Natural Selection and Adaptation, Part I

36-149 The Tree of Life

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Plan

- Review of Natural Selection
- Detecting Natural Selection (discussion)
- Examples of Observed Natural Selection

..... Next Time:

- Adaptive Traits
- Methods for Reasoning about and studying adaptations
- Explaining Complex Adaptations (discussion)

Overview

The theories of common descent and natural selection play different roles within the theory of evolution.

Common Descent explains the unity of life.

Natural Selection explains the diversity of life.

An *adaptation* (or adaptive trait) is a feature of an organism that enhances reproductive success, relative to other possible variants, in a given environment.

Adaptations become prevalent and are maintained in a population through natural selection.

Indeed, natural selection is the only mechanism of evolutionary change that can satisfactorily explain adaptations.

Darwin's Argument

Darwin put forward two main arguments in support of natural selection:

An analogical argument: Artificial selection

A logical argument: The struggle for existence

(As we will see later, we now have more than just argument in support of the theory.)

The Analogical Argument: Artificial Selection

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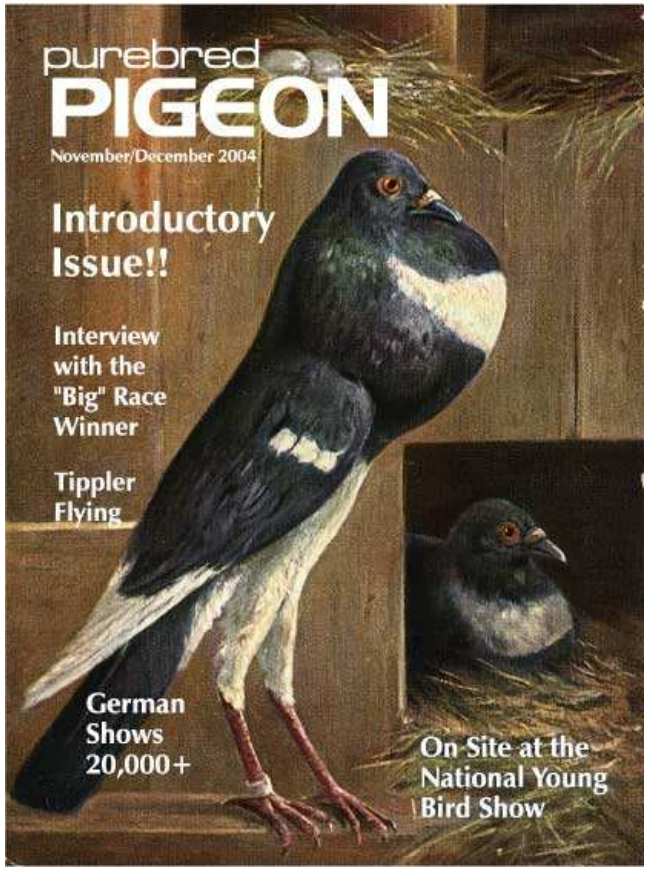
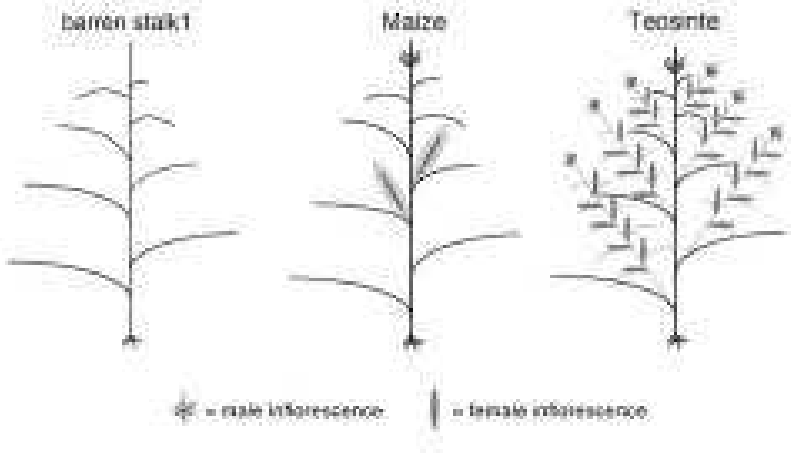


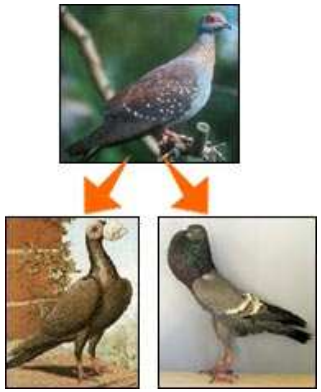
The Analogical Argument: Artificial Selection

Teosinte to Corn



The Analogical Argument: Artificial Selection

- Darwin was intimately familiar with the efforts of breeders in his day to produce novel varieties.



