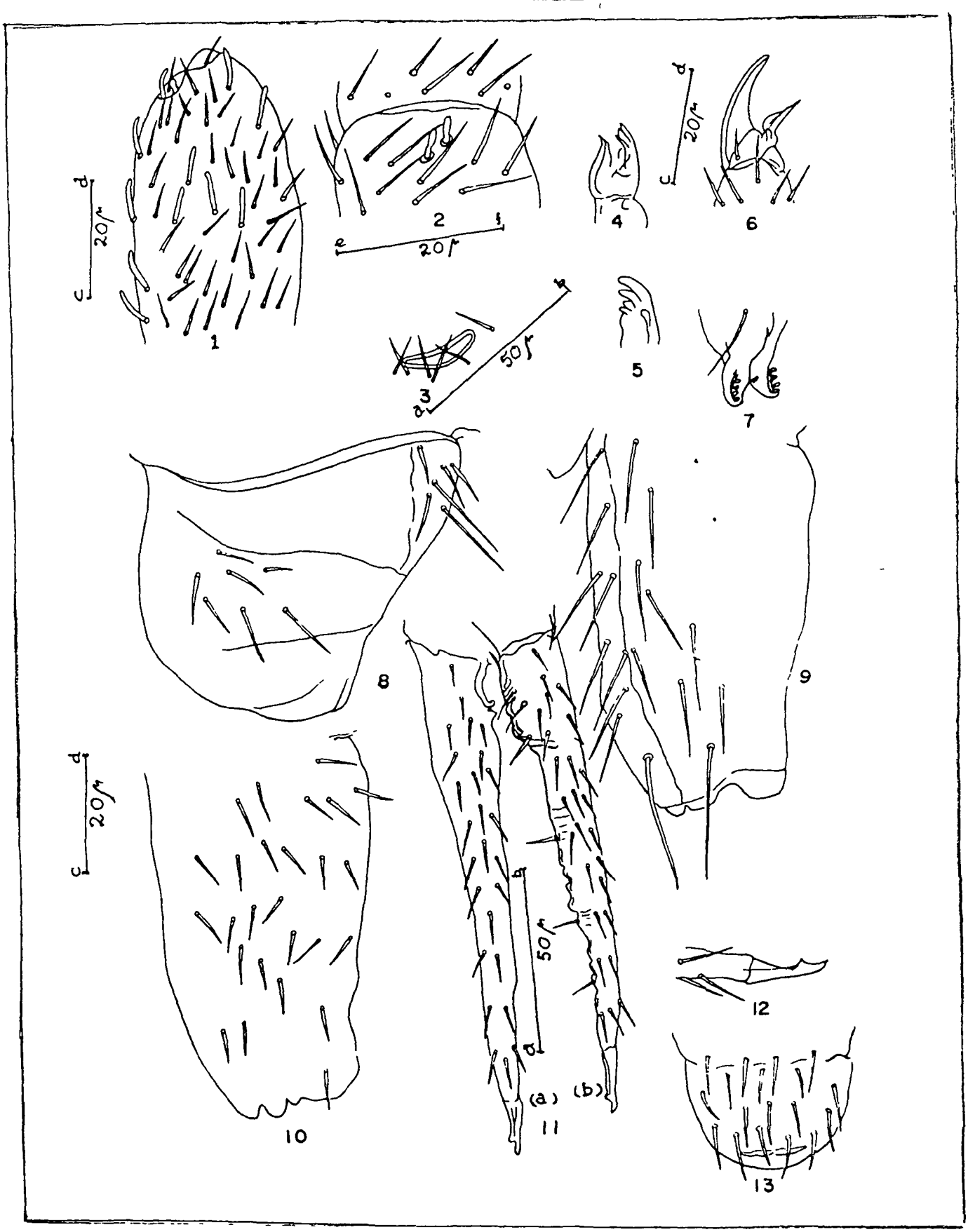


Plate IV : Figs. 1-18 : Figs. 1-10 *Isotoma (Desoria) trispinata* MacGill.

(1) eyes and PAO (2) apex and Ant. IV (3) labrum (4) hind claw (5) tenaculum (6) ventral tube (ant.face) (7) ventral tube (post.face) (8) femal genital opening (9) distal portion of manubrium and proximal part of den (lateral) (10) mucro.

Figs. 11-18 : *Isotoma (s.str.) jayasrae* n.sp.

(11) antenna IV sense organs (12) antenna III sense organs (13) anterior eyes and PAO (14) fore claw (15) manubrial marginal thickening and spiny setae (16) mucro (17) tenaculum and setal distribution (18) ventral tube (post.face).

Scales : (a-b) Figs. 1-4,6,7,9,11,16; (c-d) Figs. 5,8,14,15,18; (e-f) Figs. 10-12; (g-h) Figs. 13,17,

PLATE IV

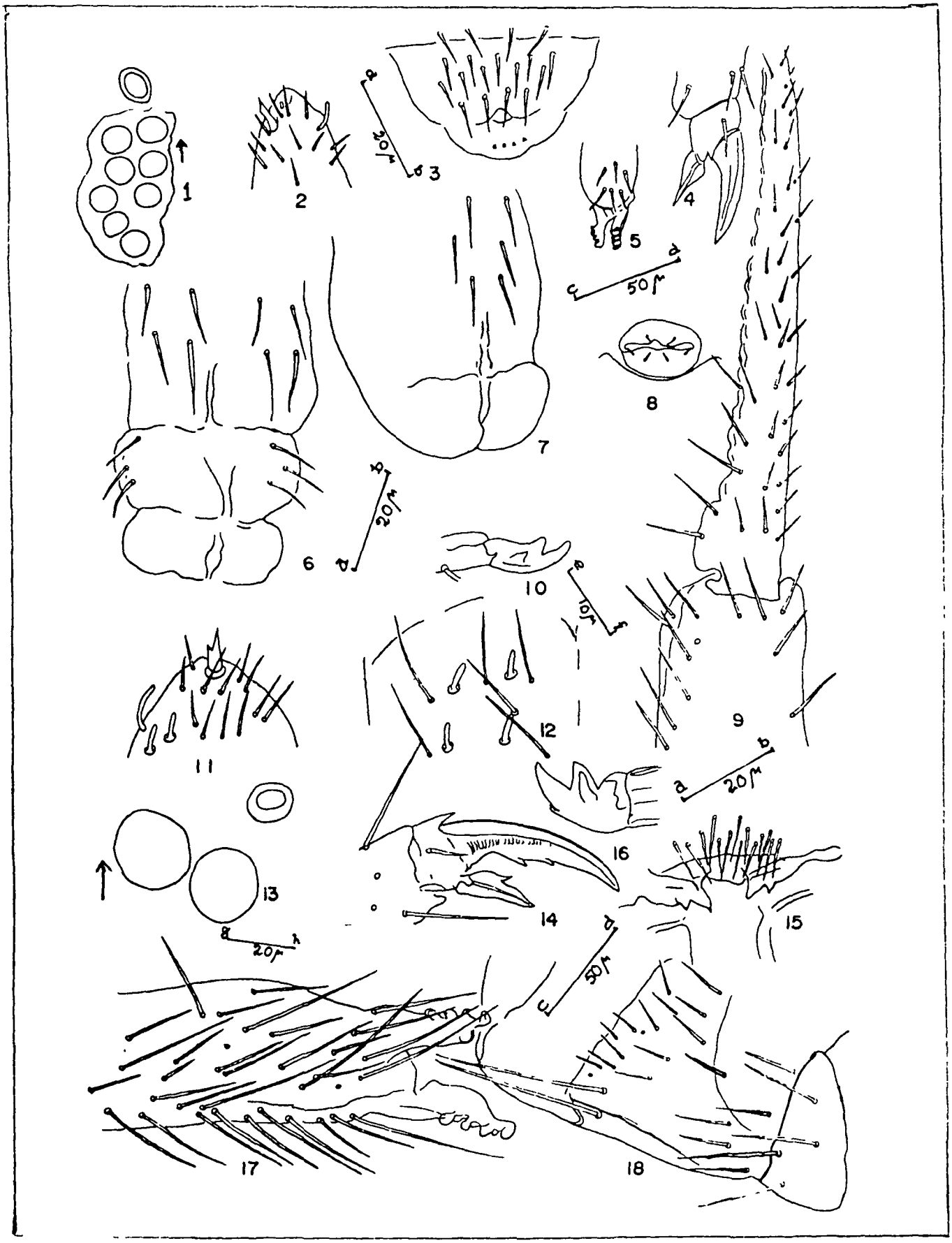


Plate V : Figs. 1-10 : *Sinella (s.str.) montana* Imms.

(1) Labrum (2) fore claw (3) hind claw (4) hind claw (another ex.) (5) P-seta of tibiotarsus (6) trochanteral organ (7) ventral tube (ant.face) (8) Cephalic chaetotaxy (half portion) (9) trunk chaetotaxy (half portion) (10) falcate mucro and basal spine.

Scales : (a-b) Fig. 3; (c-d) Figs. 1,2,10; (e-f) Figs. 4-7; Figs. 8 and 9 semidiagrammatic.

PLATE V

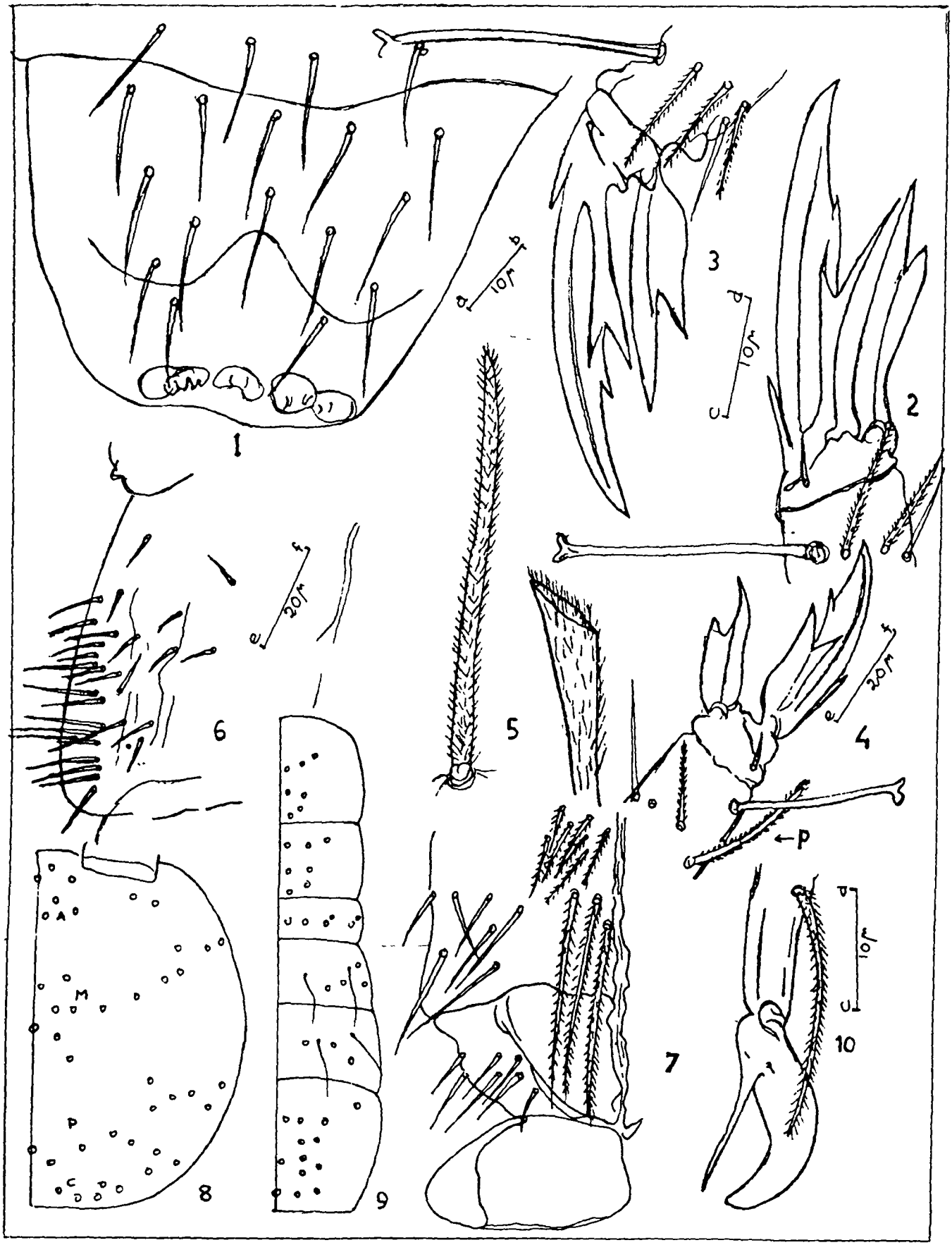


Plate VI : Figs. 1-10b : *Sinella (s.str.) curviseta* Brook:

(1) Ant. III sense organs (2) labral margin (3) retinaculum (4a and b) hind claw (5) trochanteral organ (6) ventral tube (post.face) (7) ventral tube (ant.face) (8) cephalic chaetotaxy (half portion) (9) trunk chaetotaxy (half portion (10a and b) mucro.

Scales : (a-b) Fig. 2; (c-d) Figs. 1,3-5,7,10(b); (e-f) Fig. 6; (g-h) Fig. 10(a); Figs. 8 and 9 semidiagrammatic.

PLATE VI

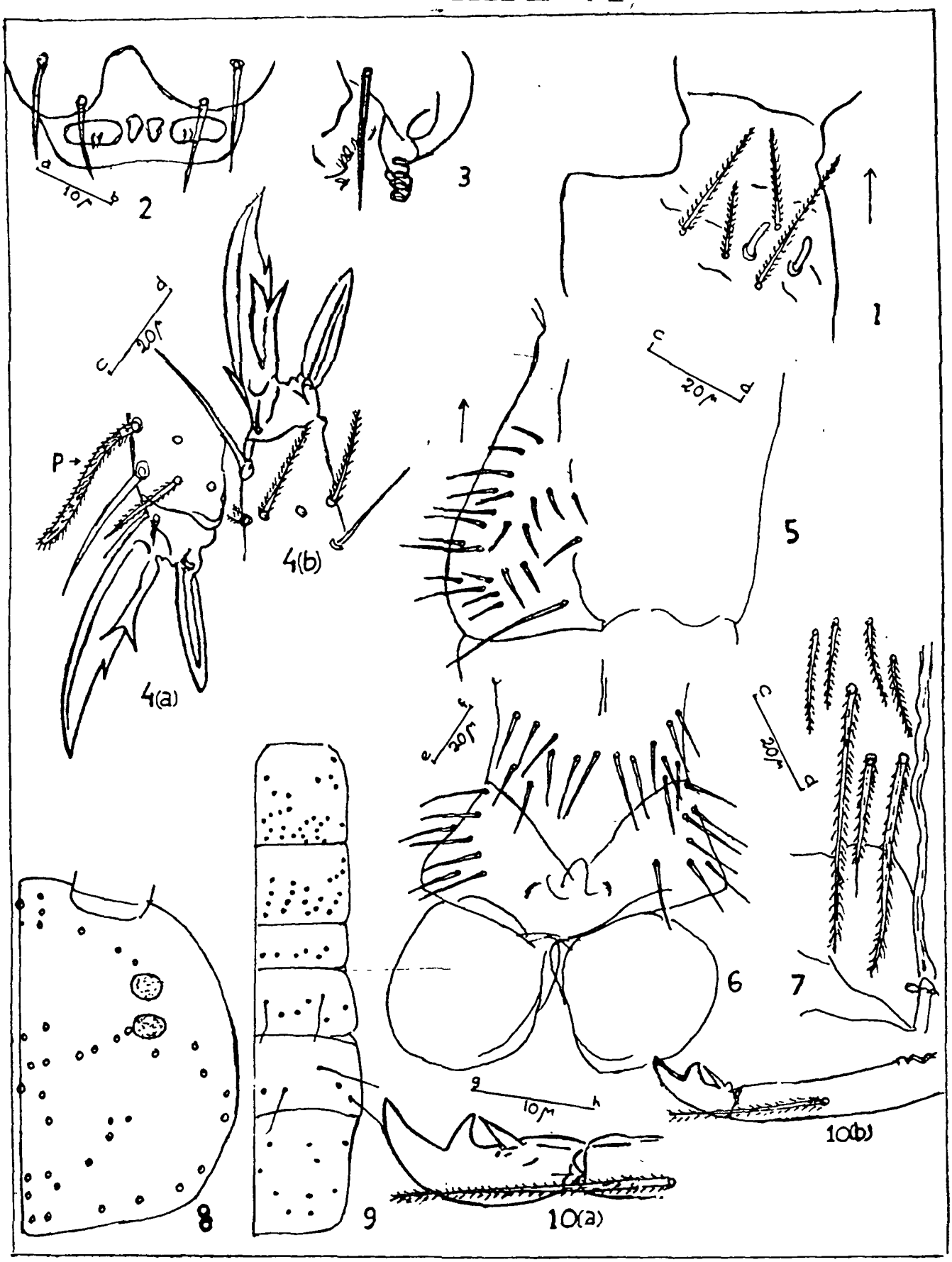


Plate VII : Figs. 1-16b: *Dicranocentrus fraternus*

(1a and b) Ant. IV apex and antenna complete showing annulation and verticilating setae of Ant. V and Ant. VI (2) head of mandible (3) head of maxilla (4) labral margin (5) Ant. III sense organs (6) retinaculum (7) metathoracic claw (8) eyes and ocellar setae (9a and b) body scale and macro seta (10) ventral tube, anterior half; (11) trochanteral organ (12 and 13) cephalic and trunk chaetotaxy (half portion) (14) manubrium-den-joint ventral (15) dentes showing plumose setae (16a and b) mucro with complete and broken basal spine.

