Chapter 5

Evolution and Classification

This chapter discusses the origin of insects and their evolutionary history (**phylogeny**). The basics of **taxonomy** and **classification** of insects and their allies are briefly introduced and their kinship to other organisms in the animal kingdom is indicated. The outline of the main features of spider-like animals and hexapods comprises their general biology as well as their economic and ecological significance. The description of common insect families encountered in Papua New Guinea together with the illustrations and the colour plates can be used as a field guide for the **identification** of insects.

5.1 Phylogeny of Insects

The evolutionary history called **phylogeny** obtains support mainly from **morphology** but increasingly also from **biochemistry**. The comparison of morphological features and molecules provides valuable information for phylogeny. The most important tool for phylogeny is **homology**, the structural similarity due to common ancestry. The various types of insect legs, shown in **fig. 2-20** are adapted for fulfilling different functions like walking, jumping, digging, etc. However, all legs are composed of the same parts, coxa, trochanter, femur, tibia, and tarsi, thus showing structural similarity despite the different functions. Another example are the mouthparts of insects, discussed in **chapter 2.1.2.2**, that allow deduction of common ancestry from homology. Further evidence for phylogeny is provided by **palaeontology**, the study of fossils, described in **chapter 5.2**.

Insects most probably evolved from a worm-like ancestor, as shown in **fig. 5-1**. One characteristic of insects and their postulated ancestors is **metameric segmentation**. The body of segmented animals is composed of repeated organisational units. These are obvious in **Annelida** such as the earth worm but less conspicuous in insects due to the fusion of segments. The insect head for instance is the result of such fused segments.

During the course of evolution, articulated legs developed on each segment. Insects have three pairs of legs associated with the three thoracic segments. The legs of the other segments either were reduced or serve purposes other than locomotion. Structures like mandibles, maxillae, antennae and terminal appendages are homologous to legs, adapted for different functions but of the same origin. The development of wings is closely associated with the evolutionary success of insects. Wings are unique structures, since insects are

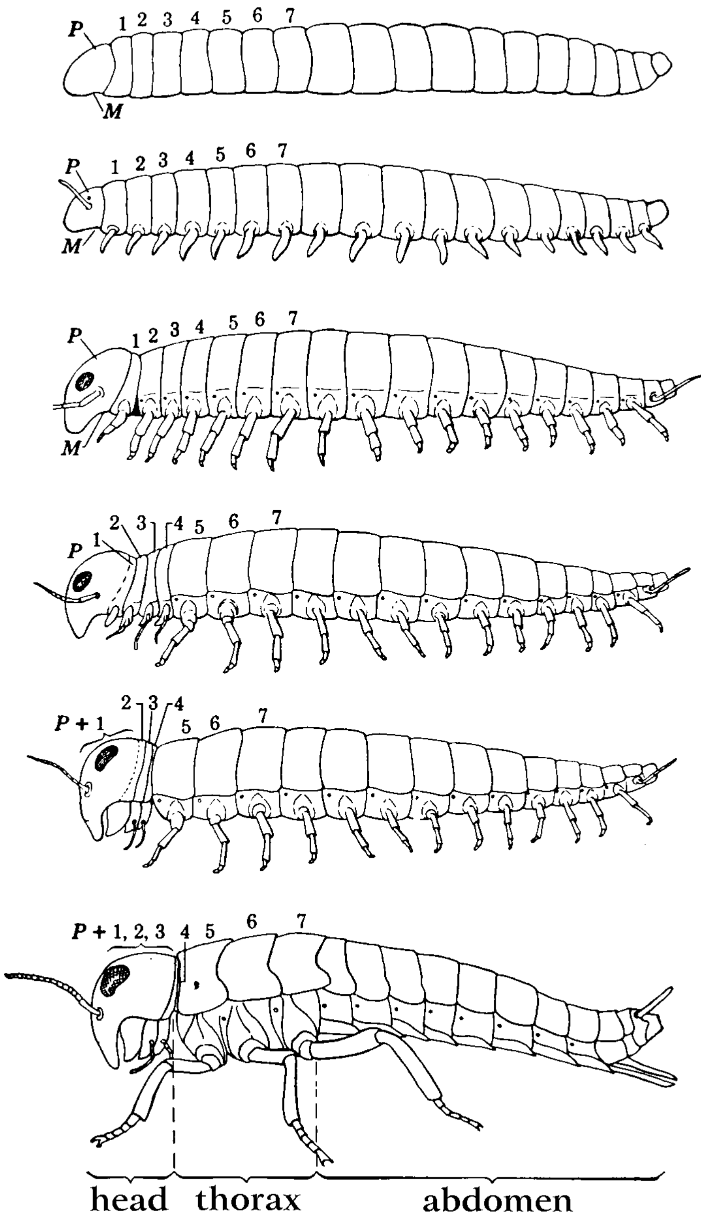


Fig. 5-1: Hypothetical stages in the development of body regions and appendages from a worm-like ancestor (top) to a primitive insect (bottom). **P:** prostomium, **M:** mouth (reproduced from Ross, H.H. et al., 1982)

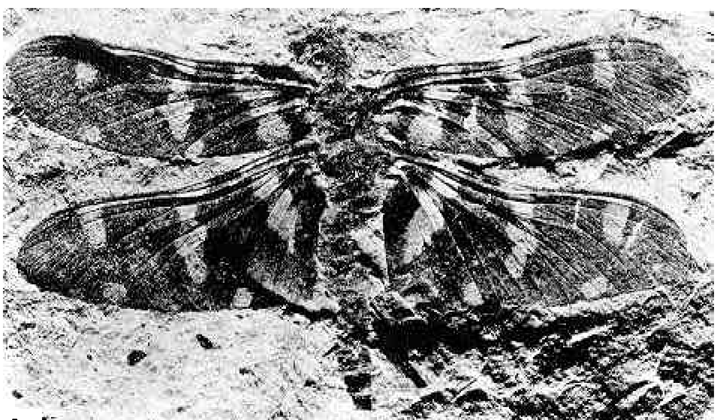
the only class of **Arthropoda**, in which they have evolved. Apart from insects, there are some vertebrates which have the ability to fly. Their wings however, are modified pentadactyl limbs, that are **analogous** to insect wings. On the way to the modern winged insects, there were ancestors with three pairs of wings, one pair on each thoracic segment. The prothoracic wings were lost during evolution so that only two pairs of wings were left on the meso- and metathorax.

5.2 Fossil History

Palaeontology studies fossils and the evolutionary history of organisms, that formed them. The earliest hexapod fossil, a springtail (**Collembola**), was dated back to the Lower Devonian Era, 380 million years ago. The first insects seem to have been present during the Devonian Period. Quite a diversity of insects had evolved in the Upper Carboniferous and a number of now-extinct orders like **Meganisoptera**, **Megasecoptera** and **Palaeodictyoptera** lived 300 million years ago. Meganisopteran insects resembled dragonflies and were the largest known insects, some with gigantic wingspans of up to 75 cm. Fossils revealed that piercing-sucking mouthparts for feeding on plants had already evolved during the fern-dominated Carboniferous. The diversification of insects however coincides with the appearance of **Angiosperms** in the Cretaceous, 135 to 65 million years ago. From this time, the oldest **Lepidoptera** and **Hymenoptera** are known and the modern insect fauna started to develop. Excellent specimens are preserved in amber, as shown in **fig. 5-2 B**. Amber originates from hardened resin and insects are sometimes entrapped. Amber is transparent, therefore it is an outstanding preservative. Amber specimens are in a much better condition than specimens derived from compression fossils. However, an amber specimen with an enclosed mosquito that had sucked blood from a dinosaur is not suitable for extraction of dinosaur DNA from blood remains in the mosquito's gut in order to reconstruct the dino. This story narrated in the movie '**Jurassic Park**' is, of course, fiction.

5.3 Taxonomy and Classification

The task of **taxonomy** is to describe, name and classify insects. Taxonomy is very time-consuming work, to sort out thousands of specimens requires considerable skills. The major obstacle to insect taxonomy however, is the large number of insect species. Most scientists assume that only 5 to 20% of the insect species, ie. 750,000 species are described so far. The conflicting total number of species of all organisms ranges between 4.4 million and 100 million. Therefore it is sheer speculation whether there are in total 3 to 5 million undiscovered species, or 30 million unknown arthropods, or almost 100 million species yet to be described, as extrapolated from **canopy fogging**. Whatever number is right, a common conception is that more than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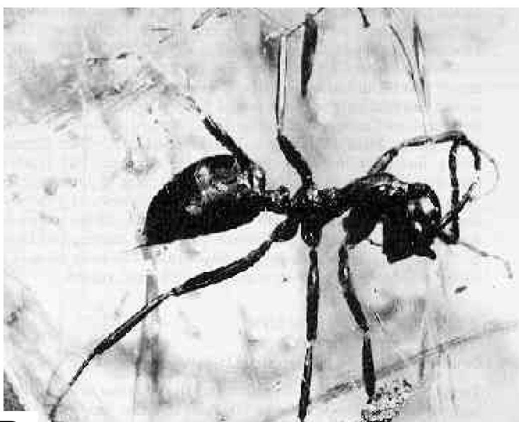

B

Fig. 5-2: Fossil insects: (A) *Dunbaria fasciipennis* from Lower Permian, (B) the oldest known ant *Sphecomyrma freyi* from Upper Cretaceous preserved in amber (reproduced from Ross, H.H. et al., 1982)

56% of all species are insects. However, this figure might be slightly lower, since recent surveys of the deep sea floor revealed very high numbers of marine organisms, estimating a total of 10 million marine species.

Somebody calculated that there are 425 described species per insect taxonomist. Taking the above estimates into account, there is a tremendous amount of work to be done by insect taxonomists. In other words, perhaps 1000 to 10,000 species are to be described by each insect taxonomist. It is assumed that about 6% of the world's total number of species can be found on New Guinea island. How many hundreds of thousands or even millions of insect species are left to be described only in Papua New Guinea? This is definitely a good incentive to train a large number of *mangi binatang*.

Regarding the relative number of species in the various orders of the animal kingdom, shown in **fig. 1-1**, some adjustments might be necessary. The beetles are estimated to be by far the most diverse order of organisms. However, recent studies of the rain forest canopy on Borneo elucidated higher species numbers of **Hymenoptera** and **Diptera.**

From all these figures, the dilemma of taxonomy - the diversity of insects - becomes quite evident. **Systematics** studies the kinds and diversity of organisms and their interrelationships. As in taxonomy, diversity hampers the progress of systematics. To uncover the origin of **taxa**, the taxonomic units such as genera or families, systematics requires the study of closely related specimens. These are often not available because only a tiny fraction of insect species is described so far. As a result of this dilemma, only the major taxa like insect orders are commonly recognised by all taxonomists. Controversial debates however ignite amongst scientists, when it comes to families and other subordinate taxa. Moreover, the position of certain higher taxa such as **Coleoptera** and **Hymenoptera** is still unclear, hence will be subject to further revision. In this chapter the systematics proposed by 'The Insects of Australia' (CSIRO, 1991) was adopted.

The findings of phylogenetic, taxonomic and systematic studies are compiled in **cladograms**, exhibiting the relationships of particular taxa in tree-like diagrams. This is the task of **classification**. A cladogram of major animal groups illustrating the position of the **Arthropoda** including insects is shown in **fig. 5-3**. The evolutionary relationships of hexapod orders are indicated in **fig. 5-11**. As shown in **box 5-1**, each scientific name has a particular suffix appended indicating the respective taxonomic category (**taxon**).

