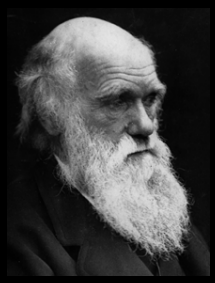
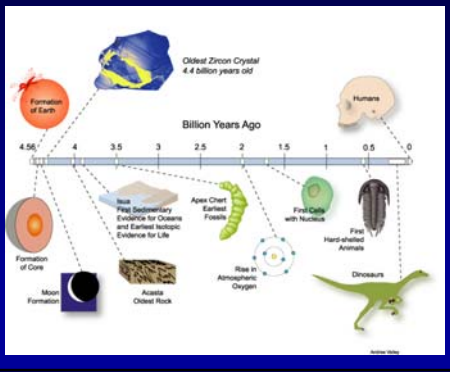
Evolution



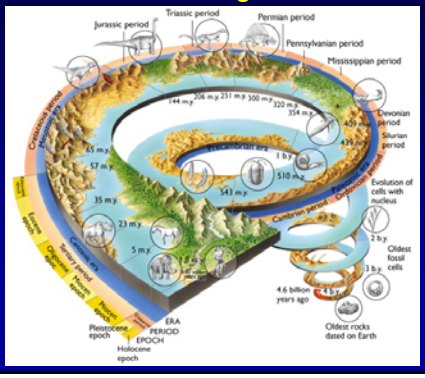
Change Through Time

- The prevailing beliefs of 19th century Europe was that God created the earth, plants & animals 6,000 years ago. No change has ever occurred.
- Geologist started finding more and more fossils and observed that fossils found in deeper sediment were more simple than those found above.
- 1873 - Charles Lyell couldn't take it anymore and wrote *Principles of Geology*. He challenged the churches control of "facts" with his **theory of uniformity**.
  - The earth is extremely old.
  - The earth has gradually changed through time.
  - Life has gradually changed through time.

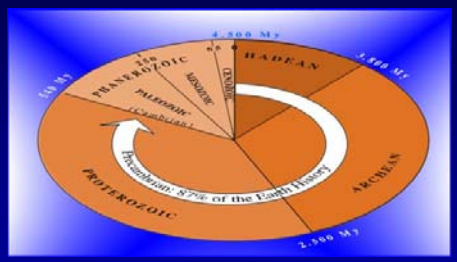
Geologic Time



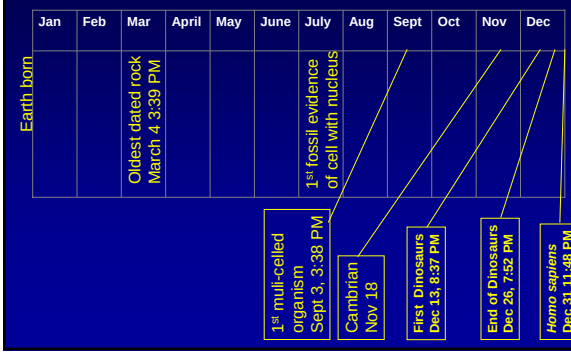
Geologic Time



Geologic Time



Earth History relative to Calendar Year



Theories to Explain Life

- Plato/Aristotle
  - Every species is a fixed essence in the mind of God.
- Christianity
  - "Great chain of being" "Scala Naturae"
  - Perfect gradation of form from inanimate to simple life to humans to angels. Any suggestion that change has occurred implies that God was imperfect.

Confounding Discoveries

- Early natural scientists endeavored to understand the links in the "great chain of being" to understand the wisdom of God.
- Ironically, scientists discovered that most of what the church claimed about nature was in direct conflict with what they were observing.
- WRONG AGAIN!

Confounding Discoveries

- Biogeography
- Comparative anatomy
- Geology
- Paleontology

Timing

- As more and more scientist openly questioned the church, the philosophical environment was ripe for more creative hypotheses.

