

Hemiptera...It's a Bug's Life

Editor's Introduction | There is a great variety of Hemiptera, more commonly known as bugs, in existence. They have evolved an extraordinary range of body forms and lifestyles--some live on land, some live in water, some feed on plants while others are voracious carnivores or scavengers. Jon Martin and Mick Webb present a fascinating overview of the lives of two of the three major groups of Hemiptera.

Hemiptera are a major group of insects--there are estimated to be from 50,000 to 80,000 species of Hemiptera. They are divided into 3 major groups--Heteroptera, Auchenorrhyncha and Sternorrhyncha.

The Hemiptera are united by their modified mouth parts and method of feeding. All hemipterans have a piercing rostrum or labium which is in distinct segments. In addition, a pump (for sucking), a precibarium (for tasting), and muscles which operate the pump are present. Acting together these structures enable the insects to feed on liquid substrates. There is a close analogy to human beings employing drinking straws for beverages. These sucking mouthparts are formed from much modified tubular structures called stylets. In other insect groups these stylets are the palps that surround the jaws.



The Natural History Museum
Bedbug, *Cimex lectularius*.
The rostrum sits centrally
on the head.

The stylets of the lower jaw (mandible) are serrated and the stylets of the upper jaw (maxilla) are smooth, the former surrounding the latter. The smooth stylet pair are longer. This is because the serrated mandibular stylets are put into the feeding substrate first and are used for cutting and bracing against the substrate. The smooth maxillary stylets are then pushed forward further into the substrate, releasing saliva containing enzymes that partially digest the food source. The resultant 'soup' is sucked back into the insect's gut. The maxillary stylets interlock, allowing for only a sliding movement backwards and forwards into the substrate. It is crucial that any food source for bugs has to be liquid for ingestion via the tubular, sucking, mouthparts. Hemiptera have no way of chewing food sources.

Hemipteran life cycles follow a pattern known as hemimetaboly--rather than larvae they have wing-less nymphs which otherwise resemble the adults to a greater or lesser degree. In other words, the creature resembles a 'proper insect' from birth. The final nymphal stage, which is the fifth instar in Heteroptera, has obvious developed wing buds.

Two of these Hemiptera groups, the Heteroptera and the Auchenorrhyncha include the largest individuals with the most diverse life histories. These two groups are discussed below.

Approximately 32,000 Hemiptera species, in 77 families, belong to the Heteroptera. In contrast to other Hemiptera, the Heteroptera include insects which feed not only on sap and other plant material, but also on the haemocoel (the liquid that is equivalent to blood in mammals) of insects and other small arthropods, as well as other animal sources including the blood of mammals and birds.

The Heteroptera can be split broadly into 5 different groups--the truly aquatic group, the water surface group and three groups of terrestrial bugs. These groupings are not based purely on differences in structure but also on mode of life.

The first terrestrial group are the predaceous species such as the assassin bugs, flower bugs and damsel bugs; there are also some examples of otherwise plant-feeding families which contain some

predaceous species. Another group comprising the vast majority of the terrestrial Heteroptera, are the purely phytophagous (plant-feeding) bugs. Finally there is a small but very important group of terrestrial Heteroptera--the obligate blood-suckers.

One of the terms used for a lot of Heteroptera is 'stink bugs'. Pick one up, particularly a member of the Coreidae and Pentatomidae families, and they will secrete an unpleasant-smelling substance which might also leave orange or yellow stains on fingers. These secretions come from a pair of glands on the thorax.

The typical Heteropteran mating position is with the two animals back-to-back--they are not flexible enough for both to face forward. The bugs are remarkably reluctant to de-couple when disturbed--this may have something to do with the complexity of their genitalia. For example, shield bugs are so unwilling to decouple that the Natural History Museum Heteroptera collection is full of mounted insects which never came apart, even when they were put into killing jars or spirit. This has sometimes been very useful to researchers because there are cases in which the two sexes are so different in appearance that they might never have been recognised as being members of the same species. Heteroptera quite often mate together in large groups.

