BIO 111 - Principles Of Life I: Biomolecules, Genetics And Evolution

Module: Evolutionary Biology

Part II: Species and Speciation

Varsha 2025

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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

- It is challenging to find one definition of species that works in all contexts

Many Species Concepts have been propose. In practice, the two most widely used concepts are

- Biological Species Concept
- Typological Species Concept

Biological Species Concept

First conceptualised by John Ray. Ernst Mayr later modified 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.”

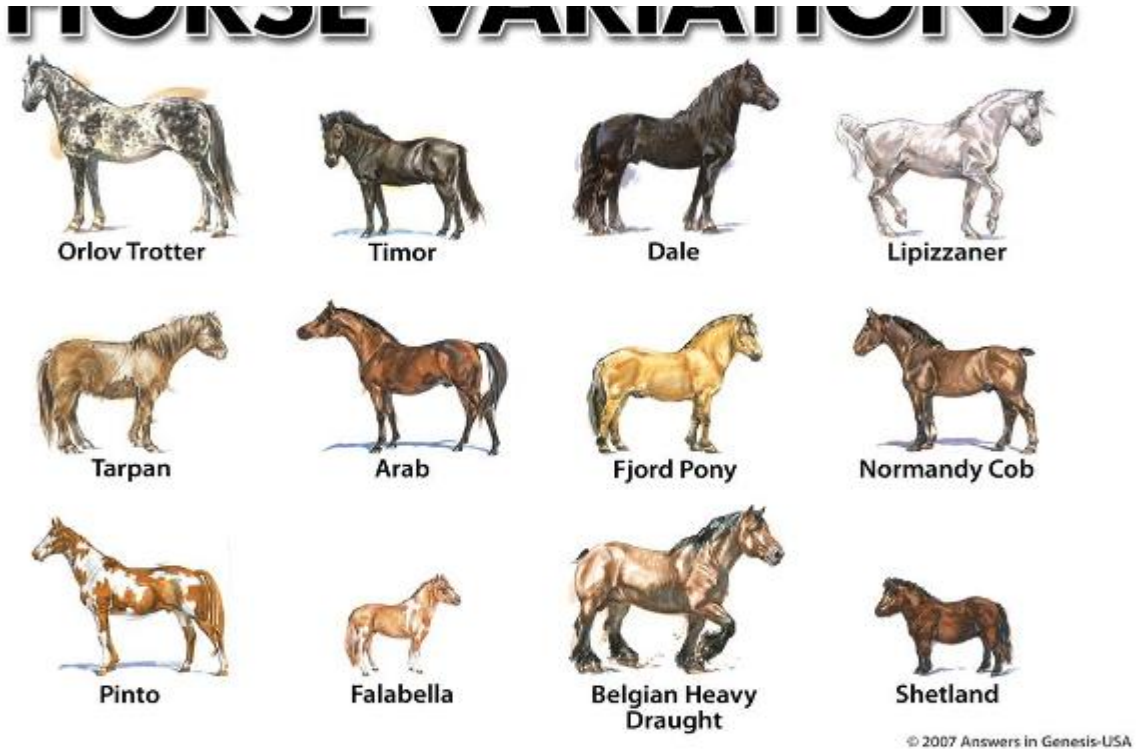

A female horse mated to a male donkey can give birth to a.....

Adapted from slides by Neil Buckley

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

Adapted from slides by Neil Buckley

There is variation within the two species. But, there are also some consistent differences between them.