TAXON		SUFFIX	EXAMPLE	COMMON NAME
Class			Insecta	Insects
	Subclass		Pterygota	(winged insects)
	Infraclass		Endopterygota	(wings develop internally)
Order			Lepidoptera	Butterflies and moths
	Infraorder		Heteroneura	
	Series		Ditrysia	
	Suborder		Glossata	
	Superfamily	-oidea	Papilionoidea	
Family		-idae	Papilionidae	Swallowtails
	Subfamily	-inae	Papilioninae	
	Supertribe	-itae		
	Tribe	-ini	Troidini	
	Subtribe	-ina or -iti		
Genus			Ornithoptera	Birdwings
	Subgenus			
Species			*O. priamus*	Priamus Birdwing
	Subspecies		*O. priamus poseidon*	
	Form		*O. priamus poseidon* f. *kirschii*	

Box 5-1: Taxonomic categories and their standard suffix

5.4 Identification of Specimens

Specimens are usually identified by the use of identification keys. These keys lead the investigator through a sequence of choices between exclusive character descriptions. Finally, all specimens except the one under observation are eliminated. Most commonly used are biforked **dichotomous** keys offering two options per character description. These are either in spider-format as shown in **fig. 5-4** or in the more convenient linear format, eg.:

107(106) Cerci with 4 or more segments 108
Cerci with 1-3 segments 110
108(107) Head hypognathous or ophistognathous; pronotum shield-like and rounded in outline, usually covering all or part of head; body dorsoventrally flattened and oval ....
.................(wingless cockroaches) **Blattodea**
Head proganthous; pronotum not shield-like and not covering head; body cylindrical and more elongate 109

There are some problems with dichotomous keys. The key has to be strictly followed from the beginning and a choice has to be made for each character description. Identification is almost impossible, if a feature of the specimen is missing, for instance because it is broken off the specimen. Furthermore, beginners who are not yet familiar with the specific taxonomic terminology might face considerable problems understanding which feature the key is talking about. It can become a very time-consuming enterprise, if one has to tackle a huge key, as for instance the key to hexapod orders in 'The Insects of Australia' (CSIRO, 1991). In case the specimen belongs to an order described at the end of this key, one has to find his way through up to 116 different character descriptions. However, other key formats and types of keys exist, that are more user-friendly. Outstanding examples are computer-supported interactive multimedia keys, like **LucID Player** - Contemporary Identification Tools for Biology:

University of Queensland, Department of Entomology and Cooperative Research Centre for Tropical Pest Management (1997): LucID Player - Contemporary Identification Tools for Biology, CD-ROM; Version 1.0; Brisbane; Australia

Interactive keys allow identification to start with any feature of the specimen and usually lead to the right insect order after three to four options. A large number of supportive figures as well as explanations enable even beginners to quickly identify the order of a specimen. Furthermore, the software can be used for creating personal keys, for instance to the identification of particular groups of insects.

5.5 Synopsis of the Animal Phylum Arthropoda

80% of the animal species belong to the group **Arthropoda**. Arthropoda are characterised by

- segmented body with paired appendages
- improved locomotion due to segmentation of legs (Arthropoda = jointed-legged)
- development of chitinous exoskeleton
- posterior appendages involved in feeding
- ventral nervous system
- open circulatory system
- gas exchange via spiracles and tracheae.

Arthropoda, **Annelida** (segmented worms) and a few other smaller taxa form the group **Articulata**, shown in **fig. 5-3**. Arthropods can be further divided into three subphyla, the **Trilobita**, **Chelicerata** and **Mandibulata**. The extinct marine Trilobita were the earliest known members of the Arthropoda, that lived 600 to 200 million years ago. Chelicerata and Mandibulata are further outlined below, the features of selected groups are summarised in **box 5-2** and **fig. 5-4**.

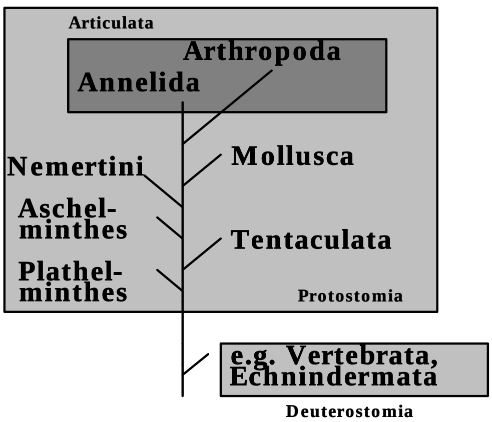


Fig. 5-3: Evolutionary tree indicating the relationship between **Arthropoda** and other animal groups (graphic Schneider, M.F.)

Class	Order	Pairs of Legs	Pairs of Wings	Mouth-parts	Develop-ment	Pairs of Antennae	Tagmata	Other Features
Crustacea	crabs, lobsters crayfish, prawns	5 or more	nil	chewing	with meta-morphosis	2	C, A	limy exo-skeleton
Arachnida	spiders, mites/ ticks, scorpions, harvestmen	4	nil	various types	gradual	nil	C, A	only simple eyes; chelice-rae, pedipalps
Chilopoda	centipedes	9 or more	nil	chewing	gradual	1	H, A	poison fangs
Diplopoda	millipedes	two pairs per segment	nil nil	chewing	gradual	1	H, A	body many-segmented
Insecta	**Isoptera**	l: 3		chewing	gradual	1		
		a: 3	2	chewing		1	H, T, A	
	Orthoptera	l: 3		chewing	gradual	1		
		a: 3	2	chewing		1	H, T, A	
	Hemiptera	l: 3		piercing-sucking	gradual	1		
		a: 3	2	piercing-sucking			H, T, A	
	Coleoptera	l: 0 or 3		chewing	complete			
		a: 3	2	chewing		1	H, T, A	
	Diptera	l: nil ✤		chewing	complete			
		a: 3	1	various types		1	H, T, A	
	Lepidoptera	l: 0 or 3		chewing	complete			
		a: 3	2	siphoning-tube type		1	H, T, A	
	Hymenoptera	l: nil ✤		chewing	complete			
		a: 3	2	various types		1	H, T, A	

key: C = **cephalothorax** H = **head** T = **thorax** A= **abdomen** ✤ **no true legs** l = **larva** a = **adult**

Box 5-2: Summary of features of selected arthropod groups

5.5.1 Subphylum Chelicerata

The body of **Chelicerata** is divided into two major regions, **cephalothorax** and abdomen, also called **ophistosoma**. The cephalothorax, specialised for feeding and locomotion, bears six pairs of appendages, four pairs of walking legs, one pair of **pedipalps** and one pair of **chelicerae**. The chelicerae are prehensile appendages associated with the mouth and homologous to antennae. The pedipalps are homologous to walking legs and are often **chelicerate**. True antennae are lacking. The abdomen, specialised for reproduction, lacks appendages. Three classes belong to the Chelicerata, the **Merostomata**, **Pycnogonida** and **Arachnida**. The Arachnida or spider-like animals are further discussed below.

Class Arachnida

Spider-like animals are mainly terrestrial, only a few mites are aquatic. The abdomen of Arachnida is typically larger than their cephalothorax. The development is gradual without metamorphosis. Many species of this group, mainly ticks and mites, transmit diseases or are pests of various crops. Therefore, spider-like animals are included in entomology. The class is further divided into nine to ten orders. A summary of features is given in **box 5-2**, **figs. 5-4** and **5-5**.

5.5.1.1 Order Araneae (True Spiders)

General biology: About 30,000 species of true spiders can be found world-wide. Neither pedipalps nor legs are chelicerate. The abdomen is constricted to form a thread-wasted joint with the cephalothorax. The pedipalps of males are involved in the transfer of sperm and are of diagnostic importance. The sperm is placed on a spun net, filled into the pedipalps and transferred to the female genital organs. Males are usually smaller than females and are sometimes eaten by the females when approaching or after copulation. The females usually guard the eggs and young spiders (**brood care** and **parental care**). The eggs of many species are placed in a cocoon, that is attached to the mother’s body and carried around.

Another characteristic of true spiders is the three to four pairs of abdominal **spinnerets**. These produce a complex, elastic but strong thread, sometimes consisting of many supportive individual threads and sticky liquid coatings or droplets. The thread is used to build nets and cocoons. Young spiders mainly disperse along a thread, spun into wind. The form and shape of nets is utterly diverse and species-specific, thus used for diagnostic purposes. Nets can be wheel-like, funnel-like, triangular-shaped, ladder-like, bower-like or work like pitfall traps. The nets are almost invisible, therefore small animals might get trapped and become entangled in the system of threads. The movement of the prey alerts the spider, that immediately comes to kill it. For this purpose spiders possess poison glands in their chelicerae. The venom is injected into prey in order to immobilise or kill it or is used for defence. Large hairy hunting spiders can cause painful bites, but it is doubtful whether the poison is fatal for a healthy adult human.

The exclusively predacious spiders live on insects and other smaller animals. Spiders developed a wide range of strategies to get hold of prey. It is a common misconception that most spiders use nets to snare prey. A large number of species hunt prey by means of jumping at it or running it down. Even ambush is common as in crab spiders that hide in flowers and wait for insects searching for nectar. Most spiders are terrestrial, but some conquered aquatic habitats and hunt on the surface of water. However, prey is not necessarily killed instantly, in some cases the trapped prey is tied up and wrapped in web for consumption at a later time. Prominent horrifying species are the bird-eating spiders (**fig. 5-6 B**) of Papua New Guinea, and tarantulas and black widows which originate from tropical and subtropical America. Other examples occurring in Papua New Guinea like *Nephila maculata*, are shown in **fig. 5-6**.

Economic and ecological importance: Spiders are truly beneficial animals, since they are very important for the regulation of insect populations.

5.5.1.2 Order Acari (Acarina: Mites, Ticks)

'Dancing on the head of a pin' is definitely impossible for most animals. However, a large number of mites, the smallest Arachnida could do it. The size of these creatures ranges from a fraction of a millimetre, invisible to the naked eye, to about one centimetre in ticks.

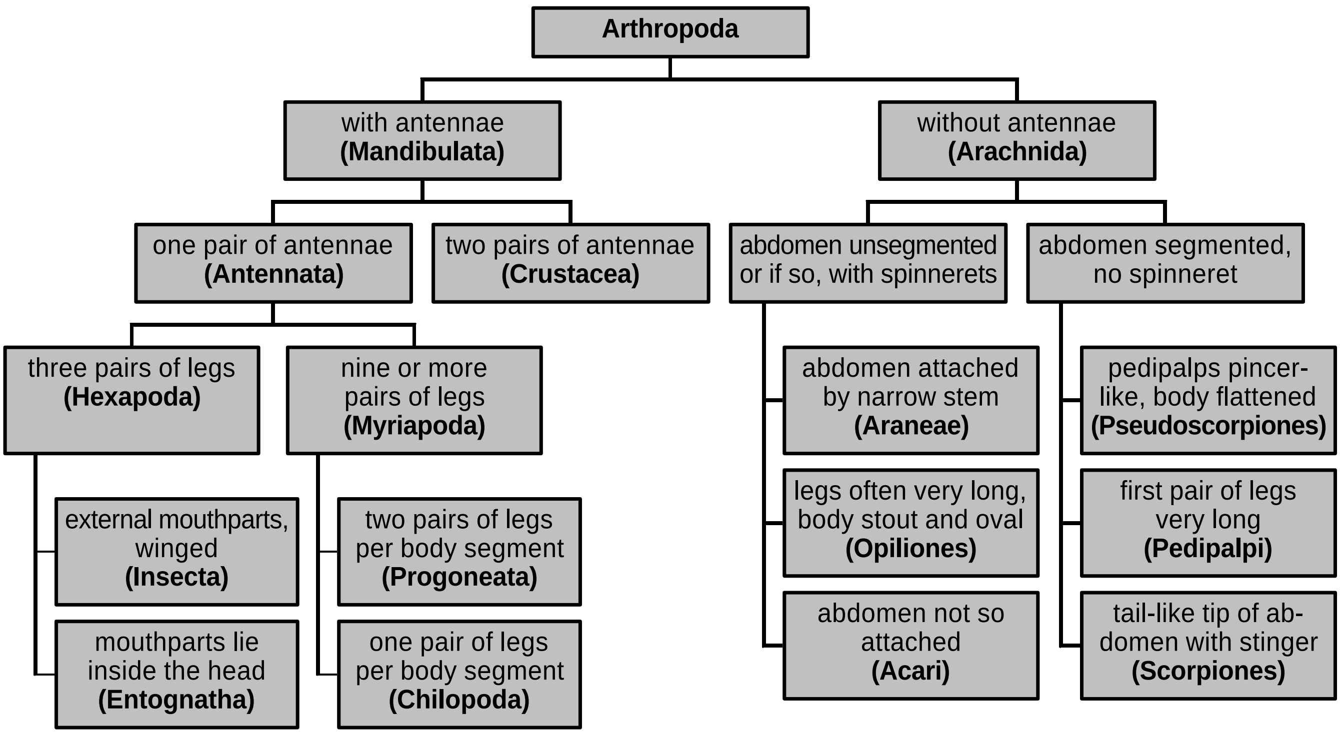


Fig. 5-4: Key for the identification of selected groups of Arthropoda (graphic Schneider, M.F.)

