Economic and ecological significance: Some of the exclusively phytophagous stick insects are known to defoliate fruit trees like Guava and tree crops like Eucalyptus, and therefore have to be considered as pests.

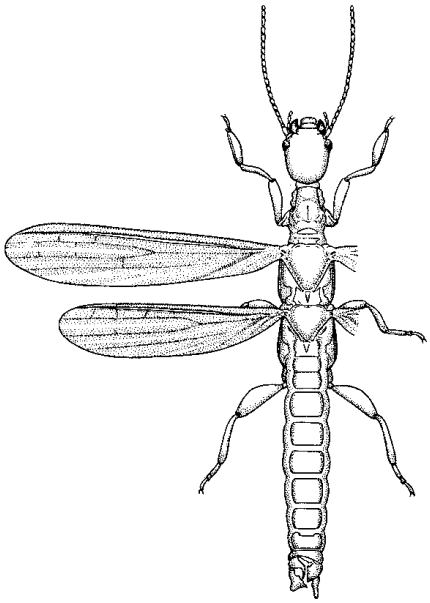

Fig. 5-22: Embioptera (Web-, Foot-Spinners): *Notoligotoma sp.* ♂ (Notoligotomidae) (reproduced from CSIRO, 1991)

5.6.3.13 Embioptera (Web- or Footspinners) [lively wings]

General biology: Small, elongate, flattened exopterygote Neoptera with large, strongly prognathous heads possessing chewing mouthparts and noticeable jaws. The eyes are well developed, ocelli are absent. The antennae are elongate, multisegmented and filiform. The legs are short and stout with enlarged front tarsi. The females are wingless, the males either winged or wingless. Wings, if present, are equal, membranous and have reduced venation. The cerci are one or two-segmented and asymmetric in males (**fig. 5-22**). Embioptera, also called **Embiidna**, are so tiny that they are often only recognised by the presence of the tubular silk galleries which they weave wherever they go. The silken thread is spun by approximately 200 silk glands housed in the enlarged tarsi of the forelegs. The nymphs undergo incomplete development. The immature stages are remarkably similar to the adults, particularly in the wingless species. The wing pads of the winged males develop internally. External wing buds, typical for immature hemimetabolous insects, appear only during the last larval instar.

Economic and ecological importance: Web- and Footspinners mainly occur in the Tropics and subtropics. They live aggregated under loose bark, stones, on the ground or are associated with dung. They are not considered as pests, thus of no economic significance.

5.6.3.14 Psocoptera (Psocids, Bark-, Booklice) [biting wings]

General biology: Small, free-living exopterygote Neoptera with large mobile head. The chewing mouthparts bear asymmetrical mandibles. The compound eyes are large or reduced. The long and filiform antennae are composed of 13 to 50 segments. The prothorax is small, the legs are slender with 2- or 3-segmented tarsi in adults and 2-segmented tarsi in nymphs. The wings are present, reduced or absent. If present, the membranous wings show reduced venation and are held roof-wise over the abdomen. The forewings much larger than the second pair of wings. Cerci are absent. Gradual metamorphosis with relatively short life span.

Economic and ecological importance: The mostly fungivorous Psocoptera can be encountered in many habitats, associated with rotting plant material. However, some species are common pests of stored products such as food stuff and can occur in insect collections, libraries and herbaria, encouraged by poor storage methods. There they feed on mould, cereals, starches, glue and paper, Well known representatives of this order are the common booklice *Liposcelis divinatorius* and *Trogium pulsatorium*. See **fig. 5-23**.

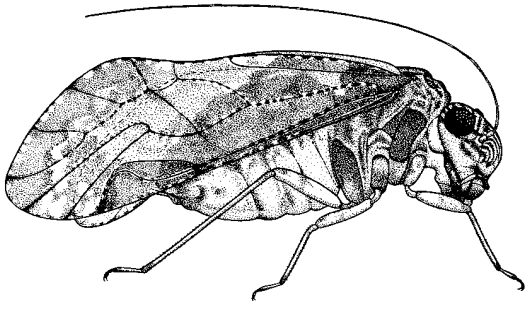

Fig. 5-23: Psocoptera (Booklice): *Myopsocus sp.* (Myopsocidae) (reproduced from CSIRO, 1991)

5.6 3.15 Zoraptera

[purely wingless]

General biology: Minute exopterygote Neoptera with chewing mouthparts and moniliform, 9-segmented antennae. Alate forms are blind, winged forms possess compound eyes and distinct ocelli. The tarsi are 2-segmented. Wings, when present, are membranous with only one or two veins. The wings are shed by adults, leaving only small buds. The cerci are short and one-segmented. Females with or without ovipositor. Gradual metamorphosis. Fewer than 20 species are known, most of them occurring in tropical America. Zoraptera do not occur in Papua New Guinea.

Economic and ecological importance: Zorapterans live in rotten wood or under dead bark, often in 'colonies' of a few to a hundred animals. The insects feed on small arthropods like mites.

5.6 3.16 Phthiraptera (Lice)

[wingless lice]

General biology: Small, exoparasitic, wingless, dorsoventrally flattened, exopterygote Neoptera. The head is sessile or with limited movement, bearing chewing or piercing-sucking mouthparts, depending on the suborder. The antennae are 3 to 5-segmented, filiform or capitate and are sometimes hidden in a groove of the head. The compound eyes are reduced or absent, ocelli are always absent. The thorax is small and sometimes indistinct, the legs short, stout, but well developed. The tarsi are 1- or 2-segmented bearing a single or two claws for clinging to feathers or hair of the host. Wings are always absent. The abdomen has 5 to 8 segments. Gradual metamorphosis with three instars only. There are a few important families in four suborders:

Amblycera with a reduced type of chewing mouthparts feeding upon shed skin and dried blood associated with wounds of the host:

- **Boopiidae** found with a few exceptions on Australian and Papuan marsupials
- **Menoponidae** found world-wide on wild species of birds and domestic poultry, like *Menopon gallinae*

Ischnocera, like the **Amblycera** with a reduced type of chewing mouthparts:

- **Philopteridae** like the introduced ectoparasites of domesticated poultry *Columbicola columbae* and *Goniocotes gallinae*
- **Trichodectidae** occurring on mammals, and introduced with their respective hosts. Pests on livestock and pets are *Bovicola bovis* on cattle, *Bovicola ovis* on sheep, *Bovicola caprae* on goat, *Trichodectes canis* on dog and dingo and *Felicola subrostratus* on cat

Ischnocera and **Amblycera** were formerly in the group **Mallophaga**.

Anoplura (sucking lice) with piercing-sucking mouthparts to penetrate the host's skin and to suck its blood:

- **Linognathidae** on pets and livestock like *Linognathus vituli* on cattle, *L. pedalis* and *L. ovillus* on sheep and *L. setosus* on dog and dingo
- **Haematopinidae** on ungulates like *Haematopinus suis* on pig, *H. asini* on horse, *H. eurysternus* and *H. quatripertusus* on cattle
- **Pediculidae** on primates like the body louse *Pediculus humanus*, shown in **fig. 5-24 B**, and the head louse *P. capitus* on man
- **Phthiridae** with only one sibling species, the human crab or pubic louse *Phthirus pubis*.

Rhyncophthirina with only one known species not occurring in PNG.

Economic and ecological importance: As **ectoparasites** found only on mammals and birds, lice are of medicinal and veterinary significance. Lice spend their entire life more or less specifically on one particular host. They prefer warmer, hairy body parts of their respective host, eg. the pubic region for the pubic or crab louse *Phthirus pubis*. The minute eggs called **nits** are firmly attached to feathers or hair of the host and are hard to remove. Apart from the fact that lice are a nuisance for the host causing severe skin irritations, they are vectors for various diseases of man and livestock, especially poultry. For instance the body louse or cooty *Pediculus humanus* can transmit **typhus** and other severe diseases in humans.

