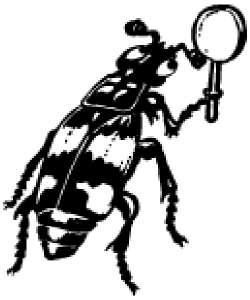


Introduction to forensic entomology

So, you wonder what Forensic Entomology is?

I will tell you:

Forensic entomology can be said to be the application of the study of insects and other arthropods to legal issues. It can be divided in three subfields: urban, stored-product and medicolegal. It is the medicolegal aspect that I will discuss in this document.

Medicolegal forensic entomology includes arthropod involvement in events such as murder, suicide and rape, but also includes physical abuse and contraband trafficking.

Since the earth is a predominantly arthropod world, it is not uncommon that we mere humans comes in contact with these creatures. They make the world go round, as they pollinate, eat other arthropods, eat living plants and trees, dead plants and trees, living vertebrates, dead vertebrates and vertebrate dung and urine and a lot of other things.

The feature with arthropods that are most important in medicolegal forensic entomology is that they are important carrion feeders, that is they eat dead vertebrate bodies, including man. Thus they perform a valuable recycling of organic matter in our ecosystem.

One of the first groups of insects that arrive on a dead vertebrate is usually blowflies (Diptera: Calliphoridae). Usually the female oviposits within two days after death of the vertebrate. Then the blowfly goes trough the following stadiums: egg, 1. instar larvae, 2. instar larvae, 3. instar larvae, prepupae, pupae within puparium, imago. More on this in chapter 3.

If we know how long it takes to reach the different stadiums in an insects life, we can calculate the time since the egg was laid. This calculation of the age of the insects can be considered as an estimate of the time of death. But even if the estimate of the insect age is correct, the death of the victim (usually) occurred before the eggs were laid. This period is quite variable and depends on temperature, time of day the death occurred, time in year the death occurred, whether the corpse is exposed or immersed in soil or water. As a general rule insects will lay eggs on a corpse within two days after the corpse is available for insects.

I will discuss this further in chapter 3 in this document.

Insects can also be of help in establishing whether the corpse has been moved after death, by comparing the local fauna around the body, and the fauna on the body. This you can read more about in chapter 5

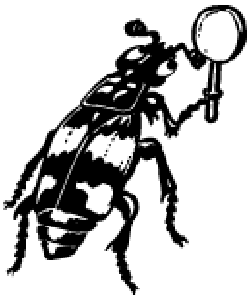
In some instances, movement of suspects, goods, victims or suspect vehicles can be traced with the help of insects. Insects parts, or whole insects can for example be captured in different car parts, such as in radiators or tyre treads. By identifying the insects found, and plotting the distribution of each insect, as well as the biology of each species one can find the greatest degree of overlap, and describe the areas where the suspect has been. See for example case history number 21 where the country of origin of cannabis was determined by the insects found in the cannabis container. More on this can be found in chapter 6

Many arthropods lives in close relation to carrion, take a look in chapter 7 for an introduction to some of them.

Do you want to know what goes on at the scene of the crime? What to look for, how to collect and such things? Say no more, chapter 8 is the thing for you.

If you are fascinated with how forensic scientists solve the most difficult cases, take a look at the casehistories.

And at last, if you want to know where you can get further information of this fascinating field of forensic science, take a look at the bibliography.



What happens after death?

Everybody will die, that is one thing that we are absolutely certain of. What exactly is death, and what happens in the time after death? From a biological point of view, death is a process, not an event. This is because the different tissues and organs in a living body dies at different rates. We can divide death into somatic death and cellular death. Somatic death is when the individual is not longer a unit of society, because he is irreversibly unconscious, and unaware of himself and the world.

Cellular death is when the cells quits respiration and metabolism. When all cells are dead, the body is dead. But all cells do not die simultaneously, except perhaps in a nuclear explosion. Even in a victim of a car bomb, where the body becomes fragmented, individual cells will continue to live for a few minutes or longer. Different celltypes can live for different times after cardiac arrest. Nervous cells in the brain are particulary vulnerable to oxygen deprivation and will die within 3-7 minutes after complete oxygen deprivation.

In many countries brain stem death is considered legal death, even if the body is kept alive with artificial means. This opens up for organ transplants of heart, liver and lungs, where the donor has to be dead.

What we will discuss in this text, is what happens after cardiac arrest in a body wich is lying dead outdoors (or indoors).

One of the first things that happens after death is that the temperature in the body starts to drop. Before the temperature in the body core drops, a temperature gradient must be established from the outside to the core. After this gradient has become established the body temperature will drop with a theoretically predictably rate. This fact can be used to estimate time of death. Even if one succeeds in predicting when the temperature of the body core was 37 degrees Celsius, one has to remember that the time it takes to form the temperature gradient will vary from individual to individual, and will vary from almost no time, to over two hours.

After the onset of putrefaction (about two days after death) the body temperature will increase again, due to the metabolic activity of the bacteria and other decomposing organisms.

Rigor mortis

Rigor mortis is a well known phenomenon, and is due to a complex chemical reaction in the body. In the living body muscles can function both aerobic and anaerobic. In the dead body muscle cells can only function anaerobically. When muscle cells work anaerobically the end product is lactic acid. In the living body, lactic acid can be converted back, by means of excessive oxygen uptake after an anaerobic exercise. In the dead body this can not happen, and the breakdown of glycogen in the muscles leads irreversebly to high levels of lactic acid in the muscles. This leads to a complex reaction where actin and myosin fuses to form a gel. This gel is responsible for the stiffness felt in the body. This stiffness will not be over before decomposition begins.

As rigor mortis is due to a chemical reaction, the reaction time is due to temperature and the initial concentrations of lactic acid. High metabolic activity in the time just before death, for example when running, leads to higher levels of lactic acid, and shorter time for the rigor mortis to develop. Higher environmental temperature also leads to a shorter reaction time.

In temperate regions the following rules of thumb can be used in estimating death, but must be used with caution:

Temperature of body	**Stiffness of body**	**Time since death**
Warm	Not stiff	Not dead more than three hours
Warm	Stiff	Dead between 3 to 8 hours
Cold	Stiff	Dead between 8 to 36 hours

Cold	Not stiff	Dead in more than 36 hours

Rigor mortis should never be the only basis for estimating time of death.

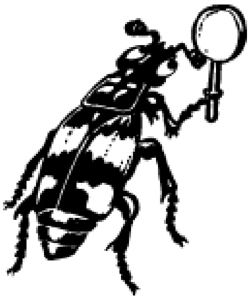
After death, a lot of internal organisms in the intestine will become very active. *Escherishia coli* and others will start multiplying, and the decomposition begins. First the intestine and the blood will be attacked, and when gas formation and other things leads to rupture of the intestine other organs will be attacked.

Organs starts decomposing at different times after death, and may also be used in estimating time of death.

The decomposition of a body can be divided into several stages, even if the duration of each stage will vary a lot:

Stage	**Description**
Initial Decay	The cadaver appears fresh externally but is decomposing internally due to the activities of bacteria, protozoa and nematodes present in the animal before death
Putrefaction	The cadaver is swollen by gas produces internally, accompanied by odour of decaying flesh
Black putrefaction	Flesh of creamy consistence with exposed parts black. Body collapses as gases escapes. Odour of decay very strong
Butyric fermentation	Cadaver drying out. Some flesh remains at first, and cheesy odour develops. Ventral surface mouldy from fermentation
Dry decay	Cadaver almost dry; slow rate of decay

In the rest of this document we will focus on the telltale signs that insects can provide in the investigation of suspicous deaths.



Estimating time of death with Forensic Entomology

After the initial decay, and the body begins to smell, different types of insects are attracted to the dead body. The insects that usually arrives first is the Diptera, in particular the blow flies or Calliphoridae and the flesh flies or Sarcophagidae.

The females will lay their eggs on the body, especially around the natural orifices such as the nose, eyes(2), ears(2), anus, penis and vagina. If the body has wounds the eggs are also laid in such. Flesh flies do not lay eggs, but deposits larvae instead.

After some short time, depending on species, the egg hatches into a small larvae. This larvae lives on the dead tissue and grows fast. After a little time the larva molts, and reaches the second larval instar. Then it eats very much, and it molts to its third instar. When the larvae is fully grown it becomes restless and begins to wander. It is now in its prepupal stage. The prepupae then molts into a pupae, but keeps the third larval instars skin, which becomes the so-called puparium. Typically it takes between one week and two weeks from the egg to the pupae stage. The exact time depends on the species and the temperature in the surroundings. A table of life histories to some species of blow flies and flesh flies are available here, and an illustration of the blowfly life cycle is available here.

The theory behind estimating time of death, or rather the post mortem interval (PMI for short) with the help of insects are very simple: since insects arrive on the body soon after death, estimating the age of the insects will also lead to an estimation of the time of death.

How to estimate age of blowfly eggs, larvae, pupae and adults

Eggs:
When blow flies oviposit, their eggs has come very short in their embryonic development. The eggs are approximate 2 mm in length. During the first eight hours or so there is little signs of development. This changes after that, and one can see the larvae through the chorion of the egg at the end of the egg stage. The egg stage typically lasts a day or so.

Larvae:
The blowfly has three instars of larvae. The first instar is approximately 5 mm long after 1.8 days, the second instar is approximately 10 mm long after 2.5 days, the third instar is approximately 17 mm long after 4-5 days. Identifying the right instar is the easiest part, and is done relatively easy based on size of larvae, the size of the larva's mouth parts and morphology of the posterior spiracles. The time it takes to reach the different instars depends very much on microclimate, i.e. temperature and humidity.

Prepupae:
At the end of the third instar the larva becomes restless and starts to move away from the body. The crop will gradually be emptied for blood, and the fat body will gradually obscure the internal features of the larvae. We say that the larva has become a prepupa. The prepupa is about 12 mm long, and is seen 8-12 days after oviposition.

