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# FORENSIC ENTOMOLOGY: A NOVEL APPROACH FOR CRIME INVESTIGATION

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***Abstract:*** *Forensic science is the application of scientific techniques and principles to provide evidence to legal or related investigations and determinations. The importance of forensic science in solving crimes has been increasing noticeably. Insects are usually the first organisms to arrive on a body after death, and they colonize in a predictable sequence. Carrion (dead tissue) feeding blow flies (Calliphoridae) and flesh flies (Sarcophagidae) are those most useful in death investigations. Entomological evidence collected from a corpse can be used to make inferences about the location or cause of death, but is most frequently used to estimate the time of death. Upon death, the putrefaction of a body attracts a variety of large scavengers and smaller arthropods. Observations of the insect fauna taken at the time of the corpse's discovery can be used to estimate the amount of time that has passed since death, commonly referred to as the post-mortem interval (PMI). The study of the entomo-fauna associated with cadavers has been an extremely effective tool to clarify numerous cases of homicides, sexual abuses and traffic of organs. Today, forensic entomology is not limited to finding PMI only. A forensic entomologist has acquired an important role in death investigation like finding time since death, season of death, geographical location of death, movement or storage of remains after death, time of decapitation or dismemberment, submersion interval, specific sites of injury on the body, post-mortem artifacts on the body and the crime scene, use of drugs, sexual molestation, identification of suspects. As part of the forensic team, have necessitated the need for an increase in awareness of emerging sciences like forensic entomology and its applications in forensics.*
***Keywords:*** *Forensic Science, Insects, Scavengers, Crime Investigation and Post-Mortem Interval (PMI).*

**Introduction:** Forensic science is 'the application of scientific techniques and principles to provide evidence to legal or related investigations and determinations' [1]. Defines forensic science as "a broad, interdisciplinary group of applications of physical and biological sciences and various technologies to issues in civil and criminal justice" [2]. Forensic entomology is a branch of forensic science that applies the study of arthropods and insects in the investigation of criminal matters. The importance of forensic science in solving crimes has been increasing noticeably. Insects are usually the first organisms to arrive on a body after death, and they colonize in a predictable sequence. A corpse, whether human or animal, is a large food resource for a great many creatures and supports a large and rapidly changing fauna as it decomposes. The body progresses through a recognized sequence of decomposition stages, from fresh to skeletal, over time. During this decomposition, it goes through dramatic physical, biological and chemical changes [3, 4]. Each of these stages of decomposition is attractive to a different group of sarcosaprophagous arthropods, primarily insects. Some are attracted directly by the corpse, which is used as food or an oviposition medium, whereas other species are attracted by the large aggregation of other insects they use as a food source. Four ecological categories can be identified in a carrion community [5], as follow: (1) Necrophagous species, feeding and breeding on the carrion. (2) Predators and parasites of necrophagous species, feeding on other insects or arthropods. This group also comprises species which feed on carrion at first, but many become predaceous in later larval stages. (3) Omnivorous species such as wasps, ants and some beetles feeding both on the carrion and its colonizers. (4)

Other species, such as springtails and spiders, which use the carrion as an extension of their environment.

Insects colonize in a predictable sequence, with some species being attracted to the remains very shortly after death and others are attracted during the active decay stage and still others being attracted to the dry skin and bones. Insects continue to colonize a body until it is no longer attractive. When the insects migrate from the remains, they invariably leave evidence of their presence behind, such as cast larval skins, empty puparium cases and even peritrophic membrane [5]. Several factors restrict the colonization of a corpse, such as its burial [6] and most Dipterans are not able to colonize bodies buried deeper than 30cm [7, 8]. Burial, therefore, will influence the time required for insects to reach the carcass as well as the species composition of the necrophagous fauna [9, 8]. Such delay may not only occur in buried corpses, but in those that are covered or wrapped [10].