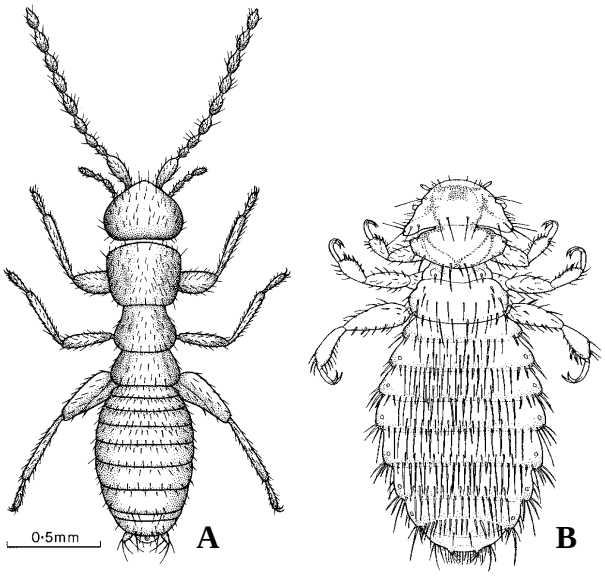

Fig. 5-24: (A) *Zorotypus sp.* (Zoraptera), (B) *Pediculus humanus* (Phthiraptera: Pediculidae, Lice) (reproduced from CSIRO, 1991)

5.6.3.17 Hemiptera (Aphids, Leafhoppers, Scale Insects, Cicadas, True Bugs, etc.)
[half wings]

General biology: Diverse, very small to medium-sized exopterygote usually winged Neopteran insects with piercing-sucking mouthparts. The mouthparts consist of a hinged stylet-like beak (**proboscis**) formed by mandibles and maxillae (**figs. 2-11**, **2-13** and **2-14**). The proboscis is held backwards and rested in an anterior ventral groove between the coxae when not in use. The mouthparts are absent in adults of some species of aphids (**Aphididae**) and scale insects (**Coccoidea**). The antennae are usually 3- to 10-segmented, the compound eyes are various and large but sometimes absent, the number of ocelli varies from two to three. The legs are usually cursorial and similar. The forelegs of some predacious Heteroptera like **Reduviidae** are raptorial, in aquatic **Gerromorhpa** adapted for swimming or walking on the surface of water, others have forelegs or hindlegs developed for jumping. In females of scale insects (**Coccoidea**) the legs are reduced or absent. The coxae are free, the tarsi are 2- to 3-segmented, the pretarsal structures are diverse. Usually two pairs of wings are present that are held roof-like over the body during rest in **Stenorrhyncha** and **Auchenorrhyncha**, or lie flat over the abdomen, or are **coleopteroid** (as in beetles). The forewings are homogenous, transparent or translucent, membranous in **Stenorrhyncha**, **Auchenorrhyncha** and some other groups. In most **Heteropterans**, the true bugs, the forewings may be entirely or at basal portion (**corion**) of harder consistency than the thinner, transparent or translucent and membranous hindwings (name: different wings, see fig. **5-26**). If winged, the wing venation is in general reduced and the base of the wings is separated by a large conspicuous **scutellum**. Cerci are absent. The abdomen of females of many species bears a well-developed sheath-like or saw-like ovipositor. Gradual metamorphosis with two to seven, commonly five larval instars (**fig. 2-37**). Parental care occurs in some species (**fig. 2-34**). **Auchenorrhyncha** like cicadas have complex sound producing mechanisms, discussed in **chapter 3.1.1**. A fundamental feature of true bugs (**Heteroptera**) is the presence of scent glands or **stink glands** that release an unpleasant deterrent odour when disturbed (**chemical defence**). **Mimicry** by means of imitating ants, thorns or other distasteful stink or assassin bugs is common. Hemipteran defence and the mutualistic relationships between ants and homopterans like plant lice or scale insects are outlined in **chapter 3.2.3** and **4**.

Economic and ecological importance: Most species are **phytophagous** sucking on plants. A number of predacious or parasitic species feed upon animal body juices, sucking blood of mammals or fish, or hemolymph of insects. Hemipteran predators of insects play an important role in the natural control of their prey populations and are therefore considered as beneficial insects. However, many species are of agricultural, veterinary and medicinal significance since they are common and severe ectoparasites of man and domesticated animals or destructive pests of cultivated plants. Moreover, many of the pest species are capable of transmitting diseases. Pest species are indicated with an **asterisk** and discussed in the context of the respective family.

Hemipterans are one of the very diverse insect orders, divided into more than a hundred families of three suborders **Stenorrhyncha**, **Auchenorrhncha** and **Heteroptera**. The term **Homoptera** (half wings) is also widely used and comprises the two suborders **Stenorrhyncha** and **Auchenorrhncha**.

Suborder **Stenorrhyncha** with four superfamilies:

- **Aphidoidea*** (aphids, plant lice, green fly, black fly) Of importance is the family **Aphididae** (**figs. 5-25 A**, **8-7 D**) causing considerable damage on foliage and roots of agricultural crops. Some species produce **galls**. Aphids are small, soft-bodied, winged or wingless with long threadlike or short antennae, 2-segmented tarsi and one pair of **cornicles** at the posterior end of the abdomen. Aphids reproduce often by means of **parthenogenesis**. Some species are covered with woolly fibres. The mutualistic relationships between aphids and ants is discussed in **chapter 3.2.3**. The sweet secretions of aphids, called **honeydew**, sometimes drip onto leaves, offering good conditions for mould to grow on. The blackish stains of mould are then referred to as **black sooty mould**. Aphids show very poor flight performance, usually they depend on wind for dispersal. Aphids are not very diverse in natural habitats in the tropics. This is because the probability of drifting to a suitable host tree is minute due to high species diversity and low abundance of a particular host species. However, aphids are quite likely to become pests in **monocultures**. In PNG the pine woolly aphid *Pineus pini* (**Adelgidae**), shown in **fig. 6-3 I**, is of economic significance in *Pinus caribaea* plantations.

- **Psylloidea*** (lerps, jumping plant lice or psyllids) Of importance is the family **Psyllidae**, with some members similar to aphids while others look like the miniature of cicadas, shown in **fig. 5-25 B**, but with much longer antennae. Psyllids have strong jumping legs with enlarged femora. Lerps spin conical scales (**lerps**) to shelter underneath, as shown in **figs. 5-25 C**, **6-3 J** and **box 6-1 N**. The sugar lerp *Spondyliapsis eucalypti* is sucked by some people for its sweetness (‘**manna**’). Nymphs may produce white waxy secretions or **honeydew**. Most species have to be considered as pests of agriculture because they feed on plant juices. Some transmit viral diseases or produce galls. However, some are suitable as biocontrol agents if their host is a weed. *Heteropsylla spinulosa* for instance is used for the control of the giant sensitive plant *Mimosa invisa* in PNG. Pests of tree crops in PNG are *Glycaspis spp.* and *Cardiaspina spp.* sucking on young shoots of *Eucalyptus spp.*, shown in **box 6-1 N**, **O** and **fig. 6-3 J- L**.

- **Aleyrodoidea*** (whiteflies) Minute insects that might be confused with moths, as shown in **fig. 5-25 D**. Their wings are covered with white waxy powder. Immature stages sessile and scale-like and sometimes covered with woolly fibres, shown in **fig. 5-25 E**. Many species cause severe damage of agricultural crops like citrus (**fig. 8-7 E**).

