Plastic fantastic
Linking physiological and evolutionary timescales

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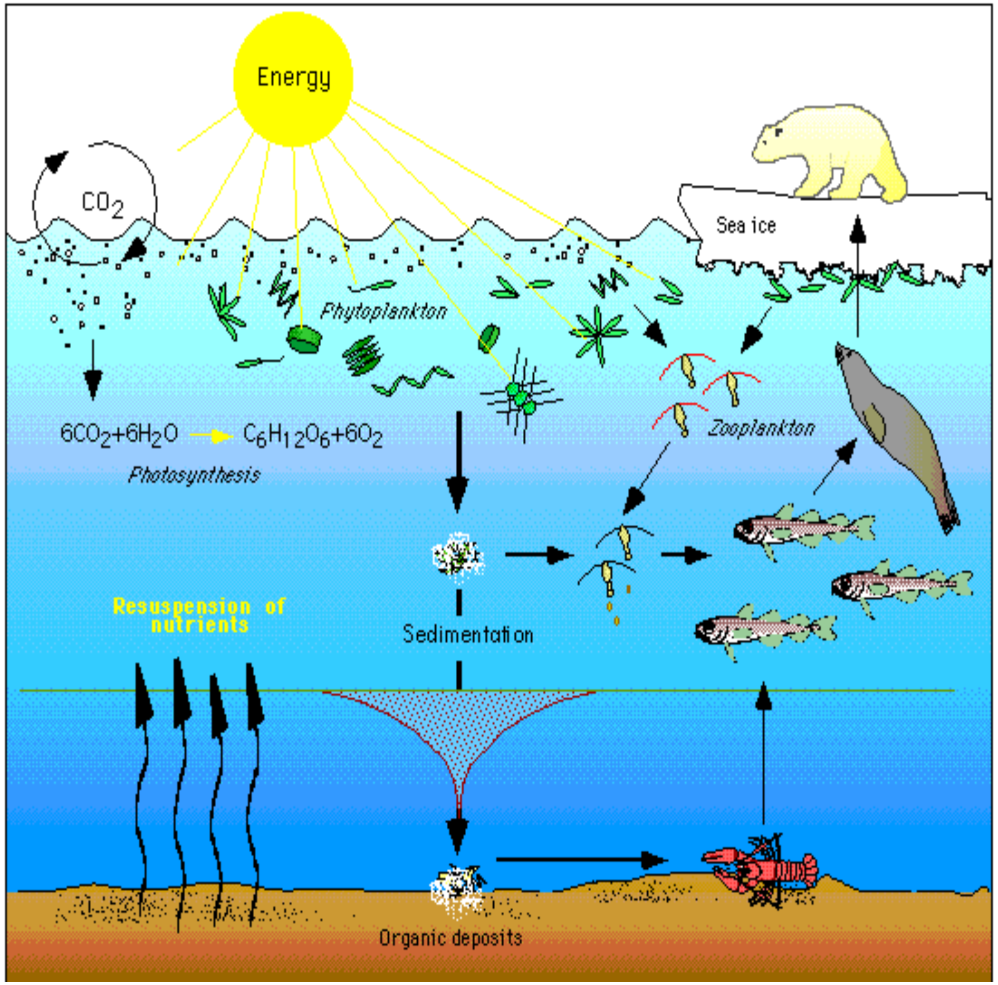
Unpublished data removed.

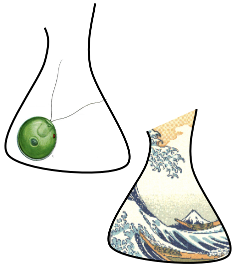
evolution in marine microbes

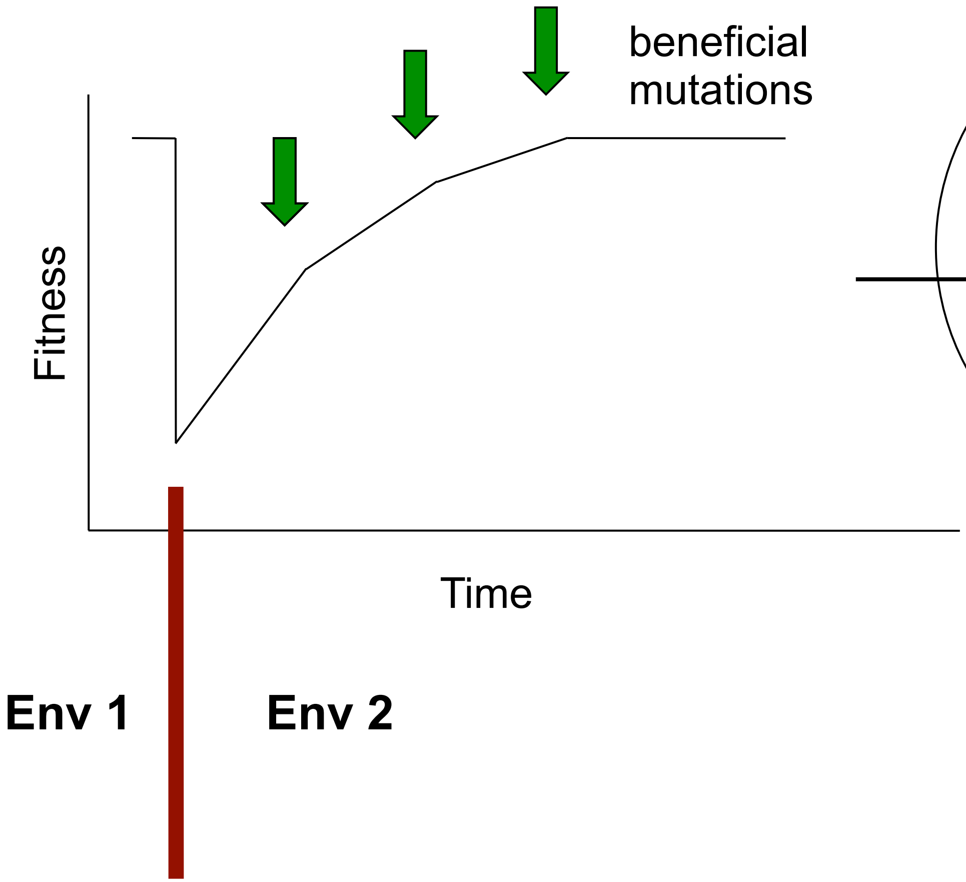
- Which populations are more likely to evolve?
- Why?
- Which short-term responses are good indicators of evolutionary potential (beyond genetic variation?)
- Will evolution matter?

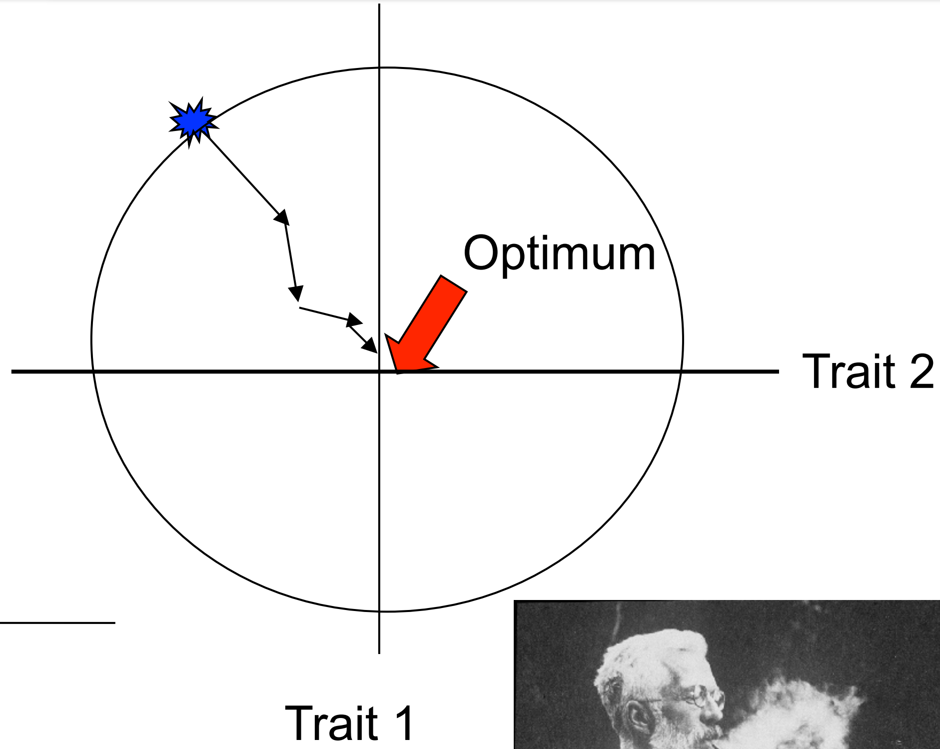


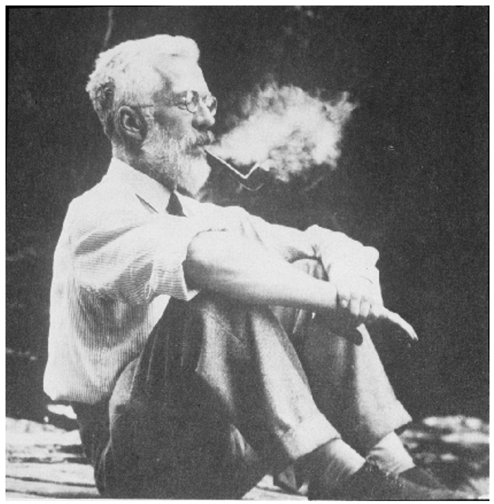
courtesy of Christopher Krembs 2004, altered

adaptive walks

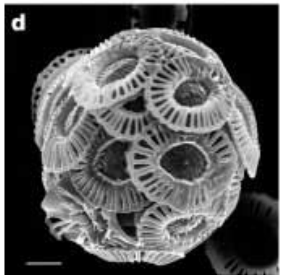




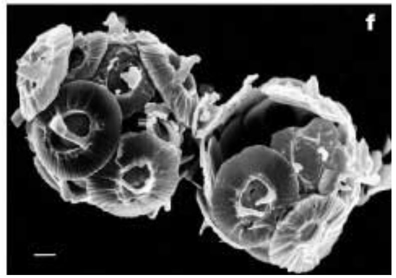




predicting evolution

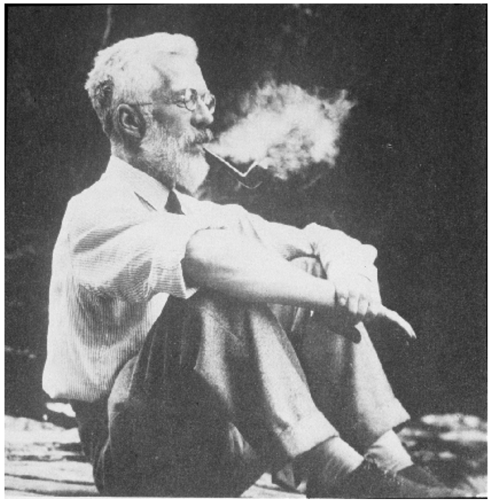


This is E.hux

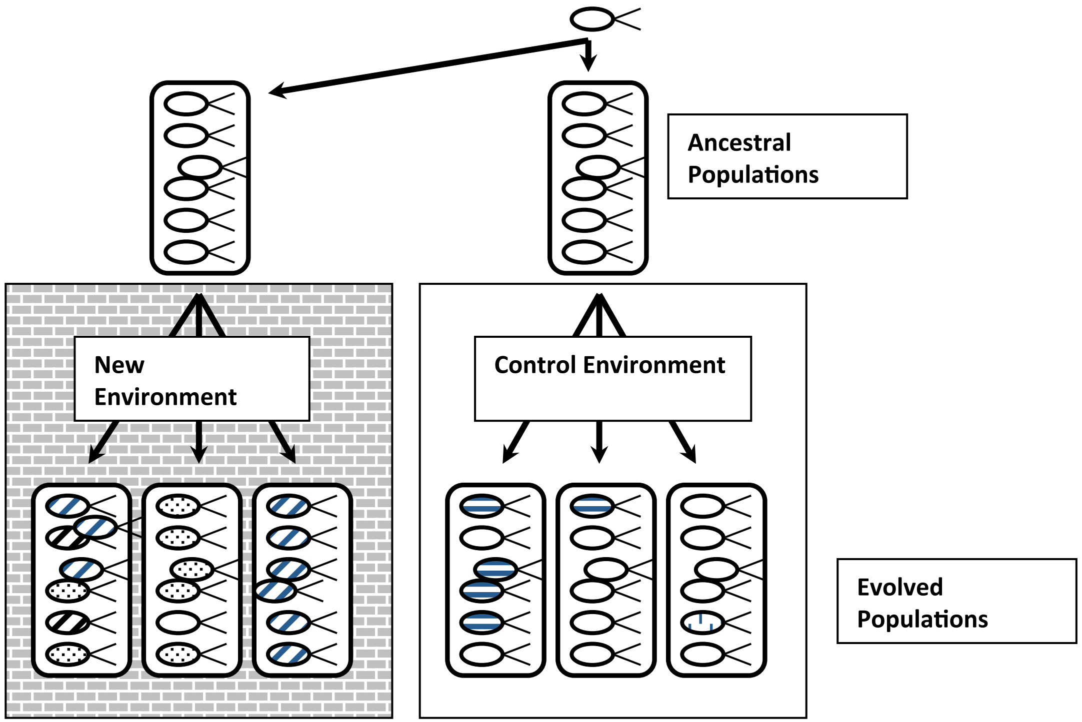


This is E.hux
on acid

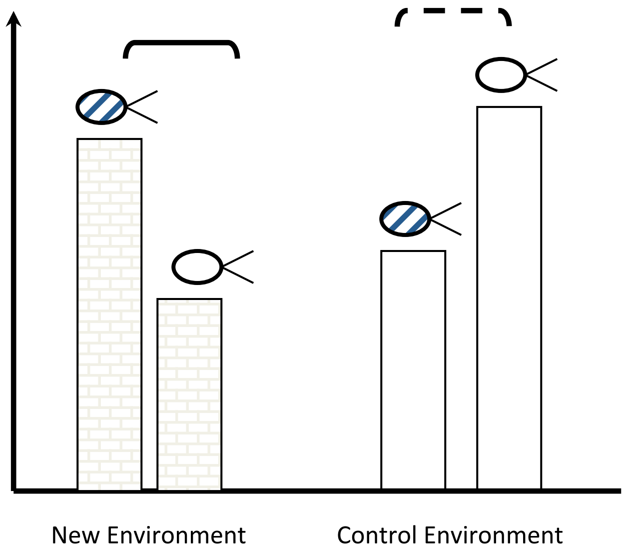
What can short-term responses tell us about the speed and outcome of evolution?



experimental evolution

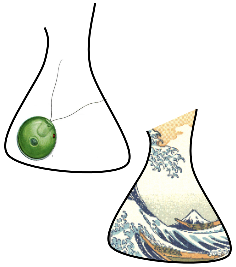


standard election experiment

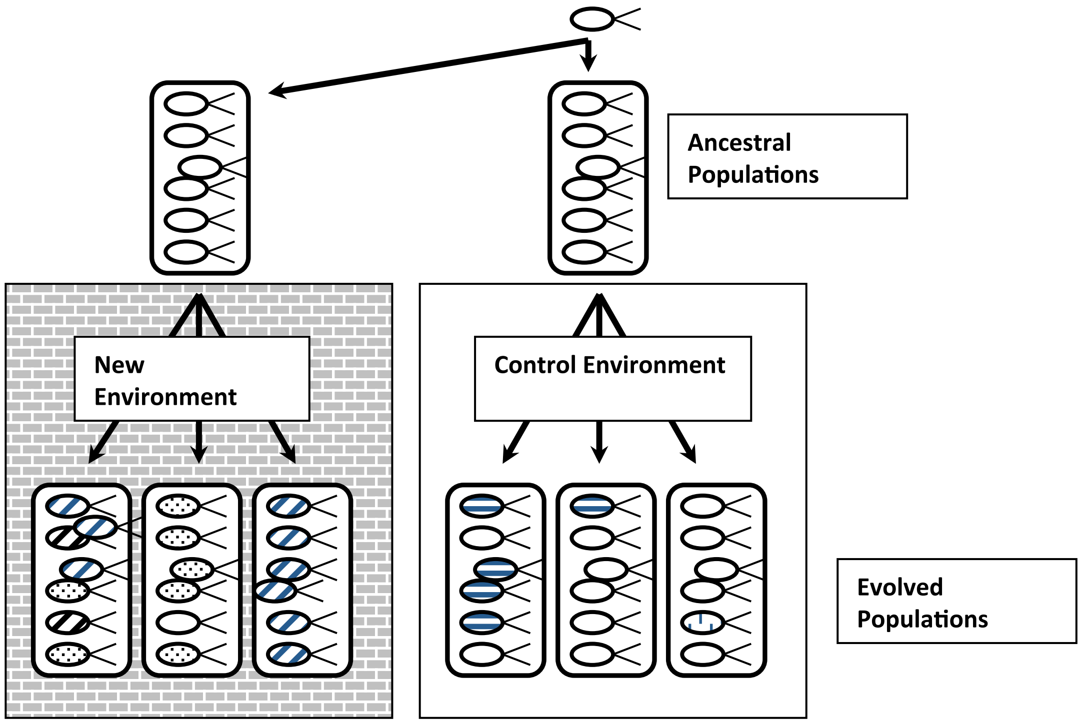


hopeful representation of results

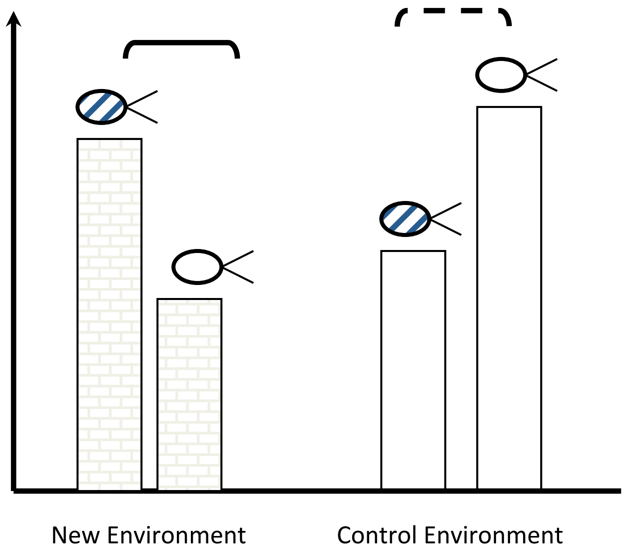
from Collins 2010 Evol Biol 38:3-14



but why?