Scales : (a-b) Figs. 1a,2,3,5,7,8,9c,16; (c-d) Figs. 6,10,14; (e-f) Figs. 1b,9a,11,15; (g-h) Fig. 4; (i-j) Fig. 9b; Figs. 12 and 13 semidiagrammatic.

PLATE VII

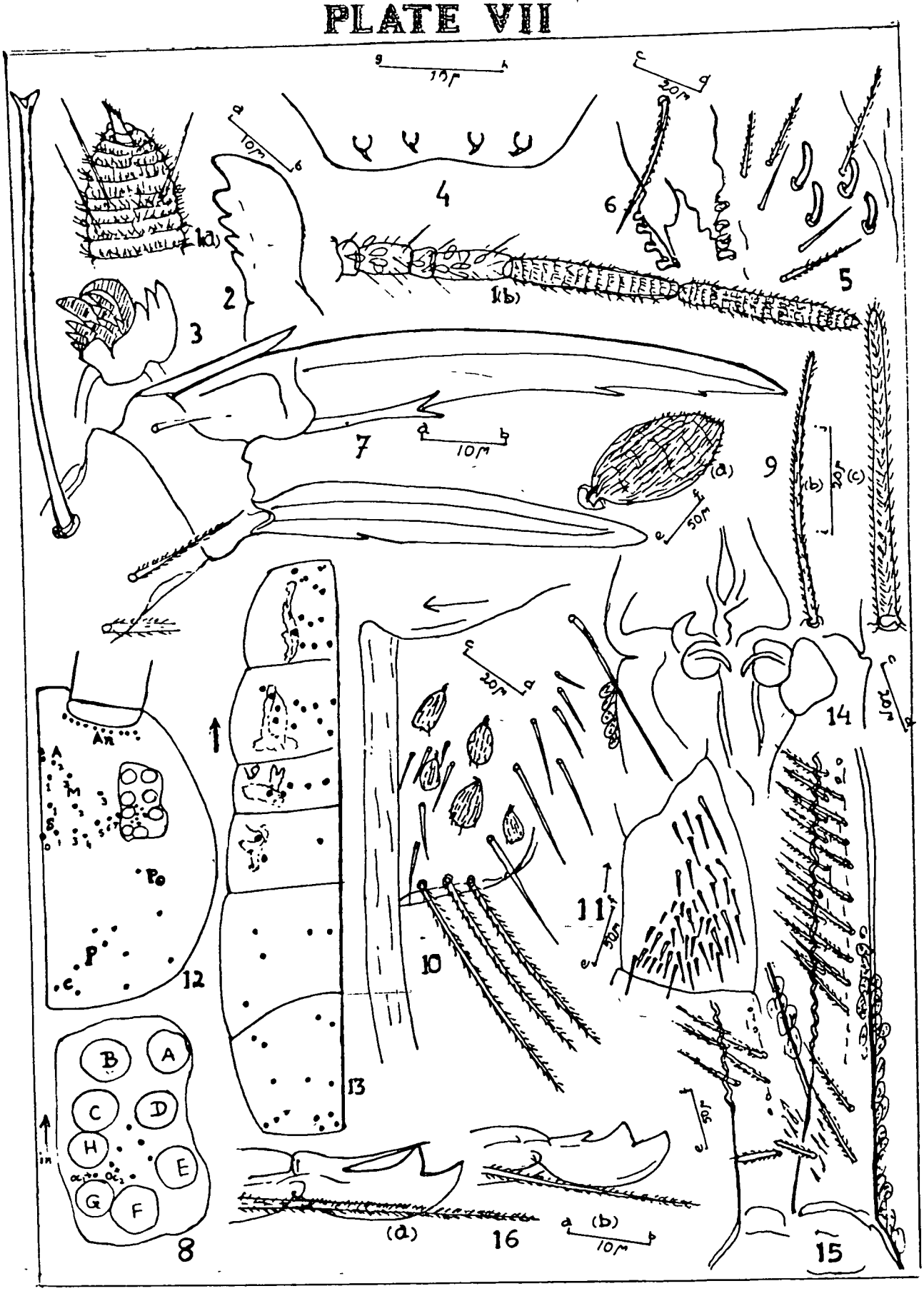

1(a)
1(b)
2
3
4
5
6
7
9
(a)
(b)
(c)
10
11
12
13
14
15
16
(a)
(b)
A
B
C
D
E
F
G
H
An
Po
P
C
M
10m
50m
20m

Plate VIII : Figs. 1-15 : *Dicranocentrus singularis*

(1) Habitus (clothing not shown) (2) Ant. III sense organs (3) outer labial papilla and its differentiated seta (4) labial triangle (5) labrum (6) labral margin (7) retinaculum (8) ventral tube (9) trochanteral organ (10a and b) lasiotrichia and typical trunk scale (11) metathoracic claw (12) mesothoracic claw (13) cephalic macrochaetotaxy (half) (14) trunk macrochaetotaxy (half) (15) mucro.

Scales : (a-b) Figs. 3-5, 8,10(a); (c-d) Figs. 7,9,10(b); (e-f) Figs. 2,15; (g-h) Fig. 6; (i-j) Figs. 11,12; (k-l) Fig. 1, Figs. 13 and 14 semidiagrammatic.

PLATE VIII

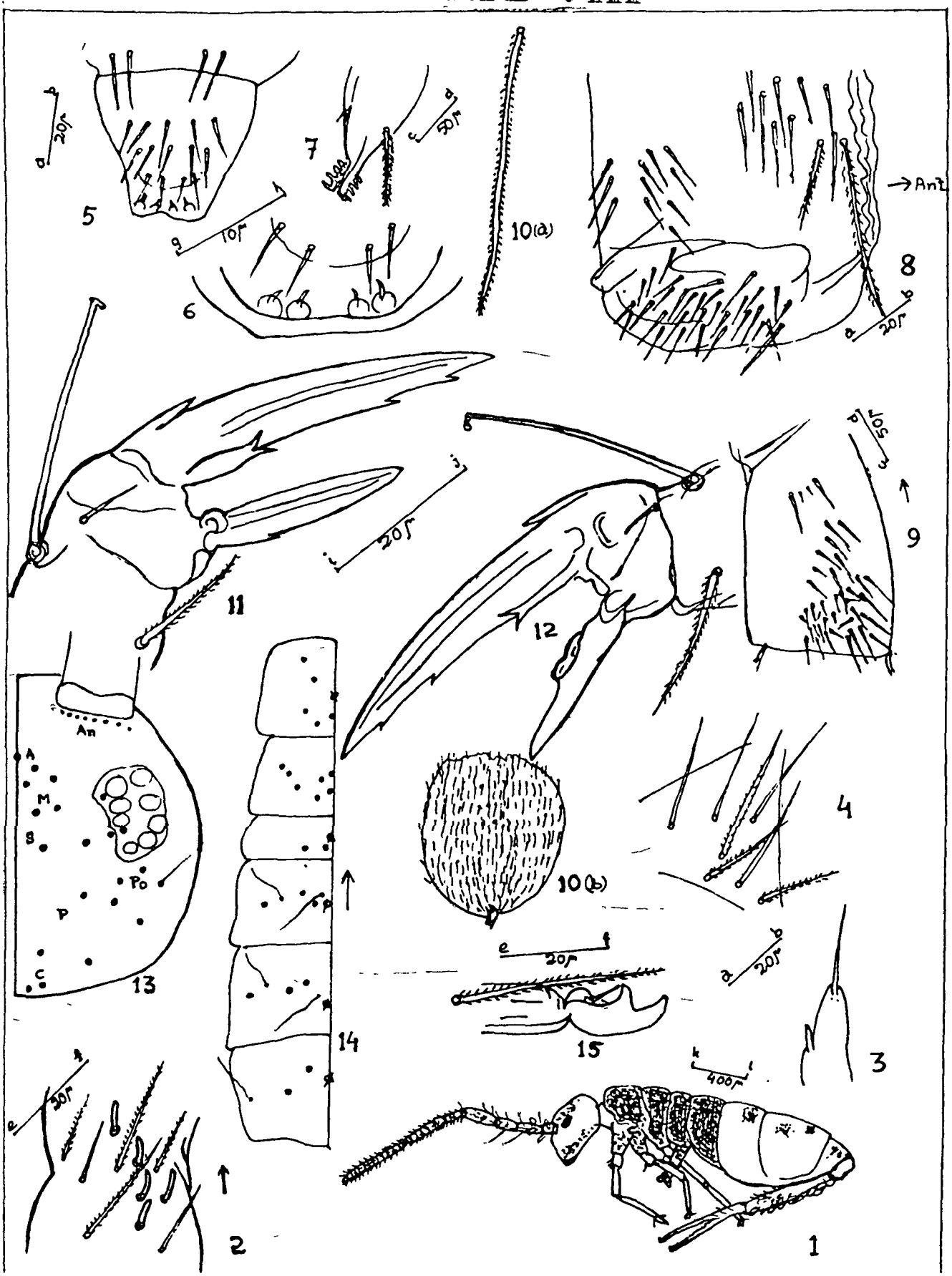


Plate IX : Figs. 1-11 : *Cyphoderus sarojini* n.sp.

(1) Trochanteral organ (2a and b) ventral tube anterior and posterior face (3a) dental clothing (3b) fringed scale of den (4) distribution of fringed scales and feathery setae on den (dorsal) (5) mesothoracic claw (6) metathoracic claw (7a and b) mucro, (8) labral margin (9) habitus (full clothing not shown) (10) typical trunk scale (11) labial triangle.

Scales : (a-b) Figs. 1,3,4,7; (c-d) Fig. 2(b); (e-f) Figs. 2(a), 5,6,8,10,11; (g-h) Fig.9.

PLATE IX

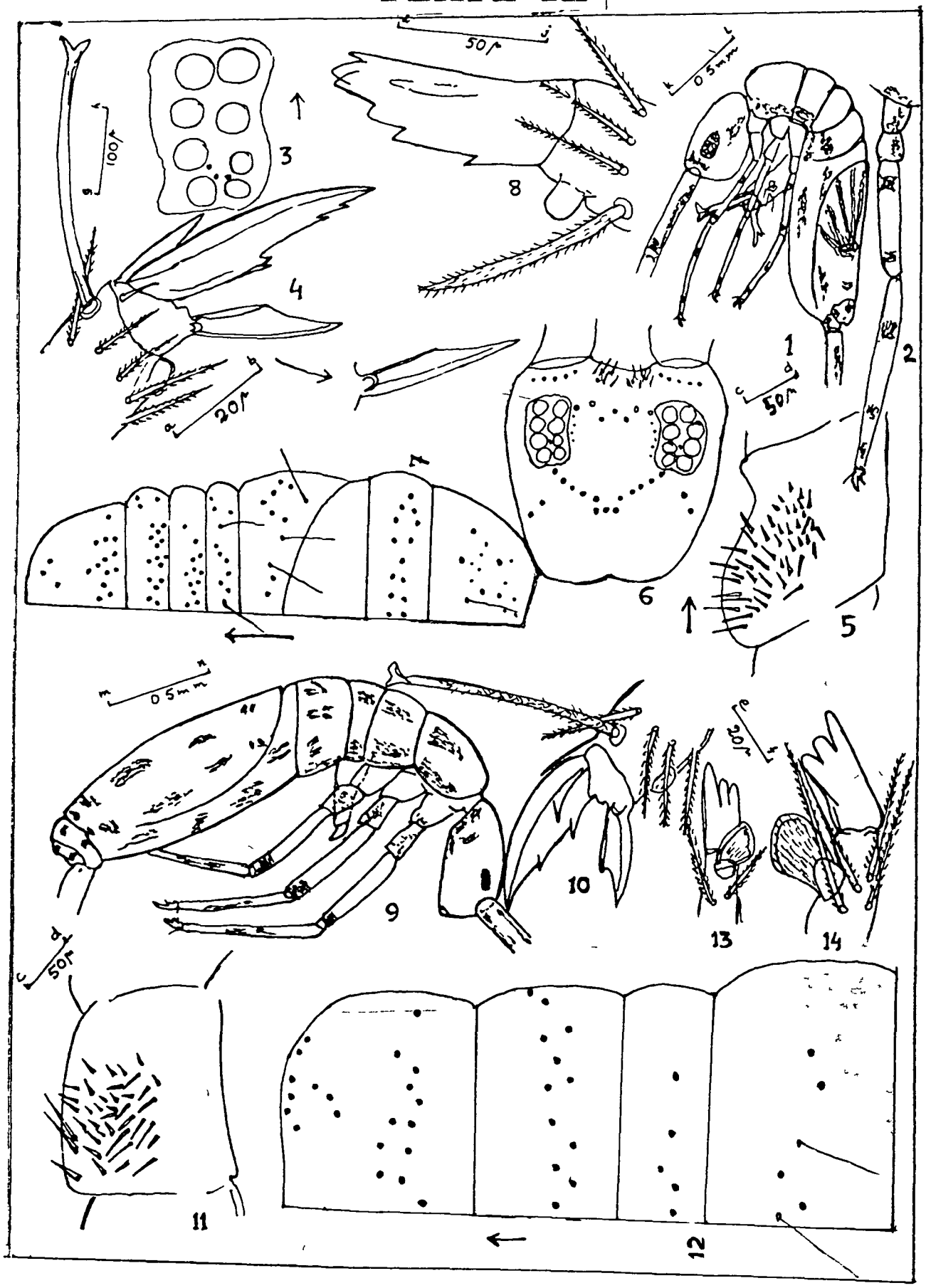


Plate X : Figs. 1-14: *Troglopedetes rasendrans* n.sp.
(1) Labrum (2) apex of Ant. IV and 2 s.s. (3) man-den-margin (ventral) (4) dental spine (5) mucro (dorsal) (6) dental ciliated seta (7) den and mucro (dorso-lateral) (8) hind claw (9) hind claw of another ex. (10) retinaculum (11) trochanteral organ (12) apex of maxilla ad mandible (diff. magnification) (13) ventral tube (post. and ant. face) (14) habitus (clothing not shown).

Scales : (a-b) Figs. 1-3,5,8; (c-d) Figs. 4,6,9,10; (e-f) Figs. 7,11,12(b),13; (g-h) Fig. 12(a); (i-j) Fig. 14.

PLATE X

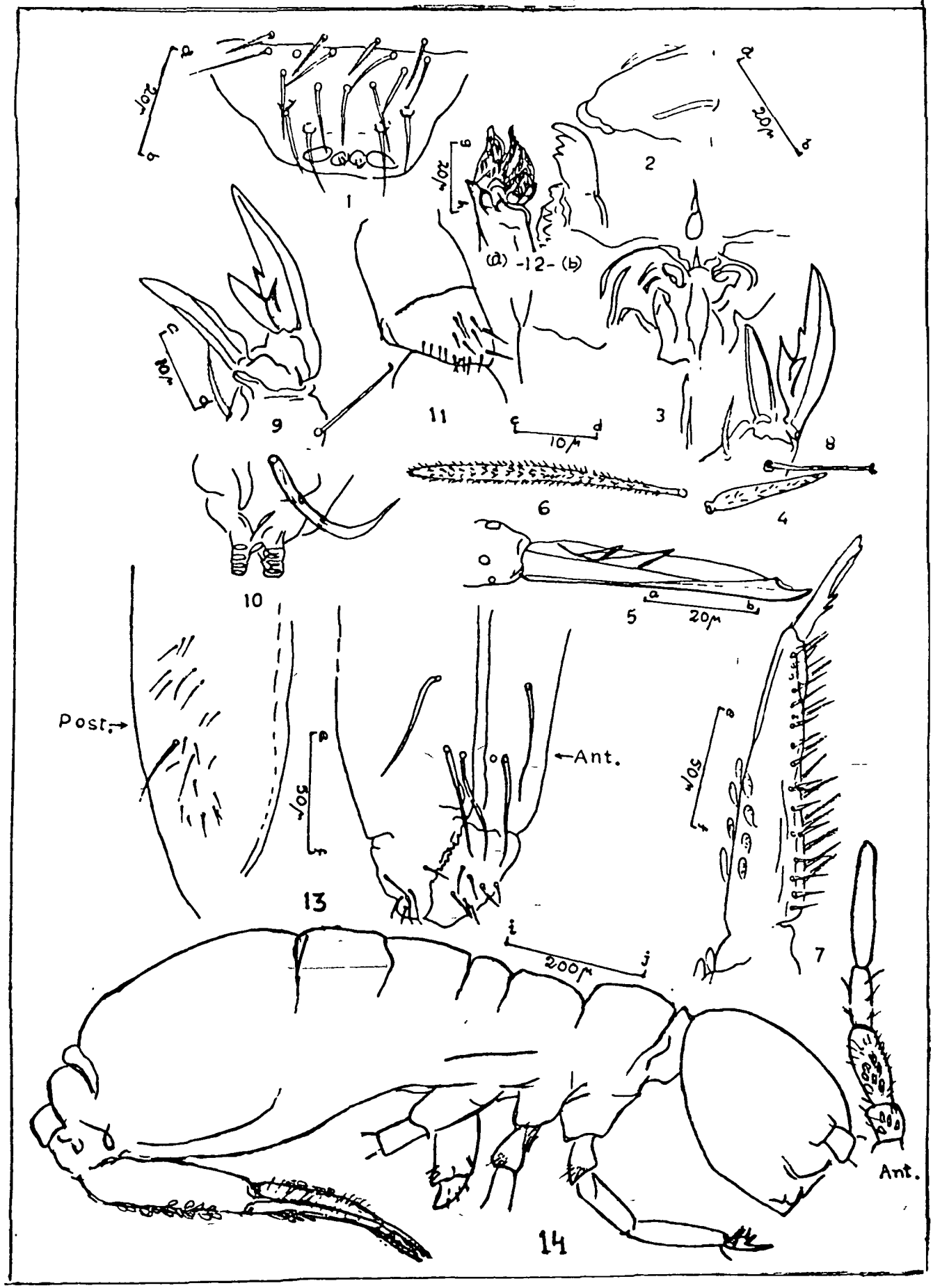


Plate XI : Figs. 1-14 : Fig. 1-8 : *Callyntrura (H.) lineata* (Parona).