History of evolutionary thought

Charles Darwin

- Observations:
  - Populations have and inherent reproductive capacity to increase in numbers through successive generations.
  - No population can indefinitely grow in size, because individuals will run out of resources.
- Inference:
  - Sooner or later individuals will begin competing for resources.

Charles Darwin

- Observations:
  - Individuals pass on traits that are heritable
  - Traits are variable & expressed as phenotypic variation in populations.
- Inference:
  - Some phenotypes are better than others at helping an individual compete for resources, and to survive and reproduce. Alleles for these phenotypes increase in the population, and other alleles decrease. In time the genetic changes lead to increased fitness (an increase in adaptation to the environment).

Charles Darwin

Conclusion:

- Natural Selection among individuals of a population is an outcome of variation in traits that affect which individuals survive and reproduce in each generation. This microevolutionary process results in adaptation, or increased fitness to the environment.

Charles Darwin

- Darwin's ideas caused a firestorm of debate among the public and church. However, among academic scholars there was very little doubt that diversity is the result of Natural selection.

Adaptation

Several definitions

1. An organisms phenotypic adjustment to the environment. Such as an individuals acclimation to altitude or temperature.
2. The process of becoming adapted.
3. The features of an organism that enhance reproductive success.

Evolutionary biology is only concerned with 2 and 3.

Adaptation

- In evolutionary terms, an adaptation is some heritable trait that improved the odds for surviving and reproducing in a given environment.
- It is the outcome of natural selection – an enhancement of the fit between the individual and the prevailing conditions.

Adaptation

- There is considerable debate about the precise definition of adaptation. You may come across a variety of different definitions as you read about natural selection. We will adopt a general definition.
- Any heritable character or set of characters that provide a reproductive advantage.

Adaptation

- Stephen J. Gould and Elisabeth Vrba tried to break adaptation into its basic elements.
- **Adaptation** – a feature that evolved for its current function.
- **Exaptation** – when a character has been co-opted for a new adaptive advantage.
- **Preadaptation** – a character that was an adaptation for something in the past but is now an exaptation.
- **Aptations** – the combination of adaptation and exaptation.

Adaptation

- **Adaptation**
  - Tail feathers of birds evolved as an adaptation for flight.
- **Exaptation**
  - Widowbird tail feathers have been modified for sexual display.
- **Preadaptation**
  - Widowbird tail feathers were preadapted for sexual display.
- **Aptation**
  - Tail feathers provide adaptive advantages in flight and sexual display.

Widowbird

Widowbird

Fitness

- An entities reproductive success. The average per capita rate of increase.
- Organisms and genes can have measurable fitness.
- Two types of fitness:
  - Absolute fitness – a raw value assigned to an individual.
  - Relative fitness – an individuals fitness relative to others in the population.

Populations evolve

- Individuals do not evolve!
- Natural selection acts on populations over many generations.
- Natural selection requires time.
- Natural selection acts on variation of phenotypes in the population.

Variation

- Phenotypic variation in a population is a manifestation of the collection of Alleles present in a population, known as the **gene pool**.
- Genes consist of alleles from parents and there can be many possible alleles for each gene.
- Variation arises from:
  - Gene mutation
  - Crossing over in meiosis I
  - Independent assortment in meiosis I
  - Fertilization
  - Changes in chromosome number or structure.

Variation

The only one of these sources of variation that introduces new alleles into the population is gene mutation. The rest shuffle existing alleles into different combinations.

Tracking Variation

- Researchers evaluate population variation over time by tracking the frequency of alleles present in a population from generation to generation.
- Let's look at a butterfly population and wing color as an example.
- Lets say we have a gene with allele combinations that produce dark blue (AA), light blue (Aa) and white (aa) wing color.

Tracking Variation e.g..

