3

Identifying beetles that are important in forensic entomology

3.1 What do beetles look like?

Beetles belong to the order Coleoptera and all share features in common. For example, they have biting mouthparts or mandibles, their antennae characteristically have 11 segments (although in some species there may be fewer than this) and the first section of the thorax (the prothorax) is usually distinctive in shape and size and can be used as an means of identifying the beetle. The beetle exoskeleton is formed from hardened plates. The plates on the top surface are called tergites, the plates on the under-surface (ventral) are called sternites. The segment plates at the side (lateral) of the body are called pleurites (the pleuron is the name for this region of the exoskeleton).

Beetle adults are composed of a head, a thorax in three parts all fused together (although the second and third parts are less visible dorsally) and an abdomen. They have two pairs of wings; the two forewings are hardened and form a protective covering over the second, membranous pair of wings. These chitinous, and on occasion ‘leathery’, protective cases are called the elytra (singular elytron).

The prothorax is well developed and, together with the head, can be interpreted as a distinct anterior section of the body. The dorsal surface of the thorax is divided into the pro-, meso- and metanotum (each plate, or tergite, is called a notum; plural nota). The pronotum (the surface of the first thoracic segment in front of the elytra) is the biggest of the thoracic segments. It is made up of only one plate (Figure 3.1). The ventral surface is correspondingly divided into three; the pro-, meso- and metasternum.

The middle region of the thorax (the mesothorax) supports a pair of hardened wing cases which meet along the centre of the dorsal surface of the body. Part of the mesonotum is located between the base of the elytra, behind the pronotum; this small plate is called the scutellum.
The membranous wings are attached to the body on the last section of the thorax (the metathorax, with which the mesothorax is fused). This pair of wings is folded under the elytra when the beetle is not in flight.

Beetles’ legs are positioned on the sternum. They are generally designed for running or walking, but in some beetles, as in the Scarabaeidae, the front legs are also modified for digging (Figures 3.2 and 3.3). The upper plates of the abdominal segments are sclerotized (made of hardened cuticle due to the formation of a protein called sclerotin). The lower abdominal plates (the sterna) are soft.
Figure 3.2  Structure of a beetle thorax: (a) dorsal view and (b) ventral view
Figure 3.3  Insect front legs modified for digging (*Geotrupes* sp.) (A colour reproduction of this figure can be found in the colour section towards the centre of the book)

Beetle heads can be structured in one of several ways. They can project forwards horizontally (*a prognathous* head), or orientate downwards (*a hypognathous* head). Located on the head are the antennae, which carry tactile, heat-sensitive, olfactory and humidity receptors. The antennae of members of the Coleoptera vary in form. Some are thread-like (*filiform*) or plate-like (*lamellate*), whilst others are elbowed (*geniculate*) or have club-like ends (*clavate*).

Beetles exhibit complete metamorphosis during their life cycles and pass through an egg stage, larval stages and a pupal stage and emerge as an adult, or imago, each of which is morphologically different. Beetle eggs are frequently difficult to locate on or around the body, as unlike fly eggs they do not often appear in batches on a body.

Beetle larvae have more distinctive morphological features than do the larvae of flies. For example, they have a sclerotized head capsule, and mouthparts which include mandibles (are mandibulate). Larvae may or may not have legs on the thoracic region of their body. *Prolegs* (limbs on the abdominal region) are rarely present in beetle larvae and this distinguishes them from the larvae of other orders.

For example, ground beetle larvae (carabids) have an elongated flattened shape with well-defined legs that end in two claws. These are called *campodeiform* larvae. Scarab beetle larvae resemble a C–shape and these beetles tend to have a brown sclerotized head and a whitish body. On the other hand, larvae of the dermestid family are particularly hairy on both the sides and the upper body surfaces and are recognized because of this coat of hairs. Examples of the shapes of forensically significant larvae are shown in Figure 3.4.
Box 3.1 Hint Structure of Cuticle

Cuticle

Insect cuticle, which is made of chitin and proteins, can be rigid or flexible. Cuticle provides protection from physical damage and water loss and a rigid structure for muscle attachment, and limits growth to those times when the cuticle is newly developing. The mechanical properties of cuticle depend on the quantity of protein present, the sequence of proteins and the degree of tanning (sclerotization).

