Last Evolution Lecture (#9) and First Ecology Lecture (#1)

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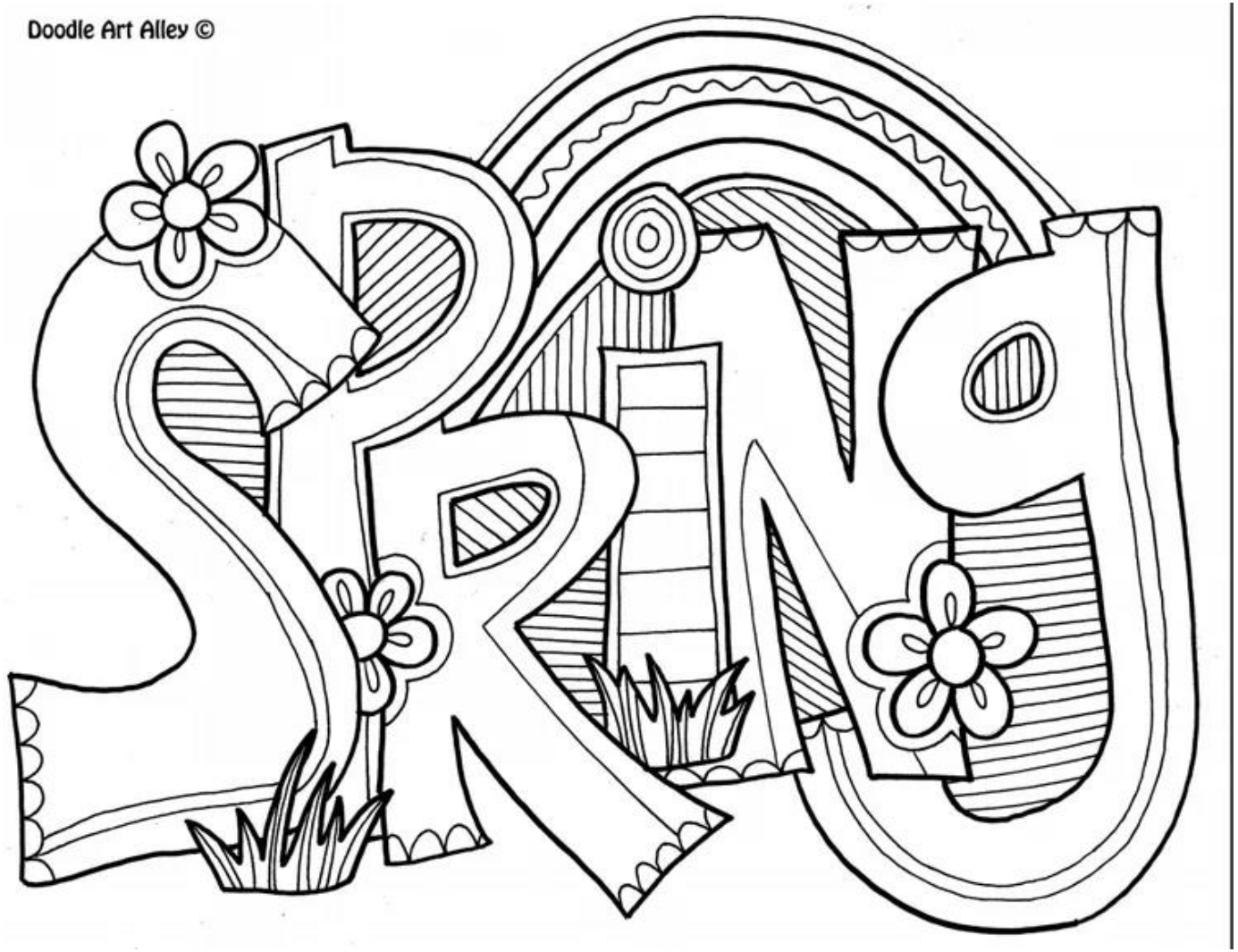


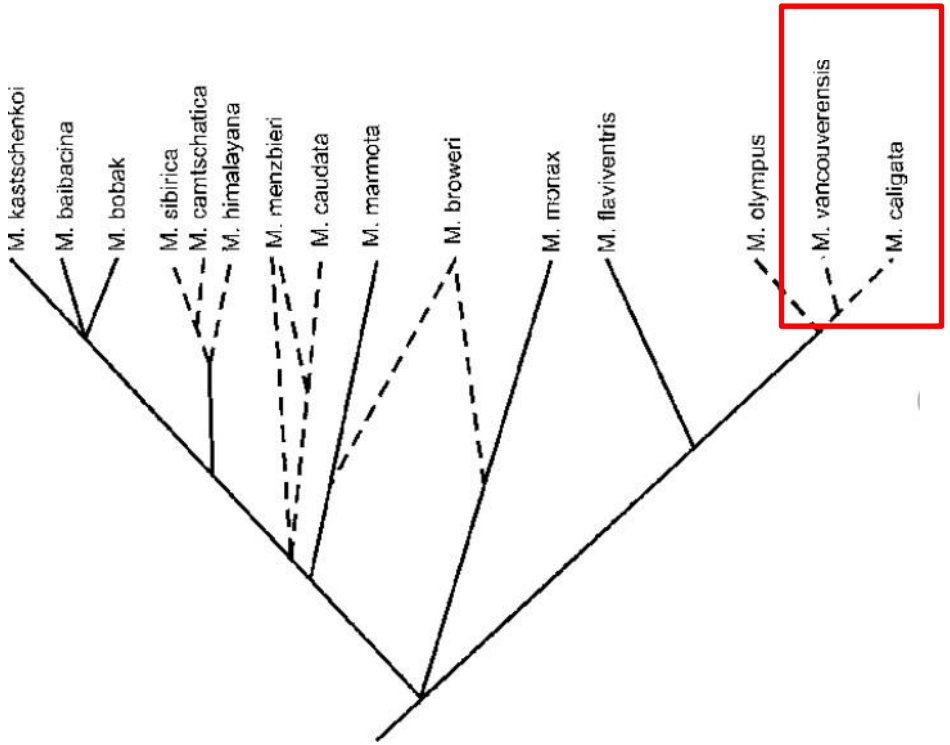
Group Project

- I will post some examples from last term by tomorrow afternoon.
- I will also answer any questions at the beginning of Thursday's class

- You can see the rubric if you click on the submission link (it is a Canvas rubric).
- All content requirements are described in the Group Project Description on Canvas > Group Project Information.

Species Concepts Question

Marmots are the largest member of the squirrel family (Family Sciuridae). In British Columbia, the Hoary Marmot (***Marmota caligata***) inhabits mountainous regions on the mainland. The Vancouver Island Marmot (***Marmota vancouverensis)*** is the only marmot species found on Vancouver Island and likely represents the descendants of a small population of Hoary marmots that became isolated from the mainland population after sea levels rose at the end of the last ice age, approximately 10,000 years ago. The table below has information on the characteristics of both species.



Factor	Vancouver Island Marmot	Hoary Marmot
Fur Colour	Chocolate Brown with white patches	Silver Gray
Weight	Up to 5 kg (adult)	Up to 10 kg (adult)
Length	Up to 47 cm (adult)	Up to 82 cm (adult)
Habitat	High alpine meadows and rocky slopes	High alpine meadows and rocky slopes
Diet	Herbivore – eat plant material such as ferns, mosses, grasses, berries	Herbivore – eat plant material such as ferns, mosses, grasses and berries
Predators	Wolves, cougars, golden eagles	Wolves, cougars, golden eagles

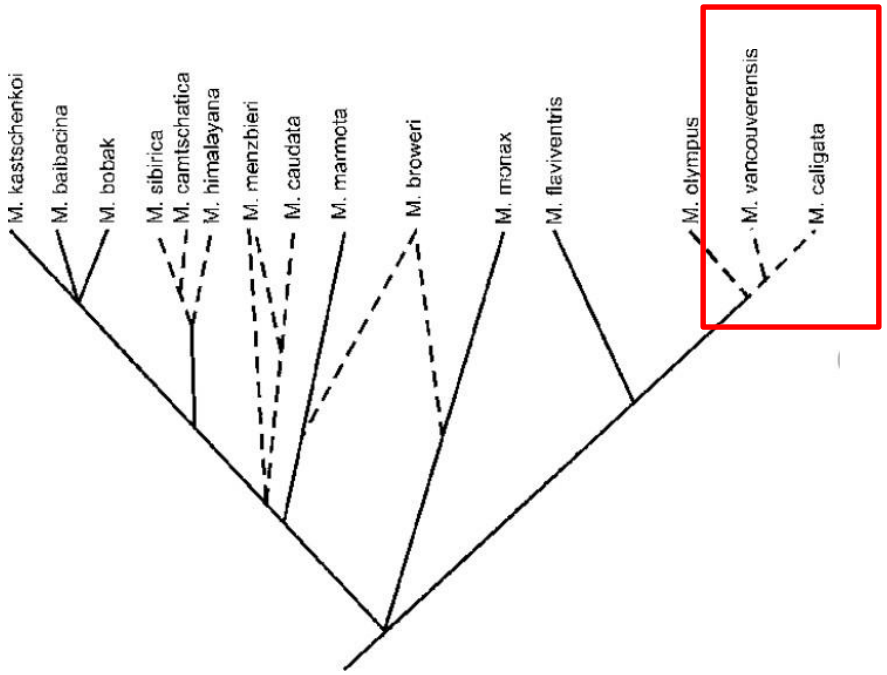
Vancouver Island Marmot (***Marmota vancouverensis***)

Hoary Marmot (***Marmota caligatas***)

iClicker Question

Which species concepts could be used to justify classifying the Vancouver Island Marmot and the Hoary Marmot as two separate species:

A. Biological Species Concept
B. Morphological Species Concept
C. Ecological Species Concept
D. Phylogenetic Species Concept
E. Band D



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Answer

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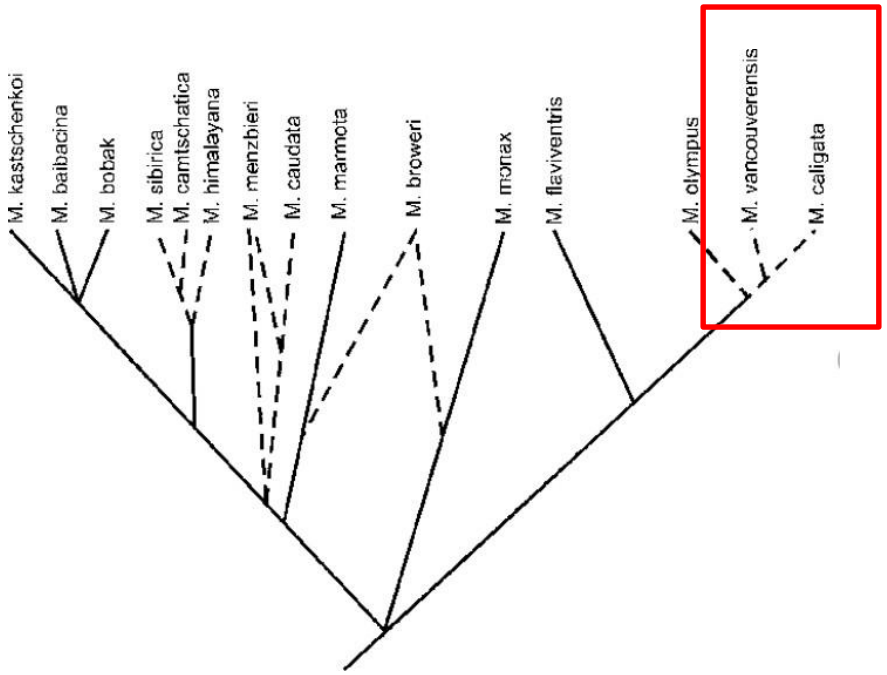
E. Band D

New Question: Provide a written answer to this question using the Morphological Species Concept.



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Example Answer

- Claim: The morphospecies concept would justify the classification of the two marmots as separate species.
- Logic/Reasoning: According to the morphospecies concept two taxa can be classified as separate species if they have different morphological traits. The two marmots differ in their body size and fur colour.
- Evidence: The Vancouver Island Marmot is smaller than the Hoary Marmot. Specifically, the VIM is lighter (up to 5 kg) than the Hoary Marmot (up to 10 kg) and is shorter in body length (up to 47 cm vs 82 cm). The Vancouver Island Marmot also has brown fur, whereas the Hoary marmot has grey fur.
- Reasoning (So, hence, therefore): Therefore, given that the differences in body size and fur colour make the two taxa morphologically distinct, the morphospecies concept would justify their classification as two separate species.

iClicker Question

Order the statements below to match the typical steps in the process of speciation

1) A combination of mutation, genetic drift and natural selection cause the populations to become genetically different from each other over time.

2) Individuals of two species are unable to breed successfully with each other because of prezygotic or postzygotic reproductive barriers.

3) Individuals from a parent population establish a new, separate population

A. Correct statement order: 1, 2, 3

B. Correct statement order: 2, 1, 3

C. Correct statement order: 2, 3, 1

D. Correct statement order: 3, 1, 2

E. Correct statement order: 3, 2, 1

Answer

Order the statements below to match the typical steps in the process of speciation

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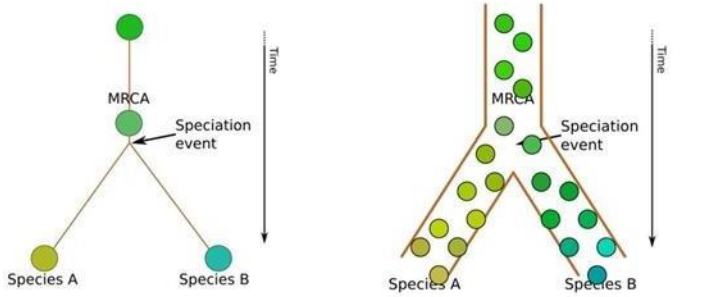
E. Correct statement order: 3, 2, 1

3 steps to speciation – order of steps is important

1. All or part of a population becomes genetically isolated from other members of the population/species.
   - No gene flow!!

2. Isolated populations diverge genetically
   - Due to mutations, natural selection, and/orgenetic drift affecting populations independently.



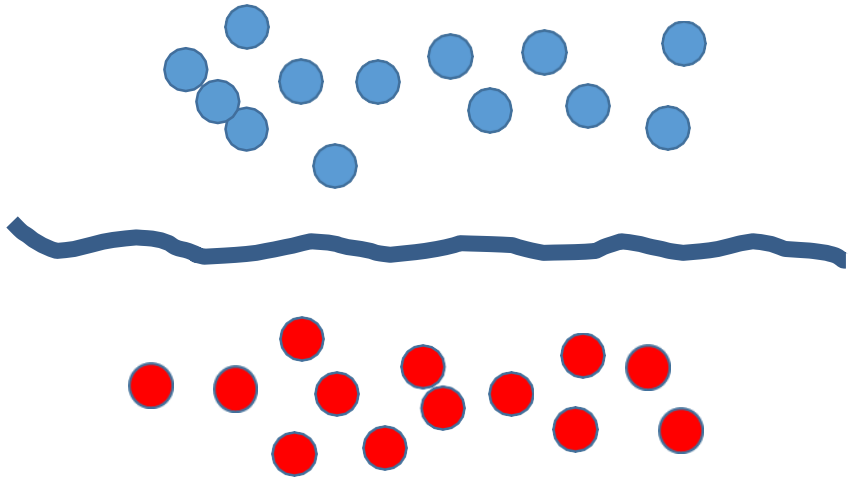
3. Reproductive isolation

   Prezygotic/postzygotic barriers to reproduction evolve (see examples under BSC).
   - So, if two populations that have been isolated from each other come into contact again…
   - They would would be unable tomate, and/or could mate but produce offspring with low survivorship and/or low fitness.

Two* mechanisms of speciation

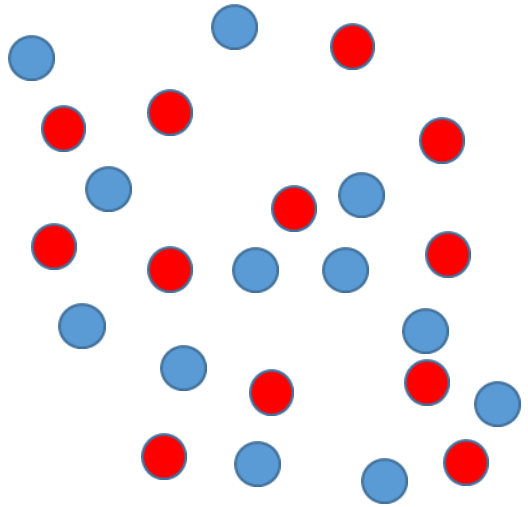
Allopatric Speciation

- Geographic separation of populations (e.g. barrier or distance).
- No gene flow between populations



Sympatric Speciation

- No physical barrier to separate individuals in the population.
- Some other mechanism results in reproductive isolation between populations



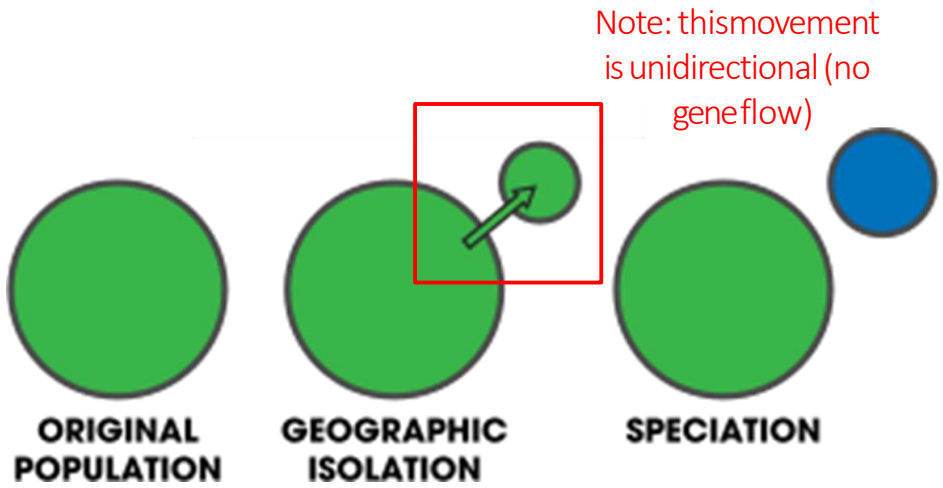
* There are others

Allopatric speciation

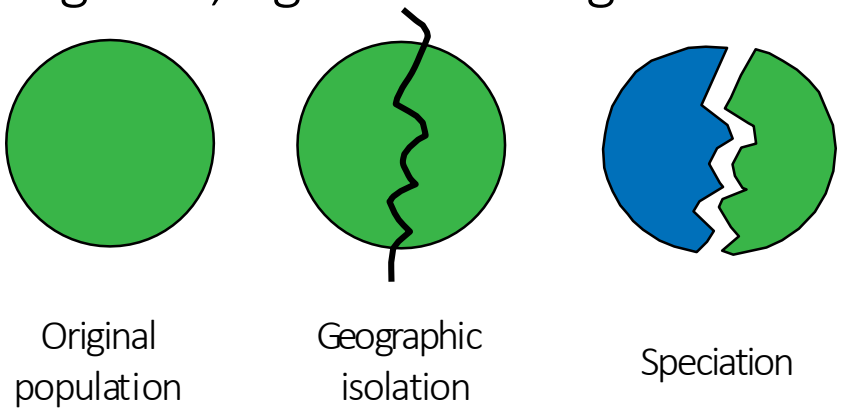
Populations become <u>geographically isolated</u>.

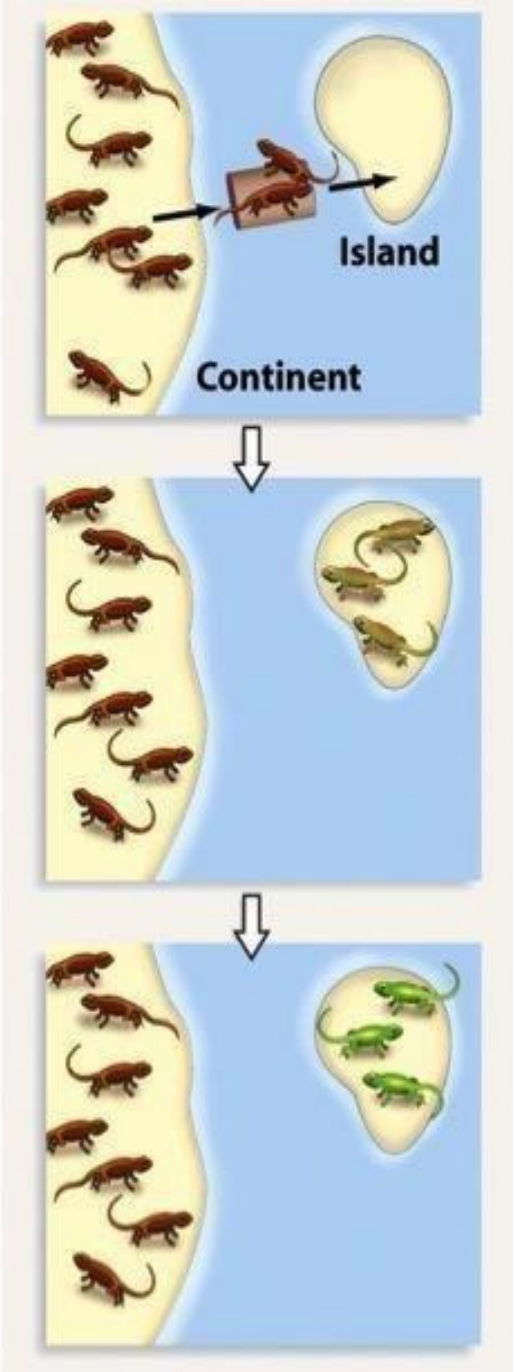
Two ways this can happen.

1. Dispersal: movement of individuals away from their source population (founder event).



2. Vicariance: physical splitting of one population into two or more smaller populations due to the formation of a geographic barrier, e.g. a river changing course, a road being built, a glacier forming





Allopatric speciation: dispersal

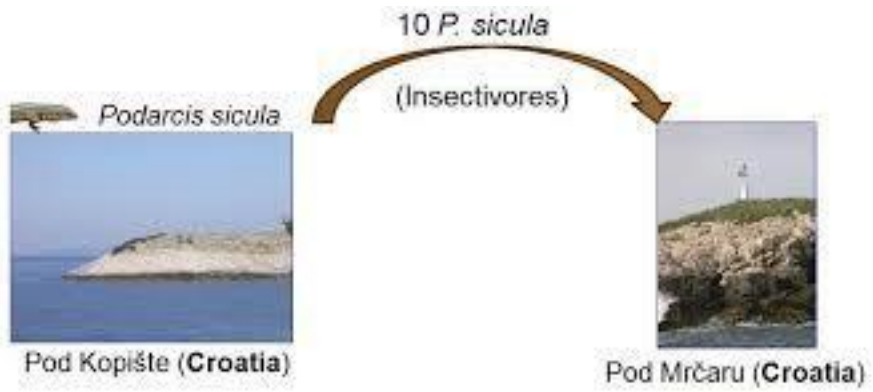
1. Some individuals from a population <u>disperse</u> to a new location
   - No gene flow between populations.
2. Allele frequencies of colonists begin to diverge from source population
   - Genetic drift (e.g., founder effect)
   - Natural selection (e.g., new habitat differs from source habitat)
   - Mutation (plus natural selection and/or genetic drift)
3. Pre-/post zygotic isolation develops
   - Even if colonists and source population individuals meet again, they are unable to produce fertile offspring

   Speciation is complete!

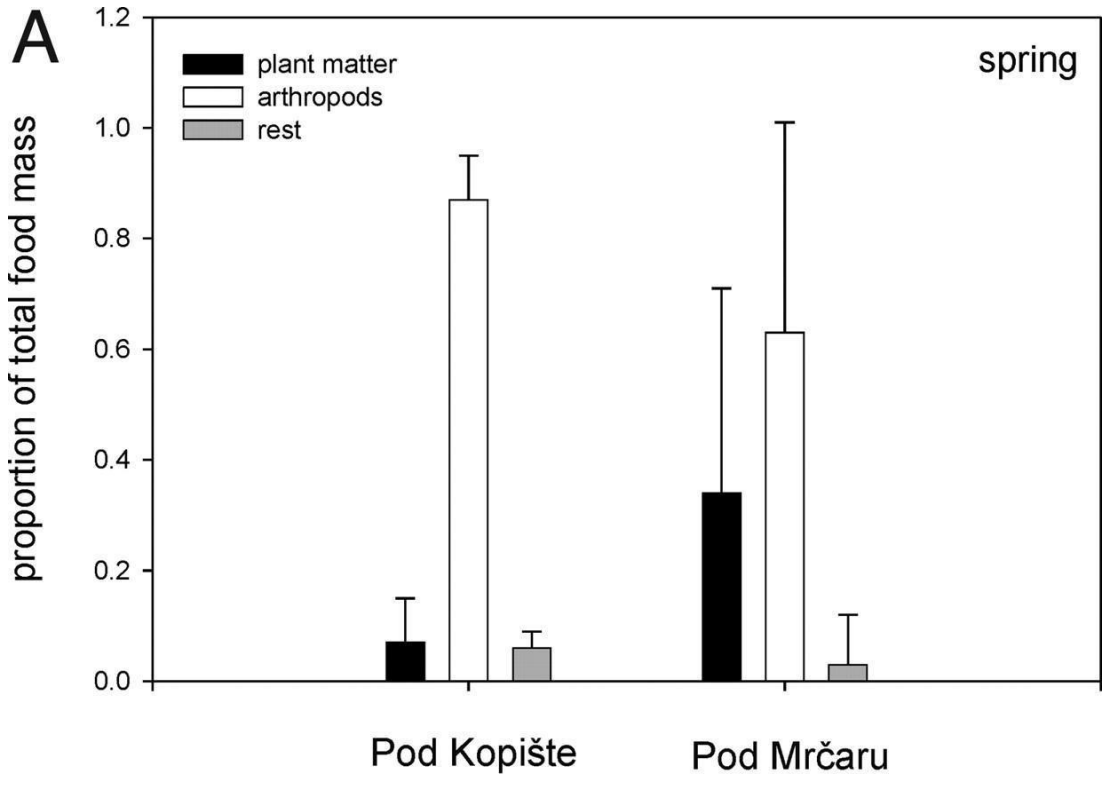
Note – issue with this figure – the population on the mainland should also be evolving; so imagine that it too changed colour, or evolved spots or something ☺ .