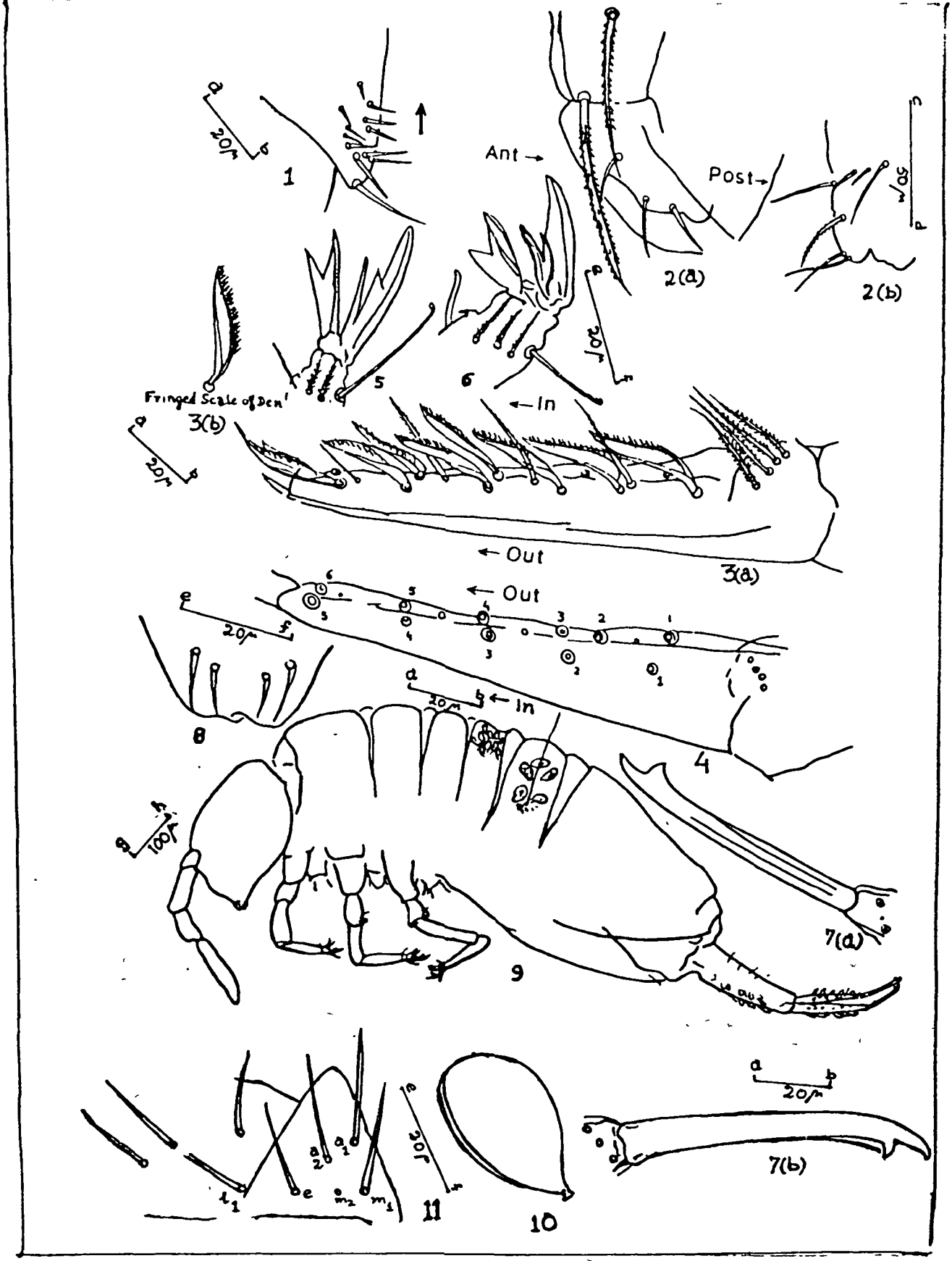
(1) Habitus (clothing not shown) (2) leg showing color pattern (3) eyes and ocellar setae (4) metathoracic claw (5) trochanteral organ (6) cephalic chaetotaxy (7) trunk chaetotaxy (half portion) (8) mucro and dental scale appendage.

Figs. 9-14: *Salina striata* (Handischin)

(9) Habitus (clothing not shown) (10) metathoracic claw (11) trochanteral organ (12) trunk setae (Th. II - Abd. II) Figs. 13 and 14 mucro and dental lobe or scale appendage.

Scales : (a-b) Fig. 4; (c-d) Figs. 5,11; (e-f) Figs. 10,13,14; (g-h) Fig. 3; (i-j) Fig. 8; (k-l) Fig. 1; (m-n) Fig. 9; Figs. 6,7, and 12 semidiagrammatic.

PLATE XI


1
Ant →
Post →
2(a)
2(b)
Fringed Scale of Dent
3(b)
← In
← Out
3(a)
← Out
4
← In
8
9
7(a)
7(b)
11
10

4 DISCUSSION

The present investigation incorporates collection, fixation and preservation as well as identification of twelve species of Collembola from four North-Eastern States viz. Assam, Meghalaya, Nagaland and Tripura. In course of this work some significant features relevant to springtail taxonomy were noted, which are briefly discussed below.

4.1 Habitat and adaptation :

Four major biotopes were analysed viz. moss, litter, soil and bark. It is worth noting here that some species like D. singularis and I.(S.Str.) jayasrae are predominantly muscicolous species, while Cyphoderus sarojini and Troglopedetes rasendrans are restricted to specific habitat below thick moss cushions and never obtained from litter, while Hypogastrura prabhoo inhabits heavily decomposed Pine or Arenga seeds. Callyntrura (H.) lineata shows wide diversity in its habitat, inhabiting moss, litter as well as bark. In general, habitat correlates adaptation of the species and compared to soil and litter, moss and bark due to fluctuating ecological condition harbour less number of Collembola . Muscicolous species are with heavy coloration, well developed mucro, modified unguis and well developed eyes while those species which inhabit deeper soil layer or sand particles under thick moss cover (2-4 mm thick) are without eyes and pigmentation suggesting somewhat cavernicolous adaptation due to regressive evolution (Christiansen, 1986) viz.

Folsomia candida distincta, Sinella (S.Str.) montana S. (S.Str.) curviseta (2 pigmented spots and ill-developed ocelli), Cyphoderus sarojini and Troglopedetes rasendrans. Species inhabiting bark or litterine species (eg. Callyntrura (H.) lineata and Salina striata) also show well developed mucro with scale appendage and heavy clothing of scales and setae. All these characters might be considered while species separation or grouping is done. It is interesting to note that though many species of Cyphoderus are termitophilous or myrmecophilous (Murphy and Yosii, 1987) some like the present species, Cyphoderus sarojini are found in soil, sand or mineral layer below thick moss cushions, as in the present case.

4.2 Size groups, collection and mounting :

Due to continuous growth even after maturity, various size groups of the same species may be found in a population and often some differ markedly among themselves. This requires proper understanding of the different size groups and post-embryonic development. It may be noted that number of setae, nature of teeth on claw and coloration depends on size groups specially in litter and moss inhabiting specimens. Andre's (1987) stase concept might be considered while analysing size groups. Number of trochanteral setae, claw development as well as coloration differs in different size groups of Isotoma (S.Str.) jayasrae and Callyntrura lineata. Method of

collection depending on the habitat differs among different species viz. soil forms like Folsomia candida distincta or Sinella spp. might be obtained by Berlese-Tullgren funnel sampling but for Cyphoderus sarojini and Troglopedetes rasendrans aspiration was most suitable while beating vegetations and undergrowth obtained majority of Callyntrura (H.) lineata. Regarding various methods available for slide preparation it is noted that Salmon's PVA method (1951, 1954) though very suitable being simple and without any cumbersome procedure as materials from life or any preservative might be directly mounted; in long run the slides turn yellowish and material becomes unsuitable for study. As an alternative we suggest Hoyers medium for slide preparation.

4.3 Coloration :

Various taxonomists noted adaptability in coloration. Some of the color forms or variants of Isotoma jayasrae might be geographic subspecies. Salmon, (1977, pers. comm.) indicates possibilities of microgeographic variations in populations of Callyntrura from Shillong. Mitra (1974) has noted 12 color forms of C.(H.) lineata. However D. singularis is unique in its color pattern and readily identifiable. Coloration thus provides additional data to taxonomists. However, sometimes coloration might be of prime importance specially where setal patterns of two or more species are similar viz. C.(H.) taiwanica Yosii, 1965 and C.(H.)

microphysarum Yosii, 1965. Callyntrura species obtained from Shillong are placed under C.(H.) lineata due to their color pattern and claw character uniformity with the typical C.(H.) lineata, even though in their setal pattern they mostly agree with C.(H.) vestita. It is tempting to suggest that this (Shillong population) maybe a subspecies or a sibling species which maybe revealed through further studies.

4.4 Clothing :

Setae and scales of various types and patterns are most suitable tool in the hand of taxonomists. Some genera like Callyntrura, Dicranocentrus, Troglopedetes or Cyphoderus have their specific scales and likewise genera like Sinella, Salina, Dicranocentrus and Callyntrura show macrochaetal pattern which being nonadaptive might be used for infra-generic separation of species. In general head scales are oriented towards anterior while trunk scales point towards posterior direction of the body.

4.5 Antennae :

At first instar, antennae are always 4 segmented and as growth takes place 1st and 2nd segment become subdivided giving rise to 6 segmented antennae of Dicranocentrus, specific for the genus, the last two segments also become annulated and possess short typical "verticilating setae". However number

and size of antennal segments are important only at generic level or above, and sense setae (S.S.) bulbs, cones, rods or other modified setae might be considered at specific level.

4.6 Mouth parts :

Development of maxilla, mandible, labrum and labium are direct indication of food habit of the species. In Cyphoderus and Troglopedetes mandible is not so well developed as in other genera. Setal pattern of simple or ciliated type on the labial basis might be considered in species separation in Dicranocentrus or Cyphoderus. Terminology of macrochaetae on head and trunk might be described with precision following Yosii's (1960) and Snider's (1967) views.

4.7 Postantennal organ (PAO) :

Its presence, absence or number and nature are significant in Collembolan taxonomy. PAO usually disappears in the more highly developed forms and can be considered as indicative of primitiveness. The simplest type of PAO may be single or double lined as in Folsomia sp. being a depression of elliptical or circular nature.

4.8 Claw :

Insect foot consists of a claw or unguis and accessory claw or unguiculus or empodial appendages. There is a

tendency for reduction or specialization of unguiculus according to habitat of the animal. A small reduced unguiculus is considered vestigeal (Salmon, 1959). Both Folsomia sp. and Hypogastrura sp. show somewhat reduced development of claw while Isotoma sp. and Sinella sp. show well developed claw. Winglike teeth of claw seems to be characteristic of Sinella genus.

4.9 Trochanteral organ :

Number of setae on this organ has to be analysed with reference to size group. However, pattern of setal arrangement may be specific in some cases eg. 'L' pattern in Cyphoderus sarojini. Setae on trochanter in forms dwelling on herbs and shrubs like genera Callyntrura or Salina are not so spiny. Size groups of various species might be classified according to the number of setae on trochanter (Mitra, 1973).

4.10 Furcula :

Furcula of various species investigated here show wide variation from almost a simple reduced one in Hypogastrura prabhooii through bidentate mucronal type with long flexible and mostly annulated furca of Dicranocentrus spp., to well-developed strong structure with 6/7 teeth in Callyntrura sp. However importance of furca mainly rests on number of teeth on mucro and clothing of dentes as might be noted from species

separation (Key) of Dicranocentrus into groups with spines or without spines on dentes. Presence of a single or double row(s) of spine(s) has been used to differentiate Troglopedetes from Cyphoderopsis by many workers. However, Salmon (1964, Pers. Comm.; and Yosii, 1978, Pers. Comm.) regard these differences insufficient and provisional. Bellinger (1978, Pers. Comm.) pointed out the possible significance of scale appendage in Cyphoderopsis, which is accepted in this work as well. Troglopedetina and Dicranocentruga are considered now as junior synonym of Troglopedetes (Palacios-Vargas et. al. 1985). Likewise presence of a scale like appendage on dentes might be used for separation of subgenus of Callyntrura into Callyntrura and Handschinphysa (Mitra, 1974). Mucro with prominent teeth indicate herbs and shrubs inhabitation. Size of dental scale appendage is variable but it is not restricted to one sex as stated by Salmon (1957) and is rather species - specific. Regarding dorsoventrality of furcula, Handschin's (1925) concept is favoured against Denis's (1948) concept (see terminology 2.8).

4.11 Genital plate :-

Male and female genital plate is important only at generic level and not effective in species discrimination except the number of setae on or around genital slit eg.,

Hypogastrura sp. and Isotoma sp. (Plate I, Figs. 17 and 18). However setae on the papillae of Callyntrura males might provide additional data on taxonomy.

From the foregoing discussion it appears that the most suitable and almost unique feature of Collembolan taxonomy is the chaetotaxy or broadly speaking clothing. However in genus like Sinella details of chaetotaxy have not been worked out yet (except 2 species of Sinella in this work) and in some cases atleast coloration might provide basis for species-discrimination. Furthermore, due to their multisetaceous nature, species like Isotoma (S.Str.) jayasrae or I.(desoria) trispinata may be conveniently separated on the basis of other taxonomic features like shape or position of PAO, labral margin or claw structure. It seems no single taxonomic parameter has universal application and the higher the number of features are analysed better is the species - discrimination and less risk of ending later with the problem of synonym. This is specially true for species complex of Sinella (S.Str.) and color variants of Callyntrura spp.

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*Original not seen

[....] Translated version in English

SECTION B

CYTOTAXONOMY

1 INTRODUCTION

Chromosomal informations of the species are essential to the modern taxonomists since "the species are considered to be the objective reality of some particular genetic continuity" (Manna, 1969). Cytological studies help us in three ways viz. (1) in giving an idea of natural relationship among various groups undetected by taxonomists (2) to understand various operations of cytogenetic system in evolution of different groups and (3) to solve controversial cases where taxonomists are handicapped regarding the position of some species (Manna, 1958).

Various parameters used in cytotaxonomy apart from chemical, physical and physiological properties of cytoplasm and karyoplasm are various morphological and kinetic features of chromosomes and chromosome sets or karyotypes, that represent the field of interest of cytotaxonomists (Kiauta, 1974). The major variations which can be observed from a comparison of karyotypes of related species are (1) variations in absolute chromosome size, (2) variations in staining properties, (3) chromosome morphology - type, size and number of chromosomes and position of satellite, (4) centromere - type and position, (5) polyploidy (6) sex - chromosome and sex determining mechanisms and (7) recombination index. "These differences reflect genic variations in contrast to products of gene action as modified by environmental factors in morphological variations" (Stebbins, 1971).

The realisation during 1930's that speciation is a gradual process in which the essential feature is the acquisition of genetic isolating mechanism, paved the way for "biological species concept" which developed during the next two decades (White, 1973). It therefore, seems appropriate to mention some of the significant cytotaxonomic works on some of the major groups of insects as a historical review.

It is worth mentioning here that of the thirty one orders of insects, considerable researches have been made only on six orders. The Apterygotes or wingless insects are somewhat neglected in cytotaxonomic studies. Isolated reports appear on Protura and Thysanura and Polytene chromosomal studies in Collembola. In Protura centromere is localized and the haploid number varies from 4-10, sex chromosome is not detectable (Bizzari and Fratello, 1971). Collembolan cytotaxonomy will be reviewed at the end of this chapter in details.

Among Pterygotes by far the most significant cytotaxonomic works have been made in Diptera in general and Drosophila and Chironomus in particular. Major works on Drosophila were reviewed by Patterson and Stone (1952) and Stone, 1962. The existence and properties of polytene chromosomes in Drosophila has helped to solve many important evolutionary taxonomic problems. Chromosomal stability preserves continuity and their change provides great heritable

variability for natural selection to work along with evidences of relationship leading to taxonomy. In Drosophila, "species group" or "super species" emerges as a real and important taxonomic unit. In many of the species groups phylogeny can be traced in various directions basing which taxonomic relationship is established. Study of fossil flies of Drosophila also confirm these super species range. These groups show morphological intra-group diversity but cytological similarities and are called "homosequential", (having the same gene sequence), for example Hawaiian species complex (Carson et al., 1967). Genetic crosses have established many "sibling species" in Drosophila. Throckmorton (1962) in his praiseworthy work on phylogeny of Drosophila has shown how morphological characteristics like spermathecae, ejaculatory bulbs and such other characters can be easily correlated with the cytological phylogeny. The importance of cytological studies comes from the fact that "phenotype may be adaptive and be perpetuated but genotype controlling this pattern may be sharply changed during evolution" (Dobzhansky, 1959). From genetic and cytological evidences Sturtevants' classification of the genus Drosophila (1942) have been substantiated. It has been inferred that species within a "species group" have originated from a common ancestral population (Patterson and Stone, 1952). However, by improved method of DNA estimation, autoradiography and differential banding pattern it may be possible to find very minute chromosomal alterations in these species (Sharma, 1976). Keyl (1962)

constructed phylogenetic tree of twenty three European species of the genus Chironomus and suggested through his studies of DNA contents of corresponding bands that C. thummi and C. piger are not separate species but sub-species in contrast to morphological features.

