Processes of Evolution

Evolutionary Theories

- Widely used to interpret the past and present, and even to predict the future
- Reveal connections between the geological record, fossil record, and organismal diversity

Confounding Evidence

- Biogeography
- Comparative morphology
- Geologic discoveries

Biogeography

- Size of the known world expanded enormously in the 15th century
- Discovery of new organisms in previously unknown places could not be explained by accepted beliefs
  - How did species get from center of creation to all these places?

Comparative Morphology

- Study of similarities and differences in body plans of major groups
- Puzzling patterns:
  - Animals as different as whales and bats have similar bones in forelimbs
  - Some parts seem to have no function

Geological Discoveries

- Similar rock layers throughout world
- Certain layers contain fossils
- Deeper layers contain simpler fossils than shallow layers
- Some fossils seem to be related to known species

19th Century - New Theories

- Scientists attempt to reconcile evidence of change with traditional belief in a single creation event
- Two examples
  - Georges Cuvier - multiple catastrophes

- Jean Lamark - inheritance of acquired characteristics

Darwin's Voyage

- At age 22, Charles Darwin began a five-year, round-the-world voyage aboard the *Beagle*
- In his role as ship's naturalist he collected and examined the species that inhabited the regions the ship visited

The Theory of Uniformity

- Lyell's *Principles of Geology*
  - Subtle, repetitive processes of change, had shaped Earth
  - Challenged the view that Earth was only 6,000 years old

Glyptodonts & Armadillos

- In Argentina, Darwin observed fossils of extinct glyptodonts
  - Animals resembled living armadillos
  - Huge size a key difference between glyptodonts and armadillos

Malthus - Struggle to Survive

- Thomas Malthus, a clergyman and economist, wrote essay that Darwin read on his return to England
  - Argued that as population size increases, resources dwindle, the struggle to live intensifies and conflict increases

Galapagos Finches

- Darwin observed finches with a variety of lifestyles and body forms
- On his return he learned that there were 13 species
- He attempted to correlate variations in their traits with environmental challenges

Darwin's Theory

A population can change over time when individuals differ in one or more heritable traits that are responsible for differences in the ability to survive and reproduce

Alfred Wallace

- Naturalist who arrived at the same conclusions as Darwin
- Wrote to Darwin describing his views

- Prompted Darwin to finally present his ideas in a formal paper

On the Origin of Species

- Darwin's book
- Published in 1859
- Laid out in great detail his evidence in support of the theory of evolution by natural selection

The Nature of Adaptation

- Long-term adaptation is any heritable aspect of form, function, behavior, or development that contributes to the fit between an individual and its environment
- An adaptive trait improves the odds of surviving and reproducing, or at least it did so under conditions that prevailed when genes for the trait first evolved

Populations Evolve

- Biological evolution does not change individuals
- It changes a population
- Traits in a population vary among individuals
- Evolution is change in frequency of traits

Variation in Populations

- All individuals have the same genes that specify the same assortment of traits
- Most genes occur in different forms (alleles) that produce different phenotypes
- Some phenotypes compete better than others

The Gene Pool

- All of the genes in the population
- Genetic resource that is shared (conceptually) by all members of population

Variation in Phenotype

- Each kind of gene in gene pool may have two or more alleles (such as "A" or "a")
- Individuals inherit different allele combinations
- This leads to variation in phenotype
- Offspring inherit genes, *not* phenotypes

Change over Time

- Over time, the alleles that produce the most successful phenotypes will increase in the population
- Less successful alleles will become less common
- Change leads to increased fitness
  - Increased adaptation to environment

What Determines Alleles in New Individual?

- Mutation
- Crossing over at meiosis I
- Independent assortment
- Fertilization
- Change in chromosome number or structure

Genetic Equilibrium

- Measuring genetic equilibrium can indicate if a population is not evolving
  - Allele frequencies at a locus are not changing
  - Population is not evolving

Five Conditions for Equilibrium

- No mutation
- Random mating
- Gene doesn't affect survival or reproduction
- Large population
- No immigration/emigration

Hardy-Weinberg Rule

At genetic equilibrium, proportions of genotypes at a locus with two alleles are given by the equation:

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

To put the equation into perspective with genotypes, in the Mendelian inheritance fashion:

$$p^2\,(AA) + 2pq\,(Aa) + q^2\,(aa) = 1$$

Frequency of allele $A = p$
Frequency of allele $a = q$

Microevolutionary Processes

- Drive a population away from genetic equilibrium
- Small-scale changes in allele frequencies brought about by:
  - Natural selection
  - Genetic drift
  - Gene flow

Gene Mutations

- Engine for variation in populations
- Infrequent but inevitable
- Each gene has own mutation rate
- Lethal mutations
- Neutral mutations
- Advantageous mutations

Natural Selection

- A difference in the survival and reproductive success of different phenotypes
- Acts directly on phenotypes and indirectly on genotypes

Pesticide Resistance

- Pesticides kill susceptible insects
- Resistant insects survive and reproduce
- If resistance has heritable basis, it becomes more common with each generation

Antibiotic Resistance

- First came into use in the 1940s
- Overuse has led to increase in resistant forms
- Most susceptible cells died out and were replaced by resistant forms

Results of Natural Selection

Three possible outcomes:

- A shift in the range of values for a given trait in some direction
- Stabilization of an existing range of values
- Disruption of an existing range of values

Sexual Selection

- Selection favors certain secondary sexual characteristics
- Through nonrandom mating, alleles for preferred traits increase
- Leads to increased sexual dimorphism

Balanced Polymorphism

- Polymorphism - “having many forms”
- Occurs when two or more alleles are maintained at frequencies greater than 1 percent

Sickle-Cell Trait: Heterozygote Advantage

- Allele Hb^S causes sickle-cell anemia when homozygous recessive
- Heterozygotes are more resistant to malaria than homozygous dominants

Genetic Drift

- Random change in allele frequencies brought about by chance
  - Bottleneck, founder effect, inbreeding, and gene flow are all examples
- 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
- Amish, cheetahs

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