Speciation

Introduction to Evolution and Scientific Inquiry

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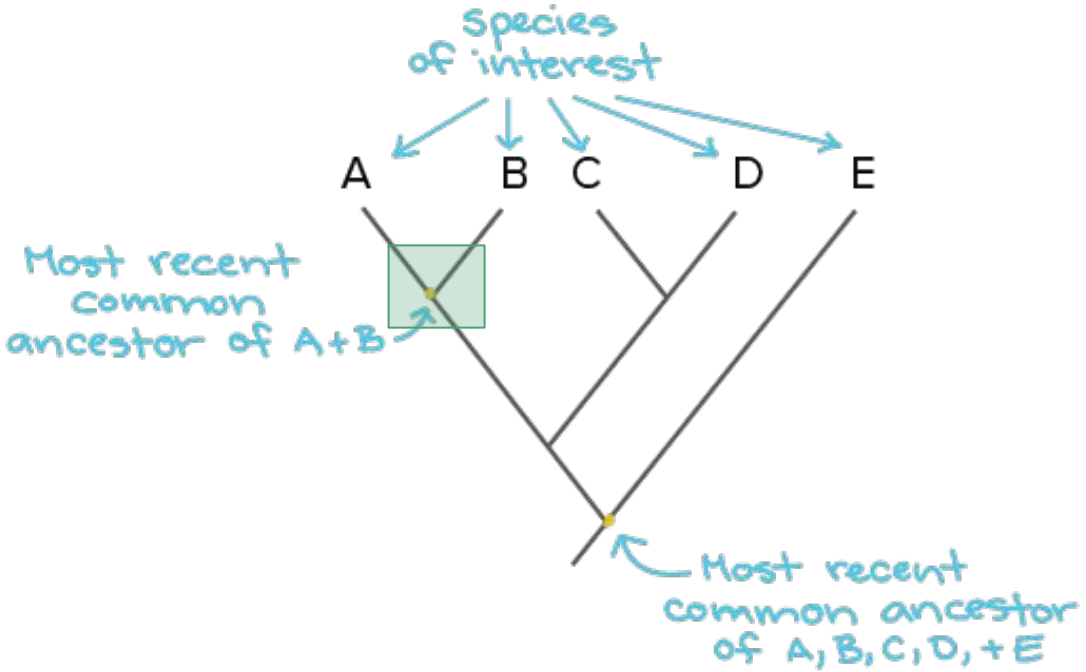
Speciation (process where 1 species → 2 species). is a long process



To study speciation, we must define "species"

- There are *many* definitions ("concepts") that have been proposed for species

1. Morphological Species Concept
2. Phylogenetic Species Concept
3. Ecological Species Concept
4. **Biological Species Concept (the main one we use)**
    5. Closely related to "reproductive species concept"

Morphological Species Concept

- **Defines species based on different morphologies (appearance)**
  - AKA "typological species concept"

- Commonly used in museum collections which have single species specimen, and similarly fossil data

- But it has **major problems**:
  - Sexual dimorphism misleads
  - Sometimes there are geographic variants
  - Morphologically different life stages

MSC tends to **oversplit** or **undersplit** species

"Cryptic Species"

Phylogenetic Species Concept

- **Defines species as closely-related monophyletic groups on phylogenies**

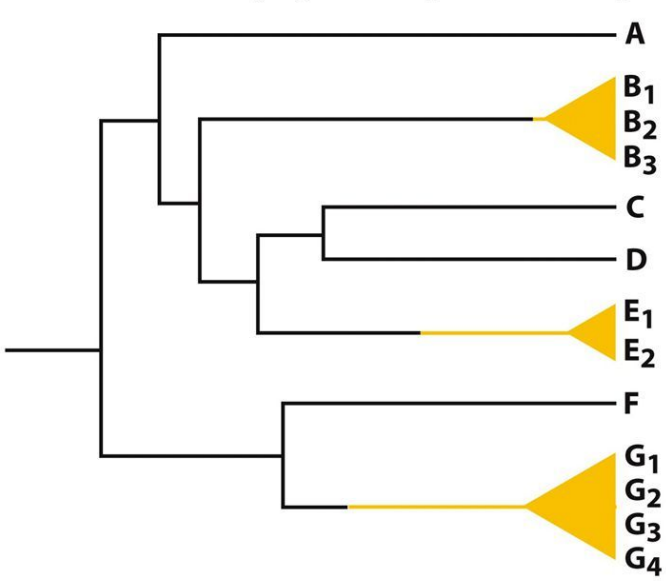


Figure 16-1 Evolutionary Analysis, 4/e
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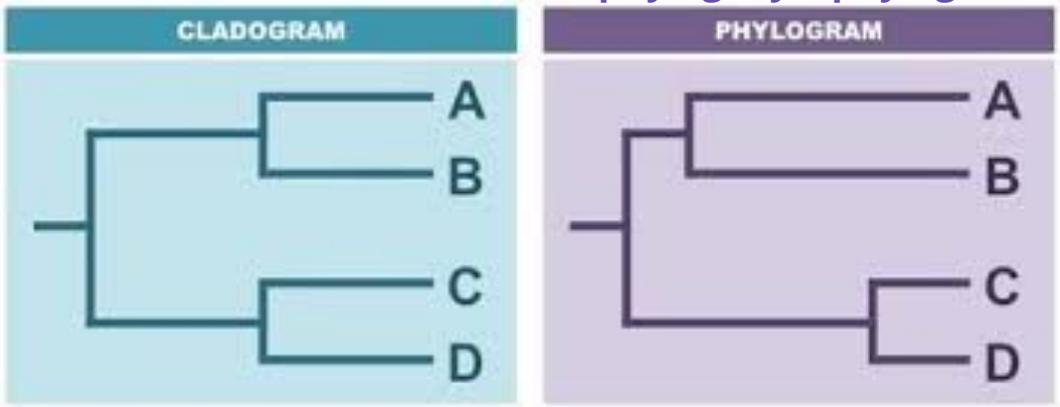
Recall: Branch lengths indicate genetic distance

(phylogeny = phylogram)



From the PHYLOGENY, we know that C/D are genetically more similar to each other than are A/B

