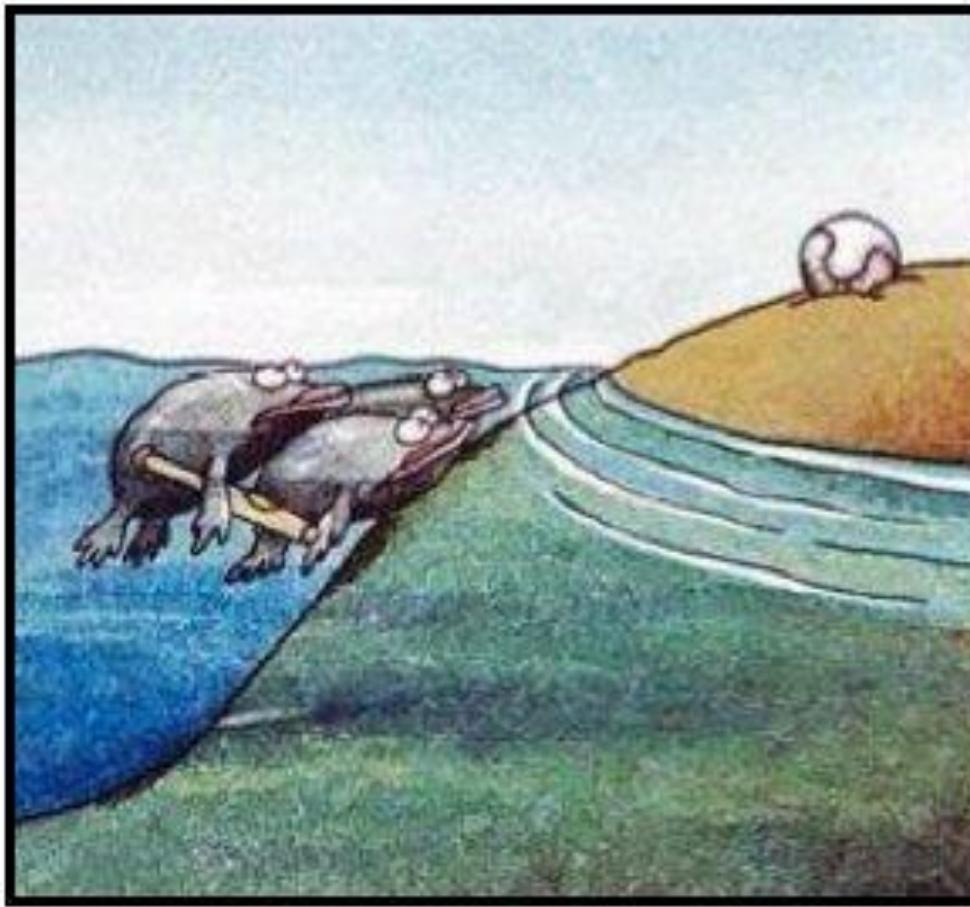


# Evolution Lecture #8 – Species Concepts & Speciation



**Great moments in evolution**

Also, if you are looking for summer work, check out UBC's Work-Learn webpage.

Funded summer jobs should now be posted.

I think postings will remain up for about two weeks.

Note: jobs for Fall 2023 are usually posted on this page starting in early August.

## Job Alert for UBC students!



Go to [students.ubc.ca/career](https://students.ubc.ca/career) and search  
"Beatty Biodiversity Museum"



Beatty Biodiversity Museum · Follow

1d ·

Job Alert! UBC students, are you interested in working at the museum?

We have a range of jobs available - from working with the museum collections to co-developing a new undergraduate course, to supporting exhibits and social media.

To find out more, log on to Careers Online (<https://students.ubc.ca/career>) and search "Beatty Biodiversity Museum".

#UBClife #UBCstudents #UBCcampus #UBC #UBCscience

# Due this Sunday

Worksheet #9 – Reading Phylogenetic Trees

Quiz 8 – Reading Phylogenetic Trees

Group Project: I know of one person in this class who is still looking for team. If your team has space, can you please send me an email to let me know ([lnorman@zoology.ubc.ca](mailto:lnorman@zoology.ubc.ca)). Thank you

# iClicker Question

Compared to midterm #1, how well do you think you did on midterm #2?

- A. Much better
- B. Better
- C. About the same
- D. A little worse
- E. A lot worse

## iClicker Question

Do you think you had enough time on midterm #2 to show your understanding of evolutionary concepts?

- A. Yes, I finished more than 10 minutes early
- B. Yes, I finished 5-10 minutes early
- C. Yes, but I barely finished
- D. No, I needed 5 more minutes
- E. No, I needed at least 10 more minutes

## iClicker Question

Overall, did you find the questions on the evolution midterm to be fair given the concepts covered in lecture?

- A. Yes, the questions were very fair
- B. Yes, the questions were mostly fair (1 unfair subquestion)
- C. No, several of the questions were unfair
- D. No, very unfair
- E. I am on the fence

# What is a species?



One or two species?

What criteria did you use to come to this conclusion?



# iClicker Question:

Are these two different species?

- A. Yes
- B. No
- C. Not sure



# Answer

Are these two different species?

- A. Yes
- B. No
- C. Not sure

What criteria did you use?



*Canis lupus familiaris*

# iClicker Question

Are these two different species?

- A. Yes
- B. No
- C. Not sure



# Answer

Are these two different species?

- A. Yes
- B. No (but different subspecies)
- C. Not sure



*Canis lupus lupus*

Subspecies (not testable): a population that has distinctive traits and genetic differences relative to other populations of the same species but that is not distinct enough to be classified as a separate species. Typically isolated geographically or due to sexual selection. At the beginning stages of the speciation process.



*Canis lupus familiaris*

# iClicker Question: Are these two different species?

- A Yes
- B. No
- C. Not sure



What criteria are you using to come to this conclusion?

