بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Agricultural Studies

Department on Plant Protection

Forensic Entymology A Review

الحشرات الجنائية

A thesis Submitted in Partial Fulfillment of the Requirements for the B. Sc. Degree in Plant Protection.

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الآية

بسم الله الرحمن الرحيم

قال تعالي:

(إِنَّ اللَّهَ لَا يَسْتَحْيِي أَنْ يَضْرِبَ مَثَلًا مَا بَعُوضَةً فَمَا فَوْقَهَا فَأَمَّا الَّذِينَ آَمَنُوا فَيَعْلَمُونَ أَنَّهُ الْحَقُّ مِنْ رَبِّهِمْ وَأَمَّا الَّذِينَ كَفَرُوا فَيَقُولُونَ مَاذَا أَرَادَ اللَّهُ بِهَذَا مَثَلًا يُضِلُّ بِهِ كَثِيرًا وَيَهْدِي بِهِ كَثِيرًا وَمَا يُضِلُّ بِهِ إِلَّا الْفَاسِقِينَ)

صدق الله العظيم

سورة البقرة الآية (26)

Dedication

To all my family

To all my teachers

To all my colleagues and friends

With love and respect.

Acknowledgement

First of all, I render my gratitude and praise to the Almighty Allah. I wish also to express my sincere gratitude to our supervisor **Prof: Awad KHalafala Taha** for his helpful guidance, encouragement and supervision of this research.

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Table of Contents

List of Figures

Fig. No. **Title** **Page No.**

Abstract

Insects are the most important , in terms of number and diversity , group of animal on earth . insects have colonized all the world s environment and are associated with both human life and death . Although their economical and saintary importance is well documented , in the bast few years they have been used also in forensic context . in forensic entomology , necrophagous insects have proved useful in ; studing postmortem interval (PMI) postmortem transfer (the movenent of body from one location to another after death) presence of drugs or poisons , and in identifying the victim or the suspect . Many species can be used to estimate the minimum , PMI (mPMI). according to the stage of cadver decomposition , body exposure , geographical region , and season the most important british flies of forensic interest are described.

ملخص البحث

الحشرات هي أهم مجموعة من الحيوانات على الأرض من حيث العدد والتنوع. لقد استعمرت الحشرات كل بيئة العالم وترتبط بحياة الإنسان وموته. على الرغم من أن أهميتها الاقتصادية والقديسية موثقة جيدًا ، فقد تم استخدامها في السنوات القليلة الماضية أيضًا في سياق الطب الشرعي. في علم الحشرات الشرعي ، أثبتت الحشرات الميتة أنها مفيدة في ؛ دراسة نقل الجثة بعد الوفاة) (PMI) نقل الجثة من مكان إلى آخر بعد الوفاة) وجود أدوية أو سموم ، وفي التعرف على الضحية أو المشتبه به. يمكن استخدام العديد من الأنواع لتقدير الحد الأدنى ، .(PMI (mPMI وفقًا لمرحلة تحلل القاذف، وتعرض الجسم، والمنطقة الجغرافية، والموسم ، يتم وصف الذباب البريطاني الأكثر أهمية في الطب الشرعي.

CHAPTER ONE

INTRODUCTION

Forensic entomology is the scientific study of the invasion of the successison pattern of arthropods with their developmental stages of different species found on the decomposed cadavers during legal investigations it is the application and study of insect and other of arthropod biology to criminal matters . it also involves the application of the study of arthropods including insects , arachnids, centipedes, millipedes, and crustceans to the criminal or legal cases. it is primarily associated with death investigations , however ,it may also be used to detect drugs and poisons determine the location of an incident , and find the presence and time of the inflication of wounds. forensic entomology can be divided into three subfields : urban , stored product and medico_legal \ medico- criminal entomology. According to Byrd, –Forensic Entomology is the use of the insects, and their arthropod relatives that inhabit decomposing remains to aid legal investigations. The broad field of forensic entomology is commonly broken down into three general areas: medicolegal, urban, and stored product pests (Byrd, 2010)

Medicolegal: Typically the need is to determine the postmortem interval (PMI) or the time since death occurred. This involves the collection of necrophagous feed- ing insects at the scene followed by ascertaining the stage of the insects' life cycles.

- *Urban*: This aspect of entomology has two aspects: civil and legal. The former reflects the damage that insects cause to property and crops. From a legal perspec- tive, the insects leave bite marks that must be interpreted correctly.
- *Stored products*: This relates to insects found in foodstuffs.

