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Medico-Legal Forensic Entomology "Use of Insects in Death Investigations"- A Review

Mohamed A. Kenawy[1*] and Yousrya M. Abdel-Hamid[2]
1- Department of Entomology, Faculty of Science, Ain Shams University, Abbassia, Cairo 11566, Egypt
2- Research Institute of Medical Entomology, The General Organization for Institutes and Teaching Hospitals, Ministry of Health, Dokki, Giza, Egypt.
E-mail: **mohamedkenawy@sci.asu.edu.eg**

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ABSTRACT

The present paper reviews the different aspects of forensic entomology (definition, history, carrion's decomposition stages, and their associated insects/arthropods, utility in solving crimes, methods of collecting entomological evidence at death site and situation in Egypt). These are important information for interesting people and officials who are willing to make use of such aspect as a helping tool to solve crimes.

INTRODUCTION

Forensic entomology (FE) is a growing field of study, incorporating an entomologist's expertise in insects including their identification, life cycles, and habitats, with an arm of law enforcement (Varatharajan, 2000; Guppy, 2001 and Byrd and Castner, 2010). Today, FE is defined as "The legal application of the science of entomology" or "The use of the insects and their arthropod relatives that inhabit decomposing remains to aid legal investigations" (Byrd, 1997), *i.e*. help solve crimes. It is one of the many tools of forensic science that divided into Medico-legal (criminal) -, Urban - and Stored Products entomology (Tuccia *et al.*, 2018). The medico-legal section focuses on the violent crime and deals with the necrophagous (or carrion) feeding insects that typically infest human remains (Anderson, 1997; Dadour *et al*., 2001 and Guppy, 2001)

The medico-legal entomology relates mainly to death investigations and includes arthropod involvement in: (1) Events such as murder, suicide and rape and (2) Other violations such as physical abuse and contraband trafficking. It also deals with the study of the insects associated with a human corpse to: (1) Determine the elapsed time since death or how long human remains have been undetected which is generally referred to as the "Postmortem interval, PMI". This is the primary purpose of FE today; (2) Find out whether the corpse has been moved to a second site after death or that the body has been disturbed at some time (either by animals, or by the killer returning to the scene of the crime); (3) Examine the manner and cause of death (the circumstances of a crime); (4) Examine association of suspects with the death scene and (5) Detection of toxins or drugs through analyses of insect larvae.

Most cases that require a forensic entomologist are 72 h. or more old, as up to this time, other forensic methods are equally or more accurate than the insect evidence. However, after three days, insect evidence is often the most accurate and sometimes the only method of determining the PMI (Anderson and Van Laerhoven, 1996; Anderson, 1998 and Amendt *et al.,* 2004).

Although FE has just recently received attention, it has its beginnings throughout history at various times. It was first reported to have been used in 13th Century (McKnight, 1981; Goff, 2000; Benecke, 2001 & 2008; Guppy. 2001 and Amendt *et al.,* 2004). In 1235 A.D., Sung Tz'u, a Chinese death investigator, wrote a book entitled "The Washing Away of Wrongs" in which forensic science as known at that time was detailed. The first actual medico-criminal entomology case was talked about in this book. Sung talked about how a murder happened in a Chinese village and how the local death investigator solved the crime (Degaro, 2003).

The first observations on insects and other arthropods as forensic indicators were documented in Germany and France during mass exhumations in the late 1880s. After the French publication of Mégnin's popular book on the applied aspects of FE, the concept quickly spread to Canada and the United States and after the World Wars, few FE cases entered the scientific literature (Benecke, 2001). Moreover, FE was used sporadically in the 19th Century and the early part of the 20th century and played a part in some major cases in Germany, France, United States, Russia, and Canada (Anderson, 1998 and Benecke, 2001). During the past few years, FE had gained widespread acceptance (Byrd and Castner, 2010) and nowadays, it has become more and more common in police investigations in USA (Anderson, 1998). Several human cases were reported by some authors (Mann *et al*., 1990; Benecke, 1998; Intone *et al.,* 1998; Campobasso *et al.*, 2004; Martınez-Sanchez *et al.,* 2011; Vanin *et al.,* 2011; Dekeirsschieter *et al*., 2013 and Bonacci *et al.,* 2014*;* Bugelli *et al.,* 2018 and Giordani *et al.*, 2018). Some of these cases were used as legal evidences in solving crimes.

The present article summaries the information on FE, its importance as a legal tool in solving crimes with an object to make such information available to officials and hoping that this aspect of entomology to find its way for application as a part of police investigations in Egypt

MATERIALS AND METHODS

Study Materials: This article is based primarily on a series of lectures presented by the first author as a course for undergraduate students at the Department of Entomology, Faculty of Science, Ain Shams University, Cairo which was lectured for more than 10 years. Moreover, a systematic review of the available published articles on the different aspects of FE and its legal uses was performed on PubMed, Research Gate and internet-based ones. In addition, several related web pages were accessed. Also, the research studies carried out in Egypt were added and discussed.