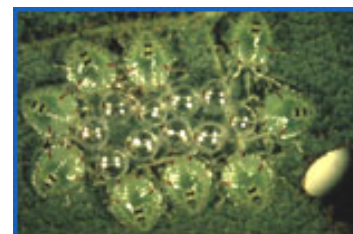
Eggs are typically laid in groups. Typical Hemipteran eggs have a 'crown' structure on the top--a point of weakness where the first instars will emerge. In some of the aquatic groups, eggs are laid onto the backs of the males which then carry the eggs when swimming. This is important because some of these bugs live in stagnant, deoxygenated water, so the eggs are aerated when the parent swims around and visits the surface.



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Male aquatic bug carrying his mate's eggs on his back.

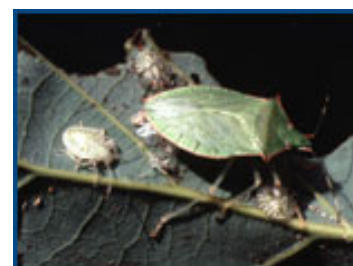
As human beings, we are used to gradually growing as we approach maturity. Arthropods (including insects) cannot do this, because of the constraints of their exoskeletons. Arthropods, therefore, have a series of life stages called instars or nymphs. They shed their exoskeletons between these stages. Immediately after each moult, the insect can expand in size before its exoskeleton hardens again.



JH Martin

First instar shield bugs feeding on bacteria on their egg cases.

Typically, the first-instar nymph of terrestrial bugs do not suck plant sap when they first emerge. Even if they are phytophagous, they spend some time ingesting bacteria which the female deposited on the eggs when she laid them, and they can frequently be found clustered around their eggs cases. They have, of course, to liquify the food source with saliva before they can ingest it through the stylets. A number Heteroptera, particularly the shield bugs, are renowned for parental care--at least one of the adults will remain with the nymphs, sometimes all the way through the life cycle.



JH Martin

Shield bug caring for its young.

Some of the Heteroptera, particularly the families Alydidae and Miridae, display very strong ant-mimicry in the nymphal stages. In the case of some mirids this mimicry extends to the adult. From above, these animals look just like ants and walk just like ants, but it is possible to determine that they are actually bugs by looking for the presence of the rostrum underneath the body.



Ken Preston-Mafham/
Premaphotos Wildlife

Ant-mimicking nymph.

Some terrestrial phytophages are bright orange-and-black or red-and-black because they are particularly nasty to eat--their colouring signals this information to birds. These acrid species, in turn, have mimics that benefit from that appearance. Some families such as the shield bugs contain a majority of phytophagous species, but also contain a small number of predators. Some shield bugs are extremely cryptic--camouflaged to blend in with their natural backgrounds--and so are very hard for their potential prey to see, and avoid. Similarly, camouflage protects them from would-be predators of their own.



Ken Preston-Mafham/
Premaphotos Wildlife

Camouflaged shield bug.

Another family which contains a mixture of predaceous and phytophagous groups is the Miridae, the largest family of the Heteroptera. There are about 8,000 mirid species and they are a mixed blessing for human beings. Many mirids are quite serious pests but there are other, predaceous, species that are very good biocontrol agents.

Of the obligate predators, two of the most important families are the Reduviidae, or assassin bugs and the Nabidae, or damsel bugs.

The reduviids have three main predation strategies--camouflage, subterfuge and bravado. A lot of assassin bugs have gone for the camouflage option--they are covered in sticky hairs and can shroud themselves in bits of detritus, becoming almost completely invisible, particularly if they are on the bark of trees or on forest floors.

Subterfuge is deployed by those species which are disguised as other creatures. Some assassin bugs appear identical to plant-eating 'cotton stainer' bugs. Cotton stainers are renowned for having garish stripes on the side of the body, which may be an indication of being nasty to eat. Some assassin bugs have copied these markings almost perfectly. Thus the assassin bug warns off its predators and dupes its prey at the same time. But most assassin bugs don't bother to hide. Overt aggressors they hunt with bravado, crawling about over plants and over the ground, overpowering any suitable prey. They are strong for their size and able to tackle prey far bigger than they are. Many of them have curious sticky pads on the front legs which aid in securing prey.



JH Martin

The predatory assassin bug on the right almost perfectly resembles the plant-eating cotton stainer bug on the left.

