

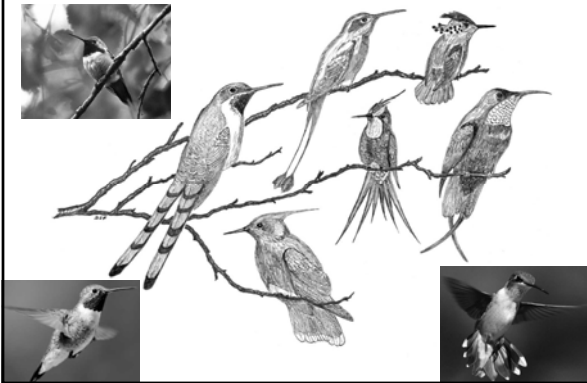
Mechanisms of Speciation



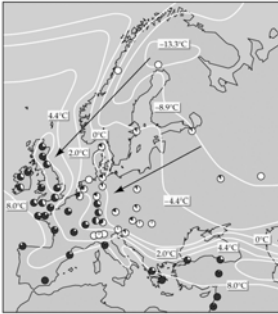
Some species show little geographic variation...



...while others vary quite a bit.



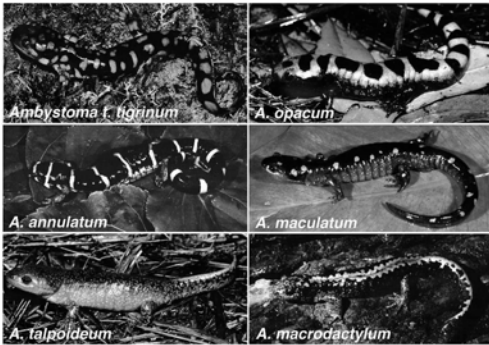
Geographic variation may be gradual...



Geographic Variation in Poisonous Clovers.

White indicates proportion not producing cyanide
Black indicates proportion producing cyanide

... or abrupt.



Terrestrial adults of six species of ambystomatid salamanders.

What is a species?

Because speciation is often a gradual process, it may be difficult to recognize boundaries between species.

TABLE 15.1 *Some species concepts*

Biological species concept Species are groups of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups (Mayr 1942).

Evolutionary species concept A species is a single lineage (an ancestor-descendant sequence) of populations or organisms that maintains an identity separate from other such lineages and which has its own evolutionary tendencies and historical fate (Wiley 1978).

Phylogenetic species concepts (1) A phylogenetic species is an irreducible (basal) cluster of organisms that is diagnosably distinct from other such clusters, and within which there is a parental pattern of ancestry and descent (Cracraft 1989). (2) A species is the smallest monophyletic group of common ancestry (de Queiroz and Donoghue 1990).

Genealogical species concept Species are "exclusive" groups of organisms, where an exclusive group is one whose members are all more closely related to one another than to any organism outside the group (Baum and Shaw 1995).

Recognition species concept A species is the most inclusive population of individual biparental organisms that share a common fertilization system (Paterson 1985).

Cohesion species concept A species is the most inclusive population of individuals having the potential for phenotypic cohesion through intrinsic cohesion mechanisms (Templeton 1989).

For All Species (Spp.) Concepts:

- Spp. consist of groups of "actual" or "potential" interbreeding pop's.
- Spp. are a fundamental unit of evolution (bridging both macroevolution and microevolution).
- Spp. share a distinguishing characteristic, which is evolutionary independence. This occurs when microevolutionary forces (mutation, selection, migration & drift) operate on each spp. separately.
 - Forms a boundary for the spread of alleles.
 - Different spp. follow independent evolutionary trajectories.

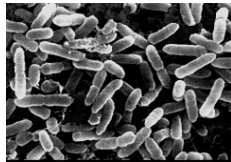
Biological Species Concept (BSC)

- Species are groups of actually or potentially interbreeding individuals that are reproductively isolated from other such groups (Mayr).
- Used by the Endangered Species Act (for better or worse).
- What about non-overlapping pop's, fossil record, & microbes?