The premise of this discussion is that insects play an important role in determining the PMI in death investigations. The reason is that in death

investigations, the time since some- one died can provide important information to the successful completion of the investiga- tion, and is a factor medical examiners, scene scientists/investigators, prosecutors and defense attorneys commonly take into consideration. Scene scientists/investigators should be aware of the two processes taking place after someone dies: the decomposition process and associated sequential appearance of entomological signs at the scene. Students and novice scene scientists/investigators need to understand this as well.

CHAPTER TOW

LITERATURE REVIEW

2.1 Forensic entomology

Forensic entomology is the interpretation of entomological evidence to help resolve a criminal investigation. Recently, the level of awareness of forensic entomology within the

entomological community, especially in the United States, has increased. The insects that have been most extensively studied in relation to their forensic uses are the blowflies--members of the Calliphoridae fly family--in particular their larvae or maggots, because: They are the insects most commonly associated with corpses. They colonise the body most rapidly after death and in greater numbers than most other insect groups. They usually provide the most accurate information regarding the post-mortem interval--the time that has elapsed since death, a major objective in forensic entomology.

The Natural History Museum

Maggots of the bluebottle blowfly *Calliphora*.

Blowfly larvae featured in the first successful use of entomological evidence in the UK, when they were discovered on decaying human remains dumped in a small ravine in Dumfriesshire, Scotland, in September 1935. The remains were later identified as those of the wife and maid of Dr Buck Ruxton of Lancaster. The maggots were aged by Dr A.G. Mearns and provided a vital clue as to when the murders took place. Dr Ruxton was subsequently found

guilty of the murders and hanged.

The Natural History Museum
Adult bluebottle blowfly, *Calliphora vicina*.

While the ageing of maggots on corpses represents the most common application of forensic entomology, insects can also be used to assist in many other types of forensic investigation. In another case, an accurate knowledge of the distributions of insects found on cannabis plants imported into New Zealand was used to determine the geographical origin of the plants.

Adult blowflies have a finely tuned sense of smell and are attracted in large numbers by the odours of decay, often within a few hours of death. The odours that attract them are mainly created by the action of bacteria on dead tissues. They sometimes swarm to wounds or open sores and ulcers on living vertebrates including humans--the action of larvae feeding on living people causes a disease condition known as myiasis.

The Natural History Museum
Maggots feeding on a live sheep--an example of myiasis.

Entomologists use precise methods to collect and present the evidence correctly--a vital precursor to accurate interpretation. They determine facts about the location of the body and its accessibility to flies at the scene of the crime. The largest and therefore oldest maggots are the most important specimens but the complete range of maggots present will be sampled because they may shed light on different aspects of the investigation. If the entomologist cannot be present at the scene of the crime, the maggots will be

collected by crime officers or pathologists who need to provide accurate information on their location on the body, times of collection and ambient temperatures. The maggots are killed by being immersed for 10-15 seconds in water heated to just below boiling point. They are then transferred to a solution of 80% ethanol. These techniques prevent the discolouration and shrinkage that occurs if living maggots are placed directly into common preservative solutions such as ethanol and formaldehyde. Shrinkage would make the maggots appear younger than they actually are.

Taxonomic identification of the insects found on corpses is essential to the reconstruction of events surrounding criminal cases involving death. Systems of classification of biological organisms are used to facilitate their identification. In the case of maggots, their location on the body can provide important information because on an uninjured body, blowfly eggs are usually laid at the openings of body orifices and it is in those areas that the emerging maggots start to feed. However eggs can also be laid at sites of injury, hence maggots found at sites other than the body orifices might indicate that some traumatic wounding took place before death.

Scientists then determine the age of the specimens to provide evidence as to when the female flies first found the dead body and laid their eggs--the minimum estimate of the post-mortem interval. This can be taken as the latest time by which death must have occurred. The estimation of maggot age relies on detailed knowledge of the fly lifecycle and the factors that influence it.

Blowflies have four life stages--egg, larva (maggot), pupa and adult. The larval stage is divided into three instars and between each instar the larva sheds its cuticle (skin) to allow for growth in the next instar. The pupa is a transition stage between larva and adult. It is found inside a barrel-shaped puparium, which is actually the hardened and darkened skin of the final instar larva. The immature stages of blowflies are poorly documented in comparison to the adults.