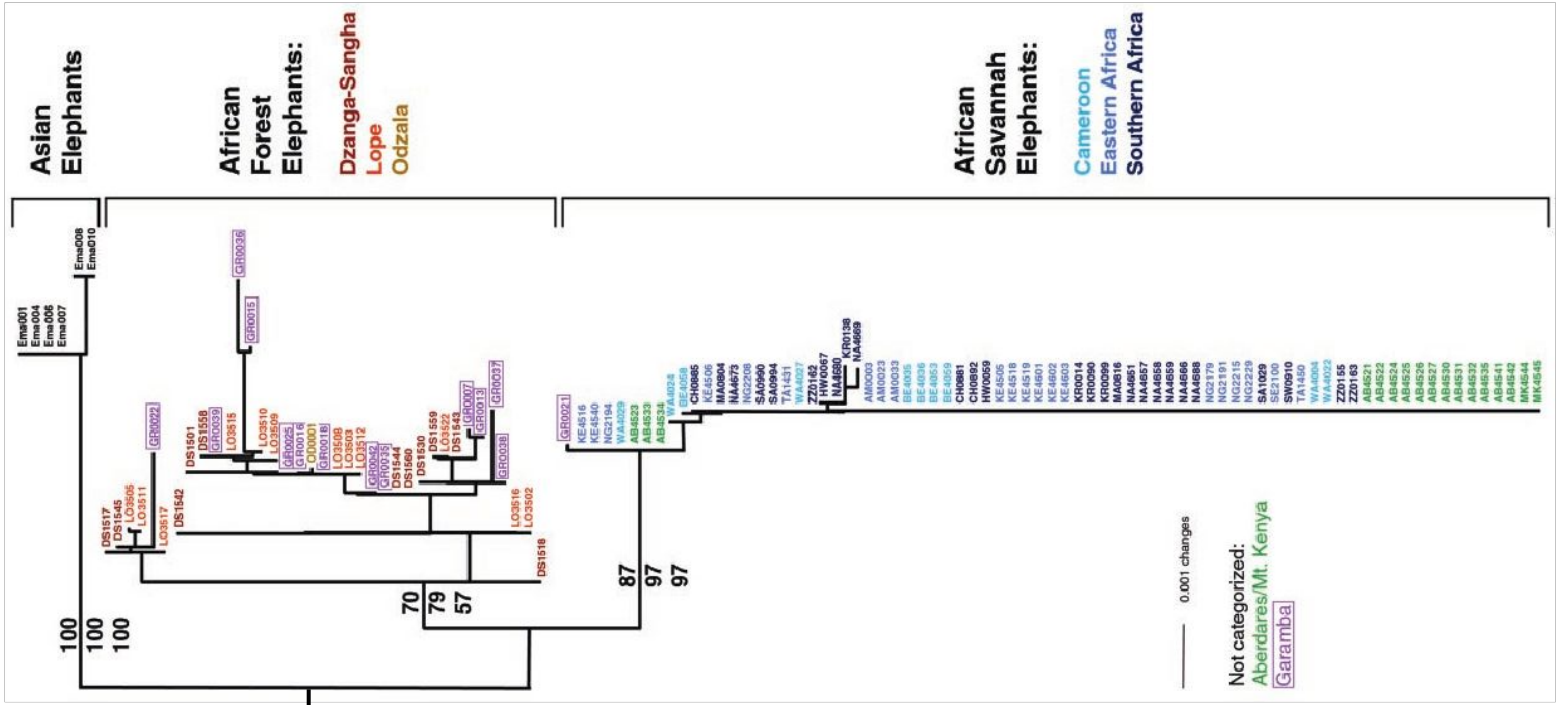
Do you expect large or small genetic distance among individuals?

WITHIN a species?

BETWEEN two species?

Example of applying phylogenetic species concept

Got DNA sequences from MANY elephants. Asked: Are elephants in different geographic regions different species?



Ecological Species Concept

- **Defines species based occupying the same niche (adapted to same <u>ecological resources)</u>**

Hawaiian Honeycreepers

Biological Species Concept (BSC) (this one!!!!!)

Most commonly, researchers use this species concept to *delimit* species

"Species are groups of actually or potentially **interbreeding** populations which are **reproductively isolated** from other such groups." - Ernst Mayr (1942)

Formal definition: Two organisms are the same species if they successfully mate AND produce fertile offspring

Under BSC definition, one species becomes two when....

- A barrier to mating forms
  - Leads to **reproductive isolation**

- Populations start to evolve separately as independent **lineages**
  - Gain separate mutations
  - Experience different selection pressures, differences in strength of genetic drift ➜ different alleles go to fixation

- Over enough time, genetic differences accumulate and species are unable to mate entirely

Isolation mechanisms (barriers) prevent gene exchange

Over time, populations that **stop exchanging genes** will **diverge** and **accumulate differences.**

If these differences **prevent successful mating**, speciation has occurred.

➜ **Reproductive isolation is a barrier to gene flow.**

Pop quiz!! Is speciation the goal of successful evolution?

Types of isolation mechanisms/barriers to mating

- **Prezygotic barriers**
  - Prevent zygote from being formed in the first place

- **Postzygotic barriers**
  - Prevent a formed zygote from being viable

- Reminder: zygote = sperm + egg fused into a single cell

Types of prezygotic barriers

- Barriers which prevent mating in the first place
  - Temporal isolation: different times of emergence
  - Ecological isolation: live in different habitats
  - Behavioral isolation: Divergence of mating behaviors (bird songs, frog chirps)

- Barriers which prevent a successful mating (even if attempted)
  - Mechanical isolation: morphological incompatibility ("parts don't fit")

