Diversity of Life

Evolution does not follow an inbuilt direction and is not linear

Species = basic unit

Continuous lineage - information passed through genes
Speciation - rise of new species

• 1.7 million species described
• ca. 10-30 million estimated
• many extinct species
  (about 90% of all species that ever lived are extinct)

Large diversity of species - speciation must be a common event

• Evolution happens when populations of organisms with inherited variations are exposed to environmental factors that favor the reproductive success of some individuals over others
Populations are the units of evolution

- A population is a group of interbreeding individuals.
- A species is a group of populations whose individuals can interbreed and produce fertile offspring.

What is evolving?

- gene pool = total collection of genes in a population at any one time
- Microevolution is a change in the relative frequencies of alleles in a gene pool.

Five agents of microevolution

1. **Mutation** changes alleles
2. **Genetic drift** = random changes in allele frequency
   - Bottleneck
   - Founder effect
3. **Gene flow** can change a gene pool due to the movement of genes into or out of a population
   - ex. Migration
4. **Nonrandom mating** within a population
5. **Natural selection** leads to differential reproductive success

Genetic drift - effects of population size:

- **LARGE POPULATION = 10,000**
  - 1000 allele frequency = \( \frac{1000}{10000} = 10\% \)
- **SMALL POPULATION = 10**
  - 1 allele frequency = \( \frac{1}{10} = 10\% \)
- 50% of population survives, including 450 allele carriers
  - allele frequency = \( \frac{450}{5000} = 9\% \)
  - Little change in allele frequency (no alleles lost)
- 50% of population survives, with no allele carrier among them
  - allele frequency = \( \frac{0}{5} = 0\% \)
  - Dramatic change in allele frequency (potential to lose one allele)

- **Natural selection**
  - results in the accumulation of traits that adapt a population to its environment
  - the only agent of evolution that results in adaptation.
There are three general outcomes of natural selection:

- Stabilizing selection
- Directional selection
- Diversifying selection

### Natural Selection

- What is a species?
- How does speciation occur?

### Species Concepts

I. **Morphological Species Concept**

Species are similar in their appearance.

New Zealand moa (extinct): females much bigger than males.

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2. **Species Concepts**

I. Morphological Species Concept - sometimes hard to apply

Two different species | One single species
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Species Concepts

I. Morphological Species Concept - sometimes gets it wrong

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Species Concepts

II. Biological Species Concept

- Does a “species” have the potential to interbreed and does it represent a separate evolutionary lineage?

Biological Species Concept

- Two individuals belong to the same species if their gametes can unite with each other under natural conditions to produce fertile offspring.
- This concept emphasizes that a species is an evolutionary unit.

Species Concepts

Biological Species Concept - problems

- Fossils - how do we know if they interbreed?
- “Good” species can sometimes produce hybrid
- Asexual organisms

“Ring Species”

- A ring of populations encircles an area of unsuitable habitat.
- At one location in the ring of populations, two distinct forms coexist without interbreeding, and hence are different species.
- Around the rest of the ring, the traits of one of these species change gradually, through intermediate populations, into the traits of the second species.

Greenish warblers
2. Species Concepts

Phylogenetic Species Concept

Species = lineage between successive speciation events

Phylogenetic species concept

- Diagnosable geographic forms of the same basic "kind" of organism should be treated as distinct species.
- Each form has a unique evolutionary history
- All a PS needs to be "diagnosed" is a single shared and derived character

Problems with the PSC

- Much less restrictive than the BSC
- Any population with a distinct feature is considered a "species"
- There would be many more species classified under the PSC than under the BSC – too many to cope with?
- Does a single, fixed nucleotide difference between populations warrant separate protection status for each population?
Example of using the different species concepts

*Ammodramus maritimus* – seaside sparrow

6 subspecies – groups that are different but not different enough to be separate species

*A.m. nigrescens* – Dusky seaside sparrow – extinct in 1987

Each subspecies of seaside sparrow has a restricted range.

Salt marsh habitats are threatened by development and rising sea level.

The subspecies separate into two groups when DNA sequences are compared.

**Phylogenetic species concept – how many species are there?**

Within each group, DNA sequences are virtually identical.

Dusky Seaside Sparrow *Ammodramus maritimus nigrescens*

- The last 6 birds brought into captivity in 1980 from a Florida marsh were all males!
- declared extinct in December, 1990
Seminar Today – Extra Credit (10 pts)
Dr. Peter Marra, Research Scientist, Smithsonian Migratory Bird Center

“Neighborhood Nest-Watch: Science in the City”
11:15 – 12:00
Room 009, Townsend Hall

Species formation
How do we get cladogenesis -- the splitting of one lineage into two?

This question is critical, because it is what produces many species from few, results in evolutionary trees of relatedness, and generates what we now call biodiversity.

Allopatric (geographic) speciation

• Different geographic regions are likely to have different selective pressures:
  • Temperature
  • Rainfall
  • Predators
  • Competitors

• Populations may also differentiate because:
  • New mutations
  • New genetic combinations occur by chance in each owing to genetic drift
  • Thus, selection will have different raw material to act upon in each population.

Isolation and Divergence in Allopatry

• Allopatric speciation occurs when populations become physically separated from each other.
  – A population can colonize a new habitat.
  – A new physical barrier can split a widespread population into two or more isolated groups.

• Natural Selection
• What is a species?
• How does speciation occur?
Often species coming back into contact not yet fully reproductively isolated.

- Natural selection may reinforce reproductive barriers and isolation.
- Species isolated by post-zygotic barriers will subsequently evolve pre-zygotic barriers.
- Why?

Reproductive isolating mechanisms

1) Prezygotic Barriers

2) Postzygotic Barriers

Secondary contact and reinforcement

Secondary contact - contact between two populations that have been isolated from each other and have been diverging genetically for a while.

What happens after secondary contact depends on whether reproductive isolating mechanisms have developed or not.

Reinforcement - the ways in which distinctness between populations is maintained so as to prevent hybridization. Eg. lowered fitness of hybrid phenotypes.

Hybrid zones are areas where interbreeding between two species occurs and hybrid offspring are common

Example: hybrid zone between Townsend's and hermit warblers
Hermit warbler
Townsend's warbler
Townsend's-hermit hybrid

Hybrids have intermediate characteristics.

- Looked at gene sequences in mitochondrial DNA (mtDNA)
- Townsend's have different mtDNA than Hermits
- Most hybrids have Hermit mtDNA

What does that say about how hybrids form?

Townsend's males mate with Hermit females

Ecological studies show that Townsend males chase Hermit males out of territory but Hermit males do not chase Townsend males

What happens when isolated populations come back together?
- Either they will stay reproductively isolated or not
- Several mechanisms keep species isolated
  - Prezygotic mechanisms
    - Postzygotic mechanisms
  - Hybrid offspring are not always sterile
    - Can reproduce and have traits that are in between the two parents
- Hybridization can also lead to new species

In some areas, all Townsend's have Hermit mtDNA

Some individuals have Townsend's mtDNA, others have Hermit mtDNA

All individuals have Hermit mtDNA

Pacific Ocean
Hybrid zone
Will Hermit warblers eventually go extinct?