

**MANUAL :
COLLECTION, PRESERVATION AND
IDENTIFICATION OF INSECTS AND
MITES OF ECONOMIC IMPORTANCE**



**ZOOLOGICAL SURVEY OF INDIA
CALCUTTA**

Manual :
Collection, Preservation and
Identification of Insects and
Mites of Economic Importance

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ZOOLOGICAL SURVEY OF INDIA
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FOREWORD

The Zoological Survey of India is an important Institution, in the department of Environment, Forests and Wildlife, Government of India. It endeavours to impart knowledge and expertise acquired by it to research workers and scientists working in various medical veterinary, agriculture and forestry departments and universities and also to amateur collectors and naturalists.

The Training and Extension Division of the Zoological Survey of India, under the charge of Dr.A.K.Ghosh, Dr.J.K.Jonathan and Dr. P.P.Kulkarni, undertakes annually a number of training courses and extension programmes in different fields of Zoology. One such course is on the Collection, Preservation and Identification of Insects and Mites of Economic Importance which is mainly for research workers in entomology and acarology. This course is of particular significance at this time when we are at a threshold to achieve break through in certain aspects of agriculture, medicine, etc. and in developing closer rapport between the Survey and other related institutions.

The present manual on the Collection, Preservation and Identification of Insects and Mites of Economic Importance has been prepared for the benefit of research students and trainees. The articles are written by specialists of various groups in the Zoological Survey and, I am sure, it will provide necessary information and guidance to the collectors for proper preservation of material in the field and relevant knowledge to beginners who wish to take up taxonomic studies as well as to experimental and control entomologists for the identification of insects of their pursuit. I hope this manual will serve the purpose for which it is intended.

**Zoological Survey of India
Calcutta**

**B.K.Tikader
Director**

P R E F A C E

The Zoological Survey of India has a large number of expert scientists working on taxonomy of various groups of animals. Through the last about seventy years of its existence, the Survey has also accumulated vast reference collections. As a result, the Survey has achieved a unique position in providing identification and advisory services to a large number of institutions and individual research workers in diverse disciplines such as medicine, veterinary, agriculture, forestry, etc. and even to amateur collectors and nature lovers.

It has, however, been observed that majority of insect and mite collections received for identification are not suitable for identification owing to faulty methods of preservation, labelling and packing. In order to help our fellow scientists in a more profitable manner it was decided to hold short-term training course in survey and preservation and to provide information and tips for identification. Since 1979, four courses have been held by the Training and Extension Division at the headquarters of the Zoological Survey of India, Calcutta. All these courses have received much appreciation from the participants and their sponsoring institutions. There is an ever increasing demand by various institutions for more number of research workers to be trained.

During the last four courses, the Z.S.I. scientists have delivered lectures on the subjects of their specialization, covering methodology in collection, preservation and identification. The xeroxed or cyclostyled copies of these lectures were distributed to the participants as hand-out, for their future reference.

Inspired by the ever increasing interests of institutions/organisations, which nominated their representatives for such a training and hand-outs, the Z.S.I. felt that all these manuscripts, with additional information, figures, references, etc., be brought out in the form of a manual which, it is hoped, will serve the basic needs of the researches in entomology and acarology. This compilation is the outcome of this effort.

We are well aware of our limitations in presenting this Manual which covers mainly the methodology in collection, preservation and identification of various groups of insects and mites.

It is primarily intended as a guide for collecting and preserving insects and mites, based on the long experience of our scientists so that the specimens are collected and preserved in a fine state and reach the expert in a condition suitable for study. In such a collaborative undertaking, the repetition are bound to occur but hope it will be a useful document for beginners on various groups.

In this manual some orders of insects are discussed in detail providing comprehensive keys to genera and species. The articles on Diptera, Lepidoptera, Trichoptera, Neuroptera, Parasitic Hymenoptera, Aquatic insects, Hemiptera, Thysanoptera and Coleoptera are discussed in detail. Ticks and Mites enjoy parallel position with that of insects; the readers will find appropriate articles on these organisms of great economic importance as well.

If this book is helpful in stimulating beginners in entomological and acarological researches and serves as a manual of collecting techniques it will prove worthy of the purpose for which this is produced.

We are indebted to the scientist colleagues who have contributed articles for this manual. We are also thankful to Shri G. Shivagurunathan, Publication Production Officer, for constant supervision during the printing of this manual and to Dr.G.S.Arora for helping us in various ways. The exacting task of typing on electronic typewriter by Shri Anil Bhattacharya and Shri Ashok Choudhury is gratefully acknowledged.

J.K.Jonathan

P.P.Kulkarni

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INSECTS : COLLECTION, PRESERVATION AND IDENTIFICATION

A.K. Ghosh

INTRODUCTION

The World of Insects presents a fascinating panorama of living natural resources. Insects outnumber, in today's world, all other living forms and can be said to represent the perfect adaptation in all possible ecological niches. The geographical location of India between 8°4'N and 36°6'N, provides a wide latitudinal extent, offering a range of climatic conditions. The altitudinal variations along with other biotic and abiotic factors lead to an array of insect-faunal elements.

India can be divided into 9 major floristic regions (Table 1) and till now some areas under each region remain moderately explored or unexplored. The forest types of India with 4 major groups and 16 subgroups (Table 2), represented in different areas of the country, can help to formulate a systematic survey of insect fauna.

The classification of Insects can be summarised in a tabular form indicating in general, the common name, size, habitat and approximate number of species in the World (Table 3) to provide a birds' eye view.

SURVEY, COLLECTION AND PRESERVATION

Insects, as can be evident from Table 3, live in diverse habitats and to collect insects during field survey, one has to use a variety of methods. These may be broadly listed as follows:

- (1) Handpicking
- (2) Sweeping and beating
- (3) Collecting with aerial nets
- (4) Collecting with aspirator
- (5) Trapping
- (6) Using Berlese funnel and separator

Hand picking: Small insects, specially the soft bodied ones are best collected by hand either with the help of a fine camel hair brush or by a forcep. The soft brush is normally dipped in the medium in which the insects are going to be preserved, so as to minimise the damage to soft skin. Forcep can be used carefully to avoid damage to the insect as in the cases of ants and many insect larvae. Hand picking needs searching in particular habitat and as such offer excellent data for biology. Insects like leaf-miners

(Diptera), aphids (Hemiptera), bark inhabiting beetles, insects living under stone and vegetable (Dermaptera and Coleoptera), termites and ants etc. are only collected by hand picking.

Sweeping: Sweeping with a proper net yield satisfactory result while collecting insects from herbage has been regarded as the most efficient method for rapid collection of free living insects in large number. Sweeping nets, because the way they are used, must be of strong cloth. A two feet long handle with 20" depth bag may give satisfactory result. The disadvantage of sweeping method has mainly been that it does not offer host plant data or specific habitat of an insect species and insects that live within flower, leaves or near ground level could not be collected by a sweeping net.

Beating: Beating is usually employed to dislodge insects from foliage or trees. Usually a long stick is used to beat the plant part with downward strokes and a tray or cloth is kept or spread over the ground to fetch the falling insects. A net may also be kept on the ground to prevent crawling or jumping insects escape, after they fall to the ground.

Aerial netting: Aerial nets are most widely used to collect free living flying insects e.g. Odonata, Lepidoptera, Hymenoptera, Diptera, etc. The length of handle, diameter of ring, depth of the net may vary on individual collectors' preference. But normally strong, light, easily manouverable handle with 15-18" diameter ring and strong, durable, nylon bags are used with a depth which is at least twice the diameter of the ring used. Soft bodied insects like Lepidoptera may be gently removed from the bottom of the bag, after it becomes enclosed in the bag by a rapid twist of the handle; often the fold of the net enclosing the insect may also be inserted into the killing bottle and the insects may be removed after they are killed by vapour of the killing agent.

Collecting with aspirator: Small active insects like leafhoppers, white flies, other Hemiptera and Coleoptera, etc. may be collected by a sucking tube or aspirator, straight from the plant surface. It is a very simple device and if used with little patience and caution may yield desirable result. It is also useful to transfer insects from sweeping nets or from rearing cages. All that one has to do is to suck the air by rubber tubing which would draw the insect into the main tube through the glass tube. The lid of the main tube may be removed and the entire content may be put inside a killing bottle.

Trapping: Traps are used to get insects which may otherwise evade attention and also to study migration, aerial dispersal and other biological phenomenon. Various types of insect traps are known which may be broadly grouped into following categories:

- (1) Traps without bait or light (e.g. Wind Trap, Water Trap)
- (2) Traps with bait (e.g. Pit fall Trap)
- (3) Traps with light (Light Trap)

Wind traps may range between a simple sock attached to a pole (Shands, 1942) in the direction of wind or may be a electrically operated suction device (Johnson, 1950). In India, not much of insect collections have been made by wind traps. Yellow Pan Water trap is a simple device to attract insect to the preferable colour, in which the pan is painted, as has been stated by Moericke (1950) in case of aphids. It is simple a metal tray painted in yellow and half filled up with water; insects being attracted to colour, fall into the water.

The odour of the particular kind, food or sex hormone, act as the principal agent in bait traps. Baits may include over-ripe fruit, piece of meat or fish, rotten fungi, animal excreta etc. and these may be put in convenient location where the insects would congregate. One of the simplest form is pit fall trap where a jar containing bait is placed below the soil level, to catch crawling insects like roaches, ground beetles, ants, etc.

Bait traps may also be used for flying insects; a simple device is to put a metal funnel, with bait suspended at the top level, inside a killing bottle, which would attract the hovering insects. Sex-hormones when used in field-traps may attract thousands of insects, like saw-flies of opposite sex.

An artificial light Petromax gas light if placed adjacent to a white mulmul cloth in field would attract a number of insects like gryllids, grasshoppers, moths, mantids, beetles, etc. Most of the insects attracted to the light would rest on the white cloth from where they may easily be picked up by hand or by aspirator. "Black light" traps are also used to collect insects at night. Simplest form would be to suspend a light source over a broad rimmed funnel which in turn may be fitted in a glass jar containing poison-vapour or other killing agent. Light traps may work all night and may also supply data indicating seasonal incidence, peak period for a population etc.

Berlese funnel: Insects inhabiting leaf litter and subsoil or inside the soil level are collected along with part of the habitat and brought to the laboratory where they are usually put in a funnel which acts as a separator. Several modifications of this device, known as "Berlese funnel" are now available, the simplest form being a metal funnel with sieve, inserted inside a can or collecting tube, the material (moss, debris, litter) is put on the sieve which is subjected to continuous heating by light bulb; the collecting tube contains preserving fluid like alcohol and the lip of

the funnel touches the fluid. Insects in order to evade the heat move down thru' the sieve and fall into the preservative.

Equipments

Net: A net essentially consists of a cloth bag or nylon net bag, a metal ring which holds the mouth of the open-bag, and a handle to which the metal ring is attached. Usually a ring of 15" diameter made up of 1/8" wire or metal is used; the ends of the ring should fit into a groove at the end of handle; the detachable ring allows to change a dirty bag or a torn one. The depth of the bag is usually 30" or twice the diameter of the ring. The handle should be sturdy but light.

For sweeping purpose, the bag used is of thick cloth instead of nylon net and the handle should also be stouter to allow quick sweep over vegetation. It may be a 8" ring with 18" handle and a bag of 12"-14" depth.

Brush, Forcep, Twigcutter, Scissors: Soft camel hair brush of No. 0 or 1 is usually used for hand collection. A forcep with bent end or straight end is used to pick insects from surface. For collecting ants, thin, fine light weight forceps yield better result. A scissor or twigcutter may be used to cut plant-part or twigs.

Aspirator: A simple field equipment made up of a collection jar having two holes at the cork stopper thru' one of which a bent glass tube (intake tube) is inserted and thru' the other a rubber tubing at the end of a small straight glass tube (suction tube) is fitted. Insects may be sucked in by putting the intake tube near its body and sucking the air thru' the rubber tube.

Axe, Knife, Hammer: These are necessary tools for collecting insects inhabiting soil, termite mound, under bark and rotten log. These are used to tear off loose bark or splitting wood or breaking open the mound or digging out the borers and miners.

Killing Bottles: Killing bottles are used to kill and preserve insect without affecting its colour. Usually glass jar with a layer of cyanide covered with plaster of paris, is used as a killing bottle. Cyanide vapour however may make small specimens brittle and even change its colour. Very often some other liquid chemicals like Chloroform, Benzene, Ether, Carbon Tetrachloride are used. Each one of these has some disadvantage but in general their vapours serve the purpose of killing the insects. The liquid may be poured over a layer of cotton and one or two filter paper or blotting paper could cover the soaked cotton and also prevent the specimen from coming in direct contact with cotton. Insects must be handled carefully while they are put inside the bottle

or taken out to prevent damage. A killing bottle with a layer of small chips and saw dust which is soaked with a few drops of ethyl acetate serves satisfactorily for a number of insects in killing and preserving the specimen which remain flexible.

Collection vials: Small specimens, which are killed and preserved in liquid, are to be kept in Homeopathic vial or similar other vials. Vials with screw plastic caps are preferable. These may be numbered beforehand and the corresponding number in the field note book may contain details about particular collection.

Hand Lens: A 10x hand lens (folding type) is useful to examine material in the field and should be kept handy.

Paper packets: Paper packets are used to keep Lepidopteran, Odonates and many other insects. As soon as they are killed specimens are transferred to these packets, made up of oil-paper, for temporary storing and transportation. These may be prepared in desirable sizes before one proceeds for field collection.

Chemicals and cotton: During field collection, preservative like 90% alcohol, killing agents like benzene or chloroform, or ethyl acetate should be carried extra, to meet any emergency; cotton may be required for packing after collection or to change the killing agent in the killing jar and should be kept handy.

Traps: Pitfall trap or Yellow Pan Water traps have already been discussed. The latter is a shallow pan trap painted yellow, which should be filled up to the half before being placed in the field. Petromax lamps are handy for light trapping and could be carried easily and used specially where electricity is not available.

White tray and Sieve tray: These may be useful to sort out debris, litter and aquatic collection during preliminary examination. After checking the material, the useless parts may be eliminated by sieving and the samples may be put in Berlese funnels.

Haver-sack, Boot and Camera: The equipments could best be carried in a Haver-sack. However a jacket which a collector may wear may be tailor-made with specification to suit the need. A number of small pockets to keep the collecting instruments handy may be provided in the jacket. One can get various kinds of other handy equipments from shops of fishing equipments viz. fisherman jacket, bags, fishing nets etc. A good quality hunting rubber soled boot would immensely help while going to the field. A field camera with f. 1.4 or f. 1.8 lens and a set of close-up accessories would be very useful for photographing ecological conditions, insect community, feeding site, habitat and other observation.

Field Note Book: A field note book is most essential for keeping all the data. Generally a numbered tag may be attached with the collection and the same number in the field note book may be used to keep the following data: (i) Date of collection (ii) Place of collection - indicate direction, approximate distance in km. from nearest road head and altitude (iii) Habitat (iv) Live colour (v) Name of host plant or animal (vi) Associated insects or animals (vii) Name of collector etc. A general note on the collection locality would provide further information, say about a Reserve Forest area, its vegetation type etc.

Lunch Packet: One should not forget to carry out a lunch packet while going in field. Easy items to carry are: Sandiwiches, fruits, water and tea or coffee in small flask.

Collections, once made, are to be preserved in a manner which provides scope to examine the specimens for identification and study and also guarantees long period of storage, with proper care. Table 4 provides in brief the methods of collection, and preservation of major insect groups, details of which are given by subject specialist in subsequent chapters of this publication.

IDENTIFICATION

Identification of insects always demand well preserved specimens and reference collection to compare with. Useful taxonomic literature along with reference collection on the group can be said to be the keystone for any short-term or long term entomological work. In the begining, one has to build up a reference collection, normally getting the identification done or getting the confirmation of tentative identification done by specialist working in Musea/Institutes in India and abroad. In order to do so, one has to assure proper packing and shipping of the specimens so as reach the destination without damage. Packing and transporting or mailing insects need special care.

Mounted insects should be firmaly pinned in a container or mailing box, with proper lining of cork or soft material like thermocole. Large specimens must have additional pins set firmly on each side of the specimens (crosspinning) so as to prevent damage. Boxes containing insect specimens, should be put in larger container with enough packing material beneath, above, and on all sides; saw dust, paper strips, cotton, etc. may be used for the purpose. The larger container should be closed firmly, wrapped in thick paper or waterproof paper, labelled with postal label, preferably written with a felt-pen or sketch-pen.

Vials containing specimens should be full of liquid, and each vial should have a cotton plug at the bottom to avoid splashing and should be fitted with leak-proof cork. Each vial should be

individually wrapped with cotton or paper and before wrapping, the mouth with lid may be dipped in sealing wax to prevent leakage. All vials after being wrapped should be put in a box with cotton lining, and cotton should also be put in between vials. The box containing vials may either be put in large box, as before, or may be shipped directly. All mailing box must be strong, made up of wood, thick card-board or thermocole, the last is suitable for small packets to be sent by air-mail.

Slide containing specimen should be packed in small lot of 10 each, being separated from the next by two thick cardboard piece, of the size of slide labels, and the location then wrapped with a plane slide in either side, by cellophane tape. The lot is then put in shipping container of thick tin preferably, the one with a screw cap, so that the packet may be opened easily and postage would be less if it could allow material for postal inspection. It is then treated as open-packet. Enough packing material on all sides are to be put inside the container to prevent breakage.

Live insects, specially young ones may be sent for rearing. Larvae must be shipped with a part of food plant which should last till it arrives at destination. Overloading of specimens or plant should be avoided. Pupae are best sent when packed in moist moss. Adult insects may be sent with a few stem of host plants and to avoid excess moisture a few holes may be made in the container.

The major Indian institutes where Insects are identified are:

1. Zoological Survey of India, 34 Chittaranjan Avenue, Calcutta 700 012 and its stations located in Dehra Dun, Shillong, Poona, Madras, Patna, Jabalpur, Jodhpur, Solan and Andaman (Port Blair), Berhampore (Ganjam), Hyderabad, Calicut, Canning.

Most of the insect collections are however identified in Calcutta as the Divisions of Entomology, with sections in major groups like Coleoptera, Lepidoptera, Diptera, Hemiptera, Hymenoptera, besides minor groups, are located at Calcutta H.Q. of Z.S.I. The Zoological Survey holds the "National Zoological Collections" and can be treated as the prime institute for systematic research.

2. Indian Agricultural Research Institute, Division of Entomology, New Delhi 110 012. This institute is the centre for identification for insects of economic importance besides other insects and possess many of the old type-collections.

3. Entomology Division, Forest Research Institute, Dehra Dun. Renowned for its excellent collections of insects, specially insects

of forest areas, the Institute holds a prime position and caters to the need of identification. Researcher in the case of Z.S.I., I.A.R.I. may also visit the Institute and compare his collection with the identified collection of F.R.I. A number of printed catalogues are available on the Insect collections at F.R.I.

4. Department of Entomology, Tamil Nadu Agricultural University, Coimbatore. This institute is well known for representative insect collections of South India and as such renders opportunity to compare South Indian Insects.

Besides sending material to the Director or Curator of a Museum with the request for identification, personal letters to specialists by name along with the material may also be sent. For this purpose, one has to know the names of the taxonomists and their address as also their specialisation. A directory of world taxonomists serve the most useful purpose; beside, a directory of Indian Zoologists is also available. These are cited below:

1. Richard E. and Ruth M. Blackwelder, 1961
Directory of Zoological Taxonomists of the World,
Published by the Society of Systematic Zoology by
Southern Illinois University Press,
Carbondale, Illinois, 404 pp.
2. Kapoor, V.C. 1974. Directory of Zoological Taxonomists
of India, Kalyani Publishers, Delhi-Ludhiana, 73 pp.

Besides the Indian Institutes where material may be sent for identification or may be compared with identified collections, a number of renowned museums abroad may render valuable services for identification of Indian Insects, a list of which is given below:

Foreign Museums:

British Museum (Nat. Hist.), Dept. of Entomology, Cromwell Road, London SW7 5BD, England.

Museum d'Histoire Naturelle, 45 me de Buffon, 75005 Paris, France.

Institut für Bodenforschung und Baugologie, Gregor-Mendel-Str. 33, A-1180 Wien (Austria).

National Museum of Natural History, Dept. of Entomology, Praha-Kunratice I, Czechoslovakia.

Museum d'Histoire Naturelle, Route de Malagnov, 1211 Geneve, Switzerland.

Zoologische Staatssammlung, Schless Nymphenburg-Nordflügel, D-8000 München 19 (W. Germany).

Mus Civ, Storia Naturale, Genova (Italy).

Musee Royal de l' Afrique Centrale, B-1980 Tervuren (Belgique).

Zoological Institute, Academy of Sciences of U.S.S.R., Leningrad 164, U.S.S.R.

U.S. National Museum of Natural History, Washington D.C. 20560, U.S.A.

The American Museum of Nat. Hist., Central Park West at 79th St., New York, N.Y 10024, U.S.A.

Bishop Museum, P.O. Box 6037, Honolulu, Hawaii 96818.

Entomology Research Institute, Canada Dept. of Agriculture, Ottawa, Canada.

National Science Museum (Natural History Institute), Hyakunin-cho 3-23-1, Shinjuku-ku, Tokyo, Japan.

Division of Entomology, CSIRO, P.O. Box 109 Coty, Canberra A.C.T., Australia.

Insects and mites of economic importance, specially from Commonwealth Countries are also identified by The Director, Commonwealth Institute of Entomology, 56 Queen's Gate, London SW7 5JR, U.K.

TABLE—1.
Floristic Regions in India

Western Himalaya	Eastern Himalaya	Indus Plain	Gangetic Plain	Central India	West Coast (Malabar)	Deccan Plateau	North East India	Andamans & Laccadive
Alpine and Subalpine, Moist temperate, Subtropical, [Kashmir Valley, Simla Hills, Doon Valley, Kumaon Hills, Garhwal Hills].	Subalpine, Moist deciduous, [Darjeeling Himalaya species, Singhalila range and Rangit Valley].	Cultivated cropland [Terai-Forest, Sal Forest at Foot Hills].		Dry deciduous, thorn [Narmada Valley, Bastar, Chotanagpur Plateau].	Moist Deciduous, Evergreen, [Western ghats, Annamalai Hills, Nilgiris, Palni and Cardomam Hills].	Dry deciduous, thorn, Dry evergreen, Swamp, [Koraput, Madumalai, Bandipur].	Evergreen, Semievergreen, Moist deciduous; Pine, Bamboo [entire region].	Wet evergreen, Moist deciduous, Dry deciduous, Mangrove, [Great Nicobar (Cambell bay) North Andaman (Dighlipur, Maya Bandar)].

TABLE—2
Forest types in India

Tropical Forest (*)	Montane Subtropical Forest	Montane Temperate Forest	Alpine and subalpine Forest
Wet Evergreen (Mh, Ka, Tn, Ke, As)	Broadleaved hill forest (Ke, Tn, Ka, Gj, Rj, Mh, Bn, Ar.)	Wet temperate (No conifers) (Tn, Ke, Bn, As)	Moist Alpine (Kas, Kum, Gr, Sik, Ar, Man)
Semi evergreen (Wg, As, Bn, Or)	Southern and Northern forms] Pine (Pn, UP)	Himalayan moist (Oaks & conifers) temperate (J & K, HP, UP, BN, As)	Dry Alpine (UP, MP, Pn, Kas & E. Him. upto 4,900 m.)
Moist deciduous (MP, Gj, Mh, UP, Bihar, Or, As, And)	Dry evergreen (Xerophytic & Scrub) (Jm, Pn)	Himalayan dry temperate (Conifers & some xerophyte) (West & East Him, J & K, Pn, MP)	
Littoral & Swamp (Coastal areas)			
Dry deciduous (MP, Mh, And, Tn, Ka, Pn, UP, Bh, Or, Bn)			
Thorn forest (MP, Mh, Tn, Ka, Pn, UP)			
Dry evergreen (And)			

(*) All except fourth & last may be divided into Southern & Northern forms.

Abbreviations used :

- (1) An=Andaman (2) And=Andhra (3) Ar=Arunachal (4) As=Assam (5) Bn=Bengal (6) Gj=Gujrat (7) Jm=Jammu (8) J & K=Jammu & Kashmir (9) Ka=Karnataka (10) Ke=Kerala (11) Kas=Kashmir (12) Or=Orissa (13) Man=Manipur (14) MP=Madhya Pradesh (15) Mh=Maharashtra (16) Pn=Punjab (17) Rj=Rajasthan (18) Tn=Tamilnadu (19) UP=Uttar Pradesh (20) Gar=Garhwal Himalaya (21) Kum=Kumaon Himalaya.

TABLE—3
CLASSIFICATION OF INSECTS

Order	Common name	Size	Habitat	Approx. number of species in the world According to (Metcalf and Flint, 1962)
Group I				
Apterygota :		Wingless, young resemble adults		
1. Thysanura (Fig. 2)	Bristle tails	6 mm.—12 cm.	Book shelf, under stone, logs debris	700
2. Diplura		Very small to 4.6 cm.	Soil, Moss, rotten wood, in damp habitat	350
3. Protura	Telsontails	less than 2 mm.	Moist soil, decaying leaves, under stone, bark	Less than 100
4. Collembola (Fig 3)	Spring tails	0.2—6 mm.	Soil, Humus layer, Moss, Caves, on Snow, in termite nests.	2000
Group II (A) Pterygota : Winged insects				
Wings develop as pad externally, larvae resemble adult but differ in habitat (Exopterygota : Orders 5-17)				
Wings develop internally, larvae usually differ from adult and have a resting pupal stage (Endopterygota : Orders 18-26).				
5. Dictyoptera (Fig. 4)	Cockroaches Mantids	6 mm.—7.2 cm.	Green Tropical vegetation, Domestic habitats	} 22,500
6. Orthoptera (Fig. 5)	Grasshoppers, Stick insects, Crickets	2.4—3.1 cm.	Open grassland, Foliage and Trees	
7. Dermaptera (Fig. 6)	Earwigs	5 mm.—4.8 cm.	Under stone, crevices Garbage	1100
8. Plecoptera (Fig. 7)	Stoneflies	4—5 cm.	Around water source	1500
9. Isoptera (Figs 8,9)	Termites		Decaying logs, Mound, Ant's nests, under stone	1900
10. Embioptera	Webspinners	1—2 cm.	Live in silk tunnel, in ground under stone, debris	150

TABLE 3—Concluded.

Order	Common name	Size	Habitat	Number of species
11. Ephemeroptera	Mayflies	3 mm.—3 cm.	Near water	1500
12. Odonata (Figs. 14, 15)	Dragon flies, Damselflies	2—15 cm.	Near water source, among tall grass and river bank	5000
13. Zoraptera		3—7 mm.	Under bark, decaying wood	20
14. Psocoptera (Corrodentia)	Book lice	2.5 mm.	As above	1100
(Fig. 10)				
15. Phthiraptera	Sucking lice, Biting lice	5—6 mm.	On birds and Mammals : on mammals	3100
(Mallophaga and Anoplura)	(Figs. 12, 13)			
16. Thysanoptera (Fig. 16)	Thrips		Aerial parts of flower and plant galls	3170
17. Hemiptera	Bugs	2—9 cm.	Plant parts and water bodies or parasitic on birds and mammals	55000
(Figs. 17, 18)				
18. Neuroptera	Alder flies	2 mm.—4 cm.	Shrubby bush, hill forests, Fresh water sponges	5000
(Figs. 19, 20)				
19. Mecoptera	Scorpion flies	1.5—2 mm.	Vegetation but feed on insects	350
20. Trichoptera (Fig. 21)	Caddis flies		Near water and damp moss	4450
21. Lepidoptera	Butterflies, Moths	20 mm —27 cm.	Vegetation, damp soil, flowers	112000
(Figs. 22, 23)				
22. Coleoptera	Beetles	0.5 mm —15 cm.	Wood, bark, fungus, ant nests, vegetation, flowers etc.	277,000
(Figs. 24, 25)				
23. Strepsiptera	Stylops	1.5—4.0 mm.	Parasitic on Hemiptera and Orthoptera	300
24. Hymenoptera	Ants, Bees and Wasps	2.0—36 mm.	Tree-nests, flowers, vegetation	103,000
(Fig. 26, 27)				
25. Diptera (Figs. 28, 29)	Flies and Mosquitoes		Vegetation, Garbage dump, near or in water within leaves, parasitic in insects	85,000
26. Siphonoptera	Fleas	1.5—4.0 mm.	On bodies of host viz. birds and mammals.	1,100
(Figs. 30)				

TABLE—4
COLLECTION AND PRESERVATION

<i>GROUP</i>	<i>COLLECT</i>	<i>KILL</i>	<i>PRESERVE</i>
I. Apterygota	By aspirator	95% alcohol/CHCl ₃ /	80% alcohol
(1) Thysanura	.. Camel hair brush dipped	CCl ₄	
(2) Diplura	.. in alcohol		
(3) Protura	.. Sweeping vegetation		
(4) Collembola	.. Putting soil, debris, leaf litter tullgren funnel		
II. (5) Dictyoptera	By Sweeping	Cyanide vapour or	(5) + (6) Dry, pinned or in
(6) Orthoptera	.. beating	Chloroform .. or	alcohol (7)
(7) Dermaptera	.. forceps	Benzene ..	
	.. flashlight	Acetic ether	
III. (8) Plecoptera	By netting while on wings	95% alcohol	80% alcohol
	.. sweeping		
	.. light		
IV. (9) Isoptera	By forcep from nest	95% alcohol	80% alcohol
	.. brush dipped in alcohol		
V. (10) Embioptera	By forcep	95% alcohol	80% alcohol
	.. brush		
VI. (11) Ephemeroptera	By nets (adults)	95% alcohol	80% alcohol
	.. light trap (adults)		
	.. beating (subimago stage)		
VII. (12) Odonata	By aerial nets	Cyanide or ether	Dry, pinned 80% alcohol

TABLE 4—Contd.

GROUP	COLLECT	KILL	PRESERVE
VIII. (13) Zoraptera (14) Psocoptera	By brush dipped in alcohol .. aspirators	95% alcohol (scale covered winged specimens in vapour and preserve dry)	80% alcohol
IX. (15) Phthiraptera	.. brush dipped in alcohol .. fine forcep (from fresh killed animal wrapped in polythene bag or directly from fur and skin)	95% alcohol	80% alcohol and mount on slides by clearing in 10% KOH, passing thru alcohol grades and mounted in Canada balsam.
X. (16) Thysanoptera	By brush dipped in 80% alcohol or in a mixture of Ethyl alcohol (50 p.) lactic acid (10 p.) water (40 p.) .. Berlese Funnel extraction .. Beating flower on white sheet or over wide mouth jar.	95% alcohol or in the mixture	80% alcohol or mount in Polyvinyl lactophenol method or in Hoyers media
XI. (17) Hemiptera	.. sweeping net and aquatic net .. beating .. aspirator .. brush dipped in alcohol .. light trap .. separator	95% alcohol or kill in cyanide bottle or in vapour (Berlese media) or pin Ethyl acetate	80% alcohol or mount in slides
(18) Neuroptera	By netting .. sweeping .. hand picking	Cyanide or other vapour	Pinned
(19) Mecoptera	By aerial net .. light trap	Cyanide or other vapour or in 70% alcohol	Pinned or wet preservative

TABLE 4—Contd.

<i>GROUP</i>	<i>COLLECT</i>	<i>KILL</i>	<i>PRESERVE</i>
(20) Trichoptera	By aerial net ,, light trap	Cyanide vapour or 95% alcohol	Pinned and spread or 80% alcohol
(21) Lepidoptera	By aerial net ,, light trap ,, Sugar-baits or sap, nectar bait ,, rearing larvae or pupae	Cyanide vapour	Pinned and spread
(22) Coleoptera	,, sweeping ,, hand picking ,, beating ,, aquatic net	Cyanide vapour, 95% alcohol (all aquatic forms), Vapour Ethyl acetate.	Pinned or in 70% alcohol
(23) Strepsiptera	,, From parasitised host (Hemiptera, Hymenoptera, Orthoptera)	95% alcohol	80% alcohol
(24) Hymenoptera	By rearing (parasitic forms) host-insects ,, beating ,, sweeping ,, light trap ,, aspirator (ants) ,, berlese funnel (ants)	Cyanide vapour Ethyl acetat vapour	Pinned or pointed, mounted on slide (microhymenoptera)
(25) Diptera	By sweeping ,, aerial net ,, aspirator ,, light-trap ,, baiting (meat, dung, rotten fruit, fungi)	Cyanide vapour, 95% alcohol	Pinned or pointed, 80% alcohol, permanent mount of genitalia.

TABLE 4—*Concluded*

<i>GROUP</i>	<i>COLLECT</i>	<i>KILL</i>	<i>PRESERVE</i>
(26) <i>Siphonoptera</i>	.. berlese funnel .. collecting galls and mines (midges, miners) By shooting and trapping hosts .. searching in hosts' nests	95% alcohol	80% alcohol, Permanent mount on slides, after cleaning in 10% KOH.

Notes :

1. In many instances, the genitalia of the insect has to be taken out for taxonomic study (Orthoptera, Lepidoptera, Neuroptera etc.) and this involves careful dissection ; the genitalia after being dissected out could either be stored in microvial in glyarine or may also be mounted on slide or mounting card as permanent preparation, passing thru' alcohol grades, clove oil, xylol and mounting in resinous substance.

2. Cyanide vapour is often disliked by many collectors and as such other agents e g Ethyl acetate, Chloroform, Ether, Benzene, Carbon tetrachloride may be used in a killing bottle, in cases where only cyanide vopour is recommended, but each of these agents have some advantages and disadvantages.

METHODS OF COLLECTION AND PRESERVATION OF APTERYGOTA

S.K. Mitra

Apterygota represents one of the two subclasses of Insecta and consists of four orders: Thysanura (Silver-fish or Bristle-tails), Diplura, Protura, and Collembola (Spring-tails).

I. Order : THYSANURA

Chief distinguishing features: Length - upto 2 cms. Distinguished by three processes (2 anal cerci and single median telson) projecting posteriorly from the terminal part of abdomen.

General abodes: Dry cavities of rock crevices, under tree bark, loose wood-land litter, loose soil, nests of ants and termites, rotting wood, under stones, domestic species occurring amongst old books, papers and objects composed chiefly of cellulose.

Collection and preservation: Direct method: Organisms may be collected directly in dry glass vessels (glass vial, petri-dishes, etc. with the help of a hair brush or a pair of fine forceps. Aspirator also can be used for direct collection. They are to be preserved in rectified spirit preferably after narcotisation by using vapour of either liquid benzene or carbon tetrachloride.

Indirect method: The soil inhabiting species and also the species living in ants' and termites' nests, in addition to direct method, can be collected by extraction of soil samples and nests' samples through a Tullgren funnel. Tullgren funnel can be constructed as follows

1. Take ordinary thin funnels (6" - 10" in diameter).
2. Place a sieve with large meshes within each funnel (sieve with fine meshes to be used for soil samples with finer particles and less organic matter).
3. Arrange a 40 W or 60 W electric bulb with a reflector for each of the funnel for glowing and generating heat to dry soil samples and to drive the animals out of them. The bulb is to be placed c.3" above on the top of each tin funnel. Wattage of the bulb is to be used according to the amount of moisture present in each soil sample.
4. Put a glass vial (collecting vessel) containing rectified

spirit just below the stem of each funnel for the collection of animals driven out from the soil samples.

5. Put soil or litter sample in each funnel on the surface of the sieve carefully so that no debris or soil pass through the sieve and fall in the collecting vessel which may pollute the spirit.
6. The bulb should be kept glowing constantly till the samples get completely dried.
7. Intermittent observations of collecting vessels may be made without disturbing the soil samples in the funnels for finding out nature of extraction of organisms and in case of depletion, rectified spirit may be added in the collecting vessel. Extraction time: C. 3-6 days.
8. Put locality label and other ecological details in each collecting vessel. Put the stopper and despatch the same to the O.C., Apterygota Section, C/o Director, Zoological Survey of India, Calcutta.

II. Order: DIPLURA

Chief distinguishing features: Length - upto 50 mm. White or yellowish in colour. Without median telson but with paired anal cerci, which may be either long or short, segmented or forceps-like (cf. Dermaptera) from the terminal part of abdomen. Compound eyes and ocelli absent.

General abodes: Deep, porous litter and also humus layers in wood land and forest soils, moist cavities beneath stones, decaying wood, grass lands, caves, etc.

Collection and preservation: Direct method: If located in the field, the animals be collected directly either by a soft hair brush, moistened with spirit, carefully by using a pair of fine forceps or by using an aspirator. Preservative to be used is rectified spirit.

Indirect method: By Tullgren funnel (Mentioned above under Thysanura). Extraction time: C. 3-6 days.

III. Order: PROTURA

Chief distinguishing features: Length - usually below 2 mm. Elongate and slender in appearance. Median telson present,

reduced or absent, anal cerci absent. Antennae and compound eyes are wanting.

General abodes: Moist forest soils, grass land soil, soils rich in organic matter, may live on the surface but usually found in greater number between 10-20 cms. of soil profile.

Collection and preservation: Direct method: Difficult to locate in the field due to their sparse distribution (vz. gregarious or semigregarious in other orders) and size. Some of the litterine species are quite large and they, if located in the field, can be collected with a soft hair brush moistened with spirit or with an aspirator. Preservative to be used is rectified spirit.

Indirect method: Both soil samples rich inorganic matter and soil samples from a depth of 10-20 cms. to be extracted through Tullgren funnel (Details given above under Thysanura). Extraction of soil samples may take even 2-3 months for driving out the organisms from soil.

IV. Order: COLLEMBOLA (Spring-tails)

Chief distinguishing features: Length - 0.50-4 mm. Usually with a springing organ (spring-tails) located on abdominal segment IV by means of which organisms jump and escape. Species without spring-tails are also common exhibiting only sluggish movement and with beautiful deep coral red or dark blue colour. No cerci and telson present at the end of abdomen.

General abodes: Decaying moist organic matter (wooden logs, leaves, etc.), litter and humus layers in forest floors, grass land, foliage of herbs and shrubs, nest of termites and ants, caves, under bark of trees, leaf mould, tide-marks of sea shore, on the surface of fresh water, amongst moss, fungus, lichens, etc. In general everywhere where little organic matter and moisture are available.

Methods of collection and preservation: Direct method: With little endeavour large species can be located in the field taking advantage of their jumping posture. If located in the field, they can be collected with a sable hair brush moistened with spirit or through an aspirator. Species with jumping posture also can be collected mechanically by placing a large petri-dish containing rectified spirit on the surface of forest floor, grass land or other substratum and consequently disturbing adjoining regions. The organisms will jump and fall inside the petri-dish containing spirit. The examples can be picked up from the petri-dish with a hair brush and placed in the vials containing rectified spirit. Species living on herbs and shrubs can be collected by beating and sweeping and subsequently picking them up from the net

or umbrella (may be used for beating) with a hair brush moistened with spirit. Since the species living on herbs and shrubs jump out very quickly, they may be narcotised by dropping a small cotton ball soaked in either liquid benzene, carbon tetrachloride or chloroform in the net immediately after each beating and sweeping. From the surface of pool they can be collected with a small enamel tray containing rectified spirit, placed on the surface of water in such a manner so that water does not fill in the tray. Then little disturbance of the adjoining regions will make the species jump and fall inside the tray containing spirit.

Indirect method: Moist soil samples rich in organic material, moist litter (decaying organic matter on forest floor or elsewhere), fungi, moss, lichens, etc. are quite suitable for extraction through Tullgren funnel. (Details given under Thysanura). Extraction time: C. 3-6 days.

COLLECTION OF SAMPLES

Scientists, going to the field for faunistic survey, may conveniently collect soil/or litter samples in polythene bags and bring them to Head Quarters for extraction. Attention should be paid not to stuff too much of samples in one bag, so that the sample does not get pressed or crumbled. The mouth of each bag may be tied with a rubber band.

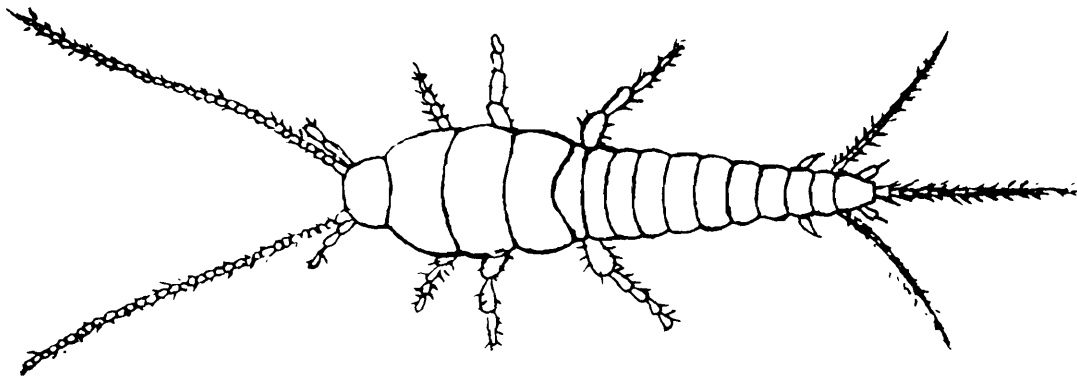
Samples supersaturated with moisture should be aerated intermittently by opening the mouth of each bag. Otherwise, the evaporation of moisture and subsequent condensation may result in the formation of water droplets on the wall of the bag in which small organisms like Collembola, mites, etc. may get trapped and die.

Locality and other ecological details (for example, nature of soil, litter, etc.) should be written in pencil on a piece of paper and dropped inside each bag containing sample.

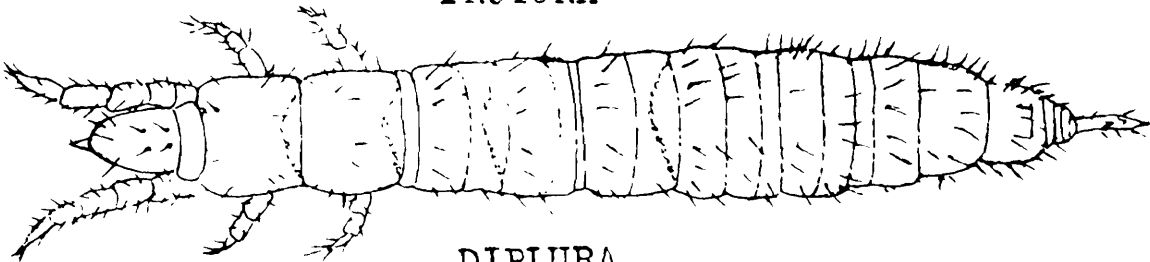
Soil samples rich in organic material and litter samples may be brought from the field.

Through this method (i.e., through collection of litter/soil samples) it is possible to make best use of time in the field and is useful for surveying Apterygota and other soil animals from new areas or in recovering fresh topotypes of old species.

THYSANURA.

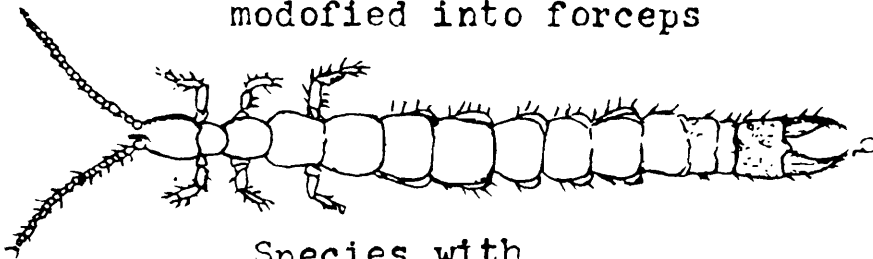


PROTURA

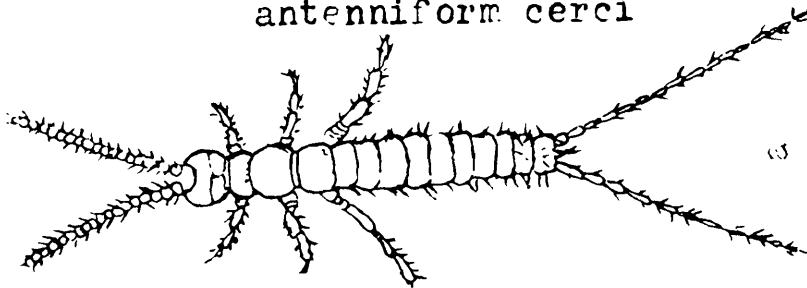


DIPLURA

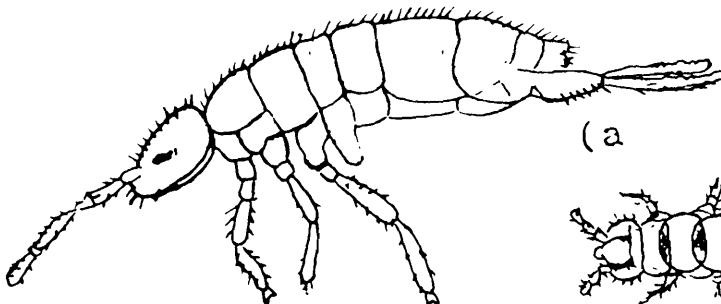
Species with cerci
modified into forceps



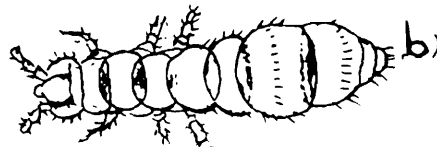
Species with
antenniform cerci



COLLEMBOLA



Species with
spring tail.



Species without
spring tail.

COLLECTION AND PRESERVATION OF ORTHOPTERA

M. S. Shishodia

This large order Orthoptera with 35 families and approximately, 20,000 species known from the world, of which 20 families and approximately 1,000 species are Indian, includes grasshoppers, locusts, grouse-locusts, crickets, mole-crickets and pigmy mole crickets.

Specimens of this group are medium to large sized, winged, brachypterous or apterous, and characterized with mandibulate mouth parts. Prothorax large, anterior legs sometimes modified for digging, posterior legs usually enlarged and modified for jumping, coxa small and somewhat widely separated, tarsi 3 to 4 segmented, rarely with 5 or fewer than 3 segments, fore-wings generally called tegmina or elytra more or less thickened with submarginal costal vein, female generally with well developed ovipositor, male genitalia symmetrical, cerci usually short and unsegmented, specialised auditory and stridulatory organs frequently developed.

A collector of these orthopteran insects is naturally interested to know as to where to look for these insects. They may inhabit widely diversified ecological conditions, but, generally they are available near the green vegetation, near water tanks, ponds or under stones, and some are attracted to light during night.

The equipments essential for collecting these insects are as follows :

1. **Nets** There are various types of nets, but generally an insect net, also known as butterfly net, is widely used.
2. **Forceps** : A fine pair of forceps of 5" size and another of 9" size, are often required.
3. **Killing bottle or killing tube** These are made by using Potassium or Sodium Cyanide, or liquid benzene, or Chloroform. Strong, large, wide-mouthed bottle or tube, about 16 cm. x 9 cm. in size, with cork or rubber stopper may be used. The stopper should be of tight fitting, so as to prevent leakage of fumes. The method of preparing the killing bottle and tube is simple. However, due to extreme toxic nature of cyanide, liquid benzene or chloroform is recommended for preparing killing bottle. The liquid chemical may be poured in a bottle, or tube first, and then a layer of cotton

should be put to cover the liquid chemical. Then one or two layers of blotting paper should also be put over the cotton to prevent the specimen from coming in direct contact with the cotton or chemical.

4. **Scissors** : Fine scissors of 4" to 6" sizes are required for cutting the blotting paper, paper labels, etc.

5. **Specimen packets** : Paper packets made up of oil-paper are needed for temporary storing and transportation.

6. **Specimen tubes** : Glass or plastic tubes of 8-10 cm. x 2 cm. and 5 cm. x 1 cm. sizes are generally required for wet collection.

7. **Cotton** : Cotton will be required for packing after collection or to change the killing agent in killing bottle.

8. **Hand lens** : A hand lens of 10X magnification power (Folding type) is useful to examine the specimens in the fields.

9. **Brush** : Soft camel hair brush of 0 or 1 Nos. may be required.

10. **Card board boxes** : These are very essential for keeping the packets containing specimens temporarily.

11. **Field note book** : It is required for recording the essential data.

12. **Lead pencil** : A lead pencil is most important for writing specimen labels in field.

Collection of insects may be achieved only by practice and patience. Most convenient method of collection of various species of Orthoptera in large numbers is by sweeping over vegetation of various types by means of butterfly net. However, hand picking with the help of forceps is employed for some group of insects. Some of the species living in bunch-grasses, in desert or plains, or on trees and high bushes that avoid being swept, by falling down at the slightest disturbance are hiding, between the stems near the ground. They ought to be carefully detected by searching and can be collected by large size forceps.

Some species of Orthoptera are attracted to light at night. These can be collected by placing two or three gas or Kerosene lamps or an electric light or mercury vapour lights over a white sheet of paper or mulmul cloth at a suitable distance. Different types of light traps are used, the details of which can be had from books dealing with the subject.

Period and time of collection : Best period for the collection of orthopteran insects is from early summer to early monsoon and again just after the monsoon, but few species may be collected even in late winters. It is always advisable to go for collection for winged forms before the sun rise when they are not much active and they can be easily picked up by hand.

Specimens are killed by keeping in a killing tube. They should not be kept in the bottle too long, generally not longer than half an hour, or else they may change their colour. For purpose of temporary storage in field these insects are kept in oil-paper packet having strips of cotton or blotting paper but it must be assured that they are reasonably dried up, otherwise moulds and fungi are likely to damage them. One to three specimens may be kept in one paper packet. However, some soft bodied insects like some crickets or pigmy mole-crickets may be preserved directly in spirit. It is always necessary to have a locality label providing information about the locality, date of collection, name of collector, altitudinal record, and brief note about its habitat. Label should be written by pencil in the field.

The specimens kept in paper packets are best laid in card board boxes. A thin layer of dry paradichlorobenzene should be spread on the bottom of empty card board boxes. Then, a thin layer of cotton should be put over the paradichlorobenzene. Now the box is ready for keeping the specimen packets. The specimen packets should be arranged very loosely in a line. When the box is full, cover it again by a thin layer of cotton, and then sparsely spread paradichlorobenzene, close and pack the box. The specimens preserved in spirit should be put in appropriate tubes according to their sizes and tightly stoppered. Each tube should be wrapped with paper, and then by thin layer of cotton and tied them with thread. Such tubes may be kept in spirit jars containing a thin layer of cotton at the bottom as well as on the top, or in a well ventilated wooden box and be packed rather tightly to avoid shaking. Care should be taken while taking out specimens from the packets or spirit tubes, as the hind legs and antennae will break off at a touch.

The larger specimens require a stiffing with chopped cotton which may be done in the following way. A slit is made by a pair of sharp pointed scissors into the thin membrane between the tergites and sternites on one side only (not more than three segments), taking care not to cut the last segments. Through this opening the thorax is cleared first and then the abdomen similarly eviscerated with a straight forceps. The abdomen, after the eviscerating, is stuffed up with cotton wool, gently working in, so as not to disturb the colouring layers lining the chitin wall and merely enough in bulk to keep the walls from collapsing. Smaller and medium size specimens do not require stuffing. Green coloured grasshoppers may be submerged in 5% formaline for about 5 minutes and then prepared afterwards, to keep their colouration.

After the collection is brought to the laboratory, it has to be made ready for study and permanent storage. First step in this direction is to relax them in a proper relaxing box. A cotton ball soaked in mixture of camphor and carbolic acid with a ratio of 1 : 3, should be put in relaxing box to prevent moulds and fungi. When sufficiently relaxed, the insects are pinned and set.

The pinning of insects is very easy. They should be pinned through base of the elytra (right or left) and not through the pronotum as often is done. The elytra and wing are spread only on one side, and the legs and antennae are set in the usual way, making it easy for their study. Depending on the size of the specimens appropriate entomological pins are to be use. Generally, in Orthoptera, pin numbers 3, 16, and 20 are used but O, 00 or 000 numbers may also be used in place of number 20. Smaller specimens, such as Tridactylids, Tetrigids, or some crickets, should be mounted on card board triangles staged on pins. If the specimen is too large or very soft, it should be supported by a piece of card board, otherwise it will sag at either end.

After pinning and setting the pith board containing these material should be placed in drying cases for a week so that the specimens may dry up completely.

Proper labelling of the specimens is of extreme importance. For dry as well as wet specimens data labels are to be written on good quality bond paper with Indian ink. Data label should contain the name of locality, altitude, name of host plant (if known), date of collection, name of collector, etc. Label should be small (10 x 20 mm.), clean and uniform.

Specimens so pinned and labelled may be arranged in drawers, which may be fitted into a cabinet or they may be kept in wooden boxes. Naphthaline powder is put into the channels or grooves, fitted around the drawers and covered with a thin layer of cotton. A ball of cotton wool, soaked in a mixture of camphor and carbolic acid with a ratio stated above, is pinned at one corner. These chemicals will prevent insect pests and fungal attack. A periodical check is very essential to refill naphthaline in grooves and resoak the ball in a carbolic mixture, or to change the ball if required. Liquid benzene can also be used for temporary storage, in the drawers

It is hoped that the above notes would prove useful for collection of orthopteran insects. However, for further reading on the subject, the following literature would give more details.

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IDENTIFICATION OF ORTHOPTERAN INSECTS

H.K. Bhowmik

The members of the order Orthoptera are popularly known as Grasshoppers, Crickets, mole crickets, grouse-locusts, etc. And the name 'orthoptera' means primitive or generalized winged insects. The Orthoptera are insects of moderate or large size; smaller forms are infrequent. They may be winged, bractyptrous or apterous. They are qualified by having : Biting type mouth parts. Prothorax large. Hind legs usually enlarged and modified for leaping or jumping. Forewings elongate and narrow, more or less thickened tegmina with submarginal costal veins and almost always modified as stridulatory organs; hind wings membranous, more delicate with an extensive anal area. Female generally with well-developed ovipositor. Male external genitalia symmetrical, concealed at rest by enlarged 9th abdominal-sternum which may or may not bear a pair of styles. Cerci usually short and almost invariably unsegmented. Specialized auditory organs may be present.

The Orthoptera forms an order of more specially terrestrial insects; some of them are good fliers. But numerous flightless species are also found in all families.

A few species of Acridoidea (the family Tetrigidae) (*Scelimena* sp.) are aquatic in habits and have their tibiae and tarsi dilated for swimming. Among Acrididae, the genera *Hygracris palustris* Uv (1921) have similar development of hind tibiae etc. Some Gryllidae are also semi-aquatic in habit and willingly enter water.

CLASSIFICATION

All the qualifying features of the Orthopteran insects are not, however, unique, except the modification of hind femora for jumping in majority cases, and presence of stridulatory organs in tegmina and presence of auditory organs, for many of these characters are shared also by other orders of insects. And none of these characters, even the unique ones, are not uniformly possessed by all the families of this order.

MORPHOLOGICAL CHARACTERS

For further discussion, a brief review of morphological characters needed to identify these insects is presented here:

Antennae - The antennae are typically long, setaceous appendages composed of many joints - they may be filiform, ensiform or clubbed.

The classification of Orthoptera in suborder, family levels depends on the size of these structure while its finer shape helps in identification at generic and specific level.

Pronotum - The prothorax or the pronotum of these insects are large. It is usually a large shield-like structure which extensively overlaps the pleura on either side. In Tettigidae it is so long as to cover the abdomen completely and conceal the hind wings, the tegmina being reduced to small scales. In Eumestricidae, the pronotum is dorsally flattened; in Acrididae it is small and divided by 2 or 3 transverse sulci whereas in Grylloidea it is undivided.

Prosternum - The prosternum may or may not provided with a spine or tubercle of varying morphological features. Its presence or absence is also significant. Femoro-alary stridulation is seen. In this sound is produced by rubbing the inner surface of hind femora, upon which there is a series of projected pegs, against the thickened basal area of the each tegmen.

Legs The legs differ very much in character among different families - the hind femora (sig. femur) are usually swollen proximally. But in Grylloalpidae (mole crickets), Pneumoridae and Cylindrachetidae and some others the hind legs are secondarily reduced to a more normal appearance. The tarsal joints vary in number but always fewer than 4. It is 4 in Tettigonidae, 3 in Gryllidae and Acridoidea and 1 or 2 or wanting in Tridactylidae (Pigmy mole crickets).

The forelegs are strongly fossorial in Gryllotalpidae and Cylindrachetidae, the tibia being broad and with large teeth. The tympana is restricted to foretibiae in Gryllidae.

Ovipositor - An exerted ovipositor is usually well developed with good exceptions. In Gryllidae it is elongated and needle-like, where as in Gryllotalpidae it is completely lost. In Acridoidea, these are short, stout structures adopted for boring into the soil; in Tettigonidae it is blade like.

Tympanic or auditory organs - These are present in all sound producing species. Each organ consists of a thin cuticular membrane or tympanum, whose vibrations are transmitted to the sensory centres by means of scolopae, which are connected with the nerve endings. In Acrididae, this is highly specialized structure and is situated on either side of the 1st abdominal segment. In Tettigonidae and Gryllidae these are different and consists of a tympanum on each fore tibia. These organs may be opened or closed externally.

Stridulatory organs - Most characteristic feature of Orthopteran insects in modern sense is the stridulatory organs for sound pro-

duction and when present, it is always in males. These are chiefly of 2 types - (i) the alary and (ii) the femoro-alary. The 1st type is seen in Gryllidae and Tettigonidae. In Gryllidae each tegmen bears a rasping organ or file and a hardened area, scraper; the file of one tegmen works against the scraper of the other. In Tettigonidae the file is functional. Only a left tegmen and the scraper on the right one. In Oedipodinae, a subfamily of Acrididae, stridulation is produced by the friction of the upper surface of the costal margin of wings working against the lower surface of hardened veins on the tegmina.

The concept of Orthopteran classification has undergone tremendous changes with time. Without going into details of history, which is beyond the scope of our present discussion, it can be mentioned that previously the order Orthoptera included chiefly 7 families, under two main groups - 4 families of running species as Cursoria and remaining 4 families of jumping insects as Saltatoria; - many of them are now raised to separate status of orders or suborders. Thus the family previously known as Grylloblattida has been ranked up now as a separate order Grylloblattodea; Blattidae and Mantidae - raised up to suborders Blattaria & Mantodea and finally united to the order Dictyoptera; Phasmidae as order Phasmida (Stick & leaf insects) and all the 4 families previously termed as Saltatoria into the order of Orthoptera.

1. Legs usually of equal size, hind femora not adapted for leaping; tarsi 5-jointed; sound producing organs absent; Ovipositor usually concealed; cerci jointed or unjointed 2 (Cursoria)

Legs of unequal size, hind femora enlarged for jumping; tarsi always with less than 5-jointed; sound producing organs present; ovipositor generally exserted; cerci unsegmented 5 (Saltatoria)
2. Apterous; ovipositor exserted; ocelli absent; cerci long, jointed Grylloblattidae

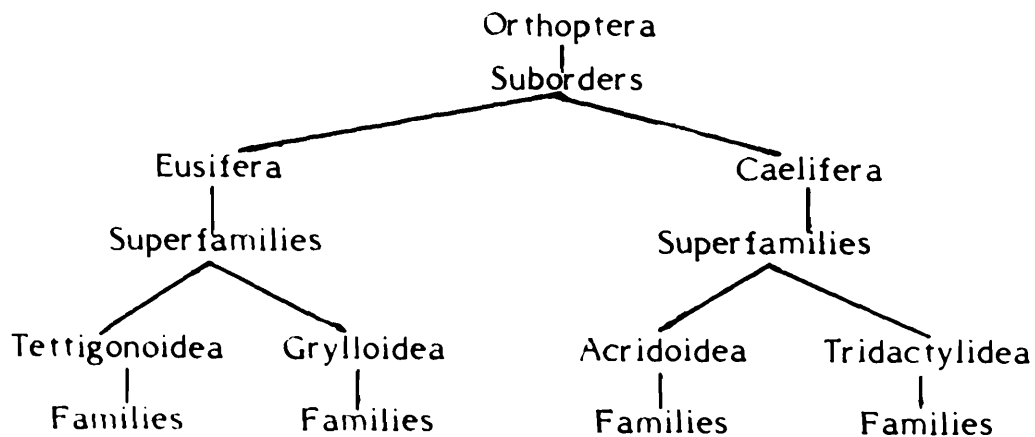
Apterous or winged; ovipositor concealed and often rudimentary cerci short 3
3. Pronotum large and shield-like; coxae very broad. Blattidae

Pronotum not large and not shield-like; coxae small 4

- 4. Fore-legs highly modified for raptorial purposes; prothorax generally very long; eyes large; ocelli 3; cerci jointed..... Mantidae
- Fore-legs normal; mesothorax very long; eyes small, ocelli usually absent. Cerci unjointed Phasmidae
- 5. Antennae shorter than body; tarsi 3 jointed; stridulatory organs on tegmina and hind femora; auditory organs at base of abdomen. Ovipositor short..... Acrididae
- Antennae almost always longer than body; tarsi may be 3 or 4 jointed; stridulatory organs on tegmina only; auditory organs on fore tibiae. Ovipositor long..... 6
- 6. Tarsi 4-jointed; ovipositor ensiform Locustidae
- Tarsi 3-jointed (rarely 1 or 2 jointed or wanting); ovipositor usually cylindrical , needle-like..... Gryllidae (Mostly)

Saltatoria

The group 'Saltatoria' is now considered strictly to represent the order 'Orthoptera' and the Indian families may be represented as follows:



- | | | | |
|---------------------|-------------------|-----------------|------------------|
| 1. Schizodactylidae | 1. Gryllotalpidae | 1. Tetrigidae | 1. Tridactylidae |
| 2. Gryllacridae | 2. Gryllidae | 2. Eumastacidae | |
| 3. Tettigoniidae | | 3. Acrididae | |
| 4. Propalangopsidae | | | |

**Modern classification after Handirsch (1930)
(Limited to oriental families)**

- 1. Antennae about as long or longer than body, many segmented, tympanal organs, when present, on fore tibiae 2 (Suborder Ensifera)

- Antennae shorter, with less than 30 segments; tympanum when present at base of abdomen..... 9 (Suborder Caelifera)
2. Tarsi 4 segmented, at least on middle and hind legs..... 3 (supfamily Tettigonoidea)
- Tarsi 3 segmented 8 (supfamily Grylloidea)
3. 2nd and 3rd segments of tarsi with large, mobile lateral lobe; wings, when present, coiled spirally in repose Schizodactylidae
- Tarsi and wings otherwise 4
4. Body elongated, apterous, rod-like; hind femora not thickened Phasmidae
- Body more thick, hind femora entangled 5
5. Tarsi depressed 6
- Tarsi compressed or cylindrical..... 7
6. Fore wings without stridulatory apparatus; fore tibiae without tympanal organs; middle and fore tibiae armed beneath with mobile spines Gryllacrididae
- Fore wings of ♀ usually with stridulatory apparatus; fore tibiae almost always with tympanal organs; tibiae without mobile spines beneath Tettigonidae
7. Fore wings of male with stridulatory apparatus; tibiae tympanal organ present..... Prophalangopsidae
8. Forelegs strongly fossorial, with tibiae expanded and digitate; ovipositor vestigial..... Gryllotalpidae
- Forelegs not markedly fossorial, with tibiae simple; ovipositor elongate..... Gryllidae
9. Tarsi almost always 3 segmented; antennae usually longer 10 (Supfamily Acridoidea)
- Tarsi 1 or 2 segmented, antennae short, with 12 or fewer segments..... 12 (Supfamily Tridactyloidea)

10. Pronotum extended backwards to cover abdomen; arolium or empodium absent; antennae longer than fore femur ..
 Tetrigidae

Pronotum normal, or if, rarely, extended behind, than empodium present; antennae may be shorter than fore femora or longer..... 11

11. Antennae shorter than fore femora; pronotum not compressed, usually flattened dorsally; prosternum unarmed.....Eumastacidae

Antennae longer than fore femora; pronotum of varying shape; prosternum may be armed or unarmed.....Acrididae

12. Small forms of more normal facies; fore legs normal, hind legs saltatorial with enlarged femora Tridactylidae

GRASSHOPPERS OF ECONOMIC IMPORTANCE IN INDIA

S.K. Tandon

INTRODUCTION

The short horned grasshoppers belong to suborder Acridoidea of the Order Orthoptera. Many species of Acridoidea are serious pests of crops and pastures in India. They have long been recognised as crop pests probably from the time when cultivation was first practised about 10,000 years ago in the middle east in association with destructive locusts. In general it is difficult to separate locusts from grasshoppers especially when one talks about these group of insects in relation to crop damage. Damage by locusts, although spasmodic in both space and time, can completely or nearly completely destroy crops over large areas causing local famine and concomitant human physiological and psychological depression. Whereas 10% loss each year can be tolerated a 100% loss every year can mean disaster, even though the total loss over the period is no greater. It is this threat of total destruction that makes the locust the most feared of all crop pests (Bullen, 1966).

In developing countries with rapidly expanding agriculture, grasshoppers (Acrididae) almost invariably become major pests of crops. Their devastation may be less spectacular than those caused by locusts, but they are more persistent so that the effect on agricultural production and particularly on planned development is much more serious. The control of grasshoppers by insecticides is highly effective but is economically sound only if applied to crops of considerable commercial values and not in the case of the majority of subsistence crops or pastures. Many species have already been recorded as occasional pests, but the damage is usually local and confined to native crops so that it does not attract much attention. However, various development schemes entail mechanised production of different crops and this may lead to grasshoppers becoming major pests due to change in soil conditions caused by cultivation. Therefore, modern agriculture is almost certain to produce both the soil and food conditions highly favourable to some species of grasshoppers, making them permanent major pests, as has happened in other continents (Uvarov, 1957).

The grasshoppers are found common in grass lands, low-herbage, general waste land etc., both in the plains and submountainous, forests areas. They are easily recognised by their shorter antennae, and strong well developed hind legs with enlarged femora which are adopted for leaping. The grasshoppers belong to suborder Acridoidea of Order Orthoptera.

SYSTEMATICS AND ECOLOGY

Order : **Orthoptera**

Suborder: **Acridoidea**

According to Dirsh (1961) the suborder Acridoidea is divided into 14 families of which the following five families occur in the Indian region.

1. Eumasticidae; 2. Trigonopterygidae; 3. Pamphagidae; 4. Pyrgomorphidae; 5. Acrididae.

Pyrgomorphidae and Acrididae are the most important families from the economic point of view.

1. Family **Pyrgomorphidae**

The Pyrgomorphidae represent a distinctive family of acridoid Orthoptera comprising 127 genera and over 400 species.

Diagnosis: Body of variable shape. Head usually conical or sub-conical with regularly incurved frons. Fastigial furrow present, apical fastigial areas mostly present. Prosternal process present. Elytra and wings fully developed, reduced or absent. Ectophallus differentiated, cnigulum capsule like, valves of penis paired, undivided. Epiphallus bridge shaped, with dorso lateral apendices, ancorae absent.

General Distribution of the family: The great majority of the Pyrgomorphidae are found in the old world tropics and subtropics but some are American and a few reach ten rate latitude both north and south (Keevan, 1959).

In Indian subcontinent the genera Chrotogonus and Colemania of Pyrgomorphidae are of major economic importance.

The members of the genus Chrotogonus cause damage to crops of cotton, sorghum, maize, wheat, groundnut and tobacco in India.

According to Keevan (1959) the genus represented in India by two species *Chrotogonus Cr. trachypterus trachypterus* (Blanchard, 1836) and *Chrotogonus Cr. oxypterus* (Blanchard, 1836).

Genus *Chrotogonus* (Fig. 1)

Diagnosis: Fastigium of vertex less short and obtuse at most not more than twice as wide as long, foveolae always well defined middle tibiae not specially slender, known in all conditions of wing development.

1. *Chrotogonus (Cr.) trachypterus trachypterus* (Blanchard, 1836)

Diagnosis: Hind wings hyaline or occasionally faintly tinged yellowish brown but never infumated or infuscated, apparently always fairly well developed and always atleast two thirds as long as tegmina, ovipositor valves broad. Pronotum less wide, with lateral margins less concave and divergent behind and interoposterior angle of pronotum less acute, frons more oblique.

General Distribution (Fig. 2): In India this species occurs chiefly in the northern part of the country and in south to about 16°N extending into Andhra Pradesh, often occurring at very considerable altitude in the north, grading into sub-species *robertsi* in eastern Bluchistan (Keevan, 1959). This species is also found in Pakistan, Bangladesh and southern Nepal.

2. *Chrotogonus (Cr.) oxypterus* (Blanchard, 1836)

Diagnosis: General size often very variable rather large and robust small forms are known among population of larger individuals. Hind wings always infumated to dark fuscous, never clear hyaline; head large and broad, fastigium of vertex shorter. Valves of ovipositor slender, sternal interspace narrow.

Distribution (Fig. 3): In India it is mainly confined to southern region and Central India to Bombay, Gujarat on to west, north east to West Bengal and Bangladesh. It is also widely distributed in Sri Lanka (Keevan, 1959).

Damage: Species of *Chrotogonus* cause heavy damage to cotton in northern India. These grasshoppers eat cotton seedling as soon as they germinate and sometimes the damage is so heavy that the crop has to be sown again. *Chrotogonus* takes a heavy toll of germinating wheat also (Pruthi, 1969).

3. **Colemania sphenarioides** Bolivar, 1910 (Fig. 4)

This is popularly known as Deccan grasshopper and is 3.5 to 5.5 mm long bluish green in color with pink and yellow stripe and is always wingless, having wing pads. Tegmina extending to the end of first segments of the abdomen, reddish with pale nervures.

General Distribution: The species is confined to whole of Deccan parts of Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu.

Damage: It is a serious pests of Jowar, Bazra and other millets. It is also found on flowers and pods of pulses, cotton and on perenial grasses. There is only a single generation in a year. Eggs are laid in the autumn, 8-10 mm deep in soft black soil, but at the base of bushes, stubles, etc. in the red soil which is very hard at the time of oviposition during October. They hatch in the following years during good monsoon showers (Pruthi, 1969).

Family Acrididae

The family Acrididae is the most numerous, most heterogenous and probably most recent and advanced family. It is divided into 17 sub-families of unequal value and probably of different phylogentic status.

Diagnosis: Body and head of variable shape. Fastigial furrow absent (rarely present, but apparently as a secondary formation). Prosternal process or spine present or absent. Tegmina and wings fully developed reduced or absent. Tympanum normally present. Stridulatory mechanism of variable structure, present in the majority of families. Lower basal lobe of hind femur mostly shorter than upper one. External apical spine of hind tibiae present or absent. Ectophallus differentiated; Cingulum differentiated; valves of penis paired, Flexure or divided. Ephiphallus mostly bridge shaped; sometimes disc shaped sometimes divided ancorae and lophi present sometimes lost.

General Distribution: This family is distributed all over the world.

The following subfamilies are known to have cause damage to our crops and pastures.

1. Hemiacridinae; 2. Oxyinae; 3. Catantopinae; 4. Cyrtacanthacridinae; 5. Acridinae.

Subfamily **Hemiacridinae**

Diagnosis: Body of variable shape. Radial area of tegmen with a series of regular, parallel stridulatory veinlets, if apterous, then body compressed and tympanum absent.

General Distribution: This subfamily is distributed in the tropics and subtropics of Africa, Asia and the Australia Archipelago and Australia and there are two genera in south America.

In India this subfamily is represented by 13 genera (Tandon, 1976) out of which the genus *Hieroglyphus* is economically very important.

Diagnosis: General coloration green or yellowish brown with yellowish brown patches.

Genus *Hieroglyphus* Krauss, 1877 (Fig. 5): From medium size to large Integument coarsely or finely pitted. Dorsum of pronotum cylindrical without lateral carinae. Fastigium of vertex trapezoidal or rounded. Elytra and wings fully developed or shortened. Epiphallus large to bridge shaped, not divided with small to moderately large ancorae and smaller large lophi. The genus known in India by seven species of which the following three are major pests of paddy, jowar, maize and millets in India. The genus is distributed in Africa and south eastern Asia.

1. ***Hieroglyphus banian* (Fabricius, 1798)**

Diagnosis: Of medium size, Integument finely rugose and pitted. Fastigium of vertex as broad or long. Tegmina and wings reaching end of abdomen. Male cercus bifurcate with upper branch of fork recurved anteriorly towards head and lower branch elongate and acute. Lower valves of ovipositor long and slender with external lateral projectors well defined and acute. Size ♂ in mm: Male 31.3 - 38.4; ♀ : Female 41.6 - 53.6.

General Distribution (Fig. 6): This species is widely distributed in India, Bhutan, Bangladesh, Burma, Vietnam, Thailand and China (Mason, 1973).

Economic Importance: *Hieroglyphus banian* is a major pest of rice and is common in India. It starts attacking the crop when it is still young and continues till it ripens. The young and adult grasshoppers feed on the leaves. When the crop is in advanced stage of growth, they cause further loss by nibbling the tender florets or gnawing into their base. There is only one generation in a year. The nymphs are found from June to July to about end

of September-October, the adults becoming mature middle of November during which month they lay eggs in the soil, mostly at the bunds. They over winter in the egg stage. In the following year, in the wake of good monsoon showers, young hopper emerge and feed on the grasses on the bunds for some time and then paddy crop when it comes up. Thus there is only one generation per year.

2. *Hieroglyphus nigrorepletus* Bolivar, 1912

General Diagnosis: Colouration buff with yellowish buff patches. Large and robust. Integument shallow, pitted, shiny. Tegmina and wings extending beyond end of abdomen, Pronotum with sides markedly expanded in metazona, dorsum with characteristic black pattern connecting all sulci by two irregular stripes. Male cercus with elongate acute apex, oblique on upper margin. Female sub-genital plate without parallel ridges. Size Male : 30 mm - 42.7 mm; Female : 37.5 - 48.2 mm.

The species has such characteristic markings on pronotum and shape of male cerci, that it is difficult to confuse with other species. It varies greatly in body size and occurs in two forms commonly short winged (brachypterous) and a rare long winged (macropterus) one. The degree of black marking on the pronotum is also variable. The hind tibiae varies from bluish green to pale buff.

General Distribution (Fig. 7): The species is found all over northern and southern India and Pakistan, east to and including Bihar and Orissa, north to Kashmir and west to southern Baluchistan; apparently confined to plains and low plateaus (Roonwal, 1976).

Economic Importance: *Hieroglyphus nigrorepletus* is polyphagous and is an important pest of several Kharif (rainy season) grain and other crops, especially millets, and for a shorter period, of some rabi (winter season) crops. It also damages rice, sugarcane, pulses, oil seed crops, grasses etc. (Mason, 1973; Roonwal, 1976).

Life-history: There is a single annual generation; eggs laid in August and September undergo a long diapause and hatch next June and July after a long overwintering and oversummering of 10-11 months. A few eggs, however have a longer diapause, of 22-23 months and there is a 2 year life cycle. Hoppers becomes adult in about 7-12 weeks (Roonwal, 1976).

3. **Hieroglyphus oryzivorus** Carl, 1916

Diagnosis: Of medium size. Integument finely and shallowly pitted. Hairy on ventral, surface. General colouration pale green or buff with yellowish brown patches. Epiphallus with lobi-form lophi and with an extra parallel lobe facing the centre of the bridge.

Distribution: This species is distributed in Gujarat, Maharashtra, Andhra Pradesh, Orissa and part of Madhya Pradesh adjoining Orissa, Rajasthan. This species is also known from Pakistan (Fig. 8).

Bionomics: There is very little published information about this species. The eggs are laid from the middle of September to the middle of November at a depth of 2-5 inches in the soil and develop the following June and July. The nymphs hatch in July and pass through six instars before becoming adult. There is only one generation a year (Mason, 1973).

Economic Importance: The food plants of economic importance are rice, jowar and sugarcane but *H. oryzivorus* is primarily a serious pest of paddy.

Apart from the above mentioned species which are important pests there are numerous others genera which are common in India, feeding on crops and grasses inhabited by pastoral communities intimately dependant on natural grazing land for their existence.

The following are the main genera:

1. *Acrida*; 2. *Atractomorpha*; 3. *Pyrgomorpha*; 4. *Truxalis*; 5. *Acrotylus*; 6. *Oedaleus*; 7. *Gastrimargus*; 8. *Aolopus*; 9. *Phlaeoba*; 10. *Trilophidia*; 11. *Ceracris*; 12. *Coptacra*; 13. *Eucoptacra*; 14. *Teratodes*; 15. *Oxya*; 16. *Gesonula*; 17. *Spathosternum*; 18. *Eyprepocnemis*; 19. *Heteracris*; 20. *Catantops*; 21. *Stenocatantops*; 22. *Xenocatantops*; 23. *Cyrtacanthacris*; 24. *Patanga*.

CONCLUSION

Damage to grazing land is therefore an important factor in the economics of these areas. Damage to grazing is difficult to assess quantitatively and even when assessed, difficult to express in economic terms. The amount of damage caused by grass hoppers to crop is a function of number of complex variable such as amount of vegetation eaten daily by a single insect differences in food preference between species, the fluctuation of population sizes, etc.

In estimating the effect of crop damage upon the economy of a country a distinction must be made between subsistence and cash crops, which require different evaluation. Cost benefit ratios for control campaign can only be evaluated when both the immediate and long term effects of control on grasshopper population dynamics have been measured and crop damage more accurately estimated. New grasshopper problems are created and existing are aggravated by agricultural developments in areas of natural vegetation (Bullen, 1966).