Pupa:
The prepupa gradually becomes a pupa, which darkens with age. The pupa which are about 9 mm in length are seen 18-24 days after oviposition. The presence of empty puparia should therefore tell the forensic entomologist that the person in question has been dead in more than approximately 20 days. Identification can be done based on the remaining mouth parts of the third instar larvae.

A more precise way to determine age of larvae and eggs is the use of rearing. For example: the body is found with masses of eggs on it, none have hatched. How long time is it since the eggs was oviposited? Note the time of the discovery, note the time when the first 1. instar larvae occur. Subtract the first occurrence time with the discovery time, call this time A. Rear the blow flies to adults, let them mate, let them lay eggs on raw beef liver under conditions similar to the crime scene, take the time from oviposition to the first occurrence of 1. instar larvae. Call this time B. By subtracting B-A, one gets C, which is an estimate of the time since oviposition to discovery. Similar calculations can be done for other instars as well. If one has good base-line data from before under different temperatures and for different species, one only needs to rear the flies to a stage where they can be identified, and that is the third stage or the adult stage.

One important biological phenomenon that occurs on cadavers are a succession of organisms that thrive on the different parts. E.g. beetles that specialize on bone, will have to wait until bone is exposed. Predatory rove beetles or parasites that feed on maggots will have to wait until the blow flies arrive and lay their eggs.

The succession on cadavers happens in a fairly predictable sequence and can be used in estimating time of death if the body has been lying around for some time. Here is a table over a succession experiment on guinea pigs performed by Bornemizza in 1957.

There are several things to note about this table:
The first groups to arrive is blow flies, followed shortly by staphylinids. As putrefaction develops, more groups arrive at the scene, with most groups present just before the body is drying out due to seepage of liquids. After the body is drying out, dermestids, tineids and certain mites will be the dominant animal groups on the body, and blow flies will gradually vanish. Note also how the fauna changes in the soil. This can also be used to estimate time since death.

Succession data can be incorporated in a database, and when the forensic entomologist investigates a case, he can use the taxa found on the body as input, and get an estimate of the time of death as output.

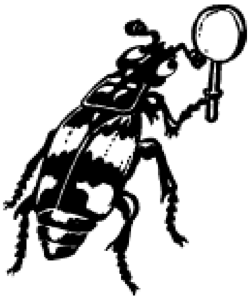
Day number										
Taxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
B	**0**	**0**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**
C	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**
D	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**0**
E	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**

The hypothetical table above shows the presence (1) and absence(0) of five different taxa (A, B, C, D and E) over ten days. The tabulated data is usually obtained from decay studies done on pigs or other animals.
Let's say the investigator finds taxa C, D and E on the remains. From the table above, we can see that taxa C occurs on the cadaver from day 5 to day 10, and taxa D from day 7 to day 9, and taxa E from day 9 to day 10. By studying the overlap, the entomologist estimate the PMI to be about 9 days.

Several insects are specialized in living in very decayed dead bodies. One example is the cheese skipper, *Piophila casei*, where the larvae usually occurs 3-6 months after death. The cheese skipper is a well known pest of cheese and bacon worldwide, and has a cosmopolitan distribution. Adult cheese skippers may occur early after death, but larvae occurs later. The earliest observation on human remains are when the body is two months, and this was under excellent summer conditions. In 1898, Potter examined 150 graves, and found remains of *P. casei* in ten of them. These graves were from three to ten years old and three to six feet deep.

In temperate regions dead bodies often appear in spring, after the snow is gone. The forensic entomologist and the forensic pathologist must then try to determine whether the death occurred during the winter or before the snow set in. If the death occurred before November, it is possible to find dead insects in and on the body. By analyzing the dead insect fauna, and estimating when the insects probably died (this can be found by looking at meteorological records). Another hint is when the different adults stop flying before the winter. For example: here in Norway, we have had some cases where the bodies have been found in the spring. In one case we found dead third stage blow fly larvae in the back of the mouth. The blow fly larva was of an species that is flying from May to October. It was from this concluded that the eggs probably was laid during October, and since it was relatively few larvae, probably late in October. In another case, we found several live insects on a dead body, and also many dead third stage larvae. The dead larvae was found on the stomach, the arms, the shoulders, and inside the head. We concluded that the live insects had colonized the dead body in the spring, and that the dead larvae had died during the winter. Based on the widespread occurrence of the larvae, we had to say it was likely that the body was colonized before October, probably in September.

If the death occurred in the winter things become difficult in outdoor settings, as very few insects are active in the winter. It is reported that larvae of the winter gnat, *Trichocera sp.* can develop on carrion in the winter. By estimating the age of these larvae, if present, it could be possible to estimate the PMI.



Finding the cause of death using forensic entomology

In a crime investigation, there is not only of great interest to find out when a victim died, but also of interest to find out how the victim died, as this can be used to find the killer.

In some instances the insects themselves are the killers, in other instances the insects occuring on the carrion can shed a light on what happened when the victim died.

Wasps and bees, for example, can inject venom through a sting. Some people are sensitive and allergic to these venoms, and can die if not treated in time. One other important aspect of wasps and bees are their effect on drivers. Many car accidents are probably caused by some wasp, bee or bumble-bee coming through the window, causing hysteria, or a distraction from the road leading to a collision or other accidents. In some cases wasps and bees has been used as murder weapons, as in case where some parents had shut their infant in a room full of wasps, in order to get rid of it.

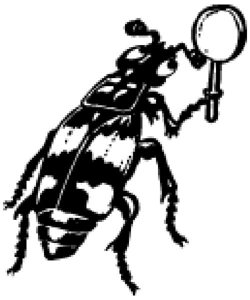
Poison can be traced in blood, urine, stomach contents, hair and nails. One other important source is maggots occuring on a corpse. After a while it will be impossible to sample stomach contents, urine and blood from the dead body, but it will still be possible to sample from maggots, empty puparia or larval skin cast. The following list of chemicals has to my knowledge been traced in maggots:

- Triazolam
- Oxazepam
- Alimemazine
- Chloripriamine
- Phenobarbitol
- Malathion
- Mercury
- Amitriptyline
- Nortriptyline
- Cocaine
- Phenycyclidine
- Heroin

Many of these chemicals will also influence the life-cycle of the maggot. For example will high dosages of cocain accelerate the development of some sarcophagids. Malathion, an insecticide, is commonly used in suicide, and is usually taken orally. Presence of malathion in the mouth may lead to a delay in the colonisation of the mouth. Presence of amitriptyline, an antidepressant, can prolong the developmental time with up to 77 hours, at least in one species of Sarcophagidae. Knowledge of drug use in the victim is therefore important not only in finding the death cause, but also in estimating the time of death.

The sites of blowfly infestation on the corpse may be important in determining the cause of death, or at least in reconstruction of events prior to death. For example: if there have been trauma or mutilation of the body prior to death, this may lead to heavy infestation of other body parts than the usual sites when the victim is not mutilated. Under a knife attack, it is usual to guard oneself with arms in front of thorax and head. This may lead to injury on the lower part of the arm. After death, blowfly may oviposit in these wounds.

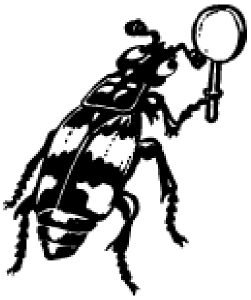
The usual sites of oviposition on dead humans are natural openings. Even here there is preference. Blowflies will most often lay their eggs in the facial region, and more seldom in the genitoanal region. If there is a sexual assault prior to death, leading to bleeding in the genitoanal region, blowflies will be more likely to oviposit in these regions. Therefore, if there is observed blowfly activity in the genitoanal region, one can start to suspect a sexual crime. This must of course be corroborated with other evidence as well. The interpretation of maggots in the anogenital region becomes very fuzzy after a few (4-5) days, as eggs will be oviposited in this region during the course of decay in the natural course of decomposition.



Has the body been moved after death?

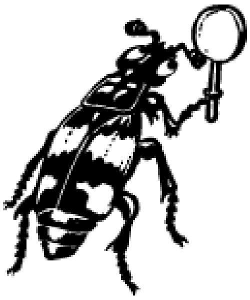
After death, a succession of fungi, bacteria and animals will colonize the dead body. The substrate on which the body is lying will also change over time. Leakage of fluids from the dead body will lead to the disappearance of certain insects, and other insects will increase as the time goes. A forensic entomologist can then look for how long the body has been there by looking at the fauna at the body, and also estimate the time the body has been lying there by sampling soil insects underneath the dead body. If there is a difference in the estimates, and the analysis of the soil suggests a short PMI, and the analysis of the body fauna suggests a longer PMI, one can suspect that the body has been moved. One can also see that a body has been lying at a particular place long time after the body has been removed, both by botanical means, and by analysis of the soil fauna.

Some times dead bodies are found in concealed environments, where blowflies have no access. If there is blowflies, it means that the body has been moved there. An example of this is given in case history no. 20.
Some Calliphorids are heliophilic, that is, they prefer to lay their eggs on warm surfaces, which means that they usually occur where the bodies lies in sunny places. Other blowflies prefer shade. For example, *Lucilia* species prefer sunlight, and *Calliphora* prefer more shady conditions. Some species are synanthropic and occurs in urban areas, other species are not synanthropic and occurs in rural areas. *Calliphora vicina* is a synantropic fly, very common in cities, and *Calliphora vomitoria* is a more rural species.



Use of arthropods in investigation of contraband trafficking

Many arthropods are found together with stored products, even such products as narcotics and other drugs. Since illegal drugs are often made in one country, and sold in others, it can be important to find out where the drugs was produced. Some times, insects and other arthropods can be found together with the drugs. If these insects are determined, and the world distribution of the different insects are plotted on a map, one can by analyzing the degree of overlap, find out approximately where the drugs came from. If one looks at the biology of the insect species found with the drugs, one can also often say something about the surroundings where the drugs were produced or packed. See for example case history 21.