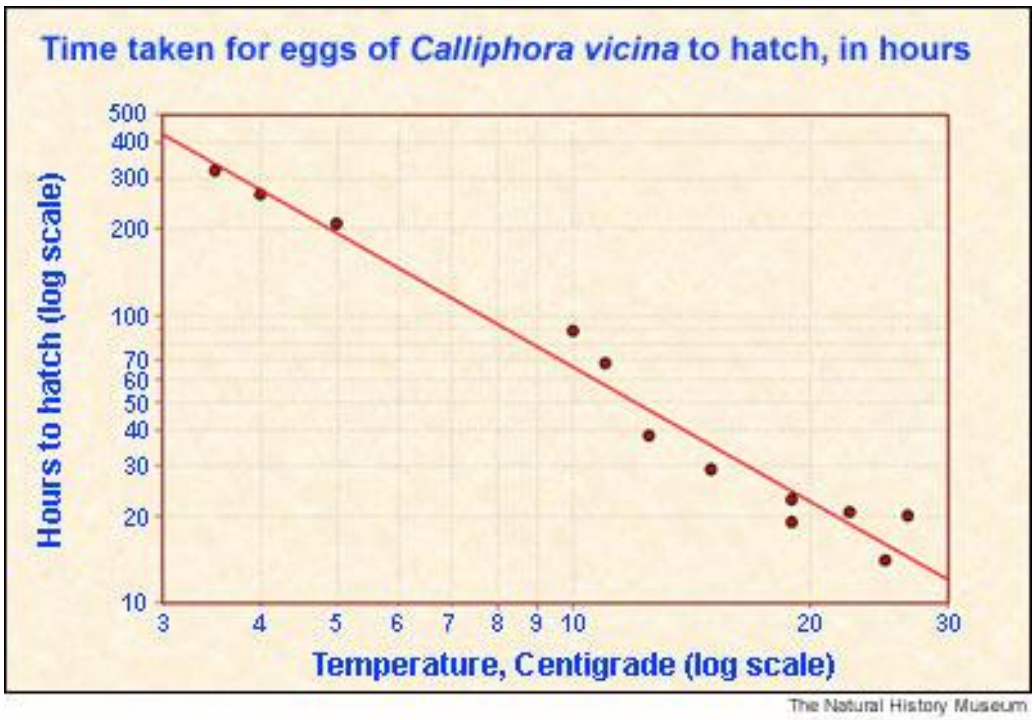
The Natural History Museum

Life cycle of a typical blowfly.

The major external factor is temperature, a parameter with which the metabolic activity of maggots, which are 'cold-blooded', is strongly correlated. They develop slower at lower temperatures and more rapidly at higher temperatures. If the hourly temperatures can be estimated at the site of discovery of the body for the period over which the maggots were developing, then the overall thermal input can be determined and the time of egg-laying can be estimated taking account of the varying daily temperatures. However, calculations are complicated by the fact that metabolic activity can cause temperatures within the maggot mass to rise by 5-20°C compared to the ambient and ground temperatures.

The Natural History Museum

A maggot mass feeding on a dead sheep.



The effect of ambient temperature on the duration of egg development for the common bluebottle blowfly, Calliphora vicina, illustrating the acceleration of development at raised temperatures.

Size is generally a function of age in that, up to the post-feeding stage, the larger the maggot the older it is. However, size can also be affected by the amount of food available and by the numbers of competing maggots i.e. decreasing the food resources and increasing the numbers of maggots can result in a reduction of the average size of maggots.

Toxic substances in or on a dead body can be accumulated by feeding larvae and can affect their rate of development. For example, cocaine and heroin significantly increase the rate of development of larvae, thereby affecting the accuracy of post-mortem interval estimates if not taken into account. In contrast, insects may take much longer to colonise and decompose a body if it is wearing clothes permeated with lubricants, paints or combustibles.

Various stages of insect succession are recognised in the decomposition of corpses and a different spectrum of invertebrate fauna is associated with each. However strict adherence to the succession timetable can be misleading as

there is considerable variability with respect to season, geographical location, body size and other variables.

The geographical location of the site of discovery of a body can have a major effect on the diversity of insects found on it. They can vary over just a few metres if for example comparing the fauna of a corpse placed in a hedgerow to one placed in nearby woodland or open pasture.

Burial effectively isolates the corpse from many of the usual insects, in particular from blowfly species which have a profound effect on the rate of decomposition. Even a soil layer of just 2.5cm can significantly delay decomposition, because only exceptionally do blowflies lay their eggs on the soil surface rather than on the corpse itself. Insect colonisation of a buried corpse will also be affected by the soil type, its permeability to odours of decay and the ease with which insects can move through it. Although insect evidence may be of little use in determining the post mortem interval in many burial cases, it may be of value in explaining what happened to the body before burial, for example, for how long it was exposed above ground.

