Lecture 4:
Natural selection & adaptation

How do adaptations arise?

Required reading: Coyne - Chapter 5

1

Fitness:

•Relative genetic contribution of individuals to next generation as a result of differences in viability and fertility (= Darwinian fitness)

Selective agent:

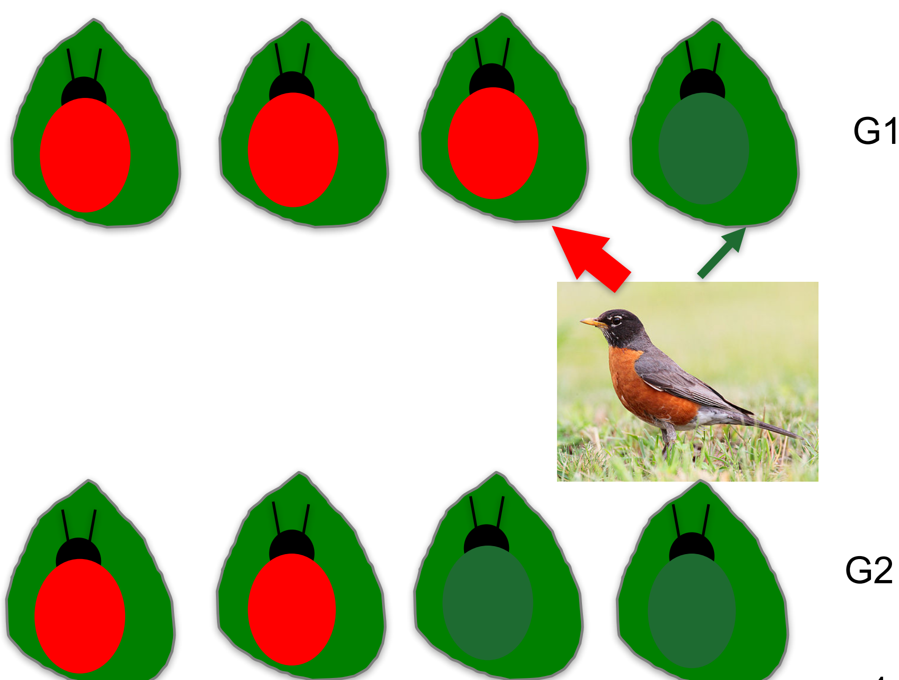
•Any factor that causes individuals with certain phenotypes to have higher fitness than individuals with other phenotypes

2

Adaptation – has two meanings; state or process

•Any trait that contributes to fitness by making an organism better able to survive or reproduce in a given environment [as a noun]
•The evolutionary process that leads to the origin and maintenance of such traits [as a verb]

3



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Many phenotypic traits show continuous distributions

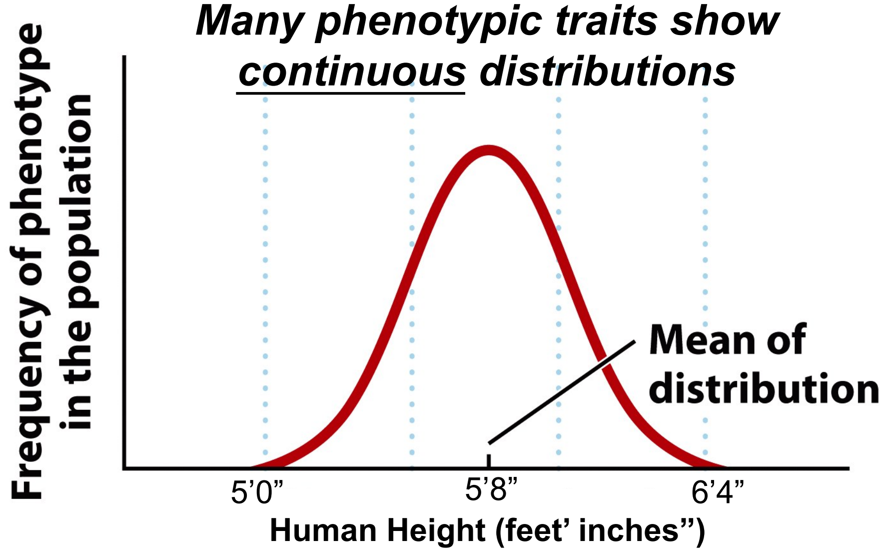

Figure 6.3
The Economy of Nature, Sixth Edition

Ricklefs p.117

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What would distribution look like for a discrete phenotypic trait?