standard election experiment



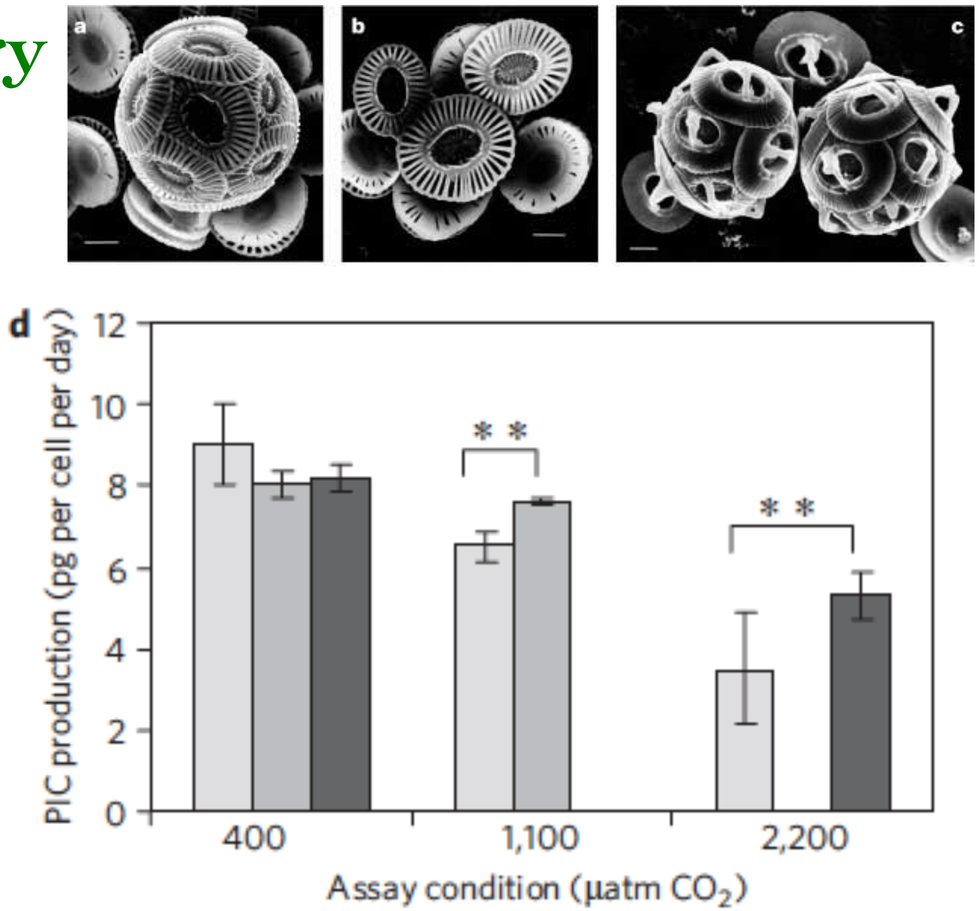
hopeful representation of results

from Collins 2010 Evol Biol 38:3-14

softcore experimental evolution

- **Uses existing evolutionary theory to understand specific biology**

- Motivated by specific organisms or processes
- Looks at a specific evolutionary outcome
- Small experiments
- Low replication

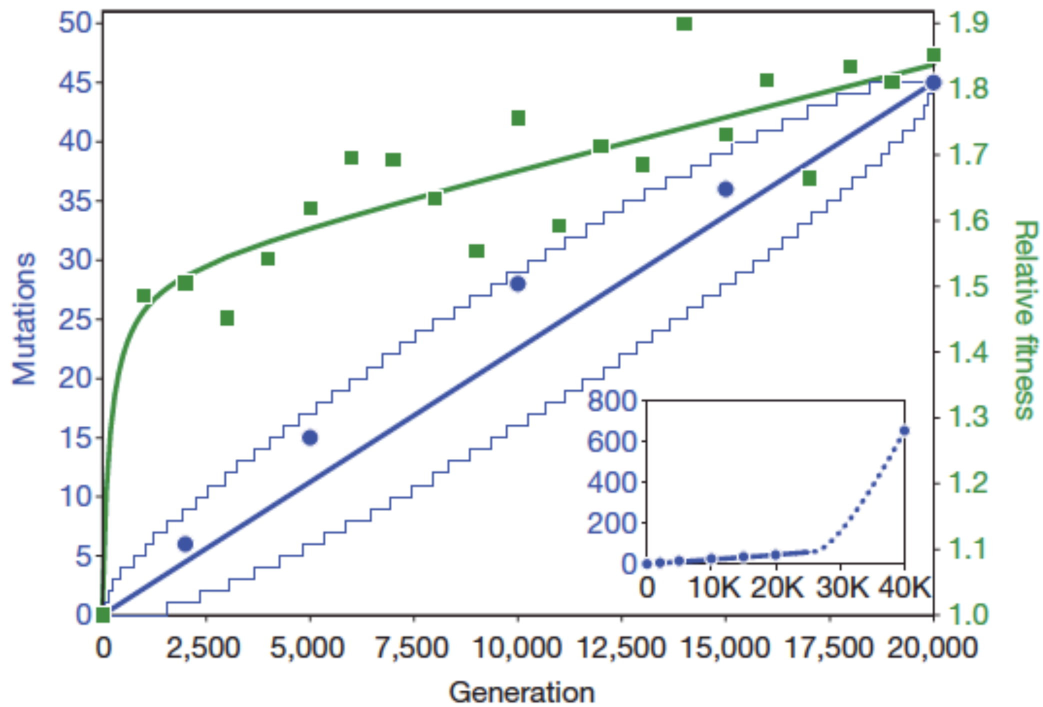


From Lohbeck et al. 2012. Nature Geosci.