Difficulties with the Biological Species Concept

- **Asexual reproduction**
- **Many geographically isolated populations**
- **Variation in reproductive isolation**
- **Hybridization and introgression**
- **Endosymbiont-caused isolation**

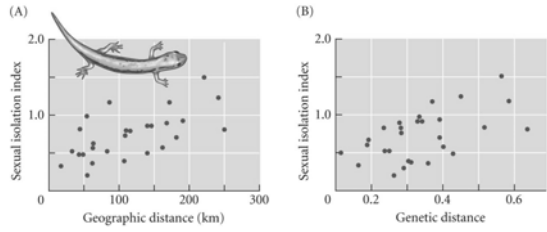
Asexual reproduction



Many geographically isolated populations

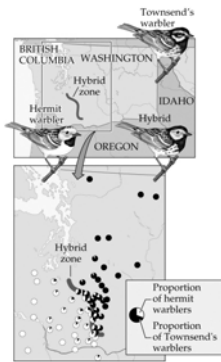


Variation in reproductive isolation



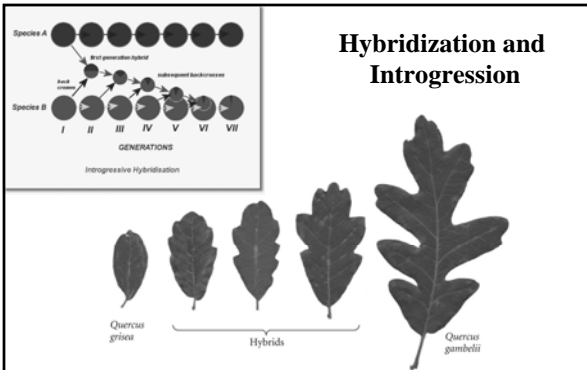
Degree of sexual isolation between populations of *Desmognathus ochrophaeus*

Hybridization and Introgression

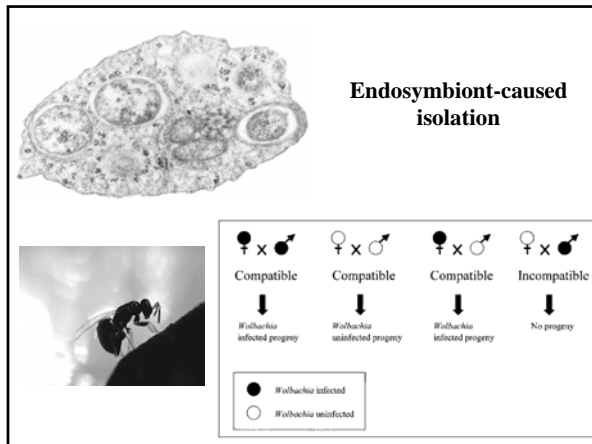


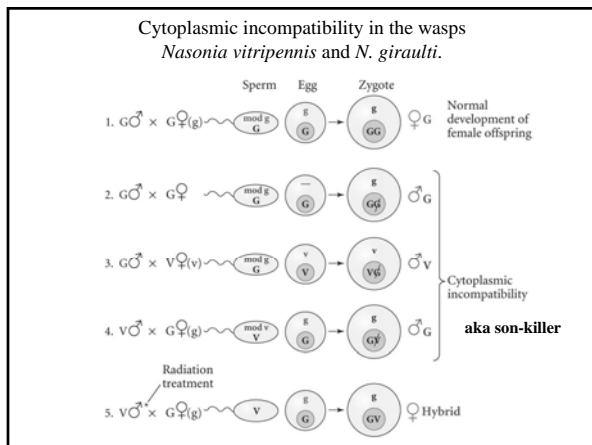
Hybrids may form if separated populations rejoin without sufficient genetic differences having accumulated.

Hybridization and Introgression



The movement of a gene from one species into the gene pool of another by backcrossing an interspecific hybrid with one of its parents.





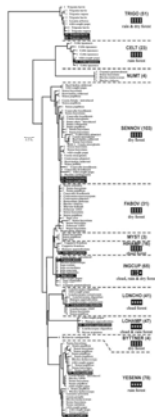
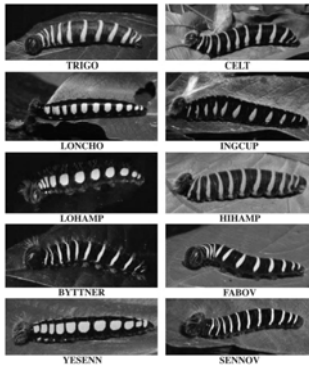
Phylogenetic Species Concept (PSC)

- The smallest aggregation of populations or lineages diagnosable by a unique combination of character states (Nixon & Wheeler).
- Monophyletic groups derived from a single common ancestor.
- Not standardized, which traits are most important?