Example of temporal reproductive isolation

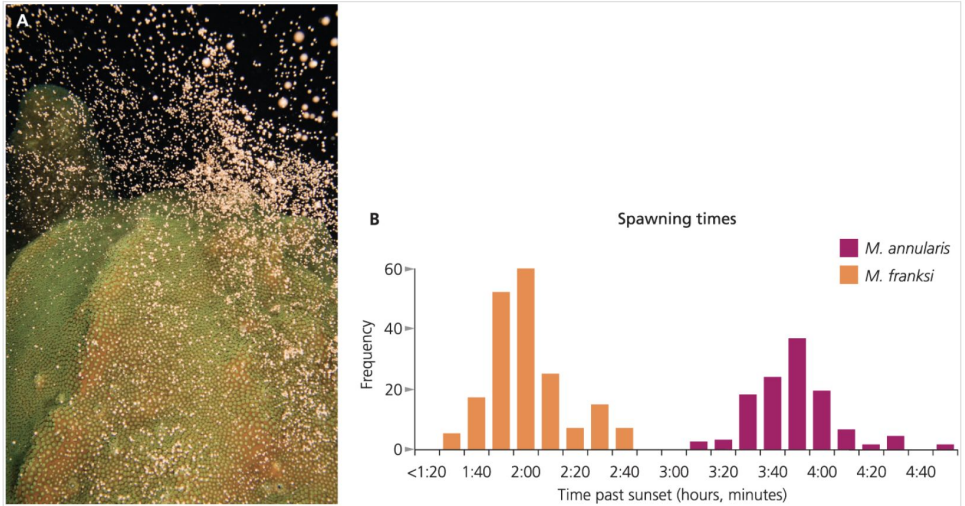


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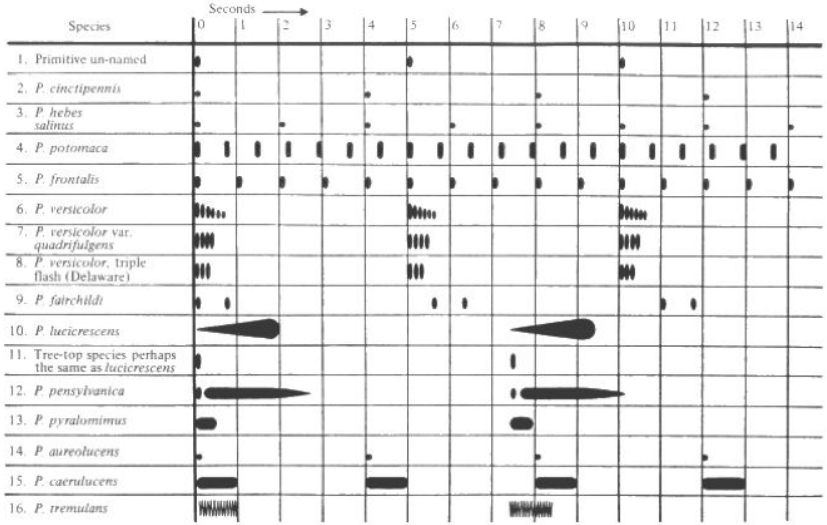
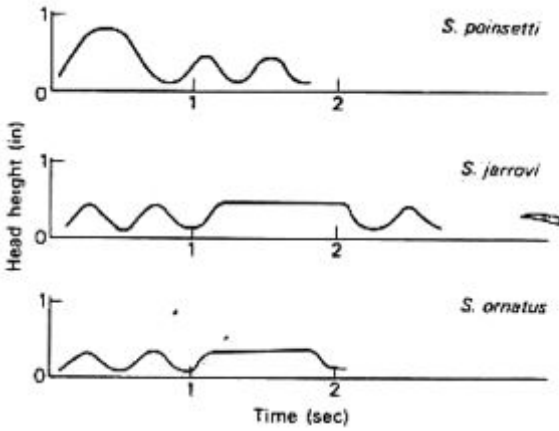
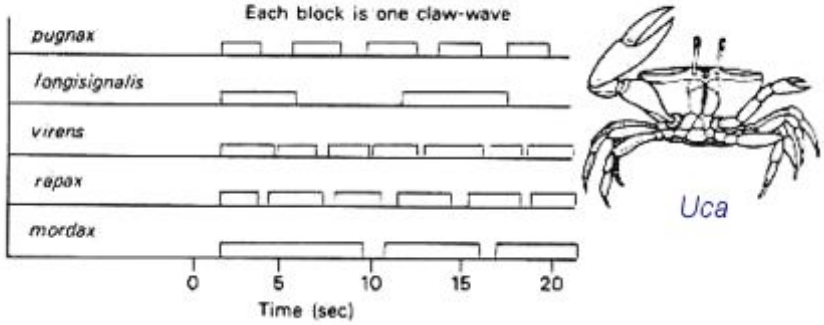
Figure 13.4 A: Corals reproduce by releasing gametes into the water. B: This graph shows how two species of *Montastraea* corals remain reproductively isolated: by spawning at different times after sunset. (Data from Levitan et al. 2004)

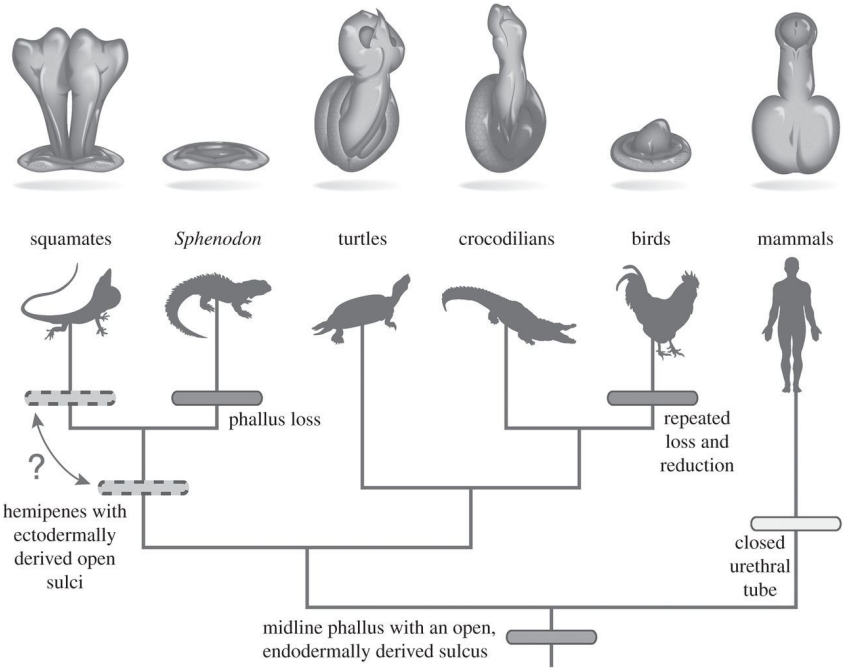
Examples of behavioral isolation (strongly related to female preference!!)





