Session 1 – The Earliest Animals

Fossils of the Ediacara Biota and what they can tell us about animal evolution

Mary L. Droser
University of California, Riverside

Our understanding of the pattern of origination, evolution and extinction of early animal life on this planet is largely based on the fossils of the Precambrian soft-bodied Ediacara Biota, representing the earliest macroscopic animals on Earth, spanning nearly 40 million years of the terminal Ediacaran Period. Much of the early work on the Ediacara Biota focused on systematic affinities and the paleobiological reconstruction of individual taxa with indecisive results. Ediacara taxa have been considered annelids, protozoans, lichen, fungi, bacteria, arthropods, sponges, cnidarians and most dramatically by Seilacher as a “failed experiment” with no living relatives. While it is likely that a number of extant phyla are represented, it remains difficult to recognize key characters in these soft-bodied organisms. A more promising approach is to focus on the ecology and biology of these organisms.

The Ediacara Member of the Rawnsley Quartzite near the Flinders Ranges, South Australia provides an unrivaled opportunity to examine the complex ecological make-up of Earth’s first metazoan habitats because: 1) it is possible to excavate large bedding planes revealing thousands of fossils and 2) many different facies are present. Body fossil genera include well-known forms typical of the White Sea assemblage. However, a range of undescribed forms have also been revealed. Even within this single facies, there is a strikingly significant level of heterogeneity between beds in terms of composition, evenness, and relative abundance. Only some of the heterogeneity can be attributed to taphonomic differences, the rest is likely a result of reflecting varying communities across small-scale environmental gradients within the shallow marine setting. Incised channel fill deposits and associated facies preserve two additional different discrete assemblages – one dominated by large fronds and organisms with a fractal morphology and another dominated by several other previously undescribed fossils. New forms include spicule-bearing multi-element morphologies and abundant tubular constructional morphologies. Evidence of complex reproduction strategies as well as population dynamics demonstrate that Ediacaran ecosystems were complex and heterogeneous. When combined with data from other Ediacaran localities we can begin to put the Ediacara Biota in its rightful place in the context of the overall radiation of animals.

References:

How did the earliest animals make ATP? Clues from the anaerobic mitochondria of modern forms.

William F. Martin  
University of Düsseldorf

The presence and function of mitochondria in eukaryotes that inhabit anaerobic environments was long a biochemical and evolutionary puzzle. Major insights into the phylogenetic distribution, biochemistry, and evolutionary significance of organelles involved in ATP synthesis (energy metabolism) in eukaryotes that thrive in anaerobic environments for all or part of their life cycle have accrued in recent years. Underpinned by many exciting advances, two central themes of that progress have unfolded. First, the finding that all known eukaryotic groups possess an organelle of mitochondrial origin has mapped the origin of mitochondria to the origin of known eukaryotic groups. Second, the phylogeny of eukaryotic aerobes and anaerobes has been found to interleave across the diversity of eukaryotic groups, erasing what once was thought to be a major evolutionary divide between eukaryotic aerobes and their anaerobic relatives. Data from gene, genome, and environmental sequencing projects are rapidly accumulating for eukaryotes that live in anaerobic habitats, giving clues as to what genes they possess or express. However, only for comparatively few organisms are specific biochemical data available concerning the enzymes and pathways that are actually used by the organisms, and the metabolic end products that are excreted by them in their anaerobic habitats. Similarly, the biochemical role that their organelles play in ATP synthesis is known in comparatively few well studied species. Based on those case studies, the talk will focus on the enzymes, pathways and end products of core ATP synthesis in eukaryotic anaerobes, including metazoans, and the participation of their mitochondria therein.

Further reading


Choanoflagellate colony development as a simple model for animal multicellularity

Nicole King
Department of Molecular and Cell Biology
University of California, Berkeley

The evolution of animals from their single celled ancestors represents one of the major transitions in life’s history. The origin of animals was shaped by extensive genomic and gene regulatory innovations, co-option of pre-existing genes to new functions in cell adhesion and signaling, rising atmospheric and oceanic oxygen concentrations, and the subsequent influence of new selective pressures. By studying choanoflagellates, the closest living relatives of animals, my lab aims to reconstruct the biology of the last common ancestor of animals. I will discuss our recent findings regarding the ancestry of animal gene families and the potential connection between genome evolution and animal origins. In addition, I will describe our development of a colony-forming choanoflagellate, Salpingoeca rosetta, as a new model for investigating the origin of animal multicellularity. Through our study of S. rosetta, we have discovered that a developmental switch in choanoflagellates is regulated by a secreted signal from environmental bacteria. Explaining how the intersection of genetic novelty, gene co-option, and environmental interactions contributed to the transition to multicellularity has important implications both for understanding early animal evolution and for identifying the foundations of animal cell biology.

References:

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The Cambrian explosion continues to defy explanation, primarily because of the difficulty in distinguishing between evolutionary origins vs. geological first appearances. The development of an accurate molecular clock though can test between these two alternatives, and recent studies show that the origins of most animal phyla occurred during the Ediacaran, and, in some cases, even during the late Cryogenian. Nonetheless, the Cambrian explosion might still be an evolutionary event as it could represent the time when maximum morphological disparity was achieved, a time characterized by a relatively high rate of morphological evolution, and/or the time when morphological complexity was achieved. A Non-Metric Multidimensional Scaling analysis of a cladistic character matrix shows that while some clades exhibit maximal initial disparity achieved during the Neoproterozoic, others have continued to explore and expand the limits of morphospace throughout the Phanerozoic. Combining this data set with the molecular data set allows rates of morphological evolution to be measured, and again although some clades show episodes of high rates of morphological evolution, none of these episodes occurred during the Cambrian. Finally, systematic surveys of metazoan microRNA repertoires reveals that simple animals like acoel flatworms are not primitively simple, but instead are secondarily reduced, and that morphological complexity was achieved early in bilaterian history, long before the Cambrian explosion. Therefore, while the Cambrian is still marked by the advent of predation with its multifarious ecological ramifications, ultimately the “cause” of the Cambrian explosion is most likely taphonomic, and represents an “explosion” of fossils rather than animals.

References: