

Chapter 13: The origin of species

How do we go about defining a species?

How does one species become two?



Reading for today touched upon Griz and Polar bears!

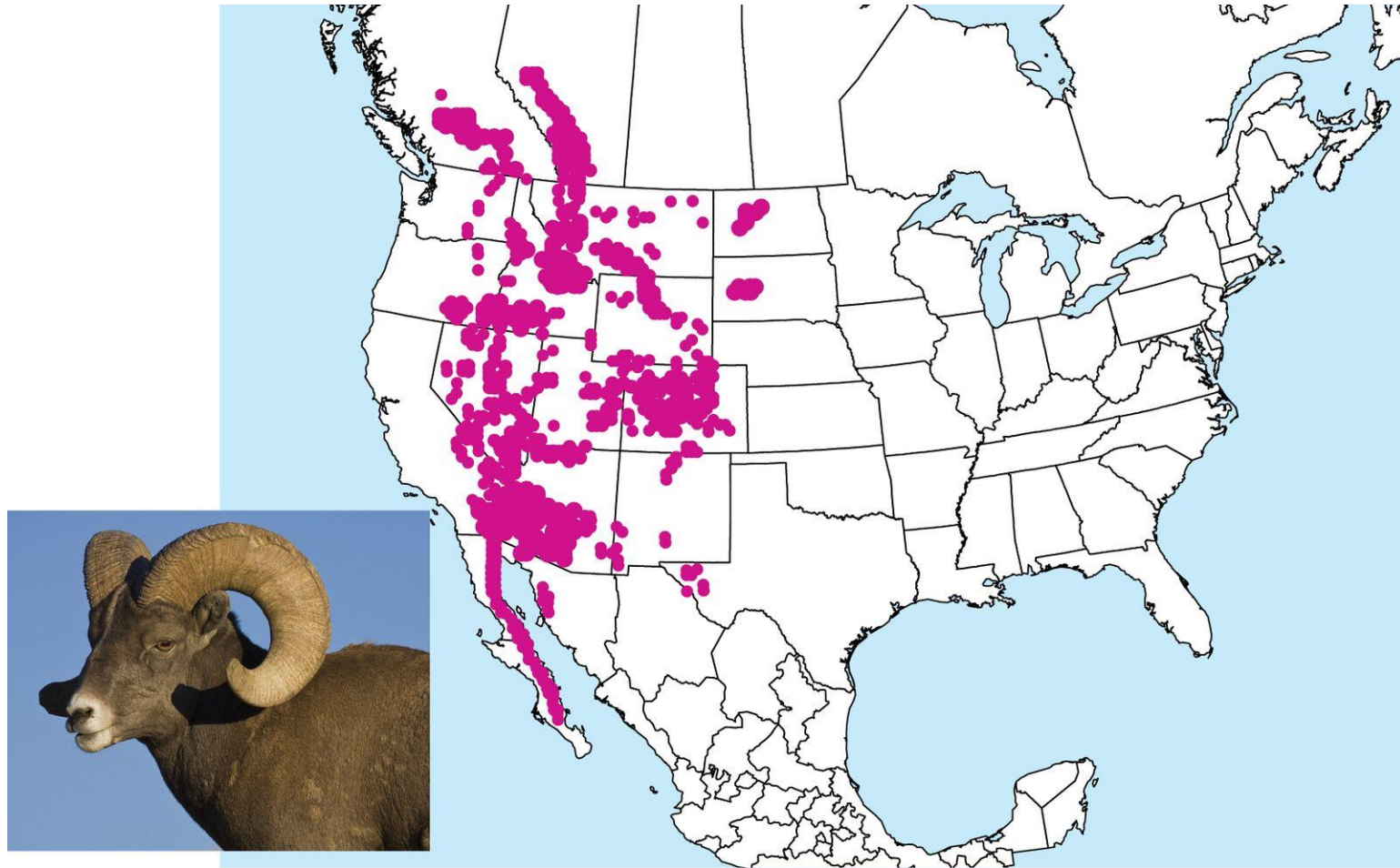
Topics for this Chapter

- **How do we define species? (3 species concepts)**
- How do new species form?
- Fate of hybrid zones
- Reproductive barriers
- Problems with bacteria
- Bears, bears, bears

FYI This chapter connects to....

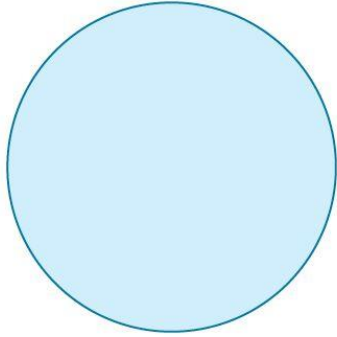
Ex. Bighorn sheep

Which populations would you expect to be genetically different from one another? Which would be similar? Why?



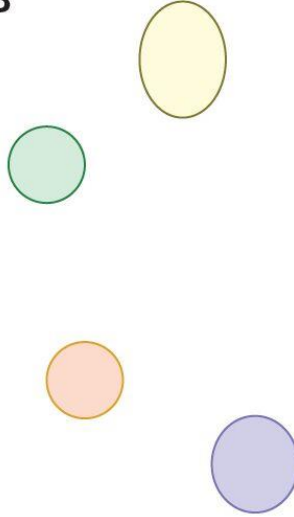
FYI This chapter connects to....

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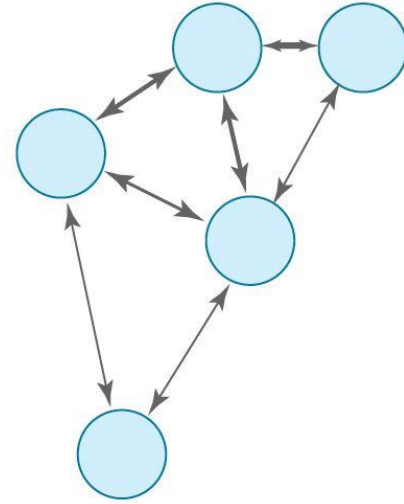
No subdivision

