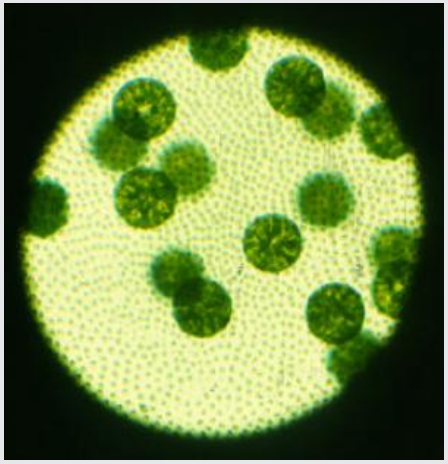
Beyond germ/soma: the evolution of many cell types



Kirk & Kirk 2004

ER Hanschen & RE Michod

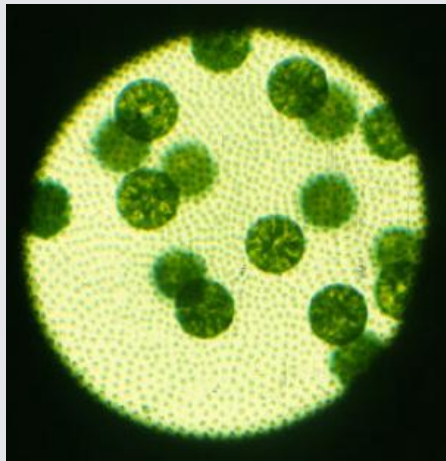
February 6th, 2013

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



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

  Michod 2006

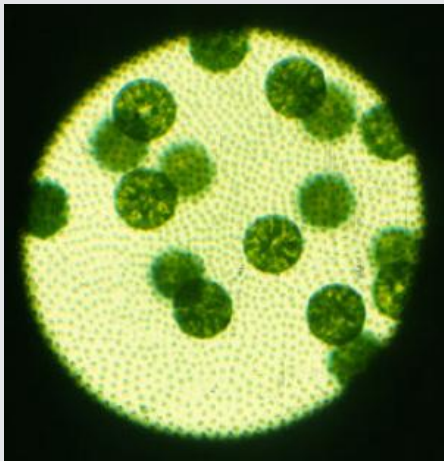
  Willensdorfer 2008

  Willensdorfer 2009

  Gavrilets 2010

  Ispolatov *et al.* 2011

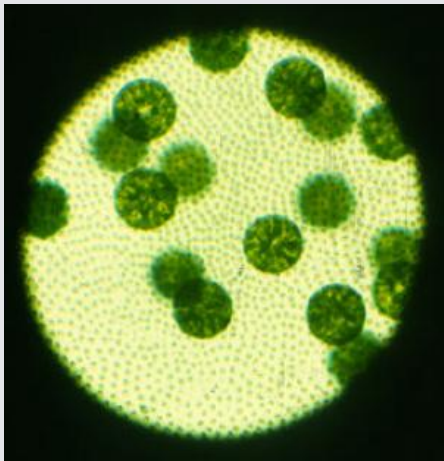
  Rueffler *et al.* 2012



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

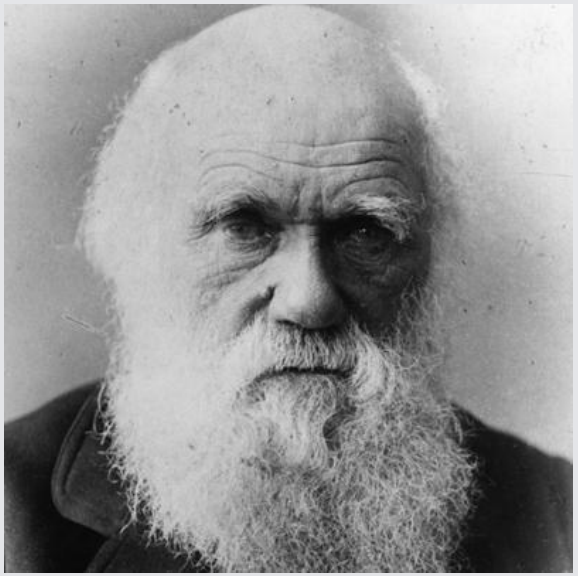


Kirk & Kirk 2004

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

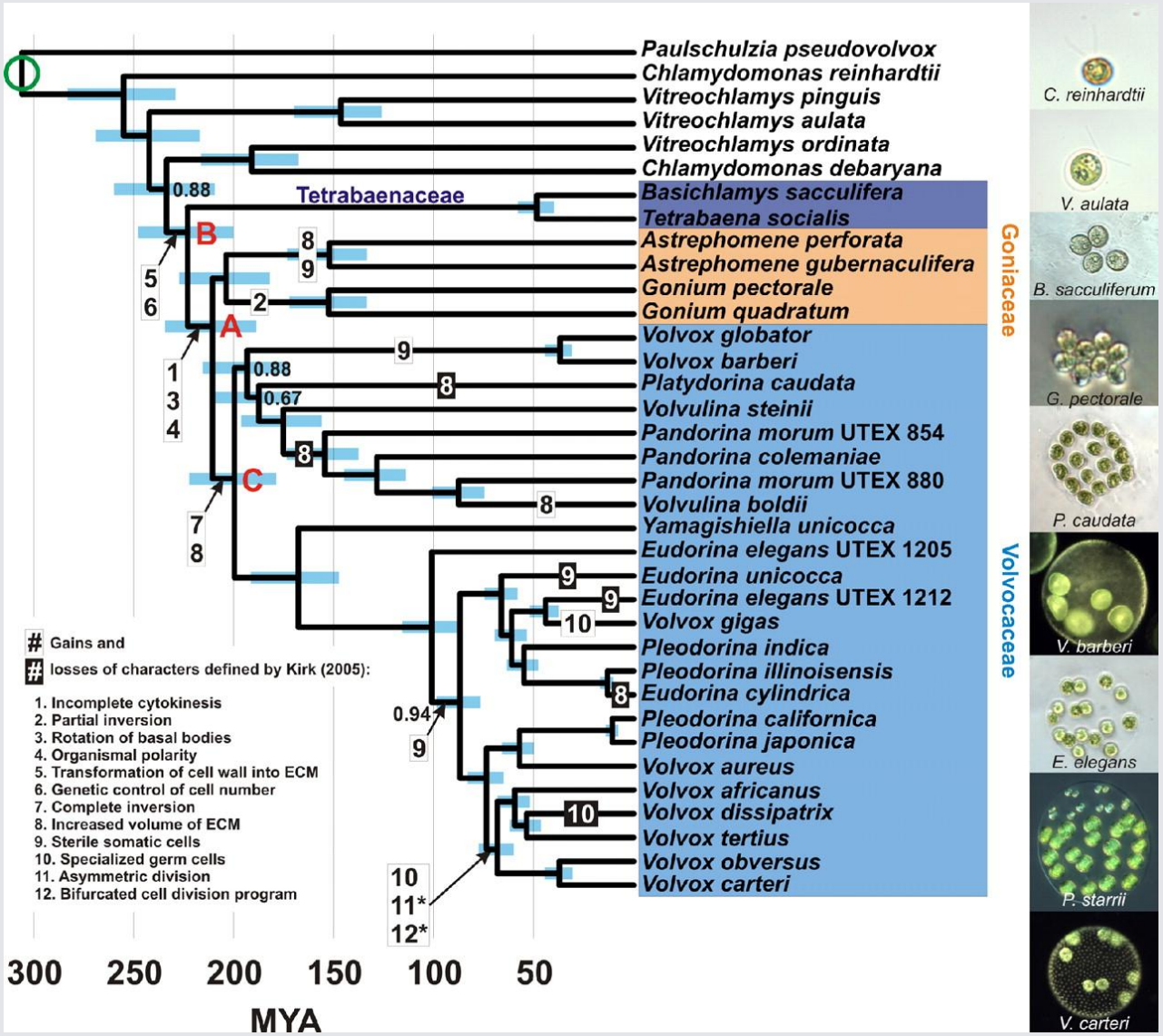


Homo sapiens

Cell type isn't limited to two…

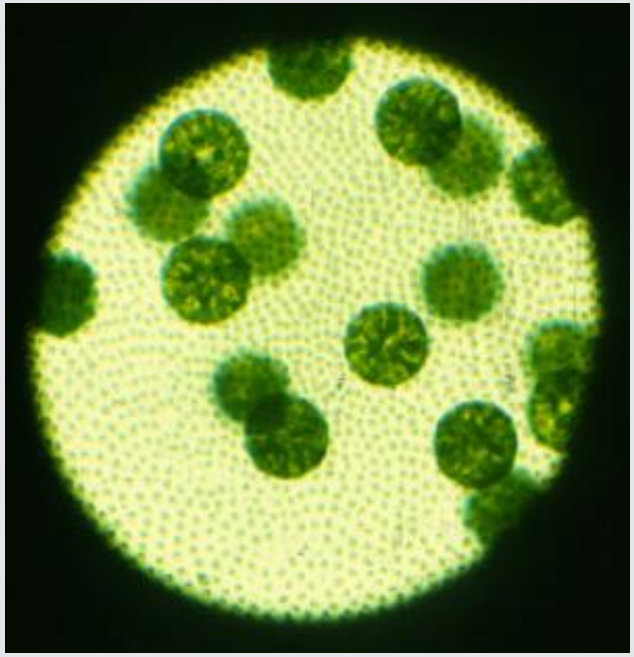
- Clearly many species have many cell types
- Previous work on the evolution of division of labor doesn't clearly generalize to 3+ cell types
- Remaining general questions:
  - Shape of the multi-dimensional fitness landscape
  - Optimal cell type proportions
  - Under what conditions does germ/soma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

Volvocine algae model



Herron et al 2009

Volvox carteri

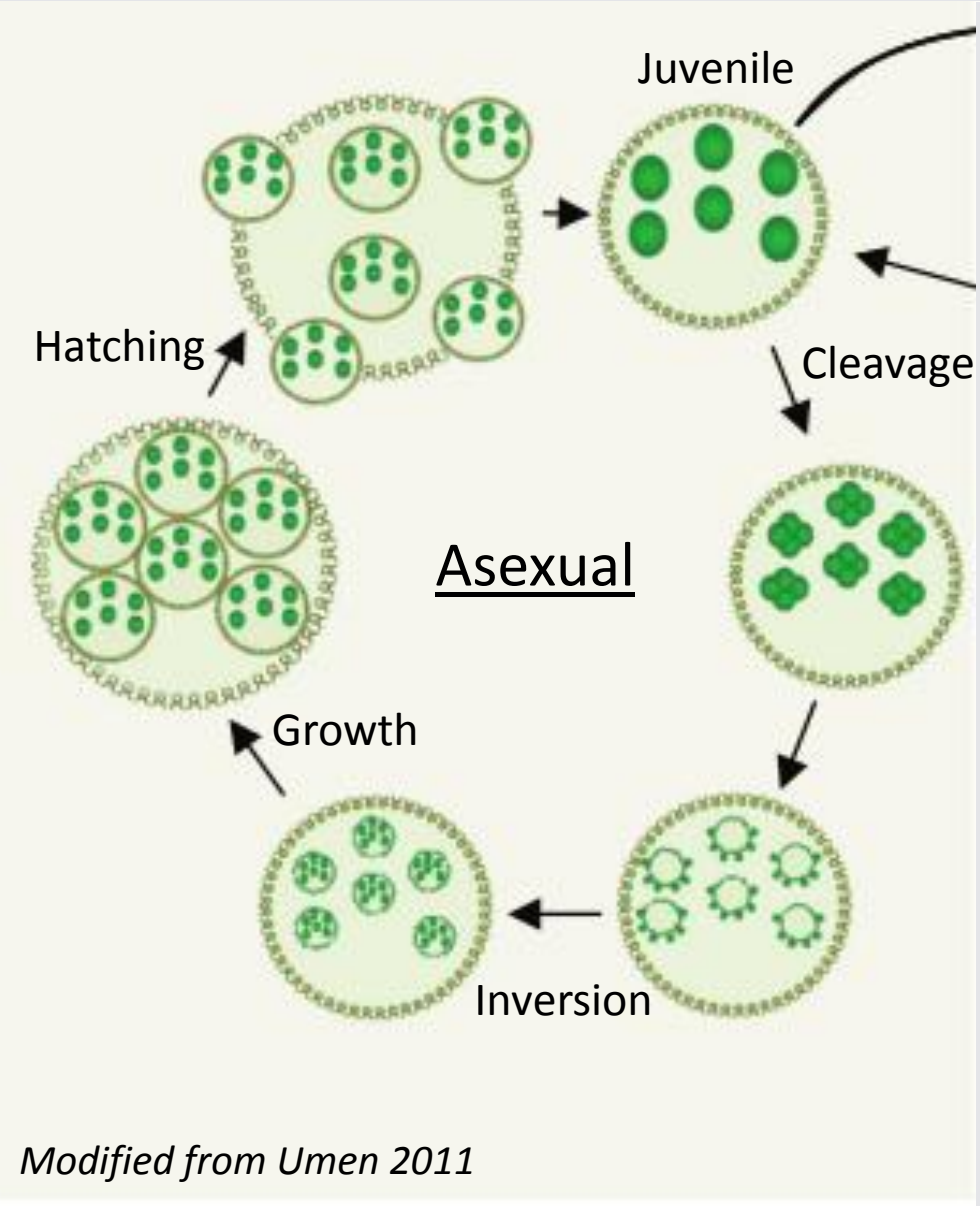


Kirk & Kirk 2004

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

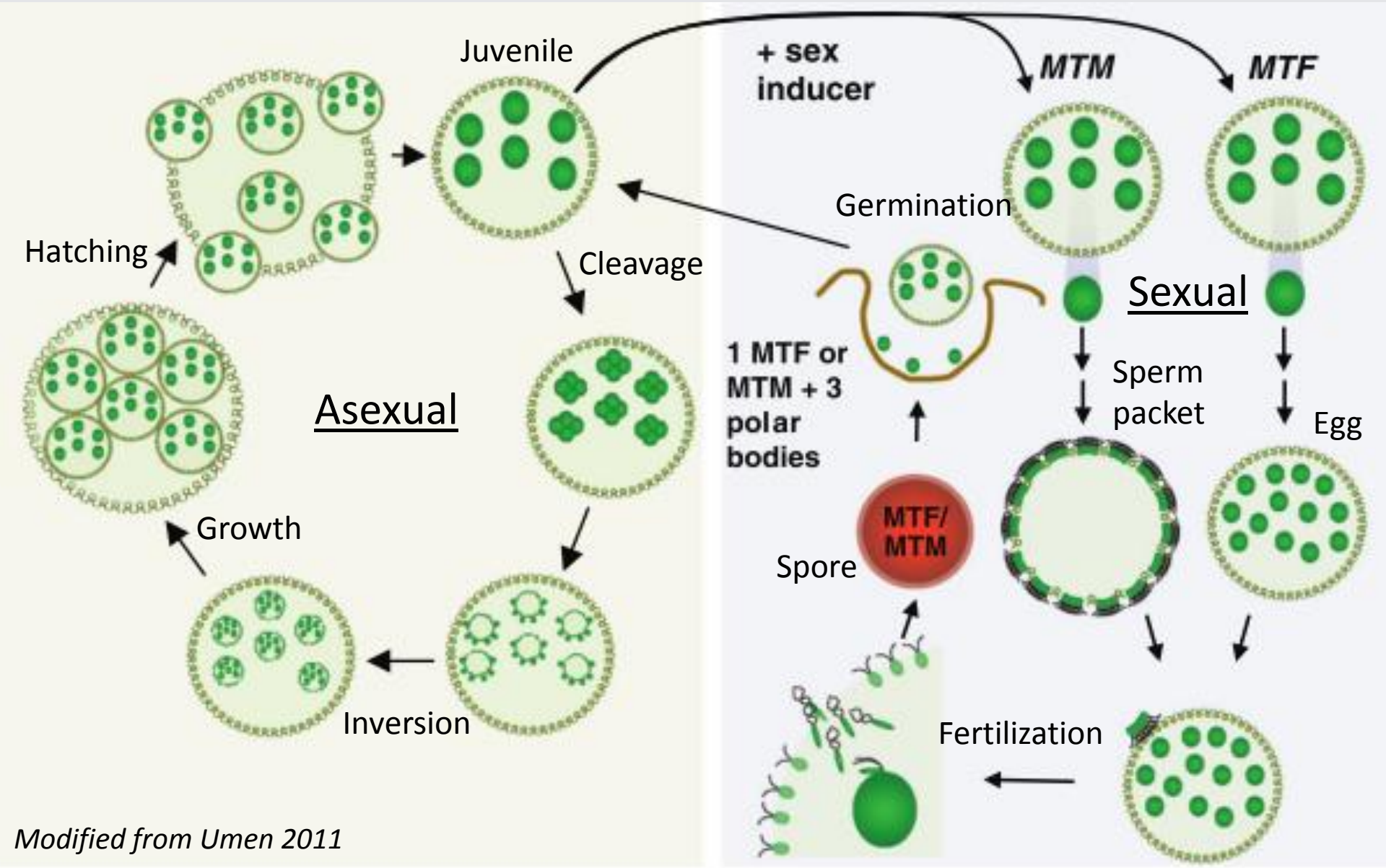
Spatial pattern of cell types

Volvox carteri life cycle



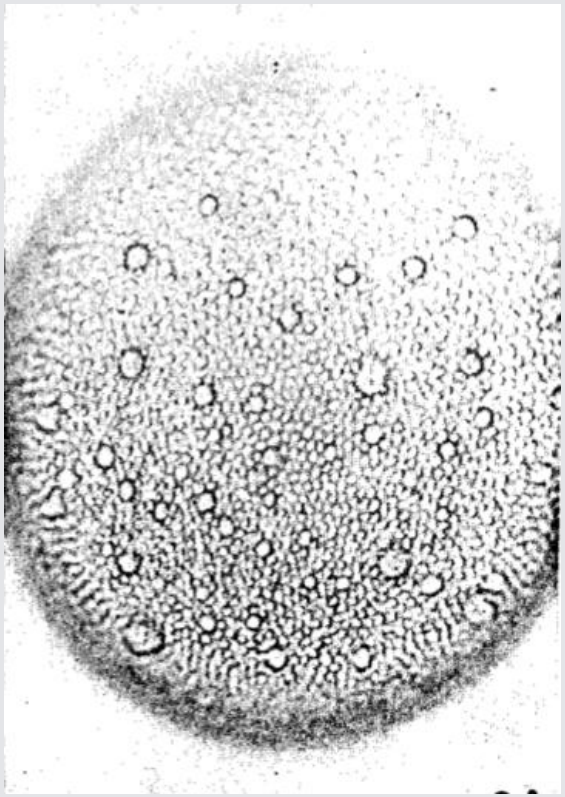
Modified from Umen 2011

Volvox carteri life cycle



Modified from Umen 2011

Volvox rousseletii

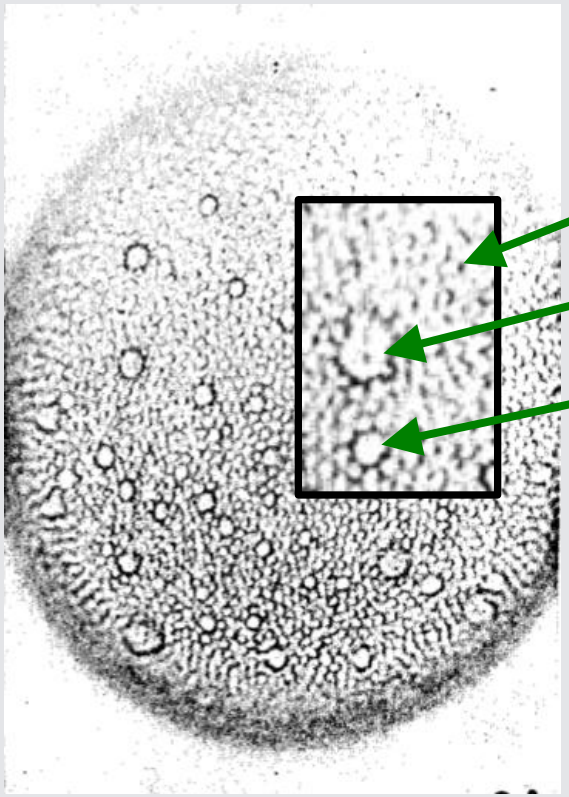


McCracken & Starr 1970

Volvocine algae with 3 cell types

- Small soma cells
- Large germ cells
- Medium cells

Volvox rousseletii

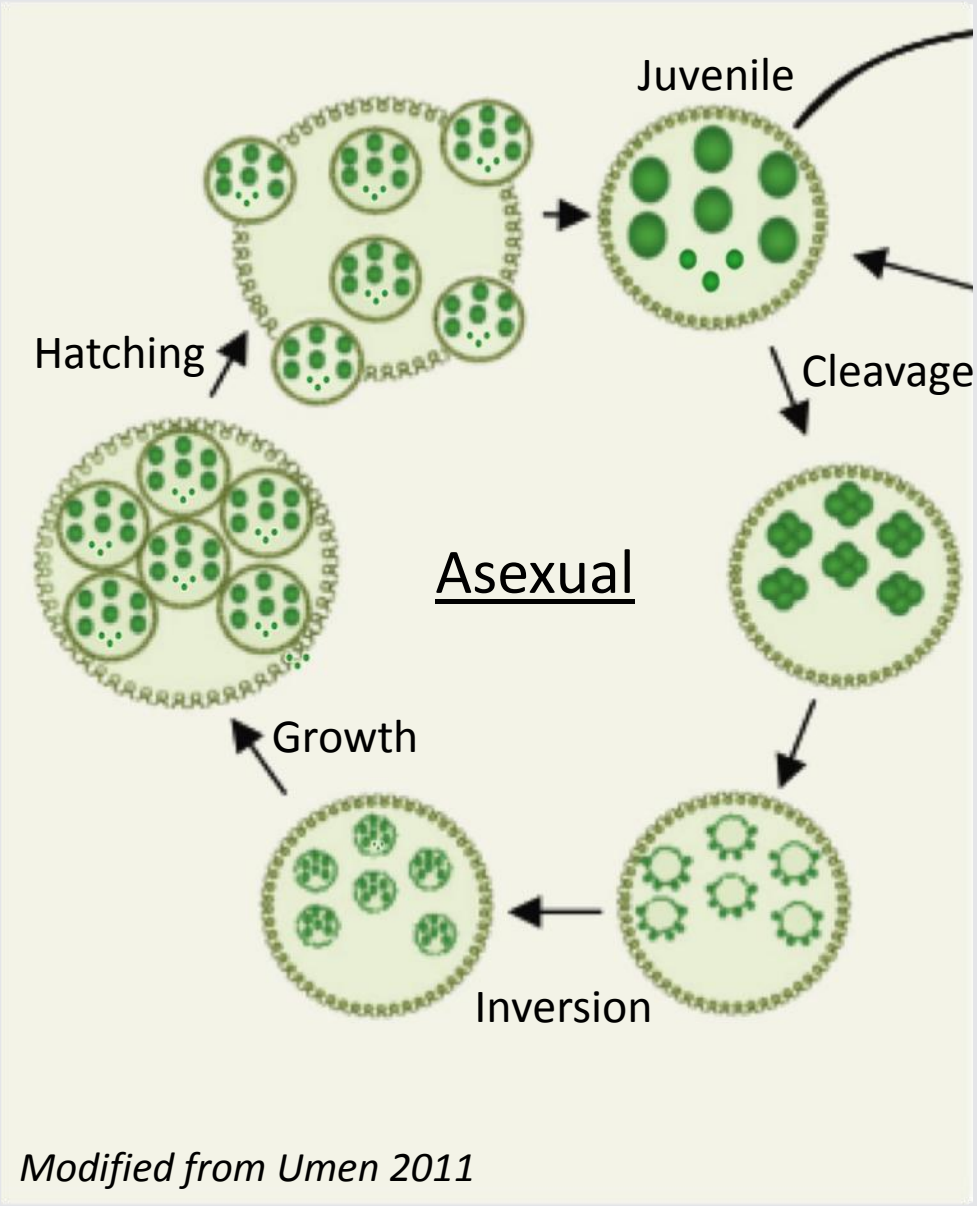


McCracken & Starr 1970

Volvocine algae with 3 cell types

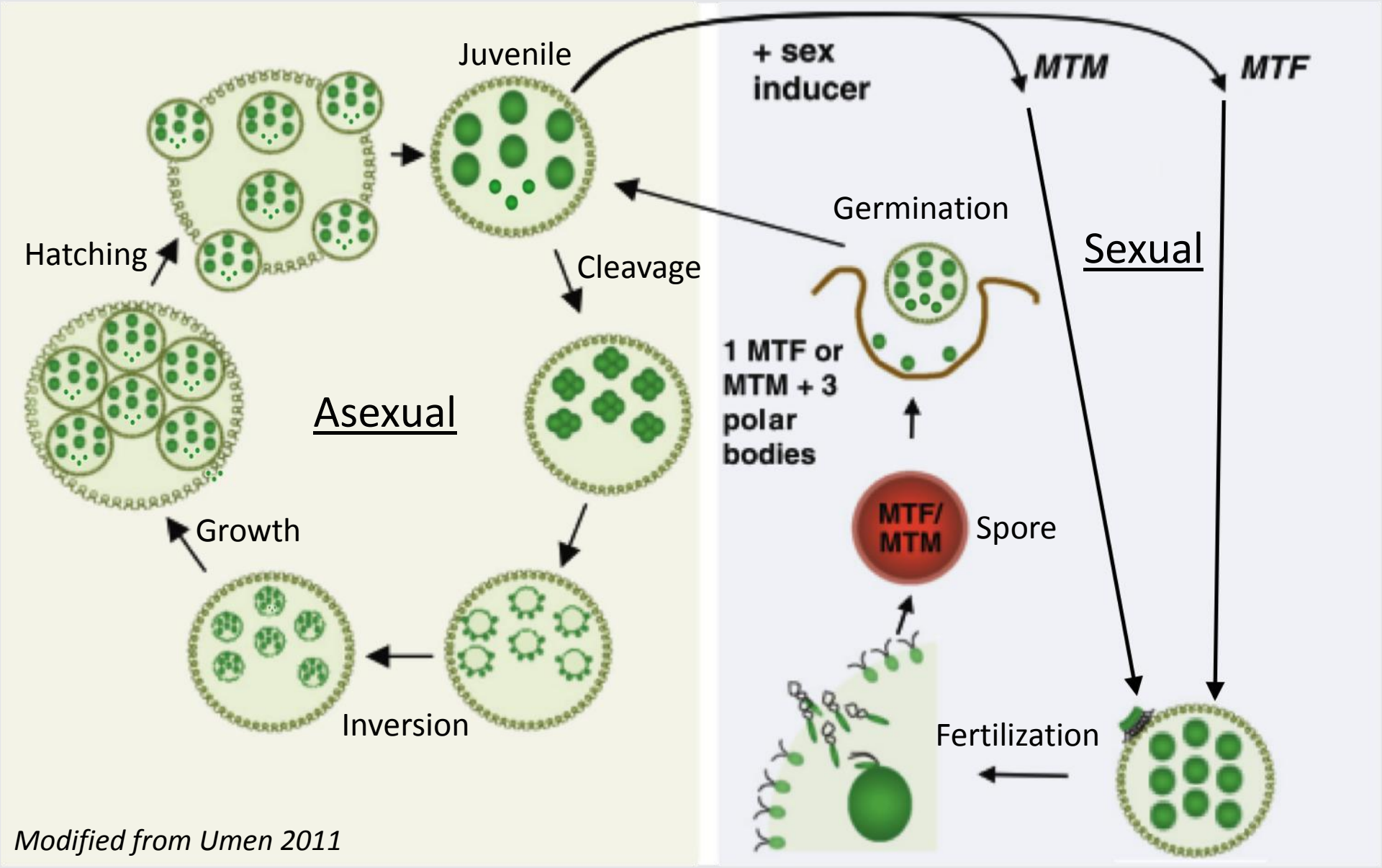
- Small soma cells
- Large germ cells
- Medium cells

Volvox rousseletii life cycle



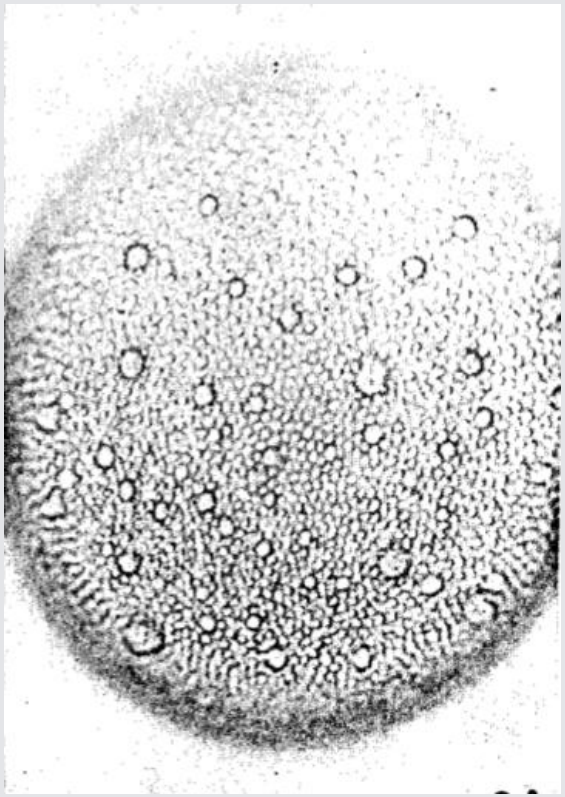
Modified from Umen 2011

Volvox rousseletii life cycle



Modified from Umen 2011

Volvox rousseletii



McCracken & Starr 1970

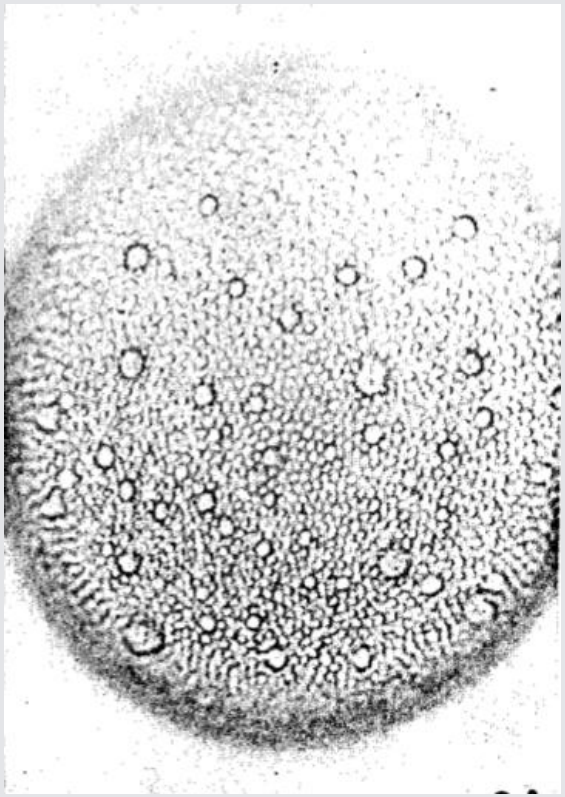
3 cell types differentiated by:

- size
- spatial orientation

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

Asexual/sexual development thought to depend on environmental conditions

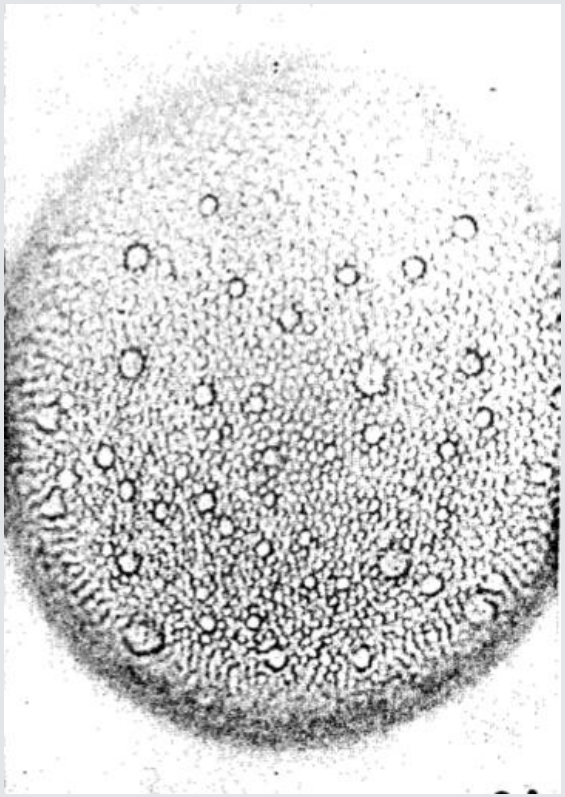
Project Proposal



McCracken & Starr 1970

- *V. rousseletii* transcriptomes
  - Look for regulatory differences between cell types

Project Proposal



McCracken & Starr 1970

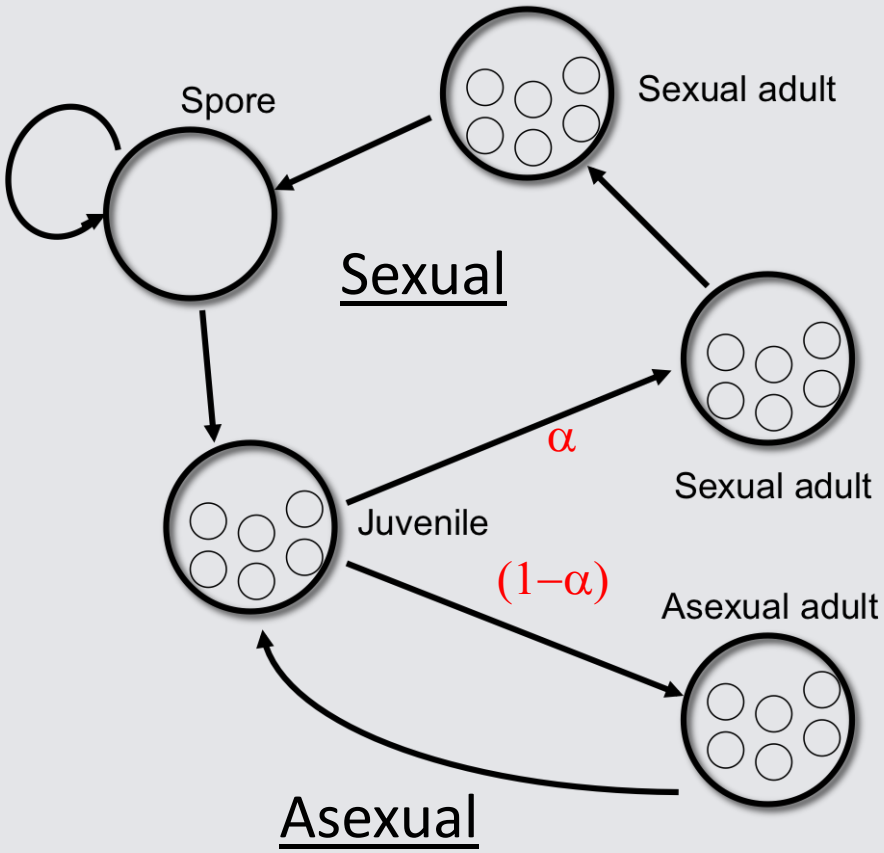
V. rousseletii transcriptomes

- Look for regulatory differences between cell types

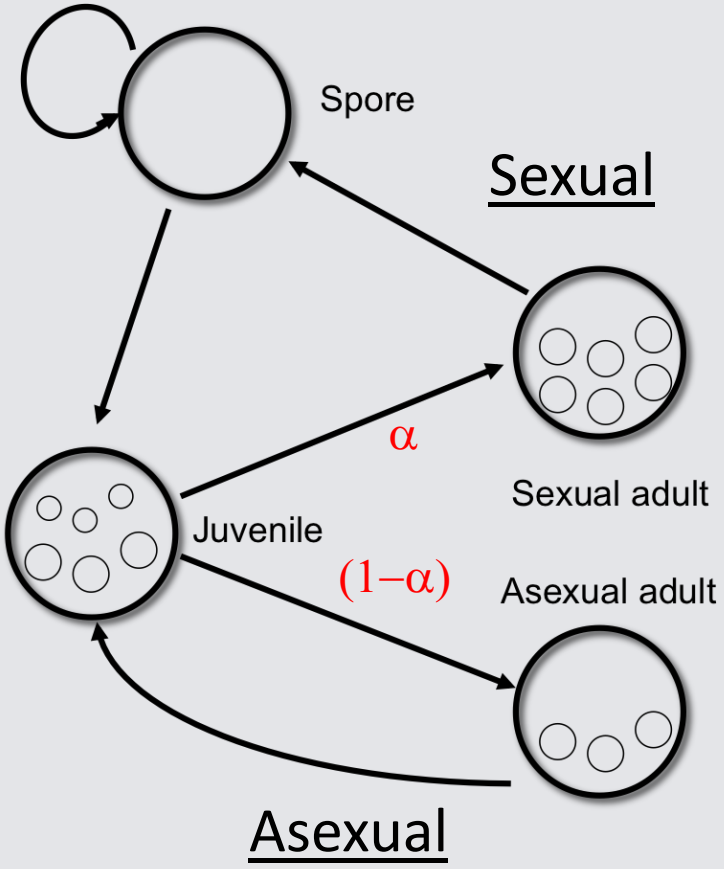
Life history modeling

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

Volvox carteri

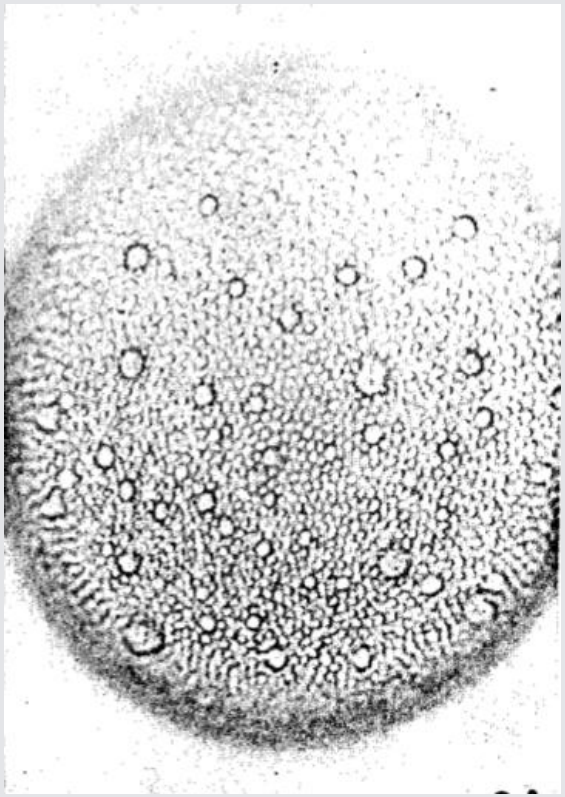


Volvox rousseletii



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

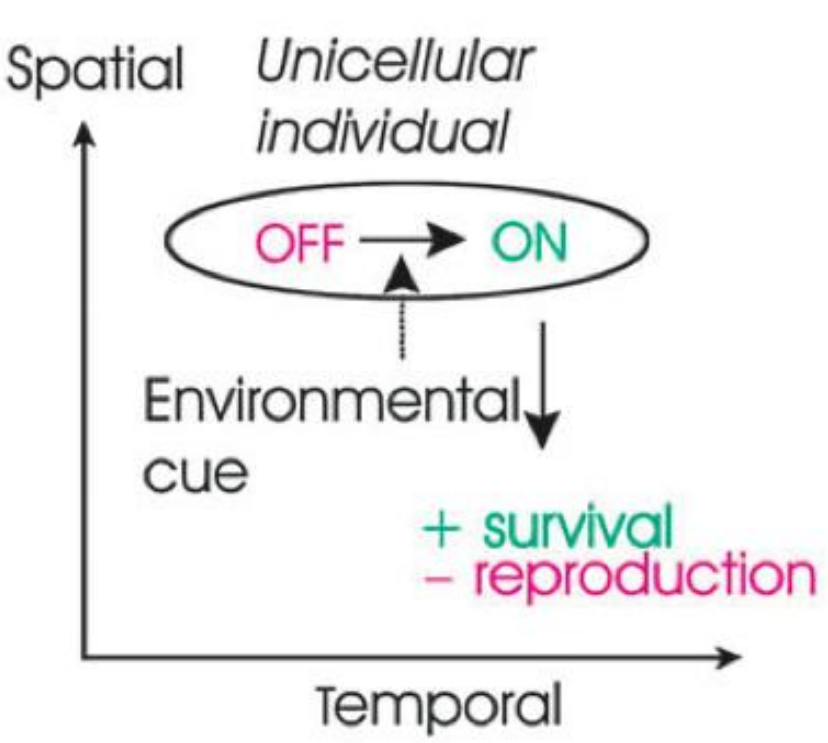
Life history modeling

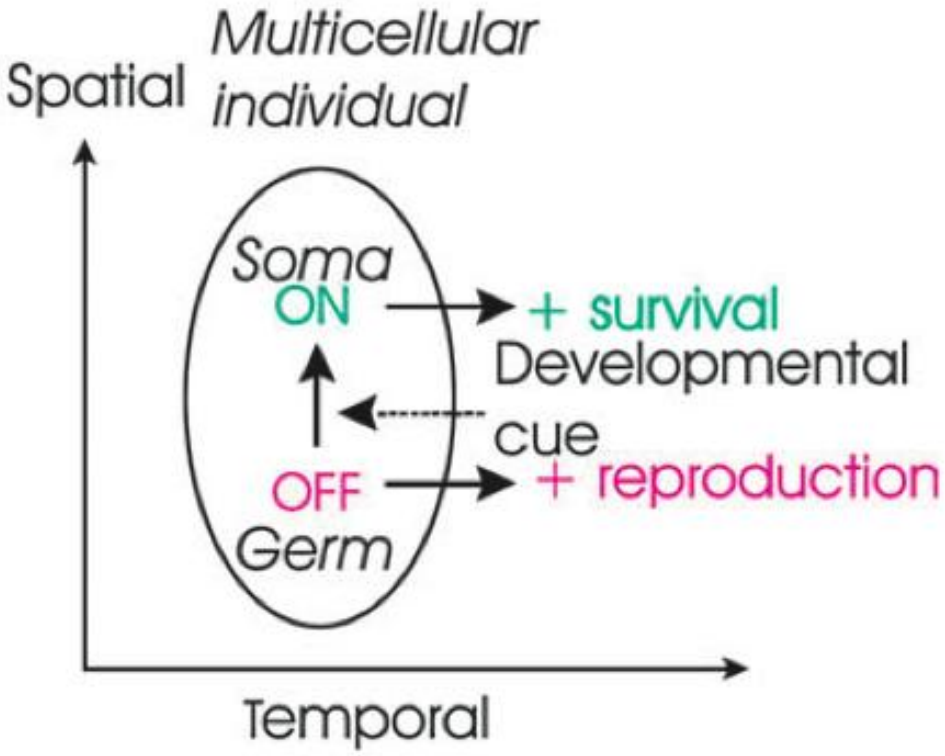
- How environmental variation (sex/asex) selects for three cell types
- Investigate optimal cell type proportion based on environment and physiology

Acknowledgements

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

Temporal to Spatial Differentiation





Nedelcu & Michod 2006

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)