In the order Odonata on the basis of integration of independent karyological, morphological and paleontological evidences, Kiauta (1967, 1969a) held that the present numerical variations in karyotypes have developed through the occurrence of breaks and fusions in ancestral form. He further stated that high chromosome number is indicative of advancement and specialization.

In the order, Orthoptera investigating on cytology of the wingless grasshoppers of subfamily Morabinae, White (1969, 1973b) has shown the evolution of chromosome numbers from primitive $2n♂ = 17$, and discussed the phylogenetic trend in the so called 'species group' of taxonomy. Orthopterans with their large chromosomes and various cytogenetic systems are one of the classical objects of cytogenetic and cytotaxonomic studies. Super family Acridoidea (short horned grasshoppers) show cytogenetic stability at $2n♂ = 23$. Variable number of supernumerary chromosomes appear in a number of families and occurrence of 'chromosomal races' or 'sibling species' is a regular feature in mole crickets (e.g. Gryllotalpa gryllotalpa). The method through which a number of

species arise from a single one by numerous chromosomal rearrangements has been termed as stasipatric speciation (White, 1973b).

Smith (1959, 1966) studied speciation mechanism in the beetle (Coleoptera) Chilocorus where majority of species differ from C. similis as its 'acrocentrics' became 'metacentric' through "addition" of heterochromatic limb that do not form chiasma at meiosis. Thus cytotaxonomic studies established chromosomal evolution in increase or decrease in the size of heterochromatic limb, assuming even acrocentrics have short heterochromatic second limb. These chromosomes are called diphasic (Smith, 1966).

In Heteroptera, evolutionary inter-relationship between various groups was advocated by Leston (1958) and Manna (1958, 1962). Recognition of Alydidae and Corizidae as separate families from Coreidae was through cytotaxonomic studies. The detection of different species of Banasa and Thyanta which systematists failed to recognise, were possible only due to cytological studies (Schrader and Hughes-Schrader, 1956). Manna (1951, 1958, 1962) made a comprehensive attempt to correlate all cytologically known species of Heteroptera to taxonomic grouping and phylogenetic relationship among different families of Heteroptera and put forward a "cytological key" characterising different families.

In Homoptera, Brown and Mekenzie (1962) divided Coccina on meiotic patterns and meritoriously correlated them with taxonomic placement.

In Blattodea, on family level (e.g. Blaberidae) and occasionally on subfamily levels the type numbers are clearly distinct. The position of the centromere is also characteristic of various species (John and Lewis, 1959, Kiauta, 1974).

Lepidoptera is the third largest order of insecta after Diptera and Orthoptera in which about 1500 species have been studied cytologically. They are characterized by diffuse centromere and wide range of chromosome number (n = 7 to 253). The type number of the order is 31, with a strongly marked mode at 29-31. Heterogametic females show achiasmatic Oogenesis (Suomalainen, 1963, 1965). In some families like Papillionidae all or almost all species have the same chromosome number. The various geographic races of the same species might differ in chromosome number, but show similarity in overall volume of the metaphase chromosomes (through size) and also in their DNA content. From this observation it can be assumed that fragmentations and fusions are responsible for variations in chromosome number (Gupta, 1964, Rishi, 1973).

From the aforementioned brief overview of the pioneering works on some major orders of insects, it has become fairly clear that major cytotaxonomic investigations on insects are

restricted to a few orders like Orthoptera, Diptera and Heteroptera where chromosome number is fairly constant and thus elucidates degree of affinity between different species or species groups. It is also interesting to note that orders possessing holokinetic chromosomes show higher chromosome number in more advanced taxa and this situation is just opposite in orders with monokinetic elements (Kiauta, 1974). In order like Heteroptera "cytological key" can be used most effectively as an additional tool for species determination (Manna, 1958, 1962). With this background it seems appropriate now to look into the cytotaxonomical researches made on "springtails". As mentioned earlier karyological works on Apterygota in general and Collembola in particular are considerably rare with only a few isolated reports occasionally from some cytologists. However, recently some important works have been done on polytene chromosomes from salivary gland nuclei of species from the Neanuridae family.

Review of literature on Collembolan cytogenetics indicates that out of more than 6000 species under approximately 752 genera and 20 families only about 75 species and subspecies belonging to 13 families have been studied so far. Table III shows major cytotaxonomic works on 65 species and subspecies of Collembola under 12 families.

Table III

Check-List of major cytotaxonomic data on Collembola (Including present work)

Species	Chromosome number ♂ (2n)	Chromosome number ♀	Chromosome number ♂ (n)	Chromosome number ♀	Sex Determining Mechanism	Reference
1	2		3		4	5
PODURIDAE						
Podura aquatica L.		8				Willem, 1900
HYPOGASTRURIDAE						
Ceratophysella armata communis(Fols.)				7 (s,1-3)		Nunez, 1962
Hypogastrura manubrialis (Tullb.)		14		7 (s,1-3)		Nunez, 1962
H. viatica (Tullb.)				7		Saure and Brummer-korvenkontio, 1958
NEANURIDAE						
Brachystomella parvula (Schaff.)		8		4		Nunez, 1962
Probrachystomella rhodosoma Rap.				6		Nunez, 1962
Anurida maritima (Guerin)		8				Claypole, 1898
Womerselya sp.		8*				Prabhoo, 1961
Paleonura spectabilis Cassagnau		8*				Cassagnau & Lee, 1982
Bilobella grassei Denis	12 (10+XY)	12* (10+XX)			XY/XX	Cassagnau, 1971b
Bilobella massoudi Cassagnau		14*				Cassagnau, 1968a
Latriopyga longiseta Caroli		12/14*		6,7		Cassagnau, Dallai & Deharveng, 1979

Table III continue

Table III continued

1	2	3	4	5
V. giselae (Gisin)		12/14*		Cassagnau & Deharveng, 1981
V. lapidicola Cassagnau & Deharveng		16*		Cassagnau & Deharveng,
V. hygrophila Cassagnau & Deharveng		16*		Cassagnau & Deharveng, 1981
Travura reticulata Cassagnau & Deharveng		14*		Cassagnau, 1980
Travura divergens Cassagnau & Deharveng		20*		Cassagnau, 1980
ISOTOMIDAE				
Ballistura scoetti (Dalla Torre)			7	Nunez, 1962
Proisotoma fatonei Rap.			7	Nunez, 1962
P. minuta (Tullb.)			4	Nunez, 1962
Folsomia candida distincta Bagnall		13		Kiauta, 1970
F. sexoculata (Tullb.)			7	Saure & Brummer-Korvenkontio, 1958
Isotoma maritima (Tullb.)			7	Saure & Brummer-Korvenkontio, 1958
I. sensibilis (Tullb.)			7	Saure & Brummer-Korvenkontio, 1958
I. viridis Bourl.			7	Saure & Brummer-korvenkontio, 1958
**I. jayasrae* Bhattacharjee	13		7	Bhattacharjee & Chatterjee, 1989
I. antennalis (Bag.)		7	X-recognizable	Nunez, 1968
**(Desoria) trispinata* MacGill.	13		7	Present work
Isotomina thermophila (Axels.)			5	Nunez, 1962
Isotomurus palustris (Muller)			7	Saure & Brummer-korvenkontio, 1958

Table III continued

Table III continued

1	2	3	4	5
TOMOCERIDAE				
Pogonognathellus flavescens (Tullb.)		6		Saure & Brummer-korvenkontio, 1958
P. longicornis Muller		6		Saure & Brummer-korvenkontio, 1958
Tomocerus minor (Lubb.)	11	6	6	Saure & Brummer-korvenkontio, 1958
T. vulgaris (Tullb.)		6		Saure & Brummer-korvenkontio, 1958
T. minutus (Tullb.)		6		Saitoh & Chiba, 1959
ENTOMOBRYIDAE				
Entomobrya atrocinta psuedoperpulchra Mills	11	6	XO/XX	Nunez, 1962
Entomobrya corticalis (Nic.)		6		Saure & Brummer-korvenkontio, 1958
E. Lanuginosa (Nic.)		6		Saure & Brummer-korvenkontio, 1958
E. lanuginosa olivacea Rap.	11 12	6	XO/XX	Nunez, 1962
E. multifasciata (Tullb.)	11 12	6	XO/XX	Nunez, 1968
E. pseudodecora Rap.	11,12 12 14	6	XO/XX	Nunez, 1862, 1968
E. cf. nigrocincta Denis	9 (8+X)			Tuzet & Manier, 1956
E. cf. nivalis (L.)	9	5	XO/XX	Tuzet & Manier, 1956
E. nivalis (L.)		6		Saure & Brummer-korvenkontio, 1958

Table III continued

Table III continued

1	2	3	4	5
E. nivalis (L.)	11	12	6	XO/XX	Grondziel, 1973
E. puncteola	11	12	6	XO/XX	Grondziel, 1973
****Sinella montana* Imms	11	12 (s,1)	6	XO/XX	Bhattacharjee & Chatterjee, 1984
****S. curviseta* Brook	11	12	6	XO/XX	Bhattacharjee & Chatterjee, 1984
Pseudosinella sexoculata Schott			6	XO/XX	Nunez, 1962
ENTOMOBRYIDAE					
Seira domestica (Nic.)		12	6	XO/XX	Nunez, 1962
****Dicranocentrus singularis*	11	12	6	XO/XX	Present work
****D.fraternus*	11	12	6	XO/XX	Present work
Orchesella villosa (Geoffr.)			6		Lecaillon, 1901
O. bifasciata (Nic.)			6		Saure & Brummer-korvenkontio, 1958
PARONELLIDAE					
****Callyntrura lineata* (Parona)	11	12	6	XO/XX	Bhatacharjee & Chatterjee, 1989
Salina striata (Hands.)		12	6	XO/XX	Bhattacharjee & Chatterjee, 1989
****Troglopedetes rasendrans* Bhattacharjee	11		6	XO/XX	Present work
CYPHODERIDAE					
Cyphoderus assimilis empodialis Rap.			6	XO/XX	Nunez, 1962
SMINTHURIDIDAE					
Sminthurides aquaticus (Bourl.)			5		Saure & Brummer-korvenkontio, 1958
Sphaeridia pumilis (Krausb.)		10	5	XO/XX	Nunez, 1962

Table III continued

Table III continued

1	2	3	4	5
KATIANNIDAE				
Katianna sp.	9	5	XO/XX	Nunez, 1962
SMINTHURIDAE				
Allacma fusca (L.)	9	5	XO/XX	Nunez, 1962
Sminthurinus mime Borner	12	6		Kiauta, 1970
S. nunezi Rap.		5	XO/XX	Nunez, 1962
Sminthuru viridis L.	9	5	XO/XX	Tuzet & Mainer,
DICYRTOMIDAE				
Dicyrtomina sp.	9	5	XO/XX	Nunez, 1962

Note: 's' means supernumerary chromosome
* indicates studies on polytene chromosomes from salivary glands,
** denotes investigations included in the present work

This list is not exhaustive and excludes works on 5 species of Onychiuridae (Fratello and Sabitini, 1980) and 3 species of Neanurid Collembola (Lee, 1980) due to non availability of details. The list also excludes reports which are not fully substantiated or are of historical importance only.

Makino (1951) in his "Atlas of the chromosome numbers" - quotes data pertaining to some of the Collembolan species viz. Anurida maritima (2n = 80 Claypole, 1898) Orchesella villosa (n = 6, Lecaillion, 1901), Podura aquatica (2n = 8, Willem, 1900). But these works are merely of historical importance as they do not establish definite chromosome number of Collembola. Cytological studies by Tuzet and Manier (1956) on Entomobrya nivalis (♂ 2n = 9), Orchesella villosa (♂ 2n = 9), Entomobrya nigrocincta (♂2n = 9) and Sminthurus viridis (♂2n = 9) and works of Saitoh and Chiba, 1959 on Tomocerus minutus (♀ n = 6) provide much more reliable cytological data for these species. Nunez (1962) gave a list of chromosome number of 20 species. Krzystofowicz (1967) reported male diploid number as 13 (12 + X) in Tetradontophora bielanensis. However, all these works mentioned above simply reported the chromosome number without going into the exact nature or structure of Collembolan chromosomes. Nunez (1962) mentioned that a number of species show XO mode of sex determination in males. However, the "Neanuridae studied by Cassagnau (1968a,b; 1970b) do not seem to show morphologically differentiated sex chromosomes" (White 1973). Prabhoo (1961) Cassagnau (1966, 1970a, 1971a,b, 1977, 1982), Lee (1980), Cassagnau and Deharveng (1980, 1981) and Deharveng (1982) studied polytene chromosomes from the salivary glands of species belonging to Neanuridae. The only family so far reported to possess polytene chromosomes in Collembola. The diploid number reported by cited authors ranges from 8-20.

Special mention should be made regarding polymorphism in two populations of Lathriopyga longiseta (Cassagnau et.al., 1979).

Kiauta (1970) reviewed germ cell cytology of different Collemboles and gave a list of chromosome number of fortysix species including two new reports by him. Grondziel (1973) gave details of karyotype of two entomobryid species : E. puncteola and E. nivalis ($2n♂ = 10 + X$ and $2n♀ = 10 + XX$).

Fratello and Sabatini (1980) studied karyotypes and habitat interrelations of five species of Onychiurus and observed that diploid number of chromosomes in these species increases with decrease in the size (width) of the animal.

In India, Prabhoo (1961) reported the presence of polytene chromosomes in the salivary glands of Womersleya sp., but no attempt has been made to study the germ cell cytology of any Indian Collembola.

With a view to fill in the lacuna in our knowledge of Collembolan cytogenetics, we have undertaken in our laboratory a chromosomal survey of North-East Indian Collembola (Bhattacharjee and Chatterjee, 1984,1987,1989). Basing on the karyotype analysis using the most suitable and established methodology, the present work incorporates investigations on the germ cell cytology of nine species of Collembola belonging to three families viz. Isotomidae, (two species), Entomobryidae (four species) and Paronellidae (three species) - all new to

cytology. In the later part of this work through a comparison of all the available cytological data (including the present ones) an attempt is made to establish the possible karyotypic evolution in Collembolans.

2 MATERIALS AND METHODS

2.1 The Material :

The materials for this work were collected from various parts of Shillong, Meghalaya, from different biotopes at different times of the year comprising of a variety of size groups of either sex.

In total 9 species belonging to 3 different families have been studied cytologically. The species are :

A Family : Isotomidae

1. Isotoma (S.str.) jayasrae Bhattacharjee, 1984
2. Isotoma (Desoria) trispinata (MacGillivary, 1896)

B Family : Entomobryidae

1. Sinella (S.str.) montana Imms, 1912
2. Sinella (S.str.) curviseta Brook, 1882
3. Dicranocentrus fraternus
4. Dicranocentrus singularis

C Family : Paronellidae

1. Callyntrura (Handschinphysa) lineata (Parona, 1892)
2. Salina striata (Handschin, 1928)
3. Troglopedetes rasendrans Bhattacharjee, 1985

2.2 Collection :

Live materials were collected by brush method, hand-picking or by aspirator.

2.3 Culture of Collembola :

Live specimens were cultured in a number of small circular plastic container with culture medium of charcoal and plaster of Paris (1:9, w/w), adding a little of yeast and water from time to time. Collembola could be reared in these boxes upto 10-12 days and sacrificed as and when required (Kyle and Long, 1967 and Hutson, 1978).

2.4 Pretreatment :

Suitable identified materials were sacrificed and punctured by a dissecting needle and transferred into a hypotonic solution of 1% trisodium citrate for 20 minutes. The material was subjected to a treatment of Colchicine for arresting the dividing cells at metaphase. But the amount of Colchicine and duration of treatment should be determined carefully as prolonged treatment leads to polyploidy or tissue degeneration. It was found 0.05% Colchicine for 20-30 minutes provides reasonably high mitotic index (Kurl and Misra, 1979).

2.5 Fixation :

The material was then fixed for atleast 30 minutes in freshly prepared aceto-alcohol solution by mixing 1 part of glacial acetic acid with 3 parts of ethylalcohol (100%)(v/v).

2.6 Squashing :

The fixed materials were dissected under a binocular or dissecting microscope and gonads were separated on a clean slide coated with a film of Mayer's albumen. Extra cuticular portion along with head, body and legs were removed from the slide. A drop of 45% acetic acid was used before covering the tissue by coverslip and squashing.

2.7 Staining :

2.7.1 Staining with Heidenhain's hematoxylin stain:

Squashed slides were either stained in Heidenhain's hematoxylin following the method outlined by Smith (1943) with some modifications or with Giemsa.