Evolutionary Species Concept (ESC)

- A single lineage of ancestor-descendant populations which maintains its identity from other such lineages and which has its own evolutionary tendencies (Simpson).
- Required for fossil record analysis.
- Must be applied carefully and consistently, i.e., “Cryptic species”.

10 Cryptic Species revealed in the neotropical skipper butterfly *Astraptes fulgerator*.

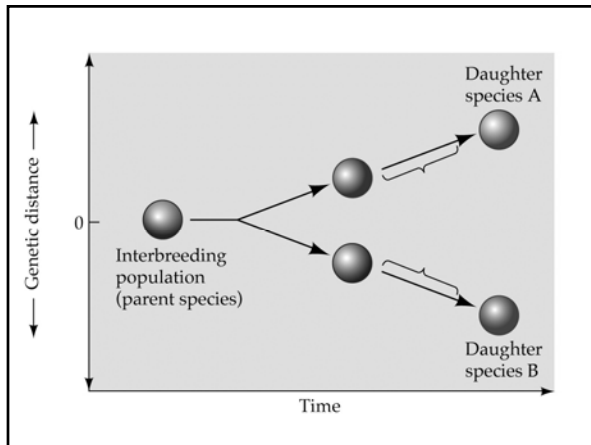


Diagnosing Species in Practice

- Morphology
- Behavior
- Molecular data

What is speciation?

- **Isolation:** Physical separation between pop's
 - May or may not be required!
- **Divergence:** In habitat use and/or mating tactics
 - Via Selection, Mutation, and/or Drift
- **Completion:** aka Reproductive Isolation
 - 2° Contact via Reinforcement
 - Hybridization events



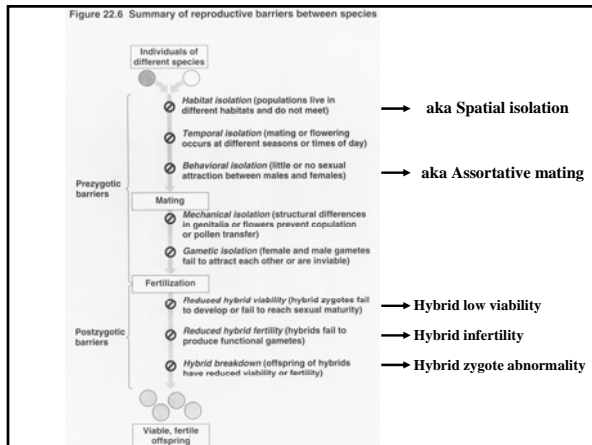
Major Questions in Speciation Research

- What is the geographic context of speciation?
- What are the roles that evolutionary forces (selection, drift, gene flow) play in speciation?
- Are few genes or many involved in speciation?
- How long does speciation take?
- Why do some lineages speciate more rapidly than others?

Under the Biological Species Concept, the key to understanding the formation of new species lies in understanding the evolution of reproductive barriers.

Intrinsic vs. extrinsic barriers

(Rem: Mass vs. Weight example)



