

# Part - IV SPECIES CONCEPTS & SPECIATION

BIO 111 Biological Diversity and Evolution  
Varsha 2017

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Acknowledgments: Some content adapted from slides by Dhanashree Paranjpe, Neil Buckley and others

# What is a species?

"... I was much struck how entirely vague and arbitrary is the distinction between species and varieties" Darwin 1859.

Exactly what a species is has been debated for a long time, and to this day there is no agreement among biologists

Many different *Species Concepts*. *E.g.*

*Typological Species Concept, Biological Species Concept, Phylogenetic Species Concept, etc*

# Typological Species Concept (Carl Linnaeus)

**'a species is a group of individuals differing from other groups by the possession of constant diagnostic characters'**

each species is thought to have certain characters that are fixed, i.e. do not change over time or across individuals of the same species

# Typological Species Concepts

conceptualized before evolution was accepted

based on descriptions of a “type” specimens for a given species

TSC - ignored one of the main principles of evolution:  
*Variation*

Variation within populations

Ladybugs (Coccinellidae)



*Claytonia virginica*

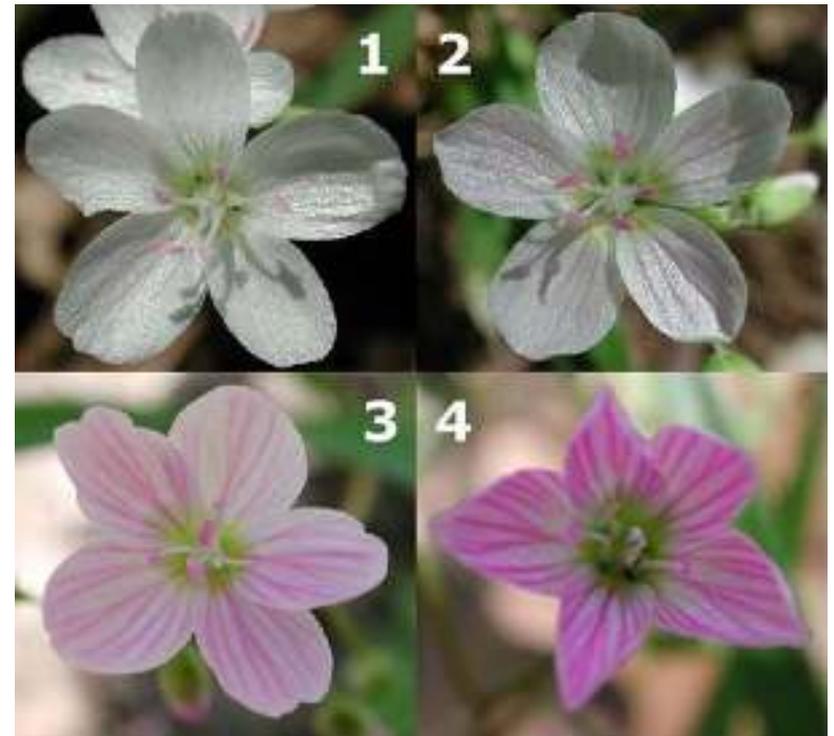


Image: Jaroslav Vanek/readingevolution.com

Frey 2004 Evolution 58:2426-2437

Geographic variation among populations  
- often regarded as 'subspecies'

*Tiger?*

TSC cannot distinguish cryptic or sibling species

**Sibling** or **Cryptic** species are two or more species that are almost identical in appearance, but are still reproductively isolated

# Biological Species Concept

First conceptualised by John Ray (17<sup>th</sup> C), who defined species as **'consisting of all individuals that can breed together and produce fertile offspring'**

- John Ray (17<sup>th</sup> Century)

Ernst Mayr (1940) updated this to the currently popular BSC. He defined species as

**“Species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups.”**

# BSC

Another definition by Dobzhansky: **“Species are the largest and most inclusive reproductive community of sexual and cross-fertilizing individuals that share a common gene pool.”**

A female donkey mated to a male horse produces.....



Adapted from slides by Neil Buckley

... a mule (which is sterile)  
Hence, donkeys and horses  
are separate species.



Adapted from slides by Neil Buckley

# Liger



Photo: [www.respeitoanatureza.blogspot.in](http://www.respeitoanatureza.blogspot.in)

Widely used in practice, although there are several problems.

## 1. Not applicable to asexual species

Prokaryotes

*Amoeba* & some other protists

Some animals, plants & fungi

2. The degree of reproductive isolation can vary between species pairs. Fertile hybrids of two species are not rare in some groups - waterfowl, terrestrial plants, freshwater fishes.

- Remember, in *sibling species* pairs, fertile hybrids may never be produced, but the species look the same. However, here we are dealing with species pairs that may be morphologically very distinct, but can hybridize occasionally

3. Not easy to assess potential to interbreed, especially in the case of geographically isolated populations

# Phylogenetic Species Concept

Joel Cracraft (1983)

“the smallest diagnosable **monophyletic** group of populations within which there is a parental pattern of ancestry and descent.”