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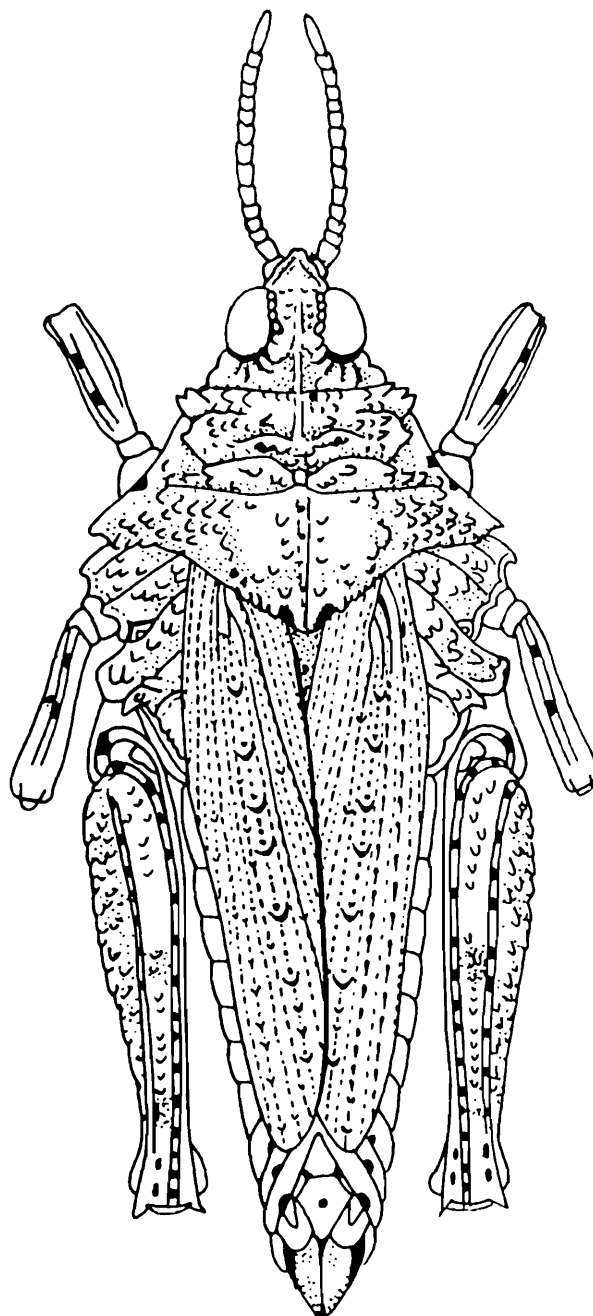


Fig.1 Genus *Chrotogonus*, dorsal view

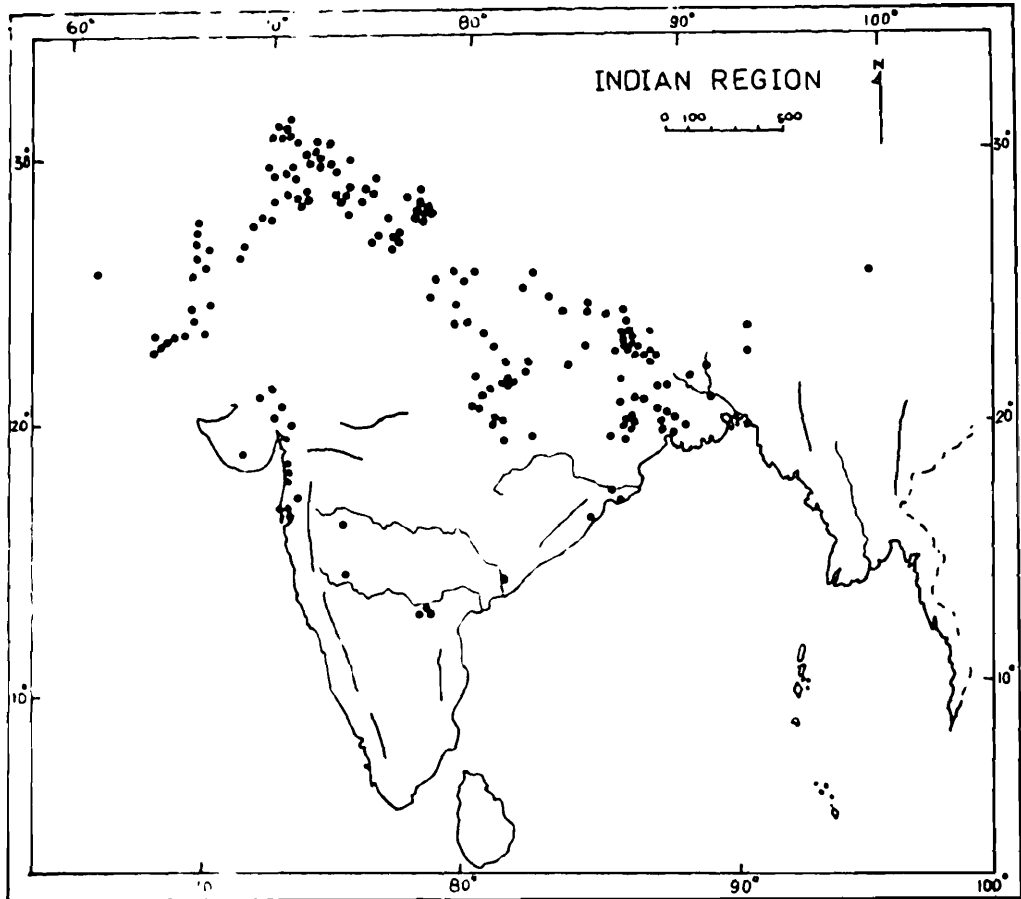


Fig. 2. Known distribution of *Chrotogonus (Cr.) tr. trachypterus* (Blanchard)

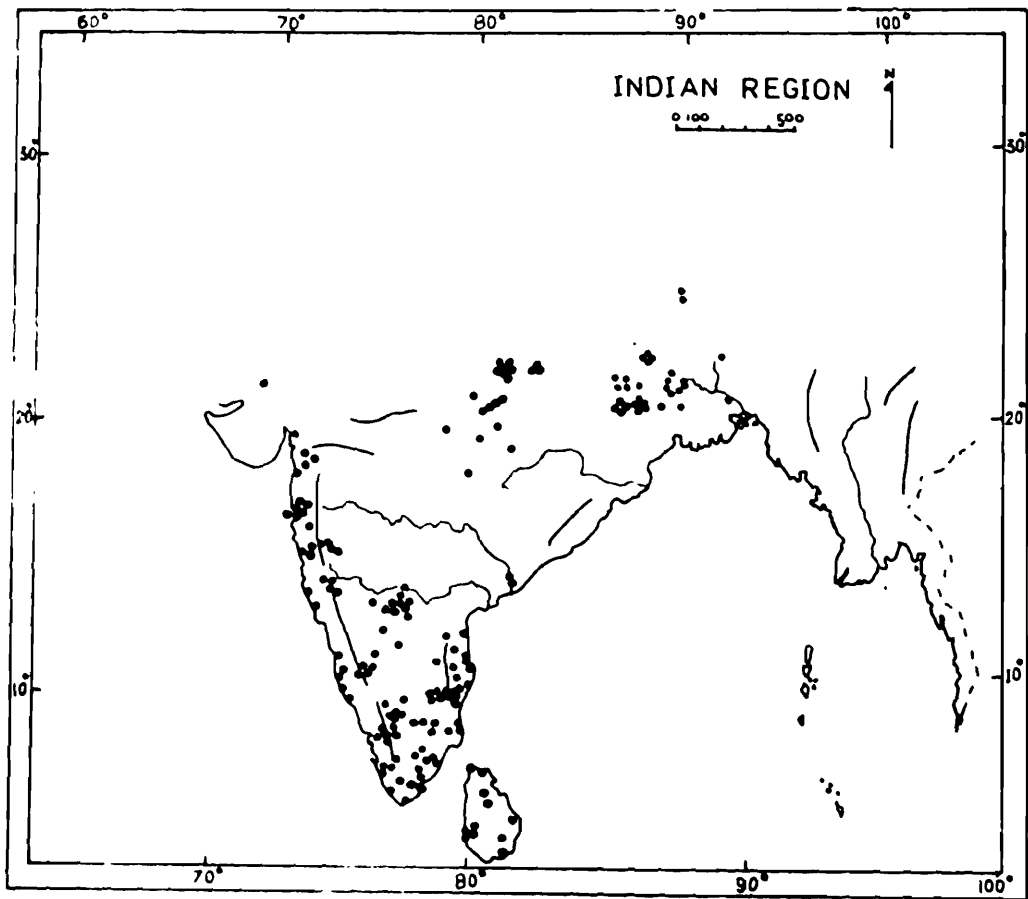


Fig. 3. Known distribution of *Chrotogonus (Cr.) oxypterus* (Blanchard)

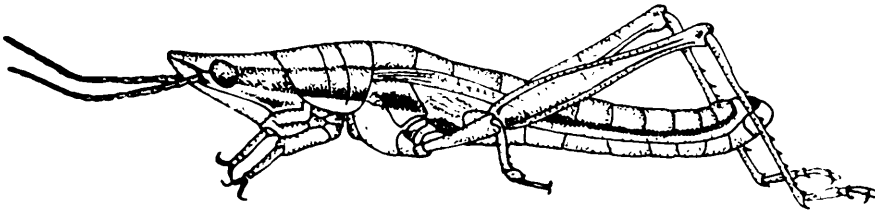


Fig. 4. *Colemania sphenarioides*, side view

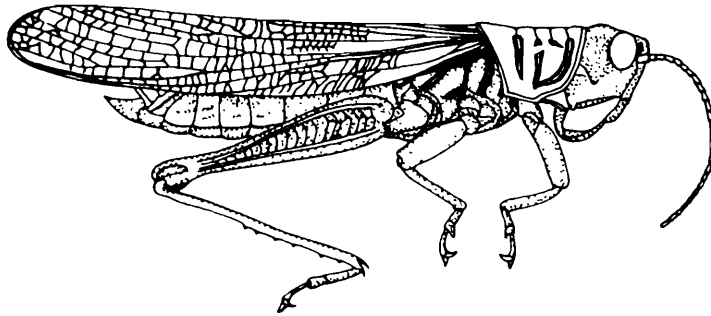


Fig. 5. Genus *Hieroglyphus*, side view

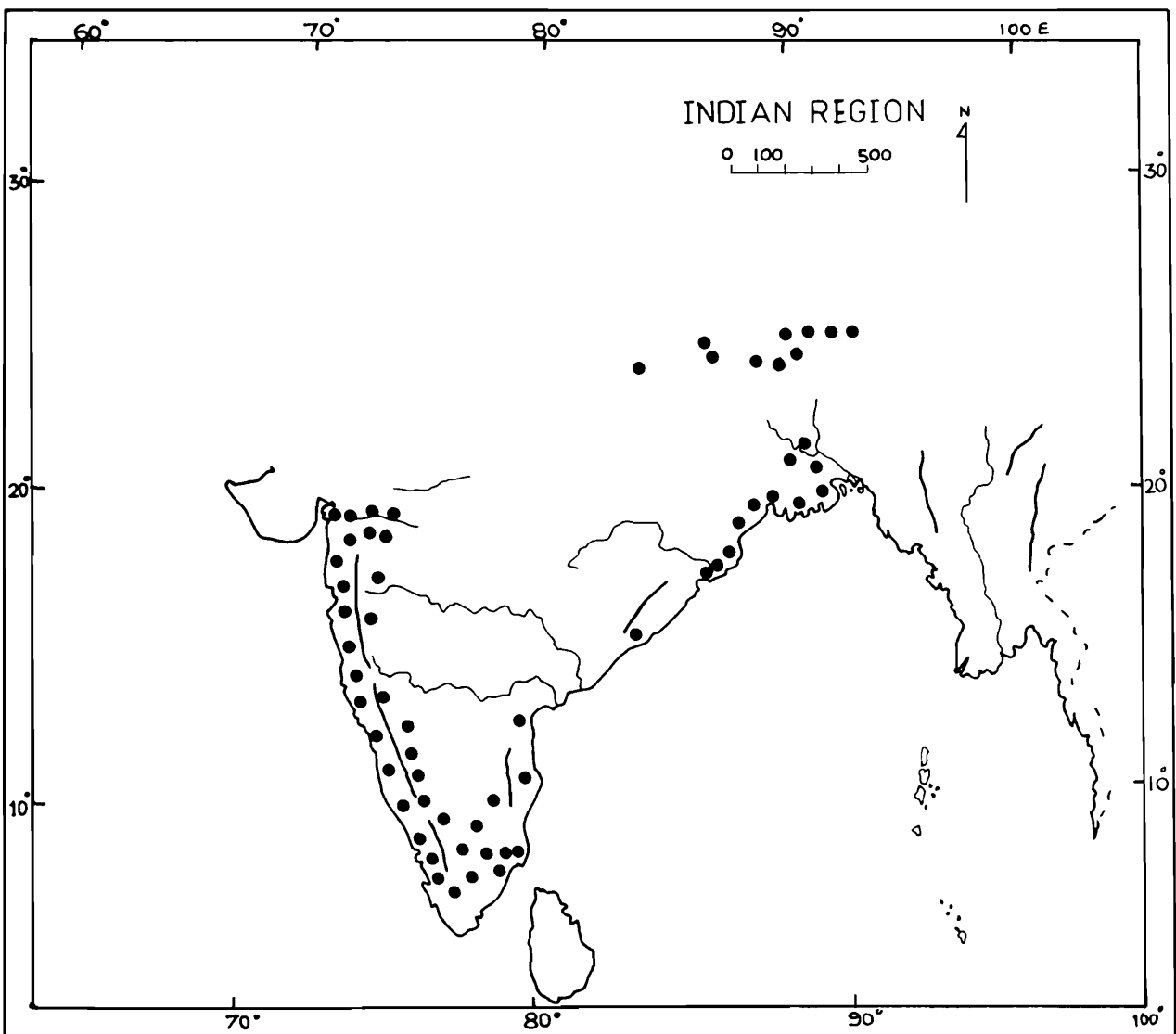


Fig.6 Known distribution of *Hieroglyphus banian* (Fabricius)

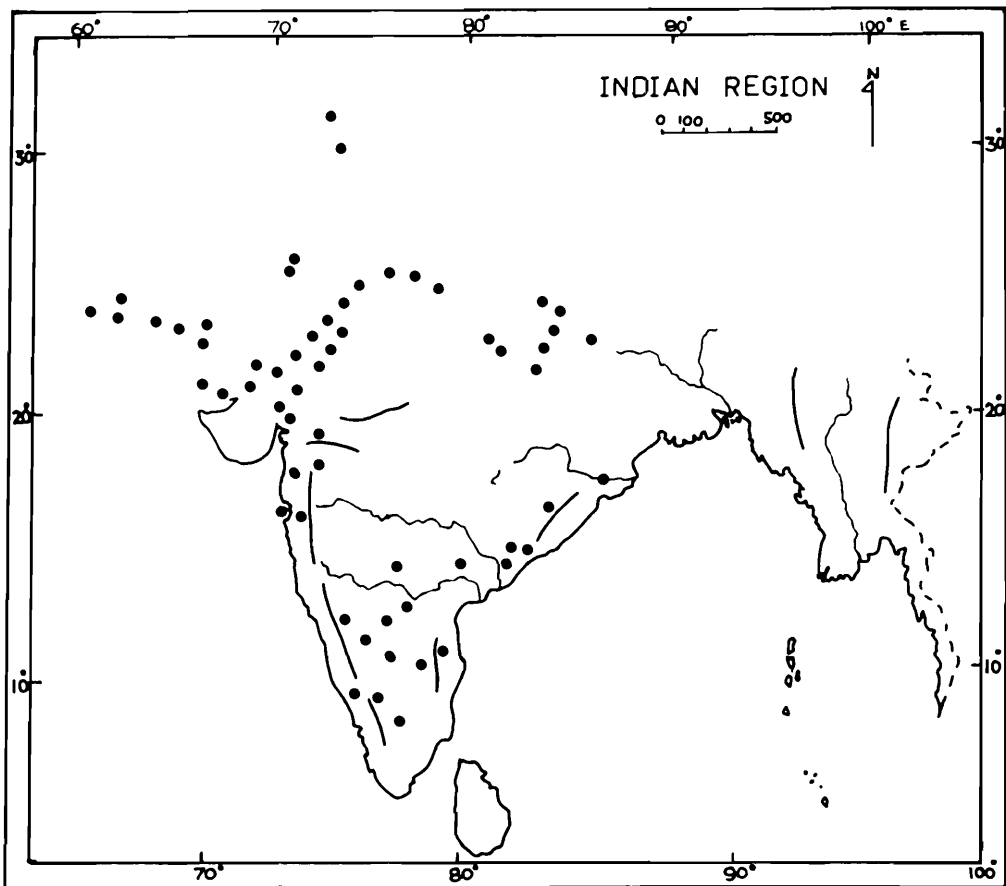


Fig. 7. Known distribution of *Microglyphus nigrorepletus* Bolivar

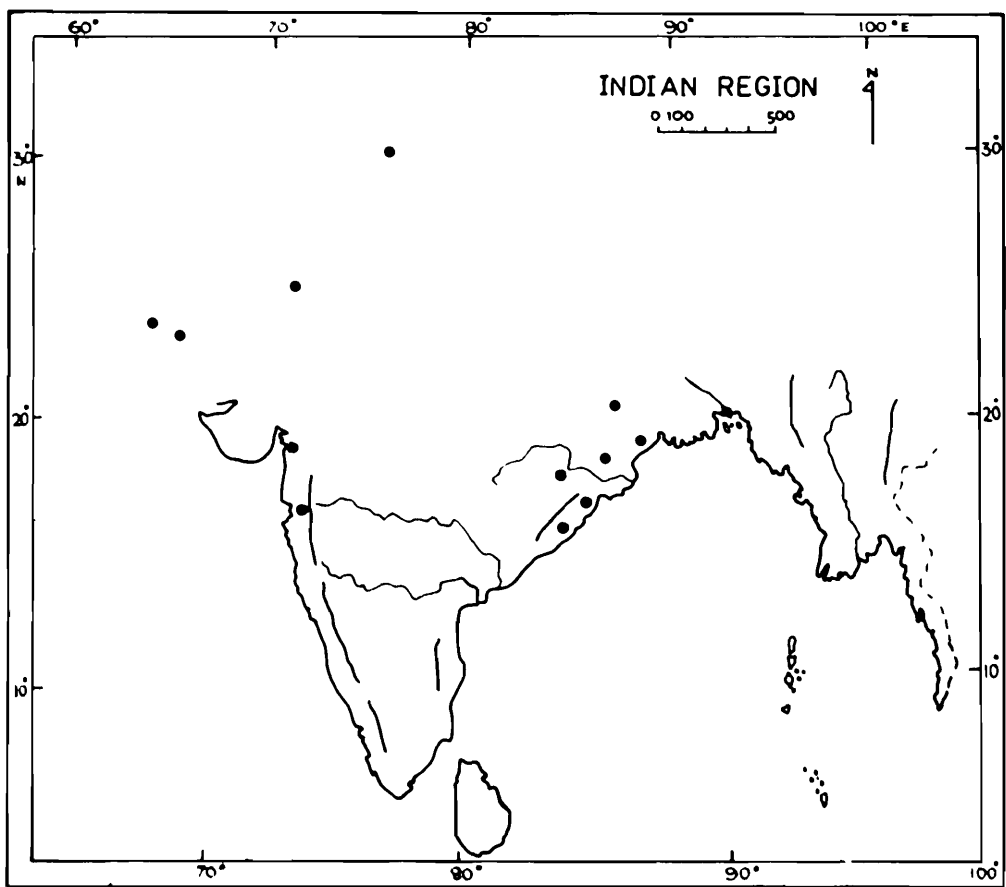


Fig. 8. Known distribution of *Microglyphus oryzivorus* Carl.

COLLECTION, PRESERVATION AND IDENTIFICATION OF DERMAPTERA (INSECTA)

G.K.Srivastava

Dermaptera or earwigs comprise fascinating group of tropical and subtropical insects with the exception of a few species found active even at great heights on snow. They are mainly characterised by the presence of three segmented tarsi and a pair of chitinous, unsegmented cerci at the hind end of body, commonly known as forceps. A little less than 2000 species of this Order, distributed all over the globe, are recorded. Besides 24 species of fossil Dermaptera are also known. Earliest fossil recorded, *Protodiplatys fortis* Martynov, dates back to Jurassic period from Turkestan near the village Galkino, East Karatsu.

COLLECTION AND PRESERVATION

Because of their nocturnal and secretive habits it is not often easy to collect a large number of species in nature. Although they are considered as subsocial often solitary males, females and even nymphs are met with. Parental care is quite common and females could be observed in field guarding eggs or early nymphal stages.

They occur in a variety of habitats such as dead and decaying matter, debris, under stones, in flowers, under the loose bark of dead decaying logs and stems of standing trees, under bamboo scales, banana sheath, in leaf axil and sometimes even in bird's nests. A number of species are fimicolous as well.

Generally, various species prefer a particular habitat where they occur more commonly but it is not unusual to find them in other habitats also. However, a little moisture is always necessary for their survival.

The members of Labiduridae, especially genus *Forcipula* Bolivar, occur under the stones on the edge of ponds, streams and river. Some of the species though denizens of sub-montane habitat are able to penetrate deep inside Himalayan ranges while

occurring along the edge of water courses. One of the most suitable habitat appears to be under the bark of trees for most of Labiidae owing to their flattened body. Majority of Chelisochidae are reported occurring either in above habitat or in the leaf axils. Besides several other species are attracted to light.

Hand picking by means of forceps is one of the convenient methods for their collection. But several species are so agile, they try to escape with slightest disturbances which makes them difficult to collect in this manner. In order to make them partially inactive for picking, it is desirable to smear the specimens with spirit. It could be easily achieved by pressing them gently with a small cotton swab soaked in rectified spirit. Sweeping over vegetation with the help of any convenient insect net is quite rewarding for the collection of a large number of species visiting flowers and lurking in foliage.

The specimens may be killed by dropping them directly in spirit or any other standard killing bottle in vogue. For temporary preservation it is advisable to keep them in rectified spirit which facilitates the extraction of genitalia. The only disadvantage of retaining material in spirit for long results in decolorisation and great distention of body segments.

The material is finally dried, pinned and arranged in drawers for permanent storage. A small card is generally passed on the pin below the specimen to give support to abdomen which tends to break off with slight jerk. Smaller specimens could be mounted on a small card with any water soluble adhesive so that when required specimen could be removed for examining ventral side. The information regarding locality data, date of collection and any other information which may be of taxonomic importance is provided on label and pinned with each specimen.

It would be worth digressing a little to point out favourable areas in India for the collection of Dermaptera. In view of their hygrophilous nature they are quite abundant on the forested slopes of Himalayas and windward side of Western Ghats. There are a number of species which occur above 3000 m in Himalayas and exhibit marked palaeartic affinities. In Peninsular India, especially along the Western Ghats and on certain hill tops of Eastern Ghats, several species are concentrated due to shrinkage of their habitats. Perhaps this may be true for the various plains of India where only common, widely distributed species could be found.

IDENTIFICATION

For the general identification of any group the best way is to consult some monographic work, if available. Besides, catalogues and check-list are also quite useful for retrieval of valuable information on the subject. Some of the important references are listed at the end which will be of use to workers for the determination of Indian species of Dermaptera.

In order to gain efficiency in identification an intimate knowledge of various morphological characters used in the taxonomy of the group should be acquired by studying authentically determined collections by specialists and comparing them with unidentified ones.

Unfortunately the taxonomy of the whole Order is based on male genitalia which is used at present extensively for separating all levels of taxonomic categories. However, for the discrimination of species, genitalia in combination with various external characters is quite useful. This reduces the risk of placing too much reliance on external characters which exhibit a great range of intraspecific variation.

For genera external morphology, the accompanying figures may be referred.

Following key (partly modified from Steinmann, 1975) will be useful for the separation of super and subfamilies represented from Indian subcontinent:

- 1(8). Neck blattoid type, i.e., anterior and posterior cervical sclerites anterior to prosternum separated from each other but hind margin of posterior sclerite may be separate or fused with apical margin of prosternum; male genitalia with two functional distal lobes, sometimes one of them reduced.....
..... Pygidicranoidea (=Pygidicranidae)
- 2(3). Antennal segments 4-5 transverse, 25 segmented or more
..... Pygidicraninae Verhoeff
- 3(2). Antennal segments 4-6 longer than broad, 20 segmented or less than that
- 4(5) Femora compressed with sharp longitudinal ridges; male genitalia with parameres armed internally in various ways
..... Diplatyinae Verhoeff

- 5(4). Formora not compressed, usually smooth, occasionally with a faint ridge; male genitalia with parameres simple (unarmed)
- 6(7). Body convex, covered with thick characteristic setae and long pubescence; femora occasionally with a faint ridge; pygidium with hind margin projecting; forceps cylindrical Echinomatinae Burr
- 7(6). Body depressed, glabrous and smooth; femora devoid of any ridge; pygidium vertical with hind margin not projecting; forceps trigonal in basal one third, afterwards depressed Prolabiscinae Bey-Bienko
- 8(1). Neck forficuloid type, i.e., anterior and posterior cervical sclerites fused and the hind margin of latter joined with anterior margin of prosternum; male genitalia with one or two functional lobes, sometimes one of them reduced
- 9(30). Male genitalia with two functional distal lobe, often one of them reduced or atrophied
- 10(29). Pygidium in both sexes vertical with its hind margin not free; forceps partially trigonal near base and moderately depressed afterwards or cylindrical..... Carcinophoridae
- 11(24). Male genitalia, if virga present, usually not wider at base and without a sinuous inner tube; otherwise denticulate pads present Carcinophoridae Popham
- 12(13). Body strongly depressed; male forceps strongly curved, female ones elongated..... Platylabiinae Burr
- 13(12). Body not so strongly depressed, weakly or strongly convex; forceps various
- 14(5). Meso- and Metasternum oblong and both with posterior margin convex or tongue shaped Titanolabiinae Srivastava
- 15(14). Meso- and Metasternum quadrate, former briefly convex or truncate posteriorly and latter narrowed posteriorly with hind margin truncate
- 16(17). Mesosternum briefly convex posteriorly Carcinophorinae Hincks

- 17(16). Mesosternum truncate posteriorly
- 18(21). 1st antennal segment longer than the distance between antennal bases
- 19(20). Mesonotum laterally with a well defined ridge
..... Brachylabiinae Burr
- 20(19). Mesonotum without any ridge laterally (occasionally a blunt fold may be present)..... Isolabiinae Steinmann
- 21(18). 1st antennal segment shorter than the distance between antennal bases
- 22(23). Male genitalia with one of the distal lobes atrophied with virga much reduced Isolaboidinae Brindle
- 23(22). Male genitalia with both distal lobes and virga well developed..... Parisolabiinae Verhoeff
- 24(11). Male genitalia with virga distinct, dilated at base with a distinct inner sinuous tube..... Labiduridae Verhoeff
- 25(26). Mesosternum strongly narrowed posteriorly with tip extending up to middle of metasternum..... Allostethinae Burr
- 26(25). Mesosternum posteriorly wider, not strongly narrowed posteriorly
- 27(28). Elytra with a sharp ridge along the costal margin; legs relatively short, posterior femora not longer than pronotum Nalinae Steinmann
- 28(27). Elytra without any sharp ridge along the costal margin; legs longer, posterior femora longer than pronotum..... Labidurinae Burr
- 29(10). Pygidium in both sexes forming a flat process with hind margin free; forceps with branches broad and flat.....
..... Apachyoidea (=Apachyidae Verhoeff)
- 30(9). Male genitalia with one functional, median distal lobe
..... Forficuloidea
- 31(36). Second tarsal segment simple Labiidae Burr
- 32(33). Body strongly depressed; pronotum anteriorly narrowed forming a sort of neck..... Sparattinae Burr

- 33(32). Body may be weakly depressed or convex
- 34(35). Third antennal segment longer than the fifth, eyes usually large and elytra glabrous and smooth or occasionally finely pubescent..... Spongiphorinae Burr
- 35(34). Third antennal segment almost equal or shorter than the fifth; eyes usually smaller (excepting *Irde*); elytra generally punctured and pubescent..... Labiinae Burr
- 36(31). Second tarsal segment dilated or produced in the form of a narrow lobe below the third segment
- 37(40). Antennae 17-22 segmented; second tarsal segment spiniform, extending below up to the middle of third, visible from sides only..... Chelisochoidea Burr
- 38(39). Elytra along the costal margin with a sharp ridge, often not complete Chelisochoidea Steinmann
- 39(38). Elytra along the costal margin without any ridge..... Chelisochoidea Burr
- 40(37). Antennae 12-16 segmented, second tarsal segment lobed, visible from above on either side third segment Forficulidae Stephens
- 41(44). Antennal joints long and slender, 4th longer than the 3rd or almost equal, both of similar build, i.e. slender
- 42(43). Elytra with a sharp ridge along the costal margin..... Cosmiinae Steinmann
- 43(42). Elytra without any ridge along the costal margin. .. Opisthocosmiinae Verhoeff
- 44(41). Antennal joints shorter and wider, occasionally apical ones long and slender, 4th shorter or almost equal to 3rd but former always wider
- 45(48). Mesosternum broader than long
- 46(47). Elytra with a sharp ridge along the costal margin. Allodahliinae Verhoeff
- 47(46). Elytra without any ridge along the costal margin Anechurinae Burr

- 48(45). Mesosternum about as broad as long
- 49(50). Forceps generally curved or elongated, cylindrical, not deplanate at base Eudohrninae Burr
- 50(49). Forceps in most of the species deplanate in basal half or less, afterwards cylindrical or depressed.
..... Forficulinae Burr

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PLATE I

External features of taxonomic importance

Male

Fig. A. Showing external features.

Fig. B. Thoracic sternites.

Fig. C. Penultimate sternite.

Fig. D & E. Genitalia.

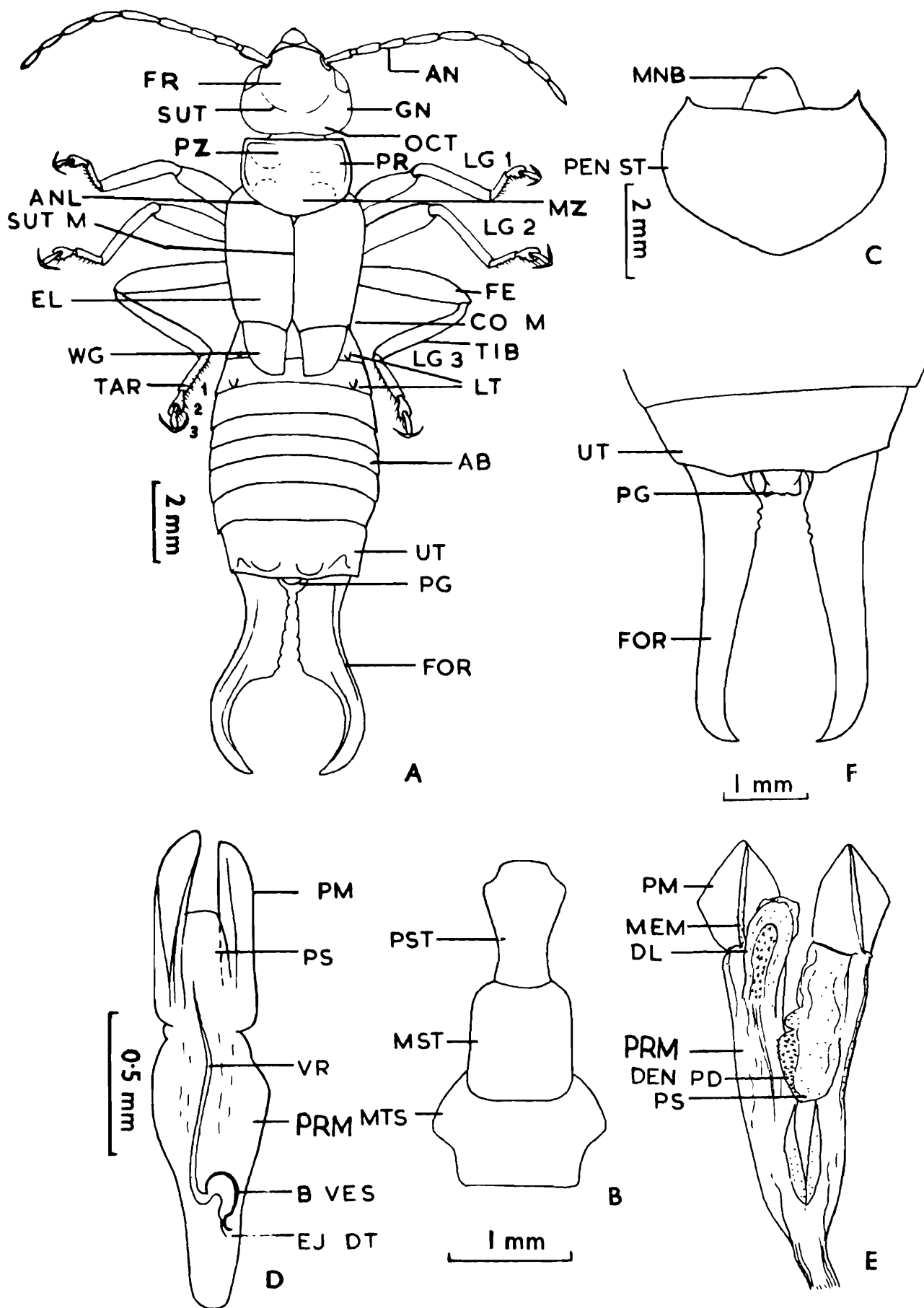
Female

Fig. F. Ultimate tergite and forceps.

Abbreviations

AB. Abdomen; AN. Antenna; ANL. Anal angle; B.VES. Basal vesicle; CO.M. Costal margin; DEN.PD. Denticulated pad; DL. Distal lobes; EJ.DT. Ejaculatory duct; EL. Elytra; FE. Femur; FOR. Forceps; FR. Frons; GN. Gena; LG1 Fore leg; LG2 Middle leg; LG3 Hind leg; LT. Lateral tubercle; MEM. Membrane; MNB. Manubrium; MST. Mesosternum; MTS. Metasternum; MZ. Metazona; OCT. Occiput; PEN.ST. Penultimate sternite; PG. Pygidium; PM. Paramere; PR. Pronotum; PRM. Proparamere; PS. Preputial sac; PST. Prosternum; PZ. Prozona; SUT. Suture; SUT.M. Sutural margin; TIB. Tibia; TAR. Tarsus (1,2,3 tarsal segments); UT. Ultimate tergite; VR. Virga; WG. Wing.

Figures D and E on same scale.



TERMITES IN AGRICULTURE

O.B.Chhotani

INTRODUCTION

Depredations caused by termites are of an immense nature, particularly in the tropical regions of the world. In the subtropical and subtemperate parts also the damage caused by these tiny insects is of quite an extensive nature.

"Some primal termite knocked on wood,
tasted it and found it good.
So that was why your cousin May,
fell through the parlour floor today"

This quotation of Ogden Nash is true of the wood-destroying termites, the damage of which is so severe that whole of the wooden structures are eaten away leaving intact only the outer thin covering of the infested woods. These insects are well known pests of forestry and a number of species of forest trees are subjected to their damage.

So far as the damage to agriculture, the termites are considered to be serious pests of wheat, maize, sugarcane, groundnut, vegetable and flowering plants, tea, fibre crops such as cotton, jute and sunn - hemp, fruit trees and rubber plantations.

There are no recent statistical data on the losses caused by these insects to agriculture but Fletcher (1912) estimated an annual loss of Rs. 280 million worth of grain crops alone and Agarwala (1955) estimated a loss of 2.5 per cent in cane tonnage and 4.5 per cent in sugar output in the state of Bihar alone due to one particular species, *Microtermes obesi* Holmgren. So severe a damage to sugarcane has been reported in certain parts of Rajasthan (Kushwaha, 1961) that the entire crop had to be destroyed to check further infestation. In Uttar Pradesh 30-50 per cent eye-buds have been reported to be destroyed by termites resulting in yield reduction. The propensity of the losses caused by termites can easily be made out from these few estimates and it may be said to be running into hundreds of crores of rupees, annually.

TERMITES DAMAGING AGRICULTURE IN INDIA

In India termites of families Kalotermitidae, Rhinotermitidae, Stylotermitidae and Termitidae are reported to cause damage to agricultural crops. Of nearly 2000 species known from the world, about 300 are recorded from India and 38 are reported to be pests of some consequence. For the identity, distribution and pest status, reference may be made to the technical monograph on "Termites Pests of Agriculture in the Indian Region and their Control" by Chhotani (1980), wherein field key for identification of the species, their diagnostic characters, distribution, biology and ecology, pest status and hosts from which recorded, are given in details.

DAMAGE TO AGRICULTURE CROPS

Wheat : Wheat is the major cereal crop in northern India. The important species reported damaging wheat crop are *Odontotermes obesus* (Rambur), *Microtermes obesi* Holmgren and *Trinervitermes biformis* (Wasmann). The damage is caused generally at germinating or during earhead stages. The species *Microtermes obesi* feeds on roots of seedlings and causes yellowing or wilting of leaves; it is reported to cause loss up to 25 per cent, with an average of 6 per cent. Generally "Barani" wheat is damaged the most while there is no or not much loss caused to irrigated crops. Seed treatment/dressing with organic hydrocarbons has yielded some good results and there are reports of an increase of 55.9 per cent from fields in Gujarat (Patel, 1962) and from 625 kg in control field to 1475 kg per hectare in Madhya Pradesh (Bindra, 1961). Aldrine and Dieldrin are reported to stimulate growth and tillering while BHC, Lindane and Chlorodane inhibit growth.

The common mound-builder species, *Odontotermes obesus*, is one of the major pests of wheat and it is advisable to destroy the mounds in the vicinity of fields by pouring water suspension of 0.005 per cent BHC at the rate of 9000 cc per 10 cu.ft. of mound volume as recommended by Roonwal and Chatterjee (1962). The mound destruction and seed treatment with 5 per cent Aldrine at the rate of 20-40 lbs per hectare are very effective for increasing the yield of wheat.

Paddy : Paddy is generally not subjected to termite damage, there is, however, a report of *Microtermes* sp. damaging autumn paddy crop in Maldah District of West Bengal. Pre-sowing soil treatment with insecticides showed good results as against 80 per cent damage in untreated plots (Ghosh, 1964).

Maize, millets & pulses : It is reported that maize is often seriously damaged in infested areas of Bihar; maize, jowar and red gram (arhar) in Madhya Pradesh; and maize, jowar and gram in Rajasthan. There are no estimates of loss but it appears to be quite high in unirrigated conditions. The common species involved are *Odontotermes obesus* and *O. gurdaspurensis* in Rajasthan and *Microtermes obesi* in Bihar. Damage is caused to Jowar seedlings of 2-3 leaf stages and the destruction is maximum in plants of less than 15 cm height. The maize plant stem is damaged and filled with earth thus blocking the food supply to the plant.

The damage to pulses has been reported to be heavy in sandy soils and rain fed areas of Punjab. The extent of damage may be in the range of 10 per cent in certain districts.

Not much attention has been paid to the control of these crops from termite damage, however, 0.2 lbs Aldrine and 0.25 lbs Dieldrine per acre mixed in top layers of soil in case of maize and 10 per cent BHC at 25 kg per hectare in case of pulses, have given good results, in experimental plots.

Groundnut : The groundnut crop is attacked by *Odontotermes obesus*, *O. wallonensis*, *Microtermes obesi* and *Trinervitermes biformis*. The termites penetrate the stem causing the plant to wilt. The seed-pods are also eaten. In the untreated plots damage up to 35 per cent has been reported and soil treatment with insecticides and seed dressing with insecticides are good remedies.

Sugarcane : The loss to sugarcane, due to termite infestation, is reported to be very heavy as has already been mentioned above and as such these insects are supposed to be very serious pests of sugarcane in our country. The damage to the cane is at two stages, first at the sowing time during the pre-monsoon period when the termites infest the eye buds and sett-ends causing the failure of germination and secondly during post-monsoon period when the stalks are attacked leaving behind only the soil-filled stems.

The species reported from sugarcane in India are *Coptotermes heimi*, *Odontotermes assmuthi*, *O. obesus*, *O. wallonensis*, *Microtermes obesi* and *Trinervitermes biformis*. Treatment of cane-setts with Dieldrin/Chlorodane and application of these insecticides in furrows are reported to not only prevent the termite infestation but also stimulate germination. There are claims of enhancement of germination from 23-52 per cent and yield from 900 to 1200 maunds per acre in experimental plots.

Tea : *Microcerotermes* spp., *Odontotermes obesus*, *O. parvidens*

and *Microtermes obesi* are reported from tea from North-eastern India and *Postelectrotermes bhimi* and *Coptotermes ceylonicus* from southern India. The damage to tea in Sri Lanka has also been reported to be quite extensive. Infestation of 50-100 per cent of bushes in Darrang and Cachar and 15 per cent of loss in the annual production of tea are reported (Das, 1962).

Treatment of soil with insecticides, destruction of termites mounds in the plantation areas and elimination of dead and infested woods and bushes for the control of soil termites and introduction of insecticides under pressure in the bushes, for wood termites, are recommended.

Fibre crops : There is a considerable damage to cotton due to termites at germinating stage under unirrigated conditions, in Rajasthan and the species reported are *Odontotermes obesus*, *Microtermes* sp. and *Eremotermes* sp., in Rajasthan Canal Command Area. The damage ranges from 1.1-15.7 per cent in different varieties. In Gujarat, two species *O. obesus* and *Trinervitermes biformis* are reported from cotton. The germinating cotton, roots of seedlings, roots and stems of mature plants and seeds are liable to termite attack. Seed dressing with insecticides has not be found to be effective in the control of termites in cotton fields as is true in case of wheat and maize, but soil treatment with Technical Sevin and Technical Heptachlor at 10 and 15 lbs per acre and drilling experiments with 5 per cent BHC at 56 lbs per acre have been found to give good results in case of "Barani" cotton with an appreciably high yield of seed cotton and lint.

Jute being a crop of wet areas is not much damaged by termites, the only species recorded is *Microtermes obesi* which damages the roots and stem. Aldrin wettable powder with a concentration of 0.04 per cent at 35 gallons per acre applied about 15 cm below ground level has been found to be effective against termite incidence.

Sunn-hemp has been found to be attacked by *Odontotermes obesus* at Sunn-hemp Research Station, Partapgarh (Uttar Pradesh), during drier months. There are no records in respect of the extent of damage and the control measures adopted to check termite infestation.

Fruit trees : Almost all the fruit trees are liable to termite attack in our country except in higher elevations. Mango is the main fruit tree all over the country and it has been found to be attacked by a very large number of species of termites including both wood and soil-inhabiting forms. Mainly the stem is attacked and the termites eat away the softer parts leaving the trunk completely hollowed out. Same is the case in respect of other fruit trees.

To prevent the damage by subterranean species it is suggested that the soil in the fruit gardens be treated with insecticides, all the infested woods be removed and destroyed by burning and the mounds in the vicinity be destroyed as suggested in case of tea above. It is difficult to check the wood-destroying termites from infesting the fruit trees but on detection of the infestation, water dispersible insecticides be inserted under pressure through the damaged portion. This will destroy the termite colonies inside the trees.

CONCLUSIONS

Since termites usually work in concealment, the damage caused by them goes unnoticed for a pretty long time. Because of this reason the control measures are not adopted in time. The major harm to the agriculture is due to the soil-inhabiting species, as such soil treatment and seed dressing, as suggested, should be adopted as routine anti-termite measures in the areas where these insects abound and particularly in the unirrigated fields.

It may be seen that only insecticidal control measures are suggested and tried in experimental conditions since no other methods are possible due to the underground and concealed activities of these insects. Use of insecticides adds to environmental pollution but until some other control methods are found we have to depend on judicious use of insecticides. Some researches however, are being carried out on hormonal control which if could be used in the field, will save us from pollution hazards.

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COLLECTION, PRESERVATION AND IDENTIFICATION OF HEMIPTERA

B. Dutta and R.C. Basu

BRIEF INTRODUCTION TO ORDER HEMIPTERA

I. The Order Hemiptera is comprised of two Suborders - Heteroptera and Homoptera. The forewings of Heteroptera are usually thickened basally and membranous apically and usually wholly membranous in Homoptera. Heteroptera involves two series namely Cryptocerata and Gymnocerata. The antennae in Cryptocerata are shorter than head and concealed in grooves beneath eyes' but longer plainly visible in Gymnocerata. The majority of common aquatic bugs pertains to Cryptocerata (nec Gerridae) and Gymnocerata includes majority of common terrestrial bugs. Gymnocerata is further subdivided into Amphibicorisae (Sup. fam Gerroidea) and Geocorisae include terrestrial or arboreal families. Homoptera covers the families namely Cicadellidae (=Jassidae), Fulgoridae, Cercopidae, Membracidae, Aphididae, Coccidae, Aleyrodidae etc. The suborder Homoptera is divided into two series. Those insects having 3 segmented tarsi and rostrum arising from ventral base of head are put under Auchenorrhyncha and those having one or two segmented tarsi and rostrum arising between legs (fore) are placed under Sternorrhyncha (Hymenelytra). The common families as Membracidae, Cicadellidae, Fulgoridae, Cicadidae, Cercopidae belong to series Auchenorrhyncha whereas the families like Chermidae (psyllidae), Aleyrodidae, Aphididae, Coccidae, Diaspididae etc. pertain to Hymenelytra.

II. The insect order Hemiptera includes a number of features, especially is the lengthwise projection of mouthparts into an elongate sucking beak. In most cases this is directed hindwards under the head.

In Heteroptera the dorsal surface is flattened and both pairs of wings lie flat over abdomen at rest. The forewings usually are hardened in basal half and dorsal half is membranous. Some Heteroptera (bed bugs) both pairs of wings are absent, in others they are reduced or very small size but affinities remain flattened shape in structure of head. In Homoptera both wings are usually completely membranous, held in a roof - like on body at rest.

Principal differences between Heteroptera and Homoptera

1. Most Heteroptera are flattened.
2. Heteropteran basal half of forewings thickened, apical half membranous. Basal half is subdivided into two halves the part close to scutellum is known as clavus, the section away from scutellum is Corium (Fig. 1).
3. Rostrum (sucking beak) except Corixidae originates anteriorly on head.
4. Head behind eyes is constricted into a neck (collum).
5. The ocelli, if present, are two in number, either lie between or behind compound eyes, never in front of compound eyes.
6. Adults are usually with a pair of stink glands on each side of metapleura (Fig. 2).
7. Female genital opening is on 8th abdominal segment, male genital opening on 9th abdominal segment.

Homoptera are all plant feeders, some Heteroptera are carnivorous. Heteroptera are found under bark, on trunks, stems, leaves, in litter. Heteroptera are common in fresh water, the marine forms (Halobatinae - fam. Gerridae) are truly oceanic.

The body is divided into Head, thorax, abdomen. Head carries mouthparts, eyes, antennae. Stylets consist of outer pair (mandibles) serrated at apex, inner pair (maxillae). The stylets while feeding move in and out to saw an entry into the host. Labrum or upper lip lies as a conical process anterior to rostrum. Fig. 3.

Antennae are usually 4-5 segmented rarely more than 5 segmented. (six segmented) in Subfamily Ectrichodinae (fam. - Reduviidae) In land bugs (Geocorinae), a section of water bugs (Amphibicorisae) antennae free, prominent from beneath (Gymnocerata), in group of water bugs (Hydrocorisae) antennae short and concealed in pit or groove.

Thorax bears 2 pairs of wings usually, and 3 pairs of legs, first pair in some forms modified to grasp prey, in other form legs are modified as swimming appendages. The abdomen contains respiratory, excretory systems. the terminal segments form male and female external genitalia.

Rostrum is the prominent distinguishing character isolating Hemipteran from others insect orders.

METHODS OF COLLECTION

A number of methods are concerned with the collection of terrestrial and aquatic Hemiptera.

Terrestrial Hemiptera:

Nets: The basic design is a light handle fitted with a ring of a stout wire to which is fastened a nylon netting. Aerial nets are usually handled for catching insects in flight and sweeping nets are swept through vegetation unsettling loose and trapping many small insects.

Beating Sheet: A sheet of canvas is drawn out over a wooden frame, fastened tightly. It is gripped under a bush and with a stick the insects are unsettled loose on the tray, otherwise, an umbrella may be applied by positioning it upside down as 'beating sheet'.

Berlese Funnel: The Berlese funnel is handy for picking up small insects in debris which is disposed of into the funnel and a strong light is fixed on top, finally, the heat and light compel the insects to move right down the funnel into a jar of 70% alcohol (Fig. 26).

Light trap: Any source of light may be used to attract varied groups of aquatic and terrestrial bugs. The uniform method of periodical sampling may guide the worker to acquaint with the seasonal incidence of any specific group of interest.

Aspirator: This is a device to collect small insects from nets, 'beating sheet', places under stones and on vegetation (Fig. 27).

Aquatic Hemiptera: The nets and light traps are usual methods of collecting both terrestrial and aquatic Hemiptera.

PRESERVATION

The collections, terrestrial and aquatic, should either be kept dry in envelop or preserved in 70% alcohol.

SLIDE MOUNTING

The specimen (whole mount) or a part of abdominal tip (for genital armature) are cleared in 10% KOH for a period 24 hrs., or may be heated for 5-10 minutes. The material is placed in acetic acid to neutralise alkali. The body contents (whole mount) are removed under binocular. Then transferred to clove oil until it becomes transparent. Before the material is transferred for mounting, it is rinsed in xylol to remove oil. Mounting is done after precise arrangement of the structure or specimen on slide with a drop of canada balsam, finally a cover slip is put. In case of aphid specimens after dechitinization in 10% KOH solution quick method is followed by processing in chloral phenol solution, then placing the specimens into choral-hydrate gum arabic mixtures. The slides, then are put on hot plate for an hour to permit drying. Ringing is done with suitable cementing material.

After preparation of the slide, the necessary information is labeled on slide as locality, date of collection etc. It is to be noted that the materials should be sorted out in the laboratory and labeled with full data to facilitate identification of the specimens. Provided the worker feels inconvenient to identify the specimens, it is desirable to send the unnamed material to specialists for identification.

IDENTIFICATION

The following important characters may aid in identifying the common families and isolating the members of the families concerned.

Heteroptera

1. Tingidae: Pronotum almost or entirely covering scutellum, Ocelli absent, tarsi 2-segmented, hemelytra and thorax with raised lace-like reticulation (Fig. 4-8).
2. Reduviidae: Front legs raptorial (adapted for seizing prey), beak stout, curved, prosternum (sclerite between forelegs) with a groove to receive tip of rostrum (Assassin bugs), ocelli, when present, behind eyes.

3. Coreidae: Ocelli present, hemelytra with numerous prominent veins, antennal insertion above a line drawn from middle of eyes, genital structures useful in identifying species (squash bugs), antennae inserted on upper part of sides of head.
4. Pyrrhocoridae: Ocelli absent, robust (cotton stainers) antennae inserted below a line drawn from eye to apex of face.
5. Lygaeidae: Membrane with 4-5 longitudinal veins, antennae inserted either on or below a line drawn from middle of eyes, ocelli present usually, (chinch bugs), cuneus absent, abdomen without pore-bearing plate or disc.
6. Miridae: Ocelli absent but present in Subfamily Isometopinae (Dist. 1904 : 414), hemelytra with a distinct cuneus (triangulate area at end of embolium) (differentiated costal part of corium in forewing) (capsids, leaf bugs), antennae/rostrum 4-segmented.
7. Pentatomidae: Scutellum very large, triangulate or moderately rounded apex, antennae 5-segmented (shield bugs), unarmed or a few scattered spines on tibiae, smaller, drab colored, larger with alternating black and yellow stripes; pronotum laterally denticulate or serrate (Fig. 9-10).
8. Cydnidae: Tibiae armed with several rows of stout spines, apices of mid/hind coxae with closely set setae or pegs.
9. Scutelleridae: Enormously large brightly colored, scutellum covering abdomen, conceal wings (scutellum large but never cover entire abdomen in Pentatomidae), hind wing with a spur-vein (hamus) in basal cell : lateral margins of head, pronotum, anterior margin of corium spinose.
10. Gerridae: Ocelli present, (ocelli absent in Belostomatidae, Nepidae, Notonectidae), abdomen ventrally clothed with silvery pubescence (soft hair femora very long, exceeding apex of abdomen (water striders) claws of last fore tarsal segment inserted before apex, head linear, longer eyes remote from base (Hydrometridae), tarsi 2-segmented (Hebridae)(Fig. 11-12).
11. Mesovellidae: Body clothed with velvety pile, at least ventrally, (pile-hairy covering giving a surface appearance like velvet), hind femora scarcely surpassing abdominal tip, legs fitted for walking on water, tarsi 3-segmented (water striders), membrane without veins. The families Notonectidae, Nepidae, Belostomatide (series Cryptocerata)

easily differ from Gerridae and Mesovellidae (Gymnocerata) by absence of ocelli.

12. Notonectidae: Head set into prothorax, antennae 4-jointed, hind tibiae, and tarsi clothed with swimming hairs, abdomen with a median ridge (keel) (Back swimmers), fore tarsi never scoop-like, sometimes with 2-claws (Fig. 14).
13. Nepidae: Head set into prothorax, fore tarsi not fringed, hind coxae globular, antennae 3-jointed (water scorpions) (Fig. 15-16).
14. Belostomatidae: Posterior tibiae flattened and fringed with hairs, fitted for swimming, antennae 4-jointed, (giant water bugs) (Fig. 17).
15. Corixidae: Front margin of pronotum overlapped by base of head, fore tarsi fringed with strong bristles, fore femur with a row of pegs (water Boatmen), foretarsi formed into scoop-like palae with a row of long hairs, never with 2 claws (Fig. 18-23).

Homoptera

1. Cicadellidae: Hind tibiae with a double rows of spines, chief distinctive traits of the family, pronotum never prolonged backwards (leafhoppers), structures of genitalia display distinguishing characteristics of the species.
2. Membracidae: Pronotum prolonged backward into a process (tree hoppers).
3. Fulgoridae: Characterized by reticulated anal area of wing, having head slightly or greatly prolonged, antennal segment terminating in a filament.

Cercopidae, tibial spurs sharply differ from Cicadellids with rows of tibial spines. (Fig. 24)
4. Aphididae: Small green, brownish or black insects, mostly with Siphons; occur in both winged or wingless forms. Wings when present are large and transparent with relatively few veins, sometimes with a definite colour pattern. They live in colonies on the shoots of plants, some are protected by curled leaves or definite gall growths, while some other are subterranean and live on the roots of plants. Many have a very complex life-history involving alternating generations which are morphologically distinguishable

and often infest different host-plants. Parthenogenesis and viviparity are common. Aphids should be carefully brushed off the food plant and preserved in 70% alcohol. (Green fly or plant lice).

5. Chermidae (=Psyllidae): Comprising of small insects; normally with relatively large transparent wings bearing few veins; living on the growing shoot of plants. Some are covered with white waxy secretion. The nymphs are often much flattened and are powerful jumpers. Wings of these insects are held at an angle over the body. Ocelli are three in number and the antennae thin and long. (Jumping plant lice) (Fig. 25).
6. Coccoidea: These are relatively small insects differing from all other parasitic forms in having sedentary females, which remain attached to the host-plants. The male pass through true pupal stage and emerge with one pair of wings, but the females retain the normal Homopterous development except that they gradually lose all organs not necessary for their existence. The coccids are of great economic importance and many are serious pests. Some coccids secrete covering scales under which they lie protected. Many species are soft bodied and covered with a copious secretion of white wax. The collection of scale insects are made from parts of the host plant to which they are attached and stored in 70% alcohol. These are one segmented tarsi and with single claw. Females are apterous and often devoid of legs. Males are dipterous with mouth parts atrophied (Scale insects and mealy bugs).
7. Aleyrodidae: These are small insects with normally opaque whitish wings and body more or less powdery. Though in some species the wings bear dark spots or bands. Unlike coccids there is a pupal stage in both sexes. All stages found on the underside of leaves of plants. Classification is based principally upon the larvae and pupae. Antennae 7 segmented; tarsi with 2 subequal segments, and pad-like empodium or spines between the claws (White flies).

We have been dealing with some common families and distinctive traits as cited above to differentiate the families from one another. According to recent trend the workers may study the genital armatures of certain important families as Cicadellidae, Fulgoridae, Cercopidae, Pentatomidae, Miridae, Coreidae, Pyrrhocoridae etc. to establish the identities of the species pertaining to families involved. In addition, sincere approach and attention should be paid to familiarise with the dissection, mounting and complex structures of genital armatures.

PLATE I

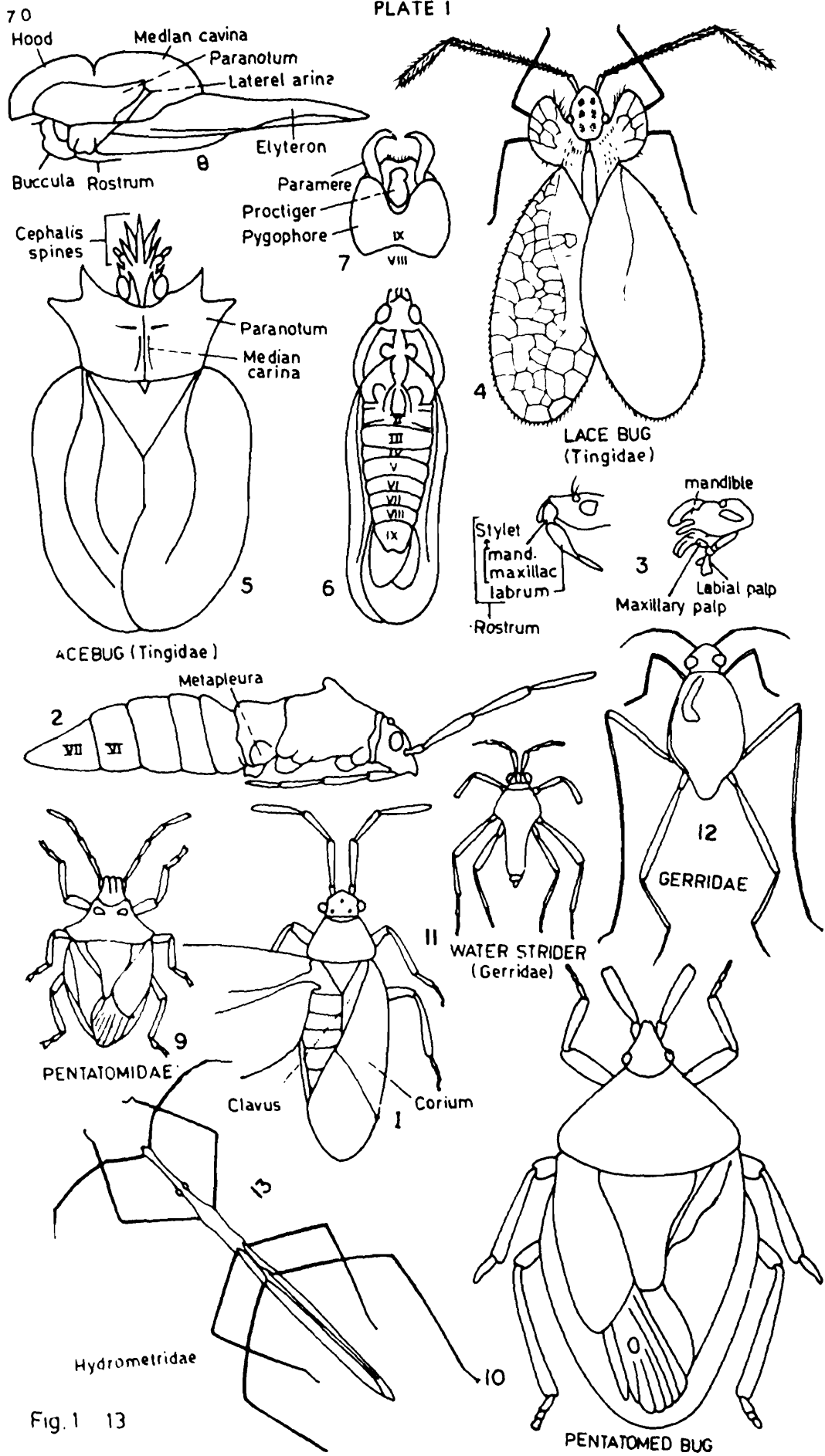


Fig.1 13

PLATE II

Palacit Corixidae

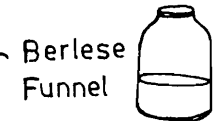
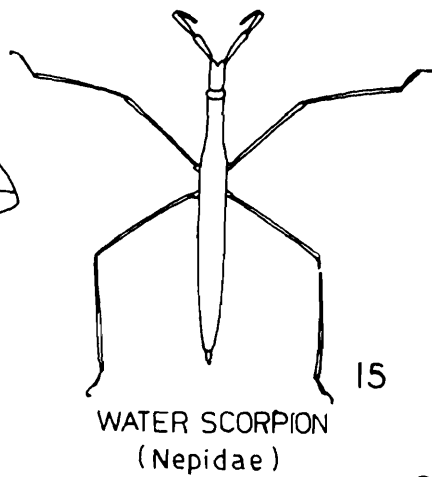
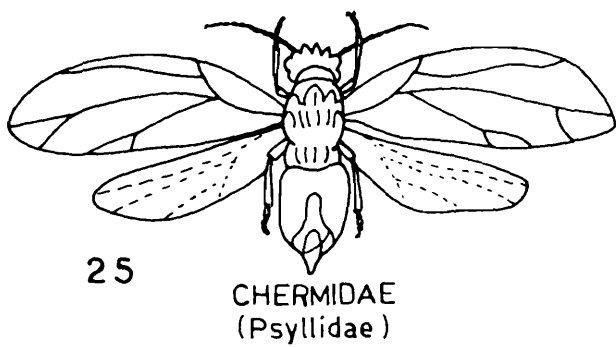
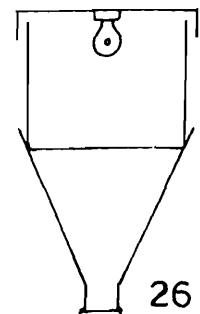
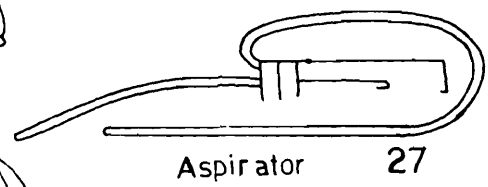
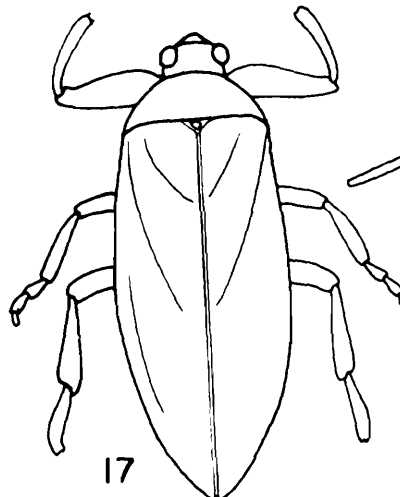
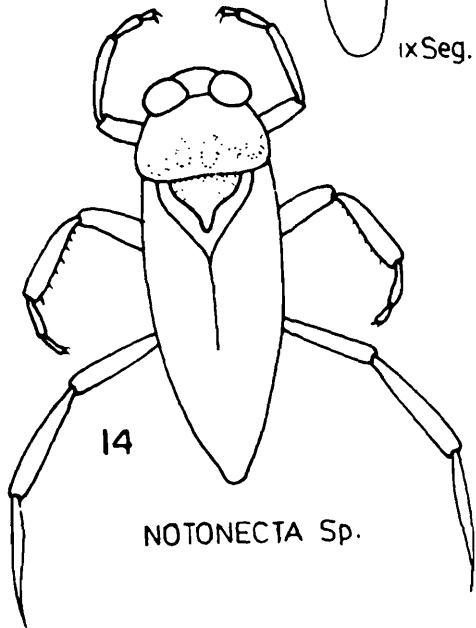
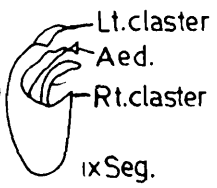
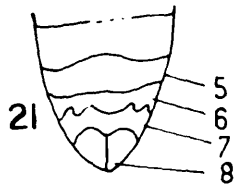
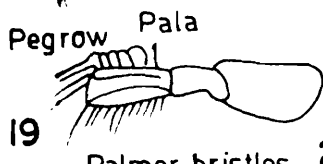
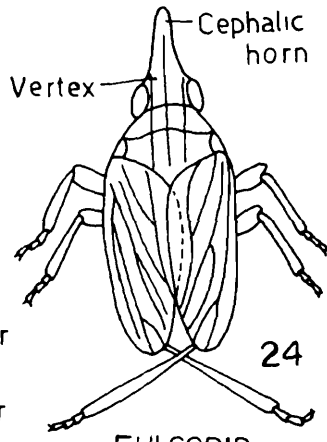
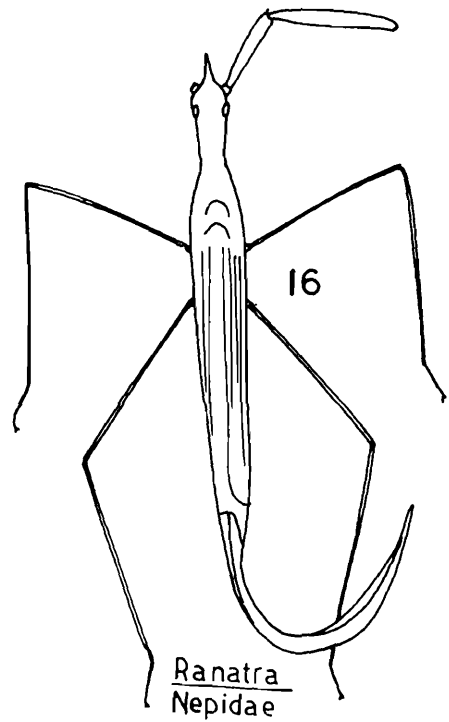
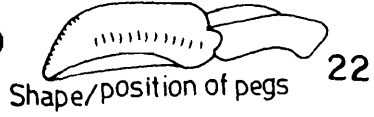
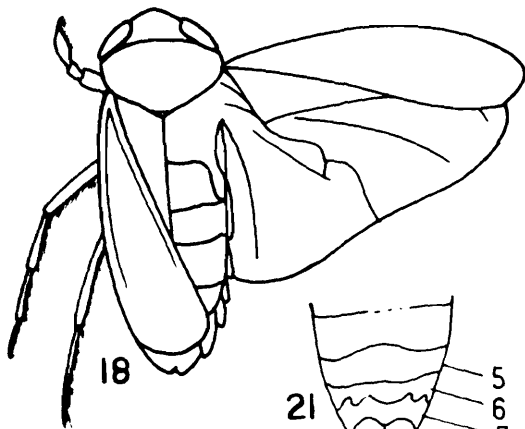


Fig.14 - 27

METHODS OF COLLECTION, PRESERVATION AND IDENTIFICATION OF HOMOPTERA

L. K. Ghosh

Hemiptera is the largest and most important order of the Exopterygote insects. These insects are easily recognised by piercing and sucking mouth parts (except in male coccids), atrophied palpi, the labium in the form of a dorsally grooved sheath receiving two pairs of bristle-like stylets (modified mandibles and maxillae), and 2 pairs of wings, forewing being often of harder consistency than hindwings.

Among the hemipteran insects, majority of homopterans are plant feeders both in larval and adult stages and are mostly injurious for plants which cause considerable damage by way of sucking up the plant sap. Certain homopterans act as vectors by transmitting viruses of diseases like "mosaic", "Leafroll", "yellows" etc., from plant to plant. An extraordinary rapid rate of reproduction is found in many Homoptera. This suborder includes most of the agricultural pests.

In the field, the homopterans are not so active as the heteropterans. They tend to remain on their food plants, often in large colonies. When disturbed, many of the large forms jump or hop away and take to flight.

The homopterans are characterised in having their head more or less deplexed, gular region small & membranous or wanting, wings usually sloping over the sides of the body, the fore pair generally of uniform texture, sometimes brightly coloured, usually transparent with distinct & often numerous veins. Wings are carried obliquely over the back like the sloping sides of the roof, the tips rarely overlapping one another. The most characteristic feature is the rostrum or suctorial beak arising from the base of the head & extending in between the front legs.

In temperate climate, June-August are best months for collection; in warmer parts, period varies from group to group. Sweeping and beating are effective methods. For the softbodied homopterans which need hand collection, host plant data are necessary for identification. Many are attracted to lights and water; suction and wind traps are used for others. For killing, cyanide bottle is usually used; specimens may be stored temporarily in alcohol but normally should be kept dried. Adult specimens are placed

in triangular paper cut (when small in size), or pinned directly. While mounting, legs and antennae are to be stretched, in some cases (e.g. Cicadidae) terminal segments of abdomen should be kept clearly visible, the arrangement of wings should be either pointed upwards (e.g. Psyllidae) or spread (e.g. Cicadidae). Pins are normally inserted through scutellum, on the right of middle line (in case Scutellum is large) or through pronotum in posterior margin on the right of middle line (in case Scutellum is small and covered by pronotum).

Habitats of soft-bodied homopterans (Viz., Aphids, Coccids, Psyllids, etc.) are leaf, stem, flower, roots and galls. In some cases like Aleyrodids (white flies) pupal cases are very important. Insects are picked by soft camel hair brush, killed and preserved in 70% alcohol. Usually these are boiled in KOH (10% - 15%) and saturated solution of Chloral phenol before being stretched and mounted on slides with suitable mounting media (Canada balsom, DPX, Gum-Chloral etc.).

For mounting soft-bodied homopterans, Gum Chloral method of mounting gives best results. This method is as follows:- boil insects in 70% alcohol (3-5 minutes), 10% KOH (5-10 minutes), Chloral phenol solution (3-5 minutes). The boiling depends upon the size and texture of the specimens. Lastly, the specimens are mounted in medium prepared by mixing gum arabic (10 gm.), glycerine (6.5 C.C.), chloral hydrate (20 gm.) and distilled water 40 C.C. After mounting, the slides are dried, labelled preferably with data like host plant, colour in live etc. and stored in the slide cabinet.

For the purpose of identification characters of body parts like head & antenna, rostrum, legs, wings, etc. are taken into consideration. In some groups, genital armature plays important role in identification.

The homopterans are broadly classified into three series : Series 1. COLEORHYNCHA, Series 2. AUCHENORHYNCHA, Series 3. STERNORHYNCHA.

Series 1. COLEORHYNCHA : Characterised by short 3-segmented antennae concealed beneath head & without terminal arista. Base of rostrum partly ensheathed by propleura. Tarsi 2 - segmented. This group is represented by a single family, viz., Pelorididae, comprising of twelve species which show many primitive characters suggesting them to be a remnant of a stock from which all other hemipterans arose. This groups is not represented in India.

Series 2 : AUCHENORHYNCHA : Antennae very short with a terminal arista, rostrum plainly arising from the head, tarsi 3-segmented. These are active forms, capable of free locomotion.

Series 3 : STERNORHYNCHA : Antennae well developed without conspicuous terminal arista, sometimes atrophied. Rostrum apparently arising between anterior coxae, or wanting. Tarsi 1 or 2-segmented. Species often inactive or incapable of locomotion.

Series 2 : AUCHENORHYNCHA

CICADOIDEA/CICADIDAE (CICADAS) : 3 ocelli on vertex. Large insects with stout bodies, blunt heads, thickened anterior femora which have spines beneath. Loud sounds or song is produced by the males. Nymphs subterranean and live on the root of plants, adults live in trees, shrubs and are not easily caught by the net.

FULGOROIDEA/FULGORIDAE (Lantern flies) (Plate I ; Fig.1) : 2 ocelli present, placed beneath or very near the eyes but never on vertex. The characteristic feature of these flies is the long stout-like bulbous expansions of the front of the head. Some are with broad coloured wings resembling lepidopterans but without scales.

CERCOPOIDEA/CERCOPIDAE (Frog hoppers) : Ocelli two on vertex. Hind tibiae with stout teeth and with short spines at the tip. The nymphs live on grasses of spittle-like froth on the aerial shoots of plants or underground at the roots of plants in cavities filled with froth. Post-clypeus greatly expanded. Hind coxae mobile, short, conical; tegmina opaque.

CICADELLOIDEA/MEMBRACIDAE (Devil-hoppers or tree-hoppers) (Plate I ; Fig.2 : Post clypeus not greatly expanded. Hind coxae mobile, elongate. Tegmina transparent or opaque. Characterised by two ocelli between the eyes, prothorax prolonged backwards in the form of a process with spines; powerful jumpers. Ants are generally found associated with the membracids.

Ananthasubramanian and Ananthkrishnan (1975) have made valuable contributions on the Taxonomy, Biology and Ecology of South Indian Membracids.

CICADELLIDAE (Leaf hoppers or Jassids) (Plate II : Figs.1-4; Plate III : Figs. 1-4) : These are slender insects, tapering posteriorly, which live on grass, shrubs and low vegetation, specially grasses and paddy fields. Although usually green or brown, often with darker markings. Large number of species are highly coloured in red, yellow, blue and green. The head more or less produced in front of the eyes and two ocelli are on the front margin of frons. Hind coxae mobile, elongate; hind tibiae with a double row of spines. Tegmina transparent or opaque.

Series 3 : STERNORHYNCHA

PSYLLOIDEA/PSYLLIDAE (Jumping plant lice) (Plate IV : Fig. 1). Normally with relatively large transparent wing bearing few veins, some covered with white waxy secretion. Nymphs often much flattened and good jumpers. Wings held at an angle over the body. Ocelli 3, antennae thin and long.

APHIDOIDEA/APHIDIDAE (Green fly or plant lice) (Plate IV : Fig. 2). These insects live in colonies on the shoots of plants, some are protected by curled leaves or definite gall growths, while others are subterranean and live on the roots. These are mostly with siphunculi which occur in both winged and wingless forms. Parthenogenesis and viviparity are common. Many have a very complex life history and involve alternating of generations which can morphologically be distinguished and often involve different host plants.

Antennae of apterae usually 4-6 segmented, of alatae 5-6 segmented, processus terminalis longer to shorter than base of last antennal segment; eyes of apterae usually multifaceted; cauda often developed; forewings with distinct radial sector vein.

Aphidoidea/Phylloxeridae : Not known from India.

Aphidoidea/Adelgidae : Members are known to be taxonomically a difficult group. Primary host of heteroecious adelgids is *Picea* and secondary hosts are only from Coniferae.

Antennae 2-5 segmented with 1-3 primary rhinaria; processus terminalis always much shorter than base of last antennal segment; eyes of apterae always 3-faceted; siphunculus absent; cauda indistinct; forewings with radial sector vein. Represented in India by 3 genera only.

COCCOIDEA : (Scale insects and mealy bugs) (Plates: V-VIII). Mostly soft-bodied and covered with a copious secretion of white wax. The females are sedentary. Males pass through three pupal stages and emerge with one pair of wings. Characterised by single segmented tarsi with a single claw. Females are apterous and often devoid of legs.

Males are dipterous with mouth parts atrophied. The coccids are of great economic importance and many are serious pests.

ALEYRODOIDEA/ALEYRODIDAE (White flies) (Plate IX) Unlike coccids there is a pupal stage in both sexes. Antennae 7-segmented, tarsi with 2 subequal segments and pad-like empodium

or spines between the claws. Normally opaque. Wings whitish and body more or less powdery. Classification is based principally upon the Larvae and pupae.

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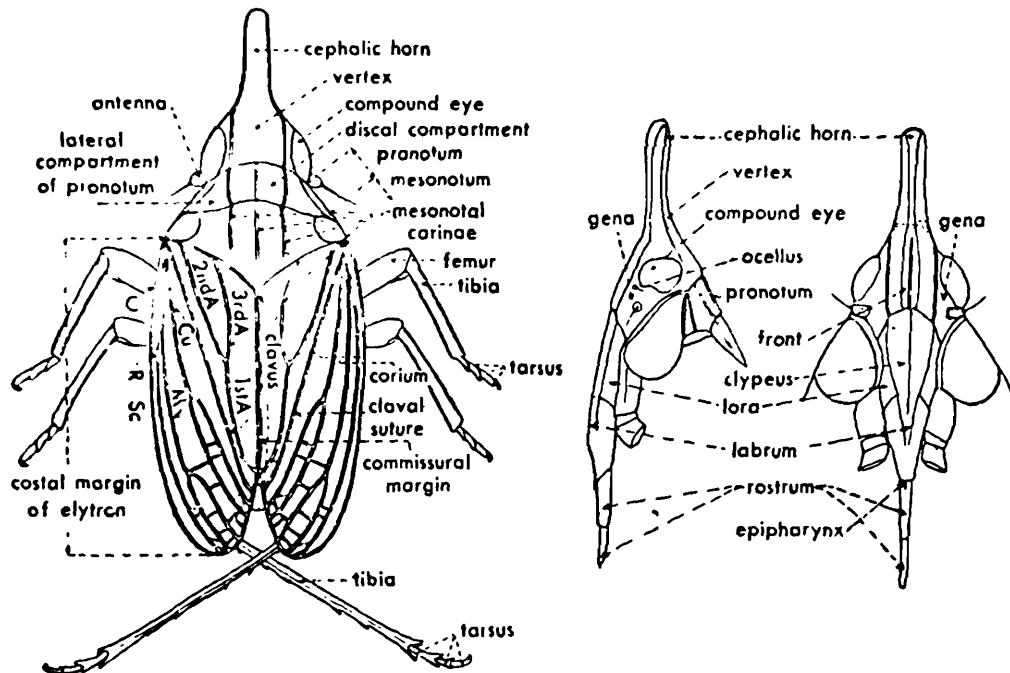


FIG. 1 The fulgorid, *Scolops angustatus* Uhler, showing important external characters. (Drawing by Garman, *Hemiptera of Connecticut*, 1923.)

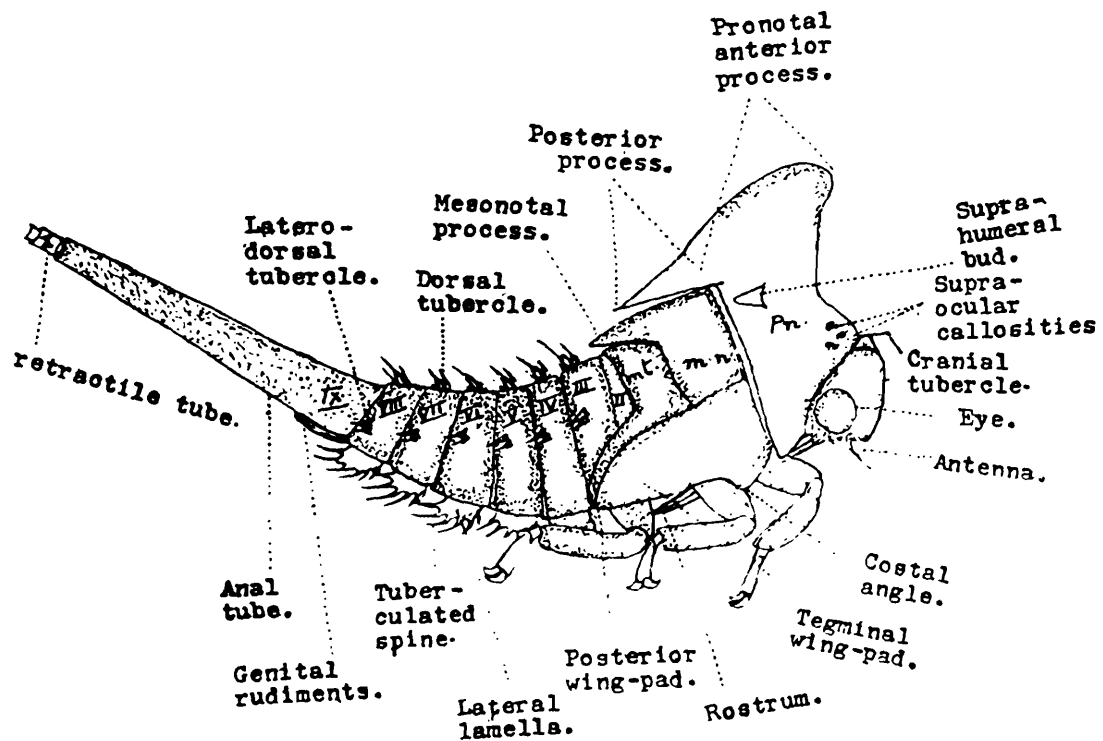
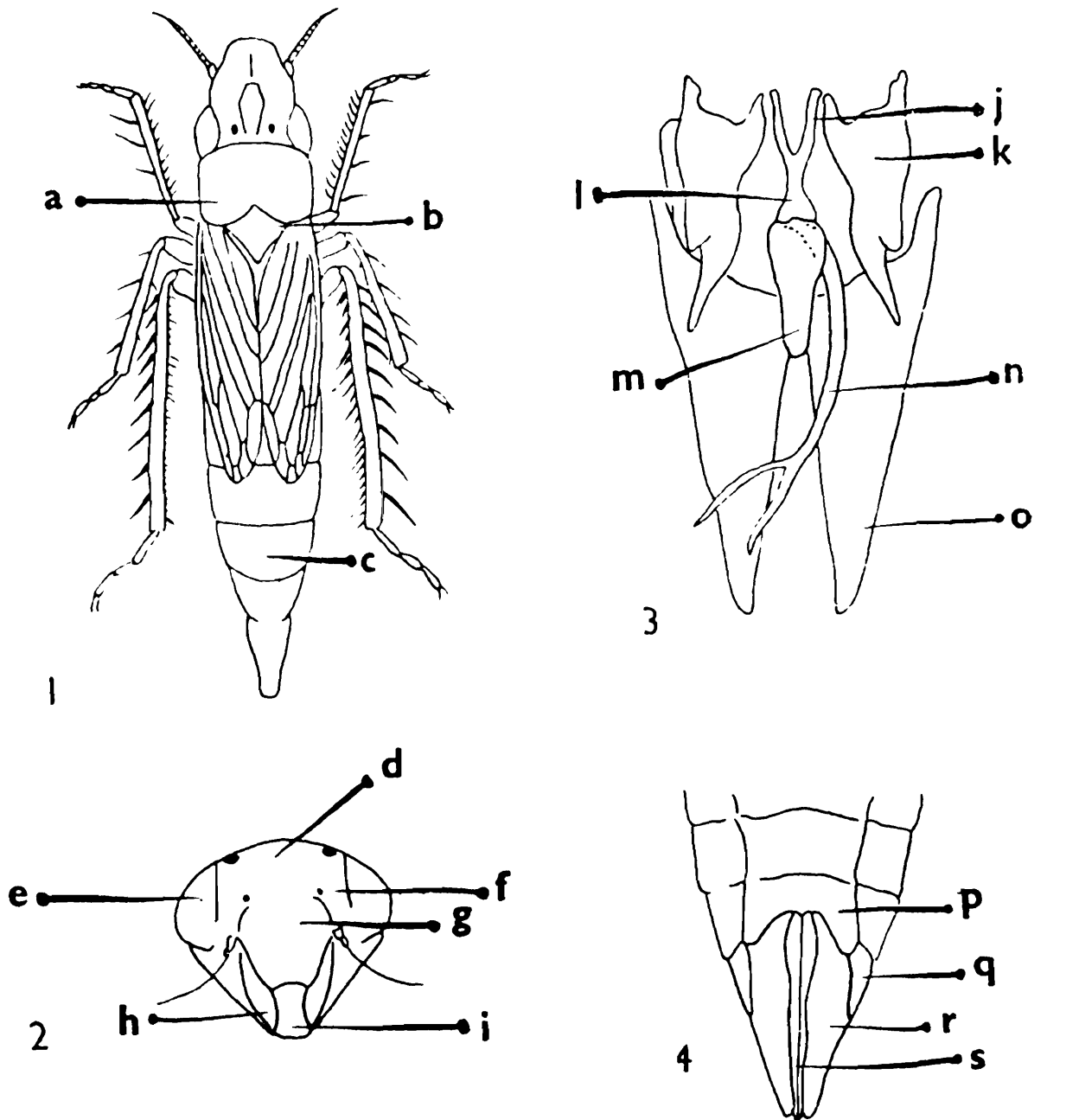


Fig- 2 A Generalised Fifth Instar.

Pn, Pronotum, mn, Mesonotum; mt, Metanotum; IX, Ninth segment forming the anal tube; X, Tenth segment forming the eversible tube.

