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Evolution of biological innovations in early complex cells

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Considerable debates still exist regarding the origin of the domain Eucarya , as well as the timing and diversification pattern of early eukaryotes between FECA and LECA (first and last eukaryotic common ancestors), and after LECA. Molecular and ultrastructural analyzes provide insights on the evolution of crown groups back to LECA. Regardless of taxonomy, the microfossil record can provide direct evidence for extinct clades and/or for the minimum age of evolution of biological innovations. Population of large (up to 300 µm in diameter) organic hollow vesicles occur in 3.2 Ga marine shallow-water shales of South Africa [1]. Up to 100 µm long, spindle-shaped, flanged, and sometimes hollow vesicles may form chains and are preserved in 3.45 Ga shallow-water marine cherts of Australia [2]. These large and sometimes complex microfossils cannot be placed with confidence in known clades, and could be early prokaryotes, early eukaryotes (between FECA and LECA), or remnants of another domain of life, before LUCA or contemporaneous of the three domains. Whichever their interpretation, these Archean microfossils illustrate the fact that, on the contrary to traditional views, early cells or vesicles do not need to be small and simple. Microfossils become more common in Proterozoic rocks and some of them can be related with confidence to (stem or crown group) eukaryotes, based on a combination of characters unknown so far in prokaryotes, including complex morphology, wall ornamentation, wall ultrastructure, recalcitrant chemistry, excystment structures, division pattern, and complex multicellularity [3]. Most of the time however, phylogenetic placement within the Eukarya is difficult, and molecular clock estimates suggest that preserved unambiguous eukaryotic microfossils (since 1.7 Ga) may belong to stem group eukaryotes (before LECA) or stem or crown lineages within major clades of the eukaryotic crown groups (after LECA) [4]. Anyhow, Proterozoic fossils provide direct or inferential evidence for many basic and important features of eukaryotic biology, including the synthesis of recalcitrant biopolymers in ornamented walls, a dynamic cytoskeleton and endomembrane system that enables cells to change shape (and, in some taxa, to synthesize and emplace plates making up walls), life cycles that include vegetative cells and resting cysts with different types of excystment structures, reproduction by budding and binary division, osmotrophy, photosynthesis (chloroplast), predation, biomineralization, and different grades of multicellularity [5].

References:

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