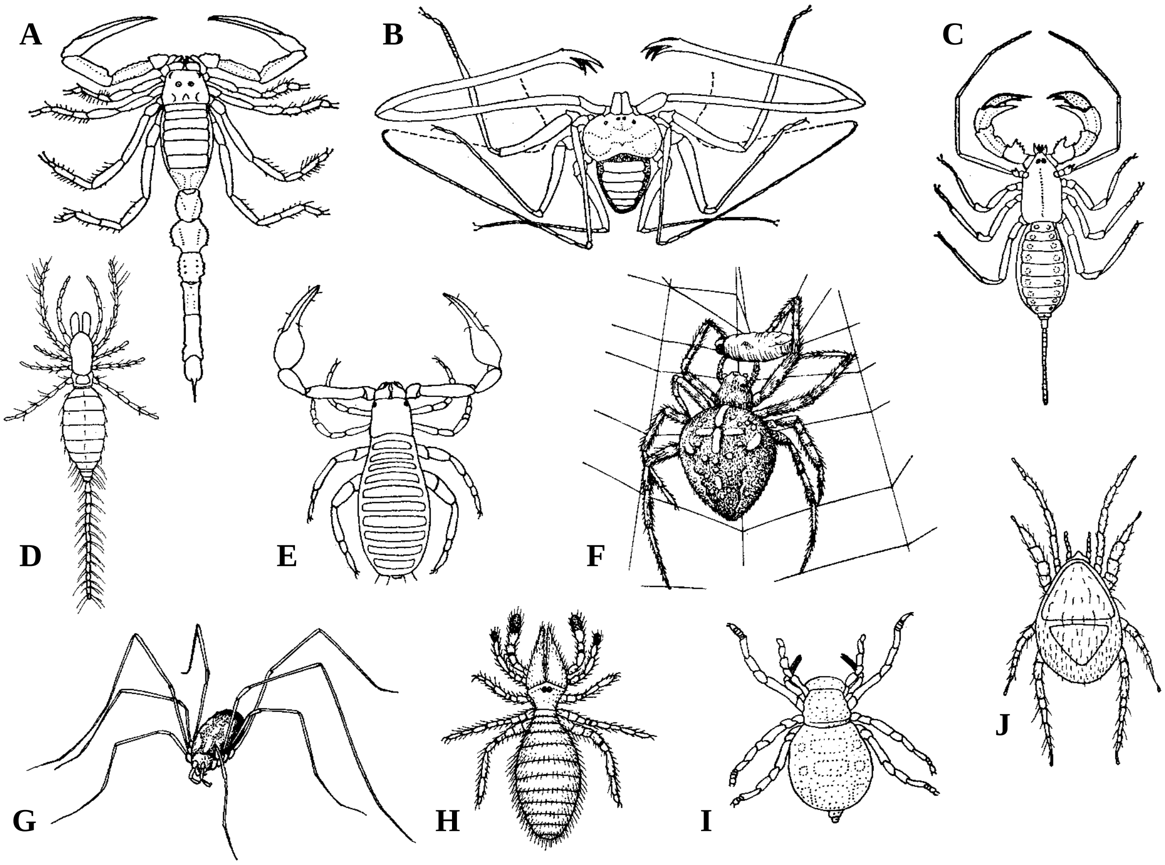


Fig. 5-5: Arachnida orders: (A) Scorpiones (B) Pedipalpi: Amblypygi, (C) whiptail scorpions (Pedipalpi: Uropygi), (D) Palpigradi, (E) Pseudoscorpiones, (F) spiders (Araneae), (G) harvest men or daddy longlegs (Opiliones), (H) Solifugae, (I) Ricinulei, (J) mites and ticks (Acari) (reproduced from Remane, A. et al., 1981)

General biology: Mites have one or more pairs of simple eyes laterally on the frontal part of the body. The body typically is without segmentation and seems to consist of only one tagma. The segments bearing chelicerae and pedipalpi are fused to form the minute so-called **capitulum** or **gnathosoma**, separated from rest of the body, the **idiosoma**. The mouthparts are of piercing-sucking type, suitable for sucking up plant juices or the blood of animals. Mites either breathe through spiracles located near the mouthparts or directly through the cuticle. The last pair of legs is often reduced. During the development

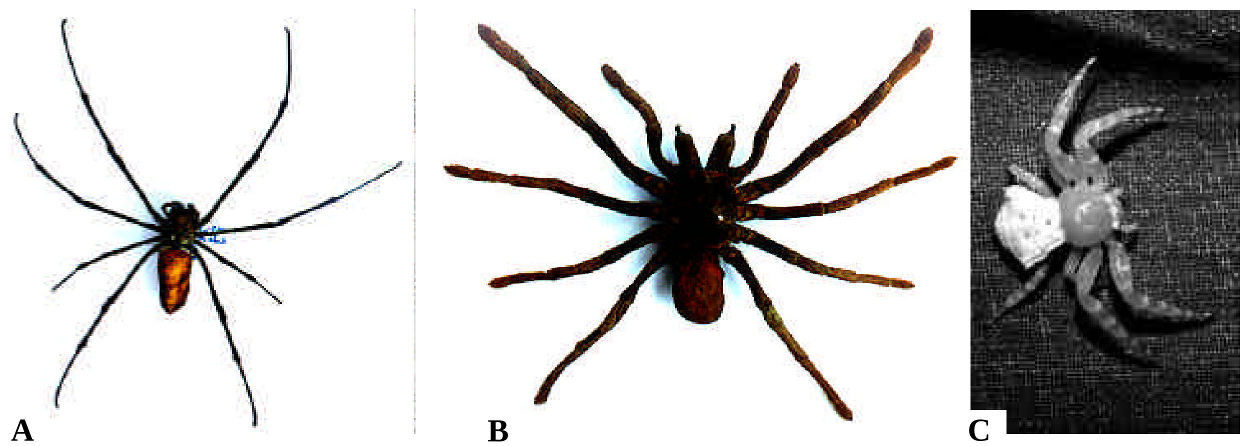


Fig. 5-6: Araneae: (A) *Nephila maculata*, (B) bird-eating spider *Selencosmis crassipes*, (C) jumping spider (photos Schneider, M.F.)

of mites and ticks, one larval instar with three pairs of legs only is followed by three nymphal instars, the **proto-**, **deuto-** and **trito-nnymph**, with four pairs of legs, shown in **fig. 5-7**. The nymphal instars resemble adults. Between the instars, prior to moults, the animals often undergo a resting stage. Under ideal conditions, it takes about one to three weeks for most species to complete their life cycle. Most Acari species are oviparous, but ovoviviparity and viviparity are also not uncommon.

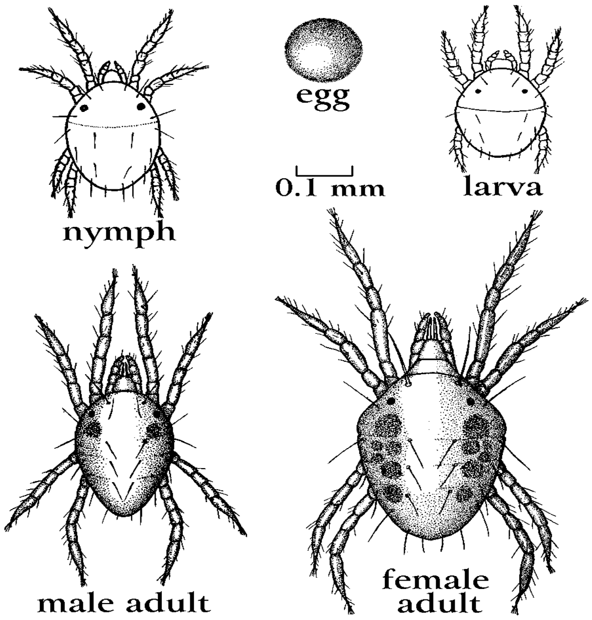


Fig. 5-7: Stages of the life cycle of the tropical red spider mite *Tetranychus cinnabarinus* (Tetranychidae) (reproduced from Hill, D.S. and Waller, J.M., 1988)

Ecological importance: Despite the general reduction of a number of evolutionary advanced Arachnida features, mites show an enormous adaptability to various habitats and sources of food. Mites are either herbivores, predators or ectoparasites (see **fig. 4-10 B**). Most species are terrestrial, but there is also a number of aquatic species. Due to their small size, mites are often neglected in biodiversity inventories. However, research has revealed a stunning diversity and abundance of this animal group in the tropical rain forest. Mite densities can sometimes exceed 10,000 individuals per m². Most of the species are beneficial predators or harmless phytophages and fungivores, feeding on fungi or micro-organisms that grow on plant surfaces. A close mutualistic interaction between predacious mites and a large number of different plants has evolved. Numerous predacious mites per leaf keep plants free of plant-parasitic mites. In return, plants provide shelter for mites during their moult, for laying eggs and protect the animals from sun, rain and larger predators. Leaf hairs, pouches and pits in vein axles and similar structures on the upper- and underside of leaves are called **domatia**, if they offer ideal hiding places for mites. The more domatia a plant has to offer, the more predacious mites will eventually dwell on the plant, hence the more effectively the plant will be protected by its ’body guards’.

Economic importance: A large range of mites and ticks are severe pests of crops and stored products or ectoparasites of man, livestock and pets. Furthermore, many species are potential carriers of diseases.

Itch mites or scabies mites like *Sarcoptes scabiei* belong to the family **Sarcoptidae**. The animals are minute and of hemispherical body shape with four pairs of very short legs. They live in the epidermis of humans and other mammals, causing itchy inflamed patches of the infested skin, referred to as **scabies** or **mange**. Mites of the family **Psoroptidae**, shown in **fig. 5-8 A**, are also minute with oval bodies and legs exceeding the body margin. These ectoparasites are restricted to particular body regions such as ears, neck, feet and tail, where the mites settle at the base of the host’s hairs and cause itchy irritations of the skin. Dogs with sore tips of the ears usually suffer from this kind of mite. The itchy sensation results in the dog scratching off the skin of its ears. A common pest of man is *Demodex folliculorum*. The minute blood-sucking chigger mites (**Trombiculidae**) are common in tropical and subtropical areas and can cause dermatitis. Furthermore, they are known vectors of scrub typhus. The domestic house dust mites like *Glycyphagus domesticus* and *Dermatophagoides pteronyssinus* can cause severe allergic reactions in humans. Hard-bodied ticks (**Ixodidae**), shown in **fig. 5- 8 B**,

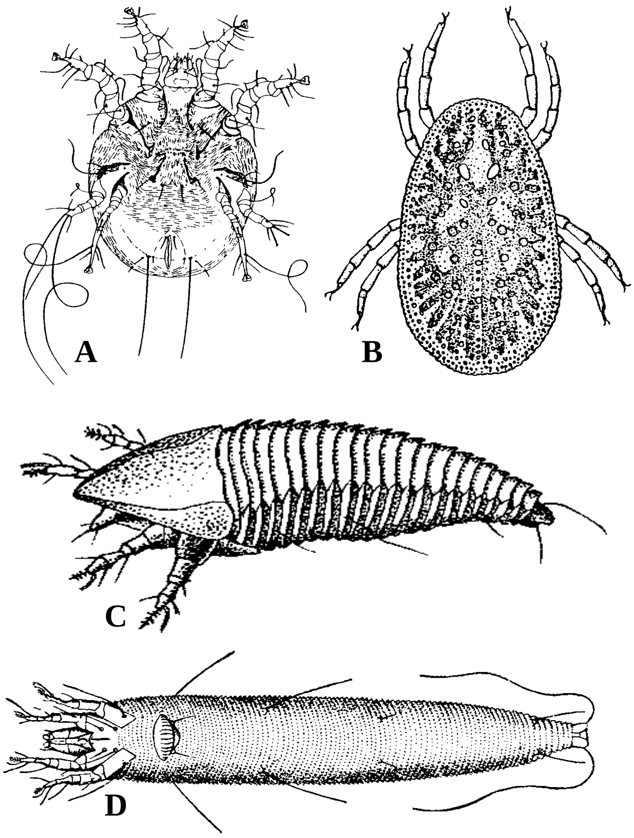


Fig. 5-8: Acari: (A[†]) sheep scab mite (Psoroptidae), (B[†]) fowl tick (Argasidae), (C[††]) citrus rust mite *Phyllocoptruta oleivora* (Eriophyidae), (D[†††]) blister mite *Eriophyes sp.* (Eriophyidae) (reproduced from Pyenson, L.L., 1980[2†]; Hill, D.S. & Waller, J.M., 1988[††]; Ross, H.H. et al., 1982[†††])

are small to medium-sized blood-sucking parasites of humans and many other animals. Characteristic for this kind of tick is their rounded, leathery body. Male ticks are completely covered, females partially, by a dorsal, shield-like **scutum**. The ticks remain attached to their host for several days until they fall off. The soft-bodied ticks (**Argasidae**) lack a scutum. The cuticle of these blood-sucking parasites is roughened and wrinkled. Some Ixodidae and Argasidae ticks transmit very severe diseases like meningitis.