(After Ananthasubramanian and Anthakrishnan, 1975)

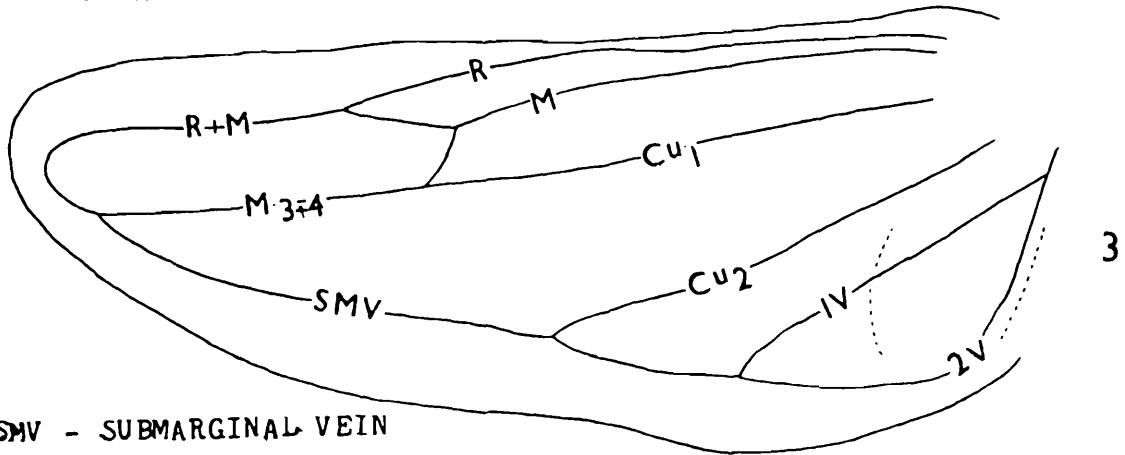


- | | | |
|----------------------|----------------------|---------------------|
| a - PRONOTUM | 1 - CLYPELLUS | |
| b - SCUTELLUM | j - CONNECTIVE ARM | |
| c - TERGITE | k - STYLE | p - VIIITH STERNUM |
| d - CROWN | l - CONNECTIVE SHAFT | q - VIIIITH STERNUM |
| e - COMPOUND EYE | m - AEDEAGAL BASE | r - PYGOFER |
| f - OCELLOCULAR AREA | n - AEDEAGAL SHAFT | s - OVIPOSITOR |
| g - CLYPEUS | o - MALE PLATE | |
| h - LORUM | | |

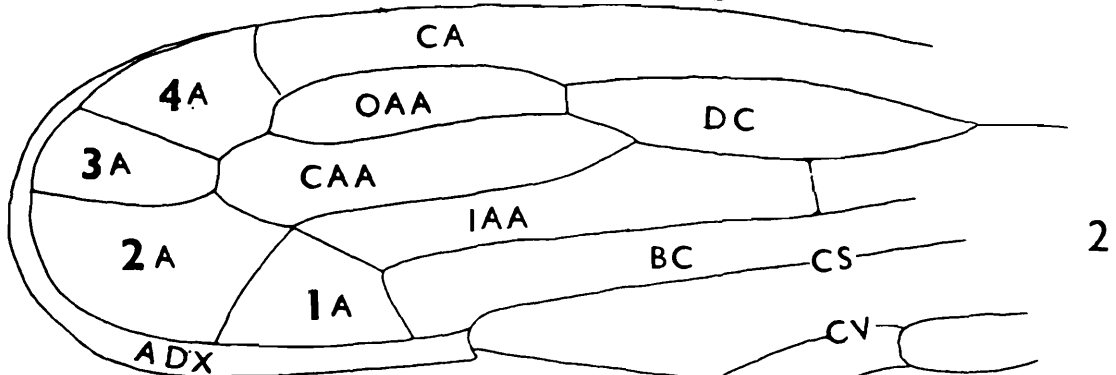
1 GENERAL VIEW OF A JASSID ; 2. HEAD
 3: MALE GENITALIA; 4: FEMALE GENITALIA



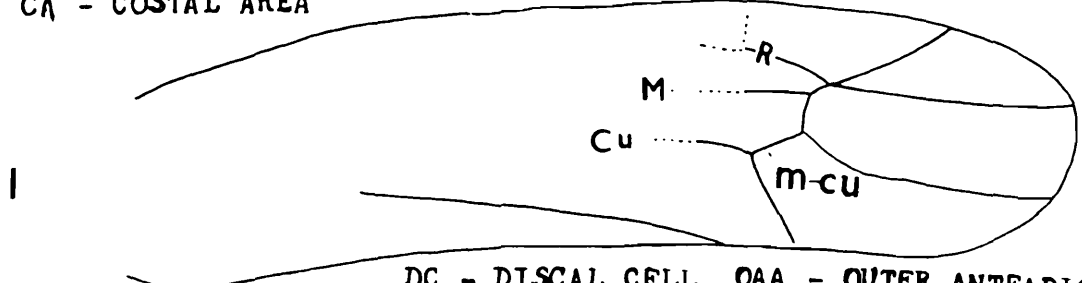
AC - APICAL CELLS



SMV - SUBMARGINAL VEIN

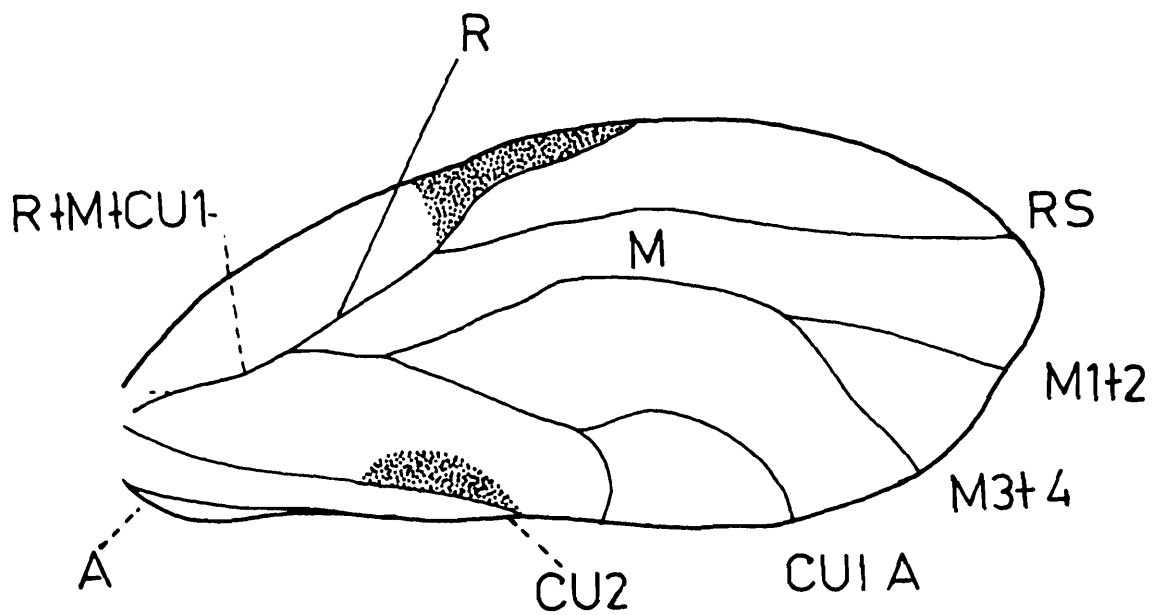


1A TO 4A - 1ST TO 4TH APICAL CELLS
 ADX - APPENDIX BC - BRACHIAL CELL CAA - CENTRAL ANTEAPICAL
 CA - COSTAL AREA

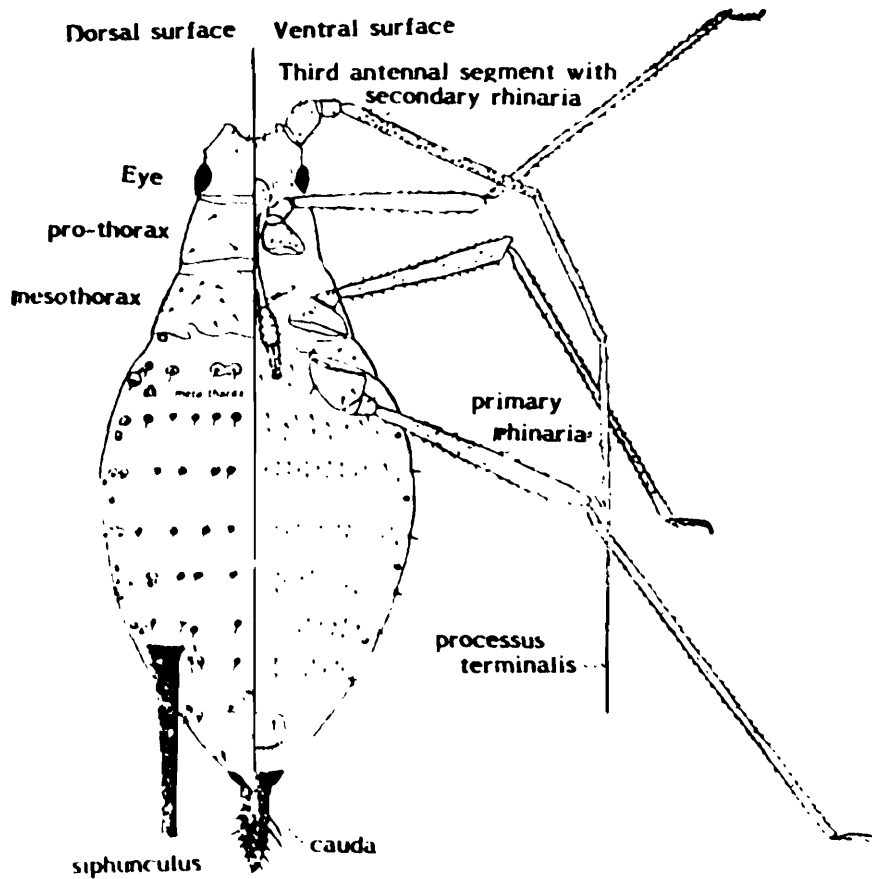


DC - DISCAL CELL OAA - OUTER ANTEAPICAL
 CS - CLAVAL SUTURE IAA - INNER ANTEAPICAL
 CV - CLAVAL VEIN

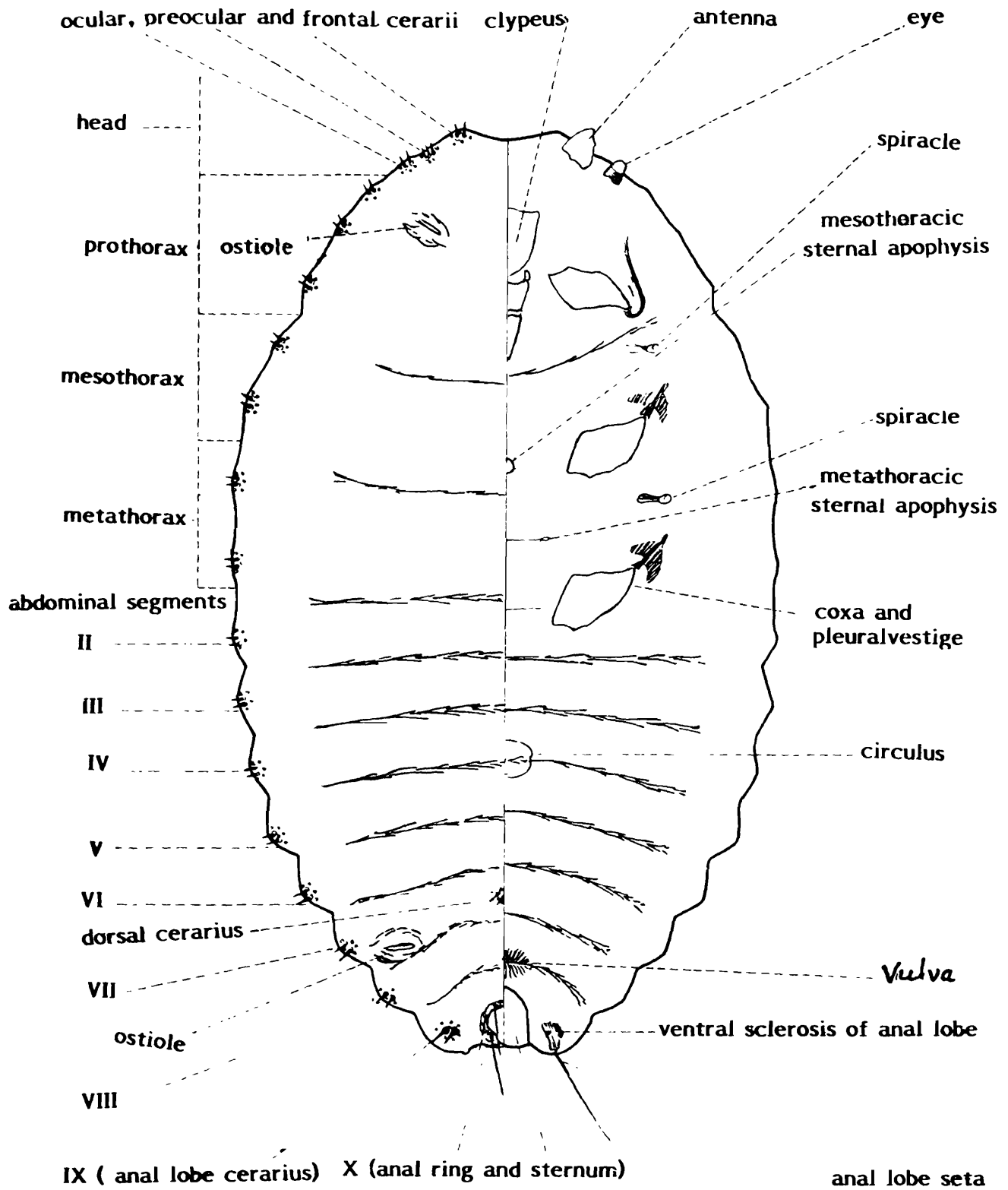
WING VENATION OF JASSID



GENERALISED WING VENATION OF PSYLLID

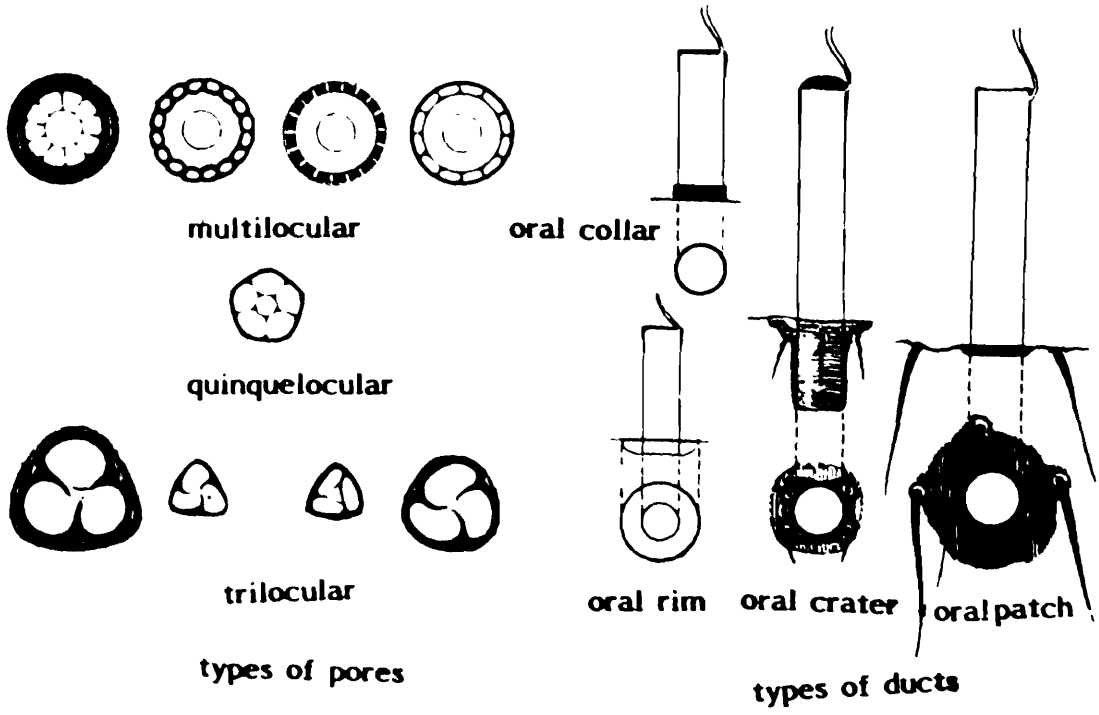
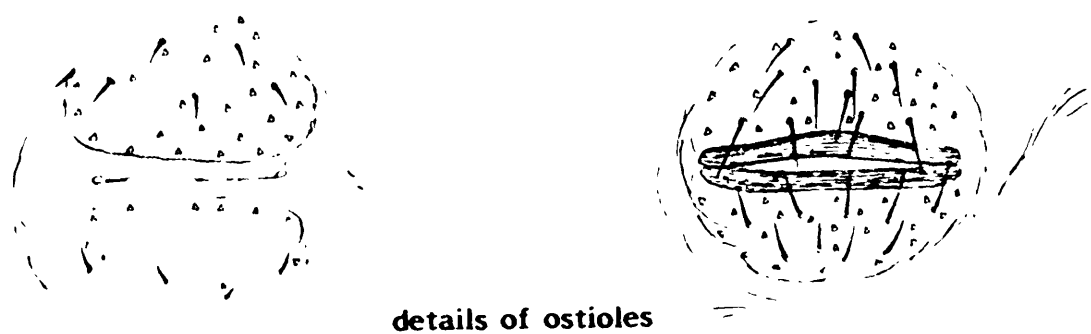
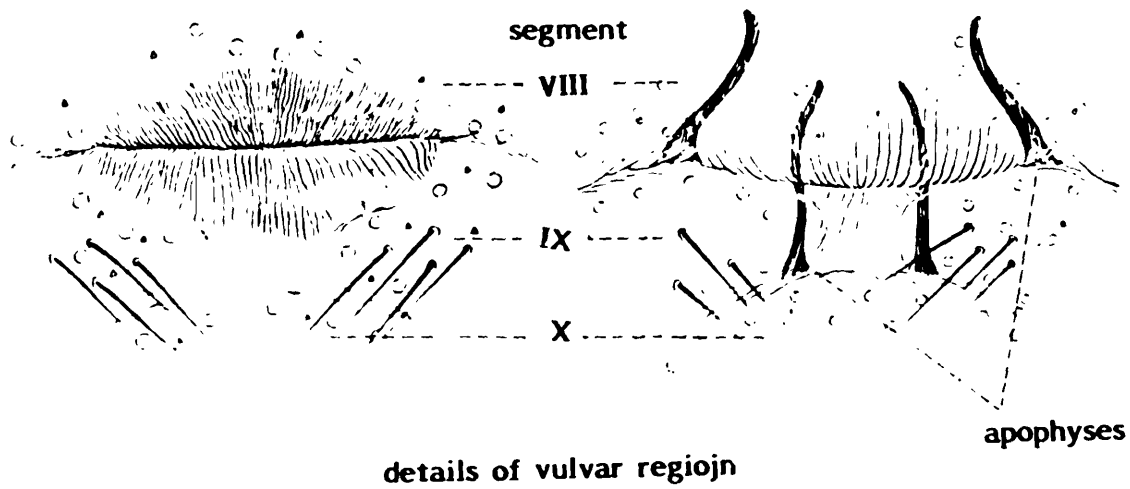


Uroleucon (Uromelan) compositae (Theobald)
Apterous viviparous female (After Eastop, 1958)

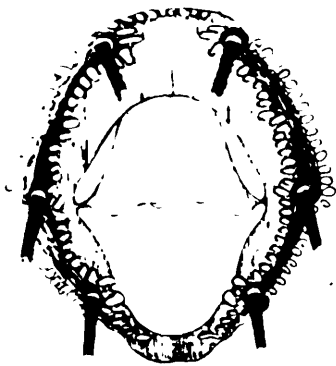


General Morphology of a Pseudococcid
(After G. F. Ferris 1950)

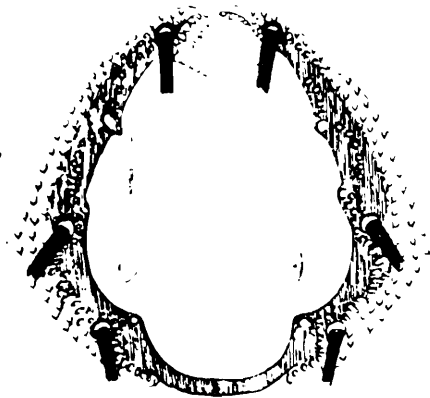
PLATE VI



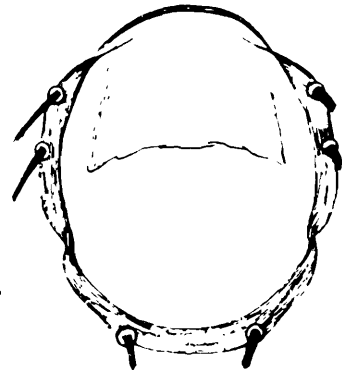
Morphological Details of Pseudococcidae
(After G. F. Ferris, 1950)



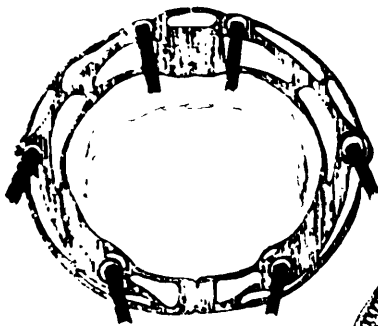
Pseudococcus



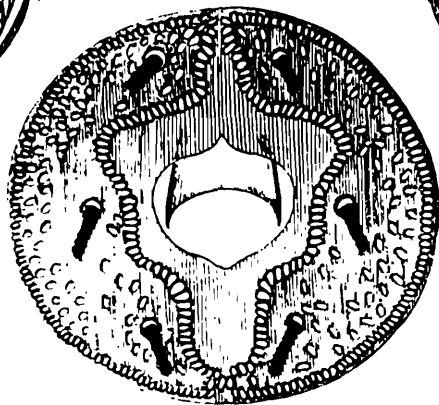
Phenacoccus



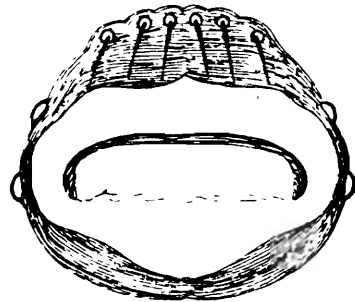
Anisococcus



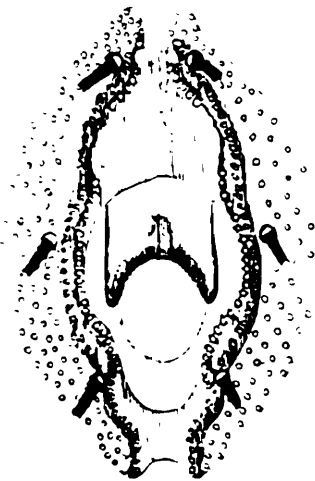
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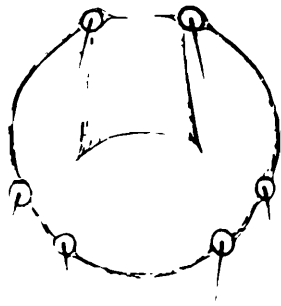
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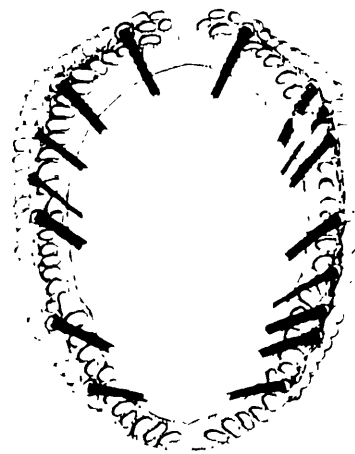
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Putolasiolum

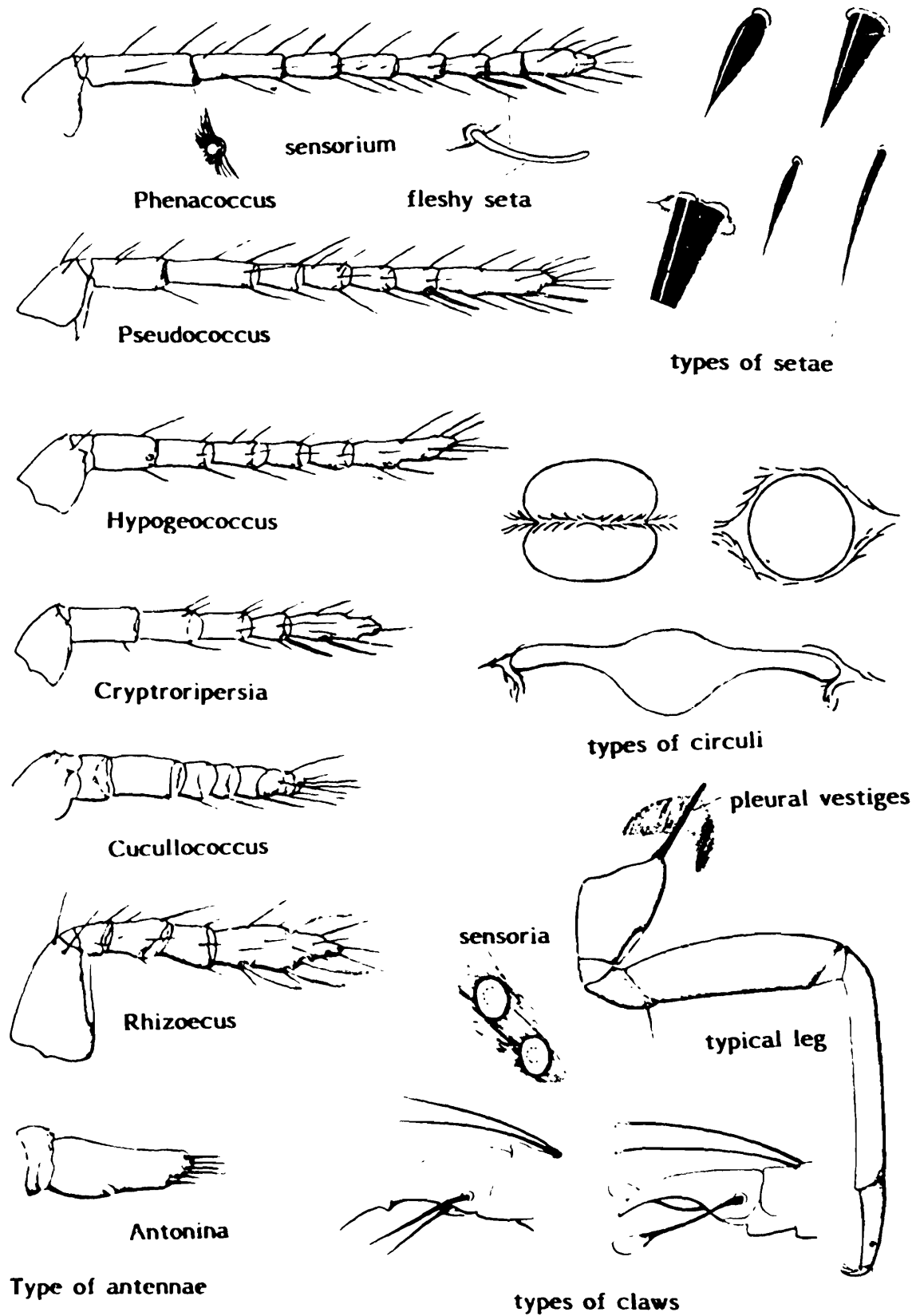


Ehrhornia "

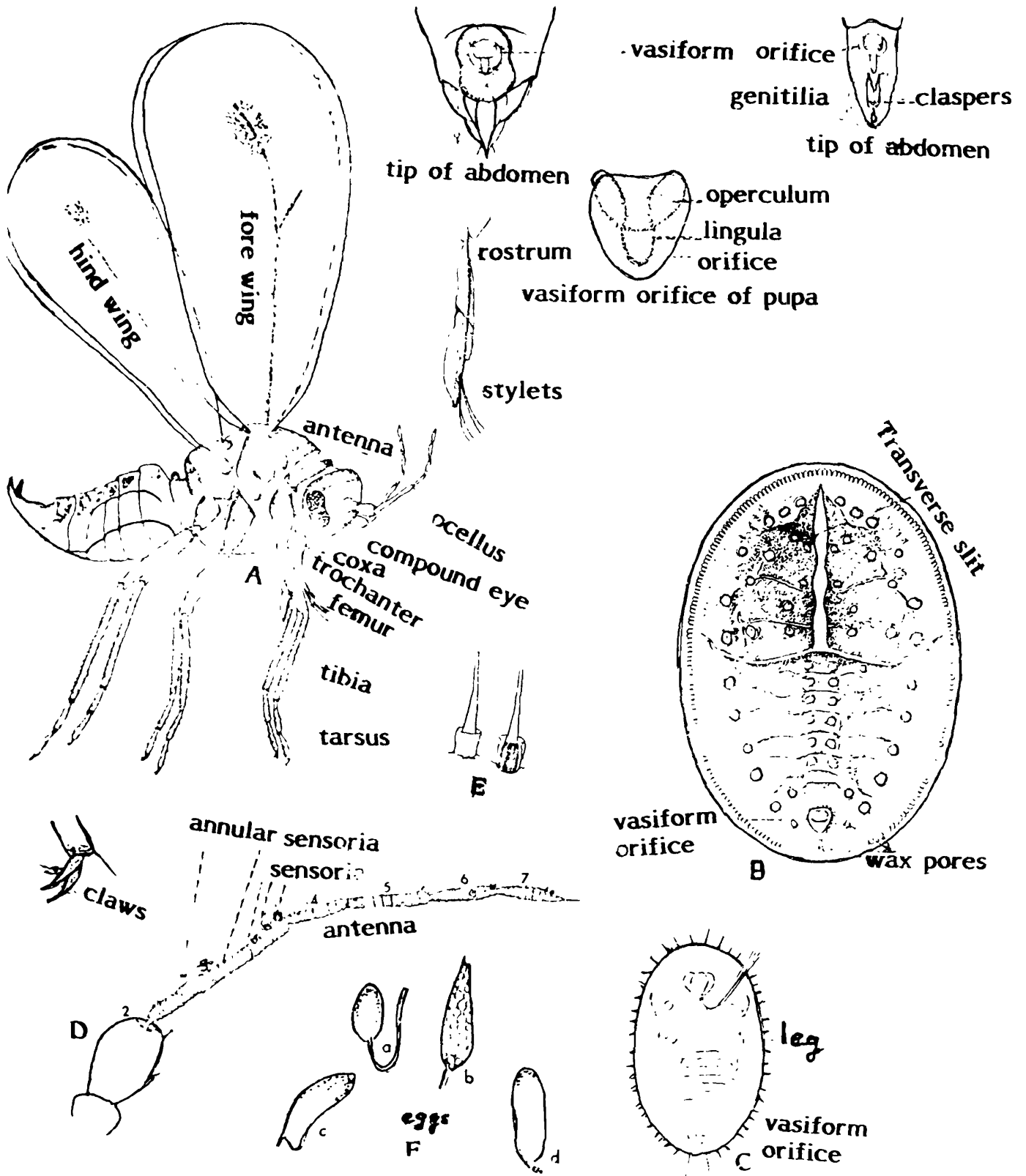


Formicococcus

Variations of the Anal Ring of Pseudococcidae
(After G. F. Ferris, 1950)



Morphological Details of Pseudococcidae
(After G.F. Ferris 1950)



Aleyrodidae. A. adult and D. antenna of the whitefly, B. nymphal exuvia and C, young individual; E, compound wax pores and F, eggs, after Quaintance and Baker, 1913.

METHODS OF COLLECTION, PRESERVATION AND IDENTIFICATION OF THYSANOPTERA

S. Sen

The insects included under the Order Thysanoptera, popularly known as thrips; or fringe wings or bladder-footed insects are one of the smallests of the pterygote insects. They possess remarkable structural peculiarities with fringed wings, asymmetrical feeding apparatus with the right mandible vestigial and a portrusible bladder at the end of all tarsi. The Order Thysanoptera received very little attention in the past by the entomologist, possibly because of its minute size and unattractive coloration. In recent years thrips have assumed considerable importance as pest of variety of crops of agricultural and horticultural value and some species are carriers of viral diseases to a number of commercial and food crops. Most of them are phytophagous, others are mycophagous feeding on spores and fungal hyphae and a few are predaceous, i.e., feeding on other thrips, mites, whiteflies and coccids. In all around 6000 species have been recorded all over the world out of which 686 species under 248 genera are recorded from India, the familywise break up being :- Aeolothripidae (10 genera - 18 species), Merothripidae (1 genus - 2 species), Thripidae (95 genera - 257 species), Phlaeothripidae (140 genera - 406 species).

MORPHOLOGICAL CHARACTERS FOR TAXONOMIC CRITERIA

Body Sculpture : Striking patterns of sculpture in different genera and species taking the form of distinct polygonal reticulations, wrinkles or irregular corrugations, anastomosing or transverse striae and granulations are important taxonomic consideration.

Setae : Number, size, position, shape and colour of the body setae are very important characters, and are termed as hair, seta, flagellum, bristle, spine and cilia depending upon the kind of setae present. Various types of setae are recognised according to the setal tip viz. pointed, knobbed or club like, blunt or rounded, lanceolate or lancet shaped, infundibuliform or funnel like, grooved, forked, fimbriate and spatulate or spoon shaped.

Head : The shape and size of head varies from strongly convex dorsally or depressed and also it may be much longer than broad or as long as broad. Anterior margin may be straight or rounded and often produced into a distinct cephalic process. Eyes are composed of varying number of ommatidia, convex or

For collection of thrips from and around grass field, several types of traps (water trap, sticky traps and suction traps) have been suggested by Lewis (1959).

For collection of thrips from leaf litter, plant debris and grass clumps Berlese funnel is very effective technique. Leaf litter of the forest floor, grass clumps is heated by a suspended bulb. The tips of the funnels are inserted with jars containing 70% alcohol. The insects are driven by the heat and fall into alcohol. Tulgren funnel may also be used for collecting thrips from litters.

A number of fixative are in use, some of which commonly used are as follows :-

1) AGA fluid : Prepared by adding 90% ethyl alcohol 8 parts, distilled water 5 parts, glycerine 1 part and glacial acetic acid 1 part (Mound and Pitkin (1972) recommended 60% ethyl alcohol 10 parts instead of 90% alcohol 8 parts). The specimen preserved in AGA needs to be mounted or transferred to 70% alcohol within one month to avoid decoloration and disintegration of internal parts.

2) 10% ethanol + 0.1% Triton X (1 in 100 part of 10% ethanol) solution. The advantage of the solution is that all the appendage including the male genitalia is extended. It is necessary to transfer the material in 70% alcohol within one month.

3) 50-60% alcohol with 0.5% ethyl acetate to prevent stiffness and store in 60-70% alcohol.

The preserved material is mounted for microscopic studies. For mounting, the material is first treated in 5% KOH (for very dark specimen 10%) from few hours to overnight depending upon the chitinisation; the treated material is then washed in distilled water several times to remove the trace of KOH. The material is then dehydrated in ascending grades of alcohol (50%, 70%, 90% and absolute) and cleared in clove oil and mounted in Canada balsum with utmost care so that the limbs and wings are well spread. For the study of thrips, perfect mounts are absolutely necessary, unless all the limbs are distended and the wings well spread, proper identification is not possible.

KEY TO THE SUBORDERS

1. Abdominal segment X rarely tubelike. Forewings mostly with veins, cross-veins and setae on veins. Female always with saw like ovipositor..... Suborder **Terebrantia**

flattened, occasionally considerably extended ventrally or contiguous in front. Cephalic chaetotaxy are important taxonomic characters, the major setae being anteo-cellars 1 or 2 pairs in front of median ocellus; interocellars 1 pair between the ocelli; postocellars forming a series commencing from below the ocelli and reaching the cheeks or genae. There are usually one pair (rarely two pairs) of well developed postoculars in Tubulifera.

Antennae : The shape, size of the segments, chaetotaxy and number and nature of sense cones are important taxonomic characters. The number of antennal segments vary from 6 to 9 in the Terebrantia and 4-8 in the Tubulifera and the terminal segments or style of the Terebrantia is 1, 2 or 3 segmented and some of the apical segments of the family Aeolothripidae may form an unit. The sensoria may take the form of sensory areas or cones (simple or forked) better developed in segments 3 & 4.

Mouthparts : The nature of mouthcone is an important character which may be short, or broad, or long and pointed or very narrowly pointed or biconcave. The maxillary stylets may be short and confined within the mouthcone whereas in the majority cases it is long and extended to the head capsule and thickness of the stylets is also important characters in the Tubulifera. The maxillary palps are 2 to 8 segmented in Aeolothripids; 2 to 3 segmented in Thripids and generally 2 segmented in the Tubulifera.

Prothorax : The shape, size and presence or absence of suture are good taxonomic characters. The pronotum may be smooth, sculptured with transverse striae or reticulations. The nature of the probasisternum and the presence or absence of praepectus or breast plate are important in the Tubulifera. Prothoracic chaetotaxy is very important taxonomic criterion and the setae are referred to according to the position as anteroangulars, antero-marginals, midlaterals, posteroangulars, epimerals, posteromarginals and surface setae.

Pterothorax : The nature of the pterothoracic endosternites; the presence or absence of median spinula in the Terebrantia; the sculpture of the metanotum and position of the median setae are useful taxonomic consideration.

Legs : The nature of the forelegs, the extent of specialization of the femora, tibiae and tarsi in the presence of various degrees of armature from setal clothing to strong bizarre teeth are important criteria for the determination of some of the taxa.

Wings : The shape of the wing may be broadly rounded or pointed, or parallel sided or constricted at middle, racket-like

or more expanded at apex also the straight or curved nature of the fore and hind margin of wing of Terebrantia are characters of taxonomic considerations. The wings are usually clear and transparent or may be banded with dark transverse or longitudinal bands or may be uniformly grey or dark. The number & position of cross-veins in the Aeolothripidae and to a limited extent in the Thripidae and the chaetotaxy in the Terebrantia of the fore wings, particularly in the number, nature and disposition of the setae is also of importance. The wings are defined in the Tubulifera as haplothripine (with a median constriction) mesothripine (narrow from base to middle and then parallel sided), stictothripine (twisted at middle) and phlaeothripine (uniformly parallel sided). The number of duplicate cilia or double fringes on the hind margin of fore wing and the number and position of basal wing setae (B_1 , B_2 , B_3) of fore wings are taxonomic value.

Abdomen : Pleurites are well differentiated in the Thripidae and bear numerous teeth-like processes ranging from blunt to typically dentate form and pleurites are absent in the Tubulifera. Glandular areas of the males are present in many Terebrantia and the shape, number, distribution are of taxonomic value. The tergite I in the Tubulifera is reduced to a small plate called 'pelta' which assume different shapes is an useful character. The number of setae on the dorsum of segment IX; 1 to 3 pairs of very stout, dark setae arising from socket in males of the Terebrantia and 3 pairs of lateral setae termed as B_1 , B_2 & B_3 of the Tubulifera are also important characters. The nature of the ovipositor whether upwardly or downwardly directed, vestigial or well developed are also important taxonomic features.

METHODS OF COLLECTION AND PRESERVATION

Thrips inhabit a variety of habitats like flowers, leaves, dry leaf litters, decaying bark and twigs, aerial roots, grass and within plant galls and a few are predaceous feeding mostly on mites, thrips, coccids, white flies and psocids. The methods of collection vary according to their habitat.

The common method of collecting thrips is by beating foliage or inflorescence, dead and decaying or fungus infested branches of trees on a stiff white paper/hard board/or plastic sheet and picking the material by a fine moistened camel hair brush.

In addition to beating, washing technique is also used for collection of thrips from leaves and flowers. Leaves and flowers brought from the field are filled in a jar containing 10% ethanol with a few drops of Triton X emulsifying agent and shaken several times. The plant parts are removed and the fluid is filtered through a fine nylon mesh. This method is very quick and a number of adults along with immature stages are recovered.

Abdominal segment X tubelike. Forewings without veins and setae. Female without saw like ovipositor
 Suborder **Tubulifera**
 (Family Phlaeothripidae Uzel)

KEY TO THE SUPERFAMILIES AND FAMILIES OF INDIAN TEREBRANTIA

1. Ovipositor curved upwards, forewings broad and rounded at apex with two longitudinal veins, front margin without the fringe of long hairs. Antennae 9-segmented.....
 Superfamily Aeolothripoidea Hood
 Family Aeolothripidae Uzel

- Ovipositor curved downwards. Wings more or less pointed at apex, fore margin with the fringe of hairs present. Antennae 6-9 segmented..... 2

2. Antennal segments moniliform, 8 or 9 segmented, style absent, segments 3 & 4 with a tympanum like area at apex and without sense cone. Fore- and hind femora greatly enlarged. Ovipositor weak. Abdomen blunt.....
 Superfamily Merothripoidea Priesner
 Family Merothripidae Hood

- Antennal segments not moniliform; style 1 to 3 segmented and distinct. Ovipositor well developed
 Superfamily Thripoidea Hood

KEY TO THE FAMILIES OF THRIPOIDEA

1. Antennal segments 3 and 4 each with a broadly based conical trichome; antennae 9-segmented. Fore tarsus usually with a claw-like appendage at base of second segment
 Family Adiheterothripidae Shumsher

- Antennal segments 3 & 4 with slender sense cones, simple or forked. Antennae 6 to 9 segmented. Fore tarsus sometimes with a claw-like appendage
 Family Thripidae Stephens

KEY TO THE SUBFAMILIES OF AEOLOTHRIPIDAE

1. Antennal segments clearly separate, not forming a close unit at apex. Body with prominent setae. Vertex of head with at least one pair of conspicuous setae. Fore tibiae without tooth, but mostly with a strong spur at apex
 Subfamily Melanthripinae Bagnall

Antennae more or less slender, with some of the terminal segments forming an unit; segments 3 and 4 without rigid setae. Body without conspicuous setae. Wings about parallel sided, sometimes slightly narrowed in basal half but never distinctly racket-like..... Subfamily Aeolothripinae Bagnall

Antennae stout, with conspicuous rigid setae on intermediate segments. Wings distinctly widened towards apex, racket shaped Subfamily Mymarothripinae Bagnall

KEY TO THE SUBFAMILIES OF THRIPIDAE

1. Dorsum of body not polygonally reticulate, atmost with transverse striae. Antennae 7 or 8 segmented rarely 9 segmented; terminal antennal segments not long and thin..... Subfamily Thripinae Karny

Dorsum of body deeply reticulate with polygonal area. Terminal antennal segments long and thin, needle like Subfamily Panchaethripinae Karny

KEY TO THE SUBFAMILIES OF PHLAEOTHRIPIDAE

1. Distance between hind coxae less than that between middle coxae. Anal setae rarely very long..... 2

Distance between hind coxae greater than between fore and mid coxae. Anal setae exceptionally long, several times longer than tube Subfamily Urothripinae Priesner

2. Maxillary stylets slender, never broadened, narrower than labial palps Subfamily Phlaeothripinae Priesner

Maxillary stylets broadened at apex, broader than labial palps Subfamily Idolothripinae Bagnall

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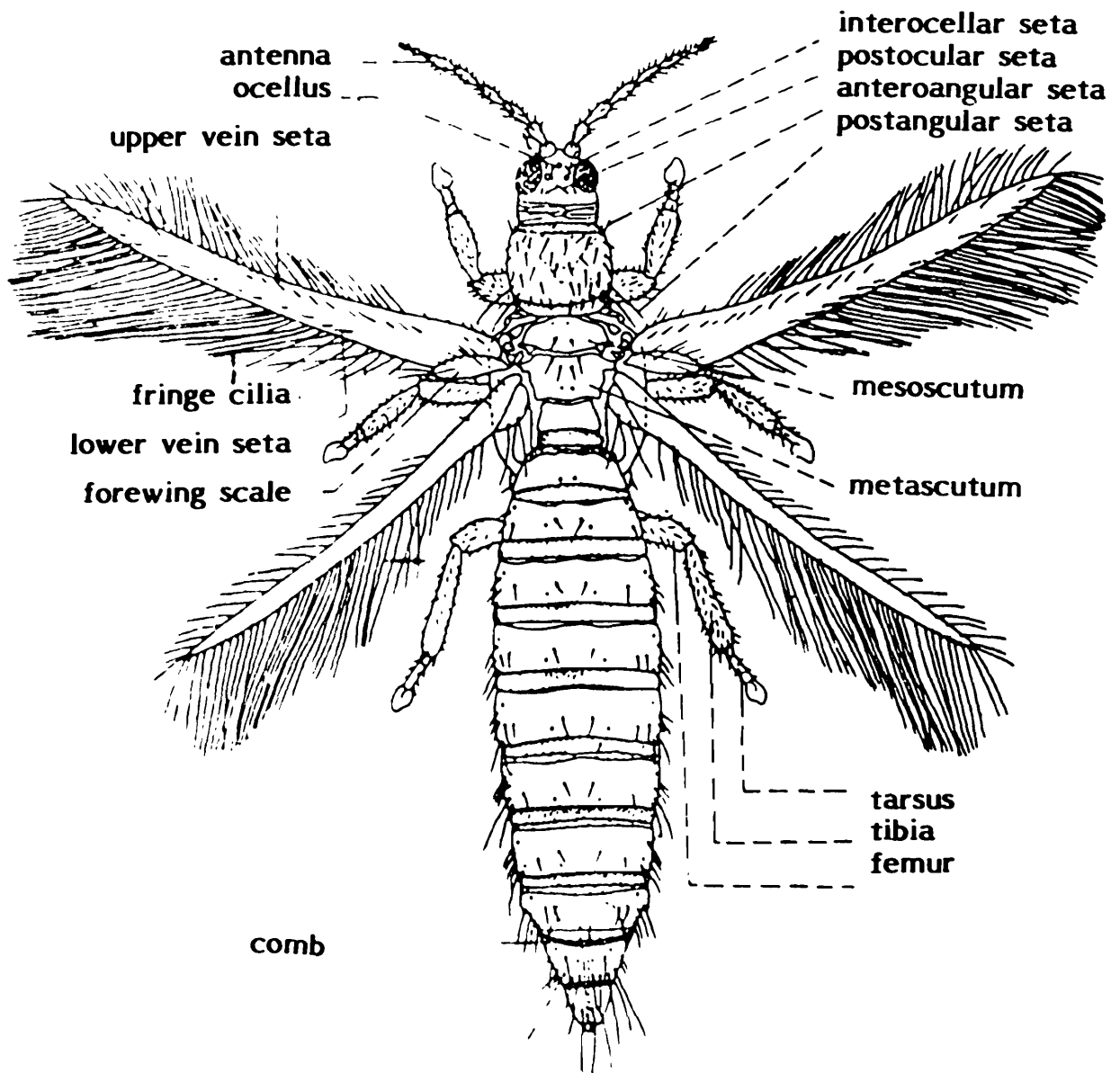


Fig. 1. Dorsal view of a typical Terebrantian

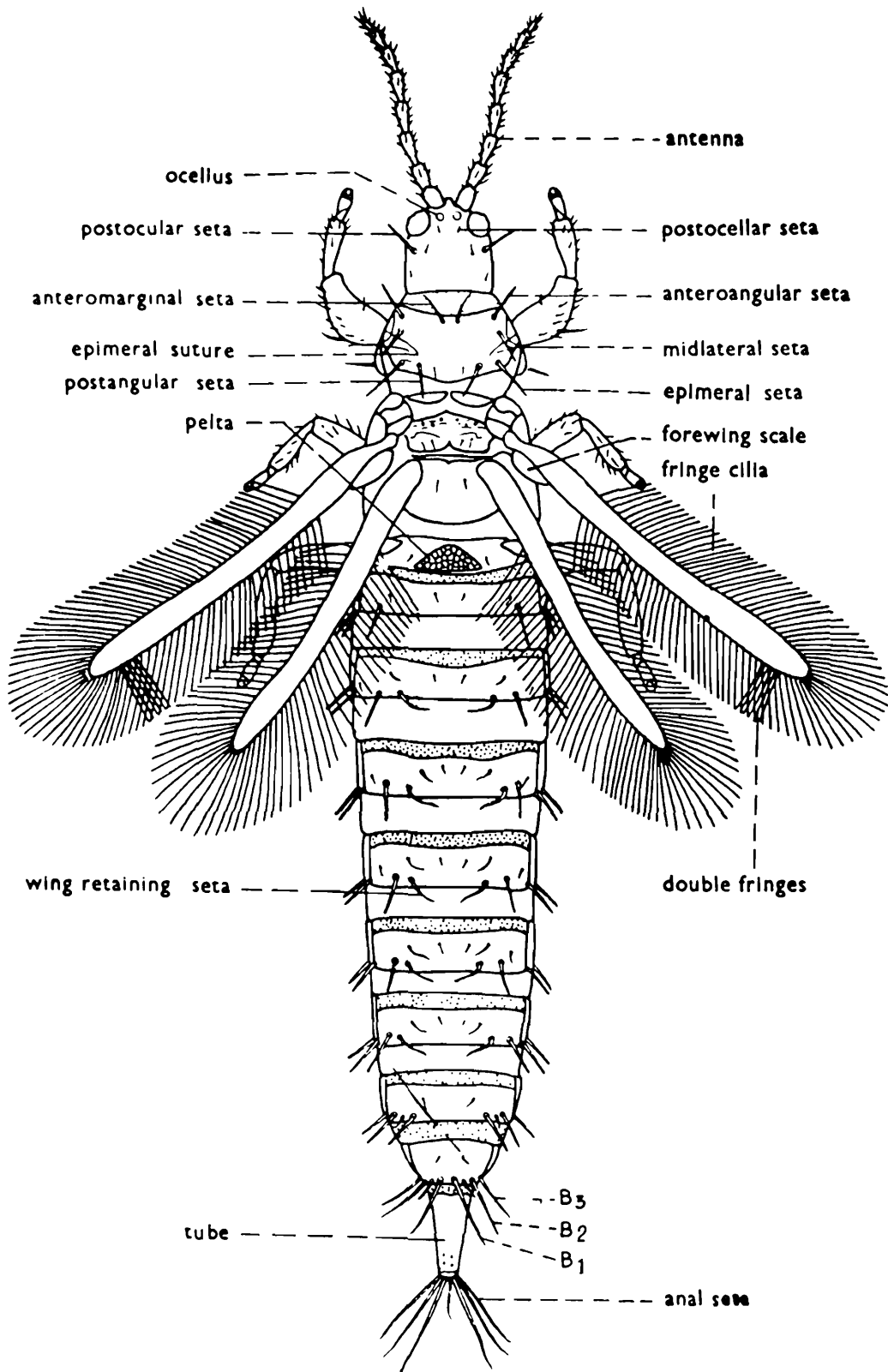


Fig. 2. Dorsal view of a typical Tubuliferan

COLLECTION, PRESERVATION AND IDENTIFICATION OF NEUROPTERA & TRICHOPTERA

S.K.Ghosh

Neuroptera, the nerve-winged insects, mostly predate on other insect groups. Several species are predacious on different insect pests in their larval and adult stages and are valuable allies of man. Some of the immature forms prey upon the aquatic larvae of various groups of other animals while a few depredate numerous obnoxious insects of both terrestrial and arboreal habits. Some larvae feed on the fresh water sponges while few neuropterans parasitise the egg capsules of spiders. Thus, Neuroptera, in general, exhibits carnivorous habits offering a better scope to the people for deploying some of these insects in biological control measure.

Trichoptera is popularly called as caddis flies or larvae caddis worms, because of the ability of the latter to construct and line with silk the cases in which they live. The trichoptera forms a well-defined order closely related to Lepidoptera particularly moths. But their movements and general anatomical features readily relegate them to a separate and distinct groups of insects. This group is entirely beneficial, the larvae not only forming a most important article of diet for freshwater fishes but also helping effectively to control the growth of water-weeds.

COLLECTION AND PRESERVATION OF NEUROPTERA AND TRICHOPTERA

Where to look for : For the collection of Neuroptera and Trichoptera one should have some idea about their habits and habitats. Several species of Neuroptera are diurnal but a great majority rest during the day and take wing at or just following sunset. They may be collected from herbage, bushes, trees, different types of vegetation including crops and also from the artificial light at night. Trichopterans are found only in the neighbourhood of rivers, streams, ponds, lakes, etc. They are either crepuscular or nocturnal and generally concealed during the day. Certain species, however, appear in sunlight during the morning or afternoon. They may be collected from herbage and rushes bordering water sources, the bushes and branches of trees overhanging water or isolated trees at a little distance from water, crevices of the bark, underside of the bridges, under stones or from the artificial light sources at night.

Methods of collection : Both Neuroptera and Trichoptera may be collected by the following methods :

(a) **Sweeping :** Sweeping with a proper net yields satisfactory results while collecting insects from herbage.

(b) **Beating :** Beating is usually employed to dislodge insects from foliage or trees. Usually a long stick is used to beat the plant part and a tray, or umbrella or white cloth, according to convenience, may be kept below to collect the insects. These insects are picked up individually either with forceps or with the help of a brush moistened with 80% alcohol.

(c) **Aerial netting :** Butterfly nets are most widely used to collect these insects on wings.

(d) **Light traps :** An artificial light like Petromax gas light, if placed on a white malmal cloth in the field at evening will attract a number of insects and these may be easily picked up by hand. Electric lamp-posts may also be checked up to collect these insects.

METHODS OF PRESERVATION

After collection, large and hard-bodied specimens are preserved in dry condition after being killed in cyanide bottles or benzene vapour while the small and soft-bodied ones are sometimes preserved in 80% alcohol though more usually they are also killed and preserved as the large sized insects. It is always preferable to preserve both these groups of insects in dry condition. The specimens preserved dry are kept in paper envelopes while those, in wet condition, are kept in a small vial containing 80% alcohol. When the collection has been brought to the laboratory it has to be made ready for study and permanent storage. First step is to relax the material in proper relaxing box, then the specimens should be set and pinned-displaying as far as possible most of the taxonomic characters. Depending upon the size of specimens the appropriate pins are to be used. The specimens should be pinned through the middle of the mesothorax. It is always necessary to have labels providing information about locality, date, name of collector and of habit etc. attached with individual specimen. For permanent preservation, the dry specimens may be kept in any standard size insect box with necessary chemicals (Naphthaline, Liquid Benzene, Camphor-carbolic) to check the growth of fungus and damage from other insects. Specimens preserved in alcohol may be kept as such with locality label in each individual vial.

IDENTIFICATION

The identification of insects upto species is not an easy task in view of the large number of species and individuals exhibiting enormous intra-specific variations. It requires thorough training and long experience. However, the identification of taxa upto the species level is possible only with the help of important literature providing keys, illustrations and descriptions. The comparison of specimen with standard identified collections is also important.

Characters of the order : Head (Fig. 1) : hypognathus, mouth parts : biting type with welldeveloped labium (Fig.2) chitinous mandibles (Fig.3), a pair of maxillae (Fig.4) with 5-segmented palpi and a labium (Fig.5) with 3-segmented palpi; antennae (Fig. 6,7) : variable, elongate or short, filiform, moniliform, pectinate, clavate or capitate; compound eyes: large and widely separated; ocelli: 3, when present; wings (Fig.9,10) : two pairs, held roof-like or flat over body at rest; transparent or cloudy or covered with fine powdery wax; normally similar in size and form; venation variable with a net work of veins; generally with complete series of costal veinlets; radial sector with closely parallel branches; with many longitudinal veins and irregular crossveins; with or without pterostigma; leg : as in Fig.8; abdomen (Figs. 11-13): 10- segmented and with 8 pairs of abdominal spiracles; ♂ genitalia with a gonareus and ♀ with a pair of gonapophysis lateralis.

The order may be divided into two suborders, viz., Megaloptera and planipennia.

Suborder Megaloptera : Branches of veins rarely bifurcated at margin of wings; Rs with a few additional branches. There are 4 families of which the fem. Corydalidae is well represented in India which is dealt with here.

Fam. Corydalidae (Dobson flies) : Large-sized insects with wing expanse more than 50 mm; ocelli : present; legs : fourth tarsal segment simple, not bilobed, wings crossveins weakly formed. Larvae are formidable-looking creatures that occur under stones, in slow or swift moving water. They are predacious on naiads of dragon flies, stone flies, may flies and other aquatic forms. The larvae are used as bait for catching fresh water fishes.

Suborder Planipennia : Branches of veins usually bifurcated at margin of wings; Rs generally with numerous branches. This suborder contains 16 families of which 11 well represented families from India are dealt with here in the key.

KEY TO THE FAMILIES OF SUBORDER PLANIPENNIA

1. Very small insects, less than 10 mm. in wing expanse; wings and most of the body covered with whitish waxy powder; costal area without or with only one or two crossveins near the root; veins with no terminal twiggings...
.....**Coniopterygidae**

- Medium sized or large insects, more than 10 mm. in wing expanse; wings and body not covered with whitish powder; costal area with many cross veins, usually with terminal twiggings2
2. Mouth produced into a short beak; hind wings quite different in shape than forewings, either ribbon-like, spoon-like or thread-shaped**Nemopteridae**

- Mouth conical without beak; hind wings of about the same shape as the fore wings3
3. Prothorax long; fore legs raptorial with strongly thickened femur **Mantispidae**

- Prothorax short; fore legs normal and cursorial.....4
4. Antennae never clubbed, nor with thickened apex.....5

- Antennae cylindrical with thickened apex or clubbed10
5. Ocelli present; discal area of wings with many cross veins, marginal area without cross vein but with many forked veinlets**Osmylidae**

- Ocelli absent; arrangement of cross veins of wings not as above6
6. Fore wings with atleast two apparent sectors arising from R7

- Fore wings with only a single sector arising from R near its base8
7. Antennae moniliform or filiform in both sexes; ovipositor not exerted; cross veins few**Hemerobiidae**

- Antennae pectinate in males; ovipositor exerted and long; cross veins numerous**Dilaridae**

8. Cu_1 in hind wings running for a long distance close to hind border**Berothidae**
- Cu_1 in hind wings not as above9
9. Wing margins with trichosors or small hairy thickenings between tips of veins; cross veins r-m in hind wings long and placed longitudinally**Sisyridae**
- Wing margins without trichosors; cross veins r-m in hind wings short and placed obliquely or transversely**Chrysopidae**
10. Antennae short, weakly clubbed or flattened towards apex; hypostigmatic cell elongate**Myrmeleontidae**
- Antennae long and slender, strongly clavate apically; hypostigmatic cell not differentiated**Ascalaphidae**

TRICHOPTERA

The identification of Trichoptera upto species level is a difficult task. To achieve this objective one has to be familiarised with the various morphological features of insects with the help of important literature and identified collections. But for the general guidelines the diagnostic characters of the order and families which are well represented in India, are given in the key. Besides, some of the important literature concerning this group are also mentioned (vide References).

Characters of the order : Moth-like, hairy; ocelli : 3, when present; antenna : long, filiform and multi-segmented; mouth parts : poorly developed; maxillary palpi (Fig. 16 a,b): 5-segmented or less; labial palpi : 3-segmented; wings (Figs, 14, 15) : 2 pairs, clothed generally with hairs and scales; folded roof-like over body at rest; with many longitudinal and a few crossveins; hind pair widest and with anal fold; legs (Fig. 17a,b): long, tibiae with spurs and tarsi 5-segmented; abdomen : 10-segmented; male genitalia as in Fig. 18a,b.

KEY TO THE FAMILIES OF TRICHOPTERA

1. Terminal segment of maxillary palpi neither annulate nor flexible6

- Terminal segment of maxillary palpi annulate and flexible2
2. Adults with ocelli3
- Adults without ocelli4
3. Mesoscutum without setal warts; tibial spurs 0-2, 4, 4.....**Philopotamidae**
- Mesoscutum with setal warts; tibial spurs 3,4,4.....**Stenopsychidae**
4. Mesoscutum with a pair of rounded setal warts5
- Mesoscutum without setal warts**Hydropsychidae**
5. First two segments of maxillary palpi of about same length**Polycentropidae**
- Second segment of maxillary palpi usually longer than first**Psychomyiidae**
6. Maxillary palpi 5-segmented in both sexes.....7
- Maxillary palpi with less than five segments in males8
7. Wings rather broad and rounded; tibial spurs 3,4,4.....**Rhyacophilidae**
- Wings narrow and pointed; tibial spurs 0-1,2-3,3-4**Hydroptilidae**
8. Adults with ocelli9
- Adults without ocelli10
9. Maxillary palpi usually 4-segmented in males, 5-segmented in females; tibial spurs usually 2,4,4**Phryganeidae**
- Maxillary palpi 3-segmented in males, 5-segmented in females; tibial spurs 0-1, 1-3, 1-4**Limnephilidae**
10. Forewing with discoidal cell11
- Forewing without discoidal cell**Molannidae**
11. Antennae as long as or slightly shorter than wings**Sericostomatidae**

- Antennae much longer than wings12
12. Tibial spurs with maximum of 2,4,4.....13
- Tibial spurs with maximum of 2,2,4**Leptoceridae**
13. Maxillary palpi long and stout; both wings with closed discoidal cell**Odontoceridae**
- Maxillary palpi long, not stout but hairy; discoidal cell lacking in hind wing**Calamoceratidae**

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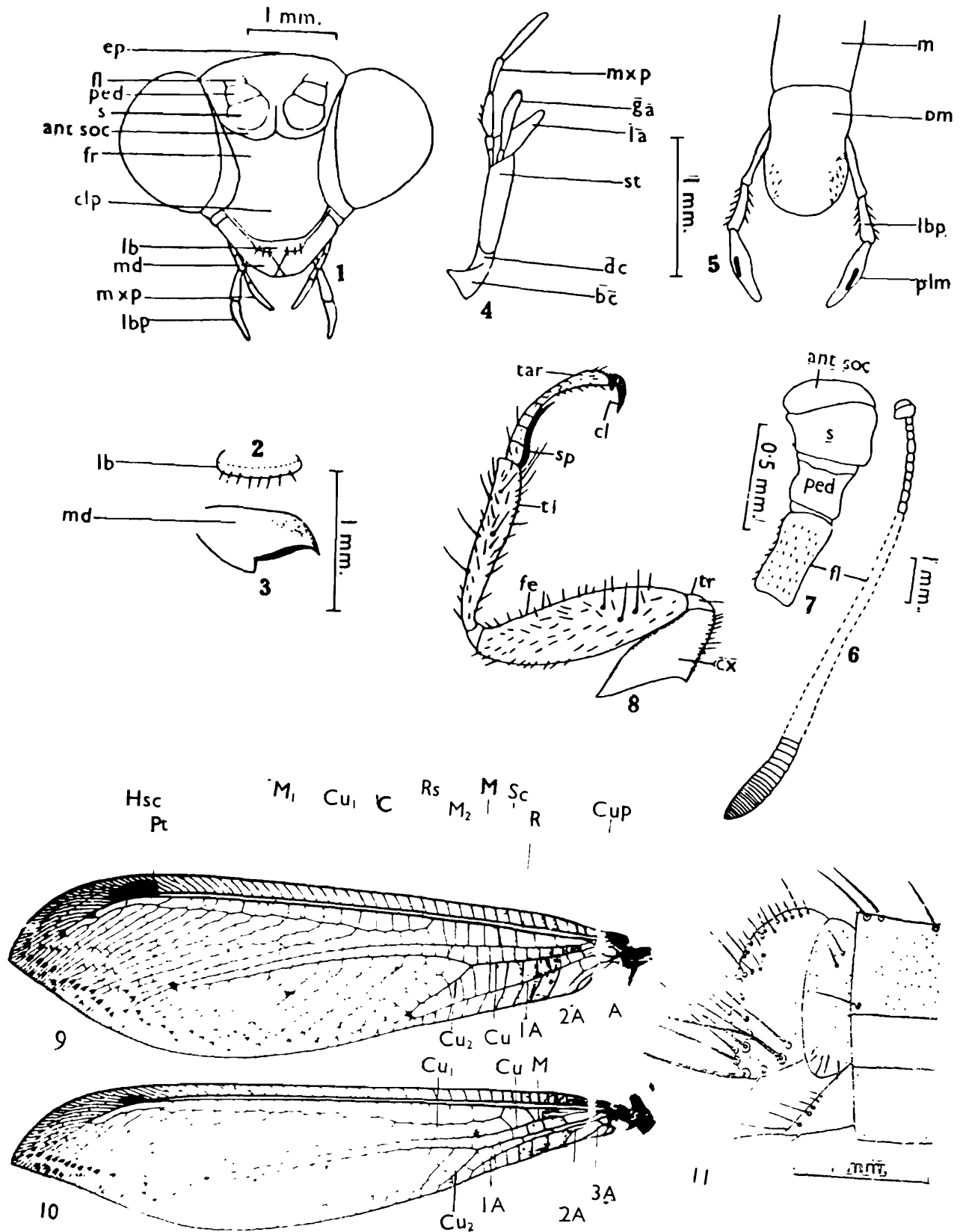
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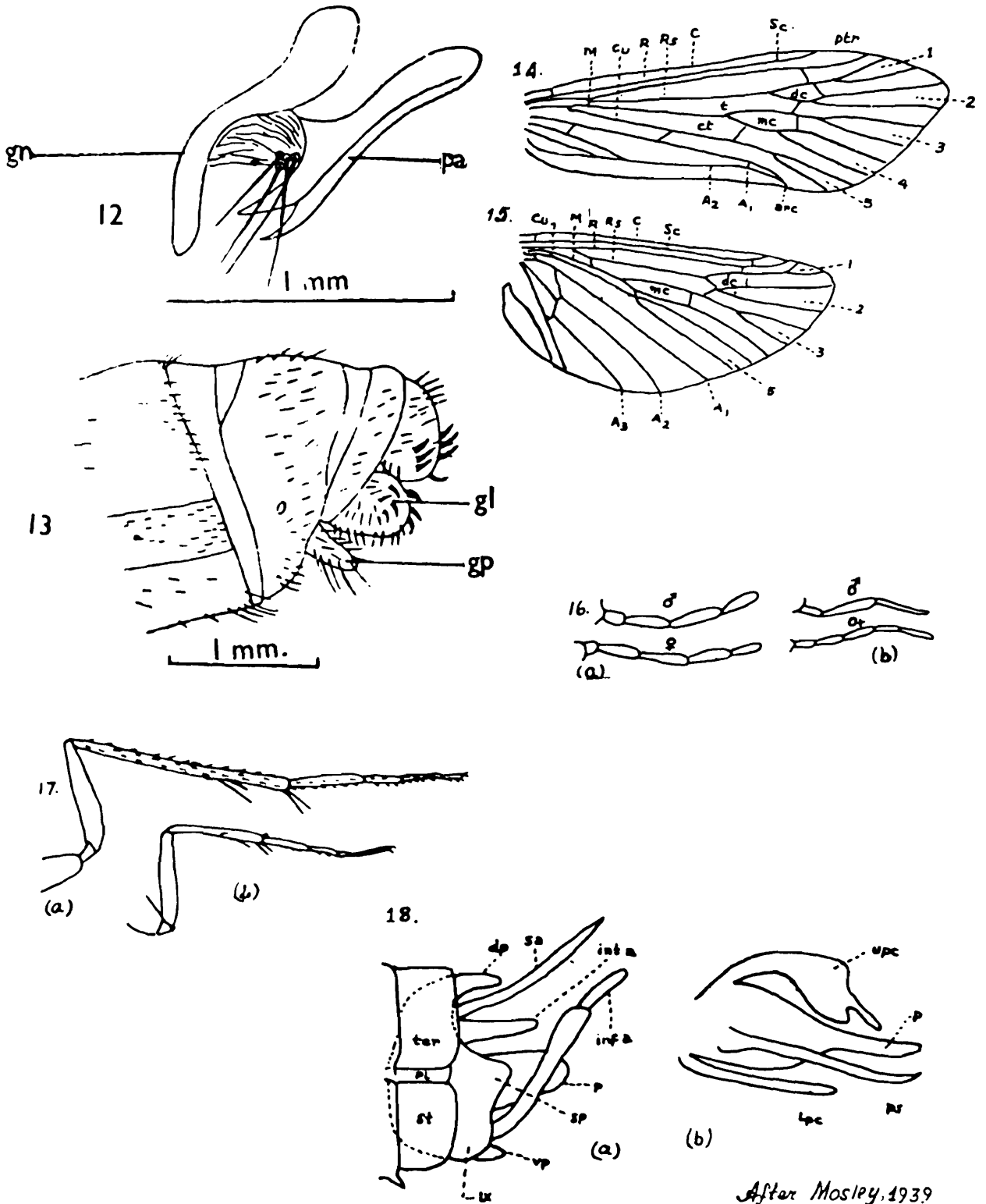
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Figs. 1-10 : Neuroptera : Head (ep, epicranium; fl., flagellum; ped., pedicel; s, scape; ant. soc., antennal socket; fr., frons; e., compound eye; clp., clasper; lb., labrum; md., mandible; mxp., maxillary palpus; lbp., labial palpus); 2. Labrum (lb.); 3. Mandible (md.); 4. Maxilla (mxp., maxillary palpus; ga., galea; la., lacinia; st., stipes; dc., distal cardo; bc., basal cardo); 5. Labium (m., mentum; dm., prementum; lbp., labial palpus; plm., palpo-macula); 6. Antenna (fl., flagellum); 7. Parts of antenna (magnified) (ant. soc., antennal socket; ped., pedicel; fl., flagellum); 8. Fore leg (cx., coxa; tr., trochanter; fe., femur; ti., tibia; sp., spur; tar., tarsus; cl., claw); 9. Fore wing (C., costa; R., radius; Sc., subcosta; Rs., radial-sector; M., media; M₁, anterior media; M₂, posterior media; Cu., cubitus; Cu₁, anterior cubitus; Cu₂, posterior cubitus; Cup., basal fork of cubitus; IA., first anal; 2A., second anal; 3A., third anal; Pt., pterostigma; Hsc., hypostigmatic cell); 10. Hind wing notations as in fig. 9; 11. Tip of abdomen, male, lateral view.



After Mosley, 1939

Figs. 12-13 : Neuroptera : 12. Male genitalia (gm., gonarcus; pa., paramere); 13. Tip of abdomen, female, lateral view. (gl., gonapophyses lateralis; gp., gonapophyses posteriores). Figs. 14-18: Trichoptera : 14. Forewing (C., costa; Sc., sub-costa; R., radius; Rs., radial-sector; M., media; Cu., cubitus; A₁, A₂, A₃, anal veins; ptr., pterostigma; dc., discoidal cell; mc., median cell; ct., cellula thyridii; t., thyridium; arc., arculus; 1,2,3,4,5, apical forks.); 15. Hindwing (notations as in fig. 14.); 16. Maxillary palp : (a, Phryganeidae; b, Limnephillidae); 17. Legs : (a, fore leg; b, hind leg); 18. Male genitalia (diagrammatic) (a : ter, tergites; dp, dorsal plate; sa, superior appendage; int a, intermediate appendage; inf a, inferior appendage; p, penis; sp, side-piece; vp, ventral plate; st, sternites; pl, pleurites; ix, 9th abdominal segment; b : penis and its processes; upc, upper penis-cover; p, penis; ps, penis-sheath; lpc, lower penis-cover).

ON METHODS OF COLLECTION AND PRESERVATION OF LEPIDOPTERA

G. S. Arora

The order Lepidoptera comprising the most beautiful insects of the nature - the butterflies and moths, are characterised by the presence of scales on fore and hind wings. These scales come off easily as dust, if touched by fingers. It is one of the most important orders of the class Insecta, since majority of these have a direct bearing on national economy, while some causing extensive damage at caterpillar stages to agricultural crops, plantations, forest trees, etc., others like silkworms are quite useful.

I. WHERE TO LOOK FOR AND COLLECT

The order Lepidoptera, including butterflies and moths, live in diverse ecological conditions at their immature as well as adult stages, so that these stages can be collected depending upon one's needs, from their natural place of occurrence. While the caterpillars, which cause damage as root borers, cutworms, stem borers, shoot or top borers, bark eaters, leaf defoliators, leaf rollers, seed or capsule borers, cob or case forming caterpillars, stored grain pests, etc., can be collected from their specified hosts during the particular seasons, and reared for the purpose of either scientific research or obtaining adults for museum. The adults can be collected from various places while on wings, or settled on flowers, puddles, by the side of streams, over-ripe fruits, etc. The following hints will be found to be quite useful in collecting butterfly and moth fauna of the various types.

(a) **Collecting in flight/near streams/puddles, etc. :** Indian climatic conditions offer enormous scope to an amateur as well as a trained collector, to collect a variety of lepidopterous fauna of a specified group. A visit to a shaded place under the trees with a lot of fallen dry and dead leaves and bushes around would be promising for the collection, particularly, of Satyridae (Melanitis, Mycalesis, Lethe, etc.). Similarly tall or low open grassland with small bushes around would yield specimens of Satyridae, Pieridae (Eurema and Appias), Danaidae (Danaus), small Lycaenidae (Grass Blues), Nymphalidae (Precis), Papilionidae (Papilio), and day-flying moths like Amatidae, Arctiidae, Zygaenidae and Pyralidae.

A large number of butterfly-species, particularly Nymphalidae and Papilionidae are fond of visiting flowers, and are easily caught. With a little patience one can collect and make observations on their habits, courtship flight, mating, etc.

Several species of butterflies, particularly Blue-Bottle and Jays, (sarpedon, doson, cloanthus), Helens, Dragontails, Lime Butterfly, Swallowtails species of Papilionidae, visit streams for a "drink" during early hours of the day. Some like Blue Bottles settle on damp ground preferably in a congregating group of Yellows and Whites of Pieridae. One is likely to find several species of Nymphalidae, Lycaenidae, Satyridae, Acraeidae and some Hesperidae in close vicinity of this area which is comparatively cool and offers quick and safe retreat to jungle once the species are scared.

Several species, particularly the "Birdwings" of Papilionidae are among the largest Indian butterflies flying above tree-tops and are difficult to capture in a normal course. To catch these, it is essential to watch their flight paths for some time and then take a suitable position on a nearby hillock or some raised place where flowering bushes are around. As soon as these visit these flowering bushes, they should be netted. Most Papilionids being in the habit of constantly fluttering their wings, while drinking nectar but never sitting, are rather alert and quickly escape with the slightest movement, so that it requires a great skill, besides patience, to capture an undamaged specimen of 'Birdwing'.

(b) **Trapping by Baits** : Quite a number of Danaids (Euploea, Danaus) can be captured on an overripe fruit or fruit damped with beer. These have also been seen to settle on rotting meat, dung or on a ground damp with urine.

(c) **Collecting at Light** : Majority of moths, being nocturnal, and some of butterflies like Evening Brown and some Eurema, are attracted to light and can be caught easily.

(d) **Collecting immature stages** : As mentioned above, the lepidopterous fauna can also be collected at their caterpillar stages and reared to adults. In fact collections acquired by way of rearing have been considered by far the best since these provide perfect specimens, besides providing sufficient knowledge on their life history, food and feeding habits, behaviour, population studies, etc.

(e) **Specialised collections** : The collections can also be made by specialised methods of using insect sex pheromon extracted

from the species concerned. Jacobson (1972) has given a comprehensive account of pheromon extraction, and its use thereof for capturing material of the relevant species.

II. HINTS ON METHODS OF COLLECTING

The basic requirement is net with a handle of specific dimensions, as mentioned later in equipments. The following methodology will be useful in catching lepidopterous specimens.

(i) **When on flight or settled on flowers :** The collector should take a good look at the specimen, follow its flight for some time while waiting for the same to come within the striking distance. Once the specimen has settled down on flower or is within the striking or sweeping distance, the collector should take suitable position and give a quick stroke of the net over the specimen immediately, otherwise it retreats into its hiding place and may not return for a long time.

As soon as the specimen has been found to be netted in, the mouth of the net must immediately be turned over (Fig. 1A) to trap it inside and the specimen be held, as early as possible, at the thorax between thumb and forefinger to stop its fluttering of wings which would otherwise damage or rub off its scales. A pressure is exerted to kill the same. Danaids particularly need a long and sustained pressure to kill them. Hesperidae, however, need to be killed in "killing" Jars kept ready in advance.

Several species while dying, reverse their wings which must be corrected to normal position while keeping them in paper triangles kept ready for temporary storage, since once dried it becomes difficult to set them back easily.

In case of congregating specimens, or settled singly on damp ground, the specimen/s must be covered with the mouth of the net, without alarming the specimens, with the other end raised above by the other hand, so that when disturbed, these fly upwards in the net.

In case of nocturnal collections, particularly in case of moths, the most conventional method is to spread out a sheet of white cloth with a strong burning light kept over it or hung against a white wall, which attracts the fauna. These have to be captured singly by covering the same with mouth of killing Jar.

III. EQUIPMENTS

(1) **Collecting Nets** : Several types (Figure 1B-D) of collecting nets are in use. The most conventional has 'Y' handle (Figure 1B), a net bag with flexible cane, the ends of which are inserted into the sockets of upper arms of 'Y' and fixed, so that the opening of the net forms a semi-circle of about 40 cm in diameter. The net can be used as such or a light and long but strong pole can be fitted in the lower arm to capture butterflies sitting high-up or at an otherwise inaccessible place. Preferably the poles may be of collapsible or jointed extensions so that these can be shortened or lengthened, as desired.

The most convenient size of the net bag is about 60-75 cm long, its opening about 30-40 cm wide and becoming gradually narrow but rounded at the other end to about 10-15 cm. The mouths of the net-bag should have a border of strong white cloth, about 4-5 cm wide and hemmed, through which the flexible cane or wire can pass easily. Very narrow end will cause extensive damage to larger specimens. The cloth used may be of mosquito netting, preferably of white colour.

Other types of collecting nets are also available where instead of flexible cane, hard and strong wires (Figures 1C-D) are used and are detachable from poles. This helps to pack them when travelling.

(2) **Paper triangulars and Envelops** : During field surveys it is preferred to place unpinned specimens in triangular paper envelops, prepared and kept ready in advance. Their size depends upon the specimen to be placed. The triangles can be made preferably of thin hand-made or translucent butter or wax-paper as illustrated in (Fig. 2A-D). Paper envelops, nearly of 9 x 7 cm measurement for storing un-pinned specimens, particularly of moths, are recommended.

(3) **Killing Jar or killing tube** : These are made conventionally by using Potassium Cyanide crystals. A great care should be taken while handling, preparing, or while using it so as to avoid direct inhaling the fumes since the chemical is extremely toxic to all living beings. After plaster of paris paste has been poured over the layer of cyanide crystals, it should be allowed to dry for some time and then covered with 2-3 layers of blotting papers. Each such bottle should bear prominent label of "POISON" in red and should be kept out of reach of children. It is always advisable to fix adhesive tape on lower half of the killing tube or jar to prevent spilling over of the material in case bottle breaks accidentally.

Very often, liquid benzene or ethyl acetate, instead of Cyanide crystals, with thick pad of cotton or cellulose tissue, instead of plaster of paris covered by blotting papers, has been found quite useful. But these need to be re-charged frequently because the chemicals are highly volatile.

(4) **Aspirators** : Useful in case of smaller moths collected in field or reared in laboratory (Figure 3A-B).

(5) **Relaxing boxes** : Conventional relaxing boxes are oval in shape (Figure 3C) and are prepared from zinc or galvanized iron, with each side lined with cork. Other containers can also be used, provided these are air-tight and lined with cork. Before the specimens are placed in boxes, the cork is slightly moistened. The specimen when placed in these boxes will again become fully relaxed and suitable for setting for permanent storage.

(6) **Entomological pins** : Butterflies should preferably be pinned on stainless steel entomological pins, which are usually of 38 mm and are of various thickness (16, 3, 5, 0, 00, 000, 20) but no. 3 and 5 are suitable for most of the species, and 20 for smaller moths.

(7) **Setting boards** : Various types of setting boards are available where their central groove is either fixed or adjustable (Figure 3D, 3E).

(8) **Storage Boxes** : For temporary storage in field, storage boxes be kept ready in advance and each day's collection, be arranged. But care should be taken to keep a constant watch to preserve collections properly by adding powdered naphthalene in boxes and exposing collection boxes to sunlight periodically to allow collections to dry-up and to prevent fungal attack.

(9) **Head band magnifier (10X)**

(10) **Forceps.**

(11) **Fine brushes.**

(12) **Specimen labelling paper.**

IV. SETTING AND PREPARING MATERIAL FOR STUDY/STORAGE

Setting the specimens is also very important, because the 'set' collection in the drawer provides an opportunity for

a quick over-view of the species without causing any damage to their delicate parts.

The collections can be set best while still fresh. Once the specimens become dead and dry, they need to be relaxed in relaxing chambers to make them soft for handling and setting.

The width of the groove of setting board should be sufficient enough to accommodate the insects' body including its legs, and should have a sheet of cork to hold pins. The sides should also be wide enough to help in stretching the wings and setting them (Figure 3E).

The specimen, when ready for setting should be held gently from the underside at the thorax, and a pin passed through the thorax and set in a groove till the bases of wings are in level with the side-boards (Figure 3E). The fore wings are gently pushed forward by placing the tip of sharp needle or a pin behind a large vein till the hind margin forms a right angle (Figure 3F) to the body and pressed firmly under a narrow strips of papers fixed by pins at one end. The free end of the strip should also be pinned at posterior end and mounted by slightly inclining the pin backwards. Additional strips may be fixed on fore wing to keep it firm and uniform till they are dry.

The hind wing is then pushed forwards till the costal margin is covered by the hind margin of fore wing and assumes a normal position (Figure 3F) in relation to its fore wing as well as abdomen and set in the same way as the fore wing.

The antennae should point anteriorly with their tips widely placed from each other and, if necessary, held firmly by pins on sides. Similarly, the abdomen be cross-pinned to keep it straight and not allowed to droop down at its posterior end.

Each specimen set on the board should bear the collection data to avoid any confusion later. These temporary labels should be replaced by permanent ones after the specimen is well dry and fit to be stored permanently (see 'Labelling'). But care should be taken to see that no specimens are removed from the boards unless dried and well set, because if removed early, particularly during humid climate, the wings are liable to droop or rise a little after some days.

V. LABELLING

As soon as the specimens are captured and killed for the purpose of scientific study, the details of location be recorded in the field, particularly about the following data:

1. Name of locality; 2. Altitude, longitude and latitude; 3. Distance and direction from well known place, if the locality is not well known; 4. Date of collection; 5. Mode of collection, whether on flight, in congregation, at light, etc.; 6. Name of the collector.

The permanent labels either printed, with the locality data, or written legibly by black Indian ink, should replace the field labels, but in no circumstances the latter be destroyed or removed away from the pinned collections. In all cases of permanent labels, the country and state where collected must precede all other data as shown below :

INDIA : West Bengal
Dist. 24-Parganas
Calcutta, Eden Garden
15.xii.1983 on Wings
B.K.Tikader coll.

All labels must be as small as possible, and should be uniformly cut and properly and evenly spaced on the pin. If required 'steps' as shown in figure 3G be used to insert various labels to space them evenly. Ordinary soft wood or pith-boards can also be used for spacing the labels.

VI STORAGE & PRESERVATION

Every specimen must properly be stored right from the field to the place of work. In case of butterflies which need to be kept in paper triangles, care should be taken to place them in such a position that their antennae and legs are secured (Figures 2A-D). These should be arranged loosely in a row in storing boxes, with plenty of naphthalene powder.

The pinned collections can be stored in insect boxes of various dimensions, generally 45 cm x 30 cm which is easier to handle. These can be single-sided or double-sided, i.e., cork is fitted either on one side or both the top as well as bottom sides. Suitable depth to avoid contact with each other be maintained. Provision should also be kept for keeping powdered naphthalene either in specially provided cell with sieved cover, or in a groove formed by double-walling of the sides (Figure 4B).

Permanent storage be done in wooden cabinets, which consist of glass top drawers (Figure 4A).

To check fungus growth, a mixture of carbolic acid and camphor in the ratio of 3 : 1 be prepared and the cotton plugs, mounted on pin-heads, soaked in this mixture be provided

in a corner of each drawer. Care should be taken to renew the chemical periodically.

Some of the specimens ooze out grease after a certain period of storage. This can be removed or cleared with the help of liquid benzene. The badly damaged specimens can be pinned on a cork and dropped in large mouthed bottle of benzene and left for a few hours, after which the specimen can be removed and allowed to dry.

VII. CONCLUSION

It is hoped that the above brief notes, mainly for the collection and preservation of lepidopterous insects would be useful for beginners as well as those who need to make specialised collections. However, for further reading on the subject, the following literature is suggested, which will give extensive information, in respect of Indian fauna for both special and general faunistic survey.

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FIG. 1

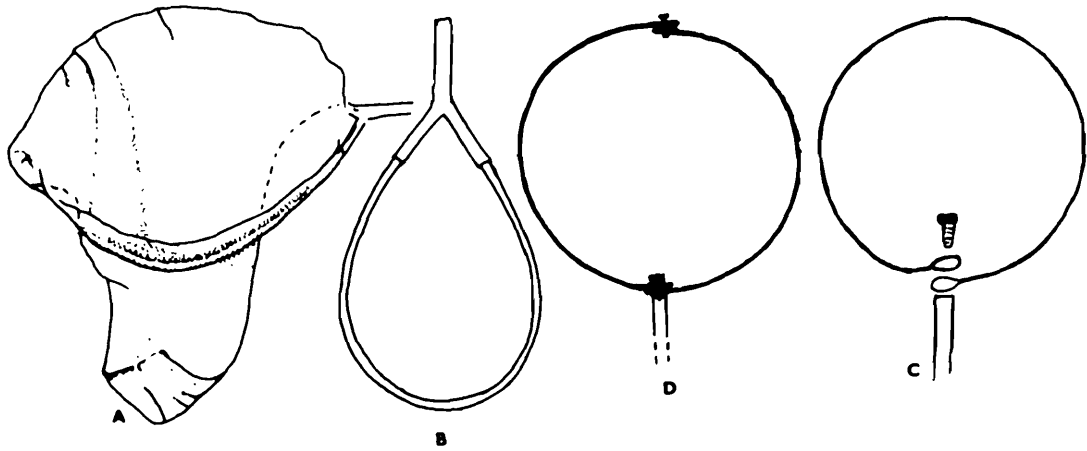


FIG. 2

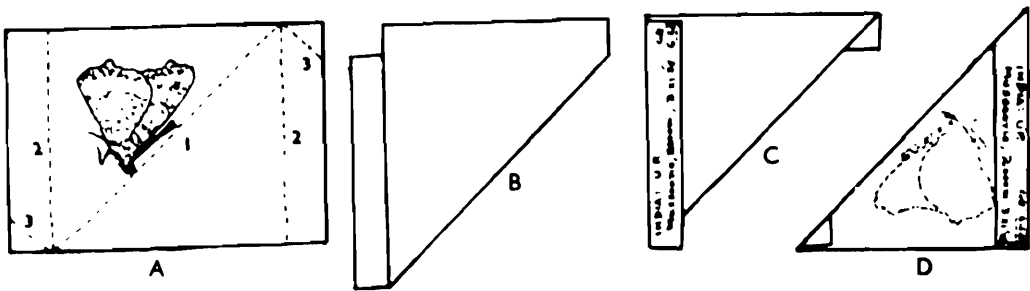


FIG. 3

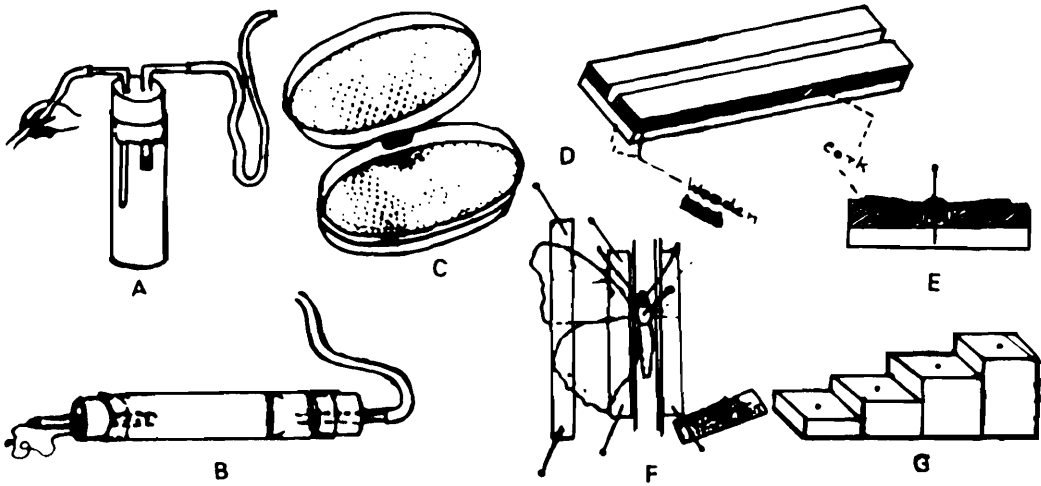
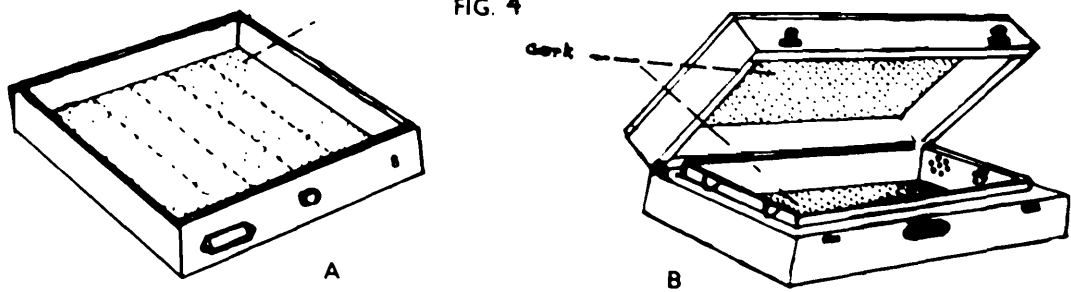
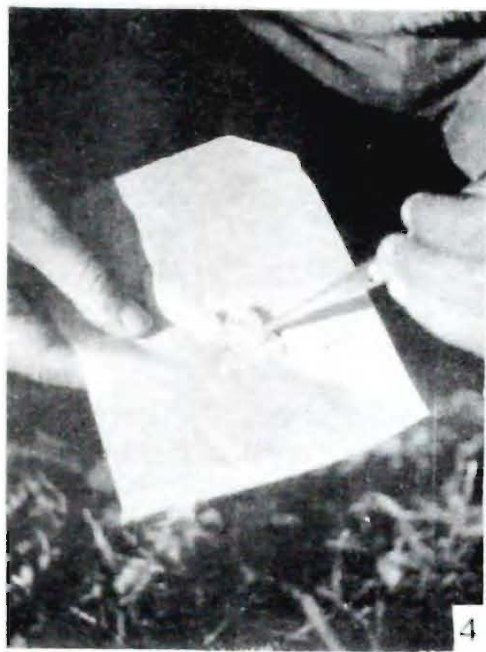


FIG. 4



Figs. 1-4. 1, A, D: A - Position of the net opening turned over after capturing the specimen; B - "Y" handle with cane-ends; C, D - wire frames. 2, A, D - Preparing triangular paper envelopes. 3, A, G: A-B - Aspirators; C - releasing chamber; D - setting board; E - setting of specimen on board; F - setting board, front view; G - steps used to place different labels. 4, A, B: A - glass-top drawer for storage; B - double-sided wooden insect box.