- Let's also say we have a population of 1,000 butterflies.
  - 490 have dark blue wings (AA).
  - 420 have light blue wings (Aa).
  - 90 have white wings (aa).
- If 490 have the AA allele combination then there are 2x490=980 A alleles in that pool.
- If 420 have the Aa allele combination then this pool ads 420 A's and 420 a's.
- If 90 have the aa allele combination then they add 2x90=180 a's.
- (2x490A) + 420A + 420a + (2x90a) = 1,400A's & 600 a's
- The frequency of alleles in this population is 1,400/2,000= 0.7 or 70% and 600/2,000 = 30%

Tracking Variation

- If the population is said to be in equilibrium then these frequencies will not change over time.
- But, the only way a population can stay in equilibrium is if:
  - No mutations occur.
  - Population is infinitely large.
  - Population is isolated from other populations.
  - Allele has no effect on reproduction.
  - All mating is random.

Mutations

Genes have established mutation rates

3 general types:

1. Lethal
2. Neutral
3. Beneficial

Most mutations are believed to be neutral with the potential of providing an advantage in future generations. "Neutral Mutation theory" Motoo Kimura (1983).

Tracking Variation

- If the population is said to be in equilibrium then these frequencies will not change over time.
- Three other processes push populations away from equilibrium.
  1. Natural selection
  2. Gene flow
  3. Genetic drift

Microevolution

Any change in allele frequencies resulting from:

- **genetic drift** - Random change in allele frequencies over time brought about by chance alone; its effect is greatest in small populations.
- **gene flow** - Physical flow of alleles into or out of a population by immigration or emigration.
- **natural selection**
- Any combination of these

Tracking Variation

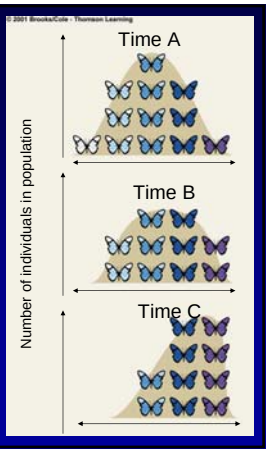
- Population biologists track allele frequencies and use the Hardy-Weinberg principles, which are the conditions of equilibrium.
- $p^2 + 2pq + q^2 = 1.0$
  where p and q are the frequencies of alleles A & a.
- Allele frequencies are monitored for change so biologists can determine what kind of selection is driving the allele frequency change.

Selection

- By evaluating the pattern of allele frequency change biologists can determine what kind of selection is acting on that character.
- Three general types:
  1. **Directional** – frequencies shifting in one direction.
  2. **Stabilizing** – intermediate forms are favored.
  3. **Disruptive** – intermediate are selected against.

Directional Selection

- A shift in allele frequency in one direction.
- Reproductive success is associated with dark blue and purple butterflies.
- Phenotypes on one end of the range become more common than those on the other end.



Direction selection

- A common example is the Peppered Moth (*Biston betularia*). Before the industrial revolution in England, the moth was mostly found in a light gray form with little black speckled spots. The light-bodied moths were able to blend in with the light colored lichens and tree bark and the less common black peppered moth was more likely to be eaten by birds. During the industrial revolution in England, many of the light-bodied lichens died from sulphur dioxide emissions. The trees became covered with soot from the new coal-burning factories. This led to an increase in bird predation for the light-colored moths (they no longer blended in as well). The dark-bodied moths, however, blended in very well with the trees.
- As a result, the allele frequency shifted towards the dark allele, as more and more dark-bodied moths survived to reproduce.

Note: much debate has arisen over this example because it turns out that no one has ever seen birds eat these moths and they are mostly nocturnal. But the shift in color occurred and is therefore still a good example of directional selection. We just do not know what exactly caused the shift.

Peppered Moth

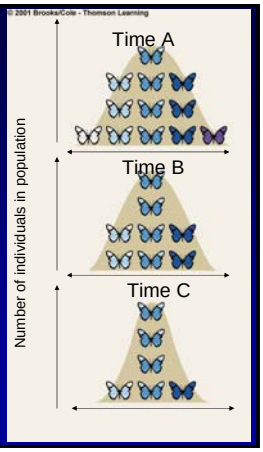
Pre-industrial revolution

Post-industrial revolution

Peppered Moth

Stabilizing Selection

- Intermediate forms of a trait are favored and alleles for the extreme are not.