Heidenhain's Hematoxylin stain components

Hematoxylin	0.5 gm
Ethanol 96%	10.0 ml
Distilled water	90 ml

A few drops of ammonium solution were added for blue toning of the chromosomes. The stain was then filtered and allowed to mature for sometime before use.

Staining with Heidenhain's hematoxylin : The procedure involved three steps as follows :

1. Treatment in mordant solution of 3% Iron alum solution ($NH_4Fe(SO_4)_2.12H_2O$).

2. Staining in 0.5% hematoxylin solution.
3. Differentiation in super staturated aqueous solution of picric acid.

The squashed slides were brought to water and kept in mordant solution for 20 minutes, rinsed in distilled water and then stained in hematoxylin stain for 5 minutes. The slides were differentiated in saturated picric acid solution and thereafter kept in running water for atleast 30 minutes. Slides were then dehydrated through ascending grades of alcohol, cleared in xylene and finally mounted in DPX.

2.7.2 Staining with Giemsa :

The procedure described by Pardue and Gall (1970) with slight modification was followed:

(i) Stock buffer solution A : m/15, di-sodium hydrogen ortho-phosphate.

(ii) Stock buffer solution B : m/15, potassium dihydrogen ortho-phosphate.

(iii) Working buffer solution : Prepared by mixing stock buffer solution A and B in equal volume, pH ranging between 6.8 to 7.2.

(iv) Working Giemsa solution : A solution made by mixing 10 ml of Giemsa stock solution (BDH) and 90 ml of working buffer solution.

The squashed air dried slides were stained with Giemsa working solution for 10 minutes. The stained slides were rinsed in distilled water, dried and kept in xylene for 5 to 7 minutes and mounted in DPX.

2.8 Chromosome analysis :

The following parameters were considered in the study of chromosome morphology :

1. Total length of the chromosome or TCL value.
2. Percentage (P.C.) length or relative length of sex

$$\text{Chromosome} = \frac{\text{Total length of sex chromosome}}{\text{Total length of entire chromosome set}} \times 100$$

3. Number of arms or NF = Total number of arms in a complete chromosome set (diploid)
4. Recombination index or genetic length of chromosomes = Haploid number of chromosome + mean number of chiasmata (Darlington, 1937, White 1973).

The metrical study was made from the projections of the negative of metaphase I chromosomes and the scale of stage micrometer through an enlarger.

2.9 Photomicrography :

The photomicrographs were taken with an Olympus photo-microscope using green filter and 10 x eye piece and 100 x oil immersion objective, Orwo panchromatic films were used for photography. The magnification of the prints have been given by the accompanying 'bar'/scale in each plate.

3 OBSERVATIONS

In the present investigation on the germcell cytology of Collembola nine species belonging to six genera comprising three families have been studied. Life cycle was usually completed within two and a half months and the insects showed five generations in a year. In any particular biotope non-simultaneous occurrence of males and females in identical periods of development restricted thorough investigation on both the sexes to some extent. However, except in a few cases both males and females have been studied. Diploid chromosome numbers have been determined for all species from well spread gonial metaphase plates. The meiotic cycle seems to be uniform in all the species, first meiotic division being reductional while the second was homeotypic in nature. The spermatogonial and oogonial divisions showed a cyclical course in all the species. Sex chromosomes could be identified by their univalent nature in males during diplotene to metaphase I. Two types of metaphase II nuclei in males, with odd (one less) and even number of chromosomes respectively, indicate XO:XX type of sex determination. However sex chromosome bivalents are indistinguishable from the autosomal bivalents in primary oocyte metaphase plates. Table III briefly reports diploid and haploid chromosome numbers along with the sex determining mechanism in sixtyfive species of Collembola including the nine species studied during this investigation. A detailed descrip-

tion of the karyotype, chromosome behaviour during meiosis and sex determining system have been given in the following pages with suitable figures.

3.1 Family : Isotomidae

Isotoma (S.Str.) jayasrae Bhattacharjee, 1984

Text figures 1,2,4 and 6

Isotoma (Desoria) trispinata MacGill. 1896

Text figures 3, 5 and 7

♂ 2n = 13 (12A + X)

♀ 2n = 14 (12A + XX)

Two species belonging to the genus Isotoma constitute the material for the present study viz. Isotoma (S.Str.) jayasrae and Isotoma (Desoria) trispinata. Both males and females of these two species have been studied.

The spermatogonial count from many well spread metaphase plates discern the diploid number as 13 (Fig. 1) while oogonial metaphase count reveals the female diploid number to be 14 in both the species (Figs.2 and 3). The chromosomes in the gonial stages appear to be small rod shaped or slightly curved with terminal centromere. However, though chromosomes of I. (Desoria) trispinata do not show marked size differences, chromosomes of I.(S.str.) jayasrae indicate slight variation in their size. At diplotene and thereafter in both the species males show 6 bivalents and a univalent chromosome with increase in meiotic condensation (Figs.4 and 5). The females of these

species reveal 7 bivalents at metaphase I. All bivalents are without much differences in size in I. (Desoria) trispinata (Fig. 7). However primary spermatocyte and oocyte stage of I.(S.str.) jayasrae reveal bivalents of somewhat unequal sizes (Fig.4&6). All the bivalents show single chiasma which persists upto late diakinesis stage. Chiasma terminalization coefficient indicates that loss of chiasmata is maximum at late diakinesis stage. The first meiotic division is reductional and the second equational showing two different types of secondary spermatocyte nuclei in both the species with different chromosome number viz 6 (all autosomes) and 7 (6 autosomes and 1 sex chromosome) and at anaphase I these chromosomes sort out in two groups of 6 and 7 each. The second meiotic cycle follows the first without a clear cut inter kinetic stage. The metrical analysis at metaphase I stage for the two species reveal the mean total chromosomal length (TCL) as 8.25 μ and 8.75 μ respectively while the relative length of sex chromosome measures to be 14% and 16% of TCL in Isotoma (S.str.) jayasrae and I. (Desoria) trispinata respectively (Table IV).

The occurrence of two different types of metaphase II plates in all male specimens of both the species, coupled with occasional observation of a minute dark structure in some interphase nuclei of Isotoma (S.str.) jayasrae males suggest males to be heterogametic sex. However at metaphase I all the 7 bivalents of females of both the species show uniform staining

(Figs. 6 and 7). Presence of an extra chromosome in females along with unequal number of chromosomes in the secondary spermatocytes in both the species indicate XO, XX type of sex determining system in this genus, i.e. ♂ 2n = 13 (12A + X) and ♀ 2n = 14 (12A + XX), the males being the heterogametic sex. Comparative study of the sex chromosomes from primary oocyte metaphase plates of these species indicate slightly bigger sex chromosome in I. (Desoria) trispinata. The autosomal bivalents and the sex chromosomal bivalents do not show separate plate formation or any "auto orientation"at primary oocyte metaphase stage in any of the species.

3.2 Family : Entomobryidae

3.2.1 Subfamily: Entomobryinae

Genus : Sinella (S.Str)

Species : montana Imms, 1912 Text figures 8,9,11, 12,14-16

Species : curviseta Brook, 1882 Text figures 10, 13,17 and 18.

♂ 2n = 11

♀ 2n = 12/12 + Is

Two species belonging to the genus Sinella constitute the material for the present study viz. Sinella (S.Str.) montana Imms, 1912 and Sinella (S.Str.) curviseta Brook, 1882. Both males and females of these species have been investigated.

The diploid chromosome number as obtained from many spermatogonial and oogonial metaphase plates (Figs. 8-10) seems to be 11 for males and 12 for females of both the species. In Sinella (S.Str.) montana males a number of nuclei in the tetraploid range have been observed (Fig. 8). All the chromosomes are rod shaped and not much different in size except one in males or a pair in females which is the smallest. From diplotene onwards in males 5 bivalents along with a univalent chromosome are observed in both the species (Figs. 11-13). The bivalent mostly form single chiasma and terminalization continues upto late diakinesis. Primary spermatocyte metaphase shows 5 bivalents and a small univalent chromosome (Figs. 11-13).

Metaphase I in females show 6 bivalents in both the species (Figs. 14 and 17) however in Sinella (S.Str.) montana primary oocyte metaphase, occasionally a small accessory or supernumerary chromosome, close to a bivalent is observed (Fig. 15). The number of this supernumerary element never exceeds one and it is found to associate always with a bivalent at metaphase I or a chromosome at metaphase II (Figs. 15-16). No such accessory or supernumerary chromosome is found in the related species Sinella (S.Str.) curviseta males or females.

In Sinella (S.Str.) curviseta some primary oocyte metaphase exhibit precocious separation by a bivalent (Figs. 17-18). Such precocious separation of a bivalent is however rare in Sinella (S.Str.) montana.

At anaphase I of males of both the species the chromosomes sort out in two groups of 5 and 6 each while in females the separating chromosomes are of equal number. In both species first meiotic division is reductional and second is equational. The fate of accessory or supernumerary chromosome of Sinella (S.Str.) montana females sometimes could be traced at anaphase I or metaphase II nuclei that showed the unequal number of chromosomes in females (Fig. 16). Secondary spermatocytes nuclei in both the species show different chromosome number viz 5 (all autosomes) and 6 (5 autosomes and 1 sex chromosome). The second meiotic division follows the first

without any inter kinetic stage. At anaphase I of Sinella (S.Str.) montana females, occasionally some sticky bridges are observed. The mean total chromosomal length (TCL) calculated from metaphase I chromosomes are 6.4 μ and 6.8 μ while the percentage length of the sex chromosome are 16 and 15 for Sinella (S.Str.) montana and S. (S.Str.) curviseta respectively. (Table IV)

The occurrence of two different types of metaphase II nuclei in all male specimens with either 5 or 6 chromosomes each while with atleast 6 chromosomes in all secondary oocyte metaphase, indicate heterogametic nature of males in both the species. Sex determining system in this genus is therefore, XO:XX viz ♂ 2n = 11 (10A + X) and ♀ 2n = 12 (10A + XX). Though sex chromosomes do not exhibit pycnotic behaviour and are indistinguishable from autosomal bivalents at metaphase I in females, the precociously separating pair might represent the sex chromosome bivalent.

3.2.2 Subfamily : Orchesellinae

Genus : Dicranocentrus

Species : fraternus Text figures 19-22,25 27,30 and 31

Species : singularis Text figures 23,24,26 28 and 29

♂ 2n = 11 (10A + X)

♀ 2n = 12 (10A + XX)

Two species belonging to the genus Dicranocentrus constitute the material for the present study viz. Dicranocentrus fraternus and Dicranocentrus singularis. Males and females of both these species have been studied.

The spermatogonial count from a number of metaphase plates suggests the diploid chromosome number for both these species as 11 (Figs. 19 and 23) while wellspread oogonial metaphase plates indicate diploid number for females of both the species investigated as 12 (Figs. 22 and 24). Many tetraploid spermatogonial metaphase plates of D. fraternus also confirms this finding (Fig. 21). All the chromosomes of either sexes in both the species are small rod shaped or slightly curved with terminal centromere. One chromosome in the males and two in females are slightly smaller than the rest. From diplotene onwards upto metaphase I the chromosomes

form five bivalents and a univalent in males (Figs. 25 and 26), while six bivalents in females (Figs. 27-29). All the bivalents show single chiasma (Fig. 25) which persists till early metaphase I. Due to increasing meiotic condensation the bivalents do not show much difference in size among themselves at metaphase I. However, at diakinesis of D. fraternus and and metaphase I of D. singularis (Figs. 25 and 26) some distinction between them could be made. Chiasma terminalization coefficient indicates that loss of chiasmata is maximum at late diakinesis stage in both the species. The bivalents do not show differential staining behaviour among themselves or with the univalent. The orientation of the bivalents either at primary spermatocyte or at primary oocyte metaphase stage does not suggest separate plate formation for sex bivalent (Figs. 27 and 28). The first meiotic division in both the species is reductional while the second homeotypic in nature. No interkinetic stage exists between the heterotypic or homeotypic division of meiosis. Anaphase I and metaphase II of male D. fraternus show sorting out of the chromosomes into two groups of 5 and 6 each (Fig. 30). The occurrence of two different types of metaphase II nuclei with unequal number of chromosomes viz 5 (all autosomes) and 6 (5 autosomes and 1 sex chromosome) along with their sorting in two groups suggest heterogametic nature of the males for both the species of Dicranocentrus. The metrical analysis at metaphase I stage

indicate the mean total chromosomal length (TCL) as 7.2 μ and 7.0 μ while the relative length of sex chromosome measures as 14% and 15% of TCL in D. fraternus and D. singularis respectively (Table IV).

At telophase I of female D. fraternus (Fig. 31) all the chromosomes are equally distributed to the poles forming almost two clumped dark stained structures separated by spindle fibres.

The presence of two types of metaphase II nuclei plates in all male specimens of both the species indicate XO, XX type of sex determining mechanism in this genus viz ♂ 2n = 11 (10A + X) and ♀ 2n = 12 (10A + XX), the males being the heterogametic sex. However, the sex chromosome bivalent in metaphase I females do not show distinctive pycnotic property or separate plate formation. At primary spermatocyte the sex chromosome could be readily identified by its lone nature and small size (Fig. 26).

3.3 Family : Paronellidae

3.3.1 Genus : Callyntrura

Species : lineata (Parona), 1892 Text figures : 32-35

♂ 2n = 11 (10A + X)

♀ 2n = 12 (10A + XX)

The only species Callyntrura lineata (Parona) represents the genus Callyntrura studied in the present investigation. Both male and female specimens were available for karyological studies.

From analysis of a number of well spread gonial metaphase plates diploid chromosome number of this species could be obtained as males having 11 and females with 12 chromosomes. Spermatogonial metaphase plates (Fig. 32) show 11 distinct rod-shaped small chromosomes without any size variation while oogonial metaphase reveals similar rod shaped 12 chromosomes with terminal centromere (Fig. 33). In females, no distinction could be made between the autosomes and sex chromosomes. From diplotene onwards in males five bivalents with a univalent chromosome is seen without much difference in size (Fig. 34) while in primary oocyte metaphase (Fig. 35) six bivalents with indistinct size difference could be ascertained. However one of the bivalents at metaphase I of females show clear negative hetero-

pycnosis. It is worth mentioning here that the univalent chromosome of males at metaphase I also exhibit similar negative heteropycnotic behaviour (Figs. 34 and 35). This behaviour of the sex chromosome is unique in this species since no other species studied during present investigation show such negative heteropycnotic behaviour. All the bivalents including sex chromosome bivalent form single interstitial chiasma which persists till late diakinesis stage. First meiotic division is reductional, the second being equational as in other species. No interkinetic gap exists between the two stages of meiosis. Anaphase I and Metaphase II chromosomes sort out into two groups of 5 and 6 in males and 6 each in females. Metrical analysis of the metaphase I chromosomes indicate mean total length of the chromosome (TCL) as 6.8 μ and percentage length of sex chromosome to TCL is 15.80 . (Table IV)

From the occurrence of two different types of metaphase II nuclei in males with 5 and 6 chromosomes each and negative heteropycnotic univalent in primary spermatocyte metaphase and similar bivalent in primary oocyte metaphase, it can be readily concluded that sex determining mechanism in this species follows XO, XX system, the males being heterogametic. The chromosome number for this species could be deducted as $\sigma^{\prime}$ 2n = 11 (10A + X) and φ 2n = 12(10A + XX). The unique feature of this species is the negative heteropycnotic behaviour of the sex

chromosomes which makes it rather easy for their identification. However, in the gonial metaphase plates no pycnosis could be detected. The sex chromosomes do not form separate plate or orientation with reference to the autosomal bivalents.

3.3.2 Genus : *Salina*

Species : *striata* (Handschin, 1928)
Text figures 36-40

♂ 2n = 11 (10 + X)
♀ 2n = 12 (10 + XX)

The lone species that was available for karyological studies of this genus was *Salina striata* (Handschin). Both males and female specimens of this species have been studied.

Spermatogonial count from many well spread metaphase plates reveals the male diploid chromosome number as 11 while oogonial metaphase plates show female diploid chromosome number for this species to be 12 (Figs. 36 and 37). All the chromosomes are either rod shaped or slightly curved with terminal centromere. Oogonial metaphase in the polar view show peripheral orientation of the chromosomes with occasional 1 or 2 chromosomes at the centre creating almost a hollow spindle (Fig. 37). In the spermatogonial metaphase, a single chromosome shows slightly positive heteropycnotic behaviour. All the chromosomes are small and not much different in size. At diplotene and thereafter in males five bivalents and a small univalent chromosome is seen while in females six bivalents of similar size and staining property are seen (Figs. 38 and 39). At anaphase I and metaphase II of males the chromosomes sort out into two groups of five and six each (Fig. 40), while at the corresponding stages in females, six chromosomes are

visible. The autosomal bivalents and sex chromosome bivalent in females are indistinguishable. Meiosis consists of usual heterotypic and homeotypic divisions, reduction of chromosome number being attained in the first division itself. TCL value for this species is 6.8 μ and length of sex chromosome is 14.5% of TCL (Table IV).

Observation of two different types of metaphase II nuclei with five and six chromosomes each or with one chromosome less in one of the nuclei clearly indicate XO,XX type of sex determining system for this species. This also accounts for the presence of one additional chromosome in the oogonial nuclei as compared to spermatogonial nuclei. It may be stated here that in the interphase nuclei of males occasionally condensed body or element is observed towards the periphery of the nuclear membrane. Though in metaphase I and II sex chromosome is not distinguishable from autosomes, from unequal number of chromosomes in metaphase II nuclei in males and difference in diploid number of chromosomes between males and females, chromosomal complement for this species can be obtained as of ♂ 2n = 11 (10A + X) and ♀ 2n = 12 (10A + XX). However, sex chromosomes do not show heteropycnotic behaviour.