Pests of stored products like flour, grain, dried fruits, cheese and meat belong to the family **Acaridae** (= **Thyroglyphidae**), like the flour mite *Acarus siro* (= *Tyroglyphus farinae*). These mites can cause dermatitis in people frequently handling infested products.

A large number of plant-parasitic mites considerably reduce yield of crops and might eventually kill their host plant. Particularly in agricultural systems, spider mites became severe secondary pests. Due to their stylet-like mouthparts, the mites are able to pierce and suck juices from individual plant cells. Thus, mites can avoid most of the defence mechanisms of the plant. In addition, short generation times of one to three weeks paired with a high reproductive potential easily allow the animals to over-exploit their hosts. Pests of crops are spider mites, red spiders or twospotted mites (**Tetranychidae**), shown in **figs. 5-7**, **8-7 A** and gall, rust and blister mites (**Eriophyidae**). Some species of the latter family, shown in **fig. 5-8 C** and **D**, cause an abnormal development of the epidermal plant cells forming **galls** or other deformations of the leaf surface. The latter kind of damage is referred to as **erineum** and can be confused with fungous growth. The piercing-sucking action of mites can also result in grey or brown mottling of the foliage.

Important agents for biological control belong to the predacious families **Phytoseiidae** and **Stigmaeidae**. Mites like *Typhlodromus* and *Phytoseiulus* are reared commercially in large quantities. After their release in an infested area, these predators effectively suppress plant-parasitic mites and other small insect pests. See also **chapter 8.7.2** and **fig. 8-7 A**.

5.5.1.3 Order Opiliones (Opilionida)

The harvestmen or daddy longlegs comprise about 3000 species world-wide. They are characterised by a stout, oval or round body shape, and legs that are usually up to five or more times as long as the body, as shown in **fig. 5-5 G**. Many species are predacious, running after their prey on trees or ground cover. Some species are minute, with short legs.

5.5.1.4 Order Scorpiones (Scorpionida)

The true scorpions are a small group shown in **fig. 5-5 A**. Scorpiones dwell in warmer tropical and subtropical areas. Characteristic are the pincer-like (**chelate**), prehensile pedipalps and a venomous stinger at the highly agile tail-like tip of the abdomen.

5.5.1.5 Order Pseudoscorpiones

Pseudoscorpions are an abundant order of small animals, hardly exceeding 8 mm in length. Like Scorpions, the Pseudoscorpions possess chelate, prehensile pedipalps, but lack the slender tail-like tip of the abdomen including the stinger, as shown in **fig. 5-5 E**.

5.5.1.6 Order Pedipalpi

Pedipalpi are tropical and subtropical small to medium-sized nocturnal animals. The order is further divided into **Amblypygi** and **Uropygi** (whiptail scorpions), that are shown in **fig. 5-5 B** and **C**.

5.5.2 Subphylum Mandibulata

The subphyllum is divided into the **Crustacea** and **Antennata**, indicated in **fig. 5-4**. The characteristics of Mandibulata groups are summarised in **box 5-2**. Typical features are:

- head separated from thorax
- head with one or two pairs of antennae
- three or four pairs of feeding appendages or mouthparts

Class Crustacea

Characteristic for **Crustacea** or **Diantennata** are two pairs of antennae, one pair of mandibles, two pairs of maxillae and five pairs of legs. The body is composed of head, thorax and abdomen, but head and thorax are often fused to form the so-called **cephalothorax**. During their development, the animals undergo metamorphosis. Most groups are aquatic, either marine or in freshwater. However, some are amphibious like crayfish or exclusively terrestrial like the sowbugs and pillbugs (**Isopoda**). The class is divided into several subclasses comprising eg. lobsters, crabs, prawns, shrimps, crayfish and isopods, shown in **fig. 5-9 A** to **D**.

Antennata

The **Antennata** (or **Tracheata**) bear only one pair of antennae and possess tracheae, that evolved independently from the tracheal system of spider-like animals. Antennata are composed of four classes, the **Chilopoda**, **Progoneata**, **Insecta** and **Entognatha**.

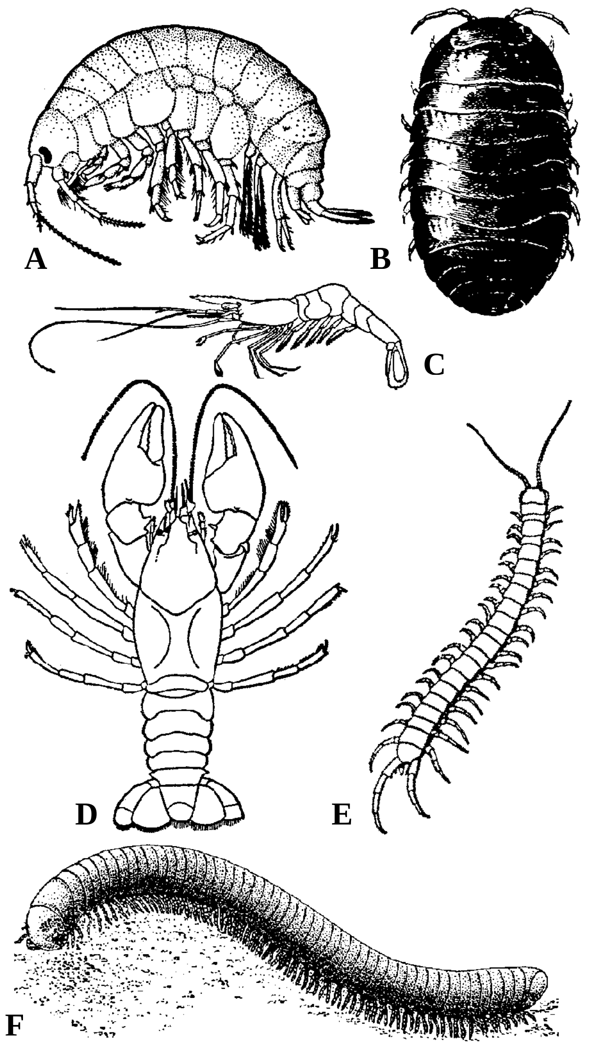


Fig. 5-9: Mandibulata: (A-D) Crustacea: (A) Amphipoda; (B) Isopoda; (C) shrimp; (D) crayfish; (E) Chilopoda (centipedes); (F) Diplopoda (millipedes) (reproduced from Ross, H.H. et al., 1882)

Superclass Myriapoda

Chilopoda together with Progoneata are by some authors referred to as **Myriapoda**.

5.5.2.1 Class Chilopoda (Centipedes)

The **Chilopoda** or centipedes (**fig. 5-9 E**) possess one pair of legs per segment and have a characteristic curved poison claw on the first trunk segment. The animals are mainly nocturnal predators, hiding under logs, stones or in soil during the day. Some tropical species like the huge *Scolopendra* gain a body length of 20 to 25 cm and can cause painful bites.

5.5.2.2 Class Progoneata (Millipedes)

The class **Progoneata** consists mainly of **Diplopoda**, called millipedes or thousandlegged worms, shown in **fig. 5-9 F**. These animals have two pairs of legs attached to almost every trunk segment, resulting in fifty or more pairs of legs. Millipedes differ from the predacious centipedes in feeding mainly on decomposing plant materials such as leaf litter. Therefore, millipedes play an important role in decompositional habitats. Upon disturbance, the animals curl up and exude a brown fluid containing irritating **tannins**. The tannins are metabolites derived from ingested leaf litter and are used for defence.

Superclass Hexapoda

The superclass **Hexapoda** - the animals with six legs - comprises the classes **Insecta** and **Entognatha**. Characteristic for Hexapoda is

- their segmented body
- three pairs of legs, each pair attached to one of the three thoracic segments
- one pair of antennae
- in winged forms one to two pairs of wings

The relationship between hexapod orders is shown in the cladogram in **fig. 5-11**. The features of some selected orders are summarised in **box 5-2** and **fig. 5-4**.

5.5.2.3 Class Entognatha

This class includes the orders **Collembola**, **Diplura** and **Protura**. Formerly the three orders were included in the subclass **Apterygota** (wingless insects). However, in contrast to insects, the primarily wingless Entognatha typically have modified chewing **entognathous** mouthparts, which lie inside the head in a cavity formed by oral folds of the **genae**. The animals are **ametabolous** and lack a **metamorphosis**. During their development Entogantha undergo multiple moults of ten or more in number and continue to moult even after sexual maturity. Most species of the three orders are small and unpigmented soil-dwellers (**fig. 4-17**), that play an important role in nutrient recycling.

Order Diplura [two tails]
The order **Diplura** comprises the most primitive Entognatha, shown in **figs. 4-17** and **5-10 A**. The animals typically lack eyes.

Order Protura [one tail]
Animals of the order **Protura** are also without eyes. Their antennae are greatly reduced and the forelegs are antennae-like (**fig. 5-10 B**). The first few abdominal segments might bear reduced legs. Some species are predacious, feeding on other soil-dwelling arthropods, as shown in **fig. 4-17**.

Order Collembola (Springtails) [sticky tail]
Collembolans, also called springtails, greatly differ from diplurans and proturans. Characteristic is the forked spring-like **furcula** that is used by the animal for saltatorial locomotion. The furcula is made of the fused vestigial legs of the fourth abdominal segment. In springtails, the number of abdominal segments is reduced to six. Most species are soil-dwellers, some can be found under bark or are associated with mosses. A few species are aquatic, living on the surface of water. Some species dwell on glaciers. See also **figs. 4-17** and **5-10 C**.