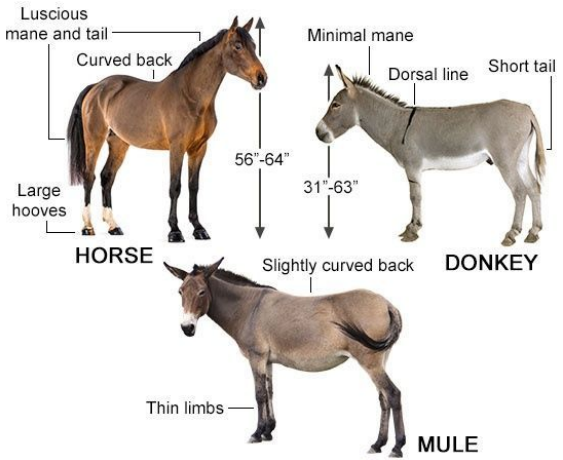


Example of mechanistic reproductive isolation



Types of postzygotic barriers

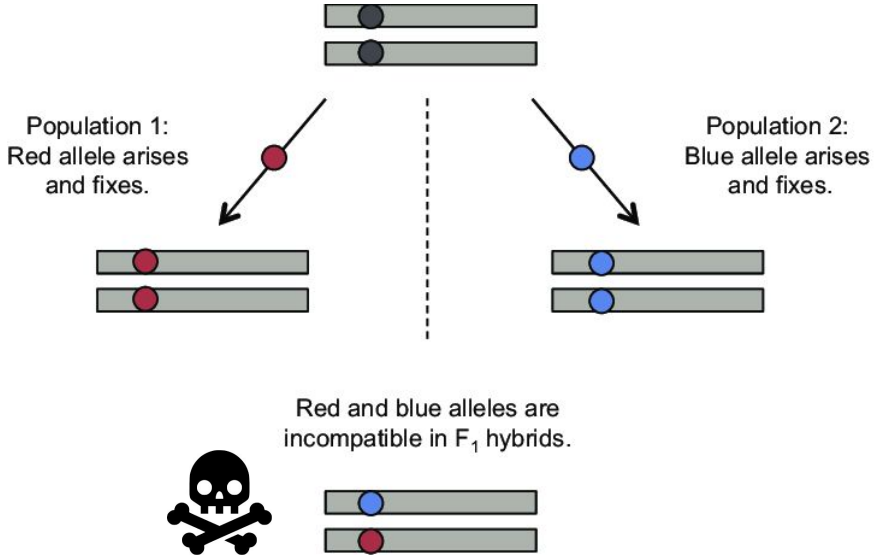
- Gametic mortality
  - sperm transferred but does not fertilize eggs
- Zygotic mortality
  - egg is fertilized but zygote dies



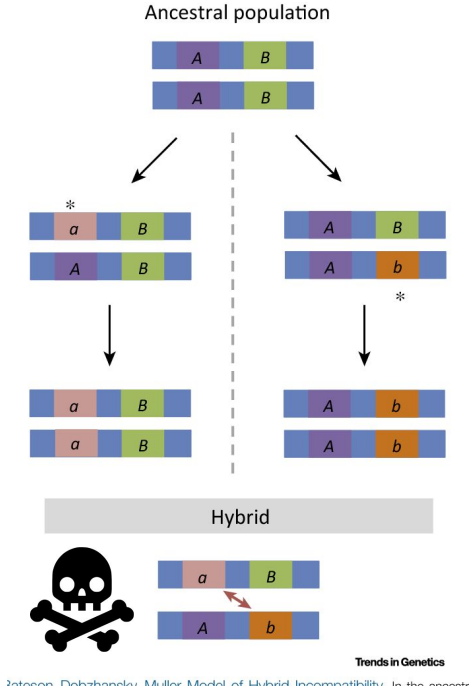
- Hybrid inviability
  - Hybrid offspring does not properly develop, dies very young if born at all
- Hybrid sterility
  - Hybrid is fine, lives to adulthood and is healthy, *but cannot reproduce*

The genetic basis of postzygotic barriers: Hybrid inviability via **epistatis**

Example: Single gene locus
New population alleles produce LOW FITNESS hybrids



Example: Two gene loci interact (epistasis!)
New population alleles when combined produce LOW FITNESS hybrids



Genetic distance and reproductive isolation

- Genetic distance example:
  - `Species 1:` **ACGTAAGGCC**
  - `Species 2:` **ACCTACGGCA**
  - `3/10 differ =` **`0.3 genetic distance`**
- Also called **P-distance**
  - Proportion of differences

- Genetic distance can be is > 1 when **more than 1 mutation** occurs at each DNA position