B



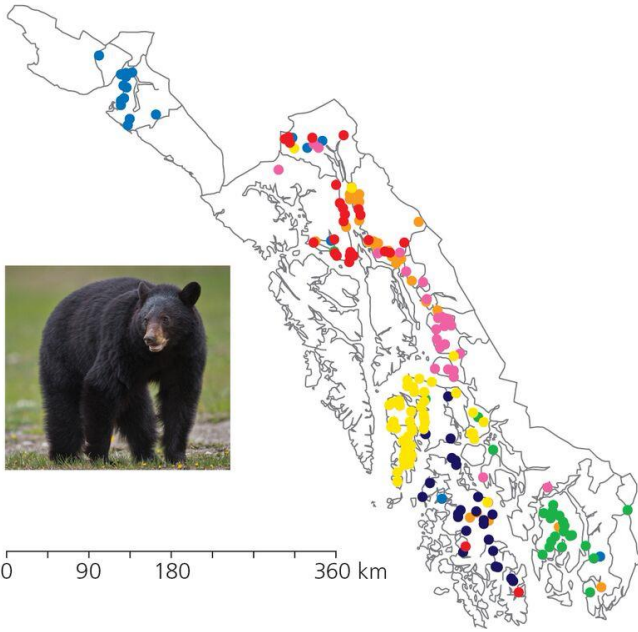
Extreme subdivision

C

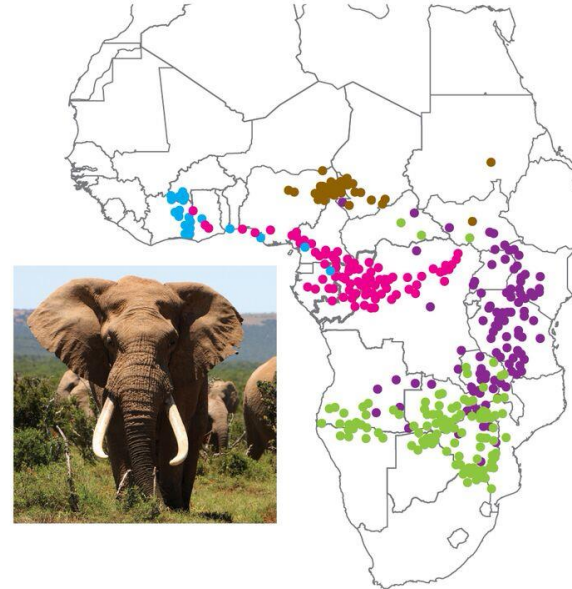


Intermediate subdivision

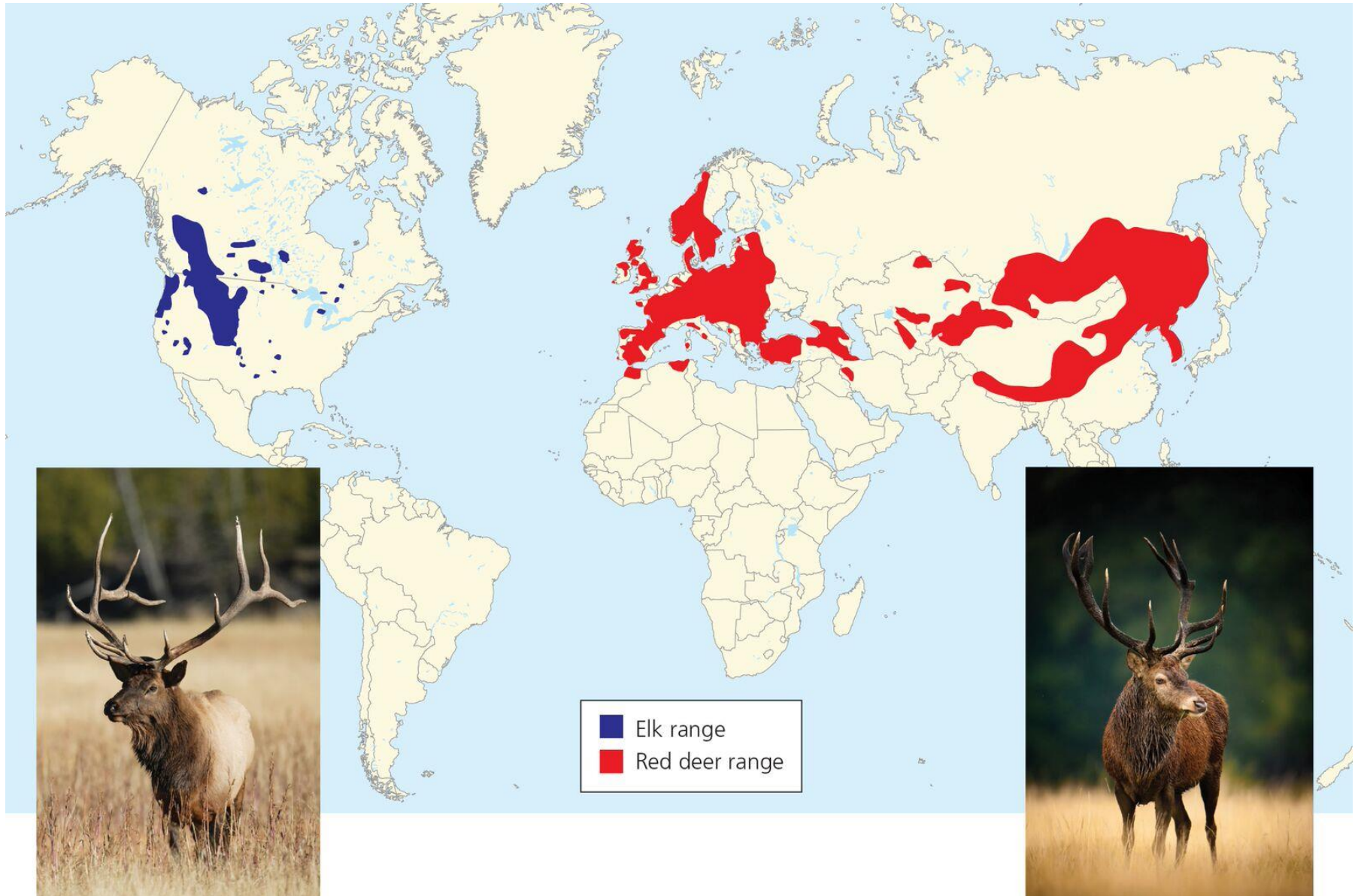
A



B

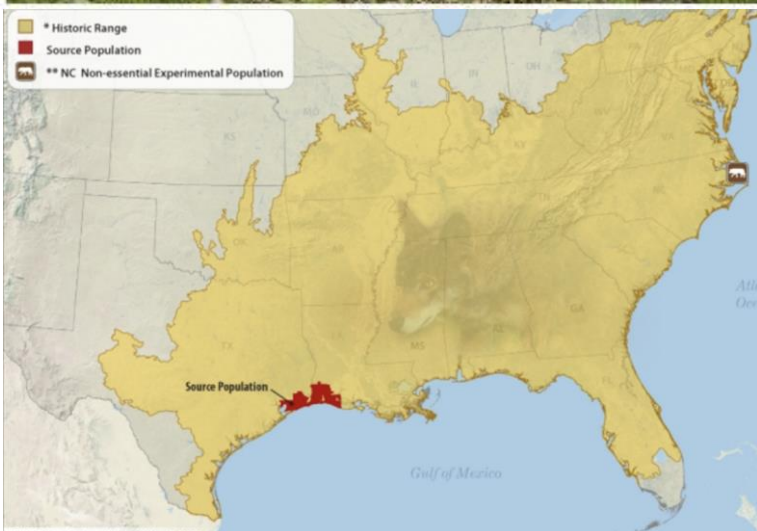


North American elk and European red deer: One or two species? (in text)



North American wolves, one or two species?

What would you want to know/measure?



Gray wolves' history and recovery

Hunting virtually eliminated gray wolves from the western U.S. by the 1930s. The Endangered Species Act offered *Canis lupus* federal protection in 1973, and wolves were reintroduced to Yellowstone National Park more than 20 years later.

Wolf distribution ■ Current range ■ Historic range



<http://www.fws.gov/redwolf/aboutredwolf.html>

• <https://graphics.latimes.com/towergraphic-la-me-wolves/>

• <https://www.fws.gov/project/red-wolf-recovery-program>

IMPORTANT for - ESA

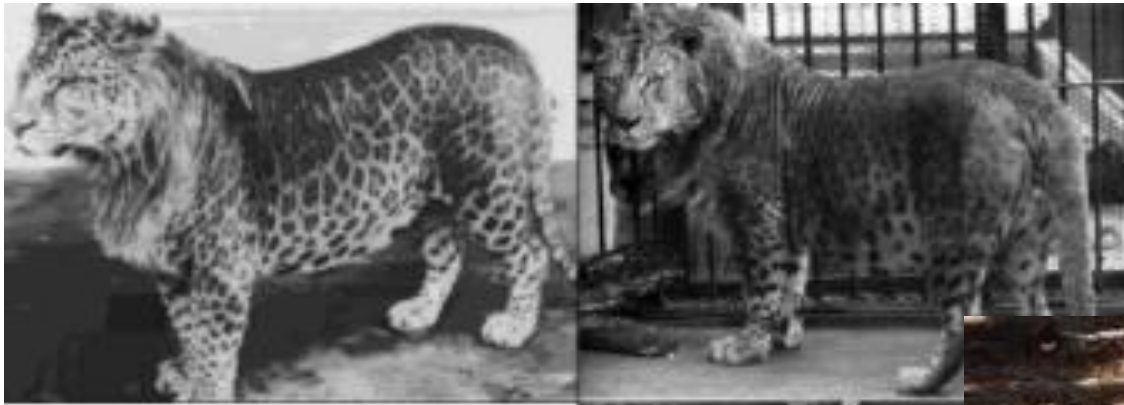
1st we had Biological Species Concept (Mayr)

Do they interbreed and produce fertile offspring?

Advantages?

Problems?

1. Asexual species...
2. Fossils
3. Geographically separated
4. Hybridizers
5. Do we really do this?



Hybrids occur and it doesn't mean the two interbreeding are the same species.

Morphological Species Concept

Do they look the same?

Advantages?

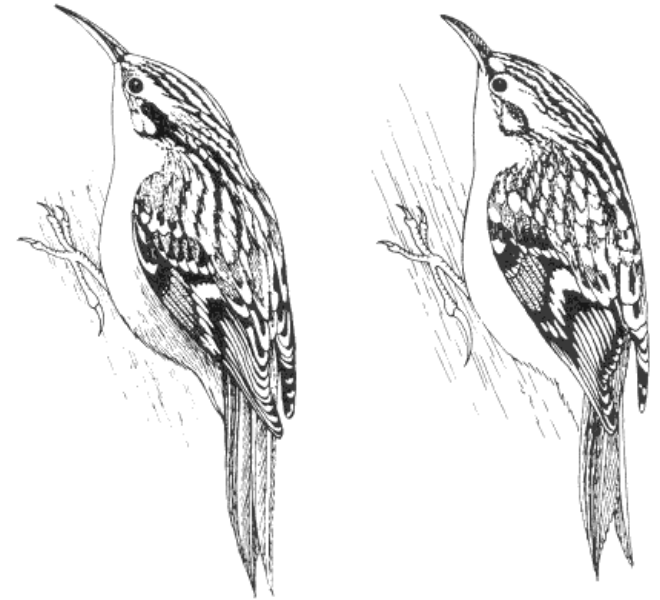
Works well for fossils!

Problems?

How different is different?

Ex. Short-toed treecreeper (*Certhia brachydactyla*) (left) differs subtly from the common treecreeper (*C. familiaris*) (right) (www.mun.ca/biology/scarr/Fut_15_03_treecreepe...)

These two can be a problem...



Often the first thing you do...until time or \$\$\$ to

Phylogenetic or Evolutionary Species Concept

How long have these two groups been on separate evolutionary paths?

Reconstruct evolutionary history of populations

(often but not always infer through molecular genetic info)

EX. Shiitake Mushrooms (Donohue and Hibbett '96)

Ranges from Japan, Thailand, Borneo, New Zealand and Tasmania

Widely cultivated

Threatened due to....?

Researchers used all three
“species concepts”



- All are **reproductively compatible** (what does that mean)
- Morphological measurements clustered in 3 groups
- ribosomal RNA-4 distinct groups
- Basically there are “**cryptic species**” here

Lets apply our 3 concepts to our 2 wolf pops

Can interbreed?

Yes! many *Canids* do!

Morphology?

Look different-RW is smaller, with longer ears and legs relative to body size, color different

Phylogenetic (genetic) analysis

examined 48,000 single nucleotide polymorphisms (SNPs) of red wolf, wolves from NE, our MN gray wolf, coyotes and dogs

Red wolves were 76-80 % coyote and 20-24 % gray wolf...

USFWS is a species



“Red Wolf” ... considered extinct in the wild by 1980.

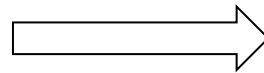
Captured individuals in ‘70s were combined with zoo populations to start a captive breeding program with **14** individuals (eek)

Have introduced some back into wild.

Today more than 200 in captivity but only a small number have persisted in wild and that # has crashed 😞

FYI..There is also a “Mexican gray wolf” which is a subspecies

Canis lupus baileyi





U.S. Fish & Wildlife Service

Red Wolf Recovery Program

Search

- Home
- Red Wolf Recovery
- Latest News
- FAQs
- Social Media
- Publications
- Events
- Education
- Partners
- Get Involved

Wild by the Numbers

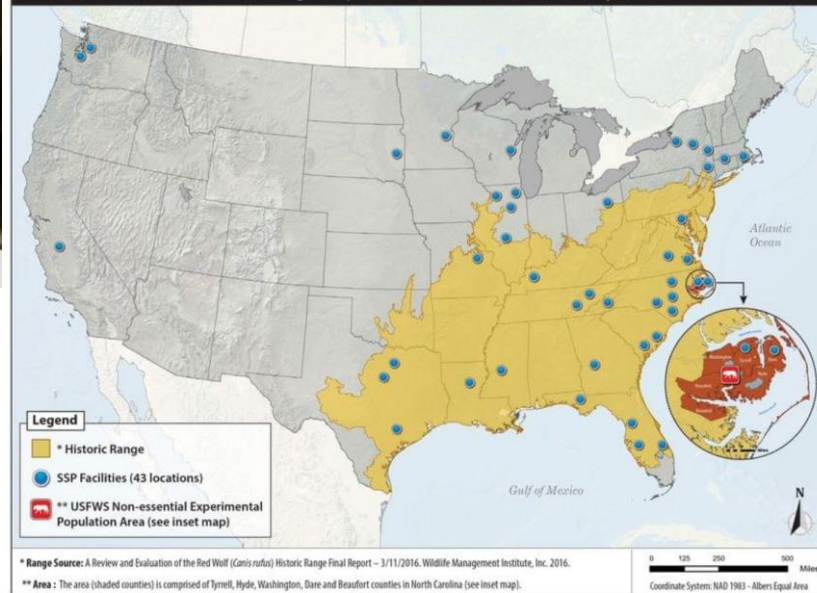
90-110

Estimated Population



What is a red wolf?
Learn more about red wolves.

Red Wolf (*Canis rufus*) Historic Range & Species Survival Plan (SSP) Facility Locations



Red wolf historic range with species survival plan facility locations. Map by Jose Barrios, USFWS.

Red Wolf Origin and Taxonomy

The red wolf (*C. rufus*) has generally been accepted as the valid designation for wolves in the southeastern United States; however, there is a lack of consensus among the scientific community regarding the taxonomy and genetic ancestry of the red wolf. For more than 30 years, various studies have reached conflicting conclusions as to the origin, and therefore, the correct taxonomic status of the red wolf. Since the 2007 5-year review, additional morphological and genetic studies have become available, all of which continue to reach conflicting conclusions.

From a U.S. Fish and Wildlife report

“In 2016, an expert workshop was convened to investigate and address key questions related to uncertainty surrounding hybridization and the potential increase in introgression with coyotes and challenges to survival of red wolves. **The main contribution of the workshop was the evaluation of competing evolutionary origin hypotheses for the red wolf, specifically whether the red wolf is a listable entity under the ESA (Pacifi and Mills 2016, p. 13). Although the attending experts did not reach consensus on a hypothesis,** they did agree that there was a logical and valid path to make a determination that the red wolf is a listable entity under the ESA either as a species (*C. rufus*), a subspecies or distinct population segment (DPS) of eastern wolf (*C. lycaon*), or a subspecies or DPS of gray wolf (*C. lupus*) (Pacifi and Mills 2016, p. 16). However, even with this conclusion, the Service must ensure the red wolf meets the definition of species under the ESA. **The term “species” under the ESA includes any subspecies of fish or wildlife or plants, and any DPS of any species of vertebrate fish or wildlife which interbreeds when mature. “**

“Genetic studies present conflicting interpretations and offer various theories on the origin of the red wolf and recommendations on the correct taxonomic status. **There are three main theories on the origin of the red wolf: (1) the red wolf originated from ancient hybridization between gray wolves and coyotes, (2) the red wolf originated from recent (post European colonization) hybridization between gray wolves and coyotes, and (3) the red wolf evolved from a common ancestor with the coyote, but is of a lineage divergent from coyotes.** Additionally, one of the mammal taxonomy authorities (Wilson and Reeder, Mammal Species of the World Third Edition 2005) **does not recognize the red wolf as a distinct species, but does recognize it as a subspecies of gray wolf.** Given the fact that the scientific community is not in agreement on the question of red wolf taxonomy, in 2017, the USFWS conducted a review of all the evidence related to red wolf taxonomy. **The most recent scientific publications continue to provide conflicting interpretations and support for different theories of origin, specifically theories 2 and 3 above; therefore, USFWS continues to recognize the red wolf as the species *Canis rufus*.**”

Topics for this Chapter

- How do we define species?
- **How do new species form?**
- Fate of hybrid zones
- Reproductive barriers
- Problems with bacteria
- Bears, bears, bears

How do new species form? (speciation)

Two step process..