A
B
C

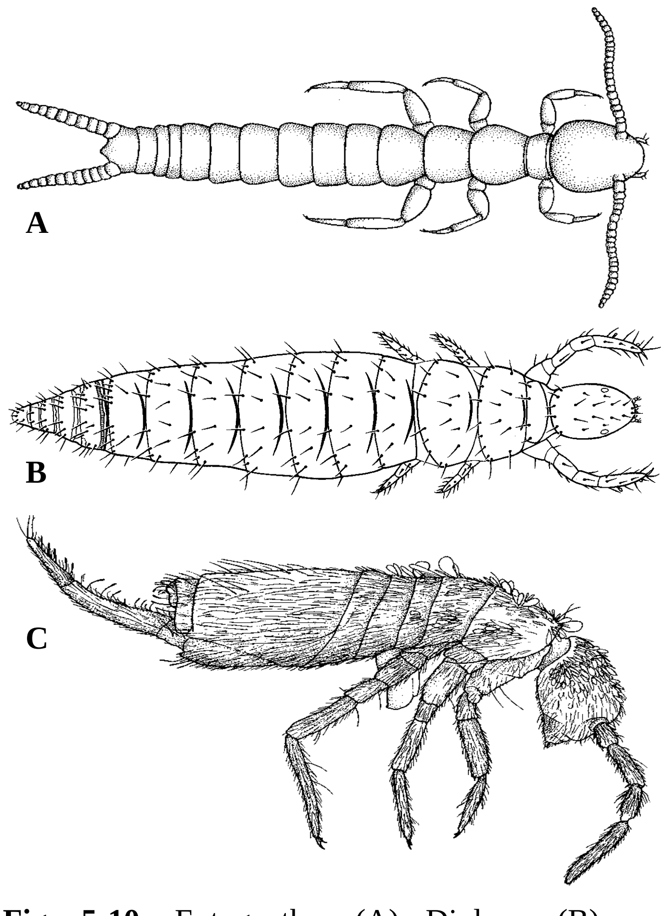


Fig. 5-10: Entognatha: (A) Diplura, (B) Protura, (C) Collembola (springtails) (reproduced from CSIRO, 1991)

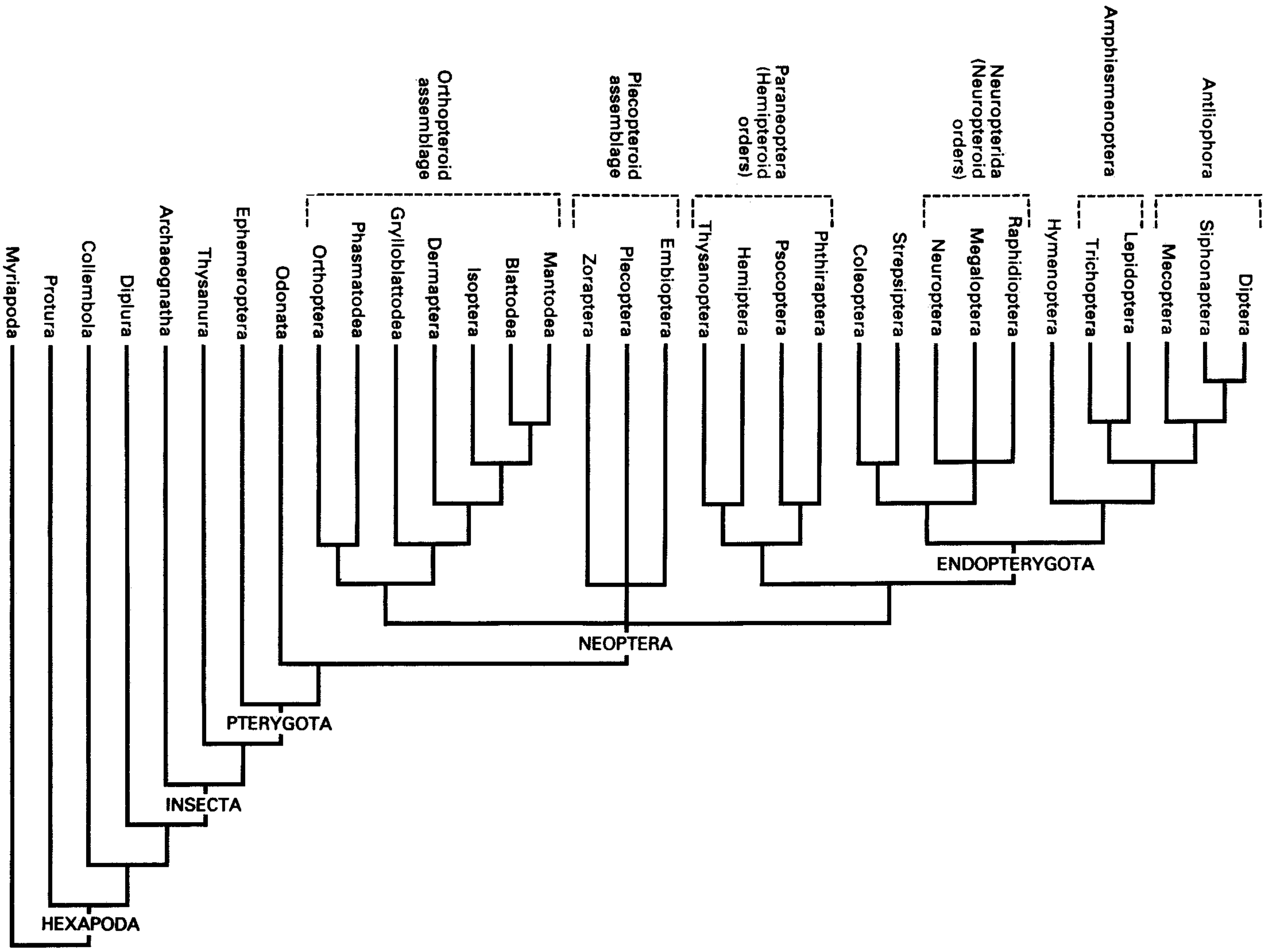


Fig. 5-11: Cladogram of hexapod orders (reproduced from Gullan, P.J. and Cranston, P.S., 1994)

5.5.2.4 Class Insecta

This class comprises hexapods with external **ectognathous** mouthparts, ie. mouthparts that are not enclosed in the head. The class is divided into two subclasses, the primarily wingless **Apterygota** and the winged **Pterygota**. The pterygote orders can be further divided into two infraclasses, the **Palaeoptera**, the ancient-winged insects that cannot fold their wings and the **Neoptera**, the more advanced insects with foldable wings. The wings of **Endopterygota** develop internally, whereas wings of **Exopterygota** develop externally (see **fig. 5-11** and **chapters 2.2.9** and **5.6.2**). Endopterygota are **holometabolous** with complete **metamorphosis** and possess a pupal stage. All Apterygota are **ametabolous**, their adults develop gradually from the immature forms through multiple moults. Insects of all other orders undergo **hemimetabolous** development with incomplete metamorphosis in Palaeoptera and gradual metamorphosis in Exopterygota. The body of an insect is typically divided into three **tagmata**, head, thorax and abdomen. Each of the three thoracic segments bears one pair of legs. In Pterygota the second and third thoracic segments bear one pair of wings each. The abdomen, usually consisting of 11 segments, doesn’t bear legs but the eighth, ninth and tenth segment have appendages modified for reproductive purposes. Insects possess an exoskeleton typical for arthropods. The major internal organs are (1) a tubular digestive tract, (2) an open blood system driven by a tube-like heart, (3) a tracheal system for gas exchange, (4) paired reproductive organs opening at the posterior end of the body, (5) an intricate muscular system, (6)

Malpighian tubules for excretion and (7) a nervous system composed of brain, paired segmental ganglia and connectives.
The class comprises 29 orders that are further outlined in **chapter 5.6**. The features of some orders are summarised in **box 5-2** and some distinguishing features between insects and other arthropod groups are shown in **fig. 5-4**.

5.6 The Insect Orders

5.6.1 Simple Key to Insect Orders

If the insect that you want to identify is
- winged, go to .... **key 1 on page 90**
- wingless, go to .... **key 2 on page 91**
- aquatic, go to .... **key 3 on page 91**

Key 1: Winged Insects

- **four wings**
  - scaly wings
    - antennae generally clubbed .... **Butterflies**, p. 144
    - antennae not clubbed .... **Moths**, p. 138
  - hairy wings
    - narrow without veins, fringed with long hair, up to 43 mm long .... **Thrips**, p. 109
    - wings obviously hairy, hind wings much larger than forewings, up to 40 mm long .... **Caddies Flies**, p. 132
  - forewings hard and horny — covering all or almost all of hindwings when folded .... **Beetles**, p. 112
  - forewings partly hard and horny - mouth formed into piercing-sucking proboscis .... **Bugs**, p. 106
  - forewings leathery
    - forceps on end of abdomen .... **Earwigs**, p. 98
    - no forceps, hind legs
      - long
        - developed for jumping .... **Crickets, Grasshoppers**, p. 98
        - thin for walking .... **Stick Insects**, p. 100
        - foreleg thickened for catching prey .... **Praying Mantids**, p. 97
      - not long .... **Cockroaches**, p. 95
  - wings membranous
    - hindwings similar in length to forewings
      - large head .... **Dragonflies, Damselflies**, p. 94
      - head small
        - hindwings wider than forewings, three-segmented tarsi .... **Stoneflies**, p. 94
        - base of hindwing folded like fan, five-segmented tarsi........... **Alderflies, Dobsonflies**, p. 110
        - no fan-like areas .... **Lacewings**, p. 111
      - mouth formed into a beak .... **Scorpion Flies**, p. 123
    - hindwings smaller than forewings
      - two or three long tails .... **Mayflies**, p. 93
      - fore- and hindwings joined together in flight by minute hook
        - no waist present **Sawflies**, p. 149
        - waist present .... **Bees, Wasps, Ants**, p. 149
- **only two wings**
  - front wings reduced to small clubbed halters ... **Stylops**, p. 122
  - hindwings reduced to clubbed halters .... **True Flies**, p. 124

Key 2: Wingless Insects

- **legs adapted for jumping**
  - body flattened at sides .... **Fleas**, p. 123
- **legs not adapted for jumping**
  - body long, with waist
    - waist has one or two knobs .... **Wingless Ants**, p. 149
    - waist without knobs .... **Wingless Wasps**, p. 149
  - body long
    - length less than 10 mm, tips of tarsi with less than four segments .... **Booklice**, p. 101
    - length 7-18 mm, tarsi 4 segmented ....**Wingless Termites**, p. 96
    - 5-segmented tarsi .... **Stick Insects** and their **Nymphs**, p. 100
      Wingless Cockroaches and their **Nymphs**, p. 95
      Praying Mantids and their **Nymphs**, p. 97
  - body flattened — body long, pointed and scaly with bristles .... **Silverfish**, p. 93
  - body covered with dense hair or scales, no tail .... **Wingless Moths**, p. 138
  - body flattened from above
    - head not prominent, antennae not visible, resembles a spider .... **Louse Fly** or **Sheep Ked** (Diptera) , p. 130
    - head prominent, antennae visible or in grooves in head, found only on mammals and birds .... **Lice**, p. 102
    - antennae long .... **Wingless Bugs**, p. 106
- **false legs on abdomen**
  - not more than five pairs of false legs, large compound eyes .... **Caterpillars** of **Moths** and **Butterflies**, p. 134
  - 6-10 pairs false legs
    - single small eye on each side of head .... **Sawfly Larvae**, p. 147
    - small compound eyes with few facets. **Scorpion Fly Larvae**, p. 123

Key 3: Aquatic Insects

- **wingless and aquatic**
  - true legs absent .... **Larvae** of **True Flies**, p. 124
  - legs not well developed: present or absent, jaws present and head prominent .... **Beetle Larvae**, p. 112
  - legs well developed
    - no tail
      - false legs at end of abdomen often enclosed in case .... **Caddis Fly Larvae**, p. 132
      - facial mask present .... **Dragon Fly Nymphs**, p. 94
    - two tails or less
      - head with jaws, short antennae, legs and gills similar and extended length of body .... **Alderfly** and **Dobsonfly Larvae**, p. 110
      - always two tails, long antennae, no mask or conspicuous jaws .... **Stonefly Nymphs**, p. 94
    - three tails
      - tails flattened or leaf-like, facial mask present .... **Damsel Fly Nymphs**, p. 94
      - tails thin, leaf-like gills at side of abdomen no facial mask .... **Mayfly Nymphs**, p. 93
- **adults with wings found on surface or underwater**
  - hindwings covered by horny forewings which meet in a straight line down middle, mouth parts with jaws .... **Water Beetles**, p. 112
  - hindwings cross each other, piercing-sucking mouthparts .. **Water Bugs**, p. 106
  - wingless and piercing-sucking mouthparts .... **Water Bug Nymphs**, p. 106

5.6.2 Synopsis of Insect Orders

Class: Insecta

The following outline of insect orders is based on suggestions given by CSIRO

5.6.3 Outline of Insect Orders

5.6.3.1 Archaeognatha (Bristletails)

[ancient jaws]

General biology: Fusiform subcylindrical, primitive wingless insects with the ability to jump when disturbed. The body is with or without hypodermal pigmentation, bearing pigmented scales. The compound eyes are large, ocelli are present. The filiform antennae are long and multisegmented, the mouthparts ectognathous. The thorax is strongly arched and has stout legs. The females lay single eggs in cracks and little cavities with their well developed slender ovipositor. The abdomen has ten complete abdominal segments, the eleventh forms the long caudal filament and bears two shorter filiform cerci (**fig. 5-12 A**). Segments two to nine bear pairs of vestigial legs called **stylets**. Ametabolous development with multiple moults, even after maturity. The immature stages resemble adults. Families: **Meinertellidae**, **Machilidae**.

Economic and ecological importance: Bristletails are associated with decompositional habitats and can be found under stones and amongst leaves where they mainly feed on humus. They are of no economic importance.