  Pigeons, dogs, horses, corn, cabbages, domestic livestock, . . .

- Breeders would selectively pair and mate based on desired traits.
- Drastic phenotypic changes can be wrought this way in a relatively short time.
- By analogy, then, nature should be able to make even larger changes over geological time.

  The only difference is that the environment rather than human choice would determine which variants leave the most offspring.

The Logical Argument: Propagation of the Fittes

Given the following conditions:

A. Phenotypic variation,

Within natural populations, traits differ across individuals.

B. Differential fitness,

Particular combinations of traits confer an advantage or disadvantage for reproductive success relative to other possible combinations within the population.

C. Inheritance,

Offspring tend to share many traits with their parents.

The Logical Argument: Propagation of the Fittes

The following will result:

1. The trait frequency distribution will differ among age classes beyond what we be expected from A and C alone.

   Organisms whose traits confer greater reproductive success will produce more offspring.

2. If the population is not at equilibrium, the trait frequency distribution of all offspring in the population will be predictably different from that of their parents.

   Offspring who tend to resemble their parents in those advantageous traits, and will thus tend to propogate

Natural Selection

> As many more individuals of each species are born than can possibly survive; and as, consequently, there is a frequently recurring struggle for existence, it follows that any being, if it vary however slightly in any manner profitable to itself, under the complex and sometimes varying conditions of life, will have a better chance of surviving, and thus be naturally selected. From the strong principle of inheritance, any selected variety will tend to propagate its new and modified form.
>
> — Charles Darwin, *On the Origin of Species* (1859)

We use fitness to mean some measure of reproductive success for a variant (trait,phenotype,or genotype) *relative* to other variants in the population.

Natural selection, then, is any systematic difference in fitness among phenotypically distinct biological entities.

Points to Remember about Natural Selection

- It is not just random change.

  Quite the opposite, in fact. Natural selection acts as a filter on random variation.

- It is not directed toward a goal.

  Reproductive success at any given time and in any given environment is the only criterion.

- It does not produce perfection.

  Natural selection operates on the structures and variation that is available.

- It does not lead to moral or ethical prescriptions.

  The Naturalistic Fallacy

Detecting Natural Selection

Discussion question: What empirical methods might we use to detect the operation of natural selection, either in the wild or in the lab?

Some key ideas:

- Experiments and Controlled Comparison
- Null Hypothesis
- Alternative Hypothesis
- Correlation

Detecting Natural Selection

Basic idea: Identify the changes and test – through proper comparison – whether they differ from what would be expected by chance alone.

The following are some of the basic methods that implement this idea.

I. Look for correlation between traits and some geographically (or temporally) varying environmental factors.

Null hypothesis: The traits of interest should vary independently of the environmental factors.

Alternative hypothesis: Geographically (or temporally) varying natural selection will produce a correlation between the trait and the factors.

Detecting Natural Selection (cont'd)

II. Compare homologous traits in closely related species within the same area.

Assumptions: a) traits are homologous, b) the related species experience the same selective pressures.

Null hypothesis: The traits should vary independently between the two species.

Alternative hypothesis: The traits should experience the same types of natural selection. Wherre the species do not interact, the traits should evolve in the same way. Where the species do not interact, the traits should diverge where the two species overlap (by competition).

III. Comparison of unrelated species in similar habitats.

Assumptions: a) species are distantly related, b) the species experience the same selective pressures.

Null hypothesis: The traits should vary independently between the two species.

Alternative hypothesis: The traits should converge because they experience the same types of natural selection.

Detecting Natural Selection (cont'd)

IV. Compare to the predictions of mathematical models

Example: Hardy-Weinberg

V. Study trait frequency distributions of a population over a long period of time.

Null hypothesis: The traits should vary randomly in time.

Alternative hypothesis: The traits should stabilize or show directional change.

Detecting Natural Selection (cont'd)

VI. Perturb the environment of natural populations

Null hypothesis: The traits should not be affected, beyond chance, by the perturbation.

Alternative hypothesis: The trait frequencies should vary systematically with the perturbation.

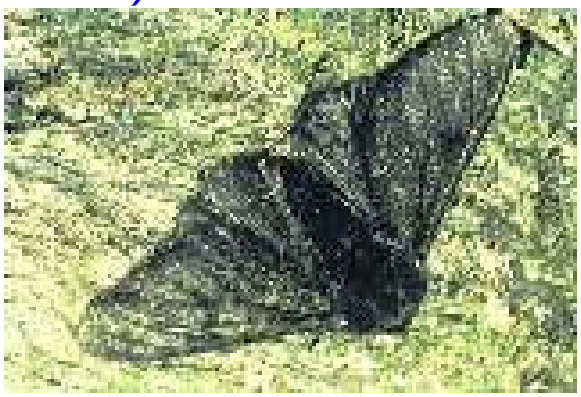
VII. Detailed study of individuals and environment in a particular cohort and time window.