There are circumstances where a lack of entomological specimens on a body should be noted. For example, the lack of blowfly larvae on a week-old corpse found outside during the summer months would indicate that the body had been shielded from insect activity for several days and therefore that it had possibly been dumped at that site only recently.

Each forensic case is unique due to the high number of variables involved and this can make it extremely difficult to assess often scanty data with great accuracy.

Although much is already known about the life cycle of the blowfly, there is considerable scope for future morphological, biochemical and molecular research to improve identification and refine estimates of the post mortem interval. Areas for investigation include details of the influence of corpse

location and covering on fly access, the influence of diurnal cycles of light and dark and of temperatures on fly and maggot activity, and ways in which the metabolic activity of a mass of maggots raises temperatures and affects their development. Scanning electron microscopy is increasingly being used for routine identification purposes and will be of considerable value in the future, especially for eggs and immature larvae.

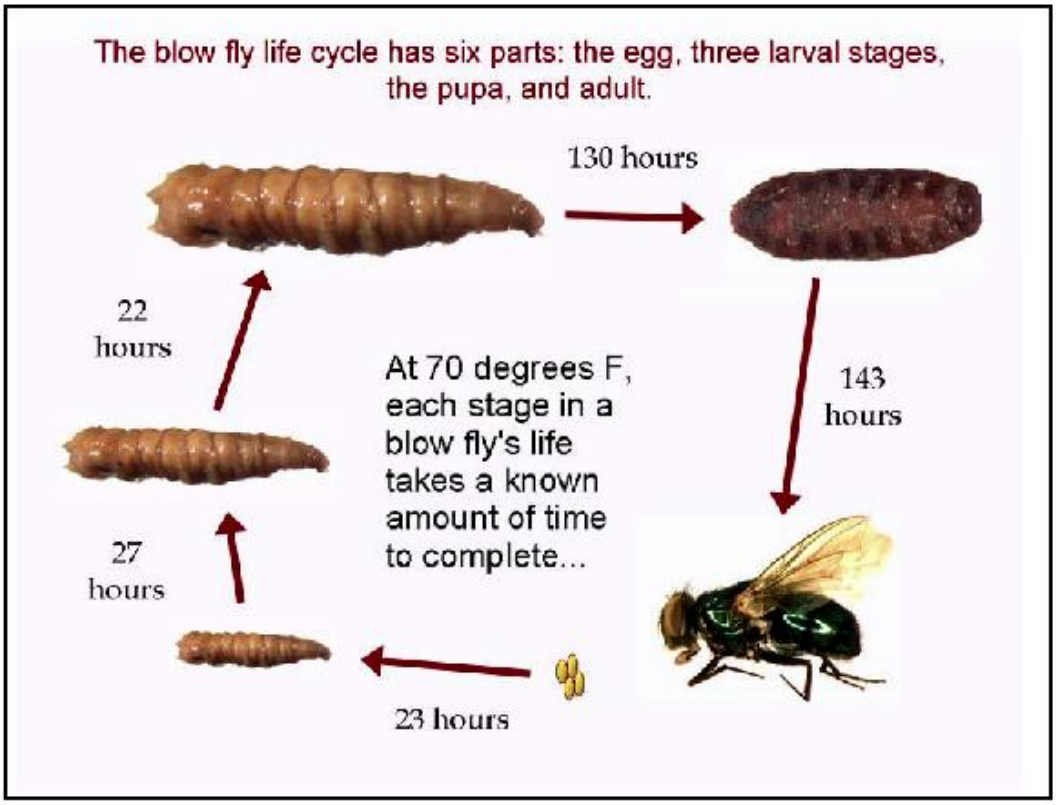
Future research will enhance forensic entomology as a genuine, quantitative scientific discipline, and improve the quality and accuracy of the case reconstructions that it makes.

2.2 Calliphoridae (blow flies)

- Shiny color (bluebottle, greenbottle)
- Among the first to arrive at a corpse

2.3 Forensic Entymology:

Flies and *maggots* also provide an approximate time of death, very useful for cases where the body has been long dead. Only certain insects will feed and lay eggs on a dead corpse and forensic entomologists study these insects, their *larvae* cycles and thereafter can determine whether a body has been dead for just one day or up to 3 or 4 weeks.



