AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 06 (June, 2026)
Available online at http://www.agrimagazine.in

Forensic Entomology: History, Methodology, Insects, and Present Scope

*Ankit Raj[1], Atul Kumar Yadav[2] and Anamika Saxena[2]
[1]Ph. D. Research Scholar, Department of Entomology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India
[2]Ph. D. Research Scholar, Department of Entomology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India
*Corresponding Author's email: ankitraj5095@csauk.ac.in

Forensic entomology is the scientific application of insect biology and ecology to legal investigations, primarily concerned with the estimation of the post-mortem interval (PMI) in death investigations. The discipline leverages the predictable succession patterns of arthropods — especially dipteran flies and coleopteran beetles — on decomposing remains to establish minimum PMI, scene geography, and evidence of body disturbance. This review provides a detailed account of the historical development of forensic entomology from ancient Chinese practice to modern molecular applications, outlines the principal insect species employed in investigations, describes standard methodological protocols, and discusses the current and emerging scope of the discipline in criminal justice, public health, stored product investigation, and wildlife forensics. The integration of molecular tools such as DNA barcoding, stable isotope analysis, and metabolomics is rapidly expanding the precision and reliability of entomological evidence.

Introduction

Death investigations represent one of the most critical intersections of natural science and jurisprudence. Among the many scientific disciplines enlisted to assist in these investigations, forensic entomology occupies a uniquely powerful niche: it exploits the biological behaviour of insects primarily necrophagous (carrion-feeding) arthropods to extract temporal, geographical, and contextual information from decomposing human or animal remains **(Amendt *et al.*, 2007)**. Insects are among the first organisms to colonize a corpse. Their arrival, oviposition, larval development, and eventual departure follow predictable ecological and thermal kinetic patterns that, when interpreted by a trained entomologist, can yield valuable forensic intelligence **(Catts and Goff, 1992)**. The most fundamental application is the estimation of the post-mortem interval (PMI), which is the time elapsed since death.

Historical Background and Development

Ancient and Pre-Modern Origins

The earliest documented use of insect evidence in a legal investigation date to 13th-century China. The Chinese jurist Sung Tz'u described a murder case in *Hsi Yuan Lu* (*The Washing Away of Wrongs*) (1247 CE), where flies were attracted to a particular sickle due to traces of blood and tissue, identifying the weapon owner as the murderer. Although the biological basis was unknown, this case is considered the first recorded application of forensic entomology **(Benecke, 2001)**. During the 16th–18th centuries in Europe, physicians and naturalists recorded insect activity on human remains, but these observations were mainly descriptive. Insects were not yet recognized as reliable indicators of postmortem interval (PMI) **(Benecke, 2001)**.

The Foundational Nineteenth Century

The scientific foundation of forensic entomology developed during the 19th century. In 1855, French physician Dr. Bergeret d'Arbois applied insect developmental knowledge to estimate the time since death of a mummified infant remains discovered in Paris, using associated moth and fly evidence to determine PMI **(Benecke, 2001)**. Later, Reinhard (1881–1894) documented insect succession in human graves, demonstrating that different arthropod species appeared at different decomposition stages. Jean Pierre Mégnin further advanced the field through his work *La Faune des Cadavres* (1894), where he proposed an eight-wave model of insect succession on corpses. Although later modified, Mégnin's work established succession patterns as a foundation for forensic PMI estimation **(Pont and Matile, 1980; Benecke, 2001)**.

The Twentieth Century: Consolidation and Expansion

The early 20th century brought important contributions, including Motter's study (1898) of insect communities associated with human graves, which provided early data on decomposition-related insect succession in North America. During the 1970s and 1980s, forensic entomology developed into a practical forensic discipline. Researchers such as Bernard Greenberg, Kenneth Schoenly, Pekka Nuorteva, and Martin Hall contributed to insect developmental studies and temperature-based PMI estimation models. Accumulated degree hours (ADH) and accumulated degree days (ADD) models allowed more accurate and quantitative PMI calculations **(Greenberg and Kunich, 2002)**. The establishment of the American Board of Forensic Entomology (ABFE) in 1984 and the European Association for Forensic Entomology (EAFE) in 2002 promoted professional standards, research collaboration, and methodological development.

The Molecular and Digital Era (21st Century)

Modern forensic entomology has expanded through molecular biology, GIS, and computational approaches. DNA barcoding using mitochondrial COI gene sequencing has improved species identification, especially for damaged specimens, immature larvae, and closely related species **(Meiklejohn *et al.*, 2011)**. Additional techniques such as stable isotope analysis and metabolomics provide information on geographic origin, host diet, and environmental history. Entomotoxicology has also become important for detecting drugs, poisons, and chemicals in insect tissues when traditional biological samples are unavailable **(Amendt *et al.*, 2011)**.

