LUCAS TESTIMONIES: CELL EVOLUTION

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Introduction. The last universal common ancestor (LUCA) represents a pivotal stage in cell evolution, serving not only as the bridge between prebiotic chemistry and modern biological systems but also providing insights into the earliest cellular structures and metabolic pathways. Understanding LUCA is essential for reconstructing the origins of cellular life and the divergence of the two domains: Bacteria and Archaea, along with the emergence of Eukaryota with its complexity.
Objective of the study. This study aims to provide a comprehensive synthesis of existing data to determine LUCA's features, evaluating competing hypotheses regarding its metabolism, cellular structure and ecological adaptations, and its impact on the development of cellular complexity.
Materials and Methods. In this literature review, we examined publications from PubMed, Nature, ScienceDirect, and Hinari sources from 1977-2025, using the keywords 'LUCA' and 'cellular evolution'. Most of the publications used dated from 2014 to 2025.
Results. LUCA serves as the foundation of all modern life, yet its precise nature remains uncertain. Researches indicates that LUCA was a community of anaerobic autotrophic cells with a highly functional metabolic system, enabling it to adapt to the conditions of early Earth. The specifics of LUCA's cellular organization remains debated, with some models proposing a membrane-less pre-cellular system, while others advocate for a rudimentary lipid membrane. Recent phylogenetic reconstructions increasingly support the idea that LUCA possessed a lipid membrane, suggesting it had a functionally robust genome capable of encoding essential components for genetic replication, protein synthesis, and energy metabolism.
Conclusions. By exploring LUCA's role in cellular evolution and reconstructing its characteristics, we can gain valuable insights into its diversification in Bacteria and Archaea, the origin of Eukaryota, and its vast complexity. However, key uncertainties remain regarding LUCA's cellular organization, metabolic systems and ecological adaptations. These differing hypotheses underscore the necessity for an integrative approach that combines genomics, phylogenetics, experimental simulations and geology.
Keywords: LUCA, cell evolution, TOL, Bacteria, Archaea, Eukaryota, evolution of metabolic systems, phylogenetic diversification, evolutionary adaptation.