# Answer - Yes

*Strongylocentrotus droebachiensis*

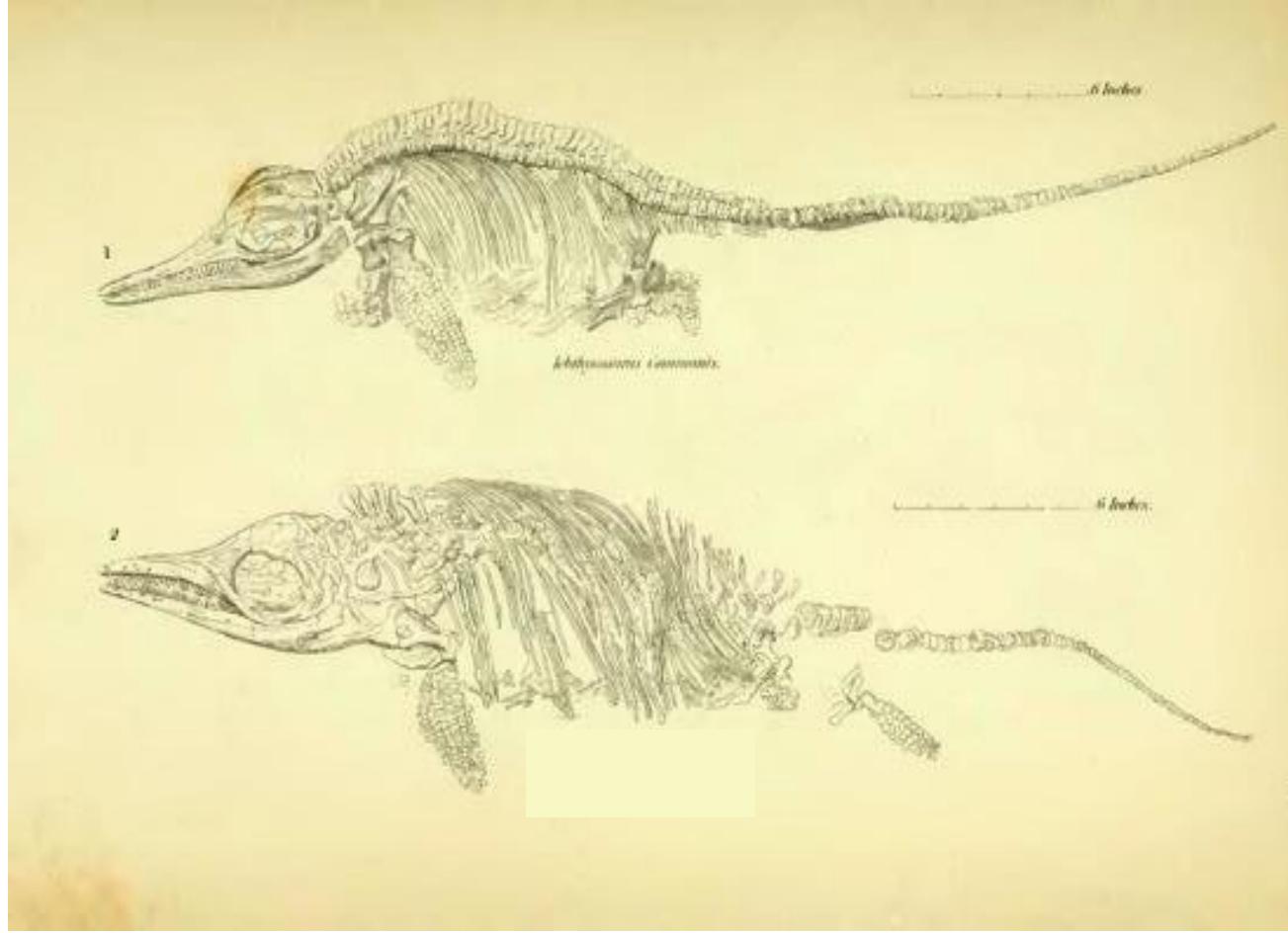


*Strongylocentrotus purpuratus*



<http://www.seawater.no/fauna/echinodermata/Echinoidea.html>; wikipedia

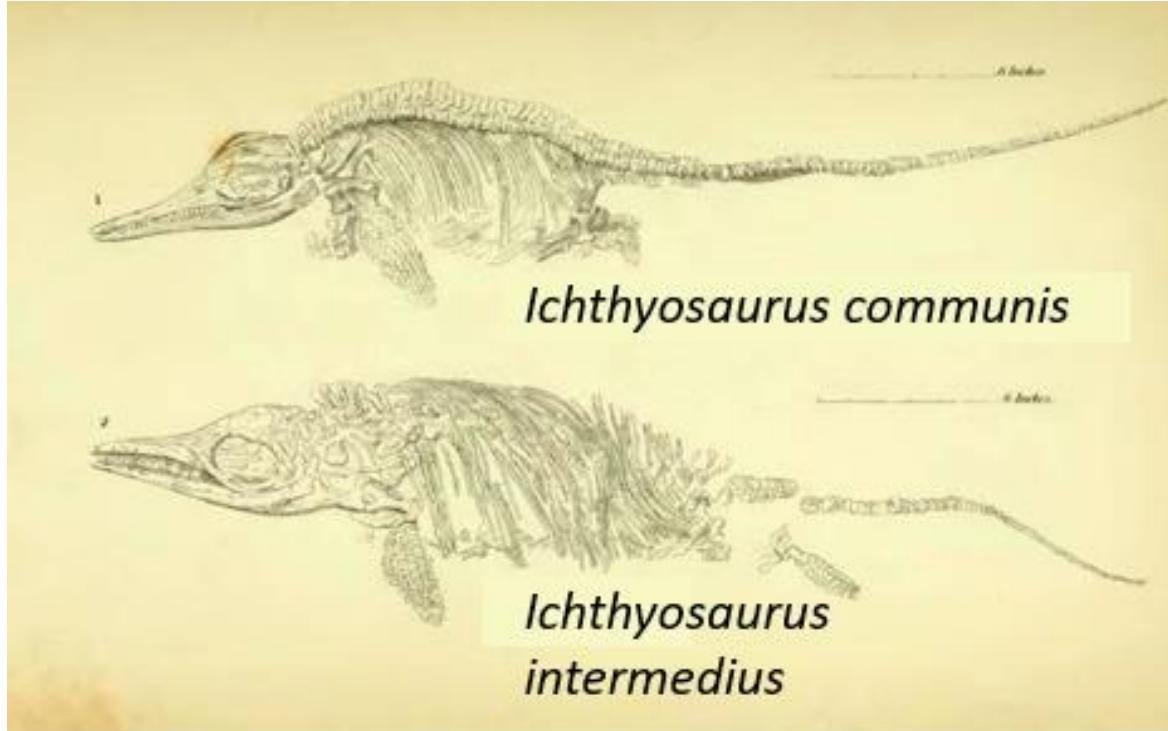
# iClicker Question: Are these two different species?



- A. Yes
- B. No
- C. I am not sure



# iClicker Question: Are these two different species?

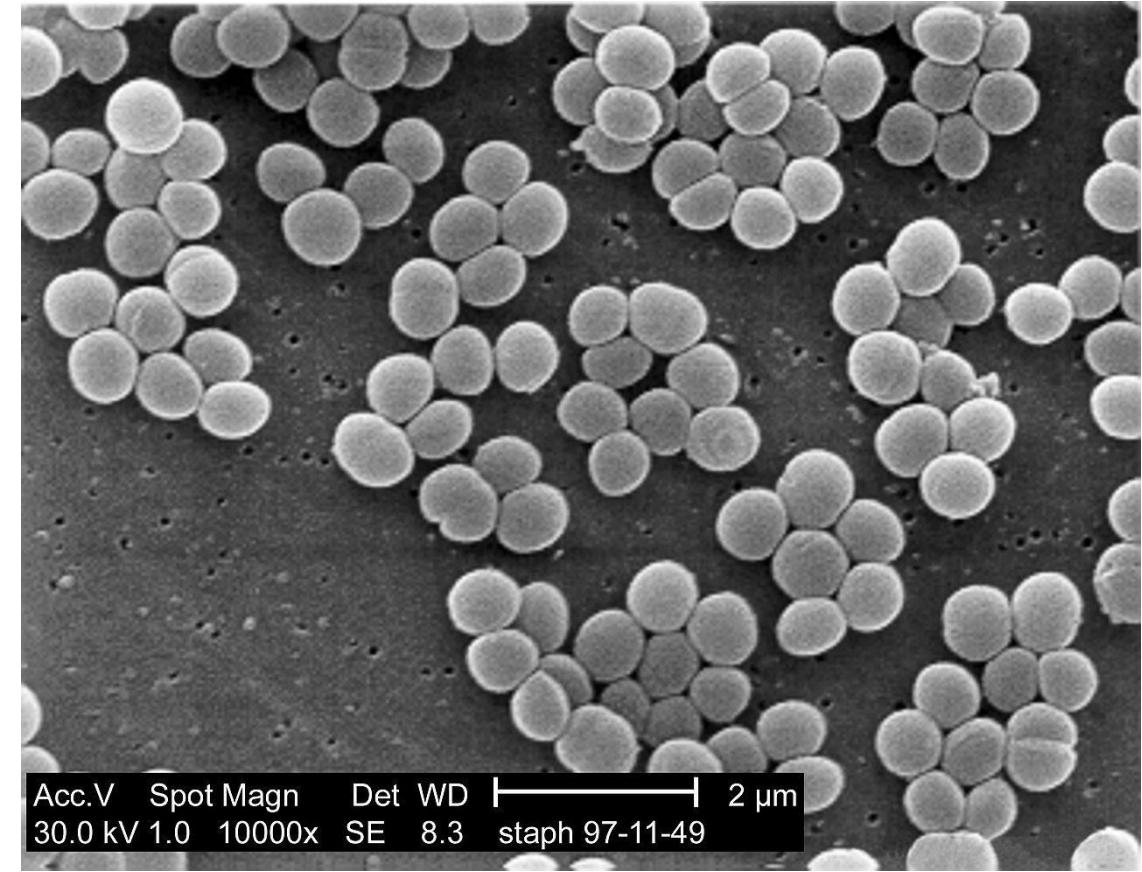
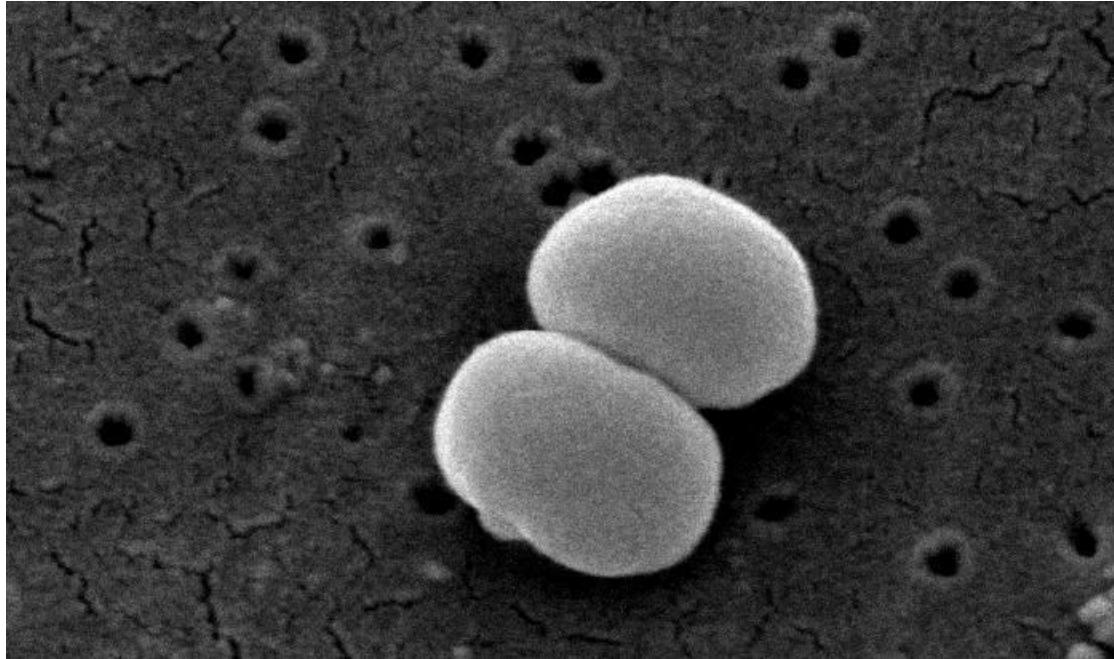


- A. Yes
- B. No
- C. I am not sure



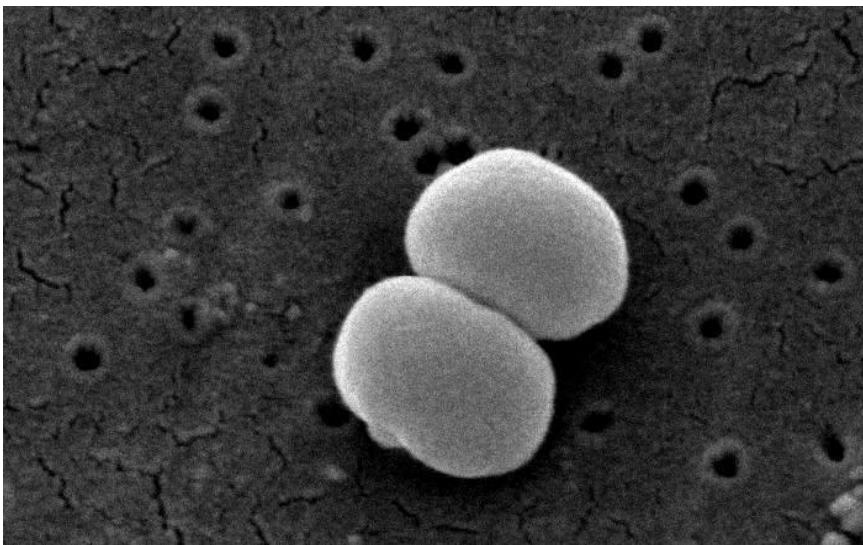
# iClicker Question: Are these two different species?

