Biology 354
Foundations in Evolution & Systematics

Profs: Ray Huey & Peter Ward
TAs: Fran Bonier, Aaron Clark, Noelle Macnicki

Text: Freeman & Herron, 3rd edition

http://courses.washington.edu/biol354/

- **Syllabus** (with links to *some* PowerPoint presentations and lab discussion assignments).
- **Policies on exams** (e.g., missed exams because of illness, oversleeping), grades, etc.
  Read these carefully!

Exams and Grading

- **Exams (~ 70% of grade)**
  - **Wed 26 April**
  - **Monday 5 June (2:30 - 3:20)** TENTATIVE
- **Lab section (~ 30%)**
  each one counts (30% / 10 = 3%)
- **Our best advice:** attend *all* lectures & discussion sections and hand in *all* assignments.

Evolution

First half (Huey) will focus on ("microevolution")

selection, phenotypic variation & genetics, phylogenies & the comparative method

Second half (Ward) will focus on ("macroevolution")

origin of life, speciation, history of life, diversity, extinctions, human evolution

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Charles Darwin **Alfred Russel Wallace**

Evolution by Natural Selection
1858 - Journal of the Linnean Society

Artificial selection was well understood at the time, and could produce remarkable (genetic) changes in just a few generations of selective breeding

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How Scientists Observe (or Manipulate) Evolution

Observational approaches:

Evolutionary shifts in bill size in a Galapagos finch

Evolutionary shifts in wing size in an introduced species of fly

Experimental approaches:

in the field, in the lab

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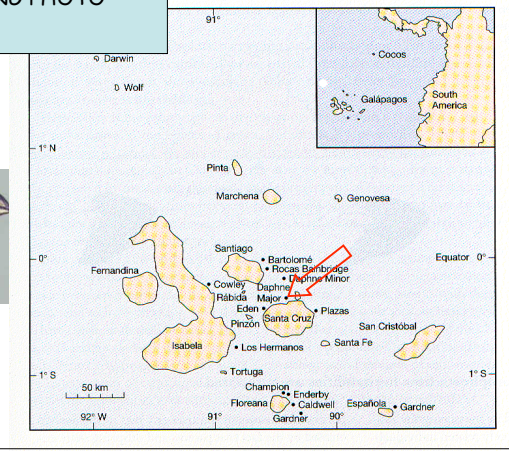
Geospiza fortis

The Galápagos Setting



The Evolution of Beak Shape in Galápagos Finches

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Peter Boag

Rosemary Grant Peter Grant

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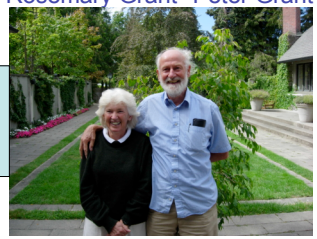
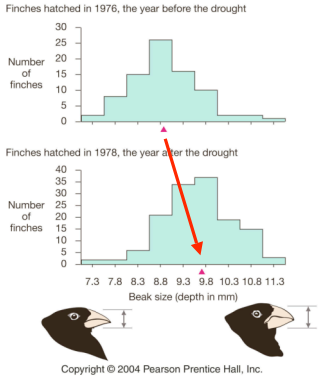


Observation: $\overline{X}$ ***bill size increased between '76 & '78***



Was this evolution in action?

What environmental factors were involved?

Was Natural Selection responsible?

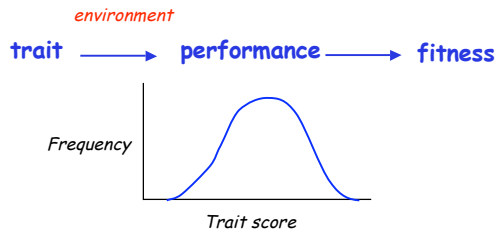
Darwin's Four Postulates

text section 3.2

- Traits of individuals are variable
- Variation has a genetic basis
- Some individuals survive and reproduce more than others
- Survival & reproduction are non-random -- individuals with certain traits (bigger, smarter) have higher probability of surviving and reproducing

If these postulates hold, then the composition of the population will change from one generation to the next. == Evolution by Natural Selection

- Traits of individuals are variable
- Survival & reproduction are non-random -- individuals with certain traits (bigger, smarter) have higher probability of surviving and reproducing



Testing Postulate 1: Is the finch population variable?

medium ground finch in Galapagos -- in 1976

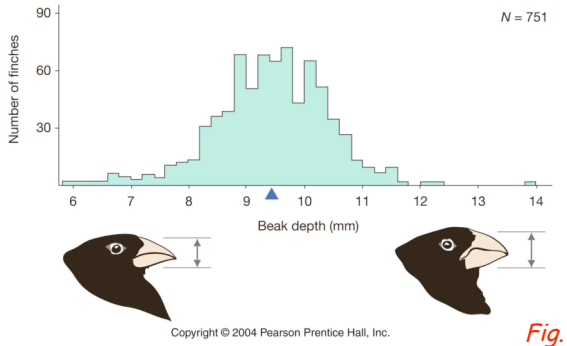
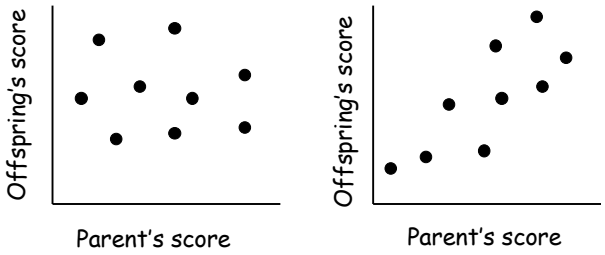


Fig. 3.6

Testing Postulate 2: Is some of the variation heritable?