**Prezygotic Barrier:
Temporal Isolation**

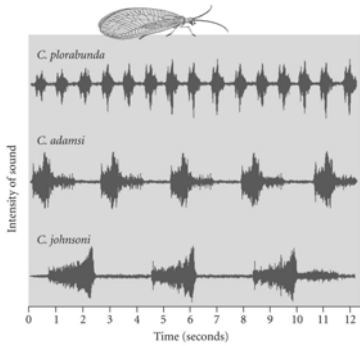


Western Spotted Skunk
• breeds in late summer

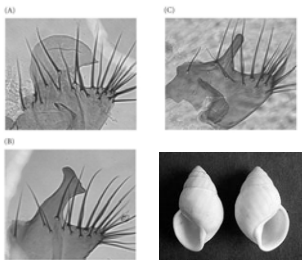


Eastern Spotted Skunk
• breeds in late winter

Prezygotic Barrier: Behavioral Isolation

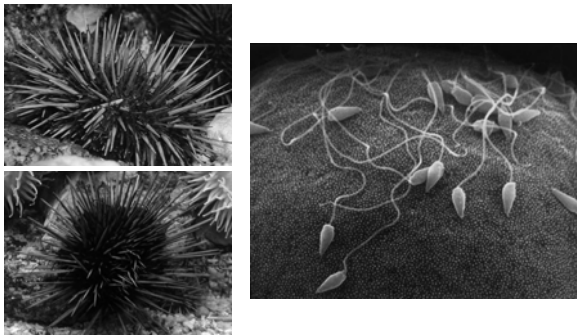


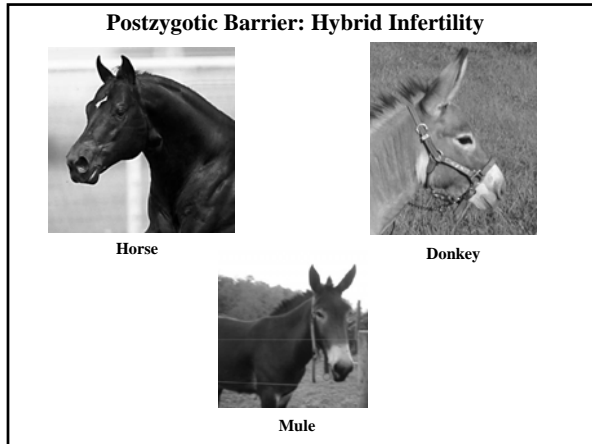
Prezygotic Barrier: Mechanical Isolation

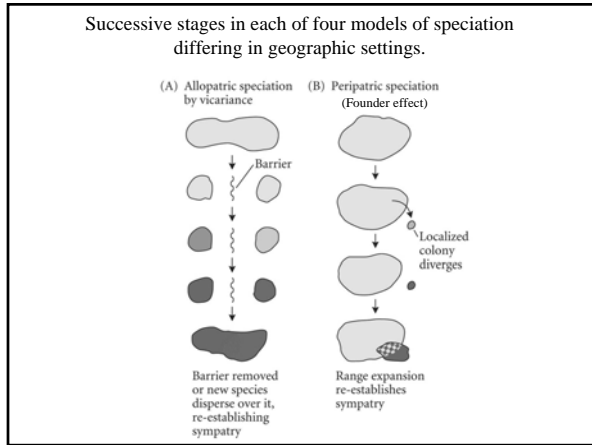


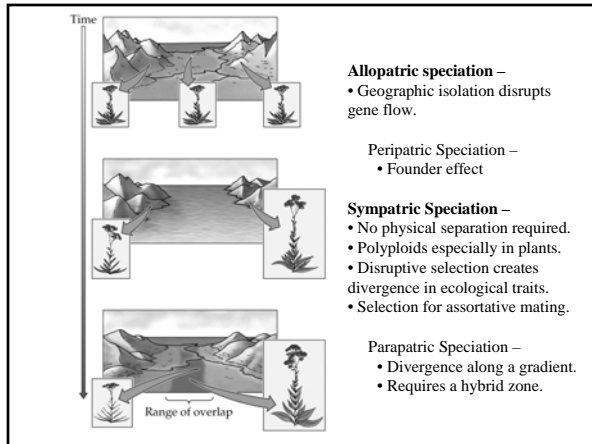
The posterior lobe of the genital arch in males of three closely related species of *Drosophila*.

Prezygotic Barrier: Gametic Isolation

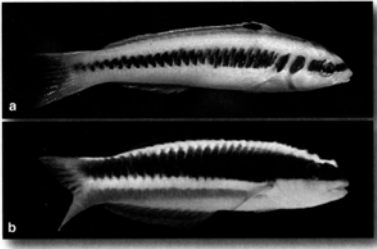
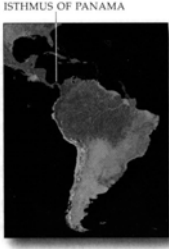









Allopatric Speciation: Vicariance

The Isthmus of Panama formed from 15 Mya to 3 Mya.

