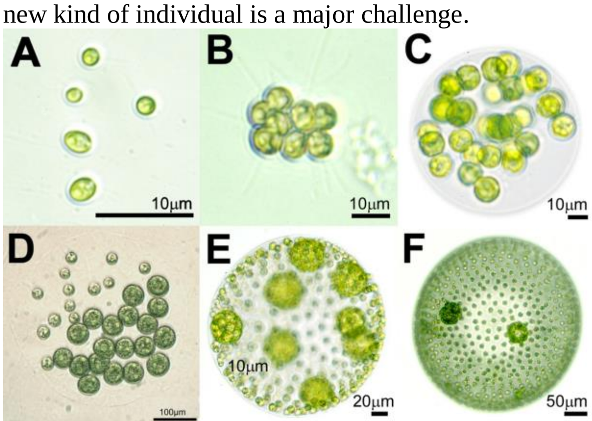
A Darwinian approach to complexity: Evolution of individuality in the volvocine green algae. R. E. Michod, Dept. Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ 85721. michod@u.arizona.

Abstract: Evolution occurs not only through mutational change in populations but also during evolutionary transitions in individuality (ETIs)—when groups become so integrated that they evolve into a new higher-level individual [1,2]. Indeed, the major landmarks in biological complexity in the hierarchy of life are a series of ETIs: from non-life to life, from genes to gene networks to the first genome [3], from gene networks to the first cell, from prokaryotic to eukaryotic cells, from single cells to multicellular organisms, and from solitary individuals to societies. Understanding why and how individuals form groups that evolve into a new kind of individual is a major challenge.



Examples of volvocine species varying in cell number, colony volume, degree of specialization, and proportion of somatic cells. (A) C. reinhardtii, a unicell. (B) Gonium pectorale, a flat or curved sheet of 8-32 undifferentiated cells. (C) Eudorina elegans, a spherical colony of 16-64 undifferentiated cells. (D) Pleodorina californica, a spherical colony with 30-50% somatic cells. (E) V. carteri. (F) Volvox. aureus. Where two cell types are present (D-F), the smaller cells are somatic cells and the larger cells are reproductive cells. Picture credit: C. Solari and M. Herron.

My research group has developed a general theory for ETIs [e.g., 2,4,5], and has been testing this theory using the volvocine green algae as an experimental model [e.g., 6,7,8]. ETI theory describes how fitness can be reorganized and transferred from a lower to a higher level, thus explaining how a more inclusive, complex unit of evolution may evolve. This theory explains why life on Earth is organized hierarchically and predicts hierarchically nested units to be a universal feature of life.

Due to the morphological diversity in these algae, we can investigate the genetic basis for the evolution of key phenotypes spanning the unicellular to multicellular ETI. In no other experimental model is such an undertaking feasible.

Germ and somatic cells present in panels D-F in the above figure correspond to the two major fitness components (reproduction and viability) of any Darwinian entity; their evolution is a critical part of explaining how and why a cell group sometimes evolves into a new evolutionary individual. We have been working to understand the evolution of the regA gene family which plays a central role in germ soma division of labor (G-S DOL) in the volvocine algae. We have identified regA-like genes in diverse species using PCR and genomic approaches [9].

Along with other labs (especially B. Olson at U. Kansas and P. Durand at WITS in South Africa), we have been using genomics to identify the genetic bases for other phenotypic steps to multicellularity. Whole genomes are being sequenced from key species, identified based on their manifestation of specific major steps to multicellularity. We and other groups are investigating the origin and complexity of gene families in terms of their role in phenotypes associated with the ETI.

Much of this work will likely be reported in other talks by the lead investigators involved. In my talk I will report on one or two projects, but at the time of writing this abstract I am not sure which projects I will talk about! Hence the very general overview given here.

References: [1] Maynard Smith, J. & Szathmáry, E. 1995 *The major Transitions in Evolution*. W.H. Freeman. [2] Michod, R. E. 1999 *Darwinian dynamics: evolutionary transitions in fitness and individuality*. Princeton University Press. [3] Durand, P. M. & Michod, R. E. 2010 Genomics in the light of evolutionary transitions. *Evolution* **64**, 1533–1540. [4] Michod, R. E. 2006. *Proc. Natl. Acad. Sci. USA* **103**, 9113–9117. [5] Michod, R. E. 2010 In *Major Transitions in Evolution Revisited* (eds K. Sterelny & B. Calcott) Konrad Lorenz Institute. [6] Nedelcu, A. M. & Michod, R. E. 2006. *Mol. Biol. Evol.* **23**, 1460–4. [7] Herron, M. D., et. al. 2009. *Proc. Natl. Acad. Sci. USA* **106**, 3254–3258. [8] Herron, M. D., et al. 2014. *Evol. Ecol. Res.* **16**, 203–221. [9] Hanschen, E. R., Ferris, P. J. & Michod, R. E. 2014. *Evolution.* **68**, 2014–25.