(one of left is at a higher magnification)



1. Yes
2. No
3. Not sure

# Answer



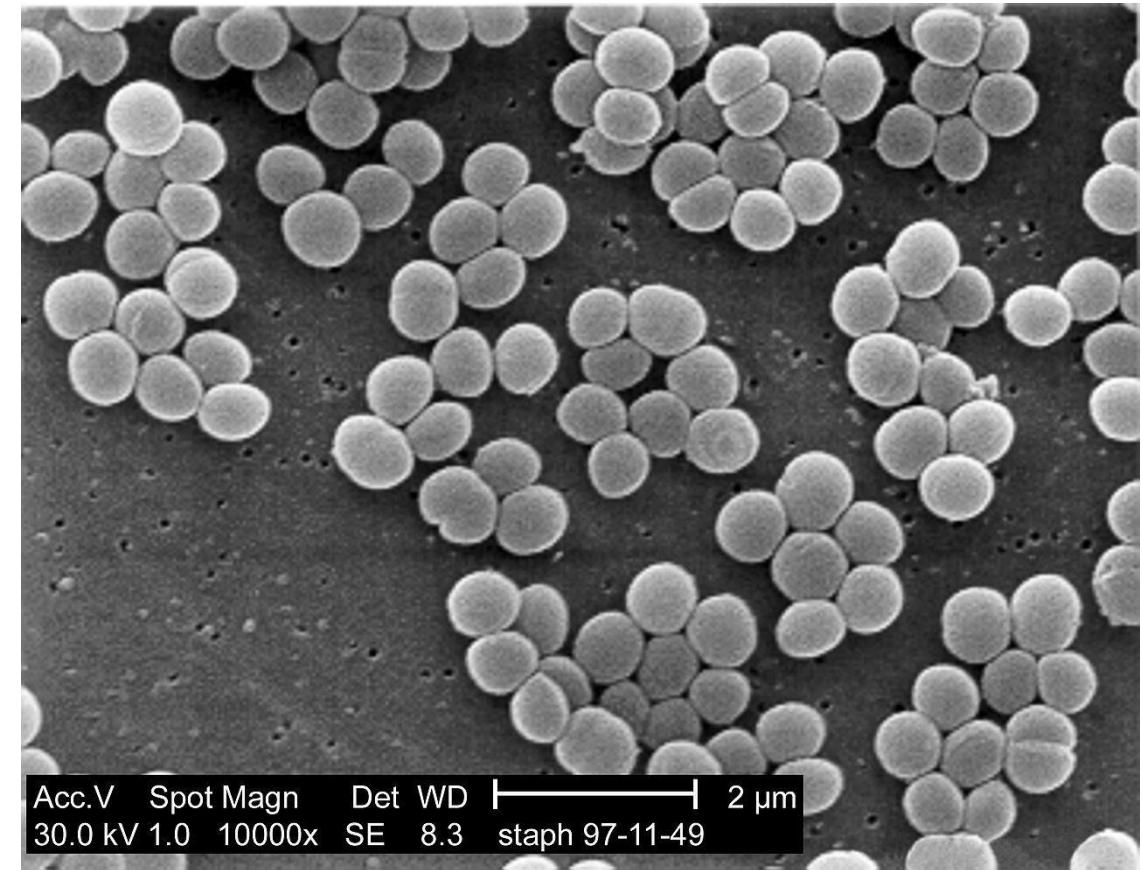
## *Staphylococcus epidermidis*

Mainly lives on skin, mostly commensal (cause no benefit or harm to host), but linked to infections from catheters and implants

1. Yes

2. No

3. Not sure



## *Staphylococcus aureus*

30% of us have it in our nose - bone infections, pneumonia, heart valve infections

# Important that we identify different species - example

- Up until 2021, African elephants were treated as one species.
- Based on new genetic evidence, African elephants are now recognized as two separate species:

- African Savannah Elephants (*Loxodonta africana*) – population size has declined by 60%. Now listed as endangered.
- African Forest Elephants (*Loxodonta cyclotis*) – population size has declined by more than 86% in the last 31 years. Listed as critically endangered



IUCN

# What is a species?

## 4 Species Concepts

- there are at least 20 species concepts
  - each concept uses different criteria to define a species
  - each concept has challenges/limitations
1. Biological Species Concept
  2. Morphological Species Concept (or Morphospecies Concept)
  3. Ecological Species Concept
  4. Phylogenetic Species Concept

## Expected Learning Outcomes – 4 species concepts

- Understand/know the 4 SPECIES CONCEPTS:
  - Know when is it appropriate to apply each of the four species concepts?
  - Be able to determine if two groups/taxa represent one or more species and explain your reasoning.
  - New: Be able to describe a limitation/challenge of each of the species concepts.

# #1 Biological Species Concept

## Biological Species Concept

- Criteria used – can individuals mate and produce via offspring or not?
- A species is a group of actually or potentially interbreeding individuals that can produce viable, fertile offspring.
- Definition of the Endangered Species Act.
- Relevant to today's lecture on speciation.



# Biological Species Concept – Reproductive Barriers

BSC - requires that some type of reproductive barrier exist between species so that individuals cannot produce viable, fertile offspring.

Two categories of reproductive barrier:

1. Prezygotic reproductive barriers (before zygote) -hinders matings or prevents fertilization of the egg. (5 common pre-zygotic barriers)
2. Post-zygotic reproductive barriers (after zygote) - hinders zygote development – reduced viability or fertility. (2 common post-zygotic barriers)

## Prezygotic Barrier - (i) Differences in timing of reproduction

Western and Eastern Skunks (*Spilogale* spp.) breed at different times of the year.



Western Spotted Skunk -  
September

<http://www.newsweek.com/tiny-skunk-handstands-evolution-climate-change-ice-age- 593970>



Eastern Spotted Skunk – late  
winter

## (i) Temporal Differences

Bishop Pine: Pollination occurs in early summer



Monterey Pine: Pollination occurs in early spring.



## Prezygotic Barrier - (ii) Habitat Isolation

Individuals are in the same area, but occupy different habitats/microhabitats, and rarely encounter each other to reproduce

### Apple maggot fly (*Rhagoletis pomonella*)



Some apple maggot flies mate and lay their fruit on hawthorn berries, other flies mate and lay their fruit on apples.

More details when we discuss sympatric speciation

# Prezygotic Isolation (iii)- Behavioural

Female fireflies give a species-specific sequences of flashes to attract males.



<https://www.flickr.com/photos/takot/4663355926>



<https://commons.wikimedia.org/wiki/File:GluehwuermchenImWald.jpg>

## Prezygotic Barrier - (iii) Behavioural

Differences in mating rituals (e.g. remember the dancing bird from last class).



## Prezygotic Barrier - (iv) Mechanical

Male and female reproductive structures and incompatible, prevent mating

Spiked penis of a beetle



# Prezygotic Barrier - (v) Gametic Barrier

- Eggs and sperm are incompatible

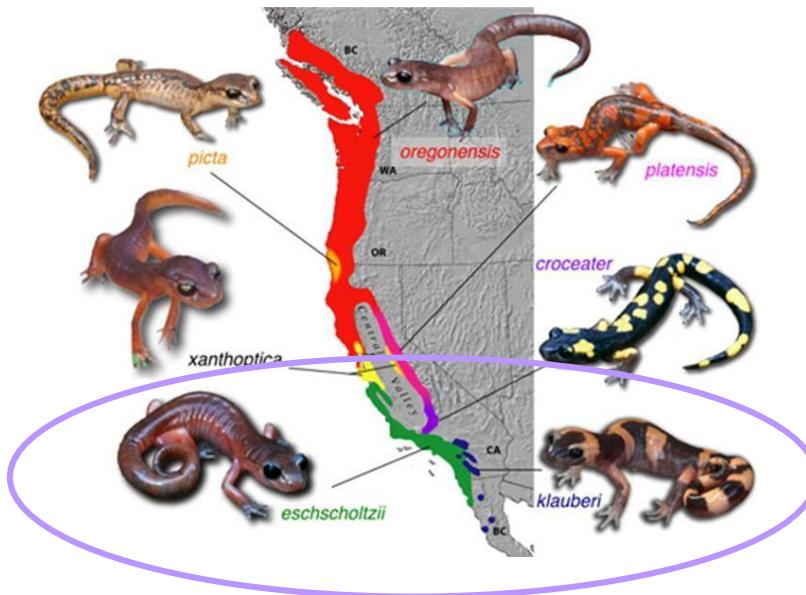
In sea urchins, a protein called bindin that allows sperm to penetrate the egg.

Differences in the amino acid sequence of bindin cause matings to fail between closely related populations.



# Postzygotic barriers - (i) hybrid inviability

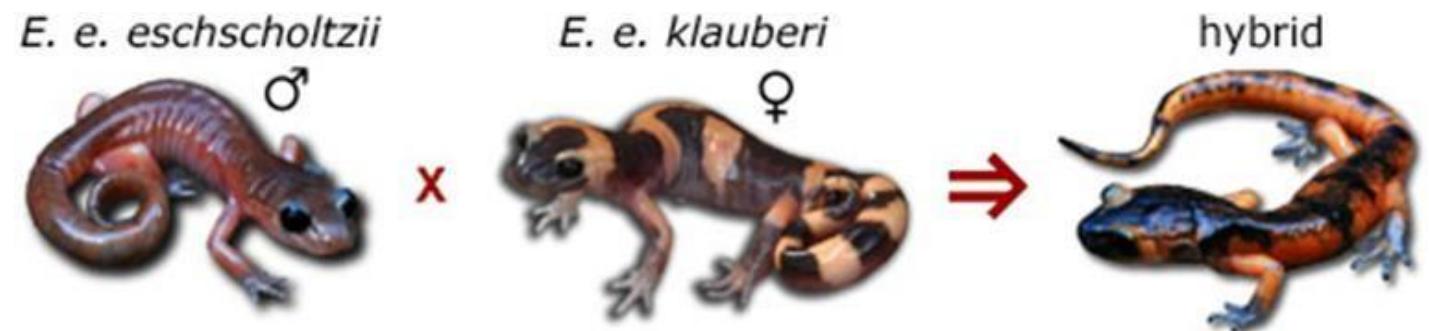
- Two individuals can mate and sperm can fuse with egg to create embryo, but:
- Hybrid embryos do not develop properly. Or offspring do not reach sexual maturity (natural selection). Or offspring fail to mate.
- *Ensatina* hybrids more visible to predators



(*E. e.* = *Ensatina escholtzii*)

<http://www.ensatina.net/FILES/research.htm>

Map from evolution.Berkeley.edu



Subspecies = populations that live in discrete geographic areas and have distinguishing features (e.g. colouration or calls), but are not yet considered distinct enough to be called separate species.

