EVOLUTION AND NATURAL SELECTION

Look for these Vocab words in today's lecture
Evolution: the change that occurs in organisms' characteristics over time

Micro/macro evolution
Adaptation
Speciation: allopatric/sympatric
Gradualism
Punctuated Equilibrium
Hardy-Weinberg Principle
Genetic Drift
Homologous/analagous structures
Convergent/divergent evolution
Bottleneck Effect
Founder Effect
Stabilizing/Disruptive/Directional Selection
Reproductive Isolating Mechanisms

Evolution is the consequence of ecology over time

- Charles Darwin (1809 -1882)
- a British Naturalist
- 1st suggested an explanation for why evolution occurred
- Published in 1859, On the Origin of Species by Means of Natural Selection
- Darwin's work on evolution challenged established worldviews
- Darwin: mechanism for evolutionary change called natural selection
- eventually became accepted as theory

Darwin voyaged from 1831 - 1836 on the HMS Beagle, a ship mapping the world's coastlines

- observed different plants/animals
- These observations played an important role in the development of his thoughts about the nature of life on earth

Darwin's evidence

- ??species evolve rather than remain fixed??
- 1)fossils of extinct organisms resembled those of living organisms
- 2)geographical patterns that suggested that organismal lineages change gradually as individuals move into new habitats
- 3)islands have diverse animals and plants that are related to yet dramatically different from their mainland sources

The Theory of Natural Selection

Thomas Malthus' Essay on the Principle of Population (1798) provided Darwin with a key insight

- human populations tend to increase geometrically,
- the capacity for humans to feed this population only grows arithmetically
- Geometric and arithmetic progressions

Darwin expanded Malthus' view to include every organism

- all organisms have the capacity to over-reproduce
- only a limited # of offspring survive and produce next generation
- survivors have certain physical, behavioral, or other attributes that help them to live in their environment
- survivors pass on favorable characteristics on to offspring

the frequency of favorable characteristics increases in a pop. through a process called NATURAL SELECTION

- favorable characteristics are specific to an environment; they may be favored in one but not in another
- organisms whose characteristics are best suited to their particular environment survive more often and leave more offspring
- often referred to as "survival of the fittest"
- Darwinian fitness does not refer always to the biggest or the strongest
- fitness, in evolutionary theory, refers to organisms who, due to their characteristics, survive more often and leave more offspring

The Theory of Natural Selection

Domesticated animals evolved through selective breeding for certain traits that breeders preferred

- the resulting differences between breeds of domesticated species are more extreme than what exists in nature
- artificial selection: breeders determined which traits were successful, rather than nature

Darwin's 1859 publication ignited controversy

But the scientific community soon accepted Darwin's arguments

The Beaks of Darwin's Finches

- Darwin's finches are a closely related group of distinct species
- all the birds are similar to each other except for the shape of their bills
- genetic differences account for the physical differences in the beaks
- birds with larger beaks make more of a protein called BMP4
- Darwin supposed that the birds evolved from a single ancestor to become individual species who specialized in particular foods

But David Lack's (1938) study found that different species of finches fed on the same kind of seeds
—does this contradict Darwin?

Peter and Rosemary Grant studied the medium ground finch on the island of Daphne Major in the Galápagos

- measured beak shape over many years and recorded feeding preferences
- finches preferred to feed on small, tender seeds
- finches switched to larger, harder-to-crack seeds when the small seeds become hard to find

  drought: larger seeds / bigger beaks
  wet: small seeds/ smaller beaks
  gave beak depth after a drought
  only large-beaked birds were able to crush the bigger seeds and survive to make the next generation

  when wet periods returned, smaller beaks prevailed at handling the then more plentiful small seeds
  Darwin's finches on the Galápagos are an example of ***adaptive radiation***

- cluster of species changes to occupy a series of different habitats within a region
- each habitat offers different niches to occupy
- Niche: how a species interacts (biologically and physically) with its environment in order to survive
- each species evolves to become adapted to that niche

Proposed by Charles Darwin in 1859

- publication of *On the Origin of Species*
- "descent with modification"
- all species arise from other, preexisting species

Macroevolution:
evolutionary change of a grand scale (changes that result in the creation of new species)

Microevolution :
evolutionary change at the level of a population (changes that occur within a species that make that species different from its immediate ancestor)

- adaptation results from microevolutionary
- increases the likelihood of survival/reproduction of particular genetic traits in a population

Darwin did not invent the idea of evolution. Prior to Darwin there was no consensus among biologists about the mechanism causing evolution

- A predecessor to Darwin, Jean-Baptiste Lamarck proposed that evolution occurred by the inheritance of <u>acquired</u> characteristics