Cuticle has three parts: epicuticle, procuticle and epidermis. The epidermis and cuticle together are called the insect integument. The epicuticle is the outermost layer. It is 0.1–3.0 µm thick and is also made of three layers. The outermost layer is a cement layer which prevents distortion of the next layer, a lipid–protein layer. Below this second layer is a glycoprotein superficial layer. The epicuticle does not contain chitin. It is not capable of providing support or extending, but does provide waterproofing and protection against mechanical damage.

Below this is the procuticle, which is 0.5–10 µm in depth and comprises a thicker endocuticle, which is light in colour, overlaid by a thinner, darker exocuticle. Procuticle is made up of a protein matrix in which layers of parallel microfibrils of chitin, an amino-sugar polysaccharide, are embedded to make a sheet. In the exocuticle the sheets of microfibrils are in the same plane, but each sheet may be orientated at a slight angle to the previous sheet. An alternate stacked or helicoid arrangement of microfibril sheets in the endocuticle results in it being a thicker layer than the exocuticle. The darkening of the thinner exocuticle is due to tanning (sclerotization).

The basal layer beneath the cuticle is the epidermis. This single layer of cells is supported on a basement membrane which separates the exoskeleton from the main body cavity. Epidermal cells regenerate by cell duplication, or mitosis. This layer secretes the cuticle-forming chemical which is needed for moulting to take place.

Types of cuticle

There are two types of cuticle, soft and hard:

1. **Soft cuticle** is flexible and the cuticle is thin and has little or no exocuticle. Larvae predominantly have soft cuticle and a hydrostatic skeleton. Soft cuticle is also important where movement is required and, for example, allows gravid females to extend their abdominal plates to lay eggs.

2. **Hard cuticle** is hardened and armour-like because of the level of tanning, the positions of the microfibril sheets and hydrogen bonding between adjacent chitin molecular chains. Hardened chitin is found surrounding the spiracles of fly larvae and is present on the head and as the mandibles of beetle larvae. It provides the strength and rigidity of the body and elytra in adult beetles.
Small, hardened structures projecting from the end of the larval abdomen are called *urogomphi*. They are recognizable, for example, in the larvae of Dermestidae, Nitidulidae and Histeridae.

The third stage of metamorphosis is called the pupal stage. The pupa has mouthparts which do not articulate (i.e. are *adecticous*) and the rest of the pupal appendages are free and visible through the pupal coat (the pupa is *exarate*) (Figure 3.5). This is not so in the staphylinids, where the pupa is covered by a hardened coat and the pupal appendages are held in place by secreted material (an *obtect* pupa).
Figure 3.5 The types of pupae and puparia illustrate the relationship of appendages to the body. (a) The limbs are distinct from the body; this type of pupa is called an exarate pupa. (b) The limbs are firmly bound to the body; this form of pupa is called an obtect pupa. In the third type of pupa (c), the pupa is retained within the final larval coat; this coat is termed a puparium and the pupa is called a coarctate pupa. Reproduced from Munro (1966) with kind permission of Rentokil Initial plc.

Some pupae pupate in a chamber within the soil. Others, like the scarabaeids, form a cocoon. In this instance the cocoon is made from material in the posterior section of the caecum (Richards and Davies, 1988).

The order Coleoptera is divided, on the basis of molecular studies, into what are treated as four suborders: Archostemata, Myxophaga, Adephaga and Polyphaga. The Archostemata is made up of three families which mostly inhabit decaying wood. The Myxophaga are made up of four families which are aquatic or are found in wet habitats and are algal feeders. Although all insects may be of importance in forensic entomology, the remaining two suborders, Adephaga and Polyphaga, contain families of beetles which are most commonly found at crime scenes. The suborder Adephaga contains 10 families and comprises predatory beetles which inhabit terrestrial and aquatic habitats and includes the ground beetles, the Carabidae. The Polyphaga contains 149 families including the families Dermestidae, Scarabaeidae and Staphylinidae.

3.1.1 Suborder Adephaga

These beetles are distinguished by the positioning of their legs. The coxae of the third pair of legs (the hind legs) are fused to the metasternum. When you look
at the underside of the beetle you see that this region of the leg divides the first visible abdominal sternal plate (Figure 3.6).