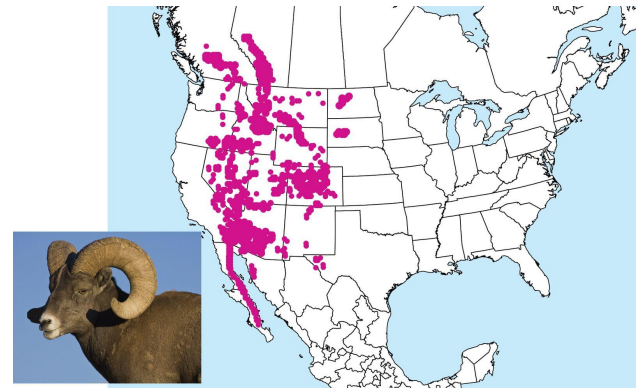
1. Must become separated, isolated or cut off from other populations...

Genes must stop flowing

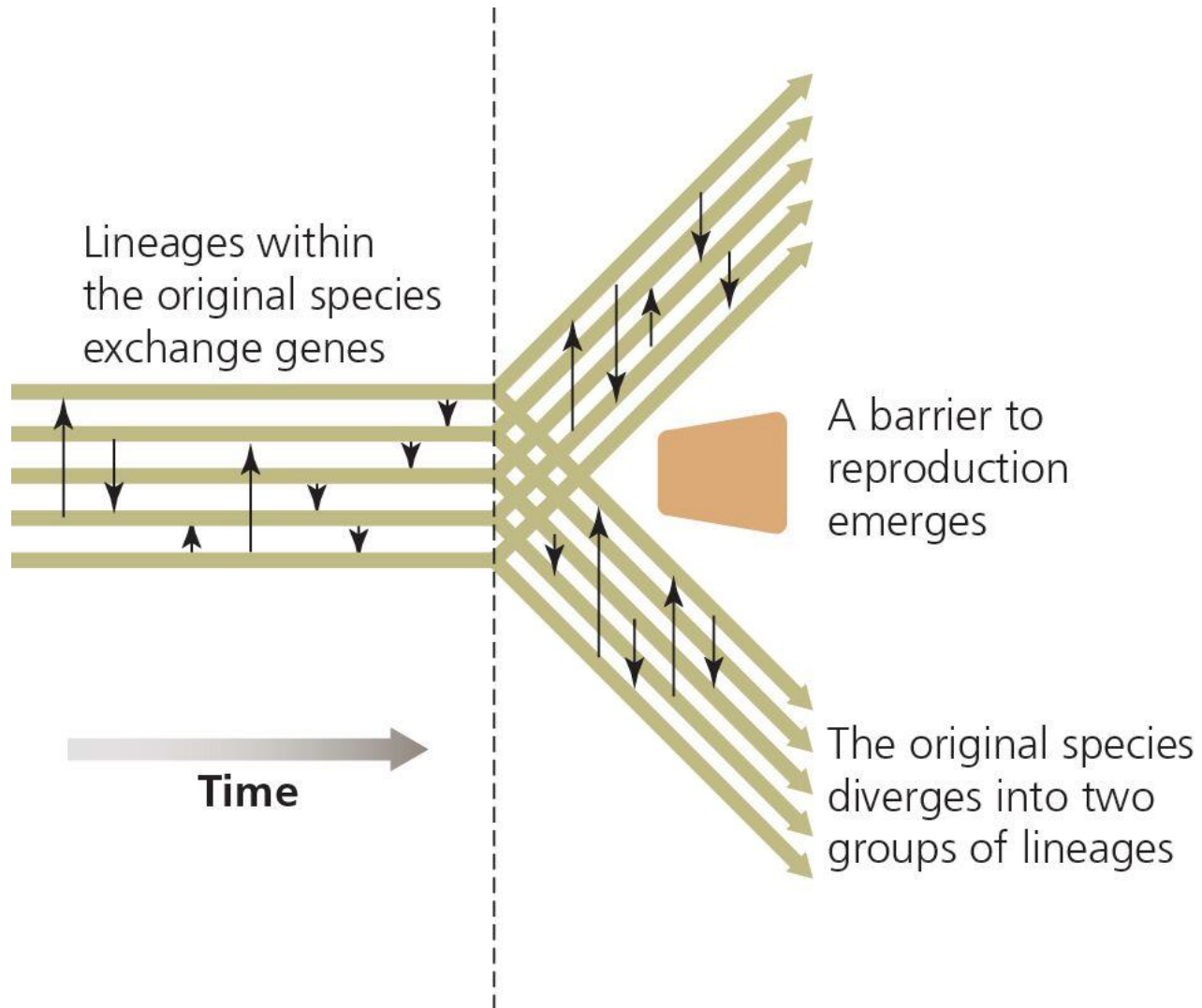
Populations must become reproductively isolated

2. Once reproductively isolated may see differences accumulate.

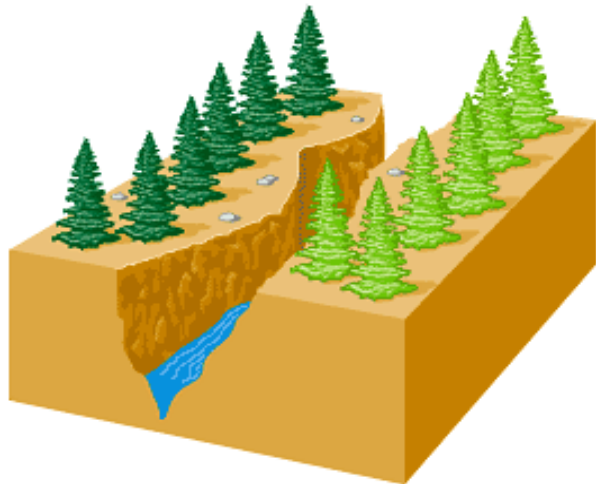
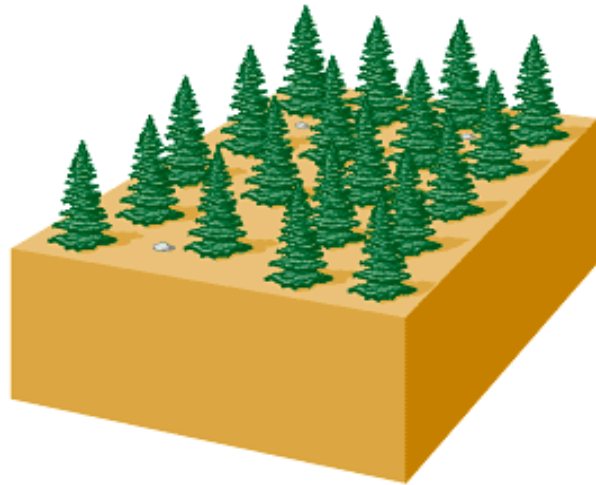
What factors or forces might drive two populations to accumulate differences (or evolve) over time?



River of Genes (concept introduced by Dawkins)



Different ways of isolating or separating a population...



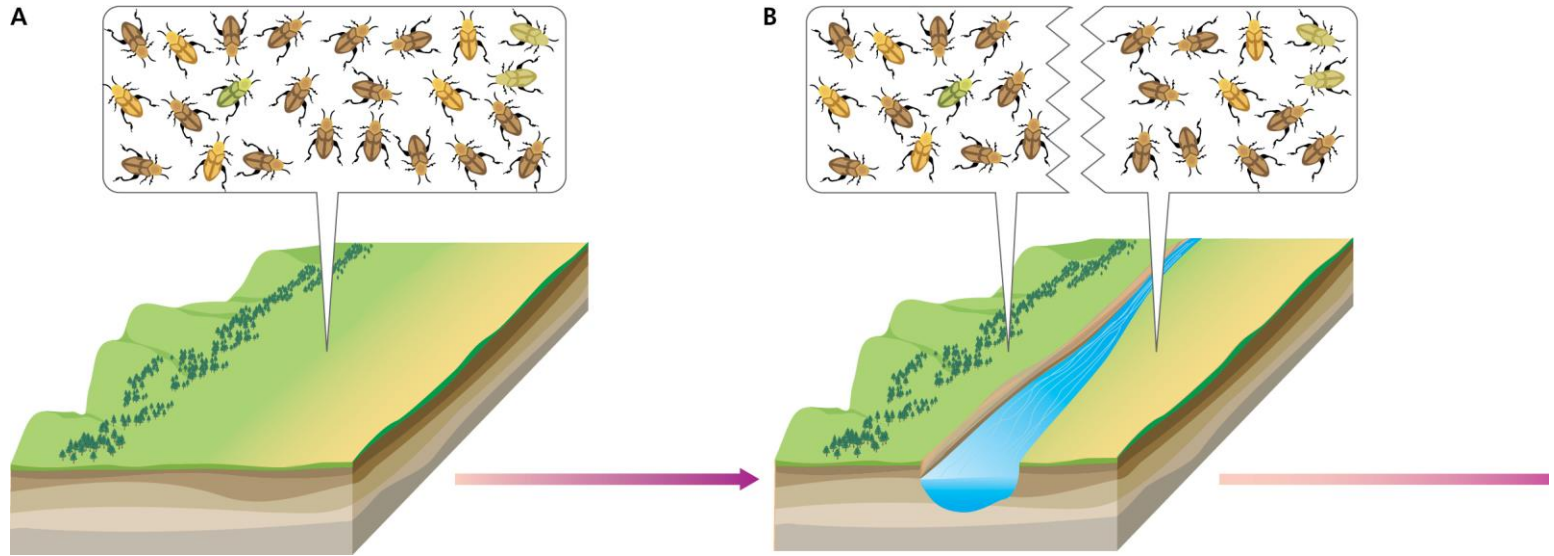
What happened here?

First way of isolating a population is through Allopatry

One big population that gets split up-physically isolated.