"like begets like"



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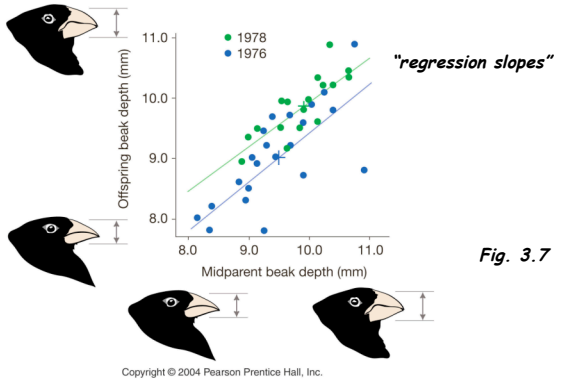
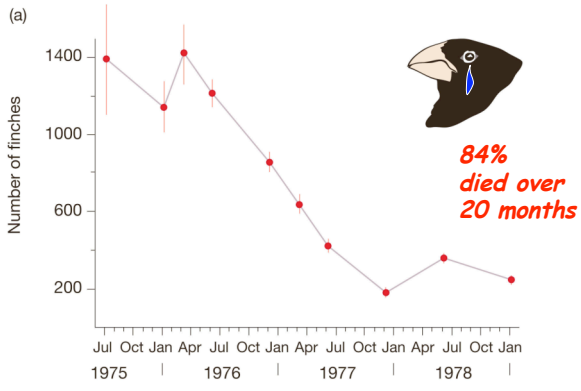


"regression slopes"

Fig. 3.7

Testing Postulate 3: Are some finches "better" than others?



84% died over 20 months

Testing Postulate 4: Is survival non-random w/ respect to traits of individuals?

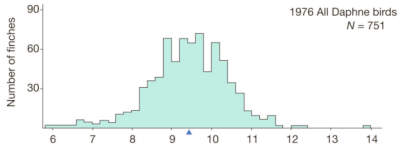
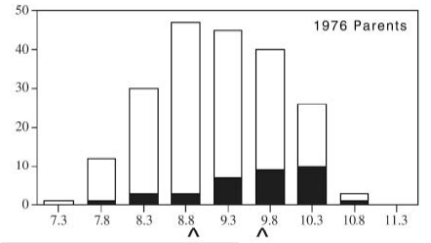


Fig. 3.9

Testing Postulate 4: Is survival non-random w/ respect to traits of individuals?



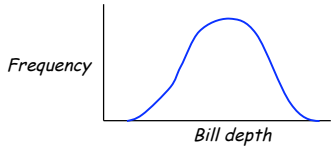
birds with big bills survived better --

Buy why?

Black bars indicate '76 birds that survived & bred in 1978

environment

trait → **performance** → **fitness**



What was happening to the environment?

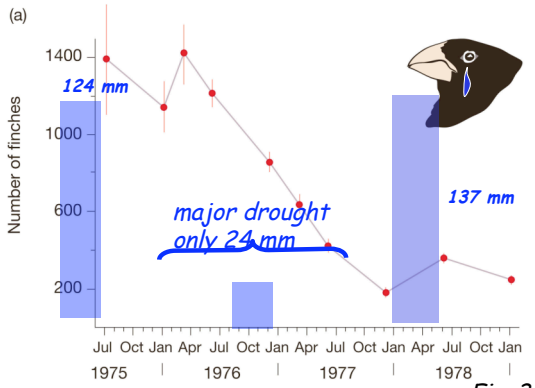


Fig. 3.8A

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Daphne Major plateau, wet year

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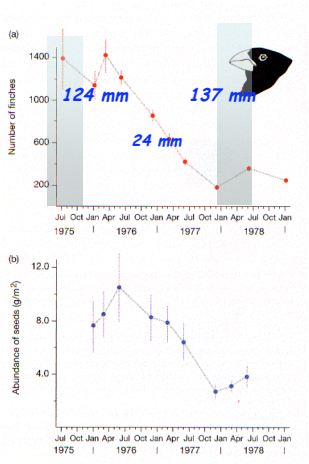
Daphne Major plateau, dry year



84% died over 20 months

Fig. 3.8a,b

birds forced to switch to larger, harder seeds

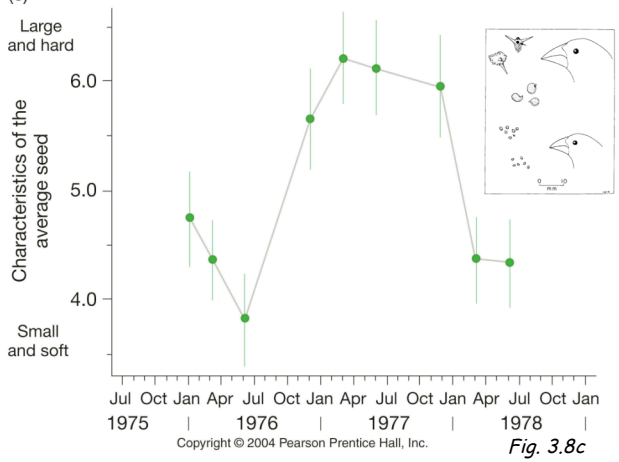
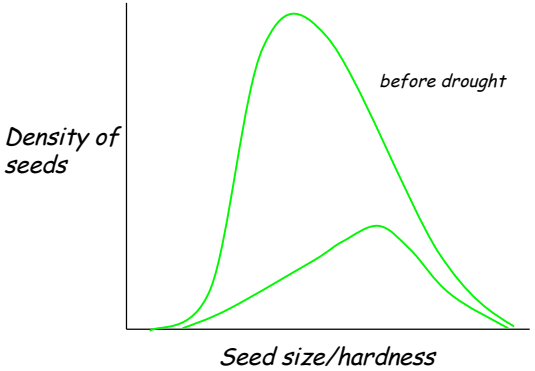
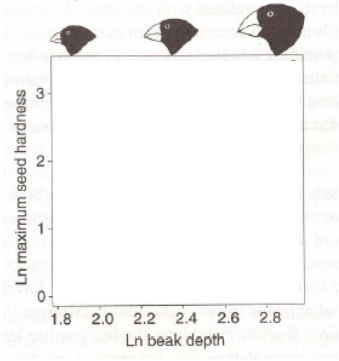