RESULTS AND DISCUSSION

Stages of Human Decomposition and Associated Arthropods:

After death, a lot of internal organisms, *e.g. Escherichia coli* and others in the intestine will start multiplying, and organs start decomposing at different times after death and may be used in estimating time of death. While a wide variety of insect species are attracted to decomposing remains and play an active role in the decay process (Campobasso *et al*., 2001), two groups, the flies (Diptera) and beetles (Coleoptera), are of major importance in most circumstances. Diptera, whose larvae are capable of living in a semi-liquid medium, are the first insects that attract to and colonize decomposing remains. Fly larvae are responsible for the dramatic consumption of the corpse's tissues. Later, when the corpse has to a large extent dried out, do species of other insect groups, notably beetles, move in and continue the process.

The decomposition of a body can be divided into 5 stages, with varying durations and the attracted insect species (Table 1)

Table 1: The decomposition stages of the human body and their associated insects/arthropods.

Stage	Associated arthropods
Fresh (Initial decay, Autolysis): Days 1-2	
It begins at the moment of death, ends when odour is first evident and body becomes fresh externally but is decomposing internally due to the activities of bacteria, protozoa and nematodes present in the body before death.	**Blowflies** (Greenbottle flies *Lucilia cuprina* and *L. sericata*) are the first to arrive and lay eggs, **hairy maggot blowflies** (e.g. *Chrysomya rufifacies*) are usually the second to arrive, **flesh flies** (*e.g.* the red-tailed flesh fly, *Sarcophaga haemorrhoidalis*) arrive later than blowflies, **ants** feeding on fly eggs and **wasps** predatory on adult flies.
Bloated (Putrefaction): Days 2-6	
Beginning of decomposition process, body is swollen by gases produced internally by the metabolic activities of the anaerobic bacteria and odour of decaying flesh.	**Blowfly eggs** have hatched, maggots are in orifices and **histerid beetles** and **Silphidae** (Carrion beetles, burying beetles, *e.g.* the sexton beetle *Nicrophorus orbicollis* and the American-carrion /burying beetle *Necrophila americana*) are typically found under the body or in the soil immediately surrounding the remains during the early stages of decomposition. Adults and larvae feed on maggots as well as carrion.
Active Decay (Butyric fermentation, Black Putrefaction): Days 5-11	
Flesh becomes creamy with exposed parts black, body collapses as gases escape, odour of decay is very strong and most of the flesh is removed by the maggots.	**Blowfly maggots** start to leave body and pupate, **beetles** feed on drier tissue and **predatory beetles** such as rove beetles (staphylinds) and histerids come to feed on other insects.
Advanced decay (Butyric- / Ammoniacal fermentation): Days 10-25	
Body drying out, some flesh remains at first, cheesy odour and ventral surface is mouldy from fermentation.	**Maggots** pupate in the soil and **carrion beetles** and **skin beetles**: dermestid beetles, museum beetle (*Anthrenus museorum*) and larder beetle (*Dermestes lardarius*) become the dominant necrophage (carrion-feeder).
Dry Decay (Skeletonization): Days 25+	
Body almost dry, mainly bones and hair remain, slow rate of decay and odor is primarily that of normal soil and litter	Some **dermestid** and **histerid** beetles, fly pupae, immature and adult **rove beetles** and normal **soil fauna** (mites) begins to inhabit the body.

Factors Affecting Body Decomposition:

Several factors that influence the decomposition process were reported and discussed by some authors (Coe, 1978; Mann *et al*., 1990; Goff, 2000; Guppy, 2001 and Sonker *et al.*, 2018), these are: (1) The state of the body is one factor that determines its invasion by insect fauna. If the body has no open wounds, the orifices such as the mouth, ears, and genitals are the first areas to be invaded. However, insects are more attracted to wounds that are present before death and large wounds lead to a faster decomposition; (2) Insects in combination with bacteria are the driving factor structuring the decomposition process in the absence of vertebrate scavengers; (3) The environment where the body is located also influences the invading species for *e.g.* (a) Exposures to the sun or shading, (b) Submerged or on land and (c) Temperature and humidity: lower temperature slows down development of microbes and insects while low humidity dries the corpse; (4) Body fat in corpse, as

more fat leads to faster decomposition; (5) Tightly wrapped or frozen bodies decompose slower, *e.g.* if no invasion of insects are apparent, it may be indicative that the body was frozen, tightly wrapped in some sort of plastic, or quickly buried relatively deep in the ground; (6) Heavy clothing slows decomposition more than thinner clothing and (7) Other factors include the time of the day, time of the year and geographic location such as the tropics, city or agricultural area.

