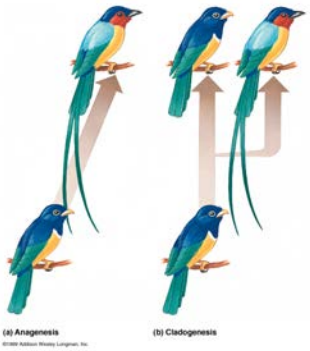
On the Origin of Species …



- **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

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

Indian rhinoceros

African black rhinoceros

Prezygotic Barriers

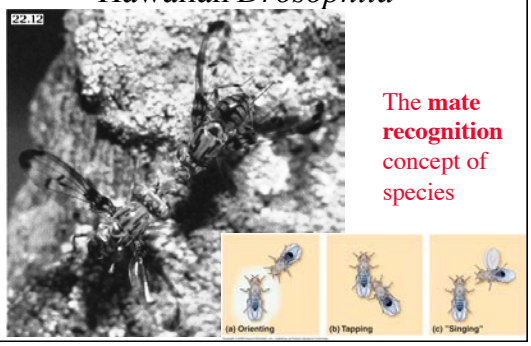
- Habitat Isolation
- Behavioral Isolation
- Temporal Isolation
- Mechanical Isolation
- Gametic Isolation

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.

Figure 24.3 A

Sexual Selection & Hawaiian *Drosophila*



The **mate recognition** concept of species

Pleiotropic Behavioral Isolation

Experiment: *Drosophila pseudoobscura* fruit flies divided into eight populations.
- Four groups raised on maltose food source.
- Four groups raised on starch food source.

•Held isolated for a year (~35 generations).
- Then one generation on standard (molasses-corn meal) food source.

•Tested for mating between flies from all combinations of all eight populations.

•Calculate **Isolation Index (I)** for each combination:

$$I = \frac{\text{(homogamic matings — heterogamic matings)}}{\text{total matings}}$$

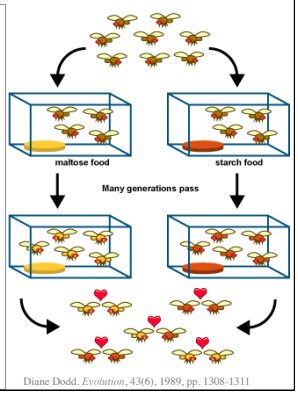
Predictions: If no isolation, **I** = 0
If mating isolation, **I** > 0
[Complete isolation if **I** = 1]
If hetergamic preference, **I** < 0
[Complete preference if **I** = −1]

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.

Results: For matings between maltose and starch populations, **I** = 0.3 to 0.5

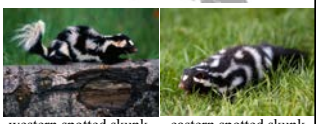
Conclusion #2: Physical separation along with directional



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

Prezygotic Barriers

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

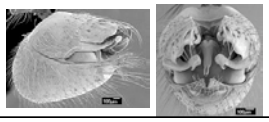


western spotted skunk mates in late summer

eastern spotted skunk mates in late winter

Prezygotic Barriers

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



insects

Variations in male genitalia among different species of *Drosophila* fruit flies

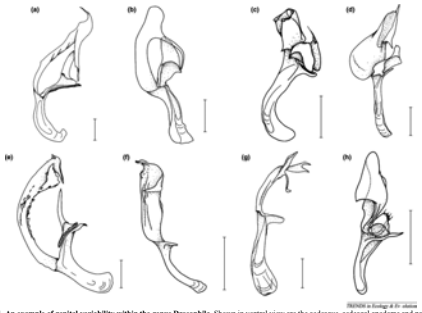
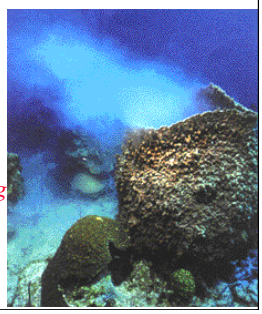


Figure 1. An example of genital variability within the genus Drosophila. Shown in ventral view are the aedeagus, aedeagal apodeme and paraphyses of D. guacamaya(a), D. papei(b), D. periquito(c), D. ranchograndensis(d), D. tschirnhausi(e), D. merzi(f), D. pittieri (no aedeagus shown) (g) and D. luisrraii(h). Scale bar=100 μm.