## Postzygotic barrier - (ii) hybrid sterility or less fertile



male donkey  
(62 chromosomes)



female horse  
(64 chromosomes)



= mule (almost always sterile)

## Biological Species Concept Limitations

- Works well for organisms that sexually reproduce and have not gone extinct.
- Cannot be tested on fossil forms.
- Is not relevant to asexual populations (e.g. bacteria).

## #2 Morphospecies concept

- Oldest of the species concepts.
- Criteria - uses differences in morphology to distinguish species.
- Can be used for both living and extinct species.

# Morphospecies Concept - Bears



GRIZZLY BEAR **vs** BLACK BEAR

The infographic compares Grizzly Bear and Black Bear morphological features through side-by-side illustrations and track/claw diagrams.

**Grizzly Bear Morphology:**

- SHOULDER HUMP
- ROUNDED, SHORT EARS
- DISHED FACE PROFILE
- LONG CLAWS

**Black Bear Morphology:**

- NO SHOULDER HUMP
- POINTED, TALL EARS
- STRAIGHT FACE PROFILE
- SHORT CLAWS

**Tracks:**

	FRONT	HIND
Grizzly Bear		
Black Bear		

**Front Claw:**

	FRONT CLAW
Grizzly Bear	2"- 4" LONG 
Black Bear	1.5" LONG 



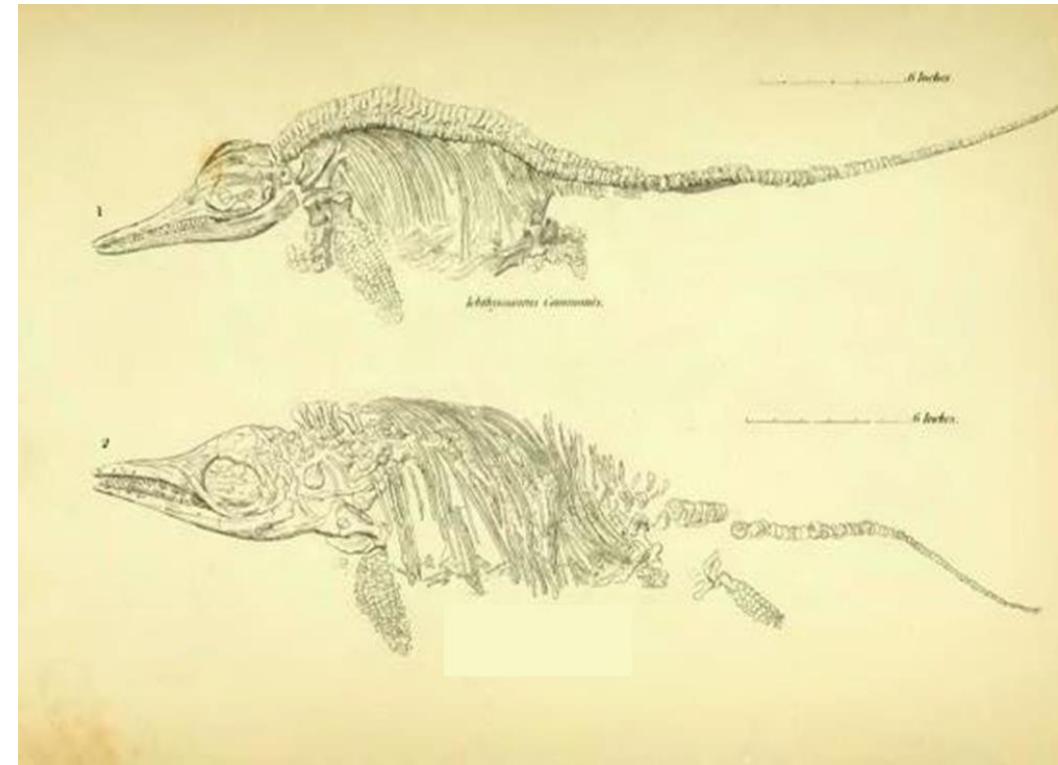
Daniel J. Burns



# Morphospecies Concept

Can be used for:

- Living and extinct species
- Species that reproduce sexually and asexually



One limitation of the morphospecies concept: Different species may look very similar .

In British Columbia – in 2017, researchers discovered that one species of flying squirrel is in fact two species (based on DNA evidence):

*Glaucomys oregonensis* (left) and *Glaucomys sabrinus* (right)



Source:  
[inaturalist.ca](https://inaturalist.ca)



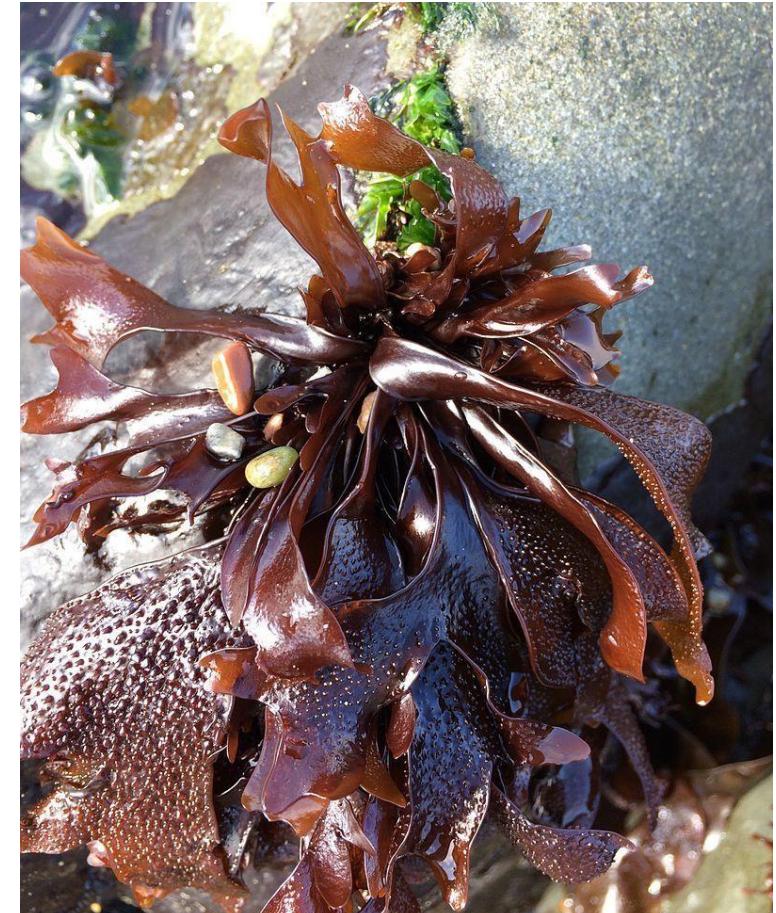
Another drawback of MSC - Individuals of the same species can look different at various life stages

### Same species – two life forms

Original name: *Petrocelis* sp. (tar spot – can live up to 90 years in this form).



*Mastocarpus* sp.



## #3 Ecological Species Concept

- Definition: Organisms are classified as the same species if they have the same ecological niche (i.e. same habitat, food, predators, etc.) and as different species if they do not.

# Ecological species concept – 2 different species



## Whale Shark

Habitat: marine

Diet: filter feeds plankton

Predators: few natural predators (other sharks when young)



## Rainbow trout

Habitat: Freshwater

Diet: Insects, small fish, decomposing flesh

Predators: larger fish, raccoons, birds, bears

# Ecological Species Concept



- Advantages: Useful for identifying asexual species, e.g. bacteria (freshwater, hot springs, human gut).
- Several challenges....

Challenge #1 – some species change their niche over time, e.g.  
caddisfly larva (aquatic), adult (terrestrial)



Source:  
Wikipedia

## Challenge #2 – different species can share the same niche

**Purple Shore Crab (*Hemigrapsus nudus*)**



Source:  
wikipedia

**Yellow Shore Crab (*Hemigrapsus oregonensis*)**



Source: <https://wsg.washington.edu/hemigrapsus-oregonensis-jaws>

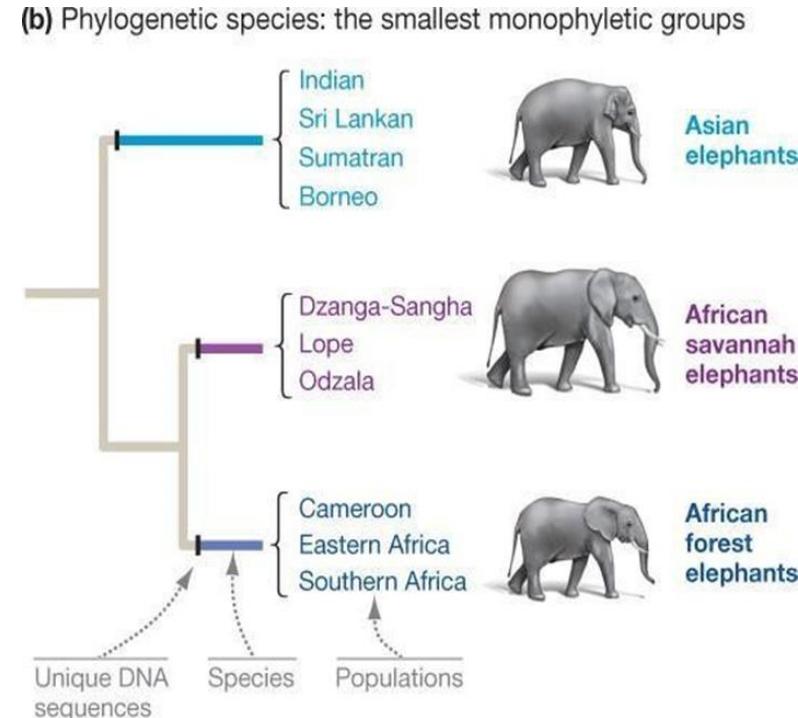
Both crabs live in the intertidal zone (e.g. Tower Beach). Both crabs feed on diatoms, macroalgae and small invertebrates. Both crabs are eaten by seabirds, anemones, intertidal fish (e.g. sculpin).

## #4 Phylogenetic Species Concept (PSA)

- Definition: PSA Concept defines a species as the smallest, non-divisible monophyletic group, distinguished by synapomorphies  
=ancestral population and its descendants and only those descendants
- Or – smallest set of organisms that share an ancestor and can be distinguished from other sets of organisms by synapomorphies
- Evidence – you need a phylogenetic tree

## #4 Phylogenetic Species Concept (PSA)

- Elephants – DNA was analyzed from multiple populations
- Unique DNA sequences found in populations of Asian Elephants, African Savannah Elephants and African Forest Elephants
- Consequently, African Savannah Elephants and African Forest Elephants are now classified as separate species.