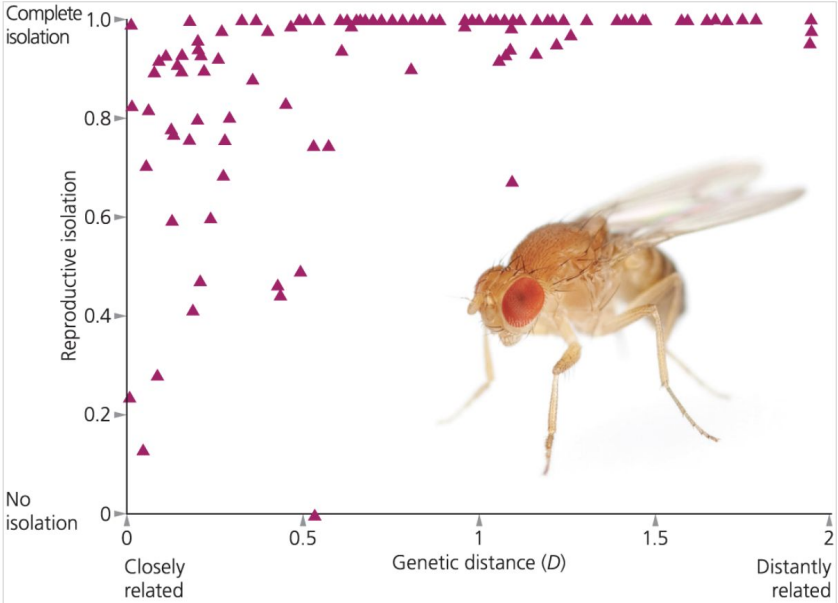


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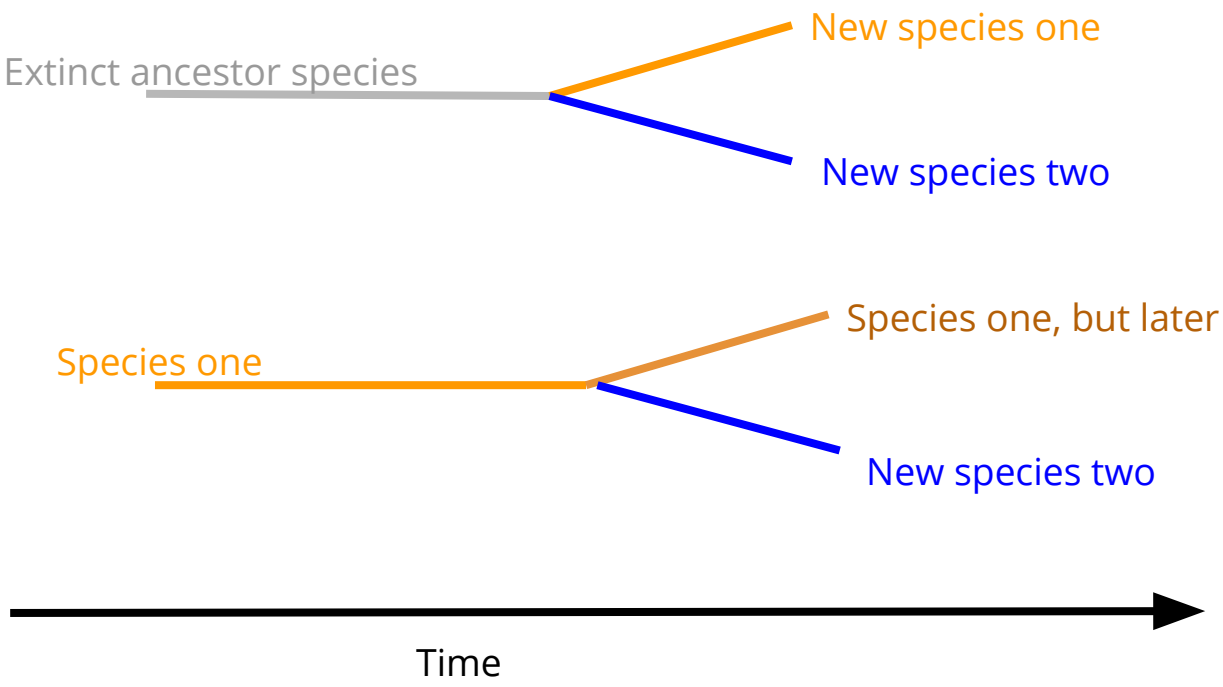
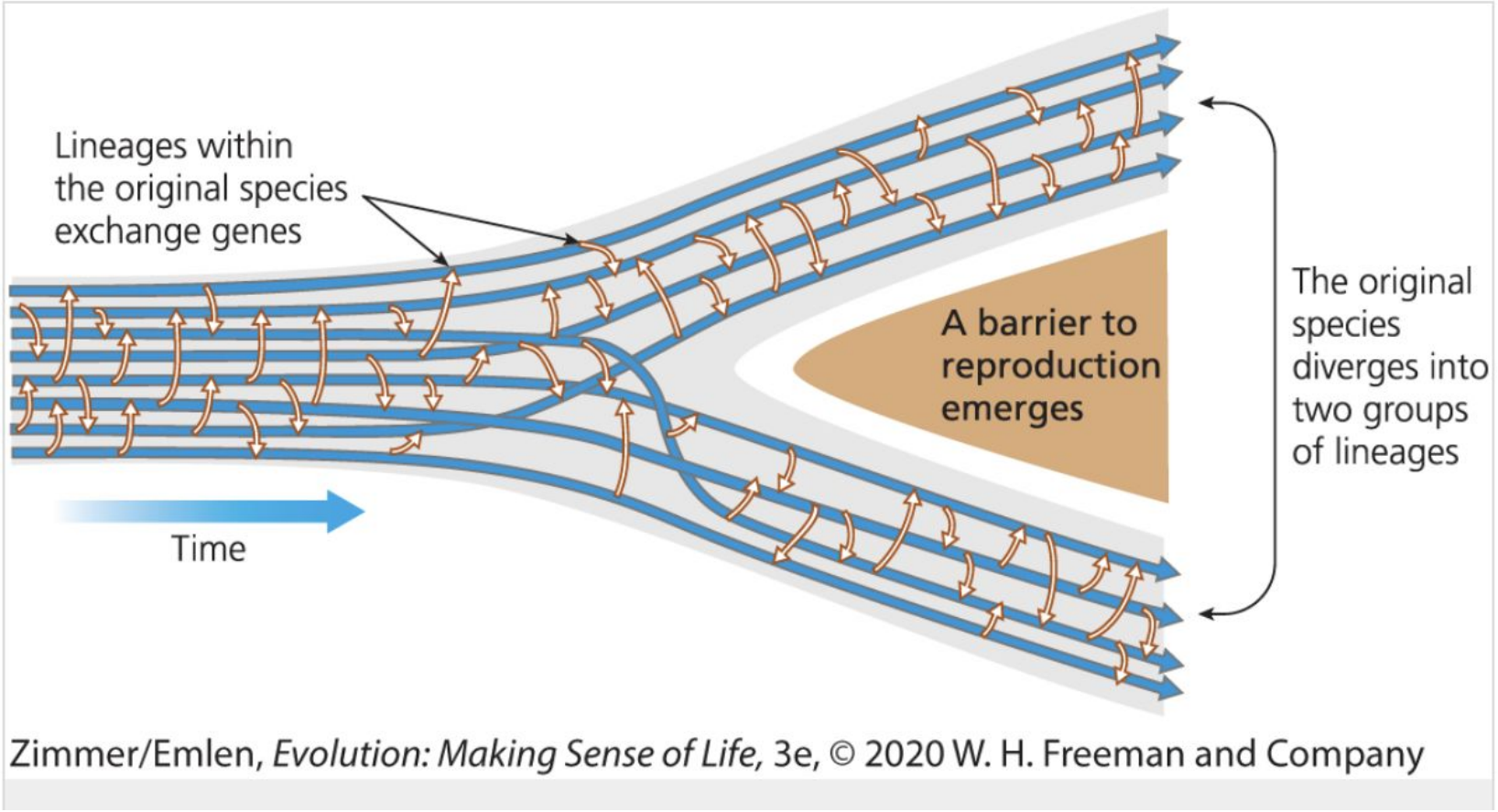
Figure 13.14 This graph shows how reproductive isolation evolved among species of *Drosophila*. The genetic distance (D) between two species increases with time. It takes roughly a million years for D to reach a value of 1. By then, a typical pair of *Drosophila* species no longer interbreeds. (Data from Coyne and Orr 2004)

