Selection, Speciation, and The Origin of Life on Earth
28 October 2003

I. Microevolution
• Hardy-Weinberg Equilibrium - No Evolution vs. Selection
• Genetic Drift
• Bottlenecks and Founder Effect
• Inbreeding
• Gene Flow = migration

II. The Gene Pool

III. What Generates Genetic Diversity Among Individuals?

IV. Selective Breeding Promotes Evolution
• Evolution is genetic change in a population reflected in phenotype through successive generations
• Selective breeding practices

V. Evolution as a Change in Allele Frequencies
• Evolution does not change individuals.
• There is variation in genetic features (genes) among individuals
• Survival and reproductive success varies among individuals with different phenotypes
• Selection acts directly on phenotypes and indirectly on genotypes
• Evolution changes the frequencies of alleles in a population.

VI. Change Over Time
• Over time, the alleles that produce the most successful phenotypes will increase in the population due to more successful reproduction
• Less successful alleles will become less common
• Change leads to increased fitness (w)

VII. Microevolutionary Processes
• Small-scale changes in allele frequencies brought about by:
  - Natural selection - Differential mortality and survival
  - Sexual selection
  - Inbreeding
  - Genetic drift
• Small-scale changes in allele frequencies are resisted by gene flow

VIII. Inbreeding
• Inbreeding - Nonrandom mating between related individuals
  E.g., Amish (small population of insular group), Cheetahs (small population)
• Leads to increased homozygosity (recessives)
• Can lower fitness (survivability and reproduction) when deleterious recessive alleles are expressed

IX. Genetic Drift
• Random change in allele frequencies brought about by chance
• Effect is most pronounced in small populations

X. Evolutionary Bottleneck
• A severe reduction in population size causes pronounced genetic drift
• Example:
XI. Founder Effect
- Effect of drift when a new population is formed
- By chance, allele frequencies of founders may not be the same as those in the original population
- This sort of effect is pronounced on

XII. Gene Flow or Migration
- Physical flow of alleles into a population
- Tends to keep the gene pools of populations similar
- This counters the variation that results from mutation, inbreeding, selection, and genetic drift

XIII. Five Conditions for Genetic Equilibrium
- No Changes in Allele Frequency =
  - No mutation (no new alleles)
  - Random mating
  - No selection (natural or sexual)
  - Large population (no genetic drift)
  - No immigration/emigration (no gene flow)

XIV. Genetic Equilibrium
- When allele frequencies at a locus are not changing, a population is not evolving.
- This has RARELY been observed. In other words, evolutionary change in populations is the rule.

XV. Examples of Natural Selection
- Selection in Natural Populations
- Selection in Human Populations
- Selection Perpetrated by Humans on Other Species

XVI. Darwin’s Finches
- Winner of the Pulitzer Prize!
- The story of the intense quantitative field study of natural selection in Darwin’s finches:
  - 25 years of field work; many generations of finches
  - Peter and Rosemary Grant (Princeton U.)

XVII. Natural Selection in Guppies
- Selective Pressures: predation and mate choice
- Habitats either have predators or not.
- In the presence of predators,
- In the absence of predators,

XVIII. Black Plague and HIV/AIDS
- CCR5 gene codes for a cell membrane receptor that is necessary for the HIV virus to enter a white blood cell (which disrupts ability to fight off infectious disease).
- Mutation of the CCR5 gene (a 32 base deletion) disrupts this receptor protein.
- CCR5 mutation confers slowed infection by HIV (heterozygote) or resistance to infection (double recessive)
- What is the Connection?
  - Hyp: Black Plague

XIX. Sickle Cell Anemia
- One amino acid change in Hb polypeptide
- Causes inability to properly bind oxygen
- Characterized by malformed red blood cells

XX. Sickle-Cell Trait: Heterozygote Advantage
- Allele $Hb^s$ causes sickle-cell anemia when heterozygous
- Heterozygotes are more resistant to malaria than homozygotes
XXI. Antibiotic and Herbicide Resistance
- Antibiotics first came into use in the 1940s; they cause selective mortality of bacteria that are susceptible to antibiotics, allowing resistant individuals to survive. Same argument can be used to explain occurrence of herbicide resistance by plants (e.g., “weeds”)
- Overuse has led to increase in resistant forms (=phenotype) due to selection
- Resistance to a particular drug is a genetic trait carried in bacterial plasmid DNA

XXII. Speciation
- How Do New Species Arise? The Process of Speciation
- What is a Species?
- Reproductive Isolating Mechanisms
- Allopatric Speciation
- Other Patterns of Speciation

XXIII. Biological Species Concept

XXIV. Speciation & Natural Selection
- Speciation can occur as a result of:
  - Genetic drift
  - Mutation
  - Selection
- In addition, restriction of gene flow among populations promotes speciation,

XXV. Genetic Divergence
- Gradual accumulation of differences among the gene pools of different populations
- Selection, genetic drift, and mutation can contribute to genetic divergence
- Gene flow resists divergence

