Speciation

*On the Origin of Species …*

- **Speciation**
  - Anagenesis
    - Change in a species gene pool and phenotype
  - Cladogenesis
    - Change in a population to become distinct from parent population
    - Branching → increase diversity

**SPECIATION**

Species: “kind”
- Biological Species Concept
- Species Barriers
- Isolation & Speciation
- Other Species Concepts
- Tempo of Evolution

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**Biological Species Concept**

Species (“…each reproducing according to its kind.”):
- Group of populations who can interbreed.

**Reproductive Isolation**
- Barriers to interbreeding between species are:
  - prezygotic - before fertilization
  - postzygotic - after fertilization

**Prezygotic Barriers**

- Habitat Isolation
- Behavioral Isolation
- Temporal Isolation
- Mechanical Isolation
- Gametic Isolation

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**Behavioral Isolation**

*Similarity between different species. The eastern meadowlark (Sturnella magna, left) and the western meadowlark (Sturnella neglecta, right) have similar body shapes and colorations. Nevertheless, they are distinct biological species because their songs and other behaviors are different enough to prevent interbreeding should they meet in the wild.*

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Heyer
Sexual Selection & Hawaiian Drosophila

The mate recognition concept of species

Experiment:
Drosophila pseudoobscura fruit flies divided into eight populations.
Four groups raised on maltose food source.
Four groups raised on starch food source.
Wild isolated for a year (~35 generations).
Then one generation on standard (molasses-corn meal) food source.
Two populations from each food source crossed from all combinations of all eight populations.

Calculation: Isolation Index (I) for each combination:
$$I = \frac{\text{(homogamic matings} - \text{heterogamic matings})}{\text{total matings}}$$

Predictions:
If no isolation, I = 0
If mating isolation, I > 0
(Complete isolation if I = 1)
If heterogamic preference, I < 0
(Complete preference if I = -1)

Results:
For matings between maltose populations, I = 0
For matings between starch populations, I = 0
Conclusion #1: Physical separation alone did not result in behavioral isolation.

For matings between maltose and starch populations, I = 0.3 to 0.5
Conclusion #2: Physical separation along with directional selective pressure did result in behavioral isolation.

Prezygotic Barriers

- Habitat Isolation
- Behavioral Isolation
- Temporal Isolation
- Mechanical Isolation
- Gametic Isolation

Variations in male genitalia among different species of Drosophila fruit flies

- Habitat Isolation
- Behavioral Isolation
- Temporal Isolation
- Mechanical Isolation
- Gametic Isolation
  - sperm can’t fertilize egg
  - esp. important for broadcast spawners

Diane Dodd. Evolution, 43(6), 1989, pp. 1308-1311
Speciation

**Postzygotic Barriers**
- Hybridization — what stops it?

- Hybridization prevents viable offspring from forming.

**Postzygotic Barriers**
- Reduced Hybrid Viability
- Reduced Hybrid Fertility
- Hybrid Breakdown — their offspring aren’t viable.

- **Hybrid offspring — “wholphin”**

**Speciation — genetic isolation is the key**
- Once populations become isolated, ...
- Separation of gene pools allows differences to increase over time.

**Sympatric Speciation**
- Cichlid fish of Lake Victoria
- Sympatric speciation from nonrandom mating / sexual selection

**Exp.**
- Male and female *P. pundamilia* and *P. nyererei* placed together in two aquarium tanks, one with normal light and one with a monochromatic orange lamp. Under normal light, the two species were noticeably different in coloration; under monochromatic orange light, the two species appeared identical in color. The researchers then observed the mating choices of the fish in each tank.

**Results**
- Under normal light, females of each species mated only with males of their own species. But under orange light, females of each species mated indiscriminately with males of both species. The resulting hybrids were viable and fertile.