Null hypothesis: The traits should vary randomly with the observed factors.

Alternative hypothesis: The traits should change systematically.

Examples of Natural Selection

Peppered Moths (*Biston betularia*)



Examples of Natural Selection (cont'd)

Galapagos Finches

Peter and Rosemary Grant have studied this population for over 20 years.

For example:

Geospiza magnirostris is a large-beaked finch that can handle large, hard types of food.

Geospiza fortis is a small-beaked finch that is likely more efficient with smaller types of food.

The Grants provided strong evidence that beak size is inherited.

They also showed that changes in beak shape and dimensions tracked environment and food supply across islands and time.

Several "natural experiments" (a missing wet season in 1977 and an extra heavy wet season in 1982) gave small but significant effects over a period of a few years.

When small seeds were scarce during the 1977 drought, *G. fortis* populations reduced relative to *G. magnirostris*.

When small seeds were in surplus during the 1982 El Niño, *G. fortis* populations increased relative to *G. magnirostris*.

Examples of Natural Selection (cont'd)

Endler's Guppies

In the 1970s, John Endler began studying Trinidad's wild guppies. He observed:

- Tremendous variation in color, size, and placement of spots among guppies in different streams or different parts of the same stream.
- Variation in predators
- Differences in gravel size and color along the stream bed.
- Strong correlation between guppy coloration and where in the stream they lived.

Endler ran experiments in the lab and the field in which he manipulated the environment (predation, bottom substrate, ...) to study changes in size and color of spots.

What is the null hypothesis in Endler's study? What are some possible alternative hypotheses? Why do the guppies even have colors and conspicuous spots?

Endler's Guppies (cont'd)

Null Hypothesis: Color and spot distributions in local guppy populations should vary independently of stream bed and predation.

(Other) Possible Alternative Hypotheses:

1. Predators more easily catch brightly colored individuals, decreasing the fitness of conspicuous phenotypes.
2. Female guppies are choosing to mate with the most brightly colored males, increasing the fitness of conspicuous phenotypes.

Endler's Results: Female preference for coloration balanced by increased predation.

Examples of Natural Selection (cont'd)

Lenski and the long-term Evolution *E. coli*

A multi-year, multi-generation study of identical lines of *E. coli*. (Started in 1988 and still ongoing; currently over 40,000 generations have been produced.)

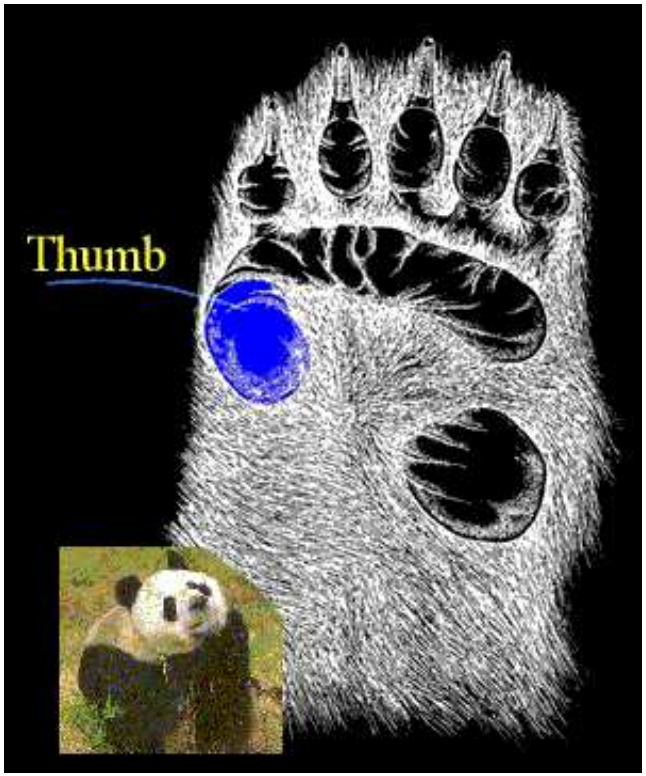
- Many parallel changes among the populations but also much variation
- Considered adaptations to temperature
- Considered adaptations to food supply
- Comparisons with ancestral stock

Examples of Natural Selection (cont'd)