Common arthropods occurring on dead bodies

Acari

The Acari, or mites as they also are called, are small organisms, usually less than a mm in length. Mites occur under the dead body in the soil, during the later stages of decay. Many mites are transported to the body via other insects, such as flies or beetles. Other mites are soil dwelling forms which can be predators, fungus feeders or detritus feeders. Most species will be found in soil samples from the seepage area under the body.

Aranea

The Aranea or spiders are predators on insects occurring on bodies. No species is specific to the carrion fauna, and will have limited or no value in estimation of the PMI.

Diptera

The order diptera contains insects with one pair of wings, the second ones modified to halteres. About 100,000 species are known to science, many more awaits discovery. Among the flies we find many members of the carrion fauna. The larvae of flies lives in very different habitats, also aquatic.

NEMATOCERA

Trichoceridae

Trichocera sp.

or winter-gnats as they also are called because the common species *Trichocera regelationis*, *T. saltator*, *T. maculipennis*, etc, fly abundantly in the winter months, although they occur at lower frequencies throughout the year. The adults resemble small crane-flies. The larvae are saprophagous and feed on decaying material. Trichocerid larvae constitutes an important part of the carrion fauna during the winter months, when the blowfly fauna are missing.

BRACHYCERA

Stratiomyidae

Larvae of *Hermetia illucens* is recorded eating on human excrement and human remains. Usually this species occur late in the decomposing process.

CYCLORRHAPHA-ASCHIZA

Phoridae

A large family of flies, containing about 3000 species. They are minute to medium-sized (0.75-8.00 mm), dull black, brown or yellowish flies of hump-backed appearance. They are generally bristly and with a very characteristic wing venation. They run about in an active erratic manner which has earned them the popular name of scuttle-flies. They breed in a wide variety of decaying organic material, in addition some develop in fungi and others are parasites. In the larval stage some species are predators. Several genera is regularly found in vertebrate carrion e.g. *Anevrina*, *Conicera*, *Diplonevra*, *Dohrniphora*, *Meopina*, *Triphleba* and some *Megaselia* species.

Conicera tibialis also known as the coffin-fly because of its association with coffined bodies that have been underground for about a year. Adult *C. tibialis* is able to bury to a depth of 50 cm in about four days. At normal grave depths (1-2 m) temperature variation is slight, about 5 degrees Celsius, so development from egg to adult will take considerable time. Development can take place independent of season, since the body is buried at frost free depth.

Syrphidae

These are the familiar hover flies, often camouflaged as wasps or bumble bees. Among the larvae of syrphids we find the famous rat-tailed maggots. These occur in filthy water, and may occur in dead bodies.

ACALYPTRATAE

Dryomyzidae

A small group of relatively rare flies. Most species are found in moist woods. Their larvae occur in decaying organic matter.

Coelopidae

These flies are small to medium-sized, usually dark-brown or black in color, and have the dorsum of the thorax flattened. The body and legs are very bristly. They occur along the seashore and are very abundant where seaweeds have washed up. Occasionally larvae may develop in other organic matter, such as a dead body which has been lying along the seashore.

Heleomyzidae

Fairly large group of small to medium-sized often brownish flies. Adults are often found in moist places, larvae in decaying plant or animal matter, or in fungi.

Sepsidae

Very characteristic flies when alive, the adults occur in large numbers around excrements and decaying materials, where the larvae develops. The adults have a peculiar habit of wing-waving. This family have been recorded feeding on dead human bodies in the time of caseic fermentation and before ammoniacal fermentation. Eggs of Sepsidae have a very long respiratory horn, often longer than the egg itself.

Sphaeroceridae

Minute or small dark flies that breed in dung.

Piohilidae

Dark, shining flies. The larvae are scavengers and are often found on dead bodies that have been lying for a while. *Piophila casei* is also called the Cheese-skipper, because the larvae jumps for a considerable height, when disturbed. This behaviour is probably a defencive tactic against predators. These flies also infests stored bacon and cheese, which, to the flies, are almost the same as dried corpses.

Ephydridae

Large group with several common species. They are small to very-small. Adults are found in moist places: marches, the shores of ponds and streams, and the seashore. The larvae are aquatic, and many species occur in brackish or even strongly saline or alkaline water.

Drosophilidae

These are the well-known fruitflies that every biologist have heard about, and probably most other people too. Minute and small flies, brown, yellow or grey with brightly colored eyes. The larvae feeds on decaying vegetable matter, but some also feed on fungi. Some species may occasionally occur on dead humans, and these are probably feeding on fungi.

Milichiidae

Minute, dark flies. Adults and larvae are scavengers.

CALYPTRATAE

Sarchophagidae

Among the Sarcophagids we find the large flesh-flies with red eyes and a grey-checkered abdomen. These flies does not deposit eggs, but larvae on the corpse. They are, together with the Calliphorids, among the first insects to arrive at the corpse. The larvae are predators on blowfly larvae, as well as carrion feeders. Many Sarcophagids are feeding on snails and earthworms.

Calliphoridae

These are the famous green-bottles and blue-bottles. There is many species of blowflies, and each species has their own biology. Some prefers to oviposit in shade, others in light. Some are mainly urban in their distribution, others mainly rural.

Fanniidae

Here we find the lesser house-fly, *Fannia canicularis* among others. These flies are mainly breeding in faeces, but can also develop in cadavers, especially if there are patches with semiliquid tissue. The larvae have fleshy processes all over the body, which assist in floating.

Muscidae

Among this large family we find the common house-fly, *Musca domestica*. These flies occur in houses, and are one of the most widely distributed species on this planet. In warm weather they can complete development in 14 days. Eggs are laid in decaying material, including, but not limited to, dead bodies.

COLEOPTERA

Several beetles occur on carrion. There exists necrophagous beetles and predators. The various groups occur in different stages of decomposition.

Staphylinidae

Staphylinids - or rove-beetles may arrive a few hours after death, and remain active throughout the decomposition process. The adult and larvae feeds on eggs and larvae of other species. They have a characteristic short elytra.

Dermestidae

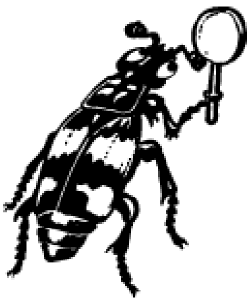
Dermestids are common beetles in the later stages of decomposition. Larvae of dermestids does not occur before the body is dry. The larvae and adults feeds on dry skin and hairs and other dry dead organic animal matter. Dermestids is a common stored product pest in homes, and a pest in insect collections and furs at museums and other places.

Histeridae

Members of this family has short elytra, but not as short as the Staphylinids. This family occurs wherever there is decay and putrefaction. They have been found during the bloated, decay and early parts of the dry stage. Both larvae and adults feed on maggots and puparia. They are usually concealed under the corpse during daylight, but becomes active in the night. *Saprinus* and *Dendrophilus* occur on dead animals and on air-dried and smoked foods. They prey on larvae of *Dermestes*.

Silphidae

In this family we find the *Nicrophorus* species, well known for their habit of undertaking small carcasses. Some of the species of *Nicrophorus* lives mainly on larger carcasses, and does not bury them. The adults prefer feeding on maggots, but also feeds on the carrion. The adults feed their larvae until pupariation. Easton reports that 13 specimens of *Necrodes littoralis* was found on the body of a man which had been lying on the North Downs for 17 days in October 1969.



Analyzing the crime scene for entomological evidence

To make the most use of entomological evidence at a crime scene, an experienced and well trained forensic entomologist should do the collecting at the scene.

The exact procedure at the crime scene varies with the type of habitat, but in general we can divide the work of the forensic entomologist in five parts.

1. Visual observation and notations at the scene.
2. Initiation of climatological data collection at the scene.
3. Collection of specimens from the body before body removal.
4. Collection of specimens from the surrounding area (up to 6 m from the body) before removal of the remains.
5. Collection of specimens from directly under and in close proximity to the remains (1 m or less) after the body has been removed.

Observation on insect activities at the crime scene may be useful, because the entomologist is trained in a different science than the crime scene investigators. An entomologist will probably observe elements that the investigators will ignore (and vice versa).

What should be looked for at the crime scene?

- The type of habitat the crime scene is located in? Is it rural, urban/suburban or aquatic? Is it a forest, a roadside, a closed building, an open building, a pond, a lake, a river, or another habitat type.

  The type of habitat dictates what types of insects that could be found on the body. Finding of insects typical of other habitats than the crime scene may suggest that the body has been dumped.
- Estimate the number and kinds of flying and crawling insects.
- Note locations of major infestations associated with the body and surrounding area. These infestations may be egg, larval, pupal or adult stages, alone or in any combinations of the above.
- Note immature stages of particular adult insects observed. These stages can include eggs, larvae, pupae, empty pupal cases, cast larval skins, fecal material, and exit holes or feeding marks on the remains.
- Note any insect predation such as beetles, ants and wasps or insect parasites.
- Note the exact position of the body: compass direction of the main axis, position of the extremities, position of head and face, noting of which body parts are in contact with substrate, noting where it would be sunlight and shade during a normal daylight cycle.
- Note insect activity within 3-6 m of the body. Observe flying, resting or crawling insect adults or larvae or pupae within this proximity to the body.
- Note any unusual naturally occurring, man-made, or scavenger-caused phenomenon which could alter the environmental effects on the body (trauma or mutilation of the body, burning, covering, burial, movement, or dismemberment)

Photographs should be taken of all this, with closeup photos of the different stages of insect found before collecting.

Collecting of climatological data at the scene

When estimating the PMI, climatological data about the crime scene is absolutely critical. The length of the insect life cycle is determined mostly by temperature and relative humidity in the environment development takes place.

The following climatological data should be collected at the scene:

1. Ambient temperature can be evaluated by taking readings at 0.3 to 1.3 m heights in close proximity to the body.
2. Ground temperature can be obtained by placing the thermometer on the ground, immediately above any surface ground cover.
3. Body surface temperatures should be obtained by placing the thermometer on the skin surface.