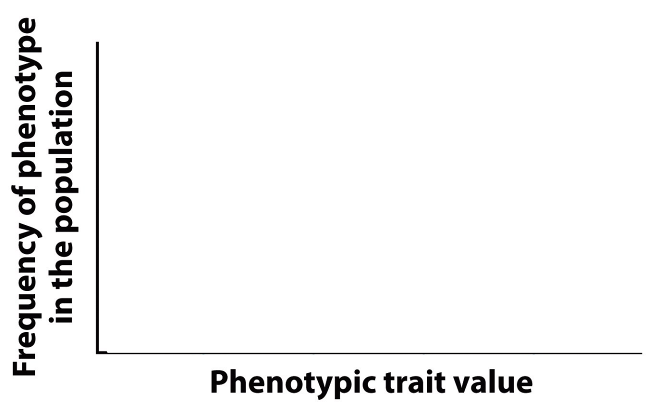

Figure 6.3
The Economy of Nature, Sixth Edition

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Types of natural selection on phenotypic traits

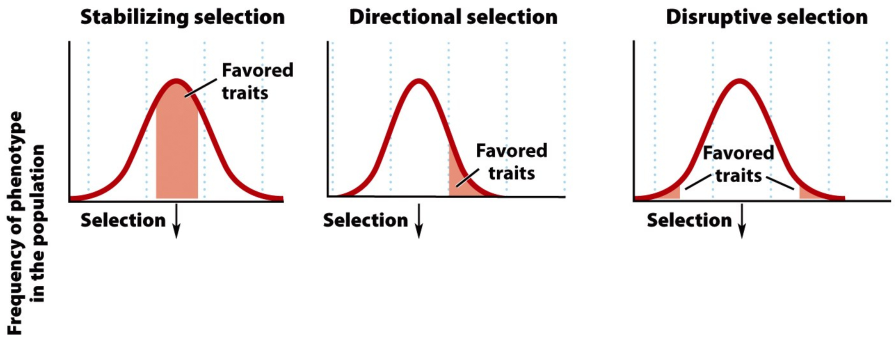
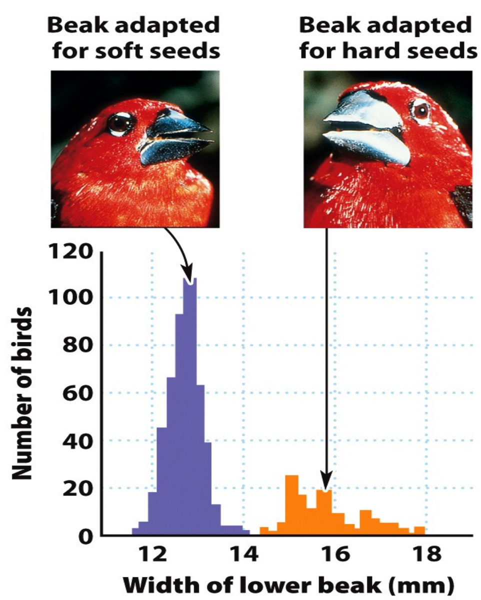


Figure 6.6
The Economy of Nature, Sixth Edition

Ricklefs p.120



Disruptive selection on beak size in African finches

- disruptive selection leads to character divergence and in some case may lead to speciation
- requires spatial heterogeneity or discrete resources

