

MODERN PARADIGMS IN BIODIVERSITY IDENTIFICATION AND TAXONOMIC SCIENCES

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Abstract

The accelerating biodiversity crisis necessitates a paradigm shift in taxonomic sciences, moving from traditional, morphology-centric methods to an integrated, technology-driven approach for efficient species discovery, identification, and classification. This review summarizes the modern methodologies that define this new era of taxonomy, focusing on the integration of cutting-edge genomics, high-throughput imaging, bioacoustics, and computational tools to overcome the limitations of classical approaches. High-throughput techniques, such as Next-Generation Sequencing (NGS) and DNA barcoding, now provide rapid, comprehensive genomic data that can resolve cryptic species and reconstruct detailed phylogenetic relationships, thereby addressing the "taxonomic impediment" caused by a shortage of specialists and slow, traditional methods. The modern paradigm of integrative taxonomy synthesizes these diverse data sources to formulate robust and rigorous species hypotheses, often using frameworks that test species boundaries with multiple, converging lines of evidence.

1. Introduction

Biodiversity forms the foundation of ecosystem stability, resilience, and human well-being, yet its rapid decline in the Anthropocene has highlighted the urgent need for accurate species discovery, identification, and classification. Traditionally, taxonomy relied heavily on morphology-based approaches, which, though invaluable, often face limitations in distinguishing cryptic species, resolving hybridization, and keeping pace with the immense diversity of life. The 21st century has witnessed the emergence of modern paradigms in taxonomic sciences, where genomics, high-throughput sequencing, bioinformatics, bioacoustics, and digitized repositories complement classical methods to provide a more holistic and precise understanding of biodiversity. This integrative approach not only addresses the "taxonomic impediment" caused by a shortage of trained experts but also accelerates biodiversity assessment, enhances conservation planning, and broadens applications in fields ranging from agriculture and medicine to climate change monitoring. By uniting traditional and modern tools,

taxonomy is transforming into a dynamic, technology-driven discipline capable of meeting the biodiversity challenges of the future.

1. Challenges and Innovations in Classical vs. Molecular Taxonomy

Classical taxonomy's challenges include its reliance on morphological characteristics, which can be ambiguous, and its difficulty in distinguishing cryptic species and resolving hybridization issues. In contrast, molecular taxonomy faces challenges in the form of high costs, the need for specialized equipment and expertise, and potential limitations in resolving deeper evolutionary relationships or handling incomplete genetic databases. Innovations in classical taxonomy involve integrating additional data types, such as internal structures and ecological information, to provide a broader perspective. In contrast, molecular taxonomy's innovations include DNA barcoding, Next-Generation Sequencing (NGS), and plastid genome sequencing, which offer greater precision, speed, and scale for identifying species and understanding evolutionary patterns.

Challenges in Classical Taxonomy

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