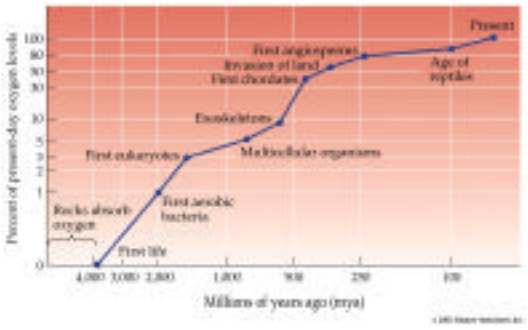
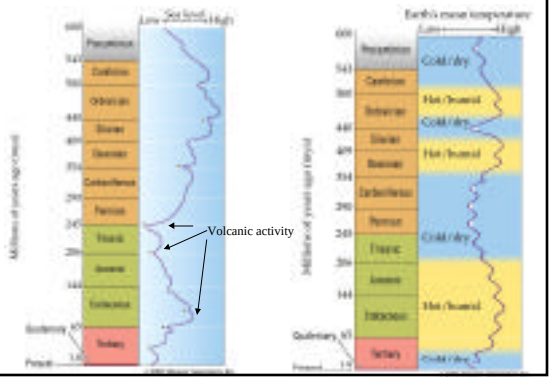
Chapter 20 and 21

History of Life on Earth and the Mechanisms of Evolution

Oxygen was key to life



Sea level, extinction, and temperature



What is evolution?

✓Species change over time.

- ✒"Descent with modification." - Darwin
  - ☞Descended from a common ancestor with changes
- ✒Heritable changes in organisms occur over time.
  - ☞**Adaptation**
    - ✍**Species adapt** to their environment.
    - ✍Environments change.
- ✒Natural selection
- ✒Artificial selection
  - ☞**Gradualism**
    - ✍**Species evolved gradually and continuously**

✓Natural Selection

- ✒Differential reproductive success of individuals due to genetically-inherited traits.
- ✒Analogous to artificial selection

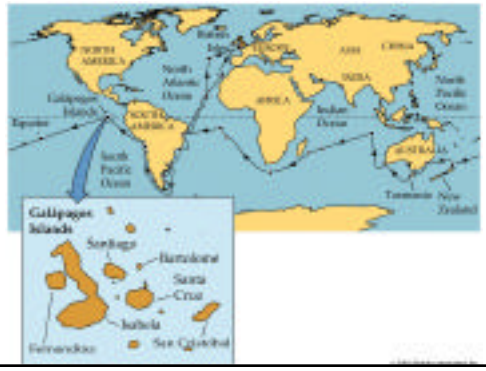
✓Artificial Selection

- ✒Process by which farmers and animal breeders create new lines of dogs, cows, corn, etc.

"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."

Charles Darwin

Charles Darwin and the HMS Beagle

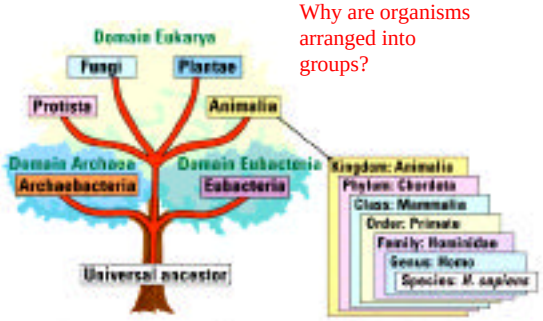


Darwin's four ideas

- ✓The world is ever-changing and is very old.
- ✓Species change.
- ✓Species are composed of populations of individuals.
- ✓Species are descended from a common ancestral species.

Linnaeus - modern taxonomy

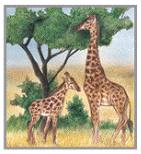
Why are organisms arranged into groups?



Lamarck versus Darwin

Lamarckism

Ancient giraffes had short necks



Darwinism

Ancient giraffes had varying neck lengths.

With climate change, giraffes stretched necks to reach tall food trees.

With climate change, long-necked giraffes could feed on tall trees; short-necked ones could not.

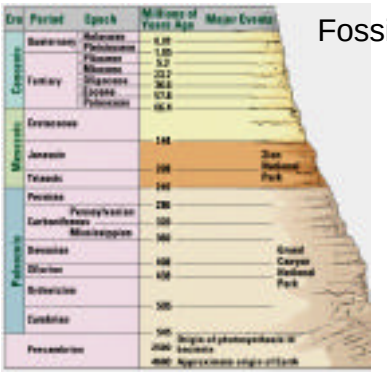
Giraffes acquired long necks from stretching for food and passed this trait to offspring.