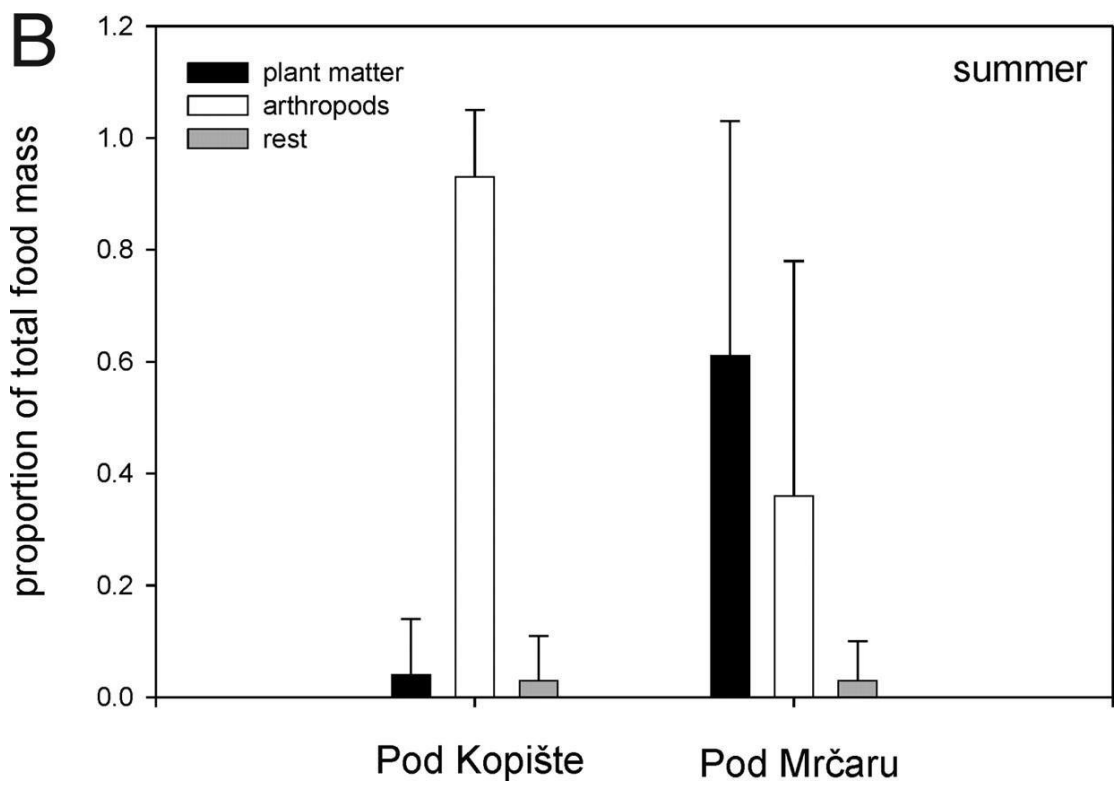
Real life example - beginning of allopatric speciation via dispersal (founder effect) – European wall lizard

- European wall lizard (***Podarcis sicula***)
- In 1971, five pairs of adult wall lizards (***Podarcis sicula***) from an island (Pod Kopiste) were introduced to an island (Pod Mrčaru) off the coast of Croatia by researchers
- Scientists returned to Pod Mrčaru in 2004-2006 (33 years later or about 30 lizard generations)
- There were >5,000 wall lizards on the island all genetically related to the original 10 lizards.
- Major evolutionary changes

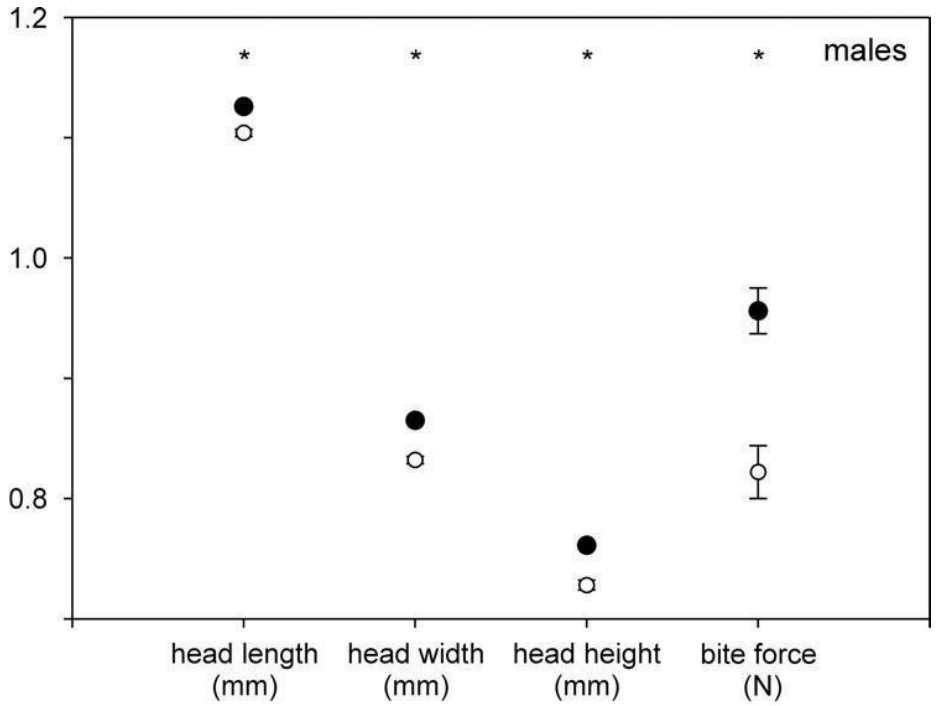


Lizards on Pod Mrčaru (new island) eat significantly more plant material (dark bars) than the lizards on the ancestral island (Pod Kopiste), especially in the summer.



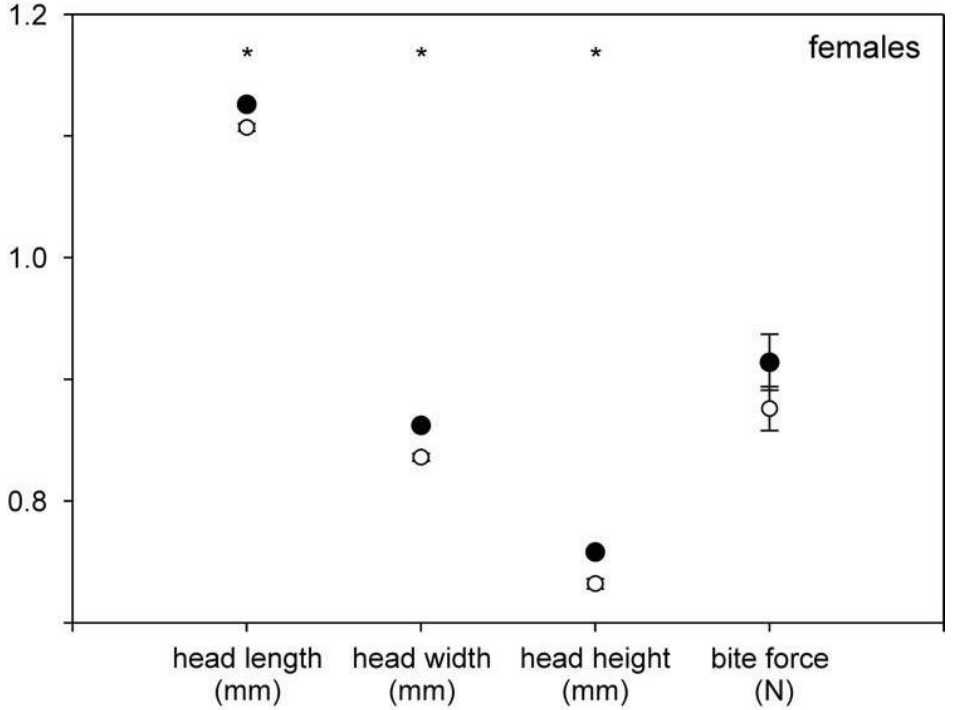


Anthony Herrel et al. PNAS2008;105:4792-4795



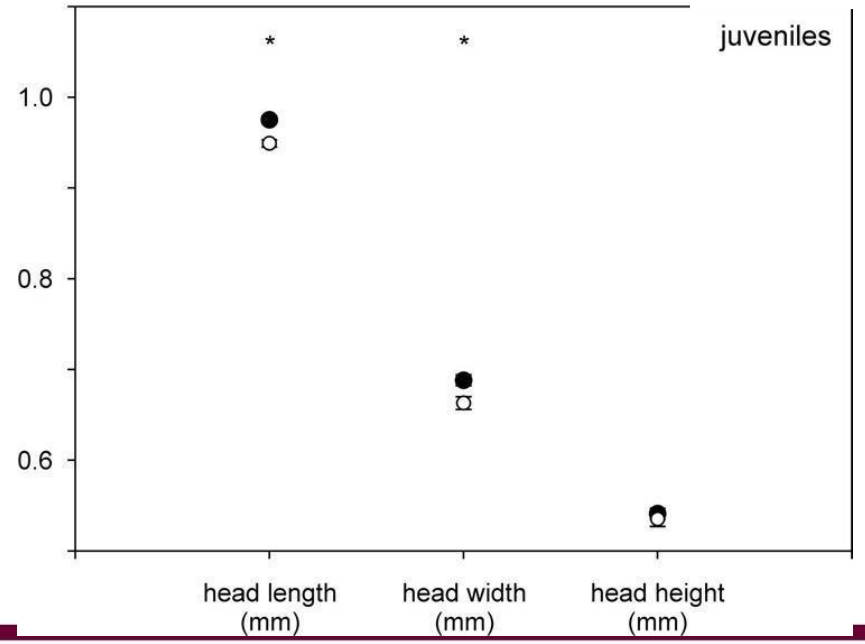
Black dots – lizards on new island

Open dots – lizards inhabiting ancestral site



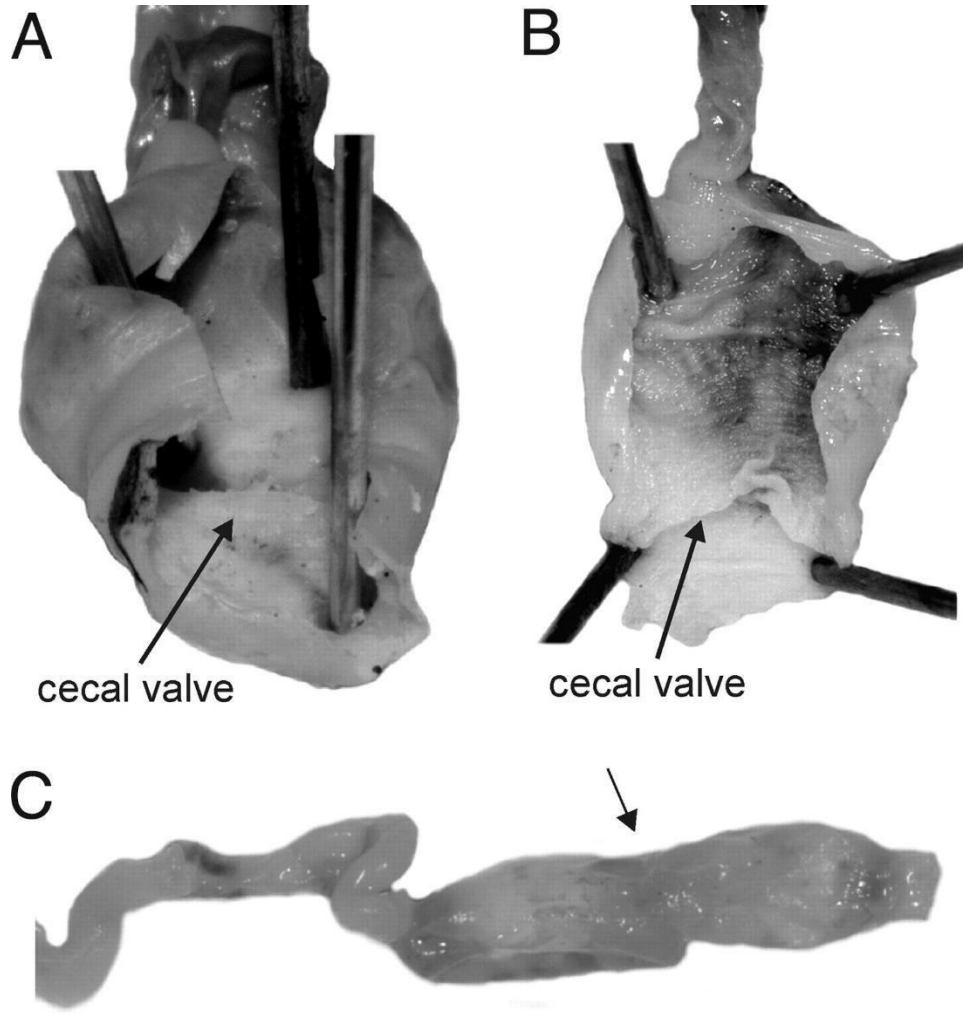
Are there morphological differences between the wall lizards introduced to the new island (Pod Mcraru) and the lizards on the original island?

A. Yes
B. No
C. Not sure



Anthony Herrel et al. PNAS 2008;105:4792-4795

Cecal valves in a male (A), a female (B), and a hatchling (C) ***P. sicula*** from Pod Mrčaru.
Not present in lizards on ancestral island (very rare in lizards in general)



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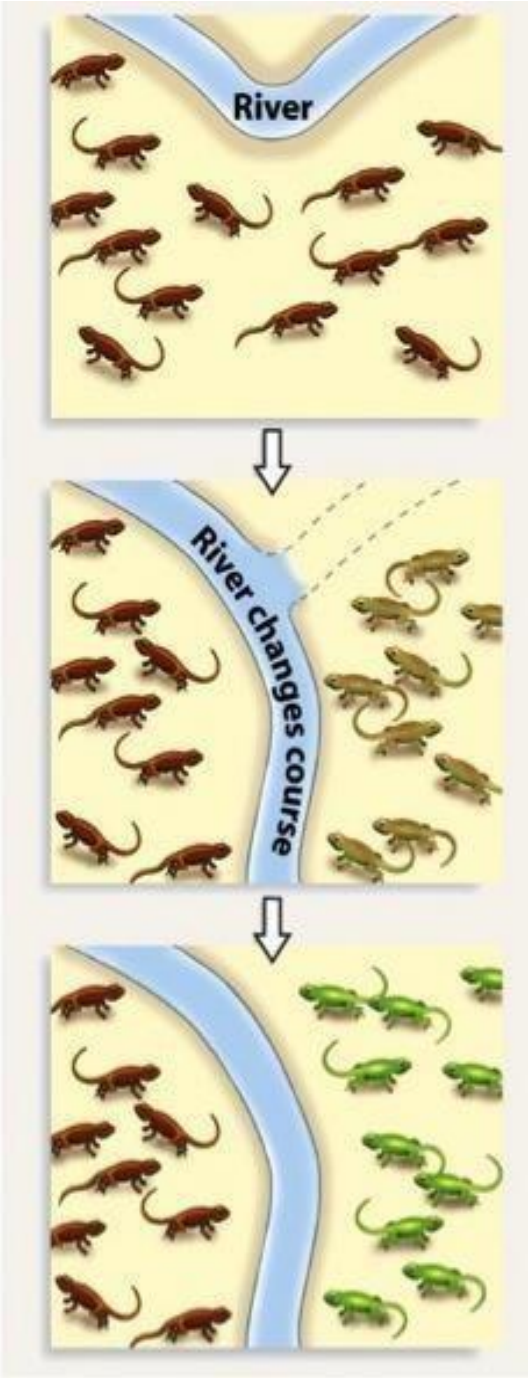


Allopatric speciation: vicariance

1. Population becomes separated into 2+ subpopulations by a **physical barrier**
   - Barrier stops gene flow
2. Allele frequencies of two populations begin to diverge
   - Genetic drift (e.g., founder effect)
   - Natural selection (e.g., new habitat differs from source habitat)
   - Mutation (plus natural selection and/or genetic drift)
3. Pre-/postzygotic isolation develops
   - Even if individuals from the two populations meet again, they are unable to produce fertile offspring

Speciation is complete!