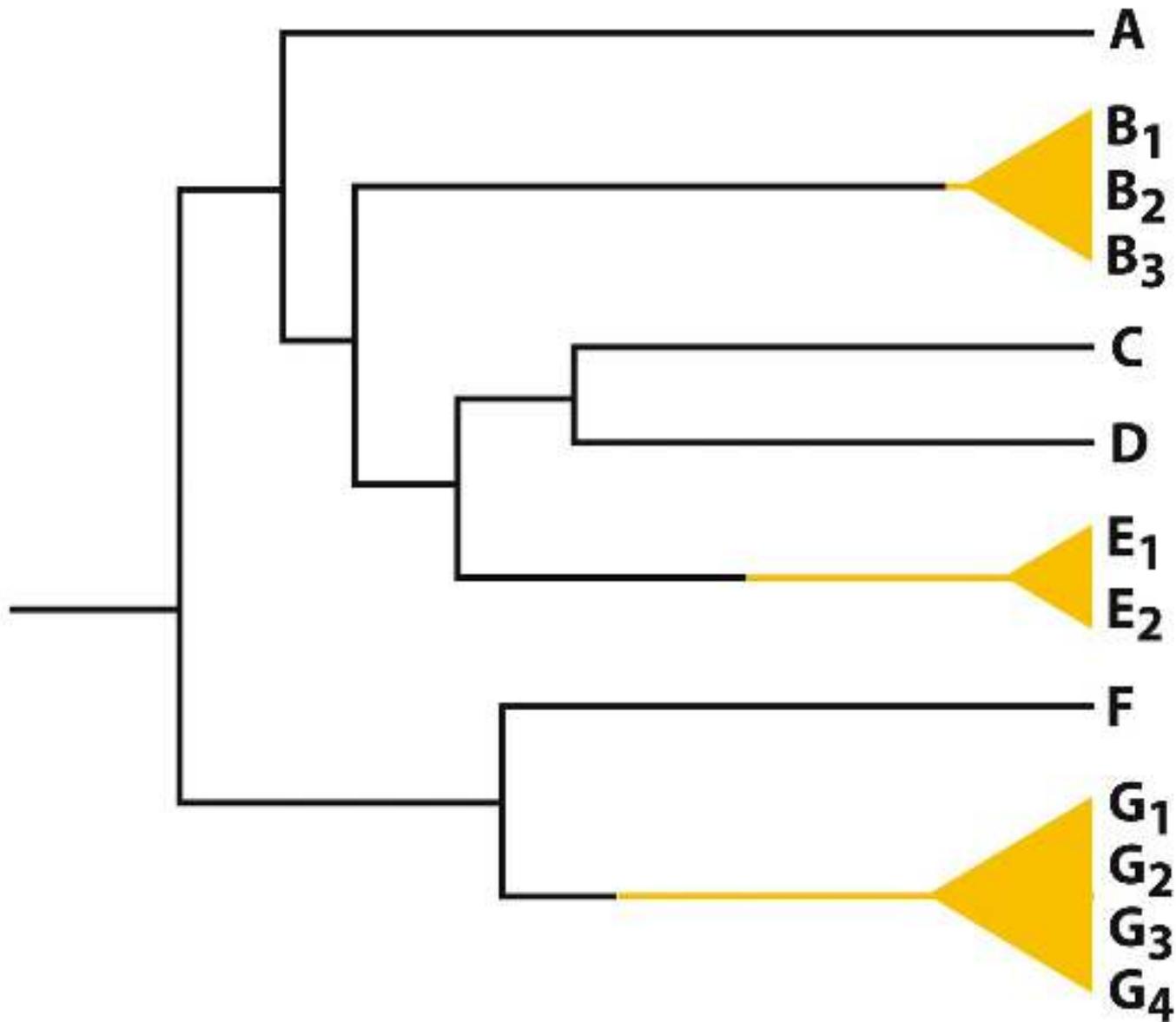


Figure 16-1 Evolutionary Analysis, 4/e  
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Source: Pearson Prentice Hall Inc.

Explicitly uses monophyly as a criterion to define species

- PSC emphasizes common ancestry. Adds an evolutionary dimension to BSC by emphasizing common descent
- Applies to both sexually and asexually reproducing species.

# Problems

1. What characters to use ?
2. What level of divergence constitutes a species?

- Many other concepts
- In practice, there is no single concept that works for all groups and all situations.
- BSC has become the most popular *operational* concept.

- If two populations regularly hybridize to produce fertile offspring, then it is unlikely that they are morphologically or phylogenetically distinct. Therefore, they are almost always considered a single species in practice.
- Generally, the mechanisms for formation of different types of 'species' (ie species according to different concepts) are the same.

It is becoming increasingly common to use molecular data to detect sibling species and to corroborate status of a species – **DNA barcoding**. But, there are several problems with this.

# SPECIATION

- Process of formation of new species  
i.e. Multiplication of species
- Link between microevolution and macroevolution
- Evolution of reproductive isolation (lets assume BSC for now)
  - Prezygotic barriers
  - Postzygotic barriers

# Reproductive Isolation

## Prezygotic mechanisms:

**Temporal isolation:** Reproduce at different seasons or at different times of the day.

**Behavioral isolation:** Mating rituals, songs, mating calls

**Mechanical isolation**

**Geographical isolation**

## *Postzygotic Isolation*

### **Hybrid inviability**

Embryological arrest: Hybrid embryos often do not develop properly; no viable offspring is created.

### **Hybrid sterility**

Infertility: Hybrid offspring might grow to viable adults but these are infertile and cannot produce further offspring (Donkey + Horse = Mule; Mule is sterile).

# Reproductive Isolating Mechanisms

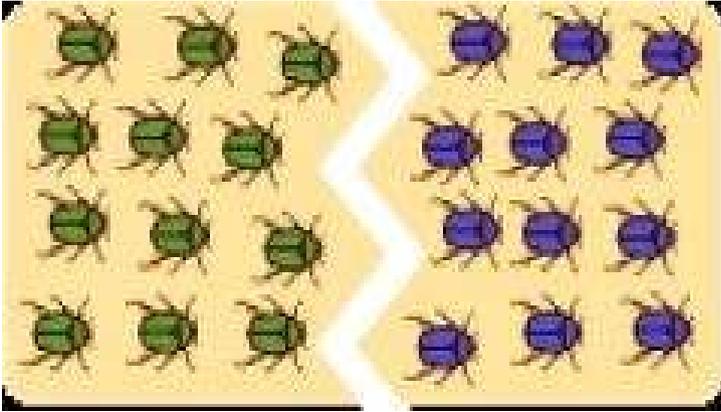
<b>Mechanism</b>	<b>How It Works</b>
<b>Prezygotic Barriers</b>	Prevent fertilization
Habitat isolation	Similar species reproduce in different habitats
Temporal isolation	Similar species reproduce at different times
Behavioral isolation	Similar species have distinctive courtship behaviors
Mechanical isolation	Similar species have structural differences in their reproductive organs
Gametic isolation	Gametes of similar species are chemically incompatible
<b>Postzygotic Barriers</b>	Reduce viability or fertility of hybrid
Hybrid inviability	Interspecific hybrid dies at early stage of embryonic development
Hybrid sterility	Interspecific hybrid survives to adulthood but is unable to reproduce successfully