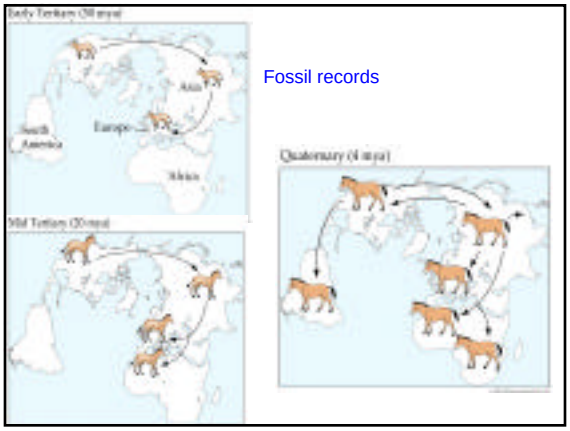
Short-necked giraffes died; long-necked giraffes survived to reproduce.

Inheritance of acquired characteristics

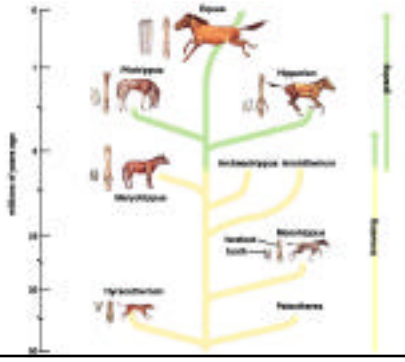
Evidence for evolution

- ✓Fossil record
- ✓Biogeography
- ✓Taxonomy
- ✓Comparative anatomy
- ✓Comparative embryology
- ✓Domestic breeding
- ✓Comparative molecular biology
- ✓Classical genetics
- ✓Population ecology
- ✓Developmental biology
- ✓Animal behavior





Evolution of the horse



Fossils

- ✓Remains or imprints of past life.
  - ✒Protected from scavengers, erosion, decay.
  - ✒Usually become buried in layers of mud and sand.
  - ✒Form sedimentary rock.

Fossils

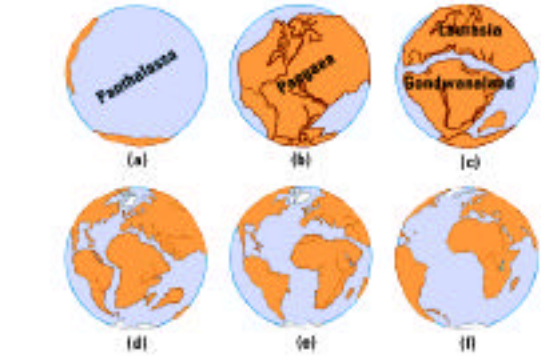
Precambrian Era

- ✓3.8 billion years
  - ✒Single cells lacking membrane-bound organelles
- ✓2 billion years
  - ✒Eukarotes appear
- ✓800 million years
  - ✒First multicellular organisms
    - ☞Resemble jellyfishes, coral, segmented worms

Paleozoic Era

- ✓570 million years
  - ✒Cambrian period (545 -505 million)
    - ☞Fungi, algae, trilobites, armored plated fishes
  - ✒Ordovician, Silurian periods (505 - 408 million)
    - ☞Bony fishes, first land plants, fungi, arthropods
  - ✒Devonian period (408 - 360 million)
    - ☞Water receded-more dry land
    - ☞Age of fishes

- ✓Carboniferous and Permian periods (360 - 245 million)
  - ✒Age of amphibia
  - ✒First reptiles, cockroaches and dragonflies ferns, horsetails, cone-bearing trees.
- ✓Pangaea--supercontinent
  - ✒(separates 200 million years ago to present)
  - ✒90% extinction



Mesozoic Era--Age of Reptiles

- ✓Triassic period (245 - 208 million)
  - ✒Dinosaurs and small mammals.
- ✓Jurassic period (208 - 144 million)
  - ✒Dinosaurs
- ✓Cretaceous period (144 - 66 million)
  - ✒Ammonites, marine invertebrates

Insects, flowering plants, birds, mammals and reptiles

Cenozoic Era (65 million to present)

- ✓Insects, flowering plants, modern birds and mammals.