Source: oneyearbiblesite.wordpress.com

Liger

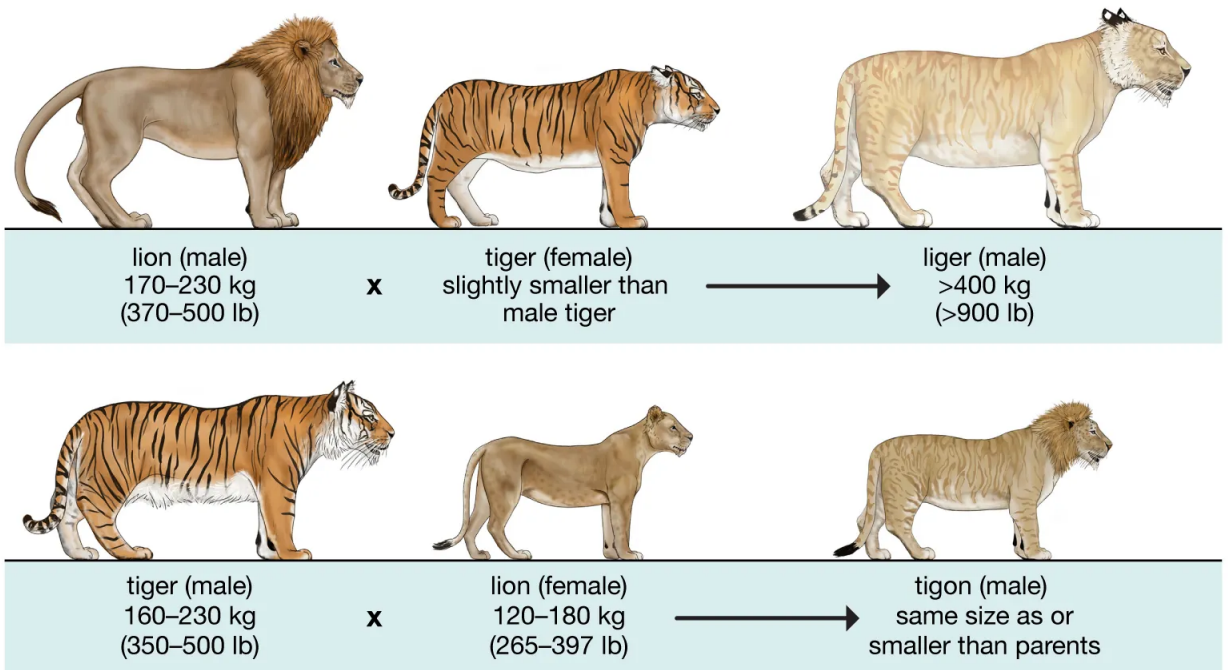


Photo: www.respeitoanatureza.blogspot.in

Widely used in practice, although there are some problems.

1. Not applicable to asexual species. E.g.,

- 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.

- **Despite occasional production of fertile hybrids, the species remain distinct (i.e., can be morphologically recognized as different species)**

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

However, if two groups of populations are reproductively isolated, the groups are expected to diverge in morphological characters. These differences in morphology allows us to use the Typological Species Concept

Typological Species Concept (Carl Linneaus)