Figs. 1-5 : 1 - A collector waiting for flower-visiting insects; 2 - collection net of the conical shape, just before netting the specimen; 3 & 5. flower-visiting species during early hours; 4 - specimen being placed in a triangular paper envelop.

METHODS OF IDENTIFICATION OF LEPIDOPTERA

G.S.Arora, S.K.Ghosh, D.K.Mandal & I.J.Gupta

I. INTRODUCTION

While dealing with any of the multidisciplinary facets on a particular group of biological science, one feels the basic need of understanding the importance of taxonomy. This prime subject is concerned with the arrangement of different forms or taxa in their appropriate hierarchical positions on the basis of affinities amongst the allied members. Thus, it tends to lead to a common goal of packing up the individuals in a manner as convenient as to help determine their true systematic position. The technique is significant enough for serving effectively the purpose of classification with "species" as the standard unit of reproductively isolated population, being inter linked by the supra-categories from "kingdom" to "super-species" on one hand, and the infracategories from "sub-species" to "form", on the other, for various branches including Entomology. While the characters at the level of supracategories are more or less static by nature, those at the species- or other infra-levels are generally dynamic with multiple facies being influenced by geographical variations, as in subspecies, or local, climatic, behavioural or even stray variations, as in morphos, di-or polyphenic, seasonal, sexual, migratory or aberrational form. In fact, only the subspecies amongst all the infra-specific forms is recognised as the lowest taxonomical category.

However, once the classification of a group is authentically built up on the basis of salient traits, it is applied to the method of identification of the same in accordance with the International Code of Zoological Nomenclature. For example, the class Insecta is recognised by the tracheate hexapodan features, at least in the imaginal state, with body incised into head, thorax and abdomen; sub-class pterygota, by the wings primarily present; division Endopterygota, by the wings fully formed in adult through complete metamorphosis from larva to pupa. Similarly, the order Lepidoptera possesses characters, as presently discussed.

II. TOOLS OF IDENTIFICATION

Amongst a number of evidences in support of the Darwinian theory of Organic Evolution, some from biogeography, biometry, cytogenetics, ecology, phylogeny and applied aspects, over and above those from morphology and bionomics, are preferably emphasized as tools on a broad team-work basis to add more knowledge

to the population concept in the light of modern taxonomy.

III. METHODS OF IDENTIFICATION

The identification of specimens, whether living or dead, is usually made on the basis of triple method : general, spot and key.

The method of general identification is concerned with the experience-based observations of overall features comprising facies, habits and habitats of living individuals mostly on profile survey. The method of spot identification involves a rough and ready check of the most diagnostic characters either at naked eyes or with hand-lenses in the concerned spot. In the last but not to the least, the method of key identification with the aid of high-powered opticals in the laboratory after fixing and preserving the specimens in a proper manner is the most convincing of all. It is applicable to all the taxonomical categories for which the aptly prepared key works through the process of gradual elimination of traits in a successful manner, as expected. The arrangement proves a great merit through a simple and direct way of dichotomy, in each step of which a choice preferably between paired and adjacent alternatives, called couplets, is harnessed to obtain the satisfactory identity of any form under study. Finally it is subject to confirmation through comparison with the named collections, as in a museum repository, or accurately illustrated description in literature, as necessarily available.

IV. PRESENT SCOPE

The Lepidoptera represents one of the highly specialised and very large orders of the class Insecta. It comprises a prolific number of species in about 100 families from the world, being mainly grouped into two convenient suborders, viz., Rhopalocera (Butterflies) and Heterocera (Moths). Imms (1957), however, considered three suborders, of which the smaller Zeugloptera and Monotrysia are exclusively recognised as Microlepidoptera, being mostly non-Indian, while the large Ditrysia includes quite a number of other Microlepidoptera besides the major Macrolepidoptera mostly from India. Amongst an approximate total of 60 families in India, only 10 are represented by the butterflies and the rest, by the moths.

Presently, the generalised features, coupled with the taxonomically salient variations of imagos of the Indian Lepidoptera based on the morphology after Hampson (1892-1896) and Talbot (1939, 1947), are briefed for the beginners under the limited scope of time and space. Further, key to superfamilies, sensu Imms (1957) has included just to highlight certain ideas on the Taxonomy of the concerned in particular fauna of India Lepidoptera.

V. IDENTIFYING CHARACTERS

Body : Usually with moderate vestiture of pigmented scales, producing variegated colours and markings of different shapes, patterns, designs and textures, particularly on wings, and often modified into immense hairs, as in Lasiocampidae, several. Noctuidae, etc. Divisible into head, thorax and abdomen, with features as follows :

HEAD : (A) Mouthparts.

1. Labium : Small and triangular, with palpi. 3-jointed and usually of moderate size; palpi often variable in length, shape, mode of orientation and scaling, particularly of 2nd and 3rd joints, in many; sometimes rudimentary, as in Saturniidae, or absent, as in Psychidae.

2. Proboscis : As modified galeae in the form of a grooved channel, being usually coiled and elongate; longest in Sphingidae and very often rudimentary or absent, as in Hepialidae, Psychidae, Eupterotidae, Cossidae, Lymantriidae, Lasiocampidae, Bombycidae, Saturniidae and also some Aegeriidae, Pyralidae, Zygaenidae, Geometridae, etc.

3. Maxillary palpi : Usually obsolete or absent, but well developed with a maximum of 5 joints of varying shape, size and scaling, as in Microlepidoptera.

4. Mandibles : Usually obsolete or absent altogether; rarely present with teeth, as in some Microlepidoptera including Tinaeidae.

5. Labrum : Almost always very minute and concealed by clypeus.

(B) **Clypeus** : Usually large, particularly in Macrolepidoptera; rarely with a lateral pair of sclerotized hairy processes, as in Sphingidae.

(C) **Frons** : Usually flat or rounded and simple; often with a distinct prominence of varying shape, as in many Noctuidae, Pyralidae, etc.

(D) **Epicranium** : Usually large, particularly in Macrolepidoptera; with sense organs, as follows :-

1. Antennae : Usually of moderate length and, simple structure and shape, with shaft dorsally scaled and approximated at origin; often variable, being considerably long, as in some Pyralidae, or short, as in

Papilionidae and Sphingidae, shaft both dorsally and ventrally scaled or naked, as in Papilionidae, terminally clubbed or hooked, stout and straight as in Rhopalocera and Sphingidae, or partly or wholly ciliate, dilate, annulate, serrate, fasciculate, or uni- or bipectinate with branches short or long, flexible or stiff, slender and curved backwards over abdomen, as in other Heterocera, or basally contorted or thickened, as in some Pyralidae, and sometimes wide apart at origin, as in Hesperidae; often marked as secondary sexual character in male, as in many Heterocera.

2. Eyes : Usually smooth and small, but sometimes hairy and large as in some Noctuidae and Lycaenidae.
3. Ocelli : Usually present, but often absent, as in some Heterocera.
4. Chaetosema : Small setiferous organ, usually absent, but present in some Microlepidoptera.

(E) **Occiput, collar or neck** : Mostly present as distinct band between head and thorax.

THORAX : Usually stouter in Rhopalocera than Heterocera; often with markings. Divisible into 3 segments : pro-, meso- and meta-. Prothorax usually reduced and without patagia, i.e., paired antero-lateral and transverse hairy processes; with spots being often developed in lower Heterocera; with a pair of forelegs.

Mesothorax usually very large and with tegulae as paired lateral and longitudinal hairy processes, often spotted as in Noctuidae, but reduced in higher forms and sterno-episternal suture being absent in Papilionidae and Pieridae; with a pair each of midlegs and forewings.

Metathorax small and often with tuft or crest of scales of hairs, as in Noctuidae and with a pair each of hindlegs and hindwings.

A. Legs (Fig.5) Forepair usually with tibiae reduced in size and bearing single small or large epiphysis; sometimes imperfect in both sexes, as in Danaidae, or reduced to short brushlike tarsi or single claw in male, as in Lycaenidae. Midpair usually large with single terminal pair of tibial spurs.

Hindpair usually developed with a pair each of mesial and terminal tibial spurs; sometimes obsolete or modified as sense

organs, as in Hepialidae and some Geometridae. As to the other general modifications in any of these pairs of legs, coxae being larger in Rhopalocera than Heterocera; femora with long hair-tufts, as in some Geometridae; tibial spurs of moderate size, with the inner one longer than the outer, or uniquely maximum, as in Pterophoridae, or highly reduced, as in higher groups, spines rarely present, as in some Noctuidae, and grooved tufts of scales or hairs as scent or sense organs, as also in other lower groups; tarsi 5-jointed, spiny and ending in paired claws with or without pulvillus and paronychium, all the pair of legs sometimes very long, as in Pyralidae, or absent, as in female of Psychidae.

B. Wings (Figs. 1-3) : Usually both the fore-and hindpairs developed; at rest, held in an erect, or more or less slanting, or half-open position in almost all Rhopalocera, or in a roof-like manner over abdomen, as in Heterocera; sometimes highly abnormal, with members of any pair being much distorted, as in the aberrants of Lymantriidae, Danaidae, etc., or otherwise affected in those of some other groups, as per any of the features to follow, or even absent altogether, as in female of Psychidae.

1. Expanse : Usually moderate; very small in Microlepidoptera except a few, like Hepialidae, etc., and also several Macrolepidoptera including some Noctuidae and Lycaenidae etc., or extremely large, as in some Saturniidae, Brahmaeidae, Papilionidae, Amathusiidae and Nymphalidae.
2. Shape : Usually entire and triangular with three sides or margins, viz., anterior or costa, exterior or outer or termen and interior or inner or posterior, called dorsum in forepair, and anal in hind pair, and three angles, viz., proximal or basal or base, as the point of origin from thorax, and double distal including apical or apex, as the free end of costa, and tornal or tornus in forepair or anal or anus in hind pair, as that of the interior margin; sometimes highly elongate and linear, as in certain lower forms, or leaf-like, as in some Noctuidae and Nymphalidae, or very often cleft into a varying number of plumules with margins and angles not regular, as in many Microlepidoptera; anterior and posterior margins often straight, or lobate, or moderately to highly arched or serrate, or dentate, or folded, and exterior margin truncate, or falcate, or crenulate or oblique, with apex, particularly of forepair, blunt or produced or pointed to a variable degree, and anal angle of hind pair sometimes lobed, as in different members of both Rhopalocera and Heterocera. Membrane

of hind pair often produced postero-exteriorly into tails of varying number, size and shape, as in Papilionidae, Lycaenidae, Saturniidae, Uraniidae and also Zygaenidae.

3. Texture : Usually with simple and minutely ribbed and furrowed scales of varied shapes, being inserted in overlapping rows within sockets on both upper or dorsal and lower or ventral sides of the fragile membranous surface and terminally modified into a row of even or crenulate cilia in both pair of wings often highly variable, with scales being transformed in male into elevated and compact scent organs, called androconia or plumules or brands which are made of accessory disc or bulb, connected by a short foot-stalk or pedicel, with an elongate or oblong or rounded lmina ending in finely fringed hairs or fimbriae, as in some Lycaenidae, Papilionidae, or may be in both sexes, raised as tufts of hairs in the form of minute pectinations in particular areas on upperside of either pair, or long fringe of hairs along the anal margin or patches, or stripes along the venins and so on ,as in different members of both Hetero-and Rhopalocera; scales sometimes highly thin and transparent or glossy, as in Ageriidae, Amatidae, Acraeidae and some Papilionidae; membranous surface often highly thick and tough, as in many Danaidae, Acraeidae and also certain Heterocera.
4. Coupling apparatus : Usually of two types : (a) Frenate type : Aided by frenulum and retinaculum; frenulum in male always as a single longer and stouter bristle, and in female usually, multiple, shorter and more slender bristles, rarely single, as in some Pyralidae, arising dorsally from costal base or humerus of hind pair and fitting ventrally into retinaculum of forepair; retinaculum as a fold, bar, hook or tuft of hairs either descending from costa or subcosta as in male, or ascending from middle or still lower part of membrane -surface, as in female of many forms. Exclusively belonging to Heterocera; often rudimentary, as in Epicopiidae, or absent, as in Uraniidae, Brahmaeidae, Saturniidae, Bombycidae, Pterothysanidae, Lasiocampidae, Arbelidae, some Geometridae, etc.

(b) Jugate type: Aided by Jugum of forepair and humerus of hind pair being tightly overlapped together, as in all Rhopalocera and also Heterocera without frenulum and retinaculum.
5. Venation : Customarily studied from underside of both pair of wings by using toluene to have a clear view

of veins; nomenclature followed after the Comstock and Needham's (1898-1899) notation. Noteworthy aspects, as follows:-

- (a) Pattern : Usually heteroneuran, with dissimilar number of veins of fore-and hind pair, but rarely homoneuran, with similar number, as in certain Microlepidoptera including Hepialidae.
- (b) Number : Forepair usually with 12 longitudinal veins, viz., one subcostal (Sc), 5 radials (R₁₋₅), 3 medians (M₁₋₃), 2 cubitals with 1st having upper and lower branches (Cu_{1-b} and Cu₂), and anal (A) often associated with 2A and also 3A, as in lower groups. Hindpair usually with 8 longitudinal veins, including all except R₁, being coincident with passing Sc, Sc + R₁ and also R₂₋₅ as radial sector (Rs). Transverse or cross veins usually a few, viz., 3 discocellulars of varying length, including lower (ldc) between M₁ and M₂, middle (mdc) between M₂ and M₃ and upper (udc) between M₃ and R₅ or Rs, thus enclosing a triangular and short or long space, called discoidal or discal cell or disc, often open in the partial or total absence of these discocellulars in one or other pair of wings, as in certain Rhopalocera or Heterocera; a short and slender or strong median spur near the base between cell and Cu₂ of forepair, as in some Papilionidae and normally absent in Heterocera; precostal or humeral vein at the base of Sc + R₁, being directed basad or distad or at right angle to costa and often proximally formed into a small precostal cell as in higher Rhopalocera; bar between Sc + R₁ and Rs, as in Sphingidae, Eupterotidae, Zygaenidae, etc., or between Sc and Costa, or between anal vein and dorsum; accessory veinlets in a series along costa of hind pair as in certain lower Heterocera. Sometimes, a few free or floating veins, called recurrent veins, protruding within discal cell, particularly of forepair, as in certain lower groups. Usually concave furrowed areas or interspaces in both pair running concurrently with, and being named after the underlying veins; sometimes developed as broad folds particularly in the baso-anal part of hind pair, as also in lower groups.
- (c) Orientation : Concerned with the origin, course and termination mainly of the longitudinal veins. Usually Sc or Sc + R₁, Cu₂ and anal veins arising from base, and the rest, from discal cell of both pair; as least 8 veins including R₁₋₅ and M₁₋₃ of fore pair almost equidistantly apart from one another at origin, as in certain Microlepidoptera; Sc sometimes highly swollen

at base as in Satyridae. Course often straight or sometimes bent or elbowed, and free, or otherwise, particularly for the adjacent veins, viz., connate, or stalked or approximated, or just touching or anastomosed slightly or strongly upto a varying extent and thus forming one, or at best, a couple of cellules, called areoles, or coincident, or forked in one or other pair of different families. Usually Sc or Sc + R₁ and anals terminating on anterior and posterior margins respectively; the rest, on exterior margin. One or more veins may be highly abnormal, or obliterate, or absent in many.

6. Zonation : Concerned with the distribution of areas retaining specific markings on dorsal and ventral sides of both pair of wings. Membrane-surface principally divided, with disc as the standard zone, into 2 imaginary sectors, viz., longitudinal and transverse; former with the anterior half extending from costa to mid-vertical level of discocellulars, and the posterior, from this level to the interior margin; proximal half extending from base to end of cell including basal, pre-discal and discal areas, and the distal, from this end to termen including post-discal, subterminal and terminal areas. Subterminal part just below apex being known as subapical area. Identifying markings on corresponding areas thus recognised as basal, discal, terminal, apical and so on
7. Colouration : As variegated markings from elementary to composite tinges of the solar spectrum in the form of sprinkled dots, striae, patches, fasciae, solid or macular or caudate spots and rings or ocelli with one or two pupils enclosed by iris all on the characteristic ground-patterns of both pair of wings in different families of Rhopalocera and also certain diurnal Heterocera; sometimes with bright iridescence and shot, as in the glossy members of Papilionidae, certain Danaidae, Lycaenidae, Zygaenidae, etc.; often showing moderate to extreme dorso-ventral differentiation as in certain Pieridae, Nymphalidae, etc., sometimes, as warning signal, as in many Danaidae and also certain Papilionidae. Terminal cilia variedly tinged either throughout or only limited at base; sometimes dominating colours coined as popular names for certain Rhopaloceran families, viz., the "Whites and Yellows" for Pieridae, "Browns" for Satyridae and "Blues" for Lycaenidae and also for some Heteroceran groups, like "Ermine Moths" for certain Arctiidae, and so on, rarely gynandromorphic as in certain Lymantriidae, Danaidae, etc., very often dull and dorso-ventrally almost unicolor, as in all nocturnal Heterocera, many Hesperidae and Acraeidae.

ABDOMEN :

Usually 10-segmented, with sternite I highly reduced and

7 pair of lateral spiracles on I-VII; cylindrical or dorsoventrally depressed, or flat, or fusiform; size moderate or appreciably shorter or longer than hindwings; mostly scaled, often with dorsal and lateral, and almost always anal tufts of hairs of varying length; anal segment sometimes with a fine and protrusible hair-pencil or rosette of plumules in male, or horny pouch called sphragis in graviid female; colouration often variable, being dorsally brown or black or white or green and ventrally or laterally red or pale, with variously oriented, bands, spots, stripes or rings, as in different families of both Rhopalo- and Heterocera. Major secondary sexual organs for reproduction, called terminalia or genitalia, mainly adopted from Klots (1956) as follows :-

(A) Male genitalia (Fig.4) : Almost always highly specialised, mostly chitinised and lodged in segments IX and X. Components, as follows :-

1. Segment IX : Large and almost entirely sclerotized; consisting of :

(a) Tegumen : Narrow or broad dorsal tergite; often with a prominent latero-apical pair of slender and curved spine-like processes, the side lobes, as in Hesperidae, Lycaenidae, etc.

(b) Vinculum : U-or-V-shaped, slender and prominent band-like sternite; anteriorly prolonged into a less chitinised structure, the saccus, of varying length, but absent in Monotrysa.

(c) Valvae or Claspers : A pair of lateral processes, usually large and well developed, as in Papilionidae, and often reduced in lower groups; basally articulated with vinculum; with several processes, viz., antero-distal or cucullus, postero-distal or valvulus, antero-proximal or costa, postero-proximal or sacculus, mid-dorsal or ampulla and midventral or harpe, the last being very often prominent as dentate organ; sometimes densely clothed with long hairs or armed with spines and setae, as in some Noctuidae.

(d) Intromittant organ or penis : Usually stout and of moderate size, but sometimes slender, long and with a markedly formed filamentous process; arising from the inter-basal valvae; composed of :-

(i) Aedeagus : Outer sclerotized sheath, being supported ventrally by vinculum and laterally by valvae; passing through a hollow ring-or cone-like structure, the anelus; with or without a ventral shield, the juxta.

(ii) Vesica : Inner eversible and membranous sac; often armed with a group of small spines, the cornutii.

2. Segment X : Usually small, mostly membranous and telescoped by segment IX; well developed in Nymphalidae.

(a) Uncus : Simple or bifid dorsal and terminal process, often fused with tegumen and hence not prominent, as in Lycaenidae, Danaidae, etc., sometimes with a basolateral pair of hairy pads or lobes, the socii, as in Lycaenidae.

(b) Scaphium : Postero-median sclerotized shield, highly prominent in Papilionidae and certain Heterocera.

(c) Gnathos : Ventral arch, being partly sclerotised and partly membranous.

(B) Female genitalia : Almost always highly generalised, mostly membranous, and often extending proximally upto VII, or sometimes a few more anterior segments, and terminally upto IX being fused with X, thus forming a more or less chitinized tube, called bursae copulatrix. Components, as follows :-

1. Corpora bursa : Irregular sac of varying length, with an anterior rod-like small chitinised and minutely serrate structure, the signum.
2. Ductus bursa : Given off from the Corpora, a chitinized duct: being very short, stout and straight or very long, slender and coiled and communicating with the next chamber.
3. Ostium bursa : Posterior-most chitinised chamber or genital plate of varied shapes, with differently oriented setae; often bearing a pair of each of ventro-lateral strong and acute processes, the anterior and posterior apophyses directed basad; opening to the exterior either by a couple of outlets, viz., the Vaginal or copulatory orifice on the intersegmental membrane between sternites VII and VIII and the terminal gonopore guarded by a lateral pair of anal papillae, also of varied shape and texture, as in Ditrysia, or only by the latter, as in many Monotrysia.

KEY TO SUPERFAMILIES

1. Antennae clavate; chaetosema present; proboscis present. Wings nonaculeate, with heteroneuran venation and amplexiform-

- coupling; hind pair with R_1 coincident with Sc, forming Rs, and Cu_2 present. Vinculum V-shaped, being produced into saccus; bursa copulatrix and gonopore opening respectively on sternites VIII and IX2
- Antennae heteromorphic; proboscis may be vestigial or absent3
2. Antennae close together at bases and knobbed at tips. Fore wings with R_3 and R_4 stalked, one or 2 other radials often missing**Papilionoidea**
- Antennae wide apart at bases and hooked at tips or geniculate. Fore wings with R_1 - R_5 , M_1 - M_3 and Cu_{1a} - Cu_{1b} equidistant at origin from cell**Hesperioidea**
3. Wings non-aculeate, with heteroneuran venation and frenate or amplexiform coupling; hind pair with R_1 coincident with Sc, forming Rs. Vinculum free from tergite, U-shaped and produced into saccus; bursa copulatrix and gonopore opening respectively on sternites VIII and IX4
- Wings aculeate. Vinculum fused with tergite and without saccus; bursa copulatrix and gonopore opening behind sternite IX14
4. Hind wings with Cu_2 present5
- Hind wings without Cu_2 , except in certain Tortricoids, Tineaoids and Pyralidoids²9
5. Antennae gradually clavate, with tips pointed and usually hooked; chaetosema absent. Frenulum almost always present. Tympanal organs absent**Sphingoidea**
- Antennae pectinate, or apically dilate, or simple6
6. Chaetosema present. Wing margins straight or rounded; hind pair with Sc + R_1 closely approximated to cell, or to Rs and with frenulum. Tympanal organs absent**Calliduloidea**
- Chaetosema absent; except in certain Geometroids7
7. Tympanal organs absent. Frenulum nearly always lost. Large stout species**Bombycoidea**
- Tympanal organs present. Frenulum nearly always present. Small to moderate-sized species8

8. Tympanal organs in metathorax. Fore wings with M_2 and M_3 usually approximated at origin**Noctuoidea**
- Tympanal organs in abdomen. Fore wings with M_2 and M_3 rarely approximated at origin**Geometroidea**
9. Antennae clavate; chaetosema absent. Fore wings with stem of M strongly developed, but M_{1+2} reduced; hind wings with frenulum**Castnioidea**
- Antennae pectinate, or acuminate, or simple10
10. Fore wings with stem of M more or less and Cu_2 often developed. Proboscis usually atrophied11
- Fore wings with stem of M and also Cu_2 reduced or absent. Proboscis usually developed. Frenulum present12
11. Fore wings with M forked into 2 branches in cell. Frenulum present**Cossoidea**
- Fore wings with M rarely forked in cell. Frenulum sometimes absent. ♀♀ sometimes apterous**Psychoidea**
12. Tympanal organs present, except in certain allies. Wings either entire, with margins sometimes scalloped, or cleft into at most 4 plumes, with venation well developed; hind pair with Sc + R_1 approximated to, or fused with Rs beyond cell, then diverging**Pyralidoidea**
- Tympanal organs absent. Hind wings with Sc + R_1 remote from Rs beyond cell13
13. Chaetosema present; labial palpi with 3rd segment usually short and obtuse. Wings entire, with margins straight or rounded; hind pair with Rs generally approximated to, or stalked with M_1 **Tortricoidea**
- Chaetosema absent; labial palpi with 3rd segment often slender and pointed. Wings may be very narrow with degenerate venation, or cleft into more than 4 plumes; hind pair with Rs more often separate from M_1 than being approximated or stalked**Tinaeidea**
14. Wing venation homoneuran and developed; hind pair with Rs 3-4-branched, R_1 separate from Sc and frenulum in both sexes not developed15
- Wing venation heteroneuran and reduced; hind pair with Rs unbranched and R_1 coincident with Sc; coupling apparatus

sexually dimorphic : fore pair with fibula rudimentary in oo, strong in oo and hind pair with frenulum strong in oo, absent and replaced by a more distal group of costal spines in oo. Bursa copulatrix opening into cloaca16

15. Fore wings with fibula; hind wings with a few costal spines and numerous aculei. Sternites with long apodemes; vinculum nearly square with 2 short apodemes; genital apertures opening into long cloaca**Eriocranioidea**
- Fore wings with a long jugum and strong humeral veinlet; hind wings without costal spines and with aculei not numerous. Sternites without apodemes; vinculum short, wide and U-shaped; genital apertures opening separately, cloaca being absent**Hepialoidea**
16. Antennae with 1st segment enlarged with scales forming an eye-cap. Sternal apodemes, when present, short, vinculum short, u-shaped or transverse; cloaca short**Stigmelloidea**
- Antennae with 1st segment not forming an eye-cap. Sternal apodemes long; vinculum very long, u-shaped with a membranous disc; cloaca long**Incurvarioidea**

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PLATE I

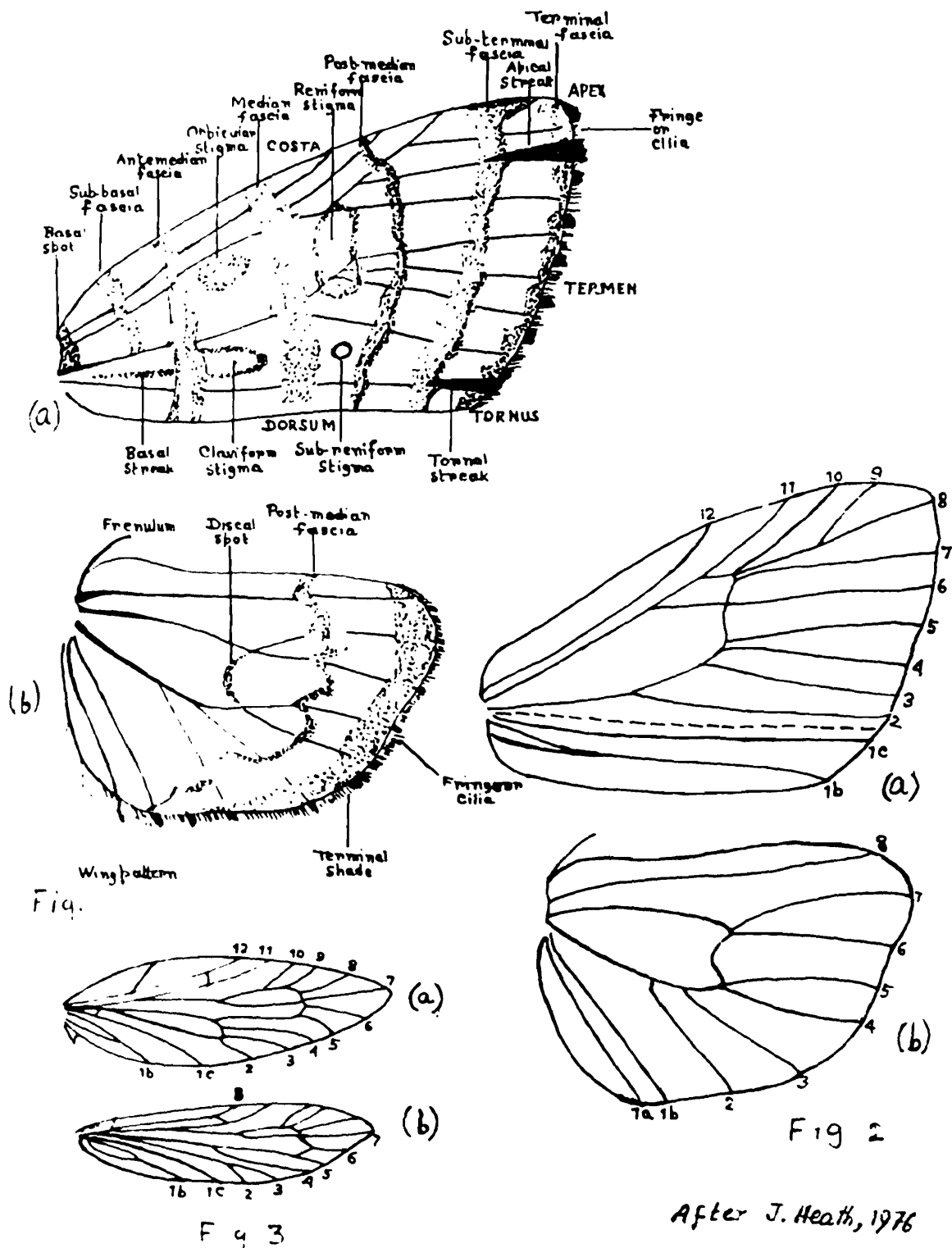


Fig.

After J. Heath, 1976

Figs. 1-3 : 1. Wing patterns : (a, fore wing; b, hind wing); 2. Wing venation (heteroneuran type); (a, fore wing 1b, anal I and II forked; 1c, second cubital; 2, lower branch of first cubital; 3, upper branch of first cubital; 4, third branch of median; 5, second branch of median; 6, first branch of median; 7, fifth branch of radial; 8, fourth branch of radial; 9, third branch of radial; 10, second branch of radial; 11, first branch of radial; 12, subcostal; (b), hind wing 1a & 1b, anals II & I free; 2, 3, 4, 5, 6, as in (a); 7, radial sector; 8, Subcostal coincident with the first branch of radial; 3. Wing venation (homoneuran type) : (a) fore wing Numerical notations as in fig. 2 (a); (b) hind wing 1b & 1c, anals forked; 1c to 7, as in (a); 8, subcostal distinct from all the radial branches, as in (a).

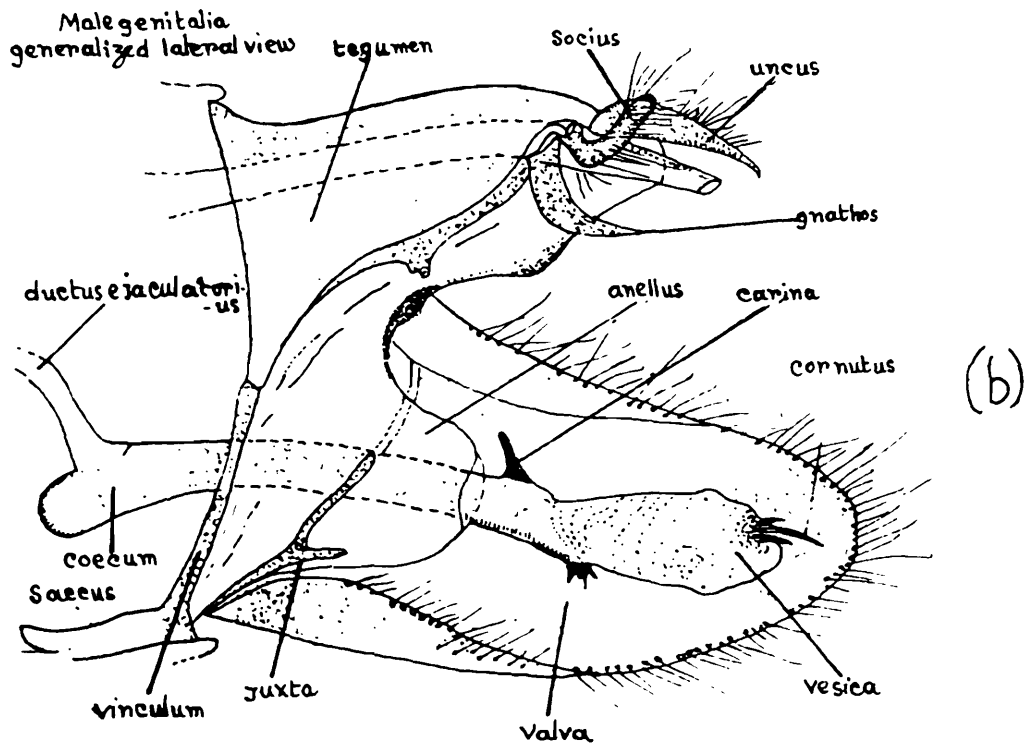
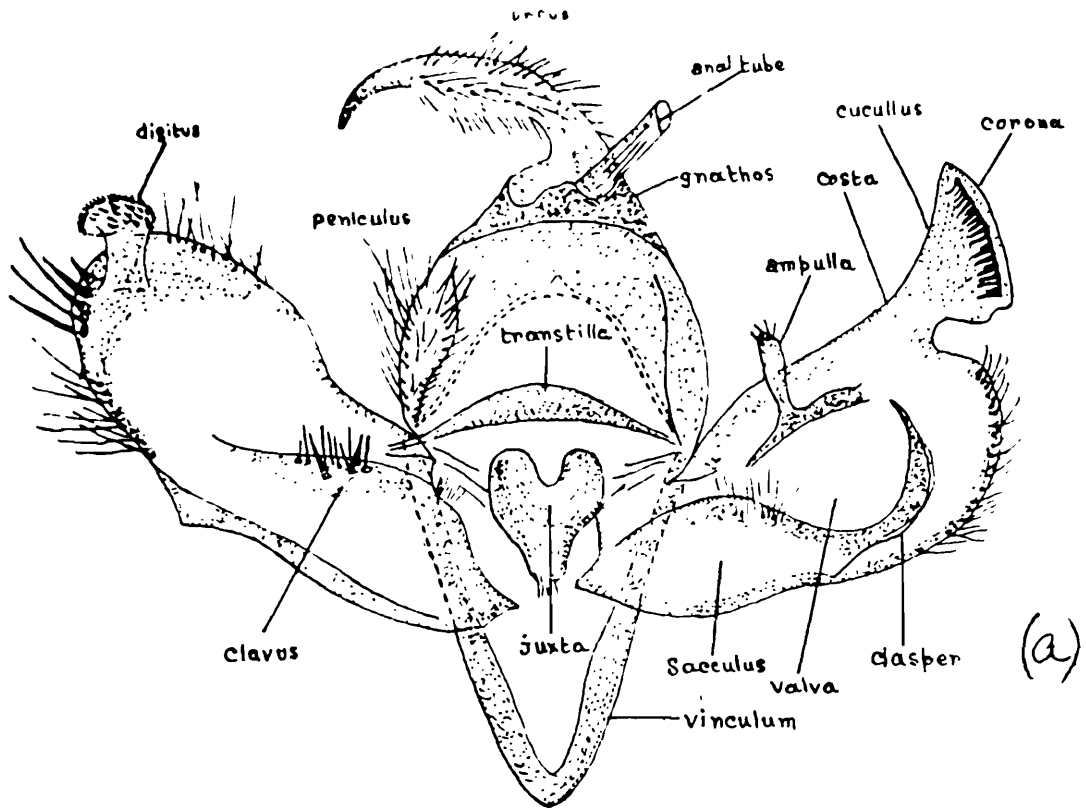


Fig 4

After Heatn, 1976

Fig.4. Male genitalia : (a) Ventral view; (b) lateral view.

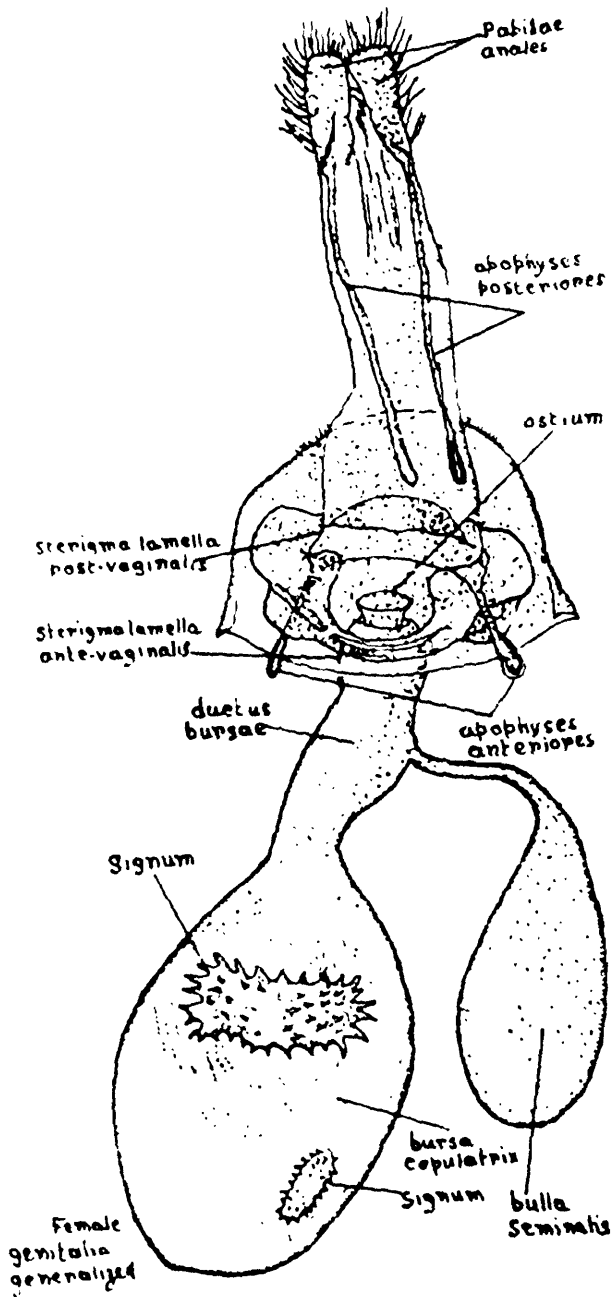


Fig 6

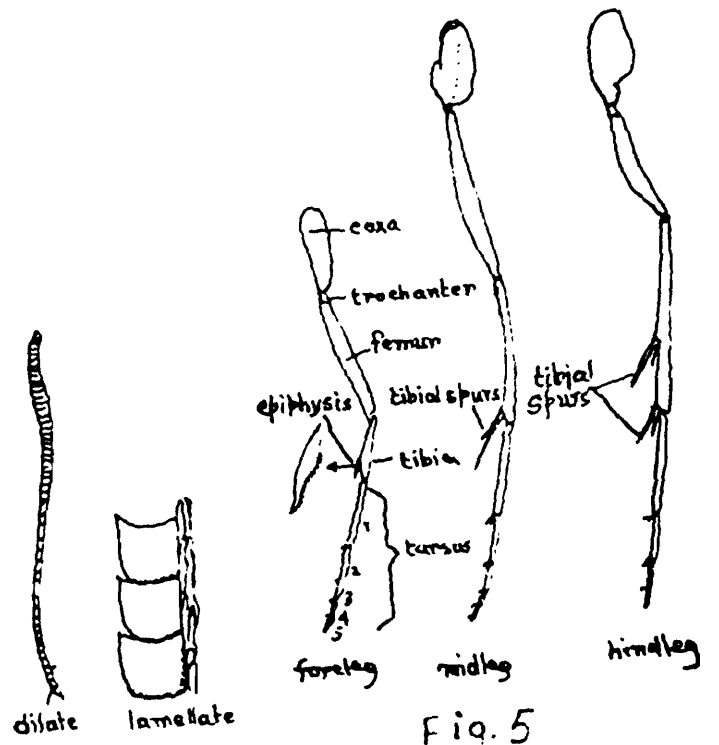


Fig. 5

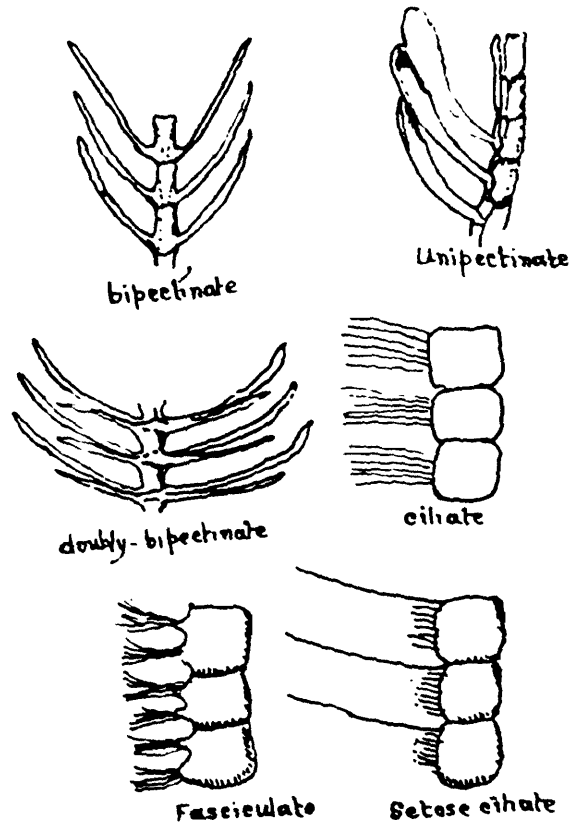


Fig. 7

After J. Heath 1976

Figs. 5-7. 5. Legs; 6. Female genitalia; 7. Different types of antennae.

IDENTIFICATION OF DIPTERA OF MEDICAL AND VETERINARY IMPORTANCE

M. Datta

A great majority of Diptera are quite harmless, but a few are offensive as annoying pests and vectors of certain diseases in their habitual effect of feeding on blood or of conveying pathogens from filth to food or of passing partial life in man and his animals causing a lot of distress to mankind. The normal transmitters of dreadful diseases like malaria, trypanosomiasis, leishmaniasis, sandfly fever, filariasis, dengue fever, chikungunya, Japanese encephalitis and certain other viral infections, in fact, belong to the Diptera. To determine the identity of the species responsible for such distress is an essential index to possible control measures and such attempts are likely to be futile without precise knowledge of what the pest is. A considerable attention has thus been paid to provide a logical plan throughout to recognize the serious pest-species of medical and veterinary importance with reference to the Indian Diptera.

DIAGNOSIS OF DIPTERA

The Diptera can readily be recognised (with a few exceptions as apterous forms) by the presence of only one pair of functional wings and a second pair of club-shaped appendages called halteres (absent in a few parasitic flies only). Moreover, in the Cyclorrhapha (true flies) the wing at base posteriorly bears a membranous lobe called alula and behind this, in many Cyclorrhapha, there are one or two additional lobes called squamae or calypters.

The mouthparts in the blood-suckers are so adapted as to form an efficient sucking and piercing apparatus. In this regard, the Orthorrhapha (mosquitoes, sandflies, blackflies, and horseflies) use the labium as a sheath for the other parts fitted for piercing and sucking, whereas in the Cyclorrhapha (stable flies, horn flies and tsetse flies), the labium itself acts as a piercing organ in absence of mandibles and maxillae, and the epipharynx and the hypopharynx form a sucking-tube. But in the non-blood-sucking flies, such as house flies, the mouthparts developed as a fleshy proboscis are used for lapping up fluids or dissolved foods. However, the mouthparts in the botflies (Oestridae and Gasterophilidae) are rudimentary and non-functional for seldom use. The antennae, palpi or legs are likewise of considerable help in diagnosis.

All Diptera have a complete metamorphosis with certain limitations. The Cyclorrhaphan larvae (maggots) especially interest us here, because they infest man and animals causing myiasis.

CLASSIFICATION OF DIPTERA OF MEDICAL AND VETERINARY IMPORTANCE

1. Adults emerge from pupae through straight or T-shaped dorsal slit; wing venation usually fairly simple; pupa not encased in old larval skin; larvae usually with well-developed or somewhat reduced head (Orthorrhapha) 2

Adults emerge through circular slit at anterior end; wing venation highly modified; pupa encased in old larval skin (puparium); larvae (maggots) without distinct head (Cyclorrhapha) 7
2. Antennae of at least 6 similar segments, and usually long; larvae with well-developed head (Nematocera) 3

Antennae short, of 3 segments, of which third may be with annulations (Brachycera) 6
3. Antennae much longer than head, with distinct whorls of hairs at joints, often plumose in males 4

Antennae not much longer than head, without long hairs; body stout and hump-backed; wings broad, with only anterior veins well-developed Simuliidae (blackflies)
4. Body clothed with scales; scales on wing veins and fringe Culicidae (mosquitoes)

Body and wings without scales 5
5. Wings with 9-11 long parallel veins, without cross-veins except at base; body hairy Phlebotomidae (sandflies)

Wing veins not all nearly parallel; body not very hairy; small and short; broad wings fold flat over abdomen, anterior veins thickened Ceratopogonidae (biting midges)
6. Third antennal segment annulated, never with a bristle; a forked vein near tip of wing; mouthparts fitted for piercing; wings held apart when at rest Tabanidae (horseflies)

- Antennae short, with a bristle or style; abdomen long and tapering Rhagionidae (snipe flies)
7. Frontal suture absent; lunule indistinct or absent; ptilinum absent (Aschiza) 8
- Frontal suture and lunule distinct; ptilinum always present (Schizophora) 9
- Head closely united with thorax; ptilinum may be present; wings reduced or wanting; flattened flies, adapted for ectoparasitic life on warm-blooded vertebrates (Pupipara) Hippoboscidae (louse flies)
8. Wing with two strong veins anteriorly extending only halfway and weak oblique veins posteriorly Phoridae (hump-backed flies)
- Wing with a spurious vein crossing r-m between R_{4+5} and M_1 , and first posterior (R_5) cell closed Syrphidae (flower flies)
9. Second antennal segment with a distinct external groove above; thorax usually with a complete transverse suture; lower calypter usually large (Calyptratae) 12
- Second antennal segment without a distinct external groove above; thorax usually without a complete transverse suture; lower calypter usually small or rudimentary (Acalyptratae) 10
10. Mouthparts vestigial, mouth opening small; R_5 and M_1 diverging distally Gasterophilidae (horse botflies)
- Mouthparts normal, mouth opening large; R_5 and M_1 parallel or converging distally 11
11. Second basal (M) and discal (first M_2) cells confluent Chloropidae (eye flies)
- Second basal (M) and discal (first M_2) cells distinct Piophilidae (skipper flies)
12. Hypopleura without a vertical series of strong bristles below spiracle 13
- Hypopleura with one or more vertical series of bristles below spiracle 14

- 13. Fourth wing vein more or less bent forward near tip of wing Muscidae (muscid flies)
- Fourth wing vein running straight to tip of wing Fanniidae (lesser house flies etc.)
- 14. Mouthparts vestigial; arista bare Oestridae (botflies)
- Mouthparts well-developed and functional; arista often plumose 15
- 15. Hindmost posthumeral bristle located lateral of presutural bristle, and usually 2 (rarely 3) notopleural bristle; arista usually plumose beyond basal half; body often metallic Calliphoridae (blow flies)
- Hindmost posthumeral bristle located even with or in middle of presutural bristle, and usually 4 notopleural bristles; arista generally plumose only in basal half; body not metallic Sarcophagidae (flesh flies)

GENERIC KEY TO MATURE LARVAE CAUSING MYIASIS

- 1 Larvae slender, barrel-shaped; segments ventrally with spines or scales but the latter not serrated; found in head-cavities of artiodactyles Oestrus Linnaeus
- Larvae shaped otherwise; found in dermal layers, urogenital organs, alimentary tract or voided with faeces of mammals including man/rarely birds 2
- 2. Body abruptly tapering posteriorly to a long tail-like telescopic breathing tube Eristalis Latreille
- Body gradually tapering posteriorly or broadly truncate 3
- 3. Small, slightly flattened larvae with short processes on dorsal and lateral surfaces; posterior spiracles on brown sclerotized tubercles, each with a narrow opening Megaselia Rondani
- Larger, mostly cylindrical larvae; without short processes on dorsal or lateral surfaces; or if long ones are present, posterior spiracles not on sclerotized tubes 4

4. Last segment broad, with a tube-like slightly retractable part bearing a pair of long fleshy processes; other two processes in-between bearing spiracles having three straight slits; larvae show skipping movement Piophila Fallén
 5
 Posterior spiracles not situated on a pair of cone-shaped protrusions and not facing one another; larvae do not skip 5
5. Posterior spiracles represented by a pair of strongly sclerotized peritremal plates, which are provided with a great number of small pores Hypoderma Latreille
 Posterior spiracles represented by three pairs of straight or tortuous slits lying in a peritremal plate or within a ring-shaped peritremal wall 6
6. Larvae stout and more or less trapezoid, with rings of papilliform spines on body Gasterophilus Leach
 Larvae slender; spines, when present as rings on body, not papilliform 7
7. Larvae with more or less depressed body, tapering at both ends and provided with a great number of slender, fleshy processes Fannia Rob.-Desvoidy
 Larvae without fleshy processes all over body (except in some Chrysomya spp. with broadly truncate posterior end) and posterior spiracles open through nearly parallel slits surrounded by a circular peritremal wall 8
8. Peritremes of posterior spiracles consist of solid plates with the slits more or less tortuous or arcuate, and which normally not sub-parallel to one another, but distinctly divergent 9
 Peritremes of posterior spiracles show a strongly sclerotized circular (open or closed) wall; inner part more translucent and contains slits which run more or less parallel to one another; a button, if distinct, located within the ring or in open part of the ring 12
9. Larvae causing dermal myiasis in various Indian birds Passeromyia Rodhain & Bequaert

 Larvae not causing dermal myiasis in Indian birds 10

10. Slits of posterior spiracles simply bent medially
 Muscina Rob.-Desvoidy
- Slits of posterior spiracles sinuous 11
11. Posterior peritremes with the button in centre; slits relatively wide apart from one another
 Stomoxys Geoffroy
- Posterior peritremes with the button excentric approaching inner margin; slits touching or at least close together and strongly sinuous Musca Linnaeus
12. Peritremal ring closed 13
- Peritremal ring open 14
13. Cephaloskeleton with an accessory oral sclerite
 Calliphora Rob-Desvoidy
- Cephaloskeleton without an accessory oral sclerite
 Phaenicia Rob.-Desvoidy
14. Last body-segment with a deep posterior cavity in which posterior spiracles are located; dorsal cornua of cephaloskeleton incised Sarcophaga Meigen
- Last body-segment without a deep cavity; dorsal cornua not incised Chrysomya Rob.-Desvoidy

IDENTITY OF SPECIES AND THEIR ROLE

Family **Culicidae** (Figs.1-3)

Females of most species suck blood and are notorious annoying pests of man and animals. Mainly, 10 species of Anopheles Meigen are the important vectors of malaria; 1 species of Culex L. and 3 species of Mansonia Blanchard of filaria; 2 species of Culex are involved in the transmission of encephalitis and 1 species of Aedes Meigen in the transmission of dengue fever and Chikungunya. A key to the species is given.

1. Free edge of scutellum semilunar; palpi as long as proboscis in both sexes Anopheles (4)
- Free edge of scutellum distinctly trilobed; palpi short in females but long in males 2

2. Well-developed pulvilli present Culex (13)
 Pulvilli rudimentary or absent 3
3. Robust body with speckled wings and legs; no subbasal
 tooth on claw Mansonia (15)
 Body ornamented with snowy white or silvery spots; subbasal
 tooth in females Aedes (Stegomyia) aegypti (L.)
4. Tips of hind legs at least dark 5
 Tips of hind legs at least white 12
5. Femora and tibia speckled 6
 Femora and tibia not speckled 9
6. Three pale bands on palpi; 3 or fewer than 3 dark spots
 on vein 6 7
 Four pale bands on palpi; more than 3 dark spots on vein
 6 8
7. Thorax mostly hairy, broad scales absent
 (Cellia) sundaicus (Rodenwaldt)
 Thoracic scales very broad (C.) stephensi Liston
8. One broad and three narrow widely apart white bands
 on palpi seen from tip to base
 (C.) balabacensis Baisas
 Three broad very close apical and one narrow basal band
 on palpi (C.) tessellatus Theobald
9. Two broad pale bands of equal length at apex; intervening
 dark area narrow 10
 Pale apical band nearly of same size or broader than sub-
 apical pale band, intervening dark area much broader than ei-
 ther of two bands 11
10. Costa with a pale interruption at base; proboscis uniformly
 dark (C.) minimus Theobald
 Costa without any interruption; proboscis may have golden
 appearance distally (C.) varuna Iyengar

11. Nearly whole of vein 3 dark (C.) culicifacies Giles
 Nearly whole of vein 3 pale (C.) fluviatilis James
12. Vein 5 mainly dark with a dark spot at its bifurcation
 (C.) annularis van der Wulp
 Vein 5 extensively pale without dark spot on stem at its
 bifurcation (C.) philippinensis Ludlow
13. Wing with costa dark unless at tip 14
 Wing with 3 pale spots on costa (including one at tip)
 Culex pipiens quinquefasciatus Say
 (= fatigans Wiedemann)
14. Mesonotum uniformly clothed with dark brown scales;
 tibiae without any pale stripe outside
 (C.) tritaeniorhynchus Giles
 Mesonotum with brown and lighter scales, mid and hind
 tibiae with pale stripe outside
 (C.) vishnui Theobald, (C.) barraudi Edwards &
 (C.) whitei Barraud (Identifiable by male hypopygium)
15. Mesonotum marked with distinct round spots of white scales
 (Mansonioides) annulifera (Theobald)
 Mesonotum marked otherwise 16
16. Mesonotum marked with a pair of sublateral greenish stripes
 on a brown ground (M.) uniformis (Theobald)
 Mesonotum dark brown, occasionally with indistinct white
 spots (M.) indiana Edwards

Family **Phlebotomidae** (Fig. 4)

Females of several species are haematophagous but only 3 species are important from the public health point of view : Phlebotomus (Euphlebotomus) argentipes Annandale & Brunetti is the vector of Kala-azar; P. (Phlebotomus) papatasi Scopoli and P. (Paraphlebotomus) sergenti Parrot are the vectors of Oriental sore; and P. (P.) papatasi causes Sandfly fever in this country. A key to these species is as follows :

1. Cibarium armed with finely toothed scales or network of lines; spermatheca with more than 8 segments and with a massive head papatasi Scopoli

Cibarium armed partly or wholly with strong backwardly directed teeth or scales; spermatheca without such head 2
2. Cibarial armature with an anterior median group of strong scales or spines and some scales forming concentric lines; spermatheca with more than 8 segments
..... argentipes Annandale & Brunetti

Cibarial armature composed of large backwardly directed teeth; spermatheca with 3-5 segments..... sergenti Parrot

Family Simuliidae (Fig.5)

Females of nearly all the species are haematophagous but their role as disease-carriers is still unknown in India. Simulium (Himalayum) indicum Becher is the most widespread pest species and besides this, S. (Eusimulium) praelargum Datta, S. (E.) gracilis Datta, S. (Simulium) rufibasis Brunetti, S. (S.) grisescens Brunetti, S. (S.) himalayense Puri, S. (S.) nodosum Puri, S. (Gomphostilbia) pattoni Senior-White, S. (G.) tenuistylum Datta etc. are the few important species. Females are often difficult to identify and so males reared from pupae are indispensable.

Family Ceratopogonidae (Fig. 6)

Several species of Culicoides Latreille and Leptoconops Skuse suck vertebrate blood and are thus notorious pests. Culicoides may act as vectors of animal diseases. The species of these genera are mainly identified by the specklings of the wing and male hypopygium. Some of the important species are : Culicoides (Avariata) actoni Smith, Culicoides (Culicoides) peregrinus Kieffer, C. (Oecacta) schultzei (Enderlein), C. (O.) shortii Smith & Swaminath, C. (Trithecoides) raripalpis Smith and C. (T.) palpifer Das Gupta & Ghosh, and Leptoconops (Leptoconops) indicus (Kieffer).

Family **Tabanidae** (Fig.7)

The so-called horse flies cause serious injury to cattle by annoyance and loss of blood. They are of much importance in connection with the transmission of surra (a kind of trypanosomiasis) in horses, cattle, camels, dogs, etc. Although several species are vicious blood-suckers, 6 incriminated in the transmission of surra are as follows : Atylotus agrestis (Wiedemann), A. virgo Wiedemann, Tabanus (Tabanus) triceps Thunberg, T. (T.) macer (Bigot), T. (T.) nemocallosus Ricardo and T. (T.) rubidus Wiedemann. A key to these species is given below :

1. Frons without callosities 2
 Frons with callosities 3
2. Abdomen brown, reddish at base, with two small round greyish spots on segments; wings without appendix; length 7.5 - 11.0 mm. virgo Wiedemann
 Abdomen blackish brown, with median and lateral greyish spots; wings with appendix; length 13.0 m.
 nemocallosus Ricardo
3. Frons with two small separate callosities one above another 4
 Frons with a well-developed basal callosity bearing a median extension 5
4. Abdomen with a blackish brown broad median and narrow lateral stripes united apically and the latter not reaching sides of abdomen agrestis (Wiedemann)
 Abdomen with narrower median stripe and broader lateral stripes extended up to segment 6 macer (Bigot)
5. Large robust species; frons with large triangular basal callosity not closely paralleling eye margins
 rubidus Wiedemann
 Smaller slender species; frons with basal callosity narrowly rectangular and narrowly separated from eye margins for most of its length triceps Thunberg

Family **Rhagionidae**

The females of Atherix (Suragina) suck blood from man, horses or cattle.

Family **Phoridae** (Figs.19-20)

Megaselia (Megaselia) scalaris (Loew) is of particular interest as the species causes wound myiasis and intestinal myiasis as well. Adults are attracted to smelling wounds. Larvae can develop themselves in the pre-existing wounds and can pass the entire life-cycle in the human colon as well. The adult is of ochraceous or brownish colour, frons furnished with 4 rows of 4 macrochaetae each; U-shaped markings dorsally on most abdominal segments; tibiae with a distinct row of very minute hairs outside. The larval posterior spiracles are situated dorsally on a pair of brownish sclerotized humps, and consist of a narrow slit apically. M. (M.) rufipes (Meigen) causes wound-myiasis in cattle. Adults lack abdominal pattern but mature larvae are with long fleshy processes.

Family **Syrphidae** (Fig.21)

Eristalis (Eristalis) tenax (L.) is of particular interest because the species causes intestinal myiasis mostly in human beings. Adults are recognised by brown-haired eyes, short pubescence on basal half of arista, uniformly dark thorax clothed with erect yellow hairs, and abdomen black and reddish yellow. The larva is provided with a long retractable breathing tube terminally with 8 pairs of prolegs ventrally; anterior spiracle short, very dark and provided with 21 facets and posterior spiracles show branched terminal setae.

Family **Piophilidae** (Figs.9; 22-23)

Piophila casei (L.) is of known medical importance. A black fly of 3.5-4.5 mm. body-length, with the lower part of head, antennae and parts of legs yellow; mesonotum with fairly rough granulation and a fatty shine, and is provided with 3 rows of short bristles. The larval characters have been keyed. Larvae cause intestinal myiasis.

Family **Chloropidae** (Fig.8)

Siphunculina funicola (de Meijere) is responsible for spreading conjunctivitis and probably skin infection also. These flies are not blood-suckers in the true sense, but many of them are habitually attracted to the skin and natural orifices of man and animals, lap-ping up perspiration, excretions, exudations of sores and wounds or blood from scratches. In Assam and adjoining areas, this species

causes another spirochetal infection called Naga sore. These are very small flies, arista microscopically feathered, wings shiny, tibiae and tarsi of forelegs and tarsi only of mid- and hind legs golden, knee joints golden in mid- and hind legs.

Family **Drosophilidae**

Drosophila (Sophophora) melanogaster Meigen is a minute yellowish fly and often swarms over ripe fruits on which it oviposits. The pupae which resemble minute seeds are sometimes encountered in human faeces and can be easily recognised by the long tubular spiracles. Cases of urinary myiasis caused by larvae have been reported. The abdomen of adults is shining black, each of first 3 segments dorsally with a basal yellowish band, mesonotum and scutellum yellowish red, inner dorsal surface of basal joint of fore tarsi with short stiff black bristles confined to one diagonal row.

Family **Gasterophilidae** (Figs.10; 24-25)

Generally, 3 species are involved in producing myiasis in the Equidae. Gasterophilus nasalis (L.) is characterised by lower marginal cross-vein situated opposite discal cross-vein (r-m), or parallel to it at a distance of less than length of r-m and by the larval third segment dorsally always with a row of spines. Gasterophilus haemorrhoidalis (L.) is characterised by lower marginal cross-vein situated much further away from the base of the wing than the discal cross-vein and by the ventral side of body-segment 3 in larvae with one medially interrupted row of spines, of segment 11 a row with a variable number of medially uninterrupted spines. Gasterophilus intestinalis (De Geer) is recognized by wings with faint infuscations forming a pattern of two dots apically and a broad vitta in the middle covering the whole width of the wing and by the mouth-hooks with a saddle-like excision before geniculate bend.

Family **Oestridae** (Figs.11; 26-30)

Hypoderma lineatum (Villers) is primarily a pest of cattle, whereas Oestrus ovis (L.) is a pest of sheep in general. The former species is recognized by mesonotum uniformly covered with mixed black and white hairs; and by larval posterior peritremes with a broad channel. The latter species is characterized by mesonotum with yellow hairs and larval segments 6-8 ventrally with 3 to 4 rows of spines. Przhevalskiana silenus (Brauer) is a pest of goats in Punjab.

Family **Muscidae** (Figs.13-14; 31-33)

The majority in this family have fleshy proboscis adapted for lapping up liquid foods and some have acquired the habit of devoting nearly all their time in search of blood or exudations. Many species are important in view of their nasty role but only common ones are dealt with here. Musca (Musca) domestica L. and its relatives, M. (Eumusca) lusoria Wiedemann, M. (Viviparomusca) bezzii Patton & Cragg, M. (Philaematomyia) crassirostris Stein, etc. are particularly important transmitters of filth germs causing distress to mankind. Muscina stabulans (Fallén) causes intestinal myiasis in human beings. Stomoxys calcitrans (L.) and Haematobia (= Lyperosia) irritans (L.) are generally blood-suckers of cattle and horses and on this account they may mechanically transmit surra. Passeromyia heterochaeta (Villeneuve), however, causes death of nestlings in maggot stage. A key to the genera is given below :

1. Proboscis long and slender, with small labellae 2
 Proboscis short and thick, with large labellae 3
2. Media of wing sharply bent Stomoxys Geoffroy
 Media of wing nearly parallel to third longitudinal vein
 Haematobia Le Peletier & Serville
3. Media of wing angularly rounded at its bend
 Musca L.
 Media of wing broadly rounded at its bend, or more or
 less straight 4
4. Eyes bare. Muscina Rob.-Desvoidy
 Eyes with hairs in both sexes
 Passeromyia Rodhain & Bequaert

Family **Fanniidae** (Figs.12; 34-35)

Several cases of intestinal and urinary myiasis caused by Fannia canicularis (L.) and F. scalaris (F.) have been reported. These two species can easily be distinguished by the mid-tibiae which in scalaris bear a distinct tubercle, and in canicularis, however, it is lacking. The larvae closely resemble but scalaris is provided with feathery lateral processes on all segments of the body.

Family **Calliphoridae** (Figs.15; 36-41)

Only 6 species are so far known to be commonly or only occasionally involved in myiasis. Phaenicia (= Lucilia) cuprina (Wiedemann) and P. sericata (Meigen) are the primary producers of sheep myiasis and Chrysomya rufifacies (Macquart) is the secondary producer. C. megacephala (F.), C. bezziana (Villeneuve) and Calliphora (Calliphora) vicina Robineau-Desvoidy cause myiasis both in man and animals. A key to these species is given below :

1. Stem vein of wing bare 2
 Stem vein of wing with a row of bristly hairs dorsally 4
2. Suprasquamal ridge without erect bristly hairs; larval last 3 segments with well-developed spinose bands vicina Robineau-Desvoidy
 Suprasquamal ridge with 2 groups of long and strong bristly hairs 3
3. Head with 3-8 occipital bristles on each side; fore femur black or dark bluish metallic; peritremal ring of larval posterior spiracles with inner projection sericata (Meigen)
 Head with only 1 occipital bristle on each side; fore femur bright metallic green; peritremal ring of larval posterior spiracles without inner projection cuprina (Wiedemann)
4. Anterior thoracic spiracle black-brown or at least dark orange 5
 Anterior thoracic spiracle white or light yellow; larval segments provided with a great number of long processes; peritremal ring of posterior spiracles with a narrow opening, and both ends more or less distinctly forked rufifacies (Macquart)
5. Thoracic squama waxy white; larval segments with belts of strongly developed spines; anterior spiracle with 4-6 branches bezziana (Villeneuve)
 Thoracic squama black-brown to dirty grey; posterior peritremes of larva more remote from each other megacephala (F.)

Family **Sarcophagidae** (Fig.16)

There are several species of the family which develop themselves in excrement, carrion or any kind of decomposing organic matter but only 3 species have been reported to produce myiasis in man and animals : Parasarcophaga (Liopygia) ruficornis (F.), P. (Liosarcophaga) misera (Walker) and P. (Parasarcophaga) albiceps (Meigen). A key to these species is given below :

1. Posterior dorso-centrals 4; larvae causing tissue myiasis in bulls albiceps (Meigen)
 Posterior dorso-centrals 5-6 2
2. Hind tibiae well-fringed; larvae causing wound myiasis in camels, bullocks and cows
 misera (Walker)
 Hind tibiae almost bare; larvae causing cutaneous myiasis in man and animals ruficornis (F.)

Family **Hippoboscidae** (Figs. 17-18)

These peculiar insects are sometimes called louseflies which are haematophagous. Two species interest us here : Hippobosca variegata von Muhlfeld (= H. maculata Leach) especially feeding on horses, dogs, camels and cattle but rarely on man, and Melophagus ovinus ovinus (L.) feeding on sheep. Their identities are as follows :

- Wings always present; squama and ante-squama of wing fringed with short white pubescence; larvae white, developing in ground variegata Muhlfeld
- Wings and halteres always absent; larvae yellowish, developing on host ovinus (L.)

CONCLUSION

The aim of this note is a practical one. It is intended to enable the Medical and Veterinary Entomologists to identify the Diptera involved in sucking blood, carrying diseases or producing myiasis in man and animals in India but those caught on the wing may belong to groups which are not dealt with here. The fact

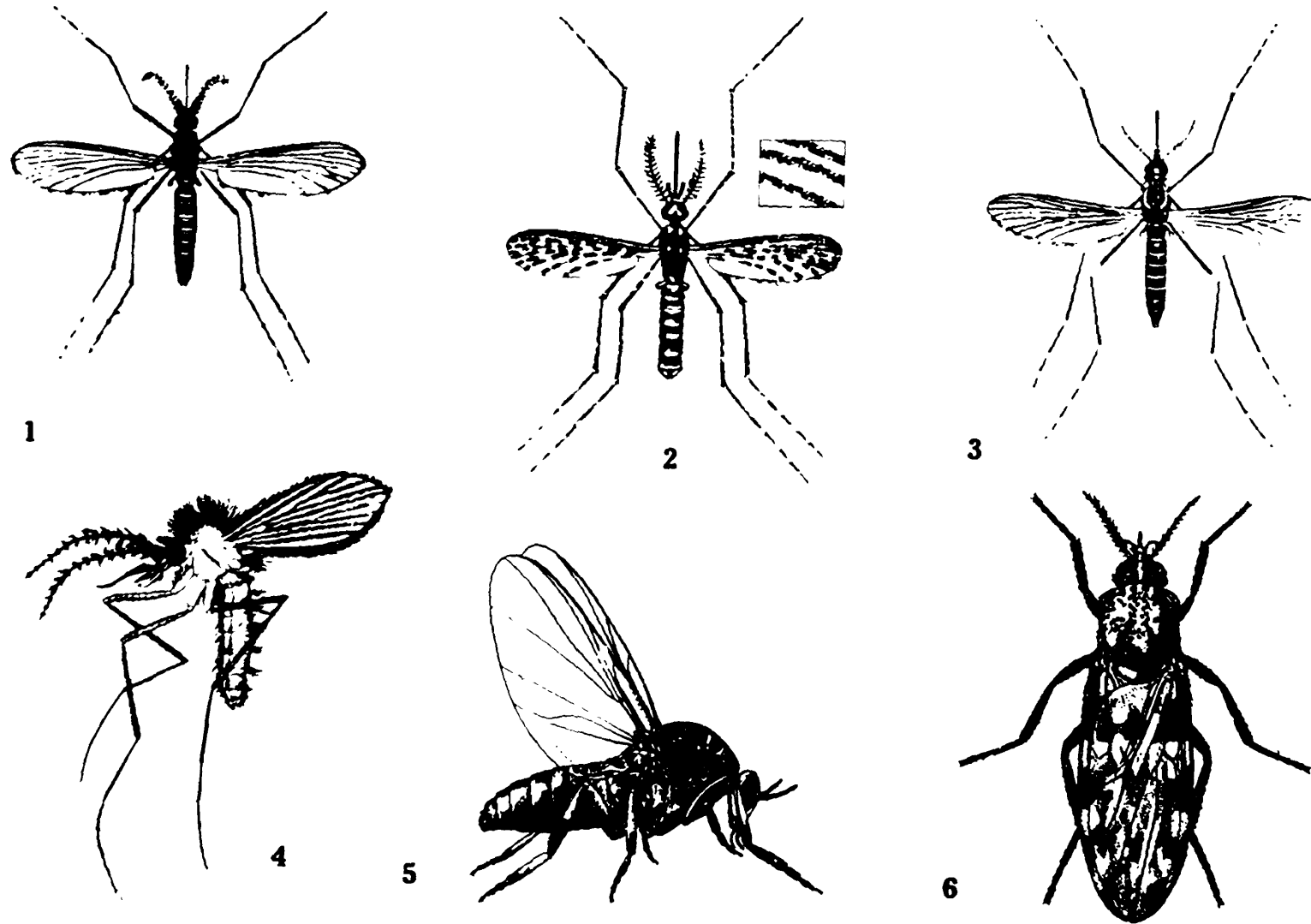
is that our knowledge on pest species, vector species or infesting other species is certainly not at all complete and further discoveries are to be expected. For this reason it is desirable to get the tentatively identified species confirmed by a specialist.

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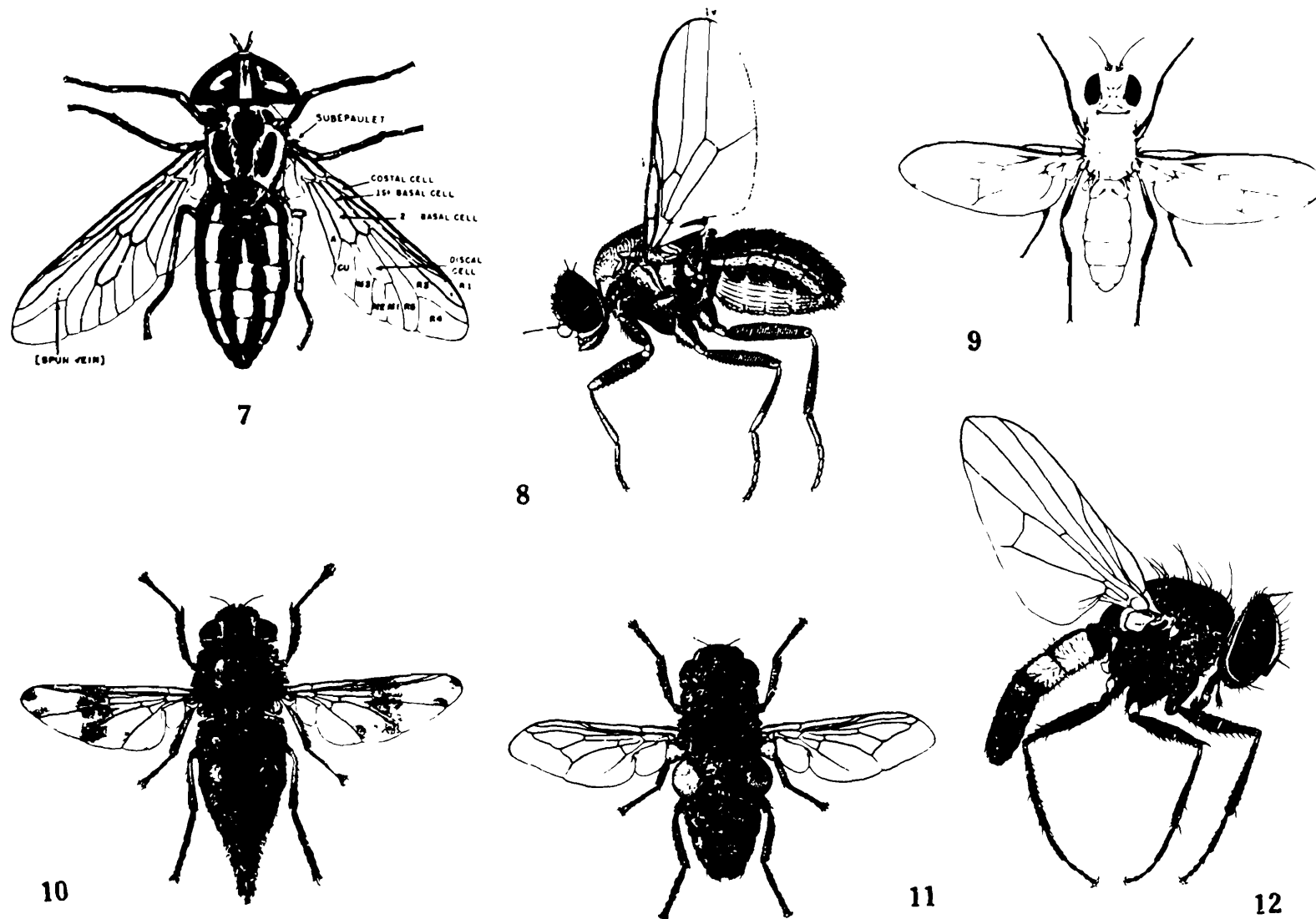
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PLATE I



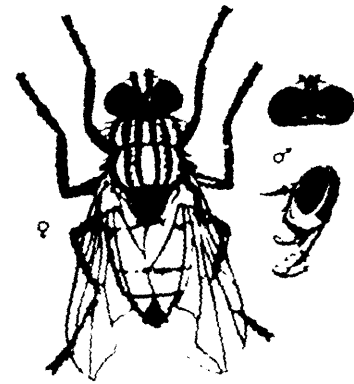
Figs.1-6 : 1. Female of Culex pipiens quinquefasciatus Say (After Roy); 2. Female of Mansonia annulifera (Theobald) (After Roy); 3. Female of Aedes aegypti (L.) (After Roy); 4. Female of Phlebotomus argentipes Annandale & Brunetti (After Roy); 5. Female of Simulium sp. (After Rubtzov); 6. Female of Culicoides sp. (After Smart)

PLATE II

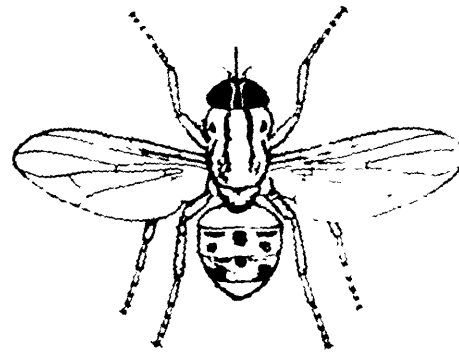


Figs.7-12 : 7. Female of Tabanus triceps Thunberg (After Philip); 8. Female of Siphurculina funicola (de Meijere) (After Smart); 9. Female of Piophilina casei (L.) (After Hennig); 10. Female of Gasterophilus intestinalis (De Geer) (After Castellani & Chalmers); 11. Female of Oestrus ovis (L.) (After Castellani & Chalmers); 12. Male of Fannia canicularis (L.) (After Zumpt).

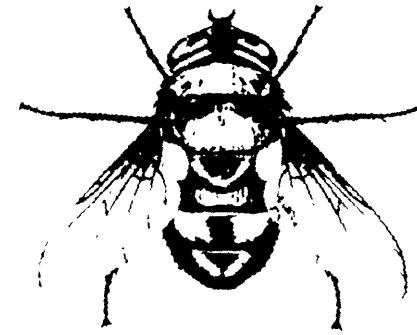
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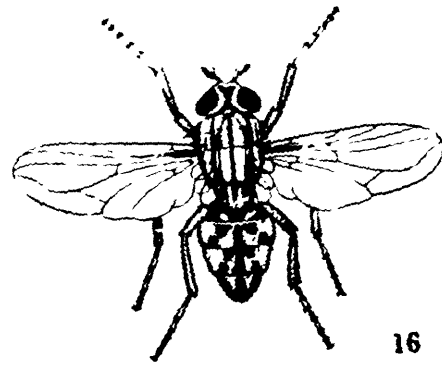
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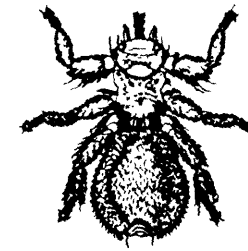
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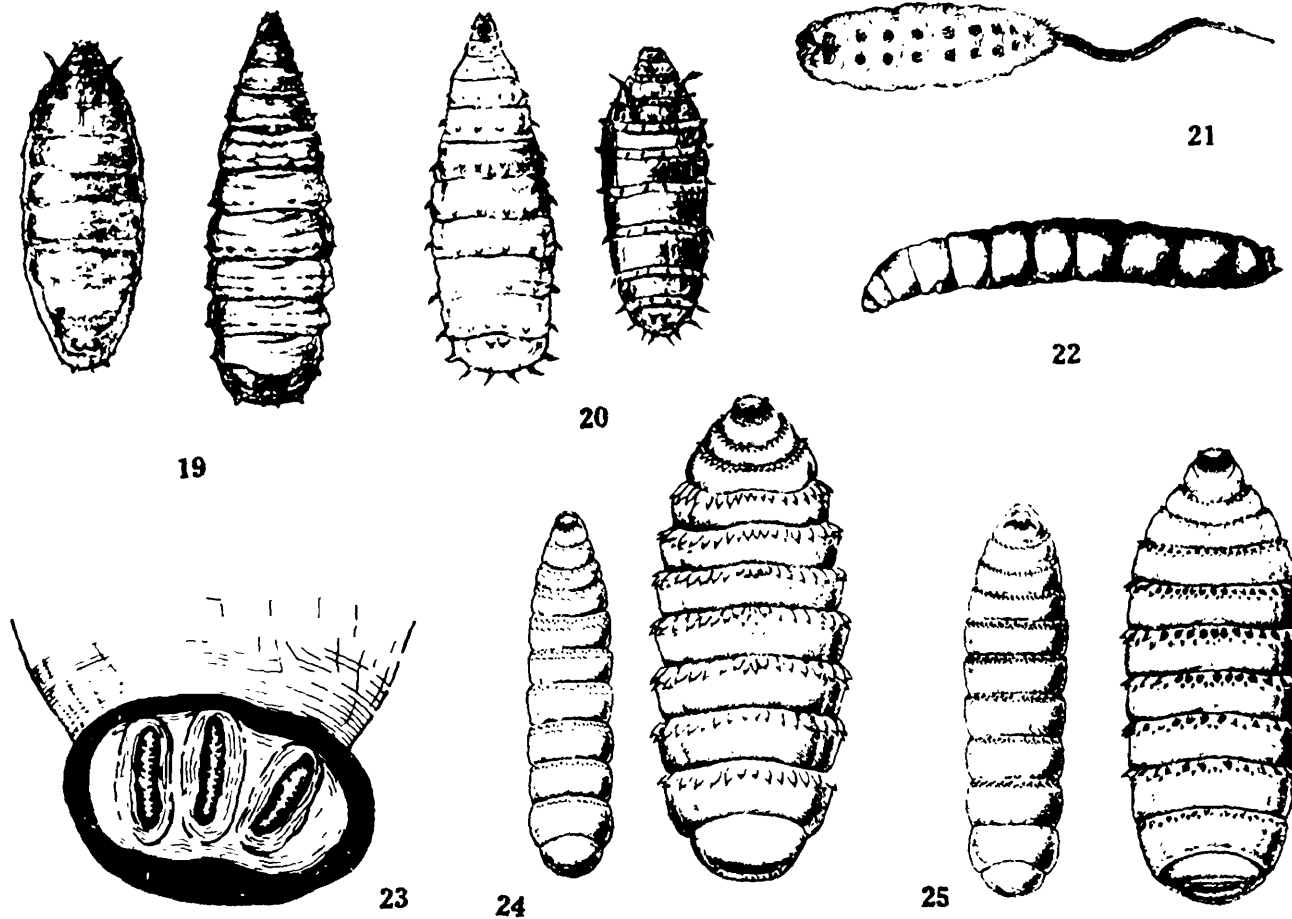
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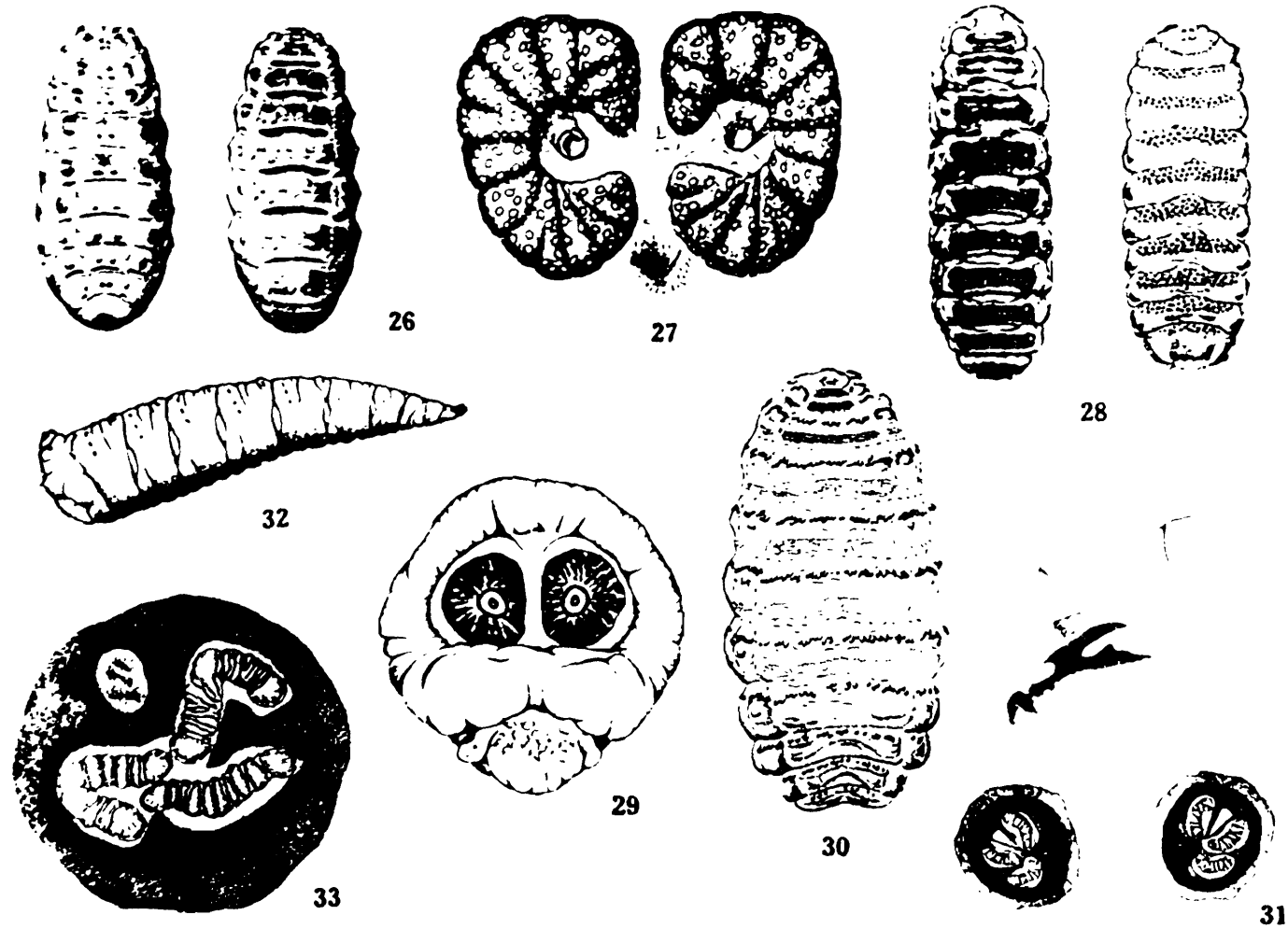
Figs.13-18 : 13. Female and male head of *Musca domestica* L. (After Zumpt); 14. Female of *Stomoxys calcitrans* (L.) (After Roy); 15. Female of *Chrysomya bezziana* (Villeneuve) (After Cuthbertson); 16. Female of *Parasarcophaga ruficornis* (F.) (After Roy); 17. Female of *Hippobosca variegata* Muhlfeid (After Roy); 18. Female of *Melophagus ovinus ovinus* (L.) (After Smart).