Three facts stand out about the fossil records

- ✓Fossils are distributed consistently.
  - ✒Rocks of same age contain same types of fossils.
- ✓The order in which organisms are laid down
  - ✒suggests a sequence of evolution
  - ✒Sequence patterns are the same
- ✓Recent fossils look like modern organisms.

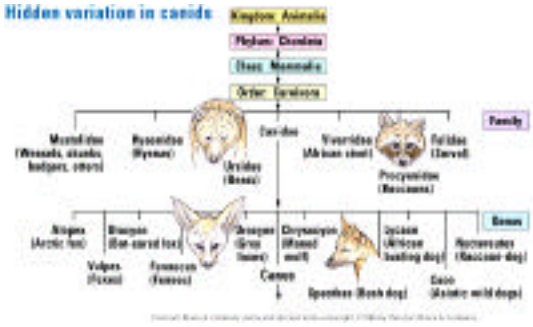
Biogeography

- ✓Study of past and present distribution of plants and animal species.
- ✓Where, how they live, and how they are related to one another.
- ✓Island species are endemic
  - ✒The have related species that resemble them in other parts of the world - close continent

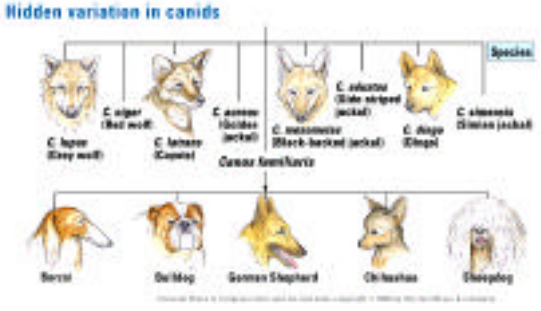
Taxonomy

- ✓Classification looks like a family tree
- ✓Grouping to family units…

Dogs, wolves, coyotes are like siblings - foxes are like cousins



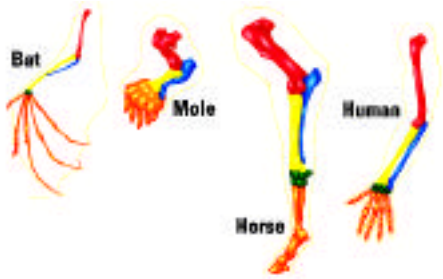
Variation among dogs is due to artificial selection



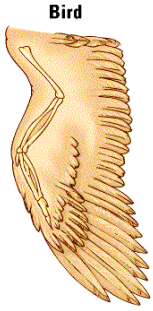
Comparative Anatomy

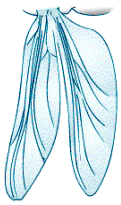
- ✓Homologous structures - Species descended from a common ancestor may evolve in different directions and yet retain some of the same characteristics.
  - ✒Forelimbs - humans, horses, bats, moles and whales - same bones -
- ✓Analogous structures - Species descended from different ancestral species may evolve to possess structures that serve the same function.
  - ✒Wings of bird and dragonfly

Homologous structures



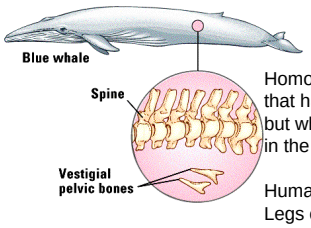
Analogous structures





Derive from different ancestral structures, but serve the same function.

Vestigial structures

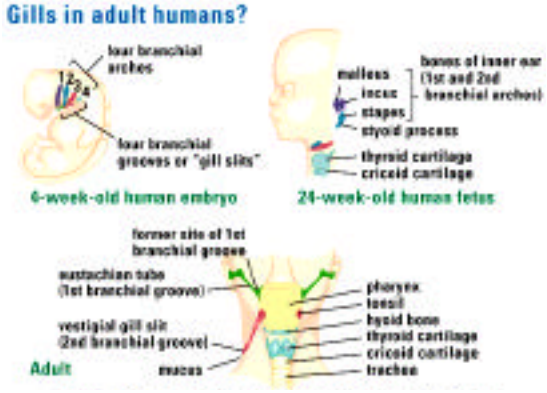


Homologous structures that have no apparent use, but which may have had use in the ancestral species.