**History of Forensic Entomology:** Historical events in forensic entomology reaching back to the 13th century have been described extensively in several studies, publications and reviews [11,12]. Insects are known to have been used in the detection of crimes for a long time and a number of researchers have written about the history of forensic entomology [13, 14]. The Chinese used the presence of flies and other insects as part of their investigative armory for crime scene investigation and instances of their use are recorded as early as the mid-tenth century [14]. Forensic entomology was first reported to have been used in 13th century in China and was used sporadically in the 19$^{th}$ century and the early part of the 20th century, playing a part in some very major cases. The oldest record is the documentation during the year 1235 A.D. The Chinese lawyer and investigator, Sung Tzu in his book 'His Yuan Chi Lu' (translated 'The Washing Away of Wrongs' by McKnight, 1981) [15], recorded the first documented forensic entomology case.

Until the mid-17th century, it was believed that under the right conditions maggots spontaneously arose from rotten meat. In 1668, Francesco Redi refuted the hypothesis of the spontaneous generation of life after the analysis of the results of his experiments in which rotting meat was either exposed to or protected from flies [16]. Redi proved by his experiments that maggots come from fly eggs deposited on rotten meat or putrefying carcasses [17,18, 19].

At the beginning of the 19th century, it was registered that flies are attracted by corpses at a very early stage of decomposition. In the year 1829, Mende compiled a list of necrophagous insects, including flies, beetles and other taxa and provided more precise account, but did not link flies to the time of death. Described the opportunities and problems associated with using insects for the estimation of the postmortem interval (PMI)[20] and many of which are still relevant today [21].

The credit for the first modern forensic entomology case goes to French doctor Bergeret. He used forensic entomology to detect the post-mortem interval (PMI) in 1855. In that case the corpse of a child was found in a house. Bergeret was called to detect the PMI. In finding the PMI he assumed that metamorphosis involves one year 25 and also that females lay eggs in summer so that the larvae would transform to pupae the next spring and hatch in summer. He found the eggs of *Musca carnaria* L. on the corpse that lays eggs before the body dries out. Using these findings he calculated that the body must have been left there at least a couple of years back [22]. Pierre Megnin can be regarded as the first person who undertook a scientific research on forensic entomology. He worked on the subject for almost a couple of decades and compiled his findings in the form of a book titled 'La fauna des Cadavres' in 1894. In this book he gave the theory of eight successional waves of insects on bodies left in the open. He also mentioned that on buried bodies insects came in two waves. He also described the morphological features of various classes of insects that helped in their identification. As the reports started pouring in that Megnin's work involved a lot of guesswork, people began modifying his findings to go with the flora and fauna prevelant at their places. This process started at the end of nineteenth century and has been continuing since [23, 22].

Carrion (dead tissue) feeding blow flies (Calliphoridae) and flesh flies (Sarcophagidae) are those most useful in death investigations. Aldrich's (1916) monograph on the Sarcophagidae made use of distinctive male genitalia, thereby enabling entomologists to identify adult male specimens from this important family [24]. Later, published descriptions and keys to many common early (first instar) maggots of flesh flies [25]. Although considerable work had been done on the blow fly fauna of North America for instance [26], monograph, 'The Blow flies of North America',

made possible the accurate identification of adults and mature larvae of most species of this family as well. The situation is somewhat better with respect to third in star or prepupal larvae (the largest maggot stage, and that most commonly observed), but only if such specimens are preserved properly.

When Watson and Crick discovered DNA in 1953, the use of DNA brought in a new era in the identification of the invertebrates. Soon DNA was being used to identify the insects at the scene of crime [27, 28, 22]. This is currently an area of active research, and this replaces the application of scanning electron microscopy for identifying the immature stages of fly [29]. In the late 1970s, the emergence of entomotoxicology as a new branch of forensic entomology was seen.

**Components of Forensic Entomology:** Divided forensic entomology into three major components [30]:

**i. Urban Entomology:** Legal proceedings involving insects and related animals that effect on manmade structures such as dwellings, house and other aspect of human environment. This category also includes the law of insecticidal abuse.

