Transcriptomic analysis of *Volvox carteri* cell types yields insights into the evolutionary origins of germ and somatic differentiation programs

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Abstract:

Germ-soma differentiation is a hallmark of complex multicellular organisms, yet its origins are not well understood. *Volvox carteri* is a simple multicellular green alga that has recently evolved a simple germ-soma dichotomy with only two cell types: large germ cells called gonidia and small terminally differentiated somatic cells. We conducted a comprehensive characterization of the gonidial and somatic transcriptomes of Volvox to uncover fundamental differences between the molecular and metabolic programming of these cell types. We found extensive transcriptome differentiation between the gonidial and somatic cells of Volvox with somatic cells expressing a more specialized program overrepresented in younger, lineage-specific genes, and gonidial cells expressing a more generalist program overrepresented in more ancient genes that shared striking functional overlap with a gene set from core metazoan pluripotent stem cells. Directed analyses of metabolic pathways revealed a strong dichotomy between cell types with gonidial cells expressing growth-related genes and somatic cells expressing an altruistic metabolic program geared towards the assembly of flagella, which support organismal motility, and conversion of storage carbon to sugars, which act as donors of extracellular matrix glycoproteins whose secretion enables massive organismal expansion. Volvox orthologs of Chlamydomonas diurnally regulated genes were analyzed for cell-type distribution and found to be strongly partitioned, with expression of dark-phase genes overrepresented in somatic cells and light-phase genes overrepresented in gonidial cells, a result that is consistent with cell type programs in Volvox arising by cooption of temporal regulons in a unicellular ancestor. Together our findings reveal fundamental molecular, metabolic, and evolutionary mechanisms that underlie the origins of germ-soma differentiation in Volvox and provide a template for understanding the acquisition of germ-soma differentiation in other multicellular lineages.