3.3.3 Genus : Troglopedetes

Species : rasendrans Bhattacharjee, 1985
Text figures 41-45

♂ 2n = 11 (10 + X)

♀ 2n = 12 (10 + XX)

The only species studied under this genus is Troglopedetes rasendrans Bhattacharjee. Both male and female specimens were available for study.

The spermatogonial metaphase spread chromosome count discerns the diploid number for this species as eleven (Fig. 41). While basing on the study of a number of oogonial metaphase plates, female diploid chromosome number is established to be 12. Unlike chromosomes of other Entomobryid species studied in the present investigation, chromosomes of Troglopedetes rasendrans are not uniform in size but rather form a series (Fig. 41). Except two chromosomes, rest are rod shaped small or medium sized with terminal centromere. The two chromosomes mentioned above form the largest pair and might be regarded as double sized acrocentric chromosome. One of the chromosomes is slightly away from the main plate (Fig. 41). Unfortunately no properly spread oogonial metaphase plate could be illustrated. However, from a number of oogonial metaphase plates female diploid number of chromosomes has been established. Sex chromosome in the spermatogonial metaphase plate is the smallest element without a corresponding partner (Fig. 41).

At diplotene and thereafter five bivalents and a univalent chromosome are observed in males (Fig. 43), while in females six bivalents of almost equal size are seen (Figs. 42 and 44), possibly due to increasing meiotic condensation. It is worth mentioning here that sex univalent at primary spermatocyte metaphase is very conspicuous by its small size compared to autosomes as expected from analysis of spermatogonial plate. At anaphase I (Fig. 45) chromosomes sort out in two groups of five and six each, sex chromosome being present only in one of the groups. All the bivalents show atleast one chiasma and the process of terminalization continues upto late diakinesis. The first meiotic division is reductional while the second is equational and at metaphase II of males two types of nuclei are met with, one having five chromosomes while the other six chromosomes. TCL value for this species calculated at this stage is 7.5 μ and relative length of the sex chromosome is 10% of the mean total chromosomal length of the species (Table IV).

The presence of two types of secondary spermatocyte nuclei as well as an additional chromosome in the oogonial metaphase plates than the spermatogonial metaphase clearly indicates XO, XX type of sex determining mechanism in this species. The diploid chromosome number of Troglopedetes rasendrans, are therefore ♂ 2n = 11 (10A + X) and ♀ 2n = 12 (10A + XX). Sex chromosomes do not show heteropycnotic behaviour or "auto

orientation" but are detectable by their size, being the smallest element in the chromosomal complement of the species. The other special feature of this species is a pair of double size acrocentric, one of which occasionally moves slightly away from the main plate.

Table IV

Metrical Analysis*

Species	Chrom. No (2n) ♂	♀	Mean TCL(μ)	%length of sex chrom	sex determining system
ISOTOMIDAE					
Isotoma (s.str.) jayasrae	13	14	8.25	14.0	XO/XX
I.(Desoria)trispinata	13	14	8.75	16.0	XO/XX
ENTOMOBRYIDAE					
Sinella (s.str.) montana	11	12 (s,1)	6.4	16.0	XO/XX
S.(s.str.) curviseta	11	12	6.8	15.0	XO/XX
Dicranocentrus fraternus	11	12	7.2	14.0	XO/XX
D. singularis	11	12	7.0	15.0	XO/XX
PARONELLIDAE					
Callyntrura lineata	11	12	6.8	15.8	XO/XX
Salina striata	11	12	6.8	14.5	XO/XX
Troglopedetes rasendrans	11		7.5	10.0	XO/XX

* Based on 10-15 Metaphase I nuclei

TABLE-V

Distribution of Female haploid chromosome numbers and Family type number in Collembola.

SUB ORDER and Family	Number of Species Studied	Number of Species with haploid Chromosome No.								
			4	5	6	7	8	9	10	Family type No.
ARTHROPLEONA										
Poduridae	1		?							?
Hypogastruridae	3					3				7
Neanuridae	16		5		4	4	2		1	?
Isotomidae	12		1	1		10				7
Tomoceridae	5				5					6
Entomobryidae	17				17					6
Paronellidae	3				3					6
Cyphoderidae	1				1					6
SYMPHYPLEONA										
Sminthuridae	7			6	1					
Total	65		6	7	31	17	2	x	1	

Plate XII : Figs. 1-7 (*Isotoma jayasrae* Fig. 1,2,4,6; and *I (Desoria) trispinata* Figs. 3,5,7)

Fig. 1 Gonial metaphase (♂)
Fig. 2 Gonial metaphase (♀)
Fig. 3 Gonial metaphase (♀)
Fig. 4 Metaphase I (♂)
Fig. 5 Metaphase I (♂)
Fig. 6 Metaphase I (♀)
Fig. 7 Metaphase I (♀)

Bar represents 10 μ

PLATE XII

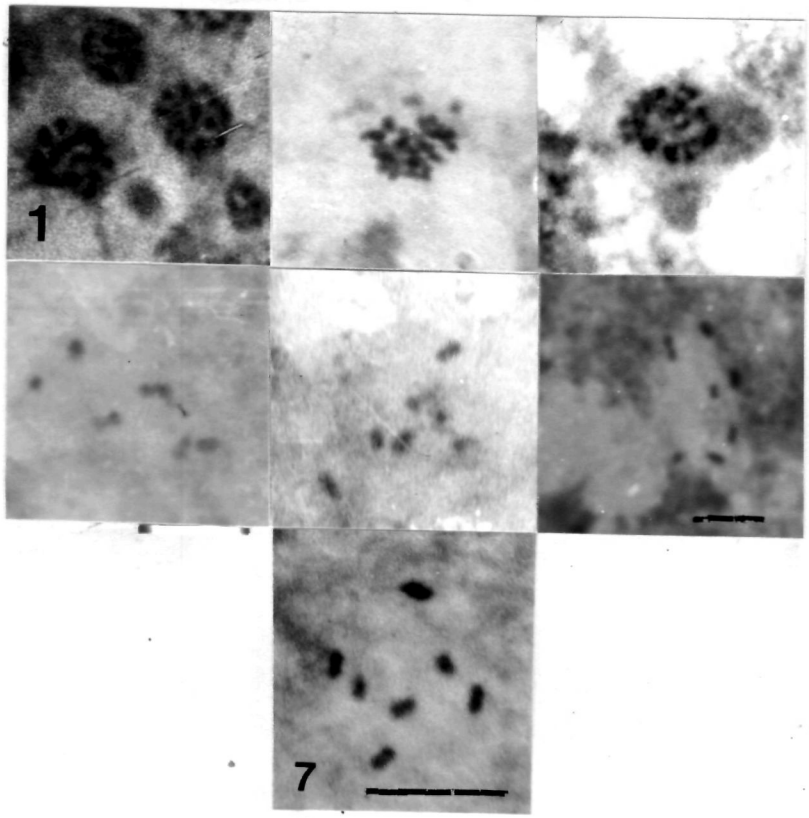


Plate XIII, Figs. 8-18 (*S. montana*, Figs. 8,9,11,12,14-16 and *S. curviseta*, Figs. 10,13,17 and 18)

Fig. 8 Gonial metaphase (♀)
Fig. 9 Tetraploid metaphase (♂)
Fig. 10 Gonial metaphase (♂)
Fig. 11 Diakinesis (♂)
Fig. 12 Metaphase I (♂)
Fig. 13 Metaphase I (♂)
Fig. 14 Metaphase I, normal (♀)
Fig. 15ab Metaphase I, with B-chrom. (♀)
Fig. 16 Metaphase II, with B-chrom. (♀)
Fig. 17 Metaphase I (♀)
Fig. 18 Metaphase I, another plate (♀)

Bar represents 10 µ

PLATE XIII

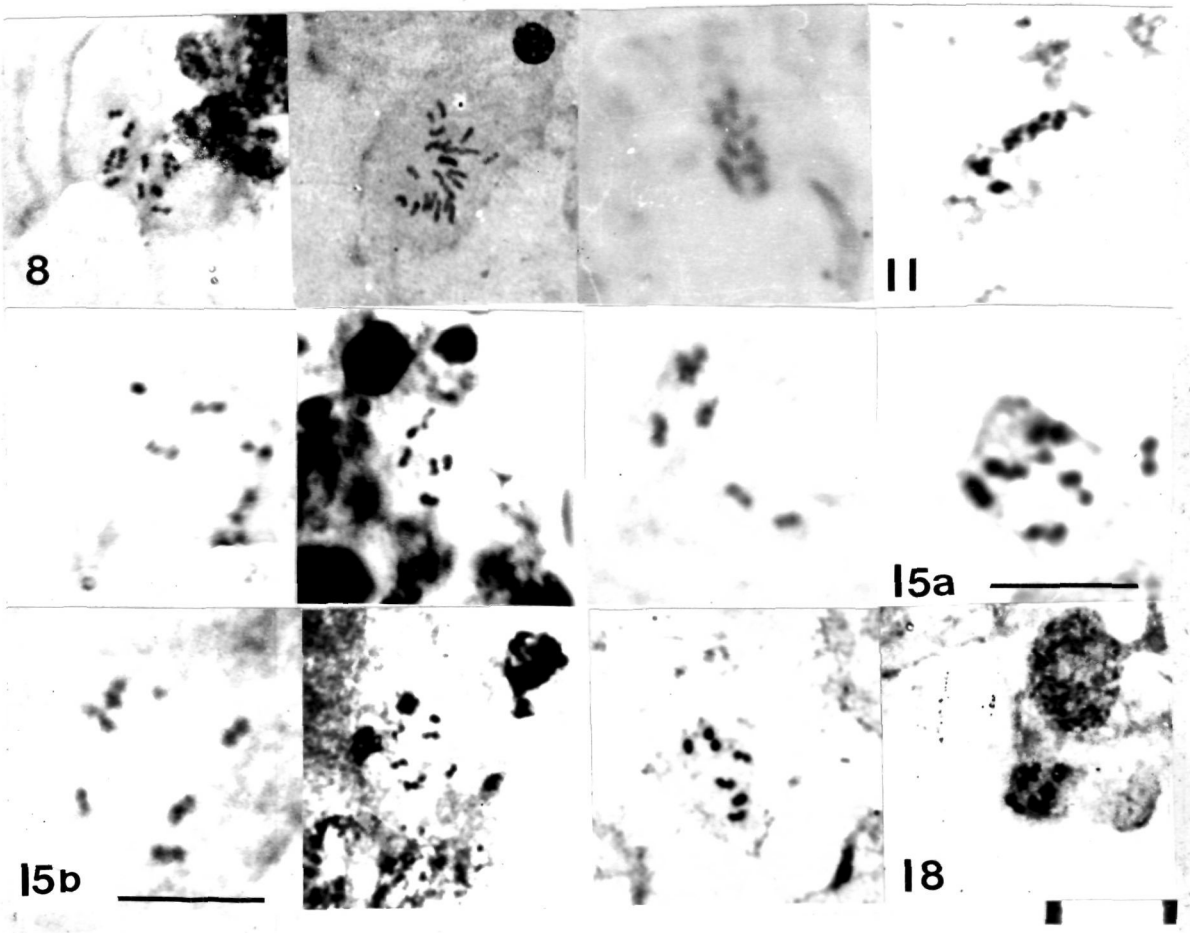


Plate XIV, Figs. 19-28 (*D. fraternus*, Figs. 19-22,25,27 and *D. singularis*, Figs. 23,24,26, and 28)

Fig. 19 Gonial metaphase (♂)
Fig. 20 Gonial metaphase, another plate (♂)
Fig. 21 Tetraploid metaphase (♂)
Fig. 22 Gonial metaphase (♀)
Fig. 23 Gonial metaphase (♂)
Fig. 24 Gonial metaphase (♀)
Fig. 25 Diakinesis (♂)
Fig. 26 Metaphase I (♂)
Fig. 27 Metaphase I (♀)
Fig. 28 Metaphase I (♀)

Bar represents 10 μ

PLATE XIV

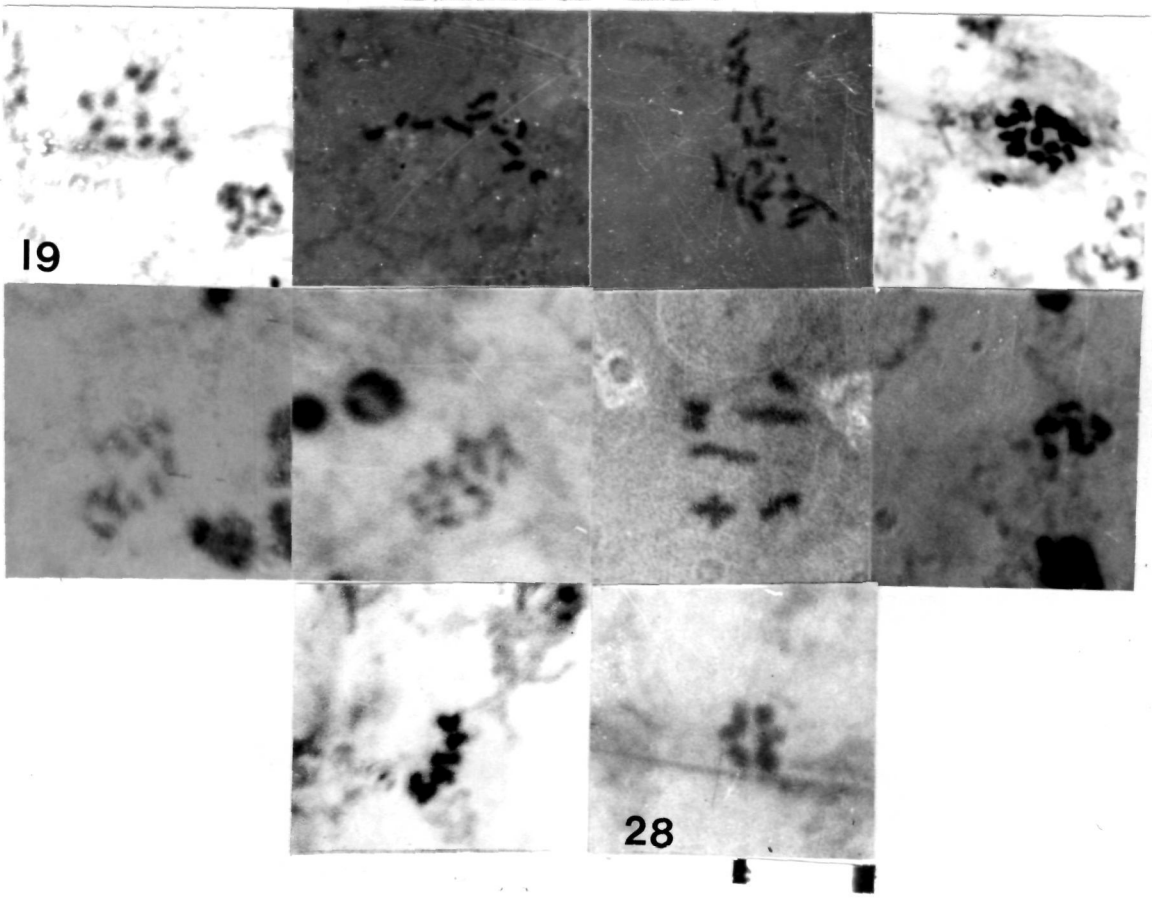


Plate XV, Figs. 29-35 (*D. singularis*, Fig. 29; *D. fraternus*, Figs. 30,31; *C.(H.) lineata* Figs. 32-35)

Fig. 29 Metaphase I (♀)
Fig. 30 Anaphase I (♂)
Fig. 31 Telophase I (♀)
Fig. 32 Gonial metaphase (♂)
Fig. 33 Gonial metaphase (♀)
Fig. 34 Metaphase I (♂)
Fig. 35 Metaphase I (♀)