PLATE IV



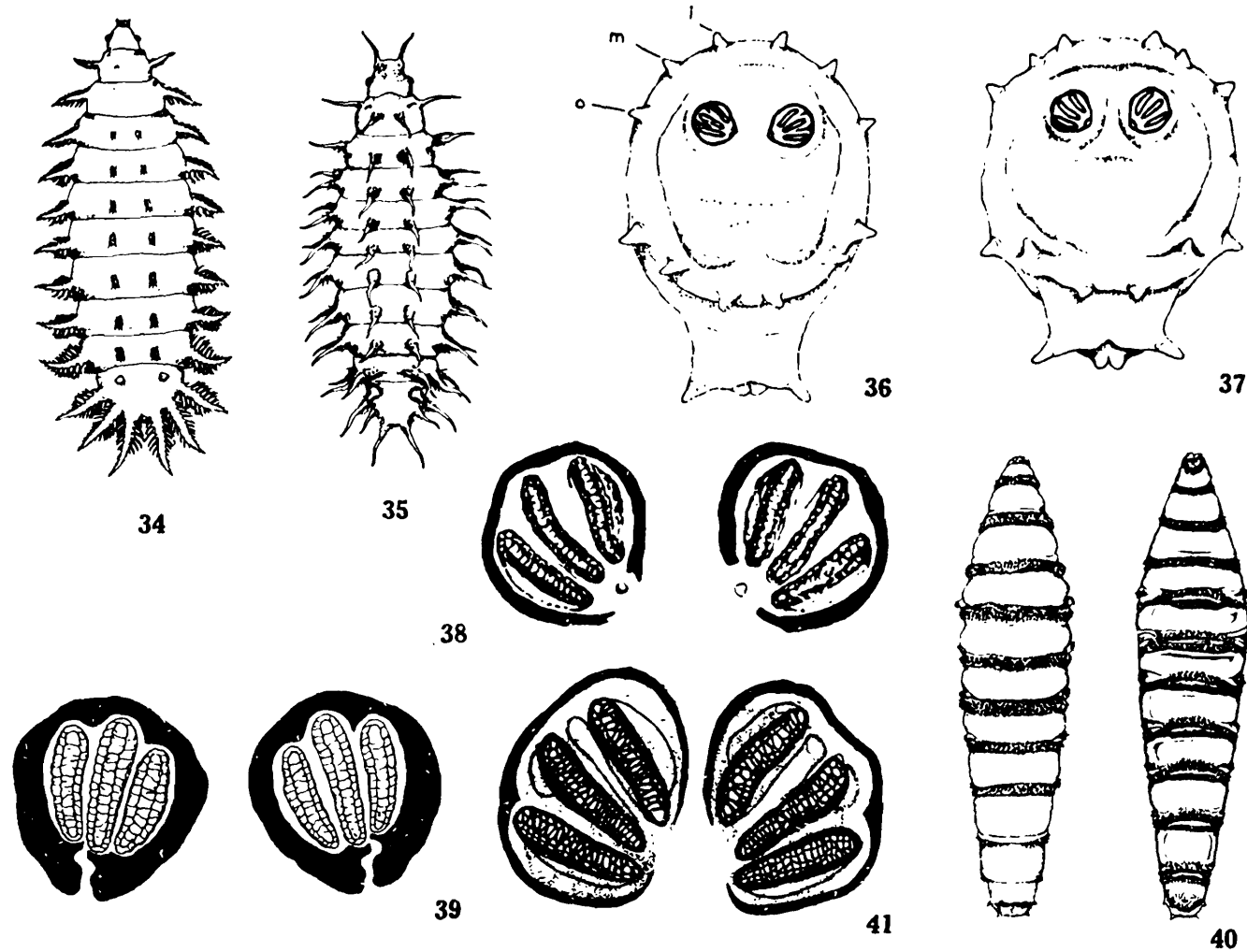
Figs. 19-25 : 19. Puparium and third stage larva of *Megaselia scalaris* (Loew) (After Patton); 20. Third stage larva and puparium of *Megaselia rufipes* (Meigen) (After Patton); 21. Third stage larva of *Eristalis tenax* (L.) (After Swartzwelder & Cali); 22. Third stage larva of *Piophilha casei* (L.) (After Hennig); 23. Posterior peritreme of third stage larva of *Piophilha casei* (L.) (After Alessandrini); 24. Second and third stage larva (ventral view) of *Gasterophilus nasalis* (L.) (After Grunin); 25. Second and third stage larva (ventral view) of *Gasterophilus haemorrhoidalis* (L.) (After Grunin).

PLATE V



Figs. 26-33 : 26. Third stage larva (dorsal and ventral view) of *Hypoderma lineatum* (de Villers) (After Grunin); 27. Posterior peritremes of *Hypoderma lineatum* de Villers (After James); 28. Third stage larva (dorsal and ventral view) of *Oestrus ovis* (L.) (After Grunin); 29. Third stage larva (posterior view) of *Oestrus ovis* (L.) (After Zumpt); 30. Third stage larva (ventral view) of *Przhevalskiana silenus* (Brauer) (After Grunin); 31. Cephalo-pharyngeal skeleton and posterior peritremes of third stage larva of *Muscina stabulans* (Fallén) (After Zumpt); 32. Third stage larva of *Passeromyia heterochaeta* (Villeneuve) (After Rodhain & Bequaert); 33. Posterior peritreme of third stage larva of *Passeromyia heterochaeta* (Villeneuve) (After Zumpt).

PLATE VI



Figs. 34-41 : 34. Third stage larva (dorsal view) of *Fannia scalaris* (F.) (After Hewitt); 35. Third stage larva (dorsal view) of *Fannia canicularis* (L.) (After Hewitt); 36. Posterior view of larva of *Phaenicia sericata* (Meigen) (After Zumpt); 37. Posterior view of larva of *Phaenicia cuprina* (Wiedemann) (After Zumpt); 38. Posterior peritremes of third stage larva of *Chrysomya megacephala* (F.) (After Patton & Evans); 39. Posterior peritremes of third stage larva of *Chrysomya rufifacies* (Macquart) (After Roy); 40. Third stage larva (dorsal and ventral view) of *Chrysomya bezziana* (Villeneuve) (After Zumpt); 41. Posterior peritremes of third stage larva of *Chrysomya bezziana* (Villeneuve) (After Zumpt).

ROLE OF PARASITES AND PREDATORS IN BIOLOGICAL CONTROL OF INSECT PESTS AND THEIR COLLECTION AND IDENTIFICATION

J.K.Jonathan

Entomophagous species are classified on the basis of certain functional relationship with their food supply, and an initial and major dichotomy is the distinction between parasites and predators. The test here is whether in their development they consume merely a single individual or must devour several in order to reach maturity. Larval predators require the consumption of more than one individual in order to reach the adult stage. On their other hand, parasites are distinguished on the basis that the immature stages develop at the expense of a single individual which is termed the host. By their parasitic or predatory habits they destroy large number of agricultural and forest pests and thus constitutes one of the major forces for preventing the undue increase of noxious species, or in other words helps in biological control of insect pests.

BIOLOGICAL CONTROL

What is biological control ? No single definition appears satisfactory because the term biological control is used with different meanings. As with the natural control, many definitions have been proposed and considerable controversy has arisen. Biological control is a phase of natural control, hence biological control could also be termed "natural control", but natural control is a broader term which includes the actions of all environmental factors, both physical and biological in the regulation, determination, or governance of average population densities. In simple words the biological control can be defined as the study and utilization of parasites, predators and pathogens for the regulation of host population densities. The basic study has a definite and highly important place in the field of biological control and should be actively supported and pursued to the fullest possible extent. This includes pure research into fundamental aspects of taxonomy, biology, physiology, ecology, behaviour, culture methods and nutrition. The purposeful introduction of new natural enemies is usually based on the fact that many, if not most, agricultural pests have been accidentally introduced into the area concerned while their indigenous natural enemies have been left behind. The augmentation of natural enemies in biological control deals with the manipulation of natural enemies themselves in order to make them more efficient in the regulation of host population densities. The conservation involves making

the environment better suited to the natural enemy. Adverse factors such as air-borne dust which kills, and ants which kill or interfere with natural enemies, can be controlled.

HISTORICAL ACCOUNT

No one knows precisely when men first became aware of the entomophagous habits of these parasites. Though predator insects were known at an early date and came to be used in a practical way by agriculturalists in parts of Asia and Europe. The common case of insect parasitism to be first recorded was of common cabbage butterfly, Pieris rapae (L), attacked by a gregarious internal parasite Apanteles glomeratus (L.) which emerged to form conspicuous cocoons on the integument of its host, these were noted by Aldrovandi in 1602.

The manner in which hymenopteran parasites accomplish their work of destruction is highly curious and interesting (Fig.1). The female introduces ~~her~~ ~~their~~ eggs into the flesh of the host with the help of a long ovipositor. In some, this ovipositor is longer than the whole body. They perceive either by their sense of smelling or by their antennae. The eggs are hatched within the body of the host larva. The parasite larva sucks the body fluid of host. At last the wounded caterpillar sinks, the enemy escapes through the skin and pupates, and finally emerges as an adult parasite.

EXAMPLES OF BIOLOGICAL CONTROL

Cottony-Cushion scale : In 1887 the citrus industry was threatened with destruction because of massive infestation of cottony-cushion scale (Fig.2). Within 15 years it spread to all the states and threatened to destroy the citrus industry. It was known that scale occurred, and probably originated in Australia and reached California by some unknown means.

C.V.Riley, entomologist of U.S.D.A. laid a plan for the control of this pest. He invited Albert Koebele, a naturalized German immigrant. Koebele arrived in Sydney in September 1888 and was able to find a tiny parasite, Cryptochaetum iceryae. Through Koebele's efforts a total of approximately 12,000 individuals of Cryptochaetum were sent to California. Koebele also discovered "Vedalia" lady bird beetle (Fig.3), which greedily feeds on eggs and larvae of scale. Koebele was the pioneer among entomologist explorers who search far places of the world for parasites and predators.

Gypsy-moth : So spectacular was Koebele's success with cottony-cushion scale that Bureau of Entomology began a large scale search in 1905 in Europe for the natural enemies of the gypsy-moth that destroys forest and ornamental plants in New England. The exploration from 1905 to 1914 covered all Europe and Japan, and again (1922 to 1927) 13 species of parasites and predators were successfully established in New England.

Likewise there are many examples where biological control of insect pest was possible. The Alfalfa weevil Hypera postica (Gyll.) a pest of alfalfa was controlled by Bathyplectes curculionis; Sugar-cane borer by Gambroides javensis (Row.), Camstock mealy bug of asiatic origin, pest of apple by two parasites. The citrus black fly Aleurocanthus woglumi Ashby in West Indies, Mexico, a native of Asia was successfully controlled by a parasite Amitus hesperidum Silv.

SYSTEMATICS IN RELATION TO BIOLOGICAL CONTROL

Without some system of classification scientific knowledge of organisms would be in a chaotic state. Therefore, it has been essential in all fields of biology to develop a science of classification termed "Systematics". Systematic is without question the most important fundamental to biological control. It is the key to all fields of research related to any biological control problem, and when properly undertaken can supply such basic information as where to undertake projects of foreign exploration, what host specificities are involved, what major biological and ecological references are available for life history, mass production studies and to what extent biological races, subspecies, sibling species are involved with any "species".

One possible answer to this problem at the present time is for all interested and properly equipped persons who are working with species problems in biological control work to undertake a systematic investigation on the particular group with which they are concerned. Another important obstacle which must be overcome if we are to enjoy the values of good systematic work is that of making it easier to publish large, well illustrated revisions and monographs.

PARASITES

The species with parasitic habit are subject to further classification into many subcategories depending upon the mode of attack and type of host. Accordingly, if the parasite develops

with-in the host's body it is an internal or endoparasitic, whereas if it feeds, from an external position, it is called an external or ectoparasite. A parasite is termed solitary if only one individual develops per host, but many species habitually develop several progeny on a single host and are therefore said to be gregarious. There are species which are egg parasites, other are larval and a few attack adults. There are some egg-larval parasites, because their development extends through the two stages of the host.

It has been noted that although entomophagous insects may have a parasitic habit, they differ from true parasites in ways sufficient to set them apart and to justify the use of the distinguishing term "parasitoid". They are recognized as being different because : (1) the development of an individual destroys its host; (2) the host is usually of the same taxonomic class; (3) in comparison they are relatively large in size; (4) they are parasitic as larvae only, the adults being free living forms, (5) as a parameter in population dynamics their action resembles that of predators more than that of true parasites.

There is a system for classifying entomophagous insects based primarily on their host relationships in any particular food chain. For example, if a parasite attacks a host which is phytophagous, then the entomophagous species is termed a primary parasite. If in turn the primary parasite is itself attacked, then its enemies are called secondary parasites. Degrees of parasitism beyond the secondary level are not common. Any degree of parasitism beyond primary is termed hyperparasitism, so this would include those parasites that are secondary, tertiary and so on. A very special case of hyperparasitism is found in certain species of Aphelinidae, where male develops as a hyperparasite but the female develops as a primary parasite this peculiar habit has been termed autoparasitism.

Finally, superparasitism is the parasitization of an individual host by more larvae of a single parasitic species than can mature in that host. Multiple parasitism on the other hand is the simultaneous parasitization of a single individual host by two or more different species of primary parasites.

PREDATORS

Predators are defined as those entomophagous species whose larvae develop by consuming more than one individual of the prey. In the predaceous species, unlike the parasites, the larval stage is forced to find several prey individuals and accordingly

the searching behaviour of the larva as well as that of the adult is important in any analysis of predator-prey population dynamics. The *Vedalia* beetle commonly deposits its eggs on the egg sac of a mature cottony-cushion scale. Another type of predaceous adult which finds food for its young is a digger wasp *Ammophila* that catches caterpillars and drags them to its nest as food for its larva. When it is hunting, a caterpillar is caught and stung and dragged into the nest. Several species of families Vespidae, Eumenidae, Sphecidae and Pompilidae are predaceous on other insect groups.

CLASSIFICATION

The following account is adapted from Schlinger & Doult in Paul DeBack : Biological control of insect pest & weeds, p. 269.

The order Hymenoptera is especially rich in families exhibiting the entomophagous habit and most of the parasitic species utilized in biological control belong to this order. Accordingly, it is desirable for all workers in biological control to have some familiarity with the biology and taxonomy of the parasitic wasps. One is often a clue to other and such knowledge is essential to efficient work in the foreign exploration and quarantine phases of biological control.

The following keys is to the groups of parasitic Hymenoptera which are most commonly encountered in biological control work. For this reason, not all the families of Hymenoptera have been included and those in the Tenthredinoidea and Apoidea have been entirely omitted. For additional information the keys given by Borror and DeLong (1954), Brues, Melander, and Carpenter (1954), and Comstock (1940) are highly recommended. Figure 4 shows the more important morphological features of a chalcid wasp used in connection with the following key to the families.

KEY TO THE ADULTS OF THE MORE IMPORTANT FAMILIES OF ENTOMOPHAGOUS HYMENOPTERA (Based primarily on winged females)

1. Hind wing with less than 3 basal cells; abdomen petiolate or subpetiolate. Ants, bees, wasps, chalcid flies
..... 2

Hind wing with 3 basal cells; abdomen broadly sessile, attached over a large area. (Caveat : this character

should not be used solely by itself as some of the minute Chalcidoidea exhibit a similar character) Saw flies, horntails (Tenthredinoidea)

2. Last abdominal sternite of female divided longitudinally, the ovipositor issuing from anterior to tip of abdomen and provided with a pair of narrow exerted sheaths as long as the ovipositor; hind wing usually without an anal lobe; trochanters 1- or 2-segmented3

Last abdominal sternite of female not divided longitudinally, the ovipositor issuing from tip of abdomen (usually as a true sting) and without a pair of exerted sheaths; trochanters of 1 segment; costal cell often present; hind wing often with anal lobe

3. Venation well developed in both fore- and hind wings; forewings with well-developed stigma; abdomen with ventral surface usually soft; antennae not elbowed and usually with 16 or more segments. Trochanters 2-segmented (Ichneumonoidea) 9

Venation of forewings reduced and usually without a stigma; antennae are filiform or elbowed and are usually with less than 14 segments

4. Pronotum extending laterally back to tegulae; antennae not elbowed; prepectus absent; trochanters usually 1-segmented. Body often compressed (Cynipoidea)35

Pronotum not reaching tegulae; prepectus usually present; antennae usually elbowed; trochanters usually 2-segmented; venation of wings much reduced (Chalcidoidea).....16

5. Pronotum extending laterally back to or nearly to the tegulae6

Pronotum short, not extending back to tegulae and with a rounded lobe on each side posteriorly

6. Wing venation well developed; hind wing with several veins, if veinless then having a basal lobe

Wing venation more or less reduced; hind wings nearly veinless, not lobed (Proctotrupoidea)

7. Hind wing with venation reduced and without closed cells (Bethyloidea)

- Hind wing with normal venation and at least I closed cell (Vespoidea)45
8. First segm. of hind tarsi slender, not broadened or thickened, and usually bare; all body hairs simple, unbranched; abdomen often petiolate (Sphecoidea)51
- First segment of hind tarsi elongate, usually thickened or flattened, and often hairy; some body hairs branched or plumose; abdomen not petiolate. Bees(Apoidea)
9. Costal cell absent10
- Costal cell present, may be narrow12
10. Ventral abdominal segments soft and membranous, with a median fold11
- Ventral abdominal segments hard, heavily sclerotized; scutellum armed with a sharp spiniform process**Agriotypidae**
11. Two recurrent veins, or if only I then with abdomen three times as long as rest of body; size variable, length (excluding ovipositor) ranging from a few millimetres to more than 40 mm (figure 5,A)**Ichneumonidae**
- One recurrent vein or none; abdomen not greatly elongate; propodeum not prolonged beyond hind coxae; mostly small insects, rarely over 12 mm in length (figure 5,B)**Braconidae**
12. Abdomen inserted on propodeum of thorax far above hind coxal bases, sometimes on nipple-like protuberance, antennae with 13 or 14 segments14
- Abdomen inserted normally, close to bases of hind coxae, between or slightly above them, antennae with 18 or more segments13
13. Forewing with 2 or 3 closed submarginal cells, antennae with 18 or more segments, head large, quadrate; mandibles with 4 teeth; hind wing with 2 large closed cells; moderate-sized, often brilliantly coloured species**Trigonalidae**
- Forewing with only I closed submarginal cell or none; antennae setaceous, with 30 segments or more; abdomen long and slender; ovipositor long; hind femora swollen and toothed before apex; head tuberculate above**Stephanidae**

14. Prothorax long and necklike; abdomen long and slender.....15
15
- Prothorax short, not necklike; abdomen short, oval, and flaglike, borne on a cylindrical petiole; marginal cell broad apically.....**Evaniidae**
15. Hind tibia strongly swollen towards the tip; forewing can be folded lengthwise**Gasteruptiidae**
- Hind tibia not swollen towards the tip; forewing cannot be folded**Aulacidae**
16. Front basitarsus more or less distinctly modified to form a strigil, the spur of front tibiae long, curved, and sometimes bifid at apex; posterior margin of mesoscutum usually transverse, the axillae usually not much produced forward beyond a line connecting the tegulae; tarsi usually 5-segmented; antennae most often with more than 10 segments17
- Front basitarsus simple, the spur of front tibiae short and straight; posterior margin of mesoscutum usually more or less excised, with the axillae usually produced forward beyond a line connecting the tegulae; tarsi usually with 3 or 4 segments; antennae usually with less than 10 segments..33
17. Forewings with normal chalcidoid venation (Figure 4), the marginal and stigmal veins both usually well developed.....18
18
- Forewings nearly veinless, the marginal vein usually extremely short and terminating about one-fourth to one-third of the length of the wing from the base, the stigmal vein much reduced or absent; wings usually with a long marginal fringe, the hind pair very narrow; tarsi with 4 or 5 segments; minute wasps, egg parasites**Mymaridae**
18. Mesopleura never convex, but more or less furrowed to receive the middle femora; spur of middle tibiae never saltatorial19
19
- Mesopleura convex or at most weakly furrowed, spur of middle tibiae large and saltatorial30
19. Gaster of abdomen more or less pyramidal or bipyramidal, thickest near the middle, the first segment as large as the remaining segments combined, or the first 2 subequal and the following segments retracted in the second20
20

- Gaster of abdomen not pyramidal in shape.....21
20. Pronotum hardly or not at all visible from above; abdomen petiolate; first segment of gaster much larger than any of the following segments, which are more or less retracted within it; mandibles slender and falcate; axillae more or less connate, usually entirely fused (except in the more generalized forms such as Orasema) and forming a transverse segment between the mesoscutum and scutellum**Eucharidae**
- Pronotum with a distinct collar, its anterior face either concave or conically produced; abdomen either sessile or petiolate; first 2 segments of gaster subequal and enclosing the following segments; mandibles stout and not at all falcate; axillae usually widely separated**Perilampidae**
21. Hind coxae more or less greatly enlarged22
- Hind coxae not enlarged26
22. Propleura not separated from the mesopleura by a prepectal plate23
- Propleura separated from the mesopleura by a linear or triangular prepectal plate24
23. Hind femora greatly enlarged, toothed or minutely denticulate beneath; pronotum with a well-developed collar; abdomen without a peculiar sculpture, globose, ovate, or conic-ovate; often with a well-developed petiole; hind coxae subfusiform to conical, and frequently elongate, never sharply angled above**Chalcididae**
- Hind femora and tibiae slender and unmodified; hind coxae compressed and rather sharply angled above; pronotum with a well-developed transverse collar; mesoscutum without parapsidal sutures; abdomen sessile, conic ovate, usually with a peculiar scalloped sculpture on the intermediate tergites, often preceded by coarse punctures**Ormyridae**
24. Prepectal plates triangular; wings not folded longitudinally.....25
- Prepectal plates linear; wings folded lengthwise; pronotum very large and quadrate; abdomen fusiform, with the tergite beyond the first fused (males); or clavate-fusiform, with the ovi-positor curved forward over the tergum (females); hind coxae compressed and somewhat angled above, the hind femora greatly enlarged and toothed beneath**Leucospidae**

25. Hind femora somewhat swollen and simple, or greatly enlarged and toothed beneath, the hind coxae compressed and more or less sharply angled above; first femora somewhat swollen and thicker than the middle pair; abdomen sessile, conic ovate to conical, the ovipositor not or hardly protruded; stigmal vein usually well developed **Cleonymidae**

Hind femora usually slender, or only slightly swollen, but sometimes enlarged and toothed beneath (Podagrion), front femora only slightly thicker than middle pair; hind coxae compressed and sharply angled above or compressed-ovate and rounded on dorsal margin (Podagrion); ovipositor always prominently produced and often very long; stigmal vein usually very short, but sometimes ending in large circular knob (Megastigmus).....**Torymidae**

26. Pronotum with a large quadrate collar27

Pronotum short, not prominent, the collar transverse28

27. Collar quite or almost as broad as mesoscutum; mesoscutum with parapsidal sutures but the parapsides not prominent; antennae inserted high on the face; abdomen usually more or less compressed**Eurytomidae**

Collar about as wide as the middle lobe of the mesoscutum and more or less conically produced forward; parapsides very prominent; antennae inserted at the oral margin; abdomen more or less depressed**Spalangiidae**

28. Axillae not or barely produced forward beyond a line tangent with hind margin of tegulae29

Axillae very large, placed in front of the scutellum, produced far forward beyond a line tangent with the hind margin of tegulae and separated by the middle lobe of the mesoscutum; the parapsides smaller than the axillae and crowded far forward; prepectal plates obscure or absent**Eutrichosomatidae**

29. Parapsidal sutures complete, usually distinct and more or less deeply furrowed; hind tibiae usually with 2 apical spurs; prepectal plates distinct**Miscogasteridae**

Parapsidal sutures incomplete, usually distinct only anteriorly; hind tibiae usually with 1 apical spur; axillae well separated; prepectal plates small, or rather small, and not very distinct..**Pteromalidae**

30. Axillae usually distinct; spur of middle tibiae without spines on inner margin31

Axillae absent, the dorsum of thorax composed of 5 more or less transverse sclerites (pronotum, mesoscutum, scutellum, metanotum, and propodeum); mesopleura hardly convex and slightly furrowed; antennae at most 7-segmented, the funicle segments all very short, the club elongate and cylindrical; middle tibiae armed with strong spines; the apical spur with a fringe of long stout spines on the inner margin**Signiphoridae**

31. Mesopleura evenly convex (except in some males), axillae not produced forward32

Mesopleura somewhat depressed and often with a slightly impressed furrow; axillae widely separated, often fused posteriorly with the scutellum and frequently produced forward into the basal region of the mesoscutum; parapsidal sutures of mesoscutum distinct; antennae rarely with more than 8 segments**Aphelinidae**

32. Mesosternum short, the middle coxae approximated to the anterior pair, mesoscutum more or less convex, rarely with parapsidal sutures, which curve outward anteriorly; antennae normally with 11 segments in female, 9 in male.....**Encyrtidae**

Mesosternum elongate, the middle coxae widely separated from the anterior pair; mesoscutum usually longitudinally impressed in the middle, the parapsidal sutures absent or incomplete; mesoscutum and scutellum usually movable at the mesoscuto-scutellar suture and upon the underlying pleural parts; males usually with the mesopleura furrowed, the mesoscutum not impressed but with more or less complete parapsidal sutures; antennae usually with 13 segments**Eupelmidae**

33. Hind coxae normal34

Hind coxae very large, and almost laminately compressed; middle and hind femora broad and compressed; tarsi 4-segmented, the middle and hind pairs elongate; mesoscutum without parapsidal sutures; axillae small and produced forward into the base of the mesoscutum; marginal vein very long, the stigmal vein very short**Elasmidae**

34. Tarsi usually 4-segmented, or rarely heteromerous; marginal vein long, the stigmal vein well developed, the postmarginal

- sutures of mesoscutum complete or sometimes poorly developed; prepectal plates usually large and triangular
**Eulophidae**
- Tarsi 3-segmented; marginal vein short, the stigmal vein short or sometimes absent, the post-marginal always absent; venation seldom reaching beyond the middle of wing and frequently ending at the basal third; pubescence of forewing often arranged in lines**Trichogrammatidae**
35. Largest segment of abdomen (in side view) tergite IV, V, or VI with at least 2 short tergites behind the petiole preceding the large tergite. Radial cell closed. Mostly large, heavy-bodied forms**Ibaliidae**
- Largest segment of abdomen (in side view) tergites II or III, and never more than 1 short tergite preceding the large tergite. Mostly smaller species36
36. Tergite II not forming one-half the abdomen
**Figitidae**
- Tergite II (or II and III fused) the largest and usually forming at least one-half the abdomen**Cynipidae**
37. Antennae inserted close to clypeus38
- Antennae inserted on middle of face40
38. Abdomen acutely margined at sides39
- Abdomen rounded at sides; marginal vein usually stigmated....
**Ceraphronidae**
39. Forewings with marginal and stigmal veins
**Scelionidae**
- Forewings at most with an incomplete submarginal vein.....
**Platygasteridae**
40. Forewings with a stigma41
- Forewings without a stigma**Diapriidae**
41. Mandibles without teeth; claws simple, antennae 13-segmented**Proctotrupidae**
- Mandibles dentate, antennae 15-segmented, calws pectinate....
**Heloridae**

42. Antennae 10-segmented, inserted close to clypeus; front tarsi of female often pincers-like (chelate); parasites of leafhoppers**Dryinidae**
- Antennae 12- or 13-segmented; front tarsi not pincers-like.....
.....43
43. Abdomen with 3 or fewer (4 in males of Parnopes) visible tergites, the last often dentate apically; venter of abdomen concave; body metallic blue or green and with coarse sculpturing.....**Chrysididae**
- Abdomen with 4 to 7 visible tergites; venter of abdomen convex44
44. Abdomen with 6 (females) or 7(males) visible tergites; head usually oblong and elongate; ovipositor a true sting.....
.....**Bethylidae**
- Abdomen with 4 (females) or 5 (males) visible abdominal tergites**Cleptidae**
45. First abdominal segment forming a scale or node, or the first 2 abdominal segments nodiform and strongly differentiated from the rest of the abdomen. Ants.
.....**Formicidae**
- First abdominal segment not scale-like46
46. First discoidal cell shorter than the submedian cell (usually very much so); forewings very rarely folded; solitary species, never living in colonies47
- First discoidal cell very long, as a rule much longer than the submedian cell; forewing almost always folded longitudinally when in repose; frequently social species, living in colonies. Hornets, yellow jackets.....**Vespidae**
47. Mesopleura divided by an oblique suture into a lower and upper part; legs, including the coxae, very long; hind femora unusually long; middle tibiae with 2 spurs. Spider-hunting wasps, Tarantula hawks**Pompilidae**
- Mesopleura not thus divided; legs shorter, the hind femora not usually extending to the apex of the abdomen.....48
48. Meso-and metasternum together forming a flat plate which is divided by a transverse, more or less sinuous suture, and overlies the bases of the 4 posterior coxae; wing

membrane, beyond the closed cells, finely longitudinally wrinkled. Large, often brightly coloured wasps.....**Scoliidae**

Meso-and metasternum not forming such a plate overlying all 4 posterior coxae; sometimes provided with a pair of thin backwardly directed plates or laminae which overlie the bases of the middle coxae49

49. Mesosternum with 2 laminae that overlie or project between the bases of the middle coxae and usually extend to the midline where they are separated by a median suture; ocelli small**Tiphiidae**

Mesosternum simple, without appendages behind, or with the laminae reduced to a pair of minute teeth-like projections.....50

50. Hind wing with a prominent separated lobe at the anal angle; body bare**Sapygidae**

Hind wing without a lobe at the anal angle, at most with an obtuse emargination at the posterior basal angle; body almost always conspicuously pilose. Velvet ants**Mutillidae**

51. Metasternum produced into a forked process posteriorly; parapsidal sutures distinct and complete; pronotum long, conically produced anteriorly, usually with a median groove; abdomen of male with 4 to 6 exposed tergites**Ampulicidae**

Metasternum not so produced; parapsidal sutures indistinct or absent; abdomen of male usually with 7 exposed tergites....**Sphecidae**

REFERENCE

- DE BACH, PAUL, 1973. Biological control of Insect Pest and Weeds (Editor), Chapman & Hall Ltd. 11, New Fetter Lane, London E.C. 4. 815 pp.

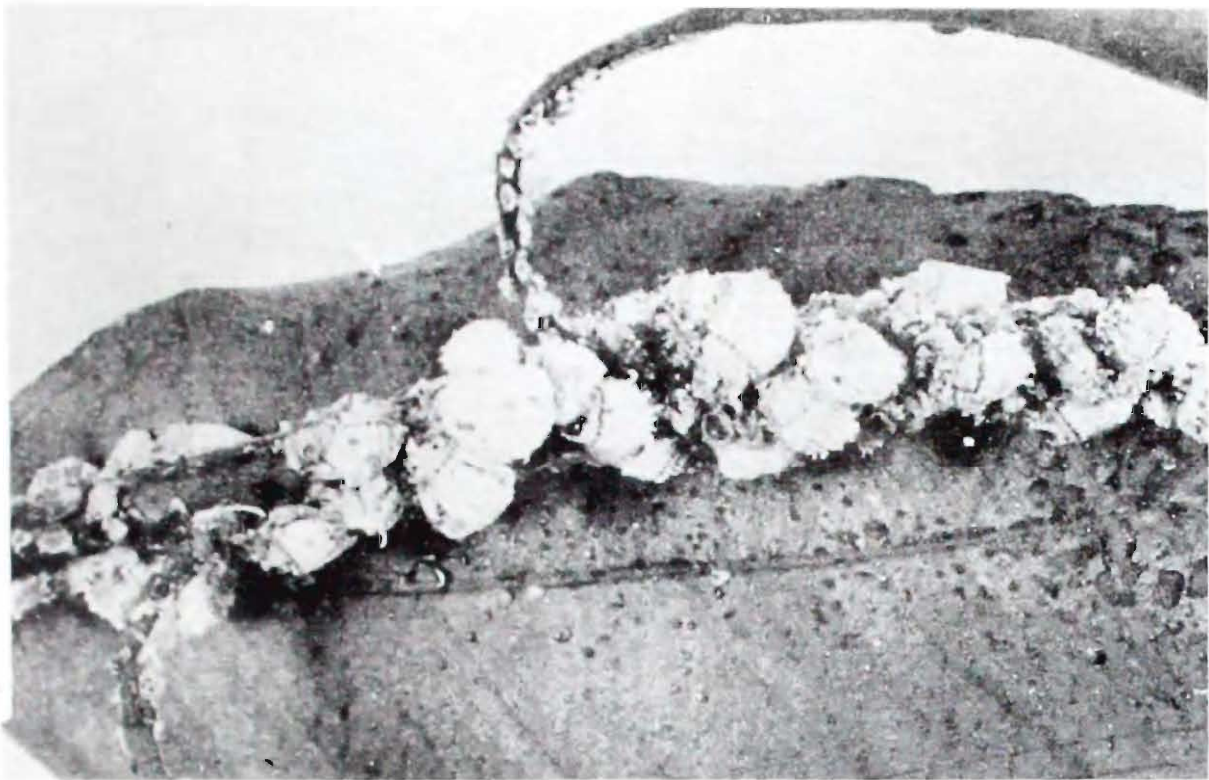


Fig.1 - Citrus twig with infestation of cottony-cushion scale (After Paul DeBach, 1964).

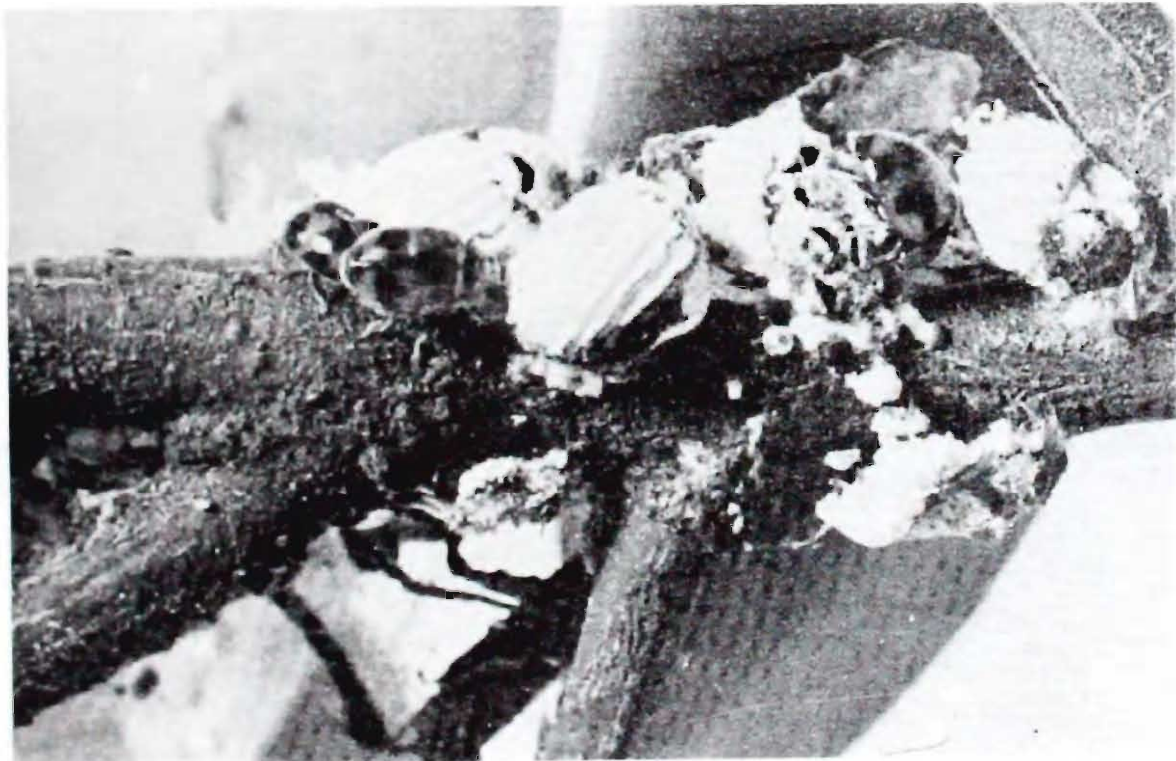


Fig. 2 - Adult vedalia beetle feeding on cottony-cushion scale.

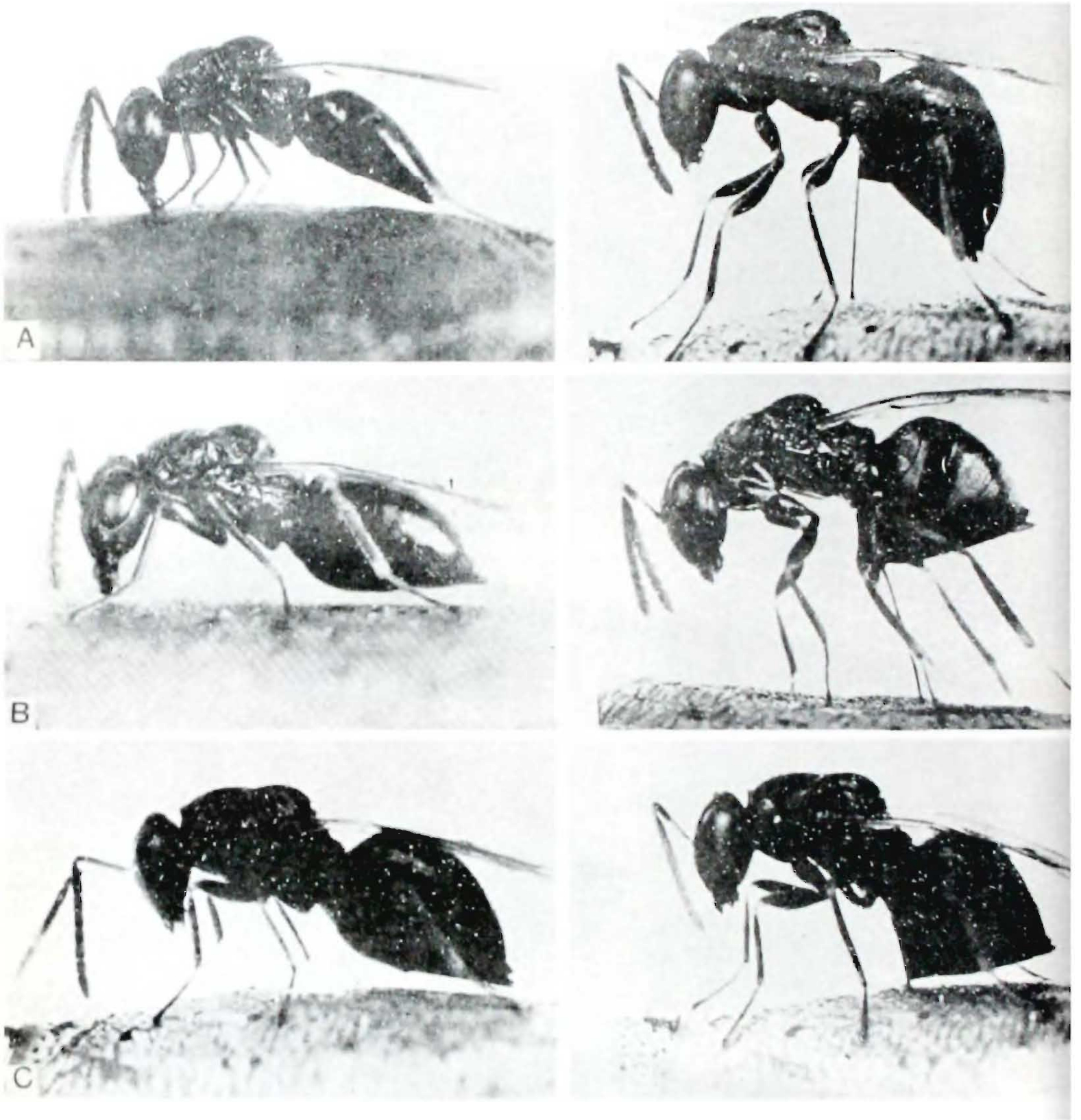


Fig.3, A-F : A-C - Female parasite feeding at puncture wound made by her oviposition on a host pupa; D-F - Ovipositional behaviour : D - Drumming, E - Drilling, F - Oviposition

PLATE III

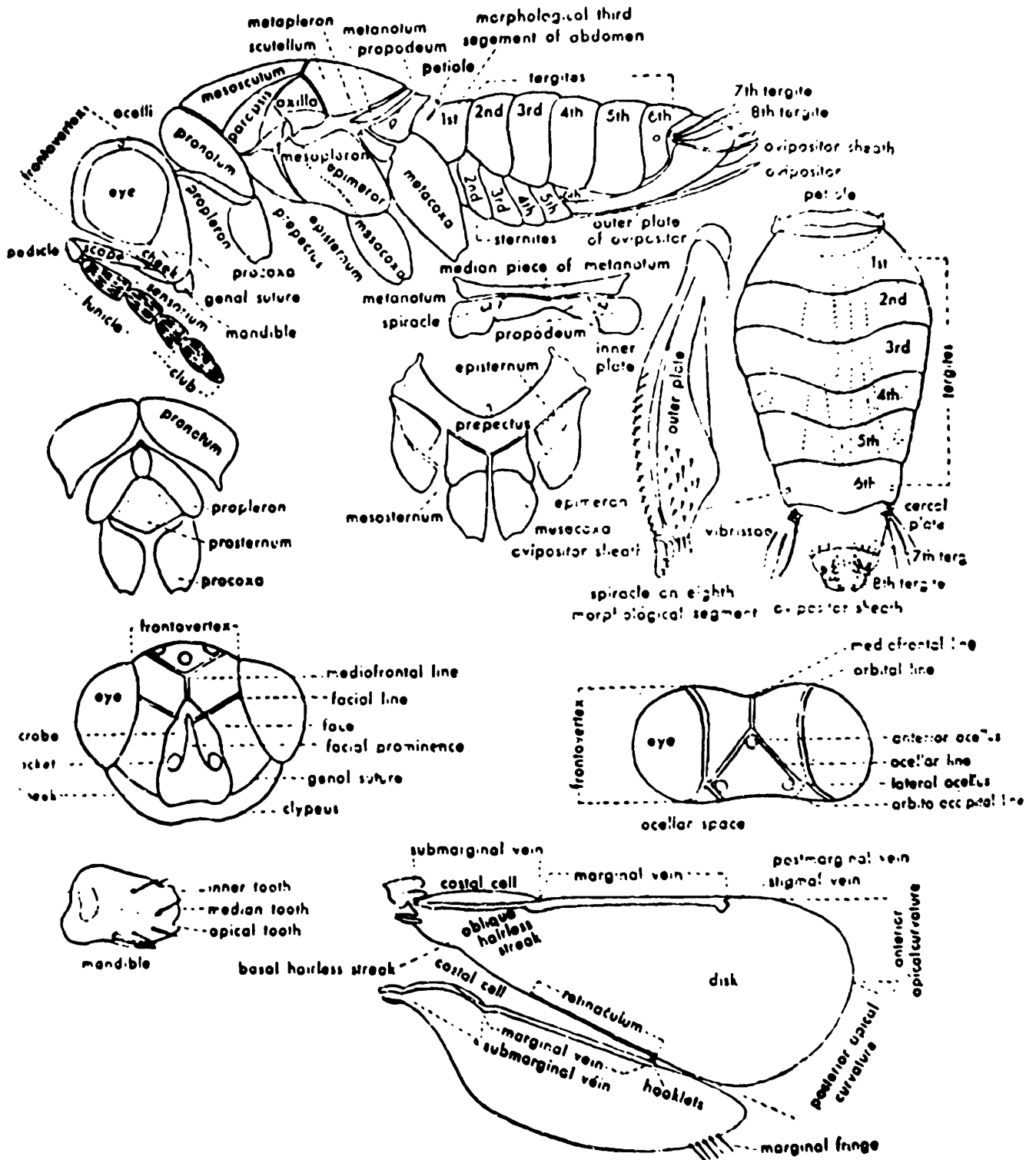
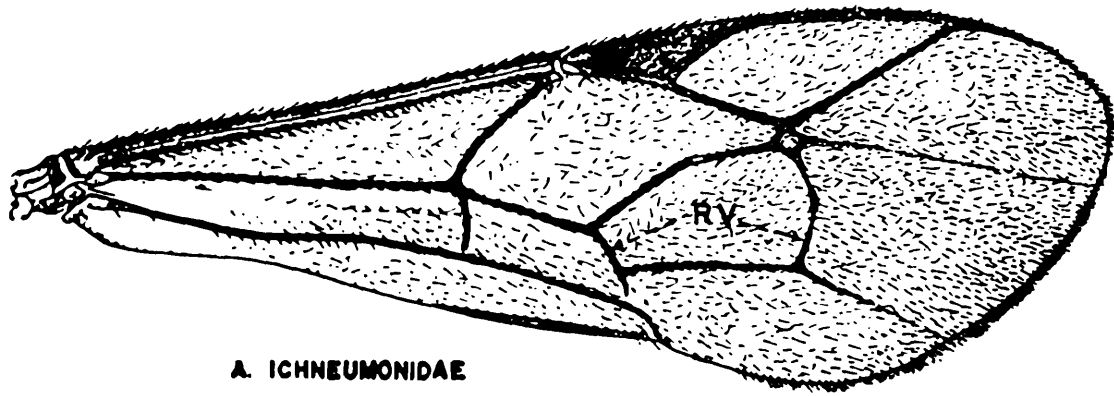
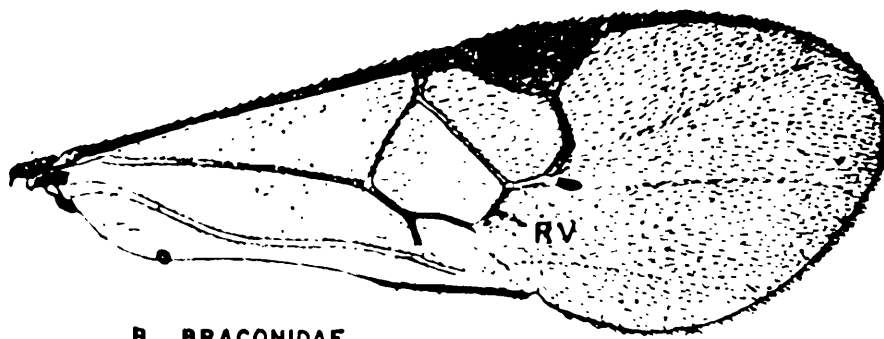


Fig. 4 - Morphological details of hymenopterous parasite (After Campere, 1931).

PLATE VII



A. ICHNEUMONIDAE



B. BRACONIDAE

Fig.5. Wing venation of a Ichneumonid and a Braconid wasp.

COLLECTION AND PRESERVATION OF COLEOPTERA

T Sen Gupta

INTRODUCTION

Members of the order Coleoptera are commonly known as beetles. It is the largest order of Insecta, favourite group to insect collector for a long time for their marvellous colour, their sculpture, etc. They are easy to collect, mount and preserve. India being situated in tropics, is well known for her richness of beetle fauna. Beetles occur in almost all habitats from high mountain to the sea-shore, leaves to roots, some are subterranean cave dwellers and some live in ants and birds' nests.

HOW TO COLLECT

One can collect beetles any time of the year. During Winter most of them hide under bark, stones, leaf litters and stored materials. In early summer one can collect larval forms with their adults. Summer season is one of the best time for collection in and around the base of the Himalayas and Nilgiri Hills. During early rainy season, both the adults and larvae can be collected all over India. In the peak of the monsoon, collection becomes difficult but one can get a large number of beetles with the aid of light traps. The best time for collection will be in the autumn (Sept. & Oct.); during these months almost all the families of beetles abundantly occur throughout India.

CHIEF HABITS OF BEETLES

1. Understone, in logs and fallen trees; for the families Carabidae, Staphylinidae and Histeridae.
2. Bark : One can get a variety of families under bark specially families like Cucujoidea, Cerambycidae and Curculionidae, etc.
3. Foliage : By beating and sweeping vegetation one can collect a variety of families, chiefly Chrysomeloidea, and families of Heteromera, Cantharoidea, Curculionoidea, etc.
4. Vegetable garbage : Most of the microcoleoptera are fungus feeders and one can collect a variety of families especially Staphylinidae, Ptiliidae, Pselaphidae,

Scarabaeidae, etc. Micro-Coleoptera are usually ignored or little known in our country.

5. Aquatic beetles are chiefly found in ponds, lakes, rivers, drains and ditches, etc. Majority of Dytiscidae, Gyrinidae and Hydrophilidae live in non acidic water whereas Haliplidae lives in still water; Amphizoidae is found in mountain streams and Dryopidae in the bottom of stream.
6. Other important habitats are : leaf litter, dung and manure heap, carrion, river beds, fungi and nests of ants, termite birds, bees and mammals. Some interesting beetles can be found in moss, slime, sand pit, caves and cones of cycads and Pines.

METHODOLOGY OF SURVEY

Beginners will find plenty to interest them by turning over a stone or log, sweeping bushes and searching waterbodies by butterfly net or water net. After that, one must try to adopt more specialized method of collection. Once collection methods are aquired, get a district or locality map from the Forest Office or Survey of India or National Atlas or road map from Automobile Association. The whole are to be surveyed should be divided into one or two inch square, different major ecological areas should be classified (e.g. high land, swamp, forest, ponds, rivers, agricultural field, etc.). Try to classify these habitats into micro-climatic niches (see charts). Selection of time, days and season are important factors (details of collection methods can be obtained from Hand book of Insect collection by Ghosh and Sen Gupta,1982). Trained collectors can organise a usefull survey and can collect maximum and varied forms of Coleopterous Insects.

1. Select a place where maximum ecological areas are represented e.g. plain land, hills, forest, streams and swamp, which yield maximum.
2. Use as many as possible kinds of traps along with collection made by sweeping, beating and searching.
3. Continue the collection from morning to evening at least for a couple of days in one collecting spot.
4. If possible try to cover all the major seasons.

These types of survey have an advantage to collect both common, abundant and rare species. One must mention date, habitat, name of the place and collector for each and every

collection. These records are of immense importance for himself and future workers.

EQUIPMENTS

Most of the equipments needed for collection are simple but all are important viz., (1) Sweeping net, (2) Beating net, (3) Tray, (4) Hatchet, (5) Knife, (6) Forceps, (7) Scissors, (8) Brush, (9) Glass vials, (10) 70% alcohol, (11) Chloroform, (12) Ethylacetate, (13) Paper packets, (14) Plastic bags, (15) Killing bottle, (16) Cotton, (17) Aspirators, (18) Water net.

METHOD OF COLLECTION

- (a) Hand picking : Probably this is the best method of collection and only experienced collector can achieve this method.
- (b) Sweeping : This is commonest method of collection, even a beginner may find a varieties of beetles in large numbers.
- (c) Beating : It is similar as sweeping, one has to beat with a stick dead branches of trees, bushes and foliage keeping an umbrella or white clothes underneath.
- (d) Collection of beetles from bark and leaf garbage: One need a tray and hatchet to collect beetles from these habitats. Professional collectors generally achieve good results from these habitats.

As regards trapping of beetles, usually pit fall traps, light traps, bait traps and Berlese funnel are usually used by Coleopterists.

Killing agents : (1) Hot water (2) Chloroform or benzene (3) Ethyl acetate (4) Potassium and Sodium cyanide (5) 70% alcohol; 70% alcohol is very good for larvae and micro coleoptera, whereas soft bodied beetles should be preserved in saw dusts with a few drops of ethyl acetate.

Preservation : One can preserve beetles both in dry and wet conditions. For dry preservation they are generally mounted in cards on pin; then kept in drying chamber for a few days and finally transferred to permanent wooden cabinet. Small, unicolour dark beetles along with larval forms can be preserved in 10% alcohol for a long time.

BEETLES AS PESTS

Stored grain pests : Various species of the families Cucujidae, Silvanidae, Tenebrionidae, Nitidulidae, Curculionidae, Dermestidae, Bostrychidae, Bruchidae, Anobiidae, Ostomidae, etc. cause serious damage to stored cereals, pulses, rice, spices, drugs, clothes, fur, wool, silk, tobacco and furniture.

Forest pests : Many species of Cerambycidae, Buprestidae, Curculionidae, Bostrychidae, Scolytidae are well known pests of forest trees. Some are borers and others are defoliators.

Fruit garden and Orchard Pests : Representatives of Scarabacidae, Curculionidae and Cerambycidae cause serious damage to fruit garden and orchards.

Field crop pests : Representatives of Chrysomelidae, Curculionidae, Meloidae and Coccinellidae are chief pests of field crops.

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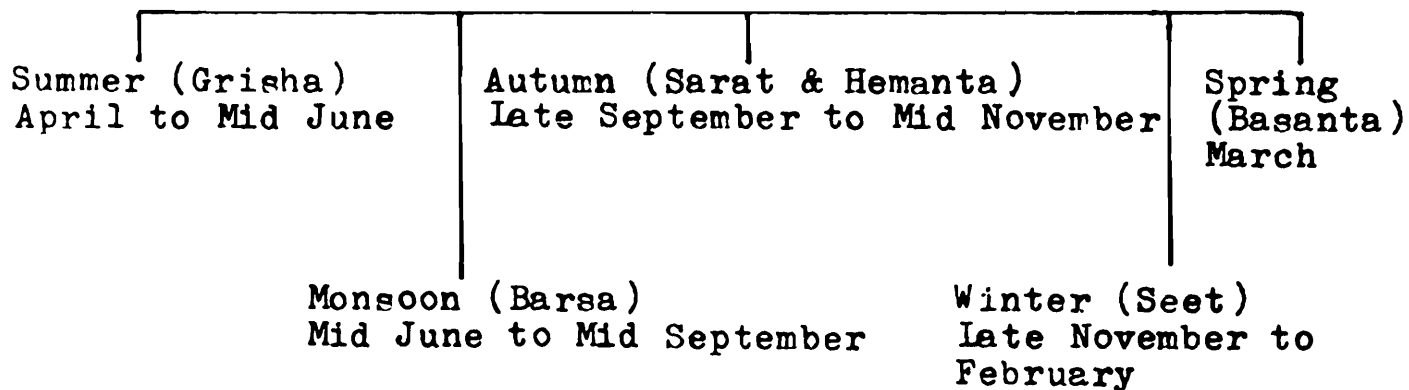
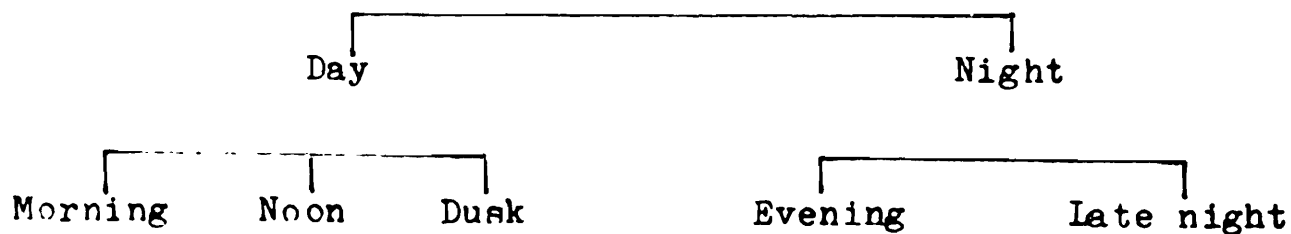
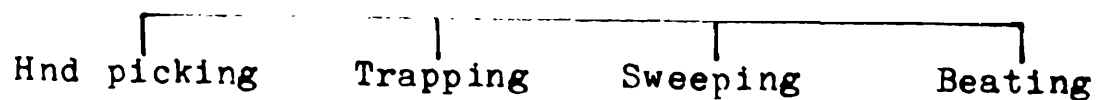
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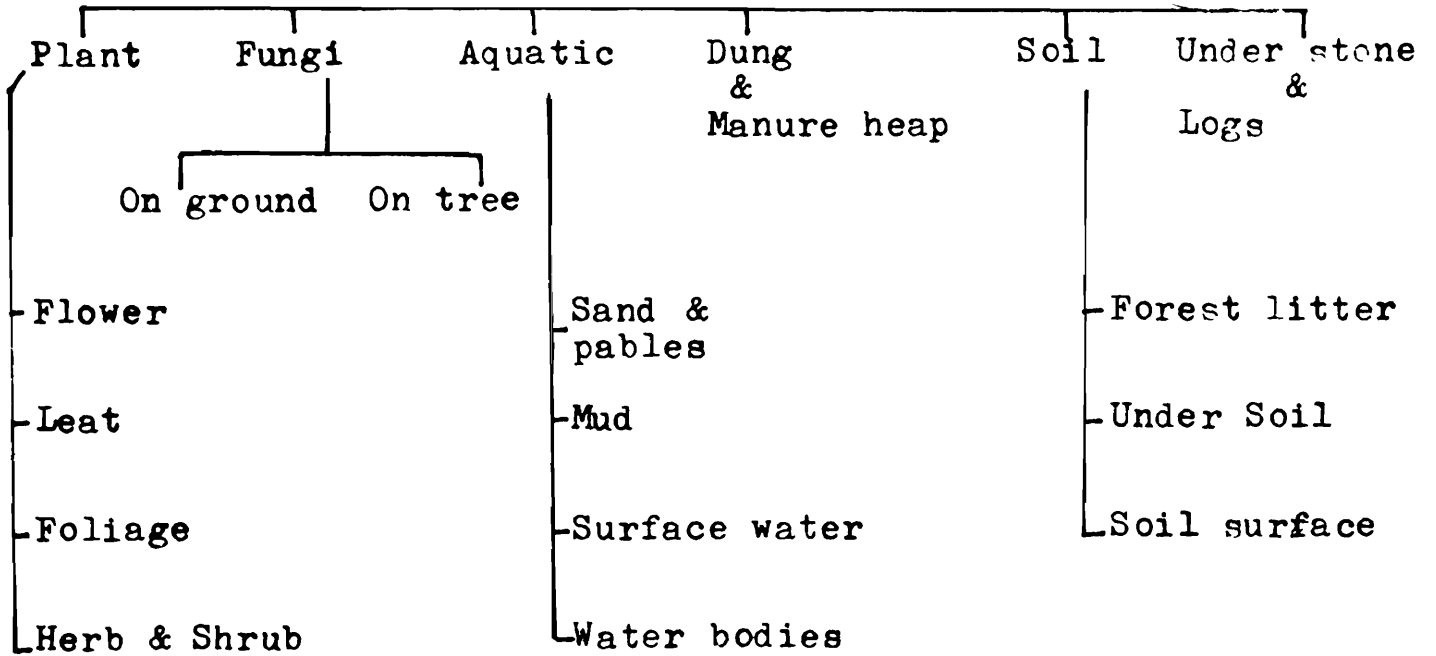
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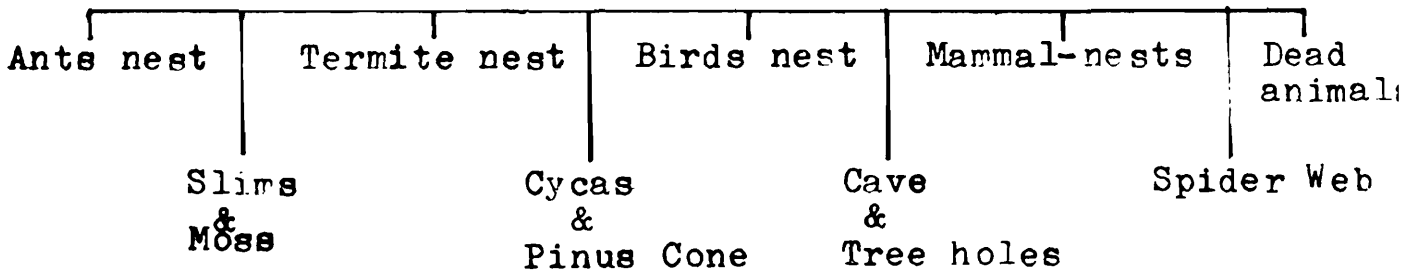
TIME OF COLLECTION(A) INDIAN SEASONS(B) PERIOD OF COLLECTION(C) PRINCIPLES FOR COLLECTION

CHIEF HABITAT

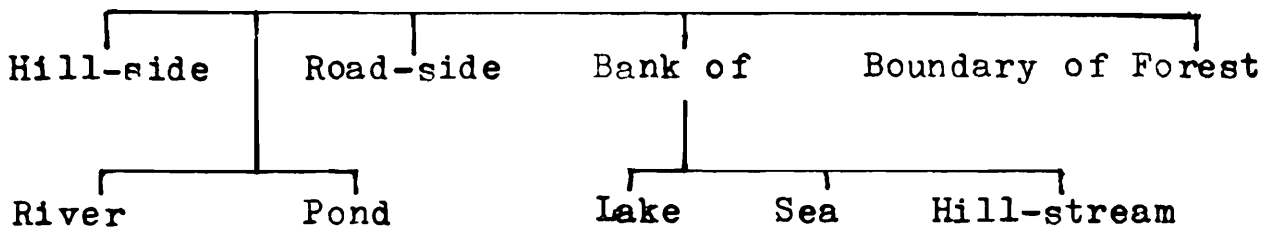
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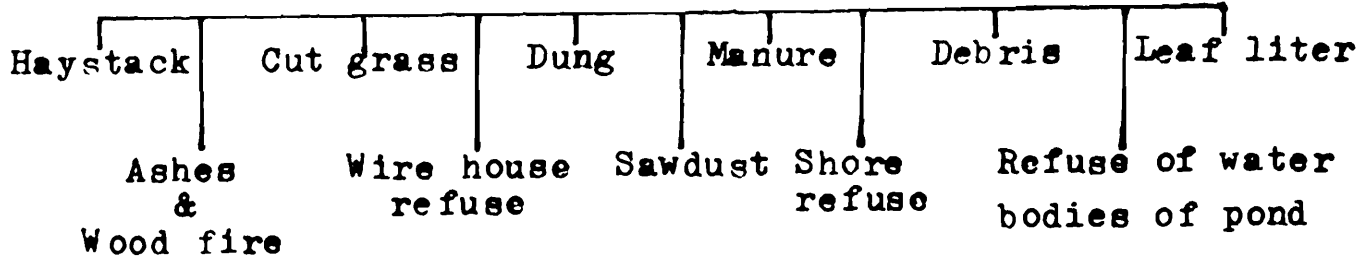
(B) UNCOMMON HABITAT
OR
QUEER HABITAT



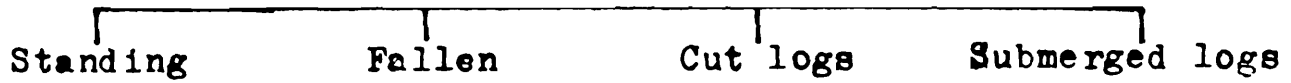
FOLIAGE



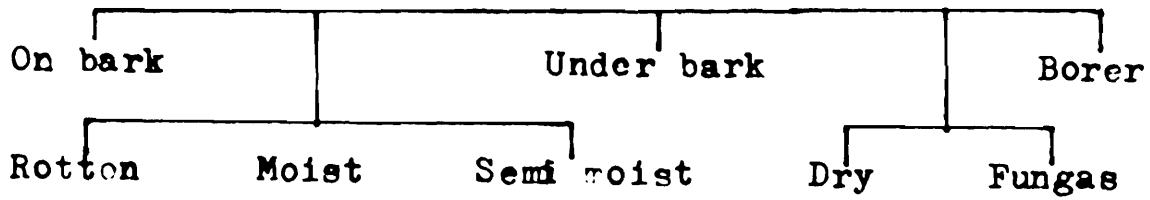
REFUSE



TREE TRUNK



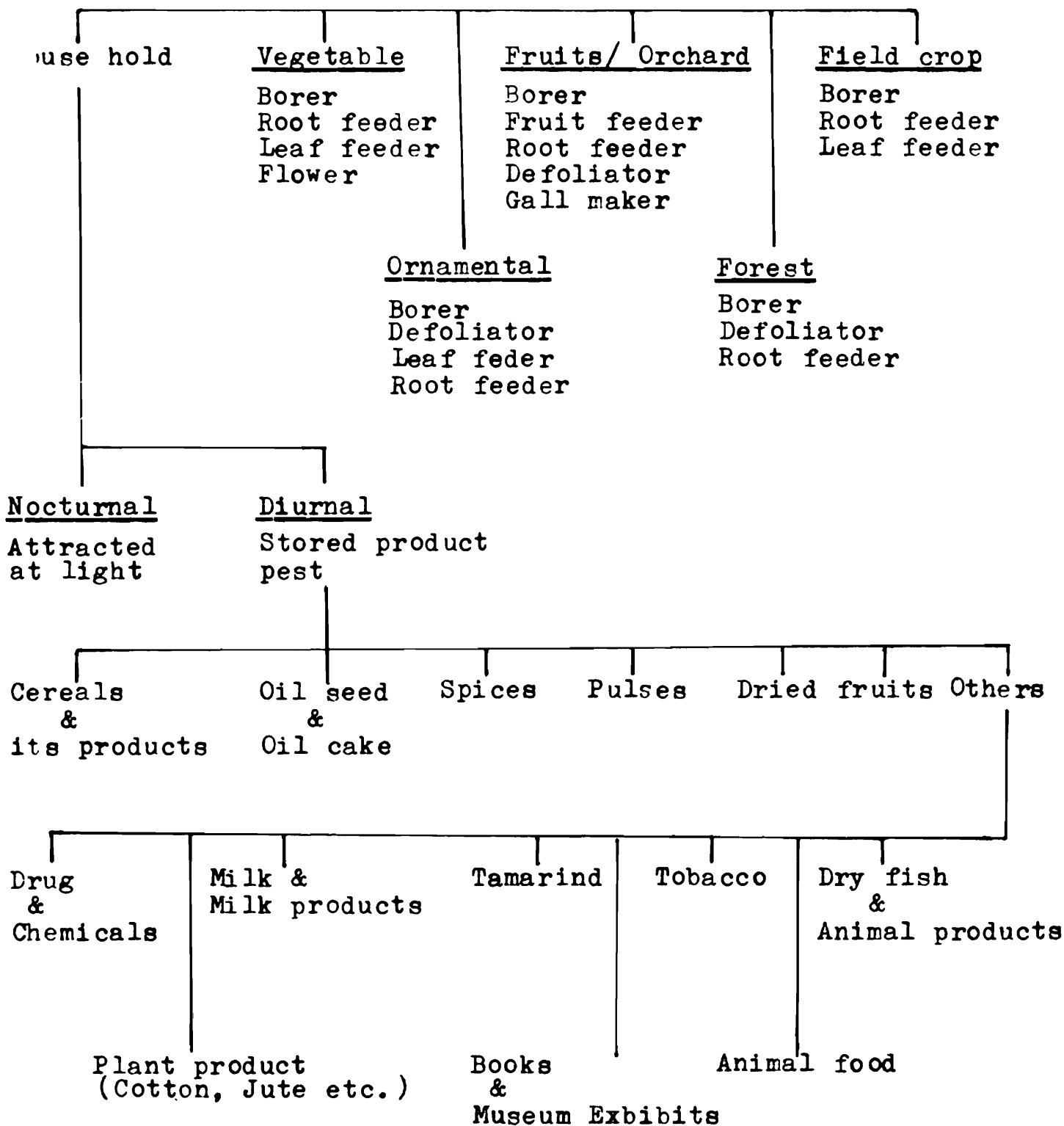
DEAD FALLEN TREE



NEST



HABITAT OF PEST





Figs. 1-9 : 1-1c. Butterfly net; 2. Aspirator; 3. Insect killing bottle; 4. Extraction funnel; 5. Berlese funnel; 6. Insect vial; 7. Vials stored in widemouth glassjar; 8. Pinned insect with labels; 9. Slide box for mailing.

APPENDIX

EVALUATION OF BEETLE FAUNA OF THE WORLD AND OF INDIA
(Upto 1965)

Sl. No.	Family	No. of species in World (Junk Col. Cat.)	Year of publication	No. of species in India and neighbouring countries	Species abundant or predominant in tropics	Types of work needed	Chief habitats
1	2	3	4	5	6	7	8
1.	Carabidae	18529	1926-33	1915 (in part)	+	New revision	Under stones, logs, bark, leaf litter.
2.	Dytiscidae	2029	1920	151	+	Monograph	Ponds, Lakes, Streams.
3.	Halipidae	103	1920	2		Survey	Pond, lakes quiet streams.
4.	(Hygrobiidae)	4	1920				Muddy ponds.
5.	Amphizoidae	5	1933	1		Survey	Mountain streams.
6.	Gyrinidae	423	1910	47	+	Survey and short revision	Standing and moving water.
7.	Rhysodidae	109	1910	14	+	"	Under bark of moist decaying logs.
8.	(Tretrothoracidae)	1	1933				?
9.	(Jacobsoniidae)	2	1933				?
10.	(Cupedidae)	19	1910				Under bark, dead, branches of trees.
11.	Paussidae	298	1910	48	+	Survey and short revision	Rotten wood on trees.
12.	Staphylinidae	19909	1910-34	2584 (in part)	+	New revision	Carrion, leaf litter, Haystack, decaying vegetable matter, soil litter, under bark, pollen of flowers, termites and bird's nest.
13.	Pselaphidae	3400	1911	101	+	Survey and short revision	Mold, forest floor, under logs and stones, moss, cave, termites and bird's nest.
14.	(Gnostidae)	2	1911				Dried animals and vegetables.
15.	Scydmaenidae	1194	1919	30	+	Survey and short revision	Leaf mold, litter, tree holes, under stones, moss, ant's and termite's nests.
16.	Silphidae	702	1914	29	+	"	Carrion, decaying vegetable, dead animals.
17.	Leiodidae	400	1929	10	+	"	Molds on decaying vegetable matter, under bark, fungi, ant's nests.
18.	Clambidae	40	1929	1		Survey	Rotting plant material, forest floor.
19.	(Platyphylidae)	1	1910				Fur of mammals.
20.	Orthoperidae	284	1910	22	+	Survey	Fungus plant material, under moist bark, ro-

1	2	3	4	5	6	7	8
							rotten wood, Haystack.
21.	(Phaenocephalidae)	1	1910				Under bark.
22.	(Discolomidae)	30	1910		+	Survey	On bark
23.	(Sphaeriidae)	6	1910				Mud, moss, roots of plants under stones near water.
24.	(Hydroscaphidae)	5	1911				Streams.
25.	Ptilidae	209	1911	6	+	Survey	Rotten wood, fungusy logs, decaying vegetable, Haystack, dung, ant's nests.
26.	Scaphidiidae	245	1910	11		"	Fungi, rotten wood, dead leaves, under logs.
27.	Histeridae	2420	1910	191	+	Survey and short revision	Carrion, excrements, decomposing plant materials oozing sap, under bark, Haystack, termite's nests.
28.	Niponidae	60	1931	9		Survey	Under bark.
29.	Lycidae	2819	1933	177		Survey and short revision	On plants
30.	Lampyridae	1109	1910	?	?	?	Foliage, debris, under bark near moist situation.
31.	(Phengodidae)	48	1927	Nil			Forest floor, under bark.
32.	(Karumidae)	4	1927	Nil			?
33.	Cantharidae	3343	1939	230		Survey and	Herbage, foliage branches of coniferous and deciduous trees shrubs and grasses near water.
34.	(Phloeophilidae)	5	1926				Under bark.
35.	(Rhadalidae)	4	1926				On plants or tree trunks.
36.	Prionoceridae	124	1926	47		Survey	Carnivorous, flowers plants.
37.	Rhagophthalmidae	9	1910	2		"	Foliage or debris near moist situation.
38.	Drilidae	79	1910	17		"	Larvae eat shails
39.	Malachidae	2118	1937	128		Survey and short revision	Carnivorous, flowers, trunk of trees.
40.	Dasytidae	1668	1929-37	42			"
41.	Dasyllidae	215	1940	12		Survey	Bushes and flowers in vicinity of water.
42.	Helodidae	499	1940	22		"	Leaf bases of bromeliads, hollow of tree, shallow ground water.
43.	(Lucinetidae)	24	1914				Detritus, bark covered with fungus.

1	2	3	4	5	6	7	8
44.	Cleridae	2285	1910	155	+	Survey and	Woody plants, under and on bark, dead twigs, branches, foliage and flowers.
45.	(Derodontidae)	38	1915				Slime mold, tulip plants.
46.	Lymexylonidae	38	1915	3	+	Survey	Decaying wood, tree trunk.
47.	(Micromalthidae)	1	1915				Decaying logs.
48.	(Telegeusidae)	1	1934				Under bark.
49.	Anobiidae	911	1912	12	+	Survey	Stored products, furniture, wood work of house, pine cone.
50.	Prinidae	421	1912	9	+	"	Dried animal substance, stored products, wool.
51.	Ectrephidae	100	1935	1		"	Myrmecophilus, dried animal substance.
52.	Bostrychidae	518	1938	67	+	Survey and short revision	Wood borers, rarely in stored products.
53.	Rhipiceridae	163	1925	10	+	"	Rotten wood.
54.	Cebrionidae	223	1911	2		Survey	Foliage
55.	Elateridae	6780	1925-27	141	+	Survey and short revision	Foliage, bushes, tree trunk, under bark, clay & sandy soil.
56.	(Plastoceridae)	31	1927				Foliage
57.	Dicronychidae	31	1927	2		Survey	"
58.	Melasiidae	1071	1928	59	+	"	Dead trees, under bark.
59.	Throscidae	190	1928	7	+	"	Flowers, roots of grass, moss, dead wood.
60.	(Cerophytidae)	10	1928				Rotten wood, under bark.
61.	(Perothopidae)	3	1928				Branches of trees.
62.	Buprestidae	2228	1926-36	426		Survey and short revision	On plants, foliages, bushes.
63.	Dryopidae	453	1910	16	+	Survey	Bottom of streams
64.	(Cyathoceridae)	1	1910				?
65.	Georyssidae	20	1910	2	+	Survey	Margin of streams, sand, mud.
66.	Heteroceridae	133	1910	13	+	"	Galleries in the mud bank, along streams.
67.	Hydrophilidae	1555	1924	81	+	Survey and	Brackish and stagnant water, streams fresh dung, moist and decaying leaves.
68.	Nosodendridae	28	1911	1		Survey	Oozing sap of trees, under bark.
69.	Byrrhidae	289	1911	30		"	Moist soil, dry sand, moss, under stones and logs, roots of grasses weeds.

IV

1	2	3	4	5	6	7	7
70.	Dermestidae	524	1911	15	+	Survey	Dried animal and plant material, dried cereal products, flowers, bee's and bird's nests.
71.	(Sphaeritidae)	1	1931				Decayed fungi, under bark, plant sap, moss, dung.
72.	Temnochilidae	534	1910	17	+	Survey	Under bark.
73.	(Byturidae)	3	1913				Flowers
74.	Nitidulidae	2185	1913	173	+	Survey and short revision	Saprophagus, mycetophagus, flowers, decaying fruits and vegetables, under bark, ant's & bee's nests.
75.	Rhizophagidae	36	1914	1		Survey	Under bark, fungus infected wood, decaying vegetable matter, ant's nests.
76.	(Thorictidae)	12	1930				Dried animal matter, stored foods.
77.	(Catpochrotidae)	1	1926				?
78.	Monoedidae	7	1926	1		Survey	Under bark ?
79.	Syntelidae	4	1926	1	+	"	Oozing sap of trees.
80.	Cossyphodidae	8	1926	1		"	?
81.	Cavicoxumidae	1	1930				Foliage ?
82.	Cucujidae	1226	1930	150		Survey	Under bark, decaying plant material haystack, stored grain.
83.	Biphylidae	195	1934	12		Survey and short revision	Garden refuses, under bark.
84.	Erotyliidae	1541	1911	58		New revision	Fleshy fungi, under bark, decayed wood.
85.	Helotidae	79	1911	11		Survey	Sap of trees, bark.
86.	Languriidae	400	1928	94		New revision	Foliage, flowers, Hays, bee's nest, male cone of cycads.
87.	Colydiidae	1368	1930	108		Survey	Under bark, leaf litter, decaying woods.
88.	Phalacridae	504	1930	29		"	Flowers, foliage decayed plant debris, smut fungi of Gramineae.
89.	(Aculognathidae)	1	1934				Ant's nests.
90.	Cryptophagidae	754	1923	28		Survey	Mold, decayed leaves, haystack, stored grain.
91.	Lathridiidae	495	1926	25		"	Moldy vegetable matter, haystack, bushes, flowers, leaf litter.
92.	Mycetophagidae	186	1930	9		"	Moldy vegetable matter, fungusy bark, haystack.

1	2	3	4	5	6	7	8
93.	Endomychidae	651	1910	54	+	New revision	Under fungusy bark, rotten wood, decayed fruit refuses, flowers.
	94. Coccinellidae	3279	1931	278	+	Monograph	Foliage, flowers.
95.	Sphindidae	20	1931	3	+	Survey	Feed on Mycetozoa, tree trunk, fungi on logs.
96.	(Aspidiphoridae)	5	1934				Decayed trees.
97.	Cioidae	237	1911	?	?	?	Rotten wood, under bark, associated with woody fungi.
98.	Oedemeridae	593	1915	3		Survey	Flowers.
99.	Pythidae	272	1928	5		"	Under bark.
100.	Pyrochroidae	116	1928	11	+	"	Shrubs, flowers.
101.	(Hemipeplidae)	7	1928				Leaf bases of plams.
102.	(Scalidiidae)	2	1934				Under bark.
103.	Scraptiidae	84	1911	4	+	Survey	Associated with fungi, dry decaying wood, under bark.
104.	Pedilidae	250	1911	10		"	Leaves, flowers.
105.	Hylophilidae	336	1910	7		"	Foliage.
106.	Anthicidae	1529	1911	105	+	Survey and	Flowers, foliage, vegetable detrius, leaf litter, haystack.
107.	Serropalpidae	423	1924	7		Survey	Dry wood.
108.	Monommidae	99	1931	1		"	Leaf debris, dead twigs, grass.
109.	Meloidae	1954	1917	68	+	Survey and revision	Bushes, trees.
110.	(Cephaloidae)	11	1917				Flowers.
111.	Mordellidae	735	1915	5		Survey	Umbelliferous flowers.
112.	Rhipiphoridae	232	1913	11		Survey	Rotten wood.
113.	(Nilionidae)	22	1910				Associated with fungi on trees.
114.	Othniidae	16	1910	1		Survey	Rotting leaves, under bark.
115.	(Aegialitidae)	4	1910				Under bark.
116.	(Petriidae)	3	1910				?
117.	Lagriidae	551	1910	13	+	Survey	Under bark, feed leaves at height.
118.	Alleculidae	1075	1910	26	+	"	Under bark, leaves, flower.
119.	Tenebrionidae	10662	1911	358	+	Survey and short revision	All habitats (except water), under bark, rotten wood, debris, under legs and stones, stored products.

VI

1	2	3	4	5	6	6	8
120.	Trictenotomidae	12	1911	5	+	Survey	?
121.	Lucanidae	750	1910	86	+	Survey and short revision	Decaying logs and stumps, bark, sandy beaches.
122.	Passalidae	486	1935	37	+	"	Decaying logs and stumps.
123.	Scarabaeidae	12220	1910-37	804 (in part)	+	New revision	Dung, fungus, carrion, rotten wood, decayed vegetation, pollen, plant sap, grass, roots, leaves, fruits.
124.	Cerambycidae	14085	1913-23	681 (in part)		"	Wood, leaves, twigs, bark, pollen roots.
125.	Chrysomelidae	18973	1913-40	1643 (in part)	+	"	Herbaceous plants, stems, leaves, roots.
126.	Bruchidae	818	1913	51	+	Survey	Seed feeder, seeds & pods of Leguminosae, fruits, stored products.
127.	Anthribidae	2197	1929	28	+	Survey and short revision	On bark, dead and dying trunks and branches of trees.
128.	(Aglycyderidae)	1	1911				Dead stems and branches or leaf miners.
129.	(Proterrhinidae)	122	1911				"
130.	Brenthidae	1279	1927	103	+	Survey and short revision	Under bark, wounded part of trees, ant's nests.
131.	Ipidae	1234	1910	93	+	"	Under bark, leaves, flowers, leaf litter.
132.	Platypodidae	323	1912	12	+	Survey	Mine galleries of hardwoods.
133.	Curculionidae	34500	1010-39	739 (in part)	+	New revision	Phytophagus, leaves, stems, flowers, roots, under bark, decaying wood, leaf litter, haystack, stored grains.

N.B. Families within brackets are not represented in India and neighbouring countries.

? Information not available or not known to me.

+, Representing abundant and scarcely distributed species respectively.

AID TO IDENTIFICATION OF INDIAN COLEOPTERA

S. Biswas and G.N. Saha

INTRODUCTION

From the available literature and reference collection present in the Zoological Survey of India, Calcutta, it has been estimated that over fifteen thousand species of Coleoptera have been described and recorded from Indian region. These belong to about two thousand genera of one hundred and nine families under twenty-two superfamilies and four suborders.

To make a reasonably satisfactory arrangement for identification of these huge assemblage of taxa upto species or even upto any suprageneric level, in a single work is practically beyond the scope of any individual worker and probably this is the precise reason why there is no such attempt on Indian Coleoptera till today. Moreover, problem becomes further acute due to the fact that generic and suprageneric classification of Coleoptera has not reached the desired degree of precision. As a result, definitions to limit various groups undergo continuous changes resulting in frequent creation, dissolution and transfer of taxa ranging from species to superfamilies.

However, an attempt has been made here to provide Keys (except for superfamily Cucujoidea) upto families. Whenever possible, sources have been indicated for identification of Indian material upto species level in the list of references provided at the end. No attempt to classify superfamily Cucujoidea is made in view of huge number of taxa it holds and authorities differ extensively in their treatment.

In preparing the present account extensive use has been made of the work of Arnett (1968), Crowson (1955, 1983), Dillon and Dillon (1961) and many other workers who have dealt with Indian Coleoptera.

It is presumed that those who will use this work are familiar with external morphological characteristics of Coleoptera. As far as possible larval and anatomical characters have been omitted from the keys provided here.

KEY TO SUBORDERS OF COLEOPTERA

Coleoptera is divided into four suborders, namely, (1) Archos-temata, (2) Adephaga, (3) Myxophaga and (4) Polyphaga.

These suborders can be separated by the following key:

- 1(2). Hind coxae immovably fused to metasternum, completely dividing 1st visible abdominal sternite; prothorax usually with notopleural suture distinct; usually 2 m - cu cross veins enclosing a cell (oblongum) (2) Adephaga
- 2(1). Hind coxae rarely fused to metasternum, if so not dividing 1st visible abdominal sternite; prothorax rarely with distinct notopleural suture; oblongum rarely distinct.
- 3(4). Prothorax usually with notopleural suture distinct, antennae filiform or serrate; wings with Rs complete to base, oblongum usually distinct. Wings with apex spirally coiled in repose (1) Archostemata
- 4(3). Prothorax rarely with notoplural distinct, if so antennae clubbed; wings with base of Rs absent, oblongum rarely present, apex of wings never coiled in repose.
- 5(6). Prothorax usually with distinct notoplural suture; wings with oblongum more or less distinct. (size very small)..... (3) Myxophaga
- 6(5). Prothorax never with distinct notoplural sutures, wings never with distinct oblongum..... (4) Polyphaga

Suborder 1. Archostemata

This is the most primitive of the group of the existing Coleoptera. The suborder has been divided into four families, namely (1) Ommadidae (2) Tetraphaleridae (3) Cupedidae and (4) Micro-malthidae. No member of this suborder has been recorded from India.

