

Organismal Diversification

Walter Salzburger
Zoological Institute

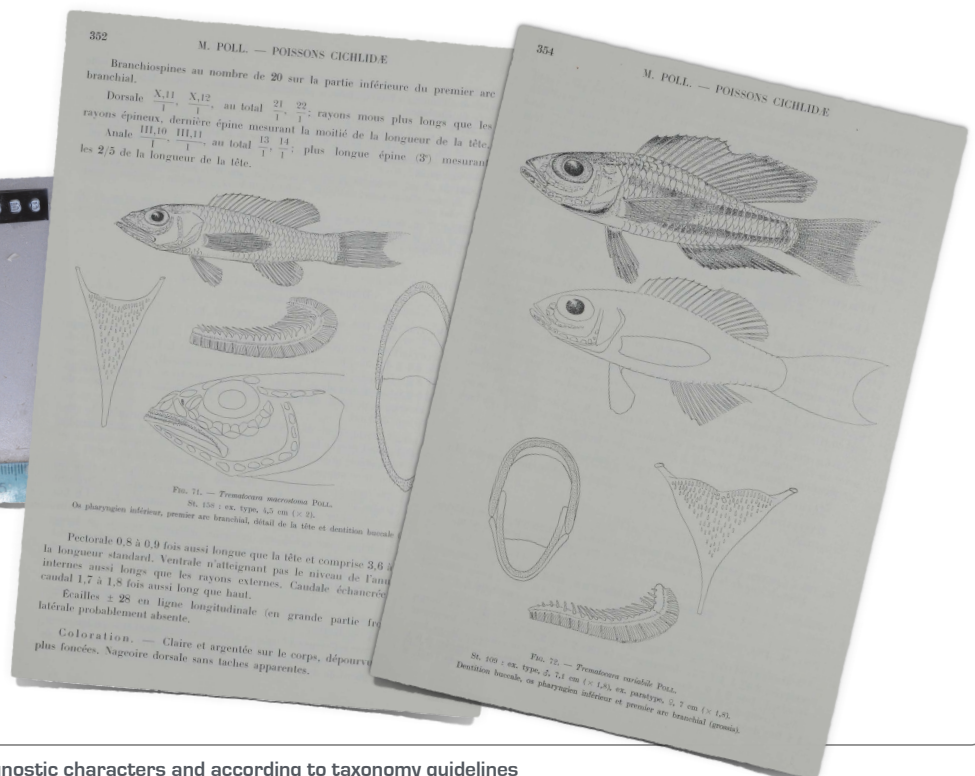


Universität
Basel

What is a Species?



