



# FORENSIC ENTOMOLOGY

Use of insects to help solve crime

## Teacher background information

Forensic entomology combines the study of insects and other arthropods with the science of criminal investigations. When a crime is committed insects can accumulate on and around the victim's body. When forensic entomology is involved, the insects become part of the evidence. Forensic entomologists can estimate time of death, whether the body has been moved and whether drugs or toxins were involved in the crime.

In most cases forensic entomology is used to aid murder investigations. However, it is also used in cases of patient or child neglect where wounds and bedsores have become infested with insects. Forensic entomology also has applications in cases where insects have damaged food (stored product entomology) and buildings (structural entomology).

### Estimating time of death

The major use of forensic entomology is estimating the time of death or the post mortem interval (PMI) of a corpse. The post mortem interval is the amount of time that has elapsed since the person died. Two main factors need to be considered when estimating a PMI; firstly the time it has taken each species of fly to reach the body and secondly the rate of development for each species.

A forensic entomologist collects and analyses the age, number and species of insects that are living on a body. Since insects arrive at the body soon after death and in a particular order, if forensic entomologists can calculate the age of the insects, then they can also estimate the PMI. In order to calculate the PMI accurately, the investigator must firstly identify the species of insect correctly.

### Identifying the species

The most crucial element in forensic entomology is species identification. Species that appear the same to the naked eye may have vastly different growth rates, behaviours and habitat preferences.

Most species cannot be identified easily just by viewing a photograph of them. They are usually identified by using a classification key. The following URL has a usual classification key that students should be able to follow:

[http://www.einsteins-emporium.com/life/animal-info/insects/insect\\_identification.htm](http://www.einsteins-emporium.com/life/animal-info/insects/insect_identification.htm)

*Accessed January 2007*



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A classification key has been also been included in FSE11.

Flies (Order Diptera) and Beetles (Order Coleoptera) are very important in forensic entomology.

## The major fly families include:

- Family Calliphoridae: Blow Flies
- Family Sarcophagidae: Flesh Flies
- Family Muscidae: Muscid Flies
- Family Piophilidae: Skipper Flies
- Family Scathophagidae: Dung Flies
- Family Sepsidae: Black Scavenger Flies
- Family Sphaeroceridae: Small Dung Flies and Minute Dung Flies
- Family Stratiomyidae: Soldier Flies
- Family Phoridae: Humpbacked Flies or Scuttle Flies
- Family Psychodidae: Moth Flies, Sand Flies and Owl Midges

## The major beetle families include:

- Family Silphidae: Carrion Beetles
- Family Dermestidae: Skin Beetles, Leather Beetles, Hide Beetles, Carpet Beetles and Larder Beetles
- Family Staphylinidae: Rove Beetles
- Family Histeridae: Clown Beetles
- Family Cleridae: Checkered Beetles
- Family Trogidae: Hide Beetles
- Family Scarabaeidae: Scarab Beetles
- Family Nitidulidae: Sap Beetles



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### Faunal Succession – what is it?

Insects arrive on a corpse in a predictable sequence depending on the stages of decomposition. This is called insect succession or faunal succession.

Forensic entomologists study this process to aid legal investigations. Primarily, forensic entomologists are employed by crime investigators to determine the time of death of a person. Time of death is estimated as the post mortem interval (PMI).

Insect succession of cadavers is fairly predictable and results from controlled experiments can be used to estimate PMI of a corpse in a crime investigation.

Environmental factors that affect succession include: season (daily temperatures), sun exposure, whether the body was found inside a building, immersed in water or in urban vs. rural area. Bodies that are buried, left in vehicles, found in enclosed spaces, hanged or burnt are also subject to varying insect succession patterns.

### Effects of geography on succession

The most important determinant of insect succession is the geographical region where the body is found. The geographical zone affects the vegetation, soil type, climate and food source which in turn affects the species of insects in the area. Blow flies and flesh flies are still likely to colonise first but the species will be different. For example: the Western Goldenhaired Blow fly is only found in Western Australia. Although this fly would be likely to colonise a corpse in the outskirts of Perth, it would not be present on a corpse in Sydney. Instead, another species of blow fly would arrive at the body.

Geography also influences the time of insect arrival. In parts of North America, dermestid beetles are considered to be late colonisers, usually arriving at a body months after death to feed on bone and skin tissue. In Hawaii, however, dermestid beetles are collected as early as three to ten days after death.

It is important that insect succession data collected in one geographical area is not used for determining time of death in another geographical area. Separate databases should be used when considering corpses in varying geographical locations.