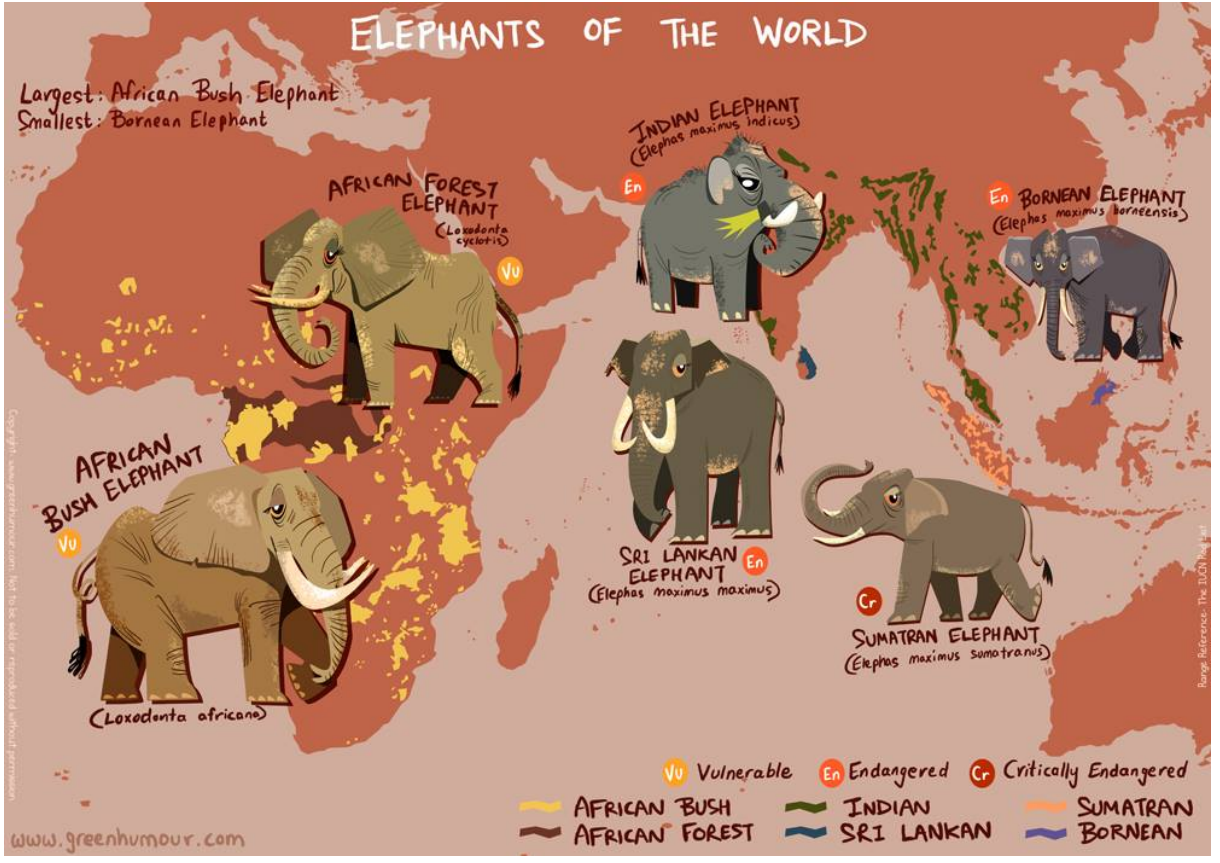
'a species is a group of individuals differing from other groups by the possession of constant diagnostic characters'

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

Emphasizes morphological differences across species

- Each species thought to have a set of diagnostic traits
- Based on descriptions of a ‘type’ specimens for a given species
- The ‘holotype’ is the most important type specimen for a species and is kept in a museum/collection

Geographic variation across populations - often classified as 'subspecies'



Reading exercise

- What are the recognized subspecies of tigers?
- Which of these have gone extinct?

TSC cannot distinguish cryptic species

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

- BSC and TSC are linked.
- If two sets of populations are reproductively isolated, over time, they are expected to become different in morphology with time.
- Thus, there will be a few consistent morphological differences between them.
- This usually leads to each species have a set of diagnostic characters that are not found in any other species

SPECIATION

- Process of formation of new species

  i.e. Divergence of ancestor into descendant/daughter species

- Evolution of reproductive isolation (assuming BSC)
  - Prezygotic barriers
  - Postzygotic barriers

Reproductive Isolation

Prezygotic mechanisms (prevent zygote formation):

- **Temporal isolation**: Reproduce at different seasons or at different times of the day.
- **Behavioral isolation**: Mating rituals, songs, mating calls
- **Mechanical isolation**
- **Gametic isolation:** Sperm-egg or Pollen-ovule incompatibility

Postzygotic Isolation (reduced viability or fertility of hybrids)

Hybrid inviability (or reduced viability)

Embryological arrest: Hybrid embryos often do not develop properly; no viable offspring is created (or offspring viability is reduced).

Hybrid sterility

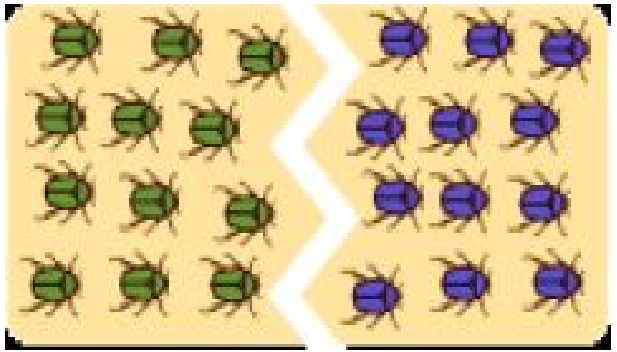
Infertility: Hybrid offspring might grow to viable adults but these are infertile and cannot produce further offspring (Donkey + Horse = Mule; Mule is sterile).