Figure 6.7
The Economy of Nature, Sixth Edition

Ricklefs p.121

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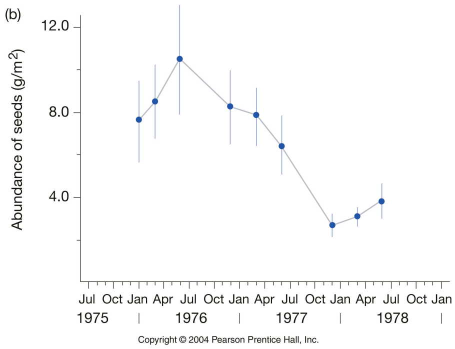
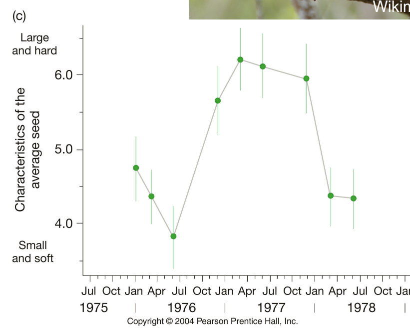
Beak size in Galápagos finch





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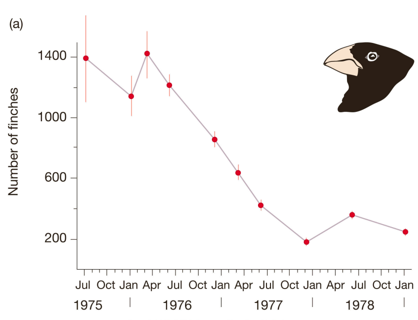
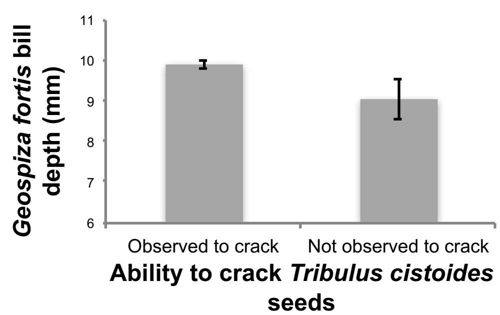
Beak size in Galápagos finch





Based on Grant (1981)

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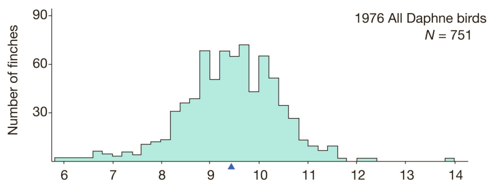
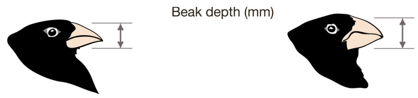
Beak size in Galapagos finch





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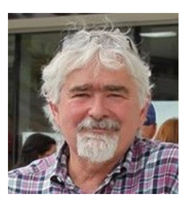
Gall size by *Eurosta solidaginis*



EEB Prof. Art Weis

- fly *Eurosta solidaginis* lays egg inside stem of goldenrod
- larvae hatches and creates protective gall
- vulnerable to predation and parasitism

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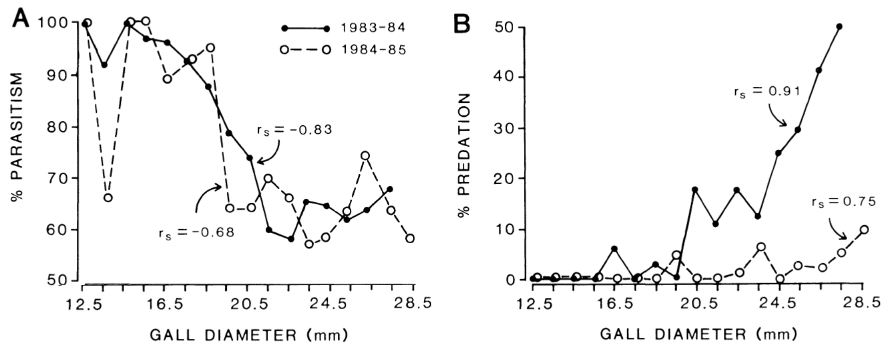
Gall size by *Eurosta solidaginis*



Weis & Abrahamson (1986)

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What kind of selection do we expect to see on gall size of *Eurosta solidaginis*?

Weis & Abrahamson (1986)

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The struggle to determine the mechanisms of selection

• Today hundreds of measurements of selection demonstrating fitness differences & evolutionary change in traits

• Fewer convincing cases that demonstrate the mechanisms (agents) of selection in natural populations – ecology is difficult!