Why insects? Why do insects play such an important role in estimating the PMI? The reason is that their life cycles predictably move from the egg to an adult in a process known as metamorphosis. This well-studied process can be correlated fairly accurately when environmental conditions are known, which means that medical examiners and/or foren- sic entomologists use this metamorphosis timeline to ascertain how long someone had been dead. Entomological PMI estimates are particularly helpful when the body has com- pleted the usual post-death medical signals (rigor mortis, liver mortis, etc.) commonly used by medical examiners to determine the PMI. The list in Figure

(1) shows the type of evidence that might be expected at scenes requiring entomological analysis. Much of this evidence would be also found in routine homicide or burglary scenes.

It is also important to realize that entomological PMI estimates are just that, *estima-tions*. What is really measured is the time it takes from insect colonization to the formation of the adult insect. Figure 16.2 illustrates the process. (Anderson, 2005)

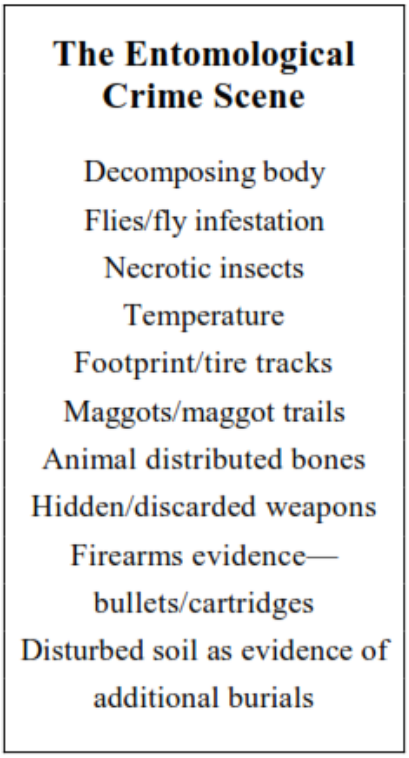


Figure 1: Entomology-related evidence.

After someone dies, such as in a murder case, insects colonize the body soon after death. As shown in the slide in Figure (2), this is time frame from when the person is murdered to the time it takes for colonization to begin. Although this length of time should be included in PMI calculations, it is not because it is unknown. The only information available to forensic entomologists is the time from colonization, based on the physical

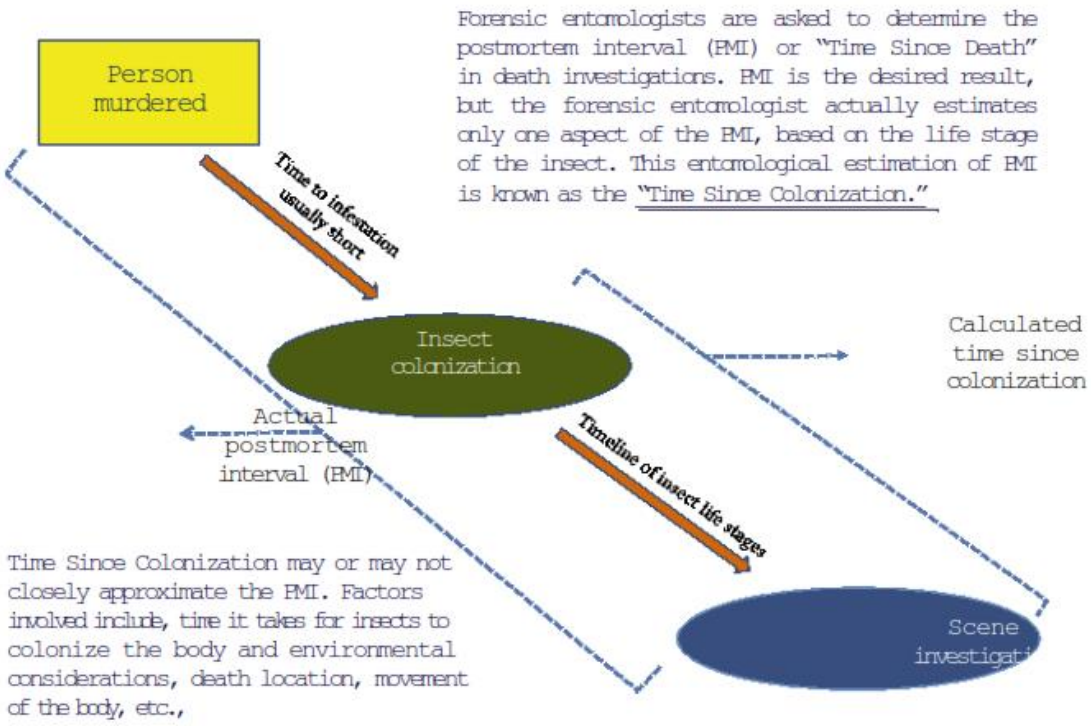


Figure 2: Postmortem interval: time since colonization.

presence of eggs, to the presence of the adult insect. Thus, calculations for PMI utilize the timeline of the insects' life stages to determine the time it took from colonization to the beginning of the scene investigation. These estimates are based on the entomological infor- mation gathered at the scene. The slide in Figure (3) shows this schematically.