Fig. 3.8c



Hypothesis: birds with big bills can eat bigger seeds and hence be favored

trait → **performance** → **fitness**



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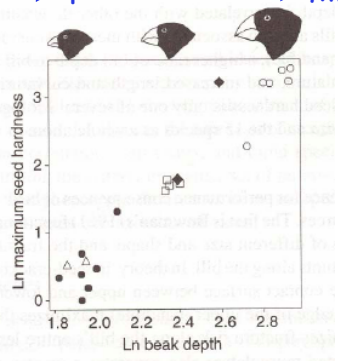
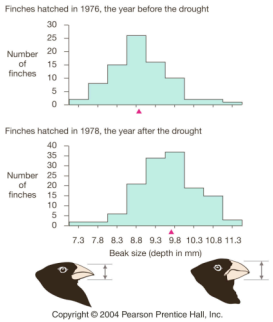


Evolution in action



Variation is large

Part is of variation is heritable

Few birds survived drought

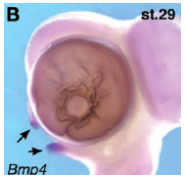
Survival was non-random

Therefore, the population evolved by Natural Selection

What's the developmental/genetic basis for differences in bill size ?

Bmp4

"bone morphogenic protein 4"



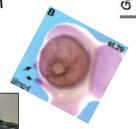
Science Sept '04

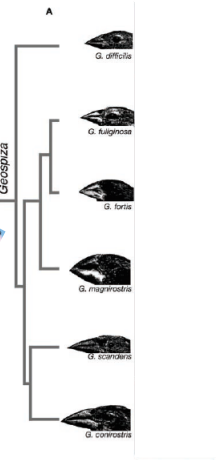
Bmp4 expression

What's the developmental basis for differences in bill size ?

Bmp4

bone morphogenic protein





Science Sept '04

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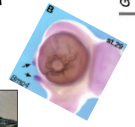
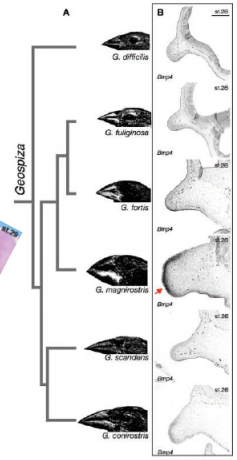




Science Sept '04

How Scientists Observe (or Manipulate) Evolution

Observational approaches:

Evolutionary shifts in bill size in a Galapagos finch

Evolutionary shifts in wing size in an introduced species of fly

Experimental approaches:

in the field, in the lab

Basic protocol for studying selection in nature
observational approaches

Collect (or rear) a large N of individuals

Measure their phenotypes (bill size, speed, color)

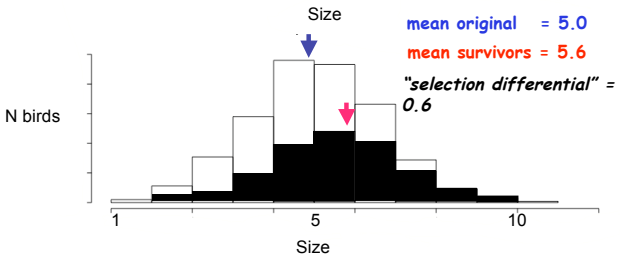
Release them back into the field

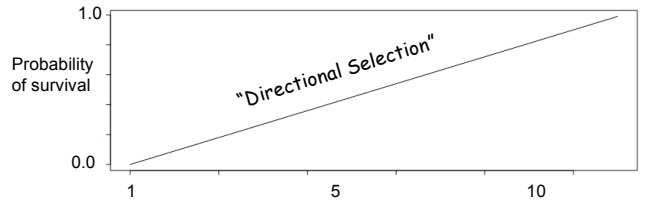
Later -- recapture and determine survivors *

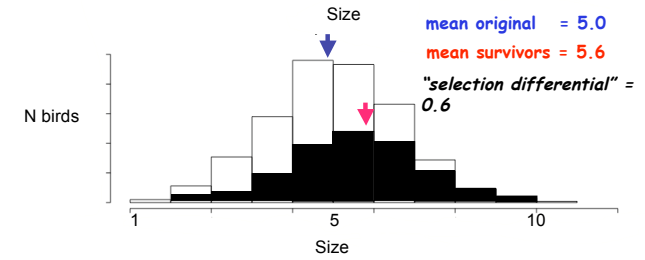
Ask -- are survivors a random subset of the the original cohort?