- According to Lamarck, individuals passed on to offspring body and behavior changes <u>*acquired*</u> during their lives

- Ie: giraffes evolved long necks because ancestral giraffes tended to stretch their necks and this neck extension was passed on to subsequent generations

- According to Darwin, the variation is not created by experience but already exists when selection acts on it

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- populations of ancestral giraffes contained variation in neck length

individuals who were able to feed higher up on the trees had more food and so were able to survive and reproduce better than their shorter-necked relatives

2 views concerning the rate of evolutionary change

1. **Gradualism:** evolutionary change occurs extremely slowly
nearly imperceptible from generation to generation
accumulates over the course of millions of years

2. **punctuated equilibrium**: species experience long periods of little or no evolutionary change (termed stasis), interrupted by bursts of evolutionary change

What is the Evidence for Evolution?

There are many lines of evidence supporting Darwin's theory of evolution

1. Fossil Record: reveals organisms that are intermediate in form between Ancestral and modern species

2. Anatomical Record: similarities in structures

3. Molecular Record: traces changes in genome.

Evidence #1. Fossil Record

- ❖ fossil record: the most direct evidence of macroevolution
- ❖ fossils are the preserved remains, tracks, or traces of once-living organisms
- ❖ they are created when organisms become buried in sediment
- ❖ by dating the rocks in which the fossils occur, one can get an accurate idea of how old the fossils are
- ❖ Fossils in rock represent a history of evolutionary change
- ❖ fossils are treated as samples of data
- ❖ data records successive changes through time

  thus, the statement that macroevolution has occurred is a factual observation

organism dies ⇒⇒ Decomposes or Is eaten by scavengers BUT if the right conditions exist it may become fossilized.

Dies near sediment ⇒⇒⇒ Buried quickly⇒⇒⇒Mineral salts enter bones and they harden ⇒⇒⇒petrification

#2 Evidence for Evolution: The anatomical record

- ❖ also reflects evolutionary history
- ❖ for example, all vertebrate embryos share a basic set of developmental instructions

Homologous structures: fundamentally similar even though they may serve different functions in the adult.

ie: wings of birds & the foreleg of a frog are homologous structures although these limbs have different functions, their embryonic of origins are similar

- ❖ Implies an evolutionary linkage between two species

Analagous structures: similar in function.

- ❖ Ie: The wings of birds and flies

They serve the same function, but obviously have different embryonic origins

one is made of bone and flesh, the other is composed largely of non-living chitin

these are the result of parallel evolutionary adaptations to similar environments

this form of evolutionary change is referred to as convergent evolution

 # 3 Evidence for Evolution: THE MOLECULAR RECORD

- Traces of our evolutionary past are also evident at the molecular level
- organisms that are more distantly related should have accumulated a greater number of evolutionary differences than two species that are more closely related
- the same pattern of divergence can be seen at the protein level

Molecules reflect evolutionary divergence

Genetic Change Within Populations: The Hardy-Weinberg Rule

Population genetics is the study of the properties of genes in populations

Gene pool is the sum of all of the genes in a population, including all alleles in all individuals

- is like a Punnett square for populations
- The Hardy-Weinberg principle used to calculate the frequency of particular alleles
- in a large population in which there is random mating,
- and in the absence of forces that change allele frequencies, the original genotype proportions remain constant from generation to generation
- If the proportions do not change, the genotypes are said to be in Hardy-Weinberg equilibrium
- If allele frequencies are not changing, the population is not evolving

The Hardy-Weinberg equilibrium only works if the following five assumptions are met

1.The size of the population is very large or effectively infinite.

2.Individuals can mate with one another at random.

3.There is no mutation.

4.There is no immigration or emigration.

5.All alleles are replaced equally from generation to generation.

Agents of Evolution
Five factors can produce significant deviations from Hardy-Weinberg predictions

1.mutation

2.migration

3.genetic drift

4.nonrandom mating

5.selection

1. **Mutation**

- ❖ change in a nucleotide sequence in DNA
- ❖ mutation rates are generally too low to significantly alter Hardy-Weinberg proportions
- ❖ mutations must affect the DNA of the germ cells or the mutation will not be passed on to offspring
- ❖ however, no matter how rare, mutation is the ultimate source of variation in a population

2. Migration: movement of individuals between populations

- ❖ the movement of individuals can be a powerful force upsetting the genetic stability of natural populations
- ❖ the magnitude of the effects of migration is based on two factors
- ❖ the proportion of migrants in the population
- ❖ the difference in allele frequencies between the migrants and the original population

