

"Sex is the queen of problems in evolutionary biology."

Graham Bell, 1982

"No area of evolutionary biology offers the curious investigator a more fascinating mixture of strange phenomena and deep intellectual puzzles than the evolution of sex and its consequences."

Stearns, 1987

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Parthenogenesis: all individuals develop from unfertilized eggs



Whiptail lizards



Aphids - 1700's



Hammerhead shark - 2001



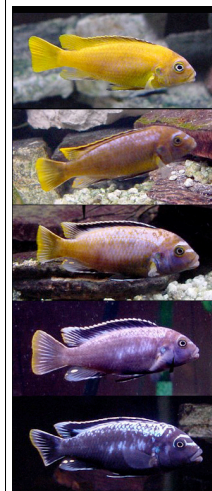
Komodo dragon - 2006

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Why sex?

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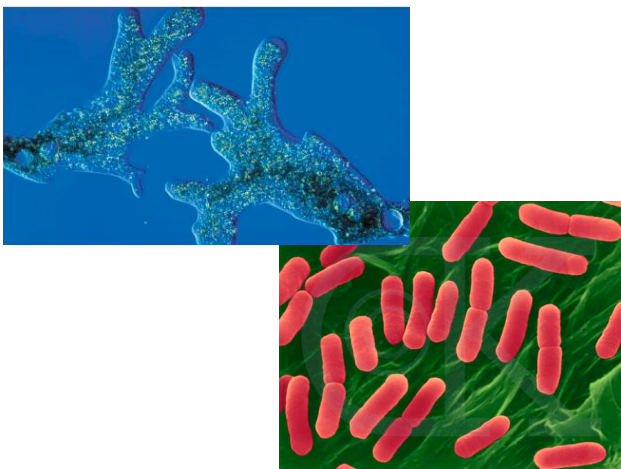


Daphnia



Bees
fert > female (workers)
unfert > male (drones)

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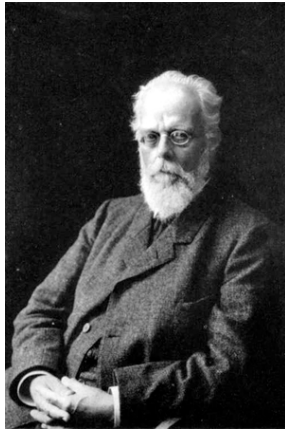


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- Propose 3 hypotheses to explain why sexual reproduction has evolved.
- Can you propose any way to test your favorite hypothesis?

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August Weismann -
sex functions to provide
variation for natural
selection to act on
(1889)



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2-fold disadvantage of sex.....

- Cost of sex = the "cost of males"

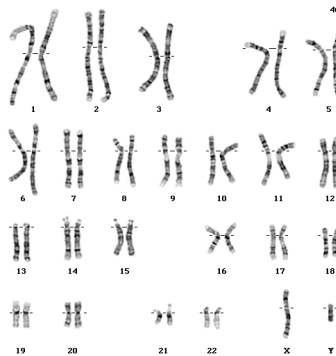
Generation	Sexuals	Asexuals	Fraction of individuals that are asexual
1	F x M	F	1/3
2	F x M F x M	F F F F	1/2
3	F x M F x M F x M F x M	F F F F F F F F F F F F	2/3

Rate of incr. of sexual genotype is ca. 1/2 that of asexual genotype

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2-fold disadvantage of sex.....

- Destroys adaptive combinations of genes

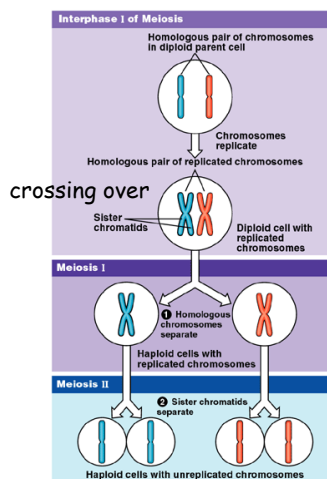


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- Can you design a way to test the hypothesis that asexual reproduction leads to a higher evolutionary fitness (i.e., leads to more progeny) than sexual reproduction?

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Linkage disequilibrium:
alleles at different loci
not inherited
independently



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- New Zealand lakes
- a/sexual
- H₀: stressful environment favors sexual reproduction



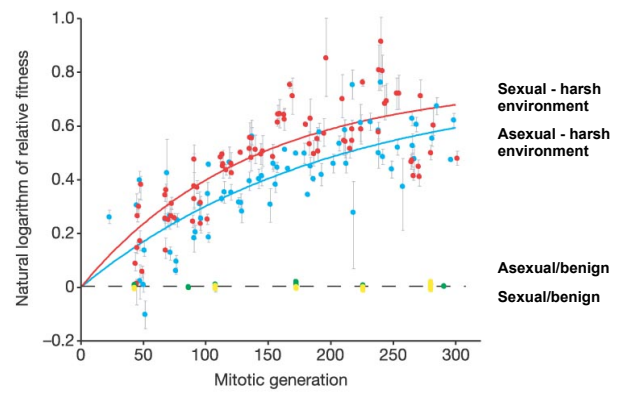
Potamopyrgus antipodarum

Curtis Lively et al.