### Effects of urban and rural scenes

Some insects are found in urban and rural areas while others only occur in one of these regions. This information can be used to determine if a body has been moved. For example, *Lucilia sericata* is generally found in urban areas.

Rural flies tend to survive on animal corpses, for example: kangaroos, while urban flies survive on discarded human food. Complications occur when urban flies are attracted to country towns where there is human habitation and hence lots of human waste.

### Effects of season and sun exposure

Seasons have a large impact on the weather and the fauna in an area and as such faunal succession is affected greatly by season. Studies in Australia have shown that season and sun exposure has a large effect on pig carcass decomposition. Many blow flies have different sized populations depending on whether it is summer or winter. Other insects are also affected and have specific activity peaks. In order to estimate correct post mortem intervals, scientists should perform controlled experiments throughout the year. This will avoid generating data for only one season.

In one case, a body was discovered ten years after the victim's disappearance and there was no insect evidence on the body. This indicated to investigators that the person had died in winter. In winter, a high level of moisture will often destroy insect evidence.

When a body is placed in sunlight, it will heat up faster and decompose faster which will affect the rate of development of colonising insects

Certain species of blow flies prefer shaded conditions while other species are found more commonly in open areas. This distribution affects the faunal succession of a corpse. There have been many studies into the effects of shade vs. sun on pig carcasses and large differences have been found in the faunal succession. Season and sun exposure are both important factors to consider when determining a PMI.



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### Effects of bodies found inside buildings, vehicles and enclosed spaces

Insects will colonise remains both inside and outside of doors. Faunal succession will be affected by species that are able and willing to enter a building, vehicle or enclosed space and how well the area is sealed. A study in Hawaii found a greater variety of fly larvae on inside remains than in outside remains. Some species have only been found inside and some only found outside. Such studies can help crime investigators determine if a body has been moved from inside a building to outside a building and vice versa. Once again, forensic entomologists must take care with assuming one species that occurs indoors in one geographical area also occurs only indoors in another geographical area.

There are many variables that affect faunal succession and a forensic entomologist must consider all factors to provide an accurate estimate of PMI.

### Sequence of insect arrival

Different stages of the decomposition process are attractive to different species of insects. The corpse changes rapidly and supports a large amount of insect life as it is a large food source. If the forensic entomologist can determine the sequence of colonising insects, the insects can be analysed to estimate the time of death.

Blow flies (Calliphoridae) and flesh flies (Sarcophagidae) are usually the first two types of insects to arrive at a corpse. Blow flies are attracted first to the corpse from a great distance by odour, generally within several hours but sometimes within minutes after death. Blow flies are no longer attracted when the remains have decomposed, are mummified or dry.

Flesh flies arrive on human remains at the same time or just after the blow flies. In some circumstances, the flesh flies may arrive first. They have been known to fly under weather conditions that would prevent most other types of flies from reaching the carrion.

Among flies, there are three waves of colonisation of a body. The primary wave includes the arrival of blow flies, the secondary wave includes the arrival of the flesh flies and in Western Australia the tertiary wave includes the Black Carrion Fly (*Hydrotaea rostrata*), among others.

Once the species of fly has been collected and identified, the forensic entomologist will develop a lifecycle model of the fly. Models can be developed from previous crime investigations or controlled laboratory experiments. Lifecycles of flies are variable between species and depending on environmental conditions.



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**Table 1:** Typical faunal succession pattern

Succession wave	Principle insect fauna	State of corpse	Age of corpse
1	Flies (blow flies)	Fresh	First 3 months
2	Flies (blow flies and flesh flies)	Odour	
3	Dermeestid beetles	Fats are rancid	3-6 months
4	Various flies		
5	Various flies and beetles	Ammonia fermentation	4-8 months
6	Mites		6-12 months
7	Dermeestid beetles	Completely dry	1-3 years
8	Beetles		3+ years

Taken from Smith, K. G. V. 1986, A manual of forensic entomology. Cornell Univ. Press, Ithaca, NY.

### Lifecycle of flies: An example: Black Carrion Fly

There are four main stages in the lifecycle of a Black Carrion Fly, which is considered by Western Australian researchers to be the most important fly in determining a PMI. A study was undertaken to determine the developmental rates of the Black Carrion Fly under different temperatures.

The following lifecycle of the Black Carrion Fly is based on development at a constant temperature of 25 degrees Celsius.

**Table 2:** The lifecycle of the Black Carrion Fly, expressed in hours required at 25°C, to develop from an egg mass to an adult.