5.6.3.2 Thysanura (Silverfish, Firebrats)

[fringed tails]

General biology: Cursorial, more or less flattened, primitive wingless insects. The body is scaled or bare, with or without pigments. The compound eyes are reduced or absent, ocelli are almost always absent. The antennae are long, multisegmented and filiform. The chewing mouthparts are ectognathous. The thorax is not strongly arched. The abdominal segments 7 to 9 bear styliform vestigial legs. Females lay eggs in cracks and other secluded places with their well developed slender ovipositor. The caudal filament and cerci are long and filiform, generally subequal in length (**fig. 5-12 B**), but might be short in some species. The cerci are strongly diverging from the body axis. Ametabolous development with large and indefinite number of moults, even during adult stage. The young develop very slowly. Some families are the **Lepismatidae** and **Nicoletiidae**.

Economic and ecological importance: The silverfish are extremely fast runners. As domestic cosmopolitans, silverfish such as the common *Lepisma saccharina* (loves sugar!) are pests of households consuming virtually everything containing starch like books or clothing. Some species are reported to transmit diseases. Silverfish like cool damp places whereas firebrats prefer warmer places. Some species are slender subterranean soil-dwellers, others live in ant nests.

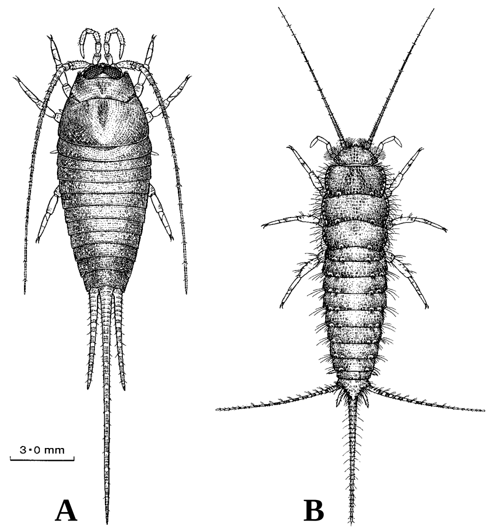


Fig. 5-12: (A) *Allomachillis sp.* (Archaeognatha, Bristletails), (B) *Acrotelsella sp.* (Thysanura; Silverfish) (reproduced from CSIRO, 1991)

5.6.3.3 Ephemeroptera (Mayflies)

[one day, temporary, short-lived wings]

General biology: Long slender, small to large, soft-bodied palaeopteran insects with short and bristle-like antennae. The aquatic nymphs (**naiads**) have well developed chewing mouthparts, adults lack functional mouthparts. The triangular wings are net-veined and can’t be folded. The second pair of wings is smaller than first pair, or lacking in some species. The abdomen of the nymphs and adults has two to three appendages, two long filiform cerci and one or no terminal filament (**fig. 5-13**). The naiads have tracheal gills on the abdomen. The adults live only for half an hour or up to several days. Incomplete metamorphosis with naiads similar in general structures to adults. The metamorphosis of mayflies is unique among insects. They are the only known example of an immature stage having functional wings. This stage is called **subimago**. Some families are the **Caenidae**, **Leptophlebiidae** and **Baetidae**.

Economic and ecological importance: The naiads can be found under rocks and logs in creeks and ponds. They feed on algae and plant matter. Ephemeroptera are important for the trophic structure in aquatic environments since the naiads are a crucial source of food for freshwater fish.

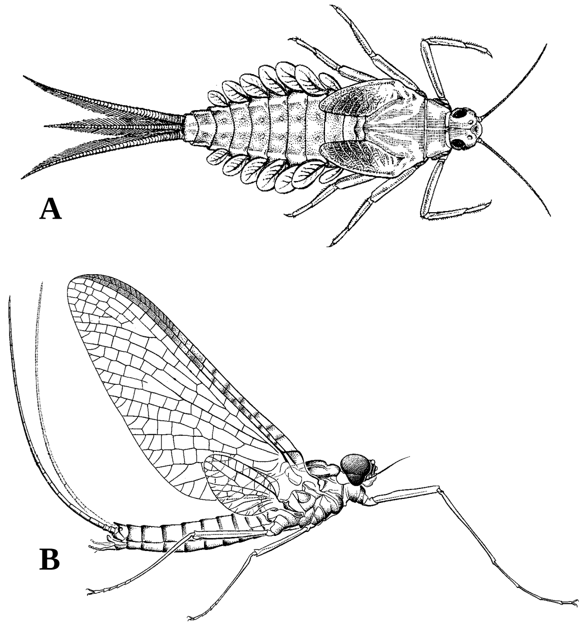
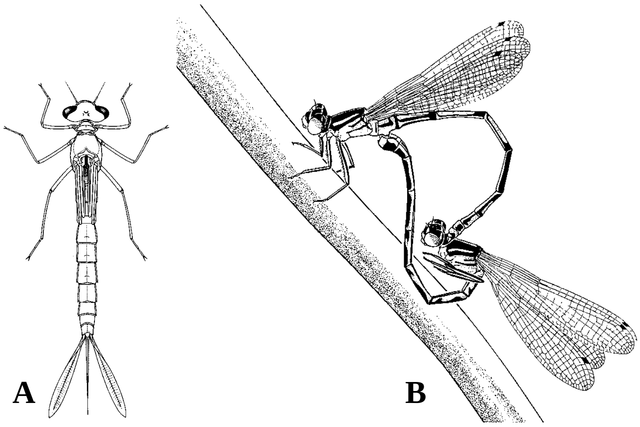


Fig. 5-13: Ephemeroptera (Mayflies): (A) aquatic nymph *Centroptilum sp.* (Baetidae), (B) adult ♂ *Atalophlebia sp.* (Leptophlebiidae) (reproduced from CSIRO, 1991)



A B

Fig. 5-14: Odonata (Damselflies, Dragonflies): (A) aquatic damselfly nymph *Caliagrion sp.* (Zygoptera: Coenagrionidae), (B) copulating damselfly adults in tandem position, *Coenagrion sp.* ♂ above, ♀ below (Zygoptera: Coenagrionidae) (reproduced from CSIRO, 1991)

5.6.3.4 Odonata (Damselflies, Dragonflies)

[toothed insects]

General biology: Predacious palaeopteran mandibulate insects. The medium-sized to large nymphs and adults possess chewing mouthparts. The adults have very short hair-like antennae, large compound eyes, two equal or subequal pairs of long elongate membranous many-veined wings with a conspicuous, dark coloured field on the proximate front part of the wings (**pterostigma**). The naiads are aquatic and have an elongate, prehensile labium for seizing prey. The nymphs of the Zygoptera (**fig. 5-14 A**) have three leaf-like terminal tracheal gills on the abdomen, whereas larval Anisoptera 'breathe' through internal ridge-like rectal gills. Hemimetabolous development with incomplete metamorphosis. The eggs are laid below the surface of water on objects like rotten logs or in ribbons or rings in the water. Odonata have very long generation times. The 17 families are divided into three suborders, the **Zygoptera** (damselflies) like **Coenagrionidae**, **Megapodagrionidae** and **Lestidae**, the **Anisoptera** (dragonflies) such as **Libelluidae**, **Gomphidae**, **Corduliidae** and **Aeshnidae**, and the **Anisozygoptera**, the latter not occurring in PNG. Damselflies are of slender and delicate appearance with a fluttering flight and a very peculiarly shaped thorax. During rest the wings are aligned almost parallel to the abdomen The colourful and stout bodied dragonflies with their strong and graceful flight hold their wings during rest extended to the sides. Adult Odonata are well known for their mating behaviour which is unique in insects. During mating the male grasps the female's neck by the help of terminal claspers. The female then bends her abdomen forward (**tandem position**), as shown in **fig. 5-14 B**.

Economic and ecological importance: Damsel- and dragonflies are utterly beneficial and important for maintaining the trophic balance in aquatic ecosystems. Both adult and immature stages are predacious. Adults catch prey such as mosquitoes, horse flies and midges on the wing with their legs. The naiads dwell on the bottom of rivers, ponds and lakes and live on other aquatic insects and crustaceans.

5.6.3.5 Plecoptera (Stoneflies)

[folded wings]

General biology: Medium-sized to large, somewhat flattened mandibulate exopterygote Neoptera. The forewings are slightly longer than the lobed hindwings. Both adults (**fig. 5-15 A**) and aquatic nymphs (**fig. 5-15 B**) have chewing mouthparts, well developed compound eyes, usually three, rarely two ocelli and multisegmented, long and slightly tapered antennae. Adults have two subequal pairs of long membranous multiveined wings. The tip of the abdomen bears one pair of short or long multisegmented cerci. The immature stages are mostly aquatic with gills on the thorax or on the first two or three abdominal segments. The naiads are either predacious, herbivorous or omnivorous, feeding on algae, other plant material. They can be easily located and collected from overturned stones in rivers and creeks. Gradual metamorphosis with up to thirty moults. The order is divided into two suborders, the **Arctoperlaria** like **Notonemouridae** and the **Antarctoperlaria** including the families **Austroperlidae**, **Gripopterygidae** and **Eustheniidae**.

Economic and ecological importance: Stoneflies are like mayflies and Odonata important for maintaining the trophic balance in aquatic ecosystems, and are thus beneficial insects. They provide a valuable source of food for freshwater fish. Furthermore Plecoptera are very sensitive to pollution and are therefore used as indicator organisms.

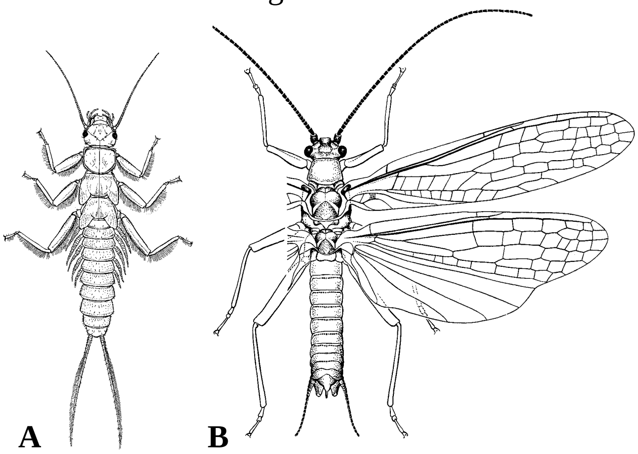


Fig. 5-15: Plecoptera (Stoneflies): (A) aquatic larva *Stenoperla sp.* (Eustheniidae), (B) adult *Illiseoperla sp.* (Gripopterygidae) (reproduced from CSIRO, 1991)

5.6.3.6 Blattodea (Cockroaches)

[insect that shuns light]

General biology: Fast running, medium-sized exopterygote Neoptera with dorsoventrally flattened body. Nymphs and adults have chewing, **hypognathous** mouthpart, that are directed downwards in repose. The head of most species is completely covered with a large pronotum. The filiform antennae are usually bent backwards and are often longer than the body. The compound eyes are well developed. The forewings, when present, are usually modified into hardened **tegmina** for the protection of the hindwings. The hindwings, if present, are membranous and broadened at the rear by the formation of an anal fan, which is an important diagnostic feature. The wings of many species or in particular sexes are reduced to wing pads. The legs are usually long and adapted for running (**cursorial**), in some species for digging (**fossorial**). The tarsi are 5-segmented. The abdomen is many-segmented and bears one pair of cerci. The eggs are enclosed in an **ootheca**, containing 15 to 40 eggs. The ootheca is glued or otherwise deposited on substrate or externally carried by females. **Ovoviviparous** and **viviparous** species keep eggs internally in 'uterus' or brood sac, until the eggs hatch. **Parthenogenesis** is common in some species. Gradual metamorphosis, shown in **fig. 2-36**, with slowly growing and very active nymphs. Adults and nymphs are often aggregated, living together in families. The Pacific wood roach *Cryptocercus punctulatus* lives in colonies and develops an almost truly social life. Cockroaches are a very ancient order of winged insects with fossil records dating back 400,000,000 years. The lifespan of cockroaches can be up to four or five years, however only a few individuals live their full lifespan. Cockroaches possess scent glands that release a very unpleasant odour for defence purposes. Most species are nocturnal and adapted to dark and humid habitats, and various climatic and altitudinal zones. The order is very diverse in the Tropics, where some species can become really huge like the giant tropical cockroach *Megaloblatta blaberoides* or the Madagascar giant hissing cockroach *Gromphadorina potentosa*. The order is divided into five families, the **Polyphagidae**, **Blaberidae**, **Nocticolidae**, **Blatellidae**, **Blattidae** and **Cryptocercidae**. The latter family is not occurring in PNG.