4. Under-body interface temperature can be obtained by sliding the thermometer between the body and the ground surface.
5. Maggot mass temperatures can be obtained by inserting the thermometer into the center of the maggot mass.
6. Soil temperatures should be taken immediately after body removal at a ground point which was under the body before removal. Also take soil temperatures at a second point 1-2 m away from the body. These temperatures should be taken at 3 levels: Directly under any ground cover (grass, leaves, etc.), at 4 cm soil depth and at 20 cm soil depth.

Weather data for the scene should be collected from the nearest meteorological station. Minimum requirements should be maximum and minimum temperature and amount of precipitation. Any other information is also welcome, and may aid in the reconstruction of the events. The climatological data should extend back to the time the victim was last seen.

Collecting specimens before body removal

A passive technique for collecting adult insects at the crime scene is by using sticky traps with a slow drying adhesive substance. These traps are made from waxed cardboards with a pup tent configuration set at a approximately 60 degree angle with sticky material on both exposed sides. This trap will collect many insects in a few minutes. An insect net can be used to collect flying insects. Eggs, larvae, pupae and adults of insects on the surface of the human remains should be collected and preserved to show the state of the entomological data at the time of discovery. Insects within the body should not be collected before the autopsy. If there is enough insects, samples of egg, larvae and pupae should be collected alive and placed on a rearing medium such as raw beef liver. Rearing to the adult stage makes identification easier, and may give vital clues to the PMI estimation. It is important that the temperature in the rearing container is as constant as possible, in the range of 20-27 degrees Celsius. It is absolutely necessary that the temperature is recorded in the rearing container.

In the laboratory

All samples, both live and dead specimens should now be processed as fast as possible. Live specimens are placed in incubators with known temperature and humidity levels. Several times each day these containers should be watched, and changes such as hatching of eggs or larvae, pupariation or eclosion of adult insect should be noted. The exact time should be noted. Pictures could be taken to illustrate to a jury or others. Each kind of larvae and adult should be determined to genus and species if possible. This may require the assistance of an expert of the taxon in question. It may be necessary to do experiments outdoors near the crime scene to recreate the environmental conditions for the larvae to estimate PMI.

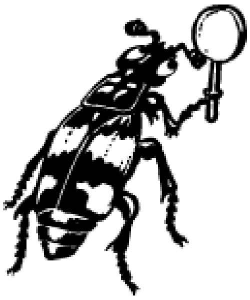
Analyzing the data

When all the data is processed it is time to make some conclusions:

Determine whether or not the remains have been disturbed or disarticulated during the PMI. Ask if there is presence of any antemortem administered drugs such as alcohol, cocaine or heroine.

Estimate the age of as many specimens as possible, based on presence of drugs, temperature and humidity conditions. Consider whether or not insect activity was delayed after death.

There are several other things to take into account, but these points can be read in the excellent book "Entomology and Death: A procedural guide" edited by Catts and Haskell.



Case histories involving forensic entomology

Throughout history, forensic entomology have been used many times in investigating crimes. Here I will share with you some of the case histories I have found in the literature. If you know of any case histories that I have not covered, please contact me via email: morten.starkeby@bio.uio.no

Dr. Bergerets case

Dr. Bergeret d'Arbois of Jura performed an autopsy of a child discovered by a plasterer while repairing a mantelpiece. He found that the flesh-fly, *Sarcophaga carnaria* had deposited larvae in 1848 and mites had laid eggs on the corpse in 1849, and concluded that judicial suspicion should fall on the occupiers of the house in 1848.

The Ruxton case

In the afternoon of 29 September 1935, the police were informed that the dismembered pieces of human remains had been found in a river near Edinburgh. Two bodies were reassembled from the pieces and proved to be a Mrs. Ruxton and her children's nurse, Mary Rogerson. The date on which the remains were deposited was established by the precence of third instar larvae of *Calliphora vicina* Robineau-Desvoidy of an age estimated at 12-14 days by Dr. A. G. Mearns. This estimate agreed with and corroborated other evidence and led to the conviction of Dr. Ruxton, although he did not confess.

The Lydney case

The prosecution's pathologist, Professor Keith Simpson, successfully used blowfly maggots to establish time of death, in spite of an attempt by the defence counsel to refute this evidence by calling an entomologist as an expert witness. The case hinged on whether the testimony of three witnesses, who claimed they had seen the victim after the supposed date of death, outweighed the evidence of the prosecution which finally depended on the age of *Calliphora vicina* Robineau-Desvoidy maggots found on the corpse in June. Simpson aged the maggots to 'at least nine or ten days old, probably not older than twelve.' In the witness box the entomologist A. W. McKenny Hughes concurred. The police estimate of time of death based on the state of disintegration of the body was 6-8 weeks!

The baby in the box

On 15 March, 1944, in freezing condition, the body of a new-born child, with placenta attached, was found wrapped into a blanket and a newspaper in a cardboard box placed in a slit trench. The floor of the trench was deeply covered with the previous years beech leaves. From its well-preserved condition, the pathologist who examined the body considered it to have been abandoned but a few hours. However, the presence in the wrappings and about the placenta of approximately thirty examples of the Staphylinid beetle *Anthobium atrocephalum* Gyllenhal suggested a much longer period. Moreover, the weather had been continuosly very cold to freezing cold during the previous two weeks and under such conditions the beetles would have required time to migrate in such numbers from hibernation among the beech leaves. The mothers subsequent confession revealed a time-factor of about nine days.

Kathleen McClung

Kathleen McClung was murdered in Guilford during the night of 20-21 June 1969. Post-mortem examination was performed by Dr. Keith Mant on June 24 and two days later Dr. A. M. Easton received from him two tubes of maggots. The first had been obtained from the mouth. They were small and dead and their identification proved difficult. The second tube contained numerous live maggots obtained from the polythene bag wrapped around the victims head when transported to the mortuary. They were second-instar larvae, the determination again proved difficult. However, some of them were reared on a diet of raw beef and a total of eight puparia were obtained between 4 and 8 July. All hatched between 18 and 23 July, the resultant flies proved to be the common *Calliphora vicina* Robineau-Desvoidy. Estimates made from consideration of the dates of pupation suggested that oviposition had occured between 21 and 24 June, a conclusion closely in keeping with the known facts.

The child behind the stove

On 21 May 1947 the police found the body of a child behind a stove in a farm at St. Hubert (Belgian Ardennes). The body was wrapped in a linen cloth in which, at the time of the discovery, there was numerous larvae of *Calliphora vicina* Robineau-Desvoidy in the final stages of their growth; in addition there was a dead female of *C. vicina* (which had died during hibernation after laying eggs), a quite recent pupae of the same species and some pupae of Phoridae. The *Calliphora* larvae had nibbled at the face of the child, causing the disappearance of the eyes and skin; they had penetrated into the frontal sinuses and from here had devoured the brain. The neck and the upper parts of the arms, as well as viscera, were also severly damaged.

The larvae of *Calliphora* produced all their pupae between 21 May and the evening of 22 May; the adults appeared from 2 June onwards, perhaps ten days after pupation. J. & M. Leqlerq had earlier reared numerous specimens of *C. vicina* and had been able to determine with the greatest precision that during the spring under the thermal conditions of a lightly warmed room, the temperature of which had never exceeded 20 degrees Celsius, and under good nutritional conditions on fatty cheese, the development of a batch of eggs of *Calliphora* required 19-20 days from the day when the eggs were laid to the formation of the first pupae.

One can suppose that the larvae found on the corpse underwent development under comparable conditions because (1) they developed in the spring, (2) the corpse had been left behind the stove which was sometimes lit, and, consequently, the temperature conditions should have been appreciably like those of a lightly warmed interior room, all the more so, because the month of May 1947 was relatively warm. The Leqlerqs had excluded the hypothesis that the larval development had been accelerated by temperatures higher than those in their experiments, because the stove had not been alight all the time and it was evidently sheltered from the rather exceptional rises of temperature on some of the days in May 1947.

They therefore agreed that there was a strong presumption that the eggs had been laid some 20 days before 21 May, perhaps about 1 May 1947. Moreover, eggs laid by *Calliphora* must have been laid on the corpse a short time after it had been abandoned. In fact:

- *Calliphora vicina* is common throughout the year, present in rural houses and passes the winter in the adult stage.
- The females very readily detect the odour of flesh that is beginning to decompose. As it was a case of a corpse abandoned in the open air at a time of the year favourable to rapid putrefaction, only a few days would have been needed before the first blowfly arrived to lay eggs.
- It is known that *Calliphora* belongs to the first wave of necrophagous species wich colonize a corpse in open air.
- It was the first generation of *Calliphora* which had been able to develop on the corpse. Every earlier generation would have left traces such as empty puparial cases under the corpse or in the cloth covering it.

Therefore they formed the hypothesis that the corpse was placed where it was during the last week of April, al little after the murder of the child. The judicial inquiry took its course and the culprit was arrested; his declarations and confessions completely confirmed the Leqlerq's conclusions.

The erroneously condemned Hungarian ferry skipper

A ferry skipper had been condemned to life imprisonment for the murder of a postmaster, whose knifed body had been found one evening in September on the ferry. The ferry skipper had arrived at 1800 on that day, and the body of the murdered postmaster had been found some hours later. The autopsy was performed the next day at 1600. Masses of yellowish fly eggs and numerous newly hatched larvae of 1 to 2 mm in lenght was present, and the finding was recorded in the autopsy report. No attention was paid to this observation at the trial, however. On assumed evidence, the ferry skipper was condemned to life imprisonment in spite of his swearing that he was innocent. Eight years later the case was reopened. At the new trial, Dr. Mihalyi pointed out that no sarcophagous flies are active in Hungary after 1800 in the month of September. He also recalled some of his experiments indicating that, at a temperature of 26 degrees Celsius, the yellowish eggs of *Lucilia caesar* (L.) hatch after 13 hours, those of *L. sericata* (Meigen) hatch after 10-11 hours, and those of *Phormia terranovae* Robineau-Desvoidy 14-16 hours after oviposition. These data, applied to the case of the ferry skipper, led to the conclusion that it was not possible that the eggs could have hatched if they had been laid during the day the autopsy was performed, and that they must have been laid during the previous day *before* 1800 since the flies are not active after this time. Dr. Mihalyi's data on oviposition was verified and, on the basis of this and other evidence, the ferry skipper was released from prison.