Vicariance – physical barrier separates a population

physical barriers can be smaller, e.g. a road

Glacial period, Pleistocene ~ 1.8 million years ago

Coastal mountains formed 100 million years ago

Canyons

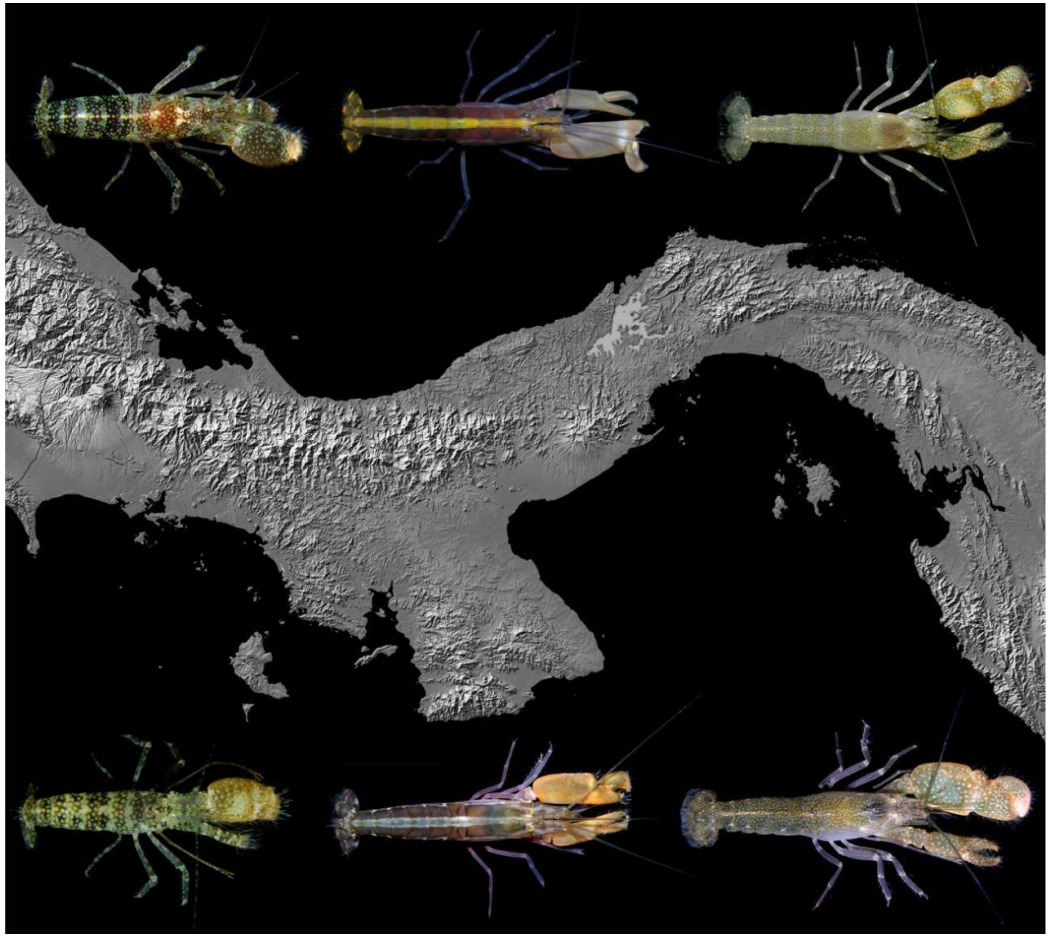
Source: Malachy Labrie-Cleary

Example #1 of allopatric speciation: Snapping shrimp

- About 5 million years ago, there was a gap between North and South America
- Ocean water covered the area where Panama and Costa Rica are today.
- Marine organisms could move back and forth between the Pacific Ocean and Caribbean sea (so gene flow could occur among populations).
- But about 3 million years ago, a land bridge, called the Isthmus of Panama formed separating the two oceans.
- This land bridge acts as a barrier to the movement of marine organisms between the two oceans, stopping gene flow.
- The separated populations could follow their own evolutionary path.

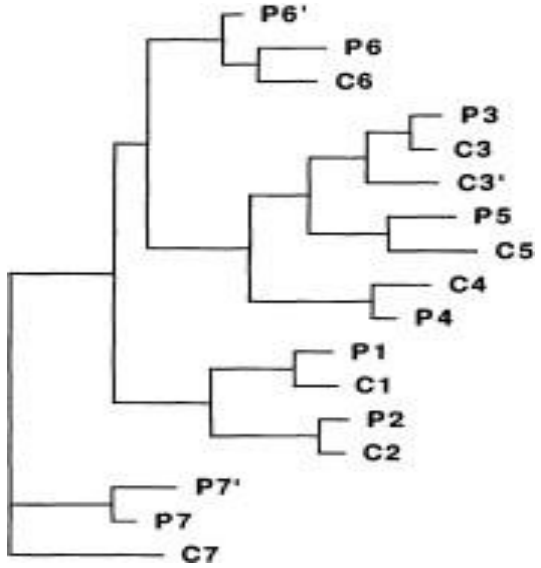
https://earthobservatory.nasa.gov/images/4073/panama-isthmus-that-changed-the-world

https://www.whoi.edu/oceanus/feature/how-the-isthmus-of-panama-put-ice-in-the-arctic/



https://insider.si.edu/2016/08/recent-connection-north-south-america-reaffirmed/

- Populations of snapping shrimp have diverged into separate species.
- In the 1980's, using morphological data, researchers identified 7 species pairs of snapping shrimp (one species of each pair in the Pacific Ocean and one in the Caribbean).
- In the 1990's, genetic analysis confirmed that the individuals in each species pair were each other's closest relatives.
- Prior to the formation of the Isthmus, the pair had once belonged to the same population, but became isolated, and diverged from each other genetically.

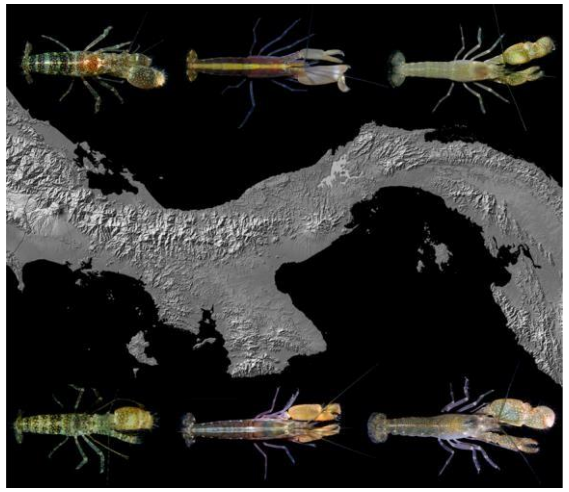


P=pacific
C=Caribbean

Knowlton et al. 1993

Example #1 of allopatric speciation: Snapping shrimp

- When the researchers (Knowlton et al. 1993) brought individuals from the pairs together, they showed little interest in mating, but they did snap at each other (aggressive)
- If they did mate, rarely produced fertile offspring



1. Isolation – due to formation of land bridge
2. Genetic Divergence
3. Reproductive Isolation

So speciation (allopatric speciation via vicariance) is complete

Local example of Allopatric speciation via vicariance

Haida Gwaii northern saw-whet owl subspecies (***Aegolius acadicus brooksi)*** separated from mainland population (***A. a. acadicus***) by Pleistocene glaciers ~ 16,000 years ago.

The Auk
Ornithological Advances
www.aou.org
Volume 131, 2014, pp. 73–85
DOI: 10.1642/AUK-13-187.1

RESEARCH ARTICLE

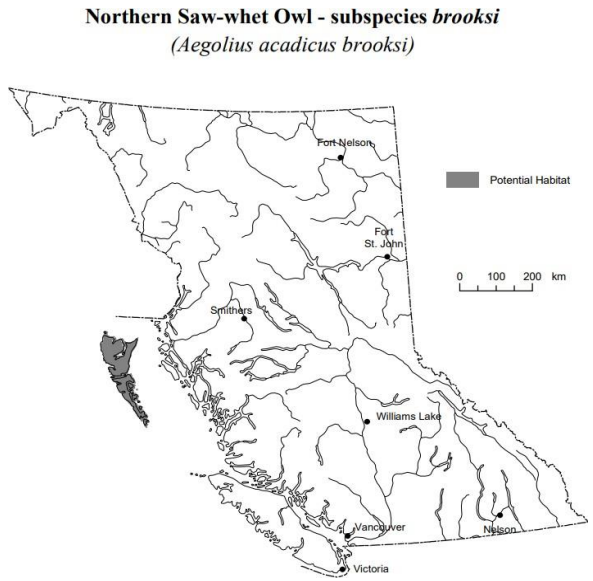
Genetics of divergence in the Northern Saw-whet Owl (*Aegolius acadicus*)

Jack J. Withrow,[1]* Spencer G. Sealy,[2] and Kevin Winker[1]

Diverged genetically from mainland population.

Speciation complete??

Fight to get Haida Gwaii northern saw-whet owl listed as a separate species. Currently listed as threatened primarily due to decreased habitat availability (logging).

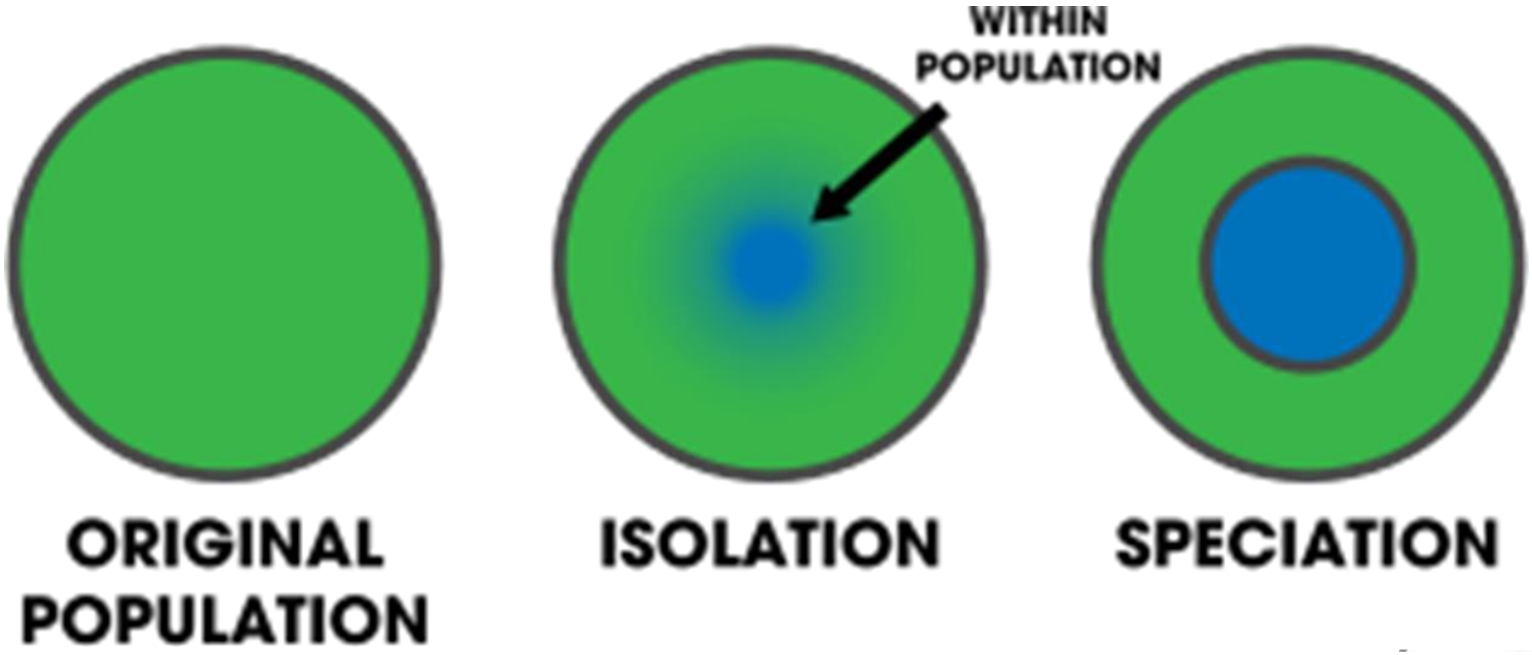


https://www.env.gov.bc.ca/esd/distdata/ecosystems/frpa/IWMS_Spatial_Data/final_maps/pdfs/b-nsow-br.pdf