- **Coccoidea*** (scale insects, mealybugs and gall-makers) differ from aphids in respect of the facts that **1.** females are always wingless. **2.** usually only the first larval instar is mobile, the other stages are sessile, covered by a soft or tough scale (**fig. 5-25 F**) or an amorphous secretion made from wax. **3.** the males that are much smaller than the females have only one pair of wings. The legs of sessile forms can be completely reduced. Important families are **Coccidae** (soft scales, wax scales) covered under hard or soft material; **Pseudococcidae** (mealybugs) without scales from wax but with waxy filaments, noticeable along the periphery of their body (**fig. 8-7 B**); **Diaspididae** (armoured scales, **fig. 8-7 C**, **F**) concealed under hard waxy removable scale and **Eriococcidae** (felted scales). The **gall** makers cause swellings of plant tissues like leaves and stem. Larvae and other stages are enclosed in galls where they suck plant juices. Some species are beneficial and useful to man. The Mexican coccineal insect *Dactylopius coccus* is used for the production of a red dye for food, drinks and cosmetics. The lac insect *Kerria lacca* is used for the production of the varnish shellac. However the majority

of species are pests rather than of any benefit to man. In Papua New Guinea's forestry sector, the pink wax scale *Ceroplastes rubens* (**box 6-1 I**) damaged *Pinus caribaea* and mealybugs infested *Acacia* and *Tectona*. Gumtree scales of the genus *Eriococcus* attack a wide range of *Eucalyptus* in Australia but are less common and severe in PNG.

The Suborder **Auchenorrhyncha** comprises two infraorders, the **Cicadomorpha** and **Fulgoromorpha**, having small, needle-like antennae and almost always 3-segmented tarsi. The **Cicadomorpha** are further divided into three superfamilies:

- **Cicadoidea*** Cicadas (**fig. 5-25 G**) of the family **Cicadidae** are large robust insects of 5 cm or more with prominent compound eyes and three distinct ocelli on the back of the head. The head bears short, bristle-like antennae. The wings are large and membranous and are held roof-like above the body. Females possess a strong, spear-like ovipositor. Male cicadas have highly developed **musical** and **auditory organs** which are discussed in **chapter 3.1.1**. The legs of some adults and nymphs are raptorial, legs of other nymphs fossorial. Females lay eggs in incisions in bark. The nymphs drop after hatch

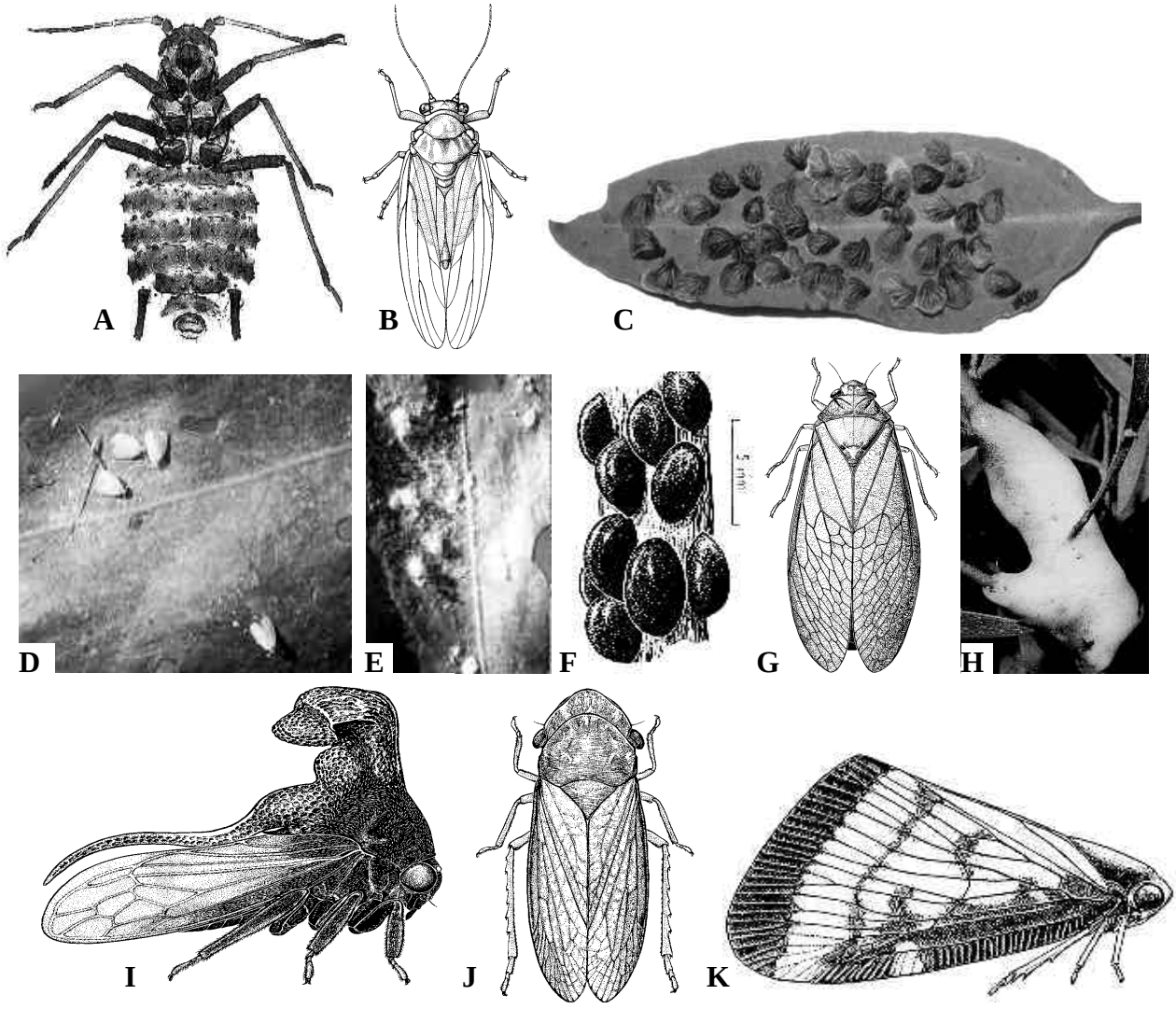

Fig. 5-25: Hemiptera, Group Homoptera: (A) *Meringosiphon sp.* (Aphididae, plant lice), (B) *Creiis sp.* ♂ (Psyllidae, lerps), (C†) *Spondyliaspis sp.* (Psyllidae, lerps) on *Eucalyptus sp.*, (D†) adult whiteflies (Aleroydidae) on *Acacia mangium*, (E†) woolly fibres produced by immature whiteflies (Aleyrodidae) on *Acacia mangium*, (F) *Parasaissetia sp.* ♀ (Coccidae, scale insects), (G) *Froggattoides sp.* (Cicadidae, cicada), (H) spittle of nymphs of spittle bugs (Cercopidae), (I) *Sertorius sp.* (Membracidae, tree hoppers), (J) *Stenocotis sp.* (Cicadellidae, leaf hoppers), (K) *Scolypopa sp.* (Fulgoroidae) (reproduced from CSIRO, 1991; Schneider, M.F. †)

ing, bury themselves in soil and attach to rootlets for piercing-sucking feeding. The **exuviae** of the last nymphal instars can be often found attached to bark or fence posts. The North American species *Magicicada septemdecim* has a prolonged subterranean life cycle. Only after 17 years the adults synchronously appear in huge swarms, cause severe damage to trees and make a lot of noise. Egg-laying punctures can harm trees, when cicadas are abundant.