Uses of Forensic Entomology:

1. **Estimating Time Since Death (Postmortem Interval; PMI):** Forensic entomologists are commonly called upon to determine the PMI in homicide investigations (Byrd, 2007). Such interval is frequently of paramount interest in medico-legal investigations and is the most source for a clue to get leads on the timeline of crime (Shukla, 2018). The use of insects in the estimation of a corpse PMI (Aggarwal, 2005) is extremely useful in cases where the decomposition of the body has exceeded the time (48-72 hr) when factors such as body cooling, muscular rigidity, other physiological changes, and chemical analyses can be used. There are two main ways of using insects to determine the elapsed time since death: (1) **Using succession waves** of insects (Goff, 1993 and Anderson, 2000) when death occurred between a month up to a year or more, or in some cases several years after death and (2) **Using maggot age and development** (Goff, 1993 and Nabity *et al*., 2006) when death occurred less than a month prior to discovery.

   a. **Using Succession Waves of Insects:** An important biological phenomenon that occurs on a dead body is a succession of organisms that thrive on the different parts. In FE, this succession implies initial colonization of a "bare" area on a corpse until complete skeletonization (Brewer, 2001). As indicated earlier, various insects are attracted to the different stages of decay (Brewer, 2001). Decay process, faunal composition, and succession are affected by some factors such as temperature, wind, and rainfall. Hence, when local climatological data are available, the sequence of colonizing fauna can be used to detect the PMI (Horenstein *et al*., 2012 and Shukla, 2018). Therefore, with knowledge of the regional insect fauna and times of carrion colonization, the insect fauna associated with the remains can be analyzed to determine the range of time in which death took place (Table 2).

Table 2: Insect faunal succession (based mainly on data of Smith,1986).

Wave	Principal insect fauna	Corpse	
		State	**Age**
1	Blowflies and houseflies	Fresh	1st 3 m.
2	Blowflies and flesh flies	Putrefaction	
3	Dermestid (skin) beetles	Active decay	
4	Various flies		3-6 m.
5	Various flies and beetles: carrion beetles, Siphidae and Histeridae	Advanced decay	4-8 m.
6	Mites		6-12 m.
7	Dermestid beetles	Completely dry	1-3 y.
8	Beetles: Tenebrionidae and Ptinidae		3+ y.

   b. **Using Maggot Age and Development:** The theory behind estimating PMI with the help of an insect's age is very simple: "Since insects arrive on the body soon after death, thus estimating the age of the insects will also lead to an estimation of the time of death". Insects are 'cold-blooded' or ectotherms, so their development is extremely temperature-

dependent. Their metabolic rate is increased with increasing temperature, which results in a faster rate of development so that the duration of development decreases in a linear manner with increased temperature, and *vice-versa* (Anderson, 1998). As mentioned before, blowflies are usually the first insects to colonize a corpse (often very soon after death) so that they are popular PMI tools in cases of death. The steps in estimating PMI based on the size of maggots (or other stages) found on a body are: (1) Collection of maggot specimens in an optimal condition, (2) Species identification, (3) Provide information on the particular species and (4) Estimation of the age mainly for the oldest stage based on: (a) Measurement of their size (length or weight) and (b) Estimation of the temperatures to which they were exposed during their growth. Therefore, if good temperature information can be determined for the period of development of blowfly stages on the body, a good estimate of the age of those stages can be made. Of course, aging maggots or other stages will not determine the actual time of death; instead it will estimate the time that blowflies laid eggs on the body which will indicate the minimum PMI (PMI_{min}) for example (Anderson, 1998), if the oldest insects are 7 days old, then the body has been dead for at least 7 days. This method, however, can be used until the first adults begin to emerge, after which it is not possible to determine which generation is present. Therefore, after a single blowfly generation has been completed, the time of death is determined using the insect succession method.

2. **Locating the Place of Death:**
   a. **Moving of the Body:** Qualified forensic entomologists can be of help in establishing whether the body has been moved after death (from the scene of killing to a hiding place) or if it has died at the scene and also give an indication of the type of the area where the murder actually took place (Anderson, 1998). They can tell this by the location and what insects are on the body, for examples: (1) Insects which live in a restricted area but are found on a corpse in a different area can prove that the body was moved after death and (2) Some flies prefer specific habitats such as laying their eggs in an outdoor or indoor environment and can also exhibit preferences for carcasses in shade or sunlit conditions of the outdoor environment. An example of this: a fly prefers indoors and a body is found outside with this fly and its eggs so it can be inferred that the person must have been killed inside and then later taken outdoors (Degaro, 2003).
   b. **The Body May Have Been Disturbed after Death:** By the killer returning to the scene of the crime. This may disturb the insect's cycle, and the entomologist may be able to determine not only the date of death but also the date of the return of the killer (Anderson, 1998)
   c. **Body Freezing or Wrapping**: Freezing or wrapping of the body may be indicated by an altered species succession of insects on the body (Byrd 2007). The complete absence of insects would suggest that after death, the body was probably either frozen or sealed in a tightly closed container, or buried very deeply.
3. **Finding the Cause and Circumstances of Death:** In a criminal investigation, it is not only of interest to find out when a victim died, but also to find out how the victim died (possible causes of death):
   a. **Poisoning or Drug Intake:** The insects recovered from decomposing human remains can be a valuable tool for toxicological analysis (Bourel *et al.*, 2001 and Gagliano-Candela and Aventaggiato, 2001). Poisons and drugs usually accumulate and traced in