Speciation occurs via cladogenesis or anagenesis



Lineage ~ population (interbreeding group of organisms of the same species)



Two main "models" of speciation (there are others)

- **Allopatric speciation**: Divergence occurs when populations live in **different areas**
  - allopatric = live in non-overlapping geographic areas

- **Sympatric speciation**: Divergence occurs when populations live in the **same, overlapping areas**
  - sympatic = live in the same geographic area

- Which is more common?

Allopatric speciation

A single species **diverges** over time due to geographic barriers.

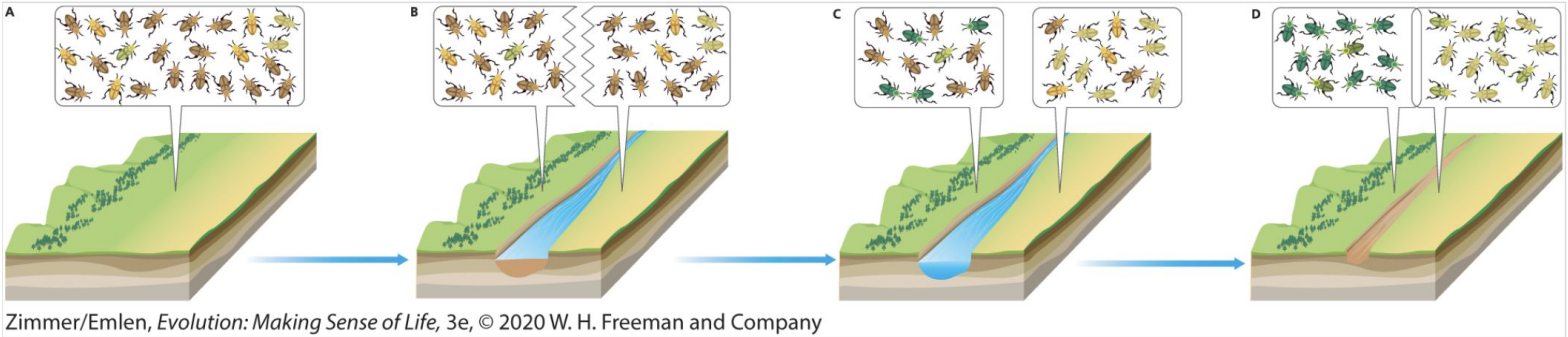


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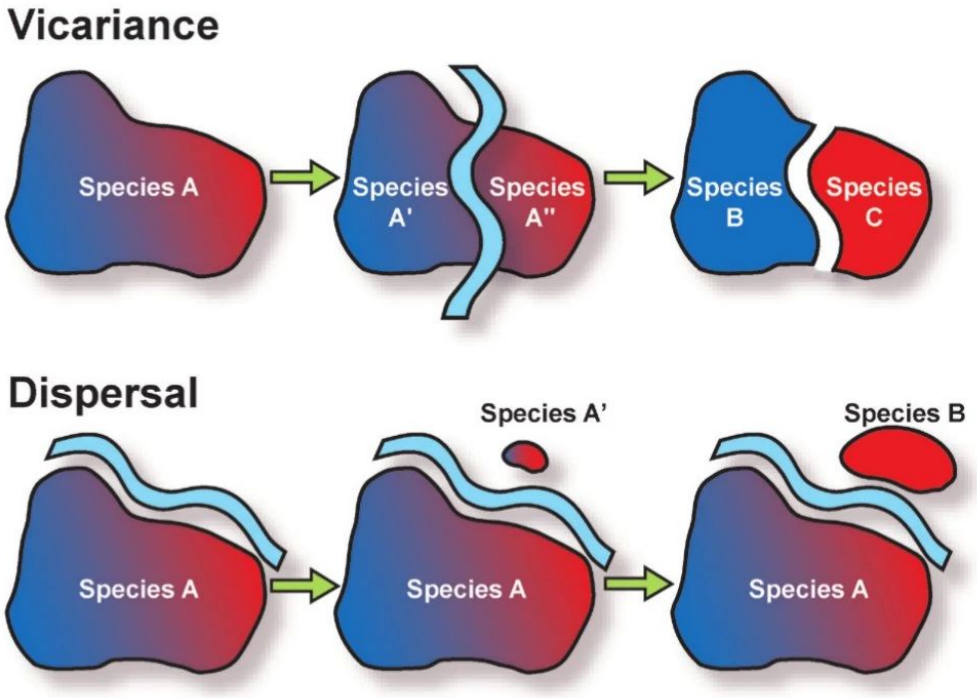
Figure 13.8 Allopatric speciation is the result of geographic isolation. A: Here, a population begins with a continuous geographic range. It contains genetic variation, but gene flow ensures that new mutations can spread across the range once they arise. B: A river divides the population into two subpopulations. C: The change of allele frequencies in the two subpopulations is no longer linked. They become increasingly divergent. D: The river later dries up, allowing the two subpopulations to make contact. During their separation, reproductive barriers may evolve, reducing the gene flow between the two subpopulations.