The two murdered hitchhiking girls

On 21 August 1971, at 1600, the corpses of two murdered girls who had been hitchhiking were discovered in a sandpit near the town of Hyvinkaa, in southern Finland. The corpses were partially covered by a polyethylene sheet. A cluster of fly eggs was collected from the hair of one of the girls; a fly larvae between 4.5 and 5 mm long was also present in one eye. Four days later, examination of the refrigerated bodies revealed four larvae 5-6 mm long in the eyes of the same girl, and five larvae 2.5-3.5 mm long in the eyes of the other girl.

An attempt was made to rear all the eggs and the larvae to adult flies. The development of the eggs into larvae 4.5-5 mm long (i.e., to the length of the fly larvae observed on 21 August) required one and a half days. Further rearing was only partially successful and a single adult fly of the species *Calliphora vicina* was obtained. Flies of the same species were also obtained from a liver growing-medium placed in a glass container on 28 August 1973 in the place where the dead girls had been found.

Since it had taken one and a half days to obtain a larva 4.5-5 mm long experimentally, it was concluded that the bodies had been in the locality where they were found from 19 August, namely for about two days after the time of death. The suspected murderer, however, had an alibi for 19 August and the following days as well. During the trial the question was raised whether it was possible that the dead girls could have been in the place where they were found on 14 August, as suggested by police investigation. The answer to this question was that, considereing the daily temperature from 14 to 19 August (well above 16 degrees Celsius during each day), a larg number of big fly larvae should have been found in the corpses. Since this was not the case, one had to draw the conclusion that either the corpses of the girls were not at that place on 14 August or they were completely covered by the polyethylene sheet. From the photograph taken by police immediately after the discovery of the corpses, it seemed possible that the polyethylene sheet at first had covered the girls completely, but later had been partially removed by the wind. The subsequent question was wether fly oviposition could have occured through possible holes in the polyethylene sheet. The sheet was immediatly inspected, but no holes were detected. The results of the police investigation, substantiated by the entomological observations, led to the conviction of the suspected murderer.

The lightly covered corpse in the forest of Ylojarvi

On 13 and 14 July 1970, the Finnish Central Criminal Police submitted nine soil samples collected from a forest in Ylojarvi (cental Finland), where the decayed corpse of a 17-year-old girl had been found on 9 July partly covered by moss and by branches of a rotten tree. Most of the soil samples revealed only non-indicative insects, but the sample collected from the area where the head had been lying contained 187 larvae of blowflies in different stages of development, plus eight scarabaid beetles of the species *Geotrupes stercorosus* (Scriba), histerid beetles of the species *Hister unicolor* L. and *H. striola* Sahlberg, and staphylinids of the genus *Philontus*. This soil sample was polluted by fluids from the decayed brain. Another sample of soil from where the pelvis of the corpse had been lying contained 91 fly larvae (all of small size) plus three *Geotrupes stercorosus* beetles and 18 staphylinid beetles of the genus *Atheta*. This sample also contained 17 fly puparia, of which seven was empty. The puparia and some of the larvae was placed in rearing cans.

From 16 to 20 of July two specimens of *Muscina assimilis* (Fallen) and some other muscids emerged from the puparia, but not a single blowfly. From the blowfly larvae taken under the head and reared on raw liver in outdoor temperatures, 34 adults of *Phormia terranovae* Robineau-Desvoidy emerged from 27 July to 4 August, three adults of *Lucilia illustris* (Meigen) emerged from 30 July to 3 August, and seven adults of *Calliphora vomitoria* (L.) emerged from 1 to 3 August.

Since no puparia of blowflies could be identified, but only full-grown larvae were detected, entomological evidence indicated that the corpse could not have been in the area where it was found much longer than a week. In contrast, the existence of mature pupae of *Muscina assimilis* indicated an earlier time of death, but the possibility existed that they belonged to the normal fauna of the locality. Although the entomological observations indicated that the corpse could not have been exposed to fly oviposition for much longer than a week, the advanced brain decay suggested that the death had occured considerable earlier. Therfore the question arose whether the murder had occured elsewhere in a flyless environment and the corpse later transferred to the locality where it was found. Information was subsequently received that the corpse was covered by a rather thick layer of moss and that only the head, one breast and a hand were uncovered. Probably the cover had been quite complete at first, but later removed by foxes, dogs or other sarcophagous vertebrates. This exposure to blowfly oviposition had presumably occured about one week prior to the detection of the corpse.

Later, the brother of the girl confessed that he had accidentally killed his sister with a karate blow to the side of the neck on 4 June 1970. He further stated that in order to hide her death he had carried the body to the woods, arranged the clothes and position of the corpse to simulate a sexual murder, and then covered it with moss and rotten tree branches.

This case shows how effectively even a thin cover on the corpse may inhibit fly oviposition. It also shows how important it is to observe closely the type and extent of the coverings on the corpse. Likewise, it indicates that the flies of the genus *Muscina* have the peculiar ability to oviposit without immediate contact with the carcass.

The crime of the cleaning woman

One summer day, a high official of the Finnish Government, on entering his office, accidentally notice numerous large, white larvae under the carpet at the threshold. He immediatly called the cleaning woman into the room and asked her how often the carpet was cleaned. She asured him that the carpet was cleaned every day and that it had been done the previous evening. The official replied that he could not believe that 'bugs' longer than 1 cm could have developed in a single night. The cleaning woman was dismissed because it was assumed that she had told a lie.

Out of mere curiosity a veterinarian working in the same building was requested to inspect the carpet and he wondered whether it was possible that the larvae had really developed by eating the carpet, which was made of a plastic material. Specimens of the larvae were collected and sent to Nuorteva for identification. They were identified as migratory larvae (yellowish fat body) or white prepupae of blowflies of the species *Lucilia sericata* (Meigen). It was concluded that the larvae had developed on the carcases of some dead mice or on some forgotten provisions in the government buildings and that they had migrated for pupation during the night into the carpet on the threshold. The cleaning woman was reinstated in her job.

The decayed corpse in a park in Helsinki

On 8 July 1973, the decayed corpse of a man was found in an isolated corner of the park in the suburban area of Oulunkyla, in Helsinki. The corpse was camouflaged by a few tree branches, but the chest and one hand were quite bare. The skin on these areas was tanned and dry. Thousands of large fly larvae were creeping over the body. In addition, numerous fly puparia were detected in the soil under the head of the corpse. Two tree branches, numerous fly larvae, puparia and soil samples were sent to Dr. Nuorteva for examination. One of the branches, from a rowan tree (*Sorbus aucuparia* L.), had dried leaves of 10-12 cm in length. The lenght of fully-grown rowan leaves generally ranges from 10 to 16 cm. Fortunately, published information existed on the development of the length of the rowan trees in Helsinki during the year 1949. According to these measurements, the growing leaves reach the mean lenght of 8.4 cm on 20 May, and soon after they had reached full lenght. The lenght of the rowan leaves found on the corpse thus indicated that the branches used to cover the corpse dated from the end of May or the beginning of June.

It was also noted that one of the rowan leaves was inhabited by a colony of moth larvae that had spun the leaflets together. It was determined to be *Yponomeuta malinellus*, and these moths spin the leaflets toghether in late May or early June. Thus, these data supported the data based on leaf growth.

Some of the puparia were quite fresh,ie. they were white prepupae, and they and the other puparia was placed outdoors in rearing cans under micro climatological conditions corresponding to those on the place where the body was found. From 12 to 22 July, 93 adult blowflies of the species *Phormia terranovae* emerged. The development from white prepupae to adult blowflies had thus lasted 14 days (from 8 July to 22 July) and the oldest flies emerged on 12 July. Meteorological data showed that the larval development had occured during a cold period (16.8 degrees Celsius as a mean), whereas it had been considerably warmer (19.4 degrees Celsius as mean) when the puparia developed. From this evidence it was concluded that fly development on the corpse had started considerably earlier than 15 June, most likely at the beginning of the month. Independent police investigation showed that the victim had been knifed on 2 June.

The murdered girl hitchhiker in Inkoo

On 19 August 1971, a police inspector submitted fly samples collected from the badly decayed corpse of a young woman discovered in a small pit in the rural parish of Inkoo, which lies not far from Bromarv (south Finland). The sample consisted of some full grown blowfly larvae, 21 puparia, and one freshly-emerged adult fly, with still wrinkled wings. The fly was identified as *Phormia terranovae*, and it was also determined later, by rearing, that the larvae and puparia also belonged to the same species.

Fortunately, on 4 July 1971, a field experiment investigating the duration of development of blowflies fed on fresh fish bait in localities of different types was in progress. The flies for this experiment had thus developed under the very same meteorological conditions as the flies in the unidentified corpse in Inkoo. For the different fly species in the experiment the minimum duration of development was as follows (at a mean temperature of 16.6C during the period from 7 July to 8 August:

Lucilia silvarum	28 days
Lucilia illustris	32 days
Muscina assimilis	32 days
Lucilia richardsi	38 days
Cynomyia mortuorum	38 days
Calliphora erytrocephala	38 days

Phormia terranovae was not included in the experiment, but it was known from the experiments of Kamal (1958) that the minimum duration of its development is 71% of that of *Calliphora erytrocephala*. Under the existing meteorological conditions, the development for *P. terranovae* should thus have been 26-27 days or probably longer, as the body was lying in a pit under a cover that shaded it. Therefore it was estimated that the death had occured more than a month previously. Later it was proved that this estimate was correct. The girl had been murdered on 12 July 1971.