several body organs and tissues. However, after a while it will be impossible to sample such tissues from the dead body and often not enough flesh left to determine drug presence. Instead, it is possible to trace them in maggots occurring on a corpse. When maggots feed on a body, they ingest any present chemicals. Thus they can be used as a reliable substrate for toxicological analysis and can sometimes provide a more suitable biosample (Nolte *et al.*, 1992). Such potential use of insects as alternative samples for detecting drugs and toxins has been well documented (Amendt *et al*., 2011). Most of the substances involved in drug-related deaths are detectable through analyses of maggots such as morphine, heroin and cocaine (Gagliano-Candela and Aventaggiato, 2001; Introna *et al*., 2001 and Verma and Paul, 2013). Maggots can be tested for such drugs, showing the possibility of drug overdose. Bourel *et al.* (2001) demonstrated morphine accumulation inside the cuticle of *Calliphora vicina* maggots. Some drugs can influence the growth rates and development of some necrophagous insects, for *e.g*., (1) Cocaine, heroin and methamphetamine accelerate the rate of fly development (Goff *et al.*, 1989; 1991& 1992 and Verma and Paul, 2013), (2) Fouda *et al.* (2017) detected Ephedrine in the homogenate of *Chrysomya albiceps* larvae that were fed on ephedrine sulphate – dead dog carcass and observed prolonged pupal and total durations of the fly colonized the Ephedrine-treated carcass as compared to control, (3) Abd El-Gawad *et al.* (2018) observed faster development of *Lucilia sericata, Chrysomya albiceps* and *C. megacephala* larvae collected off rabbits intoxicated with Warfarin (rodenticide) than those collected off control untoxicated ones ($P < 0.01$) and (4) The presence of Malathion in rabbit tissues can retard the normal growth rate of *Chrysomya megacephala* larvae (Liu *et al*., 2009). Experimentally, larvae of the flesh fly, *Boettcherisca peregrina,* developed more rapidly on tissues contaminated with cocaine and heroin than on uncontaminated tissues (Goff *et al.,* 1989 & 1991). A significantly accelerated growth rate was also observed for *Lucilia sericata* larvae fed on tissues contaminated with morphine (Bourel *et al.,* 1999) and for *Calliphora vicina* larvae fed on tissues contaminated with Paracetamol (O'Brien and Turner, 2004). Certain chemicals can repel blowflies and their maggots for *e.g*., a common method of suicide is swallowing Malathion insecticide, which is usually taken orally and this may lead to lack of blowfly infestation around the mouth. If the insects stay away from this area, suicide by this method is one of death possibilities. Malathion can also delay the initial oviposition of insects for several days (Gunatilake and Goff, 1989 and Verma and Paul, 2013).

b. The Sites of Blowfly Infestation: On the corpse may be of importance in determining the cause of death, or at least in reconstruction of events prior to death, for *e.g*.: (1) **Trauma or mutilation** of the body prior to death may lead to heavy infestation of other body parts than the usual sites (natural orifices). If the maggot activity is centered away from the natural orifices, then it is likely that this is the site of a wound, and (2) **Under a knife attack**: It is usual for the victim to guard oneself with arms in front of thorax and head which may lead to injury on the lower part of the arm. After death, blowfly may oviposit in these wounds, so that maggot activity on the palm of the hands indicates the probable presence of defense wounds (Anderson, 1998).

c. Abuse and Rape: Blowflies will most often lay their eggs in the facial region, and more seldom in the genito-anal

region. If there is a **sexual assault prior to death** leading to bleeding in the genito-anal region, thus blowflies will be more likely to oviposit in these regions. Therefore, if there is a high rate of infestation or egg-laying around genital areas of the victim, one can suspect that a **sexual crime** (rape or sexual assault) took place**.**

d. **Incapacitated Victims:** In some instances, the insects occurring on the carrion can shed a light on what happened when the victim died for *e.g.*, victims that are incapacitated (bound, drugged, or otherwise helpless) often have associated fecal and urine-soaked clothes or bed dressings. Such materials will attract certain species of flies that otherwise would not be found. Their presence can yield many clues to both ante-mortem and postmortem circumstances of the crime.