The Panda's Thumb

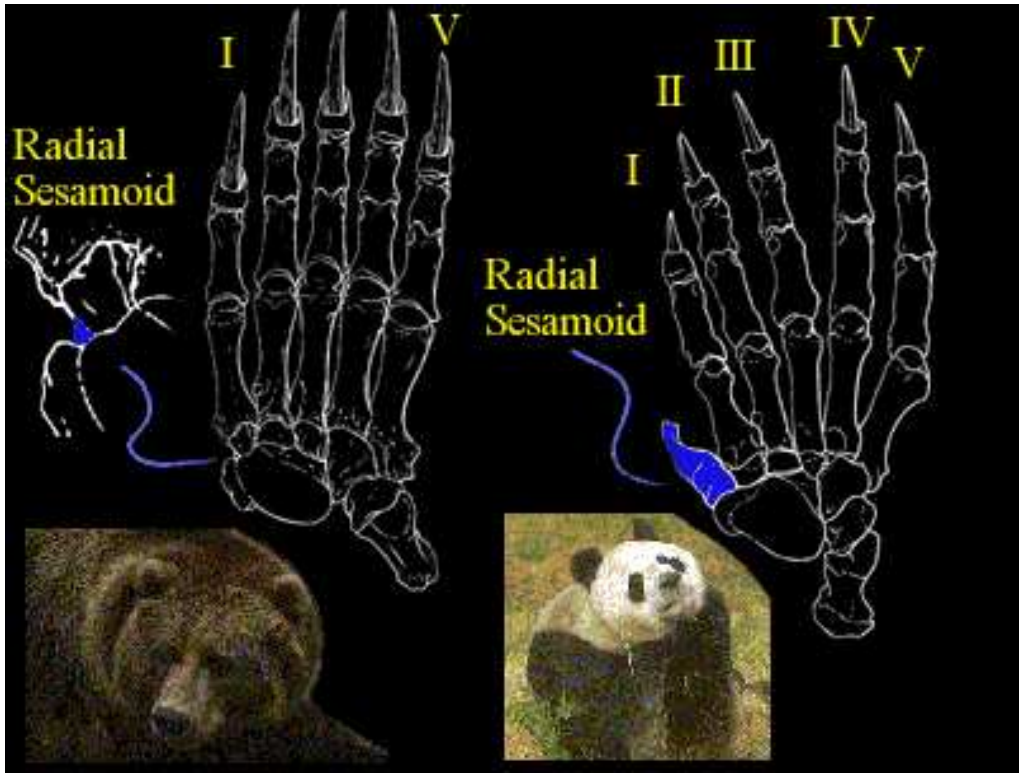
Examples of Natural Selection (cont'd)

The Panda's Thumb



Examples of Natural Selection (cont'd)

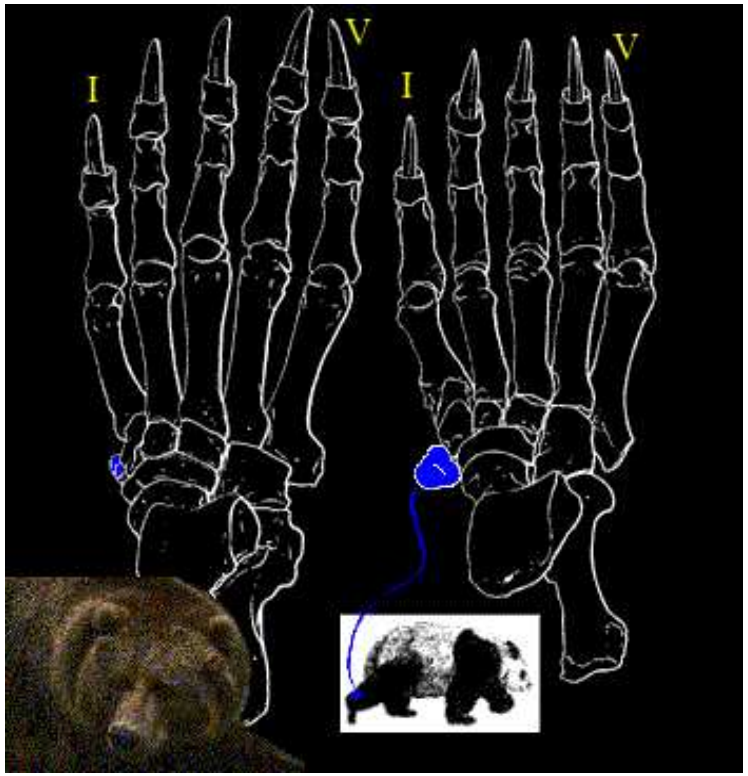
The Panda's Thumb



Can you tell an evolutionary story about how this "thumb" evolved via natural selection?

Examples of Natural Selection (cont'd)

The Panda's Feet



How does the tibial sesmasoid complicate your story?

Next Time

How natural selection produces complex traits. . .