# Limitations of the Phylogenetic Species Concept (PSA)

- Pro's - Phylogenetic trees can be used for living and extinct taxa, and sexually and sexually reproducing species.
- Drawback – few phylogenetic trees, and phylogenetic trees require a lot of resources to construct.

## Expected Learning Outcomes – 4 species concepts

- Understand/know the 4 SPECIES CONCEPTS:
  - Know when is it appropriate to apply each of the four species concepts?
  - Be able to determine if two groups/taxa represent one or more species and explain your reasoning.
  - NEW: Be able to list/identify a limitation/challenge for each of the 4 species concepts.

# A Tale of Two *Orca* (*Orcinus orca*)

Transient *Orca*



Resident *Orca*



# A Tale of Two *Orca* (*Orcinus orca*)

## *Transient Orca*

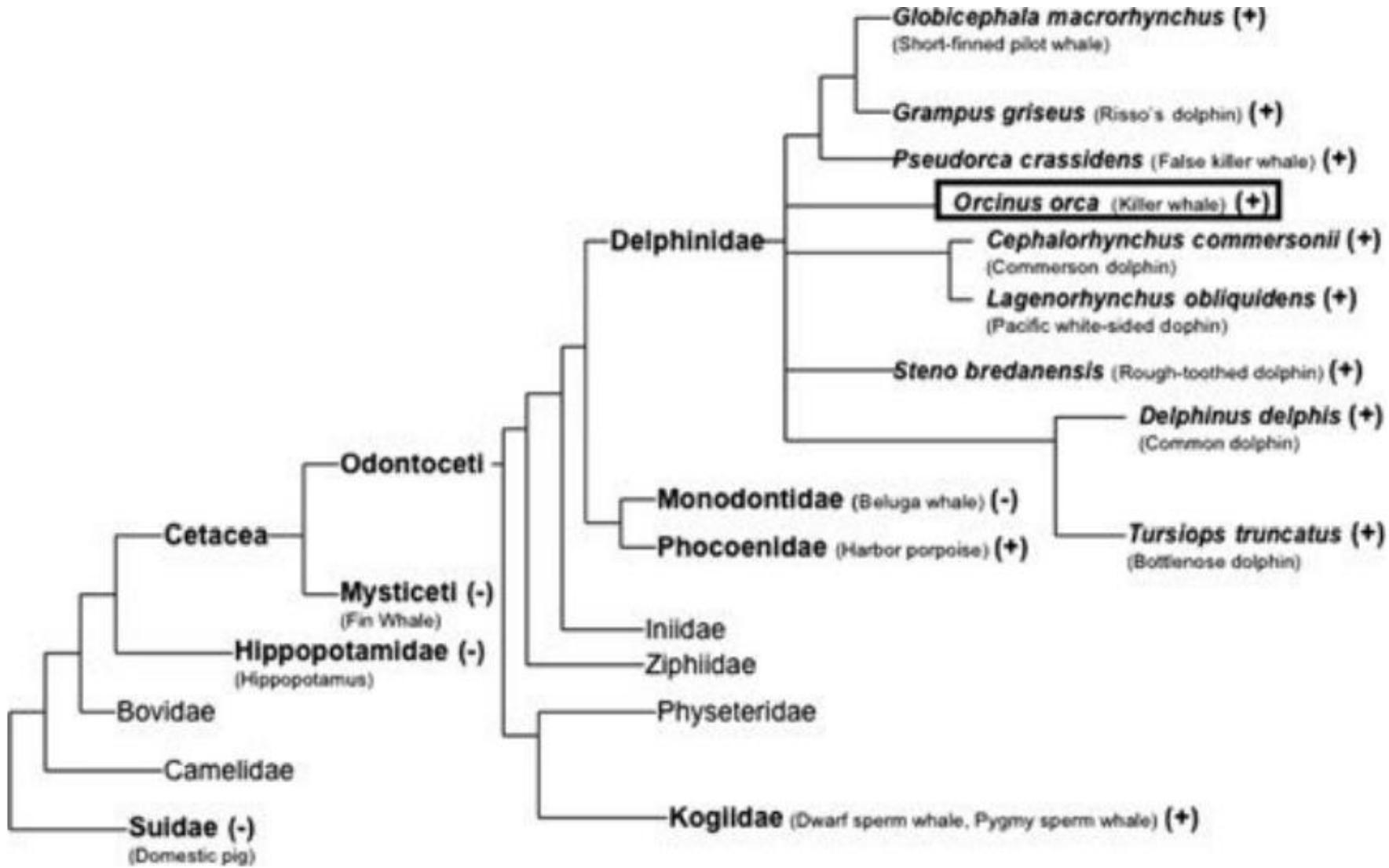
- i. Range extends from Alaska to California; also coast of Russia.
- ii. Smaller pods (not permanent)
- iii. Robust jaws
- iv. Pointed dorsal fins
- v. Feed on seals and other marine mammals
- vi. Transient *Orca* dialect (language)
- vii. Matriarchal

## *Resident Orca*

- i. Range extends from Alaska to California (southern residents) or Alaska to Washington State (northern residents).
- ii. Large pods, tight knit
- iii. More slender jaws
- iv. Round-tips on dorsal fins
- v. Feed on fish (salmon)
- vi. Resident *Orca* dialect
- vii. Matriarchal

Transients and Resident *Orca* may have diverged from common ancestor 700,000 years ago (<https://academic.oup.com/jhered/article/104/6/737/796937>)

# Phylogenetic Tree



Source: unknown

# iClicker Question

Are the transient *Orca* and resident *Orca* the same species or two different species? Talk this over with a neighbour

A = same species

B = separate species

C = not sure

What species concept (or concepts) did you use to come to this conclusion?

There is no correct answer to this question. Currently transient and resident Orca are classified as the same species.

If this were an exam question, I might ask you to identify a species concept that would justify classifying the T and R groups as separate species (or as the same species).

Note – it has been proposed that transient and residents be classified as different subspecies (see snip of paper); but, I haven't found evidence that this proposal has been accepted yet.

Original Paper | Published: 23 March 2019

Large-scale habitat segregation of fish-eating and mammal-eating killer whales (*Orcinus orca*) in the western North Pacific

Olga A. Filatova  Olga V. Shpak, Tatiana V. Ivkovich, Evgenija V. Volkova, Ivan D. Fedutin, Ekaterina N. Ovsyanikova, Alexander M. Burdin & Erich Hoyt

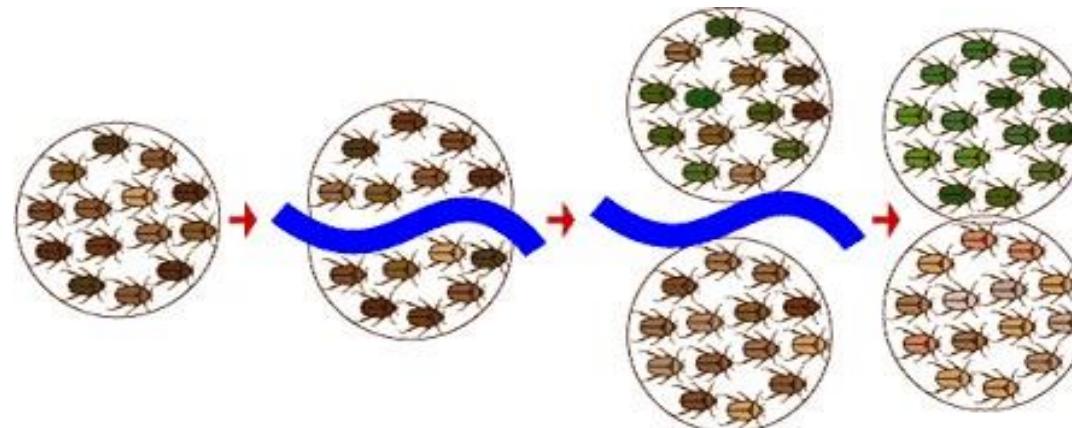
*Polar Biology* 42, 931–941 (2019) | Cite this article

1861 Accesses | 10 Citations | 17 Altmetric | Metrics

# Speciation

**Speciation** = evolutionary process by which new species form.

A species is a group of organisms that can reproduce with each other (or potentially reproduce with each other) and produce fertile offspring but is reproductively isolated from other organisms. (BSC)

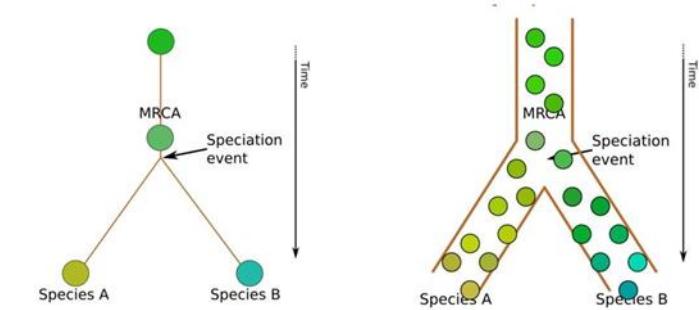


# 3 steps to speciation – order of steps is important

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/or **genetic drift** affecting populations independently.
3. Reproductive isolation

Prezygotic/postzygotic barriers to reproduction evolve (see examples under BSC).

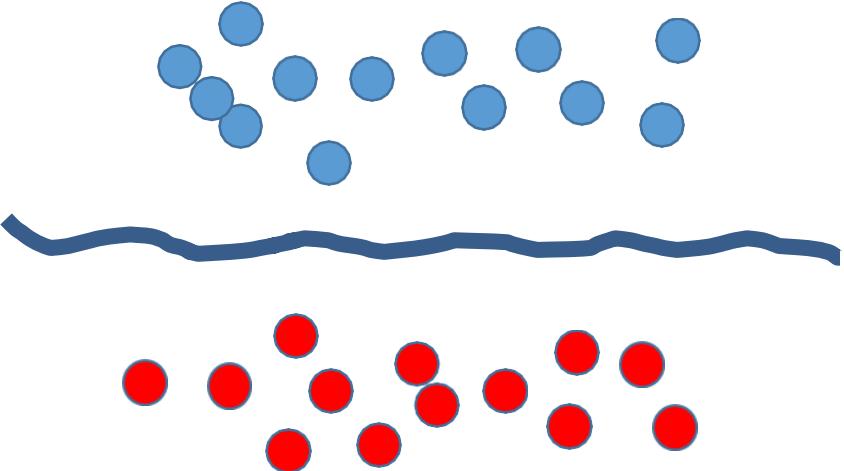
  - So, if two populations that have been isolated from each other come into contact again...
  - They would be unable to mate, and/or could mate but produce offspring with low survivorship and/or low fitness.