Suborder 2. Adephaga

Adephaga includes a single superfamily Caraboidea. Members of this group in their adult form are specialised for active predatory life. These insects are useful for checking the population of various pest species. Some species, i.e., Calosoma sp. have been used in India and other parts of the world for biological control. The superfamily Caraboidea is usually divided into nine families, namely (1) Rhysodidae (2) Paussidae (3) Cicindelidae (4) Carabidae (5) Haliplidae (6) Hygrobidae (7) Amphizoidae (8) Dytiscidae and (9) Gyrinidae. Crawson has however given family status to two more group, namely, Trachypachydae and Noteridae. The former is usually

included in Carabidae and the second in Dytiscidae. In recent years some workers question the validity of family status of Rhysodidae, Paussidae and Cicindelidae and include to treat them as subfamilies of Carabidae. Families can be separated by the following key:

KEY TO THE FAMILIES OF CARABOIDEA

- 1(8). Hind coxae not extending to the elytra; metapleura and the first visible abdominal segment are in contact. First 2-4 antennal segments glabrous. Terrestrial insects.
- 2(3). Metasternum without transverse suture in front of hind coxae which are well separated, 1st visible abdominal sternite exposed between hind coxae, 2nd and 3rd fused. [Head and prothorax with deep longitudinal grooves. Hind wing without oblongum] Rhysodidae
- 3(2). Metasternum with transverse suture in front of hind coxae which are almost or quite contiguous. 1st visible abdominal sternite not or hardly exposed between hind coxae.
- 4(5). Clypeus extending laterally in front of antennal insertions. Lacinia of maxilla usually with a hook articulated at apex, Elytra not regularly striate. Hind wing usually without oblongum Cicindelidae
- 5(4). Clypeus not extending laterally in front of antennal insertions. Lacinia of maxilla (Hexagonini of Carabidae), very rarely with such a hook.
- 6(7). Front tibia with both spurs terminal. Front coxal cavities closed behind. Elytra with a notch or fold at sides posteriorly Paussidae
- 7(6). If both front tibial spurs are terminal the fore coxal cavities are open behind Carabidae
- 8(1). Aquatic insects with the hind coxae extending to the elytra dividing the metapleura from the first visible abdominal segment. All antennal segments with similar surface ornamentation.
- 9(10). Hind coxae produced into large plates, covering first 2 or 3 abdominal sternites Halplidae
- 10(9). Hind coxae not produced into such plates.
- 11(14). Metasternum with a distinct transverse suture in front of hind coxae.

- 12(13). Front coxae conical, projecting their cavities closed behind. Tibiae and tarsi fringed with long swimming hairs Hygrobiidae
- 13(12). Front coxae spherical, their cavities open behind. Legs not adapted for swimming Amphizoidae
- 14(11). Metasternum without a distinct transverse suture in front of hind coxae.
- 15(16). Eyes not completely divided. Antennae filiform. Mid and Hind legs not very short and broad Dytiscidae
- 16(15). Eyes completely divided into dorsal and ventral parts, Antennae short and thick, 2nd segment with a process, Mid and Hind legs forming short, broad paddles.. Gyrinidae

Suborder 3. **Myxophaga**

This suborder contains 4 families : Lepiceridae, Torridinco-bidae, Sphaeriidae and Hydroscaphidae. No member of this Suborder has been recorded from India.

Suborder 4. **Polyphaga**

This suborder includes majority of Coleoptera and members of the suborder vary extremely in their mode of life. This huge assemblage of species plays an important role in our national economy, Agriculture, forestry, fishery, stored grain and in fact every kind of products of plant and animal origin is liable to be attacked by one or group of species.

There is a number of exceptional genera which are difficult to fit into the system or which still need further study.

KEY TO THE SUPERFAMILIES OF POLYPHAGA

- 1(8). Pleural sclerites of the true 2nd abdominal sternite distinct from those of 3rd, sternite itself represented by small, lateral plates, rarely fully developed when the elytra are much shorter than the abdomen. Tarsi usually with 5 segments, fore tibia often spinose or toothed. Antennae filiform or clubbed, club often made up of last 5 segments (Haplogastra).
- 2(3). Antennae usually 10 segmented, with 3-7 apical segments produced on one side to form a lamellate club. Species usually stout Scaraboidea

- 3(2). Antennae never with club of this type, species usually less stout. Wing venation of staphylinid type.
- 4(5). Maxillary palpus nearly always longer than the antenna of which the first 3-5 segments are glabrous, the next segment cup-like, and the last ones form a strong pubescent club. Head usually with a Y-shaped impressed line on the front. Wings usually with Cantharid venation Habits mostly aquatic Hydrophiloidea
- 5(4). Antennae not so constructed and not shorter than the maxillary palpi. Head without a Y-shaped impressed line. Habits rarely aquatic.
- 6(7). Antennae with last 3 segments rarely forming a compact club; if they do 1st segment not elongate, Exoskeleton rarely very hard and shining, elytra truncate and usually leaving more than 2 abdominal segments exposed. Staphylinoidea
- 7(6). Antennae geniculate with last 3 segments forming a compact club, Exoskeleton hard, black, shining, elytra truncate and leaving 1 or 2 abdominal segments exposed. Histeroidea
- 8(1). Pleural sclerite of the true 2nd abdominal sternite almost always fured to that of 3rd, sternite itself usually entirely membranous, more rarely fully selerotized, Antennal club, if developed, not usually made up of the last 5 segments..... Cryptogastra
- 9(20). Hind coxa almost always with a vertical posterior surface and with the postero-ventral edge produced into a plate which partly covers the retracted femur. Antennae filiform, serrate or pectinate, very rarely the last 1-4 segments sharply differentiated from the rest. Tarsi nearly always 5 segmented, rarely with the 4th reduced and enclosed in the lobes of the 3rd.
- 10(11). Capable of apposition against prosternum.....Fucinetoidea
- 11(10). Head not capable of apposition against prosternum.
- 12(13). Procoxae projecting, Hind coxae with well-developed femoral plate..... Dascilloidea
- 13(12). If procoxae projects, hind coxae with femoral plate either incomplete or absent.

- 14(15). Adult : Wing with radical cell nearly always closed, not or scarcely longer than its maximum width, cross veins closing it not markedly oblique; Head without distinct fronto-clypeal suture; mandibles with distinct molar part; antennae filiform to somewhat clavate; front coxae transverse with exposed trochantius; metasternum without a transverse suture; hind margin of pronotum never cremulate; form short, oval and very convex 1. Byrrhoidea
- 15(14). Adult : Radial cell nearly always elongate or open or with cross vein closing it very oblique; if mandibles with distinct molar part, fronto-clypeal suture usually distinct; if front coxae transverse with exposed trochantins, metasternum with transverse suture or shape different..... 2
- 16(17). Adult : Mandibles usually with a distinct molar part, if not, mandibles much reduced; head often with distinct fronto-clypeal suture; wings, if with closed radial cell, usually with cross veins closing it very oblique; if any tarsal segment lobed below, hind margin of pronotum usually crenulate; tarsi often with segment 5 nearly or quite as long as previous 4 together; suture between ventrite 1 and 2 complete and well-marked. 2. Dryopoidea
- 17(16). Adult : Mandibles never with molar part; rarely reduced; fronto-clypeal suture rarely distinct; wings, if with radial cell closed, with cross vein closing it rarely markedly oblique; hind margin of pronotum rarely crenulate, if so, suture between ventriles, and 2 partly obliterated. 3
- 18(19). Adult : Metasternum nearly always with well-marked transverse suture ; if not, prosternum completely dividing mesosternum and its tip received in metasternum; 2 basal ventrites fused, the suture between them partially obliterated; tarsal segments 1-4 more or less strongly lobed below; antennae short, more or less serrate; front coxae small; rounded or somewhat transverse, rarely with exposed trochantius; Corpotentorium distinct; Malpighian tubules cryptonephrie..... 3. Buprestoidea
- 19(18). Adult : Metasternum never with distinct transverse suture; prosternum never with tip received in metasternum; 2 basal ventrites not fused, suture between them complete; tarsi rarely with segments 1-4 lobed below; [Malpighian tubules never cryptonephrie; corpotentorium often absent] 4

- 20(21). Adult : Front coxae transverse or slightly projecting, trochantins never connate to sternum or hypomeron, usually exposed; hind angles of prothorax never acute; prosternal process well-developed, its apex received in a pit of mesosternum; basal ventrite with well-marked inter coxal keel; empodium often large and pleurisetose. (1) Artomestopidae (2) Calliriciphidae (3) Brachypsectrita 4. Artematopidea
- 21(20). Adult : Front coxae rounded and with trochantinal opodeme connate to sternum or hypomeron, or prosternal process incomplete or absent or front coxae strongly projecting; hind angles of prothorax more or less acute, or 1st ventrite without distinct intercoxal keel..... 5
- 22(23). Adult : Front coxae more or less rounded, trochantinal apodemes more or less connate to sternum or hypomeron; hind angles of prothorax acute; 4 basal ventrite more or less connate, the 1st with distinct inter-coxal keel; corpotentorium sometimes distinct; elytra usually with 9 or 10 striae or rows of punctures. 5. Elateroidea
- 23(22). Adult : Front coxae always projecting, trochantins almost always free from sternum and hypomera; hind angles of prothorax rarely acute; hind coxae never with well-developed femoral plates; all ventrites free, basal one very rarely with distinct inter coxal keel. [Corpotentorium never distinct] 6. Cantharoidea
- 24(9). Hind coxa rarely with a vertical posterior surface and the postero-ventral edge produced into plates; if so, the antennae has the last 3 segments very long or forming a club.
- 25(28). Fore coxa usually somewhat projecting, hind coxa often with a more or less distinct femoral plate. Tarsi of 5 segments, 1st sometimes very small. Antennae nearly always with last 3 segments differentiated from rest. 5 visible abdominal sternites.
- 26(27). Prothorax not hood-like, Tarsi never with 1st segment very small, trochanters normal, their junction with femora very oblique. 1 or 2 ocelli often present. Antennae not filiform, rarely serrate, last 3 segments not greatly elongate Dermestoidea

- 27(26). Prothorax nearly always produced over the head like a hood. Tarsi with 1st segment very small. Or trochanters elongate and joined to femur by a transverse suture. Ocelli absent Bostrichoidea
- 28(25). If fore coxa is projecting, tarsi are usually heteromorous or apparently with 4 segments, hind coxa without a femoral plate. Ocelli absent.
- 29(32). Tarsi 5 segmented but 4th segment very small and concealed by the lobes of the 3rd, 1st to 3rd with adhesive lobe beneath. Transverse suture of metasternum usually distinct laterally.
- 30(31). Head not rostrate, or if slightly so, gular suture distinct and separate. Antenna without a 3 segmented club, not received into a groove. Chrysomeloidea
- 31(30). Head more or less produced into a rostrum, gular suture nearly always confluent. Antennae usually geniculate and clubbed; 1st segment retractible into a groove (scrobe). Curculionoidea
- 32(29). If tarsi are 5 segmented with the 4th segment very small, the antennae have a marked 3 segmented club, the head is not rostrate and gular sutures are distinct. Transverse suture of metathorax not distinct laterally.
- 33(34). Tarsi always all 5 segmented; front coxae projecting or transverse and tarsi with conspicuous bisetose empodium between claws; abdomen with 5 or 6 visible sternites Cleroidea
- 34(33). If tarsi all 5 segmented front coxae rounded or transverse or aedeagus of trilobe type; empodium absent or inconspicuous.
- 35(36). Tarsi 5 segmented, filiform; all coxae more or less projecting; abdomen with 6 or 7 visible sternites; antennae short, more or less serrate; aedeagus with large parameres, approaching trilobe type Lymexyloidea
- 36(35). If front coxae projecting tarsi heteromorous; normally 5 visible abdominal sternites, if six, tarsi usually and if seven, always heteromorous; antennae filiform or clubbed, rarely serrate; aedeagus of cucujoid type, if approaching trilobe type tarsi not all 5 segmented (never with true movable parapares) Cucujoidea

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COLLECTION, PRESERVATION, REARING AND IDENTIFICATION OF WOOD-BORING INSECTS

P.K.Maiti

INTRODUCTION

The wood-boring habits of Insects mainly belonging to the orders Dictyoptera, Isoptera, Lepidoptera, Hymenoptera and Coleoptera, set them in conflict with man's need for wood. They bore into the wood in search of both food and shelter or only for shelter. In India, they usually attack wood (including bamboo) in all stages of live trees and felled logs in the forest stands, timber in storage and in use, and even in finished wood-products in human service. Therefore, their economic importance is so well recognised.

To understand their economic role, the recognition of individual species by structural (taxonomic) and non-structural (biotaxonomic) characters is the basic step of research, the success of which much depends on proper survey, collection, preservation, etc. of these insects.

Surveys provide the collector with essential information on the species concerned, regarding the distribution abundance and economic importance. The people who conduct the survey must be familiar with exact habits, habitats, seasonal occurrence, daily activity rhythms, etc. A brief account of the general biology of the borers has been taken into account. On the basis of the nature of damage, they are also classified into different groups.

COLLECTION

Since the majority of the wood-boring insects lead a cryptobiotic mode of life, it is difficult to collect them. The sight of heaps of bore-dusts or frash granules are the indirect guides for the collectors. Usually collection is made by pilling off the bark or cutting the wood by chisel or hand-axe. Care has to be taken to search even the smallest part of the wood for different developmental stages including the eggs. Adult borers specially the cerambycids are collected in numbers from the specially designed light traps.

In case of termites, special efforts to be taken to collect soldier caste, the character of which are the basic aid to the

specific identity of the species. The swarming individuals are procured by a sweeping net.

The infestation of timber-pests are sometimes detected in wood by small portable X-ray unit.

PRESERVATION

Most of the adults of these insects are preserved dry in the usual procedure, while the termites and immature stages in alcohol (80% or so) which may be changed once before the permanent storage. The larvae of bigger size (Cerambycid, buprestids, etc.) are best preserved in Pompell's fluid (Absolute Alcohol, Formalin & Acetic Acid) to maintain their natural colour.

REARING

Best method of rearing of these insects is to keep the infested logs in a galvanized cage fitted with a glass bottle at the middle of the door at one end. The emerged adults usually congregate in the bottle which can be collected without any difficulty. Care is to be taken to maintain the humidity and temperature inside the cage. Bark beetles are easily reared in between two barks placing those in a suitable container covered by fine mesh. In all cases, special attention is to be taken to keep away the attack of fungi or predaceous insects specially ants.

MAJOR GROUPS OF INSECT-BORERS

(i) **Round-Headed Borer** (Longicorn Beetles, Cerambycidae : Coleoptera) : Only the larvae of the beetles cause serious damage to standing trees, felled logs, dead and dry woods, while the adults never enter the host once they have emerged. The name roundhead borers has been probably originated from the circular holes made for the adult emergence. The females lay eggs under the bark which develop into different larval stages within the wood and feed on the wood. The length of life cycle varies from one month to many years depending on the species and host condition. About 1,000 species are serious wood-pests in India.

(ii) **Flat-Headed Borer** (Metallic Beetles, Buprestidae : Coleoptera) : Only the larvae of these beetles, with large flattened prothorax which apparently appears to be the head, do the boring in the live as well as the felled trees. They produce oval to flattened tunnels in wood which are always packed with fine bore-dust. Development from egg to adult usually requires several years. About 300 species in India are well recognised pests.

(iii) **Small Powder Post Beetles** (Bostrychoidea : Coleoptera)

The wood-boring larvae of many beetles belonging to the families Lyctidae, Bostrychidae and Anobiidae, reduce the wood to powder or granular residue. They usually bore in felled timber dried wood, furniture, and occasionally attack unhealthy standing trees. The success of brood development depends on the amount of starch available in the wood. About 100 species are of economic importance in India.

(iv) **Pin-hole Borer :**

- a. **Ambrosia Beetles (Scolytidae and Platypodidae : Coleoptera) :** Some of the adult beetles of the families of Scolytidae and platypodidae bore pin-head like holes in the wood, green logs, dying trees, stumps, and sometimes in moist freshly sawn lumber. The galleries are kept free of bore-dust and the inside walls generally stained by the ambrosia fungi cultivated therein for their food. The time required to complete one generation varies from 6 weeks to several months depending on species and climate. About some 400 species are involved in wood damage in India.
- b. **Timber Worms (Lymexylidae, Brentidae and Tenebrionidae : Coleoptera) :** Timber worms also make pin-holes that differ from those bored by ambrosia beetles, since the holes made by any species vary greatly in size. This occurs because only the larvae are wood borers. These borers usually infest wounded trees, fresh logs, and dying trees.

(v) **Termites (Isoptera) :** Termites are well known to cause enormous damage to wood works in the buildings, to dry timbers, to agriculture and forest plants, to books, clothes and other stored articles. More than 50 species in India are recognised wood pests. The termite colony is composed of different castes, of which workers are destructive to wood. The termites belonging to the families Kalotermitidae, Rhinotermitidae, Hodotermitidae are predominantly wood-borers and some others belonging to Termitidae also inflict minor damage to the wood and wood-products.

(vi) **Wood-boring caterpillars (Cossidae and Aegeriidae : Lepidoptera) :** Only a few wood-boring caterpillars belonging to the above families are serious pests of living hard wood trees. Tunnels are large, oval, irregular and wind throughout the sap and heartwood of living trees. The borings and globular excrement pellets are mostly ejected to the outside. Usually longer time is taken to complete one generation in case of these borers.

(vii) **Wood-boring Hymenoptera** : The wood-boring Hymenoptera include the horntails, the carpenter bees and the carpenter ants. The members of the latter two do not eat wood but merely use the wood for habitations.

- a. **Horntails (Siricidae)** : The large larvae infest the Pinaceae conifers, through boring the wood of dying and recently felled trees and making circular tunnels upto certain depth. The tunnels are lightly packed with fine boring dust. The females more numerous than males, bore the wood through their ovipositer and deposite 3 or 4 eggs in each hole. The resulting larvae cause the maximum damage to the wood.
- b. **Carpenter Ants (Formicidae)** : The adult ants (Camponotus spp.) bore large irregular cavities in woods of posts, timbers, logs and even living trees. Each colony contains several castes, like worker, soldier and reproductives.
- c. **Large carpenter Bees (Apidae)** : The adult bees (Xylocopa spp.) bore large circular holes mostly in soft wood which penetrate inward for an inch or so and then extend with the grain of the wood. These burrows are solely used for rearing of the brood.

IDENTIFICATION

The identification of the wood-boring insects as a whole poses great problems since many orders of insects including their numerous families, are involved in this group. Most insects found boring or living in wood are beetle larvae which are more difficult to identify due to neglence of taxonomic study in our country. Sometimes, the identification of larvae is generally made possible in collecting the larvae and adults together, if the adults are taxonomically known. However, the characters of taxonomic importance vary widely from one group to another, even in the same group in its different taxonomic categories. As such, to learn the technique of identification requires long specific training over the years, the discussion of which hardly permits any space in the present context. However, a key of some important families of some important orders of wood-boring insects, has been formulated for their easy identification.

KEY TO THE FAMILIES OF SOME MAJOR ORDERS OF WOOD-BORING INSECTS

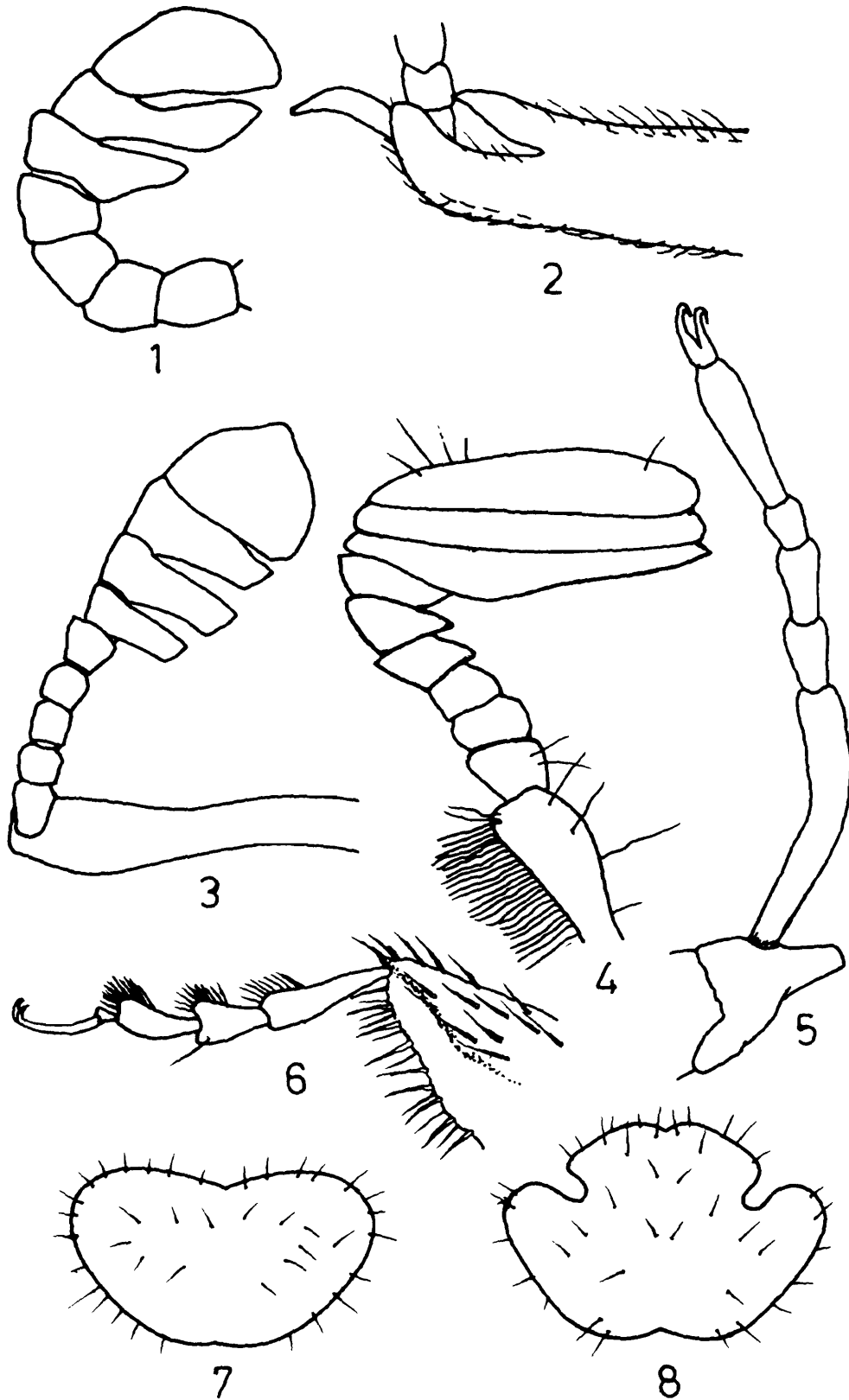
- A(B). Forewing horny (elytra), without veins, never overlapping each other Order : Coleoptera
- 1(2). Metasternum with well-marked transverse suture, prothorax normally immovable and devoid of any acute hind angle, large to small metallic colour beetles Buprestidae
- 2(1). Metasternum without a transverse suture; prothorax normally movable and always with acute hind angles Elateridae
- 3(B). Antennal apical segments 3-7 produced on one side to form a lamellate club.
- 4(5). Plates composing antennal club flattened and capable of being closely folded together (Fig.1) Scarabaeidae
- 5(4). Plates of club not so, usually not flattened.
- 6(7). Antennae straight; mentum deeply emarginate, ligula filling the emargination Passalidae
- 7(6). Antennae almost always geniculate; mentum entire Lucanidae
- 8(3). Antennal apical segments not produced on one side to form a lamellate club.
- 9(16). Prothorax always produced over the head like a hood, 1st tarsal segment very small.
- 10(13). Antennae usually with 11 segments, rarely with compact club; trochanters distally truncated.
- 11(12). Antennal sockets more or less undersides of frons, separated by more than length of segment 1, hind coxae contiguous Anobiidae
- 12(11). Antennal sockets on the frons, separated by less than length of segment 1; hind coxae more or less separated Ptinidae

- 13(10). Antennae with usually less than 11 segments and with a compact club; trochanters distally obliquely jointed to femora.
- 14(15). Fore-coxal cavity open behind; antennal club with 3 segments; pronotum hood-like; hind-coxae contiguous Bostrichidae
- 15(14). Fore-coxal cavity closed behind; antennal club with 2 segments; pronotum flattened; hind coxae separated..... Lyctidae
- 16(9). Prothorax not produced over the head like a hood; 1st tarsal segment not small, rather other segment usually small.
- 17(18). Head not rostrate, or if slightly so; gular suture distinct and separate; antennae inserted on prominent tubercles and very long, without a 3 segmented club, not received into groove Cerambycidae
- 18(17). Head more or less produced into a rostrum, gular sutures nearly always confluent; antennae usually clubbed, not inserted on tubercles; 1st segment retractable into a groove.
- 19(24). Rostrum usually moderately to very long.
- 20(21). Antennae not geniculate and not or scarcely clavate; prosternum elongate in front of fore coxae; species very elongate and glabrous, rostrum generally strongly sexually dimorphic Brentidae
- 21(20). Antennae clavate, prosternum less elongate in front of fore coxae.
- 22(23). Trochanters elongate, ventral surface of mentum with tuft of bristles on each side Apionidae
- 23(22). Trochanters rarely elongate; ventral surface of mentum without tuft of bristles on each side Curculionidae
- 24(19). Rostrum usually very short or ill developed.
- 25(26). Adult labrum distinct and separate; pronotum with lateral margins acutely raised Anthribidae

- 26(25). Adult labrum not distinct; pronotum with lateral margins hardly raised.
- 27(28). Anterior tarsi with segment 1 longer than the others 2 and 3 combined together (Fig.5); head always visible; elytral base not in contact with that of prothorax; body more than 4 times longer than wide Platypodidae
- 28(27). Anterior tarsi with segment 1 shorter than the 2 and 3 combined together (Fig.6); head sometimes visible and often invisible; elytral base in contact with that of prothorax; body less than 4 times longer than wide Scolytidae
- B(A). Forewings not horny, with veins, always overlapping each other.
- C(D). Wings partly to completely covered with scales Order : Lepidoptera
- (Since lepidopterous larvae are borers, family key for the identity of the adults, is not provided)
- D(C). Wings partly to completely covered with hairs.
- E(F). Forewing distinctly larger than the hindwing Order : Hymenoptera
- I(2). Abdomen broadly attached to the thorax, no marked constriction between the 1st and 2nd abdominal segments; larvae with thoracic and generally with abdominal legs; last abdominal segment of female with a horn-like projection; non-social insects Sircicidae
- 2(1). Abdomen deeply constricted between the 1st abdominal segment (propodeum) and the 2nd; larvae without legs; social insects.
- 3(4). Antennae elbow-shaped Formicidae
- 4(3). Antennae not elbow-shaped, rather somewhat bedded..... Apidae
- F(E). Forewing almost equal to the hind-wing Order : Isoptera

Based on soldiers

- 1(4). Head without fontanelle and frontal gland; eyes present, about the size of the antennae; mandibles with prominent marginal teeth.
- 2(3). Cerci long, with 3-8 articles, antennae with 22-23 articles Hodotermitidae
- 3(2). Cerci short, with 2 articles; antennae with 10-18 articles Kalotermitidae
- 4(1). Head with fontanelle and frontal gland; eyes if present, dot-like, much smaller than the base of the antennae; mandibles with or without marginal teeth.
- 5(6). Pronotum flat (Fig.7) Rhinotermitidae
- 6(5). Pronotum saddle-shaped (Fig.8) Termitidae



Figs.1-8. Fig.1. Antenna of Popilius (PASSALIDAE); Fig.2. Apex of protibia of Endecatomus (BOSTRICHIDAE); Fig.3. Antenna of Pseudolucanus (LUCANIDAE); Fig.4. Antenna of a scarab (SCARABAEIDAE); Fig.5. Tibia and tarsus of Platypus (PLATYPODIDAE); Fig.6. Tibia and tarsus of Eccoptopterus (SCOLYTIDAE); Fig.7. Pronotum of Coptotermes (RHINOTERMITIDAE); Fig.8. Pronotum of Odontotermes (TERMITIDAE).

COLLECTION AND PRESERVATION OF AQUATIC INSECTS

V.D.Srivastava

INTRODUCTION

Aquatic insects as the very name indicates, are more or less closely associated with water. They do not comprise a single systematic group but are scattered through number of insect orders such as Ephemeroptera (Mayflies), Odonata (Dragonflies and damselflies), Plecoptera (Stoneflies), Trichoptera (Caddisflies), Diptera (Flies), Hemiptera-Homoptera, Coleoptera (Beetles). These insects have readapted themselves to aquatic life, a niche which remains unoccupied by majority of their terrestrial counterparts. They represent only 5% of insects but are generally the most conspicuous forms of life in ponds and streams occurring in large number.

A. AQUATIC INSECT ORDERS

This group embraces those aquatic insects which are represented by 4 insect orders and are totally dependent on aquatic surrounding for completion of their early stage of life cycle. These insect orders are indicated, hereunder, along with their common names and part of life cycle they have to essentially undergo as aquatic.

Ephemeroptera (Mayflies) - Egg and larval stages strictly aquatic.

Odonates (Dragonflies and damselflies) - Egg, prolarval and larval stages aquatic.

Plecoptera (Stoneflies) - Egg and larval stages strictly aquatic.

Trichoptera (Caddisflies) - Egg and larval stages aquatic.

B. PARTLY AQUATIC INSECT ORDERS

This group of aquatic insects include those orders of which only a part is aquatic. Here again only they may be aquatic for part of their life cycle or whole of it. Many insect orders numbering 5, as indicated hereunder, represent this category of aquatic insects :

Diptera (flies) - Only egg and larval part of life cycle is aquatic members of the 5 diptera families are wholly aquatic which are Dysticidae, Culicidae, Chironomidae, Simuliidae Blepharoceridae.

Many members of 4 dipteran families viz., Tabanidae, Syrphidae, Ephydriidae, Stratiomyiidae, are aquatic for early part of life cycle.

A few member of Tipulidae, Psychodiadae are also aquatic.

Hemiptera - Heteroptera (Bugs) - are both aquatic and semiaquatic as far as 15 families which are closely associated with water.

Corixidae (Water boatman) - dive below the surface of water.

Notonectidae (Backswimmers)

Nepidae (Water Scorpions) submerged in grasses or vegetation.

Belostomidae (Water bugs) at the edge of the pond.

Veliridae (Water striders)

Gerridae (Water striders)

Stride on the surface of water

Mesovellidae (Water striders)

Hydrometridae (Water striders)

Nanororidae (Creeping water bugs)

Celastrororidae (Toad shaped bug) Near margin of streams.

Saldidae (Shore bug)

Coleoptera (Beetles) - A relatively smaller portion of Coleoptera are aquatic and are mainly represented by 4 families which are Dytiscidae, Hydrophilidae, Gyrinidae and Haliplidae.

Larvae of these are truly aquatic and adults semi-aquatic.

Neuroptera (Lacewings) Following 4 families have species with aquatic larvae.

Cordyluridae (Dobsonflies)

Raphilidae (Snakeflies)

Sialidae (Alderflies)

Sisyridae (Spongilla flies)

Lepidoptera (Moths: Only 2 groups of Lepidoptera are reported to be aquatic during their larval stage.

Pyralidiidae (genera) Elophila, Nymphula

Noctuidae (genus - Bellura - 3 spp. of genus from North America.

COLLECTION OF AQUATIC INSECTS

Aquatic insects generally inhabit different habitats and niche of freshwater ecosystem including both running water (= lotic) and standing water bodies (= lentic). Hereunder are indicated certain methods which are used for collecting aquatic insects. All these are not to be used essentially at the same time. According to the need of collection, their ecological inhabitation suitable methods are to be picked, some times with slight modifications to cater the specific need. Methods indicated do not include, collection of adults of those aquatic insects which are terrestrial as they can be collected by conventional insect nets in vicinity of water bodies and by beating vegetation. Aspirators can also be conveniently used for small insects.

A. NETS AND SCREENS : Aquatic insects can be collected by means of certain conventional nets and screens from both lotic and lentic water bodies. They don't , however, provide quantitative sampling idea. Water nets made of nylon (mesh size 24 to 32 strands per inch) supported by sturdier ring and pole can be used by side of water bodies. In streams this can be held close to the bottom and collection of insect, can be made by disturbing stones or trash which harbour them. A portion of metallic screen two ends of which are fixed through slots on wooden handle can also be used in streams. A sieve net of metal well braced, strong and connected to a long pole can be used for bottom fauna. It gathers the mud and shifts it at one operation by using it as a rake from the shore. Needham's metallic apron net is most useful multipurpose collecting device. This can be used even in habitats having thick vegetation. The coarse screen on top permits the insects to enter but keeps out most of the vegetation that would otherwise foul the net. This net may also be used for scraping up and sifting the bottom mud and sands to obtain burrowers - benthic insects.

B. DREDGE AND OTHER SAMPLERS : Several type of dredges and other samplers are used such as Ekman dredge, Peterson dredge, Surber sampler, Hess sampler, etc. These methods have the advantages as they give idea of quantum of insect occurrence.

i. Ekman dredge : This is one of the most common type of bottom sampler which can be used in lakes, ponds (=lentic water bodies) survey. The dredge is a six inch square brass box fitted with spring-operated closing jaws. The jaws are cocked open at the surface by chains attached to a release mechanism. It is lowered to the bottom by a rope, when bottom is felt it is raised a foot or so then allowed for a vertical fall. A metal messenger is then sent down the rope which trips the spring release, closing the jaws. It is pulled up but not above water level. The contents are transferred to a bucket without any spilling. The contents are sifted, sieved and collected by back poring.

ii. **Peterson dredge** : This dredge can be used for stream bed in contrast to previous one, this is most versatile stream-bed-bottom sampler which can be utilized for collecting from substratum consisting of mud, sand, grand, clay and rocks. It is a calm type and the use of additional weights. It can sample an area of 5.6 to 7.5 Sq. m. The dredge is gently lowered by rope or cable to the bottom where after securing a bits of bottom material it clamps shut. This is brought up and processed and analysed.

iii. **Surber square foot bottom sampler** : This is very often used to collect the benthic forms of a lotic ecosystem such as streams. It is very convenient to carry and consists of two light brass, one square foot frame hinged together. One of the frames is used for carrying net and other is brought parallel to the substrate to mark the area to be covered. Sampler is placed against the direction of current and the bottom rock, gravel, sand within area marked by lower frame is disturbed. The benthic insects, thus dislodged, get washed with current in direction of net. One disadvantage in this is that benthic insects thus disturbed may not all go to net but some may overpass it at the edges. This can be minimized to negligible by providing side wings to the sampler which prevents side ways overflow ensuring there by the entire fauna of the area sampled to pass into net.

iv. **Hess sampler** : It is a variation and modified version of the above designed to correct latter's disadvantage of allowing specimens to escape. It consists of $1/1/2$ " hardware cloth of a steel frame. The hardware cloth is covered except on the front to keep the smaller organisms from escaping. In the back of it a square hole is cut out and a net attached. Sampler is placed at the bottom and firmly embedded. The bottom is disturbed with hands, the resultant benthic forms flow with stream into net with out any loss.

This sampler, also like previous one, is useful to collect insect only from shallow streams having depths less than arms length.

v. **Drag type sampler** : Usinger and Neadham (1956) devised this sampler. It consists of a rectangular iron box with bans on the open face to exclude large rocks and debris. The two leading edges are provided with tines that dig into the rock and gravel of the bottom. The net bag is removeable and can be opened by means of a zipper to gather the organisms. A canaves bag (sleeve) is provided for the protection of the net. In operation the sampler is lowered into rifle and pulled. The area of the bottom covered is determined by the product of length of bottom over which it is pulled into width of the rectangular iron box.

vi. **Square foot tray** : This is also called "basket method" and is devised by Weae and Wicklife (1949). It is utilized for deter-

mining the number and type of organisms per unit area on the bottom of a lake. It consists of tray with wooden sides and 1/2" mesh screen bottom. It is placed at the bottom with clean bottom substrates and allowed to remain there long enough to allow fauna getting settled. The trays are lifted out at intervals and all the organisms analysed. In its basic principle it is comparable with artificial substrates sampler, dealt with separately.

C. ARTIFICIAL SUBSTRATE SAMPLER : These sampler basically utilize the idea of providing some artificial substratum into which aquatic insects and other organisms colonize in due time as if in natural conditions. Their use in surveying water bodies for the macroinvertebrates including insects are on increase due to certain advantageous points. They require less time to sample effectively more collecting stations. These are useful for sampling at stations that are difficult to sample by the other techniques. It also eliminates subjective judgement which is essentially a part of sampling by Nets, screens, Dredges and samplers discussed above whose collector is to put same type of effort with same degree of efficiency at each station.

i. Wire basket and Barbeque baskets : The simplest type of artificial substrate sampler constructed out of 0.5" (1.7cms.) hardware cloth or Barbeque baskets measuring 7 x 11" (17.8 x 28 cms.). These are filled with debris or rocks. Mason et al. (1967) suggested filling thirty numbers of 2" (5.1 cms) diameter lime stone or unglazed lapped porceline spheres exposing 2.62 ft² (0.24 m²) of substrate. These samplers can be either placed on the bottom of stream, or suspended at any desired depth. These are allowed to remain there for sufficient time to allow the organisms to settle. Subsequently the samplers are taken out, washed in appropriate containers and catch analysed.

ii. Multiplate substrate sampler : In this number of plate are used to provide surface for settling the fauna on artificial substrate. In its normal simplest form each plate consists of a number of 3" (7.5 cms.) square masonite plate separated by small masonite spacers and held together by a bolt through the center.

The modified Jumbo hard board sampler consists of 24 plates of tempered hard board. Each 1/2" (0.3 cm.) thick and measuring 3" square (7.6 cms.). All these are mounted on a stainless steel eye-bolt. The upper 12 plates were separated by spacers 1" (2.5 cms.) square x 1/2" (0.32 cm) thick the next six plates were separated by spacers measuring 1" (2.5 cm) square x 1/4" (0.64cm) thick and remaining six plates are separated by spacers 1" (2.5 cm) square x (1.05 cm.) thick. These together provides an exposed surface of 2.85 ft. (0.264 m²).

Jumbo sampler with discs is also used. Discs have got the advantage of easy alignment than square plates. Sampler consists of 24 discs of $3\frac{1}{2}$ " (8.89 cms.) diameter providing altogether an exposed surface of 2.86 ft^2 (0.266 m^2).

iii. Floating artificial Substrate sampler : These samplers are made of plastic web as a synthetic habitat for colonization by aquatic organisms. This web when attached with styrofoam float enables them to remain on the surface. Thus these are advantageous than other types in that they are easier to place and remove. Also because the web is artificial and permanent the separation of organisms from the sampler is simplified.

TRAPS

Traps of various types have been in use to get the emerging adults of aquatic insects before it leaves the water body and get lost among vegetation, forests etc. Further trap can help in tracing the exuvia and concerned emerged adult. This is needed for identifying the larval stage with certainty as mostly taxonomy of adult insects have developed. These have got the advantage of sampling known areas, stream or lake bottoms, or covering shore line of the water bodies. The last is more effective in covering these insects which have to essentially crawl out of water to grip a vegetation or rock for support before effective emergence. Traps are useful for many aquatic insects representing Trichoptera, Ephemeroptera, Odonata, Psocoptera and Diptera.

i. Submerged fly trap : This consists of square screen cage with an inverted cone shaped end. The trap is anchored to the bottom by rope and weight and can be lowered or raised to any depth with caution certain quantitative idea can be obtained of the emergence taking place at a given time and particular water body.

ii. Tent traps : This traps could be set on the bottom in the shallow water of a stream with large part projecting above the surface of water. Adult insects emerge and fly or crawl up the screen which are removed periodically through a side door provided for the purpose.

Some workers have used floating tent traps while studying aquatic inhabitants of Lakes.

iii. Inverted cone emergence trap or "funnel traps": This consists of two cones attached to a bottle or container and a float supported by a cord and weight enabling it to be adjusted to any desired depth. These are useful to sample insects as they emerge from the bottom of ponds or lakes. These can be used

effectively to study turn over or the annual crop of bottom organisms in contrast to the standing crop measured by other samplers.

iv. Water light trap : This trap employs the instinct of insects specially emerging ones towards light source. Needham (1924) and other have developed such traps using large flashlight or a light bulb with a reflector. This is connected by an insulated wire some source of electricity on shore. A surprisingly good variety of aquatic insects while emerging can be entrapped by this method.

KILLING AND PRESERVATION

It is but obvious that if the material collected by various sampling methods mentioned above are not properly killed preserved and prepared the whole purpose gets defeated. It is also must be born in mind that a proper label in Indian ink or soft pencil is a must. The label should include also the possible data such as type of water body, particular zone to which specimen belonged, if found attached to aquatic vegetation or under shelter provided by cobbles rocks and debris etc. This should be besides other normal points such as place where body is located, altitude, date and time of collection etc. Such records are available for posterity and are of immense help in determining and sometimes solving taxonomic status.

Each group of aquatic insects requires special handling and methods. A general principle and methodology are dealt with special reference to such insect orders like Ephemeroptera, Odonata, etc. which are not covered by other specialists in this series. (Many insect orders such as Diptera, Hemiptera, Lepidoptera, Coleoptera, etc. are dealt by various specialists). The same policy will be followed in rearing methods, aids to identification, etc.

Aquatic insects can be preserved both dry and wet, as is the case with insects in general, depending upon purpose, nature of specimens etc. All stages of aquatic insects are best preserved in 70% or 80% ethyl alcohol though such forms as moths, mosquitos, Odonates, etc. which are better and rationally preserved dry. Even in such cases where insects are preserved dry a parallel series in wet collection can help a lot.

A. Dry preservation : This should be employed only for those insects which don't get spoiled and only such of these stages like adults of Odonates, Diptera, Lepidoptera, Coleoptera, etc. (and not for their larval forms). One must be extra careful in preserving and handling dry specimens as they are very fragile and require constant care to guard against breakage and damage from museum pests.

Insects for dry preservation can be killed in Traditional

"Cyanide killing bottles". Cyanide is a deadly poison and the cyanide bottles should be used with utmost care. Safer killing bottles can be made by using Benzene, ethyl acetate, carbon tetrachloride, matrix of chloroform. These materials may be poured on to plaster of paris, cotton or tightly packed paper and bottle may be re-charged as needed.

Specimens should be removed from killing bottle, sorted out and kept in insect packets or paper triangle for larger insects such as Odonates alongwith proper labels inserted. They should be kept in number of separate envelopes, for larger forms it is preferred to keep single specimens per packet. For such of those specimens which are not spread and set immediately a proper care should be undertaken to keep them separately orderwise, lotwise and localitywise in card board boxes or polythene packets and kept in insect drying case having sufficient amount of chemical to avoid museum specimens pest such as Pscoptera, ants, moths, etc.

In brief following indicates methods for preservation of colours which is generally used for odonates, but can also be used in case of certain other insects. There are three type of pigmentation (i) Pigments in chitin-cuticular layer (ii) Pigments in Hypodermal or sub cuticular layer (iii) Pruinescence effect. The first one results into permanent colours such as Black, Brown, Orange, etc. Metallic affect in Odonates such as Emerald green, Bronze green, Copper, violet, purple etc. also belong to this category and are best preserved in dry specimens. The second one tend to decay when insect is dry preserved. Such colours like sky blue, bright red, bright orange, lemon yellow etc. belong to this category and can be well preserved by rapid drying brought in by chemical treatment or preserving in alcohol. The last one is powdery substance of whitish or pale bluish colour and are again best preserved in dry specimens.

Following methods are used for preservation of colours and are only briefly discussed below :

Degutting and quick drying by external heat - Cut a slit ventrally on abdominal segment 4, pull out the gut carefully by inserting a forcep. Stretch the specimen in usual fashion and place it on a plate or tray over a low spirit lamp, hot plate, stove taking care not to scorch the specimens.

Setting on a cork mat and immersing in methylated spirit Dragonflies are set on its back on a cork mat, pierce the thorax between legs and abdomen then float this in methylated spirit for 1-4 hrs. Subsequently it is removed and dried thoroughly.

Moore's Vacuum drying method : Moore (1951) devised vacuum drying method for preserving the colours of dragonflies and other insects. It mainly consists of glass vacuum desiccator fitted with ground glass lid and a stopcock, glass or metal water pump and a long rubber pressure tubing. Phosphorous pentoxide (P_2O_5) is used as the drying agent. A large number of Odonates can be processed at a time but damselflies and dragonflies should be treated separately as the former is subjected to partial vacuum only while latter are given full vacuum. Membrane separating abdominal sternites are punctured which facilitates drying and also prevents contortions during evacuation. 24 hrs. is usually needed for sufficient drying but larger batches of Antisopterous Odonates may need a little more drying time. The eyes are always last to dry and can be a guide point to determine when the drying is completed.

Low temperature drying method : Davies (1954) suggested preservation of dragonflies and other insects in vacuum and at low temperature which gives good result for both large and small species. It also preserves natural colour of eyes. It needs a Ice box, glass vacuum desiccator with conc. Sulphuric acid (H_2SO_4) as drying agent.

Live specimens are allowed to evacuate their last meal then killed using methods indicated earlier. These are cooled immediately afterwards upto $2.3^{\circ}C$ by placing in a ice-box at $-10^{\circ}C$. Next put the block into glass desiccator and evacuate to a pressure of less than 0.5 mm of Hg. After about 5 hrs. vacuum is slowly released, insects are taken off the block and they are ready for the cabinet.

Setting and pinning : Specimens which are killed and dried by conventional method and are needed to be set and pinned after putting them in relaxing chamber. If the specimen are freshly killed they don't need relaxing and can be set and pinned directly. Setting is done with pin of appropriate size and placing them in the region of antealar sinus of thorax dorsally and stretching the wings parallel on setting board by means of paper clip. Some times Odonates are set and pinned latterly on thorax to save space in insect cabinet but are inconvenient for study of wing venation.

The abdomen of Odonates are long and are very liable to break when dried. This could be prevented to some extent by inserting hogs bristle in case of dragonflies and fine stiff horse hair for damselflies before they are set. Bristle are sharpend by diagonal cut and inserted in the thorax ventrally between mesocoxae and run carefully down to the end of abdomen. The bristle is cut off close to the thorax with sharp scissors.

Setting and mounting : Adult of aquatic insects other

than Odonates, Coleoptera etc. which are minute enough to be pinned are mounted on pith or sharply cut triangular paper boards and fixed by using some sort of glue or adhesive. In this way dipterans, minute Coleopterans, can be mounted and preserved in insect cabinets. Larval exuvae of Odonates could also be pasted, mounted and preserved in this way.

B. WET PRESERVATIONS - The aquatic insects in their larval stages such as larvae of Ephemeroptera, Odonata, Plecoptera, Trichoptera, Diptera, etc. are best preserved in 70% or 80% ethyl alcohol. Even adult of some aquatic insects preferably Ephemeroptera, sometimes Odonates can be best preserved this way. Alcohol is better preservative than formalin which hardens the material. Alcohol penetrates into tissue and preserves them. Such preserved specimens can also be subjected to dissection or histology effectively. Large bugs, and Megaloptera larvae should not be placed in same vials with delicate specimens. In laboratory subsequently they are sorted out according to different insect orders and stocked with proper collection labels. White, fleshy crane fly larvae (Diptera) should be first killed by putting them in boiling water. This way the body proteins are fixed and prevents decomposition and blackening.

REARING AQUATIC INSECTS

Rearing of aquatic insects are very useful as most of the aquatic insects are in the immature stages and larval taxonomy of insects are not developed. To make positive identification of a larva and pupa possible when they are reared to adult and then identified (Taxonomy of adult is quite thoroughly developed). In such cases mature larvae and pupae are collected from aquatic environment reared to adults.

A general idea of rearing of aquatic insects with purpose indicated above is given in brief. For detailed and specific rearing needs and methodology literature have to be consulted as detail of the same is beyond the scope of present article.

Some times it is needed to rear the specimens in the field setting in which case transportation of live material is eliminated. It also serves the purpose of ecological correlation and emerged one for taxonomic determination and linking with larval stage. Some cages are used for this purpose. The basic principle involved is to keep the specimens in close natural condition and at the same time maintain their isolation. 'Pillow cage' is one such device which is made of screen. It is anchored in position to a stream bed or pond etc. with upper part exposed. It has been used for rearing may-flies, dragon flies, damselflies, stoneflies and caddisflies. Another common type of cage is cylinder made

of the window screen. The sleeve on the top is closed with a rubber band or piece of string which can be easily opened to remove specimens that emerge. These cages should be fixed to bottom of stream or ponds with few cobbles placed to simulate natural condition. The cloth is attached and the bottom also made of same material.

Laboratory rearing is needed for detailed study and first step involved is to transport live material from field to laboratory without damage and undue disturbance. Problems of splashing, rising of temperature and reduction of dissolved Oxygen in the process are met. For hardier specimens, such as dragonflies, they can be transported in container having bottom material which provides shelter, anchorage and reduces splashing. Other can be carried with aquatic vegetation, moss, etc. in relatively more aeriated containers. For longer distance transportation some cooling device is to be adopted or even transporting during cool hours of night and early morning may suffice.

Laboratory rearing provides many problems which are to be carefully considered for separate requirement and set of conditions. The basic idea is to provide as much nearer natural condition as could be possible. Temperature of water, dissolved oxygen, sub-stratum and support for anchorage, shelter, food etc. are some of the factors which need consideration. Rearing running water forms requires additional problem of simulating similar conditions in laboratory. The size and shape of rearing vessel is important and should be chosen carefully. Set of petridishes, wide mouthed vials, aquarium, etc. serve the purpose. These should have substrate setting as nearly possible as that under natural conditions. Water should be replenished periodically from natural source. If a domestic water supply is used it should be dechlorinated by filtering through activated charcoal or by allowing it to stand for several days. Temperature of water is maintained as normal one. The depleted amount of oxygen is replenished by air pumps. Air is pumped through a block of pumice and forming bubbles that oxygenate the water and also agitate it to certain extent. Running water throughs may be used as in fish hatcheries, for rearing lotic forms. Alternatively a simple circulating system, set in by which water is pumped in and out of aquarium, will serve the purpose. Plants feeders can be provided with aquatic vegetation whereas predatory aquatic insects should be provided with particular type of food which they consume. For stream insects, which are grazers on periphyton that coats rocks and other objects in water, small rocks, pebbles, etc. can be brought from natural source and replaced at certain intervals.

AID TO THE IDENTIFICATION

A wide range of insect orders are involved whose representative are aquatic as has been shown in detail earlier.

There identification is very specialized job and has to be done by wide range of specialists. Various major insects orders have been dealt by different specialists during the course of present programme. It is, therefore, intended to deal very briefly about Odonate and Ephemeroptera.

ODONATA

Odonates are commonly known as dragonflies and damselflies. The order is subdivisible into three suborders. Zygoptera, Anisozygoptera and Anisoptera. Zygopteran are slender forms, commonly known as damselflies, having both wings of more or less equal in shape and size. The suborder Zygoptera is divisible into 4 superfamilies (Agrioidea, Hemiphlebiodea, Coenagriodea, Lestiniodea) and 18 families of which 9 are represented in India namely Protoneuridae, Platystictidae, Platycnemididae, Coenagriidae, Chlorolestidae, Lestidae, Amphipterygidae, Chlorocyphidae and Agriidae.

The suborder Anisoptera are relatively bigger and stouter form with hinder wings broader specially in the anal area. The suborder is divisible into 2 super families (Aeshnoidea and Libelluloidea). The former has 3 families viz., Gomphidae, Petaluridae, Aeshnidae and latter has 4 families namely Synthemidae, Corduliidae, Macrodiplactidae and Libellulidae.

Intermediate between Zygoptera and Anisoptera is Anisozygoptera. This has certain characters common to both suborders. This suborder is known by 11 families viz. Tarsophlebiidae, Isophlebiidae, Mesophlebiidae, Stenophlebiidae, Sieblosiidae, Liassaphlebiidae, Archithemidae, Progomphlebiidae, Heterophletiidae, Liassogomphidae, Epiophlebiidae under 2 superfamily Tarsophlebiodea and Heterophlebiodea. The whole suborder is represented by only single living family Epiophlebiidae with a single genus Epiophlebia Calvert reported from orient only by E. laidlawi Tilyard (India) and E. superstes (Selys) (Japan).

The knowledge of their larval stage, which is only aquatic is very megere as is true for the taxonomy of immature stage of insects in general. Though approximately 450 Odonate species are known from India very small proportion of only about 50 can be identified in larval stages.

Fraser (1957) can be followed for the classification of the order. Most of the dragonflies and damselflies in their adult stage can be identified following Fraser's "Fauna of British India" Odonate Vol. I-III (1933,34,36). For larval identification work of Kumar (1971, 73(a)(b)) which describes in detail different larvae besides providing keys from superfamily down to the species level.

EPHEMEROPTERA

The ephemeroptera are commonly known as mayflies. The adults are extremely short lived, some surviving for a day only due to this ephemeral nature the order has got its name. In their larval stage they occur both in lentic and lotic ecosystem.

The order is subdivided into 6 superfamilies viz., Heptagenoidea, Leptophleboidea, Ephemeroidea, Caenoidea and Prosopistomatoidea and 20 families. Of these 12 families, namely Baetidae, Caenidae, Ephemerellidae, Ephemeridae, Euthyplociidae, Heptageniidae, Leptophlebiidae, Palingeniidae, Polymitarciidae, Potamanthidae, Prosopistomatidae, Siphoneuridae, are represented in India. 94 species and 35 genera of Ephemeroptera under just stated 12 families are recorded from India.

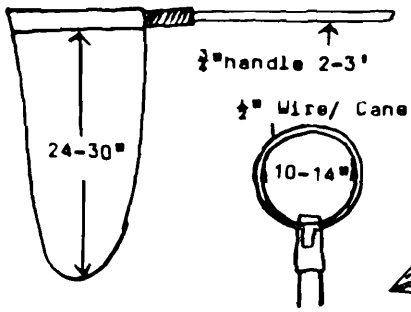
Though no consolidated key exists to the adult of all the families and subfamilies of Ephemeroptera a reference can be made to Edmunds, Jensen and Berner (1976). All the families reported occurring from India except Palingeniidae, Prosopistomatidae can be separated basing on it. Ulmer (1937-1940) can be consulted for Palingeniidae where as Gillies (1954) may be referred for Prosopistomatidae. Catalogue of Hubbard and Peters (1978) can be consulted for Indian species.

Our knowledge of larvae (Nymphs) is very scanty, however, Edmunds, Allen and Peters (1963) may be referred to for key to the nymph of all families and subfamilies of Ephemeroptera.

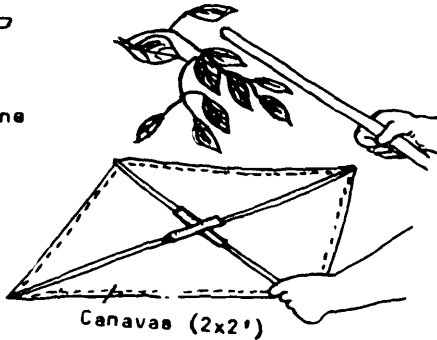
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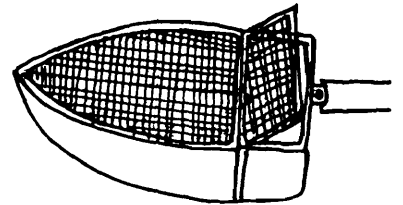
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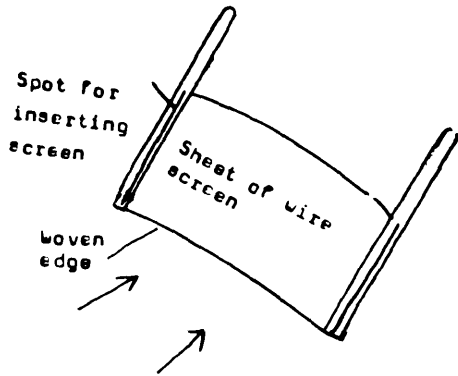
INSECT NET



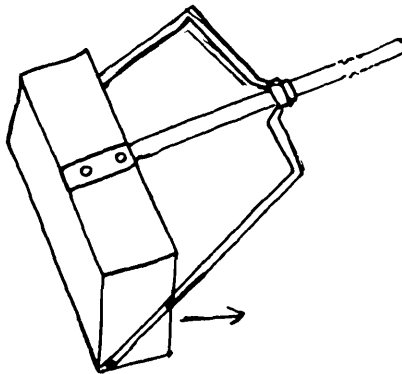
BEATING SHEET



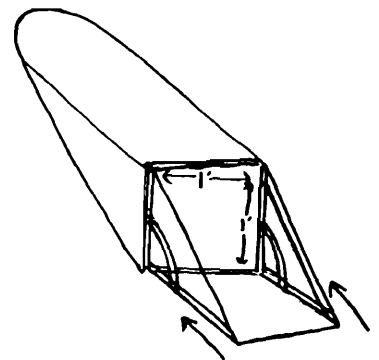
APRON NET



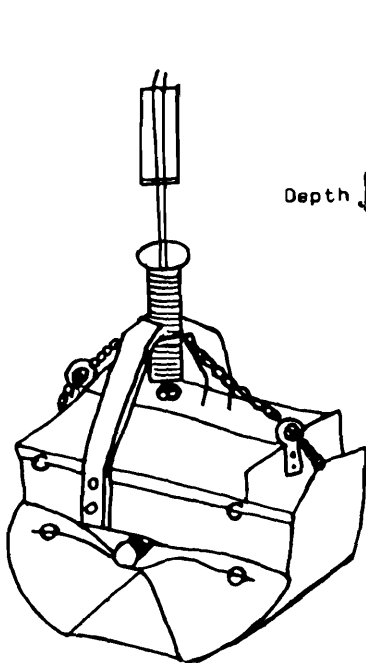
HAND SCREEN



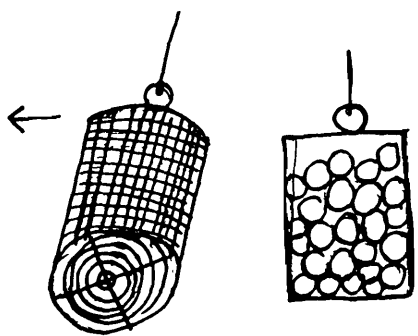
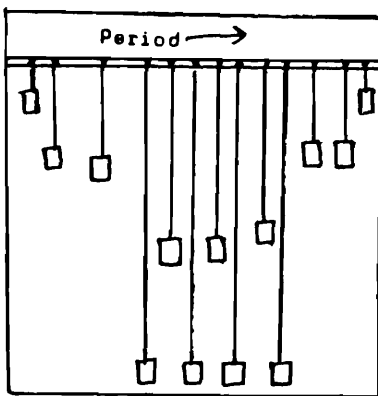
SIEVE NET OF METAL



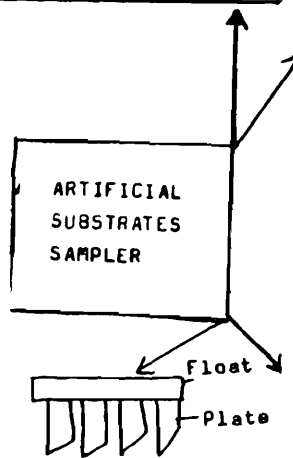
RUBBER SQUARE FOOT SAMPLER



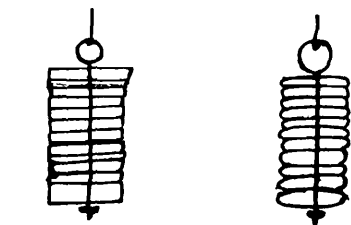
EKMAN DREDGE
(With metal messenger)



BASKET SAMPLER WITH LIME STONE
OR PORCELAIN SPHERES



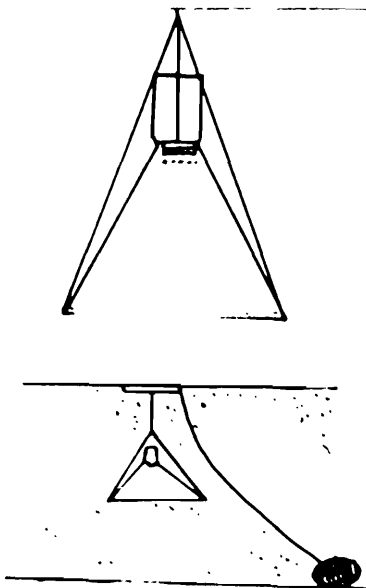
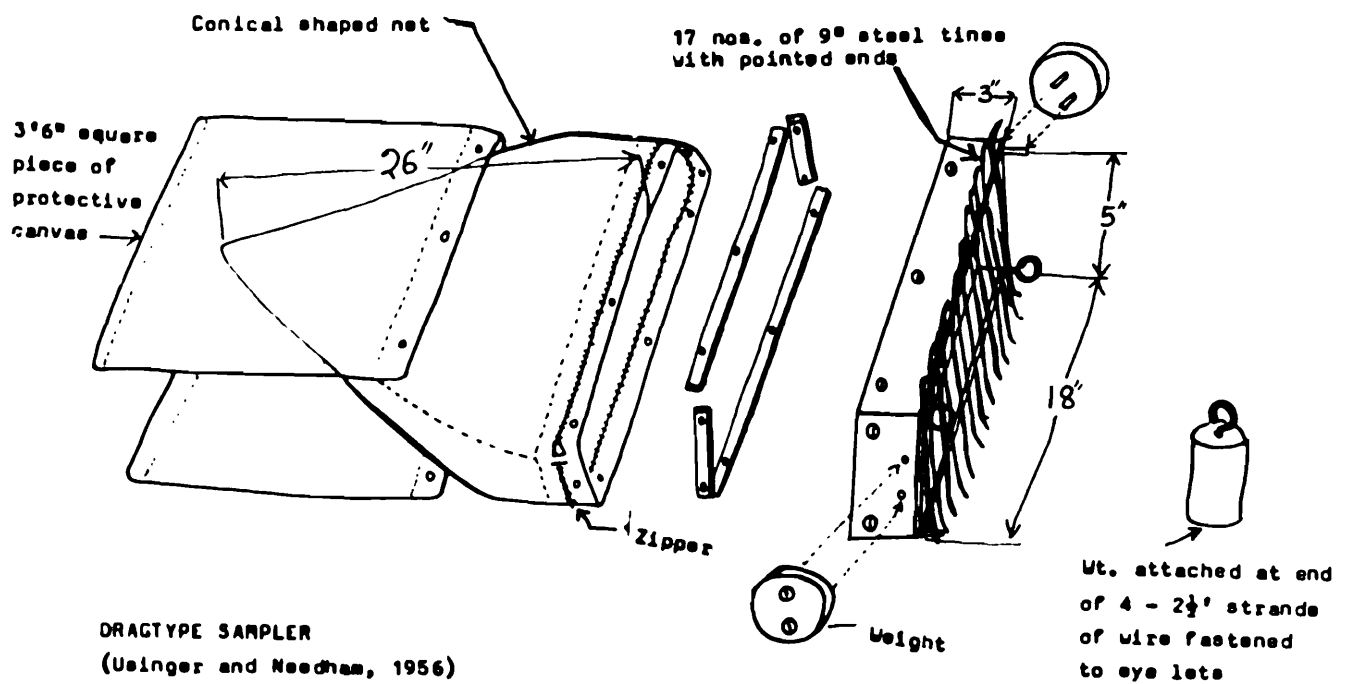
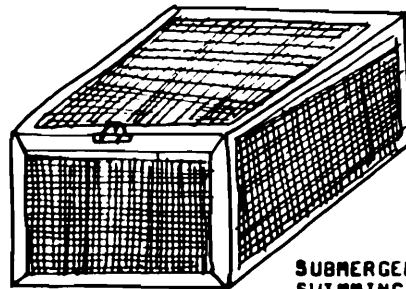
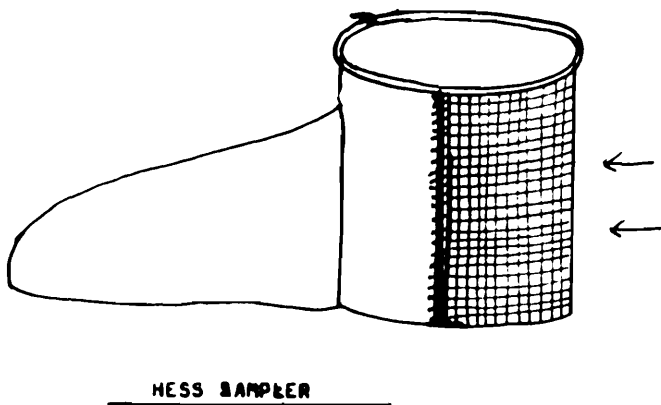
FLOATING SAMPLER



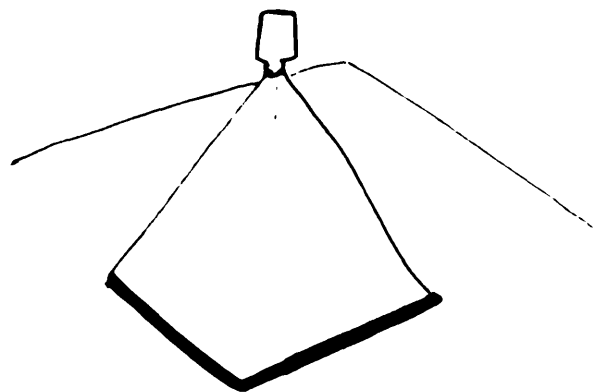
STANDARD HARD BOARD OR
PORCELAIN MULTIPLATES

AQUATIC INSECTS

COLLECTION METHODS



SUBMERGED INVERTED CONE EMERGENCE TRAP



FLOATING INVERTED CONE EMERGENCE TRAP

AID TO THE IDENTIFICATION OF ODONATA

V.D. Srivastava

Order Odonata comprises of insects which are commonly known as dragonflies and damselflies. These insects live in association with lotic and lentic aquatic ecosystems during their egg, prolarval and larval stages of life cycle. Adult or imago stage is air breathing, swift flying, double winged insects which capture its prey while flying with help of mouth parts and forwardly disposed legs. They display a large variety of maneuvering while flying, including hovering and even some backward movement. They copulate while in flight and male and female in 'tandem' are common sight in vicinity of water body. Oviposition is either exophytic or endophytic. Adult span of life is much smaller than aquatic immature stages taken together. Adult of these insects have characteristic large eyes, forwardly displaced legs and long abdomen with male copulatory apparatus on ventral aspect of abdomen 2-3 but gonopore opens as usual in other insects. Larva has abdominal gills and caudal filaments in Zygoptera which is replaced by cloacal chamber in Anisoptera and Anisozygoptera.

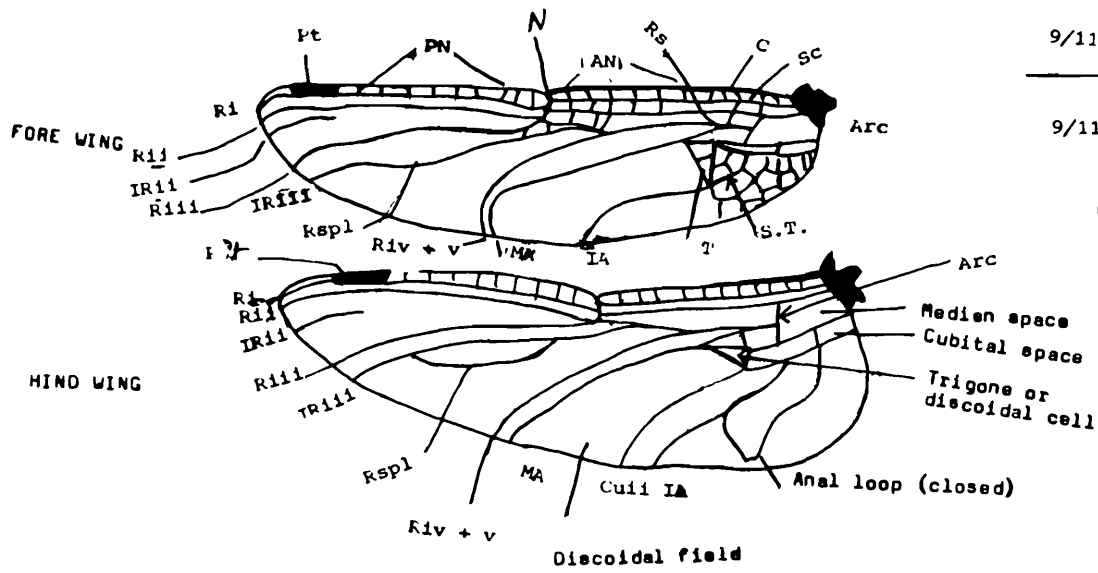
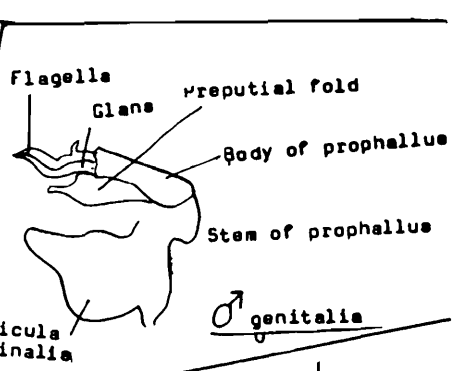
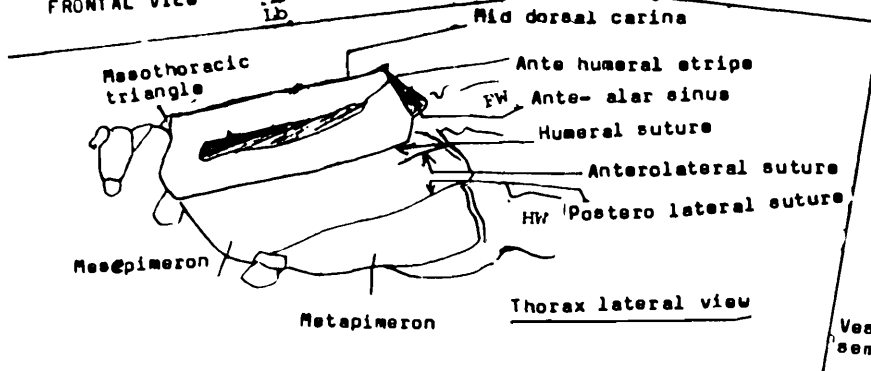
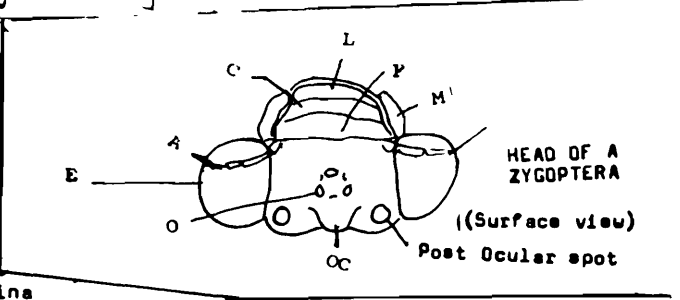
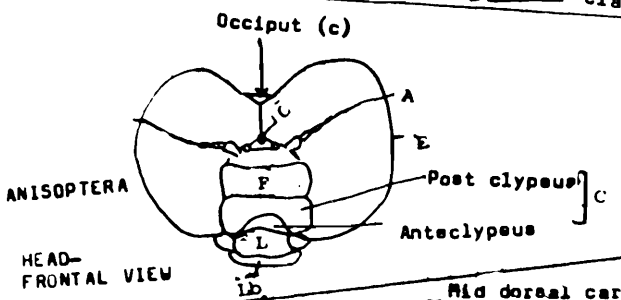
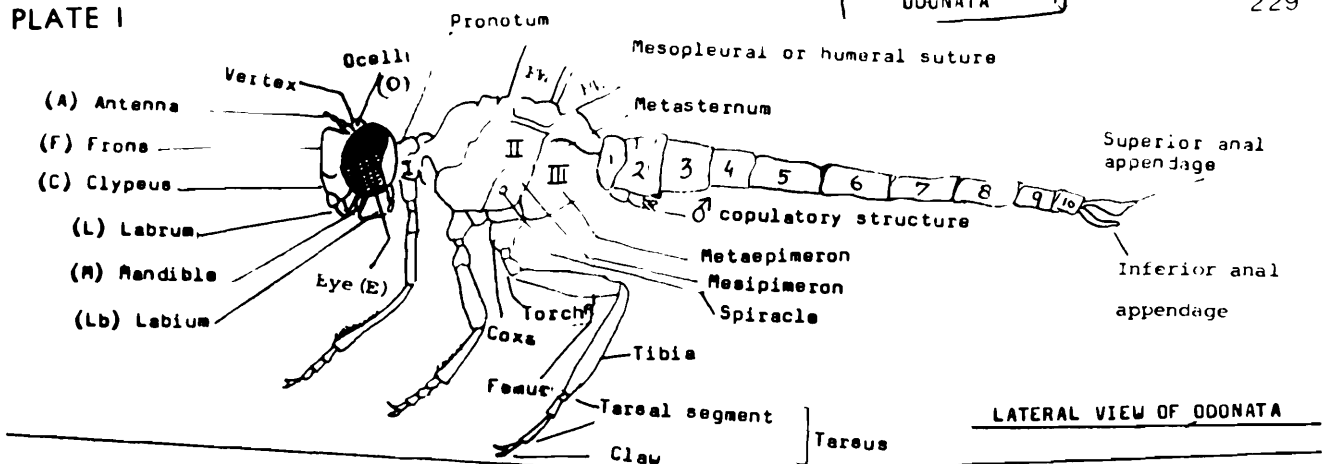
These insects are represented by 9 families (out of 18 known world over) of the Suborder Zygoptera in India. The suborder Anisozygoptera has single living family Epiophlebiidae vis-a-vis 10 extinct families. Its sole genus is Epiophlebia Calvert represented by 2 species E. laidlawi Tillyard from India, Nepal and E. superstes (Selys) from Japan, thus so far it is only known within oriental zone. Suborder Anisoptera, commonly known as dragonflies are represented by all 7 families known, within our limits.

This is an effort to provide (a) "Schematic chart of Odonates classification" (as indicated in enclosed page) followed by (b) 4 plates of Salient features supplemented by illustrations of Odonata (imago) upto family level along with recorded Indian species, genera etc. under each of them. It is followed by (c) 6 plates of Salient, illustrated features of Odonata (larva) also known as naiads, (d) 2 more plates indicate important taxonomic features of adult and larval Odonates.

Fraser (1957) can be followed for the latest classification of the order. Most of the dragonflies and damselflies, occurring in India, can be identified in their adult stages following Fraser's "Fauna of British India - Odonata", Vols. I, II, III, 1933, '34, '36). For larval identification work of Kumar (1971, '73(a), (b)), besides fauna, may be consulted. It is felt that present information, illustrations, etc. will help to recognize, classify and identify Indian Odonates.