Sympatric speciation

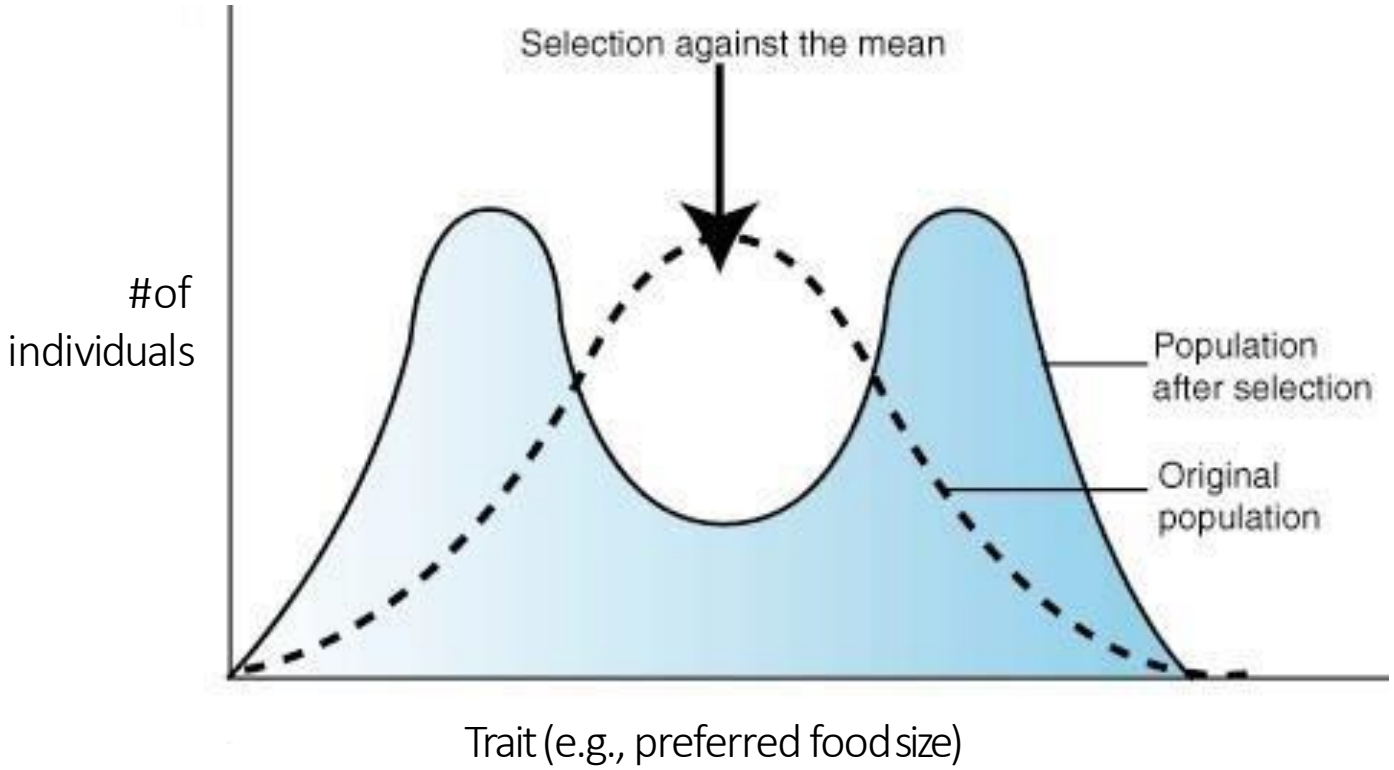
Evolution of new species from ancestral species while continuing to inhabit the same geographic area.

Some individuals in a population become reproductively isolated, even though they live in the same area…how?!



Sympatric speciation can be due to disruptive selection

If mean trait values are selected against, populations may begin to diverge (even in sympatry)!

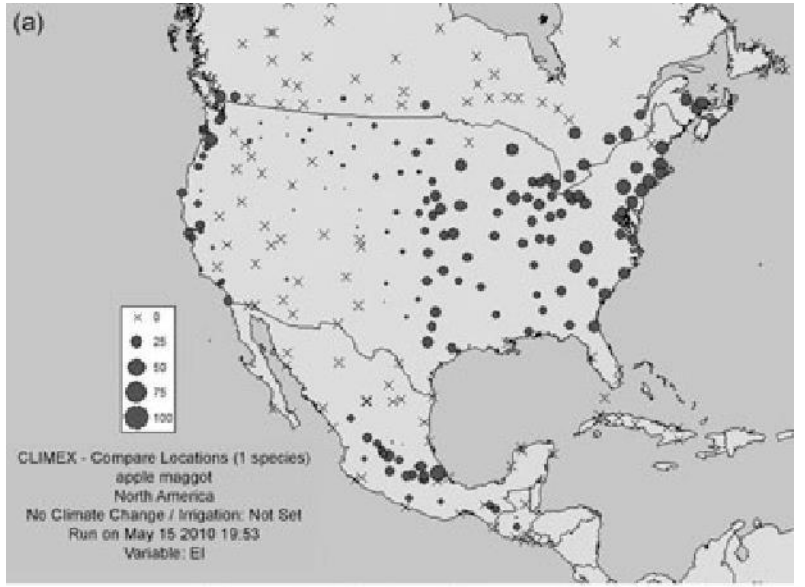


For example:

1. Historically, individuals varied in the size of food they ate (dashed line)
2. Then, mid-size food became scarce
3. Now, individuals with extreme phenotypes (eat small food or eat large food) have the advantage
4. Population begins to diverge into two preferred food types
5. Habitat or behavioural isolation
6. Populations divergence genetically
7. Reproductive barriers form

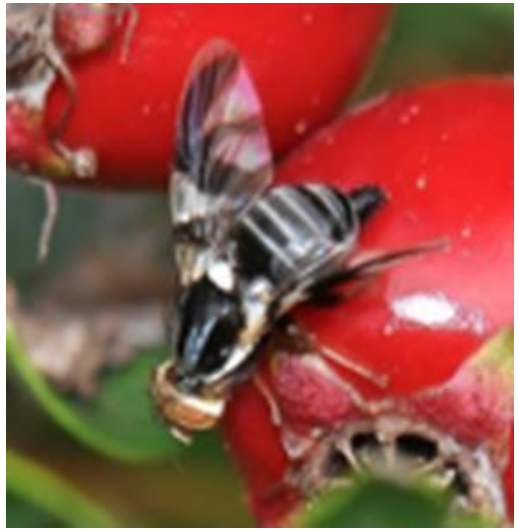
Example of sympatric speciation due to disruptive selection (in progress)
Apple fly / Hawthorn fly – Isolated by habitat preference (Disruptive)

The apple maggot fly (Rhagoletis pomonella) inhabits the eastern US. They are native to North America (not introduced). Courtship and mating occur on or near fruits.



200 years ago the ancestor of the apple maggot flies laid their eggs in the fruit of the Hawthorn plant (which is native to North America).

Today, apple flies lay their eggs in both hawthorns and apples (which were introduced to North America ~250 years ago).



Flies look the same morphologically

Apple fly / Hawthorn fly Speciation

Hawthorn maggot fly (*Rhagoletis pomonella*)

- Prefers **hawthorn** scent
- Scent preference is inherited
- Mate on **hawthorns (strong preference by both males and females)**

Apple maggot fly (*Rhagoletis pomonella*)

- Prefers **apple** scent
- Scent preference is inherited
- Mates on **apples (strong preference by both males and females)**

Linn et al. 2003

Apple fly / Hawthorn fly – Sympatric Speciation

Strong non-random mating (host fidelity = barrier to reproduction)

Only 6% of observed matings between hawthorn and apple flies.

So gene flow between the two subpopulations is reduced (1st step in speciation)

Statistically significant difference in frequencies of alleles for six different enzymes (Feder et al. 1988, 1990) (2nd step - divergence).

Apple fly / Hawthorn fly – Sympatric Speciation

Consensus:

- Disruptive selection, due to strong nonrandom mating
  Natural selection is overwhelming limited gene flow
- Populations have diverged and are incipient species (i.e. on the brink of becoming separate species)

Unclear whether this type of speciation is common or not.

Sympatric Speciation – *Orca*?

There are no physical/geographic barriers separating resident and transient *Orca*.

Preliminary studies suggest that differences in diet may be acting asa barrier keeping these populations apart.

Consequently, the residents and transient *Orca* may be on separate evolutionary pathways potentially leading to speciation.

EVOLUTION

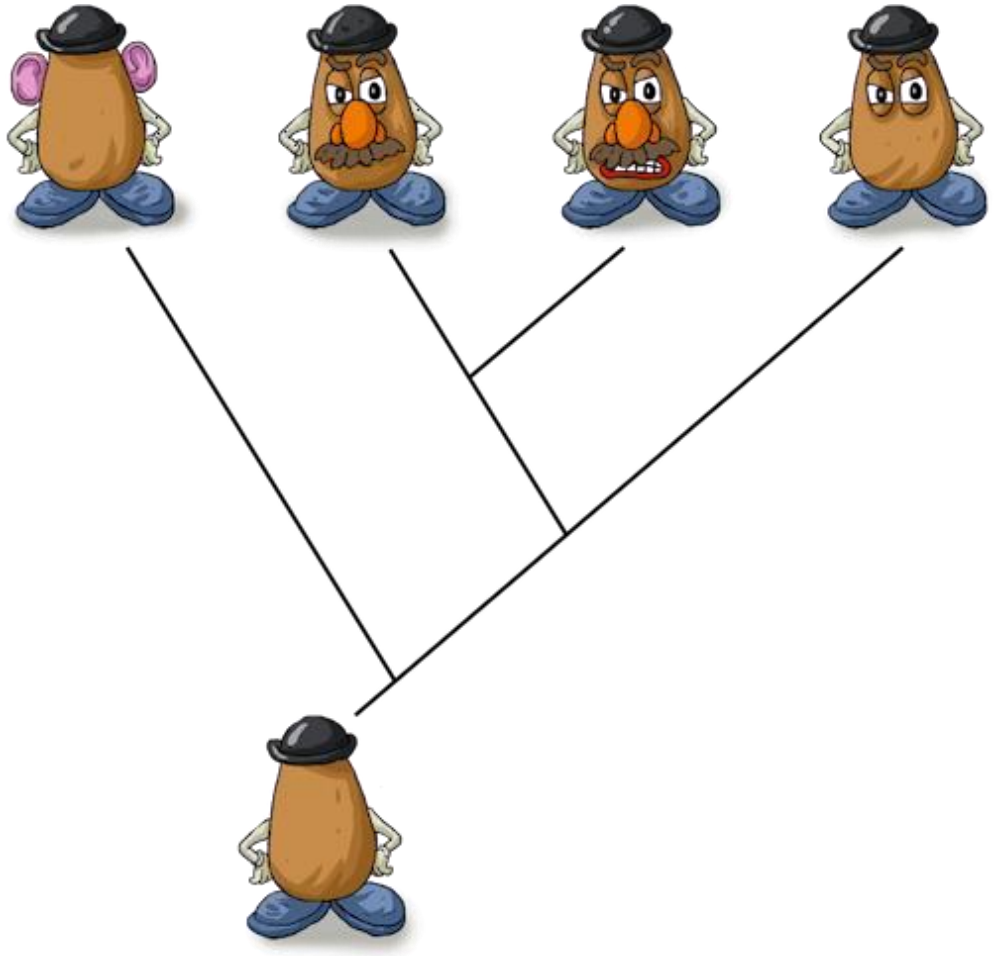
Killer Whales Are Speciating Right in Front of Us

Killer whales appear to be splitting into several separate species, perhaps because cultural differences among populations are driving them apart

By Rüdiger Riesch on November 1, 2016

Questions about speciation?

– the evolution of 2 or more distinct species from a single ancestral species



Shmoop Editorial Team. "Biology What's So Special About Speciation? - Shmoop Biology." *Shmoop*. Shmoop University, Inc., 11 Nov. 2008. Web. 23 Oct. 2017.

Speciation – iClicker Question

What is the difference between allopatric and sympatric speciation?

A. In allopatric speciation there is no geographic barrier separating populations, whereas in sympatric speciation there is a geographic barrier separating populations.

B. In allopatric speciation there is a geographic barrier separating populations, whereas in sympatric speciation there is no geographic barrier separating populations.

C. Only allopatric speciation requires 3 steps for speciation to be complete.

D. Only sympatric speciation requires 3 steps for speciation to be complete.

E. I am not sure

Answer

What is the difference between allopatric and sympatric speciation?

A. In allopatric speciation there is no geographic barrier separating populations, whereas in sympatric speciation there is a geographic barrier separating populations.

B. In allopatric speciation there is a geographic barrier separating populations, whereas in sympatric speciation there is no geographic barrier separating populations.

C. Only allopatric speciation requires 3 steps for speciation to be complete.

D. Only sympatric speciation requires 3 steps for speciation to be complete.

E. I am not sure

iClicker Question

A volcano erupts and produces a giant river of lava, isolating snakes on either side of the lava. After thousands of years apart, the snakes encounter each other again but are incapable of mating and/or producing viable offspring. This is an example of:

A. Sympatric Speciation

B. Allopatric Speciation via dispersal

C. Allopatric Speciation via vicariance

D. Not speciation

E. Not sure

Answer

A volcano erupts and produces a giant river of lava, isolating snakes on either side of the lava. After thousands of years apart, the snakes encounter each other again but are incapable of mating and/or producing viable offspring. This is an example of:

A. Sympatric Speciation

B. Allopatric Speciation via dispersal

C. Allopatric Speciation via vicariance

D. Not speciation

E. Not sure

iClicker Question

A storm washes 5 snakes from a mainland population onto an uninhabited island. Hundred of generations later, the snakes from the two populations meet, but no longer recognize each other as potential mates. This is an example of:

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iClicker Question

In a garter snake population on Vancouver Island, some individuals mate in the early Spring when they first emerge from hibernation, and other individuals in the population wait until mid summer to mate. Reproduction isolation is occurring amongst some members of the population as a result of this non-randommating. This is potentially an example of:

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Answer

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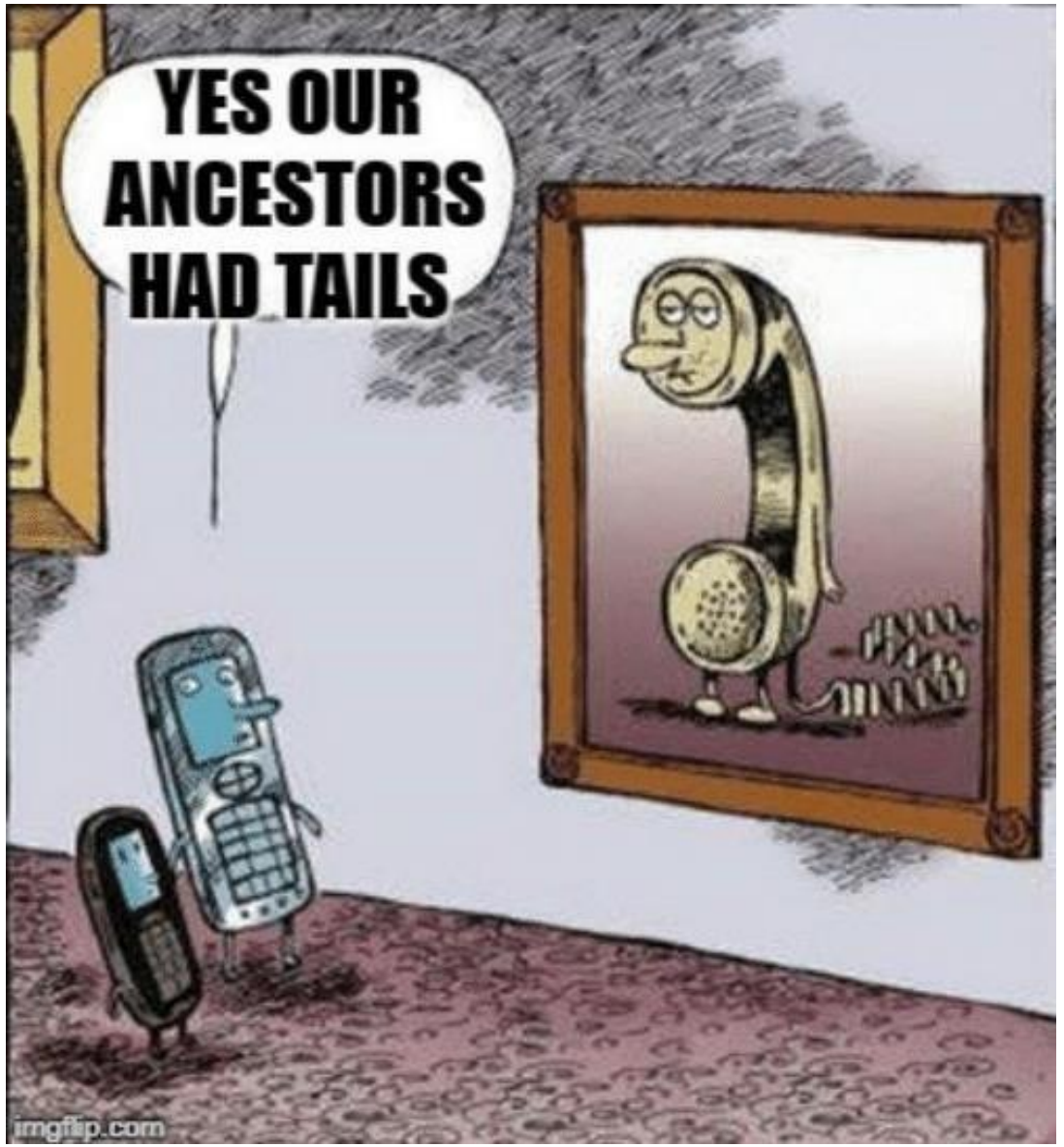
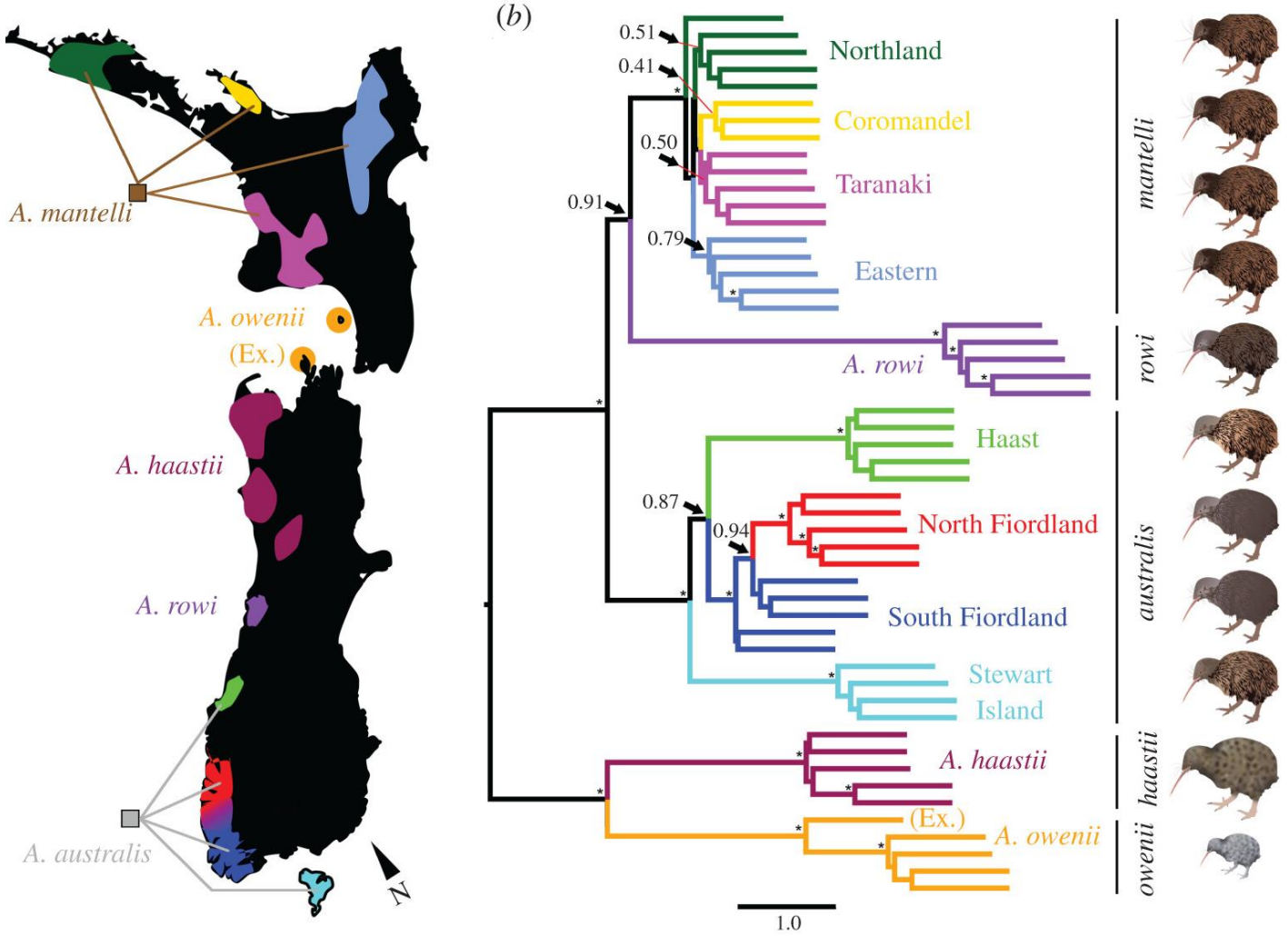
4-minute break



New Zealand Kiwis (*Apteryx*)

Until recently, only 3 species of Kiwi were believed to exist.

Recent research (Weir 2016, Bemmels et al. 2021) has identified 5 species with at least 11 unique genetic lineages.

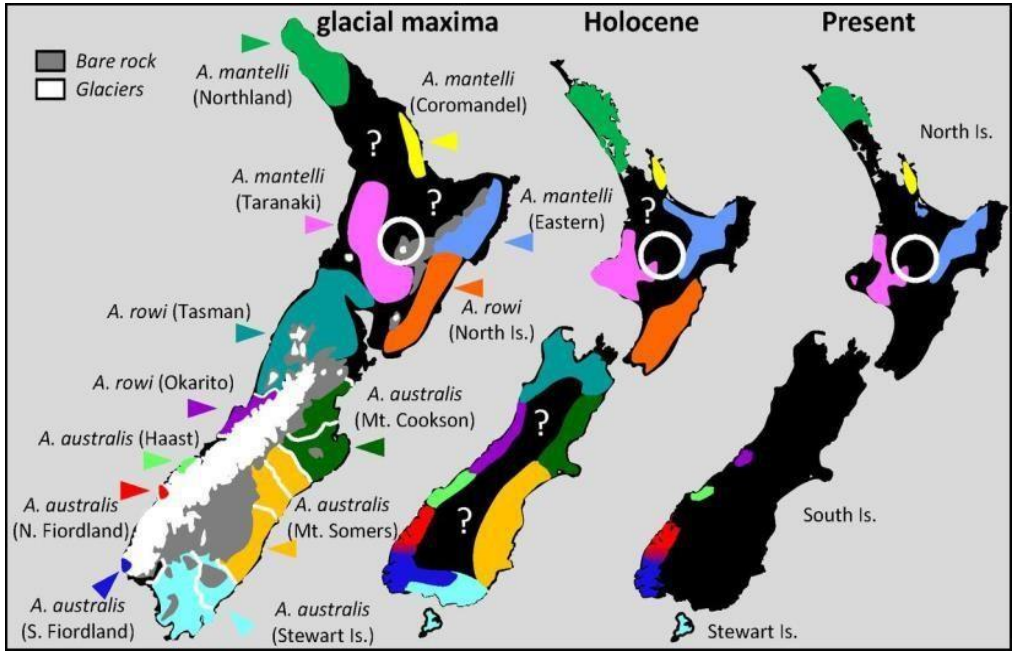


Bemmels et al. 2021

New Zealand Kiwis

Genetic research by Weir et al. (2016) indicates that the New Zealand kiwis underwent a major speciation event about 20,000 years ago (which was the last glacial period).

- On the South island, kiwis were restricted to glacial refuge (note the ring shape to the distribution)
  - genetic evidence suggests the kiwi populations on the South Island underwent bottleneck events
  - white lines = glacial rivers that may have acted as a barrier to dispersal.
- On the North Island, volcanic activity created ash fields, which would have acted as barriers to dispersal (no food)
  - white circle= Taupo Volcano.

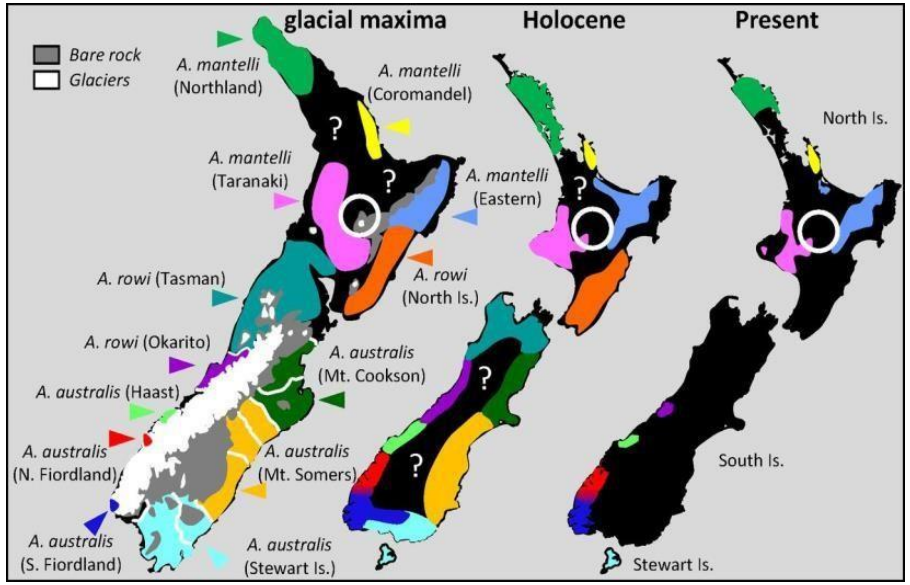


Weir et al. 2016
https://www.pnas.org/doi/10.1073/pnas.1603795113

iClicker Question

If Weir et al. (2016) and Bemmels et al. (2021) are correct, and kiwis underwent a major speciation event 20,000 years ago, this would be an example of what type of speciation?

A. Sympatric speciation;
B. Allopatric speciation via dispersal;
C. Allopatric speciation via vicariance;
D. Not sure



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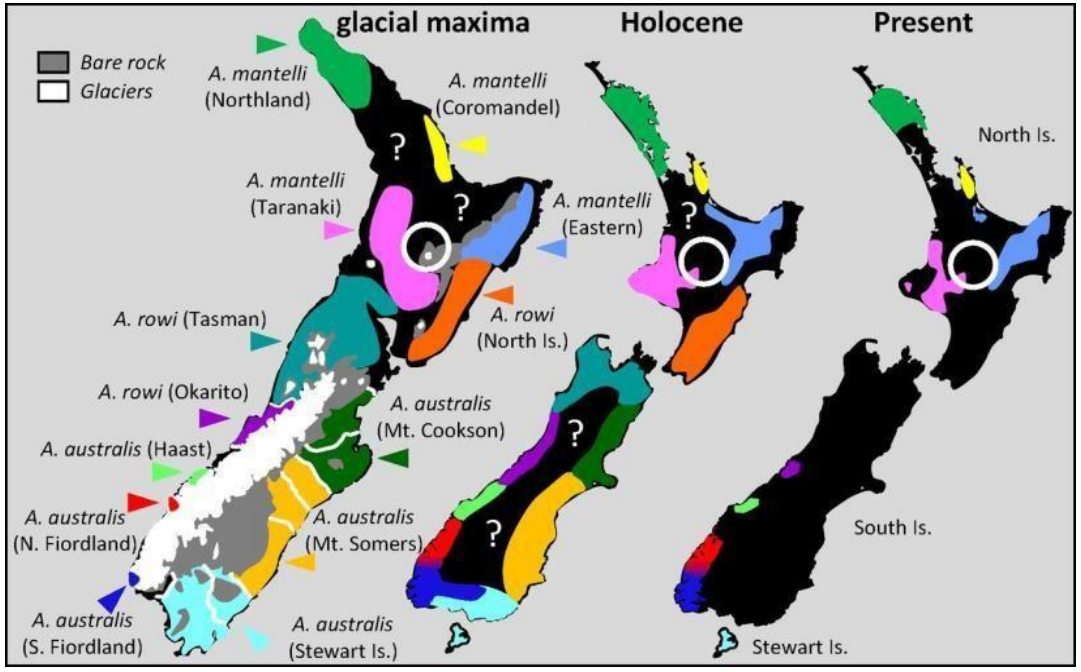


Holocene (~11,700 years ago to present day) - before humans arrived

Weir et al. 2016
https://www.pnas.org/doi/10.1073/pnas.1603795113

Exam type question – 3 minutes to discuss

Describe the evolutionary steps that would result in the Vancouver Island Marmot populations and the Hoary Marmot populations becoming two distinct species. Explain what could happen during each step to cause this result. Use the biological species concept and include references to appropriate evolutionary mechanisms in your answer. Be as specific as possible and use only information given in the question

Marmots are the largest member of the squirrel family (Family Sciuridae). In British Columbia, the Hoary Marmot (***Marmota caligata***) inhabits mountainous regions on the mainland. The Vancouver Island Marmot (***Marmota vancouverensis)*** is the only marmot species found on Vancouver Island and likely represent the descendants of a small population of Hoary marmots that became isolated from the mainland population after sea levels rose at the end of the last ice age, approximately 10,000 years ago. The table below has information on the characteristics of both species.