- **Cercopoidea*** (frog hoppers and spittle bugs) The brownish smaller but robust saltatorial cicada-like animals have antennae that are inserted between the compound eyes and possess **coleopteroid** wings. The nymphs live in self-produced '**spittle**' shelters, as shown in **fig. 5-25 H**. Some members of the family **Cercopidae** are pests of cultivated **Gramineae**, herbaceous plants and trees, causing stunted growth, and during severe infestation, eventually the death of the host.

- **Cicadelloidea*** comprise the families **Eurymelidae**, **Membracidae** (treehoppers, **fig. 5-25 I**) and **Cicadellidae** (leafhoppers and jassids, **fig. 5-25 J**), the latter being the largest family of hemipterans. The cicada-like **Cicadellidae** are small, elongate insects with wings held roof-like above the body. The hind tibiae have one or more rows of small spines. The female leafhoppers possess a strong ovipositor to cut slits in plant tissues to deposit their eggs. The nymphs walk sideways like crabs and some produce honeydew. Characteristic for members of **Membracidae** is a grotesque, hump-like, greatly enlarged pronotum ornamented with ridges, horns or prongs. Many species of **Cicadelloidea** are destructive to certain crops, not only causing stunted growth and discolouring the foliage, but also transmitting plant diseases.

- **Fulgoromorpha** with one superfamily, the **Fulgoroidea*** (planthoppers, **fig. 5-25 K**) are similar in appearance to leafhoppers. Some have leaf-like wings or bizarre projections of the head. Common pest species of cultivated plants belong amongst others to the families **Delphacidae**, **Eubrachyidae**, **Cixiidae**, **Derbidae** and **Flatidae** (**fig. 6-3 M**).

Suborder Heteroptera [different wings]. The forewings of true bugs may be entirely or in part of harder consistency than the hindwings (**hemelytra**), a feature that distinguishes true bugs from beetles (see also **box 5-4**). True bugs have dorsal stink glands on the abdomen. Most species are herbivorous, but there is also a large number of predacious species. True bugs are divided into over fifty families in eight superfamilies belonging to the following infraorders:

1. Coleorrhyncha
2. Enicocephalomorpha
3. Dipsocoromorpha
4. Lepdopodomorpha
5. Gerromorpha (**Amphicorisae**) are slender semiaquatic insects, adapted to life in or on the surface of water. Typically they have very long legs. The tarsi and at least the ventral body part is covered with water-resistant hair, buoying the bug. Many species are scavengers or predators that run quickly on the surface of water to hunt for other insects. Common are the water striders and pond skaters of the family **Gerridae**, like *Gerris spp.* and *Limnogonus spp.* (**fig. 5-26 A**) and marsh treaders or water measurers of the family **Hydrometridae** like *Hydrometra*.
6. Nepomorpha (**Hydrocorisae**) are mostly aquatic, predacious bugs. The short antennae are hardly visible from above. Some species like the giant waterbug *Lethocerus insulanus* (**Belostomatidae**, **fig. 5-26 C**) have raptorial forelegs for seizing prey such as tadpoles or fish up to twice the bug's size. This group of bugs developed a variety of breathing mechanisms while under water. Water scorpions like *Laccotrephes spp.* (**fig. 5-26 B**) or *Ranatra spp.*, both **Nepidae**, possess a respiratory siphon that is pushed up through the surface film. The giant waterbug *Lethocerus* can remain submerged up to two hours because it carries some air bubbles trapped in the hair-edged space of its abdomen for breathing. Back-swimmers belonging to the family **Notonectidae** have a keel-like back and use their feathered elongate hindlegs to swim upside-down. Other conspicuous families are the **Corixidae** (water-boatmen), **Gelastocoridae** and **Ochteridae**.

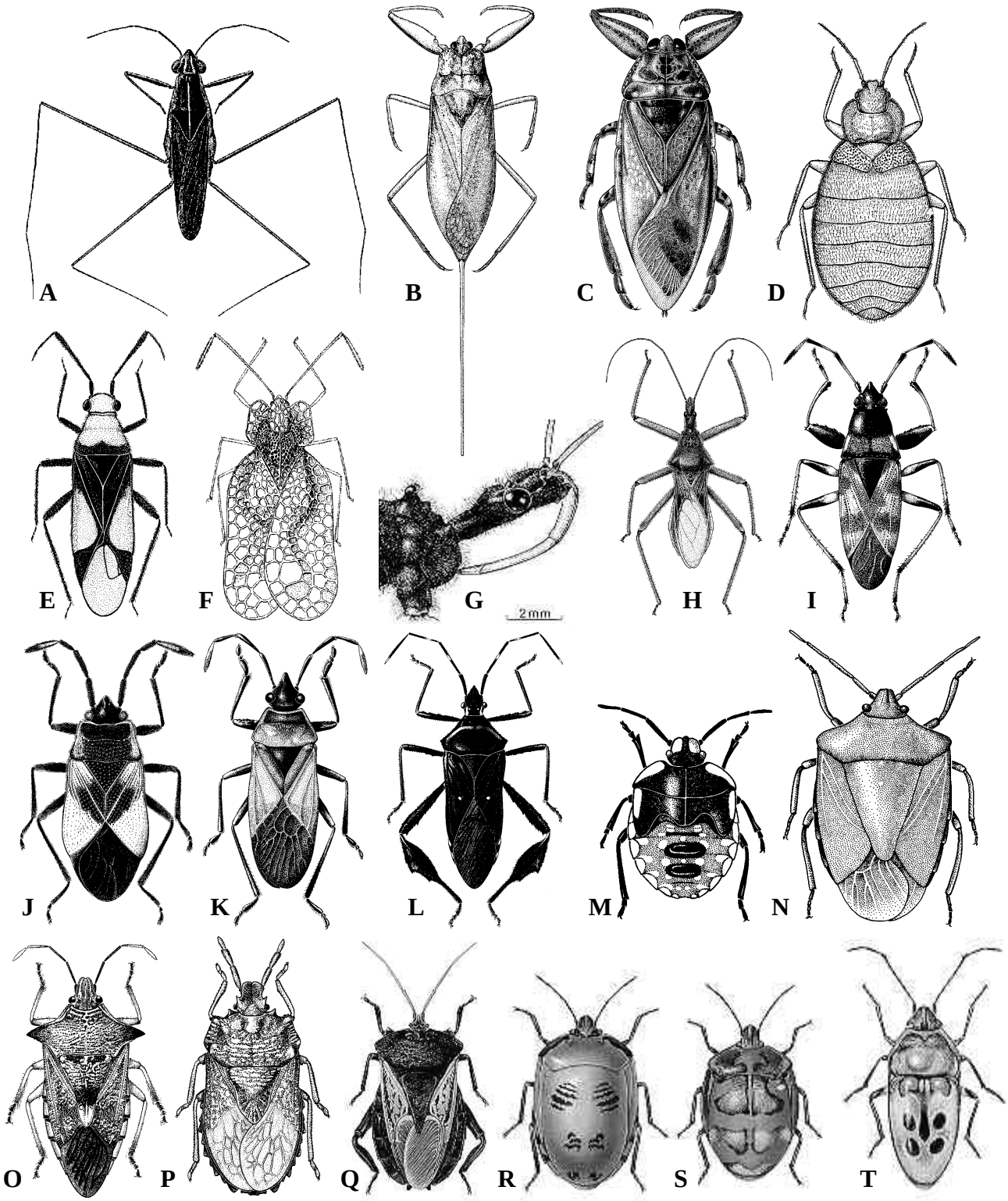

Fig. 5-26: Hemiptera, Suborder Heteroptera: (A) *Limnogonus luctuosus* (Gerridae, water striders), (B) *Laccotrephes tristis* (Nepidae, water scorpion), (C) *Lethocerus insulanus* (Belostomatidae, giant waterbugs), (D) *Cimex lectularius* (Cimicidae, bed bugs), (E) *Trilaccus sp.* (Miridae, plant bug), (F) *Stephantis sp.* (Tingidae, lace bugs), (G), (H) *Pristhesancus sp.* (Reduviidae, assassin bugs), (I) *Euander sp.* (Lygaeidae, chinch bug), (J) *Delacampius sp.* (Largidae), (K) *Dindymus sp.* (Pyrrhocoridae, red bugs), (L) *Leptoglossus sp.* (Coreidae, squash bugs), (M†) *Nezara viridula* last nymphal instar, (N†) *Nezara viridula* adult, (O) *Oechalia sp.* (Pentatomidae, shield bugs), (P) *Megymenum sp.* (Dinidoridae), (Q) *Oncomeris sp.* (Tessaratomidae), (R) *Tectocoris sp.* ♀ (S) ♂, (T) *Scutiphora sp.* (Scutelleridae, jewel bugs) (reprod. from CSIRO, 1991; Gullan, P.J. & Cranston, P.S., 1994†)