The body in the flat

A dead body of a woman was found on the floor of her flat in Helsinki on 6. september 1964. The body was exposed to sunshine through a closed window. Death had occurred on 6. august, because newspapers had accumulated since that day. The cadaver was thus about one month old and considerable decayed. The skin surface was loose, the brain semi-liquid and the viscera badly decayed. At autopsy, heart failure was found to be the cause of death. Numerous fly larvae were crawling on the skin and in the orifices of the face. Numerous larvae was also observed on the floor of the flat.

The larvae collected at the skin surface of the cadaver on the 8. september during autopsy, was transferred to a rearing cage (at low room temperature). The bulk of larvae were at this time full-grown and actively crawling. All was fullgrown at 18. september. The first puparium was detected the same day (18. september). The first adults emerged at 26-27. september and was determined to be three males and one female of *Calliphora erytrocephala (=vicina)* and one female and one male of *Lucilia sericata*. They thus emerged 52 days after the death of the woman in question. Later, during the period 29 September to 6 October, three males and three females of *C. vicina* as well as three males and 12 females of *L. sericata* emerged. For the period 11 October to 7 November, the rearing cage was placed outdoors where the temperature then dropped below zero. Later, when the cage was again at room temperature additional specimens were released from diapause and during the period 2 January to 11 February 1965 four males and three females of *L. sericata*. The diapause had at least partly occurred in the larval stage, because one larvae was seen crawling on 26 January. It pupated on 28 January and emerged as an adult fly on 11 February.

Almost simultaneously with the emergence of the first fly in the rearing experiment, flies also emerged in the autopsy room (*L. sericata* - one male on 24 September, one male on 6 October; *C. vicina* one male on 28 September, one male on 30 September, one male on 6 October and one male, two females on 8 October). When the refrigerator in the autopsy room was defrosted on 9 October, six males and eight females of *C. vicina* emerged. The larvae from which all these flies had developed had obviously crept into crevices in the autopsy room and refrigerator during the handling of the cadaver.

Conclusions based on the entomological findings.

A sample from a dead human body containing full-grown larvae of *L. sericata* and *C. vicina* indicates to the entomologist the following facts:

1. The woman in question had been dead in more than 7-8 days, because these flies oviposit on cadavers on about the second day after death and development to mature flies takes 5-6 days at the prevailing temperatures - less in warmer climates.
2. The cadaver had been in southern Finland, because the range of *L. sericata* is mainly restricted to this part of the country.
3. The cadaver had been in a city, or alternatively on a small archipelago islet, because in Finland *L. sericata* occurs only in cities and on small archipelago islets.
4. The cadaver had been in sunshine, because *L. sericata* does not usually oviposit on objects with a temperature below 30 degrees Celsius.

Validity of the conclusions.
All the entomological conclusions are valid as tested against the known facts. The situation of the cadaver in sunshine was first suggested by the entomological findings and was later confirmed by the policeman who inspected the case. The conclusion that more than 7-8 days had elapsed since death is as such true but valueless, because death had in fact occured 30 days before the detection of the cadaver. Obviously, the closed windows had delayed the advent of the attractant odour to the sensory organs of the blowflies. If the policeman had looked for the presence of puparia or adult flies in the flat, it might have been possible to draw more correct conclusions. (The development of the flies in the prevailing conditions would have taken about three weeks. Adult flies and puparia were thus probably present in the flat. The finding of newly emerged flies would have reduced the error to one week).

The badly burnt body

Twenty-five kilograms of badly burnt remains of a man was found on 25 August 1965 in an old concrete pill-box on the island of Vasikkasaari in southern Finland. The soft parts were swollen, but without noteworthy signs of decay. Autopsy revealed that death had been due to heart failure, and that this presumably had led to the accidental spread of fire to the petrol cans in the pill-box. The man had last been seen alive on 16 August 1965, and death had obviously occured short time after. The burnt body had thus been in the pill-box for approximately 8-9 days. When it was found, numerous fly larvae were observed in the ears, eyes and mouth. The length of the larvae varied between 6 and 16 mm. The larvae was reared at low room temperature. The first specimen of *Calliphora vicina* hatched on 14 September 1965, i.e. 29 days after the death of the man in question. Additional specimens of this species hatched during the period 27 September to 2 October. In this same period some specimens of *Fannia canicularis* also hatched.

Conclusions based on entomological findings:

1. The death of the man had occured before 24 August because the minimum time for the oviposition plus development of *C. vicina* under the conditions in southern Finland is 21 days.
2. The death of the man had occured before 18 August, because oviposition and development to a full grown larvae takes about 7-8 days (a 16 mm larva is in the third stage).
3. The body had been in shadow, since the heliophilic *Lucilia* had not oviposited on it, although they are in full activity in the middle of August in south Finland.

Validity of conclusions:

The determination of PMI was more accurate than in the previous case history, because of the development time of *C. vicina* was not much shorter than the actual PMI.

The body in the bed

The body of a woman was found in her bed in a flat in the centre of Helsinki, Finland on 1 September 1965. Death had obviously occured on 10 August, since newspapers had not been removed since that day. This was a case of suicide with sedatives. The cadaver was moderately decayed and greenish. The skin surface was loose and the viscera decayed. Blowfly larvae emerged from the orifices of the body. Autopsy was performed after regiration for one day and the fly larvae were collected on this occasion. The larvae were in bad condition at the start of the rearing, except for two small specimens. Rearing at room temperature yielded two small imagines of *Calliphora vicina* on 27 September.

Conclusions based on the entomological findings:

1. The woman in question had been dead in more than 7-8 days, because fly oviposition occurs on about the second day after death, and development to mature migrating larvae takes about 5-6 days.
2. The cadawer had been in shadow, because the scotophilic *C. vicina* had oviposited on it, but *Lucilia* species had not, although they were still active.

Validity of conclusions: Both entomological conclusions were validated by the known facts. The conclusion that more than 7-8 days had elapsed since death is true as such, but of little value, because death had in fact occured 20 days before discovery of the cadaver. A better result would obviously have been obtained if living full grown larvae had been taken for rearing, or if puparia or adult flies had been collected by policemen in the flat of the woman in question.

The floating body in the sea

The dead body of a man floating with a life-belt was found in the open Baltic near the Swedish island of Oland on 4 June 1966. He was from a finnish ship which had gone down in the Baltic on 14 January 1966. The man had thus been dead in approximately four and a half months. The internal organs were badly decayed and the soft parts of the face and chest had decayed away. Elsewhere adipocere formation had occured. The body was taken to Helsinki, and an immediate autopsy was performed on 10 June 1966 when fly larvae 10-12 mm long were detected in the chest. Two larvae preserved in ethanol were determined. They represented the species *Coelopa frigida* of the family Coelopidae.

Conclusions based on entomological findings:
Coelopa frigida is a species confined to wrack on the seashore. Its occurence suggested that the body at some stage had been by the seashore. Because the Baltic is still rather cold in May and early June, the larvae may have been as much as 2-3 weeks old. Oviposition had probably occured in the first half of May. The absence of blowfly larvae supports this assumption. The attractions of blowflies to carrion on Baltic Seashores does not start until the latter part of May. It may be concluded that the dead sailor in his life-belt had floated to the immediate vicinity of a shore during the first half of may.

The partly submerged woman in the sandpit

The dead body of a woman was found in an old sandpit in the city of Helsinki, Finland on 27 June 1964. The sandpit was filled with water and the body was partly submerged and covered by bits of board. Presumably, it had earlier been completely under water. It was largely decayed, but still retaining its original shape. The soft parts of the face had decayed away. Adipocere formation had occurred. At autopsy on 29 June 1964, some fly larvae and puparia were detected in one hand. The larvae were dead and dry by the time they reached the Zoological Museum for examination. In spite of this it was possible to see that three of the larvae belonged to the genus *Muscina* and one to the genus *Fannia*. No flies or fly parasites had emerged from the puparia. No blowfly larvae or water insects were found.

Conclusions based on entomological findings:
The occurence of larvae and unhatched puparia in the body indicate that it had been accessible to flies for at least one week, because in the prevailing cold micro-climatological conditions the development of *Muscina* fly egg to puparium takes about that time or a bit longer. The absence of blowfly larvae, which attack bodies in their initial phase of decay, indicated that the body had not been accessible to blowflies at that stage. Meanwhile, decay had advanced so far that the corpse was no longer attractive to blowflies, but was attractive to *Fannia* and *Muscina*. Hence it was concluded that the body had been completely submerged for a comparatively long time.

Validity of conclusions:
Police investigations showed that the woman in question had been murdered in the middle of July 1963 and had been hidden by the murderer in the sand-pit. Therefore the conclusion based on the absence of blowflies, althoug valid, had only a low degree of accuracy. The conclusion based on the occurence of larvae or puparia of the genera *Fannia* and *Muscina* was indicative of the time during wich parts of the dead body had been accessible to fly oviposition, but was of no significance for the determination of the time of death. Obviously, the hand had first emerged from the water and the flies had then oviposited on it.

The case of the blood-stained shirt

In August 1972 a very complicated crime, including two different murders and one knifing, occurred in the suburbs of the city Helsinki, Finland. During the disentanglement of this series of crimes, a policeman found a blood-stained shirt in a plastic bag in an outdoor refuse bin. About two hours before the police arrived on the scene, a man had transferred the shirt in the bag to the bin from a nearby house where one of the murders had been committed. Numerous fly larvae and some fresh puparia were found on the shirt, which was wet and smelt of decaying blood. The police wanted to know the time of the murder or knifing. They were also uncertain whether the shirt had been stained with blood during one of the houses near the bin or during an earlier murder, which had occurred in another locality.

A search was made for full-grown larvae and puparia in the house, especially in the kitchen, where the plastic bag had been lying since the time of the murder. None was found. It was also notewhorty that there were no fly larvae feeding on the ample amounts of dry blood found in one of the other rooms.

The bloody shirt with the larvae was placed in a rearing can, and the culture kept in a cool room at about 16C. The laboratory environment was very similar to the true case environment. Adult flies emerging was counted every day.