*** or reproductive success**

Individual	Size	Survival
1	3.2	0
2	4.6	1
3	6.2	1
4	4.3	0
5	3.9	0
n	5.5	1







"Mapping" trait score onto survival

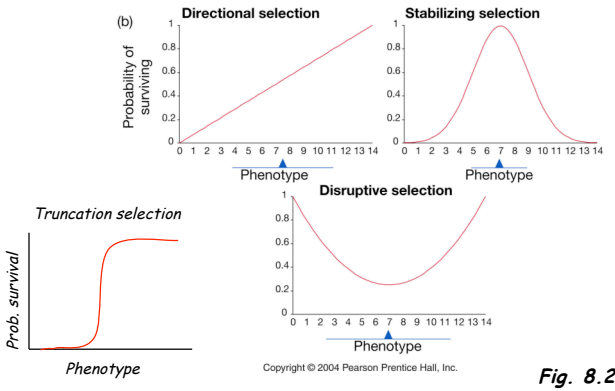
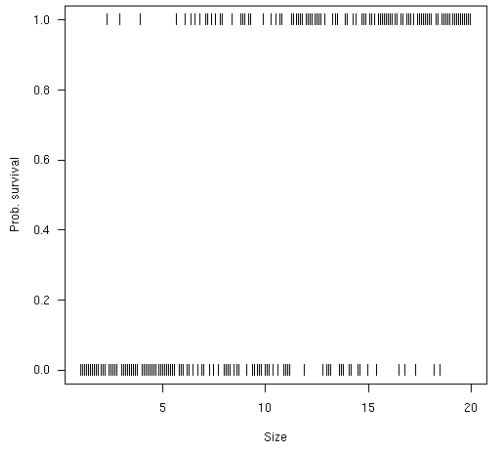


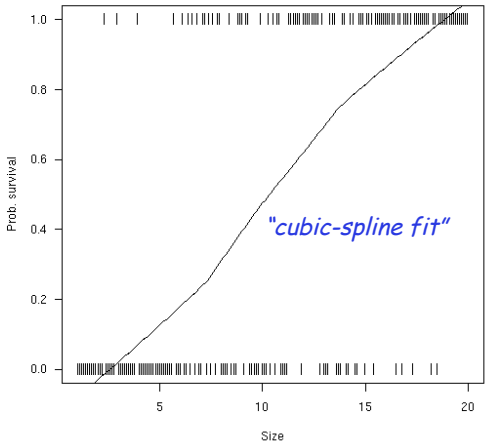
Fig. 8.23A

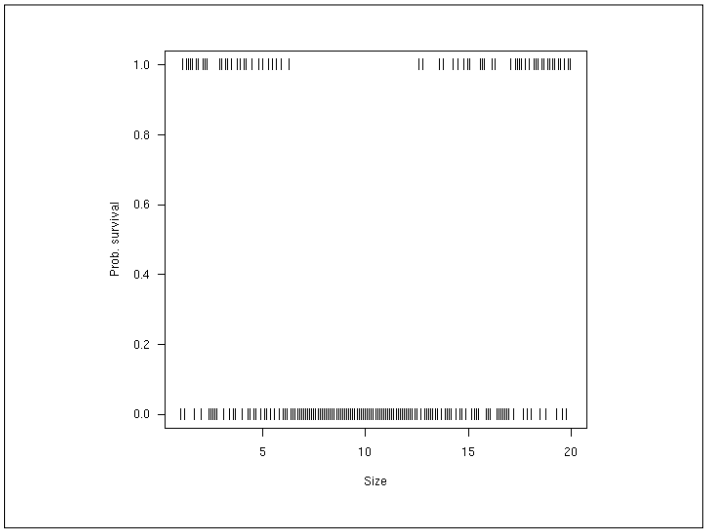
How does one determine the type of selection from capture-recapture data?

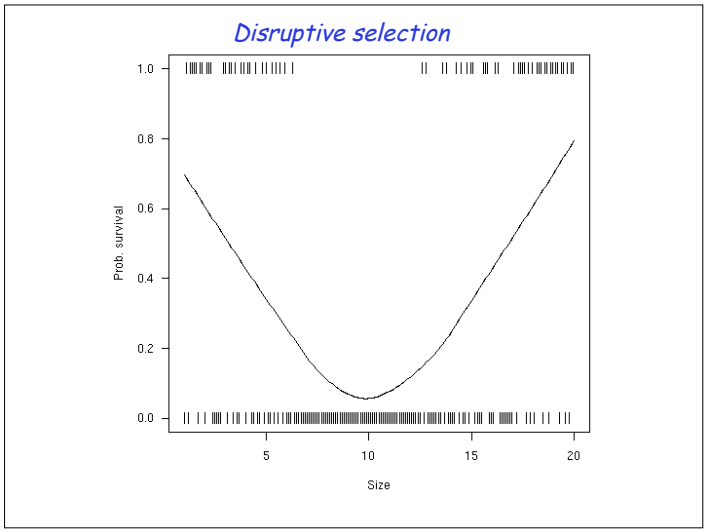
Individual	Size	Survival
1	3.2	0
2	4.6	1
3	6.2	1
4	4.3	0
5	3.9	0
n	5.5	1