**Conclusion**
- Researchers concluded that the behavior of females based on coloration is the main reproductive barrier that normally keeps the gene pools of these two species separate. Since the species can still interbreed when this prezygotic behavioral barrier is breached in the laboratory, the genetic divergence between the species is likely to be small. This suggests that speciation in nature has occurred relatively recently.

**Sympatric Speciation via Polyploidy**
- In some plant species
- Polyploidy: the presence of extra sets of chromosomes in cells due to aberrant cell division

**Autopolyploid**
- More than two chromosome sets, derived from a single species

**Allopolyploid**
- More than two chromosome sets, derived from different species

**Sympatry Vs. Allopatry**
- Reproductive isolation may develop between subpopulations within a common range
- More often (probably), reproductive isolation develops after subpopulations become geographically isolated

**Hybrid Breakdown**
- Their offspring aren’t viable.

**Genetic Breakdown**
- Their offspring aren’t viable.
Speciation

Allopatric Speciation

- Geographic Barriers
- Gene flow barriers = isolate gene pools.
- Adaptive Radiation & Islands

Formation of Geographic Barriers

Roughly 3 million years ago, the Isthmus of Panama was formed, separating populations of frogs. Today, populations along the Atlantic and Pacific coastlines are no longer able to interbreed.

Partial Geographic Barriers

Should these really be classified as distinct species?

Partial Geographic Barriers

Ensatina salamanders around the California Central Valley

Should these be classified as distinct species?

Metapopulations within a species

Metapopulation:
- overlapping sub-populations
- May seasonally become more contiguous or more isolated.
- May refer to distinct breeding population within a common range.

Human Alteration of Geographic Barriers

Egg-laying sites in mountain streams
- Regular, frequent dispersal and gene flow between subpopulations
- Long term, infrequent dispersal, minimal gene flow between subpopulations

Human Alteration of Geographic Barriers

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Speciation

Extreme Cladogenesis: Adaptive Radiation
One Diverges to Many Niches

Adaptive Radiation & Islands
- 1: Founder Event
- 2: Speciation
- 3: Dispersal
- 4: Speciation
- 5/6: Dispersal
- 7: Speciation
- 8: Dispersal
- 9: Speciation

Migrating Land Masses

Major Biogeographical Realms

Limitations of the Biological Species Concept
- The biological species concept
  - Group of populations who can interbreed
- Cannot be applied to
  - Asexual organisms
  - Fossils
  - Organisms about which little is known regarding their reproduction

Other Definitions of Species
- The morphological species concept
  - Characterizes a species in terms of its body shape, size, and other structural features
- The paleontological species concept
  - Focuses on morphologically discrete species known only from the fossil record
- The ecological species concept
  - Views a species in terms of its ecological niche
- The phylogenetic (cladistic) species concept
  - Defines a species as a set of organisms with a unique genetic history
- The molecular species concept
  - Defines species by the degree of similarity in their DNA
Speciation

Factors Speeding the Tempo of Speciation
1. Small population size
   = less gene pool inertia / more rapid genetic drift
2. Short generation time
   = more evolutionary time
3. Available niches
   = New land mass or extinction event “opens up” potential for diversification
4. Large selective pressure
   = adaptation more important
5. Gradualism vs. punctuated equilibrium

Immigration vs. speciation
• High immigration rapidly fills any niches vacated by local extinction.
• Low immigration allows niches to remain open long enough for endemic speciation.

Biodiversity vs. Island Size

Extinction Events
• Extinction of many of the original Cambrian phyla, classes, & orders opened up many niches for divergence & adaptive radiation within surviving phyla.
• CAUTION: Apparent increase may be a false artifact of increased fossil preservation & recovery in more recent strata!

Genetic Change and the Tempo of Speciation
• Speciation may occur slowly when:
  – many genetic differences build up between isolated populations.
  – “Gradualism”
• Speciation may occur quickly when:
  – a few critical genes change.
  – “Punctuated Equilibrium”

Tempo of Evolution
Gradualism – traditional neo-Darwinian model
Punctuated-Equilibrium

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