The results of the rearing was as follows:

Date	**# Muscina stabulans**	**# Fannia canicularis**	**# Fannia maculata**	**# Hydrotaea dentipes**	**Misc. notes**
23 Aug					
24 Aug					Bloody shirt detected in garbage can
25 Aug					
26 Aug					
27 Aug					
28 Aug					

29 Aug				
30 Aug				
31 Aug				
1 Sept				
2 Sept				
3 Sept				
4 Sept				
5 Sept				
6 Sept				
7 Sept				
8 Sept	2			
9 Sept	5			
10 Sept	17			
11 Sept	3	1	1	
12 Sept	4	2	3	
13 Sept	4	2	2	4
14 Sept	3	7	0	1
15 Sept	3	2	0	7
16 Sept	3	2	0	3
17 Sept	0	2	0	4
18 Sept	0	1	0	0
19 Sept	0	2	0	0
20 Sept	0	2	0	0
21 Sept	1	1	0	0
22 Sept	3	0	0	0
23 Sept	4	0	0	0
24 Sept	2	0	0	0
25 Sept	0	0	0	0
26 Sept	1	0	0	0
27 Sept	1	0	0	0
28 Sept	0	0	0	0

In all, 104 specimens belonging to four species emerged. Specimens of *Muscina stabulans* occured in two waves, the three other species in one wave only. In the present case, evidence existed that the blood-stained shirt had been exposed to flies in the rubbish bin just before it was found by the policeman. The fly eggs and youngest larvae in the shirt obviously resulted from this exposure, but the shirt also contained older larvae. Therefore, oviposition had also occured in the house where the murder was committed. There was also evidence that the shirt had been wrapped in the plastic bag in such a manner that the flies had no access to it for some time before it was transferred to the rubbish bin. It was thus to be expected that the flies would emerge in two waves when the larvae were reared in the laboratory.

In fact, the results showed two waves of emergence of the species *Muscina stabulans*. The other three species had only one wave of emergence. It was obvious that the later wave of *M. stabulans* specimens dated from the oviposition known to have occured on 24 August. The first specimens of this wave emerged 21 September, and thus the minimum time of development in the prevailing conditions was 28 days. The first specimen of the first wave occured on 8 September. From the above-noted minimal development time of 28 days, it is possible to calculate that the shirt had become stained with blood in which flies had laid eggs on August 11th. This coincided with the date of the knifing, as shown later by police investigation. The right conclusion was reached by making use of the occurrence of the two clearly separate waves of emergence of *M. stabulans*. Such a possibility does not often occur.

The headless body case

In September 1983 the headless body of a young woman was found hidden in gorse and bracken in Devon. Many full-grown larvae and puparia of *Ophyra* were found in clothing from the body, but only a few larvae and puparia of *Calliphora*. The absence of significant numbers of blowfly larvae and lack of evidence of their feeding in the natural orifices or gunshot wounds on the corpse suggested that the body had been kept elsewhere, probably indoors, for several months and only recently placed on the site it was found. The good state of preservation of the internal organs (which misled the pathologist to estimate the time of death as 7-10 days), coupled with the presence of *Ophyra*,suggested that the storage place was warm and dry. The presence of the few *Calliphora* larvae and puparia suggested either that the body had been on site for some 20 days or so and being in a dry state had only attracted a few blowflies, or that the head perhaps been exposed and available to blowflies wherever it was stored, and removed on site when a few larvae had crawled off onto the body. When the head was subsequently found it contained several larvae and puparia of *Calliphora*, but only one *Ophyra*, which suggested exposure and subsequent detachment when the differing maggot populations of head and body were then established.

Subsequent confession by the murderer established that the victim had been shot and kept in a sauna room for five months, then dumped at the edge of the wood where the body was found. The head had been removed on site and then brought back and kept in a plastic bag in the boot of a car.

The badly decomposed body in the salt water tank

In Azerbajdzhan May 5 1962, it was found a partly skeletonized and badly decompozed body in a saltwater tank used for firefighting. Laboratory experiments on live fly larvae found on the body and trousers showed that they could not survive in salt water, thus proving that the body had been in the tank for only a short time. Obviously, the death had occured at another site and the body had been moved. Based upon examination of the larvae it was estimated that the death had occured some seven to ten days earlier. Confession of the killer confirmed that the victim was shot on April 26 (9 days earlier than the discovery of the body) and the body was placed in the tank on May 4. A fly pupa related to those on the body was found on the seat of the car used to transport the corpse.

Cannabis seizures in New Zealand

There was found 60 specimens of insects in two separate seizures of cannabis in New Zealand. Of these, only the rice weevil (*Oryzaephilus surinamensis*) was known to occur in New Zealand, but eight other species were native only to Asia and yielded sufficient information to indicate the precise geographical area as follows.

- Coleoptera
  - *Bruchidius mendosus* (Bruchidae) - distributed throughout South East Asia, but is not known from Indonesia or the southern tip of the Malayan Peninsula.
  - *Tachys sp.* (Carabidae) - an abundant tropical genus normally found along the banks of streams or lakes. The specimen was not an Australian.
  - *Stenus basicornis* (Staphylinidae) - distributed throughout South East Asia, usually found on the banks of streams or lakes.
  - *Azarelius sculpticollis* (Tenebrionidae) - a rare species known only from Sumatra and Borneo. It lives as a 'guest' in the nests of termites.
  - *Gonocnemis minutus* (Tenebrionidae) - described from Laos, is known from Thailand and lives as a 'guest' in the nests of termites.
- Hymenoptera
  - *Parapristina verticellata* - a pollinator of the fig, *Ficus microcarpa*, which is distributed throughout the Indio-Australian Region from India and South China to New Caledonia.
  - *Tropimeris monodon* (Chalcididae) - known from north-west India to Sumbawa in Indonesia.
  - *Pheidologeton diversus* (Formicidae) - this ant is restricted in distribution to South East Asia from India to Indochina, including Singapore and West Indonesia. It is commonest in the Indo-Malayan region, including Thailand.

By plotting the distribution of these species, and studying the degree of overlap, it was possible to suggest that the *Cannabis* originated in the Tenasserim region between the Andaman Sea to the west and Thailand in the east. From the known habits of the insects it was surmised that the *Cannabis* was harvested near a stream or lake with fig trees and termites' nest nearby. Following presentation of this evidence one of the suspects in this case changed his plea from not guilty to guilty.

The skeletal remains of the buried young girl from Hawaii

The remains of a female child (30 months of age) were recovered from a shallow grave on a narrow ledge on the side of Koko Head Crater, Oahu, Hawaii. The skeletonized remains were buried in dirt and gravel, and some bones were partially exposed. Other bones were scattered on the surface. The skull was facing upward, and the mandible located several feet from the skull. Also present in the grave were four small stuffed dolls.

Examination of the remains at the morgue revealed largely skeletonized material. Present were the skull and mandible, most of the ribs, many thoracic vertebral bodies, the mostly sleletonized pelvis and lower extremities, the left humerus, radius, ulna and scapula. Absent were many of the cervical vertebrae, right upper extremity, and scapula. Small bones of the left foot appeared to have been chewed and showed signs of postmortem animal depredation, as did the bones of the left forearm. Apparent scalp hair remaining adjacent to the skull was blond and straight, and measured up to 15 cm in lenght. Clothing accompanying the remains in which the corpse had been buried were a hooded jacket and a pair of running shoes. A second search at the dangerously precarious burial site the day following the recovery of the remains yielded the right scapula and arm as well as additional vertebrae.

Examination of the remains at the morgue yielded a limited assortment of arthropods. Empty puparial cases of the calliphorid *Chrysomya rufifacies* were attached to the skull under the scalp, which had largely been eaten away. Adult dermestid beetles, *Dermestes maculatus*, were present on the bones, and late instar larval skins of that species were observed in areas under the scalp, inside the cranial cavity, and on the femurs. These cast larval skins of *D. maculatus* were in good condition and did not appear to have been exposed to weathering effects for any period of time. Larval scenopinids (Diptera) were collected from the scull near the bases of the hair. Adult clerids, *Necrobia rufipes*, were recovered from the bones of the left foot. A silverfish (Thysanura: Lepismatidae) was recovered from the body bag.

In the hood of the jacket, there was a quantity of soil associated with the remains. This was processed in a Berlese-Tullgren funnel and sorted by hand.

This sample yielded additional larval scenopinids and adult *D. maculatus* There was an adult histerid beetle which represented an undescribed species. Mites associated with this sample included species in the families Acaridae, Histiostomatidae, Macrochelidae, Pachylaelapidae, Uropodidae, and Winterschmidtidae.

Comparison of this assemblage with results of earlier decomposition studies conducted in xerophytic habitats on the island of Oahu resulted in a postmortem interval estimate of 52-76 days. This estimate was lowered to slightly over 52 days, based on the condition of the cast larval skins of *D. maculatus*. In the decomposition studies used for comparison, the last observed larval activity for *D. maculatus* was on day 51. The cast larval skins of *D. maculatus* disintegrate quite rapidly when exposed to weathering. The fact that these skins were in excellent condition and easily identifiable to species level indicated that they had been shed recently.

The window fly larvae (Scenopinidae) were all late instars and of a size comparable to those collected from decomposition studies on day 51 in one study and day 48 in another study. This tended to reinforce the estimate of slightly over 52 days. The mites recovered also were consistent with this time frame, and the absence of certain other mite species was indicative of the shorter portion of the computer estimate. The final postmortem interval estimate of slightly over 52 days for this case fit well with the interval established independently by confession of the suspect in this case, the victim's father. Death proved to have occurred in the morning, 53 days prior to the recovery of the remains.

The stabbed woman in Washington, DC

In November a partially clad woman's body was found by passing motorists in a wooded area approximately 50 feet from a well-travelled highway in suburban Washington, DC. The deceased was a young, adult black female, weighing approximately 116 pounds. Her body was cold, rigor mortis was absent, and only minor external decompositional changes were evident. The victim had died of multiple stab wounds to the chest and neck. During the autopsy, several large maggots were observed migrating away from the corpse. This behavior is characteristic of fully developed, postfeeding blow fly larvae. Several additional maggots were removed from the neck wounds and clothing.