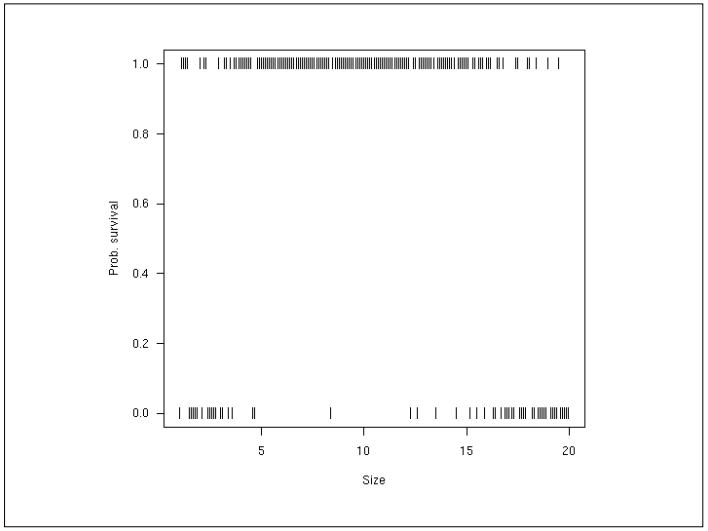
technique of D. Schluter, '88 Evolution

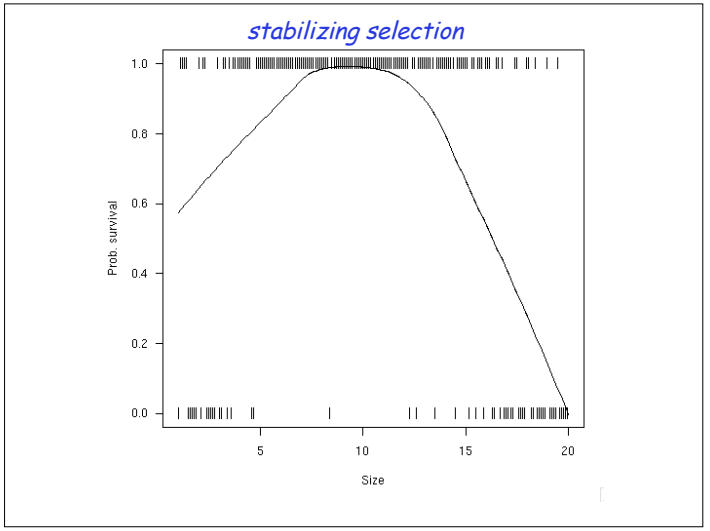




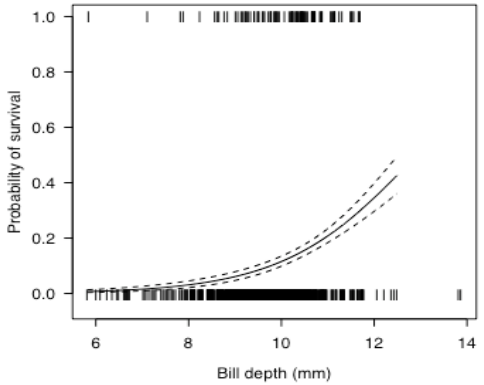

Prob. survival
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
Size


Disruptive selection
Prob. survival
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
Size


Prob. survival
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
Size

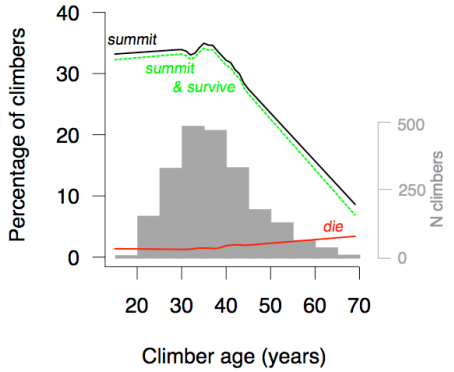

stabilizing selection
Prob. survival
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
Size

Cubic spline for the finch data, showing what type of selection?



Probability of Everest mountaineers summiting

Or dying as a function of their age (N climbers in gray). Does youth outwit age and experience?



"selection differential" = mean after - mean before
(10.1-9.6) = 0.5

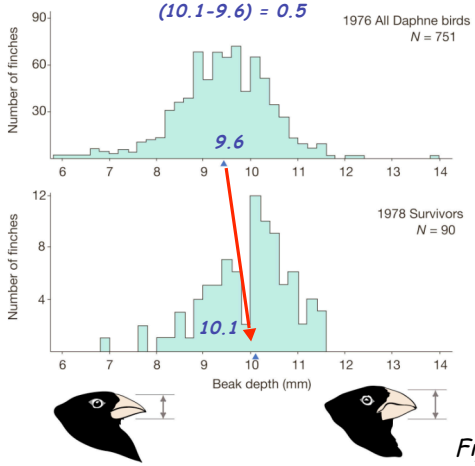


Fig. 3.9

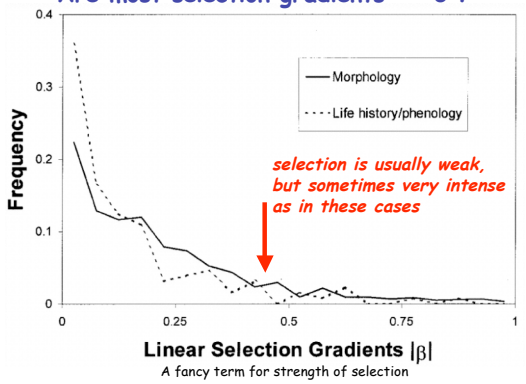
How strong is directional selection?

Are most "selection gradients" >> 0 ?

Kingsolver et al. 2001 Am Nat

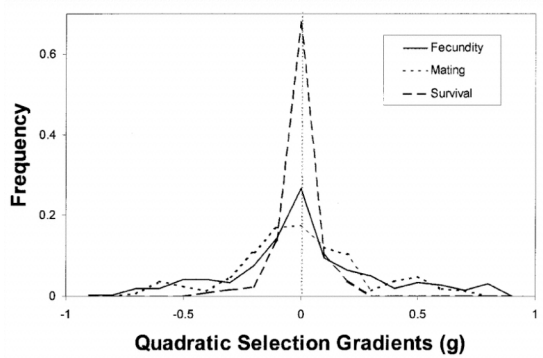
Reviewed 63 field studies of many traits. For each study measured the strength of selection, and then looked at the frequency of studies showing strong (or weak) selection.

How strong is directional selection?
Are most selection gradients >> 0 ?



Kingsolver et al. 2001 Am Nat

How strong is stabilizing selection?
Are most selection gradients >> 0 ?