Key Insect Taxa in Forensic Entomology

Order Diptera (True Flies) — Primary Colonizers

Dipterans are the most important forensic insects because of their rapid colonization of fresh remains and well-studied development patterns **(Byrd and Tomberlin, 2019)**.

Family Calliphoridae (Blow Flies)

Blow flies are usually the first insects to arrive after death and are major indicators for PMI estimation. Important species include *Calliphora vicina*, *Calliphora vomitoria*, *Lucilia sericata*, *Lucilia cuprina*, *Phormia regina*, *Chrysomya megacephala*, *Chrysomya rufifacies*, and *Cochliomyia macellaria*. Their larval development, especially the third instar, is used with ADD/ADH models to estimate time since colonization **(Amendt *et al.*, 2011)**.

Family Sarcophagidae (Flesh Flies)

Flesh flies deposit live larvae instead of eggs, allowing rapid colonization but making age estimation more complex. Genera such as *Sarcophaga* are important secondary colonizers.

Family Phoridae (Humpbacked Flies)

Species such as *Megaselia scalaris* can access buried or enclosed remains and are important in concealed body investigations **(Byrd and Tomberlin, 2019)**.

Order Coleoptera (Beetles) — Secondary and Tertiary Colonizers

Beetles become important during advanced decomposition when fly activity declines.

- **Staphylinidae (Rove beetles):** Predators of fly larvae and indicators of earlier insect activity.
- **Silphidae (Carrion beetles):** Associated with decaying remains.

- **Dermestidae (Hide beetles):** *Dermestes maculatus* and related species occur during dry decomposition and consume dried tissues.
- **Cleridae, Tenebrionidae, and Nitidulidae:** Associated with later decomposition stages **(Catts and Goff, 1992)**.

Order Hymenoptera (Ants, Wasps, Bees)

Ants may remove or consume fly eggs and larvae, disrupting normal succession and affecting PMI estimation. Parasitoid wasps can attack fly pupae and provide additional forensic information.

Order Lepidoptera (Moths)

Moths are mainly associated with dry and skeletal decomposition stages. Species such as *Aglossa pinguinalis* and *Tineola bisselliella* feed on dried tissues and have forensic importance, including in historical cases **(Benecke, 2001)**.

Other Arthropods

Mites (Acari), woodlice (Isopoda), and springtails (Collembola) contribute supplementary information, particularly in concealed, mummified, or moist decomposition environments.

Methodological Framework

Scene Collection Protocols

Collection of entomological evidence at crime scenes follows standardized protocols recommended by organizations such as ABFE and EAFE. Proper collection and preservation are essential to maintain evidence reliability. Major steps include recording temperature at the scene, ground level, and beneath/within the body; collecting larvae for both preservation and rearing; collecting pupae and puparia; sampling adult insects; and collecting specimens from body surfaces, natural openings, wounds, soil, and surrounding areas. Weather records are also obtained to reconstruct temperature conditions for insect development analysis **(Amendt *et al.*, 2011; Byrd and Tomberlin, 2019)**.

Species Identification

Accurate species identification is the foundation of forensic entomology. Morphological identification is performed using taxonomic keys based on characters such as chaetotaxy, body structures, coloration, and adult characteristics. Larval specimens may require rearing to adults for confirmation. Molecular identification through DNA barcoding, particularly mitochondrial COI gene analysis, has become an important tool for identifying degraded specimens, immature stages, and closely related species complexes **(Wells and Škaro, 2023)**.

Post-Mortem Interval Estimation

PMI estimation using entomological evidence relies mainly on insect development data and succession patterns. Developmental stages of insects recovered from remains are compared with experimental growth data to estimate the minimum time since colonization **(Goff and Benecke, 2000)**.

Thermal Accumulation Models: Thermal accumulation models, including accumulated degree days (ADD) and accumulated degree hours (ADH), estimate insect age based on temperature-dependent development rates. Development occurs above a species-specific threshold temperature, and accumulated thermal units are compared with laboratory developmental data to estimate PMI.

$$ADD = \Sigma[(T_{max} + T_{min})/2 - T_{base}]$$

The estimated larval age, environmental temperature, and oviposition timing are combined to calculate the minimum PMI **(Amendt *et al.*, 2011)**.

Succession Analysis: When the first generation of insects has completed development, succession analysis is used. Different insect communities associated with decomposition stages (fresh, bloat, active decay, advanced decay, and dry remains) provide PMI estimates. This approach depends on regional climate, habitat, and insect diversity.

Entomotoxicology

Entomotoxicology involves detecting drugs, poisons, and chemical substances from insect larvae feeding on decomposed remains. Larvae can accumulate toxic compounds when human tissues are unavailable. Analytical techniques such as GC-MS, HPLC, and immunoassays are used to identify substances including opioids, cocaine, pesticides, antidepressants, and heavy metals. Since some toxicants may accelerate or delay insect development, they must be considered during PMI estimation **(Introna *et al.*, 2001)**.

