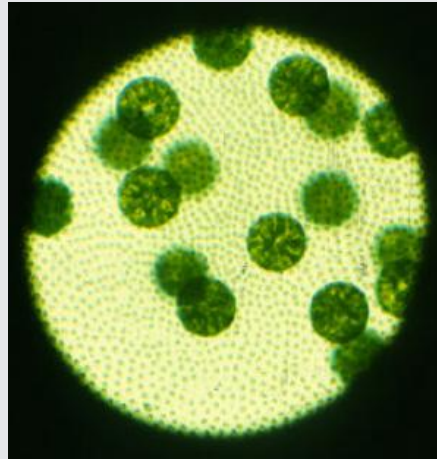


# Beyond germ/soma: the evolution of many cell types



*Kirk & Kirk 2004*

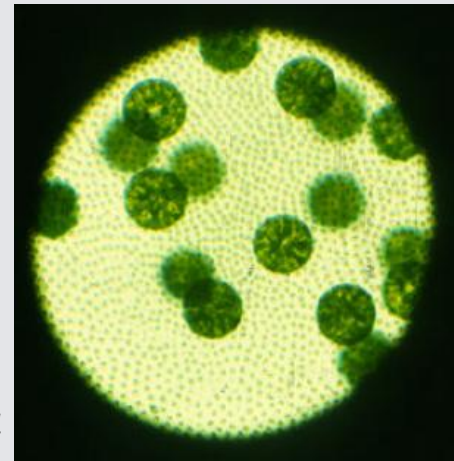
ER Hanschen & RE Michod

February 6<sup>th</sup>, 2013

KITP Cooperation and the Major Evolutionary Transitions

# Evolution of Division of Labor

- Feature of evolutionary transitions such as multicellularity  
(Michod 2006, Michod 2007)
- Functional integration and fitness decoupling



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Michod 2006

Willensdorfer 2008

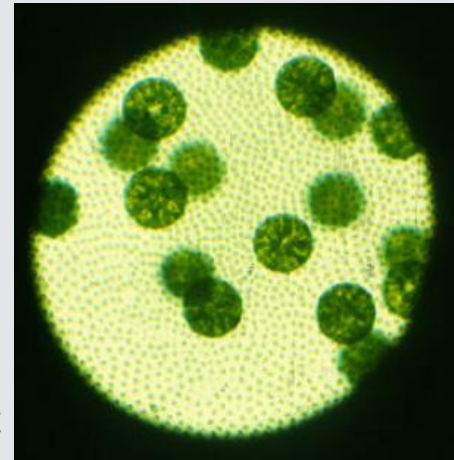
Willensdorfer 2009

Gavrilets 2010

Ispolatov *et al.* 2011

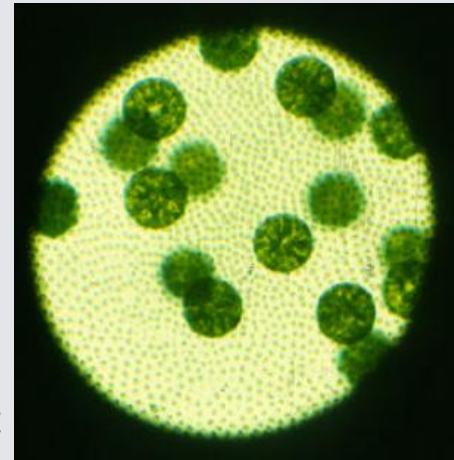
Rueffler *et al.* 2012

Kirk & Kirk 2004



# Evolution of Division of Labor

- Feature of evolutionary transitions such as multicellularity  
(Michod 2006, Michod 2007)
- Functional integration and fitness decoupling
- Many recent models assume two selection pressures and study evolution of two types
- General themes:
  - proportion of each cell type
  - shape of cell level tradeoffs
  - fitness landscape shape

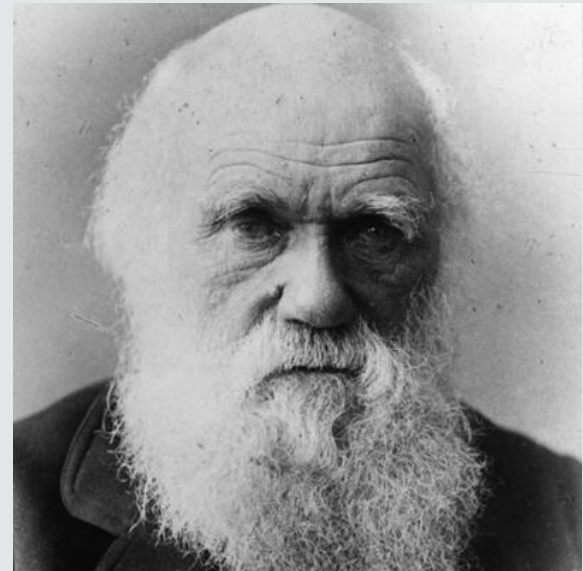


# Cell type isn't limited to two...

- Clearly many species have many cell types
- Previous work on the evolution of division of labor doesn't clearly generalize to 3+ cell types