Adapted from  
slide by Scott  
Bowling

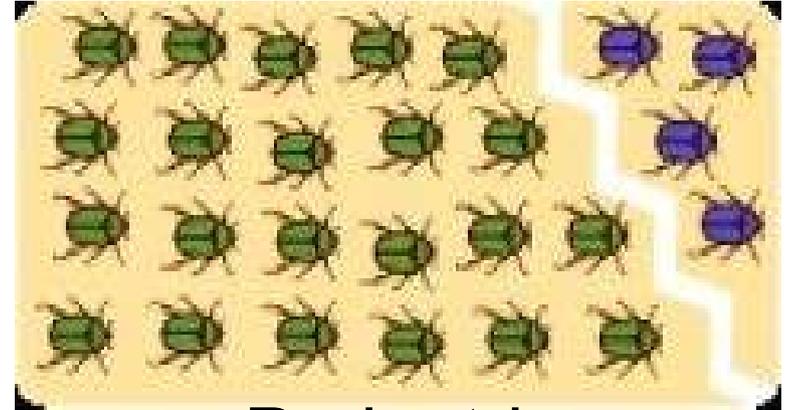
# Modes of Speciation

- based on degree of geographic isolation

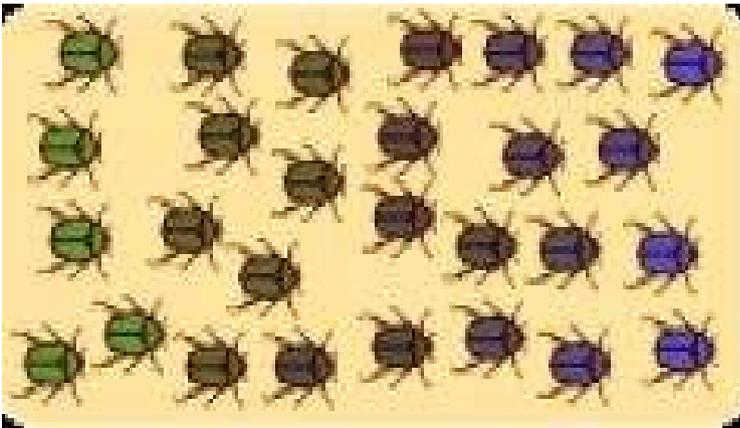
- Allopatric (No gene flow)
  - Peripatric (No gene flow)
- Parapatric (Very limited gene flow)
- Sympatric (Highest potential for gene flow)



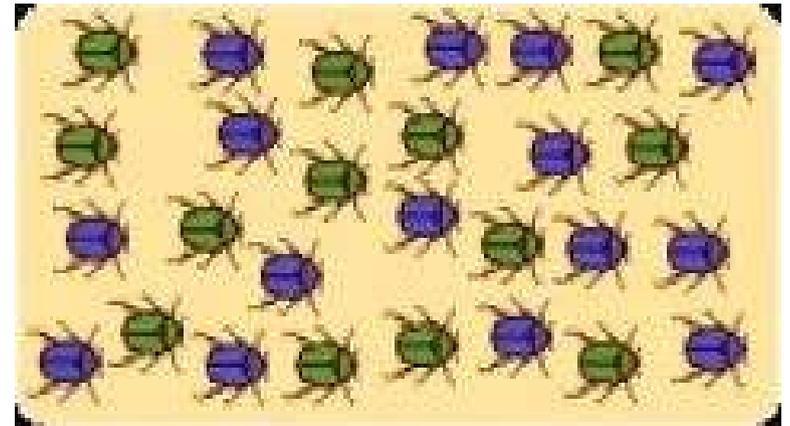
Allopatric



Peripatric



Parapatric



Sympatric

# Allopatric speciation

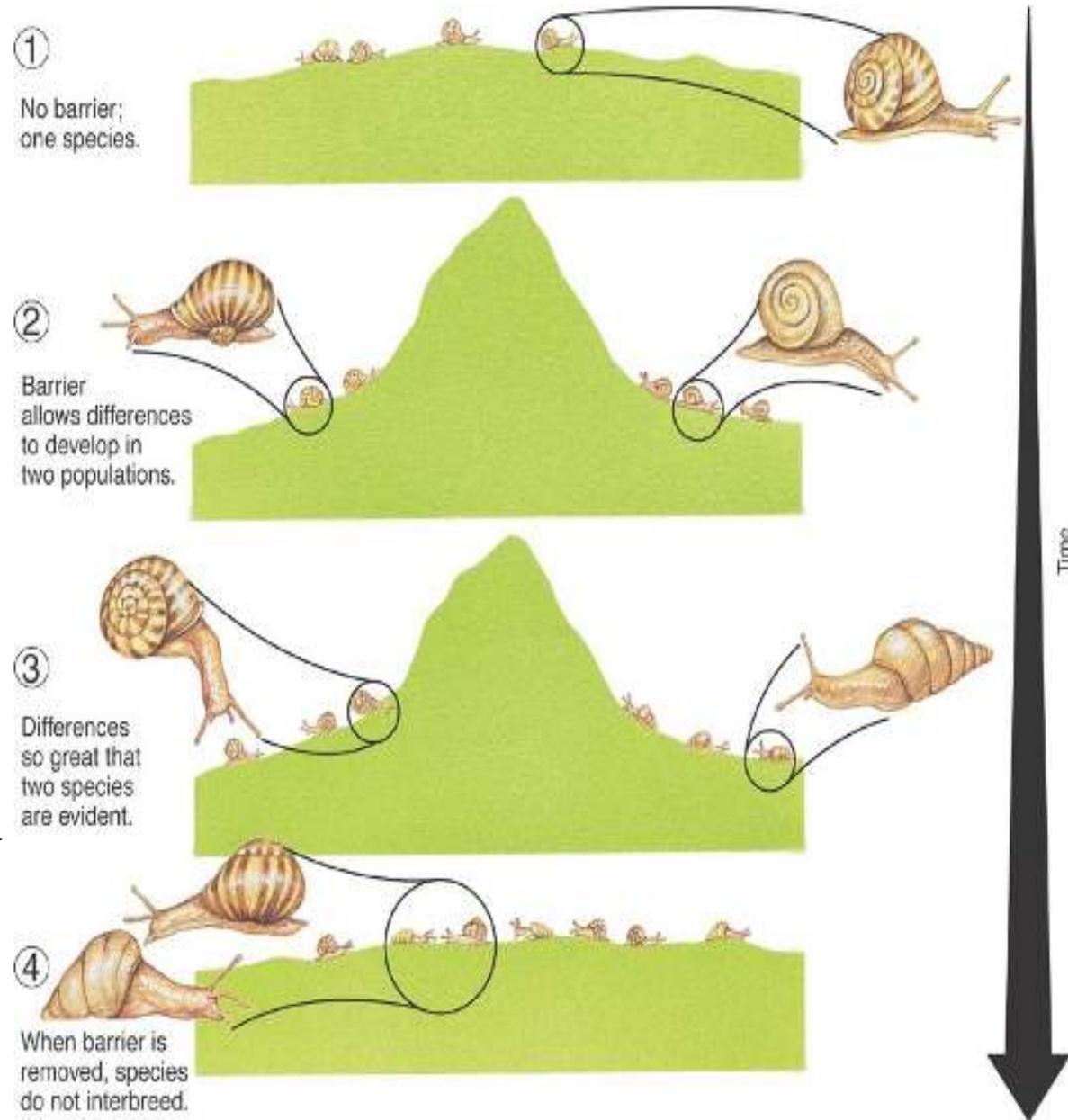
- Two populations are geographically isolated by physical barriers.
- Reproductive isolation occurs in complete geographic isolation (*no gene flow*)
  - Rivers & Oceans
  - Mountain ranges
  - Deserts
  - Land (in case of aquatic organisms)

