BIO 221
Invertebrate Zoology I
Spring 2010

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http://www4.nau.edu/isopod

Lecture 2

Components of the Scientific Process

1. Observation
2. Generalization
3. Hypothesis formation
4. Hypothesis testing
5. Conclusion (and reformulation of hypothesis)

What does all of this have to do with the biology of invertebrates?

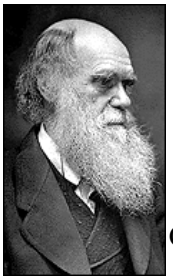
Biological Science Generates Information About Living Systems

By systematically observing, forming hypotheses and testing them, possible explanations for biological phenomena are successively ***eliminated***.

Eventually, one or a very small number of explanations that ***cannot*** be eliminated, remain.

This explanation, or explanations, are accepted until continued experimentation provides ***a more complete*** explanation.

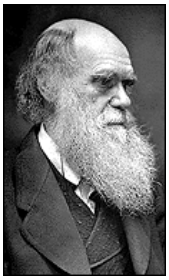
Natural Selection



The current hypothesis for explaining biological diversity

Crystalized by Charles Darwin and Alfred R. Wallace in 1858.

Natural Selection



Darwin and Wallace made similar observations (5) and inferences (4).

These are easily made by ***any*** naturalist.

Observation 1:

All species have great potential fertility.

- Two elephants: 20 yrs to maturity, 2 years gestation.
- In 750 years: 19,000,000 elephants!

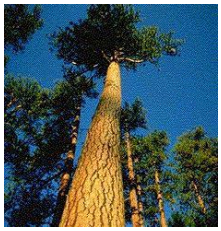
Observation 1:

All species have great potential fertility.

- Two fruit flies: 12 from egg to maturation.
- In 3 months: exponential growth!

Observation 2:

Natural populations are unexpectedly constant in size.



Observation 3:

Natural resources are limited, yet these also remain constant in supply.

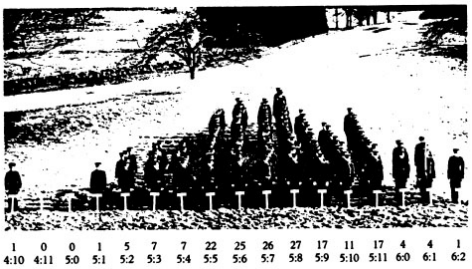
Inference 1:

Populations are somehow held in check

1. A ***struggle for existence*** occurs.
2. Many individuals ***do not survive***.

Observation 4:

Variability exists - no two individuals are alike.



Inference 2:

Survival within populations is non-random.

Certain individuals bear ***characteristics*** that confer ***survival advantages***.

Observation 5:

Much phenotypic variation is heritable

Inference 3:

Favored characteristics are passed to offspring

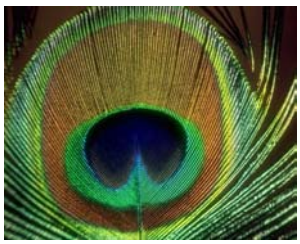
This process is similar to the **ARTIFICIAL SELECTION** used to produce domestic animals and plants.

But in nature, Darwin and Wallace called this **NATURAL SELECTION**.

Inference 4:

With time and continued selection, the characteristics of individuals in populations will ***change***.

This process is called ORGANIC EVOLUTION



Observations

1. All populations have great potential fertility.
2. Natural populations are unexpectedly constant in size.
3. Natural resources are limited, yet these also remain constant in supply.
4. Variability exists - no two individuals are alike.
5. Much phenotypic variation is heritable.

Inferences

1.Populations are somehow held in check.
2. Survival within populations is non-random.
3. Favored characteristics are passed to offspring.
4. With time and continued selection, the characteristics of individuals in populations will change.

Natural Selection

Differential ***survival*** and ***reproduction*** of individuals in populations due to their possession of traits that enhance these abilities.

Heritability

A tendency for offspring to ***resemble*** their parents; allows favored traits to be passed to the next generation.

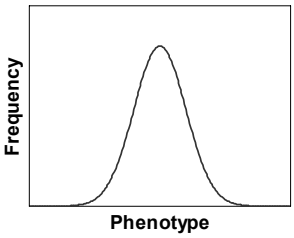
Evolution

A change in a population's average phenotype due to the action of ***natural selection*** on ***heritable characters***.

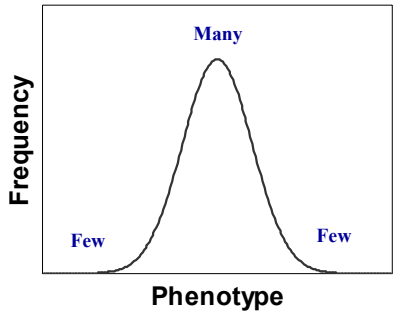
How does evolution proceed over short periods of time?

Phenotypic Distributions

Most populations of characteristics can be described by a bell-shaped (i.e, normal) curve.