hardcore experimental evolution

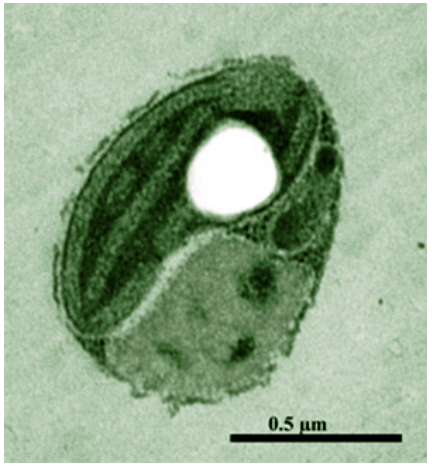
- **Uses experimental evolution as a tool to make new theory**

- Motivated by understanding evolutionary processes
- Generalizable results
- Large experiments
- High replication



From Barrick et al. 2009. Nature.

Ostreococcus: small but mighty



- Smallest (?) free-living eukaryote found yet
- Cosmopolitain – marine + brackish
- Divides ~ once per day
- Freezable (La +, usually)
- Transformable (very slow for now)
- Can grow in small cultures (2-20 ml)
- **12.6 Mb genome**, highly condensed, 20 to 21 chromosomes
- Giant virus (200 000 bp)
- Characterised ecotypes that are probably locally adapted and differ from each other.

Linking physiological and evolutionary timescales

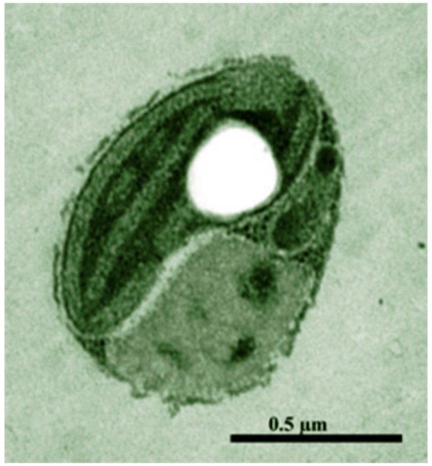
- Plasticity – variation in phenotype that does not require a genetic variation.
- Can be adaptive or not.
- Lots of theory.

- Is there variation in plastic responses within species?
- Does variation in plasticity explain changes in relative fitness?
- Does variation in initial plasticity explain variation in microevolutionary outcomes?

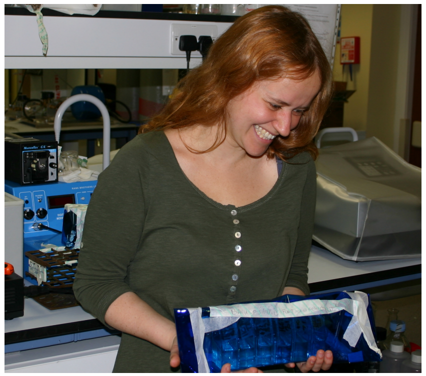
phenotypic plasticity and evolution

- Plasticity can facilitate genetic adaptation/ population persistence by allowing population size to remain high (Chevin et al. 2010)
- Plasticity can impede genetic adaptation by attenuating selection pressure
- Plasticity can facilitate phenotypic adaptation/ evolvability by giving combinations of traits directions to vary in (Draghi and Whitlock 2012)

plastic fantastic



O. tauri



E. Schaum

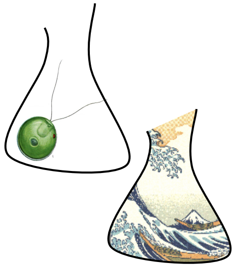
collecting ecotypes

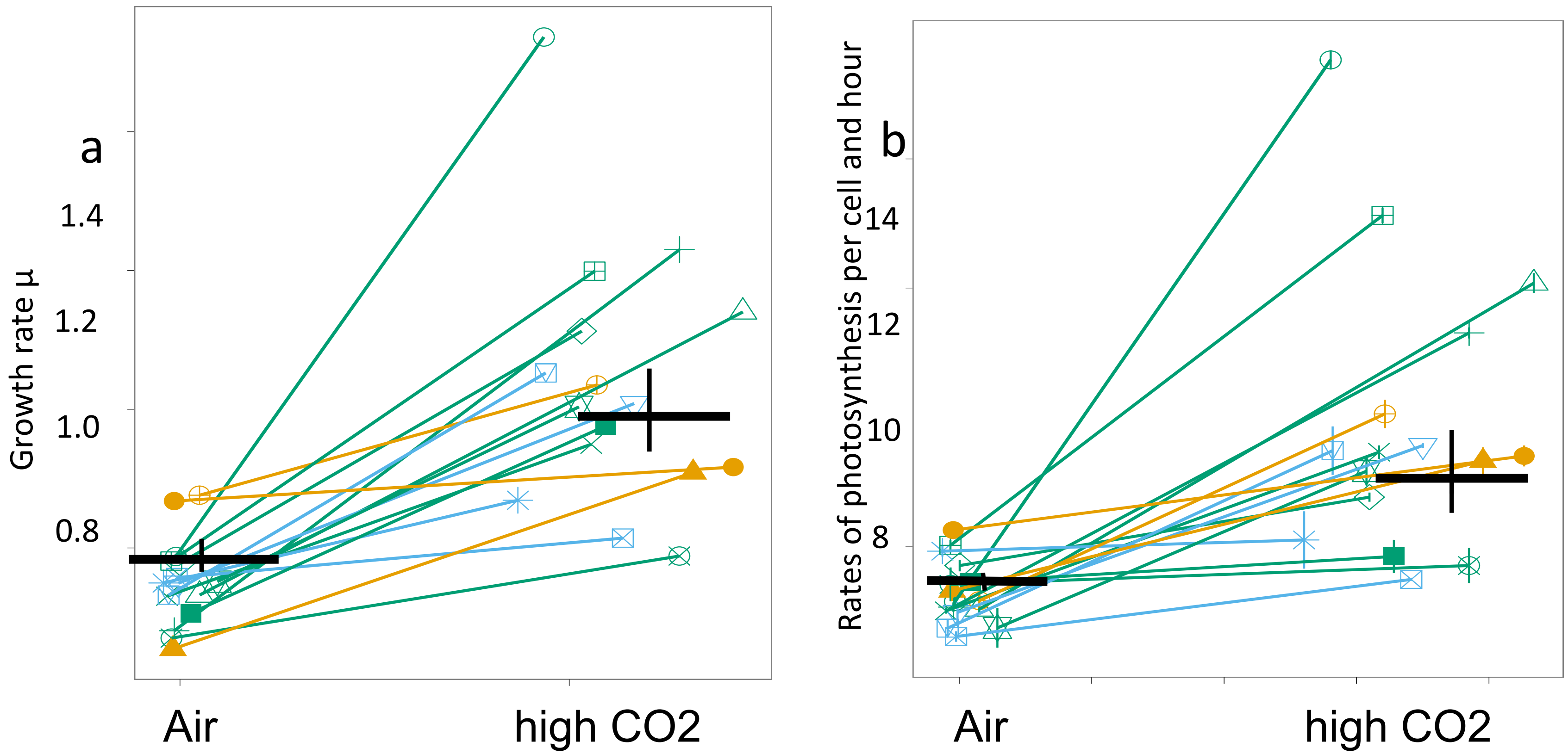
and now, the obligatory contentious definition