There are lines down the sides of the thorax called sutures (the indents are positions where there is internal strengthening of the exoskeleton). An example of this is the suture between the notum and the sternum (sutures are readily recognized

![Image](image_url)

**Figure 3.6** The distinction between the Polyphaga (a) and the Adepagha (b), ventral view. In the Adepagha the hind coxa is fixed immovably to the metasternum, i.e. the coxa cannot move. It completely splits the first visible abdominal sternite. In contrast, in the Polyphaga the hind coxa is able to move, i.e. it articulates with the metasternum; usually does not generally divide the first visible sternite (A colour reproduction of this figure can be found in the colour section towards the centre of the book)
as the large transverse indentations across the thorax of the fly). The majority of beetles in this suborder have thread-like (filiform) antennae.

Larvae of insects in this suborder have legs with five segments which end in two claws (only rarely is it one claw). These larvae are mostly elongated and flattened (Luff, 2006; in Cooter and Barclay, 2006). Most beetles in the Adephaga are predaceous; in consequence they may feed on the insects inhabiting a cadaver.

3.1.2 Suborder Polyphaga

This suborder contains the majority of families of beetles with which the forensic entomologist may be concerned. The following features characterize this suborder. The hind coxa is rarely fused to the metasternum (it moves, or articulates) and so does not divide the first visible abdominal sternite. The thorax in this suborder does not have lines (sutures) across its dorsal surface. The types of antennae in the suborder vary, so they cannot be used as an indicative feature.

Polyphaga larvae are of many different shapes. They have legs with four segments which end in a claw. Some larvae in the suborder Polyphaga have legs which are reduced, others have vestigial legs, or the legs may even be absent altogether.

Polyphaga adults eat a variety of food. Some beetles are predaceous, but in the suborder as a whole many are phytophagous. Only beetles which are predators are of immediate importance to the forensic entomologist. A number of beetles visit a dead body, either because the body itself forms food and a habitat, e.g. the Dermestidae, or to feed on the insects already present, e.g. the Staphylinidae. The families of insects from this suborder that are important in forensic entomology include the Silphidae, Staphylinidae, Histeridae, Trogidae, Dermestidae, Cleridae and Nitidulidae.

3.2 Features used in identifying forensically important beetle families

3.2.1 Carrion beetles (Silphidae)

Silphidae have a flat body with sharp margins and their heads are small relative to the size of the thorax. The beetles of this family have antennae in which the sequence of antennal segments tends to thicken as the segments progress to the end, or the antennae are distinctly clubbed. The distance between the points of insertion of the antennae is wide. These are large, robust beetles and some, such as Necrophorus vespilloides Herbst, have orange or red markings on their elytra. Others, such as Necrophorus humator (Gleditsch) (Figure 3.7), are black in colour.
One of the main identification features of this family is that abdominal segments protrude from the hardened upper wings (the elytra). If the beetle is turned over, six abdominal sternites are visible.

3.2.2 Rove beetles (Staphylinidae)

Staphylinidae are active beetles which are easily recognized because, when the insect is viewed from above (Figure 3.8), their short elytra expose at least half of the abdominal segments, so that seven to eight protrude. They range in size from tiny to large. For example the largest British staphylinid species *Ocyopus olens* Müller (whose English common name is the devil’s coach horse), has been recorded at 28 mm long (Richards and Davies, 1988). This family, however, are accomplished fliers and have strong membranous wings packed away under their shortened elytra. Some species have the habit of curling up their last few abdominal segments over their ‘back’. This makes them look very aggressive and the action is reminiscent of a scorpion. If you see specimens reacting like this as you approach them, then you are most likely seeing a staphylinid beetle.

Staphylinid beetles are predators and are attracted to the corpse to feed on the larvae of Diptera. A number of species of rove beetles (Staphylinidae) have
been found on a body; e.g. Goff and Flynn (1991) recorded the presence of adult Philonthus longicornis Stephens from a 23 year-old Caucasian male in Hawaii; and Creophilus maxillosus (Linnaeus), which Centeno et al. (2002) recognized as forensically relevant in their Argentine studies and which Chapman and Sankey (1955) also recorded from rabbits in exposed conditions in Surrey, UK.