Forensic entomologists require specific types of information to make PMI calculations (see Figure (3). Sometimes, the only people on the scene capable of providing some of this information are the first ones present, which could be the first responder to the scene or even someone not associated with the police but instead a passerby. Obtaining this information is important, though. Usually, the appropriate information should be obtained by a trained forensic entomologist or someone from the medical examiner's office who is trained to collect the data.

Still, scene scientists/investigators need to learn to recognize the stages of decomposi- tion and the insects associated with each. By understanding metamorphosis and the insects of interest, they will have the intellectual tools to know where to look for insects associated with decomposition and they will

be in a better position to protect the appropriate evi- dence at the scene.

So, to what extent should the scene scientist/investigator know or understand forensic entomology? The answer is simple. Scene investigators are probably neither forensic ento- mologists nor medical examiners, and they should never make the calculations involved in PMI estimations from the entomological data because there are variables that can affect the PMI calculations. Also, it should not be assumed they will ever know how to identify specific insects, except in the very broad sense. However, they can understand the funda- mental approach forensic entomologists take to investigating a scene and thus can protect entomological evidence from damaging effects stemming from the investigation. And, with specific training, they can learn to obtain relevant data for subsequent use. Thus, their role can be a crucial spoke in the wheel of the PMI estimation process.

From the slide in Figure (3), it is apparent that most of the data necessary for PMI estimations are collected at the scene: obtaining the appropriate temperatures, capturing adult insect species, larvae, and pupae. If forensic entomological expertise is not available, the scene scientist/investigator should immediately recognize the need to obtain these important items of evidence. This begins with an understanding of the death–decomposition sequence and the insects associated with each stage. (Anderson, 2005)

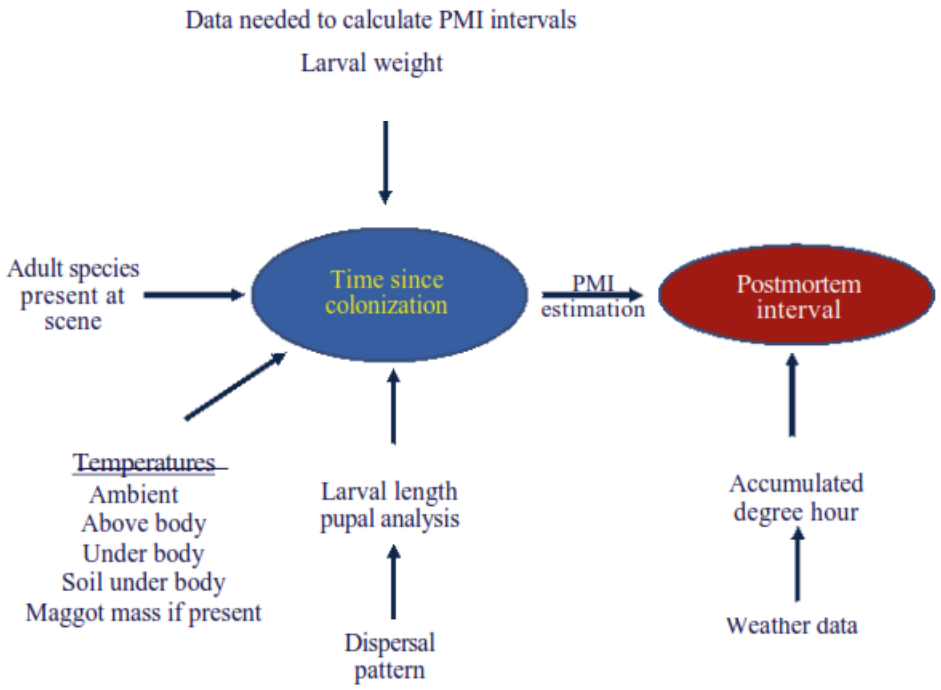


Figure 3: Data needed to calculate postmortem intervals

2.4 History

historically, there have been several acconts of applications for , and exeperimentation with forensic entomology. the concept of forensic entomology dates back to at least the 13th century . how ever , only in the last 30 years has forenisic entomology been systematically explored as afeasible source for evidence in criminal investigation . through their own experiments and interest in arthopods and death , sung Tzu, francesecov Redi, bergeret d Arbois , jean pierre megnin and the physiologist hermann Reinhard have helped to lay the foundations for today`s modern forensic entomology .