The victim was subsequently identified as a 21 year-old mother who resided with her infant and parents in an urban apartment complex in southeast Washington, DC. She had been reported missing by her parents 18 days prior to the discovery of her body. She was last seen alive during the early morning hours on Wednesday, 26 October in the apartment of the primary suspect, who had a history of sex-related offenses and violent crimes and had recently been realeased from prison.

Witnesses recalled having seen a man and woman struggling and having heard a woman screaming in the vicinity of the apartment house during the early morning hours 18 days prior to her discovery. Hais from the victim's head and pubes was found on bed sheets in the suspect's apartment. A shoe belonging to the deceased was subseqently found in a secluded urban woodlot located a short distance away. Samples of blood and hair taken from the suspect's car also were identified as belonging to the victim. An analysis of auto carpet fibers, removed from the victim's clothing, further demonstrated that she had been transported in the same vehicle.

While considerable circumstantial evidence pointed to the suspect, an accurate estimate of the time of death was critical in establishing the sequence of events surrounding the death. Several conflicting estimates of postmortem interval, varying from 2 to 8 days, were offered by medical examiners and case investigators, based primarily on the physical appearance of the body, and the extent to which autolytic changes had occured within various organs.

The maggots observed in and around the body during the autopsy were identified. Rearing of maggots to the adult stage was not possible as none of the specimens had been maintained alive. Soil samples yielded no additional specimens. Numerous photograps depicting the crime scene, the surrounding vegetation and terrain, and the body itself were examined.

Climatological data, including maximum and minimum temperature, cloud cover, rainfall, wind speed and direction, and relative humidity were obtained from a National Weather Service (NWS) observatory located less than a quarter of a mile from where the victim's body was found. Additionally, reports describing the condition of the body when found and detailing autopsy procedures and results were reviewed.

The largest fly larvae inhabiting the remains were fully engorged third instar larvae and post-feeding larvae of *Calliphora vicina*. One specimen showed morphological signs of pupariation.

Based on temperature records for the relevant period, the numbers of days necessary for *C. vicina* to develop from egg to prepupa was calculated. Because the average daily temperature to wich the developing flies were exposed was cool (10C) and because to few larvae were present within the corpse to elevate microenvironmental temperature, the postmortem interval was estimated to be 15 days.

Based on entomological data and other evidence acquired during police investigation, the suspect was arrested and charged with first degree murder, kidnapping, and felony rape. He was eventually tried, found guilty of all charges, and was sentenced to a lenghty prison term. Later it was learned that he had murdered the victim during the early morning 18 days prior to discovery and had hidden the body, by covering it with tree branches, a mattress, and other debris, in a nearby urban woodlot. Three days later, again during the early morning hours, he had transported the corpse to the location where it was found. The materials used to hide the body may have prevented oviposition by adult *C. vicina* during the first few days following death. The fifteen day postmortem interval was valid.

The Body in the Boot

contributed by Trevor K. Crosby

On 2 January 1993 N.Z. Police discovered a badly decomposed body in the luggage compartment of a completely closed Ford Telstar hatchback vehicle parked in a street in Mt Albert, Auckland. Fly maggots had developed on the body, and maggots and puparia were collected from the luggage compartment on 3 January 1993. These were identified as being the European greenbottle, *Lucilia sericata* (Meigen) (Diptera: Calliphoridae), and the common house fly, *Musca domestica* (Linnaeus) (Diptera: Muscidae). The inferred rate of development of the flies suggested that death had occurred 8 or 9 days earlier. Subsequent tests were carried out in the vehicle on the temperatures in the luggage compartment. As well a pig's head was used to find out the elapsed time before flies oviposited on it in the luggage compartment, and the rate of development of maggots that hatched from the egg masses. These tests showed that death had occurred 9 days before the specimens were collected on 3 January, and had occurred no earlier than 1900 h on 24 December 1992 and no later that 1200 h on 25 December 1992. At the trial the insect evidence was validated as it was established from other evidence that death had occurred in the early hours of 25 December 1992.

The burnt body in the car

The following story is taken from "Bones: a forensic detective's casebook", by Dr. Douglas Ubelaker and Henry Scammell.

The victim failed to show up for work one morning, and he was reported missing by his employer. 18 days later, two dirt bikers driving through a rural area just a few miles away came across a burned-out car, and inside, slumped across the back seat, they saw the charred body. The police arrived, and a call went out for the forensic team on Knoxwille, Tennessee. Bill Bass and his crew surveyed the crime scene, removed the corpse from the car, and when they returned to the laboratory they performed an autopsy on the blackened cadaver.

Live maggots were observed througout the surface of the body. But when they removed the top of the skull, cooked maggots were found inside the brain. This was a significant discovery. It meant that the victim had been dead long enough for flies to leave larvae, for maggots to grow and eat away much of the decaying outer tissue and enter the braincase. By comparing the length and weight of the maggots inside the brain with his own charts of maggot development, Bill Bass concluded that the maggots had died between 14 and 16 days after the victim himself was killed. The maggots outside the body was determined to be approximately 2 days old. Bill Bass and his colleagues also found knife marks in the vertebrae.

Based on this evidence, very much of what had happened could be reconstructed. The man had been murdered with one or more knife stab and left in the back seat. Some two weeks later the people who did it came back and set fire to the car, maybe in the hope of getting rid of the corpse, or creating the impression he had died in an automobile accident. The fire went out, and the body cooled enough for the flies to come back and lay more eggs on the burnt material.

The chigger bites that convicted a man for murder

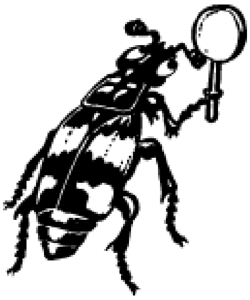
In 1982, deputies of the Ventura County Sheriff office noticed that a murder suspect had chigger bites similar to the ones investigators at the crime scene had on their wastelines, ankles and behind the knees. The entomologist Jim Webb was contacted, and by analyzing the bites, Webb connected the suspect to the crime scene where the naked body of a 24-year-old woman was found on August 5, 1982. She had been strangled with her own blouse.

They did several test at different places, but the only place they found chiggers in was a narrow strip near a eucalyptus tree under which the woman had been found. This meant that the suspect had to be at the crime scene at some point, which did not correlate with his testimony. The suspect claimed to have seen the woman the last time at a bar.

The suspect was convicted for first-degree murder and sentenced to life without parole.

The cockleburs on a skimask, that convicted a rapist

One midnight in midsummer in a suburb of Chigago a woman parked her car and walked toward her apartment building. Suddenly a man wearing a ski mask leaped from the shrubbery, attacked her, and then disappeared. The police began to suspect one man in the building, and with a warrant they searched his apartment and found a ski mask, which he claimed he had not used since the previous winter. The victim identified the man in a voice lineup, but this was not enough for a conviction. There were two cockleburs sticked to the ski mask and the detectives sent them to forensic entomologist Bernhard Greenberg for examination. Within the cockleburs were live weevil larvae. Examination of the cockleburs found on the crime scene proved to be of the same species as the weevil found on the ski mask. The species was identified as *Rhodobaenus 13-punctatus* Illiger, and is also known as the billbug. This species has a 1-year life cycle, and the larvae pupate in the cocklebur and emerge in the latter part of the summer, and then hibernate. Larva do not overwinter, and they would not survive the winter within a dessicated cocklebur in a heated apartment. The suspect was then caught in a lie. The court trusted this evidence, and the rapist was convicted.



Forensic Entomology References, or what I used to make these pages

Here is the references to the sources I have used to make these pages. I also give a comment about each reference.

You can also visit the Forensic Entomology Bibliography page that I am constructing for more references to literature about the subject.

Catts, E. P. & Goff, M. L. 1992. Forensic entomology in criminal investigations. Annual review of Entomology 37:253-272.

This article is good, and is more recent than Smiths book, and reviews some of the progress made in forensic entomology since about 1985. Especially interesting is the part that deals with detection of drugs in maggots.

Catts, E. P. & Haskell, N. H. 1990. Entomology & Death. A procedural guide. Joyce's Print Shop, Inc., Clemson, South Carolina.

This book is excellent! Very nice hand-drawn illustrations made by E. P. Catts, some of them are actually funny, and 26 case histories. Collection procedures, and laboratory procedures, as well as guidelines to behaviour in court as an expert witness.

Keh, B. 1985. Scope and application of Forensic Entomology. Annual review of entomology 30:137-154

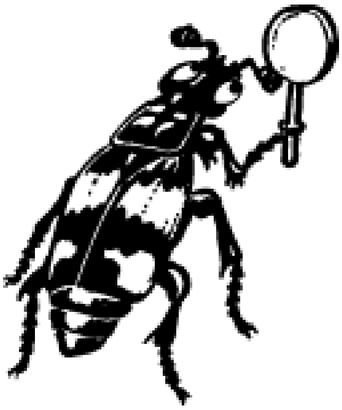
A very interesting review of forensic entomology, with some case histories.

Knight, Bernard. 1991. Simpson's Forensic Medicine. 10th edition, Edward Arnold, London. 324 pages.

Not a forensic entomology book, but an introduction to forensic medicine. The use of entomology is briefly mentioned, but no references are given. Lacks a reference list, but has a small section called "Recommended reading".

Smith, Kenneth G. V., 1986. A manual of Forensic Entomology. The Trustees of the British Museum (Natural History). 205 pages. ISBN 0-565-00990-7

This is a very good book, and one of the two books dealing with forensic entomology as I know of. It begins with describing the faunal succession on dead bodies, and treats exposed, buried, mummified, and burnt bodies. There is also a discussion of how the environmental conditions as temperature and humidity, light and shade influences the fauna on the body. 18 case histories are cited, and a large part of the book is devoted to the different taxa occuring on dead bodies. A good reference list and a glossary is also included. The book is out of print, but sometimes it is possible to get a used copy.



Blowflies

Here are some images of adult blowflies.