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Evolution of cyanide resistance - scale insects

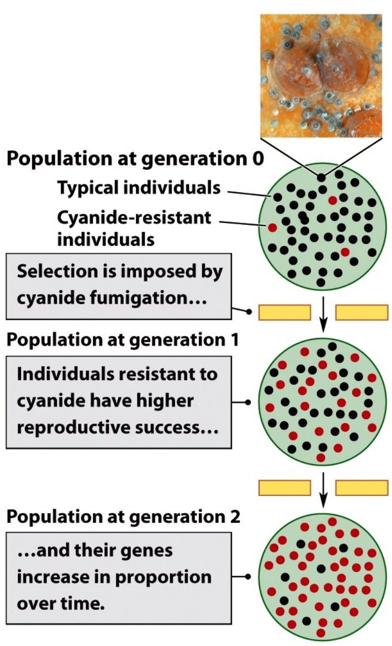

Figure 6.4
The Economy of Nature, Sixth Edition

• Alleles conferring cyanide resistance are found at low frequency in populations

• resistance spreads through the population when selection is imposed by cyanide fumigation

• this process serves as model for the evolution of many forms of resistance e.g. antibiotics, insecticides, herbicides

Ricklefs p.118

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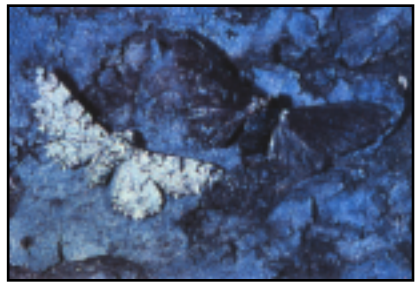
Evolution by pollution

- Evolution of industrial melanism in the peppered moth



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The peppered moth (Biston betularia) and industrial melanism

- Light and dark forms of species that rest on trees
- In UK, before 1850 dark moths rare; caused by single dominant allele
- Industrial pollution blackened tree trunks near cities resulting in increase in black form
- Black variant replaces white in polluted areas; white form predominates in rural unpolluted areas
- Mechanism of selection thought to be predation by birds and differences in crypsis (camouflage) depending on the background of tree trunks

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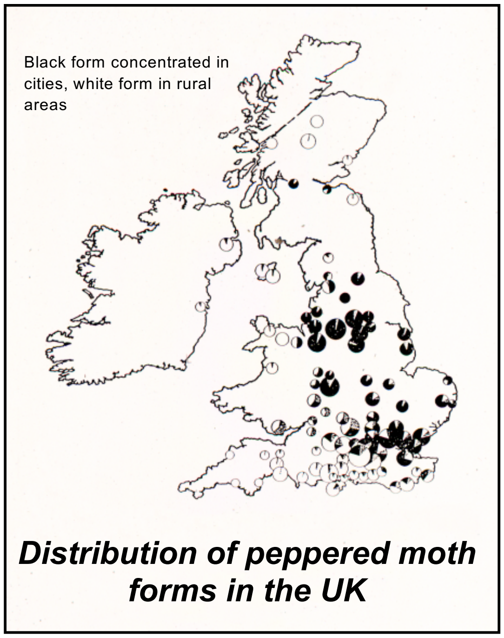
Tree in rural area

Tree in city



Distribution of peppered moth forms in the UK

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Kettlewell's triumph

• E.B. Ford recruits Kettlewell to Oxford to investigate the bird predation hypothesis

• observations and experiments in the 1950s involving mark and recapture of moths provide support for the hypothesis

• his findings thought to provide the first demonstration of the mechanism of natural selection in the wild and now feature in most biology textbooks and museums

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Kettlewell's experiments

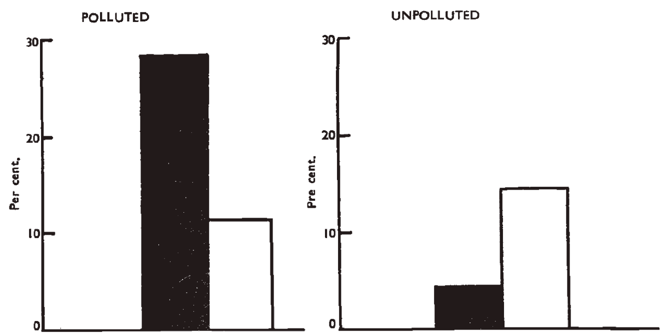

FIG. 1a.—Recapture Frequencies.