One very important predator group are the Anthracoridae, sometimes called 'timid' predators. Anthracorids are very important bio-control agents. They specialise in eating prey that can't fight back--soft bodied species that are unable to run away such as aphids, mealybugs and insect larvae. The bug spears its prey with its rostrum, raises it from the plant and moves off with the prey

struggling helplessly.

This specialist group includes the notorious and highly unpleasant bed bugs. Bed bug mating is extremely peculiar. The female has a notch on the underside of her abdomen known as the Ribaga's organ--an invagination of the body wall. Males have a single laterally-placed dagger-like paramere (clasper)--a fearsome-looking organ. Bed bugs mate, unusually for bugs, with both individuals facing forwards. The male puts this paramere inside the entrance to the Ribaga's organ and literally pierces the body wall of the female. The spermatozoa migrate through the haemocoel (blood equivalent) to the genital tract. The terminology for this is apt--'traumatic insemination'.

Bed bugs can bite without alerting their human victims--a highly successful survival strategy. They feed at night and hide away in the morning light. Their victims wake up to find spots of blood on their sheets and pillowslips, and after a little while may get sensitised and develop itches and rashes whilst remaining completely unaware of the cause.

The other important blood-sucking group are the so-called 'kissing bugs', a group of the assassin bug family. Again 'kissing' bugs refers to the fact that they feed on their prey without attracting attention. They suck blood, usually from around the mouth or eyes of their human victims, and then hide away under floorboards or up in rafters before people wake up. Their actions have more serious consequences because they can carry *Trypanosoma cruzi* which is the vector of Chagas disease in Central and South America.

Aquatic bugs live in, on or around water. Those that actually live *under* water have a completely different body structure. They are streamlined, and this body shape becomes progressively more accentuated in those that live in faster-moving water. Their antennae are much reduced. Most terrestrial bugs' antennae have four or five segments which are used for detecting pheromones and other chemical signals. Underwater these delicate structures would not be of much use and would be at risk of being damaged or snapped off.

All the water bugs are predators. The 'water boatmen' comprise two major groups. The Corixidae are very common in British ponds and streams and have an unusual anatomy--every pair of legs is modified in a completely different way. The other family is the Notonectidae, which in America are called 'back swimmers' because they swim around upside down.



The Natural History Museum

Water boatman, Hemiptera corixidae.

'Water scorpions', the family Nepidae, live in stagnant or slow-flowing water. They get their air supply by coming up to the surface and connecting to it via respiratory siphons. They then swim down into the mud at the bottom of the pond or stream to hunt.

Aepophilus bonnairei is a typical land-based bug with long antennae, but it actually lives below sea level, in little cracks in the rock where there are air pockets. The only time it is actually found on the land surface is at spring tides when it appears at the extreme low water mark and wanders around in the kelp. They scavenge for animal material, such as dead or dying small copepods.

The Gerridae are associated with water but have got long antennae--so they are technically terrestrial. Using their enormously long legs they spread their body weight so well that they can

literally skate and manoeuvre their way around on the surface of the water. In Britain the gerrids are referred to as 'pond skaters' while in America they are commonly called 'water striders' or 'Jesus bugs'--because of their ability to walk on water. They are quite pugnacious predators--with a short rostrum curving backwards. The gerrids include the only truly marine-pelagic insects, the genus *Halobates*, which can be found on patches of flotsam on the open oceans.

Compared to the Heteroptera, the Auchenorrhyncha have very similar life styles--they are all terrestrial and are all plant sap feeders. The Auchenorrhyncha hold their wings over the body in a roof-like fashion and the forewings are generally of uniform texture. Their antennae are quite small with few sensilla and the antennae are not particularly mobile compared with other bug-groups. These antennal features result in a reduction in both plant surface exploration, prior to feeding, and sensory ability to detect pheromones.

The Auchenorrhyncha comprise four superfamilies: the Cicadoidea: Cicadas the Cercopoidea: Spittlebugs or Froghoppers the Membracoidea: Leafhoppers and Treehoppers the Fulgoroidea: Planthoppers

The last three superfamilies are collectively referred to as hoppers because they are all capable of long distance jumping by means of their long spiny legs. The different arrangement of leg spines is one means by which specialists can separate the various groups.