# Two\* mechanisms of speciation

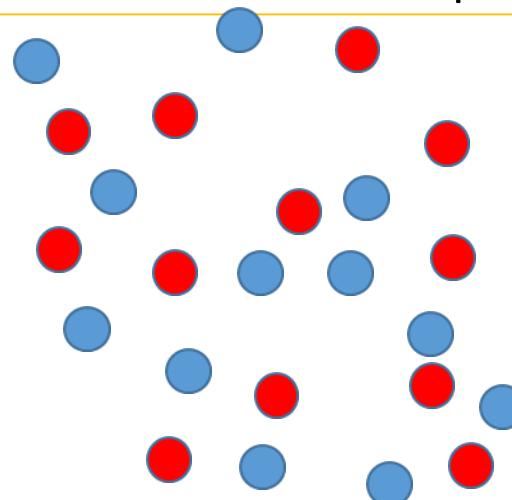
## Allopatric Speciation

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



## Sympatric Speciation

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

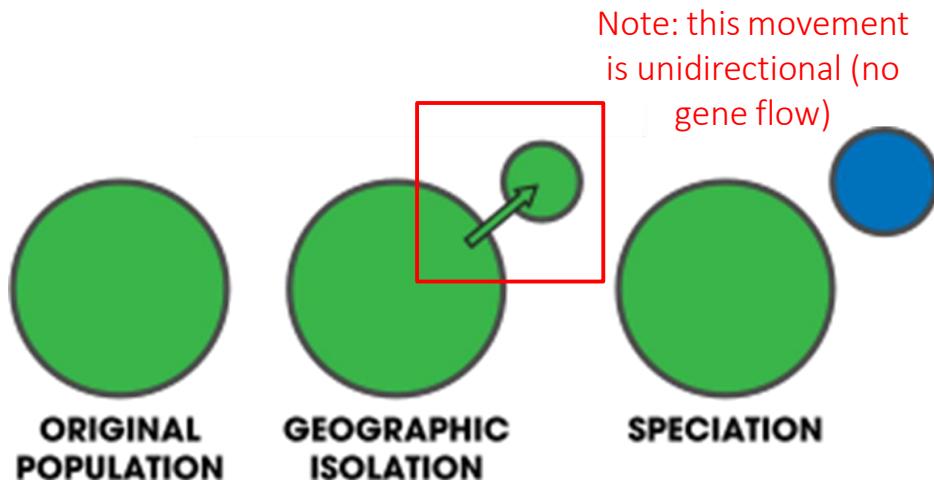


\* There are others

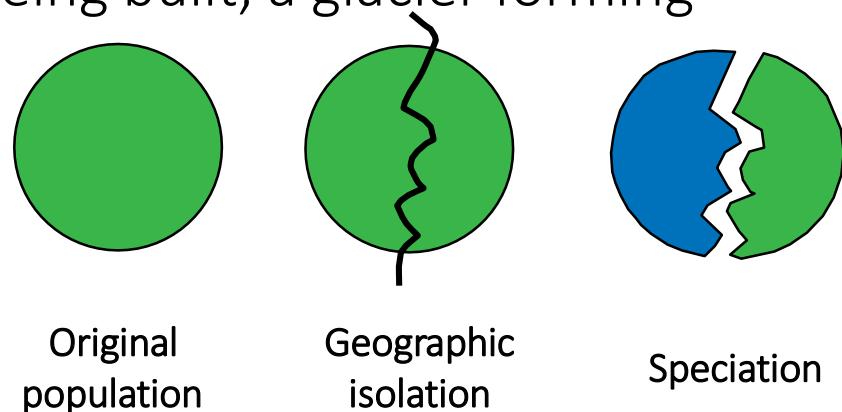
# Allopatric speciation

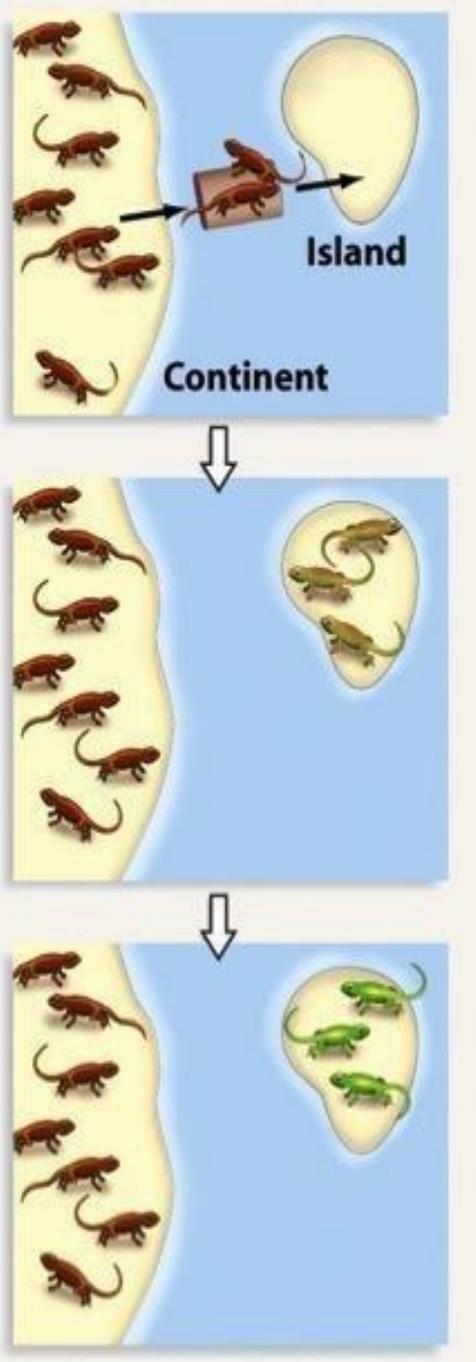
Populations become geographically isolated. Two ways this can happen.

**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

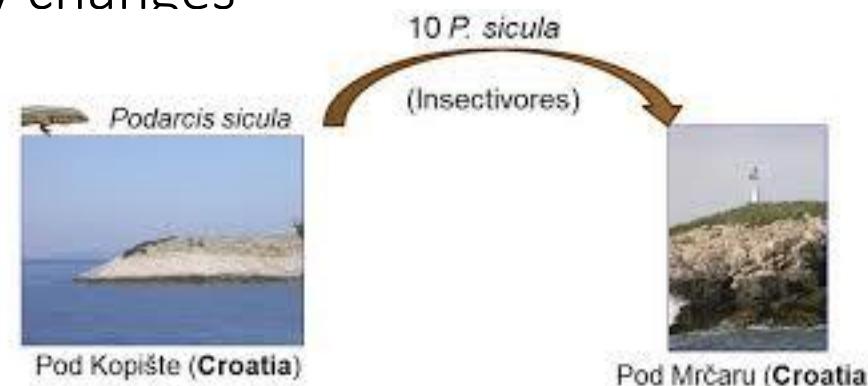
1. Some individuals from a population disperse to a new location
  - No gene flow between populations.
2. Allele frequencies of colonists begin to diverge from source population
  - Genetic drift (e.g., founder effect)
  - Natural selection (e.g., new habitat differs from source habitat)
  - Mutation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

Speciation is complete!