Kettlewell (1956)

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Doubts raised about Kettlewell's bird predation experiments

- Moths raised in the lab and this may have influenced behaviour
- Moths put on trunks at unnaturally high densities
- Moths rarely seen on trunks
- Releases conducted during the day
- Possibility of bat predation not investigated

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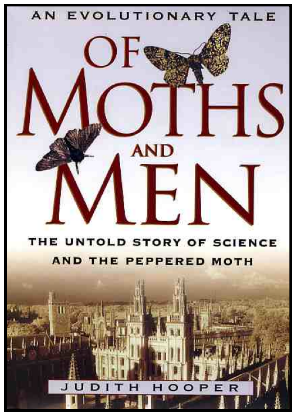

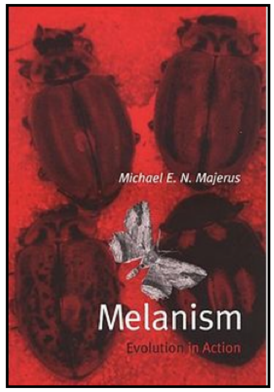

Michael Majerus - Cambridge

"Majerus concludes, reasonably, that all we can deduce from this story is that it is a case of rapid evolution, probably involving pollution & bird predation. I would, however, replace "probably" with "perhaps". B. bistularia shows the footprint of natural selection, but we have not yet seen the feet."
Nature (1998)

Jerry Coyne - Chicago

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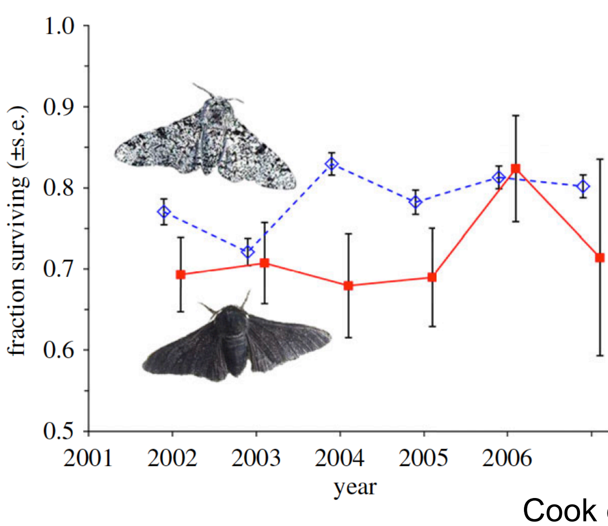
Revising Kettlewell's experiments



Cook et al. 2012

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Decline in frequency of the black (melanic) form after introduction of the 'Clean Air Act' in the UK in 1956