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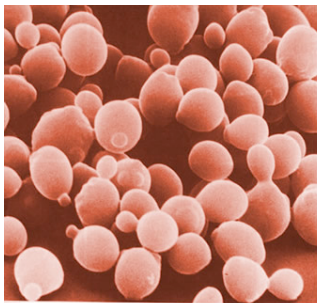
- Before carrying out the experiment, why did Lively et al. expect there would be a difference in fitness between sexual and asexual snails in ponds with different degrees of parasitism?
- Are the data they obtained consistent with Weismann's hypothesis? Explain your thinking.

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Goddard, M.R., H.C.J. Godfray and A. Burt. 2005. Sex increases the efficiency of natural selection in experimental yeast populations. *Nature* 434: 636-640.

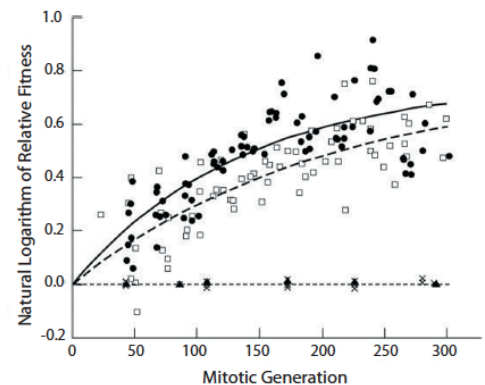
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- yeasts (single-celled fungi)
- practical advantages
- normally asexual, but under stress \rightarrow sexual
- Genetic manipulation (removed *spo11* & *spo13*) \Rightarrow pure strains (sexual & asexual)
- fitness in harsh & benign environment

Goddard, M.R., H.C.J. Godfray & A. Burt (2005) *Nature* 434: 636-640

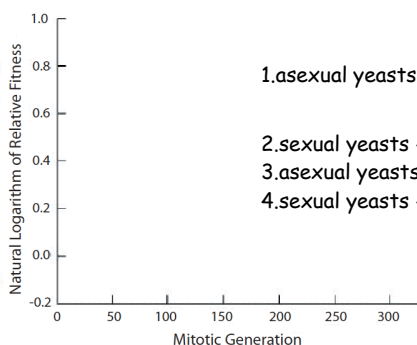
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The change in natural logarithm of fitness of asexual and sexual populations of yeast in benign and harsh environments. Points show fitness measurements for individual populations. (O) Asexual strains in the benign environment; (●) Sexual in the benign environment; (□) Asexual in the harsh environment; (■) Sexual in the harsh environment.

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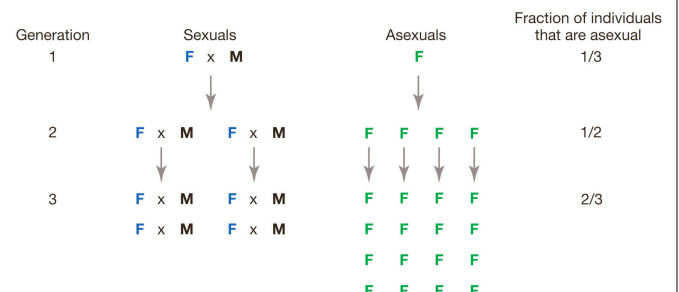
Plot the results you would expect if Weismann's hypothesis were correct....



1. asexual yeasts - benign conditions
2. sexual yeasts - benign conditions
3. asexual yeasts - harsh conditions
4. sexual yeasts - harsh conditions

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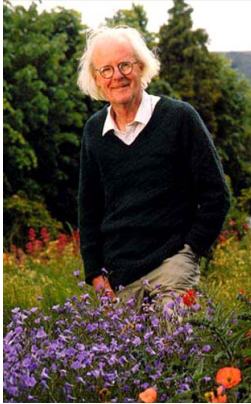
John Maynard Smith's null model



Rate of incr. of sexual genotype is ca. 1/2 that of asexual genotype

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John Maynard Smith



Assumes...

female's reproductive mode

- doesn't affect # of offspring she can produce
- doesn't affect probability of offspring survival

field & lab data =>
Assumption 2 wrong!

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Mutational deterministic process

- if deleterious mutations show "synergistic epistasis"
- sexual pops purge deleterious mutations >> asexual pops
- mean fitness higher in sexual pops

Kondrashov model (1988)

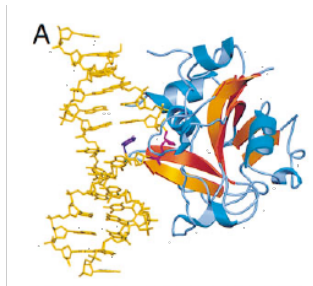
- rate of del mutations high enough?
- E.coli expt => not synergistic

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What advantage is sexual reproduction?