Sexual selection and genital evolution. (2004) *Trends in Ecology & Evolution* 19 (2):87–93

Prezygotic Barriers

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



Postzygotic Barriers

male false killer whale

- Hybridization
  - what stops it?

female bottlenose dolphin

hybrid offspring — "wholphin"

Postzygotic Barriers

Rana pipiens

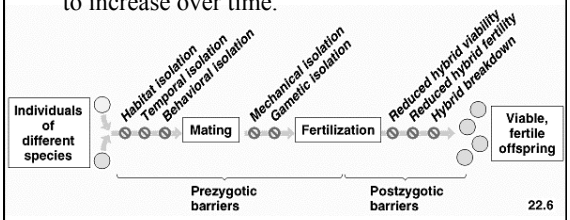
Rana sylvatica

- Reduced Hybrid Viability
- Reduced Hybrid Fertility
- Hybrid Breakdown
  - their offspring aren't viable.

horse x donkey = mule

Speciation — genetic isolation is the key

- Once populations become isolated, …
- separation of gene pools allows differences to increase over time.

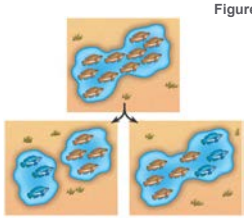


- If all barriers are crossed, hybrids may occur.

Sympatry Vs. Allopatry

- Reproductive isolation may develop between subpopulations within a common range
  - **Sympatric speciation**
- More often (probably), reproductive isolation develops after subpopulations become geographically isolated
  - **Allopatric speciation**

Figure 24.5



(a) Allopatric speciation. A population forms a new species while geographically isolated from its parent population.

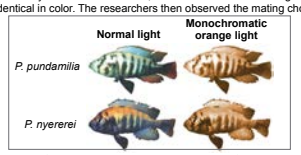
(b) Sympatric speciation. A small population becomes a new species without geographic separation.

Sympatric Speciation

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

Figure 24.10

EXPERIMENT Males and females of *Pundamilia pundamilia* and *P. nyererei* placed together in two aquarium tanks, one with natural light and one with a monochromatic orange lamp. Under normal light, the two species are noticeably different in coloration; under monochromatic orange light, the two species appear 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.

CONCLUSIONS The researchers concluded that mate choice by 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

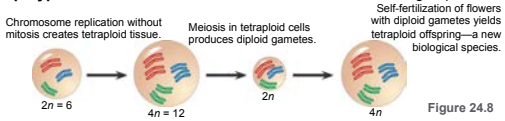


Figure 24.8

•**Allopolyploid**: more than two chromosome sets, derived from different species

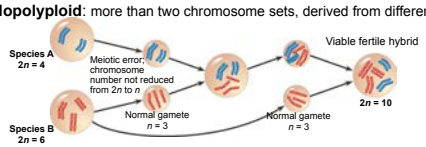


Figure 24.9

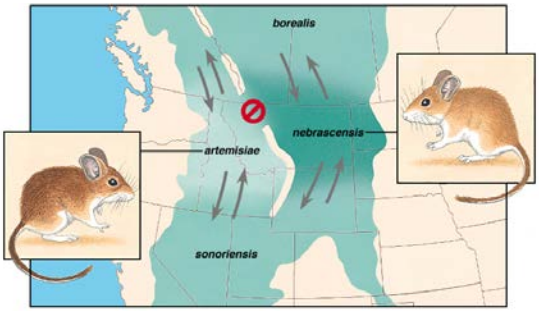
Allopatric Speciation

- 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 fish. Over time, the populations diverged. Today, their descendants, closely related Atlantic and Pacific species, are no longer able to interbreed.

Partial Geographic Barriers



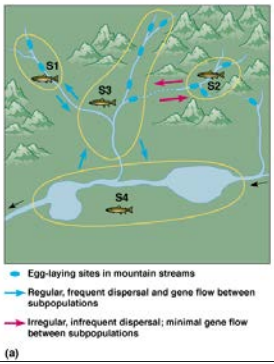
Should these really be classified as distinct species?

Partial Geographic Barriers

***Ensatina* salamanders around the California Central Valley**

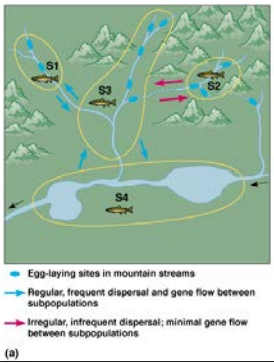
Should these be classified as distinct species?