Geolocation and Scene Reconstruction

Insect evidence can assist in determining whether a body was moved after death. Differences in insect species composition between locations may indicate relocation. Species associated with specific environments can provide information about the original death site. Stable isotope analysis of insect tissues can further support geographic origin estimation by reflecting environmental signatures.

Present Scope and Applications

Medicocriminal Entomology

The primary application of forensic entomology is PMI estimation in homicide investigations. Forensic entomologists assist law enforcement agencies by analyzing insect evidence and providing expert testimony. Modern acceptance of this field depends on validated research, developmental databases, and standardized protocols **(Amendt *et al.*, 2011)**.

Urban and Stored Product Entomology

Forensic entomology is also applied in food safety and stored product investigations. Insect identification, developmental stage, and infestation patterns help determine contamination timing, source, and responsibility in legal disputes involving food products.

Wildlife Forensics

In wildlife crime investigations, insect evidence helps estimate the time since death of illegally killed animals and provides information about carcass movement and poaching timelines. This supports conservation law enforcement and illegal wildlife trade investigations.

Entomology and Civil Investigation

Forensic entomology contributes to civil cases involving insurance claims, property damage, food contamination, and infestation disputes. Insect presence and developmental stages can help determine the origin and duration of infestations.

Emerging Technologies and Future Directions

Future developments in forensic entomology include:

- **Genomic and proteomic approaches:** Advanced molecular techniques may improve species identification from damaged or degraded specimens.
- **Artificial intelligence and machine learning:** Image-based identification systems are being developed for rapid insect recognition.
- **Environmental DNA (eDNA) and remote sensing:** These approaches may provide supplementary ecological and temporal information.
- **Expansion of tropical databases:** Developmental data from tropical and subtropical regions is needed because insect species and growth patterns vary geographically.

Conclusion

Forensic entomology is a unique field that applies insect science to legal investigations. From its origins in 13th-century China to its current role as an advanced forensic discipline, it has evolved through developments in ecology, molecular biology, toxicology, and analytical technologies. Its most important application remains the estimation of the post-mortem interval (PMI) using insect development and succession patterns, particularly when conventional methods are ineffective. Beyond criminal investigations, forensic entomology now contributes to food safety, wildlife forensics, and civil litigation. With continuing advances in molecular techniques, artificial intelligence, and digital analysis, the field is expected to play an increasingly important role in modern forensic science.

References

1. Amendt, J., Campobasso, C. P., Gaudry, E., Reiter, C., LeBlanc, H. N. and JR Hall, M. (2007). Best practice in forensic entomology—standards and guidelines. *International journal of legal medicine*, *121*(2), 90-104.
2. Amendt, J., Richards, C. S., Campobasso, C. P., Zehner, R. and Hall, M. J. (2011). Forensic entomology: applications and limitations. *Forensic science, medicine, and pathology*, *7*(4), 379-392.
3. Benecke, M. (2001). A brief history of forensic entomology. *Forensic science international*, *120*(1-2), 2-14.
4. Bergeret, M. (1855). Infanticide, momification naturelle du cadavre. *Ann Hyg Publique Med Leg*, *4*, 442-452.
5. Byrd, J. H. and Tomberlin, J. K. (Eds.). (2019). *Forensic entomology: the utility of arthropods in legal investigations*. CRC press.
6. Catts, E. P. and Goff, M. L. (1992). Forensic entomology in criminal investigations. *Annual Review of Entomology*, *37*, 253–272.
7. Goff, M. L. and Benecke, M. (2000). A Fly for the Prosecution: How Insect Evidence Helps Solve Crimes. *Nature*, *405*(6784), 276-276.
8. Greenberg, B. and Kunich, J. C. (2002). *Entomology and the law: flies as forensic indicators*. Cambridge University Press.
9. Introna, F., Campobasso, C. P. and Goff, M. L. (2001). Entomotoxicology. *Forensic science international*, *120*(1-2), 42-47.
10. Meiklejohn, K. A., Wallman, J. F. and Dowton, M. (2011). DNA-based identification of forensically important Australian Sarcophagidae (Diptera). *International journal of legal medicine*, *125*(1), 27-32.
11. Motter, M. G. (1898). A contribution to the study of the fauna of the grave. A study of on hundred and fifty disinterments, with some additional experimental observations. *Journal of the New York Entomological Society*, *6*(4), 201-231.
12. Pont, A. C. and Matile, L. (1980). Découverte de quelques Insectes de J.-P. Mégnin; identité d'Ophyra cadaverina Mégnin (1894) [Dipt. Muscidae]. *Bulletin de la Société entomologique de France*, *85*(1), 41-43.
13. Wells, J. D. and Škaro, V. (2023). Application of DNA-based methods in forensic entomology. *Forensic DNA Applications*, 285-304.