Factor	Vancouver Island Marmot	Hoary Marmot
Fur Colour	Chocolate Brown with white patches	Silver Gray
Weight	Up to 5 kg (adult)	Up to 10 kg (adult)
Length	Up to 47 cm (adult)	Up to 82 cm (adult)
Habitat	High alpine meadows and rocky slopes	High alpine meadows and rocky slopes
Diet	Herbivore – eat plant material such as ferns, mosses, grasses, berries	Herbivore – eat plant material such as ferns, mosses, grasses and berries
Predators	Wolves, cougars, golden eagles	Wolves, cougars, golden eagles

Vancouver Island Marmot (***Marmota vancouverensis***)

Hoary Marmot (***Marmota caligatas***)

3 evolutionary steps – an example

Step 1. Stop gene flow. According to the scenario, the VIM populations on Vancouver Island, and the Hoary Marmot populations on the mainland became isolated about 10,000 years ago when sea levels rose. This stopped gene flow allowing evolution to act independently on the VIM and HW populations.

Step 2. The VIM populations and HM populations **genetically diverge** from each other. *Note – any plausible explanation invoking at least one evolutionary mechanism would be acceptable; but must refer to both populations.*
e.g. The VIM populations and HM populations may have diverged genetically due to genetic drift. Genetic drift is a change in allele frequencies in a population due to chance. It affects all populations, but the effects are larger in smaller populations. If the isolated VIM populations were small, then random differences in survival and/or reproductive success would likely have had a large effect on allele frequencies in these populations. And, this would have resulted in the VIM populations genetically diverging from the HM populations, where the effect of genetic drift may have been smaller.

Step 3. Reproductive isolation. *Note – any plausible explanation invoking at least one evolutionary mechanism would be acceptable; but must refer to both populations.*
e.g. If the eggs and sperms of the VIM populations and HM population marmots were incompatible due to genetic changes, then they would be unable to produce offspring that could survive and/or produce offspring. Speciation would be complete.

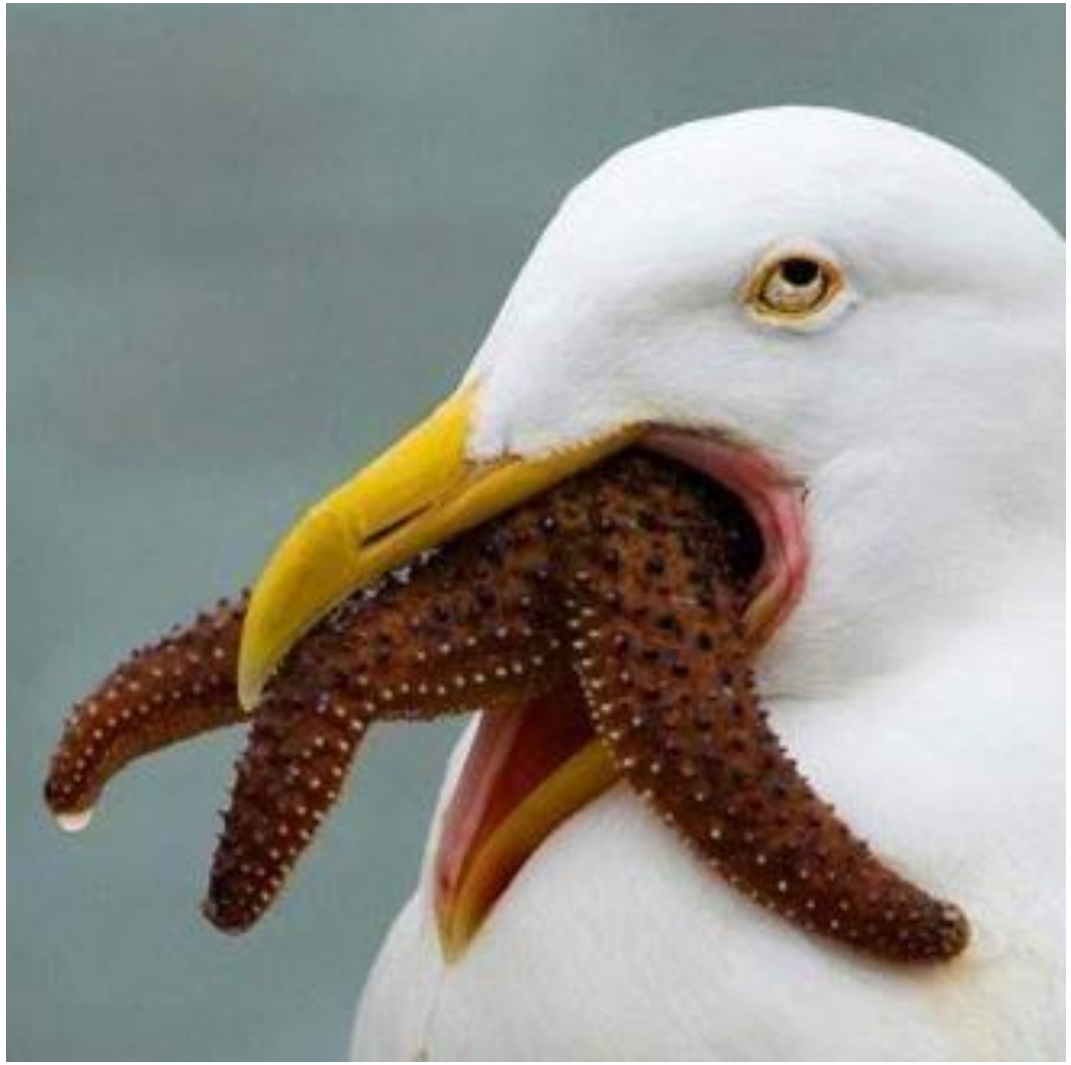
Expected learning outcomes - speciation

If provided with a scenario, be able to:

- identify whether allopatric speciation via vicariance, allopatric speciation vis dispersal, or sympatric speciation is occurring.
- describe and/or explain the three steps that could lead to speciation for both allopatric and sympatric speciation.

Starting the Ecology Unit

What is ecology?



Source:

What is Ecology?

Ecology is the scientific study of how organisms interact with each other and with their environment.

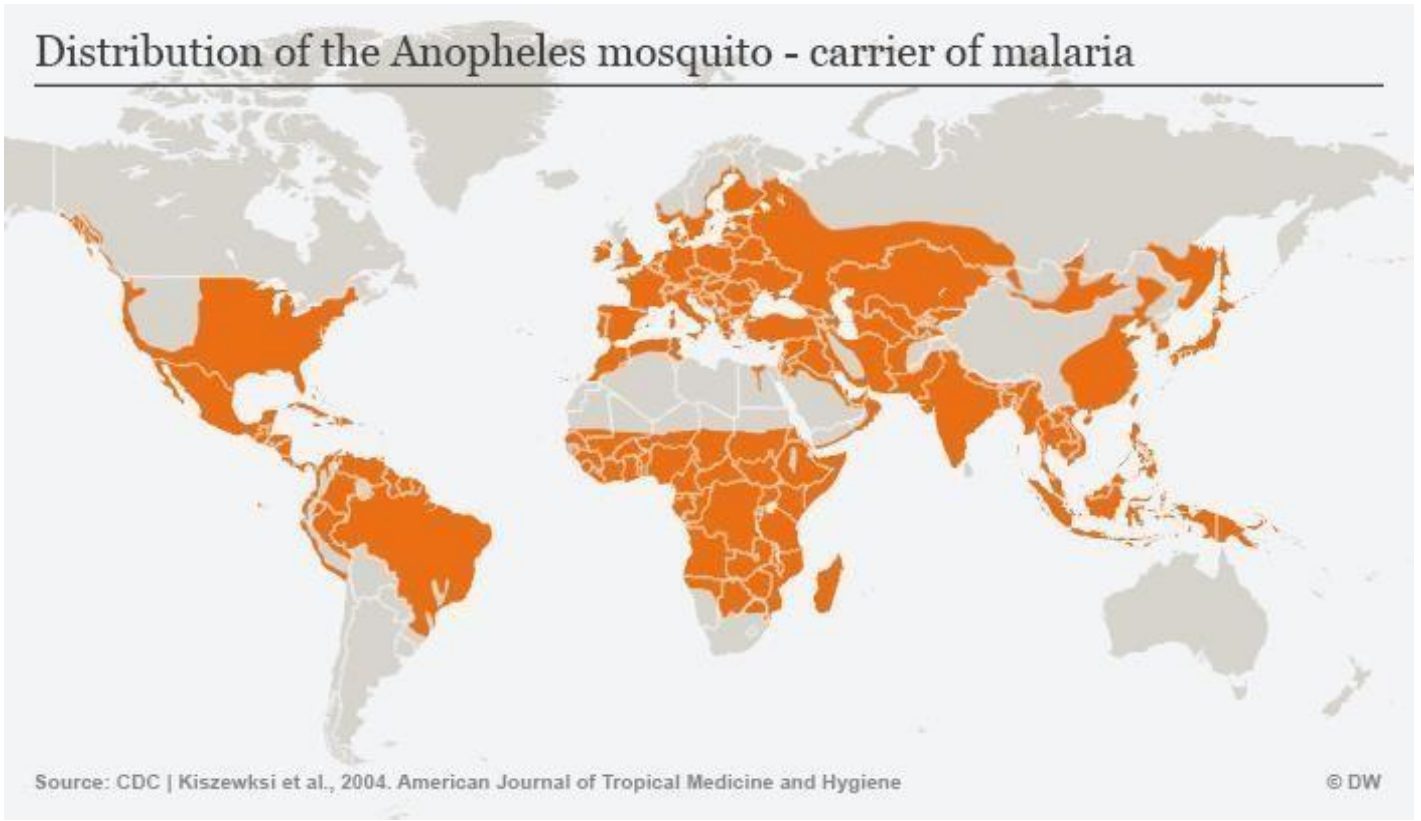
Two main goals of ecological research are to:

1. Describe/quantify the patterns of distribution and abundance of organisms; and
2. Understand what factors can affect these patterns.

Distribution = where, Abundance = number of individuals or density of individuals

Importance of understanding a species ecology.

www.theguardian.com



Ecology studied at different levels

How do INDIVIDUALS interact with each other and the environment,
e.g. what behavioural and/or physiological mechanisms do individuals use to meet ecological challenges? (Autecology)

Source: https://en.wikipedia.org/wiki/Sea_otter

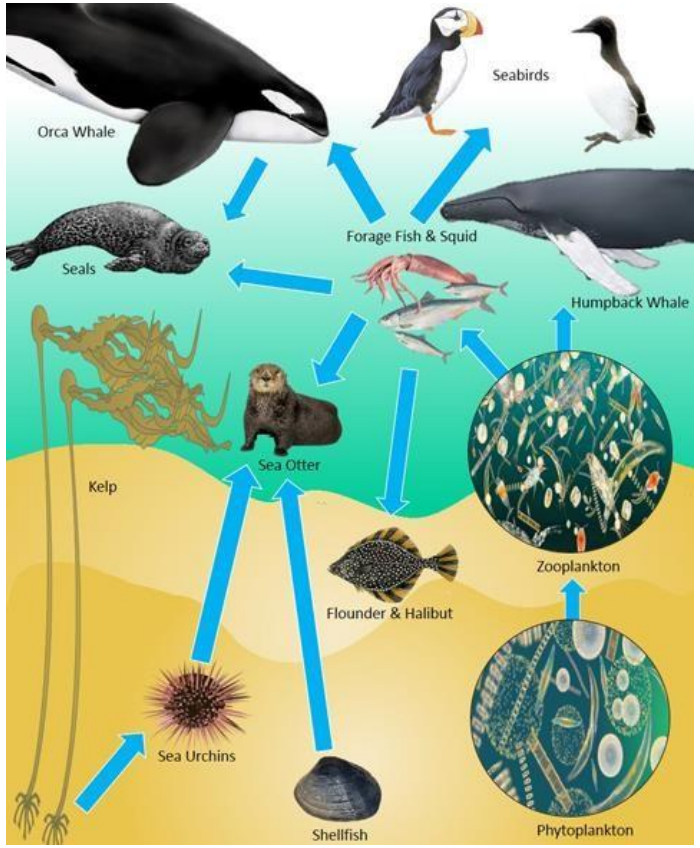
How and why do POPULATION sizes change over time? What factors affect population size/growth/structure?

Source: https://alaskamagazine.com/authentic-alaska/wildlife-nature/the-rebound-of-the-sea- otter

How do species interact with each other and what are the consequences for COMMUNITY structure?

Source: https://www.climate.gov/news-features/featured-images/caring-sea-otters-offers- climate-bonus

How do energy and nutrients cycle through an ecosystem (ECOSYSTEM ECOLOGY)?