**ii. Stored Product Entomology:** Legal proceedings involving insects infesting stored commodities such as cereal and other kitchen products. This usually involves both criminal and civil proceeding involving food contamination of variety of commercial products

**iii. Medico-legal Entomology:** Medico-legal entomology or sometimes termed 'forensic medical entomology' and in reality 'medico-criminal entomology' (because it focuses more on violent crime), relates it to primary aspects [31, 32], as follow: (a) Determination of the time (PMI or post-mortem interval) or site of human death (b) Cases involving possible sudden death (c) Traffic accidents with no immediately obvious cause (d) Possible criminal misuse of insects.

**The Post-mortem Interval (PMI):** Entomological evidence collected from a corpse can be used to make inferences about the location or cause of death, but is most frequently used to estimate the time of death. Upon death, the putrefaction of a body attracts a variety of large scavengers and smaller arthropods. Observations of the insect fauna taken at the time of the corpse's discovery can be used to estimate the amount of time that has passed since death, commonly referred to as the post-mortem interval (PMI). This estimation is accomplished by observing the types of species present on the corpse and estimating the immature insect specimens. Although a wide variety of insects may be found on or around a decomposing body, flies and beetles are the two most frequently encountered and forensically useful groups [13, 16].

As well as the PMI, insect evidence can indicate the season of death. Insect evidence can indicate whether the death occurred in an urban or rural setting. Insect evidence can be used to determine whether a buried body was on the surface for some time after death and then buried. Insect evidence also indicates whether a body has been previously buried [33, 34, 29]. Aquatic insects can indicate the season and conditions under which the body came to be in the water. An aquatic insect on a body found on land indicates death in wetter season or movement of the body [35].

Insects begin to arrive at a corpse in less than ten minutes after death [36, 34]. In buried bodies, colonization can be found as much as ten years after death [33]. Insect colonization can be found on bodies sealed in plastic bags, rugs and cars [29]. Insect colonization occurs on bodies indoors and those which have been buried. This means that insect evidence can be used in wide variety of circumstances and over much longer periods of time as opposed to other widely used methods for estimating the PMI [33, 29].

**Insects of Forensic Importance:** There are about 86,000 fly species described worldwide [37]. The study of the entomo-fauna associated with cadavers has been an extremely effective tool to clarify numerous cases of homicides, sexual abuses and traffic of organs [38]. Eighteen species of cyclorrphagic flies were identified, consisting of: i) *Chrysomya megacephala* ii) *Chrysomya rufifacies* iii) *Chrysomya villeneuvi* iv) *Chrysomya nigripes* v) *Chrysomya bezziana* vi) *Chrysomya pinguis* vii) *Chrysomya sp.* viii) *Sarcophaga sp.* ix) *Lucilia sp.* x) *Hermetia sp.* xi) *Hermetia illucens* xii) *Hemipyrellia ligurriens* xiii) *Hemipyrellia sp.* xiv) *Ophyra spinigera* xv) *Ophyra sp.* xvi) *Calliphora sp.* xvii) *Synthesiomyia nudiseta* xviii) *Eristalis sp.*

The proper identification of the insect and arthropods species for forensic importance is the most crucial element in the field of forensic entomology. It is the species identification that allows the proper developmental data and distribution ranges to be applied to an investigation. If the species determination is incorrect, then the estimated post-mortem interval would be invalid [39].

Flies and Beetles Carrion flies are most frequently collected as forensic evidence due to their ability to quickly locate a corpse, sometimes within minutes after death. Although not much is known about the specific chemical compounds that attract carrion flies to a decomposing corpse, the carrion does provide an attractive environment for the flies to feed, mate and deposit eggs. The many different species of flies (Order: Diptera) [40] that can be associated with a corpse, most of them belong to one of the following three families namely Calliphoridae (commonly called blow flies), Sarcophagidae (flesh flies) or Muscidae (house flies and related species). These large flies produce a large amount of eggs, larvae and pupae that are easily seen and collected by investigator. Flies have large compound eyes with mouthparts of various types. However, most flies associated with a corpse have sponging mouthparts. The larvae of flies are called maggots and most are cream coloured, soft, legless and lack a visible head [14]. Various species of beetles (Order: Coleoptera) are attracted to the corpse throughout the decomposition process and are therefore helpful in cases when the corpse remains undiscovered for a longer period of time [41]. Similar to flies, adult beetles are attracted to the corpse as a source of food and as a medium to deposit eggs. Beetles will not only feed on the corpse itself, but many will also consume the eggs or maggots present on the corpse. Just as with flies, beetle eggs will hatch and grow through a complete metamorphosis pattern. Because different beetles are attracted to the body at different times throughout the decomposition process, the presence of a certain species on the corpse can be an indication of how long the body has been decomposing. This knowledge of insect succession, coupled with an estimation of the age of the immature insects developing on the body, forms the basis for post-mortem interval estimations [42, 43].