XXVI. Barriers to Gene Flow
Whether or not a physical barrier deters gene flow depends upon:
- Organism’s mode of dispersal or locomotion
  - Terrestrial organisms will be blocked by mountains, water, temperature gradients
  - Flying organisms will be blocked by wind direction
- Degree of movement (e.g., distance)

XXVII. Extensive Divergence Prevents Interbreeding
- Populations separated by geographic barriers will diverge genetically, because different populations are NOT genetically identical
- If divergence is distinct enough it will prevent interbreeding of two populations, even if the barrier later disappears (= speciation)

XXVIII. Reproductive Isolating Mechanisms
- Prezygotic isolation =
  - Ecological Isolation-
  - Temporal Isolation-
  - Behavioral Isolation -
  - Mechanical Isolation -
  - Gametic Mortality -
- Postzygotic isolation =
  - Zygotic mortality - the zygote dies; development stops
  - Hybrid inviability - offspring not viable
  - Hybrid sterility - offspring are sterile

XXIX. Mechanisms of Speciation
How do species achieve genetic divergence?
Where do new species arise?
- Allopatric speciation
- Sympatric speciation
- Parapatric speciation
XXX. Allopatric Speciation
- Probably most common mechanism of speciation
- Some sort of barrier arises and prevents gene flow (Rise of barrier = “vicariance”)
- Effectiveness of barrier varies with species
- Speciation occurs in populations that are geographically isolated from one another.

XXXI. Archipelagos - An Opportunity for Allopatric Speciation
- Island chains some distance from continents
  - Galapagos Islands
  - Hawaiian Islands
- Colonization of different islands

XXXII. Speciation on an Archipelago

XXXIII. Giant Galapagos Tortoises
- Isolation on tops of different volcanoes on the same island; they do not move around much.
- allopatric speciation

XXXIV. Hawaiian Honeycreepers

XXXV. Allopatric Speciation in Wrasses
- Isthmus of Panama arose and separated wrasses in Atlantic and Pacific = vicariance.
- Since separation, genes for certain enzymes have diverged in structure
- Result:
  - This process

XXXVI. Speciation Can Occur Without an Apparent Barrier
- Sympatric speciation
- Parapatric speciation

XXXVII. Sympatric Speciation in Cichlid Fishes of the African Rift Lakes
- Species in each lake are most likely descended from single ancestor
- No physical barriers within either lake
- Some ecological separation
- These fishes

XXXVIII. Parapatric Speciation
 Adjacent populations evolve into distinct species while maintaining contact along a common border

XXXIX. History of Life on Earth

XL. Before Life Began
- Big Bang produced universe 14 Bya (billion years ago)
- Elementary particles formed H shortly after the Big Bang
- H gave rise to the other elements
- Our galaxy was formed ~10 Bya
- Our solar system was formed ~4.6 Bya

XLI. The Origin of Life
- Life =
  - All life probably originated from a single ancestor (b/c we share certain features)
  - Research and the Origin of Life
XLII. Precambrian Life
- Precambrian = 3.6 Bya – 543 Mya
- First definitive sign of life = 3.5 Bya (bacteria)
- No O$_2$ for early life, but photosynthetic and/or chemosynthetic bacteria produced O$_2$, which slowly built up in the atmosphere
- By 543-505 Mya, modern-day levels of O$_2$ existed.
- Eukaryotes arose from prokaryotes 1.4 Bya

XLIII. Paleozoic Life: Cambrian Revolution
- Cambrian = 543 – 500 Mya
- Almost all modern phyla and classes of skeletonized marine animals suddenly appear
- Burgess Shale of British Columbia is one of the best records
- Mass extinction at the end of the cambrian

XLIV. Paleozoic Life: Ordovician-Devonian
- 500-354 Mya
- Following the cambrian extinction, many phyla diversified (open niches)
- Fishlike vertebrates appeared
- Another mass extinction ~440 Mya = probably due to sudden drop in temperature
- First evidence of terrestrial life ~409 Mya: plants
- First land animals appear ~400 Mya: chelicerates
- First land vertebrates appear ~370 Mya: ichthyostegid amphibians

XLV. Paleozoic Life: Carboniferous-Permian
- 354-251 Mya
- Gondwanaland and Laurasia supercontinents merged late in Permian to form Pangaea
- Terrestrial Life
- Aquatic Life
- At the end of the Permian, the most massive extinction in water occurred (cause unknown)

XLVI. Mesozoic Life
- 251-65 Mya: Age of Reptiles
- Pangaea broke up during Triassic into Gondwanaland and Laurasia again
- Another mass extinction at the end of the Triassic and one at the end of the Cretaceous
- Terrestrial Life

- Marine Life

XLVII. Cenozoic Era
- 65 Mya-present
- Laurasia breaks up into Europe/Asia and North America
- Bering land bridge formed between Asia and N. America
- Gondwanaland
- Aquatic Life

XLVIII. Cenozoic Era: Terrestrial Life
- Modern frogs, birds appear
- Snakes radiate
- Mammals explode: marsupials, shrews, ungulata, primates, rodents, marine mammals
- Worst fossil evidence from the paleocene makes it difficult to study mammalian evolution

XLIX. Pleistocene Events
- 1.8 - .01 Mya