CLASSIFICATION OF ODONATA

- Suborder I. ZYGOPTERA
- Superfamily 1. **Agriodea**
- Family i) Chlorocyphidae
 ii) Epallagidae
 iii) Aeriidae
- Superfamily 2. **Coenagrinoidea**
- Family i) Platystictidae
 ii) Protonuridae
 iii) Platycnemididae
 iv) Coenaagrioniidae
- Superfamily 3. **Lestinoidea**
- Family i) Lestidae
 ii) Chlorolestidae
- Suborder II. ANISOZYGOPTERA
- Family i) Epiophlebiidae
- Suborder III. ANISOPTERA
- Superfamily 1. **Aeshnoidea**
- Family i) Aeshnidae
 ii) Petaluridae
 iii) Gomphidae
- Superfamily 2. **Cordulegastroidea**
- Family i) Cordulegasteridae
- Superfamily 3. **Libelluloidea**
- Family i) Corduliidae
 ii) Macrodiplactidae
 iii) Libellulidae

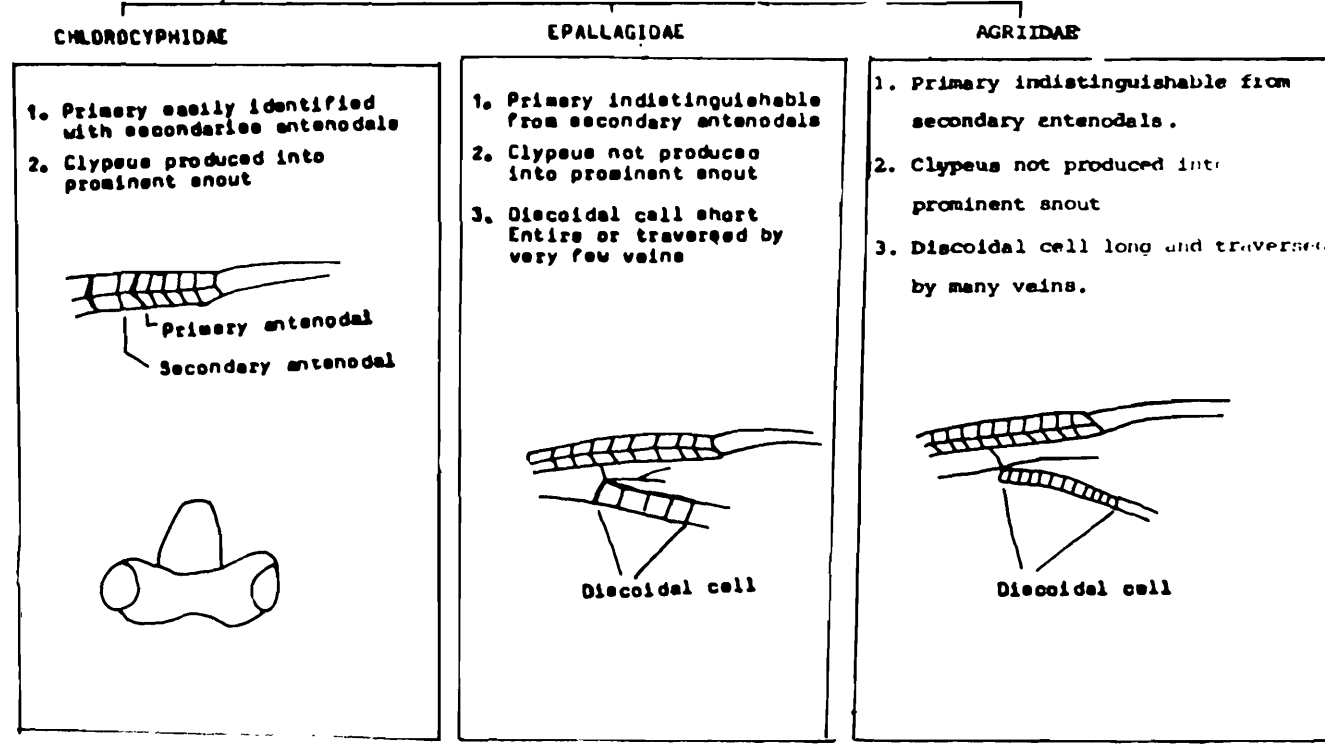
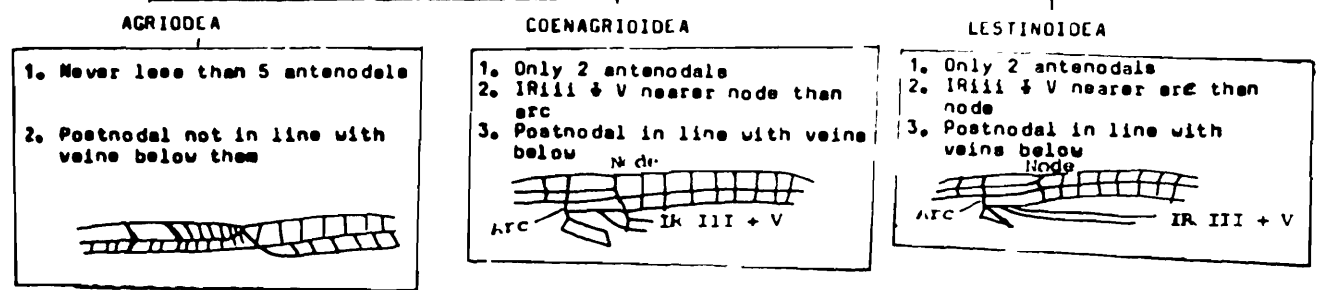
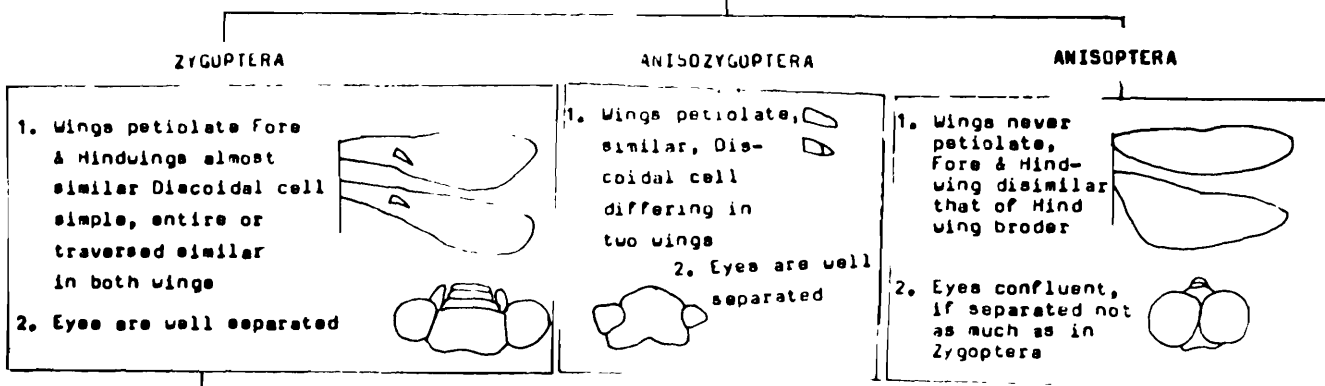


9/11	R-FW
9/11	R-HW

NODAL INDEX

WING OF ODONATE SHOWING MAIN VENATIONS

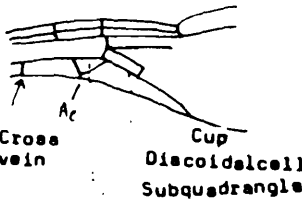
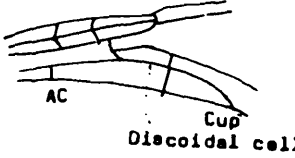
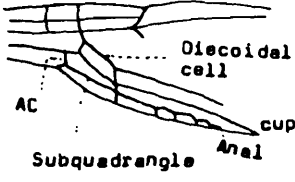
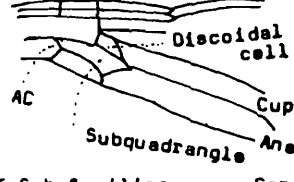
ODURATA (IMAGO)



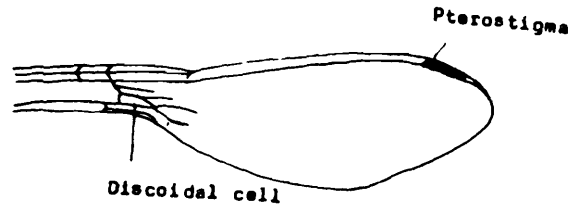
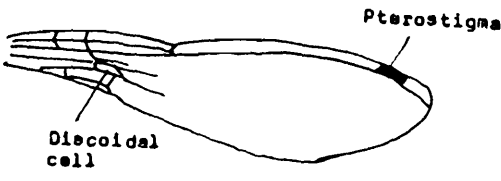
Indian Genera - 4
Indian species - 29

Indian genera - 5
Indian species - 12

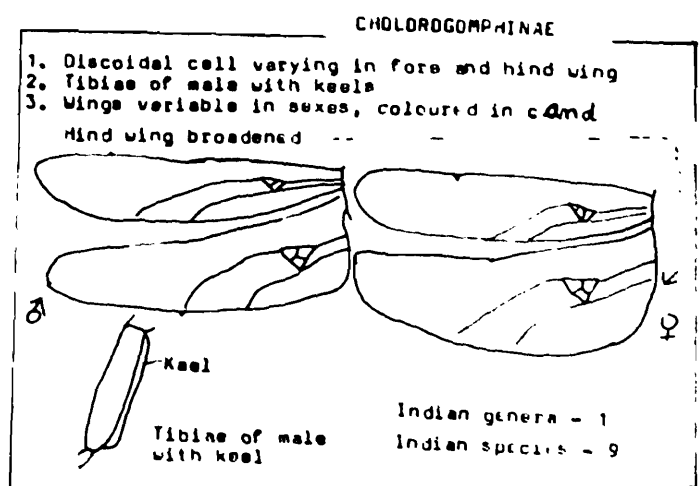
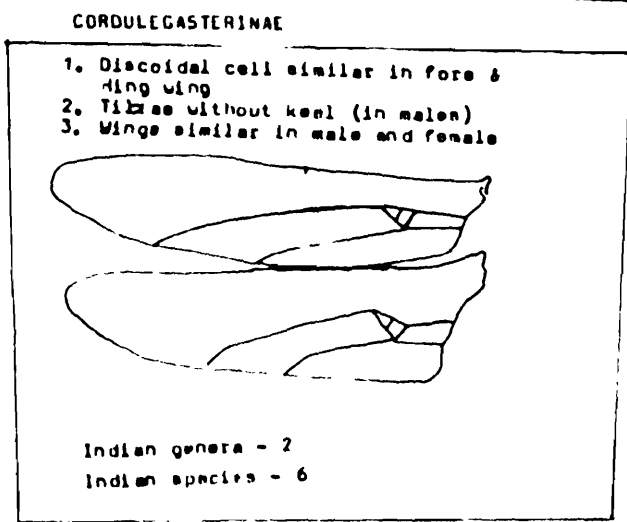
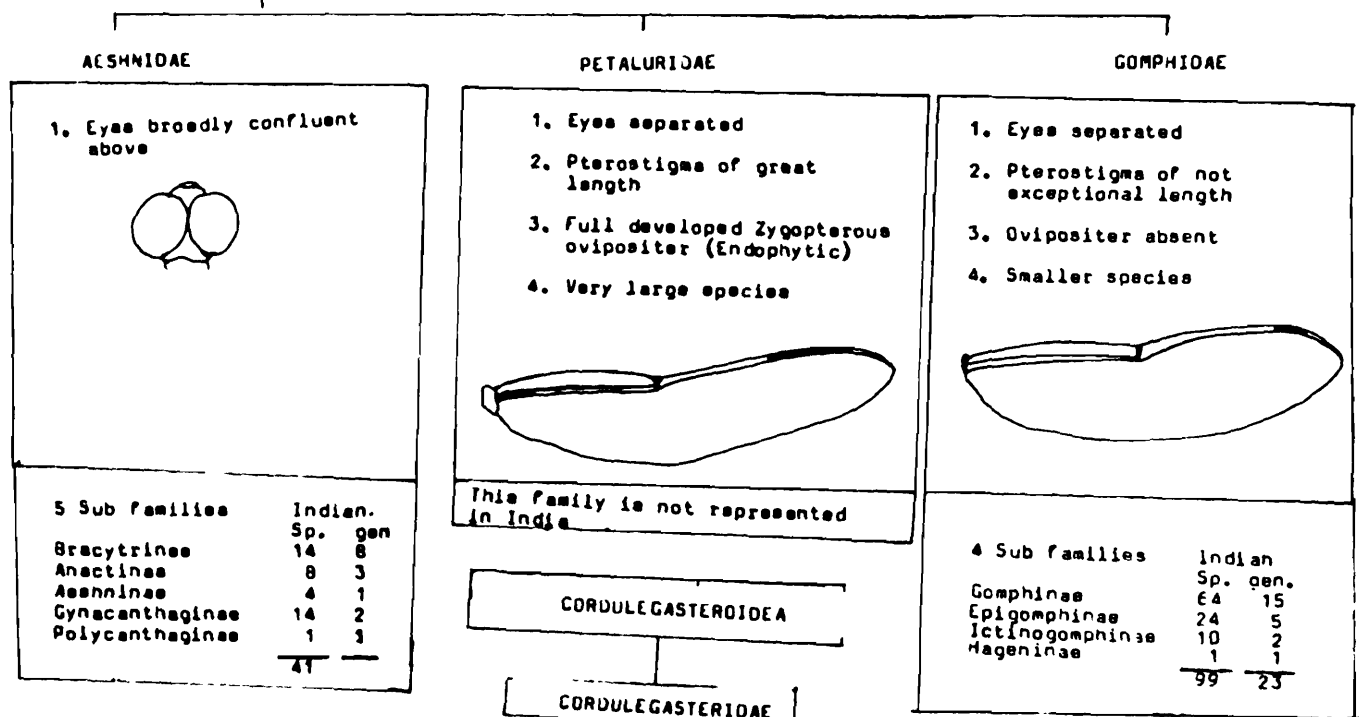
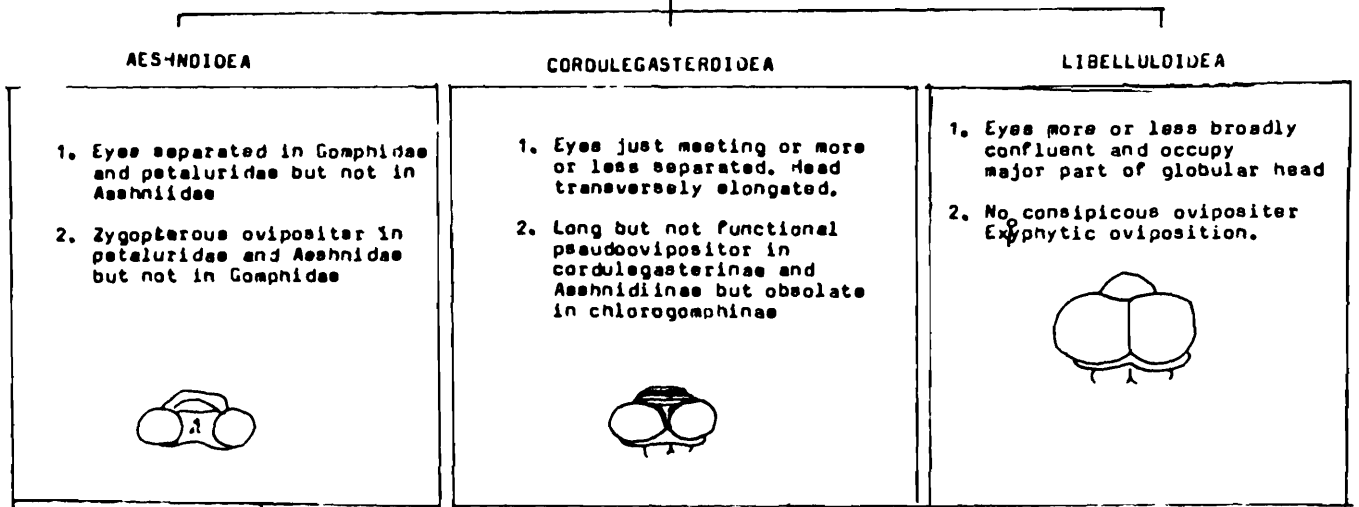
2 Subfamilies
Agriinae - Species - 16
 Genera - 6
Celiphalinae - Species - 1
 Total species - 17

PLATYSTICTIDAE	PROTONEURIDAE	PLATYCNEMIDIDAE	COENAGRIDIDAE																																																			
<ol style="list-style-type: none"> 1. Anal vein absent or greatly reduced 2. Cup of varying length 3. A cross vein at the base of wing joining cup with the border of wing proximal to AC  <p style="font-size: small;">Cross vein Cup Discoidal cell Subquadrangle</p> <p>Indian genera 3 species 11</p>	<ol style="list-style-type: none"> 1. Anal vein absent or greatly reduced 2. Cup of varying length 3. No cross vein in the cubitoanal space  <p style="font-size: small;">AC Cup Discoidal cell</p> <table style="width:100%; border-collapse: collapse; font-size: small;"> <tr> <td>3 Subfamilies</td> <td>Sp.</td> <td>Gen.</td> </tr> <tr> <td>Protonurinae</td> <td>6</td> <td>2</td> </tr> <tr> <td>Disparoneurinae</td> <td>6</td> <td>1</td> </tr> <tr> <td>Caconsurinae</td> <td>9</td> <td>4</td> </tr> <tr> <td>Family Total</td> <td>21</td> <td>7</td> </tr> </table>	3 Subfamilies	Sp.	Gen.	Protonurinae	6	2	Disparoneurinae	6	1	Caconsurinae	9	4	Family Total	21	7	<ol style="list-style-type: none"> 1. Anal vein and cup of normal length 2. Discoidal cell elongate, anterior and posterior side subequal  <p style="font-size: small;">Discoidal cell AC cup Subquadrangle Anal</p> <table style="width:100%; border-collapse: collapse; font-size: small;"> <tr> <td>2 Sub families</td> <td>Sp.</td> <td>Gen.</td> </tr> <tr> <td>Platycneminae</td> <td>6</td> <td>2</td> </tr> <tr> <td>Calcneminae</td> <td>10</td> <td>3</td> </tr> <tr> <td>Family Total</td> <td>16</td> <td>5</td> </tr> </table>	2 Sub families	Sp.	Gen.	Platycneminae	6	2	Calcneminae	10	3	Family Total	16	5	<ol style="list-style-type: none"> 1. Anal vein and cup of normal length 2. Discoidal cell short, anterior side much shorter than posterior  <p style="font-size: small;">Discoidal cell AC Cup Subquadrangle Anal</p> <table style="width:100%; border-collapse: collapse; font-size: small;"> <tr> <td>6 Sub families</td> <td>sp.</td> <td>Gen.</td> </tr> <tr> <td>Agrinae</td> <td>1</td> <td>1</td> </tr> <tr> <td>Amphicneminae</td> <td>1</td> <td>1</td> </tr> <tr> <td>Pseudagrinae</td> <td>22</td> <td>2</td> </tr> <tr> <td>Coenagrinae</td> <td>2</td> <td>2</td> </tr> <tr> <td>Ischnurinae</td> <td>19</td> <td>4</td> </tr> <tr> <td>Agriocneminae</td> <td>11</td> <td>2</td> </tr> <tr> <td>Family Total</td> <td>56</td> <td>12</td> </tr> </table>	6 Sub families	sp.	Gen.	Agrinae	1	1	Amphicneminae	1	1	Pseudagrinae	22	2	Coenagrinae	2	2	Ischnurinae	19	4	Agriocneminae	11	2	Family Total	56	12
3 Subfamilies	Sp.	Gen.																																																				
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Family Total	56	12																																																				

LESTNOIDEA

CHLOROLESTIDAE	LESTIDAE												
<ol style="list-style-type: none"> 1. Large, robust built damselfly 2. Wings of male frequently marked or banded with blackish brown or opaque white 3. Pterostigma always more than twice as long as broad. 4. Discoidal cell not well removed from posterior border of wing.  <p style="font-size: small;">Pterostigma Discoidal cell</p> <p>Single Indian S. Family</p> <p>Megalestinae - Indian species - 2 Indian Genera - 1</p>	<ol style="list-style-type: none"> 1. Small or medium, moderately robust 2. Wings of male not so marked 3. Pterostigma always longer than broad (but not twice as longer) 4. Discoidal cell well removed from posterior border of wing.  <p style="font-size: small;">Pterostigma Discoidal cell</p> <table style="width:100%; border-collapse: collapse; font-size: small;"> <tr> <td>2 Sub families</td> <td>Sp.</td> <td>Gen.</td> </tr> <tr> <td>Lestinae</td> <td>16</td> <td>3</td> </tr> <tr> <td>Sympectmatinae</td> <td>3</td> <td>1</td> </tr> <tr> <td>Total</td> <td>19</td> <td>4</td> </tr> </table>	2 Sub families	Sp.	Gen.	Lestinae	16	3	Sympectmatinae	3	1	Total	19	4
2 Sub families	Sp.	Gen.											
Lestinae	16	3											
Sympectmatinae	3	1											
Total	19	4											

ANISOPTERA (IMAGO)



LIBELLULOIDEA

CORDULIIDAE

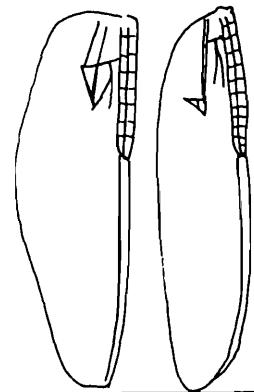
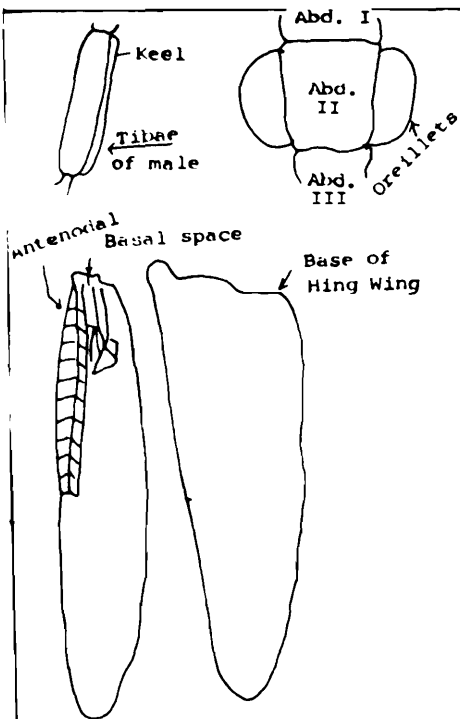
MACRODIPLACTIDAE

LIBELLULIDAE

1. Tibiae of males with an elongate lamina-shaped keel on flexor surface
2. Base of hind wing more or less angulated or notched
3. Ocelllets present on the sides of abdominal segment 2
4. Body usually coloured metallic
5. Primary antenodal atrophied and inconspicuous
6. Basal space free of cross vein

1. Tibiae of male without such keel.
2. Base of hind wing rounded in both sexes
3. Ocelllets absent
4. Body rarely metallic
5. Primary antenodals atrophied and inconspicuous
6. Sector of arc diverging from their origin
7. Distal antenodal always complete
8. 6-7 Antenodals in fore wings.

1. Tibiae of male without such keel
2. Base of hind wing rounded in both sexes
3. Ocelllets absent
4. Body not metallic
5. Primary antnodal absent
6. Sector of arc fused at their origin and arising from a common long stalk
7. Distal antenodal complete or incomplete
8. Antenodals in fore wing more and highly variable



2 Indian Sub families :-

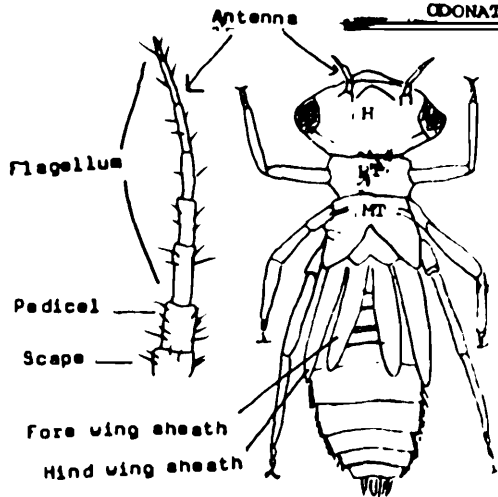
	Sp.	gen.
Idomacromiinae	25	2
Cordulinae	22	3
Total for family	47	5

Indian genera 4
 Indian species 4
 (No further subdivision of this family into subfamilies)

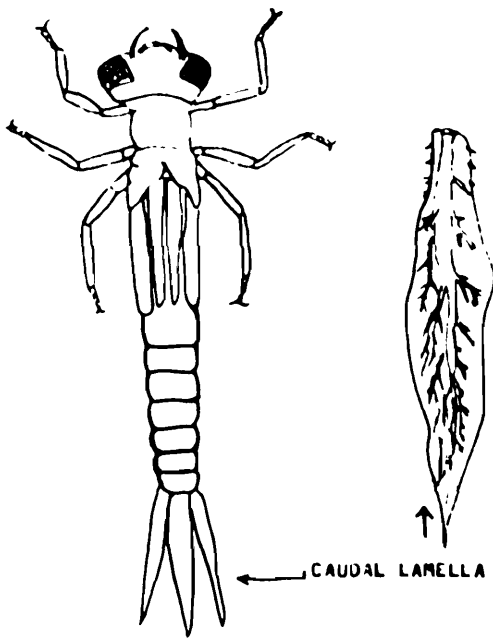
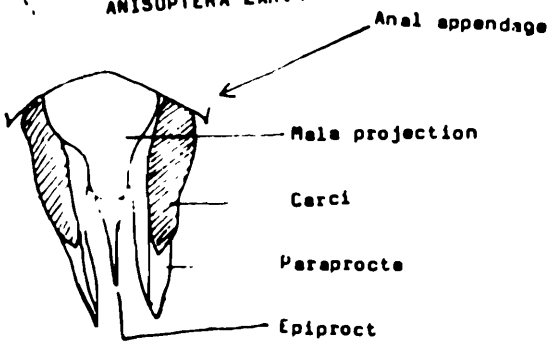
11 Indian Subfamilies:-

	Sp.	gen.
Tetratheminae	4	2
Libellulinae	27	8
Diastatopidinae	2	1
Brachydiplactinae	4	2
Sympetrinae	22	7
Tritheminae	4	1
Zygonictinae	3	1
Onychotheminae	1	1
Zyxommatinae	2	2
Rhyotheminae	4	1
Pantaliinae	5	4
Total for family	78	30

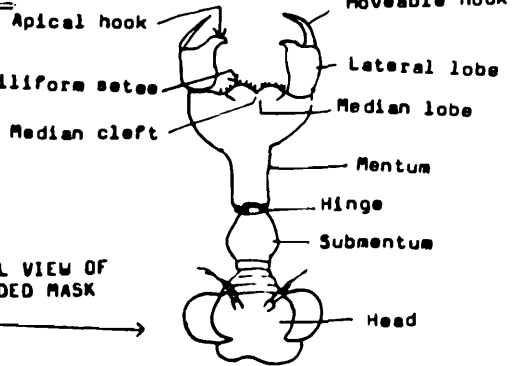
ODONATES LARVA



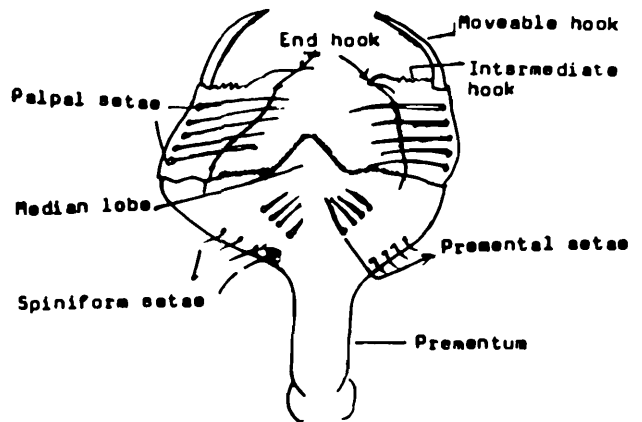
ANISOPTERA LARVA



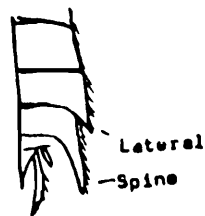
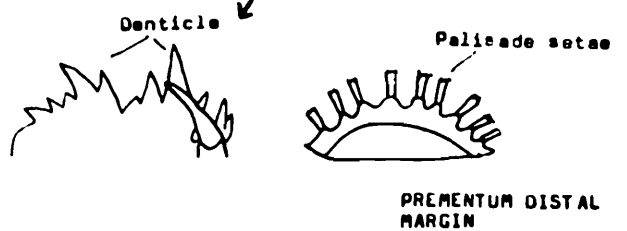
ZYGOPTERA LARVA



DORSAL VIEW OF EXTENDED MASK



DETAIL STRUCTURE OF LABIAL MASK



ODONATA (LARVA)

ZYGOPTERA

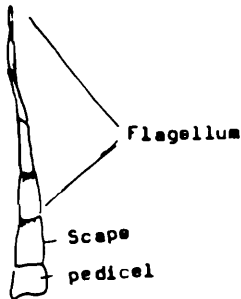
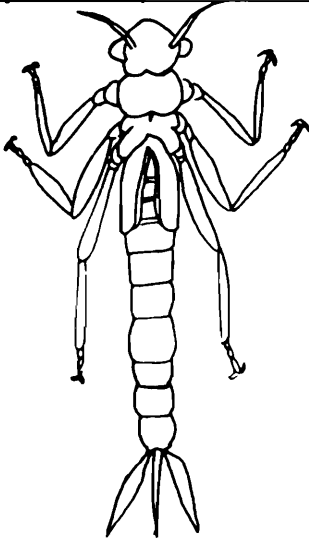
ANISOZYGOPTERA

ANISOPTERA

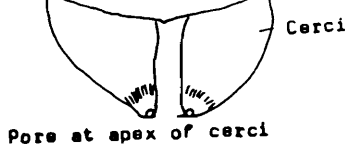
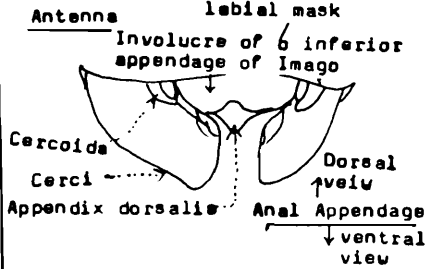
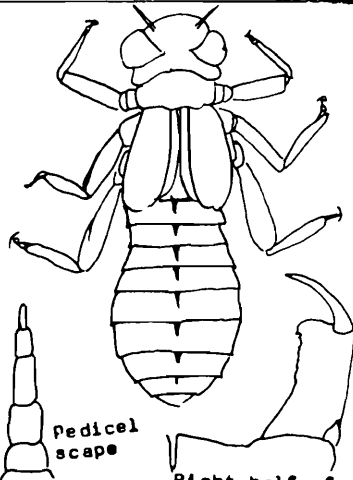
1. Larva slender, delicate, many times longer than broad
2. Abdomen terminating in caudal lamellae - generally three
3. Inhabit littoral zone of the water body as periphyton

1. Larvae not slender, stoutly built longer than broad but not as many times longer than broad as in Zygoptera
2. No terminal caudal gill-respiration by cloacal chamber
3. Anal appendage small with appendix dorsalis not as long as segment 10, triangular in shape, small somewhat conical cercoids on either side of appendix dorsalis
4. Cerci broad somewhat leaf like appendages, more than twice as long as appendix dorsalis
5. Gizzard with armature of 16 folds (comes closest to 16 folded Gizzard of Calypterygidae-Zygoptera)
6. Known to inhabit fast mountain stream (Lotic water body)

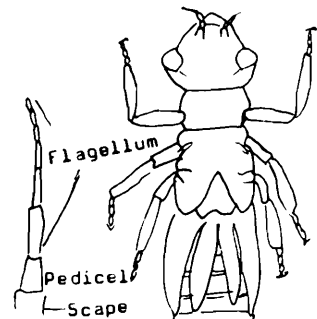
1. Larvae not slender, stoutly built, longer than broad but not as long than broad as in Zygoptera
2. No terminal caudal gill-respiration by cloacal chamber
3. Anal appendage more bigger and conspicuous, appendix dorsalis generally longer than abdomen 10 and mid-dorsal in position.
4. Cerci are long pointed.
5. Gizzard with armature of only 4 folds generally or else 8 folds in petalurinae.
6. Inhabits littoral zone as periphyton or as benthic form in littoral and lentic zone of both lotic & lentic water body



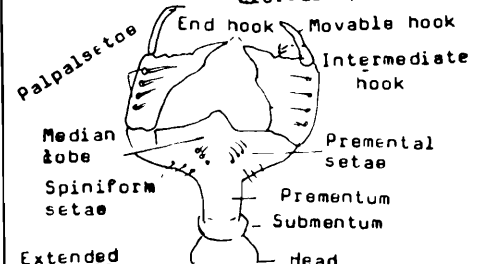
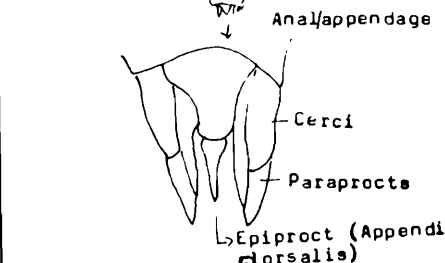
Antenna



Pore at apex of cerci



Antenna



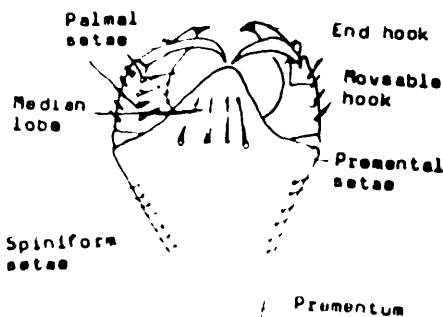
Extended mask

COLNAGRIDIDEA

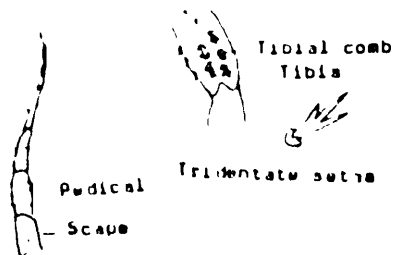
LESTINOIDEA

AGRIDIOIDEA

1. Antennae with scape much less than the total length of the remaining segment
2. Labium almost triangular in outline, median lobe of prementum without cleft in the middle. Labium with major premental and palpal setae (except in Protonneuridae). No major setae present on moveable hook.
3. Caudal lamellae lamellate type and with secondary branches at oblique angles to the median tracheae.
4. Tibial comb mostly consists of tridentate setae



Labium
(*Colpura serrulata*)

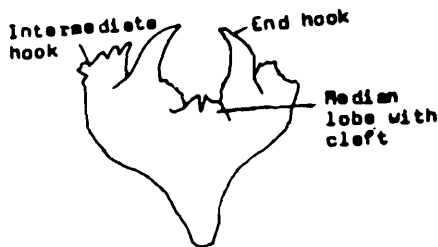


Antenna

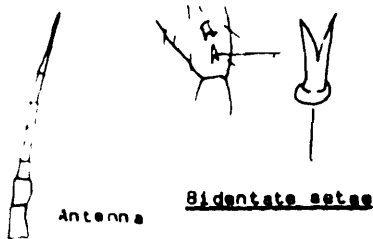
Paraproct
(Lateral lamella)
(*Disparoneura campioni*)

Epiproct
(Median lamella)

1. Antennae and scape together much less than the total length of the remaining segment.
2. Labium greatly contracted basally, median lobe of prementum with a cleft in the middle and with major premental and palpal setae. Moveable hook armed with major setae.
3. Caudal lamella type and with secondary branches at right angles to the median tracheae.
4. Tibial comb consists of number of bidentate setae.



Labium



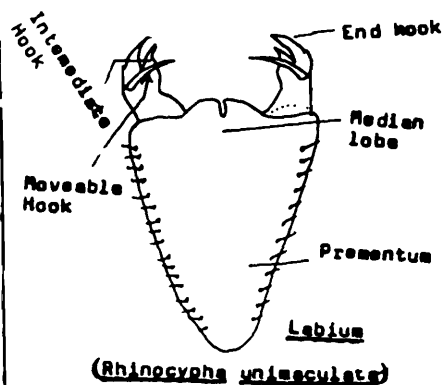
Antenna

Bidentate setae

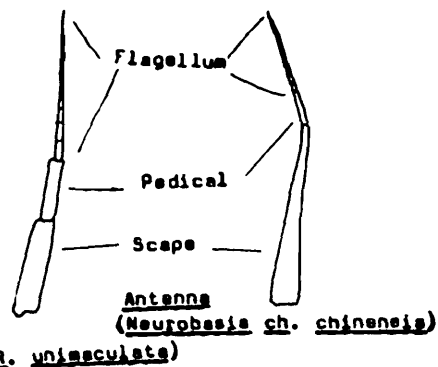


Paraproct
Epiproct
Caudal lamellae
(*Lepta praerufa praerufa*)

1. Antennae with scape longer than the total length of the remaining segment
2. Labium without major palpal and premental setae.
3. Caudal lamella saccoid or triquetral type

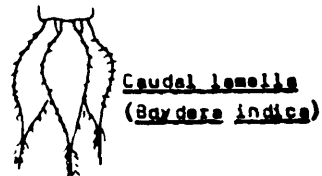


Labium
(*Rhinocypha unimaculata*)

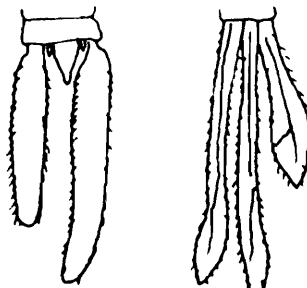


Antenna
(*Neurobasis ch. chinensis*)

(*R. unimaculata*)



Caudal lamella
(*Baryscia indica*)

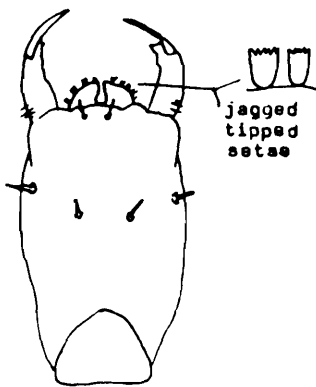


(*R. unimaculata*) (*N. Ch. chinensis*)

COENAGRIOIDEA (LARVA)

PROTONURIDAE

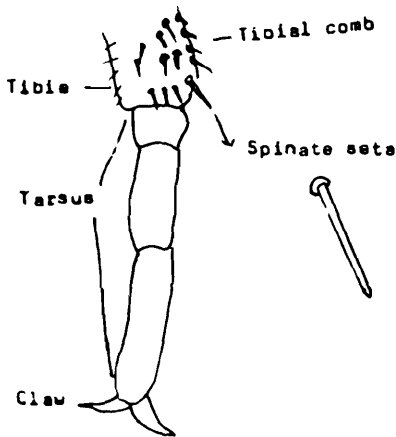
1. Labium without major premental or palpal setae, distal margin of prementum has a median cleft and is beset with jagged tipped palpal setae
2. Caudal lamellae saccoid type
3. Tibial comb consists of a number of spinate setae.



LABIUM (*Disparoneura canapioni*)



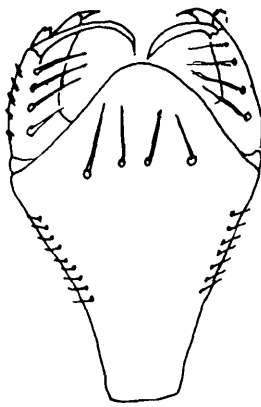
SACCOID CAUDAL LAMELLAE
(*D. CAMPIONI*)



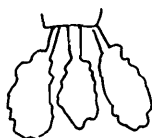
TIBIA AND TARSUS
(*D. CAMPIONI*)

Platycneimididae

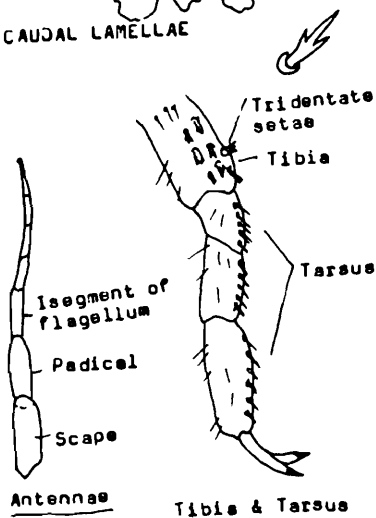
1. Labium with major premental and palpal setae, distal margin of prementum has no median cleft. It is formed of crenations, each bearing a single claviform seta.
2. Caudal lamellae lamellar type - subnodate, paddle like, marginal setae long hair-like, not differentiated into antenodal and postnodal setae.
3. Tibial comb with number of tridentate setae.
4. Antennae with first segment of flagellum shorter than pedicel.



LABIUM (*COPERA MARGINIPES*)



CAUDAL LAMELLAE



COPERA MARGINIPES

COENAGRIIDAE

1. Labium with major premental and palpal setae, distal margin of prementum has no median cleft. It is formed into crenations, each bearing a single claviform seta.
2. Caudal lamella lamellar type - denodate or nodate type, marginal setae thick and differentiated into stout antenodal and fine post nodal setae.
3. Tibial comb with number of Tridentate setae.
4. Antennae with first segment of flagellum longer than pedicel.



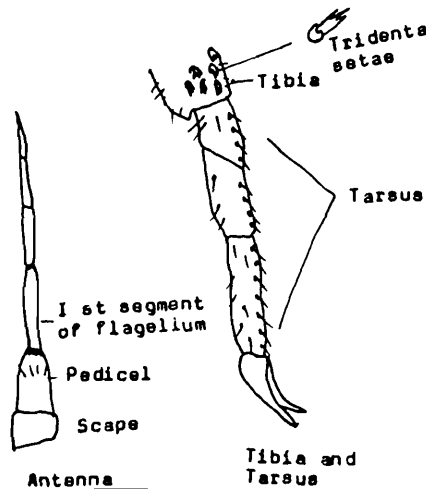
LABIUM
(*PSEUDAGRION RUBRICEPS*)



CAUDAL LAMELLAE



CERIAGRION COROMANDELIANUM
ISCHNURA DELICATA



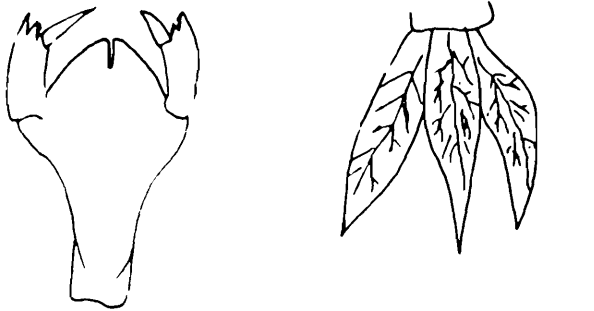
Ischnura delicata

LESTINIOIDEA (LARVA)

CHLOROLESTIOIDAE

LESTIOIDAE

1. Mask long median lobe without setae but with short and robust movable hook, two apical robust teeth and the biting border minutely dentate - median lobe also slightly (narrowly) and deeply cleft.
2. Caudal lamella lamellate, lanceolate, oar shaped.



LABIUM MEGALESTES CAUDAL LAMELLA

1. Mask with lateral lobe greatly expanded, concave, deeply and irregularly toothed, Middle lobe simple, not fissured, Moveable hook of great length.
2. Caudal lamella long, rounded at apex, paddle shaped.



LABIUM CAUDAL LAMELLAE (LESTES PRAEMROSA PRAEMROSA)

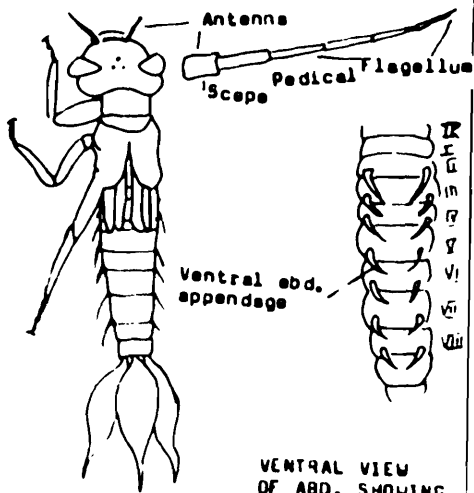
AGRIOIDEA (LARVA)

EPALLAGIDAE

CHLOROCYPHIDAE

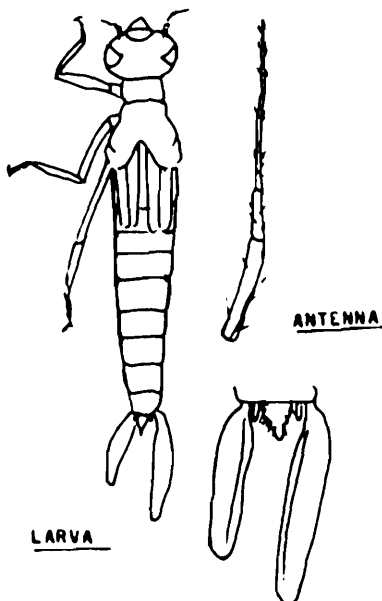
AGRIIDAE

1. Length of scape much less than the total length of remaining antennal segments.
2. Abdomen with paired ventral appendages on segments 2 to 8.
3. Caudal lamellae seccoid type.



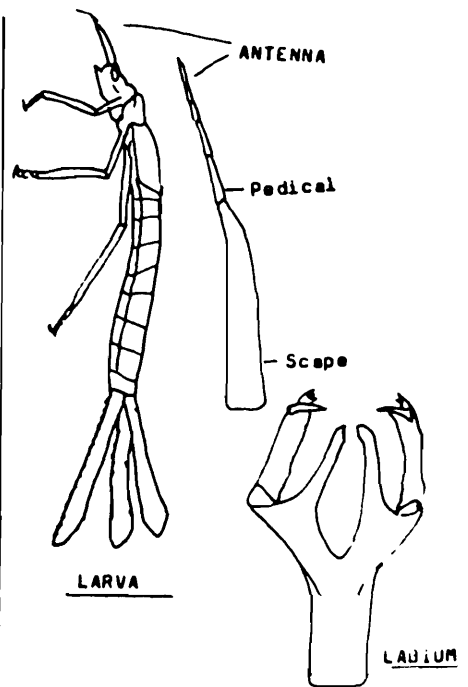
LARVA (BAYDERA INDICA)

1. Length of scape more than the total length of the remaining segment.
2. Abdomen without paired appendage
3. Caudal lamellae triquetral type and forcep like. (Epiproctreduced)
4. Antennae 7 segmented.
5. Medium sized larvae (26.4 to 28 mm), Mottled in appearance



LARVA CAUDAL LAMELLAE (EPIPROCTREDUCED) (RHINOCYPHA UNIMACULATA)

1. Length of scape more than the total length of remaining segment.
2. Abdomen without paired appendages.
3. Caudal lamellae triquetral, broadened at apex. Epiproct not reduced.
4. Antennae 6 segmented.
5. Large spider like larvae (42 to 45.5mm.) uniformly sepia colour.

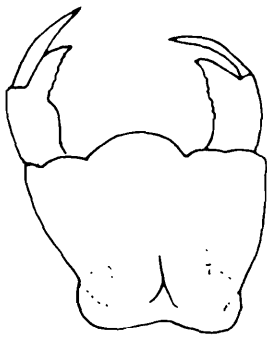


LARVA LABIUM (NEUROBASIS CAINEUSIS CHINENSIS)

ANISOPTERA (LARVA)

AESHNIOIDEA

1. Labium flat without major premental or palpal setae
2. Distal margin of palpus without crenations, produced into an end hook.

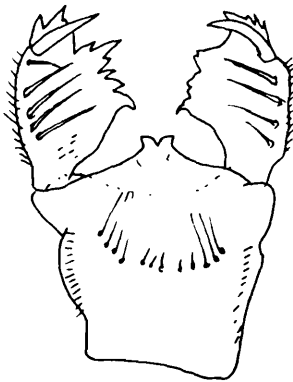


LABIUM

(ANISOGOMPHUS OCCIPETALIS)

CORULEGASTERIOIDEA

1. Labium spoon-shaped, with a number of major premental and palpal setae.
2. Distal margin of palpus with crenations or denticulated.
3. Large elongated larva



LABIUM

(CORULEGASTER)

LIBELLULIOIDEA

1. Labium spoon-shaped, with a number of major premental and palpal setae.
2. Distal margin of palpus produced into a number of crenations each bears a number of seta.
3. Medium sized larva.

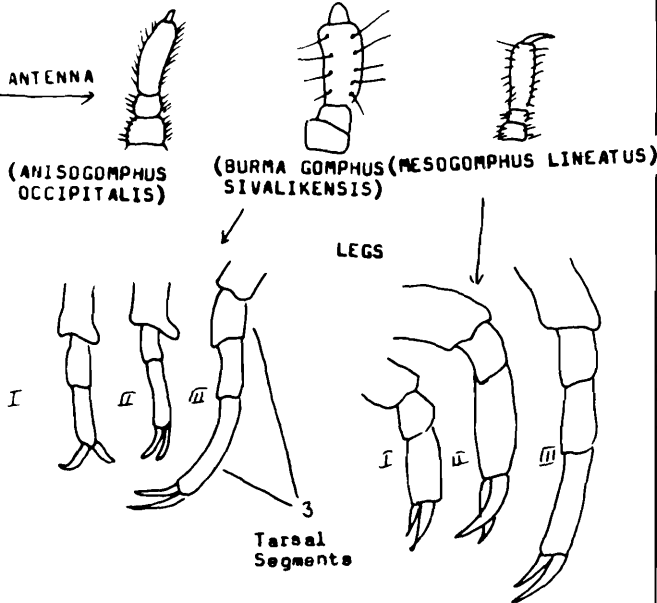


LABIUM

(ORTHETRUM SABINA)

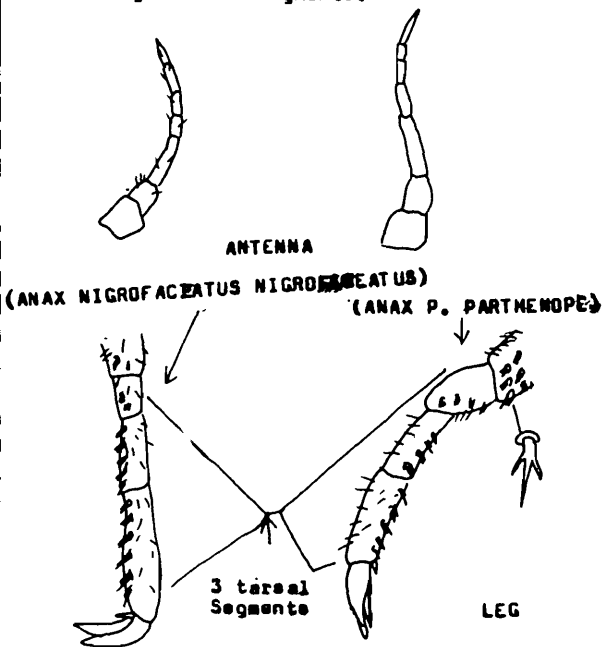
GOMPHIDAE

1. Antennae 4 segmented
2. Fore and middle legs with 2 and those of hind legs with 3 segments.



AESHNIDAE

1. Antennae 7 segmented.
2. Tarsal of all the three pairs of legs with 3 segments.

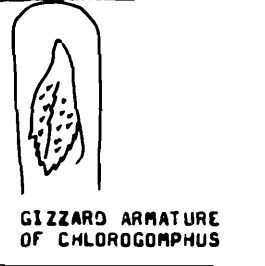
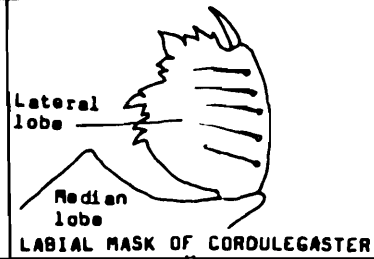


CORDULEGASTEROIDEA (LARVA)

CORDULEGASTERIDAE

(This is the only family of the super order)
 (In India this family is represented by 15
 species - 6 cordulegasterinae, 9-
 chlorogomphinae)

1. Nympha of elongate, fusiform shape.
2. Head quadrate with frons produced into a ridge like structure employed for delving mud or sand.
3. Mask deeply concave or spoon shaped with broad concave lateral lobes, furnished with many setae and with opposed borders deeply serrate.
4. Legs moderately long and robust.
5. Gizzard with 4 folds each with a single robust spine.



LIBELLULOIDEA (LARVA)

CORDULIDAE

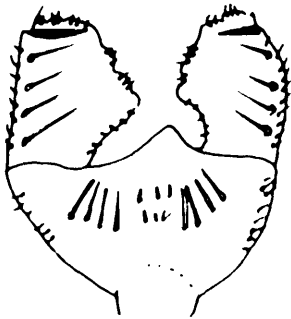
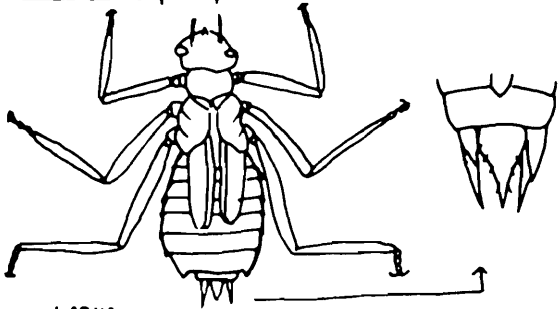
1. Long spider like leg
2. Distal margin of palpus formed into deep crenations
3. Cerci more than half the length of paraprocts

MACRODIPLACTIDAE

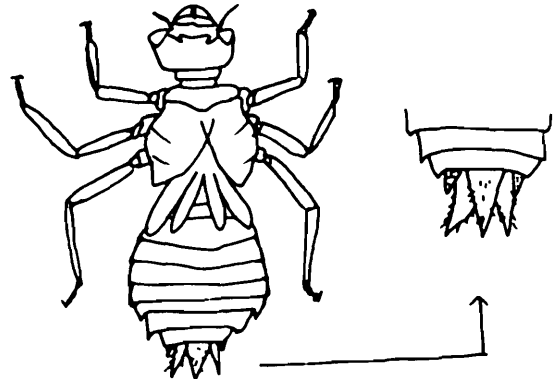
1. Labium concave type.
2. Gizzard with one fold one robust tooth

LIBELLULIDAE

1. Medium sized legs
2. Distal margin of palpus formed into shallow or flattened crenations.
3. Cerci less than half the length of paraprocts.



(MACROBIA BOREI)



(POTAMARCHA OBSCURA)

TECHNIQUES FOR THE CHROMOSOME PREPARATION FOR CYTOTAXONOMIC STUDIES

Kacker, R.K., Kulkarni, P.P. and Singh, Ashok K.

Ever since the discovery of chromosomes and understanding their direct role in the heredity of characters through generations, attempts were made to use them in solving the problems in animal taxonomy, phylogeny and evolution. The advancement in the various techniques and microscopy has now made us possible not only to observe the chromosome numbers, their morphometry and behaviour in mitosis and meiosis, but also to differentiate them among each other. Various banding techniques are utilized for this purpose, which can determine centromeric positions and distribution of euchromatin and heterochromatin. All these aspects when put together facilitate us in the comparison of individual chromosomes within the karyotype of the species and also between different species. As the chromosomes are regarded to be relatively stable units during the evolutionary process, they throw light in the taxonomic, systematic as well as phylogenetic position and relationship of the species. Thus the existing techniques have clearly solved many, if not all, problems specially in mendelian, sibling and ecological species and races, where solution was impossible through traditional morphotaxonomy.

The basic prerequisite for cytological studies of any groups is the procuring of live material. Usually the material is obtained from somatic as well as reproductive tissues, where these regions show active cell division. Thus in the case of insects in addition to the gonades, portions from hepatic caeca and midgut can be utilized to have mitotic dividing cells. This material is given some pretreatments for better chromosome spreads, which is then fixed; squashed and stained. Details of certain basic techniques are given here which are usually applied for insects and some higher vertebrates. More sophisticated methods and treatments are required for advanced studies which involve tissue culture techniques.

1. PROCEDURE FOR PREPARATION OF INSECT CHROMOSOMES :

1. Inject 0.02 to 0.04 ml. of 0.05% colchicine (Depending upon the size of the insect).
2. After 4 to 6 hours, dissect out the desired tissues (Testes, hepatic caeca, midgut, ovaries or embryos as the case may be) in 0.67% NaCl.

3. Clean the tissues and transfer them separately in to (a) 0.56% KCl for 5 to 10 minutes, OR (b) 0.9% Tri Sodium Citrate solution for 30 to 90 minutes.

The timings are to be adjusted with trial and error method. This treatment is very critical.

4. Transfer the tissues in freshly prepared fixative (1 part acetic acid X 3 parts of methanol V/V mixture). Allow fixing, up to a minimum of 30 minutes. Material can be stored in this fixative even for 2 to 3 months at 4°C.
5. Transfer the fixed material to 50% Acetic Acid till it becomes soft.
6. Squash the material with a drop of 50% Acetic acid between well cleaned slides and cover slips. Store the slides in vapours of 50% Acetic acid at 4°C for over night.
7. Take out the slides, bring them to room temperature and immerse in 1:3 acetic acid and methanol mixture for an hour.
8. Remove the cover slips and dry the slides and cover slips separately at room temperature, in a dust proof chamber.
9. Stain in buffer giemsa (pH 6.8 to 6.9). Dry and mount in DPX.

Special care is to be taken while squashing. The cover slip should not move and the slides are to be protected from dust as far as possible.

2. AIR DRY TECHNIQUES FOR VERTEBRATES (FROM BONE MARROW CELLS) :

1. Inject the animal intramuscularly with Colchicine (1/2 mg./kg. body weight in 1 ml. of distilled water) about two hours before killing.

(Make 1% Colchicine solution in distilled water. Inject 0.03 ml. of this solution in to the animal weighing roughly 200 gms.).

2. Paralyse the animal by breaking its neck. As

soon as the animal is paralysed, cut out long bones (femur and humerus) and cut open both their ends with a bone cutter.

3. Flush-out the bone marrow in to a centrifuge tube with the aid of Hypodermic syringe filled with pre warmed (about 37°C) solution of 0.95% Tri sodium citrate.
4. Agitate the tube with a rubber agitator and then add warm (37°C) Trisodium citrate solution (0.95%) to make 10 ml.
5. Incubate it at 37°C for 30 minutes.
6. Centrifuge at 1000 to 1200 r.p.m. for 5 minutes.
7. Pour off supernatant smoothly, without disturbing sedimented cells. Agitate the tube for some time.
8. Add two drops of fixative i.e., 1 part of Acetic acid and 3 parts of methanol V/V, and agitate. Add 4-5 drops more and agitate. Fill the tube to 10 ml mark. Agitate fluid by pipette with force to make it homogeneous. Keep at the room temperature for 30 minutes.
9. Centrifuge at 1000-2000 r.p.m. for 5 minutes, pour off all fixative and keep the tube inverted on a piece of blotting paper to drain off fixative as much as possible. Take care that cells remain at the tip of the tube.
10. Drop in an amount of fresh fixative about 5 times of the volume of the packed cells. Do not agitate this time (Can be slowly agitated to make it homogeneous).
11. Mix cells gently with a pipette.
12. Keep a clean slide in one hand and drop down the drops of the cell suspension from a distance over it (at least from about 6").
13. Mark the slides with diamond pencil. After a day or two stain them in buffer giemsa (pH 6.8 to 6.9). Dry at room temperature and mount in DPX.

BANDING TECHNIQUES

For all the procedures mentioned below (Banding techniques) the air dried slides prepared by the techniques 1 and 2 are to be used before staining them with giemsa.

C - banding techniques :

Procedure I :

1. Treat the slides in 0.07 N NaOH in 2x SSC for 5 to 15 seconds. This is a critical step in the procedure.
2. Rinse in distilled water.
3. Pass through 70%-90% and Absolute alcohol (each for 5 minutes).
4. Dry the slides.
5. Incubate in 2 x SSC at 55°C for 12 to 16 hours.
6. Rinse in distilled water.
7. Stain in Giemsa for one hour at pH 6.8.
8. Rinse in distilled water and dry the slides.

Procedure II :

1. Treat the slides in 0.2 N HCl for 30 to 60 minutes.
2. Rinse in distilled water (two changes) and then dry.
3. Weigh approximately 3 to 4 grams of Barium Hydroxide $\text{Ba(OH)}_2 \cdot 8\text{H}_2\text{O}$ and dissolve it in boiling double distilled water. Filter while still hot. Wait till it reaches 55° to 60°C. Keep it in an incubator set at 55°C.
4. Treat the slides in this solution of Ba(OH)_2 , at 55°C for 1 to 5 minutes. (Critical step, needs standardization).
5. Rinse the slides in warm double distilled water (two changes).
6. Put the slides in 2 x SSC for 1 to 2 hours at 60°C.
7. Rinse in distilled water.

8. Stain in buffered giemsa pH 6.8 for an hour. Rinse in distilled water. Dry at room temperature and scann.

Procedure III. Trypsin treatment Method. (G-banding technique)

1. Take 100 ml. distilled water and adjust its pH with acid and alkali to 7.2 to 7.4.
2. Dissolve 25 mg. of trypsin in the distilled water mentioned at step 1.
3. Treat slides for 20-40 seconds at room temperature. (Treatment time needs to be standardized).
4. Rinse in distilled water.
5. Rinse in 70%; 90% and absolute alcohol, then air dry.
6. Stain in buffered giemsa pH 6.8 for 5 minutes.
7. Rinse twice in distilled water, dry and scann, mount in DPX.

Procedure for N banding (Nucleous organizing region).

1. Mix 1 gm. of Silver nitrate (AgNO_3) to 2 ml double distilled water.
2. Filter through milipore.
3. Put 3 drops per slide.
4. Cover with cover slip.
5. Incubate at 50°C in moist chamber (do not allow drying) for 4 to 18 hours.
6. Rinse in distilled water.
7. Dry and mount in oil immersion oil.
8. Examine, preferably under phase contrast.

Fluorescence Banding : Q and M banding procedures.
(Quinacrine dihydrogen chloride and Quinacrine mustard)

1. Transfer the slides to absolute alcohol bring down to distilled water through progressively dilute alcohol grades.

2. Soak the slides in McIlvaine's or Sorensen's phosphate buffer, pH 4.1 to 7.0.
3. Stain either in quinacrine dihydrogen chloride 5 mg/ml buffer or quinacrine mustard 50 mg/ml buffer for 20 to 30 minutes at room temperature.
4. Wash the slides in three changes of buffer of the same pH as used for staining in step 3.
5. Mount in same buffer and observe under fluorescence and photomicrograph immediately.

Hoechst 33258 Fluorescence banding :

1. Soak the slides in McIlvaine's buffer pH 5.3 to 5.4 for 5 to 6 minutes.
2. Stain in Hoechst stain 0.05 mg/ml in the same buffer for 10 to 15 minutes at room temperature.
3. Rinse the slides in same buffer (two changes).
4. Mount in the same buffer or in Glycerine and examine under fluorescence and photomicrograph immediately.

Preparation of Reagents, Stains and Stock solutions mentioned in the procedures :

- | | | |
|----|---------------------------------|---|
| 1 | 2 X SSC | Dissolve 17.52 gms. of Sodium chloride and 8.823 gms. of Trisodium Citrate in one litre of distilled water. |
| 2. | 0.2 N HCl | 2 ml of concentrated HCl and 108 ml of distilled water to make 110 ml of 0.2 N HCl. |
| 3. | 0.07 NaOH | 0.28 gms of Sodium Hydroxide to be dissolved in 100 ml of distilled water. |
| 4. | $0.02 \text{ Na}_2\text{HPO}_4$ | 35.6 gms of Na_2HPO_4 dissolved in 1000 ml of distilled water. |
| 5. | MacIlvaine buffer : | |
| | | (A) 35.6 gms of Na_2HPO_4 dissolved in 1 litre of distilled water. |

- (B) 21.01 gms. of Citric acid dissolved in 1 litre of distilled water.

Mix solutions A and B to adjust pH as desired.

6. Giemsa Stain :

- (A) Stock solution : Dissolve thoroughly 1.0 gm of Giemsa powder in 66 ml of glycerine, keep the solution at 55 to 60°C for 2 hours. Then add 66 ml of Methanol. Filter and store in freezer at 4°C.
- (B) Working solution : Add 1.5 ml of Methanol to 1.5 ml of 0.02 Na₂HPO₄. Add to this solution 2 ml of Giemsa stock solution (A). Make up to 50 ml with distilled water.

KARYOTYPING

Regardless of the cytological methods employed, the cells with good chromosome spreads are photomicrographed. The diploid number is determined by basic or most predominant number observed. Most cytologists cut out the individual chromosomes from the photomicrographs of the metaphase chromosomes to construct karyotype. This procedure is to be preferred as against the camera lucida drawings which reduces the subjectivity and error of the investigator. After tailoring chromosomes which appear similar in morphology are paired. They are grouped depending up on length, centromeric positions and general appearance. In some insects centromeres can not be located, so usually chromosomal lengths alone provide workable methods.

CONSTRUCTION OF IDIOGRAMS

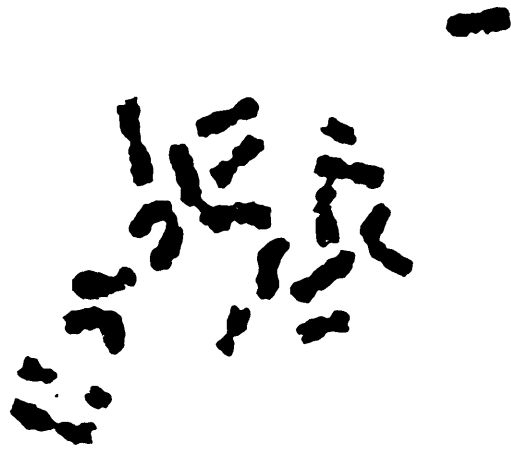
An idiogram is an idealized karyotype or the statistically represented karyotype. Even the most accurate actual photograph does not singly represent the idiogram. It can be constructed after normalization of many karyotypes. The usual practice is to measure the length of each arm or the entire chromosome with the help of their photographs. The measurements can accurately be measured with a dial caliper. Their relative percentage lengths in relation to the total length of the complement is calculated. So also arm ratio can be calculated by dividing the length of longer arm with the shorter one. However, it is to be remembered that conventional karyotype and idiogram have many limitations since it is impossible to determine reciprocal translocations, inversions of equal proportions without observing the meiotic behaviour.

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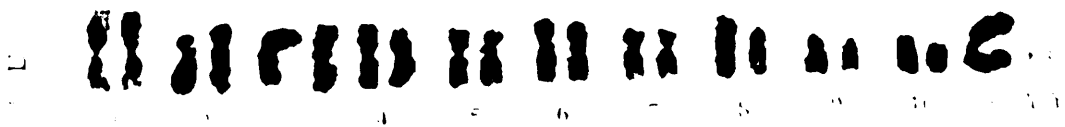
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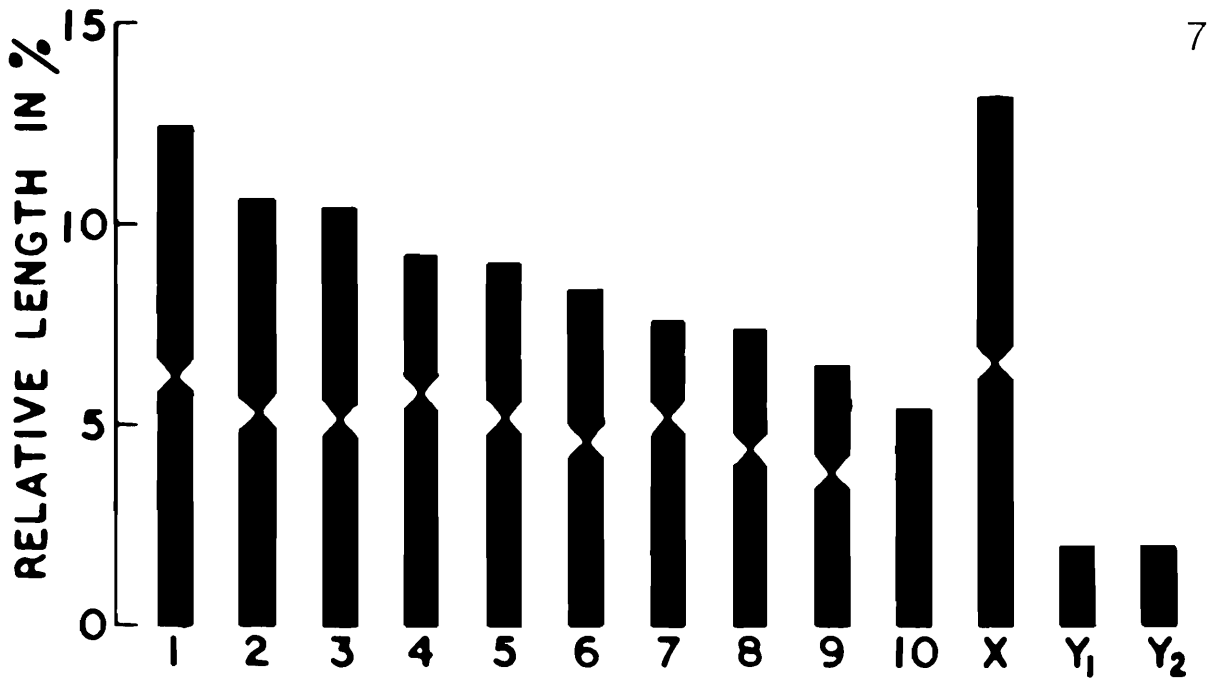
1. Photograph of chromosomes, 2. Karyotype of Oxya fuscovittata (Marschall). (Orthoptera). 3. Photograph of chromosomes, 4. Karyotype of Myzus persicae (Sulzer) (Aphididae).



5



6



7

5. Photograph of chromosomes, 6. Karyotype and 7. Idiogram of *Astycus lateralis* (Coleoptera).

APPLICATION OF BIOCHEMICAL ANALYTICAL METHODS IN THE TAXONOMIC STUDIES

R. K. Varshney

In the modern taxonomic studies, taxa like the genera, species and infraspecific forms of animals are not only studied from the conventional concepts of morphological dissimilarity, but from some other angles as well, for example their biological and ecological characteristics. There are cases, where a study of either the embryological structures, or physiological peculiarities, or cytogenetics, etc., has thrown more light on the differences between the two related populations than their morphological features. Such studies obviously involve specialised methods of study. Based on the different sciences, when applied to taxonomic studies, these are called 'Numerical taxonomy', or 'Cyto-taxonomy', or 'Chemo-taxonomy', etc.

Chemo-taxonomy is broadly speaking, that branch of science where biochemical analytical methods are utilized for taxonomic purposes. Such studies have been carried out on various groups of animals to know the composition of the proteins or carbohydrates or fatty acids, etc. and the differences observed between two taxa, if found constant, are referred as chemo-taxonomic characters.

This approach of using biochemical analytical methods for taxonomic studies is comparatively a new tool. In our country, stray studies have been carried out on the use of paper chromatography in distinguishing some species of fishes. Paper chromatography of the blood plasma was also resorted to in bird taxonomy, for separating two related species of myna. In insects, a number of chromatographic and fluorescent studies have been found quite successful, e.g., segregation of the Pipiens complex of Culex mosquitoes. Drosophila is another example, where amino acid composition has helped in understanding the various mutant forms.

PAPER CHROMATOGRAPHY

In it the unknown substances are analysed by the flow of solvents on filter paper. The paper works as an inert support, while one solvent works as mobile phase and the other as immobile phase, and the substances are separated due to their differential migration.

In the simplest method, a drop of the unknown solution (e.g. blood or honeydew) is applied on one end of the specially prepared filter paper. When dried, this end is placed in a suitable solvent system comprising two or more solvents. The solvent system passes over the spot and moves further on the filter paper, called the development of the chromatogram. When it has reached near the

other end, the 'chromatogram' is removed and dried in an oven. After drying, special chemical reagents are sprayed, or the filter paper itself is dipped in it, to reveal or locate the coloured spots of various constituent substances. It is mostly done by keeping the papers in oven at high temperature for few minutes.

The various constituents are identified either by their comparison with the known standard substances, or by calculating their R_f value, which is the relative rate of flow of the solute in a given solvent and is always different for different compounds. The R_f can be calculated as follows :

$$R_f = \frac{\text{Distance travelled by the substance}}{\text{Distance travelled by the solvent}}$$

A chromatogram can be developed in descending or ascending direction. When a chromatogram developed in one direction is again developed, after drying, in another solvent system, at the right angle of the first, it is called two dimensional. Sometimes even radial development is attempted in horizontal direction (circular chromatography).

It may be stated that for precaution, special papers, like the whatman chromatographic filter papers ought to be used. Amino acids can be separated in many solvent systems, as for example in Ethanol-water-ammonia solution (20 : 2.5 : 2.5 v/v) or n-Butanol-acetic acid-water (30 : 6 : 14 v/v). They can be located by spraying 1% solution of ninhydrin in acetone.

Sugars can also be separated in a number of solvent systems, as for example in a solution comprising Ethyl acetate-pyridine-water (14 : 6 : 6 v/v), and then located either by a silver nitrate solution, or by a mixture of benzidine and trichloro-acetic acid in acetone. The solvent systems and the locating reagents are obviously selected depending on the nature of substances going to be analysed. A number of them have been reported by various workers in experimental studies.

PAPER ELECTROPHORESIS

For separating the biological fluids, which are often available in very meagre quantity, paper electrophoresis is widely used. It is the process of separation by migration of charged substances under the electric field. Carbohydrates, enzymes, amino acids, alkaloids, etc. in blood and other extracts can be examined by this process, as it results in absolute separation of the components.

The paper to be used is first made wet with a buffer solution. Then it is placed in the apparatus comprising of two compartments (anode and cathode) in horizontal position dipping one end in each. A drop of the experimental material is put in the middle of paper. Weakly dissociated acid and base buffer solutions are used as electro-

lytes in the compartments. A current of approx. 250 volts is passed. Buffer solutions serve the purpose of conductors and the wet paper as the connecting bridge. After some specified time the current is put off and the 'electrophoretogram' is dried. The substances are revealed by the locating reagents as reported above in the paper chromatography. Electrophoretic mobility is measured on the basis of distance travelled.

As for example, for separation of the amino acids, a solution of 10 ml pyridine with 8 ml of glacial acetic acid made upto 250 ml with distilled water will serve as the buffer solution and a 1% solution of ninhydrin in acetone will serve as locating reagent.

FLUORIMETRY

Fluorescent compounds present in a biological fluid can be separated in different solvent systems, as shown above by paper chromatography or electrophoresis methods. These developed papers are then examined in the Ultra-violet light, which shows the location and different colours of the fluorescent substances present in the material. Their presence, number and the rate of migration can be utilized in distinguishing populations.

PRELIMINARY STATISTICAL TECHNIQUES IN INSECT STUDIES

A. K. Hazra

INTRODUCTION

It may be useful to discuss a few terms and elementary methods in statistical analysis which are routinely used in taxonomy. To consider taxa as populations and aggregates of populations led automatically to a statistical approach. The taxonomist deals with samples from natural population and can make estimates on the characteristics of these populations only with the help of statistics.

The statistics can be defined as "The numerical statements of fact capable of analysis and interpretation and the science of statistics is a study of the principles and methods used in collection, presentation, analysis and interpretation of numerical data in any sphere of enquiry".

IMPORTANCE OF STATISTICAL STUDIES

The science of statistics is associated with all the other important sciences both physical as well as social. In fact, today the domain of statistics is very wide, it is almost universal and it is difficult to imagine any science worth the name where statistics has not proved its usefulness in some form or other. The statistics is so important because, it simplifies complexity; measures results; studies relationships; enlarges human experience.

TAXONOMIC UNITS TO BE CONSIDERED FOR STATISTICAL ANALYSIS

Taxonomic papers are occasionally published with highly elaborate statistics that make no contribution what so ever to the taxonomic analysis. Statistics can not improve heterogeneous original data or unreliable measurements. The experience has shown that morphological measurement usually show a normal distribution. A strong deviation from normality required that we examine the material for bias and possibility. Statistical analysis may also give us important information as to weight which we should assign to certain characters. When countable characters, such as the number of segments, scales, spines or chaetae vary, we speak of meristic or countable variation. Some characters are excludingly

constant, such as the number of eyes in mammals, others may have a greater or lesser variability which is usually characteristics for a given species. Examples are the number of scales in snakes or finrays in fishes. In most groups of insects not only length but also width and antennal and tarsal formulae should be given. These data should be recorded as a routine matter regardless of their immediate diagnostic value. Special measurements are traditionally given in particular taxonomic groups, such as length of the rostrum in Hemiptera, length of wings in some Diptera etc. It is important for comparative purposes to give measurements that confirm with system which is customary in the group under study to present them in a standardised sequence.

TYPES OF STATISTICAL UNITS

Broadly the statistical units are of two types (a) Units of collection; (b) Units of analysis.

a) Units of Collection : Are the units in which figures relating to a particular problem are either enumerated or estimated.

b) Units of analysis : These are the units with which statistical data are analysed and interpreted. They include ratios, percentage and correlations, etc.

Classification, Seriation and Tabulation of Data : Classification: The process of arranging data in groups or classes according to resemblance and similarities is technically called classification. Seriation : If two variable quantities can be arranged side by side so that the measurable differences in the one correspond to the measurable differences in other and the result is said to form a statistical series. Tabulation : Tabulation is an orderly arrangement of data in columns and rows.

Types of averages :

a) Mathematical averages :

- i) Arithmetic average or Mean.
- ii) Geometric mean, not of much use in taxonomy.

b) Averages of position :

- i) Median
- ii) Mode

Arithmetic mean : It is the figure obtained by dividing the total value of the various item by their members. $a = \frac{\sum m}{n}$

Median : Median is the value of the middle item of a series when it is arranged in ascending or descending order of magnitude.

$M =$ Size of $n/2$ item. Where M stands for median and n for the number of items.

Example : Find out the median length of the insect having the following length. 5,7,9,12,10,8,7,15,21 mm.

Solution : Items arranged in ascending order of magnitude.

Serial No. of insect	length (in mm.)
1	5
2	7
3	7
4	8
5	9
6	10
7	12
8	15
9	21

Median length is the length of the middle insect, i.e., insect no.5

So, $M = 9$ mm.

In the series of odd items the middle item will be $n+1/2$ item.

Mode : In a discrete series the value of the variable against which the frequency is the largest would be the modal value.

Example : Find out the mode of the following series.

Size	Frequency	Size	Frequency
5	48	13	52
6	52	14	41
7	56	15	57
8	60	16	63
9	63	17	52
10	57	18	48
11	55	19	40
12	50		

Solution : Location of mode by grouping

Size of item (m)	Frequency (f)					
	(1)	(2)	(3)	(4)	(5)	(6)
5	48	100	-		-	-
6	52			156		
7	56	116	108		168	
8	60					
9	63	120	123	180		179
10	55				175	
11	50	105	112	157		162
12	52					
13	41	93	102		143	
14	57					150
15	63	120	98			
16	52			161		
17	48	100	115		172	163
18	40		88	140		
19						

To find out the data of maximum concentration the data can be arranged in the shape of another table as follows.

Analysis table

Column	Size of item containing maximum frequency						
(1)			9				16
(2)			9	10		15	16
(3)		8	9				
(4)		8	9	10			
(5)			9	10	11		
(6)	7	8	9				
No. of items size occur	1	3	6	3	1	1	2

Since, the size 9 occurs maximum number of items it is the modal size or mode is 9.

Measures of dispersions :

(a) Mean deviation : Mean deviation of a series is the arithmetic average of the deviations of various item from a measure of central tendency (mean, median and mode).

Symbolically

i. $\delta = d/n$

ii. $\delta_m = dm/n$

Where δ and δ_m stands for mean deviation from mean and median respectively and n for the number of item.

(b) Standard deviation : Standard deviation is the square root of the arithmetic average of the squares of the deviations measured from the means.

$$\delta = \sqrt{\frac{\sum d^2}{n}}$$

Where δ stands for the standard deviation $\sum d^2$ for the sum of squares of the deviation measured from the arithmetic average and "n" for number of items.

Co-efficient of variation : It stands for the percentage which the value of standard deviation is to the value of the mean.

$$v = \delta/a \times 100$$

Thus, if the mean of the series is 50 and standard deviation is 10, the v should be $10/50 \times 100 = 20\%$ i.e. the standard deviation is 20% of the mean.

Correlation : The term correlation indicates the relationship between two such variables in which with changes in the value of one variables, the values of the other variable also change.

(a) Positive and negative correlation : Correlation can be either positive or negative, when the value of two variables move in the same direction correlation is said to positive (Fig.1). If, on the other hand, the values of two variables move in different direction correlation is said to be negative (Fig.2).

(b) Linear and non-linear correlations : When variation in the value of two variables are in constant ratio, correlation is said to be linear. But in case of biological sciences the ratio of change in two variable is generally not constant. The correlation in such cases is known as curvi-linear or non-linear.

Correlation in two or more series :

This can be studied by one of the following methods.

(a) Scatter diagram; (b) Co-efficient of correlation.

a) Scatter diagram : Diagrams can be drawn to have an idea about the relationship between one or more variables. Thus, if the plotted points do not show any trend, the two variables are not correlated (Fig. 3). If the trend of points is upward rising from left bottom and going upwards to the right top, the correlation is positive (Fig.1). And, if, the tendency is reverse i.e., the points show a downward trend from the left top to the right bottom, then the correlation is negative.

b) Coefficient of correlation : According to Karl Pearson's formula, "The Co-efficient of correlation of two variables is obtained by dividing the sum of the products of the corresponding deviations of the various items of two series from their respective means by the products of their standard deviation and the number of pairs of observations".

This is $x_1, x_2, x_3, \dots, x_n$ are the deviations of various items of the first variable from its mean value and $y_1, y_2, y_3, \dots, y_n$ are the corresponding deviations of the second variable from its mean value, the sum of products of these corresponding deviation would be $\sum xy$. If further, the standard deviation of the two variables are respectively, δ_1 and δ_2 and if 'n' is the number of pairs of observations. Karl Pearson's coefficient of correlation represented by 'r' would be

$$r = \frac{\sum xy}{n \times \delta_1 \times \delta_2}$$

Perfect correlation : If the relationship between two variables are such that with an increase in the value of one, the value of the other increases or decreases in a fixed proportion, correlation between them is said to be perfect. When both the series move in same directions and the variations are proportionate, there would be a perfect positive correlation between them (Fig. 4). On the other hand if both the series move in reverse directions then it would be an example of perfect negative correlation (Fig.5).

Example : Find out the correlation coefficient between length of abdomen and antenna of an insect from the following data.

Length of abdomen in mm. : 165,166,167,168,169,170,172

Length of antenna in mm. : 167,168,165,168,172,169,171

Solution :

Length of abdomen in mm. ($\sum m_1$) = 1344

Deviation from Average length (x) = 0

Square of deviation ($\sum x^2$) = 36

Length of antenna in mm. ($\sum m_2$) = 1352

Deviation from Average length (y) = 0

Square of deviation ($\sum y^2$) = 44

Product of deviation ($\sum x y$) = 24

Average length of abdomen = $\frac{1344}{8}$ = 168 mm

Average length of Antenna = $\frac{1352}{8}$ = 169 mm.

Standard deviation of length of Abdomen $\delta_1 = \sqrt{\frac{\sum x^2}{n}} = \sqrt{\frac{36}{8}} = 2.12$ mm.

Standard deviation of length of Antenna $\delta_2 = \sqrt{\frac{\sum y^2}{n}} = \sqrt{\frac{44}{8}} = 2.34$ mm.

$$r = \frac{\sum xy}{n \times \delta_1 \times \delta_2} = \frac{24}{8 \times 2.12 \times 2.34} = 0.6$$

Figure 6 reveals the relationship between body length and Antenna length with scatter diagram in praying mantid.

Interpretation of co-efficient of correlation :

1. If the coefficient of correlation is less than its probable error, it is not at all significant.
2. If the coefficient of correlation is more than 6 times its probable error, it is definitely significant.

CONCLUSION

Lastly reproductive isolation (species criterion) and degree of morphological difference are not always closely correlated. Sibling species may be almost identical morphologically, while intra population variants and subspecies are often strikingly different. Taxonomist must also keep in mind that what may be significant for the statistician may not at all be significant for a biologist or at least for a taxonomist.

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PLATE I

Positive Correlation

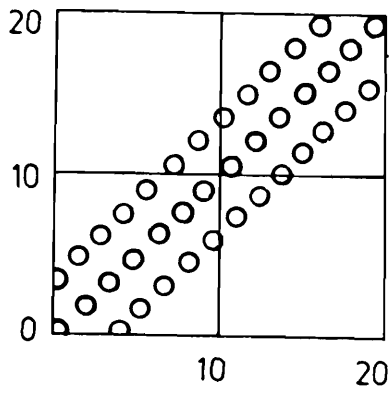


fig.1.

Negative Correlation

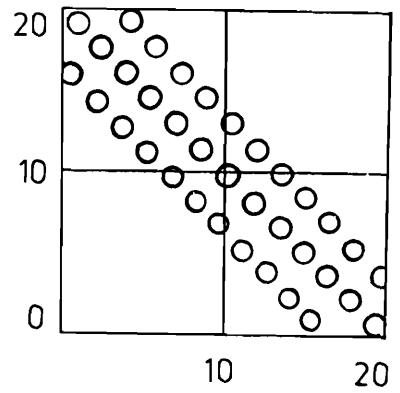


fig.2.

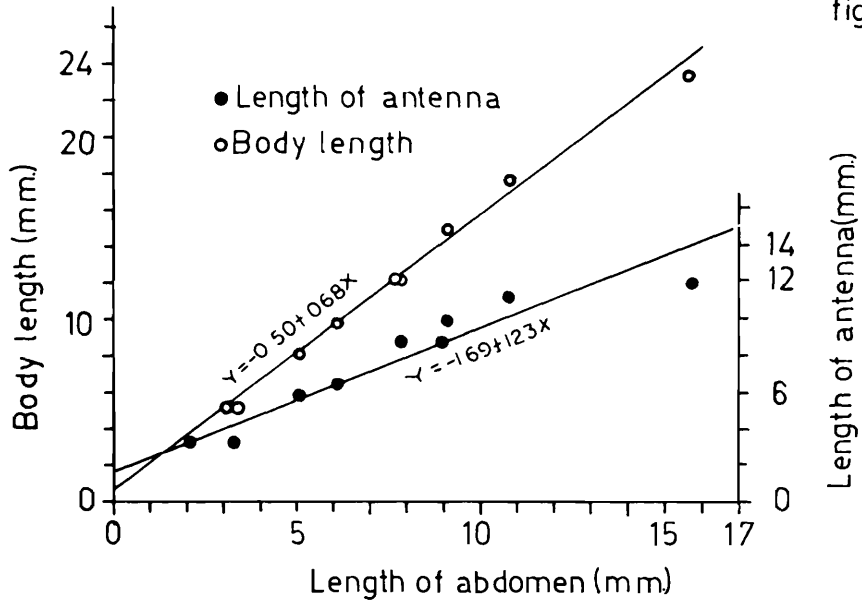


fig 6.

Absence of Correlation

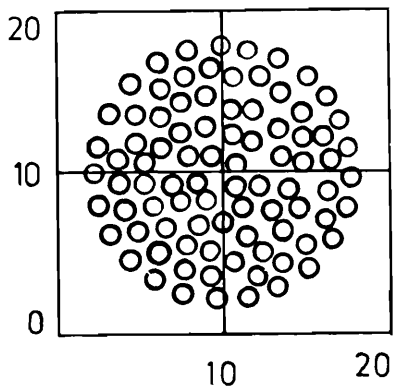


fig.3.

Perfect Positive Correlation

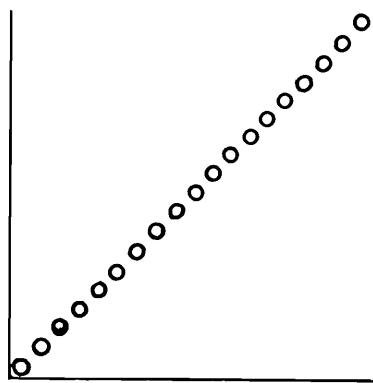


fig.4.

Perfect Negative Correlation

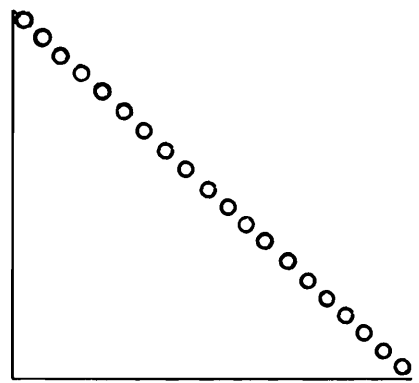


fig.5.

COLLECTION, PRESERVATION AND IDENTIFICATION OF WATER MITES

A.K. Sanyal

INTRODUCTION

The acari constitute an important animal group distributed from polar region to highest altitudes and with its very different ecology, it has a prospect of playing significant role in national economy. The Hydracarina, a group of acari which live in water commonly known as water mite, constitute an important group of aquatic organisms and are occasionally encountered as planktones. They are usual inhabitants of freshwater lakes and ponds, rivers, streams and ditches. Some groups viz., Pontarachnids and Halarcarids are permanent inhabitants of marine environment. Hydracarina are known from all major land masses except antarctica.

Most of the water mites are parasitic in habit. The adults of some water mites are parasitic on the gills of freshwater mussels and snails. The larvae are parasitic on various groups of aquatic insects as well as on some vertebrates, e.g. Chelonia. Fishes are also parasitized by mites. Hydrozetes lacustris parasitises the skin and gills of fish. It mainly attacks fry and is also a pest of spawn.

COLLECTION

A number of methods are in practice for collection of water mites and the choice of the method depends upon the nature of investigation to be done.

The following methods are commonly used for collection of water mites.

Handpicking: The parasitic water mites can be collected directly from the host with the help of fine brush.

Dipping: This method is most frequently used for collection of water mites. The collecting tools like white enamel bowl and wide mouthed pan with long handle are immersed in water and lifted with water with a quick movement. The water sample is then observed under binocular microscope and the mites are collected in preservative.

Netting: Nets are very useful tools for collecting free living water mites. The visible water mite can be scooped up with the help of a small net made from an iron ring to which a narrow mesh

nylon bag is attached. Another type of net, the Birge net, is also used for collection. A fine mesh nylon net and a fine sieve is fitted with the wider mouth of a funnel. The narrow end is open and a long wire is attached to this end which helps to pull the net in water. The collected materials are sorted out and mites are collected in preservative.

PRESERVATION

The water mites collected for taxonomic studies should not be preserved in alcohol or formalin. Alcohol and formalin make the specimens brittle and these chemicals fix the muscles and other tissues for which preparation of a perfectly cleared slide takes long time. To avoid this problem a glycerine - acetic acid - water mixture commonly known as Koenike's fluid is normally used by the workers. This preservative successfully fix the internal structures and makes the specimen perfectly preserved. The mixture is prepared by using Glacial acetic acid - 10 parts, Glycerine - 45 parts, Water - 45 parts.

CLEARING

The optical study requires clearing of preserved specimens for high degree of transparency. This is accomplished by using some clearing agents. If the mite is preserved in Koenike's fluid the specimen should easily be cleared by use of either an basic or acid corrosive.

Basic corrosive: The most effective basic corrosive is potassium hydroxide in a 5-10% solution. Generally it does not destroy the colour pattern of the specimen. KOH solution is to be taken in a 3-4 mm deep watch glass in which the specimen is transferred with the help of 'bent' tools. Due to osmotic differences the body of the mite will swell and the legs distended. After the legs are properly distended a cut is made on the side of the body with the microscalpel and runs along the periphery in a soft bodied mite. But in case of heavily sclerotized specimen the microscalpel is inserted in the dorsal furrow and the specimens is kept in the solution for not more than two hours. Otherwise the cuticle may be damaged.

Acid corrosive: This is usually known as Andre's fluid. It destroys the colour pattern immediately. But the great advantage of this solution is that the specimens may be kept in the solution for a long period without damage to the cuticle. It is prepared by mixing equal parts by weight of Glacial Acetic Acid, Chloral Hydrate and Water.

If, for any reason, the specimen is preserved in alcohol or formalin it should be cleared in a solution of lactophenol or lactic acid. The lactophenol is prepared by mixing Lactic acid - 50 parts, Phenol crystal - 25 parts, Distilled water - 25 parts. A week or more is required for clearing in lactophenol at room temperature. The process may be accelerated by gentle warming of the material.

MOUNTING

Temporary mounting: The temporary mounting is done by transferring the cleared specimen in a drop of lactic acid on a slide, oriented and covered with a suitable coverslip. If necessary, the specimen may be placed in any position simply by movement of the coverslip. It is necessary to transfer the specimen into preservative after study and store with proper label in a safe place.

Permanent mounting: As the mites are to be dissected for identification at the species level, it is necessary to orient the dissected parts in a suitable mounting medium on the slide. Glycerine jelly is probably the best mounting medium for permanent preparations. There is more than one method of making glycerine jelly slides but the most successful one is double cover slip method. In this method the cleared specimen is transferred to a water bath for removing clearing agents and then into glycerine. It is better to mix the glycerine with an equal volume of water as direct transfer of specimen to pure glycerine may cause distortion in weakly sclerotized mites. After introducing the specimen, the excess water can be evaporated off.

The mite is then taken out from glycerine and placed on a 12 mm cover slip for dissection of different parts *viz.*, dorsum, venter, legs, palps and chelicera. Sufficient glycerine will be added to the cover slip to prevent drying of the parts. Next glycerine jelly is placed on the coverslip containing dissected specimens. After sometimes additional glycerine jelly is added and while the second application of glycerine jelly is still soft, a 22 mm round cover slip is carefully placed on top. This double cover slip preparation is then transferred to a dustfree cabinet with the larger coverslip down for two or three days of drying. The final step is to place pure canada balsam on a slide and place the double coverslip preparation in it. During this preparation minimum amount of glycerine jelly is to be used for study under oil immersion lens.

Polyvinyl alcohol (PVA) and Hoyer's mounting media may also be used for mounting the water mites.

TERMINOLOGY USED IN IDENTIFICATION

A general knowledge of terminology used in describing water mites is essential for identification. The terms for body regions such as gnathosoma, idiosoma, etc. so commonly used in terrestrial acarina, are rarely assigned in the adults of water mites. The names of the leg segments also differ in both the groups. The coxae in water mites are usually greatly flattened and expanded which looks like body sclerites. The leg is indicated by a Roman numerical and leg segment by an Arabic numeral. So the second segment (basifemur) of the first leg would be designated I - Leg-2, would be IV - Leg-6. The palp of water mite is five segmented and designated as P-I, P-II, P-III, P-IV and P-V.