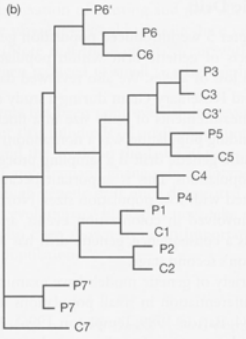
Speciation in snapping shrimp across the Isthmus of Panama



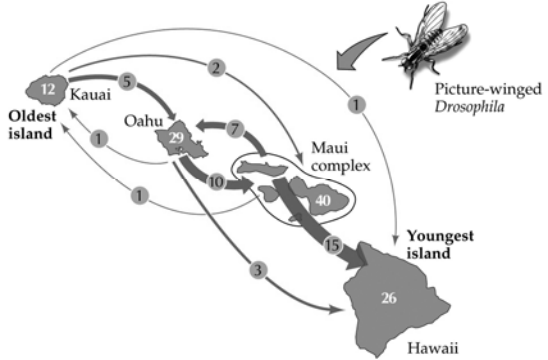
7 morphospecies w/o repro

Closest clades show "Final Break" at ~3 Mya

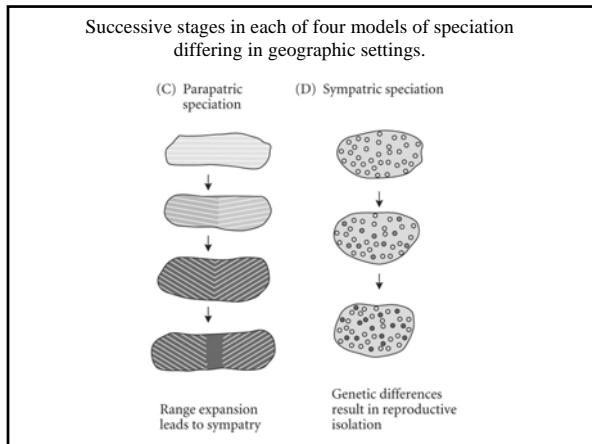
(*) = cryptic species



Allopatric speciation is common in island archipelagoes via Dispersal & Colonization



Picture-winged *Drosophila*



Reproductive Isolation

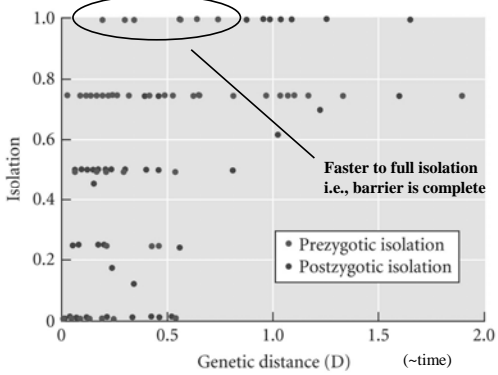
Byproduct (Mayr) vs. Reinforcement (Dobzhansky)

Reinforcement – type of selection that leads to assortative mating and prezygotic isolation.

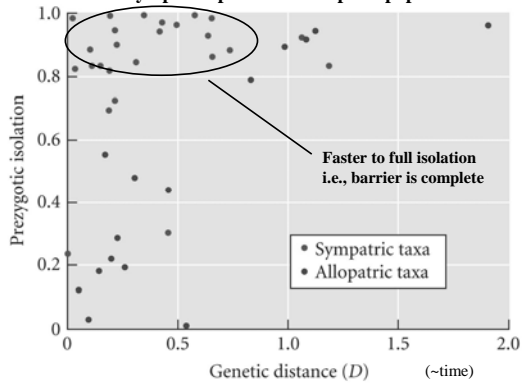
Reproductive isolation revisited:

- Both prezygotic and postzygotic barriers increase gradually over time for either model.
- Reinforcement speeds up prezygotic barriers in sympatric sister species through assortative mating.