3.2.3 Clown beetles (Histeridae)

These are small, shiny black beetles (Figure 3.9) with an exoskeleton that has a hard, often leathery or sculptured texture and a more or less oval shape. Their antennae are elbowed (geniculate) and the final segments of the antennae are formed into an obvious club. Histerid legs have flat tibiae. The significant identification feature of this family, when looked at from above, is the square-cut to the ends of the elytra, which reveal the last two abdominal segments.

Both larvae and adults are found on the corpse, as they feed on those insects attracted to decaying organic matter. The larvae also eat fly larvae and prey on other insects. The adult beetles respond to being handled by withdrawing their heads and pulling their legs, and any other projections, into the body, which is sculptured to allow this, and ‘playing dead’ (exhibiting thanatosis)
3.2.4 Trogid beetles (Trogidae)

These are medium-sized beetles which are dull brownish in colour (Figure 3.10). The dorsal surface of the body appears roughened and the elytra can sometimes be hairy. The segments at the tip of the antennae are plate-like. The legs of trogid adults are not broad or modified for digging.

Trogidae larvae characteristically have long, sharp claws. Chinnery (1973) indicates that species of the genus *Trox* are not common in the UK. They are found at the dry stage on small carcasses and, in particular, feed on hide, fur, leather, feathers and dry matter. These beetles will also exhibit thanatosis if disturbed.

3.2.5 Hide and skin beetles (Dermestidae)

Dermestidae range from very small to medium in size (1.5–10 mm) and have an oval to elongated shape (Figure 3.11). Their antennae are made up of 5–11 segments, ending in a club made of two or three segments (Peacock, 1993).

Adult members of the genus *Dermestes* lack a simple eye (an *ocellus*) on the head. The coxa on the front leg is conical and sticks out prominently from the coxal cavity (Figure 3.12). The femur of the hind leg is covered by the hind coxa, which is flattened into a plate. These beetles have the capacity to pull all their appendages into the underside of their body so that nothing protrudes.
3.2 FEATURES USED IN IDENTIFYING FORENSICALLY IMPORTANT BEETLE FAMILIES

Figure 3.10 A trogid beetle

Figure 3.11 Dermestes lardarius (L.) (A colour reproduction of this figure can be found in the colour section towards the centre of the book)
Figure 3.12 The front coxa of the dermestid projects from the coxal cavity (A colour reproduction of this figure can be found in the colour section towards the centre of the book)

Larvae of forensically-relevant Dermestidae are brown to black in colour and have hairs of varying lengths (setae) over the dorsal surface; there are frequently tufts of hair on the sides or posterior edge of the body. Indeed, the larvae of *Dermestes maculatus* DeGeer (Figure 3.13) are commonly known as ‘woolly bears’ as a result of this profusion of hairs. The larvae are 6–13 mm (1/4–3/8 inches) long and have two horns (urogomphi) on their terminal segment.

*Dermestes lardarius* Linnaeus is known to pupate in a puparium for 40–50 days at 18–20°C. They have one generation per year. Male *Dermestes lardarius* pass through four instars, whilst the female have five instars.

### 3.2.6 Checkered (or bone) beetles (Cleridae)

These beetles are usually brightly coloured on at least some part of their body (Figure 3.14). They are elongated and cylindrical in shape and appear to have a ‘neck’, because the first part of the thorax (the pronotum) is less broad than their elytra. The adults can be hairy. An example of a forensically significant member of the Cleridae is *Necrobia rufipes* DeGeer, the red-legged ham beetle, which can be found in association with bodies later in the decomposition sequence. In Hawaii it has been found in the soil under a corpse at a PMI of 34–36 days (Goff and Flynn, 1991). This species is a predator of fly larvae.
3.2 FEATURES USED IN IDENTIFYING FORENSICALLY IMPORTANT BEETLE FAMILIES

Figure 3.13  Life cycle of *Dermestes maculatus* DeGeer (A colour reproduction of this figure can be found in the colour section towards the centre of the book)

Figure 3.14  Clerid beetle (A colour reproduction of this figure can be found in the colour section towards the centre of the book)

### 3.2.7 Sap-feeding beetles (*Nitidulidae*)

These are very small beetles, and are not often longer than 7–8 mm (Figure 3.15). The *Nitidulidae* have recently undergone taxonomic revision. The antennae are usually
composed of 11 segments, ending in a three-segmented club. The elytra are often truncated, but with rarely more than three abdominal segments visible dorsally. The fore- and mid-coxae are transversely orientated, whilst the hind-coxa is flattened. The tarsal formula for this family is most frequently 5–5–5 (this means that the tarsus of each of the legs is made up of five tarsomeres). The first segment (tarsomere) of the tarsus is not shortened and all of the tarsal segments are more or less dilated.