From	To	Cumulative Time (h)	
Egg mass	Larvae (maggots)	26	A fly will typically lay its eggs at openings of the body, including the nose, eyes and anus.
1 <sup>st</sup> instar	2 <sup>nd</sup> instar	(69.5) 95.5	At the first instar, the larvae are an average of 2.37mm growing to 5.47mm by the 2 <sup>nd</sup> instar.
2 <sup>nd</sup> instar	3 <sup>rd</sup> instar	(32.5) 128	By the third instar, the larvae are 14.8mm long
3 <sup>rd</sup> instar	Pupae	(244) 372	
Pupa	Adult	(146.7) 518.7	The development from egg to adult took a total of 21.6 days.



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1. The Black Carrion Fly takes an average time of 26hrs to hatch after oviposition.
2. Upon completion of the egg stage, the organism enters the first of three instars of the larval stage. It takes a certain number of hours (69.5 hours) at a temperature of 25°C to develop from the first instar to the second and further time (32.5 hours) to develop from the second instar to the third. Larvae are also called maggots.
3. *Pupal stage:* It took a further 244 hours for the Black Carrion Fly at the third larval instar to develop to the pupal stage. The pupae becomes darker as it is developing. The pupal stage is also known as the 'cocoon stage' in some species of fly.
4. *Adult fly:* Once the blow fly has developed and reached adulthood, the fly can lay its own eggs. This leads to a second generation of fly larvae (maggots). The development from egg to adult took 21.6 days (518.4 hours) under the constant temperature of 25°C.

### Lifecycle: Rate of development

The rate of insect development is reliant on many variable factors. When determining the age of an insect, forensic entomologists must consider the current weather and seasonality, the presence of a maggot mass, the food type, drugs and toxins, geographic region, preservation method and potential insect colonisation before death. Temperature is the most important factor affecting the rate of insect development.

### The effects of temperature on rate of development

Insects require a certain amount of heat to develop from one point in their lifecycle to another point. For a fly to develop, the temperature must remain between a minimum value, called the lower developmental threshold and a maximum value, called the upper developmental threshold for a certain amount of time. On either side of this temperature range, the insect will not develop or the rate of development will decrease.

The total amount of heat required for an organism to develop from one point in its lifecycle to another point is measured in units called degree-days. See the section on Accumulated Heat below.

The ambient temperature (weather and season) and the temperature inside the carcass both have a bearing on the rate of insect development. If a maggot mass is present, a large amount of metabolic heat will be generated and this will increase the amount of heat that the insects are subject to.

### The effects of food type on rate of development

Maggots can develop on a range of different foods. If a scientist is investigating a food contamination case, it might not be appropriate to use data on insect development obtained from a cadaver study. It is important to determine what the maggot has been eating.

### The effects of drugs and toxins on rate of development

Chemicals have a variety of effects on the rate of insect development. The growth can be accelerated or stunted depending on what chemicals are present. Drugs and toxins are likely to be present in a corpse that was killed by a drug overdose or drug-induced suicide. Scientists can deduce what drug a victim has died from by analysing maggots feeding on the corpse.

### Accumulated heat

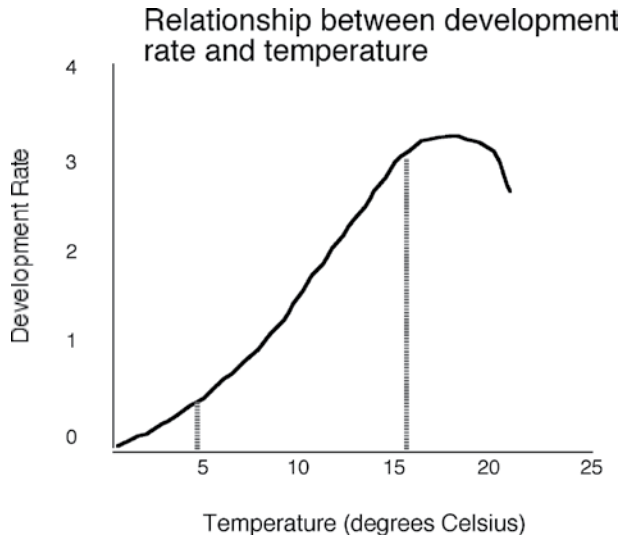
The rate of development for many plants and invertebrate animals (including insects or cold-blooded - poikilothermic - animals) is dependent on temperature. Insects require a certain amount of heat to develop from one stage in their lifecycle to another. This is due to the heat requirements of enzyme-controlled biochemical reactions. The amount of heat that is accumulated controls the rate of development. Accumulated heat can be measured as physiological time, in units called degree-days - °D (or degree-hours).