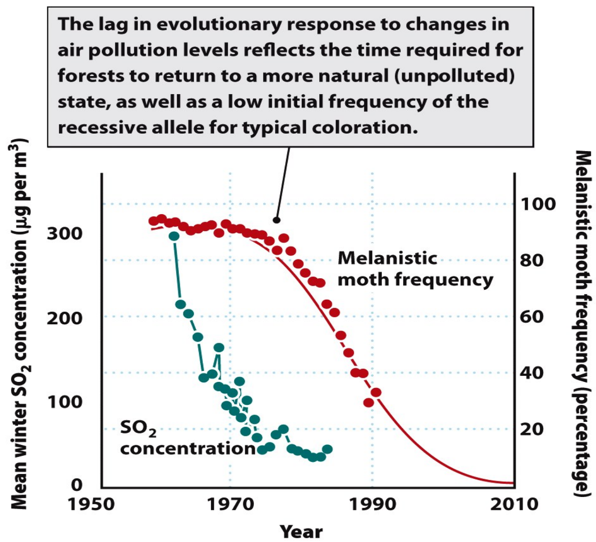

Figure 6.9
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Ricklefs p.123

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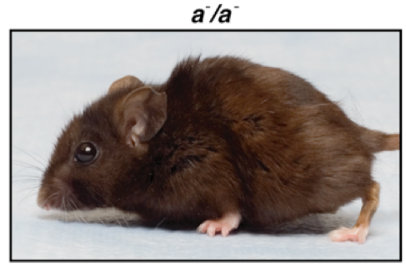
Mouse coat colour polymorphism in contrasting habitats

Hopi Hoekstra - Harvard

A *A^+/A^+ or A^+/a^-*

B *a^-/a^-*



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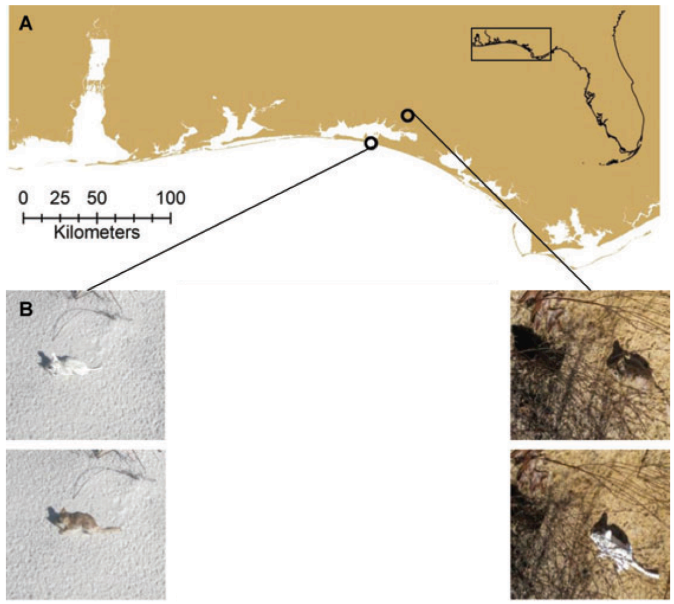

Vignieri, Larson & Hoekstra (2010)

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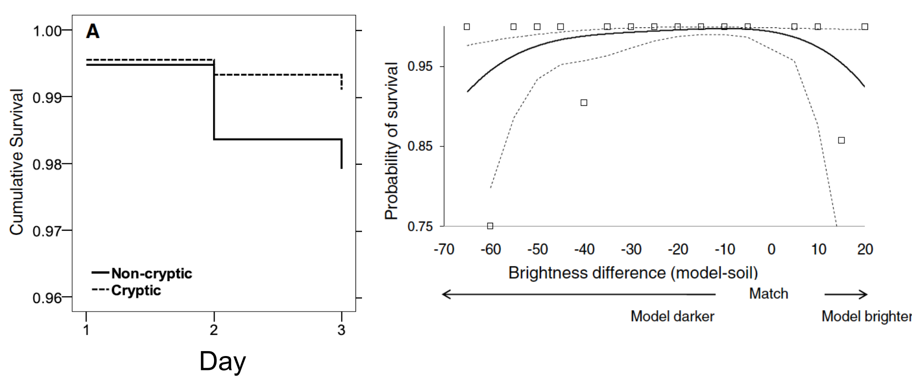

Vignieri, Larson & Hoekstra (2010)

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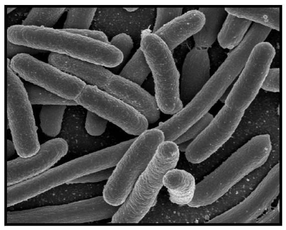
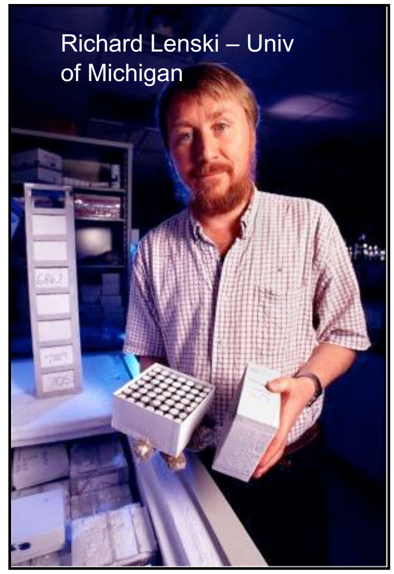
Evolution in the lab – ʻexperimental evolutionʼ

Lenski – founder of ʻexperimental evolutionʼ – 30 yr. experiment with *E. coli*



> 50,000 generations of evolution!