Phenotypic Distributions

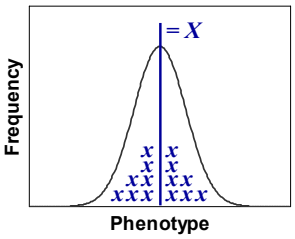


The Average

A measure of central tendency

Calculated as:

$$X = \sum x_i / N$$

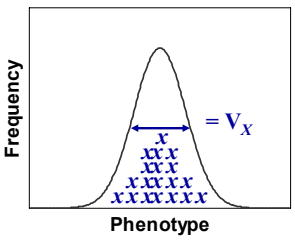


The Variance

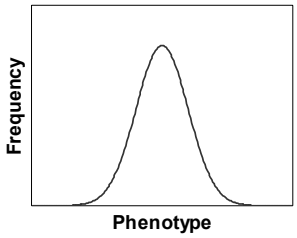
A measure of the width of the distribution.

Calculated as:

$$V_X = (\sum x_i^2)/N - X^2$$



This WHY You Need Statistics for Biology



It helps you describe distributions typical of ***all living things***.

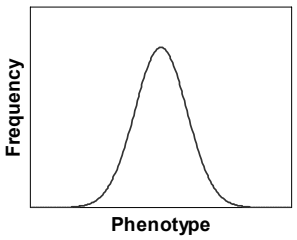
What Causes the Variation?

1. Variation in environmental conditions during development.

a. Differences in food, temperature, disease.

b. Maternal effects.

c. Variation in current conditions.

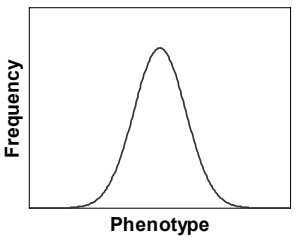


What Causes the Variation?

2. Genetic Variation, factors inherited from parents and which to contribute to phenotypic variation in future generations.

a. Several components to genetic variation.

b. The part that makes offspring resemble their parents is ***additive genetic variance***.



Heritability

The tendency for a character to be inherited by progeny is its *heritability*

1. $h^2 = 1$, character is completely heritable.
2. $h^2 = 0$, character is not heritable.

Fitness

We can define FITNESS as the ability of an individual to leave viable progeny.

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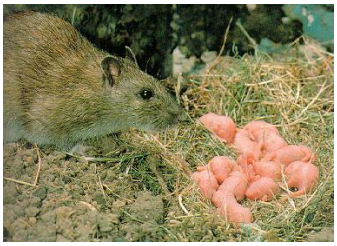
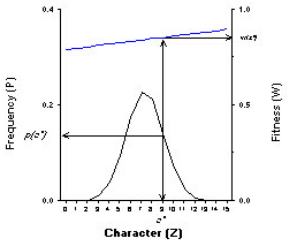
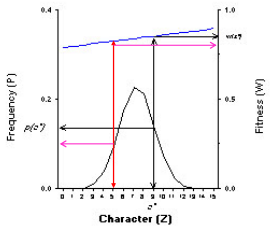


Fitness Function

The relationship between a phenotypic character (z) and fitness (w).



The Strength of Selection



the slope of the function shows how strongly selection is operating.

$p' = p(z)w(z)$

So,

$p' = p(z)w(z)$

>

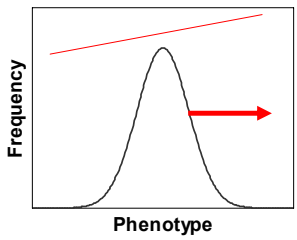
$p' = p(z)w(z)$

The Response to Selection

The higher the heritability, the *more rapid* the response to selection.

The lower the heritability, the ***slower*** the response.

When h^2=0, ***no response*** is possible.



Values for $h^2 < 1$

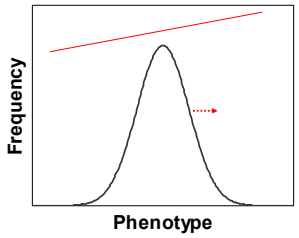
Are due to:

a. Environmental effects.

b. Non-additive genetic variation

1. dominance, epistasis

All factors contribute to the bell-shape of the phenotypic distribution.



How Evolution Appears to Proceed

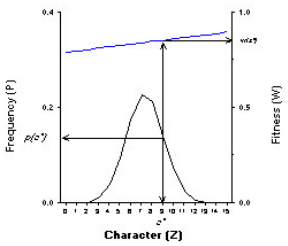
Natural selection acting on phenotypic variation within populations generates

three basic modes

of evolutionary change.

The Shape of the Fitness Function

The relationship between a phenotypic character (z) and fitness (w).



Stabilizing Selection

If the relationship between phenotype and fitness is Gaussian, the population phenotype remains constant.

This is STABILIZING SELECTION.

