**Evolutionary transitions to multicellular life: Principles and mechanisms**

**Editors Inaki Ruiz-Trillo and Aurora M. Nedelcu**

Twenty two articles are here divided into five sections describing 1) research aimed at locating examples of multicellularity in the Tree of Life; 2) model multicellulars; 3) different theoretical approaches to multicellularity; 4) insights from comparative genomics; and 5) insights from research into molecular mechanisms underlying multicellularity.

The aim of the collection is to explore the ‘How?’s, ‘Why?’s, ‘When?’s and ‘Where?’s of the transition to multicellularity, but there is also considerable discussion of ‘What?’ It is noticeable that most papers in the collection begin with a statement about the frequency with which transitions to multicellularity have taken to place and that, furthermore, these statements vary wildly. The highest estimate is of 26 independent transitions (Sebé-Pedrós & Mendoza), shrinking to nine independent origins of differentiated cell types (Herron & Nedelcu), 7 origins of ‘extensive spatial cellular differentiation’ (Sebé-Pedrós & Mendoza) and five independently evolved eukaryotic groups (Cock & Collén). Valentine & Marshall claim that only *two* clades - metazoa and embryophyta – evolved properly complex multicellularity.

This is to be expected when there is plasticity in the underlying concept. Some authors adopt a very permissive definition, allowing an organism to qualify as multicellular as long as there is physical attachment between cells (Solé & Duran-Nebreda) that may be transient or only facultative (Herron & Nedelcu) while others are much stricter, accepting only lineages with sophisticated gene regulatory networks (Valentine & Marshall). Most authors are explicit that any threshold is arbitrary (although Cock & Collén mount an unconvincing argument for excluding organisms with less than 8 cell types) as they endeavour to identify key traits, common to all multicellulars, at the level of morphology, genomics or proteomics.

Several chapters bust the myth of any simple correlate of increasing complexity in multicellular lineages, although the hypothesis that complexity correlates with the abundance of transcription factors is evidently popular. Srivastava’s article stands out for the clarity with which it describes the phylogenetic points of origin of various multicellularity-asssociated genes, as well as for the important caution that we may yet have underestimated the complexity with which so-called simple animals are organised (p. 290).

Along with the usual suspects - metazoans, slime moulds and volvocine algae - new models are presented from overlooked groups such as red and brown algae (Cock et al; Cock & Collén) filastereans and ichthyosporeans (Suga & Ruiz-Trillo). These yield some important correctives to the metazoan bias, including the identification of a third mode of multicellular development – cellularisation of a syncytium – to go alongside incomplete separation and aggregation of cells (Suga & Ruiz-Trillo, p. 125); and the recognition of polyploidisation as an important mechanism for generating transcriptional diversity (Lang & Rensing). It is interesting to see that the inclusion of additional lineages has led to a downwards revision of earlier claims about genes that are unique to multicellular animals (Tweedt & Erwin; Suga & Ruiz-Trillo).

There are some truly pioneering perspectives, such as an article which details a neat study subjecting various adaptive hypotheses for multicellularity to empirical investigation (Solari et al); another proposing a compelling hypothesis implicating optical physics in the evolution of multicellular polarity (Kessler et al); and another an interesting proposal for viewing life cycle evolution as driven passively by variation in cellular birth and death rates, rather than by selection (Rossetti & Bagheri).

Altogether the collection provides a comprehensive explanation for why there are no simple answers to when multicellularity first appeared, how many times it appeared, or why/how.

Ellen Clarke, All Souls College, University of Oxford, 27 High Street, Oxford OX1 4AL