$$\text{Fitness response} = \frac{\text{Growth rate at high } CO_2 - \text{growth rate at low } CO_2}{\text{growth rate at low } CO_2}$$

$$\text{Plastic response} = \frac{\text{Photosynthesis (PS) rate at high } CO_2 - \text{PS at low } CO_2}{\text{PS at low } CO_2}$$

fitness and plastic responses

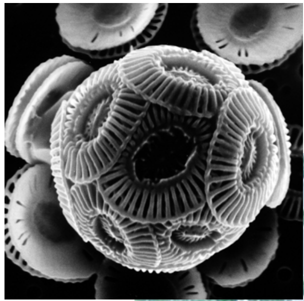


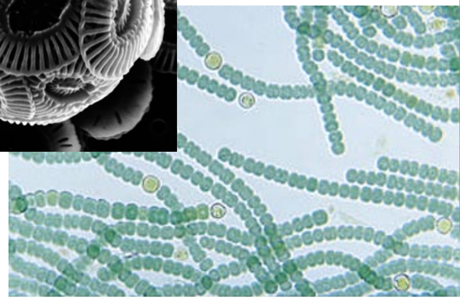


Schaum et al. 2013

…just for reference

- There is as much variation in plasticity between ecotypes of a single species as between functional groups

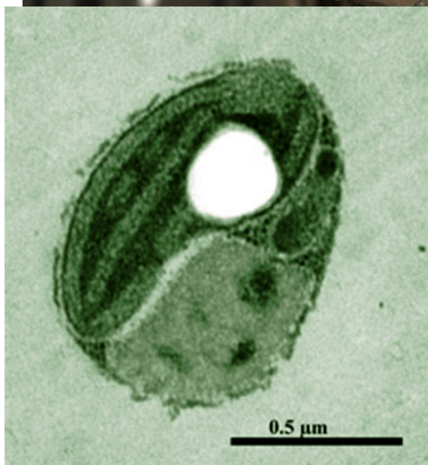


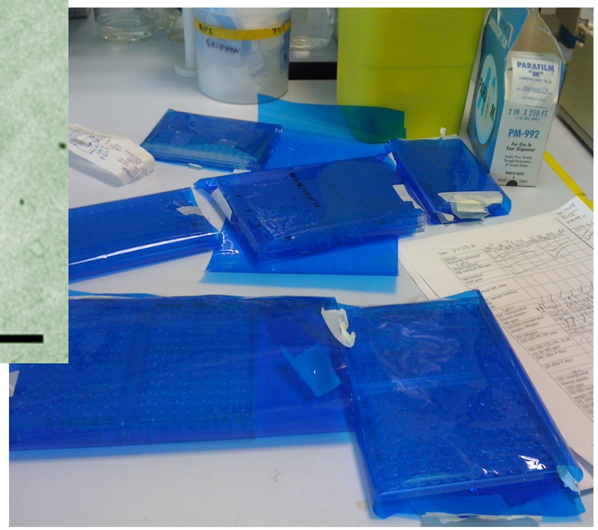


Functional group	Mean fold change in growth	Within group variance in growth response	Between group variance in growth response
Cyanobacteria	1.5	0.04	0.1
Diatoms	1.1	0.03	0.1
Coccolithophores	0.91	0.04	0.1
Green algae	1.5	0.36	0.1