The following two infraorders are also referred to as **Geocorisae** (terrestrial bugs)

7. Cimicomorpha* are bugs that prey on other animals, mainly arthropods. A number of families are of economic importance:

- **Cimicoidea** Bed bugs and relatives suck blood of birds and mammals like bats and humans. The nocturnal bedbugs (**Cimicidae)** are small with broadly-oval flattened bodies and vestigial wings. They possess short filiform antennae and a 3-segmented proboscis. The bed bug *Cimex lectularius*, shown in **fig. 5-26 D** was introduced into PNG, Australia and other South Pacific countries from Europe. Bed bugs are quite a nuisance causing very itchy and irritating bites, but do nor transmit any diseases. Exposing the infested bed and mattress to the sun quite likely eradicates the pest.
- **Miroidea*** typically have a 4-segmented labium. The plant or leaf bugs (**Miridae**, **fig. 5-26 E**) are a prominent family of this group and one of the most diverse groups of true bugs. These bugs are small elongate or oval and vividly marked. Typically they have a triangular section called **cuneus** in the apical tip of the hardened part of the hemelytra with two enclosed cells. Most are phytophagous and can become serious pests of cultivated plants.
- **Tingoidea*** are close relatives of the **Miroidea** and possess a 4-segmented labium. The chiefly phytophagous lace bugs (**Tingidae**, **fig. 5-26 F**) are small flattened bugs with lace-like wings, a broadly flattened pronotum and bizarre, spiny nymphs. They feed on foliage of trees and shrubs, causing defoliation.
- **Reduvioidea** comprise the predacious assassin bugs (name), that can be easily identified by their sickle-like, 3-segmented proboscis, shown in **fig. 5-26 G**, that is not 'parked' in a ventral groove during rest. The head is separated from the rest of the body by a 'neck'. They can produce sound by scraping the tip of their proboscis along a file on the ventral part of the thorax, as shown in **figs. 3-1** and **3-3**. Some have arrays of spines on the forelegs for grasping and holding prey. Assassin bugs are harmless for humans, although being pierced is quite painful due to the injected saliva that might cause an inflammation of the wound. Assassin bugs are considered as beneficial insects, however they are not suitable as biocontrol agents due to their unspecific predation.

8. Pentatomorpha* Bugs of this infraorder are called '**stink bugs**' due to their well developed scent glands, releasing an unpleasant deterrent scent upon disturbance. Most species are phytophagous and can cause considerable damage to agricultural crops. Some families are:

- **Aradoidea**, which include the family **Aradidae**. The so-called flat bugs or bark bugs are commonly encountered under bark, usually gregariously, where they feed on fruiting bodies of wood-decaying fungi. Many flat bugs are apterous.
- **Lygaeoidea*** are phytophagous, with many being pest species of cultivated plants. Bugs of the family **Lygaeidae***, shown in **fig. 5-26 I**, are called seed bugs or chinch bugs, reflecting their feeding habits. The bugs are small elongate and sometimes colourful. Ocelli are usually present. In some species short and long-winged forms can be found. Some feed on seeds and plant juices of **Gramineae**, causing serious damage of the host. **Largidae***, shown in **fig. 5-26 J**, are similar to Lygaeidae and Pyrrocoridae and comprise a number of pest species. **Pyrrocoridae*** or red bugs are medium-sized to large bugs of rounded to elongate shape with small heads and large compound eyes. The forewings have many-branched veins and crossveins. Some species are short-winged. A number of species cause damage of seeds, eg. of cotton and other crops. See **fig. 5-26 K**.
- **Coreoidea*** including the **Coreidae*** (**figs. 2-37**, **5-26 L**) or squash bugs which are typically large-sized, elongate-oval bugs of brownish colours with strong repellent odours. The membranous part of the hemelytra is many-veined. The hind legs often have stout femora and expanded or spined tibiae. Squash bugs preferably suck on various legumes, Eucalyptus, **Cucubitaceae**, etc. The

crusader bug *Mictis profana* (**fig. 6-3 N**) can be easily recognised by the yellowish cross-like markings on the closed hemelytra. It feeds on shoot tips of *Acacia* causing them to wilt. *Leptoglossus* (**fig. 5-26 L**) and *Pternistria* feed on *Tectona* and *Eucalyptus*. Members of the family **Alydidae*** are brown or grey with long antennae and legs. Many Coreoidea are severe pests of vegetables, fruits, **Gramineae** and tree crops.

- **Pentatomoidea*** The shield or stink bugs typically have a large triangular or sometimes semi-elliptical **scutellum** that reaches at least to the apex of the **clavus** or might even cover the whole abdomen. The antennae of adults are usually 5-segmented, the feelers of nymphs with 4 segments. Many of the mainly brown or greenish, broadly-oval, medium-sized to large phytophagous shield bugs of the family **Pentatomidae** are well known pests in PNG's gardens. They feed on a variety of cultivated plants. The introduced green vegetable bug *Nezara viridula*, shown in **fig. 5-26 M** and **N**, is the horror of horticulturists. Other common genera are *Catacanthus nigripes* (**Plate 3 E**), *Oechalia* (**fig. 5-26 O**), *Oncocoris*, *Vitellus*, *Biprorulus*, *Cuspicona*, *Eribotes*, *Glaucias* and *Alcaeus*. Bugs of the family **Tessaratomidae** are small to large, vividly coloured phytophagous bugs. Some of these pests are of economic importance. *Oncomeris flavicornis*, shown in **fig. 5-26 Q**, can be commonly encountered in PNG. The small to large **Scutelleridae** are also referred to as jewel bugs, because of their vividly iridescent or metallic body coloration. The basic colour is mainly green or blue and one quite conspicuous feature is the greatly enlarged **scutellum**, that covers both pairs of wings. Due to this feature they might be mistaken as beetles. There are some precious jewels amongst the **Scutelleridae** in PNG, that are desperately wanted by insect collectors. The cotton harlequin bug *Tectomeris spp.* is shown in **figs. 2-34**, **5-26 R** and **S**. Others are shown on **Plate 3 D** and **fig. 5-26 T**. The small brownish, very active bugs of the family **Dinidoridae** (**fig. 5-26 P**) suck on vegetables and are considered as pests.