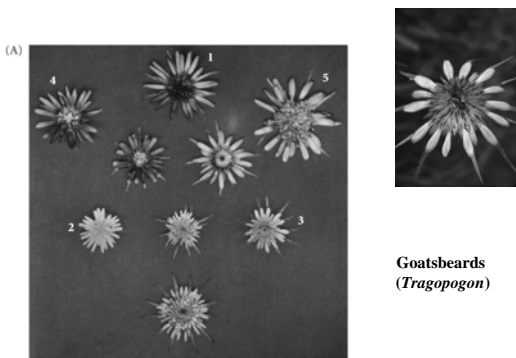
Pre- or postzygotic reproductive isolation between pairs of populations & species of *Drosophila*

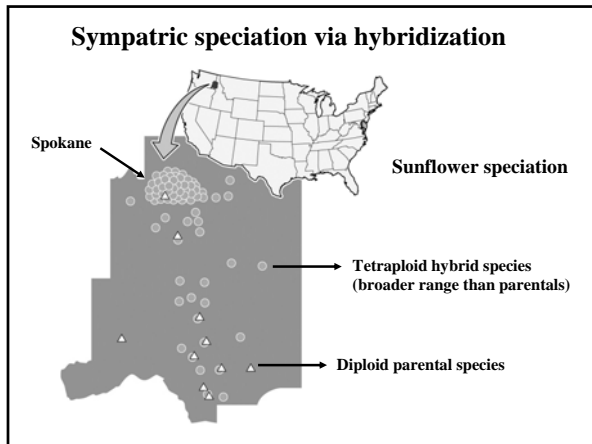


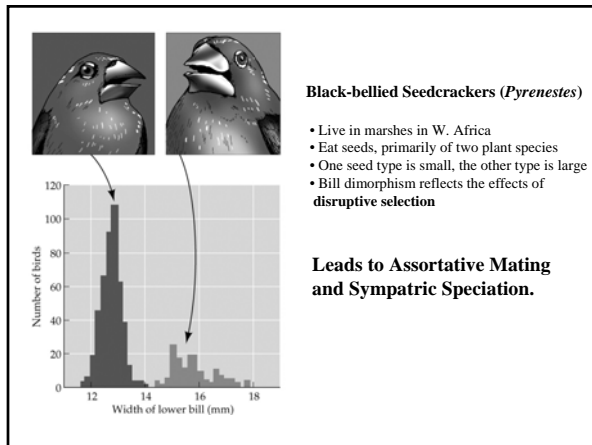
Level of prezygotic isolation between allopatric and sympatric pairs of *Drosophila* populations

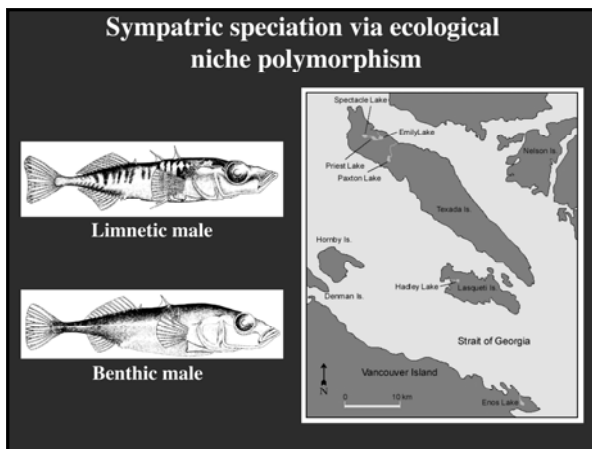


Sympatric speciation via hybridization

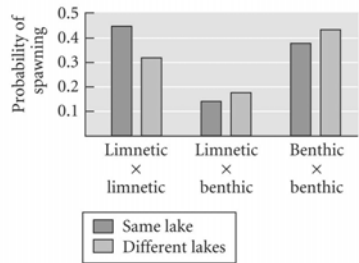




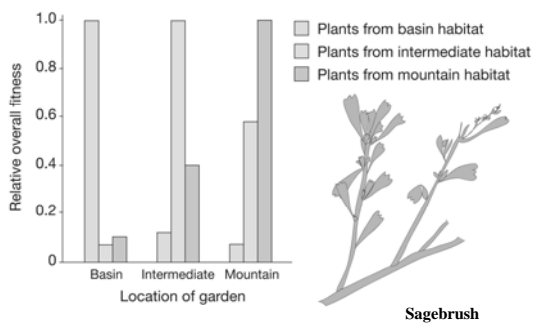




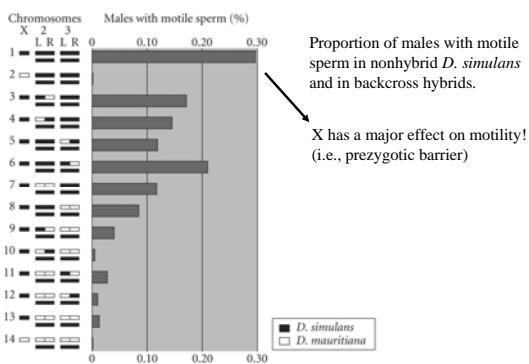
Sympatric speciation in the three-spined stickleback