1. A single species is an interbreeding reproductive community

2. A barrier develops dividing the species

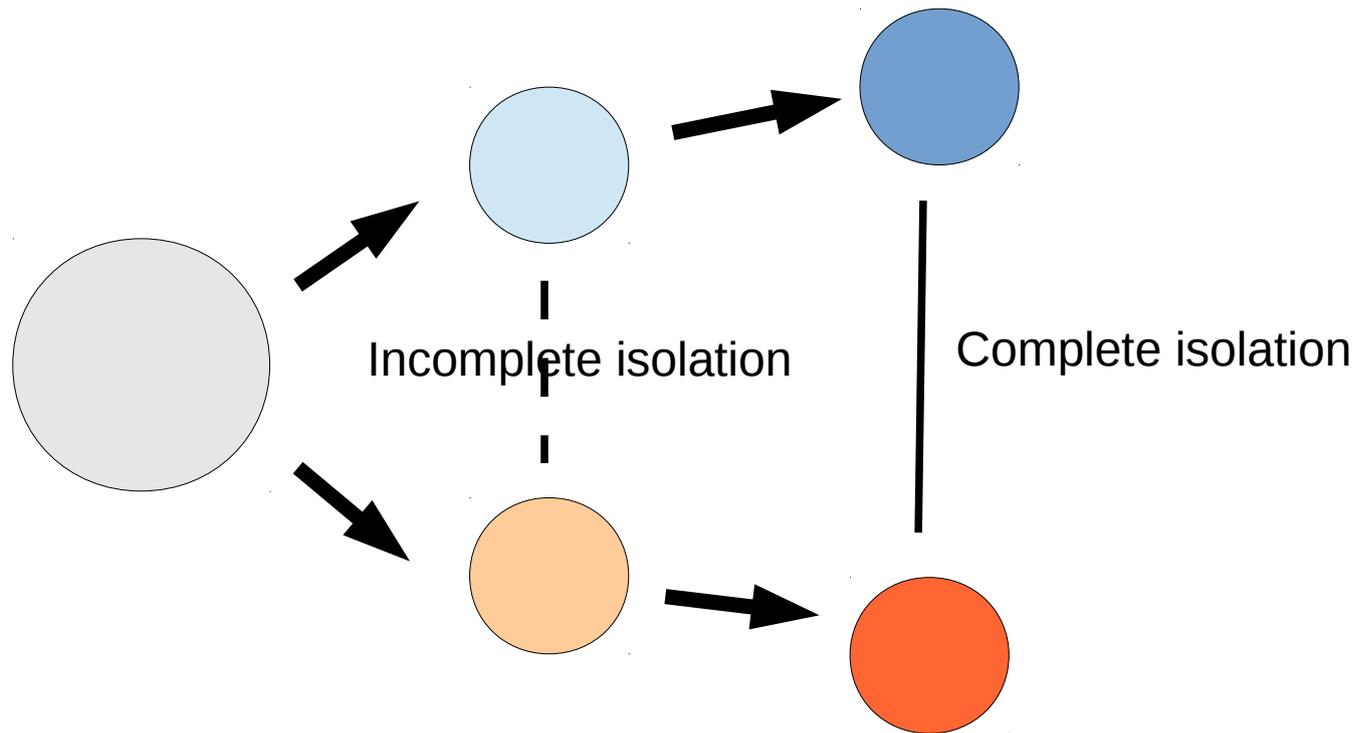
3. The divided populations diverge through the accumulation of gene and trait differences

4. The separate populations become so different that, if and when the barrier disappears and they overlap again, interbreeding does not occur



Adapted from slides by James F. Thompson

Intermediate stages of speciation, ie two groups of individuals with incomplete reproductive isolation, are sometimes called *Incipient Species*