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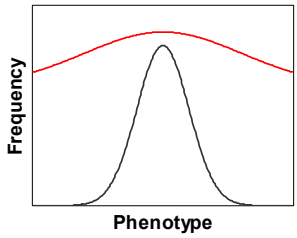
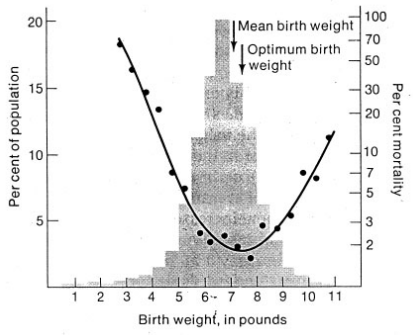


Stabilizing Selection



Deep Time

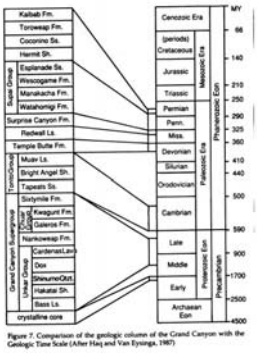


Figure 7. Comparison of the geologic column of the Grand Canyon with the Geologic Time Scale (After Hoj and Van Eysinga, 1987)

Deep Time

An example suitable for movie going students:

a. Standard speed for movie is 24 frames/second

1. lasts a little less than 2.5 hours.

2. if every frame represented a year, the film would just about cover the duration of *Homo sapiens sapiens* existence on Earth (about 200,000 years)

Some Perspective…

1. Most of your lives have lasted < 1 second

a. about 3 seconds since WWII began

b. 6 seconds since Civil War

c. 9 seconds since Revolutionary War

d. 23 seconds since Spanish Conquest of Mexico

6. 30 seconds since Norman Conquest

7. 1 minute and 20 seconds since birth of Christ.

Deep Time

A 2.5 hr film would cover the duration of *Homo sapiens sapiens* existence on Earth (about 200,000 years)

A film would have to run 752 hours (1 month of 24 hour days) to cover time since extinction of ammonites/dinosaurs

1. About 65 myr

Deep Time

Film would need to run 4,780 hours (6 months of 24 hr days; e.g. every day since 12 July 2009) to cover time since vertebrates crawled out onto land.

1. about 413 Myr
2. Insects invaded land about 10 myr ***earlier***.

(120 additional hrs)

Stabilizing Selection

If the relationship between phenotype and fitness is Gaussian, the population phenotype remains constant.

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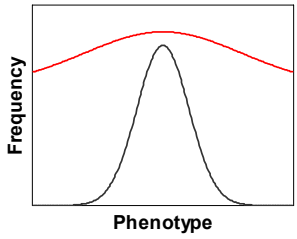
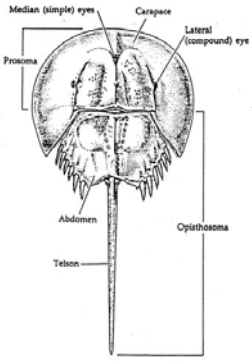


Stabilizing Selection



Horseshoe crabs (Merostomata) have remained almost unchanged in external morphology for over 400 myr.

A possible example of STABILIZING SELECTION.

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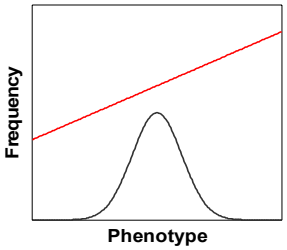
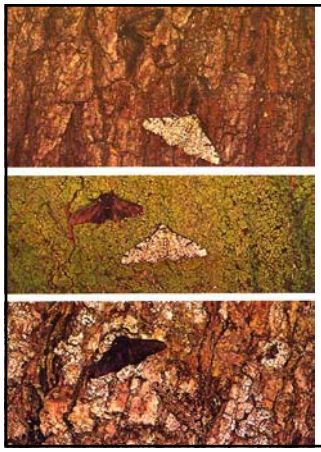
Directional Selection

If the relationship is linear (+ or -), the population mean shifts.

This is **DIRECTIONAL SELECTION**.





Industrial Melanism in *Biston betularia*

In polluted woods, the dark form has a much better chance of surviving undetected.

Since pollution abatement programs were put in place after World War II, the light form has been making a comeback in the Liverpool and Manchester areas.

Transformation

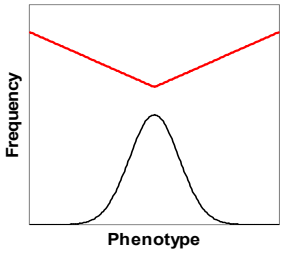
If directional selection occurs, for prolonged periods, populations evolve over time species may TRANSFORM.

Disruptive Selection

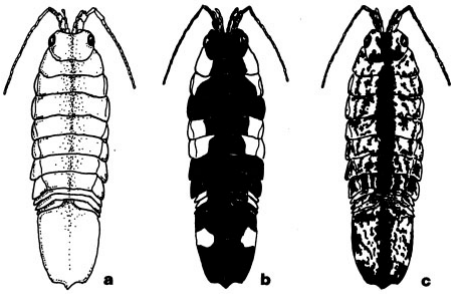
If the tails of the distribution undergo directional selection in opposite directions.

The population DIVERGES in character.

This is **DISRUPTIVE SELECTION**.



Disruptive Selection



Divergence

Populations may change for a variety of reasons.

1. Exploitation of new habitat, food resources.
2. Change in environmental conditions.
   a. ***Abiotic***: temperature, humidity, salinity, stress.
   b. ***Biotic***: competition, predation, parasites
3. Change in social conditions.