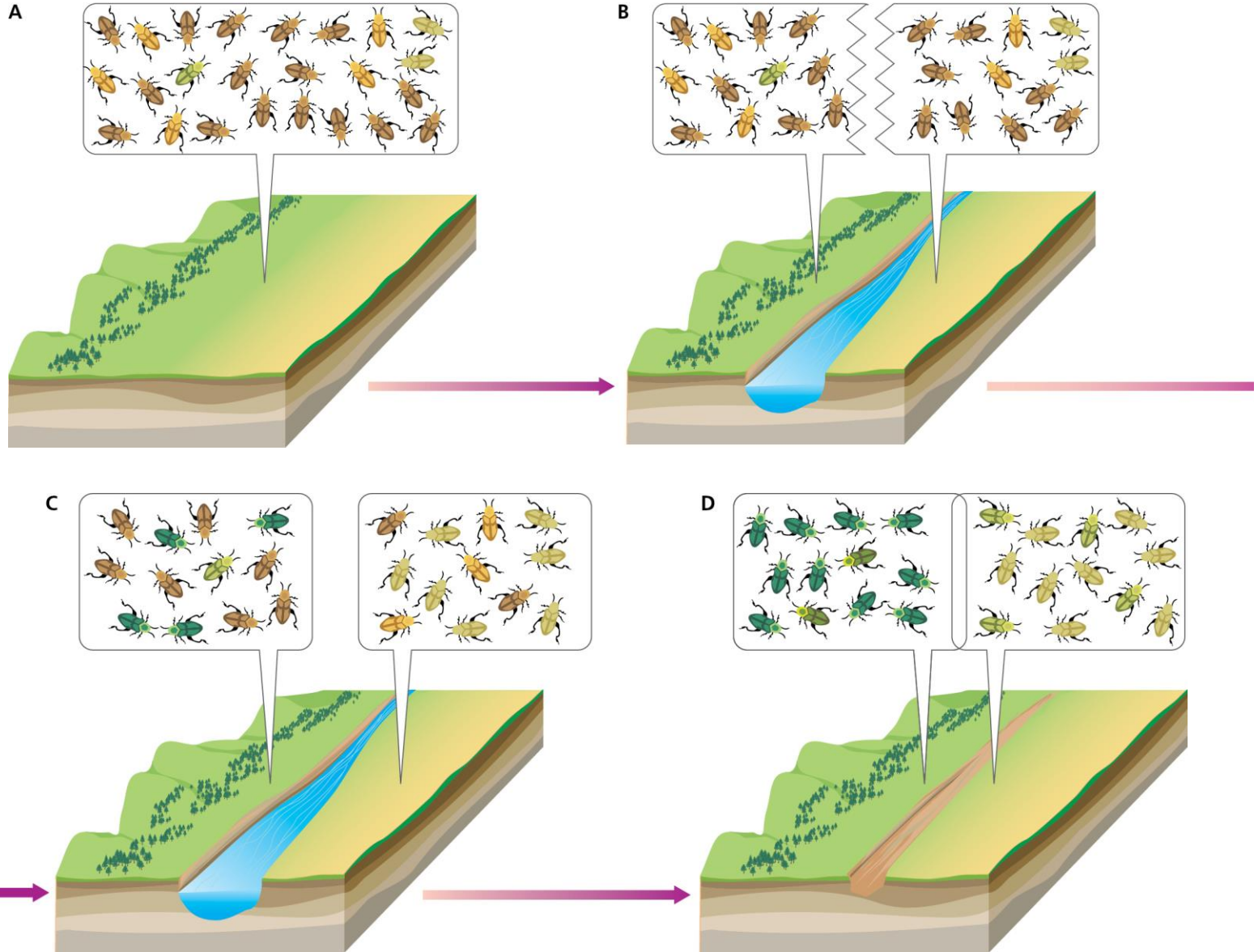
(a) Allopatric speciation

Allopatric speciation



Then over time...

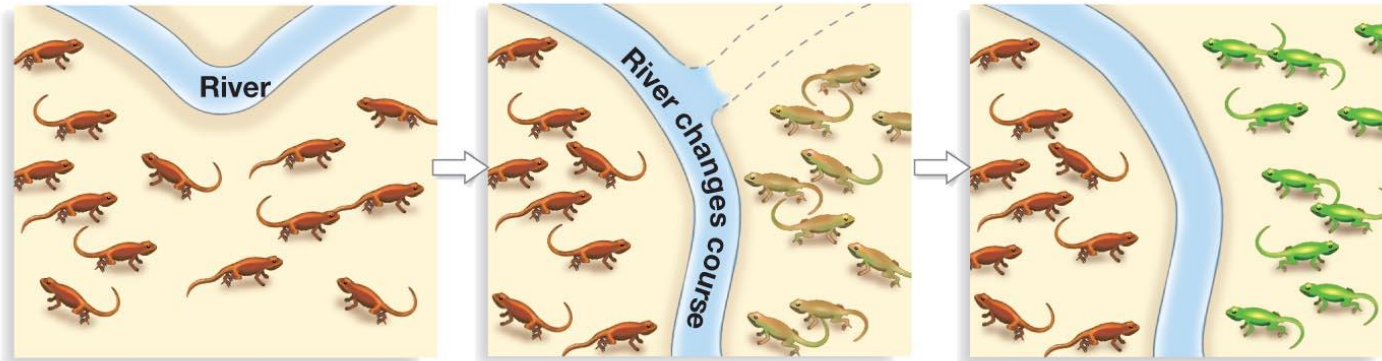
Allopatric speciation



Two kinds of Allopatric (your text does not distinguish between these)

1. Vicariance events- pop is split into two or more parts

(b) VICARIANCE CAN ISOLATE POPULATIONS.



1. Start with one continuous population. Then a chance event occurs that changes the landscape (river changes course).

2. Isolated populations begin to diverge due to drift and selection.

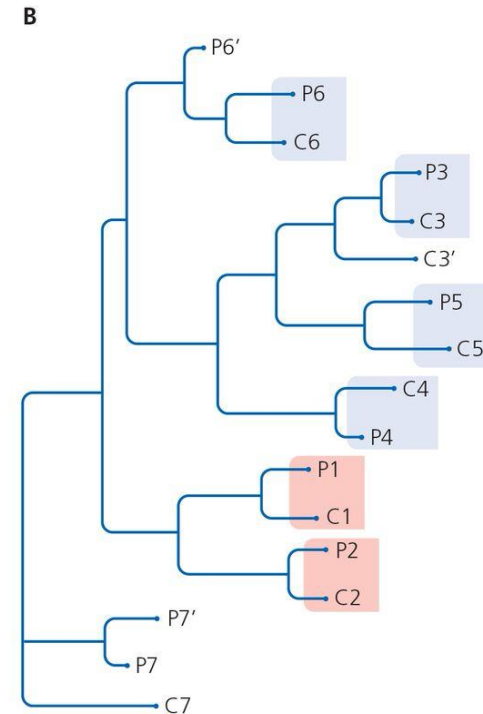
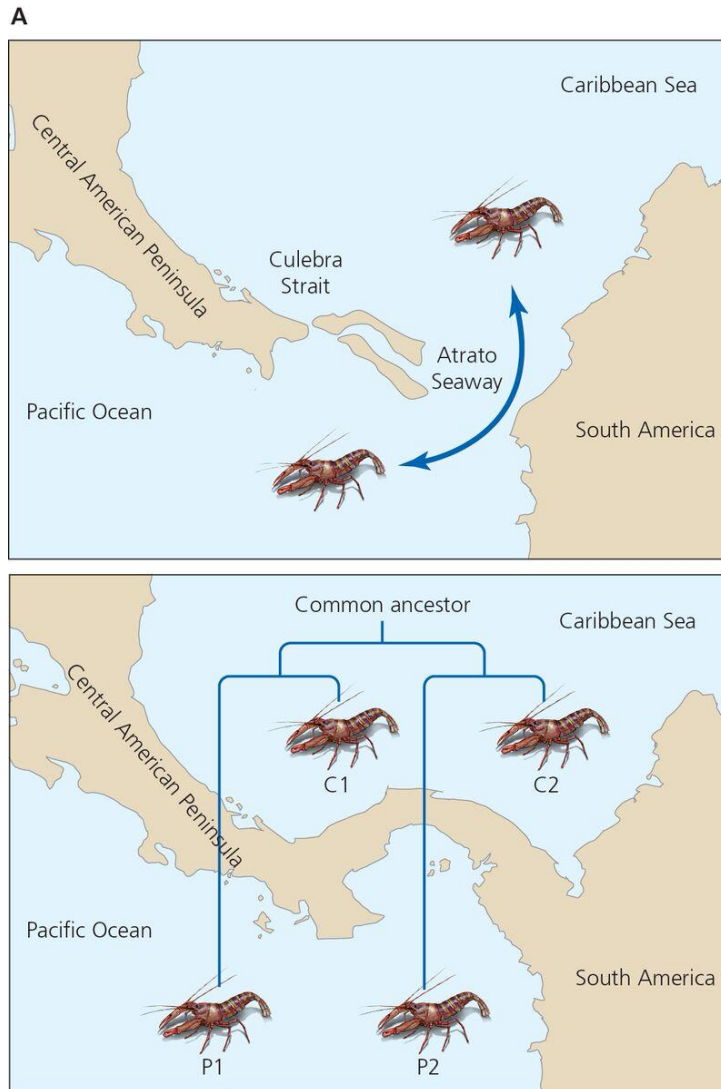
3. Finish with two populations isolated from one another.

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What is with the color change??

Ex. Shrimp in Pacific and Caribbean p428

Phylogenetic evidence for allopatric speciation



Vicariance

EX. Grand Canyon.. Antelope squirrels

Vicariance



Other vicariance events

(rivers and canyons are not the only landscape features that divide or generate barriers between populations...glaciers do this too)

EX. Orioles-east and west populations separated by glaciers until 15,000yrs ago



The Bullock's Oriole (left) and Baltimore Oriole (right) were once lumped together as one species, the Northern Oriole, because they can mate and produce viable offspring. *Photos by Brian Small.*

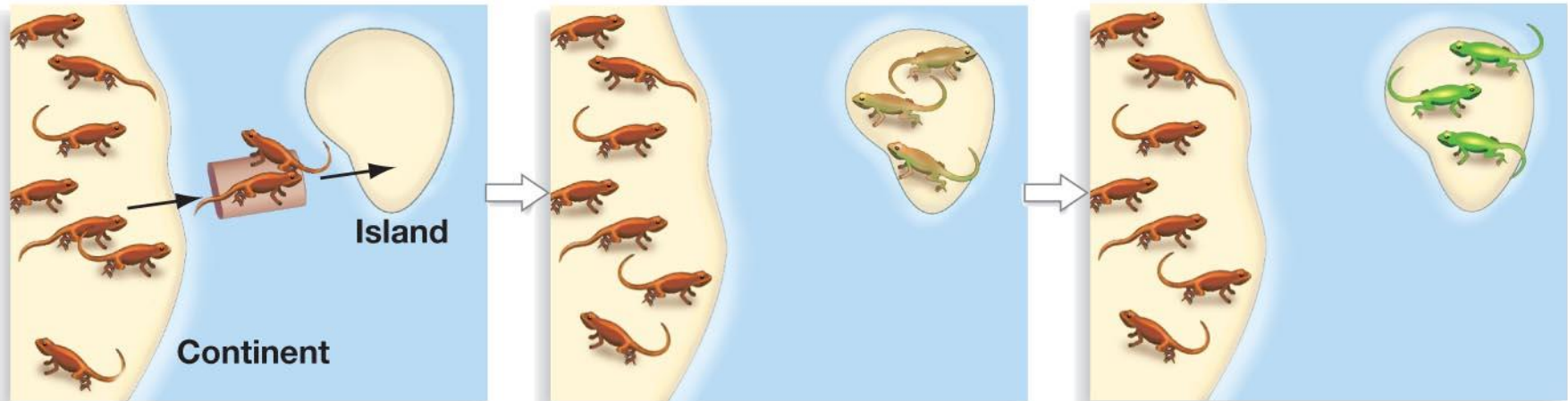
Allopatric Speciation

1. Vicariance events

2. Founder events

Individuals arrive at new island, isolated valley, ponds

(a) DISPERSAL AND COLONIZATION CAN ISOLATE POPULATIONS.