1. **The Repair H^o**: recombination evolved as DNA repair mechanism with sexual reproduction as byproduct

- too elaborate
- permanent diploid, polyploid parthenogenic



✓ origin of recombination

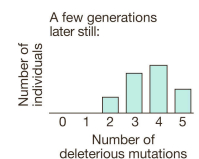
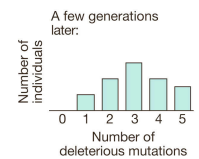
X evolution of meiosis, distinct sexes or maintenance of sex

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3. Muller's ratchet:

asexual reproduction leads to accumulation of deleterious alleles & extinction

- irreversible
- 'mutational meltdown'
- strong only in small pops
- describes long-term, but not short-term adv. of recombination

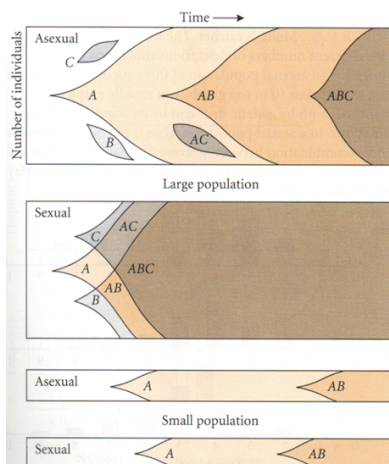


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2. Fixation of rare beneficial mutations

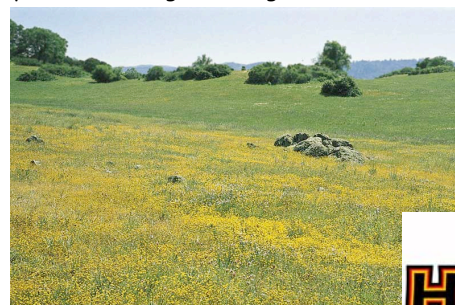
A & B

expt.
confirmation in
Chlamydomonas
pops



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4. "The Tangled Bank": spatial variation in environment provides strong advantage to sex

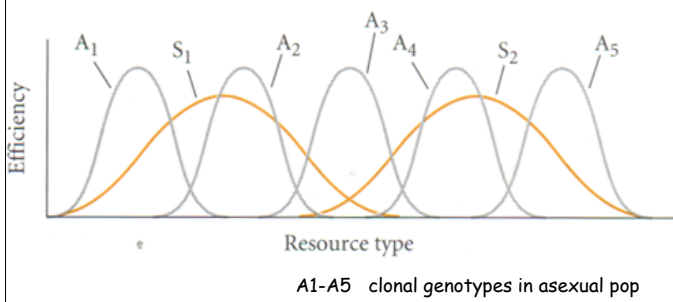


e.g. sibling competition?

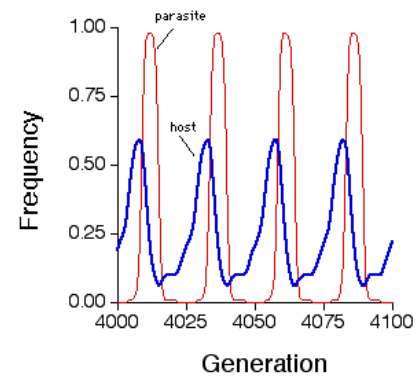


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But 'Frozen niche variation model' (Vrijenhoek)



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e.g. *Potamopyrgus antipodarum*

- Sexual form of snail >> asexual form in high trematode areas
- Common asexual clones more heavily infested than rare clones

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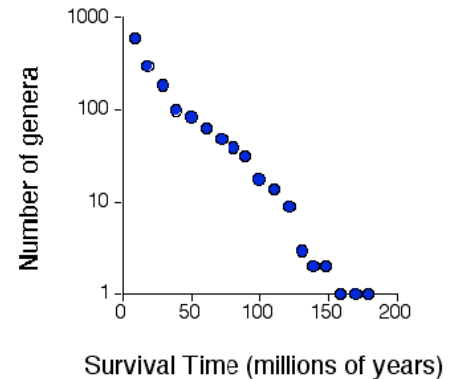
5. Adaptation to fluctuating (int or ext) environments (Van Valen)

e.g. polygenic character subject to stabilizing selection

A,B,C,D additively increase trait
a,b,c,d decrease trait

=> both long and short-term advantage to sex

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Macroevolutionary Red Queen
- extinct Echinoidea

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"The Red Queen"



Alice & the Red Queen

• environment of taxon deteriorates because of other spp (competitors, predators, parasites)

• each spp has to 'run' to stay in the same place

• evidence

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No definitive answer.....

Long-term advantage of sex

- e.g. compare morphology & ecology of parthenogenic & related sexual lineages

Short-term advantage of sex

- Evidence for 'Tangled bank'- geographic distribution of related a/sexual (asexual @ higher latitudes/altitudes, in physically harsher but biotically less complex habitats)
- Evidence for 'Red Queen'- plant data showing individual grass plants had higher fitness grown in competition with other genotypes

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