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

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
The Evolution of Beak Shape in Galápagos Finches

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Peter Boag Rosemary Grant Peter Grant

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Observation: \( \bar{x} \) bill size increased between '76 & '78

Was this evolution in action?

What environmental factors were involved?

Was Natural Selection responsible?

Darwin’s Four Postulates

* 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. \( \Rightarrow \) Evolution by Natural Selection
Testing Postulate 1: Is the finch population variable?

medium ground finch in Galapagos -- in 1976

Testing Postulate 2: Is some of the variation heritable?

"like begets like"

Offspring's score

Parent's score

Fig. 3.6

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

84% died over 20 months

Fig. 3.7
Testing Postulate 4: Is survival non-random with respect to traits of individuals?

Fig. 3.9

Birds with big bills survived better -- Buy why?

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

What was happening to the environment?

(a)

![Graph showing number of finches over time with major drought only 24 mm and 137 mm.](Fig. 3.8A)
Daphne Major plateau, wet year

Daphne Major plateau, dry year

Fig. 3.8a,b

84% died over 20 months

Fig. 3.8c

birds forced to switch to larger, harder seeds
Hypothesis: birds with big bills can eat bigger seeds and hence be favored

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

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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 original cohort?

* or reproductive success

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<th>Survival</th>
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<td>3.2</td>
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<td>4.3</td>
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<td>3.9</td>
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mean original = 5.0
mean survivors = 5.6
"selection differential" = 0.6

"Directional Selection"

N birds

Size

Probability of survival

1.0

0.0

N birds

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

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 técnica de D. Schluter, '88 Evolution

"Mapping" trait score onto survival

Fig. 8.23A

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

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"cubic-spline fit"
Disruptive selection

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

**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 $\gg 0$?

Kingsolver et al. 2001 Am Nat

A fancy term for strength of selection

selection is usually weak, but sometimes very intense as in these cases

How strong is stabilizing selection? Are most selection gradients $\gg 0$?

Kingsolver et al. 2001 Am Nat

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Observational approaches:

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Experimental approaches:

in the field, in the lab
Experimental studies in nature

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

Making “small eggs”
Sinervo’s technique

Making “big eggs”
Sinervo’s technique

side-blotched lizards
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

lab natural selection  artificial selection

Can thermal sensitivity evolve quickly?

C. elegans

Climate change and mal-adaptation

Climate change and adaptation
Laboratory natural selection
*D. melanogaster* (Linda Partridge lines)

- 1984
- 1985
- 1989

Temperature:
- 16.5 °C
- 25°C

Development time and Lifetime progeny:
- Days: 18, 20, 22, 24
- Temperature: 18, 20, 22, 24

Response to laboratory natural selection:
- Development time: 18, 20, 22, 24
- Lifetime progeny: 18, 20, 22, 24

Knockdown Temperature:
- H₂O: 30° to 50°C at ~1°C/min.
- Fractionate at 0.5°C intervals

Selection Protocol:
- High: top 25%
- Low: 25% ~37.0°C
- Control: random 25%
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*

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An inadvertent transplant study!

Raymond B. Huey (U. Washington),
George Gilchrist (Clarkson U.),
Luís Serra, Joan Balanyà, Marta Pascual (U. Barcelona)
*A grand experiment in evolution...*

began in February 1978

*F. J. Ayala et al., 1989

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

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

Århus, DK
56.2°

Valencia, SP
39.4°
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. equinoxialis
- 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.

<table>
<thead>
<tr>
<th>% variance</th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
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<tbody>
<tr>
<td></td>
<td>82.3</td>
<td>14.5</td>
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The European Baseline Cline

NA evolved cline by 1997
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?

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