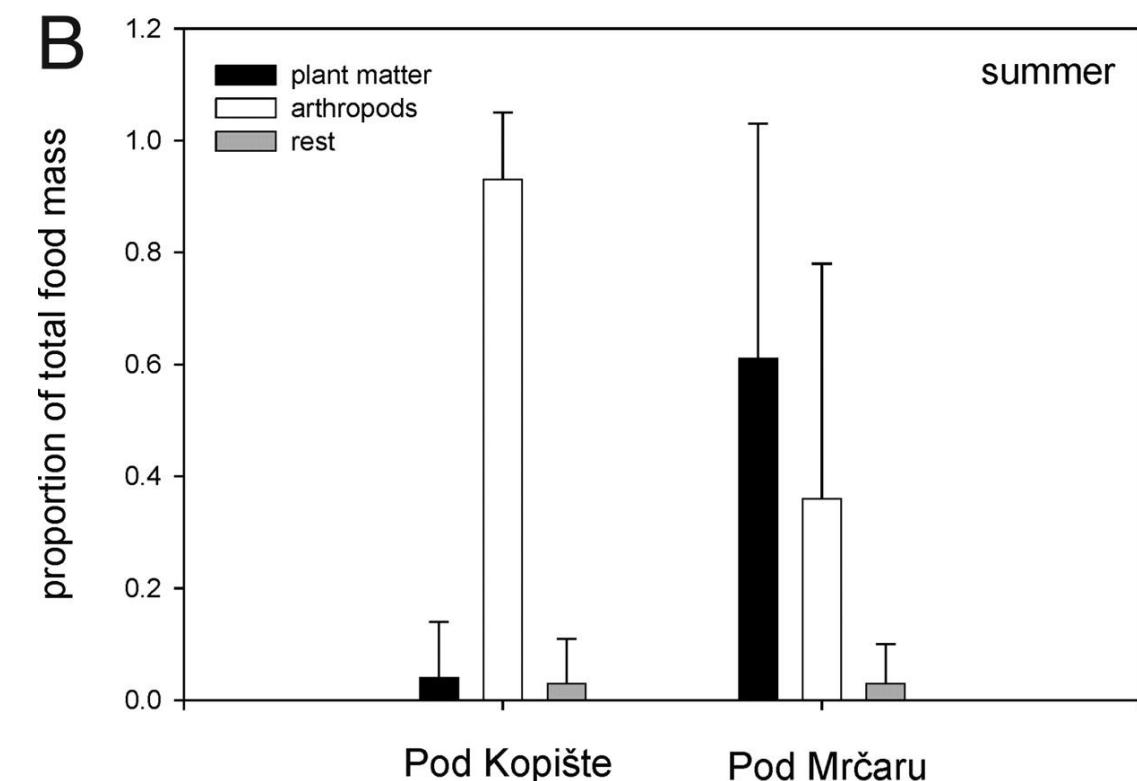
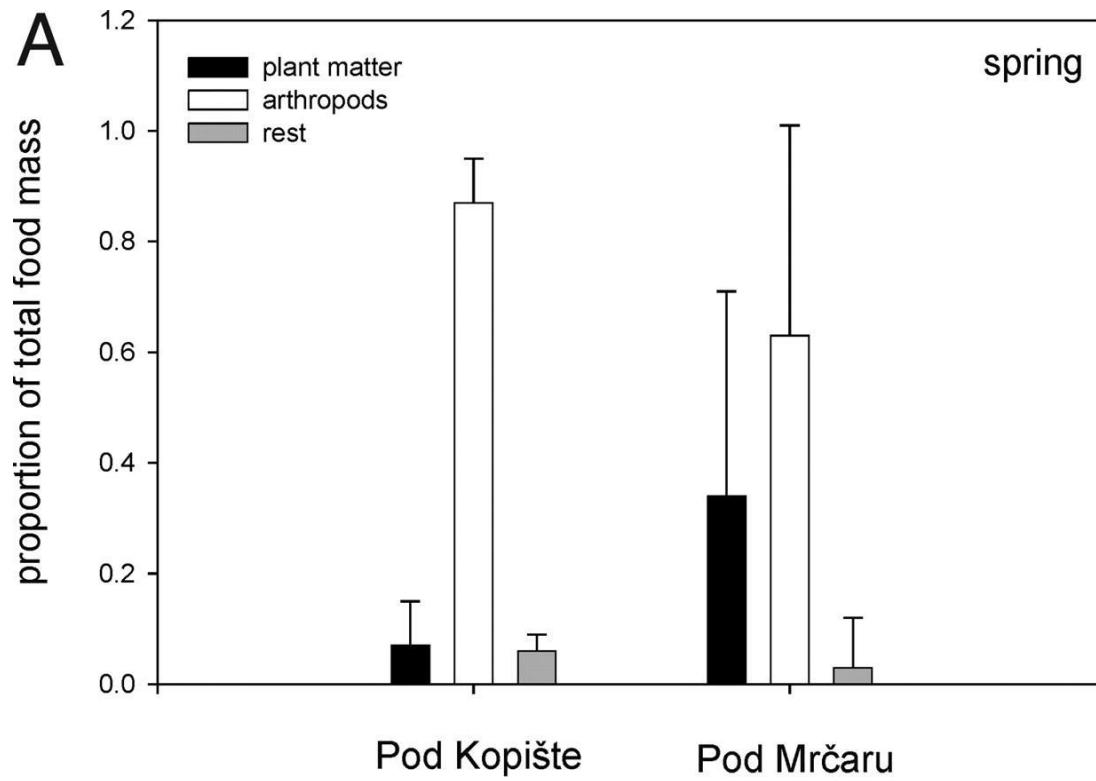
Note – issue with this figure – the population on the mainland should also be evolving; so imagine that it too changed colour, or evolved spots or something ☺.

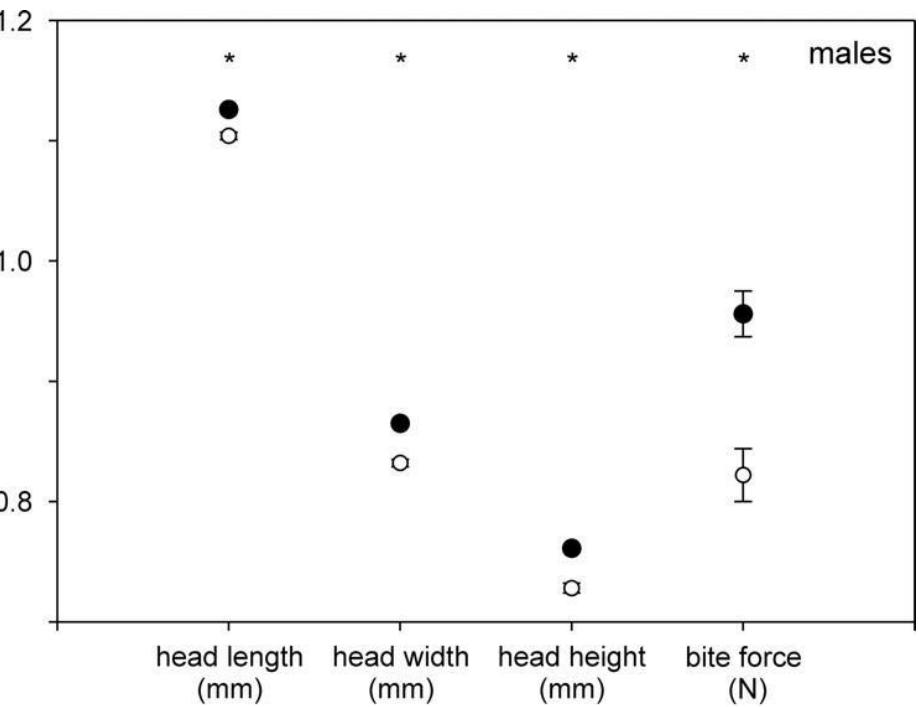
# Real life example - beginning of allopatric speciation via dispersal (founder effect) – European wall lizard

- 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



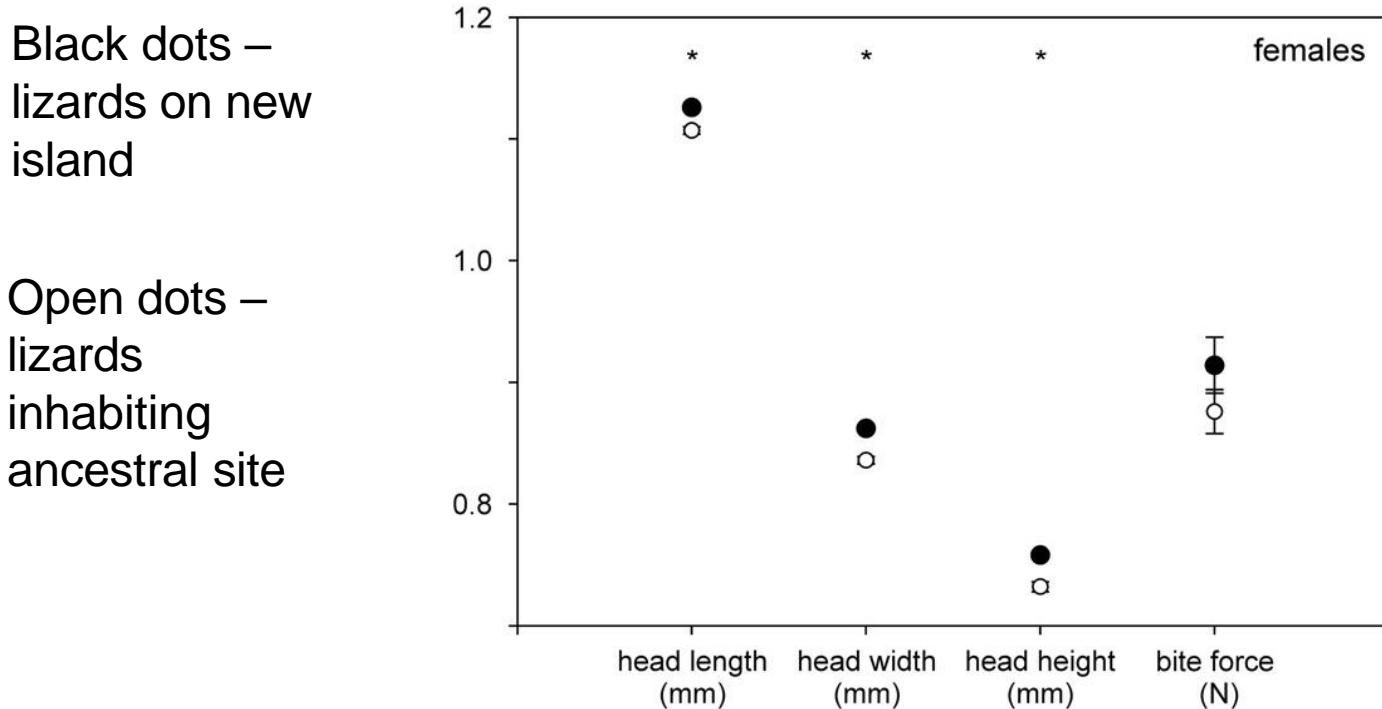
Lizards on Pod Mrčaru (new island) eat significantly more plant material (dark bars) than the lizards on the ancestral island (Pod Kopiste), especially in the summer.