5.6.3.18 Thysanoptera (Thrips)
[fringed wings]
General biology: Small, slender, dorso-ventrally compressed exopterygote Neoptera. The broad-based head bears asymmetric rasping-sucking hypognathous mouthparts in a cone-like beak on the ventral side of the head. The compound eyes are variable from almost holoptic (round view) to only three facets in some wingless species. Three ocelli are present in some species. The antennae have 4 to 9 moniliform or filiform segments. the pronotum is conspicuous. The legs are slender but have sometimes large tarsal teeth and swollen femora. The tarsi are 1- to 2-segmented. The wings are slender and fringed at one or more margins (**fig. 5-27 C**). Thrips are characterised by a peculiar type of development and their metamorphosis is intermediate between complete and incomplete. The first two or three immature stages resemble the adults, whereas the two to three quiescent, pre-imaginal instars are 'pupal' stages termed **prepupa** or **propupa** (**fig. 5-27 A**, **B**) These 'pupal' stages possess wing rudiments and have probably evolved independently from the true pupal stage with internally developing wings of the holometabolous insect orders. The relatively small order comprises eight families, of which four occur in Australia and probably in PNG.

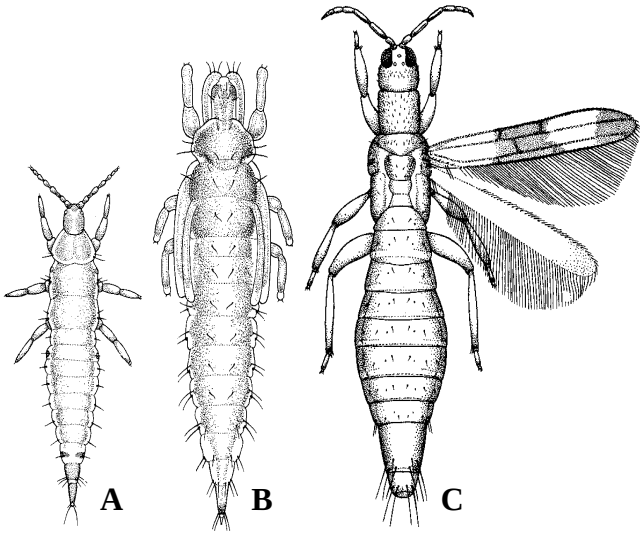

Fig. 5-27: Thysanoptera (Thrips): (A) *Teuchothrips sp.*, larva, (B) *Teuchothrips sp.*, pupa II, (C) *Desmothrips sp.*, adult (reproduced from CSIRO, 1991)

Economic and ecological importance: There are predacious and phytophagous species of thrips. The predators hunt for mites and small insects under bark of dead trees and in the ground cover. Phytophagous thrips can be often found associated with flowers, where they search for pollen. A number of species are pests of agriculture, inducing galls and other symptoms on commercial crops such as tobacco, onions, beans and fruit trees.

5.6.3.19 Megaloptera (Alderflies, Dobsonflies)

[large wings]

General biology: Medium-sized to large mandibulate, endopterygote Neoptera with broad and prognathous head. Ocelli might be present or absent, the compound eyes are large. The multisegmented antennae are long and slender, either filiform, moniliform, serrate or pectinate. The mouthparts are of the chewing type, with strong, enormously elongated mandibles in males. The pronotum is large. All legs are similar and well developed. The tarsi of all legs are 5-segmented and generally with two simple claws. The two pairs of functional, subequal, similarly textured, membranous, large wings can reach a span of 20 to 175 mm. The wings possess many crossveins. The abdomen is very soft and without projecting cerci. Adult Megaloptera (**fig. 5-28 B**) resemble adults of the order **Neuroptera**. The aquatic larvae, shown in **fig. 5-28 A**, are mandibulate with a large prothorax, functional legs, paired lateral abdominal gills and in some groups with a long terminal process. The pupae are active, **decticous** and **exarate**, similar to that of some Coleoptera. Complete metamorphosis with long generation time.

Economic and ecological importance: Alderflies and dobsonflies are a small order, mainly occurring in temperate climates. Since larvae as well as adults are predators they are a significant link in food chains. They dwell in both lakes and streams, where the larvae hunt for small aquatic animals. The larvae are reared and commonly used as baits by fishermen.

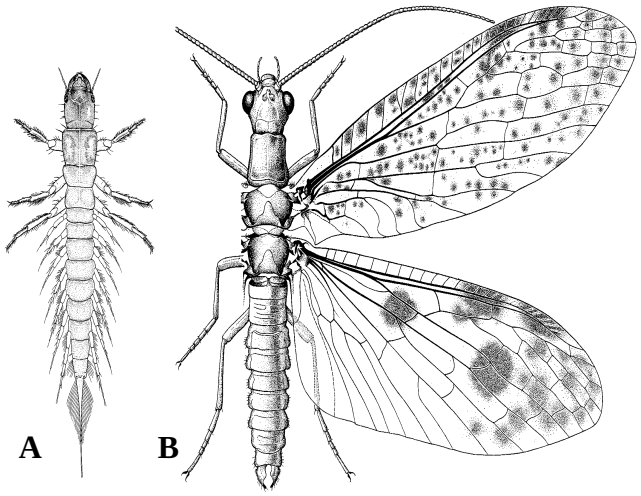

Fig. 5-28: Megaloptera (Alderflies and Dobsonflies): (A) *Stenosialis sp.*, aquatic larva, (B) *Archichauliodes sp.*, adult (reproduced from CSIRO, 1991)

5.6.3.20 Raphidioptera (Camelneck-Flies and Snake-Flies)

[fused wings]

General biology: Large, mandibulate endopterygote Neoptera similar to Megaloptera, but distinguished by their long serpentine 'neck'. The prognathous, flat, elongate head is basally tapering or broad, extremely flexible and strongly sclerotized. The antennae are long, multisegmented and filiform, rarely moniliform. The large compound eyes are situated laterally and are always present. Three ocelli are present or absent, depending on the family. Raphidioptera have chewing mouthparts. The prothorax is elongated and very mobile, the pronotum shield- or tube-like. All legs are equal, cursorial, the tarsi are 5- segmented and bear two very small claws. The transparent wings are membranous, subequal and elongate. Females have a long and flexible ovipositor, as shown in **fig. 5-29 A**. Complete metamorphosis with **decticous** pupa. About hundred species are described world-wide and divided into two families.

Economic and ecological significance: Snake-Flies are a small group of diurnal predators without economic importance. They are restricted to Holarctic forests and can't be found in PNG. The larvae (**fig. 5-29 B**) occur under loose bark where they hunt small insects.

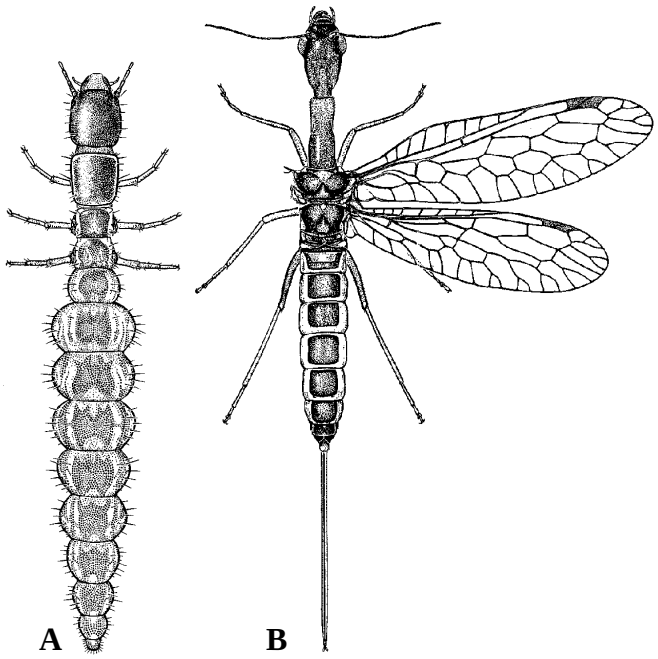

Fig. 5-29: Raphidioptera (Camelneck-flies, Snake-flies): (A) larval *Phaeostigma sp.*, (B) adult *Raphidia sp.* ♀ (reproduced from CSIRO, 1991)