For an insect to develop, the temperature must remain between a minimum value, called the lower developmental threshold and a maximum value, called the upper developmental threshold for a certain amount of time. On either side of this temperature range, the insect will not develop or the rate of development will decrease.



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**Figure 1:** The relationship between development rate and temperature.

One degree-day is the amount of development that occurs in one day (24 hours) when the temperature is one degree above the lower development threshold. Degree-days accumulate over time. Each day the temperature is above the lower developmental threshold, more degree-days are accumulated. ADD – accumulated degree days.

*For example, if the temperature is 5°C above the lower development threshold for 2 days the number of degree days is 10: 5°C x 2 days. One degree above the lower development threshold for 10 days equals 10 Degree Days (or 240 degree hours).*

Each insect species requires a certain total number of degree-days to complete its development. The amount of heat required does not change and so ADD provides a common reference between species.

Degree days are calculated from actual temperature data.

**Table 3:** The number of accumulated degree days (ADD) required for the development of some forensically important insects in Western Australia.

Species	Minimum Temp °C	ADD
<i>Chrysomya rufifacies</i> – Hairy maggot blowfly	10	158 ± 16
<i>Calliphora vicina</i> – European bluebottle fly	6	302 ± 29

Donovan, S.E., Hal, M.J.R., Turner, B.D. & Moncrieff, C.B. 2006, Laval growth rates of the blowfly *Calliphora vicina*, over a range of temperatures. *Medical and Veterinary Entomology*, 20: 106-114.

For example, if the minimum threshold temperature for a weevil is 9°C on a day when the average temperature is 10°C, one degree day has accumulated. If the next day has a temperature of 11°C, a further two degree days accumulate. The daily accumulations are added together over time and used to predict insect development. When a certain number of degree days have accumulated the adult insect will emerge.

Constant temperatures are uncommon in the natural environment where most insects live and grow. Insect development is affected differently by cyclic and constant temperature conditions, even when the mean of the cyclic temperatures is equal to the constant temperature.

Changes in environmental temperature cause changes in development rate from day to day and even from hour to hour. A forensic entomologist must consider both the internal and ambient temperatures when calculating the age of the fly larvae. Both temperatures influence the amount of degree-days and the rate of larval development.

To calculate ADD - the number of degree days:

1. Calculate the mean (average) temperature for that day.
2. Compare the mean to the organism’s lower developmental threshold.
3. If the mean is three degrees higher than the lower developmental threshold, then there have been three degree-days.

NB: A Celsius degree-day is not the same as a Fahrenheit degree-day. It takes nine Fahrenheit degree-days to make five Celsius degree-days.



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**Table 4:** Developmental data for *Phaenicia sericata* (Greenbottle blowfly) over three constant temperatures.

	15.8 °C		20.7 °C		23.3 °C	
	Time to reach stage (hours)		Time to reach stage (hours)		Time to reach stage (hours)	
Stage	Min	Max	Min	Max	Min	Max
1 <sup>st</sup> instar	40.6	44.4	20.9	23.6	21	22
2 <sup>nd</sup> instar	94.3	103.3	52.3	52.3	45	45
3 <sup>rd</sup> instar	135.7	158.7	78.3	95.3	77	77
Prepupal	233.7	246.7	127.9	145.3	145	159.5
Pupal	382.3	392.3	245.7	356.9	264	270
Adult	775	917	486.2	647.8	468.5	624.5

Data has been adapted from: Anderson, G.S. 2000 Minimum and maximum development rates of some forensically important Calliphoridae (Diptera), *Journal of Forensic Science*, Vol. 45(4), pp. 824-832. Some of the data has been simplified.

At 15.8 °C, the larvae take a longer time (more hours) to develop to an adult fly than at 20.7 and 23.3 °C. This is because the larvae need exposure to a certain amount of heat to develop from one stage in their lifecycle to another

## Key words

- Degree-day °D:** a unit of measure for recording how hot or cold it has been over a 24-hour period. Each species requires a defined number of degree-days to complete its development.
- Entomologist:** a scientist who studies insects
- Forensic entomology:** the application of insect biology as reliable evidence in criminal or civil cases.
- Instar:** Stages of an insect or arthropod between moults.
- Larvae:** a developmental stage of the fly lifecycle. Commonly referred to as maggots. Larvae do not have legs and do not have well-developed heads.
- Moult:** shedding the outer covering of the body – the exoskeleton.
- Physiological time:** measure of how much heat is required to complete a particular organisms development.