Bar represents 10 μ

PLATE XV

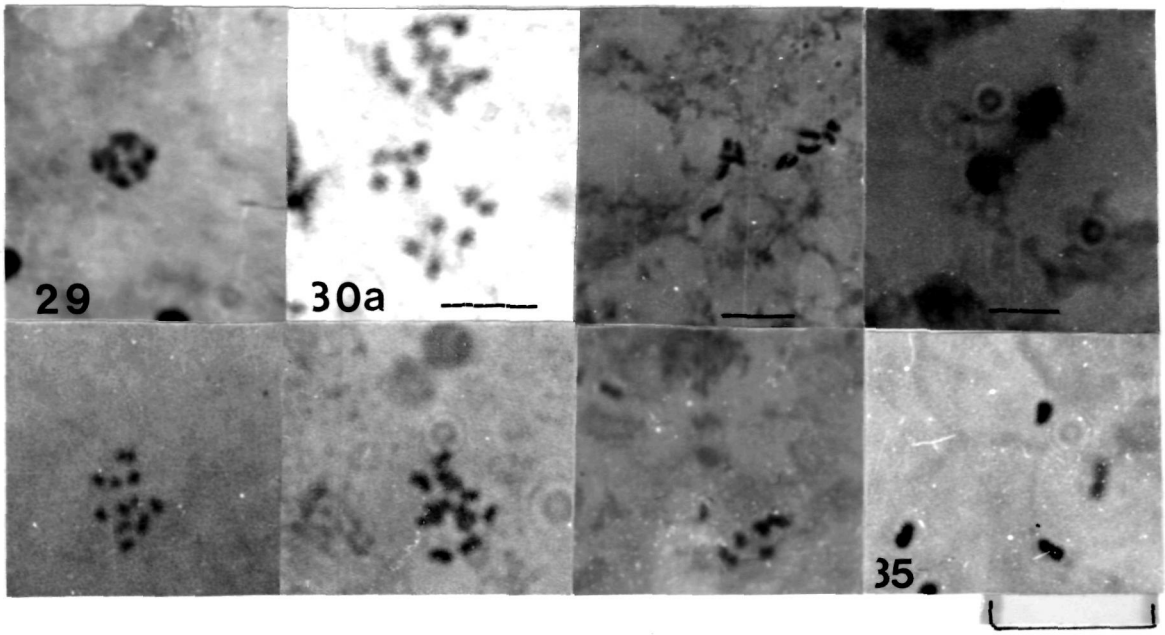
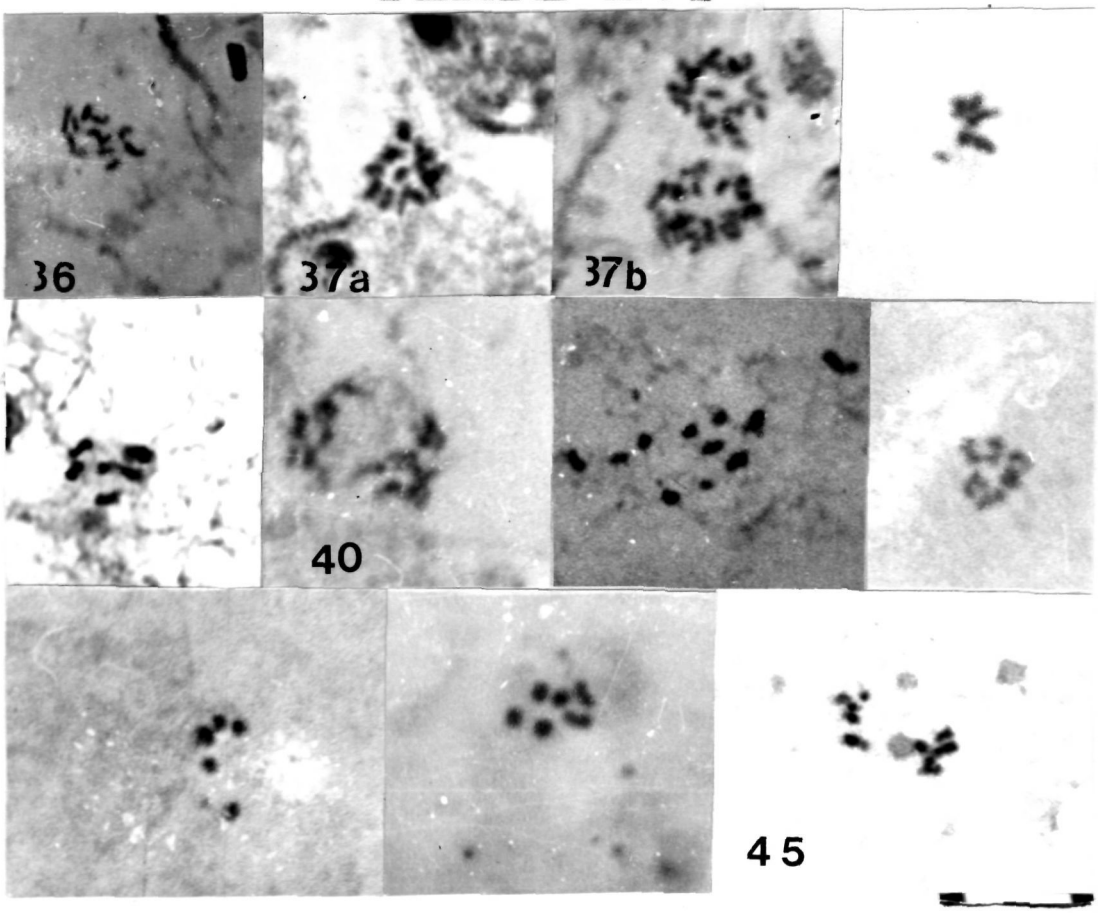


Plate XVI, Figs. 36-45 (*Salina striata*, Figs. 36-40; *I. rasendrans*, Figs. 41-45).

Fig. 36 Gonial metaphase (♂)
Fig. 37ab Gonial metaphase (♀)
Fig. 38 Metaphase I (♂)
Fig. 39 Metaphase I (♀)
Fig. 40 Anaphase I (♂)
Fig. 41 Gonial metaphase (♂)
Fig. 42 Diplotene (♀)
Fig. 43 Metaphase I (♂)
Fig. 44 Metaphase I (♀)
Fig. 45 Anaphase I (♂)

Bar represents 10 μ

PLATE XVI



4 DISCUSSION

The Collembolan germ cell chromosomes are extremely minute in size, the TCL for nine species investigated ranges from 6.4 μ to 8.25 μ. This coupled with their almost uniform size and shape prevents identification of individual chromosomes. This perhaps has shifted the attention of cytogeneticists to the study of polytene chromosomes of these insects. However, so far only in the tribe (subfamily) Neanurinae polytene chromosomes have been reported. With the meagre data on Collembolan chromosome cytology attempt to generalize chromosome behaviour in meioses or to establish karotypic inter relationship among various species studied during present investigation will be premature. However some significant features which come up from observations in the preceding chapter, might be analyzed with reference to earlier findings.

It will be worth mentioning here that none of these nine species have been studied earlier and even out of six genera investigated under the present work, except genus Isotoma, no attempt was made to study karyology of any representative type of any other genus.

The haploid chromosome number of ten species belonging to the family Isotomidae are seven, including the present ones viz. Isotoma (S.str.) jayasrae Bhattacharjee and Isotoma (Desoria) trispinata MacGill. However Nunez (1962) claims 4 and 5 as the haploid number for Proisotoma

minuta (Tullb.) and Isotomina thermophila (Axels.) respectively. Kiauta (1970) studied Folsomia candida distincta Bagnall and illustrated prometaphase in primary oocyte stage showing seven elements, one of which is slightly smaller. He (Kiauta, 1970) comments that the type number for Isotomidae is definitely n = 7, though in each of the two sub-families one species deviates from the general pattern. In oocyte diakinesis of Isotomurus palustris (Muller) Saure and Brummer-Korvenkontio (1958) observed next to six bivalents an additional univalent which represents an "accessory chromosome" according to them. It is probable that this chromosome is a "sex chromosome". The observation on Isotomina thermophila (Axels.) by Nunez (1962) was based on a single specimen and therefore not much reliable. The present work agrees with the illustration made by Kiauta (1970) indicating that sex chromosomes do not show pycnotic behaviour in Folsomia candida distincta Bagnall (Fam. Isotomidae). However the size of the chromosomes in I.(S.Str.) jayasrae Bhattacharjee and I.(Desoria) trispinata MacGillivary seem to be smaller than Folsomia sp. (1-2μ, Kiauta 1970). Regarding sex determination univalent sex element could be recognized with certainty in primary spermatocyte anaphase of Isotoma antennalis (Bagnall) by Nunez (1968). The present work reveals sex chromosomes in males to be univalent while in females they are bivalent without showing heteropycnotic behaviour.

The sex determining system is therefore XO, XX for ♂ and ♀ respectively.

Family Entomobryidae has been studied more extensively by earlier authors (eleven species under subfamily Entomobryinae and four species of subfamily Orchesellinae). It is interesting to note that all these species show female haploid number as six, which might be considered as 'family type' or 'modal number'. In the present work four more Entomobryid species have been studied (two of the subfamily Entomobryinae and another two under subfamily Orchesellinae), all show ♂ 2n = 11 (10A + X) and ♀ 2n = 12 (10A + XX) chromosomal complement. All the chromosomes are acrocentric in nature and are not much different in size except the sex chromosomes which are the smallest element in the karyotype. Males are heterogametic. The TCL in the presently studied species ranged from 6.4 μ to 7.2 μ. In S. curviseta Brook the precociously separating pair in the female might be the "sex chromosomes". Such a pair has been observed by Nunez (1962) in other species of the family Entomobryidae. No heteropycnotism (as seen in grasshoppers), despiralized state (as seen in certain spiders) or attachment to any particular pair of autosomes (as observed in water bugs) have been observed in any of the Entomobryid species studied. Anaphase sticky bridges as observed in S. montana have been observed

in other Collembolan species as well (Nunez, 1962), and it is presumed that they might appear as the distal ends of some of the chromosomes remaining terminally paired when others have moved apart. Supernumerary or accessory or B-chromosome as observed in S. montana are not new to Collembolan cytology. Nunez (1962) reported 1 to 3 supernumerary chromosomes in Ceratophysella armata communis (Fols.) and Hypogastrura manubrialis (Tullb.). In S. montana the number of supernumerary chromosome never exceeds one. According to Darlington (1956) supernumerary or the accessory chromosomes may be responsible for imparting variability to a species and possibly they originate as heterochromatic centric fragments. According to White (1973) these are special types of genetic polymorphisms not subject to Mendelian inheritance. Evidence indicates that a low number of supernumerary chromosomes might exert a favourable impact on plant vigour. They differ from normal or ('A') chromosomes in their variable number and greater degree of heterochromatisation. Sharma (1976) holds that gradual loss of functions of some extra chromosome and its subsequent hetorochromatisation leads to the origin ofasupernumerary chromosome. Whatever way they originate they must have come from regular karyotype. Muntzing (1967) regards that at least in some cases their action is deleterious. They are retained in the population

due to some accumulation mechanism (Nur, 1969). In the present species S. montana, it is interesting to note that this species shows cosmopolitan distribution and is variously described by taxonomists as S. montana, S. hoefti, S. coeca and S. submontana - possibly all of these might be synonymous to the same species (Yosii, 1978 Personal Communication). It is tempting to suggest (corroborating Darlington's 1956 view) that a single supernumerary chromosome might provide this species its wide range of diversity. It might be worth mentioning here that the related species S. curviseta, which does not exhibit any supernumerary chromosome is not a problem species to Collembolan taxonomist. However the accessory chromosome is not observed in all specimens (less than 20% of the population and unlike most grasshoppers so far only in females) and no hereropycnotic behaviour has been noticed. At secondary oocyte state (Fig. 16) the accessory chromosome still retains its somewhat unexplained association with a chromosome. It seems that the accessory chromosome has divided at the second meiotic division equally. Similar observation was made in grasshoppers by White (1973). In the primary oocyte metaphase of Entomobrya lanuginosa (Nic.) Saure and Brummerkorvenkontio (1958) observed a bivalent with clearly heterokinetic behaviour ("autoorientation") and considered it to be a 'sex element'.

From the drawing of Tuzet and Manier (1956) of the primary spermatocyte metaphase of E. (cf.) nivalis (L.) the 'X' element appears heteropycnotic at prophase. Nunez (1962) also reported such element in early spermatocyte prophase of E. pseudodecora Rap. In the present finding sex chromosome shows positive heteropycnotic behaviour at the primary spermatocyte metaphase stage of S. montana (Fig. 12).

Dicranocentrus fraternus MariMutt and Bhattacharjee and D. singularis MariMutt and Bhattacharjee (Subfamily Orchesellinae) also conform to the pattern of the chromosomes and their behaviour at meiosis as in other Entomobryid species mentioned above. However in both these species sex chromosome is indistinguishable from the autosomes. At diplotene, mostly single chiasma (shown by cross bivalents) are visible as in other species (Fig. 25). In Orchesella villosa (Geoffr.) Tuzet and Manier (1956) observed heteropycnotic behaviour of 'X' element at prophase. However no such behaviour is observed in the presently studied species.

In the available literature no karyological report devoted to any species of the family Paronellidae was found and possibly the three species studied in this investigation make the beginning. Though Salina striata

(Handschin) show close similarities with the general pattern of the species under the family Entomobryidae (eg. D. fraternus) in its shape and size or nature of chromosomes and their behaviour at various stages of meiosis, other two species viz. Callyntrura lineata (Parona) and Troglopedetes rasendrans Bhattacharjee show some unique features like negative heteropycnosis of sex chromosome(s) in the former and spermatogonial metaphase chromosomes differing widely in their size with an unusually big acrocentric pair in the latter species (Fig.34,35,41)Darlington and Lacour (1962) maintained that negative heteropycnosis is caused by "nucleic acid starvation", however, White (1973b) overrules this concept holding that the negative heteropycnosis is due to relative uncoiled nature of the chromosome or chromosomal segment. In the latter view negative heteropycnosis is considered to be a state that can be reversed. In Callyntrura lineata negative heteropycnotism is reflected only at the metaphase I stages of males and females sex chromosomes, possibly indicating uncoiling of DNA at this stage, which is reversed to uniform staining in the subsequent stages of meiosis. In grasshopper Monistria vinosa negative heteropycnosis is found only in mitosis and female meiosis but not in males. However no such sex based differentiation is observed here.

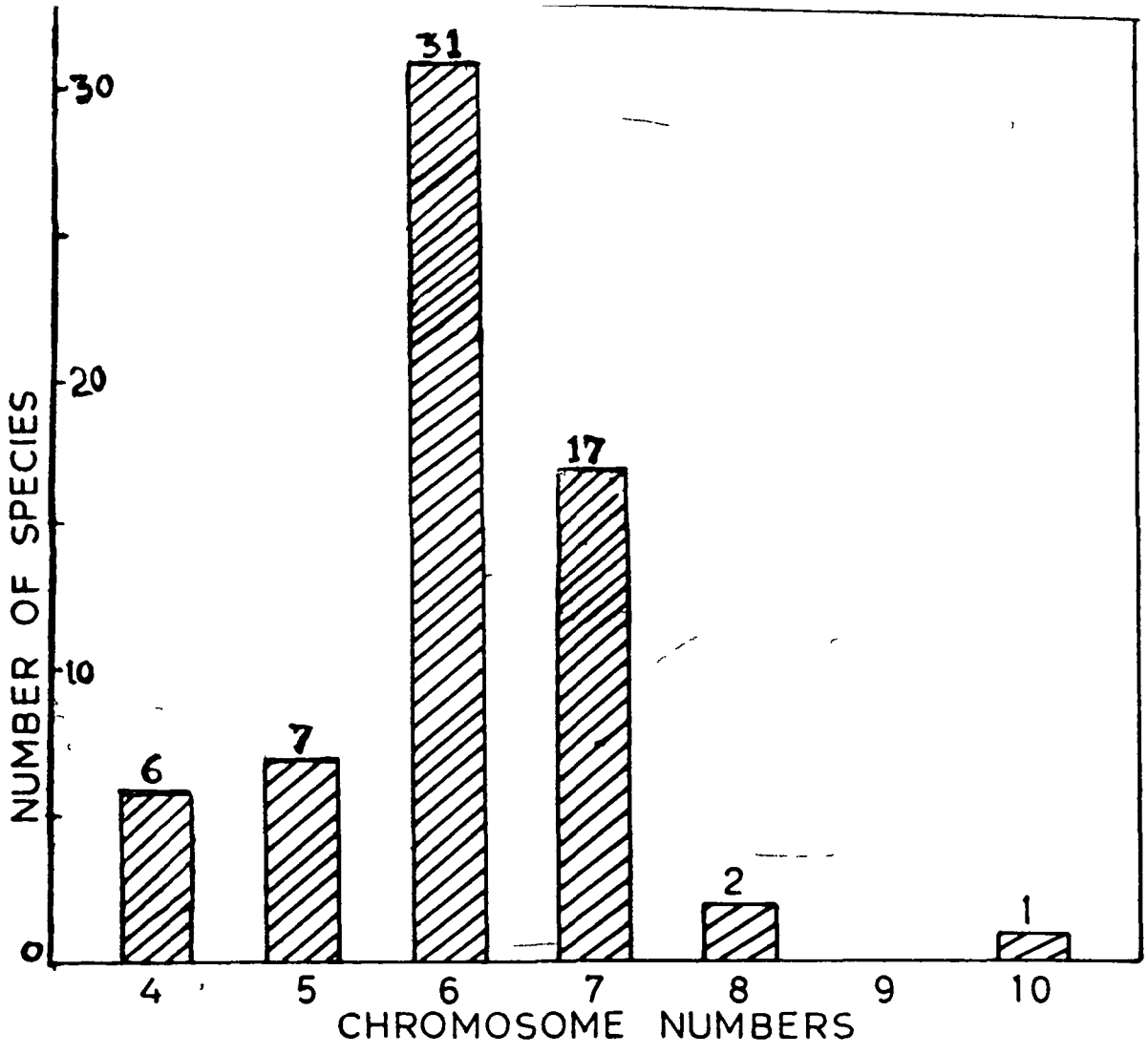


Fig.46 Histogram of the haploid chromosome numbers in Collembola (♀).

The asymmetrical unimodal type of karyotype of Collembola specially Troglopedetes rasendrans might provide (1) ease of separation of the chromosomes at anaphase and (2) accumulation of beneficial genes to the single arm of the chromosome with progressive shortening of the other arm.

Having discussed chromosomal behaviour at meiosis of presently investigated species along with earlier findings, it is tempting to look into the possible karyotypic evolution in Collembola and its cytotaxonomic implications.