# Dodd experiments

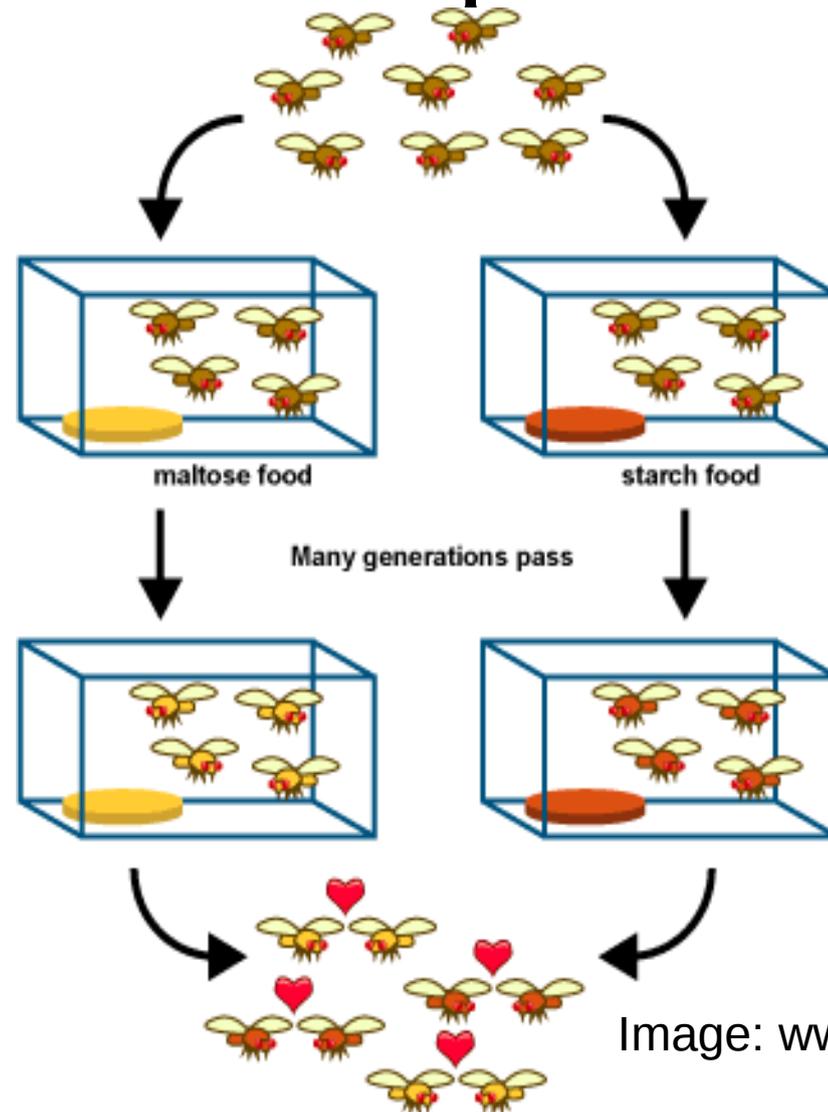
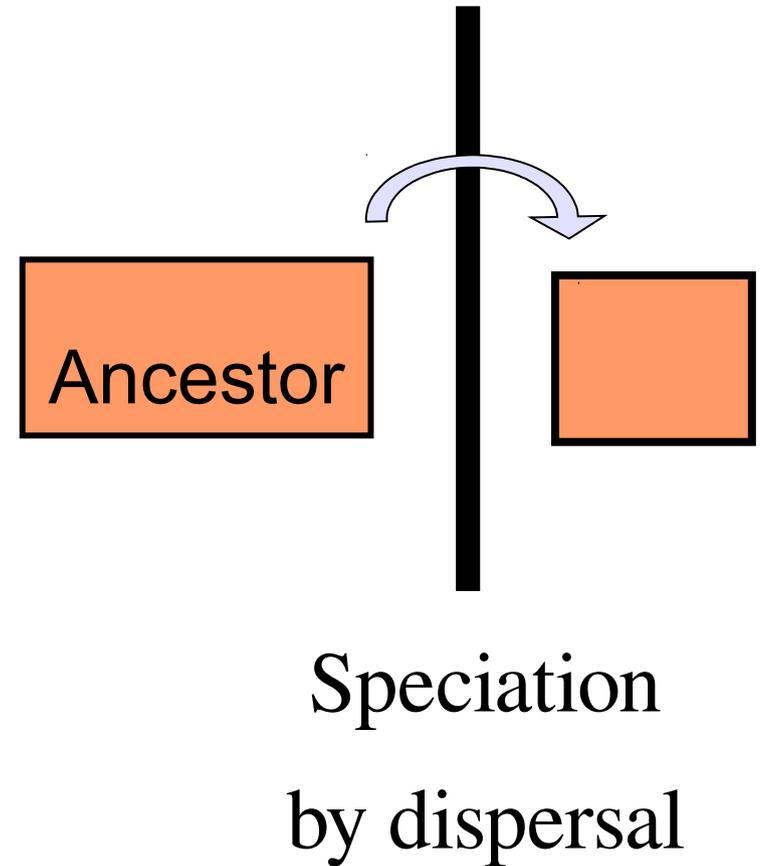
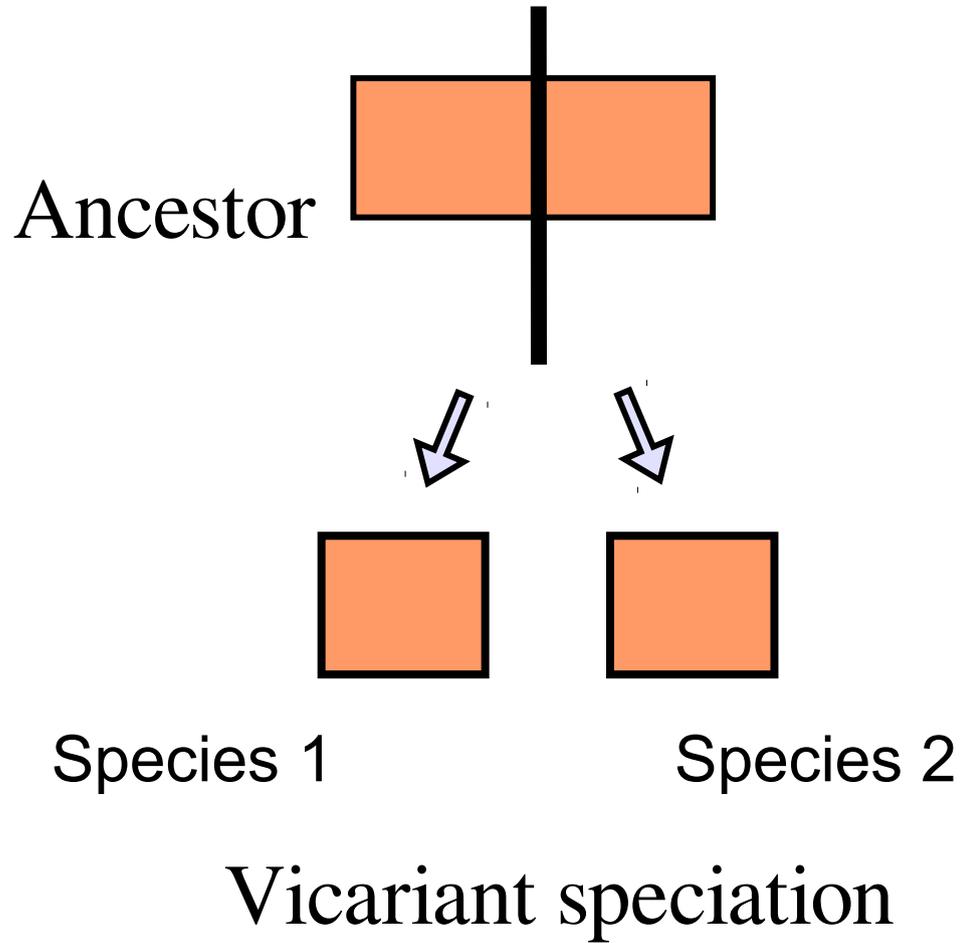