How does reproductive isolation/incompatibility evolve?

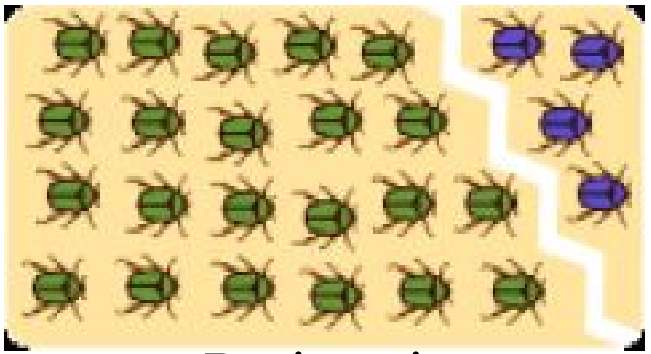
Reproductive incompatibility between two individuals or between two groups of individuals can reduce fitness, and, therefore, should be selected against. If so, how can reproductive incompatibility evolve?

We can identify modes of speciation, based on degree of geographic isolation

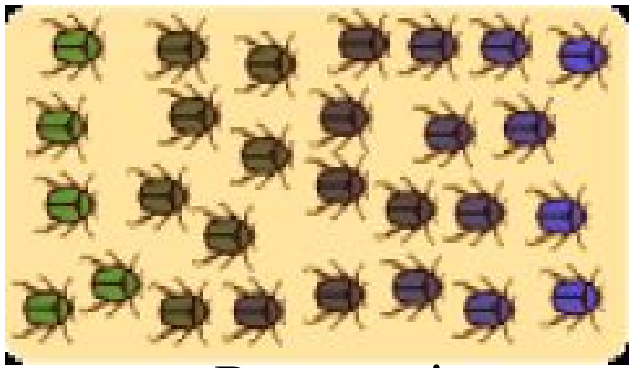
- Allopatric
  - Peripatric
- Parapatric
- Sympatric



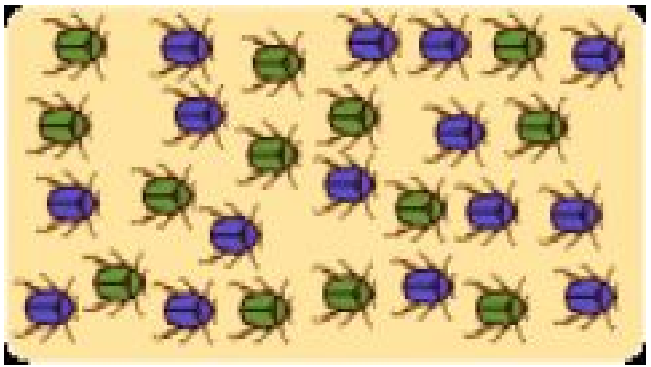
Allopatric



Peripatric



Parapatric



Sympatric

Images from http://evolution.berkeley.edu

Allopatric speciation

- Two populations (or sets of populations) of an ancestral species are geographically isolated by physical barriers.
  - Rivers & Oceans
  - Mountain ranges
  - Deserts
  - Land (in case of aquatic organisms)

Allopatric speciation

- The populations (or sets of populations) diverge because they evolve under different selection pressures.
- Over time, some form of reproductive isolation develops, thus leading to formation of two daughter species.
- Speciation occurs in complete geographic isolation (low probability of *gene flow* between diverging populations)