1. Start with one continuous population. Then, colonists float to an island on a raft.

2. Island population begins to diverge due to drift and selection.

3. Finish with two populations isolated from one another.

Iguanas rafted more than 8,000 km from North America to Fiji

Simon G. Scarpetta  , Robert N. Fisher , Benjamin R. Karin,  , and Jimmy A. McGuire  [Authors Info & Affiliations](#)

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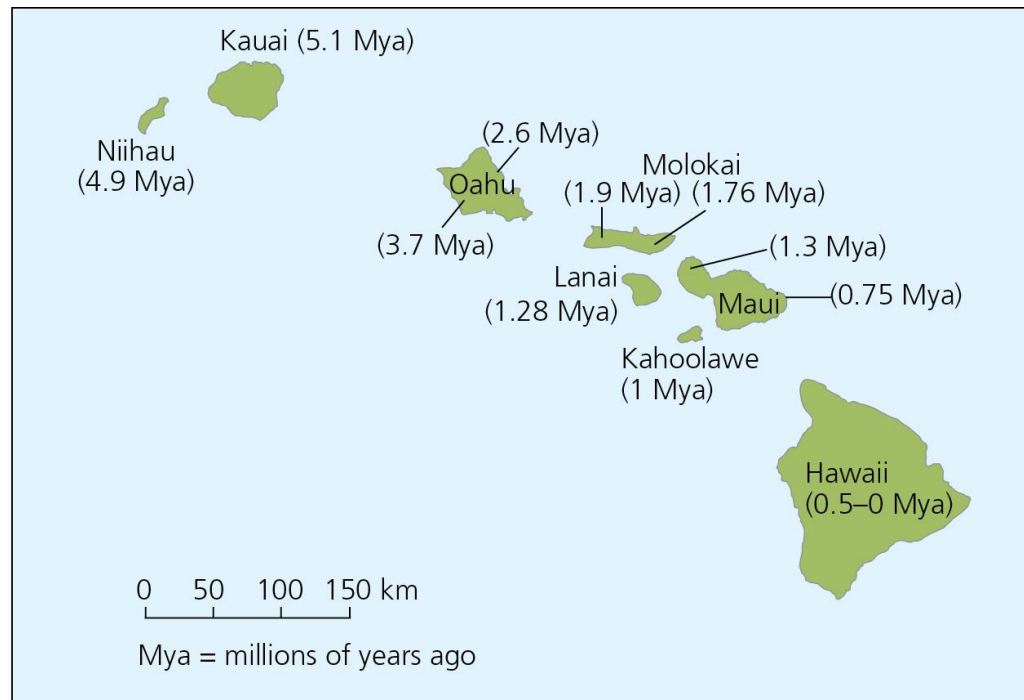
Abstract

Founder-event speciation can occur when one or more organisms colonize a distant, unoccupied area via long-distance dispersal, leading to the evolution of a new species lineage. Species radiations established by long-distance, and especially transoceanic, dispersal can cause substantial shifts in regional biodiversity. Here, we investigate the occurrence and timing of the greatest known long-distance oceanic dispersal event in the history of terrestrial vertebrates—the rafting of iguanas from North America to Fiji. Iguanas are large-bodied herbivores that are well-known overwater dispersers, including species that colonized the Caribbean and the Galápagos islands. However, the origin of Fijian iguanas had not been comprehensively tested. We estimated the phylogenetic relationships and evolutionary timescale of the iguanid lizard

Ex. Galapagos finches!

Islands provide opportunity for allopatric speciation

(FYI: Text example of **crickets** shown below fits in here too...but I am not going to focus on-principle is similar to finches.)





Ex. Snails in Hawaii

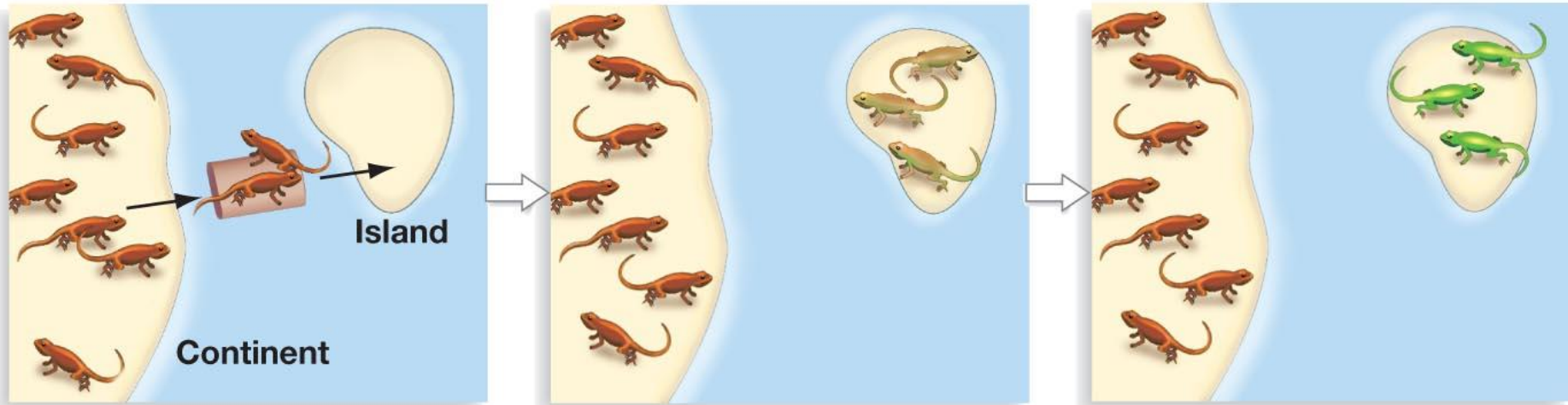
Experienced a series of **founder events** as they cross into valleys and then became isolated there.



What affects the likelihood of speciation occurring? (in either a vicariance or founder event situation)

Pops are on different islands-what factors will influence whether they speciate or evolve to be quite different after being separated....?

(a) DISPERSAL AND COLONIZATION CAN ISOLATE POPULATIONS.



1. Start with one continuous population. Then, colonists float to an island on a raft.

2. Island population begins to diverge due to drift and selection.

3. Finish with two populations isolated from one another.

Likelihood of speciation may

Depend on **selective pressures** in each location.....

More likely if..

Less likely if...

Depend on **size** of population...

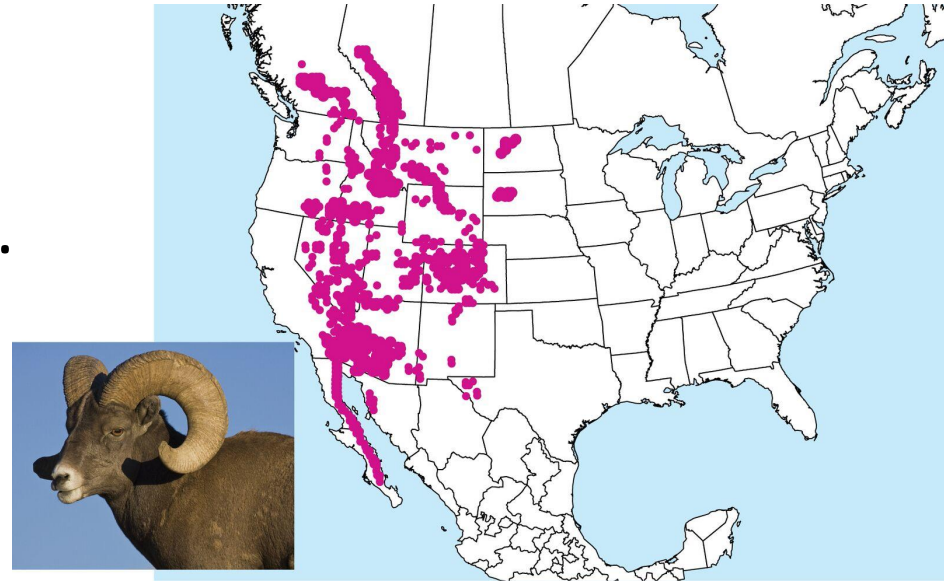
More likely if..

Less likely if...

Depend on **passage of time**...

More likely if..

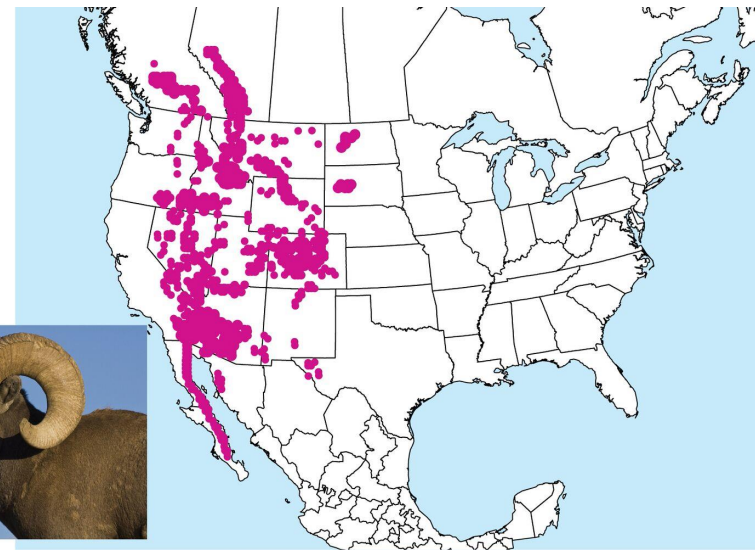
Less likely if...



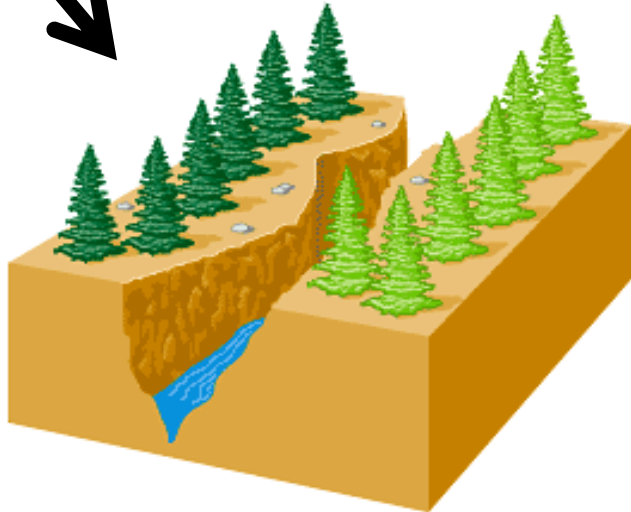
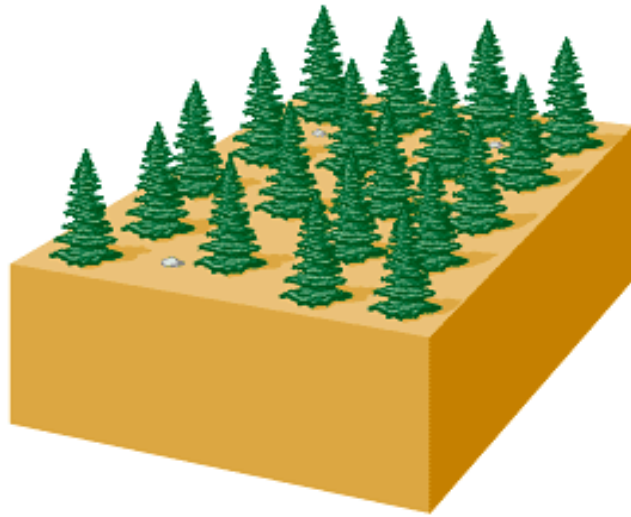
Remember

What stops gene flow in one species will be different from what stops gene flow in another species.

A feature in the landscape (a barrier) that might stop gene flow for a snail, a terrestrial beetle or a small rodent would not work for a bird or large mammal!