Image: [www.evolution.berkeley.edu](http://www.evolution.berkeley.edu)

Dodd, D.M.B. (1989) "Reproductive isolation as a consequence of adaptive divergence in *Drosophila pseudoobscura*." *Evolution* 43:1308–1311

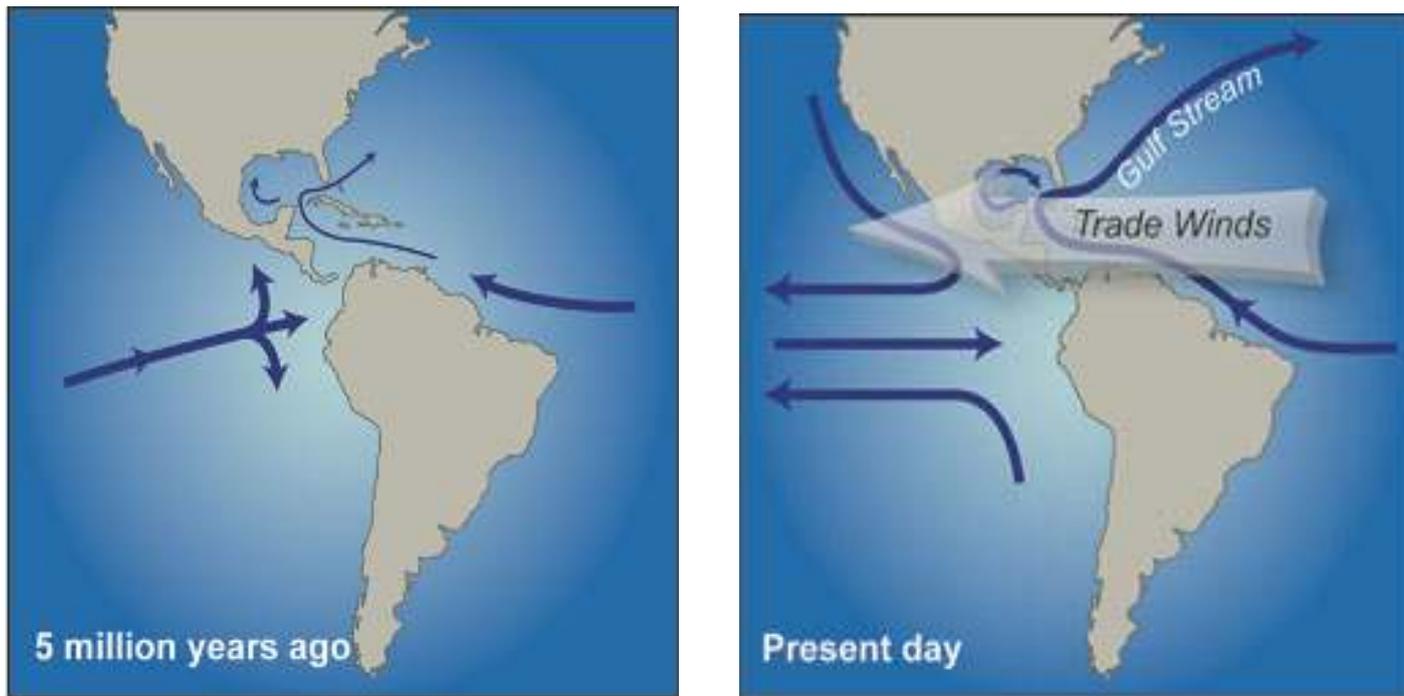
# Allopatric speciation by *Vicariance* and *Dispersal*



Colonization ***before*** v/s ***after***

South and North America isolated for a very long time

Reconnected 3 mya by the *Isthmus of Panama*, which resulted in vicariant speciation Eg. Snapping shrimps (*Alpheus*)