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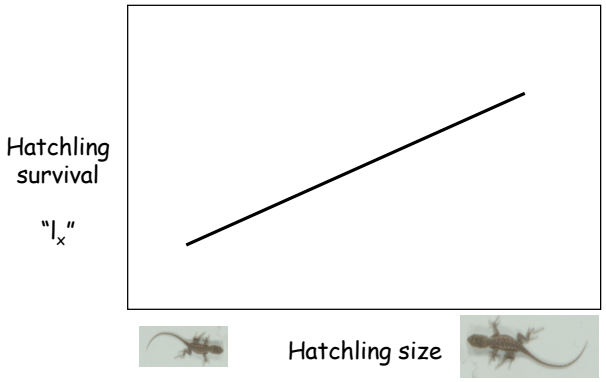
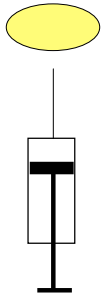


Experimental studies in nature

I. Manipulate organism's own phenotype
"phenotypic engineering"
Barry Sinervo (UC Santa Cruz)

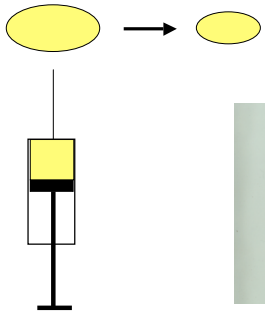
Making "small eggs"

Sinervo's technique



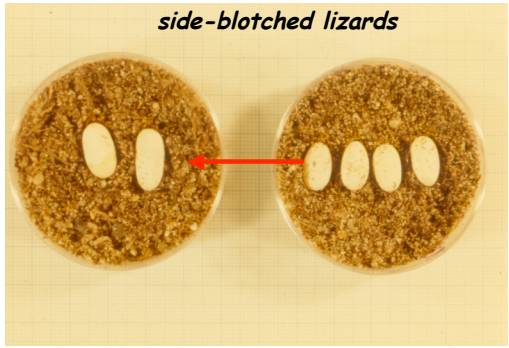
Making "small eggs"

Sinervo's technique



Making "big eggs"

Sinervo's technique



If "bigger is better"

Experimental studies in nature

II. Manipulate environment -
- add predators

David Reznick (UC Riverside)

If add predators, observe shifts in life history traits, or rate of aging, or in speed of escape ?

Experimental studies in nature

III. Transplant to organisms to different environments

Doug Schemske
Toby Bradshaw
Amy Angert

& Mimulus

Experimental evolution in the lab

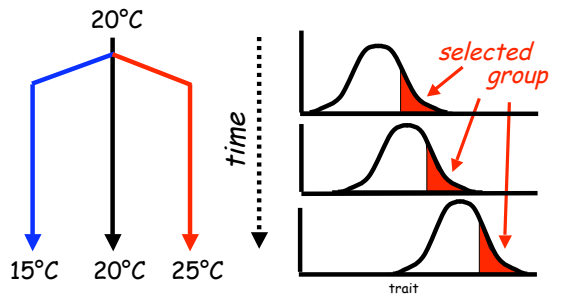
Advantages

Gain control
over environment
over what being selected

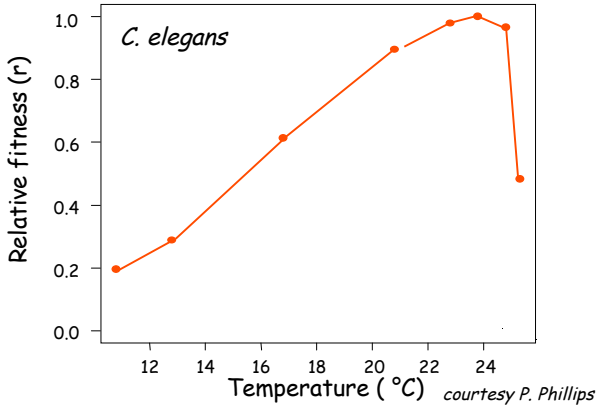
Can replicate !

Can do in the privacy of your own lab -- no need to get wet and dirty !

Experimental evolution in the lab

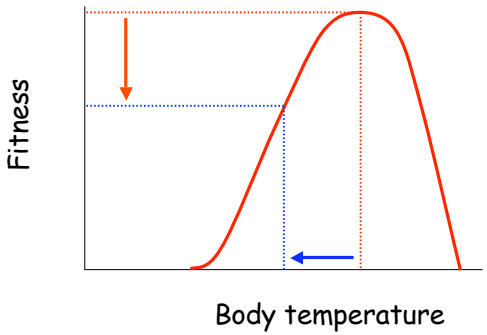


Can thermal sensitivity evolve quickly?