Allopatric speciation can occur via dispersal or vicariance

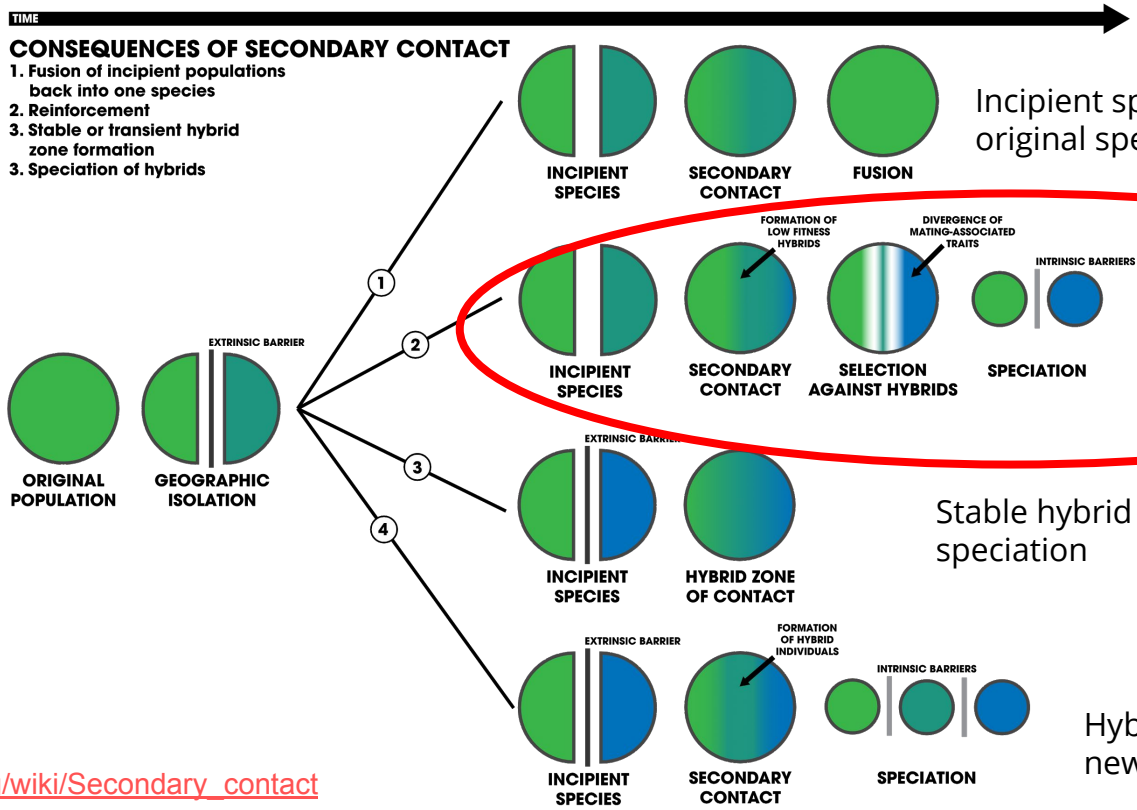


Geographic separation does not always lead to full speciation

- **Remember: Speciation is not a goal of evolution. Sometimes we observe it, sometimes we don't. Biology is very messy and rules usually have a million exception.**

- "Successful" allopatric speciation relies on incipient species remaining isolated if/when re-introduced
    - Incipient species = two populations in the process of diverging into two species
- Re-introduction is called **secondary contact**
- AKA: Speciation is "solidified" when it turns out they really don't mate anymore, when given the new opportunity.

Upon secondary contact, incipient species could...



Incipient species merge back up into original species ("reticulation")

Successful speciation!

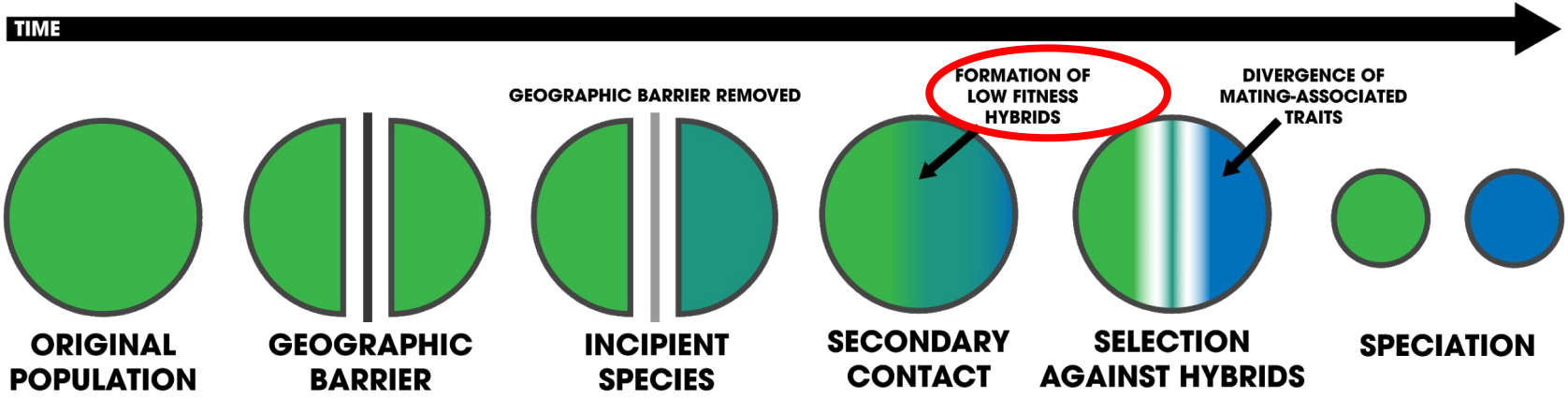
Stable hybrid zone - not "full" speciation