4. **Proving a Child or Senior Abuse/Neglect:** Some insects will colonize wounds or unclean areas on a living person "cutaneous myiasis". In these cases, the victim is still alive, but maggot-infested. Such cases occur, particularly in young children and seniors. A forensic entomologist will be able to tell when the wound or abuse occurred, for *e.g.*: (1) In the case of **neglected children**, maggot infestation on the skin surface under the diaper (anal-genital area),will give the minimum time interval since the child had a diaper change, *i.e*. how long children had been neglected by their parents (Anderson, 1998) for *e.g.*: close co-operation between forensic scientists, medico-legal doctors, and police forces make it possible to estimate the time since a child was neglected (Benecke and Lessig, 2001) and (2) **Neglected elderly persons** is a common problem among those in need of care (Benecke *et al.,* 2004 and Benecke, 2007). This can be diagnosed or proved through examinations of uncared wounds on such persons.

5. **Linking of Suspects to the Crime Scene (Association of Suspects with the Death Scene):** Persons can be placed as suspects and linked to the scene of a crime by having been bitten by arthropods specific to the vicinity, or having patterns of an insect bite on them similar to those on the victim, for instance, an insect inside a cocklebur was used to connect a rapist to the rape site (Anderson, 1998). New technology in the field of DNA analysis is providing an important subfield for use in FE (Wells and Stevens, 2007) not only to help in determining insect species but also to recover and identify the blood meals taken by the blood-feeding insects. The analysis of DNA of human blood meals from the digestive tract of an insect can provide a wealth of information about the host that blood was taken from for *e.g.*, police in Finland caught a car thief "who was in the police registers" through DNA analysis of a sample of his blood found inside a mosquito caught inside the car which was stolen and soon found (ABC News, 2008). Thus, it is possible to come up with a suspect at a known location within a definable period of time, because the suspect's DNA was found that make inferences about who killed person (Degaro 2003) or commits another crime.
6. **Tracing of Contraband Trafficking:** In some instances, movement of suspects, goods, victims or suspect vehicles can be traced with the help of insects. Insect's parts or whole insects can, for example, be captured in different car parts. By identifying the insects found, and knowing the distribution and biology of each identified species, one can describe the areas where the suspect has been.

Collection of Entomological Evidence at Death Scene:

The first and most important stage of the procedure involved in FE involves the careful and accurate collection of insect evidence at the scene (Anderson, 1998) which includes knowledge of the insect's behavior. The exact procedure at the crime scene varies with the type of habitat, but in

general the work of the forensic entomologist is divided into:

1. **Death Scene Observations:** Before insect collections are made, notes should be taken as to the general habitat, location of the body and description of the microhabitat immediately surrounding the body (Byrd 2007). Observations of the scene should include: (1) The type of habitat as this indicates 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 moved; (2) Location of the body in reference to vegetation, sun or shade conditions, and its proximity to any open doors or windows if recovered indoors; (3) Locations of insect infestations on the body as well as what stages of insects are observed; (4) Predation of eggs and larvae by other insects such as beetles, ants and wasps; (5) Evidence of scavenging by vertebrate animals and (6) Number and kinds of flying, resting or crawling insects and their activities within 3-6 m of the body.
2. **Collection of Climatological Data:** When estimating the PMI, climatological data about the crime scene is absolutely critical. The length of the insect life cycle (as mentioned before) is determined mostly by temperature and relative humidity in the environment where development takes place. Such data should include: (1) Ambient air temperature at the scene taken in close proximity to the body (approximately at chest height) with the thermometer in the shade; (2) Maggot mass temperature (obtained by inserting the thermometer into the center of the maggot mass); (3) Ground surface temperature; (4) Body surface temperature; (5) Temperature at the interface of the body and ground (simply place the thermometer between the body and the ground surface); (6) Temperature of the soil directly under the body (taken immediately after body removal) and (7) Weather data that includes the maximum and minimum daily temperature and rainfall for a period from 1-2 weeks before the victim's disappearance to 3-5 days after the body was discovered. Such information can be gathered from the nearest meteorological station.
3. **Collection and Processing of Insects:** It is important to note that the collection of insects and other arthropods from a death scene may disturb the remains. Therefore, utmost care should be taken during insect collection so that the remains are disturbed as little as possible. Samples of insects of all stages should be collected from different areas of the body, from the clothing and from the soil/carpet, *etc*.
    a. **Collection of Insects From the Body at the Scene:** The first insects that should be collected are the adult flies and beetles (Pankaj and Satpathy, 2001). These insects are fast-moving and can leave the crime scene rapidly once disturbed (Byrd, 2007). Once the adults have been collected the collection of larval specimens from the body can begin (Hall and Turner, 2003 and Cook and Dadour, 2008). First the investigator should search for the presence of eggs, which are easily overlooked. Collected adult flies are immobilized in a "killing jar" containing cotton balls or plaster soaked with acetone. The jar is then capped and once adults are immobile they can be easily transferred to a vial of 75% (or 80%) ethyl alcohol. A proportion of the larvae should be preserved immediately for two reasons: (1) to show the collected instars and (2) to present as evidence in the court. Maggots are first killed by brief immersion (15 seconds) in boiling water and then transferred to 75% ethanol. The majority of larvae should be kept alive for rearing purposes (Figure 1). The living specimens should be placed in a vial or styrofoam cups, with air and food (chicken or beef liver).