Necrophages, more specifically blow flies (Calliphoridae) are usually the basis for determining PMI because they are often the first to colonize human corpse, arriving minutes after death [11]. Adult females prefer to lay eggs (oviposition) in the wounds and orifices of a body because newly hatched larvae cannot break skin barriers, these locations on the decomposing body allow access to a liquid protein food source which is essential for their development, as well as providing a moist and humid environment that enhances survival. Blow flies are not the only insects to colonize decaying remains, others include flesh flies (Diptera: Sarcophagidae), carrion beetles (Coleoptera: Silphidae), rove beetles (Coleoptera: Staphylinidae) as well as others [8].

The use of insects in forensic entomology has become one of the most helpful tools for estimating PMI. Within minutes of death, Calliphoridae flies colonize human corpse and are the most accurate to estimate PMI. The scientific study of insects, entomology, has given crime investigators new hope in obtaining the estimation of 'time of death'. The role of forensic entomology may enable the investigator to obtain 'real-time' information based upon stages of development in species associated with the death scene [11]. Larval development is dependent on temperature [44] and every species has a slightly different growth rate [45].

It is thus crucial to identify the larval species feeding from a corpse correctly to calculate the PMI properly. To ensure correct species identification, established molecular methods were transferred to the forensic field [27, 46, 47]. Calliphoridae are one of the earliest visitors infesting a corpse with their larvae [48].

**Do Forensic Entomology is Really Useful to Investigate Crime?:** Today forensic entomology is not limited to finding PMI only. A forensic entomologist has acquired an important role in death investigation like finding time since death, season of death, geographical location of death, movement or storage of remains after death, time of decapitation or dismemberment, submersion interval, specific sites of injury on the body, post-mortem artifacts on the body and the crime scene, use of drugs, linking a suspect to scene of crime, in child neglect, sexual molestation, identification of suspects [8]. The presence of toxins in the invertebrate decomposers was detected and was used as a method of finding the cause of death. Now the use of forensic entomology was graduating from finding only PMI to finding the cause of death [49, 50]. The use of forensic entomology in child abuse and sexual abuse cases can be seen from the case described by Mark Benecke. This case marked a landmark in the use of entomology in child abuse [13]. The presence of certain fly species associated with the victim may indicate neglect or abuse. This can be corroborated by estimation of the age of recovered maggots to reveal the length of neglect. Forensic entomologists are always presented with the task of reconstructing the death scene conditions as closely as possible. A

model for the calculation and handling of the data is crucial for the credibility of this discipline [39]. Now, at the beginning of the 21st century, forensic entomology is recognized in many countries as an important forensic tool [51].

**Limitations of Forensic Entomology:** Despite great advances in the studies on flies most commonly associated with forensic entomology, there are limitations to the practice. Each case requires careful consideration. Each case is unique in presenting variables that may affect the development times of fly larvae, thus influencing developmental rates. Other complications include difficulties in identifying species. Many dipteran species resemble another, particularly during the larval stage of development. Correct identification can also be hindered due to the introduction of foreign species from overseas. Today however with advanced DNA technology this issue can largely be overcome. By analysing mitochondrial DNA one can obtain a reliable identification of collected specimens [52].

**Conclusion:** Forensic entomology is an evolving field in forensic sciences, where the insects feeding on corpses are studied. It has become an important tool in criminal investigations. As part of the forensic team, have necessitated the need for an increase in awareness of emerging sciences like forensic entomology and its applications in forensics.

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