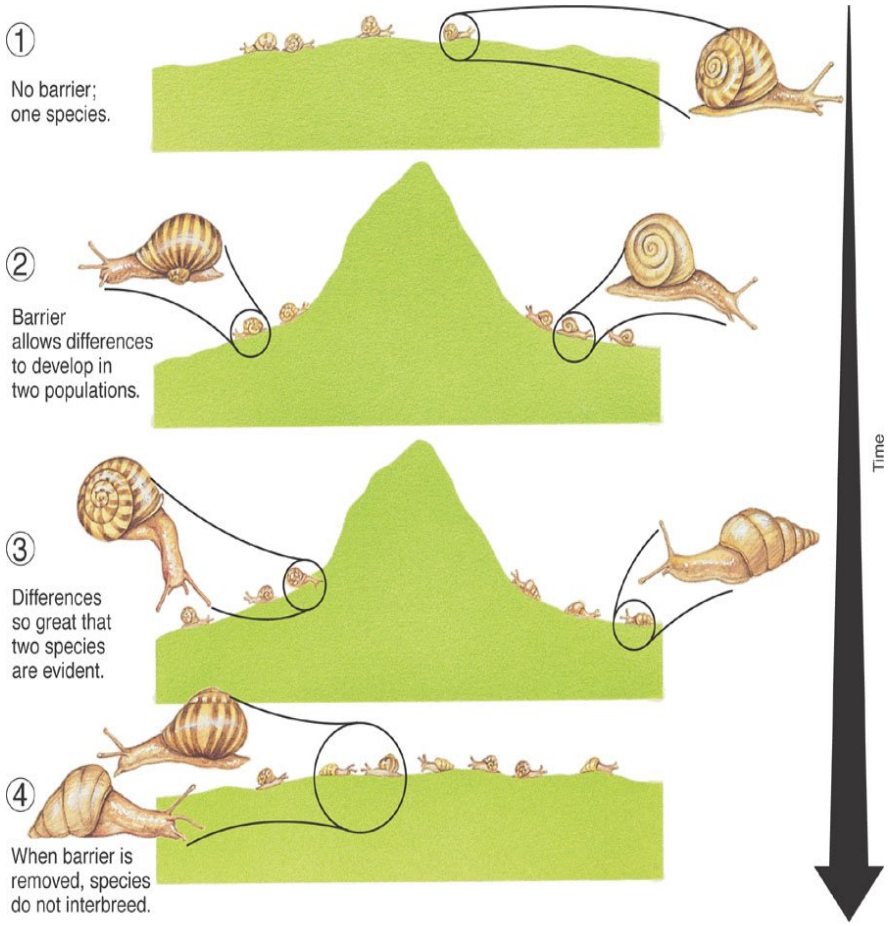
Allopatric speciation

1. A single ancestral species

2. A physical (geographic) barrier develops dividing the species

3. The divided populations diverge through the accumulation of genetic and phenotypic 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

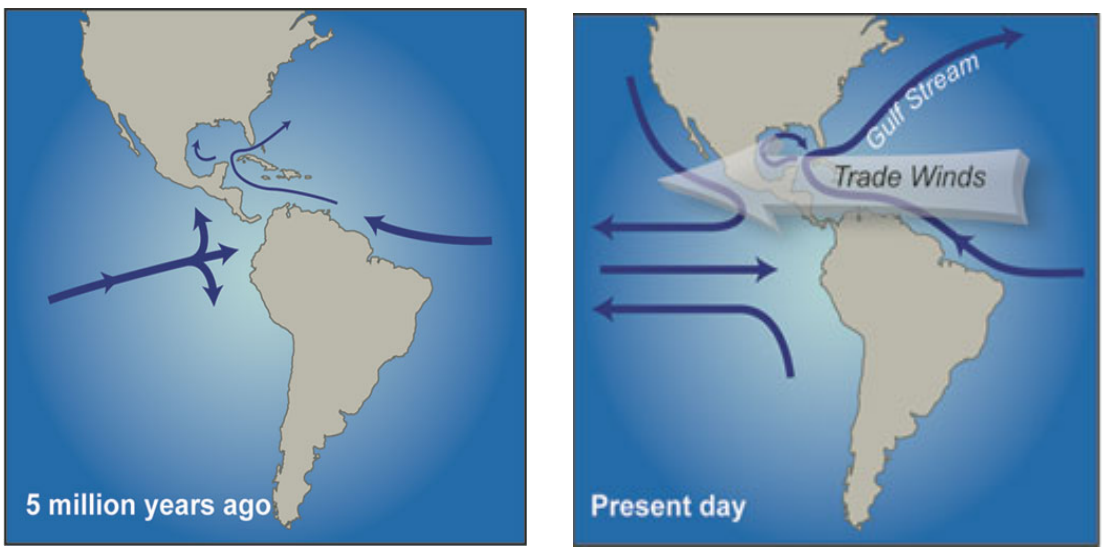
The Grand Canyon (USA) was carved by the Colorado River. Initially, there was single squirrel ancestral species. The canyon eventually formed a barrier that led to allopatric speciation (estimated to have happened about 10,000 years ago). Today the newly diverged sister species are allopatric: the Kaibab squirrel is found only in the north and the Abert squirrel is found only in the south.

