Eras of Insect Diagnosis: From Historical Insights to the Future Innovations

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ABSTRACT

The classification and identification of insects have evolved over centuries, beginning with Aristotle's Historia Animalium in 384–322 BC, where he described species like bees, ants, and butterflies. Carl von Linné, in 1758, revolutionized taxonomy with his binomial nomenclature, classifying insects into seven orders. Edward Baker, in 1878, emphasized the significance of male genital structures in differentiating species, a method still in use today. While Aristotle established early foundations for studying insects in the Western world, the origins of insect concepts in East Asia are less clear (Ro). Unfortunately, Aristotle's views also contributed to longstanding prejudices against women in scientific studies, a bias that persisted well into the 20th century (Patterson). Despite these limitations, Aristotle's ideas on insect development and classification have had a lasting impact on entomology.

Paul Hebert introduced DNA barcoding in 2003, allowing species identification through genetic markers. This method complements traditional taxonomy by providing quick, accurate identification for researchers and non-experts alike. DNA barcoding has since grown, leading to the creation of the Barcode of Life Database (BOLD), which provides a platform for managing and analyzing genetic data. In recent years, technological advancements have further transformed insect diagnosis.

DNA barcoding using the cytochrome c oxidase I (COI) gene has emerged as a powerful tool for insect identification, complementing traditional morphological methods (Szyp-Borowska & Sikora, 2019; Kachhawa, n.d.). This technique allows for rapid and accurate species identification, particularly useful for cryptic species, larvae, and morphologically similar taxa (Kachhawa, n.d.). The COI gene's effectiveness has been demonstrated in various insect groups, including dragonflies and neuropterans (Almansoori *et al*, 2019) (Zamani *et al*. 2019). However, DNA-based identification may not always provide conclusive results, necessitating morphological verification in some cases (Almansoori *et al*., 2019). The creation of comprehensive DNA barcode reference libraries enhances the efficiency of insect identification and contributes to biodiversity assessments, pest management, and conservation efforts. Despite its limitations, DNA barcoding represents a significant advancement in insect taxonomy, offering a standardized and accessible approach to species identification and phylogenetic analysis (Szyp-Borowska and Sikora, 2019; Zamani *et al*. 2019).

Artificial intelligence and digital object detection systems are now used to automate species identification, though accuracy is still improving. The development of 3D models of common insects, now available on various online platforms, has significantly enhanced the accuracy of identification. These innovations have made insect diagnosis more accessible and precise, highlighting the progress from ancient observational techniques to modern AI-driven tools. The journey through these eras shows how insect identification has transitioned from history to the cutting-edge future of scientific discovery. Insect identification has evolved from traditional methods to automated systems using image processing and machine learning techniques. These systems offer faster and more accurate identification compared to manual methods (Miranda, Gerardo and Tanguilig). Various approaches have been developed, including wing outline analysis using Elliptic Fourier transformation and support vector machines (Yang *et al*. 2015), and order-level identification using artificial neural networks and support vector machines (Wang *et al*. 2012). Recent advancements incorporate

both traditional machine learning and deep learning algorithms for automatic image identification of insects (Gao *et al*. 2024). These systems typically involve image acquisition, preprocessing, segmentation, and detection steps. They have been applied to various insect orders, including Coleoptera, Lepidoptera, Hymenoptera, Diptera, and Orthoptera. Future research directions include constructing reliable public datasets, minimizing photographic subjectivity, exploring interpretable deep learning, and expanding the diversity of studied insect species (Gao *et al*. 2024).

For the present generation, it is crucial to adopt advanced technologies for insect identification, especially for agriculture and related fields. Incorporating DNA barcoding and genetic tools will enhance accuracy and speed in identifying species, including cryptic ones. Artificial intelligence (AI) and machine learning can automate identification processes, allowing real-time monitoring of pest populations. Emphasizing the development of open-access databases and comprehensive datasets will make insect identification more accessible. Additionally, integrating traditional taxonomic knowledge with digital tools ensures holistic and sustainable approaches for future agricultural practices.

Keywords: Insect, Artificial Intelligence, Taxonomy, BCOL, Diversity, Auto Detection.

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