2.5 Hermann R einhard

the first systematic study in forensic entomology was conducted in 1881 by Hermann Reinhard , a german medical doctor who played a vital role in the history of forensic entomology . H exhumed many bodies and demonstrated that the development of many different types of insect species could be tied to buried bodies . Reinhard conducted his first study in east germany ,and

collected many Phorid flies from his initial study . He also concluded that the development of only some of the insects living with corpses underground were associated with them , since there were 15 year- old beetles who had little direct contact with them . Reinhard`s works and studies were used extensively in further forensic entomology studies .

2.5 Forensic entomology subfield

2.5.1 Urban forensic entomology

typically conceens pests infestation in buldings gardens or that may be the basis of litigation between private parties and service providers such as landlords or exterminators urban forensic entomology studies may also indicate the appropriateness of certain pesticide tretments and may also be used in storerd products cases where it can be help to determine chain of custody , when all points of possible infestation are examined in order to determine who is at fault .

2.5.2 Blow fly

scientific classification

kindom : Animalia

Phylum : Arthropoda

Class: insecta

Order : Diptera

Superfamily: oestroidea

Family : calliphoridae

supfamilies :

* Auchmeromyiinae

*Calliphorinae

*lucilinae

*Melanomyinae

S/N: *Calliphora vicina*

The name blow fly comes from an older english term that had eggs laid on it which was said to be fly blown .

Blow flies are usually the first insects to come in contact with carrion because they have the ability to smell dead animal matter from up to 2 kilometres (1mile) away upon reaching the carrion ,females deposit eggs on it .blow fly , any of large family of flies known for the habit of the larvae , or immature flies of , infesting animal carcasses . they are found worldwide ouccurring nearly every place in habited by people blow flies are slightly larger than true house flies , and the bodies of many are metallic blue or green in color. Worldwide there are about 1200 species of blow flies , and in north america there are 80 . the femaile blow fly typically lays her eggs on the body of a recently killed animal . the eggs hatch guickly and the maggots then feed on the decaying tissues . in warm weather , some species can complete their larval growth within a week . they then burrow into the soil and pupate , to emerge later as adult flies . blow fly maggots are important in forensic analyses in cases of homicide and other human death . because the maggots grow at constant rates , their size and stage of development can provide clues to the time and conditions of death.

2.5.2.1 Arthropodes and their association with postmortem changes of the human body:

as soon as death occurs , cells start dying and enzymes starts digesting the cells inside out in process called autolysis . The body starts decomposing . Bacteria present in The gastrointestinal track start destroying the soft tissue

producing liquids and gases like hydrogen sulphide ,carbon dioxide , methane , ammonia , sulfur dioxide and hydrogen .

according to smith (1986) four categories of insects can be found on decomposing carrion , necrophagous species feeding on carrion , predators and parasites feeding on the nicrophagous species this group also contains schizophagous species which feed on the body first and which become predaceous on the later stages , omnivoeous species feeding on the carrion and other arthropods like ants, wasps and some beetles , other species like springtails and spiders which use the corpse as an extension of their environment. the frist tow groups are found to be more important for purpose of forensic entomology . they are mainly from the species of the order Diptera (flies) and coleoptera (beetles) .

Insect mostly involved in the forensic investigations are true flies or diptera . The predominant species in this order are calliphoridae (blow flies) , sarcophagidae (flesh flies) and muscidae (house flies) . calliphoridae and sarcophgidae may arrive withn minutes following death , house flies delay colonization until the body reaches bloat stages of decomposition . calliphroidae adults are commonly shiny with metallic coloring , often with blue , green or black thoraxes and abdomen . sarcophagidae are medium sized flies with black and gray longitudinal stripes on the thorax and checkering on the abdomen . the adult muscidae are 8-12 mm long . their thorax is gray , with foure longitudinal dark lines on the back the whole body is covered with hair like projections . usual areas for egg laying are the natural body opening and wounds . when they hatch , they produce a larva called maggot . they are small peg - shaped organisms with a pair of mouth hooks on the anterior end for feeding , maggot grow rapidly passing through the three stages or instare reaching the full size and the feeding stop with the full size and they migrate to drier areas and they begin pupariation (pupa formation) .