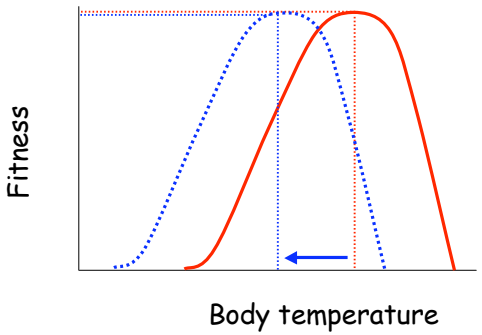


courtesy P. Phillips

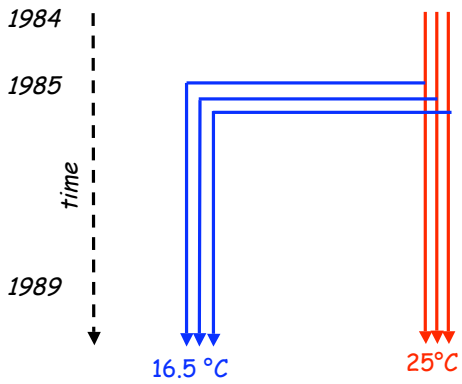
Climate change and mal-adaptation



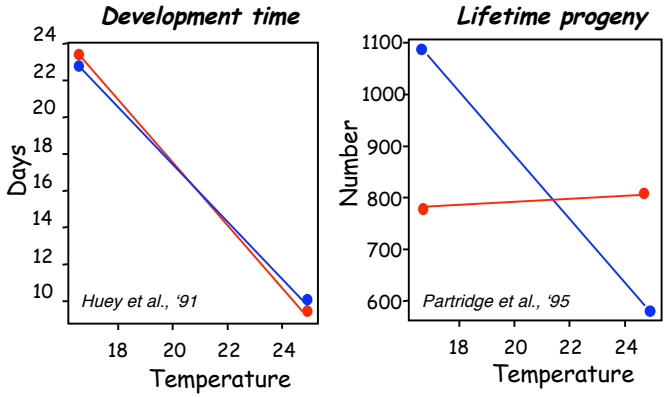
Climate change and adaptation



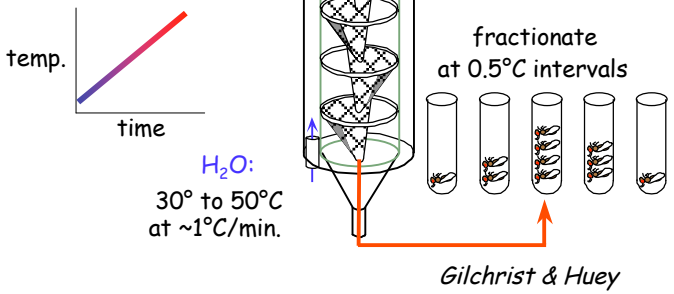
Laboratory natural selection
D. melanogaster (Linda Partridge lines)



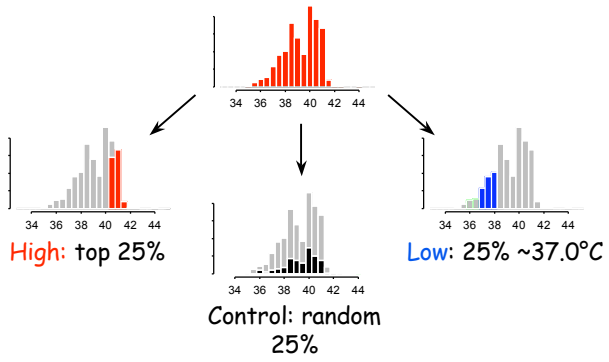
Response to laboratory natural selection



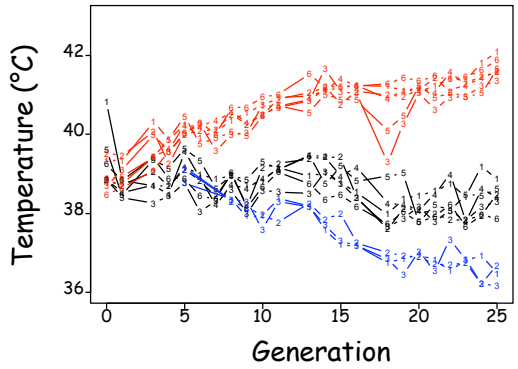
Knockdown Temperature



Selection Protocol



Selection on KD Temperature (males)



Experimental evolution in the lab demonstrates

Populations have standing genetic variation for traits (e.g., thermal sensitivity) –
*thus have the genetic **potential** to evolve quickly*

But are laboratory studies relevant to nature?

Lab experiments provide insight into what can happen in nature ***but not necessarily what will happen***.

Why not?

1) *Laboratory environments are highly artificial*
2) *Biotic interactions are only intraspecific*
3) ***Compensatory behavior is "deactivated"***

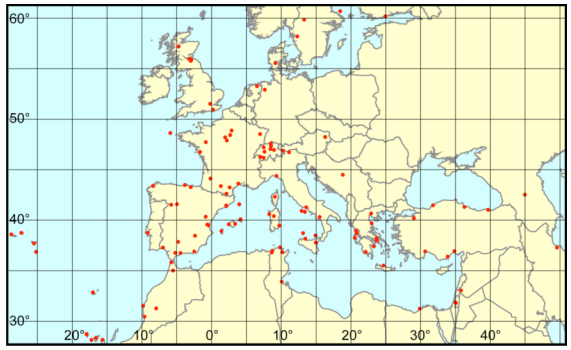
Rapid evolution in an introduced species: ***Drosophila subobscura***

MISSING PHOTO

An inadvertent transplant study!

Raymond B. Huey (U. Washington),
George Gilchrist (Clarkson U.),
Luís Serra, Joan Balanyà, Marta Pascual (U. Barcelona)

Drosophila subobscura is widespread in the Old World

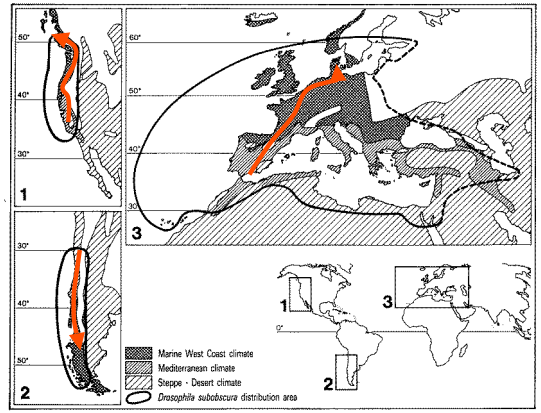


*"A grand experiment in evolution..."**
began in February 1978

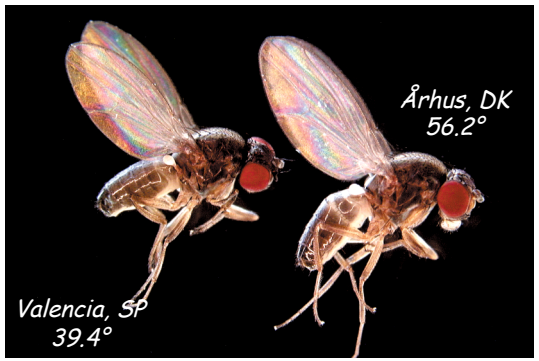
MISSING PHOTO

photo of Puerto Montt, Chile, where flies first detected in 1978

**F. J. Ayala et al., 1989*



Clinal variation in size in Old World flies:
body size increases with latitude

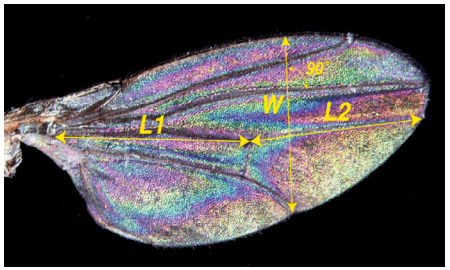


How rapidly can body size *clines* evolve?