*Arabidopsis thaliana*

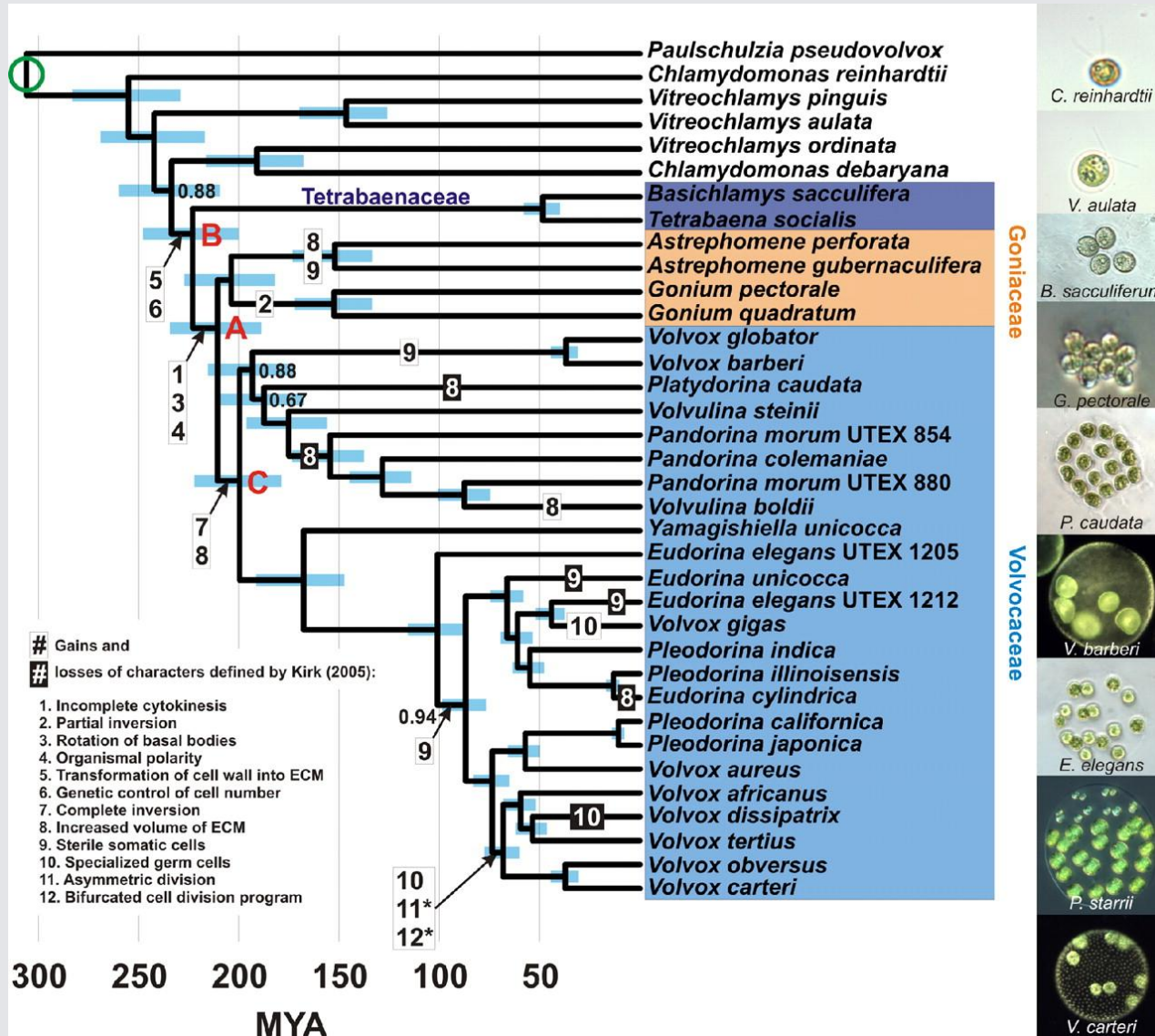


*Homo sapiens*

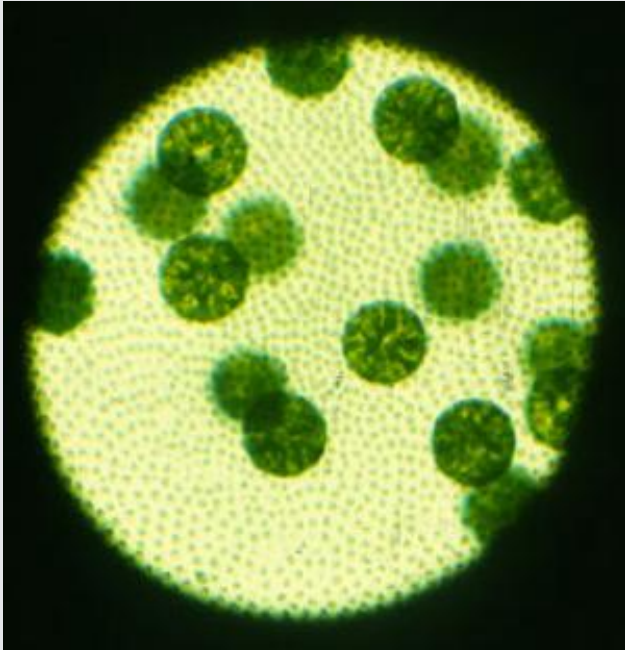
# Cell type isn't limited to two...

- Clearly many species have many cell types
- Previous work on the evolution of division of labor doesn't clearly generalize to 3+ cell types
- Remaining general questions:
  - Shape of the multi-dimensional fitness landscape
  - Optimal cell type proportions
  - Under what conditions does germ/soma diversify?

# Volvocine algae model



# *Volvox carteri*



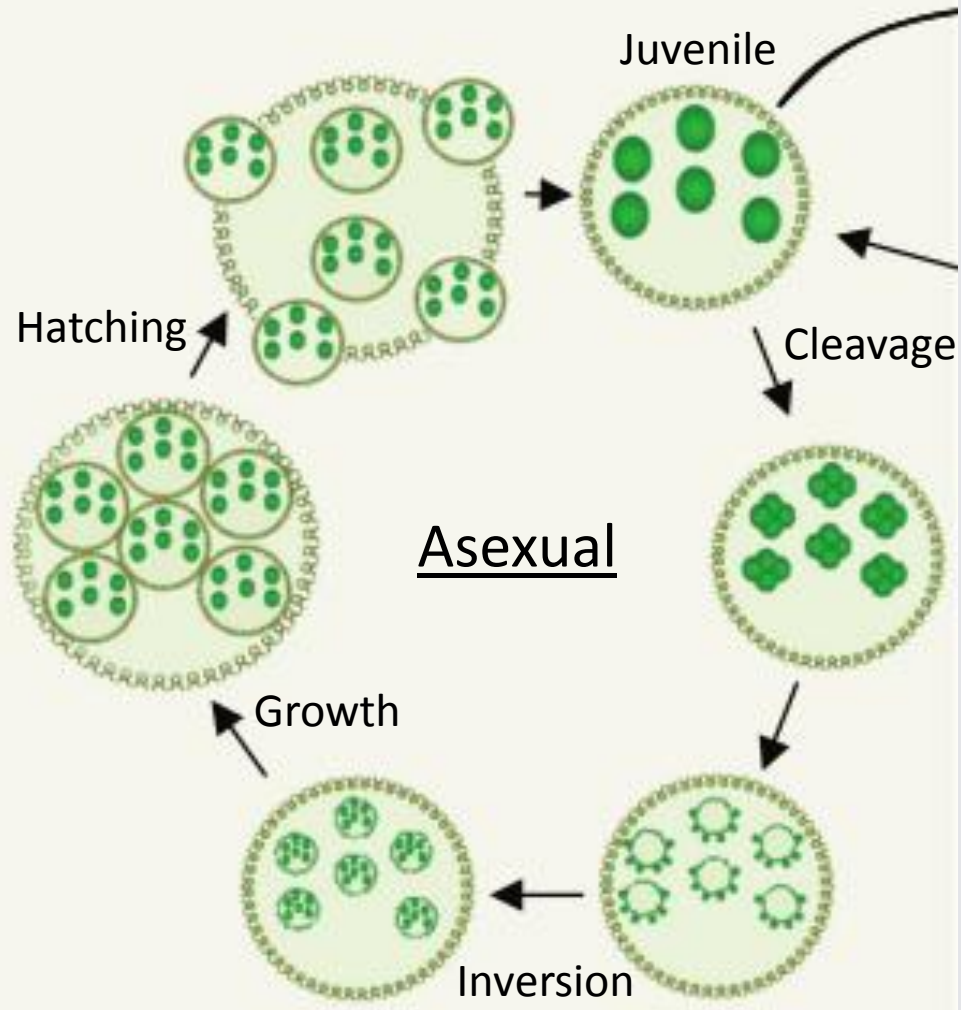
*Kirk & Kirk 2004*

Germ (large) and soma (small) are response to reproduction/survival trade off

Spatial pattern of cell types

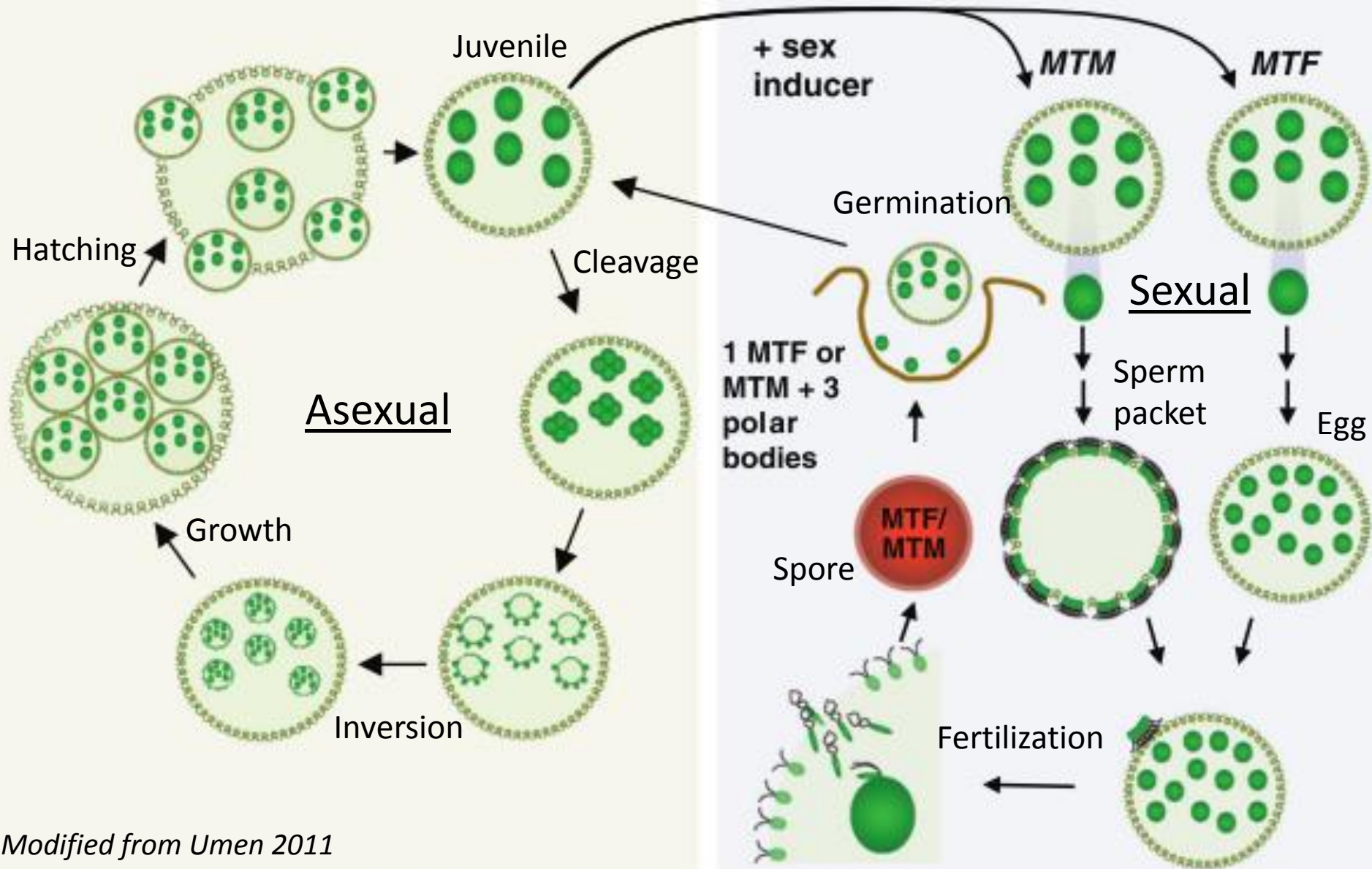


# *Volvox carteri* life cycle



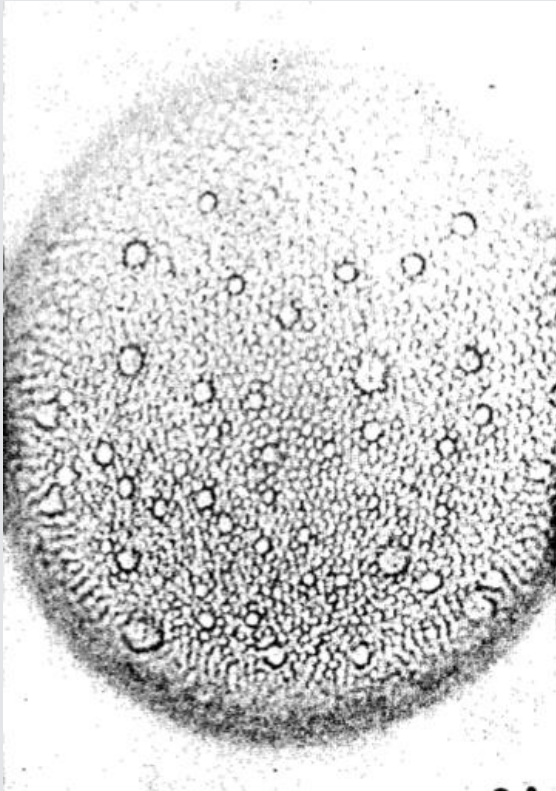
Modified from Umen 2011

# *Volvox carterii* life cycle



Modified from Umen 2011

# *Volvox rousseletii*



*McCracken & Starr 1970*

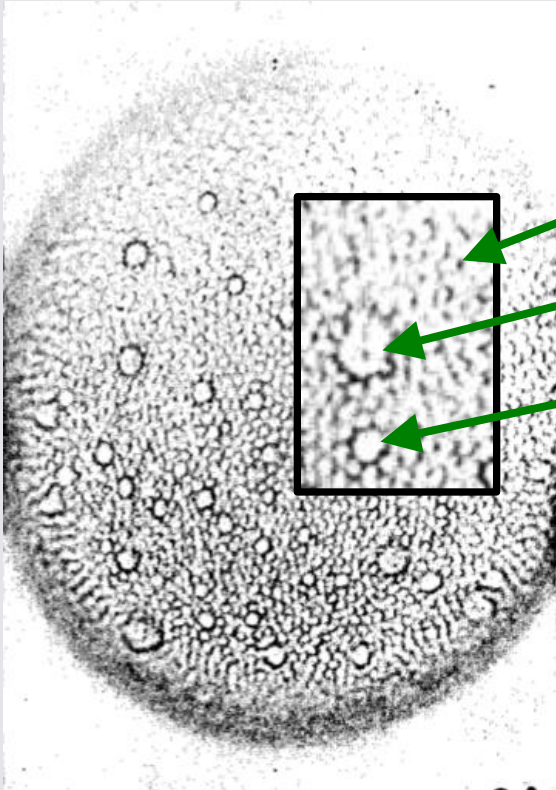
Volvocine algae with 3 cell types

- Small soma cells
- Large germ cells
- Medium cells

# *Volvox rousseletii*

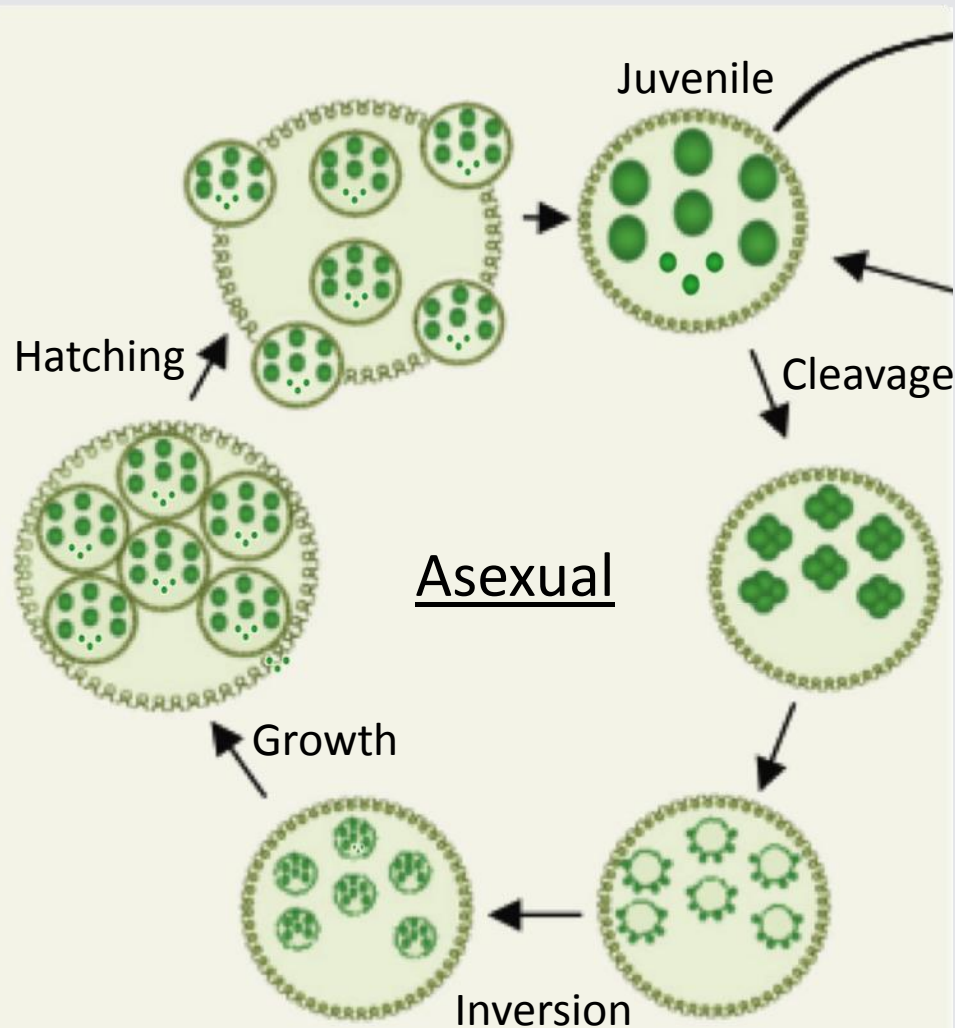
Volvocine algae with 3 cell types

- Small soma cells
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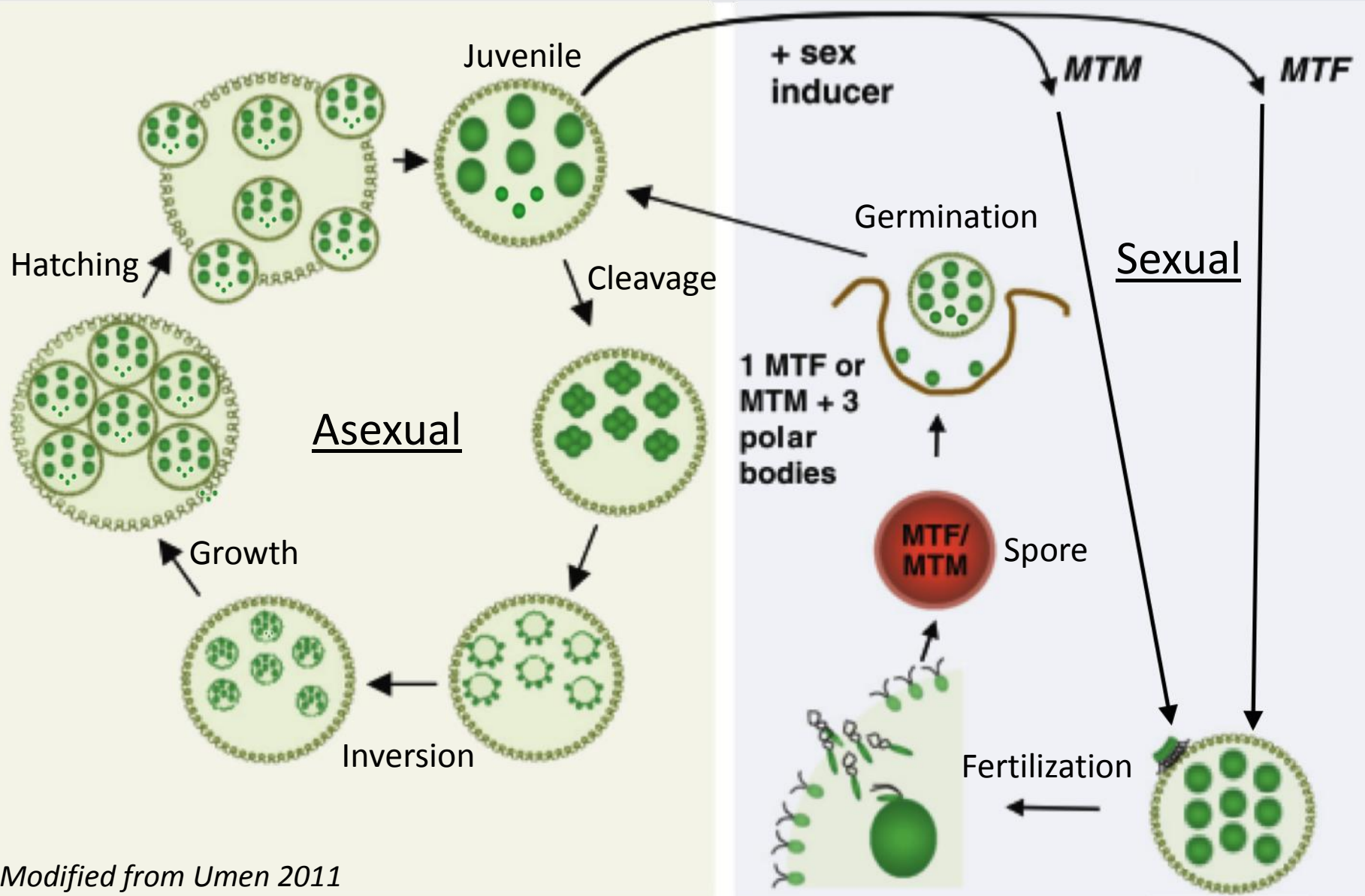


*McCracken & Starr 1970*

# *Volvox rousseletii* life cycle

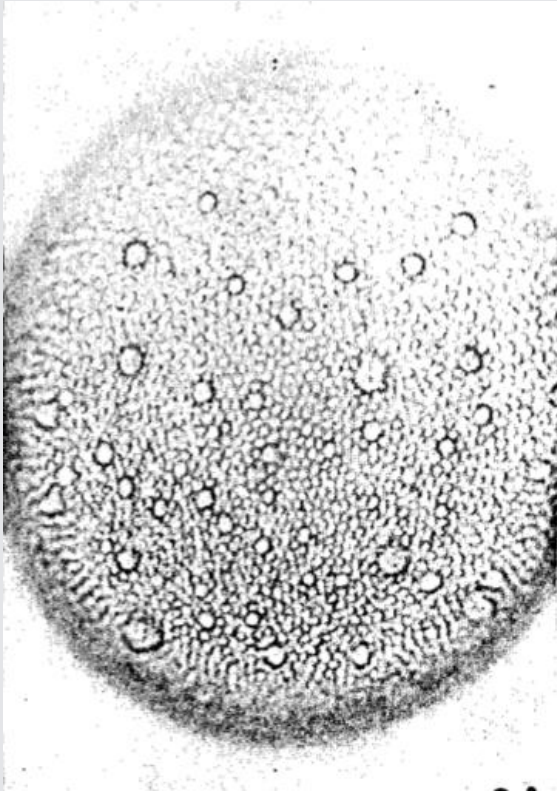


# *Volvox rousseletii* life cycle



Modified from Umen 2011

# *Volvox rousseletii*



*McCracken & Starr 1970*

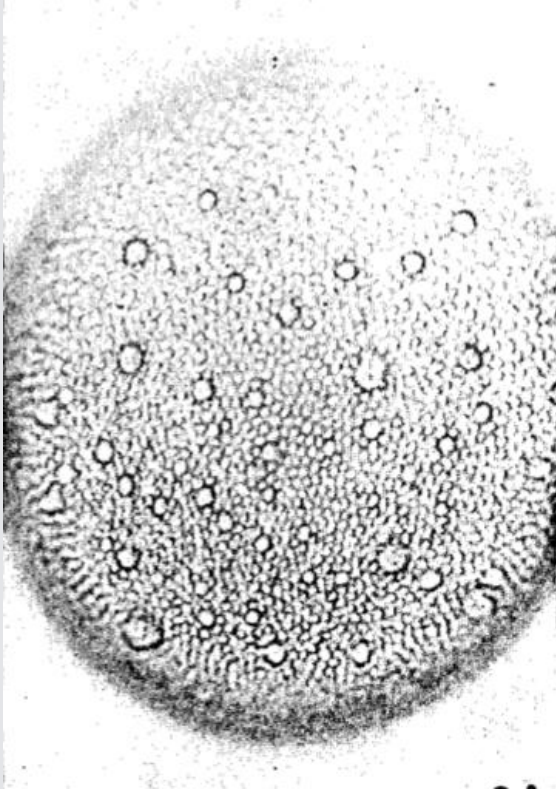
3 cell types differentiated by:

- size
- spatial orientation

3<sup>rd</sup> cell type may be adaptation to asexual/sexual trade off

Asexual/sexual development thought to depend on environmental conditions

# Project Proposal



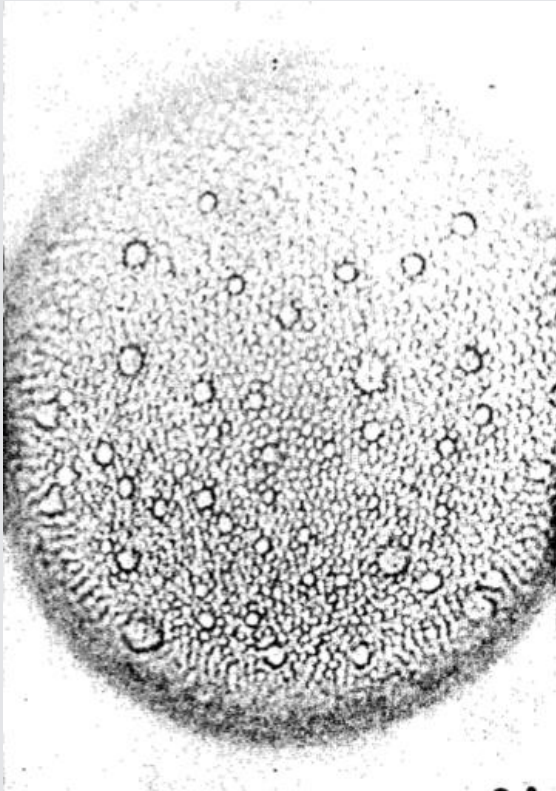
*McCracken & Starr 1970*

*V. rousseletii* transcriptomes

- Look for regulatory differences between cell types



# Project Proposal



*McCracken & Starr 1970*

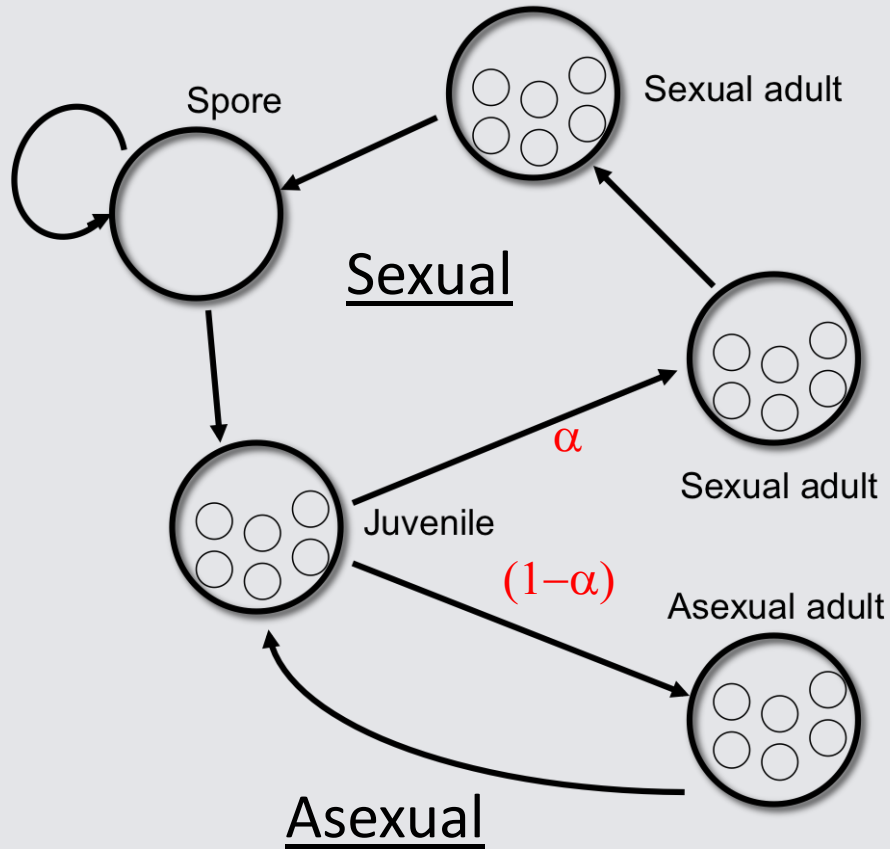
## *V. rousseletii* transcriptomes

- Look for regulatory differences between cell types

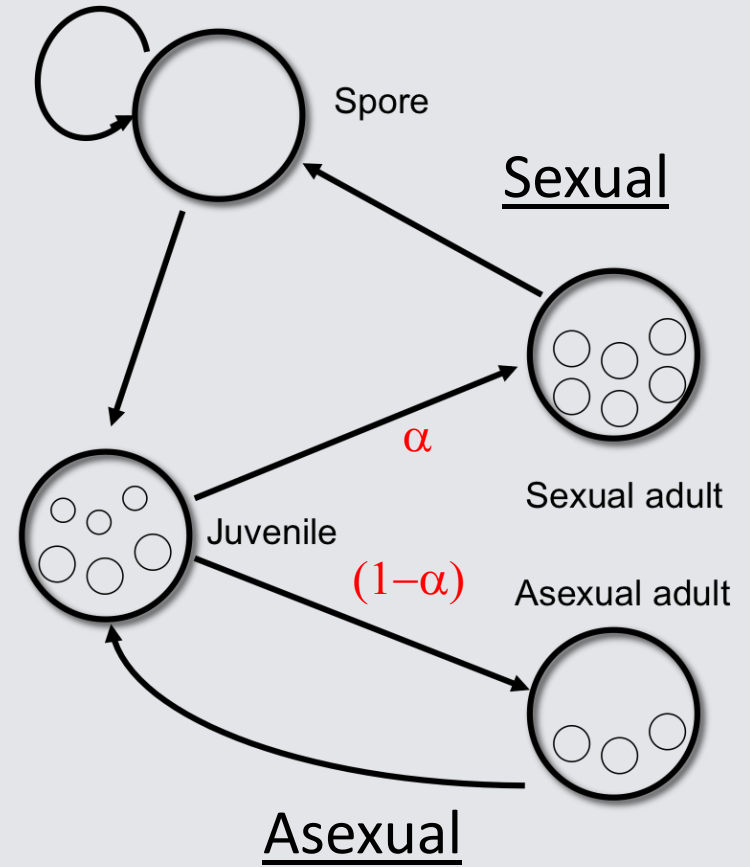
## Life history modeling

- How environmental variation (sex/asex) selects for three cell types

*Volvox carteri*

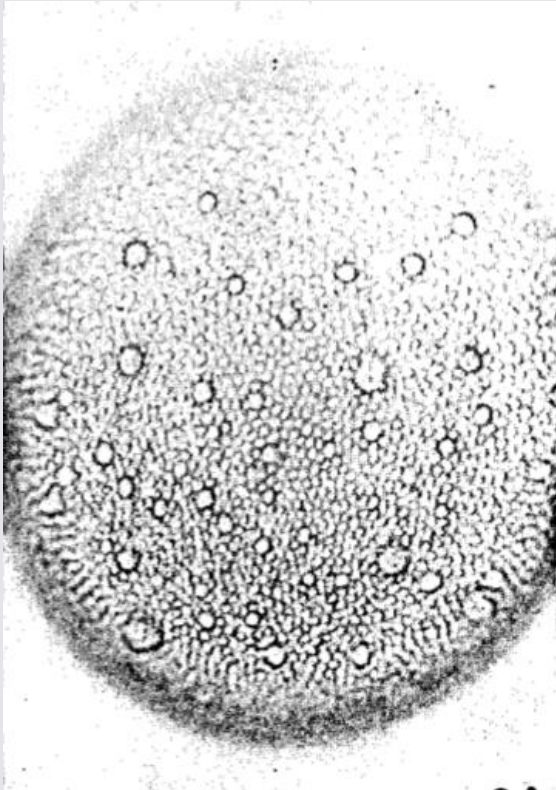


*Volvox rousseletii*



Model changing frequency of sex (based on environment) and autocorrelation of sex

# Project Proposal



McCracken & Starr 1970

## *V. rousseletii* transcriptomes

- Look for regulatory differences between cell types

## Life history modeling

- How environmental variation (sex/asex) selects for three cell types
- Investigate optimal cell type proportion based on environment and physiology

# Acknowledgements

- Michod Lab: Deborah Shelton, Patrick Ferris, Zach Grochau-Wright
- Régis Ferrière (UA), Bradley Olson (KSU), Aurora Nedelcu (UNB)
- Will Driscoll



**THE SECOND INTERNATIONAL VOLVOX CONFERENCE**

Fredericton, New Brunswick, Canada  
July 31st – August 3rd, 2013

**SESSIONS**

- Life Cycle
- Development and Cell Differentiation
- The Physics of Being Multicellular
- Evolution
- Genomics
- Molecular and Evolutionary Genetics
- Taxonomy and Phylogeny
- Genome Data Analysis

"...I saw a very many great round particles, of the bigness of a great corn of sand drive and move in the water...This was to me a very pleasant sight, because the said particles, as often as I did look on them, did neither lye still, and that their motion did proceed from their turning round; and that the more, because I did fancy at first that they were small animals, and the smaller these particles were, the greener was their colour ... These particles had each of them within included 5, 6, 7, nay, some to 12 small round globules, of the same shape as the body wherein they were included." (van Leeuwenhoek, 1700)

Organizer:  
Aurora M Nedelcu – UNB, Canada

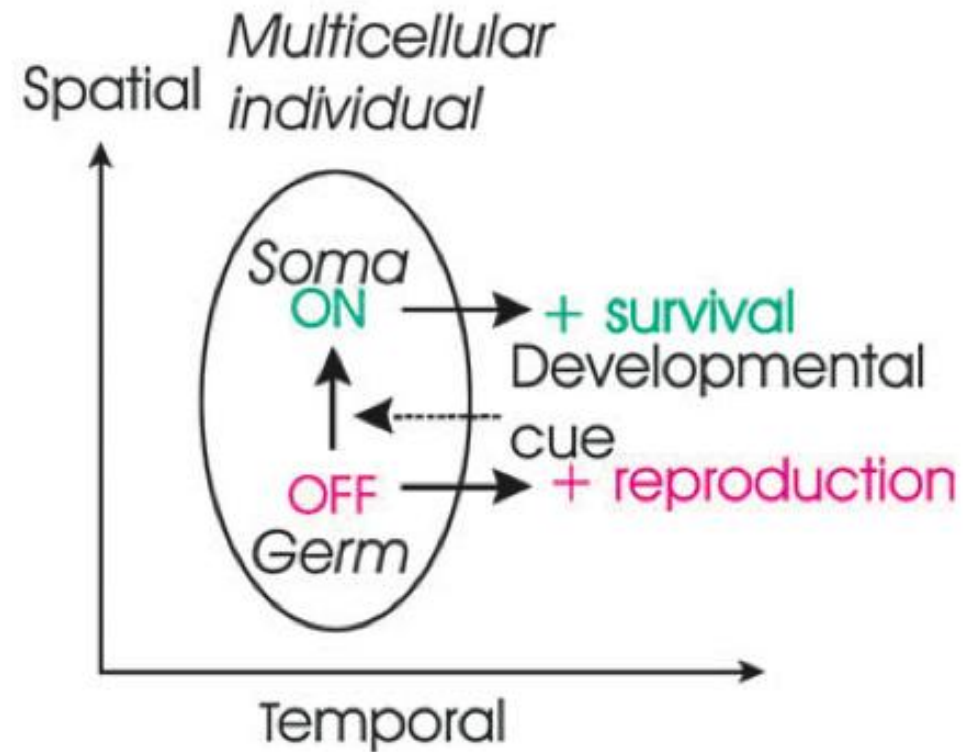
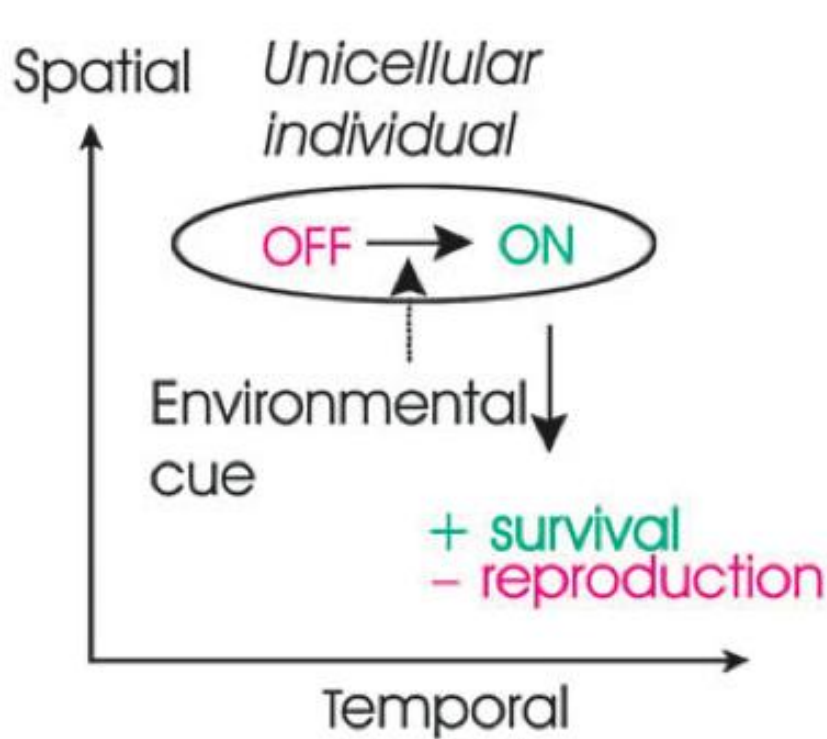
Organizing Committee:  
Matthew Herron – U Montana, USA; Erik Hanschen – U Arizona, USA; David Smith – UBC, Canada; Hisayoshi Nozaki – U Tokyo, Japan; Jim Umen – Donald Danforth Ctr, USA; Stephen Miller – UMBC, USA; Armin Hallmann – U Bielefeld, Germany; Aurelia Honerkamp-Smith – Cambridge, UK.

Sponsorship

Development DMM  
Cell Science  
Environmental Biology  
Biologists

<http://www.unb.ca/vip/IVC2013>

# Temporal to Spatial Differentiation



# Does *V. rousseletii* really have three cell types?

- No: not cellular specialization on unique fitness component
- Yes: cellular specialization on some fitness component
- Yes: cell traits “clearly” advantageous for group level, disadvantageous for cell level
- Yes: distinct cellular development and morphology
- Yes: spatial context of developmental cues maintained and expanded

# Role of Plasticity in Cell Type Evolution

- Schlichting 2003 “Origins of differentiation via phenotypic plasticity”
- Recent work often utilizes plasticity to model the evolution of germ/soma
- Volvox model:
  - *Chlamydomonas* (1 cell type)
  - *Eudorina* (1 type in bad environment, 2 types in good)
  - *Volvox carteri* (2 cell types)
  - *Volvox rousseletii* (3 cell types, depends on environment)