+

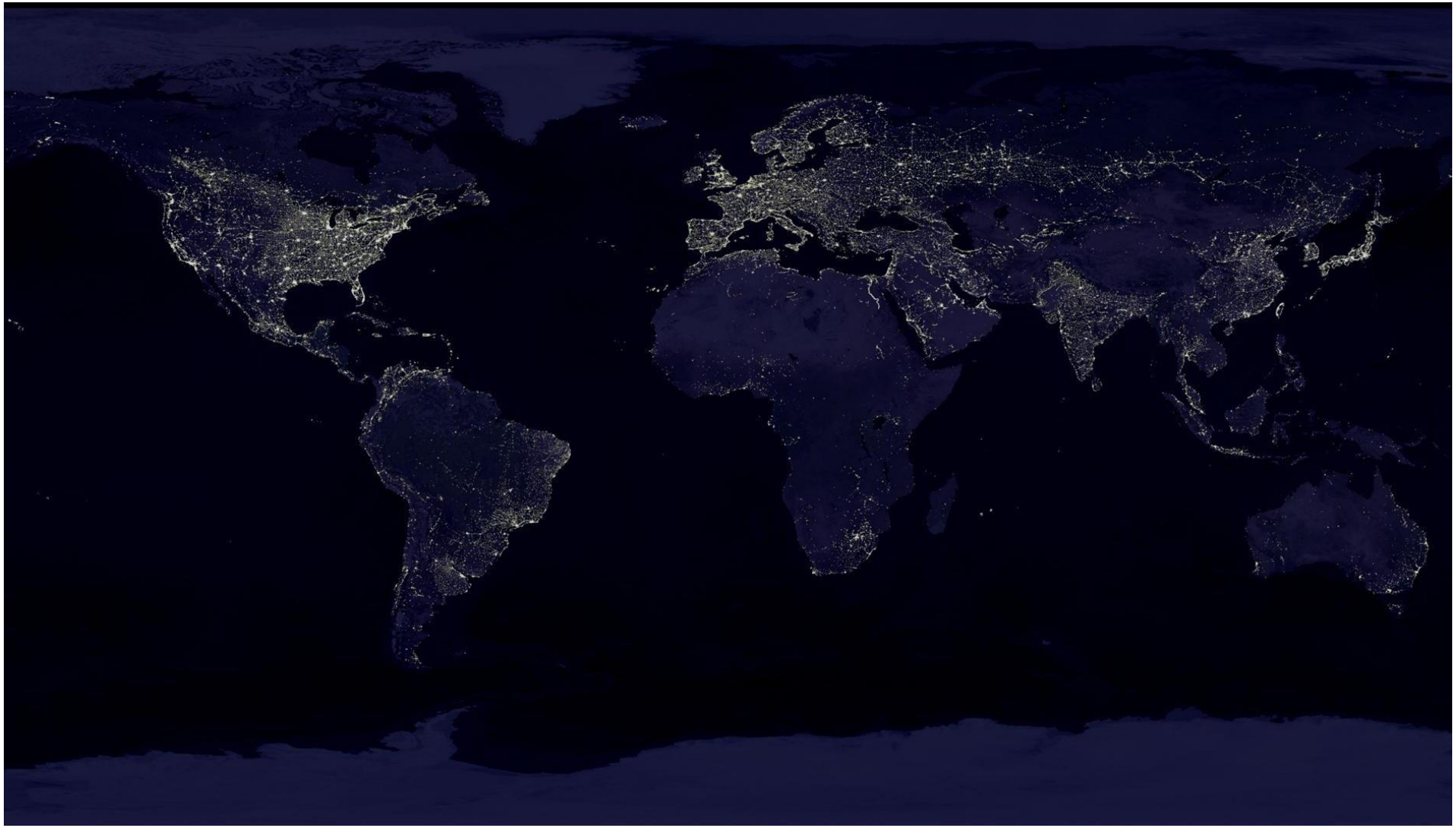
https://www.alaskasealife.org/gulfwatchblobvft_investigation

Rest of today's class

- Introduction to some ecological terminology (only discussed distribution)
  - distribution, abundance
  - abiotic factors and range of tolerance (optimal, suboptimal, lethal)
  - biotic factors
  - intertidal zone, high and low intertidal zone

A head's up there is a snake photo.

Patterns of Distribution (where organisms are found) – no species is found everywhere on Earth, not even us



Source: https://www.nasa.gov/topics/earth/earthday/gall_earth_night.html

Patterns of distribution on a global or large scale…

- We have a pretty good idea what factors limit the distribution of a species on a large scale.

- Physical and climatic barriers prevent the dispersal of individuals from their place of birth to new geographic locations.

*Dispersal refers to the one-way movement of individuals or gametes usually from a site where an individual is born to a new geographic area (sometimes used interchangeably with migration – but the two terms mean different things).

Example of a physical barrier to dispersal -oceans

Brown Bear (*Ursus arctos*)

Source: Wikicommons

Originated in Asia about 1.3 million years ago.

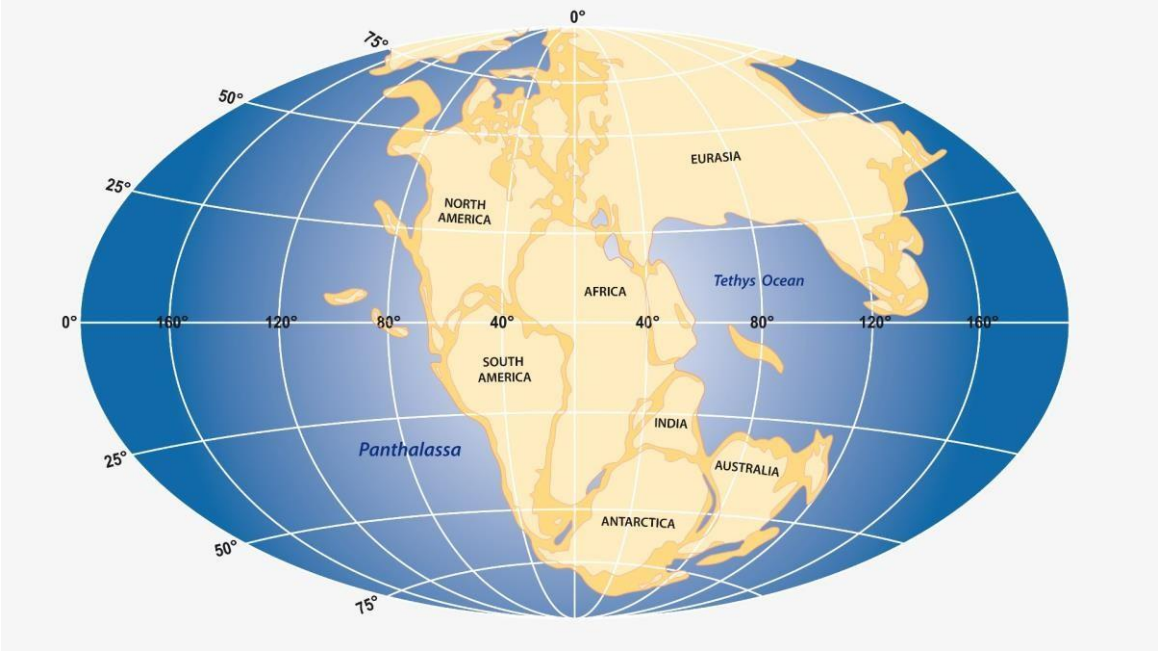
About 200,000 years ago, they crossed the Bering land bridge into North America.

Source: https://www.livescience.com/38218-facts-about-pangaea.html

Why are brown bears not found in Australia?

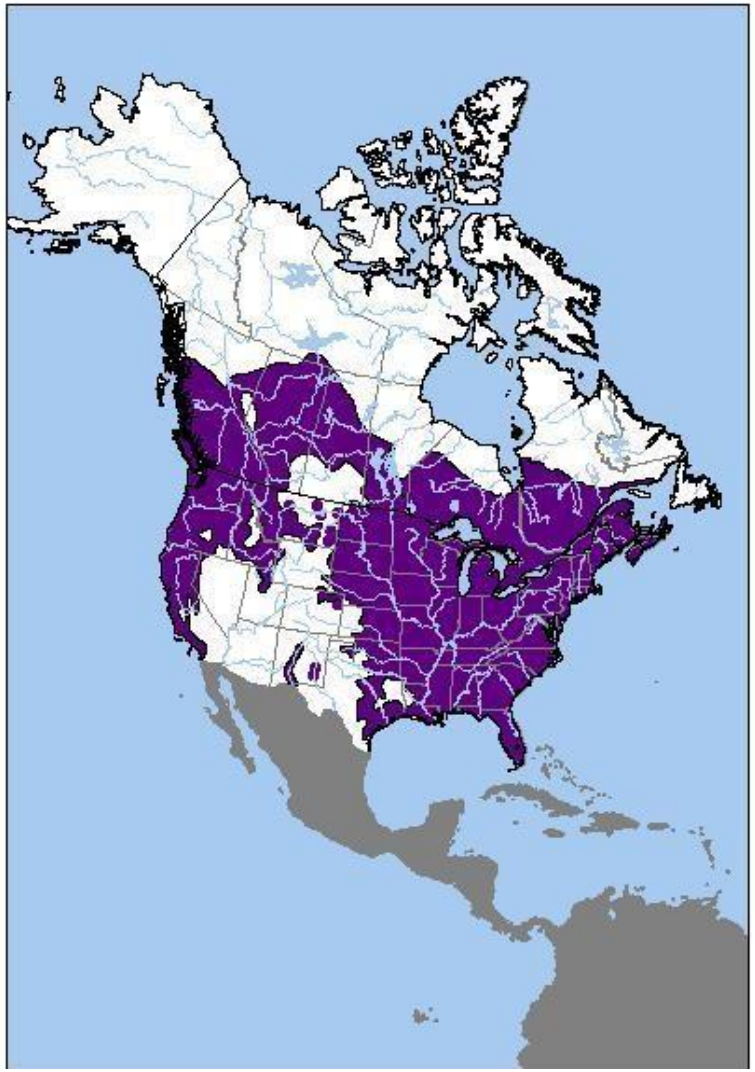
Ocean acts a physical barrier to dispersal.

The last time, Australia was connected to Asia was about 250 million years ago – super continent Pangea – before bears had evolved



Example of a climatic barrier to dispersal

Temperature – snakes have no freeze tolerance; so not found at high latitudes.

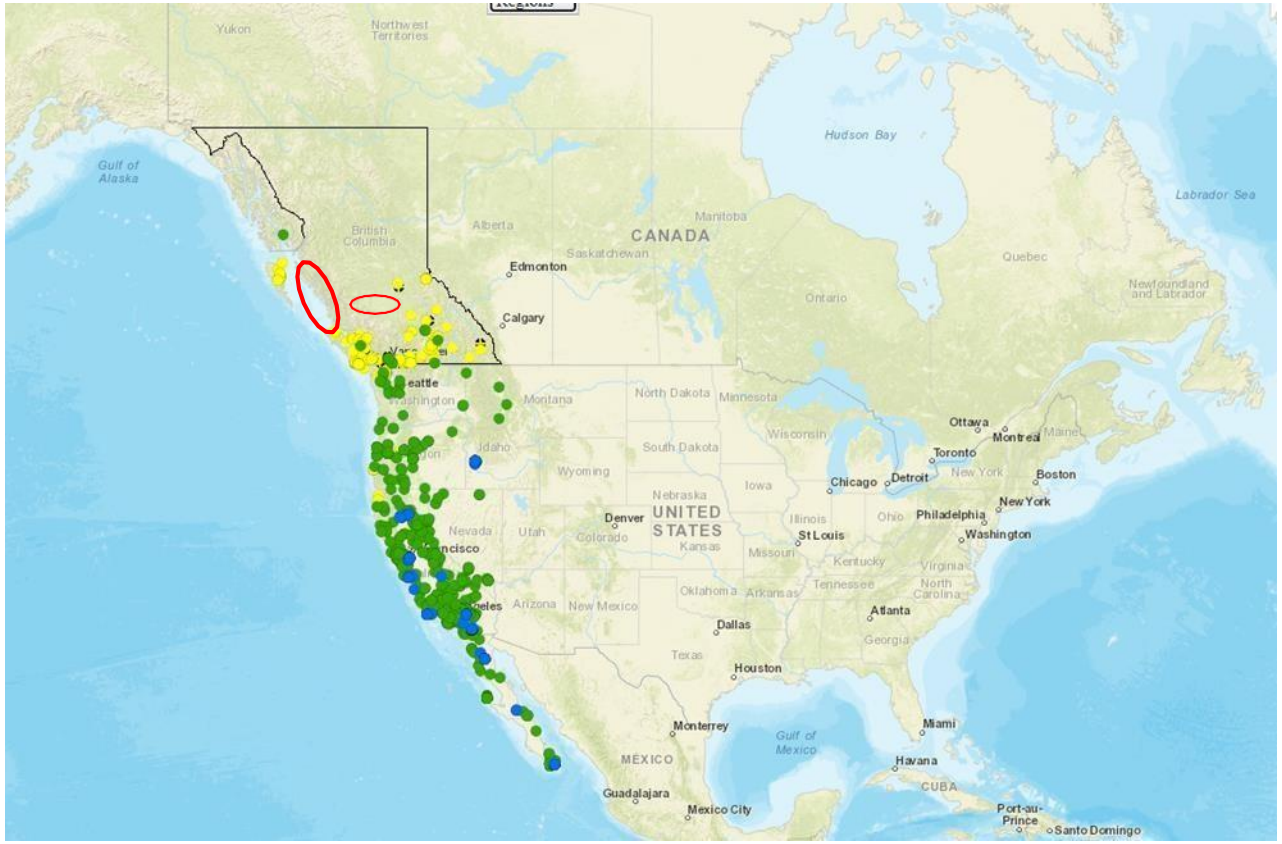


http://fieldguide.mt.gov/speciesDetail.aspx?elcode=aradb36130

On a more local scale

- Our understanding of the factors affecting the distribution of a species on a local scale are less well understood.

e.g. Why is the Pacific Tree Frog not found in the area marked in red?



http://linnet.geog.ubc.ca/efaunamap

Learning goals up to this point in class

- Be familiar with the following terms:
  - Distribution ☺
- By the end of Thursday's class, also be familiar with:
  - Abundance
  - Abiotic Factors
  - Range of Tolerance
    - Optimal Conditions
    - Suboptimal Conditions
    - Upper and lower limits of tolerance
  - Biotic Factors

Next class – A bit about snake ecology + start Population Ecology

- Continue with terminology (see list on previous page)
- A bit of intertidal ecology
- A bit of snake behavioural ecology (Lynn's research)
- Start population ecology

https://twitter.com/padi/status/1119148665145135106