Body size in many animals covaries with latitude. In general, animals increase in size from the equator toward the poles. This pattern has been found in:

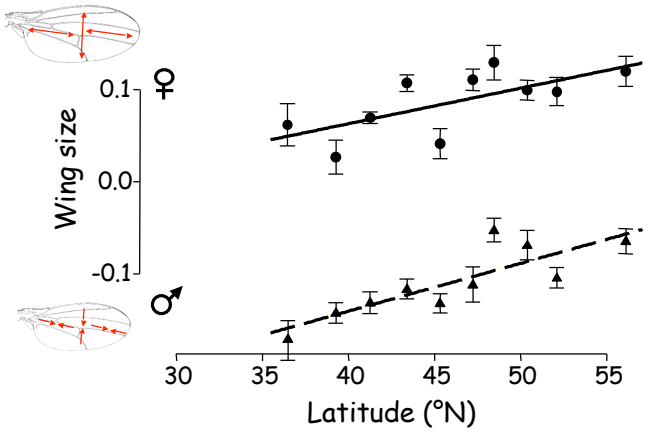
- *D. subobscura* (Europe)
- *D. melanogaster*
- *D. equinoxalis*
- *D. persimilis*
- *D. pseudoboscura*
- *D. simulans*
- *D. willistoni*
- ...and most ectotherms.

Flies from each site on each continent reared at uniform density in a "common garden" for ~10 generations; then a PC analysis on wing dimensions.

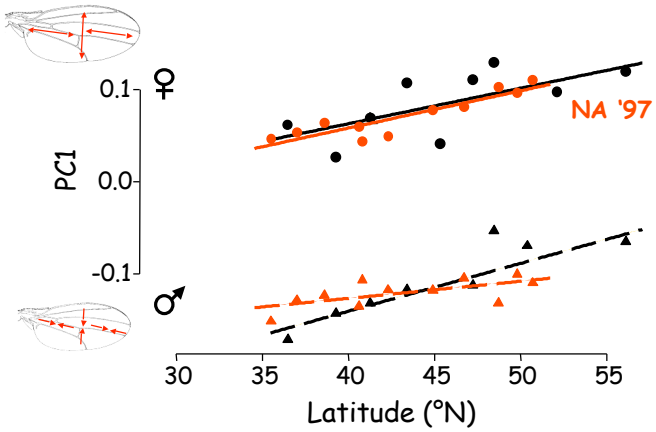


	PC1	PC2	PC3
% variance	82.3	14.5	3.2

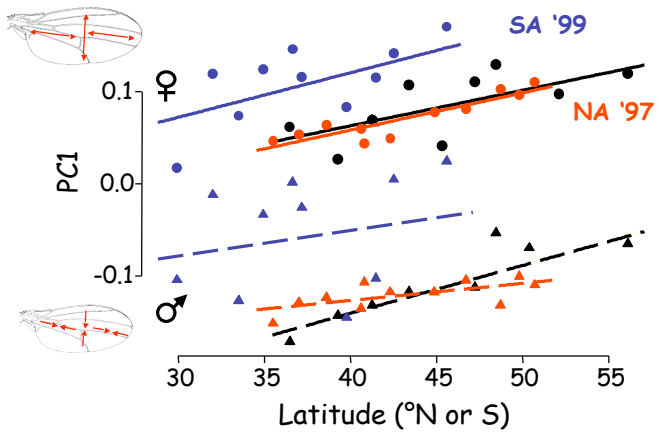
The European Baseline Cline



NA evolved cline by 1997



and SA evolved cline by 1999

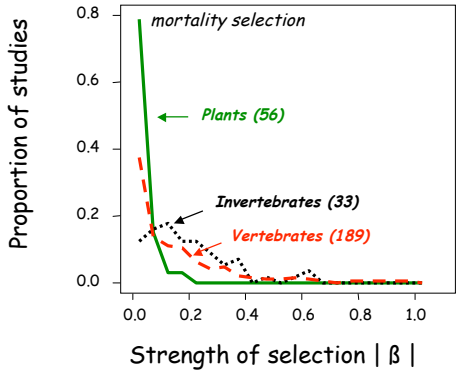


Selection in Plants vs. Animals
Strength of Selection?

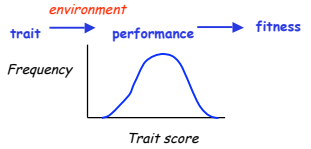
"… it is the plants which are more likely to suffer from the environment. As a result… *characteristics of plants are likely to be subject to high and effective selection pressures.*"

A. D. Bradshaw, 1972
Some of the evolutionary consequences of being a plant

In fact, most studies of plants detect very weak selection, contrary to Bradshaw's prediction ! Why?



How Scientists Observe (or Manipulate) Evolution



Observational approaches:

Evolutionary shifts in bill size in a Galapagos finch

Evolutionary shifts in wing size in an introduced species of fly

Experimental approaches:

in the field, in the lab