Hybrids themselves lead to **three** new species

https://en.wikipedia.org/wiki/Secondary_contact

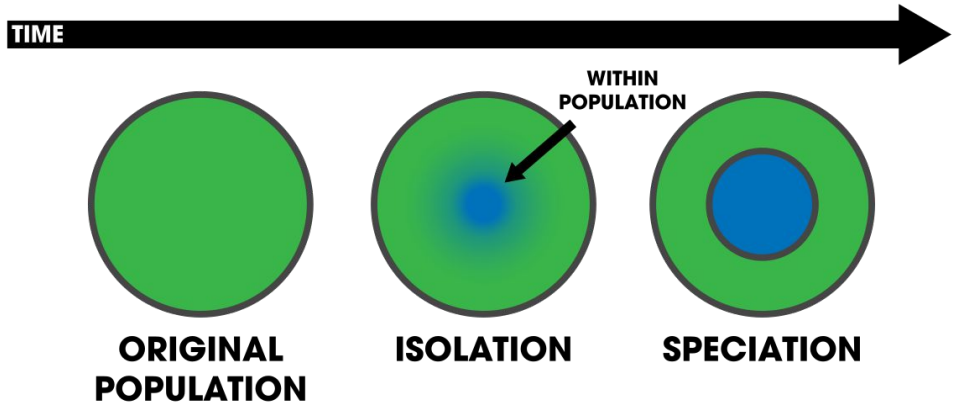
Secondary contact can reinforce speciation

- Low fitness hybrids means incipient species will not merge back up
- This is analogous to disruptive selection:
  - Hybrids have lowest fitness ("heterozygotes" analogy)
  - Incipient species individuals have high fitness ("homozygotes" analogy)



Sympatric speciation

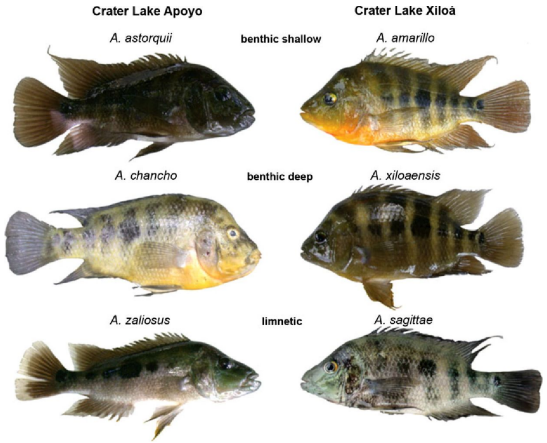
Speciation WITHOUT a geographic barrier

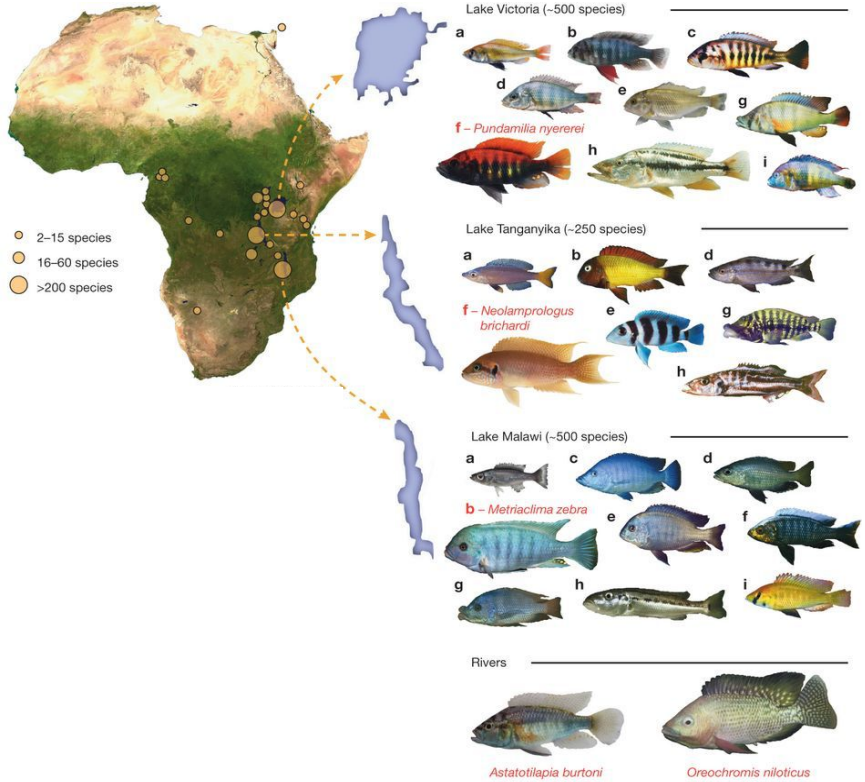


QUESTION: Do you expect isolation mechanisms to be stronger in allopatric or sympatric speciation?

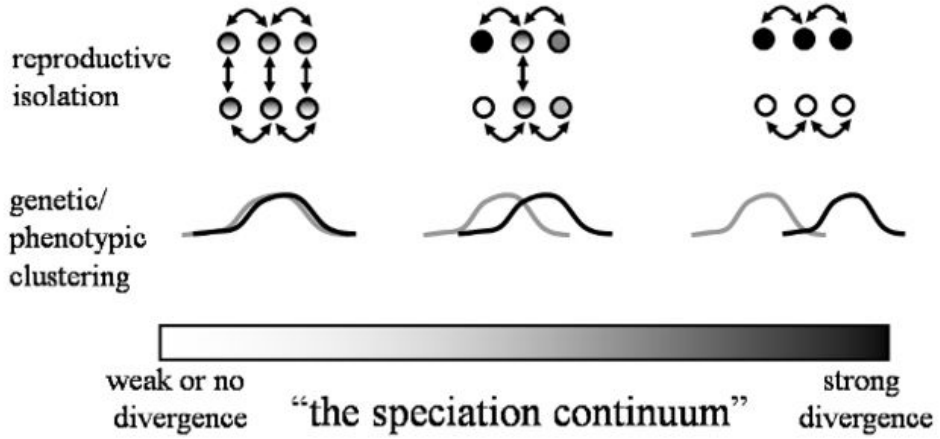
Sympatric speciation is very rarely observed

- One clear example is speciation in **cichlid fish**





Species and speciation as a continuum



arrows point to mates

divergence = genetic change