b. Collection of Insects From the Scene after Body Removal: Many of the insects that inhabit a corpse will remain on, or buried in the ground after the body has been removed. Therefore it is important to search the soil under and around the body (directly under and in close proximity to the remains *i.e.*, 1 m or less) for the fly pupae and other insects that might have migrated from the body. Each soil collection area should be about 4-6 square inches and be taken from underneath the head, chest, and extremities. All soil samples should be placed in a cardboard container, labeled and forwarded to the lab along with the insects collected from the body (Byrd, 2007)**.**

c. Labeling: Insects collected from different parts of the body (or from the soil) should be separately kept. Similarly, different insect species should be kept separate. It is extremely important that the collected specimens are properly labeled with a pencil (not ink, as alcohol can dissolve the ink from the paper). The label should contain the following information: Geographical location, date and time of collection, case number, site of collection: body/soil, insect stage and its location on the body and name of the collector.

d. Laboratory Processing: In the laboratory, the specimens of live insect immatures are examined and measured, then placed in a jar containing a suitable feeding media. In the case of blowflies, this is usually a beef liver, which is placed on top of sawdust. When the insects reach the prepupal stage and leave the food source they will burrow into the sawdust to pupate. The insects are checked daily and when pupate they are removed and placed in a Petri dish with damp filter paper. The date of pupation and the date of adult emergence are noted for each specimen to help in calculating the age at the time of collection. When the adults emerge, they are killed and pinned, then placed in an insect box. Each adult has a detailed label. Any adults collected directly from the corpse are immediately killed and pinned.

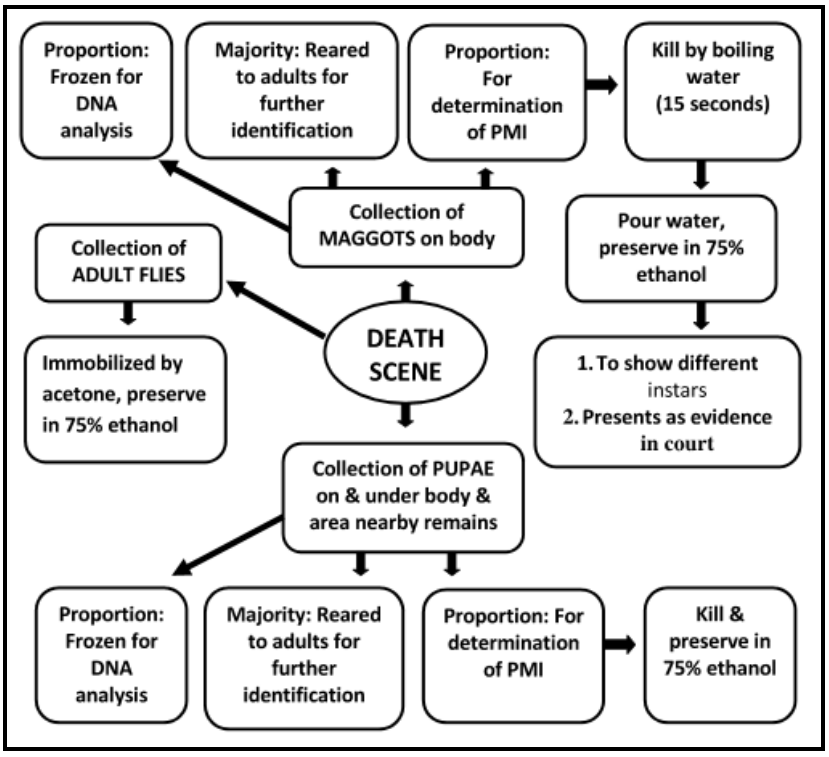

Fig. 1: Collection and processing of fly maggots and pupae at death scene

Forensic Entomology in Egypt:

Several studies (Hegazi *et al.*, 1991; EL-Kady *et al.*,1994; Tantawi *et al.*,1996; Shalaby *et al.*, 2000; El-Ghaffar *et al.*, 2008; Abd EL-Bar and Sawaby, 2011; Aly *et al.*, 2013 & 2017 ; Ibrahim *et al*., 2013 ; Zeariya *et al.*, 2015 & 2018; Abd El-Bar *et al.*, 2016; Abd El-Gawad, 2018; Abd EL-Gawad *et al.*, 2018 & 2019 and Zeariya and Kabadaia, 2019) were carried out in some parts of Egypt to examine the type and composition of entomofauna that were attracted to different decomposition stages of animal carcasses: rabbits (*Oryctolagus curicullus* and *Lepus cuniculus*), guinea pigs (*Cavia porcellus*.) and dog (*Canis lupus familiaris*). Only two available studies were carried out on human remains. Galal *et al.* (2009) used human leftover parts from orthopedic theatre that were placed on the roof of Faculty of Medicine, Assiut University Campus. Assiut city and inspected adults and immatures of flying and crawling insects in relation to decomposition stages. El-Mehy *et al.* (2015) examined the insect fauna of 15 human putrefied corpses which were found in 6 localities in Middle of the Delta and referred to the Forensic Medicine Directorate, Ministry of Justice during the period from February 2004 up to January 2006. However, no actual death cases were investigated and the legal use of FE as a part of police investigations is not yet implemented in Egypt.

These studies resulted in the collection of 108 species (including 23 unidentified sp., Usp.) representing 39 families belonging to 7 orders (Tables 3, 4 and 5.). The reported orders are: Diptera (14 F, 44 sp. & 7 Usp.), Coleoptera (8 F, 24 sp. & 5 Usp.), Hymenoptera (8 F, 11 sp. & 5 Usp.), Dermaptera (5 F, 4 sp. & 4 Usp.), Zygentoma and Blattodea (1 F and 1 sp. each) and Hemiptera (2 F and 2 sp.). All of these species were on animals while very few samples (Diptera: 5 sp. & 3 Usp.; Coleoptera: 1 Usp. & Hymenoptera: 1 Usp.) were collected on human remains. Of the reported fly species, *Scathophaga litorea* (Diptera: Scathophagidae) was found for the first time as an addition to Egyptian fauna (Abd El-Gawad *et al.*, 2019).

Table 3: Reported forensic insects in Egypt (Order: Diptera)

Family / Species	**Family / Species**	**Family / Species**
Muscidae	**Sarcophagidae**	**Syrphidae**
Musca domestica (a+h)	*Wohlfahrtia nuba*	*Eumerus amoenus*
Musca sorbens	*Wohlfahrtia magnifica* (a+h)	*Eupeodes corollae*
Musca autumnalis	*Wohlfahrtia* sp. (a+h)	*Allograpta cubana*
Muscina prolapsa	*Sarcophaga carnaria* (a+h)	Ephydridae
Muscina stabulans	*Sarcophaga hertipes*	*Scatella* sp.
Stomoxys calcitrans	*Sarcophaga argyrostoma*	**Ulidiidae**
Synthesiomyia nudiseta	*Sarcophaga aegyptica*	*Physiphora alceae*
Helina lasiophthalma	*Sarcophaga* sp. (a+h)	*Physiphora demandata*
Ophyra leucostoma	*Boettcherisca peregrine*	**Phoridae**
Atherigona varia	*Parasarcophaga africa*	*Megaselia scalaris*
Calliphoridae	*Parasarcophaga ruficornis*	*Diplonevra peregrine*
Calliphora vicina	*Agriella setosa*	**Scathophagidae**
Calliphora sp.	**Piophilidae**	*Scathophaga litorea*
Chrysomya albiceps (a+h)	*Piophila casei*	**Sepsidae**
Chrysomya megacephala	**Psychodidae**	*Sepsis fissa*
Chrysomya rufifacies	*Tinearia alternata*	**Fannidae**
Lucilia sericata (a+h)	*Psychoda* sp. (a+h)	*Fannia canicularis*
Lucilia cuprina	**Sphaeroceridae**	*Fannia leucostica*
Phormia regina	*Coproica vagans*	**Drosophilidae**
Pollenia sp.	**Hippoboscidae**	*Drosophila replete*
	Hippobosca equine	*Scaptomyza* sp.

(a+h) on animal and human remains, all other spp. are on animals

Table 4: Reported forensic insects in Egypt (Order: Coleoptera)

Family/ Species	**Family/ Species**	**Family/ Species**
Histeridae	**Dermestidae**	**Staphylinidae**
Saprinus chalcites	*Attagenus faciatus*	*Creophilus maxillosus*
Saprinus furvus	*Dermestes maculatus*	*Trachyderma hispidae*
Saprinus caerulescens	*Dermestes frischii*	*Philonthus stragulatus*
Saprinus semistaiatus	*Dermestes ater*	*Philonthus longicornis*
Saprinus lugens	*Dermestes vulpinus*	*Zophosis abbreviate*
Saprinus gilvicornis	*Dermestes* sp.(a+h)	*Mesostina puncticollis*
Saprinus semipunctatus	**Tenebrionidae**	*Atheta* sp
Hister sp.	*Trachyderma hispidae*	**Anobiidae**
Cleridae	*Zophosis abbreviata*	*Lasioderma* sp.
Necrobia rufipes	*Creophilus maxillosus*	**Nitidulidae**
Pteromalidae	*Mesostina puncticollis*	*Carpophilus hemipterus*
Nasonia sp.		