3. Genetic drift: random changes in allele frequencies

- ❖ the frequencies of particular alleles may be changed drastically by chance alone
- ❖ in extreme cases, individual alleles of a given gene may be
- ❖ all represented in few individuals
- ❖ accidentally lost if individuals fail to reproduce or die
- ❖ A series of small populations that are isolated from one another may come to differ strongly as the result of genetic drift
- ❖ **founder effect** occurs when one of a few individuals migrate and become the founders of a new, isolated population at some distance from their place of origin
    - o their alleles become a significant % of the new population's gene pool
- ❖ **bottleneck effect** occurs when a population is drastically reduced in size (earthquake, tsunami, flood, genocide)
    - o the surviving individuals constitute a random genetic sample of the original population

4. Nonrandom mating

- ❖ occurs when individuals with certain genotypes mate with one another either more or less commonly than would be expected by chance
- ❖ sexual selection is choosing a mate based on, often, physical characteristics
- ❖ nonrandom mating alters genotype frequencies but not allele frequencies

5. Selection

- ❖ according to Darwin, occurs if some individuals leave behind more progeny than others
- ❖ the likelihood that they will do so is affected by their individual characteristics
- ❖ artificial selection: breeder selects for the desired characteristics
- ❖ natural selection: conditions in nature determine which kinds of individuals in a population are most fit

Types of Selection

Stabilizing: eliminates the extremes	Birth weight
Disruptive: eliminates the intermediate Group	Beak sizes in finches
Directional: eliminates 1 extreme	Fruit flies that moved toward the light became fewer & fewer

Sickle-Cell Anemia

- Autosommal, recessive
- Must be homozygous recessive to express this gene (2/1000 AA)
- Carriers OK
- Those with the disease die younger

Why does this disease not get selected out?

- The defective allele has not been eliminated from Central Africa because people who are heterozygous are much less susceptible to malaria
- the payoff in survival of heterozygotes makes up for the price in death of homozygotes
- this is called heterozygote advantage
- stabilizing selection occurs because malarial resistance counterbalances lethal anemia

The Biological Species Concept

Speciation: the macroevolutionary process of forming new species from pre-existing species

- it involves successive change
- first, local populations become increasingly specialized
- then, if they become different enough, natural selection may act to keep them that way
- Ernst Mayr's Biological Species Concept
    - "*groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups*"
    - Populations whose members do not mate with each other and cannot produce fertile offspring are said to be reproductively isolated and, thus, members of different species

Reproductive Isolating Mechanisms

Barriers that cause reproductive isolation by preventing genetic exchange between species

prezygotic isolating mechanisms

- ❖ prevent the formation of zygotes (5)

postzygotic isolating mechanisms

- ❖ prevent the proper functioning of zygotes once they have formed

6 different prezygotic reproductive isolating mechanisms

1. geographical isolation
    a. occurs simply in cases when species exist in different areas and are not able to interbreed

2. ecological isolation
    a. results from two species who occur in the same area but utilize different portions of the environment and are unlikely to hybridize
    b. Lions and tigers are ecologically isolated

3. temporal isolation
    a. results from two species having different reproductive periods, or breeding seasons, that preclude hybridization

4. behavioral isolation
    a. refers to the often elaborate courtship and mating rituals of some groups of animals, which tend to keep these species distinct in nature even if they inhabit the same places

5. mechanical isolation r
    a. esults from structural differences that prevent mating between related species of animals and plants

6. prevention of gamete fusion
    a. blocks the union of gametes even following successful mating
    b. If hybrid matings do occur, and zygotes are produced,

Postzygotic Isolating Mechanisms

- many postzygotic factors may prevent those zygotes from developing into normal individuals

- in hybrids, the genetic complements of two species may be so different that they cannot function together normally in embryonic development. Embryos die.

- even if hybrids survive the embryo stage, they may not develop normally

- many hybrids are sterile

Speciation is a two-part process

1st: identical populations must diverge

2nd: reproductive isolation must evolve to maintain these differences

There are two mechanisms for speciation
Allopatric Speciation

Sympatric Speciation

1. **allopatric speciation**: geographically isolated populations become new species due to their evolving reproductive isolation

2. **sympatric speciation** one species splits into two at a single locality (non-geographic)
Speciation is much more likely in *geographically isolated* populations

- ❖ population splits into two geographically isolated allopatric populations (habitat fragmentation)
- ❖ The isolated populations then undergo genotypic and/or phenotypic divergence as they
  - o become subjected to dissimilar niches or
  - o they independently undergo genetic drift.

When the populations come back into contact, they have evolved such that they are reproductively isolated and are no longer capable of exchanging genes.

Populations can become geographically isolated for a variety of reasons
a) colonization

b) barriers to movement

c) extinction of intermediate pops leaves remaining pops isolated from each other