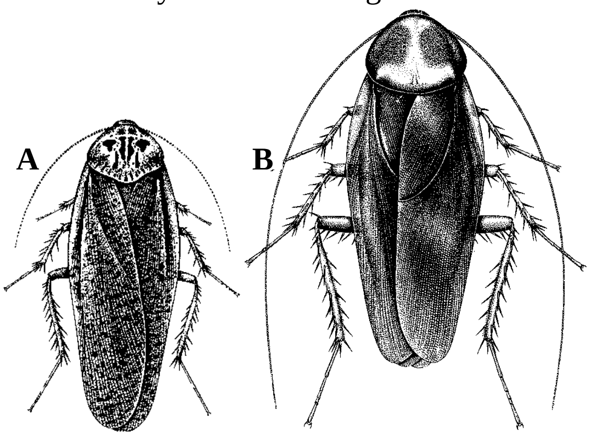


Fig. 5-16: Blattodea (Cockroaches): (A†) *Blatta germanica* (Blattidae), (B††) *Periplaneta americanus* (Blattidae) (reproduced from Ross, H.H., 1982†; CSIRO, 1991††)

Economic and ecological importance: Most species are harmless omnivorous forest dwellers. However, two species of undesired but common cockroaches, shown in **fig. 5-16** and **box 5-3**, are cosmopolitans dwelling

Feature	German Cockroach (*Blatta germanica*)	American Cockroach (*Periplaneta americanus*)
Appearance	light brown with dark streaks down the back	reddish brown
Size	small, 5 - 15 mm	large, 35 - 45 mm
Number of offspring/year	400,000	800
Feeding habits	look for food in small area, eg. kitchen, usually travel no more than one metre	movement free-ranging, travelling from room to room in search for food
Preferred locations	generally found in large groups in warm and moist locations like cooking areas	found in bathrooms, laundries, around pipes or near sewer drains

Box 5-3: Features of common cockroaches associated with human habitations

houses of man. Both species were accidentally dispersed all over the world and can be also found in PNG. These pests search for food during the night, leaving behind faeces and a typical unpleasant odour. However, cockroaches are not known to transmit any diseases. Interestingly, the common names of these two species vary in French, English and German, according to the former political 'enemies'. The common name of *Blatta germanica* in English is 'German Cockroach', the animal is called 'Prussian' in French and 'Russian' in German.

5.6.3.7 Isoptera (Termites)

[equal wings]

General biology: Termites are **eusocial** insects living in colonies and are organised in three distinct **castes**, the **reproductives** (queen, king, winged alates, de-alates and neotenics), the wingless **soldiers** (intercastes) and the wingless **workers**. Due to the caste system, termites vary tremendously in their morphology (**polymorphism**). The biology of termites is outlined in **chapter 3.2.1**. Both nymphs and adults have moniliform antennae and chewing mouthparts. The jaws of **mandibulate** soldiers of particular species are greatly enlarged. The cuticle of soldiers and workers is not sclerotized, but soft and not pigmented. Therefore they are bound to moist and dark environments and have to avoid sunlight ('sunburn' and desiccation). The elongate and membranous wings are held flat over the body at rest. The alates are capable of shedding their wings after the mating flight by means of basal **sutures**. The abdomen of a mature queen is markedly enlarged and adapted for laying 1000 or more eggs per day. The cerci of termites are short. The gradual metamorphosis is shown in **fig. 3-9**. Most termite species are found in tropical countries. Only two termite species occur in southern Europe but there are 246 species in Australia. Families of termites occurring in PNG are **Mastotermitidae**, **Kalotermitidae**, **Termitidae** (*Nasutitermes*, *Microcerotermes*, *Amitermes*, *Pericapritermes*), **Rhinotermitidae** (*Coptotermes*, *Rhinotermes*, *Schedorhinotermes*) and **Termopsidae**. Their soldiers, shown in **fig. 5-17**, are used for identification. The term '**white ants**' for termites is rather misleading since the only feature ants and termites have in common is the fact that both are insects. Therefore this term should be avoided.

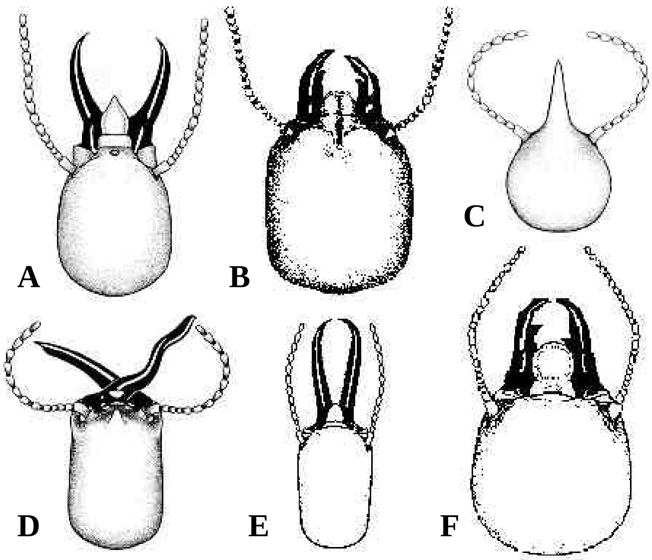


Fig. 5-17: Soldiers of Isoptera (Termites): (A) *Coptotermes elisae* (Rhinotermitidae), (B) *Schedorhinotermes spp.* (Rhinotermitidae), (C) *Nasutitermes novarumhebridarium* (Termitidae), (D) *Pericapritermes spp.* (Termitidae), (E) *Microcerotermes biroi* (Termitidae), (F) *Mastotermes spp.* (Mastotermitidae) (reproduced from CSIRO, 1991)

Economic and ecological importance: Most species are beneficial and play an important ecological role as decomposers of decaying wood. However some species can cause considerable economic loss as insect pests of households, forest plantations and forest products as further outlined in **chapter 6.2.1**. **Predators** of termites are echidnas, some birds like parrots and kingfishers and meat ants of the genus *Iridomyrmex*. However, none of these predators can effectively control the large number of individuals.

5.6.3.8 Mantodea (Praying Mantids)

[prophet]

General biology: Medium-sized to large, predacious, diurnal and nocturnal insects with freely mobile head of characteristic triangular shape. The head bears chewing mouthparts, huge compound eyes and multisegmented, usually shorter, filiform antennae. The prothorax is prolonged, the forelegs are raptorial with sharp hooks and a series of spines for grasping and holding prey. The forelegs are raised in repose in a 'praying' attitude and possess large mobile coxae. The mid and hindlegs are cursorial. The tarsi are almost always 5-segmented. The forewings are modified into hardened **tegmina**, the hindwing are membranous. The wings of some species or sexes, particularly females are reduced or even absent, as shown in **fig. 2-44 A**. The cerci are short and multisegmented. The eggs are enclosed in an **ootheca** as shown in **fig. 5-18 A**. Gradual metamorphosis. The order comprises eight families, however only three can be found in PNG, the **Hymenopodidae**, the **Mantidae** and the **Amorphoscelidae**. Common species occurring in PNG are *Orthodera ministralis* (**fig. 5-18 B**) and *Archimantis latistylus* (**fig. 2-44 A**), both **Mantidae**. Praying mantids have developed a number of defence strategies like **crypsis** and **camouflage**, ie. the resemblance of leaves or twigs (**fig. 4-8**); **scare tactics**, ie. the wings are often very colourful and are opened when disturbed; and **chemical defence**, ie. the animals regurgitate deterrent digestive fluids from their mouth. The story, that female praying mantids are cannibals eating their males after copulation has to be considered as not true and probably such observations are due to captive conditions.

Economic and ecological importance: As predacious insects mantids play an important role in the natural control of insects. Attempts to use these animals as biocontrol agents, however fail due to the fact that praying mantids are non-specific predators consuming other beneficial insects as well as pest species.

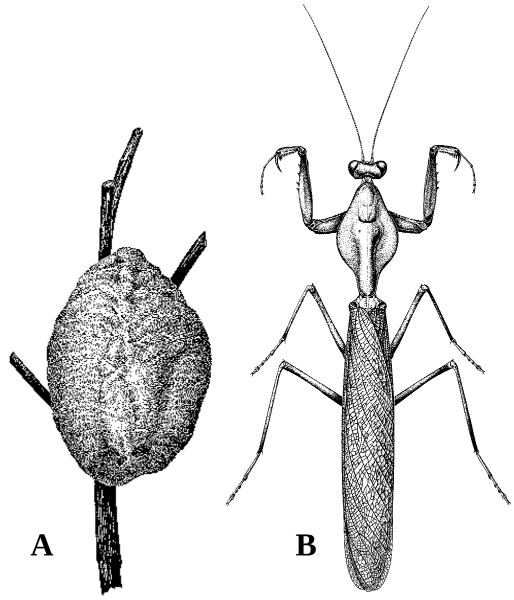


Fig. 5-18: Mantodea (Praying Mantids): (A) *Archimantis spp.* ootheca (Mantidae), (B) adult *Orthodera ministralis* ♀ (Mantidae) (reproduced from CSIRO, 1991)

5.6.3.9 Grylloblattodea (Ice Crawlers)

[cricket that shuns light]

General Biology: Apterous mandibulate exopterygote Neoptera. The prognathous head bears large, heavily sclerotized mandibles and filiform, multisegmented antennae. The small animals lack ocelli. The legs are cursorial with large coxae, wings are not present. The cerci are long, flexible and segmented. The ovipositor in females is strongly projecting. The nymphs are subterranean soil dwellers. See **fig. 5-19 A**.

Economic and ecological importance: The grylloblattids are bound to temperate climates and there are no recorded species of this order in the southern hemisphere. World-wide there are 21 described species.

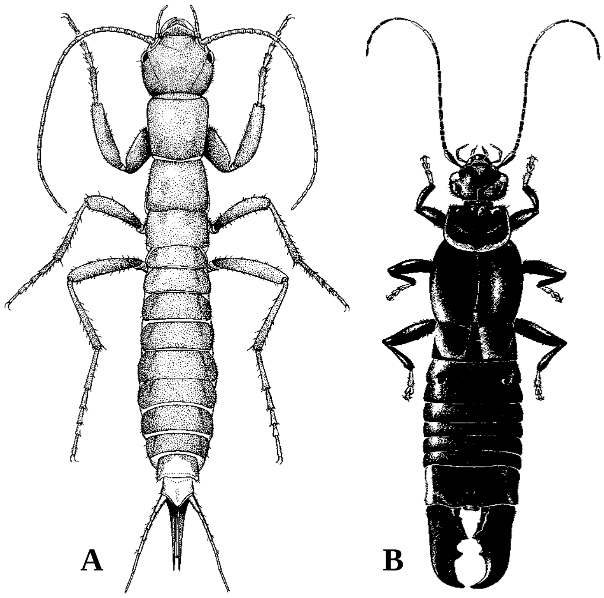


Fig. 5-19: (A) *Grylloblatta spp.* (Grylloblattodea, Ice Crawlers), (B) *Chelisoches spp.* (Dermaptera: Chelisochidae, Earwigs) (reproduced from CSIRO, 1991)

5.6.3.10 Dermaptera (Earwigs)

[skin-like wings]

General biology: Medium-sized, elongate, heavily sclerotized, and thus brown to black exopterygote Neoptera. The head is prognathous, bearing chewing mouthparts at its apical tip. The compound eyes are large, ocelli are lacking. The antennae are long, slender and multisegmented. The adults are winged or wingless. The forewings, when present, are reduced to small **tegmina**. The hindwings are membranous and semicircular, are almost entirely made up of an anal fan and are completely hidden by the tegmina at rest. The relatively short, cursorial legs have 3-segmented tarsi. The cerci are modified into conspicuous unsegmented terminal forceps, shown in **fig. 5-19 B**. The nymphs of some species possess long, multiarticulate cerci instead of forceps. Gradual metamorphosis with up to six moults. Some species are viviparous. The females often guard the eggs and nymphs, until the young can care for themselves. World-wide there are ten families in three suborders, however most species occur in the Tropics. Seven orders can be found in PNG: **Anisolabididae**, **Labiduridae**, **Apachyidae**, **Spongiphoridae**, **Forficulidae**, **Chelisochidae**, **Pygidicranidae**.