Human tailbones
Legs on a snake

Comparative Embryology

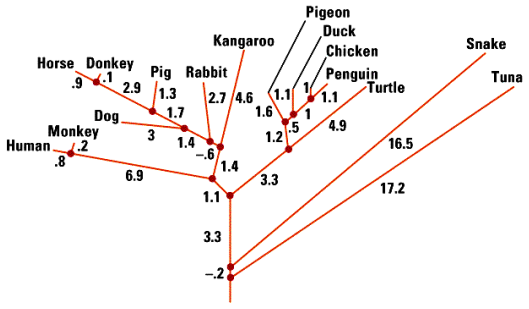
- ✓The early embryos of mammals resemble the embryos of birds, reptiles, amphibians and fishes.
- ✓All vertebrate embryos have tails and gill slits.

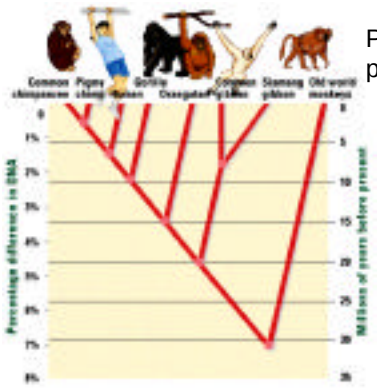


Comparative molecular biology

- ✓All cells use DNA as a source of genetic information.
- ✓RNA, proteins, and same genetic code, 20 amino acids, and ATP as an energy source is used by all animals.

Cytochrome-c phylogeny





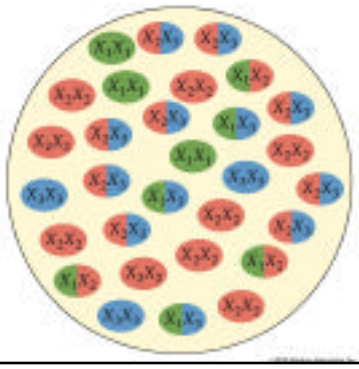
Phylogeny of primates

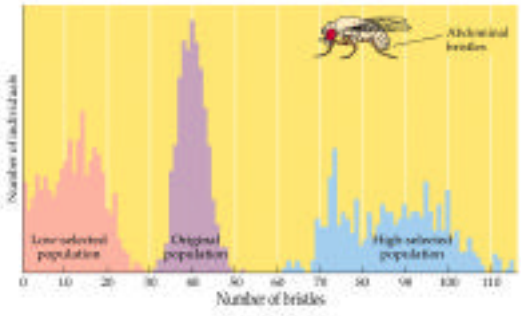
Natural Selection

- ✓ Rate of change depends on intensity of selection, on the extent of inherited variation, and on the extent of variation in a population.
- ✓ Natural selection depends on reproductive success.
- ✓ Adaptive traits accumulate within a population.

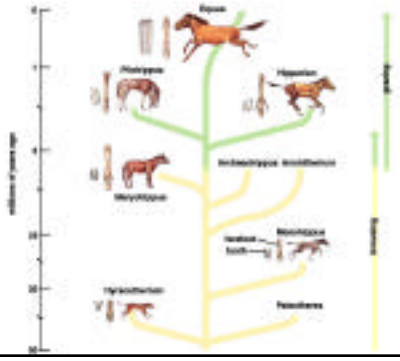
Gene Pool

$X_1 = 0.20$
$X_2 = 0.50$
$X_3 = 0.30$





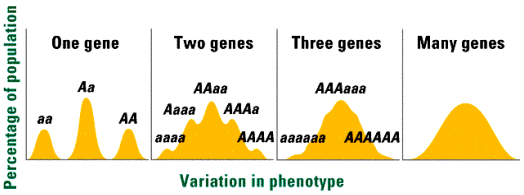
Evolution of the horse



Population genetics

- ✓Explains the processes by which variation is generated and passed on within populations of organisms in precise mathematical terms.
- ✓Describes microevolution or the changes in the frequencies of alleles in a population.

Genetic variation



Most traits are polygenic

Factors influencing variation

- ✓The rate at which mutations accumulate in the DNA.
- ✓The rate by which changes spread through the population.
- ✓The rate by which deleterious mutations are eliminated from a population by natural selection.