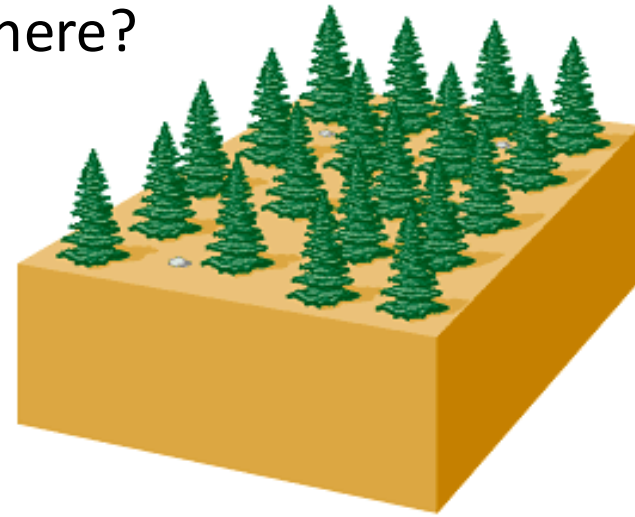


So is this a good visual to represent allopatric speciation?



(a) Allopatric speciation

Now what is happening here?



(b) Sympatric speciation

- Allopatric
 1. Vicariance
 2. Founder

- Sympatric Speciation
 1. Polyploidy
 2. “meet and mate” (my language) **Skip**

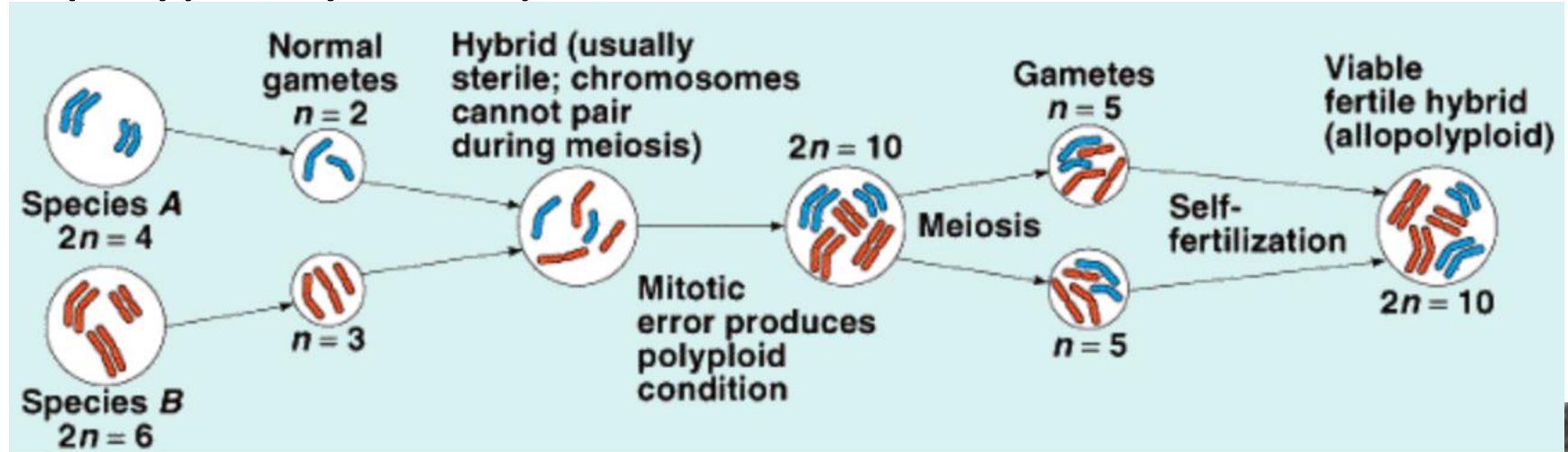
Sympatric Speciation occurs within the geographic range of parent species-gene flow is theoretically possible..

Polyploidy (allopolyploidy and autopolyploidy)

De Vries-primrose

Oh my what is happening with these gametes???!

Allopolyploidy-two species



Autopolyploidy-one species

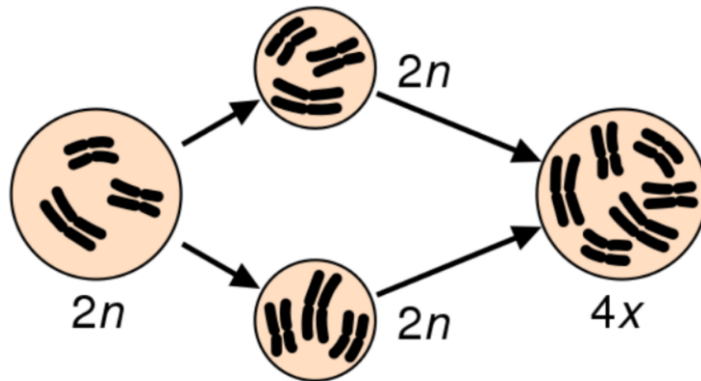


Figure 1: Autopolyploidy

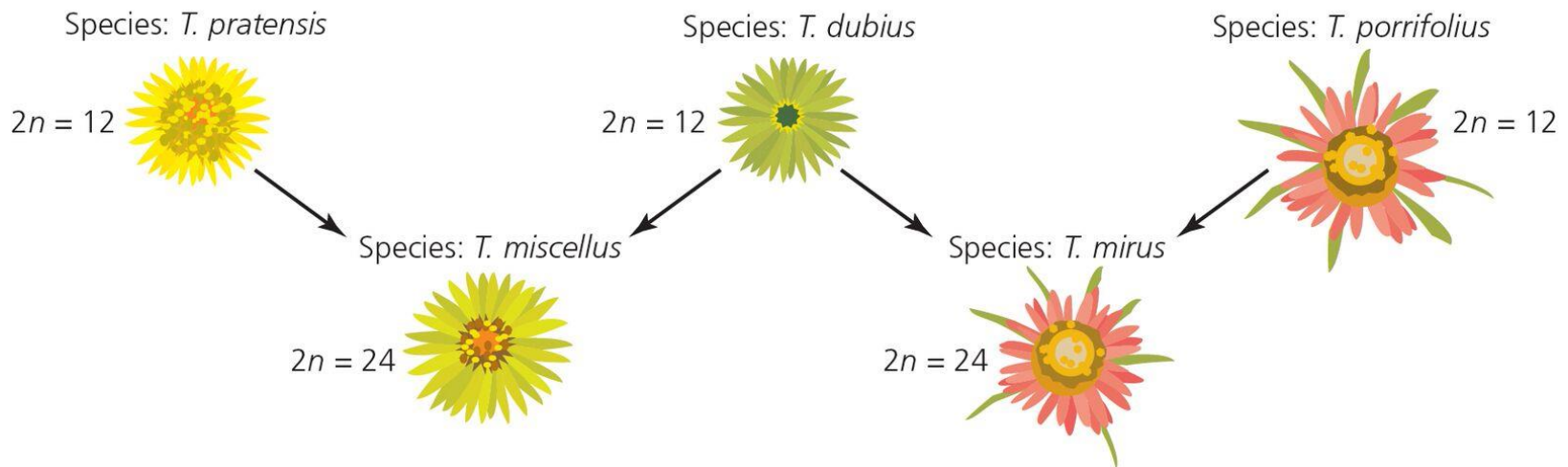




Goat's beard-a
local roadside
species!



Genus: *Tragopogon*



Polyploidy is an instant, easy, way to make a new species in **plants**..extremely common

(we went over this example earlier in semester)

Oats, cotton, potatoes, tobacco, wheat.....

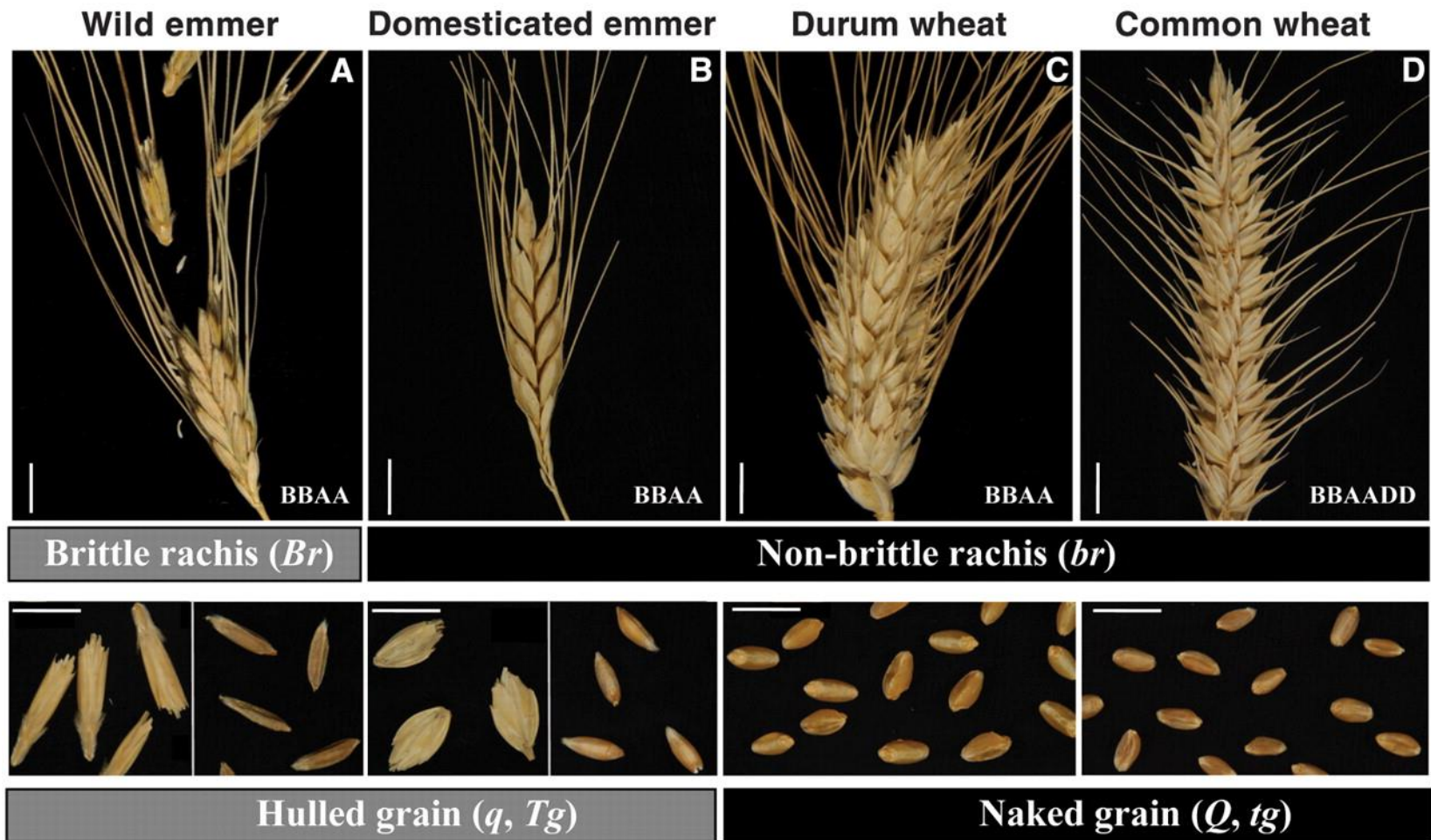
Wild wheat is normal and diploid (2x) like us...but has 2 each of 7 different chromosomes=14 chromosomes total

Durum wheat is 4x=tetraploid

Bread wheat is 6x=hexaploid

Spelt wheat is 6x=hexaploid

Fig. 1. Wheat spikes showing (A) brittle rachis, (B to D) nonbrittle rachis, (A and B) hulled grain, and (C and D) naked grain.



Jorge Dubcovsky, and Jan Dvorak Science 2007;316:1862-1866

- Allopatric
 1. Vicariance
 2. Founder
- Sympatric Speciation
 1. Polyploidy - common
 2. “meet and mate” (my language) Cool but **Skip**

Sympatric Speciation occurs within the geographic range of parent species-gene flow is theoretically possible..