Economic and ecological importance: Most earwigs are nocturnal omnivores. The animals live hidden under bark, logs, stones, in soil and cavities of any sort during the day. Some species are predacious. Earwigs are of little economic importance, although a few phytophagous species are reported to cause damage to ornamental plants and agricultural crops.

5.6.3.11 Orthoptera (Crickets, Katydids, Grasshoppers and Locusts)

[straight wings]

General biology: Medium-sized to large, elongate mandibulate exopterygote Neoptera. The hypognathous head has chewing mouthparts and large mandibles both in nymphs and adults. Orthoptera have medium to large compound eyes and usually three, ocelli, that can be absent or reduced in number in some species. The antennae are short or several times as long as the body with the number of segments varying from 7 to many. The saddle-like pronotum has large descending lateral lobes. The hindlegs are elongate with enlarged femora, usually saltatorial, the fore- and midlegs are gressorial. The forelegs of some species have spines for grasping or are fossorial. The tarsi are 1- to 4-segmented, terminal claws are mostly present. The wings are usually well developed but can be reduced or absent. The forewings are formed into narrow and hardened **tegmen** that cover the hindwings and overlap across the median. The hindwings are membranous and many-veined, folded fan-like in rest and are very colourful in some species. The cerci are unsegmented and short. The females possess an ovipositor. Many species have **stridulatory files** for sound production and **tympanal organs** for hearing, eg. on tibiae of the forelegs, further outlined in **chapters 2.2.6** and **3.1.1**. The nymphs usually undergo five larval instars with gradual metamorphosis. Twisted wing buds (**fig. 5-20 G**) can be found in mature nymphs. The order comprises some of the largest insects with a body length of more than 11 cm and wingspans of more than 22 cm. The world's largest katydid *Siliquofera grandis* (**Tettigoniidae**: **Phyllophorinae**) can be found in PNG. The order Orthoptera is relatively diverse with more than 20,000 described species. World-wide there are 28 families. 14 families can be found in PNG belonging to the two suborders **Ensifera** and **Caelifera**.

Suborder Ensifera: nocturnal insects having long antennae with more than 30 segments, crickets excepted. Some families are:

- **Gryllidae** Crickets are chirping insects similar to Tettigoniidae, but with fewer than 30 antennal segments. The head is concealed under the large pronotum. The forewings are held flat and are broader at their base. The tarsi are 3-segmented, the ovipositor slender and needle-like, the are long cerci. Common in PNG is *Teleogryllus spp.* (**fig. 5-20 A**).
- **Gryllotalpidae** Mole crickets have large and broad fossorial forelegs that are used as a shovel. The antennae are much shorter, but have more than 30 segments. Common in PNG is *Gryllotalpa spp.* shown in **fig. 5-20 B**.
- **Tettigoniidae** Katydids, bush crickets or long-horned grasshoppers are vegetarians with very long antennae and 4-segmented tarsi. The females have a short, sickle-like or long sword-like ovipositor. The wings are sometimes short or absent. The tympanal organ is located at the inner side of the tibiae of the forelegs, shown in **fig. 2-29**. Common in PNG are *Siliquofera grandis*, *Phasmodes* (**fig. 5-20 C**), *Phaneroptera*, *Holochlora* and *Caedicia* (**fig. 5-20 D**, **Plate 3 B**).

Suborder Caelifera: with shorter antennae (fewer than 30 segments). Some families are:

- **Pyrgomorphidae** are characterised by their conical heads as in the case of *Atractomorpha similis* (**fig. 5-20 E**), *Desmoptera* and *Psednura*.
- **Acrididae** Plague locusts and grasshoppers have a tympanum on each side of the first abdominal segment near the base of the hindwings. The ovipositor is short. *Valanga irregularis*, one of the world's largest short-horn grasshoppers, occurs in Australia and PNG. Common in PNG are *Chortoicetes terminifera* (**fig. 5-20 G**), *Acrida*, *Sphingnotus*, *Locusta migratoria* (**fig. 3-8**) *Gastrimargus* and *Nomadacris guttulosa* (**fig. 5-20 F**).

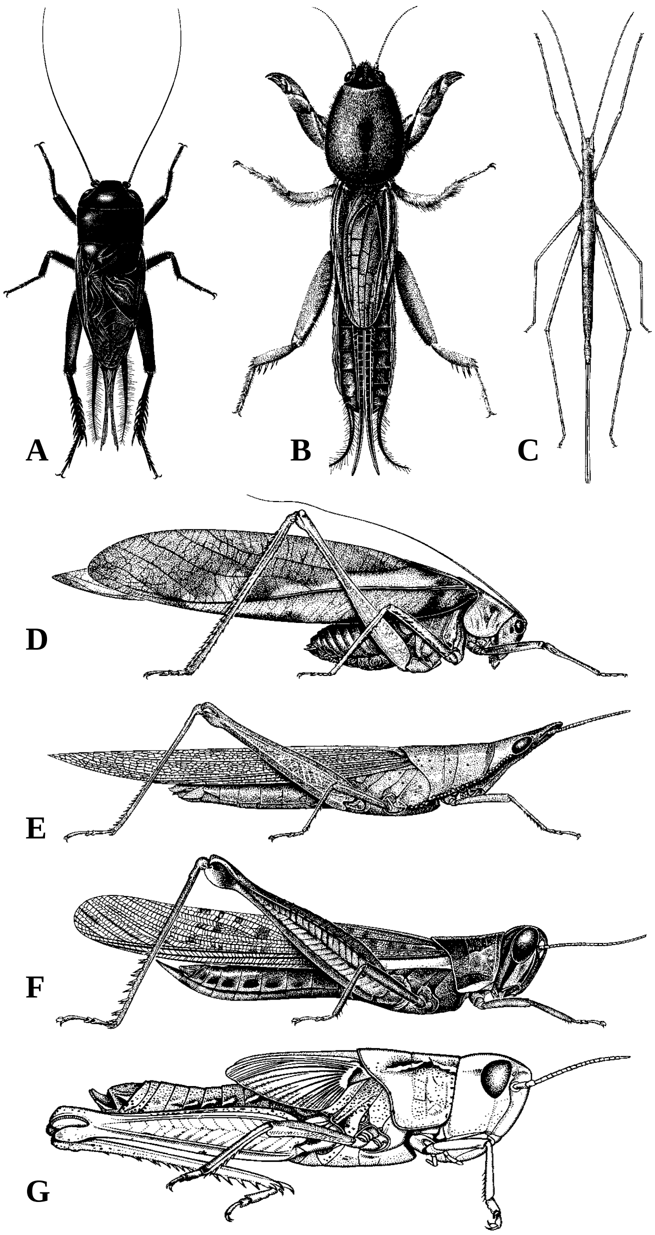


Fig. 5-20: Orthoptera (Crickets, Mole Crickets, Grasshoppers): (A) *Teleogryllus spp.* ♂ (Gryllidae), (B) *Gryllotalpa spp.* ♀ (Gryllotalpidae), (C) *Phasmodes ranatriformis* ♀ (Tettigoniidae), (D) *Caedica major* ♀ (Tettigoniidae), (E) *Atractomorpha similis* ♀ (Pyrgomorphidae), (F) *Nomadacris gullulosa* ♂ (Acrididae), (G) *Chortoicetes terminifera* last larval instar ♀ (Acrididae) (reprod. from CSIRO, 1991)

Some locusts exhibit the phenomenon of **phase polymorphism**, discussed in **chapter 3.2**. Two morphologically distinct phases can be found, the **solitary phase** of singly living, non-migrating individuals and the **gregarious phase** of migrating and swarm-forming individuals. The different appearance of the two phases, shown in **fig. 3-8**, made scientists believe for a long time, that they belonged to different species.

Economic and ecological importance: Migrating grasshoppers also called plague locusts, are mainly recruited from the super-family **Acridoidea**. The mostly phytophagous insects can cause considerable damage to agricultural crops and pastures in the tropics during outbreaks (**calamities**). Adult as well as larval plague locusts are able to form swarms of innumerable individuals as described in the **Old Testament**:

"... I will bring locusts into your country tomorrow. They will cover the face of the ground so that it cannot be seen. They will devour what little you have left after the hail including every tree that is growing in your fields. They will fill your houses ..." **Exodus 10:4-6**

During sustained flights, locusts can travel several hundreds of kilometres. During an outbreak of the Desert Locust *Schistocerca gregaria* in West Africa in the late 80's, a huge swarm succeeded in crossing the Atlantic ocean. This incredible exercise becomes even more stunning, if one realises that the distance between the American and African continent is about 5,000 km and that there is no island in between for repose. During outbreaks, a large number of people, deprived of their crops, depend on locusts as a source of food. Apart from damage caused to agricultural systems, grasshoppers are also pests of forestry. The insects are able to ringbark and eventually kill young seedlings and saplings in nurseries or newly established plantations.

5.6.3.12 Phasmatodea (Stick and Leaf Insects)

[phantom, ghost or spectre]

General biology: Medium-sized to large mandibulate, phytophagous, exopterygote Neoptera. The stick- or leaf-like, mainly elongate and slender insects have a round, prognathous head with chewing mouthparts. The antennae are short to very long and slender, having 8 to more than 100 segments. The head bears three or sometimes fewer ocelli. All three pairs of legs are gressorial, long and slender, sometimes thorny. Wings are present or absent mostly in females. The tegmen are nearly always short, covering only a small part of the hindwings and overlapping each other in repose. The remigium of the hindwings is tough, the large anal areas are membranous. Females are often much larger than the males. The males are absent in some species like *Carausius morosus* and the females reproduce **parthenogenetically**. The eggs are free with a tough, thick shell and a conspicuous cap-like lid (**operculum**), shown in **fig. 5-21 A**. The eggs are laid singly and dropped into leaf litter. Gradual metamorphosis with prolonged egg development. The order is divided into three families, two are present in PNG, the tropical **Phyllidae** (leaf insects), eg. *Phyllium spp.* (**fig. 5-21 B** and **Plate 1 D**) and **Phasmatidae** (stick insects or walking sticks). One of the world's longest stick insects, *Hermachus morosus*, can be found in PNG. Other common species in PNG are the bizarre ghost insects *Extatosoma papoi horridus* and *Eurycantha horrida* shown in **figs. 5-21 D** and **4-13 A** and *Phasma gigas*. Phasmatodea are very well **camouflaged** and hard to detect in their natural habitat, as shown in **fig. 4-11 B**. Stick insects move very slowly and feign death, when disturbed.

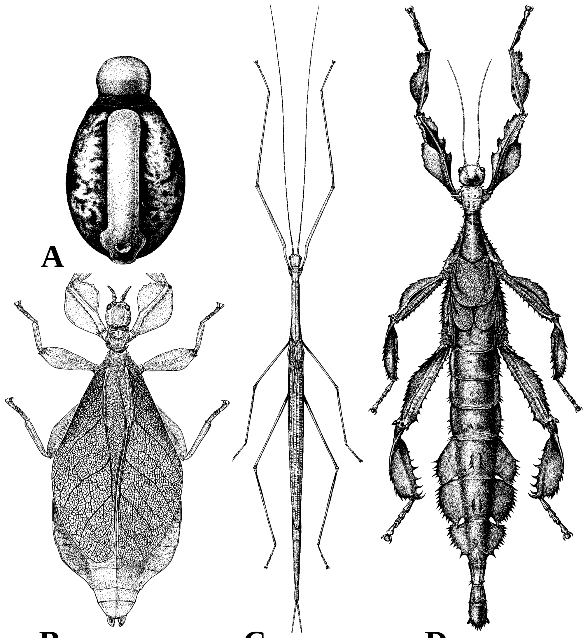


Fig. 5-21: Phasmatodea (Stick and Leaf Insects): (A) *Extatosoma sp.* egg, (B) *Phyllium sp.* ♀ (Phyllidae), (B) *Sipyloidea sp.* ♀, (C) *Extatosoma spp.* ♀ (Phasmatidae) (reproduced from CSIRO, 1991)