Microevolution

In any population:

Frequency of allele $A = p = \frac{2N_{AA} + N_{Aa}}{2N}$

Frequency of allele $a = q = \frac{2N_{aa} + N_{Aa}}{2N}$

For Population 1:

$N_{AA} = 90$, $N_{Aa} = 40$, and $N_{aa} = 70$

so

$p = \frac{180 + 40}{400} = 0.55$

$q = \frac{140 + 40}{400} = 0.45$

For Population 2:

$N_{AA} = 45$, $N_{Aa} = 130$, and $N_{aa} = 25$

so

$p = \frac{90 + 130}{400} = 0.55$

$q = \frac{50 + 130}{400} = 0.45$

Hardy-Weinberg Equilibrium

- ✓A stable distribution of genotypic frequencies is maintained by a population from generation to generation.

Allelic frequency

- ✓Proportion of number of copies of a given allele in a population to the sum of all alleles in the population.
- ✓Example:
  - ✒353 AA
  - ✒494 Aa
  - ✒153 aa

Calculating allelic frequencies

$$f(A) = \frac{2(353) + 494}{2(1000)} = 0.6$$

$$f(a) = \frac{494 + 2(153)}{2(1000)} = 0.4$$

Therefore, f(A) + f(a) = 1
or p + q =1

$$(p + q)^2 = 1^2$$

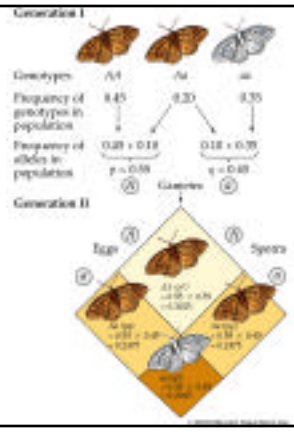
$$p^2 + 2pq + q^2 = 1$$

$$p^2 = (0.6)^2 = 0.36$$

$$2pq = 2(0.6)(0.4) = 0.48$$

$$q^2 = (0.4)^2 = 0.16$$

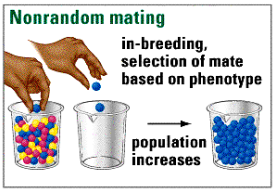
Reproduction does not change allelic frequencies



Assumptions that must be met for Hardy-Weinberg equilibrium

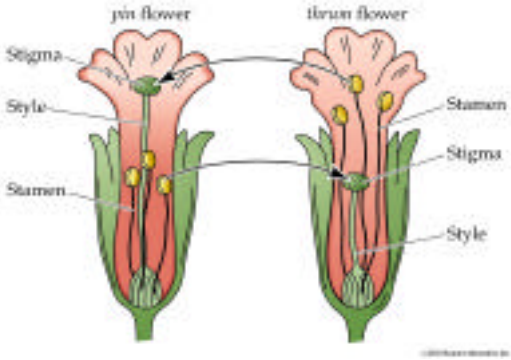
- ✓Mating is random
- ✓Population size if very large
- ✓No migration between populations
- ✓No mutation
- ✓No selection

Nonrandom mating

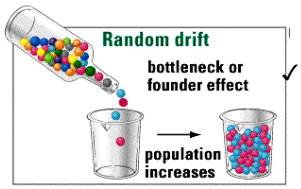


- ✓Assortative mating is where individuals express preference with whom they mate.
- ✓Inbreeding is an extreme form of assortative mating.

Some flower structure fosters assortative mating



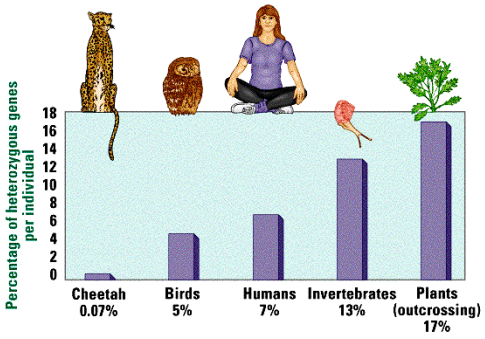
Random drift



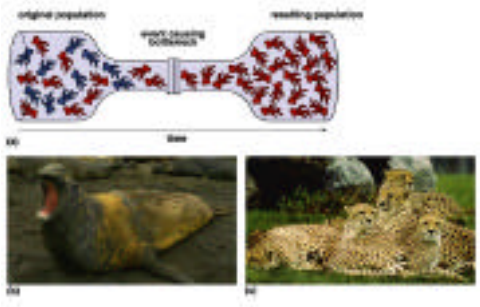
- ✓ Change in gene frequency due to random events in a small population.
- ✓ Bottleneck or founder effect is observed when a small subset of a population founds a new population.