Black dots –  
lizards on new  
island

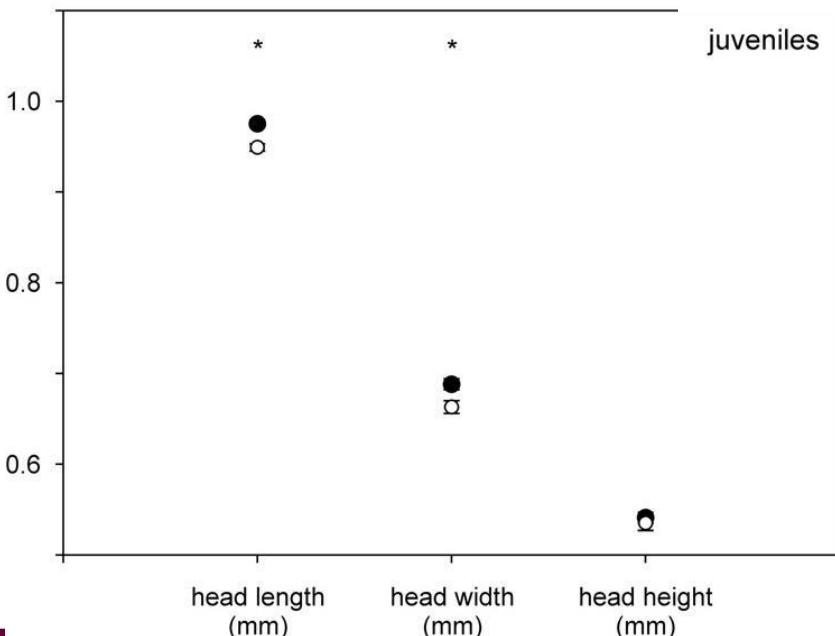
Open dots –  
lizards  
inhabiting  
ancestral site

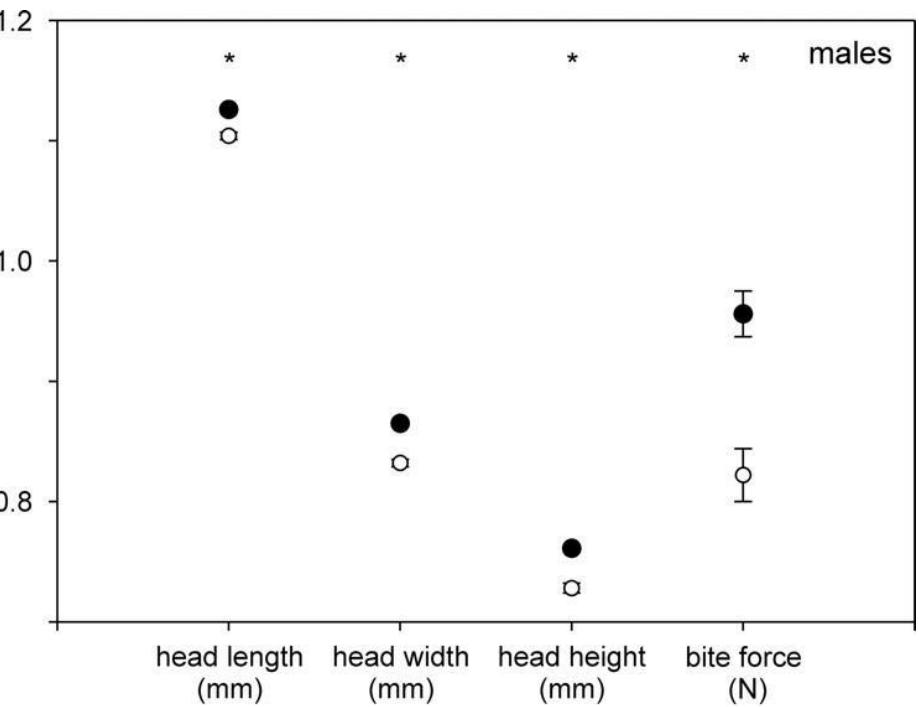


Are there morphological differences between the wall lizards introduced to the new island (Pod Mraru) and the lizards on the original island?

- A. Yes
- B. No
- C. Not sure

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



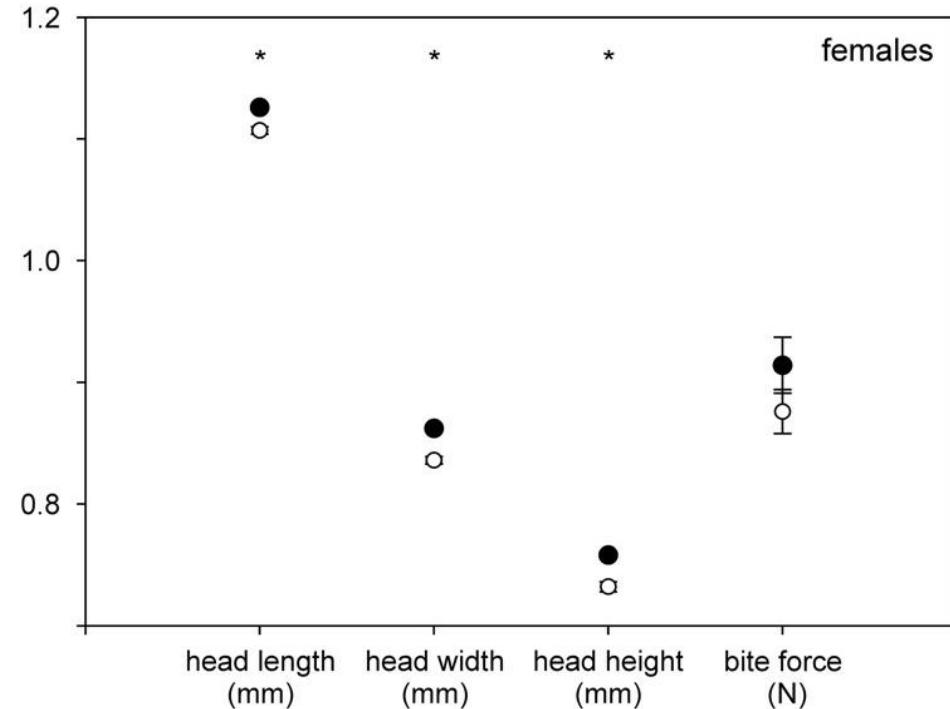


Black dots – introduced lizards  
Open dots – lizards inhabiting ancestral site

head length (mm)    head width (mm)    head height (mm)    bite force (N)

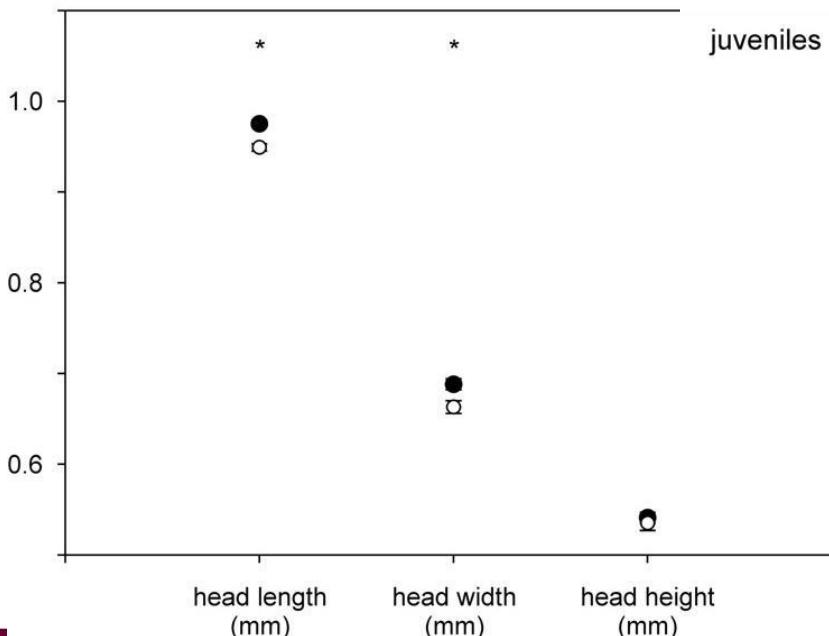
Are there morphological differences between the wall lizards introduced to the new island (Pod Mraru) and the lizards on the original island?

- A. Yes
- B. No
- C. Not sure



females

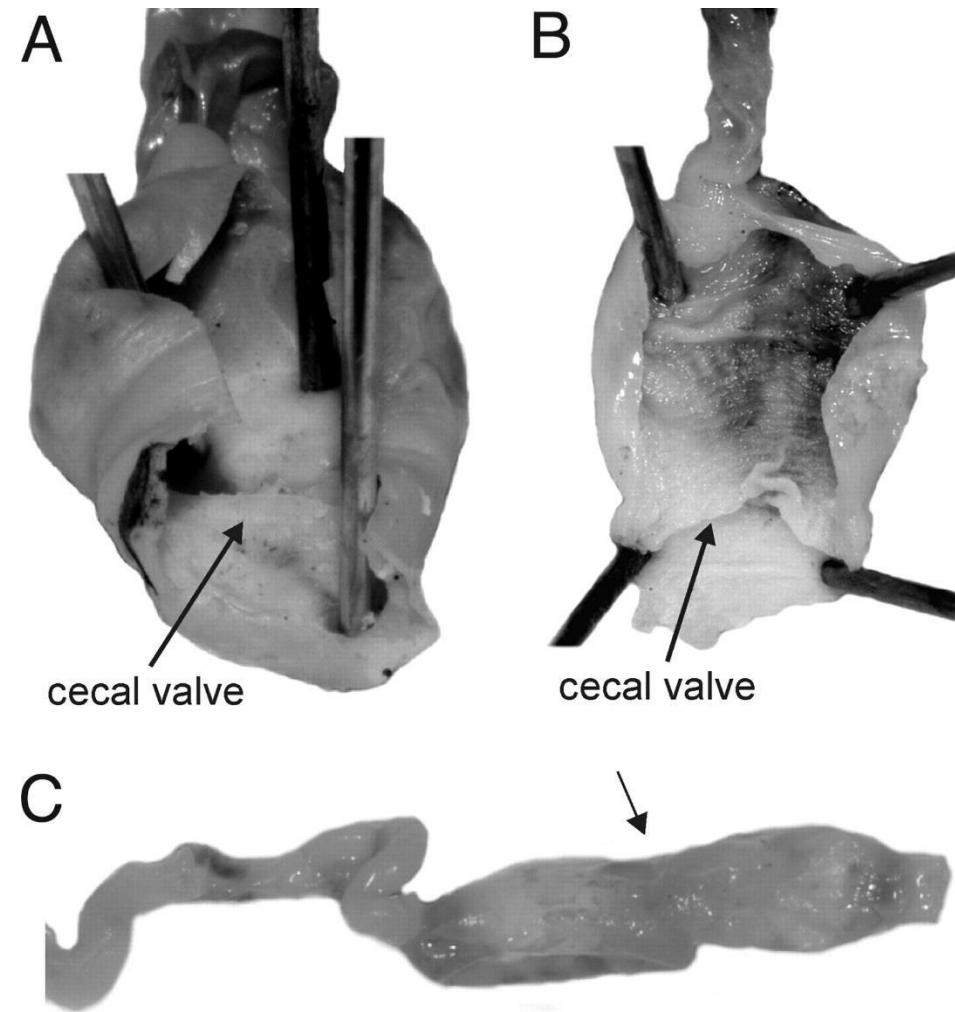
head length (mm)    head width (mm)    head height (mm)    bite force (N)



juveniles

Introduced lizards: significant changes to head shape (longer & wider); and males have a significantly stronger bite force than lizards inhabiting ancestral site.

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)



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

# Next class

Finish speciation: Allopatric Speciation via Vicariance & Sympatric Speciation

Start Ecology Unit