Human infant mortality and birth weight

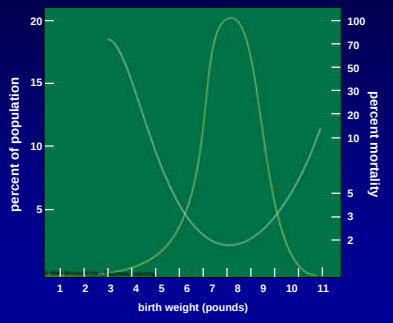
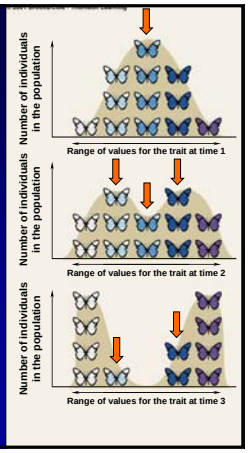


Fig. 16.17, p. 251

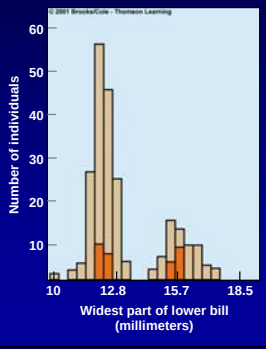
Disruptive Selection

Forms at both ends of the range of variation are favored over intermediate forms.



African Finches

- Selection favors birds with very large or very small bills
- Birds with intermediate-sized bill are less effective feeders



Sexual Selection

- We often see large phenotypic differences between sexes in nature.

Sexual Selection

- These differences often involve elaborate and sometimes very large features that would seem to reduce ones fitness.
- Remember that fitness is reproductive success and if elaborate features are favored by the opposite sex then those features will continue to be prominent in spite of any disadvantage they may pose.

Irish Elk

(*Megaloceros giganteus*)

The Irish Elk, not actually and Elk nor exclusive of Ireland, lived in Northern Great Britain during the final days of the ice age. This animal was actually a very large deer species that was over 6 feet tall at the shoulders and had antlers over 13 feet across.

Some believe that the antlers were a product of extreme sexual selection and eventually led to its extinction.

Sexual Selection

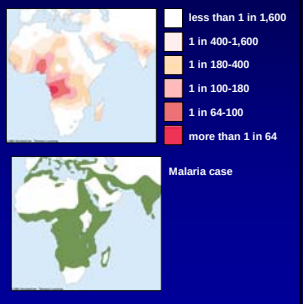
- Sexual selection can maintain variation in a populations.

Balanced Polymorphism

- Polymorphism - “having many forms”
- Occurs when two or more alleles are maintained at frequencies greater than 1 percent
- Another source of maintaining variation in a population.

Sickle-Cell Trait: Heterozygote Advantage

- Allele Hb^S causes sickle-cell anemia when heterozygous
- Heterozygotes are more resistant to malaria than homozygotes



Gene Flow

- Physical flow of alleles into a population
- Tends to keep the gene pools of populations similar
- Counters the differences that result from mutation, natural selection, and genetic drift

Genetic Drift

- Random change in allele frequencies brought about by chance
- Effect is most pronounced in small populations
- Sampling error - Fewer times an event occurs, greater the variance in outcome

Bottleneck

- A severe reduction in population size
- Causes pronounced drift
- Example
  - Elephant seal population hunted down to just 20 individuals
  - Population rebounded to 30,000
  - Electrophoresis revealed there is now no allele variation at 24 genes

Founder Effect

- Effect of drift when a small number of individuals start a new population
- By chance, allele frequencies of founders may not be same as those in original population
- Effect is pronounced on isolated islands

Inbreeding

- Nonrandom mating between related individuals
- Leads to increased homozygosity
- Can lower fitness when deleterious recessive alleles are expressed
- Cheetahs, Elephant seal