(a+h) on animal and human remains, all other spp. are on animals

Table 5: Reported forensic insects in Egypt (Other orders)

Order / Family/ Species	**Order / Family/ Species**	**Order / Family/ Species**
HYMENOPTERA	**HYMENOPTERA**	**DERMAPTERA**
Vespidae	**Evaniidae**	**Eulophidae**
Vespa orientalis	*Evania appendigaster*	*Tetrastichus* sp
Dolichovespula sp	**Chalcididae**	**ZYGENTOMA**
Dolichovespula sp	*Brachymeria* sp.	**Lepismatidae**
Apidae	**Chrysididae**	*Thermobia aegyptiaca*
*Apis mellifer*a	*Chrysis* sp.	**BLATTODEA**
Formicidae	**DERMAPTERA**	**Blatellidae**
Monomorium pharoanis	**Labiduridae**	*Blatella germanica*
Cataglyphis bicolor	*Forficula auricularia*	**HEMIPTERA**
Pheidola megacephala	**Carcinophoridae**	**Cydnidae**
Solenopsis geminata	*Euborellia annulipes*	*Cydnus aterrimus*
Paratrechina longicornis	**Chalcididae**	**Cicadellidae**
Camponotus maculatus	*Brachymeria fonscolombei*	*Empoasca decipiens*
Unidentified sp.(h)	*Euchalcida* sp	
Braconidae	*Chalcis* sp	
Microplitis rufiventris	*Brachymeria fonscolombei*	
Pteromalidae	**Pteromalidae**	
Nasonia vitripennis	*Pteromalus* sp	

(h) on human remains, all other spp. are on animals

In addition, such studies revealed that:

1. Five decomposition stages of rabbit carcass (fresh, bloated, active decay, advanced decay, and skeletonization) were observed (EL-Ghaffar *et al.*, 2008**;** Abd EL-Bar and Sawaby, 2011; Zeariya *et al*., 2015; Abd El-Bar *et al.*, 2016; Aly *et al.*, 2017 and Abd El-Gawad *et al.*, 2019**)** while Tantawi *et al.* (1996) and Galal *et al.* (2009**)** observed only four stages (fresh, bloated, decay, and dry).
2. Rabbits intoxicated with Warfarin rodenticide (Abd El-Gawad, 2018 and Abd El-Gawad *et al.*, 2019) or pirimiphos-methyl, an organophosphate insecticide (Abd El-Bar and Sawaby, 2011) decayed faster than the control untreated ones. This may indicate that the toxin did not mask the odour of the

carcasses which is the main attractant factor for invading insects (Abd El-Bar and Sawaby, 2011).

3. Insignificantly more adults and immature (P>0.05) of flies and beetles were attracted to black rabbit carcasses than to black-white or to white ones (Abd El-Gawad, 2018). However, further studies are needed to examine whether carcasse colour can actually affect the number of attracted insects.
4. Warfarin rodenticide had an effect on producing abnormal and malformed fly adults (Abd El-Gawad *et al.*, 2018). Such effect was not observed for coleopteran adults (Kenawy *et al,* in prep.) or for other toxicants (Abd El-Bar and Sawaby, 2011)

CONCLUSION

From the above discussion, it is obvious that FE is an important and interesting aspect of medical entomology with useful applications to help in solving crimes and in aiding justice. Despite the enormous usefulness, no legal application of such an approach in Egypt or any other Arabian or African country. The police investigations will be enhanced if this branch of science can be utilized.

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ARABIC SUMMARY

مراجعة علم الحشرات الجنائي "استخدام الحشرات في تحقيقات الوفاة "

محمد امين قناوى[1] ويسريه محمد عبد الحميد[2]

1- قسم علم الحشرات، كلية العلوم، جامعة عين شمس، العباسيه، القاهره 11566
2- معهد بحوث الحشرات الطبية، الهيئه العامه للمعاهد والمستشفيات التعليميه، وزارة الصحه، الدقى، جيزه، جمهورية مصر العربيه

تستعرض هذه الورقة وتراجع الجوانب المختلفه لعلم الحشرات الشرعى/ الجنائى (التعريف، نبذة تاريخيه، مراحل تحلل الجيف وما يرتبط بها من الحشرات/ مفصليات الارجل، الآستخدام فى حل الجرائم، طرق جمع الادله الحشريه فى موقع الوفاة، والحالة فى مصر). هذه معلومات مهمه للأشخاص والمسؤلين للأستفاده من هذا الجانب كأداة مساعده لحل الجرائم.