Founder effect with *Drosophila*

Humans are heterozygous in 7% of their 100,000 genes.

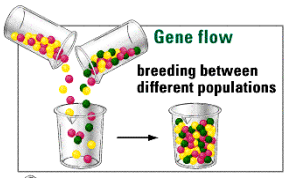


Bottle neck



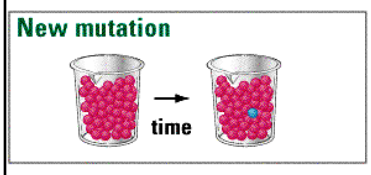
Gene flow

- ✓ Breeding between populations.
- ✓ Immigration of individuals into a different population brings new alleles into the gene pool.

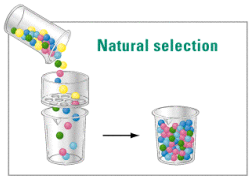


New mutation

- ✓ Mutations will either be eliminated or spread through a population.

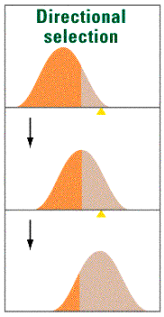


Natural selection



✓ Reduces the frequency of deleterious alleles.

Directional selection

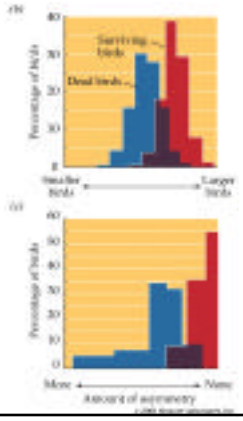


✓ The frequency of one or more traits is increased to favor one allele form over the other form.

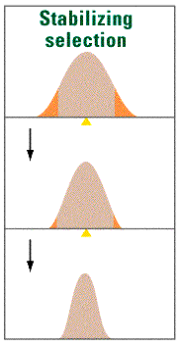
✓ Ex. Industrial melanism, pesticide or antibiotics

Directional selection

Cold weather favored the large and more symmetrical swallows



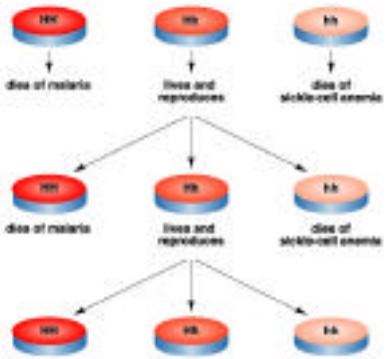
Stabilizing selection



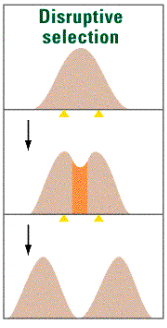
✓ The extremes of a phenotype are selected against, so that the average phenotype is advantageous.

✓ Ex. Wasps: the average wasps will survive the winter better.

Malaria stabilizes sickle cell allele



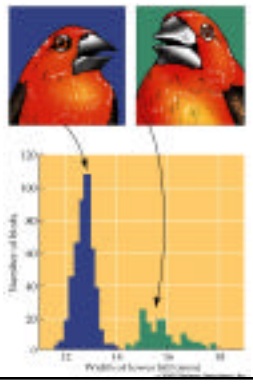
Disruptive selection



✓ Increases the extremes of phenotypes in a population, so that intermediate forms are selected against.

✓ Ex. African swallowtail butterflies The extremes are spared - the intermediates are eaten.

Disruptive selection



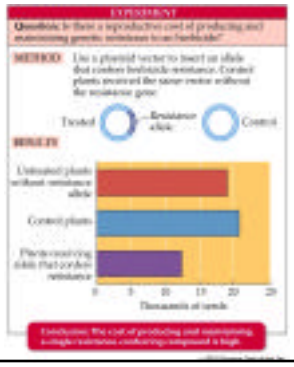
Sexual selection

- ✓Female choice (male choice)
  - ✒Male courtship behavior
- ✓Male competition
  - ✒Competition for territory and access to females
  - ✒Leave more descendants

Balanced polymorphism

- ✓Heterozygous superiority
  - ✒Sickle cell anemia
- ✓Selective pressures

Costs of evolution



Environmentally induced variation