The terms very often used in describing water mites are given below:

Acetabular Plates - Sclerites associated with the genital field which bear the genital acetabula.

Acetabulum (Acetabula) - Minute cup-like structures on the genital field.

Antagonistic Bristle - A thickened seta present on the dorsoventral portion of the fourth segment of an uncate palp.

Body pores - Small semicircular areas of thin integument in sclerotized water mites.

Dorsal furrow - The narrow area of soft integument separating the dorsal and ventral shields.

Epimeroglandularia - Two parts of glandularia closely associated with the coxa.

Genital Flaps - A pair of movable sclerite which cover the gonopore when closed.

Glandularium (Glandularia) - A pair of special gland associated with seta.

Pharynx - The heavily sclerotized ventral portion of the pharyngeal pump.

Polyacetabula - When numerous pairs of acetabula are present.

Postocularia - The most posterior two pairs of seta with their associated setal bases, located in the anterior portion of the dorsum.

Swimming Hairs (Swimming Setae) - Long hair-like setae attached to the distal parts of the leg.

Uncate - A condition in which the ventral portion of the fourth segment of the palp is greatly expanded and the fifth segment is able to fold against this expanded portion.

For details Cook (1967, 1974) may be consulted.

KEY TO THE FAMILIES OF WATER MITES FROM INDIA

1. Genital acetabula absent 2
 Genital acetabula present 3
2. Posterolateral extension of suture lines between third and fourth coxae or more or less laterally placed Hydrovalziidae
3. Palp chelate, with P-I comparatively long and P-IV shorter than P-III; chelicera one-segmented and lying in a long rostrum; more or less heart-shaped genital field, with most acetabula lying anterior to gonopore Hydrachnidae
 Palp either not chelate or if chelate P-IV is longer than P-III and P-I is shorter than P-II; chelicera two segmented 4
4. Mouth opening surrounded by a large circular, membranous fringe; lateral eyes, if present, incorporated into a median anterior sclerite; palps not chelate 5
 Mouth opening either with only a very small membranous fringe or none; lateral eyes, if present, not incorporated into a median anterior sclerite; palps may or may not be chelate 6
5. Eye plate typically as wide as or much wider than long; third and fourth coxae narrowly joined medially on their respective sides Eylaidae
 Eye plate much longer than wide; third and fourth coxae broadly joined Limnocharidae
6. Palp chelate, with dorsodistal portion of P-IV extending far beyond insertion of P-V; lateral eyes widely spaced on their respective sides; integumental lenses but not capsules present Hydrodromidae
 Palp either not chelate or, if chelate, dorsodistal portion of P-IV extends only moderately beyond insertion of P-V; lateral eyes variable, but not as Hydrodromidae 7
7. Palp typically chelate; or if not chelate, with a heavy seta at dorsodistal or distal end of P-IV and the body soft and greatly elongated or some of the genital acetabula are on long stalks Hydryphantidae

Palp not chelate; if there is a heavy seta dorsally or medially at distal end of P-IV, body is not greatly elongated and the acetabula are not stalked 8

8. Genital acetabula located very close to each other in two medial rows (rarely the posterior acetabula may be shifted laterally); these acetabula typically covered by movable genital flaps, but occasionally the genital flaps show varying degrees of reduction..... 9

Genital field not as described above; if movable genital flaps are present, some or all of the acetabula lie on the flaps..... 12

9. Dorsal and ventral shields present; dorsal shield typically consisting of a large plate and two or four anterior platelets or several peripheral platelets; if only a single dorsal plate is present, an indication that it is the result of fusion of the smaller plates is evident; ventral shield with a Y-shaped suture line extending anteriorly from genital field to tips of first coxae..... *Torrenticolidae*

Not with the above combination of characters 10

10. Suture line between second and third coxae present anteriorly and posteriorly but obliterated in middle; palp of a characteristic shape with a long distoventral seta on P-II and five to seven long setae on medial surface of P-III *Lebertiidae*

Not with the above combination of characters 11

11. Fourth legs with well developed claws; lateral eyes in capsules; a solid ventral shield never present; third pair of acetabula usually not oriented at right angles to other two pairs; if third pair oriented somewhat at right angles to other two pairs, the third pair not as elongated as other pairs *Sperchontidae*

Fourth legs typically without claws and lateral eyes typically not in capsules; four genera, *Bandakia*, *Utaxatax*, *Bharatonia* and *Sigthoriella*, which belong in the present family have well developed claws on the fourth legs; all but *Bharatonia* have solid ventral shields and the third pair of acetabula are placed at right angles to (and are as long as) the other two pairs in the latter genus *Anisitsiellidae*

12. P-II with a single hair-like or peg-like seta on ventral side, this seta either sessile or located on a tubercle of variable length; palps not uncate; claws usually absent from fourth leg; dorsal and ventral shields rarely present Limnesiidae

P-II without a single hair-like or peg-like seta on the ventral side; rarely more than one seta may be present on the ventral side of P-II 13

13. Cheliceral claw with numerous dorsal serrations, in addition to the genital acetabula in the gonopore region there are numerous acetabula lying free on the ventral shield which extend for anterolaterally but these are extremely difficult to see because they are not on acetabular plates and superficially resemble body pores..... Harpagopalpidae

Cheliceral claw not serrate; acetabula usually confined either to gonopore or to acetabular plates flanking the gonopore; in a few instances acetabula are present in both the gonopore and on the ventral shield but on the latter do not extend for anterolaterally and are on recognizable acetabular plates 14

14. Palp uncate; dorsal and ventral shields present 15

Palp not uncate; body varying from soft to heavily sclerotized with dorsal and ventral shields present 17

15. Seven or less pairs of genital acetabula present and these confined to a single row on each side in the gonopore Mideopsidae

Acetabula usually not confined to the gonopore, if acetabula confined to gonopore, they are either in more than one row on each side or more than eight pairs of acetabula are present 16

16. P-II with two well developed setae present ventrally or proximomedially; genital acetabula located in gonopore of male Hungarohydracaridae

Setae on P-II variable but not as described above; no acetabula present in the male gonopore; genital acetabula usually extending well laterally on distinct acetabular plates in both sexes..... Arrenuridae

17. Body laterally compressed and noticeably higher than wide; dorsum with a narrow median strip of soft integument which may contain small sclerites Aturidae

Body not laterally compressed; if body is heavily sclerotized, there is not a narrow, median unsclerotized strip..... 18

18. Fourth coxae bearing a pair of glandularia; usually soft bodied; if dorsal and ventral shields are present there is usually a down turned seta at distal end of I-leg - 5Hygrobatidae

Fourth coxae lacking glandularia 19

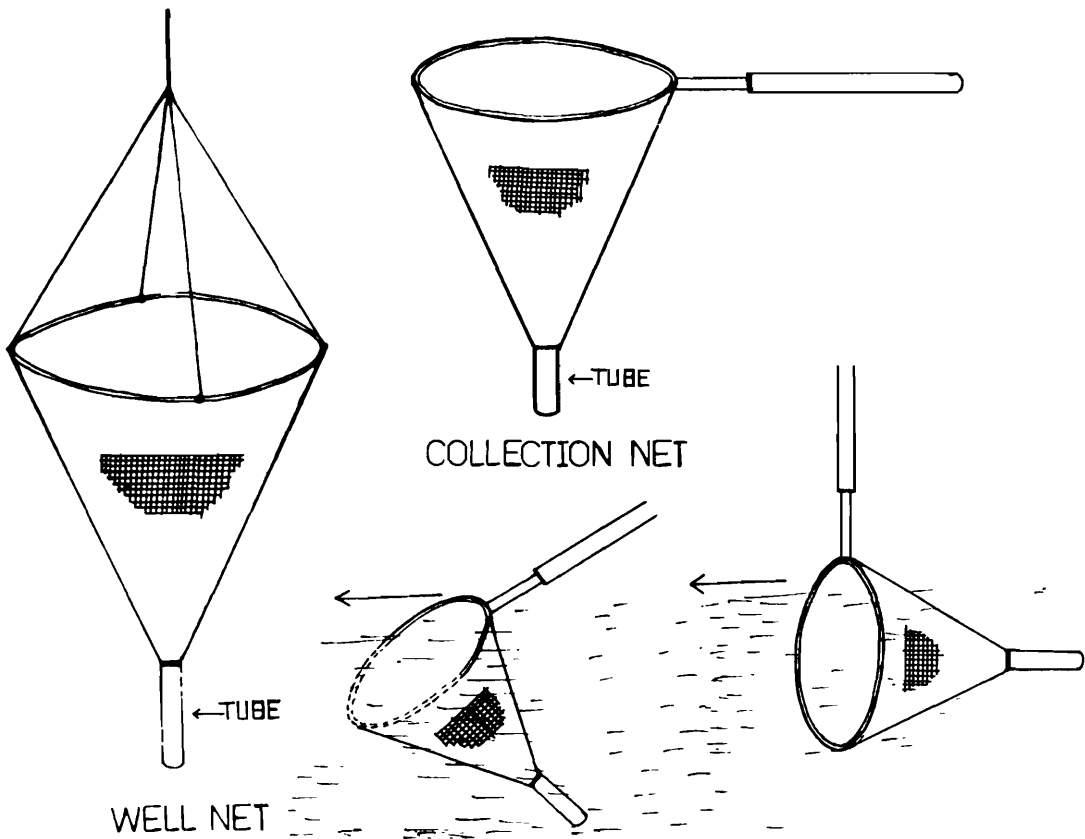
19. Dorsal and ventral shields present; genital acetabula numerous (more than 10 pairs) and either IV-leg - 4 concave on one side and contains numerous peg-like setae or median surface of P-IV with a peg-like seta at distal end and there are no well developed projections associated with insertions of fourth legs Pionidae

Soft bodied or with scattered sclerites, but distinct dorsal and ventral shields are absent; peg-like seta of P-IV, if present, variable in position, but often ventral or distoventral; posterior margins of fourth coxae more or less truncate or rounded Unionicolidae

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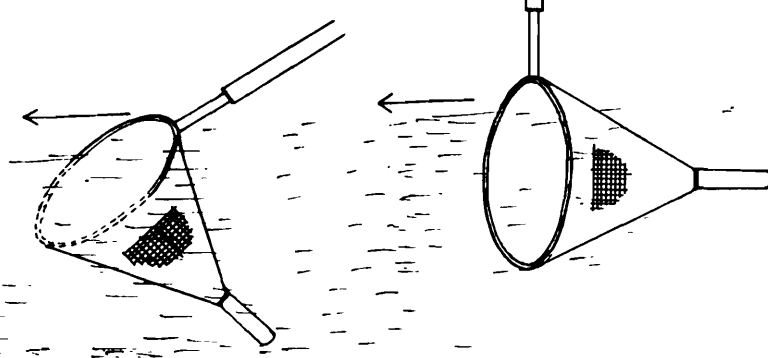
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PLATE I

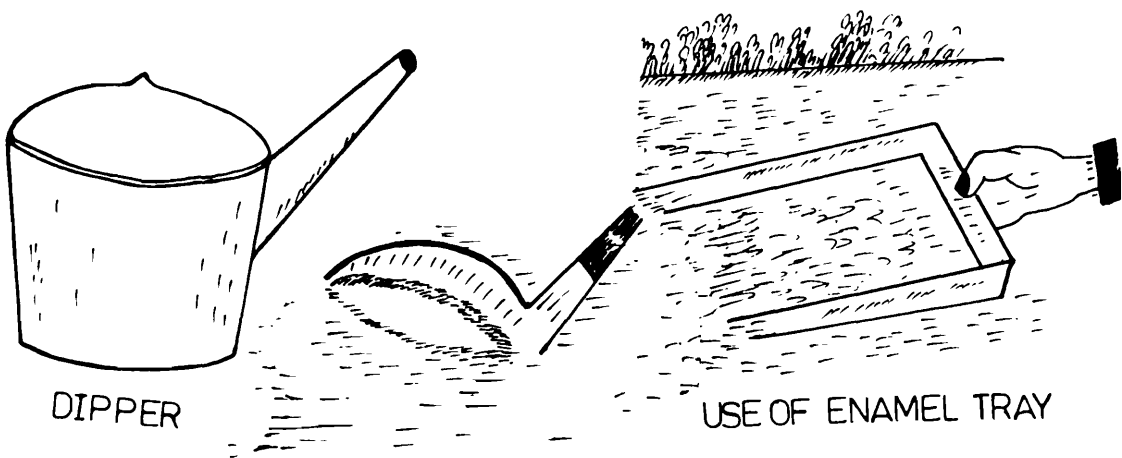


WELL NET

COLLECTION NET



CORRECT METHOD OF USE INCORRECT METHOD

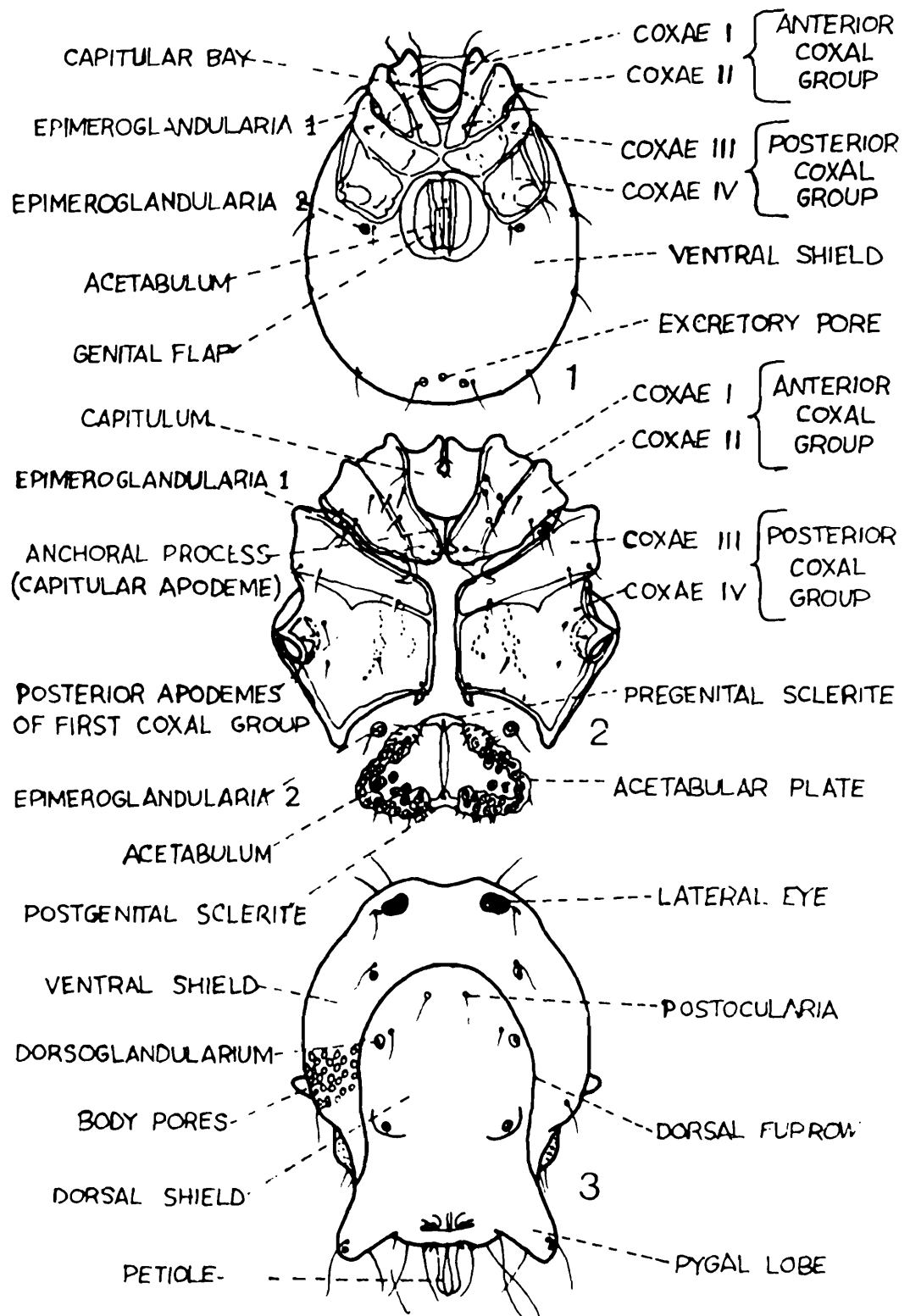


DIPPER

USE OF ENAMEL TRAY

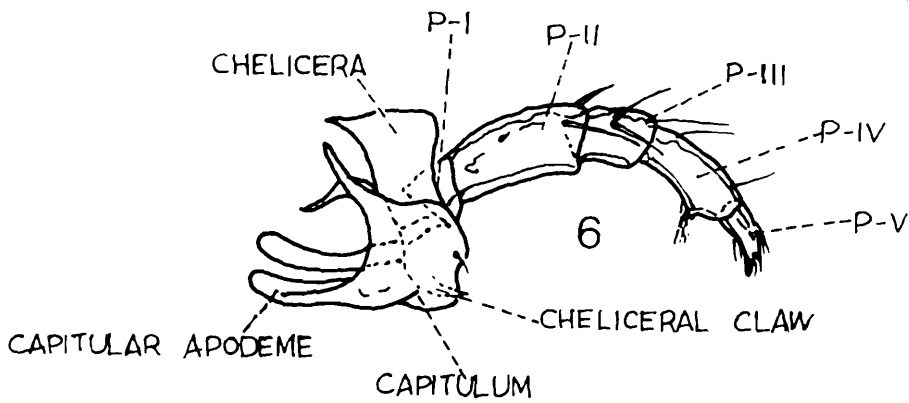
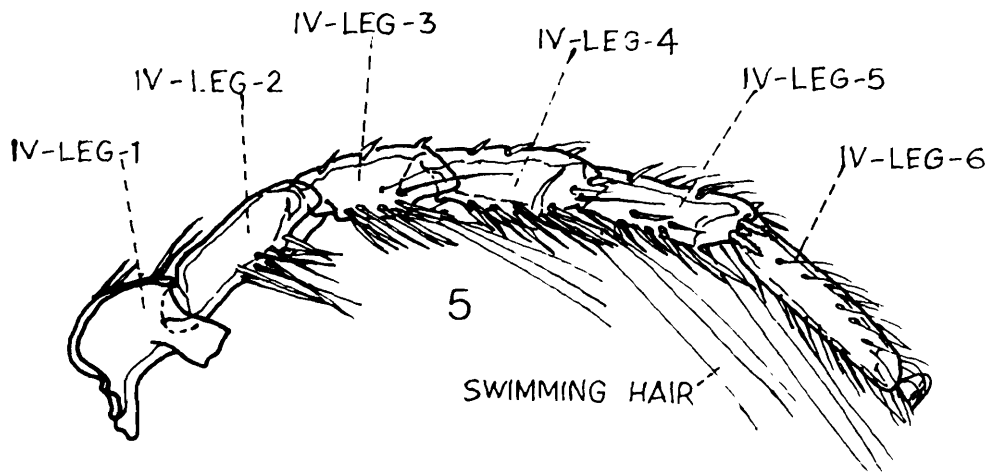
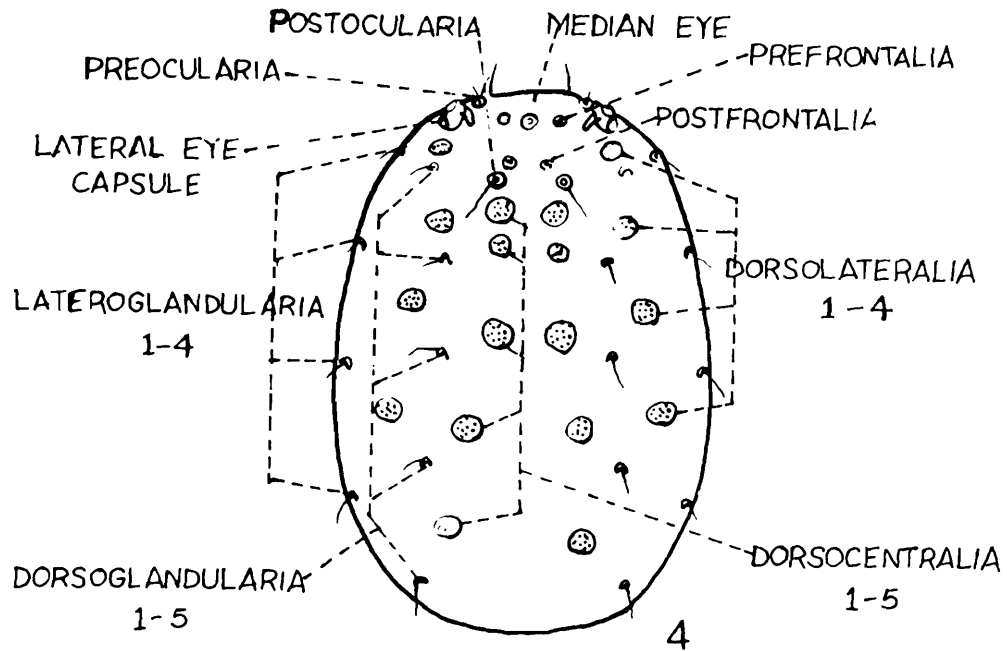
USE OF DIPPER

PLATE II



Figs. 1—3. Body Parts of Water Mite: 1, Platymamersopsis mysorensis (ventral view female); 2, Piona mahisa (ventral view); 3, Arrenurus pseudoaffinis (dorsal view).

PLATE III



Figs. 4-6: 4, *Thyas pachystoma* (dorsal view); 5, Fourth leg of *Bharatohydracarus imamurai*; 6, Lateral view of mouthparts (*Koenikea concava*).

COLLECTION, PRESERVATION, REARING AND IDENTIFICATION OF ORIBATID MITES

A.K. Sanyal

INTRODUCTION

Among the arthropods commonly inhabiting the soil, mites appear to be predominant and of these oribatids are more common and important from an ecological point of view. Oribatid mites form a complex group of the order Acarina, frequently designated as "beetle" or "moss" mites. These mites occur predominantly in soil, litter, humus and compost heaps. They are also found in other habitats like tree trunks, moss, lichens, etc. These mites are responsible for promoting soil fertility through decomposition of organic matter (Murphy, 1955). Some of them are now used as biological control agents particularly of water hyacinth (Cordo and DeLoach, 1975, 1976) and soil nematodes (Rockett and Woodring, 1966). They are also responsible for disseminating plant viruses such as root rots and produce injury to plants by inoculating fungal diseases (Jocot, 1930). Some of these mites also act as intermediate hosts of tapeworms of domestic ruminants (Anantharaman, 1951). Oribatid mite complexes have been identified as the soil type bioindicators of different ecosystems (Popp, 1970; Krivolutskii, 1976).

COLLECTION

A number of methods are in practice for collection of oribatid mites but the choice of the method of collection and extraction of samples depend upon the aim of the investigation. Two probable approaches of study have been suggested viz., i) community and ii) trophic.

Community Study

In community approach the main emphasis is given on the qualitative analysis of the community involving comparisons between species lists. Both direct and indirect methods are followed for this study.

Direct methods: Oribatid mites may be collected directly from soil, litter, plant, moss, lichen, etc. A small portion of sample is taken on white enamel tray, examined with 10x lens or stereo-binocular microscope and the specimens are picked up with the help of a fine brush moistened with alcohol. In this way specimens can also be collected directly from plant.

Aspirating - This method is more or less similar to the first method but here aspirator is used instead of brush and aspirating helps to collect specimens directly into the collecting tube.

Beating - A large petridish with 70% alcohol is placed under the selected part of the plant or litter and these are beaten gently. The specimens will fall inside the petridish and these may be collected with the help of a fine brush.

Indirect method: This method can be divided into two steps viz., sampling and extraction.

Sampling: The soil samples rich in organic matter and litter or plant material may be collected in polythene bags. It is desirable not to take too much of samples in one bag. The mouth of each bag containing samples supersaturated with moisture should be kept open intermittently. Otherwise, the mites may get trapped in the accumulated water droplets on the wall of the bag and die.

Extraction: Two main methods of extraction are recognised viz., i) The "behaviour" methods in which animals are induced to leave the sample by attractant or repellent stimuli and ii) the "mechanical" methods by which animals are removed as a result of differences in physical properties from the surrounding medium.

Although a number of behaviour methods have been devised but most of the Zoologists have been using the Tullgren funnel apparatus for extraction. The funnel made of glass or galvanized sheet is fitted on a stand and a fine gauged (1.5-2.5 mm) sieve is placed within the funnel. A 40 W electric bulb with reflector is fitted over the funnel. the funnel leads into a glass tube containing 70% alcohol. The soil, litter or plant parts are put into the funnel and the light is switched on. The duration of extraction period is 2-4 days depending upon the amount of moisture present in the sample.

In mechanical separation methods the powers of movement of the animals are ignored so that immobile stages such as eggs, egg capsules and pupae may be extracted and indeed there is no other way of extracting them apart from waiting for them to hatch into mobile stages. Fluids of different densities can be used so that bodies of corresponding densities also come to rest at definite boundaries or difference in rates of sinking can be exploited to achieve separation. Among different methods devised by Ladett (1936), Lange et al. (1955), Raw (1955) and Kuhnelt (1976), the most satisfactory one is Ladell's floatation method.

Trophic study

In trophic approach a greater range of related species is encountered and distinctions between them are often critically important in detecting changes in community composition. This study requires more accuracy in collection and for this only indirect method is followed.

Sampling - Soil oribatids are collected with the help of a soil corer which helps to maintain a definite sample size. The corer is pushed down the soil and lifted with the help of a sampler holder. For collection of mites from litter a wooden rectangle is placed and litter is collected from the area surrounded by the rectangle. The surface area and depth also should be recorded.

Extraction - Oribatid mites can be collected through Tullgren funnel apparatus or floatation method (mentioned above). The cores containing sample should be placed upside down on the sieve within the funnel.

Live mites can be collected through Tullgren funnel where instead of alcohol water or moistened filter paper is used in the collecting vessel.

PRESERVATION

The mites can be fixed and preserved in 70% alcohol to which few drops of 5% glycerol may be added to prevent evaporation of alcohol. Oudemans' fluid (Glycerol 5 parts, 70% alcohol 87 parts, Glacial acetic acid 8 parts) is a good preservative when prolonged preservation is needed. The vials containing specimens should be plugged with cotton or corks and kept in wide-mouthed jars also filled with alcohol.

CLEARING

The optical study requires clearing of preserved specimens for high degree of transparency. This is accomplished by the use of some clearing agents. The most popular clearing agent is lactophenol, which is prepared by using Lactic acid - 50 parts, Phenol crystal - 25 parts, Distilled water - 25 parts.

A week or more is required for clearing in lactophenol at room temperature. The process may be accelerated by gentle warming of the material.

Another good clearing agent is Vitzthum's fluid and is prepared with Chloral hydrate - 10 parts, Phenol - 9 parts, Distilled water - 1 part

The heavily sclerotized oribatid specimens can be cleared by keeping them in equal mixture of 90% alcohol and lactic acid in a small vial. The vials are kept open, at room temperature, in dust proof cabinets. The alcohol soon evaporates and the mites remain in lactic acid. Mites become transparent within 2-10 weeks.

MOUNTING

The permanent closed mounting is not suitable for oribatid mites. The temporary open mount is made by transferring the preserved specimen in a drop of lactic acid on a cavity slide, oriented and covered with a suitable coverslip. The mite may be manipulated into any position by movement of the coverslip. Having finished the study the specimen is transferred into preservative and stored with proper label.

Permanent mountings are, however, useful to the soil ecologists as they need ready reference collections for comparative study. The following two mounting media are widely used.

	Berlese (Hoyer)	Evans
Distilled water, ml	50	50
Chloral hydrate, g	200	50
Glycerol, ml	20	20
Gum arabic, g	30	30

The ring of the coverslip should be sealed by nailpolish in order to prevent taking up of water from the atmosphere by the mounting medium.

REARING

The method used in rearing must provide required humidity along with convenience of microscopic examination. The most widely used system employs glass or plastic cells with a mixture of plaster of Paris and activated charcoal substrate on which a suitable food material is placed and water is added intermittently to maintain the required humidity. Many workers used moistened filter paper on the floor of the cell instead of plastercharcoal mixture. For details a reference to Evans et al. (1961) is suggested.

IDENTIFICATION

The Cryptostigmatid mites or oribatid mites are placed as a suborder under the order Acarina (Arthropoda : Arachnida). The suborder can be separated from other suborders by the presence of following characters:

Generally strongly sclerotized mites; almost always with a pair of sensory organs (pseudostigmatic organs) inserted in a cup-shaped pseudostigmata on the propodosoma; tracheal system, when present, opening through the pseudostigmata or in the acetabular cavities of legs I and III; usually with three pairs of genital "discs" flanking the genital aperture; both genital and anal apertures are covered by pair of plates.

For an assessment of the taxonomic features useful in species determination, an idea of the external morphology appears vital and for this the important characters for identification of oribatid mites are described here.

The body of oribatid consists of an anterior propodosoma comprised of head and throax and a posterior hysterosoma being comprised of abdomen. The dorsum of propodosoma and hysterosoma is named as prodorsum and notogaster respectively.

The propodosoma can be movably articulated or sometimes folded like the blade of a penknife to the hysterosoma or it may be immovably fixed to the hysterosoma. There are 4-6 pairs of setae on the prodorsum. The propodosoma is separated from the notogaster by a suture, sutura dorsosejugal. Occasionally it may be interrupted at middle or completely absent. From the base of the prodorsum and towards the rostrum there usually remains on either side an appendage called lamellae. Sometimes this may be ill-developed in the form of narrow rib called costula. Frequently the apex of lamellae are connected by a narrow transverse ridge called translamella. The apical portion of the lamella is named as cuspis. Near the basal and lateral sides of the propodosoma usually a cup-shaped structure, bothridium is found. From the bothridium originates an organ named sensillus which is of variable shape.

The ventral side of the propodosoma bears gnathosoma or capitulum, epimeral or coxisternal plates and legs.

Hysterosoma

The notogaster is usually undivided but may be divided into 1-4 parts by transverse sutures. In primitive oribatids generally 16 pairs of notogastral setae are present. Higher oribatids generally possess 10 pairs of setae, sometimes the number may be upto 14 pairs or may be less than 10 pairs or may be 35-36 pairs or occasionally extremely reduced to alveoli. Sometimes especially in primitive oribatids, there appears numerous setae of different shape on the pygidium called pygidial neotrichy. Notogaster bears some paired larger openings called areae porosae. Sometimes another type of slit-like or dot-like openings are found on notogaster, these are called sacculi or pori.

Antero-laterally on the notogaster in higher oribatids, appears a characteristic wing-like appendage, the pteromorpha.

The ventral side of the hysterosoma may be uniform or divided partly or completely by parabolic or semicircular or straight transverse suture. The anterior half bears the genital plate and the posterior half, the anal plate. These two plates may occupy the entire length of the ventral plate (Macrophyline type - characteristic of primitive oribatids) or more or less circular or narrowly triangular and usually set apart (Brachypyline type - characteristic of higher oribatids).

In primitive oribatids the genital plate may be divided by transverse suture or may be undivided. The genital setae usually 4-6 pairs, sometimes increasing to 18-20 pairs or reduced to only 1 pair.

In some oribatids an unpaired preanal plate lies in front of the anal plate. The anal plates are joined by an adanal plate. The anal and adanal plates bear setae.

KEY TO THE MAIN GROUPS OF ORIBATID MITES

1. The propodosoma can be shut back like the blade of a penknife to hysterosoma; genital and anal plates meeting on ventral side and occupying whole length ...
..... Oribatei Inferiores

The propodosoma can not be shut back like the blade of a penknife to hysterosoma; genital and anal plates usually well separated and not occupying whole length of ventral side Oribatei Superiores.....2

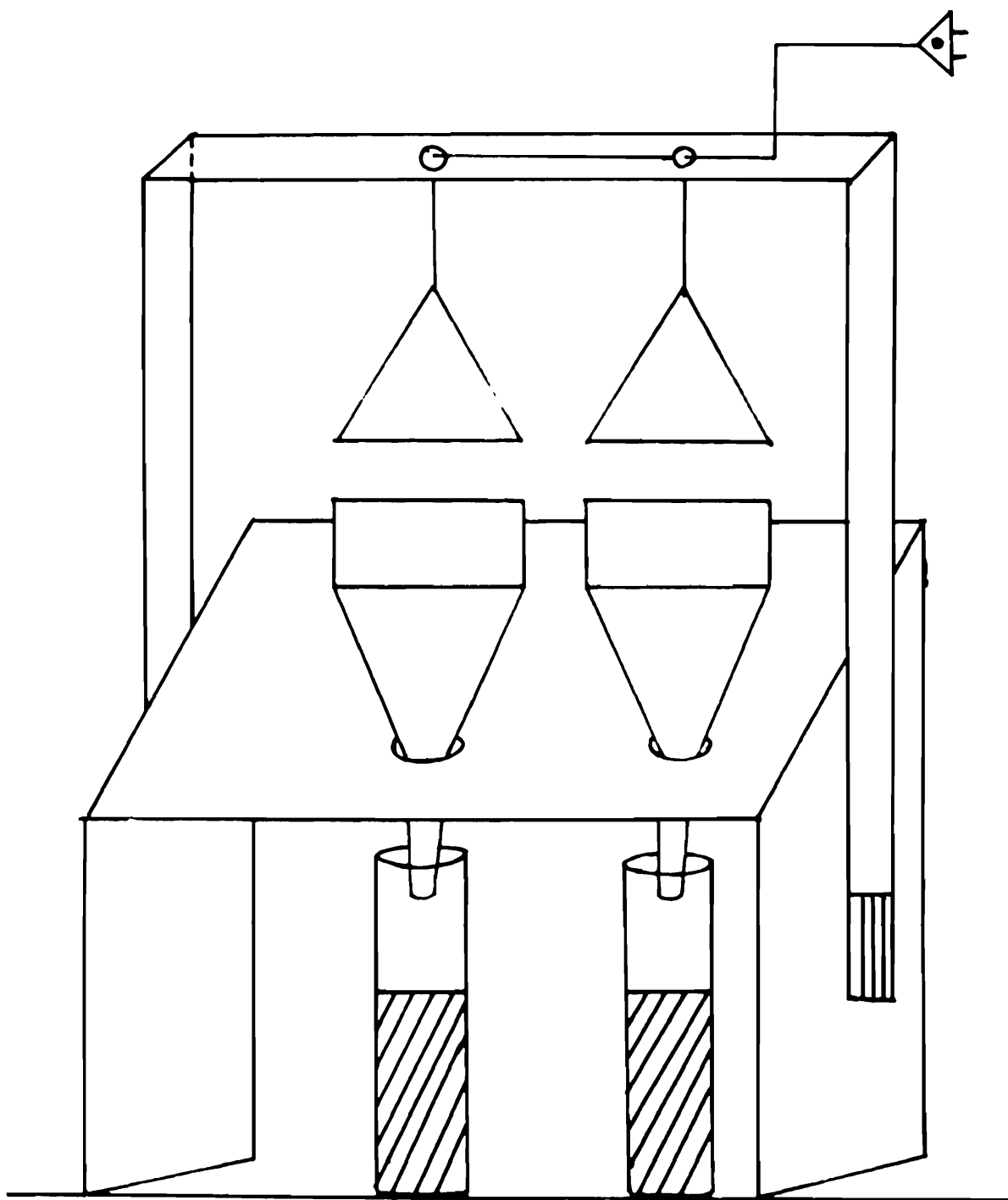
2. With pteromorphae; areae porosae, sacculi, pori present on notogaster..... Pterogasterina-Poronota

Without pteromorphae; areae porosae, sacculi, pori absent on notogaster..... Apterogasterina-Gymnonota

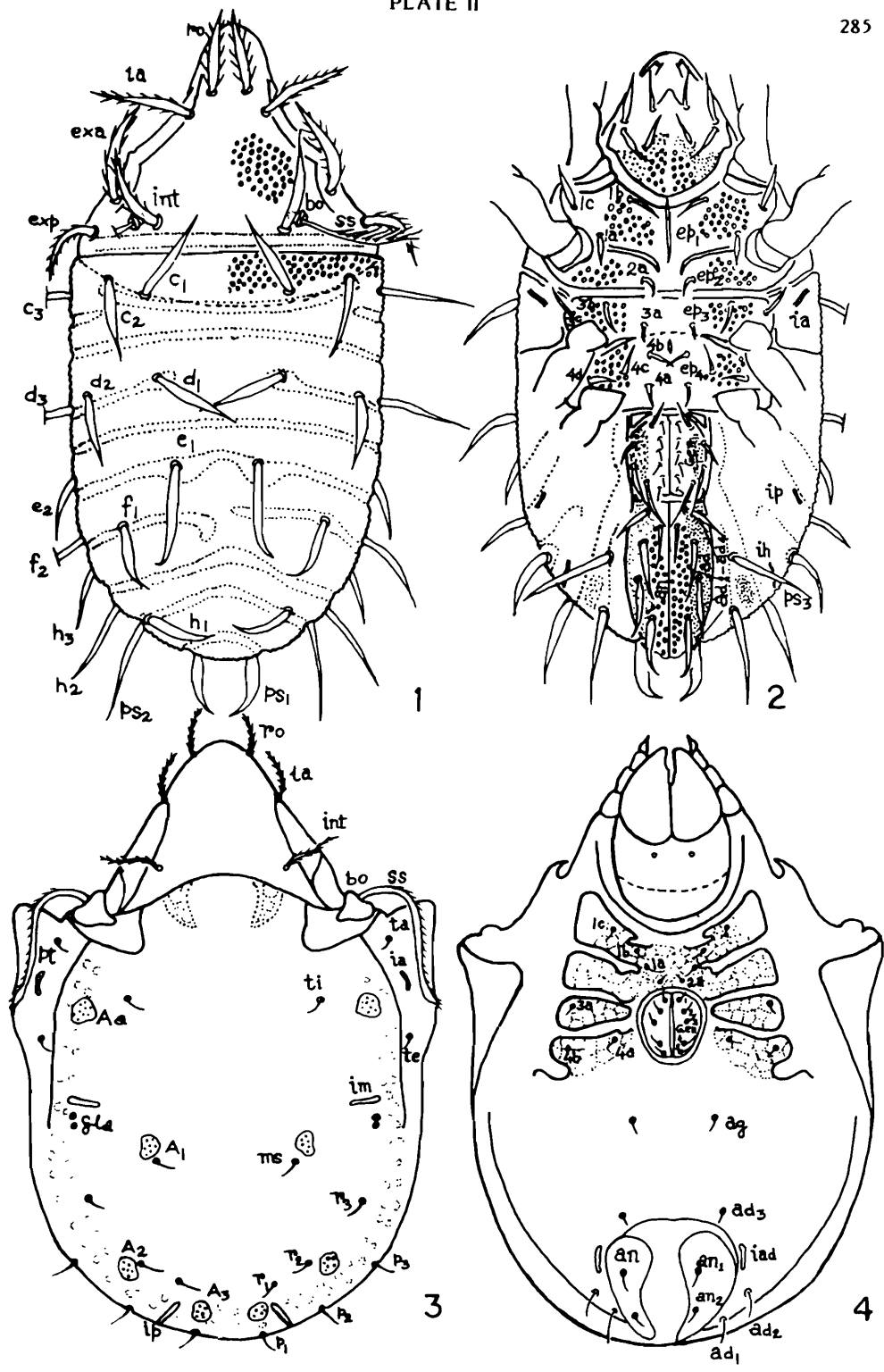
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MODIFIED TULLGREN FUNNEL



Figs. 1-4. External Morphology of Oribatid Mite: 1, primitive oribatid (dorsal view); 2, primitive oribatid (ventral view); 3, higher oribatid (dorsal view); 4, higher oribatid (ventral view), ro-rostral setae, la-lamellar setae, exa-anterior exostigmatal setae, exp-posterior exostigmatal setae, int-interlamellar setae, bo-bothridium, ss-sensillus, c₁, c₂, c₃, d₁, d₂, d₃, e₁, e₂, f₁, f₂, h₁, h₂, h₃, ps₁, ps₂, ps₃, ta, te, ti, ms, l₁, l₂, l₃, l₄, -notogastral setae, Aa, A₁, A₂, A₃, -sacculi, ia, im, ip, ih, iad -pori, gla-opening of glandulae, ep₁, ep₄ epimeral plates, la 4d-epimeral setae, gen-genital plate, an-anal plate, ad-adanal plate, ad₁ -ad₄ adanal setae, ag-aggenital setae.

COLLECTION AND PRESERVATION OF MITES

S.K.Bhattacharyya

Mites are joint-footed animals and belong to the phylum Arthropods, class Arachnida, subclass Acarina. Arachnids differ from other arthropods in the absence of antennae and in having mouth parts consisting of chelicerae and pedipalps instead of mandible and maxillae. Acarina differs from other Arachnids in that they show very little body segmentation, abdominal segmentation is inconspicuous or absent.

The mites are widely distributed and have agricultural medical and veterinary importance. Phytophagous mites are of particular importance because it attacks a great number of economic crops. Heavy infestations cause spotting of leaf, leaf curling, leaf fall, etc. Some phytophagous mites are also known to carry plant viruses (Slykhuis 1963). Several parasitic mites are vectors of pathogenic organisms viz. protozoa, bacteria, viruses, etc. The house-dust mites causes asthma and allergic reactions of different types in man (Spieksme and Spiekama-Beezeman 1967). The food grains, flour infested by mites may become toxic to man and domestic animals. Some mites when consumed with food cause intestinal and urinary afflictions in animals and in more serious cases cause abortion and paralysis. (Speransky 1971). A few soil inhabiting species are not parasitic, but act as intermediate hosts of cestodes parasitic in domestic animals. Several parasitic acarina do harm directly by feeding on blood or by making injury to the skin of the hosts, etc.

COLLECTION

Most phytophagous and predacious mites live on shrubs, herbs and trees. They are found on the undersides of leaves, leaf axils, stipular axils, etc. The clover mite is remarkable because it is found both on the foliage and on the woody parts of the tree. Some occur in crevices on the stems, in buds, bulbs and galls.

Other parasitic acarina occur on plumage, pelage, hair follicles, skin, beneath epidermal scales of legs, respiratory passages, air sacs, body cavity, the surface of the liver, frontal sinus, etc. of snake, birds and mammals. Parasitic acarina infect a wide range of organs and a thorough examination of host is needed for their collection.

A number of collection techniques of parasitic acarina have been developed from time to time. The choice of collection technique depends upon the aims of its investigator. Some of the collection techniques which are often used are given below.

Hand Picking Phytophagous and predacious mites may be individually picked upon by a fine brush moistened with water or alcohol. Minute mites as eriophyids can be collected by examining plant parts with 10X hand lens and placing infested plant parts in a vial containing 70% alcohol. For gall inhabiting mites, galls are first carefully opened up for collection.

Many ectoparasitic acarina are collected either by direct examination under binocular microscope or by keeping the host for 2-4 days in a screen cage over a pan of water. As many parasites are not obligate, they will drop from the host after feeding. Parasites can also be collected by combing carcasses over a polythene sheet or a white enamel dish. Chiggers infested skin pieces may be placed in water in cavity blocks or pinned to the cork of 2" x 1" tube, and kept overnight for larvae to detach.

The house-dust mites may be collected by screening centrifuged house dust samples.

Scraping : The infested plant parts or the wound of mammals may be scraped gently with a scalpel, and then examined in water or alcohol for mites.

Beating : Infested leaves may be beaten on a 1/2" mesh screen covering a large enamel tray, for collection of mites.

Flushing : Internasal mites are recovered by flushing nasal cavities with a stream of water under high pressure. Yunker (1961) discussed this technique in detail. The tip of a 20-gauge needle is cut off 2 mm from its base. The end is grounded to a smooth, rounded tip. The dead animal is grasped firmly by the throat, in order to close the trachea and oesophagus. The needle is attached to a 5 c.c. syringe filled with water, and introduced into one of the nostrils. The water is pumped forcibly through one of the nasal passages and is collected as it emerges from the other nostril and mouth. The procedure is repeated 2 or 3 times alternately in both the nostrils. Internasal chiggers, if present, will generally be found in the sediment along with mucous strands and occasionally, blood. Epidermoptid and Speleognathid mites may also be recovered by this method. The latter, being extremely hydrophobic, are nearly always found floating on the surface of the washings.

Autopsy : Splitting of the bill of the dead host between

nares often also facilitates the recovery of mites. The nasal cavities of dogs are examined by sawing transverse sections through the head, oral cavity, frontal sinus. Lung also may be examined for mites.

Heat Desiccation : Feather mites can be collected by spreading the feathers on a fine meshed wire gauze (preferably 2 mm mesh) placed on a funnel, with a over hanging electric bulb to drive parasites by heat and desiccation. A small container is placed below the lower end of the funnel. The container is filled with water if live animals are needed, or by 70% alcohol. Parasites from detritus has to be sorted out under the dissecting microscope. Nidicolous ectoparasites or mites that live in soil and or house dust mites can be also collected by this technique.

Application of Detergents : Ectoparasitic acari may be obtained by submerging the carcasses of birds, small rodents, etc., in detergents like soap and shaken vigorously. The mites leave the host and can be collected from decanted washings.

Application of Acaricides : Insecticides or acaricides such as compounds containing Sulphur, Pyrethrum, systemic insecticides or commercially available "Dry-die", Chloroform, etc., may be applied either directly by spraying or dusting on the host. Care should be taken to protect nose, eyes, and mouth or bill if live host has to be examined. After spray acarina leave the body. The host body can be tapped and mites can be collected either from the cloth on which the hosts are tapped, or from the polythene bag itself.

Dissolution Technique : Parasitic mites may be recovered from the skin of the dead host by Hopkins dissolution technique. Fresh or dried skin pieces should be placed in 5-15% Potassium or Sodium hydroxide KOH or NaOH solution over a water bath, till the hairs dissolve completely in the solution. The contents of the beaker were then filtered while hot, through a fine mesh of stainless steel gauze. The solid residue on the gauze was washed well in to pertridish and examined for parasites. This technique has been modified by several workers. The residue is treated with $ZnSo_4$ soln. Parasites float on the surface of solution and can be easily removed.

PRESERVATION

Preservation in Liquid : Collected mites are preserved in 70% alcohol to which glycerine (upto 5%) may be added to prevent the evaporation. Dried specimens may be preserved by warming in 60% lactic acid.

Temporary Slide Preparation : Prior to examining under microscope, a high degree of transparency in the mites is needed. At first the specimens are directly transferred from the preservative to lactic acid on a slide, orientated and covered with a suitable coverslip. The slide is then placed on a warm plate until the specimen is sufficiently cleared. Heating the specimens in lactic acid reduces the normal opacity of mites and enhances the appendages to extend.

Permanent Slide Preparation : Heinze -PVA mounting medium and Hoyer's medium are found quite satisfactory. The former is more satisfactory in hot and humid climate.

Heinze medium :

Polyvinyl alcohol	10 gms.
Distilled water	40-60 cc
Lactic acid (85-92%)	35 cc
Glycerine	10 cc
Phenol-water solution (1.5%)	25 cc
Chloral hydrate	100 gms

All ingredients must be of highest quality. Water is added to the PVA powder in a large beaker and heated on a water bath. Constant stirring of the mixture is required. The Lactic acid is added after a few minutes. Then glycerine is added and stirred again. The mixture is allowed to cool to lukewarm condition and then Chloral hydrate dissolved previously in the Phenol solution is added. After thorough stirring it is filtered through filter paper. Glass wool filtering is not satisfactory. The filtering will be slow, and may take a day. The Heinze-PVA medium should always be stored in brown bottles. Slide preparations using Heinze-PVA medium need not be heated and should be kept for drying at room temperature. Refractive index of the mountant is 1.515. The slide should be properly labelled.

Hoyer's medium :

Distilled water	50 gms
Gum arabic (crystals)	30 gms
Chloral hydrate	200 gms
Glycerine	20 gms

The ingredients are added in the order shown and prepared at room temperature. After preparing the medium, the preparation should be filtered through clean gauze in order to remove the sediments. The edge of covership should be sealed with gold size, cutex or any other suitable cement.

Both Heinze and Hoyer's media are soluble in water. The mounted specimens can be easily saved and remounted, if needed, by soaking the slide in water.

PRECAUTIONS

Host must be placed in mite-proof containers as soon as collected, so that mites can not crawl from one host to another. When the hosts are transported to the laboratory, care must be taken, that they should not be compressed and for this reason, it is advantageous to pack them in larger boxes. Each host must be kept in a separate container to avoid contamination. Parasites from each host should be kept in separate tubes for studying host specificity. Tubes with collections should be labelled with the name of the host, locality and date, name of the collector, etc. The exact location or micro habitat need to be mentioned on the labels. When the specimens are sent to specialists for identification, they should be in alcohol and not mounted on slides, since the examination often differs from individual to individual, or species to species.

Rearing of mites : Evans et al. (1961) discussed the rearing of various mites in detail. A reference to this work is invited on this subject.

COLLECTION OF TICKS

Flag Dragging : Unattached ticks are collected from vegetation by dragging a flannel cloth of about one meter square. Ticks will adhere to the cloth as it is dragged along.

Hand Picking : Ticks can also be collected from the infested host by means of forcep and brush.

KEY TO THE ORDERS OF THE ACARI

1. Tarsus of pedipalp with one or two terminal claws; hysterosoma with at least four pairs of dorsolateral stigmata Notostigmata
 Tarsus of pedipalp without terminal claw(s), apotele absent or represented by two, three or four-tined claw-like structure near the inner basal angle of the tarsus..... 2
2. Hypostome with recurved teeth; stigmata behind coxae IV laterally above coxae II-III; tarsus of leg I with "Haller's organ" Metastigmata
 Hypostome without recurved teeth; tarsus I without such "Haller's organ" 3

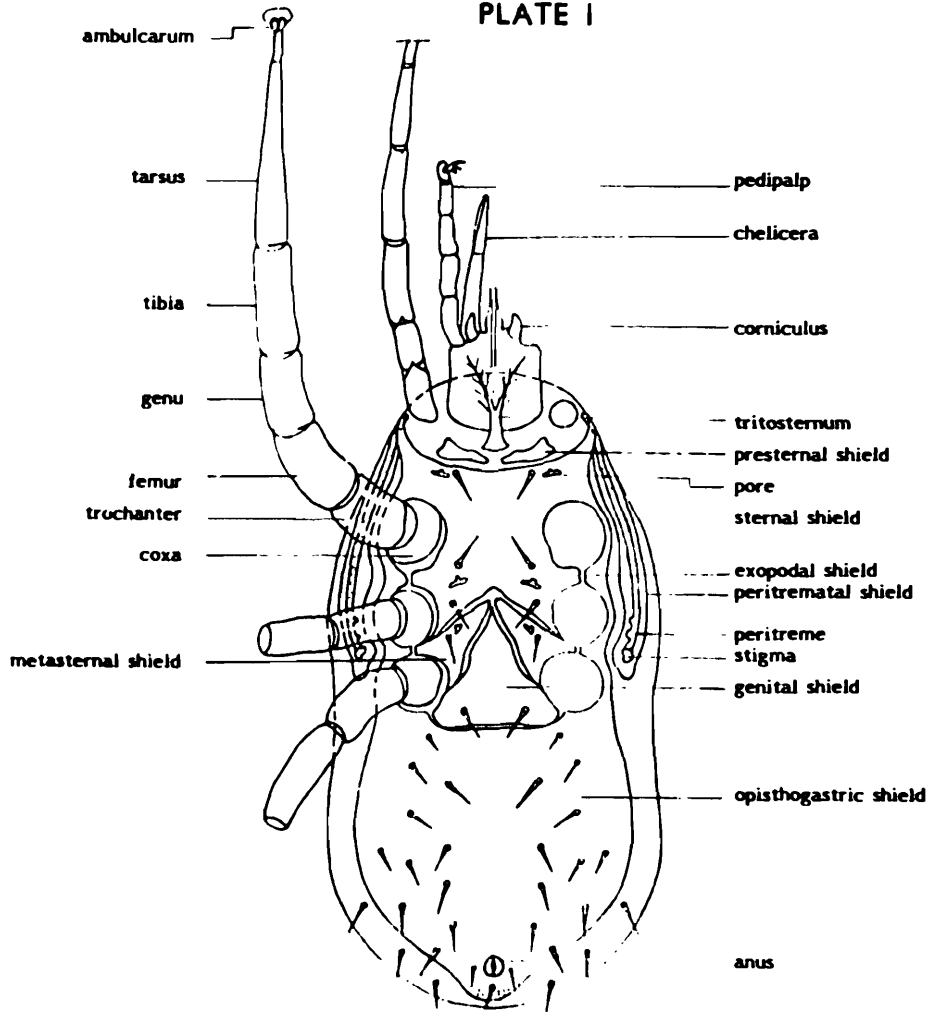
3. Pedipalpal apotele present but rarely absent in endoparasitic forms; stigmata situated lateral to coxae II-IV and one on each side and usually with elongate peritremes..... 4
- Apotele absent; stigmata never situated lateral to coxae II-IV..... 5
4. Hypostome with 3 pairs of setae; tritosternum usually with lacinia or laciniae; anal valves of adult nude or at most with a pair of euanal setae Mesostigmata
- Hypostome with more than 3 pairs of setae; tritosternum markedly reduced or absent, rarely with laciniae; anal valves of adult with many euanal setae..... Tetrastigmata
5. Pedipalps two-segmented; ambulacra of legs comprising a median claw with an associated pulvillus or a sucker-like pulvillus; stigmata and tracheae absent; idiosoma without trichobothria Astigmata
- Pedipalps usually three- to five-segmented ambulacra of the legs otherwise; idiosoma usually with trichobothria 6
6. One pair of propodosomal trichobothria almost invariably present and comprising piliform, barbed or clavate pseudostigmatic organs arising from pseudostigmata; pedipalpal tibia never with a distal spur; tracheal system, when present, opening to the exterior in the acetabular cavities of legs I and II or in the form of "brachytracheae" opening on to legs I and III or the pseudostigmata Cryptostigmata
- Propodosomal trichobothria; when present, usually without conspicuous pseudostigmata; pedipalps various, often with tibia and tarsus forming a "thumb-claw"; tracheae, when present, opening by paired stigmata situated between the chelicerae or on to the dorsal surface of the propodosoma and usually with peritremes..... Prostigmata

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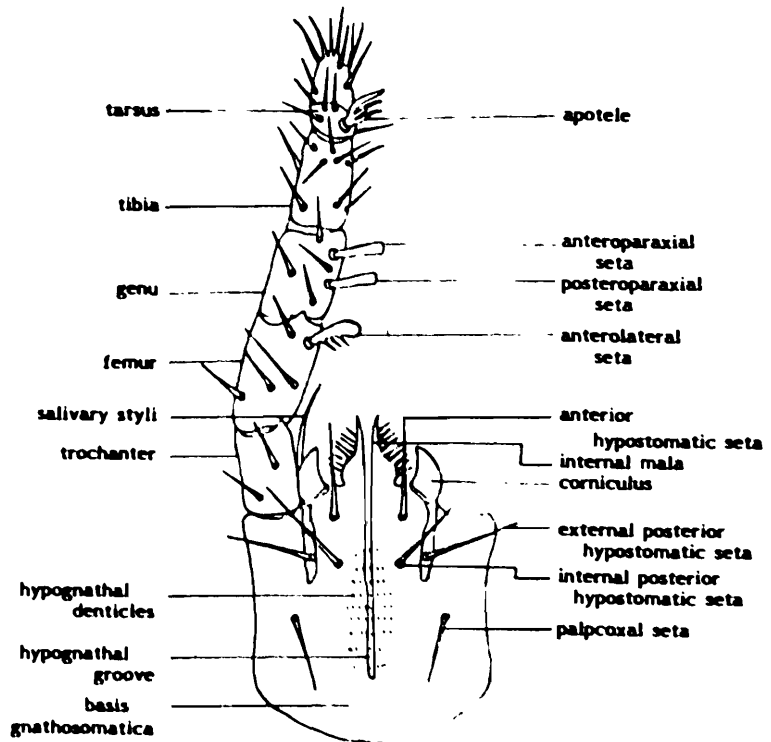
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PLATE I



Venter of a female parasitine mite



Venter of the gnathosoma (excluding chelicerae)

COLLECTION, PRESERVATION, MOUNTING, REARING AND IDENTIFICATION OF PLANT MITES

S.K. Gupta

INTRODUCTION

Mites play important role in agriculture as many species cause direct injuries resulting in malformations and deformations of plants as well as stunting of growth. Some act as vectors of plant viral diseases. All these affect on the yield. Plant mites belong to four major groups, viz., phytophagous (Families : Tetranychidae, Tenuipalpidae, Tarsonemidae, Eriophyidae); predatory (Families : Phytoseiidae, Ascidae), scavengers (Families : Acaridae, Glycyphagidae) and fungivorous (Oribatid mites).

HABIT AND HABITAT

It is absolutely needed to know the habit and habitats of mites before one goes for their collection. The mites on plants are usually found on the undersurface of leaves either in colonies like the spider-mites and false-spider mites or in solitary condition as most of the predatory mites. Majority of the tetranychid mites cover their colonies with webs. The phytophagous mites are normally negatively phototropic and are found on the undersurface of leaves in the angles formed by the mid-ribs and other veins but when the population increases, those may migrate to the upper surface of leaves as well. A good number of mites may be seen in the axils of leaves, flower buds, galls, crevices of stems, under-bark and on twigs.

COLLECTION OF MITES

Several methods are known for collection of plant mites and any of those can be adopted.

Hand-picking: Though it is strenuous but yet sometimes it is profitable as varied groups of plant mites can be collected by this method. The infested leaves are directly examined under 10x lens, if it is in the field, or under stereobinocular microscope, if it is in the laboratory, and the mites are collected with the help of a fine sable-hair brush moistened with alcohol.

Sweeping: Low herbaceous plants, grass land etc. when swept with a butterfly net, a large number of mites will be lodged on the inner walls of the net and those can be picked up with a sable-hair brush moistened with alcohol.

Beating: A white enamel tray with a cotton pad at the inner surface is kept under the portion of the plant from where the mites need to be collected. The plant part is beaten with a wooden rod which will dislodge the mites and those will fall in the tray and get entangled in cotton. Later, those are picked up with a fine brush.

Aspirating: A Singer-type aspirator (Singer, 1964) is quite convenient for collection of plant mites as it helps in collecting the mites from the habitat into the preservative directly, eliminating the necessity of handling the specimens.

Brushing: This is done by holding the leaf between two contrarotating brushes operated by a 6 volt battery. All those mites which will be dislodged will fall on a collecting plastic disc smeared with vaseline. The mites brushed off from the leaves will get entangled into vaseline and can be picked up with a brush. This is a very efficient method and all the stages of mites will be collected in a much lesser time with greater degree of precision. The leaf should be worked forward and backward for a number of times to get better result.

Scrapping and Teasing: Infested plant parts like inflorescence when scrapped or galls when teased gently, the mites come out and can be easily collected.

Special method for collecting gall forming mites and other eriophyids: Gently opened galls are put into an open glass jar and the latter is kept in an airy room away from direct sunlight. The galls start drying and the mites come out and crawl on the inside wall of the glass jar. The inside wall of the glass jar is wiped with glycerol upto 5 cm below the mouth of the jar to avoid escape of mites. Later, previously warmed chloropicric acid is poured over the dried plant part and the cylinder is vigorously shaken. The plant material is then allowed to settle and the liquid containing the mite is poured off into a suitable container and stored.

The eriophyids are best collected by wrapping the infested plant material in a tissue paper and the whole thing is kept in an envelope. The mites are subsequently recovered by simmering the dried plant material in Keifer's preparatory solution which is prepared with the following ingredients:

Resorcinol 50 gms; Diglycolic acid 20 gms; Glycerol - 25 ml;
Iodine enough to produce the desired colour; Water about 10 cc;

When mites are warmed in this medium the mites get expanded and cleared and become suitable for study. In case of leaf vagrants, the infested plant parts are put into a vial (10 cm x 2.5 cm) and the liquid (a thin sorbitol syrup in 25% solution of isopropyl alcohol and Iodine crystals) is put into it after returning to the laboratory. Data are written in the outside wall of the tube.

Heat treatment: A good number of plant mites can also be collected by subjecting the plant material to heat treatment in modified Tullgren's funnel.

Flotation method: In this method leaves plucked in the fields are shaken vigorously in a glass jar containing water and Teepol (a detergent). The mites will be dislodged and then the liquid is filtered. The residue containing mites is washed with alcohol in a cavity block. Instead of water, alcohol (70%) can also be used.

PRESERVATION

The mites are best preserved in ethyl alcohol (70% - 80%). A few drops of 5% glycerol may be added to avoid drying of specimens through evaporation of alcohol. Some workers prefer the use of Oudemans' fluid which is made of the following ingredients. Alcohol (70%) - 87 parts; Glycerol - 5 parts; Glacial acetic acid - 8 parts.

In this preservative, the mites are killed with their appendages extended making better orientation of the specimens. However, when lactic acid is used for clearing of specimens, this preservative is unnecessary. Mites for anatomical and histological studies should be preserved in special preservative. Eriophids should not be preserved in 70% alcohol, rather the infested plant parts should be wrapped in tissue paper and then allowed to dry and these can be stored indefinitely. The recovery of mites are done by simmering in Keifer's preparatory solution described earlier.

CLEARING

Mites should be cleared preferably before study and this can be done by using lactic acid 50-60% for soft bodied specimens and 80-100% for heavily sclerotized forms. Some favour the use of Nesbitt's solution which is prepared as : Chloral hydrate - 40 gms, water 25 ml, HCl - 2.5 ml.

MOUNTING

Temporary mounting: It is done in lactic acid (50-100%) depending upon the sclerotization of specimens and by gently warming the slide over an electric lamp for a few seconds. Tetranychids, tydeids and cunaxids should preferably be mounted in cavity slides to avoid damage of specimens. After studying, the specimens may be transferred back in alcohol or are permanently mounted. Broken pieces of coverslips should be used while mounting in lactic acid.

Permanent mounting: Either Heinze's medium or Hoyer's medium are commonly used. The media are prepared with the following chemicals when mixed in the order as mentioned.

Henzie's medium: Polyvinyl alcohol - 10 gms; Distilled water - 40-60 ml; Lactic acid - 35 ml; Glycerol - 10 ml; phenol 1% aqueous soln. - 25 ml; Chloral hydrate - 100 gms.

Hoyer's medium: Distilled water - 50 gms; Gum arabic - 30 gms; Chloral hydrate - 200 gms; Glycerine - 20 gms.

Besides, some other mounting media (Evans *et al.* 1961) are also available in literature and those can be attempted. However, experience shows that in tropical climate none of these mounting media are perfect and in most of the cases the medium gets dried up causing shrinkage of specimens. Ringing the slides with good quality nailpolish may be of some help.

Mounting of eriophyids: Jeppson *et al.* (1976) suggested Kono's medium. This involves mounting in 2 stages. The primary medium which is made of chloral hydrate - 100 gms, glycerol 10 gms, water - 50 ml and conc.HCl - 1 cc. Mites are gently cooked in Kono's preparatory mixture and when cleared they are needled over into a wash of Hoyer's and to the final slide. Final slide should not be heated. There is another mounting medium for eriophyids i.e. Formaldehyde medium consisting of the following ingredients : Sorbitol - 3 gms, Gum arabic powder - 1 gm, Iodine crystal 0.02 gm and 4% Formalin soln. - 5 cc. These materials are allowed to dissolve with agitation for 24 hrs. or more and then the following are added. Chloral hydrate crystals - 14 gms, Glycerol 20 drops, Potassium iodide - 0.1 gm or 0.2 gm. Formalin soln. (4%) may be added further, if necessary. While preparing slide, 2 drops of F. medium is put in the cavity of a slide and the mites are needled into it. A drop of HCl soln. and a drop of phenol are added into it. The slide is then gently heated on a hot plate set below the boiling point of water till a gentle boiling is reached. Later, it is transferred to a drop of fresh F. medium to wash and to a drop of medium on a final slide. Some support to coverslip may be given by putting small broken pieces of coverslip or kapkok fibre to prevent crushing of mites.

REARING

The most convenient method of rearing plant mites is to confine those in isolated leaves in small cages of Huffaker's type. For details regarding construction of cages, the readers may refer to Evans et al. (1961). Phytophagous mites feeding on plants have been reared in cells by cutting a circle out of the centre of small felt disc. These felt washers are fastened to the leaves with waterproof glue and covered with glass or cellophene. Mites can also be cultured in seedlings kept in pots. A ring of petroleum jelly around the base of stem is applied to prevent the escape of mites. A most convenient method of rearing plant mites is the use of excised leaf and keeping the same in Petridish (2" dia.) over a cotton pad supersaturated with water. Leaf is periodically changed and water is added daily to maintain a film of water at the margin of leaf to prevent escape of mite. Phytoseiids are best reared in plastic cages (Swirski, Amitai & Doriza, 1967).

IDENTIFICATION

The identification of plant mites is a difficult job and needs a thorough training and long experience. It is difficult to explain the taxonomic characters involved in the various groups in this article, however, only the salient features of the various groups are discussed here. For details, the interested workers may refer to Baker and Wharton (1952), Krantz (1970), Jeppson et al. (1975) and Gupta (1985).

The four orders of mites occurring on plants can be separated with the help of the following key:

KEY TO THE ORDERS OF PLANT MITES

1. With a long whip-like solenidion arising from dorsal extremity of tibia I and II and usually extending beyond the end of tarsus 2
 - Without such a whip-like solenidion 3
2. Well sclerotized mites with a pair of prominent sensillae or pseudostigmatid organs (Fig. 16,t) arising from dorsal surface of propodosoma near its posterior margin Cryptostigmata

Feebly sclerotized mites, without prominent pseudostigmatic organs, no stigmata..... Astigmata

3. Stigmata easily seen usually situated on the sides of the idiosoma and associated with a tubular peritreme
..... Mesostigmata

Stigmata difficult to see, usually situated on or at the base of gnathosoma (Figs. 17, 17a) and sometimes associated with peritreme..... Prostigmata

Order **Mesostigmata** (Figs. 12, 13, 13a-d) : Stigmata located dorsolaterally or lateroventrally on the hysterosoma; tritosternum present; palptarsus with forked seta (Figs. 13e, 13f); when occur on plants, normally predatory in habits.

Order **Prostigmata** (Figs. 1-11, 18): Stigmata situated at the base of gnathosoma (Fig. 17) or between chelicerae (Figs. 17a); empodial elements of legs II-III pad-like (Fig. 18p), rayed or membranous rarely claw or sucker-like; chelicera typically styliform (Fig. 18) or hook-like rarely chelate; palpi often modified into thumb-claw complex (Fig. 6a). Normally phytophagous but may be predators too.

Order **Astigmata** (Figs. 14, 15) : Without stigmata, empodium claw or sucker-like with fleshy caruncle; usually with 2 pairs of genital discs; chelicerae chelate, dentate; normally weakly sclerotized, usually scavengers.

Order **Cryptostigmata** (Fig. 16) : Tracheal system when present open through acetabular cavities of legs I and III, on the legs themselves or through pseudostigmata; propodosomal sensory setae clavate or club-shaped; 3 pairs of genital discs; normally fungivorous.

KEY TO THE FAMILIES OF PROSTIGMATA

1. Body worm - like or annulate (Fig. 3)..... Eriophyidae
Body rounded, not worm-like or annulate 2
2. Gnathosoma with minute palpi lying closely appressed laterally, chelae tiny and stylet-like with 4 pairs of legs or less; stigma of female opening behind gnathosoma on propodosoma; male without stigma or tracheae; empodium usually a membranous flap-like organ attached to claws, leg IV of female ending in terminal and subterminal whip-like setae (Fig. 4)..... Tarsonemidae

- Gnathosoma usually conspicuous with large chelicerae palpi usually well developed: rarely without 4 pairs of legs; stigma opens at base of chelicerae; empodium free, pad-like or claw-like arising from tarsi 3
3. Without a palpal thumb-claw complex..... 4
- With a palpal thumb-claw complex (Fig. 6a), in some cases the claw may be small or obsolete; if obsolete it is replaced by a relatively long seta 7
4. Cheliceral bases fused or if not fused, not capable of lateral scissors-like motion over gnathosoma 5
- Chelicera free, attached at base and free to move scissors-like laterally across gnathosoma..... 6
5. Chelicera long, recurved and whip-like, female genital opening transverse, tarsal claws with tenent hairs, palpi simple (Fig. 2).....Tenuipalpidae
- Chelicera short, needle-like, easily visible genital opening not transverse (Fig. 5)..... Tydeidae
6. With 2 pairs of genital suckers, the relatively long palpi turned inward, distal segment usually claw-like, free living (Fig. 8). Cunaxidae
- With 3 pairs of genital suckers the relatively long palpi elbow-like with distal setae, free living (Fig. 9)..... Bdeiliidae
7. Body densely clothed with setae (Fig. 11), larvae usually heteromorphic. Gnathosoma large incapable of withdrawing into body; propodosoma not elongate anteriorly; larvae parasitic on arthropods, adults free living Erythraeidae
- Body seta relatively few, arranged in transverse rows, larva homomorphic 8
8. Chelicera free, hooked, hinged at base so that they are capable of scissors like movements in a horizontal direction (Fig. 10)..... Anystidae
- Cheliceral bases fused or partly fused with needle-like or hook-like movable chelae 9

9. Cheliceral bases closely fused with gnathosoma and without indication of suture; peritremes usually M-shaped, may be present on gnathosoma (Fig. 6) Cheyletidae
- Cheliceral bases fused with each other but not with gnathosoma, having suture conspicuous; peritreme usually present on anterior portion of propodosoma 10
10. Movable chela forming a long whip-like stylet curving within the body; cheliceral bases fused to form a stylophore (Fig. 1c); leg I and II with specialised duplex setae (Fig. 1a, 1b), female genitalia wrinkled Tetranychidae
- Movable chela strong, stiff and relatively short, no stylophore. Chelicerae pointed, generally independently movable, but may be adnate or stylophore-like in a few genera; coxae II and III not contiguous; legs I and II directed anteriorly and III-IV posteriorly (Fig. 7)..... Stigmaeidae

KEY TO THE FAMILIES OF MESOSTIGMATA

1. Dorsum with 25 or less pairs of setae (Fig. 12), J series typically of 2 pairs of setae Phytoseiidae
- Dorsum with more than 25 pairs of setae; J series comprising of more than 2 pairs of setae (Fig. 13).....
..... Ascidae

KEY TO THE FAMILIES OF ASTIGMATA

1. Propodosoma and hysterosoma may not be separated by suture (if suture present, the dorsal setae foliate or bilaterally pectinate) skin tough, granular, scale-like or densely striated, dorsal body setae pectinate or fan-like, free living (Fig. 15)..... Glycyphagidae
- Propodosoma and hysterosoma separated by a suture; skin smooth, scale-like or wrinkled; some dorsal body setae long and whip-like; cervical setae present, lens-like eyes absent (Fig. 14). Acaridae.

ORDER CRYPTOSTIGMATA

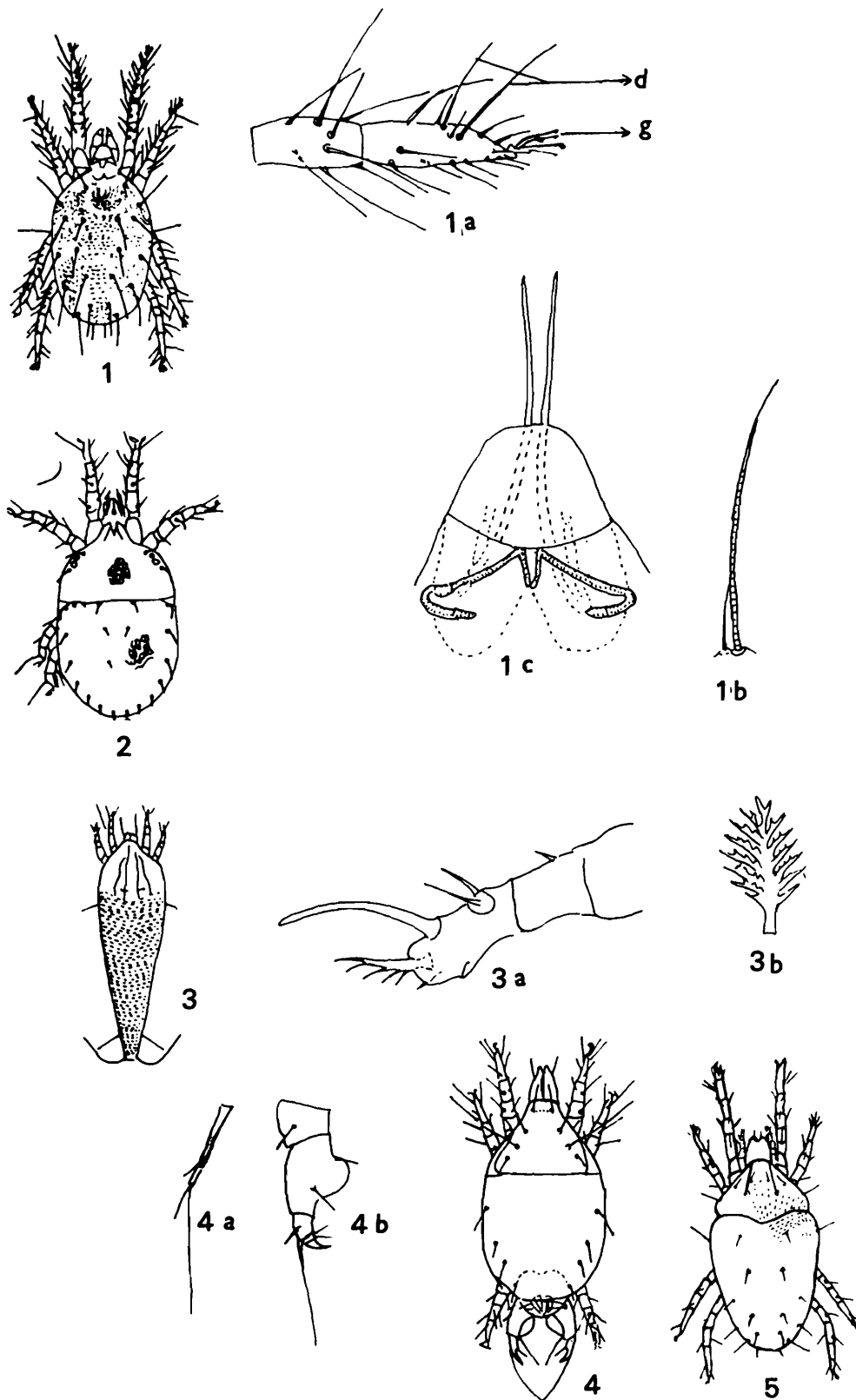
Oribatid mites (Fig. 16): Strongly sclerotized, highly convex body; gnathosoma not visible from above; pseudostigmatid organ usually present. Balogh (1961, 1972) may be referred to for other details.

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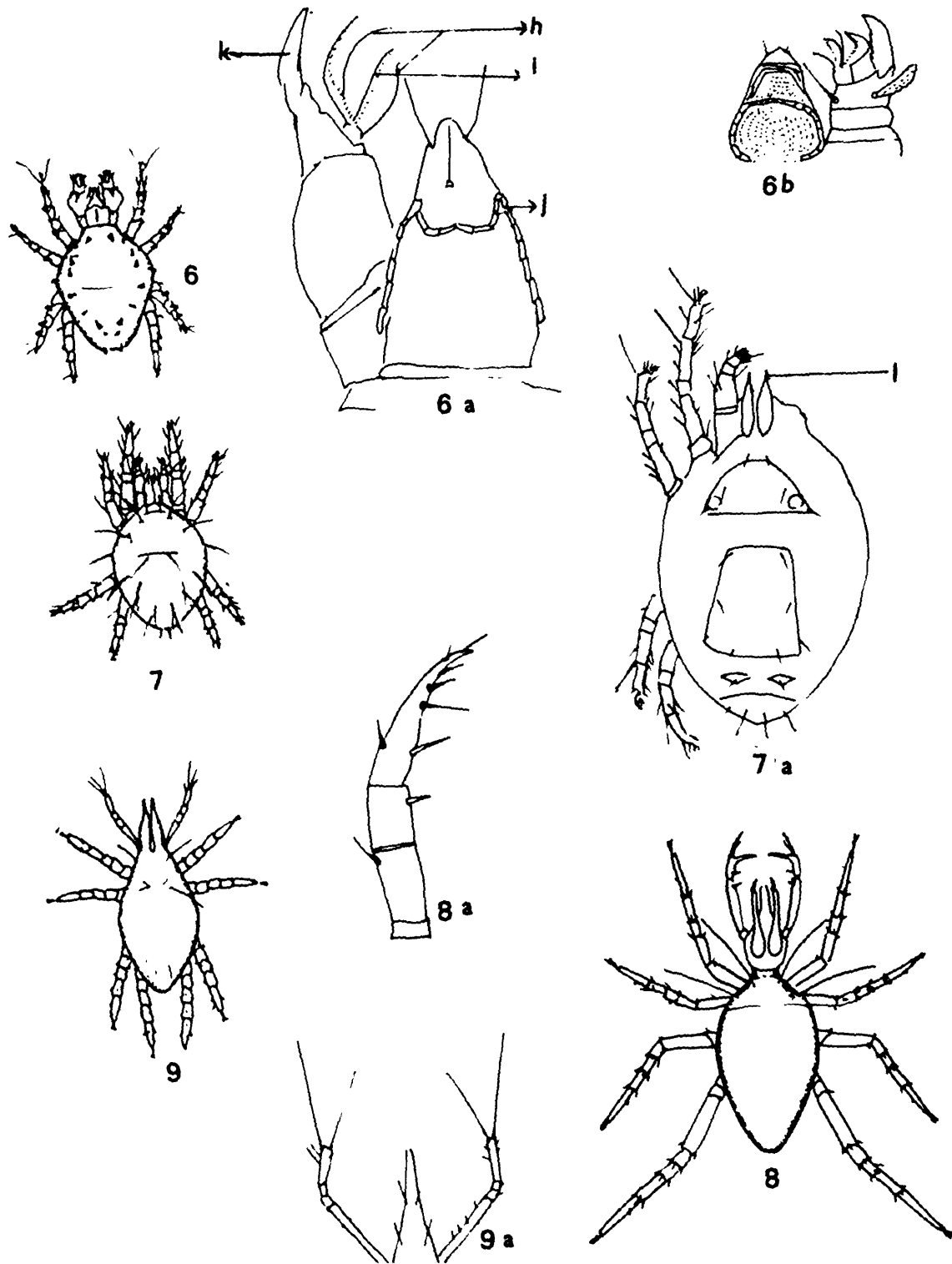
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PLATE I



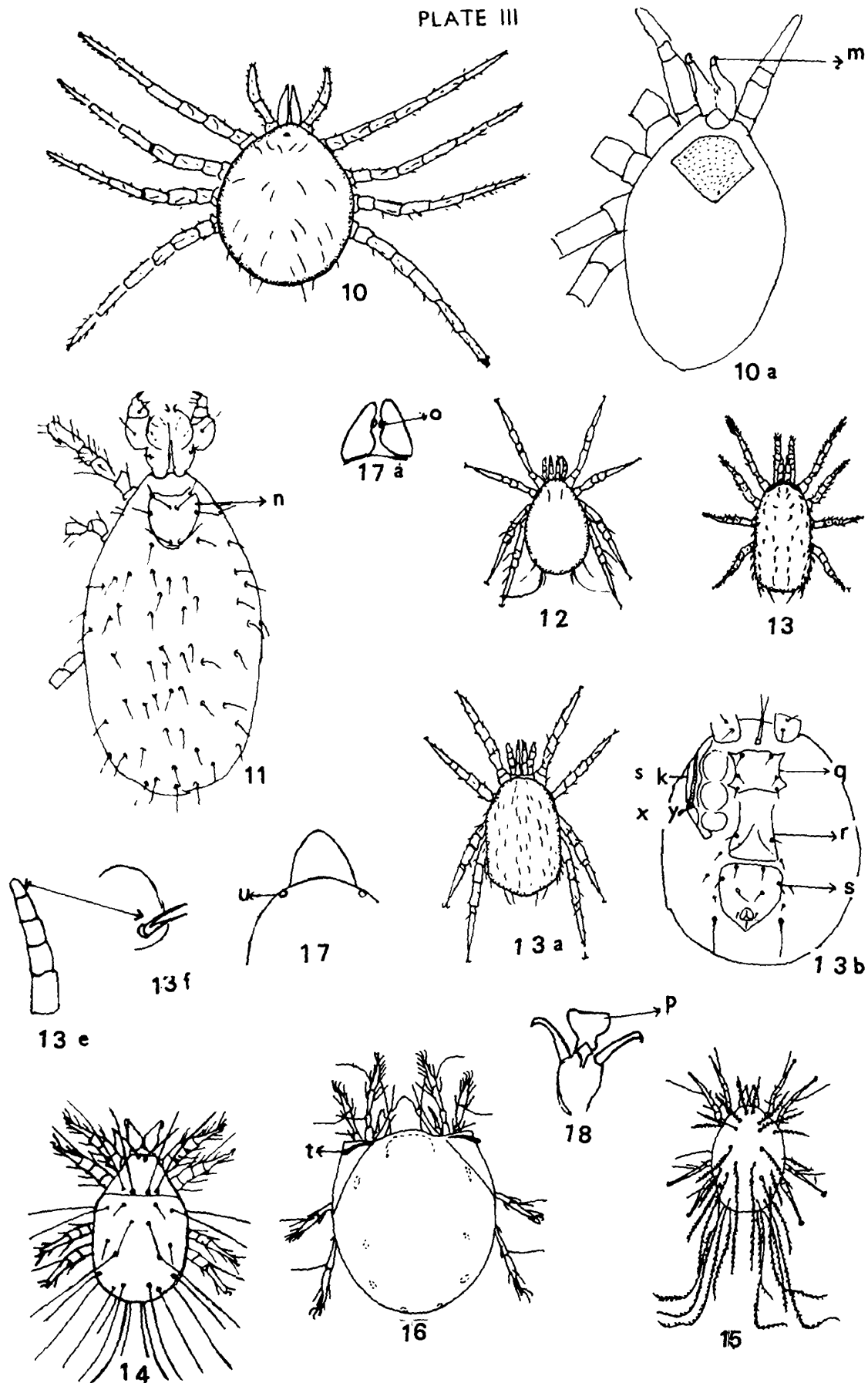
Figs. 1-5. 1 Tetranychid mite, 1a Tibia and tarsus of leg I (female) showing duplex setae (d), tenent hairs (g), 1b Enlarged view of duplex setae, 1c Enlarged view of chelicera and peritreme; 2 Tenuipalpid mite; 3 Eriophyid mite, 3a Magnified view of terminal leg segments showing feather claw, 3b Highly magnified view of feather claw; 4 Tarsonemid mite, 4a Tarsal segment of female showing terminal and subterminal setae, 4b Tarsal segment of male showing claw; 5 Dorsal view of tydeid (all in dorsal view).

PLATE II



Figs. 6-9. 6 Cheyletid mite showing sickle-shaped setae (h) and comb-like (i) and M-shaped peritreme (j), 6b Gnathosomal part of Cheyletid mite; 7 Stigmaeid mite showing the dorsal plates and also needle-like chelicera (i); 8 Cunaxid mite, 8a inwardly curved palp showing chaetotaxy; 9 Bdellid mite, 9a Elbowed palp of bdellid mite with terminal whip-like setae (all in dorsal view).

PLATE III



Figs. 10-18. 10 - Anystid mite, 10a - Anystid mite showing dorsal plate and hooked chelicerae; 11 - Erythraeid mite with *Crista metopica* (n); 12 - Phytoseiid mite; 13, 13a - Ascid mite, 13b - Ventral surface of mesostigmatid mite showing ventral plates, viz. sternal plate (q), genital plate (r), ventrianal plate (s), peritrematal plate (sk) with stigmata (xy), 13c - Palp with forked setae, 13e - Magnified view of forked setae; 14 - Acarid mite; 15 - Glycyphagid mite; 16 - Oribatid mite showing pseudostigmatid organ (t) (all in dorsal view); 17 - Hypothetical diagram showing stigmatid position at the base of chelicerae; 17a - Stigmatid position between chelicerae. 18 - Diagram showing pad-like empodium on leg of prostigmatid mite.