This family is a colonizer of corpses in the later stages of decomposition. According to Cooter and Barclay (2006), in the British Nitidulidae, the subfamily Nitidulinae includes two genera, *Nitidula* and *Omosita*, which are particularly associated with bones and dried carrion. Wolff *et al.* (2001) undertook a preliminary study in Medellín, Colombia, and found that 0.2% of the total number of families visiting a dead pig, which they had set up in an experimental ‘crime scene’, were members of the Nitidulidae. All members of this family were recorded from the advanced stage of decay which occurred 13–51 days after the pig died.

### 3.2.8 Ground beetles (*Carabidae*)

Ground beetles have a characteristic beetle shape. They can be found in a number of habitats, including grassland and forests. Carabids are members of the Adephaga because their first abdominal sternite segment is divided by the hind coxa. Their antennae are usually filiform, although some may be bead-like (moniliform), and are located on the head, between the eyes and jaws. The beetle head is prognathous.
Figure 3.16 Carabid beetle, illustrating the striations on the elytra

In carabids the elytra are usually sculptured, for example with striations, so that one sees nine regular ridges and furrows along the elytra (Figure 3.16). They are frequently fixed in position and, where this is the case, the beetle has only the vestiges of membranous wings.

Carabid larvae are long or elongated in shape. The larva has a pair of sharp pincer-like mandibles and six simple eyes (ocelli) down each side of the head. The larval abdomen has 10 segments and on segment nine there is a pair of cerci. The larvae have legs which end in two claws. Carabid larvae are very quick in their movements and tend to be nocturnal, so they may not be obvious members of the corpse assemblage.

3.3 Identification of beetle families using DNA

The same techniques of mtDNA analysis, use of RFLP and RAPD for the identification of flies, which are described in Chapter 2 (Section 2.3), are used in forensic entomology for the identification of beetles. Indeed, these techniques are also used in phylogenetic investigations of beetle species, such as that undertaken to separate members of morphologically similar ground (carabid) beetles of the Nebria–Gregaria group, on Queen Charlotte Islands in British Columbia, Canada. Clarke et al. (2001) concluded from RAPD and mtDNA analysis that only one species of the group could be separated out, on molecular grounds, from the particular group of carabids.
RAPD analysis of beetle DNA has been a successful tool in crime analysis (Benecke, 1998). The families investigated included the carrion beetles (Silphidae), e.g. *Oiceoptoma thoracicum* Linnaeus, for which a DNA profile (Figure 3.17) was determined from a badly decayed body in October 1997 (Benecke, 1998). Mitochondrial DNA has also been used to identify the larvae of beetle species present on a body and also for additional purposes, such as identification of the human host from the gut contents of the larvae upon whom it had been feeding. Di Zinno *et al.* (2002) analysed specimens from the nitidulid genus *Omosita* in order to match mtDNA to a human host; this was successfully achieved.

Dobler and Muller (2000) explored the phylogenetic relationship of the Silphidae using 2094 base pairs (bp) of COI and COII, as well as tRNA. With the longer lengths of mtDNA, they were able to obtain a greater resolution of the genetic make-up of the family, providing an increased identification profile for use by the forensic entomologist. Zehner *et al.* (2004a) explored intra-species variation within the clerid beetles (based upon different mitochondrial genomes for the same species of organism – heteroplasmic). They showed that within the cytochrome oxidase I gene, in both *Necrobia rufipes* and *Necrobia ruficollis* Fabricius, there was a high degree of heteroplasmic which did not express itself as much in *Necrobia violacea* (Linnaeus), another species of clerid. This variation has to be considered when interpreting a profile from a specimen from the crime scene.

Less research has been undertaken on the molecular profiles of forensically important Coleoptera than for the Diptera. However, since the techniques are in place, further profiling of beetle species will expand this base as more crime scene investigations occur.

### 3.4 Further Reading


Useful website

www.Coleoptera.org