5.6.3.21 Neuroptera (Lacewings, Antlions)
[nerve- or net-like wings]
General biology: Small to large and slender, endopterygote, mandibulate Neoptera. The orthognathous head bears large, well separated compound eyes, ocelli are usually absent. The mouthparts of adults (**fig. 5-30 B**) are of the chewing type. The mandibles and maxillae of larvae (**figs. 4-9 B** and **5-30 A**) are extended and usually form two distinctive, sickle-shaped sucking jaws for sucking up body juices of prey through a mandibular-maxillary groove. The long antennae are multisegmented, filiform or moniliform and tapering or variously thickened and longer than those of **Odonata**. The prothorax is freely movable. The legs are usually cursorial, but the forelegs of some species are raptorial. The tarsi are 5-segmented and usually end in two claws. Adults have two pairs of large, equal or subequal transparent membranous wings, that often have numerous cross-veins. The wings are of diagnostic importance and are usually held over the body during rest. A **frenulum** is sometimes present for coupling of wings. Complete metamorphosis. Eggs are laid on long and slender stalks, placed on the surface of leaves. The mainly terrestrial larvae usually have well-developed heads, thoracic legs, but lack abdominal legs. The order is divided into about 20 families. Some families are **Osmylidae**, **Sisyridae** (sponge flies, the only family with aquatic larvae), **Ithonidae** (dust flies), **Myrmeleontidae** (antlions), **Psychopsidae**, **Mantispidae**, **Nemopteridae**, **Ascalaphidae**, **Nymphidae** and **Chrysopidae** (green lacewings).
Economic and ecological importance: Most adult lacewings and their larvae, called antlions, are predators. Antlions of the family **Myrmeleontidae** are abundant in very dry sandy, poor soils such as under houses. Their peculiar way of catching prey by the help of a funnel-like pitfall trap is described in **fig. 4-9**. Adults of the most diverse lacewing family **Mantispidae** resemble praying mantids. Their forelegs are greatly enlarged and raptorial to catch prey. The larvae of sponge flies (**Sisyridae**) are aquatic and feed on freshwater sponges. In general, **Neuroptera** are purely beneficial insects. The larval green lacewing *Mallada signata* (**Chrysopidae**), shown in **fig. 8-7 D**, is used as a general predator in agriculture for the biological control of aphids, mites, whiteflies, scales, mealybugs and small caterpillars. The specific use for the control of one particular pest species however, is not yet well established.

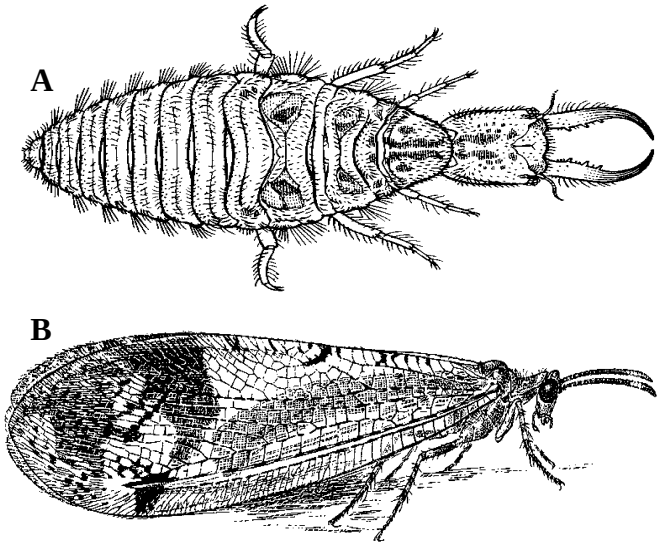

Fig. 5-30: Neuroptera (Lacewings, Antlions): (A) myrmeleontid antlion, (B) adult *Glenoleo pulchellus* (Myrmeleontidae) (reproduced from CSIRO, 1991)

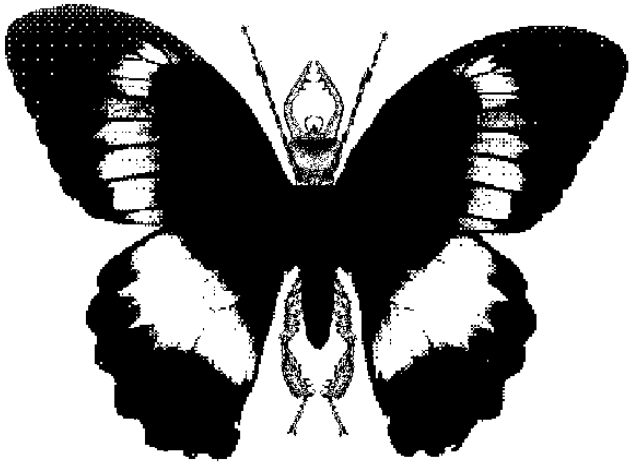

Fig. 5-31: Lentilburgeroptera: yet unnamed species (reproduced from Giam, A.N., Hamb, A.K., Noga, T. and Mask, I., in press)

5.6.3.22 Lentilburgeroptera

General biology: Little is known about this peculiar mandibulate insect group, shown in **fig. 5-31**. Apparently these insects have an unique feature: the wings are attached to the **prothorax** and **mesothorax**, as reported by the first-time collectors Giam, A.N., Hamb, A.K., Noga, T. and Mask, I. The only records of the Lentilburgeroptera are from Papua New Guinea, where they were just recently discovered. The only specimen collected so far is kept in the collection of the Bulolo University College. The family is also referred to as **Coleolepidorthoptera** by the same authors. These insects are closely associated with **Lentilburgeraceae** (name!). There are no further data available on the ecology of this order.

5.6.3.23 Coleoptera (Beetles) [sheath wings]

General biology: Small to large, hard-bodied, rounded to elongated endopterygote Neoptera. The adults almost always have chewing mouthparts that face forward (prognathous head). The mandibles, when thickened and enlarged, are armed with ridges or teeth-like tubercles (**mola**). The mandibles of males of some species like **Lucanidae** are greatly enlarged and are used for combating other males. The compound eyes are usually conspicuous and variable, in some species absent or in others so large that they meet above and/or below the head. The number of ocelli varies from zero to three. The well developed antennae are usually 11-segmented, but the number of segments can be reduced to 7 or increased to 30 or more. The length and shape of the antennae are very variable and characteristic for particular families or taxa, therefore very important for the identification of beetles. The antennae may be moniliform, pectinate, serrate, clavate, filiform or capitate (see **fig. 2-5**) and are often longer in males than in females, eg. in longicorn beetles (**Cerambycidae**). The antennae are usually developed for chemosensation, but might be modified. They are for instance involved in the gas exchange in aquatic **Hydrophilidae**. The prothorax is large and well developed and almost always free. Together with the head it forms a distinct fore body, contrasting with the hind body which consists of the small mesothorax, the larger metathorax and the abdomen. The body is more or less depressed. The **mesoscutellum** is usually visible from above between the elytral bases. The heavily sclerotized legs are often gressorial or cursorial, and normally increase in size from front to rear. The legs of some species are adapted for jumping, swimming, burying in soil or tunnelling in wood. The tibiae often possess a comb of spines or a pair of enlarged spines (**tibial spurs**). The number of **tarsomeres** is of diagnostic importance and is indicated in some identification keys as

Fig. 5-32: No chewing of 'beetle nut', but how about betelnut? (photo Hertel, H.)