Many insects communicate with pheromones but Auchenorrhyncha signal their intentions to potential mates acoustically either through aerial sounds, as with the cicadas, or by body vibrations through the plant. In early classification schemes the cicadas were identified as the noisy species and the smaller Auchenorrhyncha as the silent ones, but in fact all Auchenorrhyncha produce sound.

Male cicadas call to females with tymbals--shell-like 'drums' situated at the base of the abdomen which vibrate by the action of powerful muscles. Cicadas hear these calls using stretched membranes called tympana also at the base of the abdomen. Other Auchenorrhyncha hear calls with specialised organs on the legs.

Although Auchenorrhyncha are all plant feeders, they are not necessarily able to feed from all parts of the plant, the bug must find the right type of tissue. The majority of Auchenorrhyncha feed from the plants' vascular system. This system comprises specialised cells to transport either water (xylem cells) or food (phloem cells) throughout the plant. Cicadas and spittle bugs feed from xylem, planthoppers from phloem and the other hoppers from either (or both) xylem and phloem. In addition, some very delicate leafhoppers feed from non-vascular cells i.e. they take the contents from individual surface cells of the leaf, often giving it a stippled appearance. Paradoxically, although these cells offer the most well balanced food they are used the least. In contrast, the xylem contains very little food and the phloem carries mainly sugar.

Most plant-feeding insects need to process large amounts of food because there are low levels of usable nutrients in leaves and stems. In consequence, fluid feeders need to deal rapidly with large volumes of fluid whilst avoiding dilution of their blood.



Ken Preston-Mafham/
Premaphotos Wildlife

Leafhoppers excreting honeydew.

In common with other fluid feeders, Auchenorrhyncha have elongated, convoluted guts to allow for maximum contact with the food. In addition they possess three excretory specialisations--wax glands, special storage and secretory cells of the Malpighian tubules (the insect equivalent of a kidney), and a filter chamber.

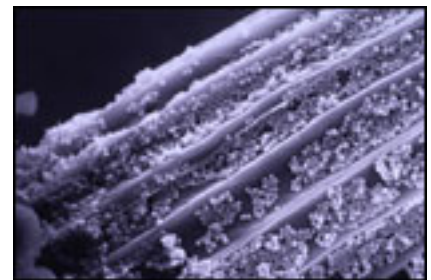
The Malpighian tubules remove the waste products from the insects' blood or haemolymph, but in certain Auchenorrhyncha they also manufacture, store and secrete various substances associated with conditioned excreta. The filter chamber selectively allows excess water from xylem or excess sugar from phloem to by-pass the main absorptive portion of the mid-gut. The ingested fluid is expelled as droplets. The droplets are either in weak form from xylem, or in concentrated form (referred to as honey dew) from phloem. The wax glands produce wax in the form of powder or wax strands. Its function is possibly to put the unwanted by-products of digestion to good use. It is thought that the wax is used to protect the insect from its own honey dew and to ward off predators.



Ken Preston-Mafham/
Premaphotos Wildlife

Planthoppers with secreted wax.

Leafhoppers and treehoppers condition their excreta with minute inclusions called brochosomes produced in the Malpighian tubules. This liquid is placed on the insects' skin (the integument) via its spiny legs during bathing or grooming activities, particularly after each moult.



Max Day

Part of a leafhopper's leg spine coated with minute brochosomes.

The Auchenorrhyncha are favourite prey of various animals including birds, reptiles and other arthropods. In order to defend themselves, cicadas rely on camouflage and are excellent fliers. In addition to jumping to avoid predators the remaining Auchenorrhyncha use various other means of defence including coating their bodies and eggs with a wax-like secretion, living in spittle, gaining protection from ants and bees in exchange for their excreted honey dew, living underground and mimicry--one harmless leafhopper looks identical to a stinging wasp, a group of flatid bugs bears an uncanny resemblance to a flower stalk and a fulgorid bug has evolved to look just like a lizard.

Thus the Hemiptera have adapted to thrive in a huge range of environments, from the forest floor to the high seas, making them one of the most prolific and successful animal groups on earth.

Premaphotos (www.premaphotos.co.uk) Images of British insects (www.bioimages.org.uk)

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