Topics for this Chapter

- How do we define species?
- How do new species form?
- **Fate of hybrid zones**
- Reproductive barriers
- Problems with bacteria
- Bears, bears, bears

NOW what can happen when **two species ranges** begin to overlap?

Imagine one species diverged into two species because they were geographically separated by glaciers.

As the glaciers recede what are the possible outcomes?

A. Sometimes they are fully reproductively isolated or reproductive barriers may prevent them from interbreeding.

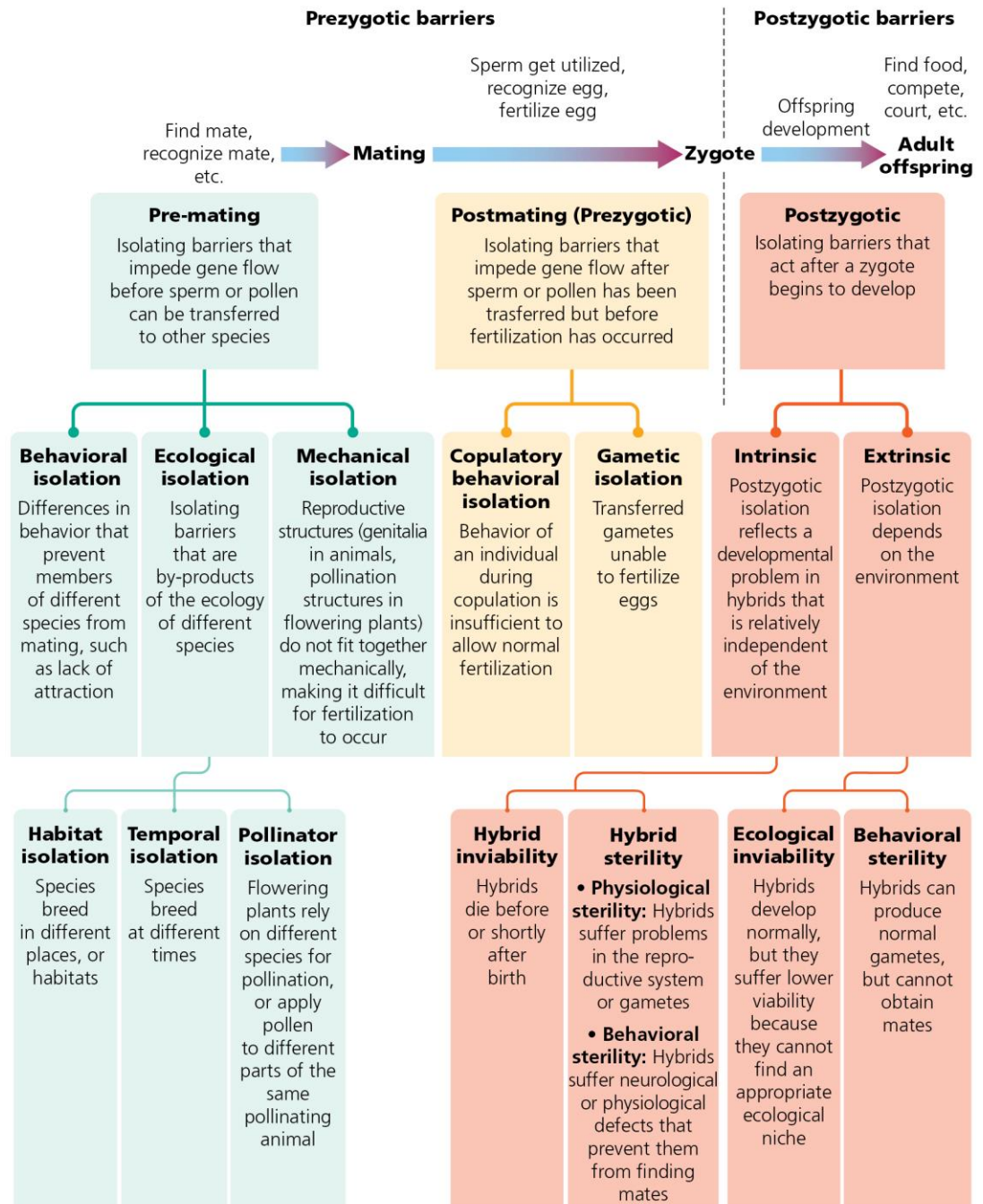
What does this mean?

Why might they not interbreed?

Tons of examples!

REPRODUCTIVE ISOLATING BARRIERS

Overview of different ways of reproductively isolating two species



My Overview of examples in text....

(All of these can keep species from breeding with one another and thus keep them separate species...)

1. What fruits you meet on to mate and lay your eggs (flies)
2. Timing of when you release your eggs and sperm in to the ocean (corals)
3. Who pollinates your flowers and when are they pollinated (monkey flowers)
4. What flashing pattern you flash when advertising to mate (lightening bug)
5. Whether the “lock” gets stuck in the keyhole of the female (carabus beetles)
6. Whether your sperm’s binding patterns recognize eggs of your species in the ocean (sea urchins)
7. Whether your offspring are fertile or not (mules =donkey x horse cross)

NOW what can happen when **two species ranges** begin to overlap?

Imagine one species diverged into two species because they were geographically separated by glaciers.

As the glaciers recede what are the possible outcomes?



A. Sometimes they are fully reproductively isolated

(reproductive barriers may prevent them from interbreeding)



B. Sometimes they interbreed and hybrid individuals might survive creating a **hybrid zone**.

Several interesting things happen in hybrid zones!

What does this mean?

Why might they not interbreed?

Tons of examples!

B. Sometimes they interbreed and hybrid individuals might survive creating a **hybrid zone**. (**SKIP**)



Bullock's (left) and Baltimore (right) Orioles often hybridize in the Great Plains, creating intermediates like the hybrid at center. Photos, left to right: Brian Small, *Bryan Calk/Macaulay Library*, David Speiser.

Over time this hybrid zone might.... <https://www.allaboutbirds.org/analysis-hybrid-birds-are-supercolliders-of-speciation/>

- 1. Fuse** - hybrids interbreed successfully with parental populations across generations-**cline**
- 2. Be a stable hybrid zone** - continue to produce hybrids (some of whom have some reproductive issues so don't do great but do ok...)

B. Sometimes they interbreed

1. Fuse

2. Hybrid zone

3. Reinforcement might evolve! (**SKIP**)

What is this?

When hybrids are less fit we often see selection in favor of individuals that prefer to mate with their own species!

“pickiness for own species evolves”

Maybe they develop the ability to perceive differences in mating song (if a bird) (short finch video we watched?)

Any individuals that have that ability will be selected for.

NOW what can happen when **two species ranges** begin to overlap?

Imagine one species diverged into two species because they were geographically separated by glaciers.

As the glaciers recede what are the possible outcomes?



A. Sometimes they are fully reproductively isolated

(reproductive barriers may prevent them from interbreeding)

What does this mean?

Why might they not interbreed?

Tons of examples!



B. Sometimes they interbreed and hybrid individuals might survive creating a **hybrid zone**.

**Take Away Point:
Interesting things
happen in hybrid
zones!**

- How do we define species?
- Reproductive barriers exist!
- How do new species form?
- Fate of hybrid zones
- **Problems with bacteria**
- Bears, bears, bears

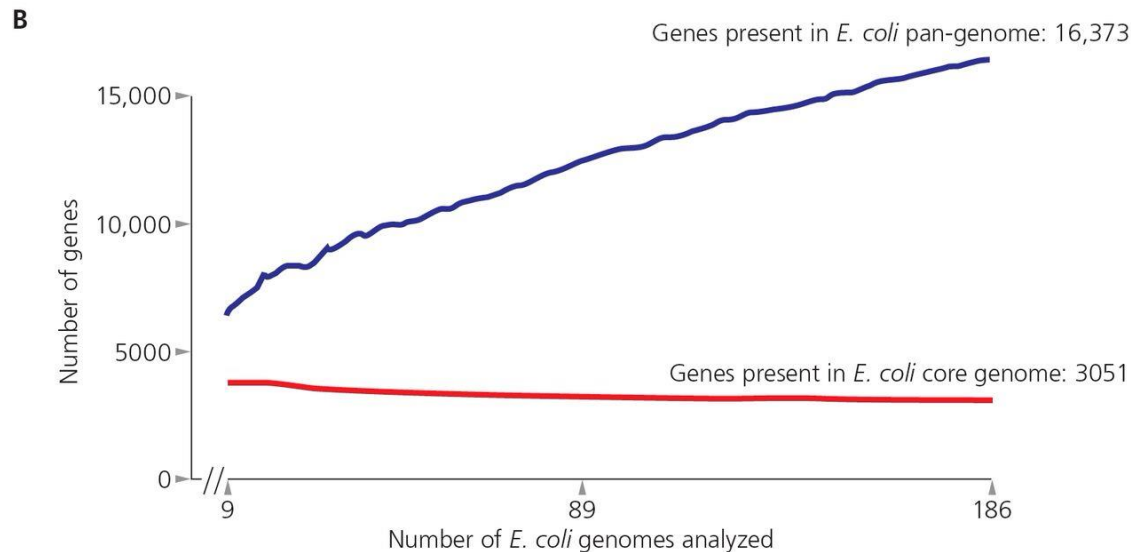
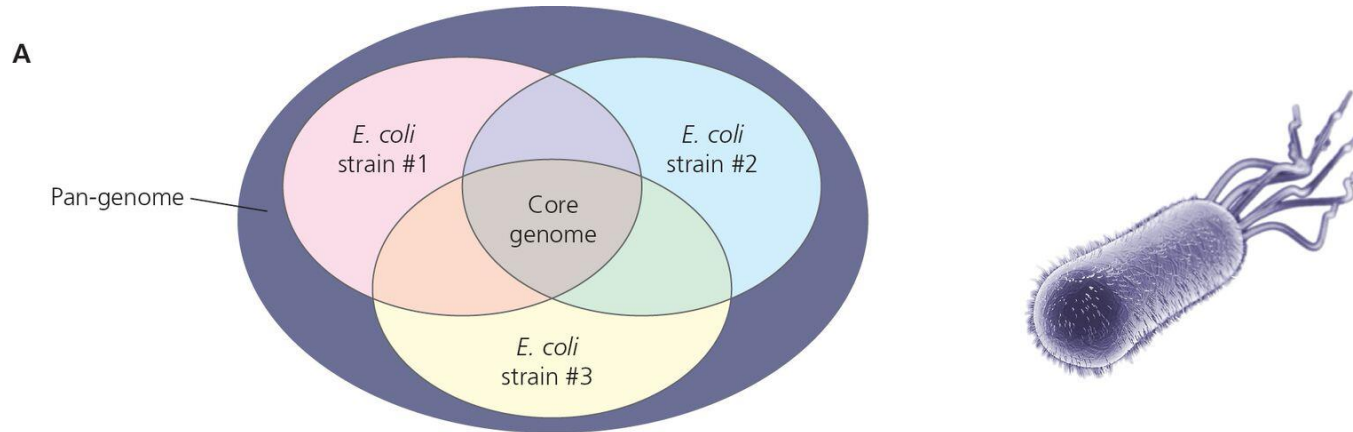
What are some of the problems with defining species in bacteria?

(Go back to our species concepts or species “definitions.”)