tarsal formula. In beetles it is normally 5-5-5, indicating that the tarsi of the fore-, mid- and hindleg possess 5 tarsomeres each. However, the number of tarsal segments might be reduced to 4 or 3 in particular pairs of legs. Sometimes the tarsomeres are fused in such a manner that eg. four tarsomeres might be mistaken as three tarsal segments. Particular tarsal segments of some species bear **tarsal pads** or **adhesive setae**. The terminal **pretarsus** usually has two claws. Beetles normally have two pairs of wings which can be greatly reduced in some species or taxa, eg. in rove beetles (**Staphylinidae**). The first, mesothoracic pair of wings is modified into more or less hardened, veinless, non-foldable, rigid **elytra**, which usually meet edge to edge in a straight line at rest and partly or wholly cover the hind wings and abdomen. The metathoracic wings, when developed, are membranous, folded and alone used for propulsion in flight. The elytra are one of the main distinguishing feature between adult bugs and beetles, other differences are listed in **box 5-4**. The abdominal sternites are almost always heavily sclerotized. Adult beetles can vary in size from less than a millimetre up to 10 centimetres. Their coloration can be dark and dull, however, there is a large number of very colourful beetles, eg. the rose chafers (**Scarabaeidae**, **Cetoniinae**) and jewel beetles (**Buprestidae**). Beetles undergo a complete metamorphosis with 3 to 5 larval instars. The larvae have a distinct head capsule with antennae, chewing mouthparts and three pairs of thoracic legs, but lack abdominal legs in most cases. The larvae or grubs are either **scarabaeiform**, **campodeiform**, **eruciform** or **apod**, as shown in **figs. 2-42** and **5-33**. The pupae are mostly **adecticous** and **exarate** and rarely **obtect**, as shown in **fig. 2-43**.

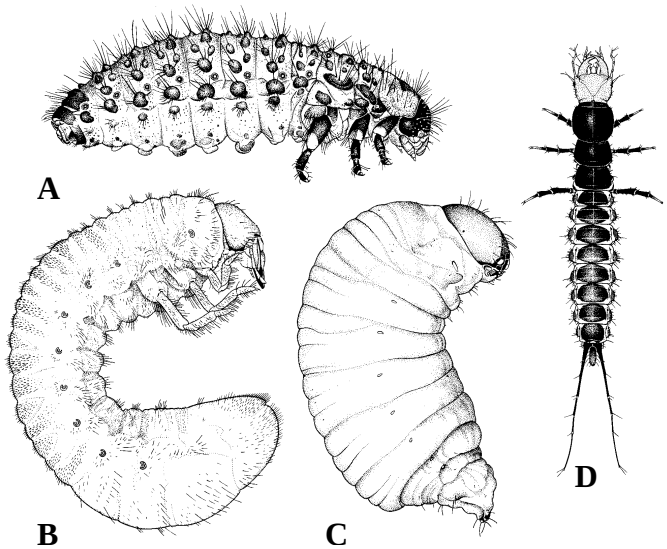

Fig. 5-33: Types of beetle larvae: (A) eruciform *Paropsisterna sp.* (Chrysomelidae), (B) scarabaeiform *Anoplognathus sp.* (Scarabaeidae), (C) apodous *Trigonotarsus sp.* (Curculionidae), (D) campodeiform *Eudalia sp.* (Carabidae) (reproduced from CSIRO, 1991)

General biology: Beetles are the largest group of animals and organisms in general with more than 300,000 named species. About 50% of all insect species, 30% of all animal species and 24 % of all organisms are beetles. In PNG there are probably more than 25,000 species of beetles, making almost 10% of the world's total. However, many species are yet to be described. The evolutionary success of this insect order is mainly due to the development of elytra protecting the hindwings when not in use and allowing the occupation of cryptic (hidden) habitats by the adults. The elytra also protect beetles from predation and infection by microorganisms.
Various chemical defence strategies by means of scent glands were developed by many groups. Some of the excreted products simply act as deterrents whereas others are potential lethal poisons: some larvae of leaf beetles (**Chrysomelidae**) release the stored deadly poison **hydrogen cyanide**. Others like the **bombardier beetle** *Pheropsophus verticalis* (**fig. 5-34 A**) possesses a binary weapon: upon disturbance, an explosive mixture of hydrogen peroxide and hydroqinones is ignited in an abdominal combustion chamber. This peculiar defence mechanism is further described in **fig. 4-15**. Other effective, non-chemical defence strategies are camouflage (**plate 1 B**), protective structures, snapping as done by click beetles (**Elateridae**), dropping, feigning death and many more. Some species of **Elateridae** and **Lampyridae**, called 'fire flies' or 'glow worms' have the ability to produce glowing light for courtship signalling and

distinguishing feature	adult bug	adult beetle
mouthparts	piercing-sucking	chewing
first pair of wings	sclerotized proximate and membranous apical part of the forewings (‘half wings’)	first pair of wings form hardened elytra, covering the abdomen and the hindwings
development	hemimetabolous	holometabolous

Box 5-4: Main distinguishing features between adult bugs and beetles

prey-luring. Often both sexes and all stages of the life cycle, even the eggs may glow. The **bioluminescence** organs can be located almost anywhere on the body. During courtship, the mobile male emits light. A sedentary female responds and thus indicates her location.

Economic and ecological significance: Most adult and larval beetles are herbivores or predators of other insects. Some beetles are scavengers on decomposing organic matter. Usually adults and larvae of the same species have the same feeding habits, eg. both are phytophagous. A wide range of beetles is of economic importance since they interfere with agricultural and forestry crops, timber products, stored products, etc. In the following section, families and other taxa of **common coleopteran pests** are indicated with an asterisk *****. However, beetles do not transmit any diseases of man or livestock. Due to the fact that there are many predators, herbivores and scavengers amongst the beetles, they play an important role in maintaining the ecological balance in natural systems. Furthermore, many host-specific species are in use as biocontrol agents of insect pests and noxious weeds. Apart from this, many beetles are important for the pollination of plants, as discussed in **chapter 4.2.2**, mainly by means of walking on smaller, inconspicuous flowers such as **Umbelliferae**. Most of these flowers release a carrion-like scent that attracts beetles but which humans find unpleasant.

The order is divided into more than 500 families, belonging to four suborders. About two thirds of the families are believed to occur in PNG:

1. Archostemata

2. Myxophaga

3. Adephaga: A relatively large group of highly specialised, mainly predacious beetles, having immobile hind coxae. **Tarsal formula** 5-5-5. The largest family of this suborder are

- **Carabidae** (ground beetles). The nocturnal, minute to large-bodied, very active beetles vary in shape and coloration. Some are oval whereas others are elongate with either black, dull, bright or metallic coloured bodies. The beetles usually have long, cursorial legs for running down prey and prominent, strong and pointed mandibles. The adults usually have filiform antennae and large compound eyes. Due to the predacious character of most adults and larvae (**fig. 5-33 D**), some species are suitable for the biological control of insect pests. This family includes the subfamily **Cicindelinae** (tiger beetles), which is considered as a separate family by some authors. Species of this subfamily have large protruding compound eyes. Common genera and species in PNG are *Colpodes*, eg. *C. habilis*, *Scopodes*, *Demetrida*, the **bombardier beetle** *Pheropsophus verticalis* (**fig. 5-34 A**), *Clivina*, *Catascopus* and the tiger beetles (**Cicindelinae**) *Cicindela*, *Therates labiatus* (**fig. 5-34 B**), *Tricondyla aptera* and *Megacaphala*

4. Polyphaga This is the largest coleopteran suborder. Some of the series and families are:

Staphyliniformia:

- **Hydrophilidae** Water scavengers are aquatic beetles with predacious larvae and herbivorous adults. The 7- to 9-segmented, clubbed antennae of the Hydrophilidae are involved in gas exchange. The beetles are generally poor swimmers, since their legs are not adapted for swimming. The silvery