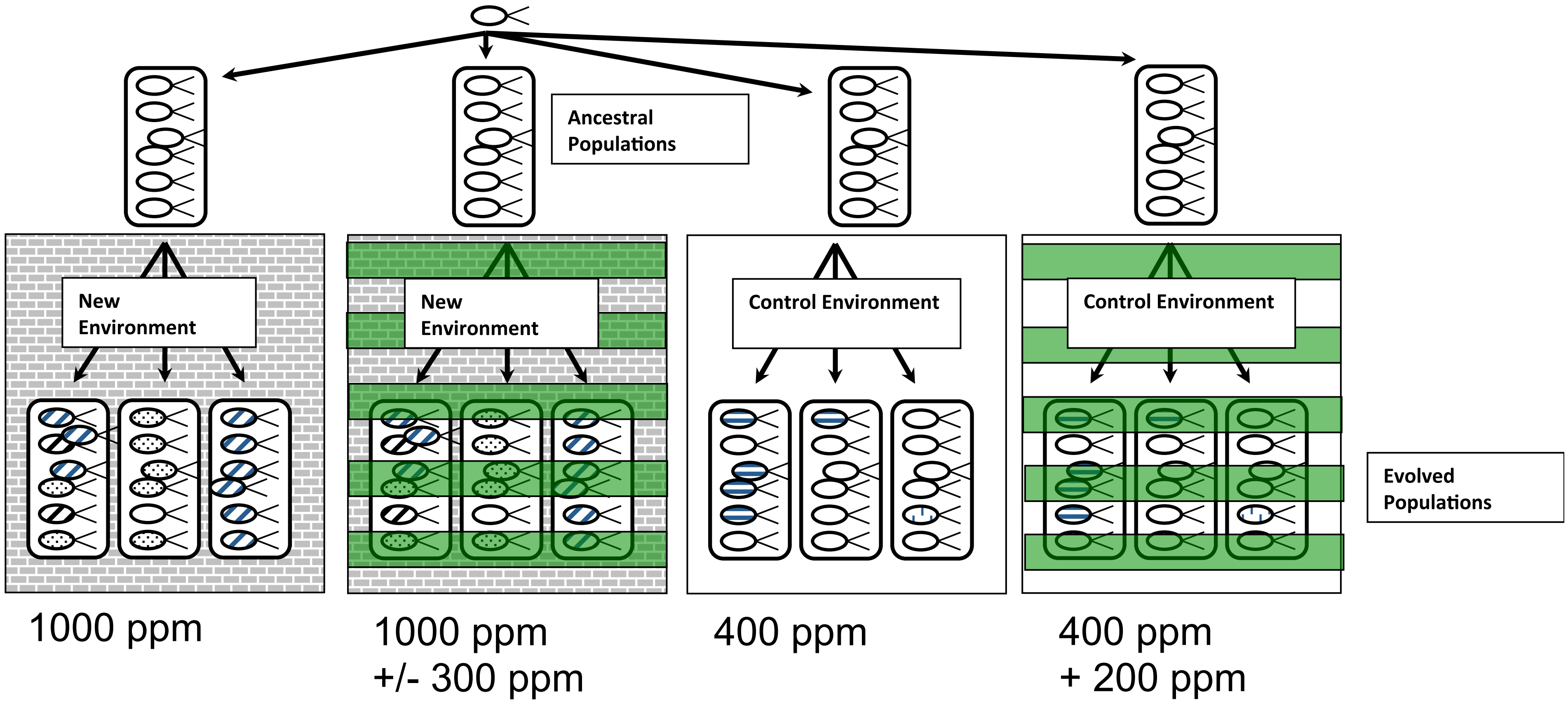
variation in plasticity there is

- There is lots of variation in the magnitude of plastic and fitness in response to changes in CO_2 in *Ostreococcus*
- The variation correlated with location
- Larger, faster growing cells with high C:N.



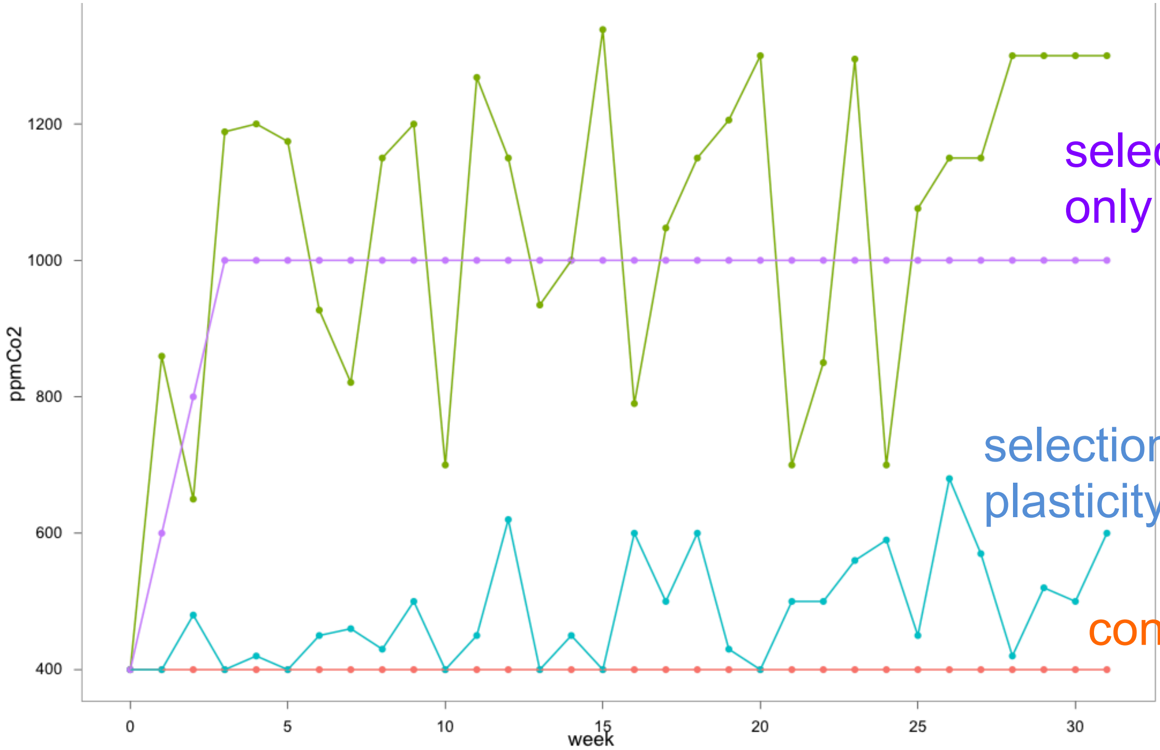


what does plasticity tell us about evolution?