Images: Taken from slide by John McCall

*What patterns would you expect on a phylogeny?*



# Speciation by dispersal (island-hopping)

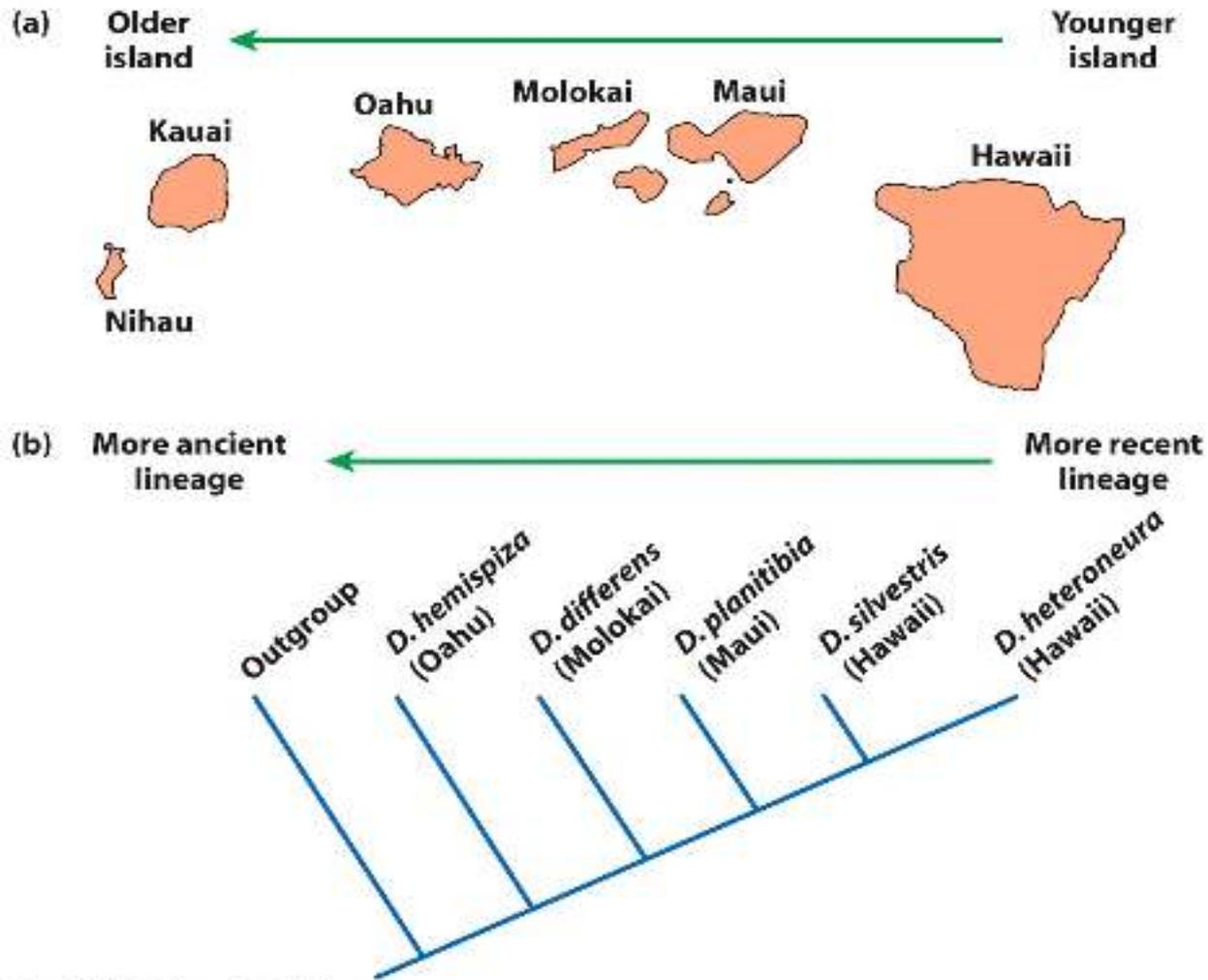


Figure 16.7 Evolutionary Analysis, 4/e  
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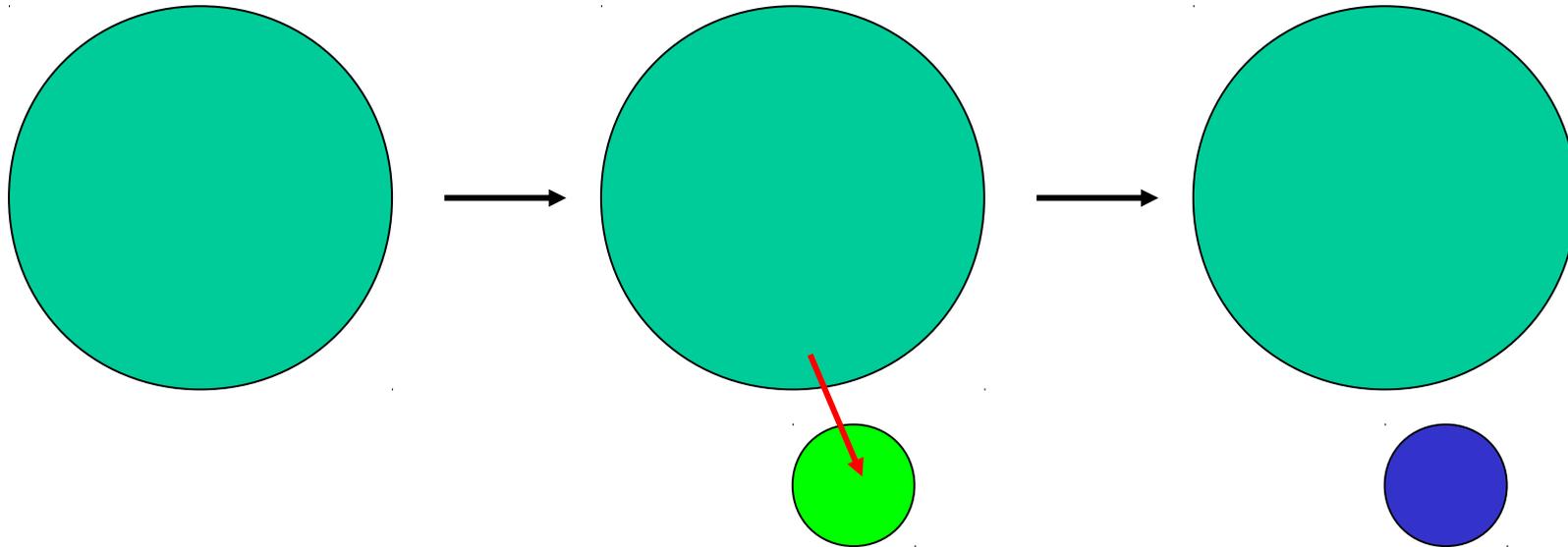
Adapted from slides by Dhanashree Pranjpe

# Peripatric speciation

- Similar to allopatric speciation (*no gene flow*)
- One of the isolated populations has very few individuals. Hence *Genetic Drift* plays a very important role. Eg colonization of an island from the mainland by very individuals

# MODEL OF PERIPATRIC SPECIATION

ANCESTRAL  
POPULATION

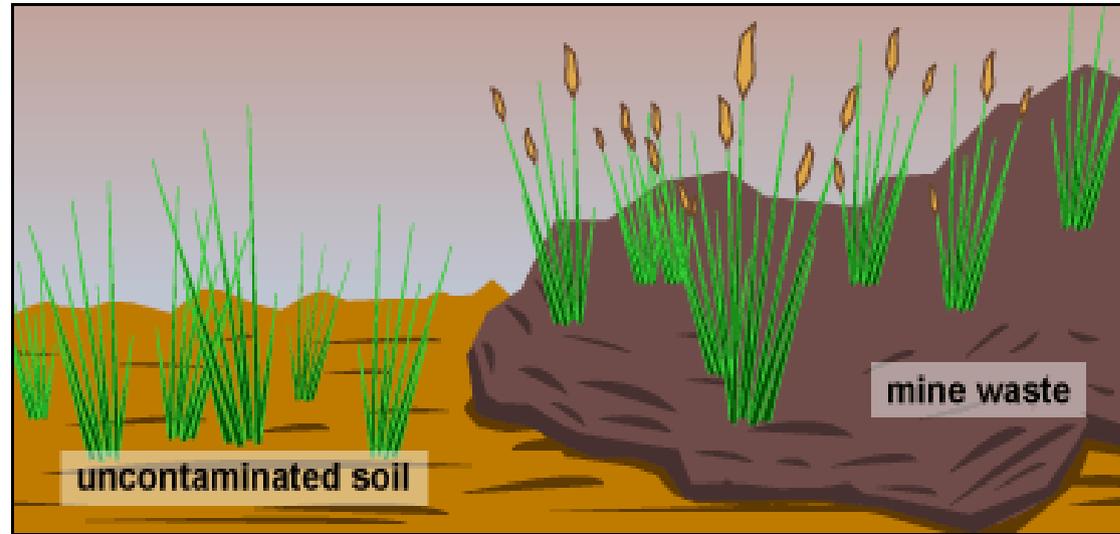


PERIPHERAL ISOLATE

- In small populations **DRIFT** and **NATURAL SELECTION** may cause rapid divergence from the parental population

# Parapatric speciation

reproductive isolation occurs without complete geographic isolation (*some gene flow*).