According to the studies done by K.tullies and M.L Goff on exposed carrion in tropical rainforest , it was found that the decomposition process was best divided into five stages on the basis of physical apperance of carcasses , internal tempreatures and characteristic insect population :

1- fresh stage (day1-2) which begins at the moment of death and ends when the bloating of the carcass is observed . even though autolysis occurs at this stage gross morphological changes do not accur at this point . the estimation of the time of death by entomological data after 24 houres is more accurate than medical examinaers estimation based on the soft tissue examination . insects were seen attracted within the frist 10 min of death to thr carcass but no egg laying was found during this stage . cellular breakdown occurs during this stage without morphologic alteration .

2- Bloated stage (days2-7) :

putrefaction begins at this stage gases produced by metabolic activities of anaerobic bacteria cause an inflation of the abdomen a balloon like apperance during the later part . Arthropods ctivities combined with the putrefaction processes cause internal temperatures of the caecass to rise . the greatest number of adult diptera were attracted to the carcasses during this stage . by the fourth day , frist and early second -instar or larval stages Diptera were present . by the beginning of day 12 , several predators of Diptera larvae were also recoverd from the carcassesv .

3- Decay stage (days 5-13)

Abdominal wall is penterated , resulting in the deflation of the carcass and ending the bloated stage , the intarnal temperature rises tp 14 degrees .

4- post decay stage (days 10-23)

It begins when most of the diptera larvae leave the carcass , leaving behind bones , cartilage , hair ,small portion of tissue and alarge amount of wet ,

viscous material known as byproducts of decay (BOD) the BOD is the major site of arthropod activity during this stage .

5- remains stage (days18-90+)

this stage is characterized by bones with little cartilage remaining and the BOD has dried up the transition from post decay to remains stage is gradual with declining adult and larval Diptera populations .

2.5.2.2 Blow flies life cycle :

The life cycle of blow fly occurs in six parts :

1- frisr, the eggs are laid , especialy at wound areas or around openings , such as eyes, ears , and nose

2- next, the eggs hatch into frist stage larvae (maggots) within 24 hours .

3-the larvae feed and molt into second -stage maggots.

4- after more feeding , they molt into third stage maggots.

5- Finaly, they become pupae on the ground .

6-Last , adult blow flies emerge to begin the peocess again.

The life cycle of the blow fly begins when the female lays eggs . approximately 250 to 300 eggs can be deposited by one female , usually done over winter . the life cycle takes tow to three weeks to complete . the female blow fly has to consume some protein before she can mate, whereas the male blow fly is sexually mature when it is born . The eggs are usually laid in openings of cadaver or wounds . the larvae then feed on the decaying material . it then takes 24-48- hours for the eggs to hatch . (Gomes, 2006)

2.5.2.3 Estimation of the time death :

After a murder occurred , the estimation of the time elapsed since death until the discovery of the cadaver is the main task of Medico-legal forensic entomology . How long a dead body has been exposed to the environment is defined as post mortem interval (PMI) . PMI estimation is crucial in every legal investigation because it is the starting point to go back in time to reconstruct the criminal events and to define the circumstances of death. (Voss, 2008)

2.5.2.4 Species identification:

in forensic entomology , the correct identification of the species is extremely important to estimate the mPMI because insects development is specie-specific and depends on temperature . to methods are used to reach this aim. (Voss, 2008)

2.6 What Happens After Death:

Understanding the stages of decomposition a body undergoes after death is an important first step in determining the PMI and the role insects play in that process. Importantly, insects are an integral part of decomposition. From an understanding of the stages of decomposition, the scene scientist/investigator can learn to associate the number and types of insects present in each stage. Thus, by associating which insects are present with each physical state of the body, the entomological evidence has a better chance of being pre- served. Table (1) shows the sequence of infestation—the faunal succession—of various insects and the stages of decomposition associated with each. (Voss, 2008)

2.7 Casess Blue Fly case

In the year 1235 a murder occurred on a farm and the perpetrator was not known, so the owner of the farm collected the peasants and their scythes and

placed sickles on the ground, and after a short time the blue shrew gathered in one of the machetes as a result of it smelling the smell of blood and that was the sickle used in the crime, so he knew who the killer was.

Table (1) Faunal Succession Associated with Decomposition

Succession	Principal Insect	State of Decomposition	Time of Decomposition
1	Flies: blow flies	Fresh	First 3 months
2	Flies: blow flies and flesh flies	Odor	—
3	Dermestid beetles	Rancid fats	3–6 months
4	Various flies	—	—
5	Various flies and beetles	Ammonia/fermentation	4–8 months
6	Mites	—	1–12 months
7	Dermestid beetles	Completely dry	1–3 years
8	Beetles	—	3+ years

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