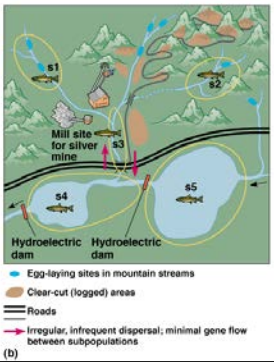
Metapopulations within a species



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

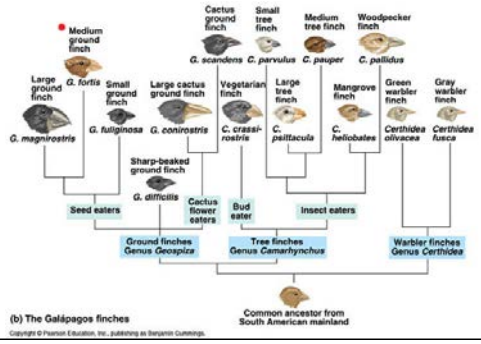
Human Alteration of Geographic Barriers





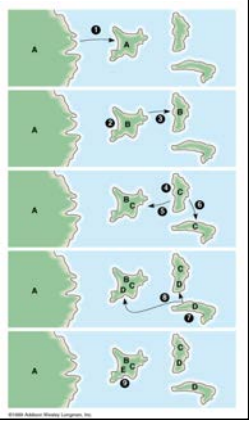
Extreme Cladogenesis: Adaptive Radiation

One Diverges to Many Niches

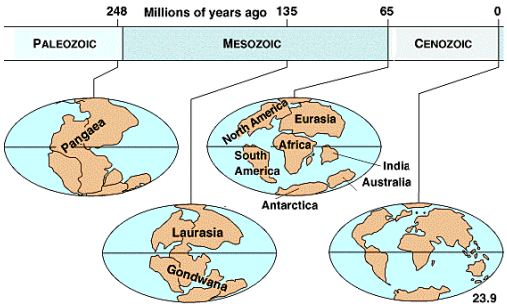


Adaptive Radiation & Islands

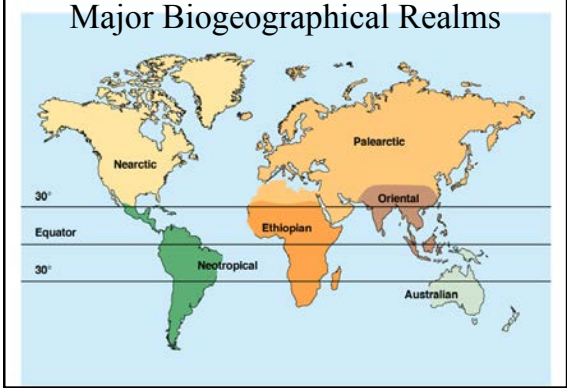
- 1: Founder Event
- 2: Speciation
- 3: Dispersal
- 4: Speciation
- 5/6: Dispersal
- 7: Speciation
- 8: Dispersal
- 9: Speciation



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

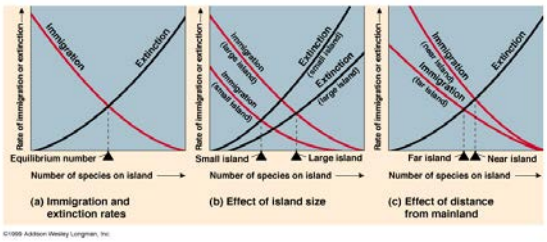
- The morphological species concept
  - Characterizes a species in terms of its body shape, size, and other structural features
- The paleontological species concept
  - Focuses on morphologically discrete species known only from the fossil record
- The ecological species concept
  - Views a species 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

Factors Speeding the Tempo of Speciation

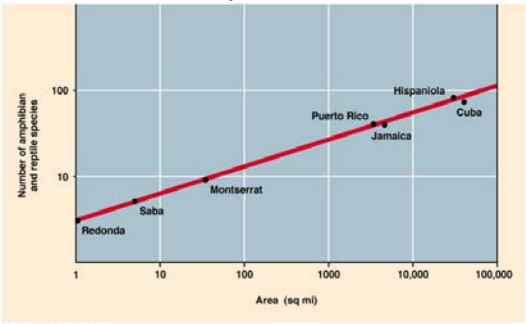
1. Small population size
   = less gene pool inertia / more rapid genetic drift
2. Short generation time
   = more evolutionary time
3. Available niches
   – New land mass or extinction event "opens up" potential for diversification
4. Large selective pressure
   = adaptation more important
5. Gradualism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

Immigration vs. speciation

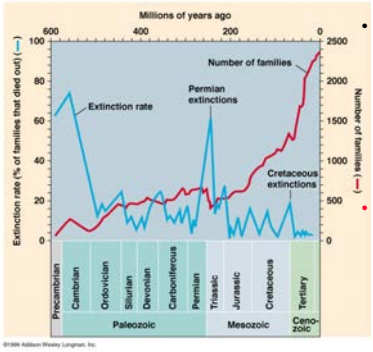
- High immigration rapidly fills any niches vacated by local extinction.
- Low immigration allows niches to remain open long enough for endemic speciation.



Biodiversity vs. Island Size



Extinction Events



- Extinction of many of the original Cambrium 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