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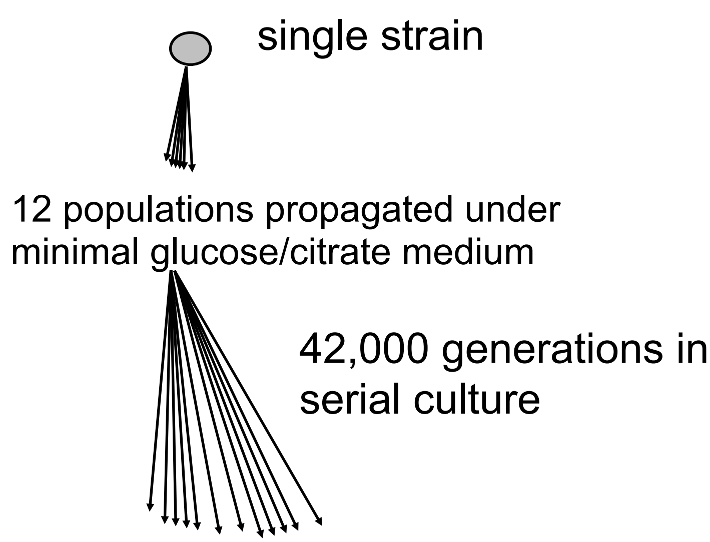
Experimental evolution with E. coli



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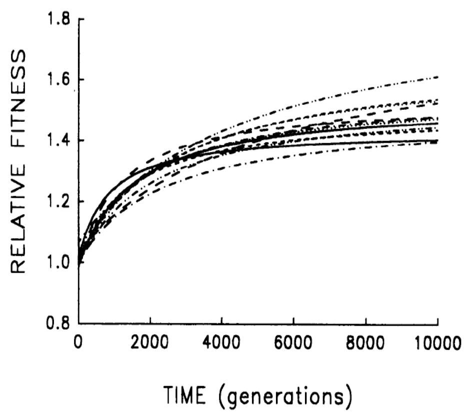
Experimental evolution with E. coli



Samples frozen every 500 generations allowing relative fitness of different generations to be compared – "Fossil record"

- all populations rapidly increased in fitness
- similar adaptations across strains (e.g. larger cell sizes, higher maximal growth rates on glucose)
- parallel mutations at same genes
- some unique adaptations and distinct genetic changes

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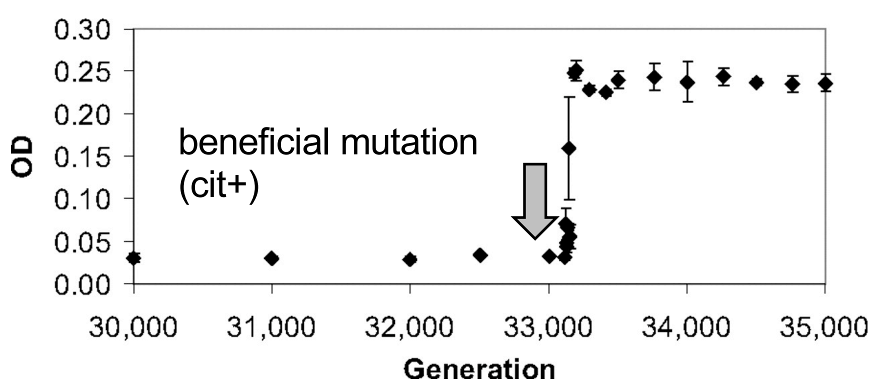
Novel adaptation in single strain after 33,000 generations!



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