Kaibab squirrel (*Sciurus kaibabesis*)

Abert squirrel (*Sciurus aberti*

All photos: Grand Canyon NPS/Flickr

South and North America isolated for millions of years. Reconnected 3 million years ago by the *Isthmus of Panama,* which resulted in allopatric speciation in Snapping shrimps (*Alpheus*)

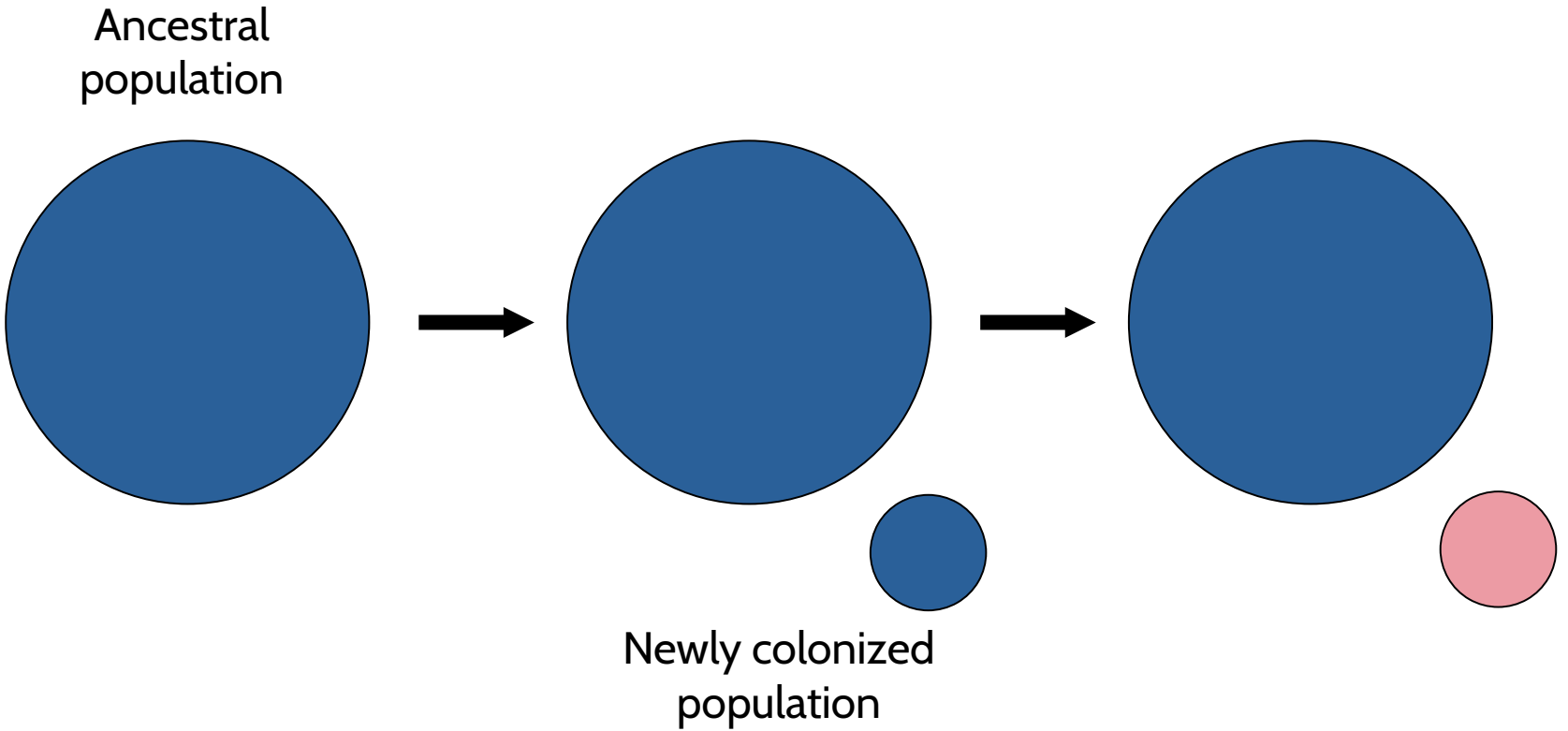


Images: Taken from slide by John McCall

Peripatric speciation

- Similar to allopatric speciation – *low probability gene flow between diverging populations*
- One of the isolated populations has a small population size (i.e, has very few individuals).
- Compared to allopatric speciation, *Genetic Drift* plays a more important role in peripatric speciation compared to allopatric speciation.
- Both Genetic Drift and selection play a role

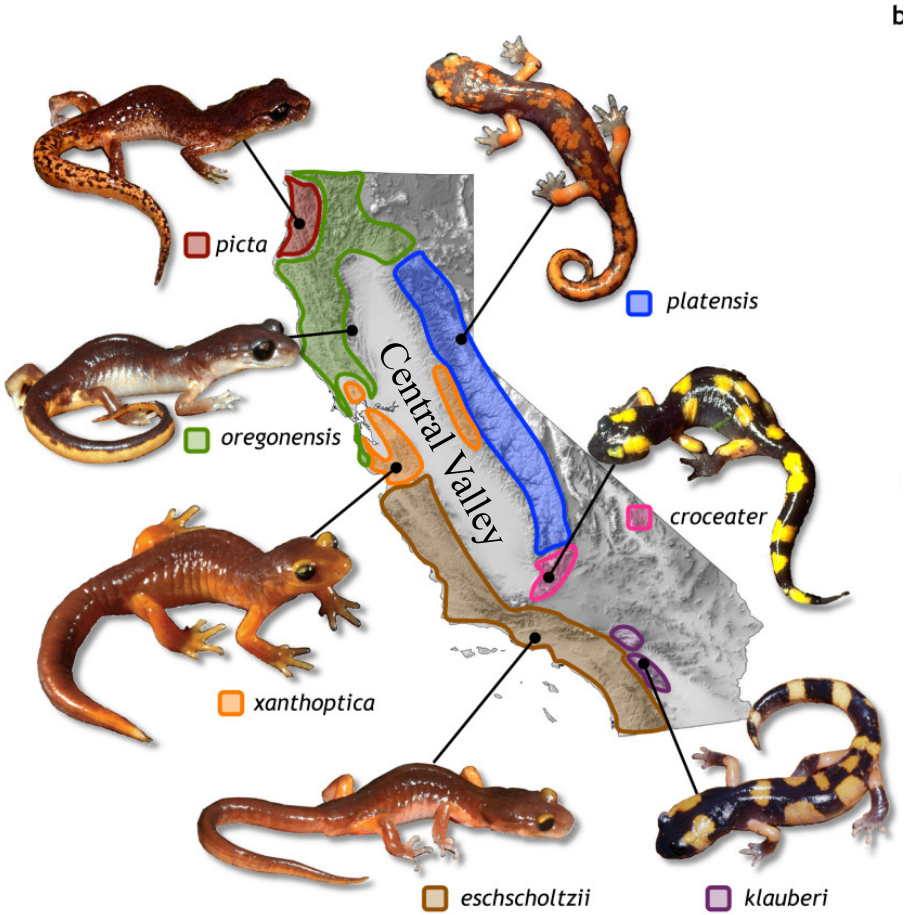
E.g. Colonization of an island from the mainland by very few individuals. Here, genetic drift through the founder effect plays an important role



Parapatric speciation

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

E.g. Ring species in *Ensatina* salamanders



Central Valley, California

Source: Pereira *et al* 2011 *BMC Evolutionary Biology*

Sympatric speciation

Sympatry – living in the same area

Speciation without geographic isolation

High probability of gene flow between diverging lineages

E.g., Sympatric speciation in the apple maggot fly, *Rhagoletis pomonella*

Two ‘host races’ specializing on different hosts (apple and hawthorn). These ‘host races’ are thought to represent intermediate stages of speciation

Chapter 16 Opener Evolutionary Analysis, 4/e
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