Approx 400 asexual generations, for 16 ecotypes

selection regimes



selection for plasticity + high CO_2

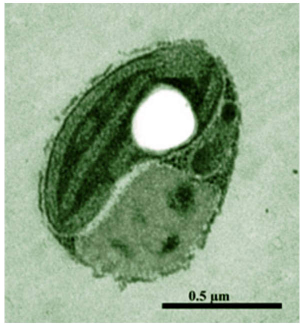
selection at high CO_2 only

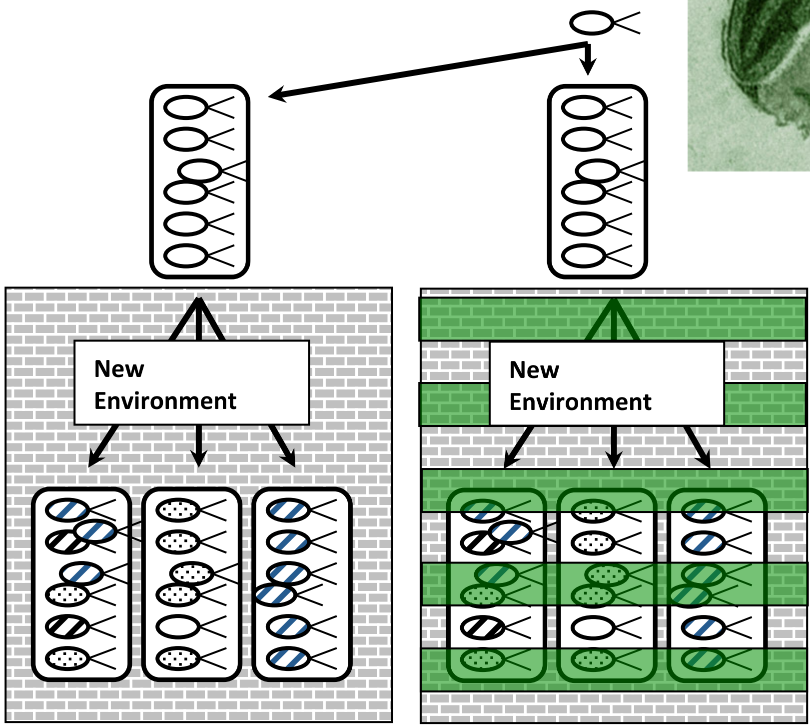
selection for plasticity only

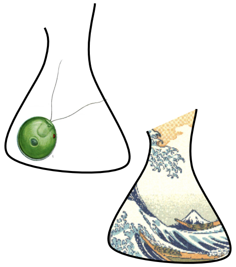
control

plasticity facilitates evolution

- Plasticity can evolve in fluctuating environments
- Populations with higher initial plasticity evolve more, and this effect is stronger in fluctuating environments





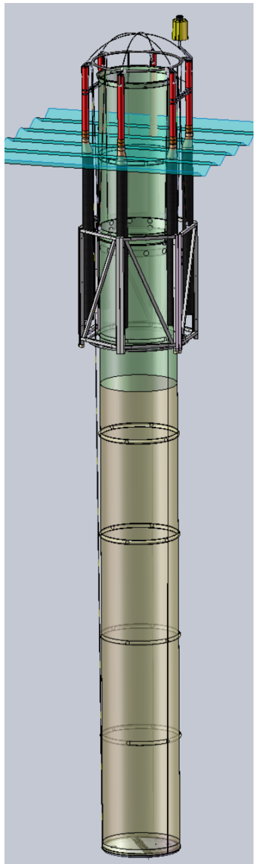


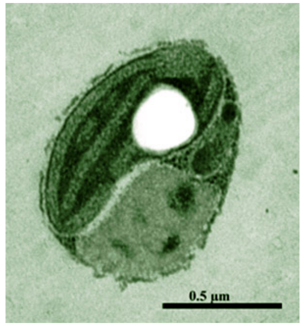
summary

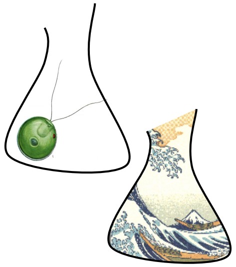
- Plasticity evolves or is maintained in fluctuating environments
- Plasticity predicts the magnitude, but not the direction, of evolution
- All else equal, plastic populations evolve more.
- High CO_2 increases fitness in O.tauri initially, but becomes stressful over hundreds of generations.

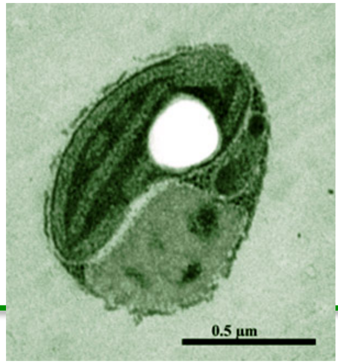
small but mighty

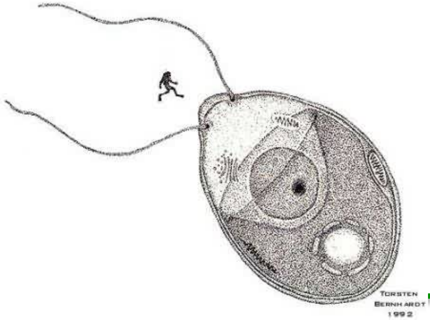
- Theory –experiments in the lab – experiments in the field – various omics.











- short-term responses that don't involve any genetic change can (and do) affect evolution that uses de novo mutation
- we have a lot of theory, and almost no tests of it
- Expt evol. with reasonably cooperative marine microbes lets us go from theory – lab expts – field expts. Yay!

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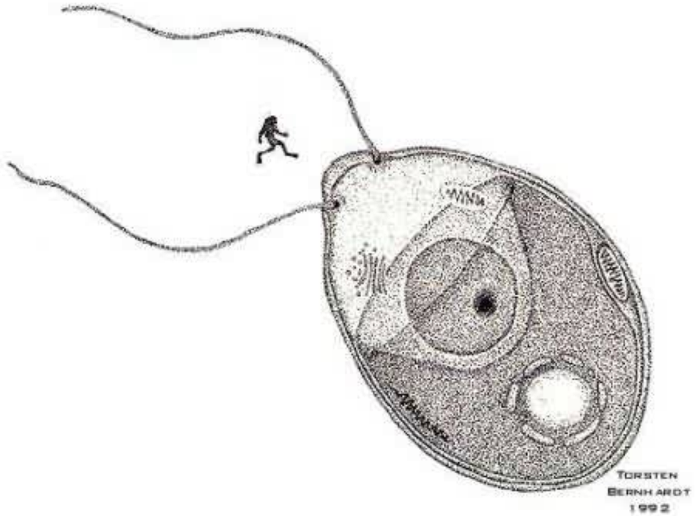
small but mighty!

Cooking

- Plasticity
- Multiple simultaneous stressors
- Epigenetics
- Ecological competition vs. evolutionary adaptation
- Mapping the evolvable CCM
- Evolutionary convergence/ divergence
- Evolutionary responses to OA
- In situ ocean enrichment experiments

Just-baked

- Rates of environmental change
- In vitro evolution model systems



www.smallbutmighty.bio.ed.ac.uk