1. Interbreeding?
2. Morphology?
3. Phylogenetic (this can work-kind of)

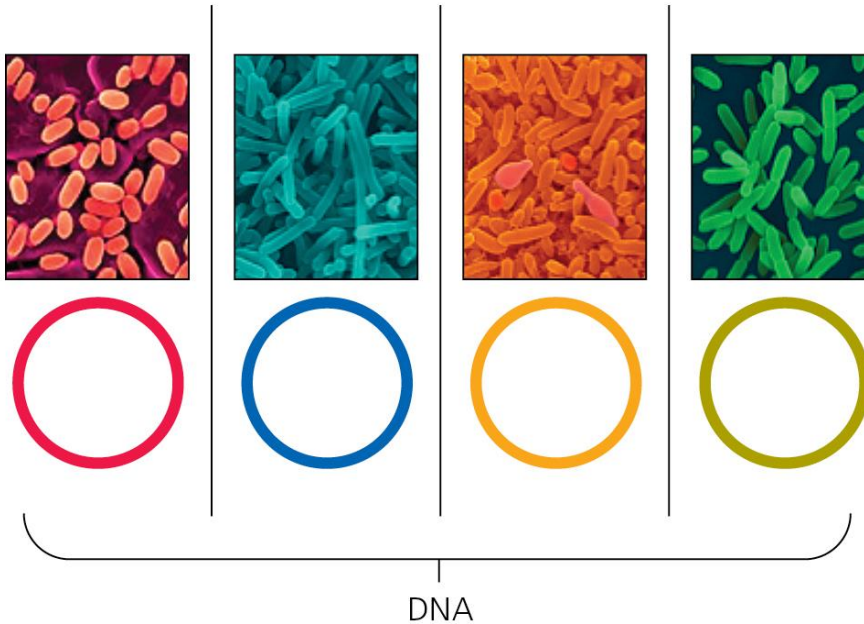
Three strains of single species had only a small part of their genome in common!

The **genetic structuring** of bacterial populations is totally different than in Eukaryotes!

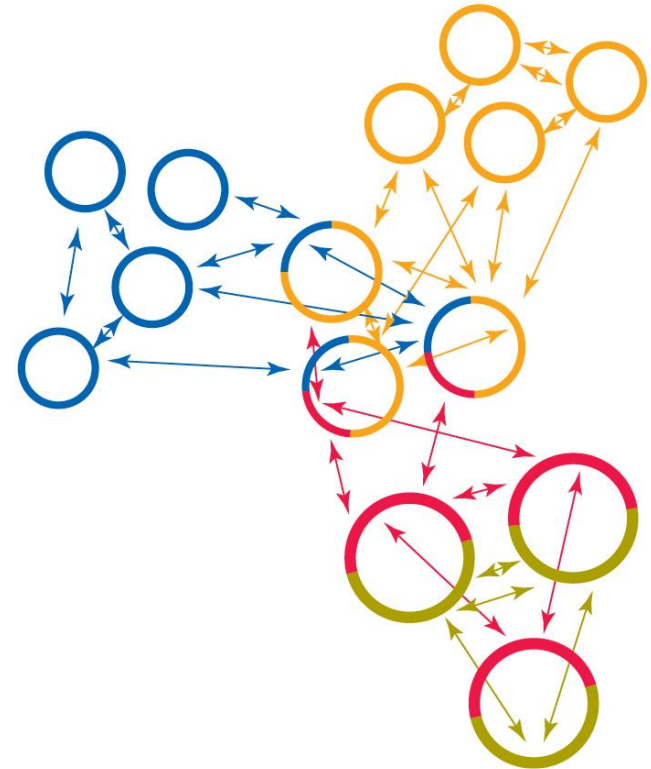


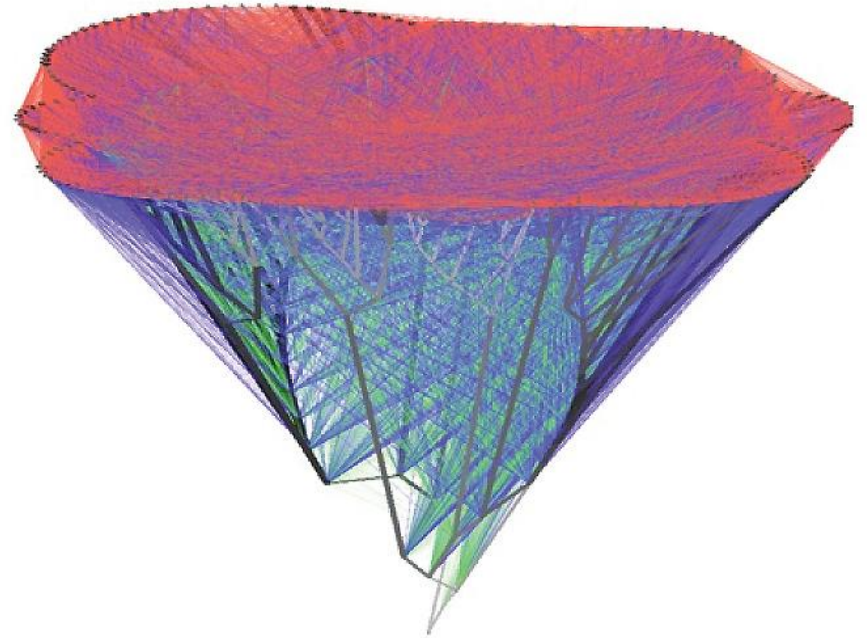
Horizontal gene transfer really messes things up when we are trying to define species!

Instead of being neatly divided by species barriers ...



...the genomes of microbes have been mixed together by horizontal gene transfer.





Horizontal gene transfer is common..basically gene flow in bacteria is HGT!

This is what happens when we try to visualize it.

Bears, bears, bears

Polar bears diverged from brown or grizzly bears pretty recently.

(FYI there are also black bears - that is what we have in MN)

Hypothesis for divergence date #1
based on fossils
150,000-800,000

Hypothesis for divergence date #2
based on molecular clock
343,00-479,000

Population that evolved into polar bears were probably an isolated population of brown bears that began to experience strong selection for certain traits.



How do we figure out whether differences in genes between the two are a result of selection?

“strong selection can sweep alleles to fixation, carrying with them flanking stretches of DNA” p435

(So just like lactase persistence!)

Many of the regions that show signs of strong selection are important to their new ecological niche (their way of life)

- One region involved in pigmentation

Why important?

- One region helps them handle large amounts of cholesterol

Why important?

- One region is related to heart function

Why important?

Gene flow between these two species has occurred since divergence
(interbreeding=introgression=admixture!)

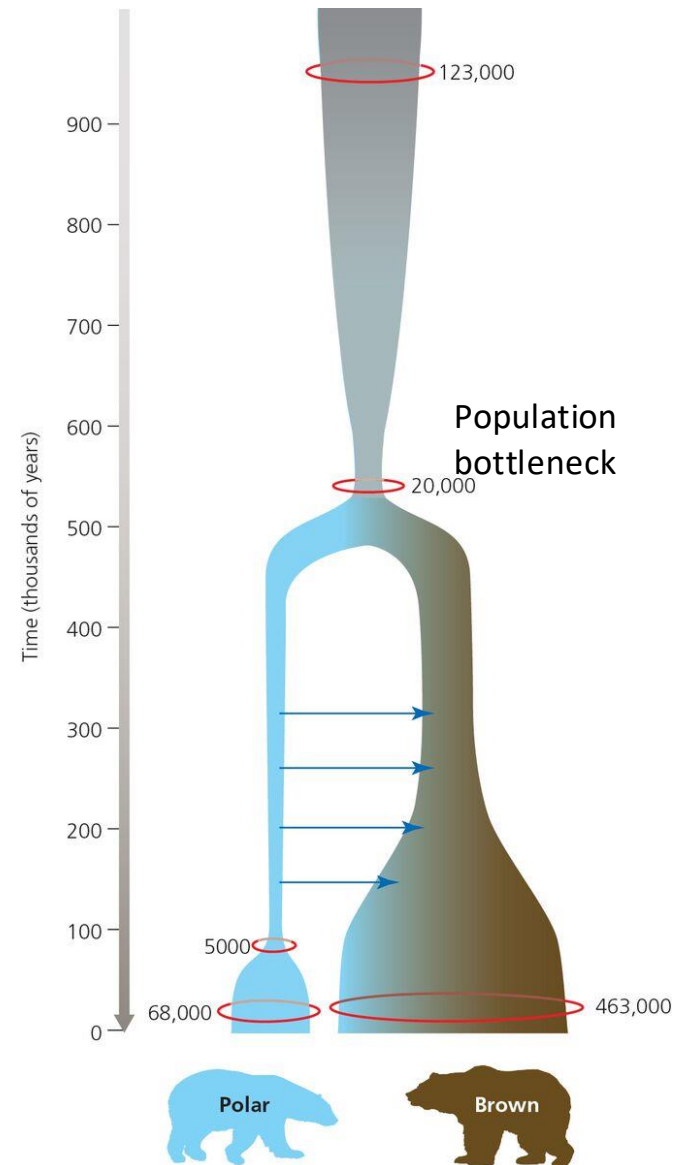
But cool because only occurring in one direction-we only find polar bear genes in brown bear pops!!

What might cause polar bear genes to show up in brown bear populations when brown bear genes are NOT showing up in polar bear populations?

Selection!

It must be that _____ bear genes are being selected against in _____ habitat.

Has happened in past but may be becoming more common due to climate change!



If you found a hybrid bear, how could you tell what species the mother was and what species the father was?

Be sure to Read
Love in the time of climate change.

- What did you learn?
- What do they mean when they say *“I hate to say it but from a genetic perspective its quite likely grizzly bears will eat polar bears up.”*

Grizzlies and polar bears are now mating regularly



You might consider checking in on your understanding of the following review questions....

- Speciation is always about stopping_____.
- What are the three main species concepts we talked about?
- What is allopatric speciation?
- What are the two different kinds of allopatric speciation?
- Sympatric speciation is....?

Perspective

Common misconceptions of speciation

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A nice recent review!

There is no unified, consistent, or clear-cut concept or working definition for species that all speciation researchers use. Ultimately this derives from the fact that natural diversity is not organized into clear-cut boxes of individuals with unambiguous ecological, phenotypic, or genetic divisions between them. This is, in part, a consequence of most speciation processes not being instantaneous. Any process of divergence that is protracted over long time periods necessarily implies that the boundaries between 'species' are fuzzy in many cases. In other words, even if the label of 'species' is helpful in describing patterns of divergence that have evolutionary significance, no amount of agreement over species concepts and definitions can overcome this fundamental constraint.

But even putting this aside, researchers may differ greatly in their views of how to define species in practice. There are many concepts of what 'species' represent, each assigning different importance to various forms of distinctiveness, including ecological, phenotypic, phylogenetic, reproductive, and genetic distinctiveness. And within each concept, researchers working with different taxa or with different approaches might adopt different working definitions in order to delineate species in practice. Some of the concepts have well-known flaws. In many schools, students are taught that species are groups of individuals that can interbreed to produce fertile offspring and that are reproductively isolated from other such groups [the strict 'Biological Species Concept' (Mayr 1970)]. That is certainly true if one compares, say, a penguin and a zebra, but looking at more closely related species, it gets complicated. A definition for species that relies on complete reproductive isolation is incompatible with the widespread occurrence of hybridization between pairs of lineages that can be quite distantly related and are sufficiently ecologically, phenotypically, and genetically distinct that assigning the label of 'species' is useful from an evolutionary perspective. We now recognize that a large proportion of lineages have a history of hybridization with at least one other lineage that is described as a different species (Mallet 2005, Ellstrand 2014). In our view, the important question is not whether hybridization is zero but whether reproductive isolation between two lineages is sufficient that they can coexist without merging due to hybridization. However, many recently diverged taxa have little overlap of distribution ranges and in areas of contact they show intermediate levels of reproductive isolation. Where we set the threshold of 'sufficient reproductive isolation' is arbitrary. To complicate matters further, reproductive isolation can change over time and space and depend on environmental factors. A clear classification into species is thus often not possible.