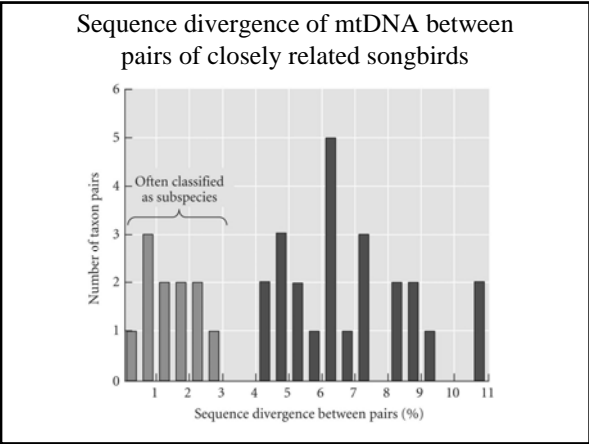


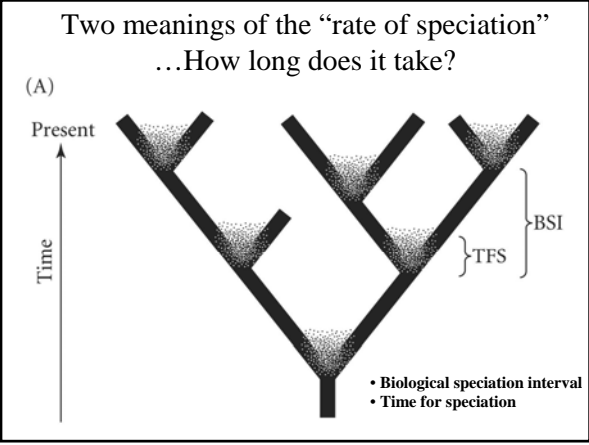
Hybridization – fitness of hybrids determines hybrid zone and eventual outcome.

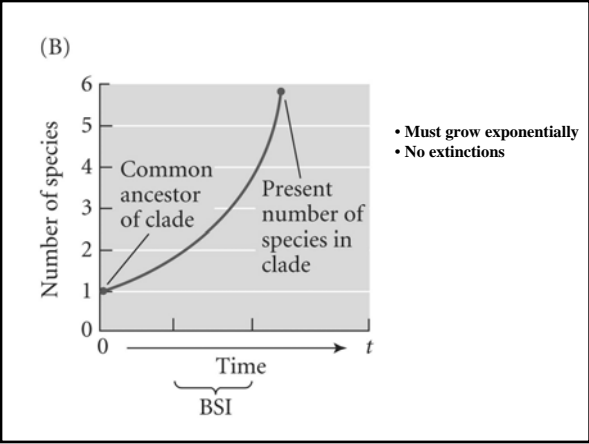


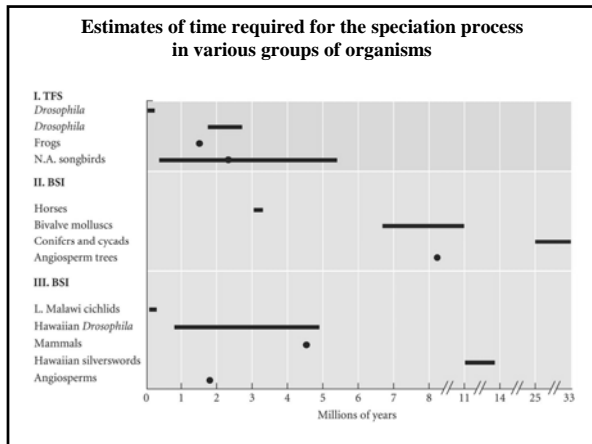
How many genes are involved in speciation?











- ### Factors promoting rapid speciation
- Many species
 - Opportunities for geographic isolation
 - Limited mobility
 - Short generation time
 - Sexual selection
 - Ecological specialization