Karyotype being a constant and definite feature of each species elucidates the degree of affinity between species of same genus or higher systematic categories (Benazzi, 1973). In some groups like Odonata, Diptera and Coleoptera chromosome number is fairly constant whereas in Lepidoptera, Trichoptera, scorpions and fishes it displays marked variation. Interrelationship between various species of Heteroptera have been established through cytological key by Manna (1958) and Leston (1958). No attempt has been made in this regard in Collembola. Collembolan chromosomes are in general small (size 0.5 μ - 2.0 μ) mostly acrocentric, rodshaped structures (accepting the view expressed by White (1973b) that all naturally occurring rodshaped chromosomes are acrocentric, the short arm being invisible due to high degree of condensation) with terminal centromere ('t' type). However,

Grondziel (1973) reported some metacentric and submetacentric chromosome in two Entomobryid species. According to Stebbin's (1971) classification these chromosomes form asymmetrical unimodal or 'Au' type of karyotypes without microchromosomes. The female haploid chromosome number varies between n = 4 to n = 7. However, subfamily Neanurinae shows wide range of variability (n = 4 to 10) and appear to be a conglomerate of heterogeneous forms (Kiauta, 1970) (Histogram, Fig. 46). It is possible to obtain "type" or "modal" number for families like Isotomidae, Entomobryidae and Sminthuridae as 7,6,5 (Table-V) respectively. It is interesting to note that in four out of five cytologically studied species of Tomoceridae (belonging to 2 genera) one 'extra large bivalent' was observed for which a 'trivalent' structure was suggested (Saure and Bummer-Korvenkontio, 1958 and Saitoh and Chiba, 1959) and according to Kiauta (1970) basing on this aspect of cytology of Tomoceridae, this family might be regarded as a link between the two families viz. Isotomidae and Entomobryidae. Morphotaxonomic studies of various species under above four families viz. Isotomidae, Tomoceridae, Entomobryidae Sminthuridae reveal increasing specialization or phylogenetic advancement in the same order in these families as mentioned above. Karyological studies as mentioned above corroborate already established morphotaxonomic affinities between these families. However

in contrast to the general trend of insect phylogeny of advancement and specialization coupled with increase in chromosome number (Kiauta 1967, 1968), the Collembolan situation is opposite (Kiauta, 1970). Our findings in the nine species also support the view that phylogenetic advancement is followed by a gradual reduction in chromosome number from family Isotomidae, Tomoceridae, through Entomobryidae to Sminthuridae. Unfortunately, data pertaining to chromosome cytology of vast majority of species are still lacking and complete interrelationship could not be established at present.

Regarding the possible pathway of evolution of karyotypes in Collembola, mutation or chromosomal rearrangement might be considered. However since most of the chromosomes in different species studied so far are 't' type (like Acridoid grasshoppers) sole centric fusion is over-ruled. Centric fusion followed by pericentric inversions or tandem fusions might give rise to single large "doublesized" acrocentric from two small acrocentric with elimination of a centromere (as in some Australian grasshoppers), thereby reducing the number of chromosomes in the karyotype without changing the type of chromosomes as observed in T. rasendrans. Decrease in the chromosome number is one of the most frequent tendency in karyotypic evolution leading to increased gene-concentration that might be caused also by reciprocal unequal translocation (Benazzi, 1973). By repeated occurrence of same type of chromosome alterations (Orthoselection) during

evolution a balance might be reached between the genetic variability and biological efficiency and stability of the organism. Gradual accumulation of "linked geneclusters" by paracentric inversions and translocations in the long arm of the acrocentric chromosomes, stability might be attained. It might be well to mention here that Collembola due to low recombination index and low genetic length of the chromosomes (having less number of bivalents and less chiasmata) have "greater degree of genetic constancy of the population" (Stebbins, 1950) which is of great survival value for insects having five generations per annum and consequently subjected to a lot of environmental fluctuations (Mather, 1953 suggested this in Drosophila). However paracentric inversions are usually not detectable at meiosis.

Thus possible means of chromosomal rearrangements in Collembola may be summarised as:

(i) Tandem fusion and subsequent elimination of a centromere;

(ii) Centric fusion followed by pericentric inversions; and

(iii) Paracentric inversions incorporating geneclusters in one area and subsequent reduction of the short arm.

It seems that the usual pattern of karyotypic evolution in other insect orders or arachnids (=spiders) of gradual attainment of symmetrical karyotype through metacentrics from a primitive asymmetrical karyotype consisting of acrocentrics (as in most grasshoppers) is not established here. However it might be only due to lack of sufficient data that no such picture is yet emerging.

Turning towards the sexchromosome and mechanism of sex determination, it is observed that in Protura (another order of Apterygota) sex chromosomes are not detectable morphologically (Bizzari and Fratello, 1971). However the other Apterygote order, Thysanura shows multiple sex chromosomes (Charlton 1921). Collembola seems to be somewhat intermediate between these two orders. A number of species of Collembola have XO males, according to Nunez (1962) but the Neanuridae studied by Cassagnau (1968a,b; 1970) do not seem to show morphologically differentiated sex chromosomes. It will be evident from a glance at the Table III sex determining mechanism column that though very little is known on the sex chromosomes and mechanism of sex determination, at least majority of species show XO, XX type of sex determining mechanism. In almost all species under suborder Symphypleona and most of the species under the family Entomobryidae, sex determining system have been established as XO, XX type, male being always the heterogametic sex. It might be worth mentioning here that in all

the nine species presently investigated the same system was recorded. Saure and Brummer-Korvenkontio (1958), Tuzet and Manier (1956) and Nunez (1962, 1968) mentioned heteropycnotic behaviour of sex chromosome in various species. Negative heteropycnosis of sex chromosome and sex bivalent have been observed in Callyntrura lineata in the present studies. Moreover the precociously separating pair in Sinella curviseta primary oocyte metaphase might be sex bivalent since similar pair has been observed in other Entomobryid species by some cytologist (eg. Nunez, 1962). Apart from pycnotic behaviour, Collembolan sex chromosome was invariably found to be the smallest element in the karyotype (Saure and Brummer-Korvenkontio (1958), Grondziel (1973 and present work).

In the polytene chromosomes of various species under subfamily Neanurinae (Family : Neanuridae) Cassagnau (1968a, 1980, 1982), Cassagnau and Deharveng, 1981, Cassagnau et. al. 1979, Lee (1980) and Deharveng (1982) found no differentiation in the sex chromosomes and autosomes while studying mitotic (=Salivary gland) chromosomes. However a very interesting observation has been made by Cassagnau (1971b) in Bilobella grassei Denis, where he reported for the first time (possibly the only report so far) XY, XX type of sex determining mechanism. The males and females of the cited species possessed twelve polytene (=2n) chromosomes of which ten were autosomes

and two sex chromosomes (either XY or XX). From the available literature no substantiating data on the karyology of any other species of Collembola could be obtained and hence *Cassagnau's observation of XY, XX type of sex determination* in Collemboles should be kept in abeyance for the present, pending further studies.

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SECTION C

CONCLUDING REMARKS

In this work we have attempted a combined approach to study morpho- and cytotaxonomic aspects of Springtails through critical analysis of various parameters with special reference to Shillong population. The present work incorporated under two separate sections our investigations on Collembola of North Eastern States including first report of Collembola from the State of Tripura. All together twelve species under five families have been studied including six new species. Some practical and easier methods of collection have been suggested. We have incorporated new dichotomous keys for facilitating easy identification of all new species as well as separation of two related genera Cyphoderopsis and Troglopedetes. The new species have been compared with their related described species. Some new synonymy have been suggested through critical analysis of their characters. Detailed study of chaetotaxy (both cephalic and trunk) of Sinella species are made for the first time in this work, hopefully for future solution of controversial position of Sinella montana species complex reported under different names from diverging geographical localities. This work in general supports earlier findings of many taxonomists regarding adaptive nature of coloration. However, Yosii's (1965) work on Callyntrura spp. of Taiwan viz. C.(H). taiwanica Yosii, 1965 and C(H.) microphysarum Yosii, 1965, suggests that coloration may be primary rather than secondary criterion for taxonomic evaluation in some cases. Our observation on C.(H.) lineata

provides a parallel case where two species may be differentiated by distinct color patterns while exhibiting almost similar chaetotaxy. One may, therefore, be tempted to suggest the occurrence of a sibling or new species in between C.(H.) lineata and C.(H.) vestita by resembling the former in color pattern and the latter in setal patterns.

Absence or presence of an extra tooth on the claw or number of setae on trochanteral organ or body require careful study through ecological background of the species. Presence or absence of dental scale appendage is taken as the basis of separation of Cyphoderopsis and Troglopedetes as suggested by Bellinger (Pers. comm. 1978).

Cytotaxonomic studies incorporated in this work present interesting observations like low chromosome number corresponding to several (5/6) generations per annum (Mather, 1953) and low recombination index providing high survival value to Collembola which are often under great environmental fluctuation within a short time. Our observation of a supernumerary or B-chromosome in Sinella montana explains to some extent the phenotypic diversity of this species or 'species complex' and throw some light on the possible adaptive role of a single supernumerary chromosome in a population, thus supporting Darlington's (1956) observations.

Plate XVII, Figs. 1-6, SEM studies (*D. fraternus*, Figs. 1-4; *C.(H.) lineata*, Figs. 5 and 6)

Fig. 1 Ocelli and ocellar setae
Fig. 2 Trunk scales
Fig. 3 Apex of antenna and whorl of setae
Fig. 4 Mucro
Fig. 5 Ocelli and ocellar setae
Fig. 6 Trunk scales

Bar represents 10 μ

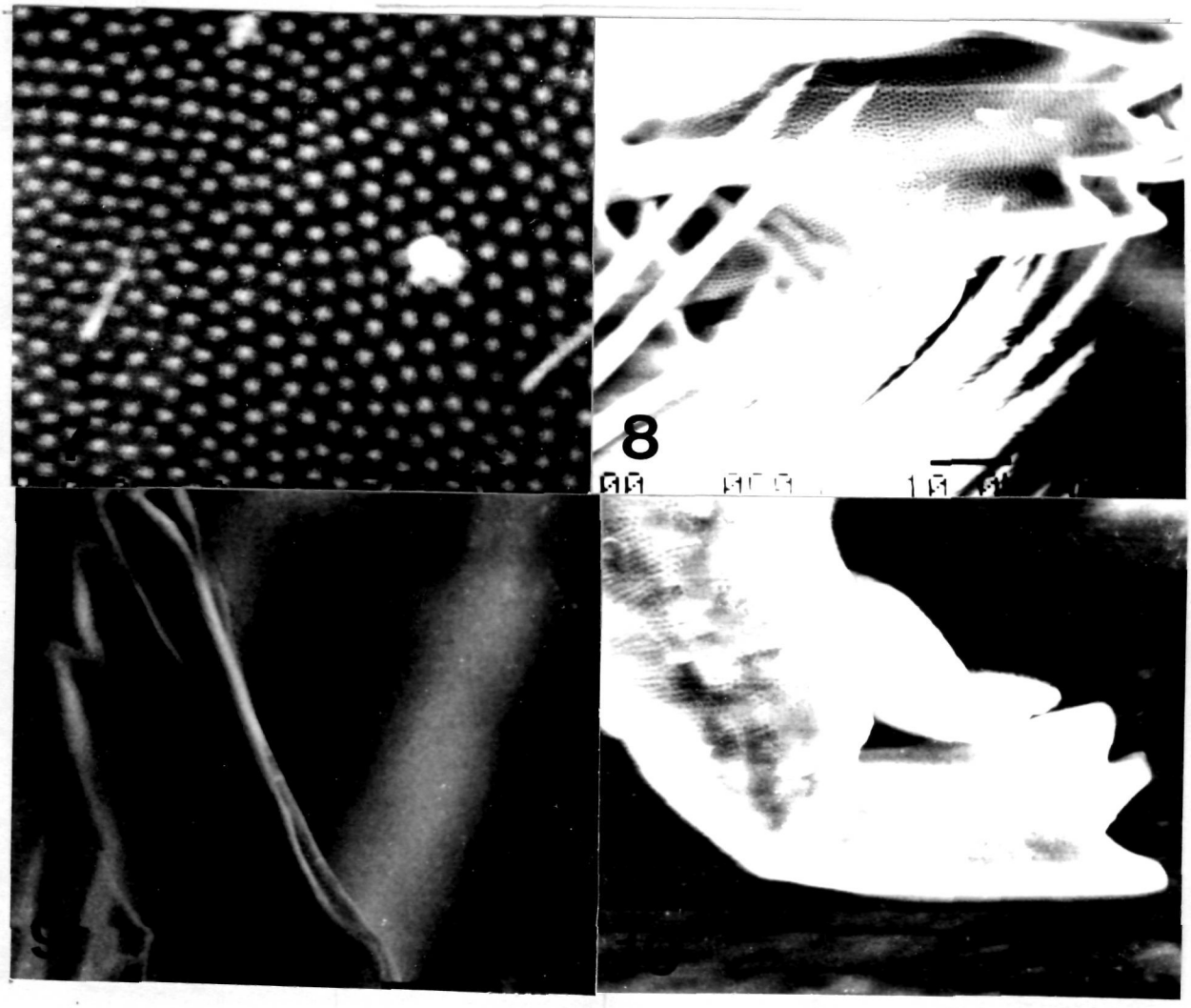
PLATE XVII

Plate XVIII, Figs. 7-10, SEM studies (*C.(H.) lineata*, Figs. 7-9, *Salina striata*, Fig. 10).

Fig. 7 Cuticle
Fig. 8 Mucro and clothing of setae
Fig. 9 Mucro without clothing
Fig. 10 Mucro

Bar represents 10 μ

PLATE XVIII



Though the univalent sex chromosome during spermatogenesis is readily identifiable, sex chromosomes in Collembola usually remain undetectable, however, in this work we have noted differential staining behaviour of sex chromosome(s) in some species which surely enables us to identify them. Occasionally sex chromosomes show somewhat precocious separation of sex bivalents during oogenesis. This coupled with hetoropycnotic behaviour in some other species might be considered characteristic of sex chromosomes in Collembola. Due to minute size and almost a general uniformity of shape in majority of the species studied, our attempts of C-banding and NOR investigations were unsuccessful. However, taking suitable material like Troglopedetes rasendrans having great size variations among the chromosomes future studies on banding technique might be carried on.

In our attempt to correlate morpho- and cytotaxonomic studies we have noted that low chromosome number in different species of Collembola is an indication of its advancement and this is true for the families we have investigated viz. Isotomidae, Entomobryidae, Paronellidae and Cyphoderidae. Similar observations were made by Nunez (1962) and Kiauta (1970). Present findings also confirm once again non-adaptive and constant feature of karyotype

of specimens collected from diverging localities and from different biotopes. However, a significant observation is the correlation between adaptation and genotypic plasticity through supernumerary chromosomal element in Sinella montana. At the phylogenetic level from detailed comparison of data available from morpho- and cytotaxonomy as well as critical analysis of this order with Protura, Diplura and Thysanura cytogenetic findings provide little support to Sharov's (1966) upgrading the order Collembola to a class status including Protura and Diplura.

As a follow up project of this work we would like to suggest some banding (specially C-banding) technique along with biochemical studies on allozyme patterns of various species (Hart and Allamong, 1979; Grimmes, 1986) and application of numerical taxonomy (Hermosilla et.al. 1985) for species determination. Further studies of dominant types of Collembola from other states and different ecological niches might resolve the most controversial topic regarding relative importance of two major taxonomic parameters viz. chaetotaxy and coloration in Collembolan biosystematic studies. As an additional tool to biosystematic investigations Scanning Electron Microscopic (SEM) studies were carried out in R.S.I.C., Shillong Campus with a Jeol Jsm - 35CF microscope and photographs were taken in ORWO (B/W 120) films. Three species representing three different genera viz. Dicranocen-

trus fraternus, Callyntrura lineata and Salina striata were selected for SEM studies due to their easy availability and comparatively bigger body size. Scales of D. fraternus (PL.XVii, Figs. 1 and 2) being oval or round with truncated apex show clear and characteristic variations in striations and shape from lanceolate scales of C.(H.) lineata (PL.XVii, fig. 6) thereby distinguishing Orchesellinae scales from Paronellid ones. Likewise ocelli of the cited two species show clear size variation among themselves (PL XVii, figs.1 and 5). Cuticle of C.(H.) lineata (PL.XViii, Fig. 7) indicates fine granular structure or simple sculpture of integument supporting earlier observations that Collembola with heavily protective body clothing possess simple cuticle (Dallai, 1977). Mucro of C.(H.) lineata clearly differs from other two species being well developed polydentate structure, distinct in 3/D view (PL.XViii, fig. 9). We feel, it will be much rewarding to make SEM studies of various morphological features, particularly integument and clothing of Collembolan species for reinforcement of classical taxonomy. Regarding importance of polytene chromosomes in taxonomy we agree with Cassagnau and Lee (1982) that 'polytene development being an adaptive character should not be used for systematic interpretation'. However finer details of structural and functional aspects of Collembolan chromosomes might be revealed through studies of

the giant chromosomes. It is worth mentioning here that morphotaxonomic deviations of different species may not always correlate to their karyotypic variations (Blackman et.al. 1987). A combined morpho-, cyto- and biochemical approach to Collembolan systematics surely await prospective taxonomists. It seems appropriate to conclude this work with the statement of Capanna (1973) that "the two data i.e. the karyological and the taxonomic should be never discussed separately; but only by providing a valid morphological criterion for identification of the species shall we be able to claim that we have solved the systematic problem. ... This is indeed no easy task".

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