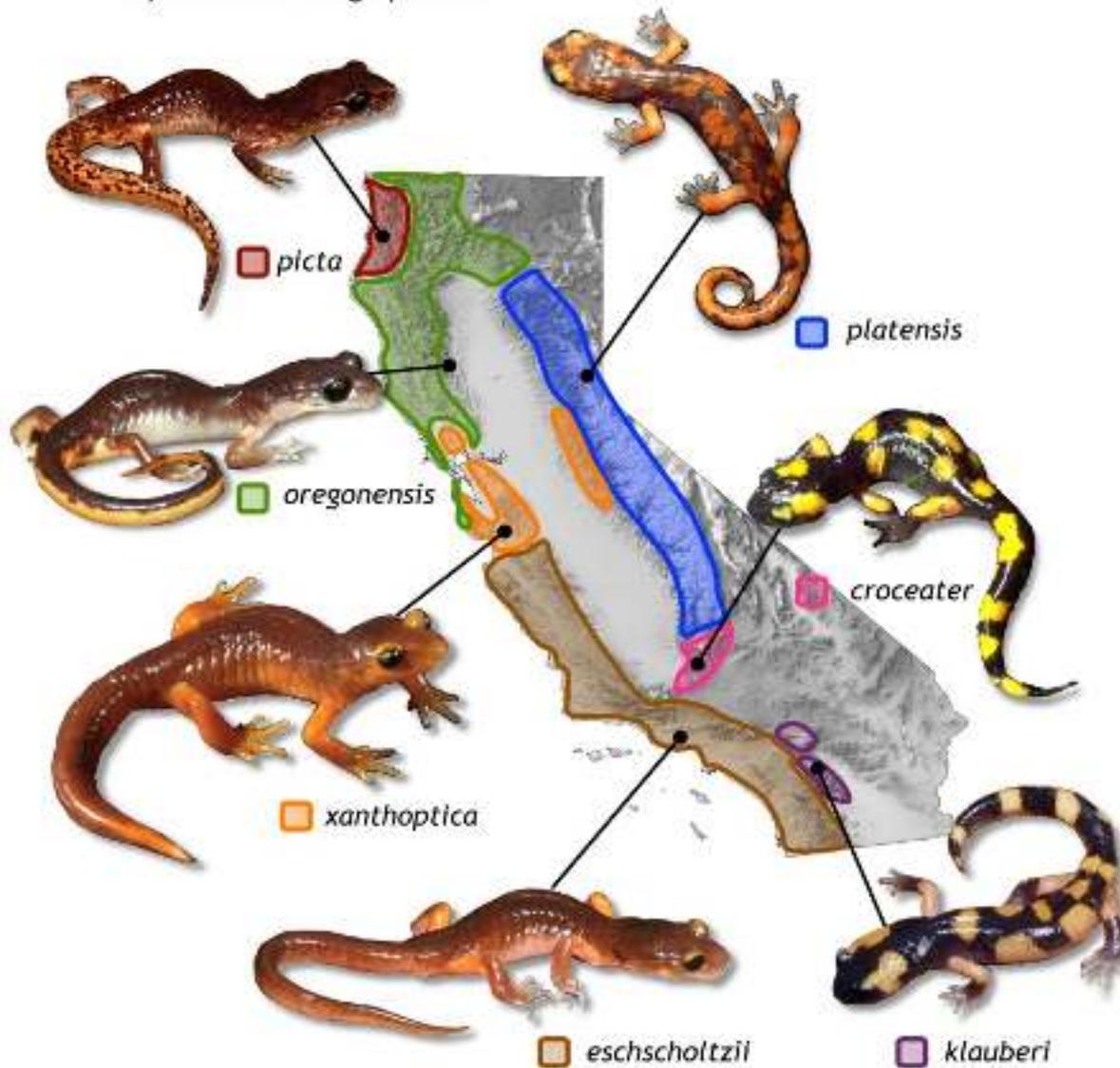


Figures: [www.evolution.berkeley.edu](http://www.evolution.berkeley.edu)

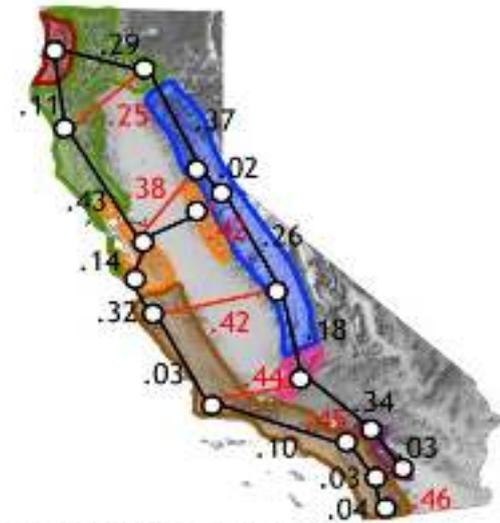
- Parapatric speciation in *Anthoxanthum odoratum*?
- Adaptation to heavy metal contaminated soils in many locations globally
- Divergence in flowering times (reproductive isolation) between the two populations suggests that speciation is under way  
*disruptive selection prevents hybridization?*

# Ring species in *Ensatina* salamanders

a) *Ensatina* ring species



b) Genetic divergence



c) Ecological divergence



# Sympatric speciation

*Sympatry* – living in the same area

**Speciation without geographic isolation**

# The apple maggot fly, *Rhagoletis pomonella*

Two incipient species specializing on two hosts (apple and hawthorn)?



Chapter 18: Genes, Evolutionary Analysis, 4/e  
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Illustration: [www.evolution.berkeley.edu](http://www.evolution.berkeley.edu)

## Sympatric speciation due to polyploidization

*Polyploidization* – production of multiple sets of chromosomes

e.g. A newly formed polyploid can potentially be reproductively isolated from the original diploid

ca. 70% of flowering plants & 95% of ferns appear to have had polyploid events in their evolutionary history.