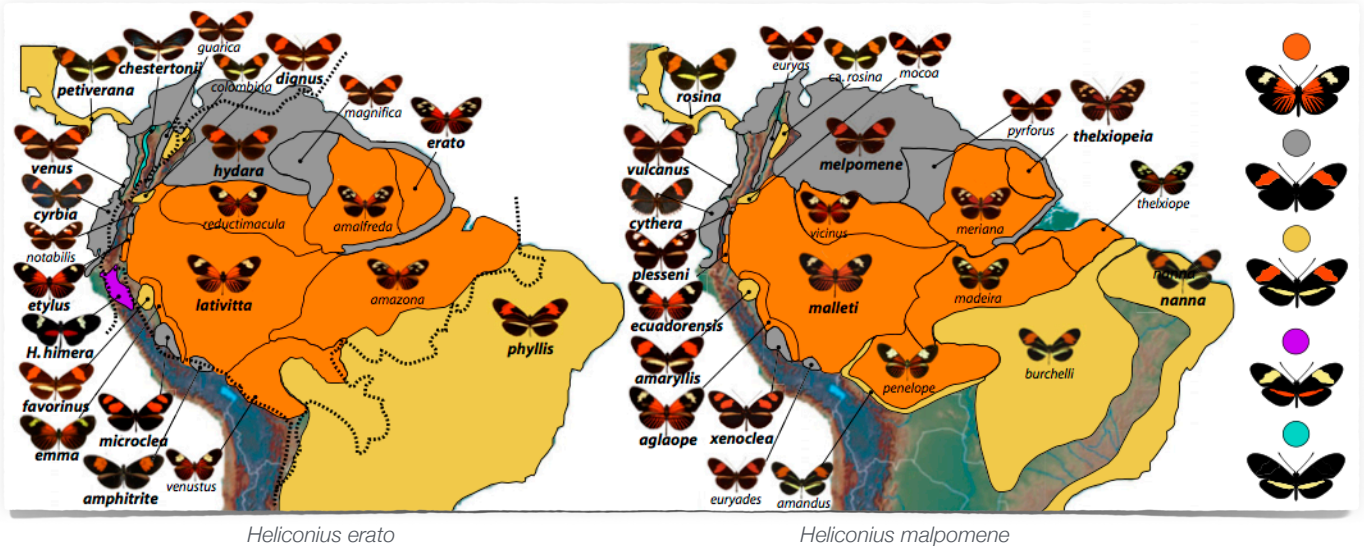
Specimen LBBB: *Trematocara macrostoma*



① Taxonomists describe species based on diagnostic characters and according to taxonomy guidelines

What is a Species?

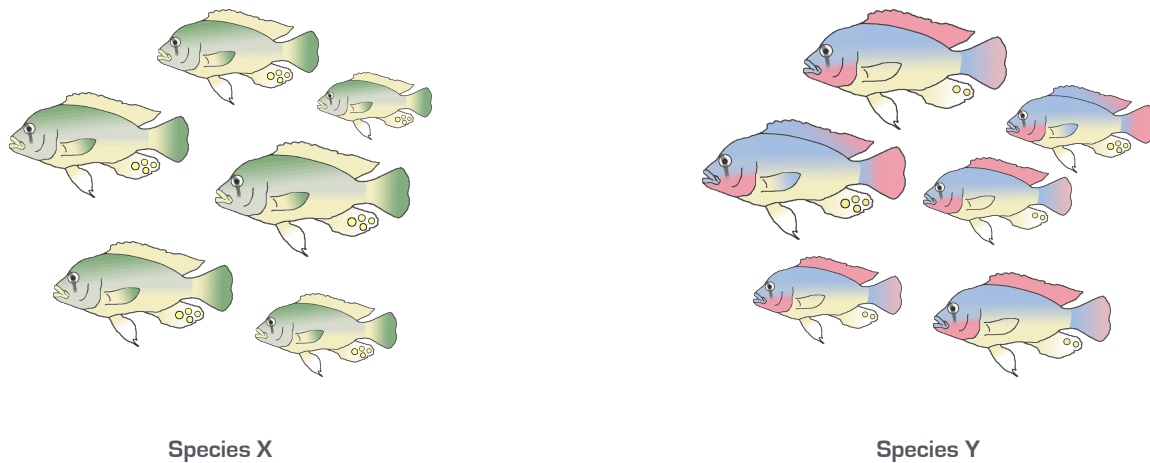
- Individuals within a species are **variable**. There is usually no "ideal" or "typical" individual.



- Heliconius erato* and *H. melpomene* are morphologically similar because of mimicry

What is a Species?

- Members of a species share a **gene pool**. Selection and drift operate within species.



- Evolutionary biologists interpret species as independent [real] evolutionary units

What is a Species?

- ▶ The category species is defined according to a **species concept**. Not one of the available species concepts provides a universally valid definition of the category species.

biological species concept

A species is a group of interbreeding natural populations that is reproductively isolated from other such groups (Mayr 1963).

cohesion species concept

A species is the most inclusive populations of individuals having the potential for phenotypic cohesion through intrinsic cohesion mechanisms (Templeton 1989).

ecological species concept

A species is a lineages (or a closely related set of lineages), which occupies an adaptive zone minimally different from that of any other lineage in range, and which evolve separately from all lineages outside its range (Van Valen 1976).

evolutionary species concept

A species is a single lineage of ancestral-descendant lineages that evolve separately from other such lineages and have their own evolutionary tendencies and historical fate (Simpson 1961; Wiley 1978).

phylogenetic species concepts

A species is the smallest monophyletic group of common ancestry (de Quieroz & Donoghue 1988). A phylogenetic species is a basal cluster of organisms that is diagnosably distinct from other such clusters (Cracraft 1989).

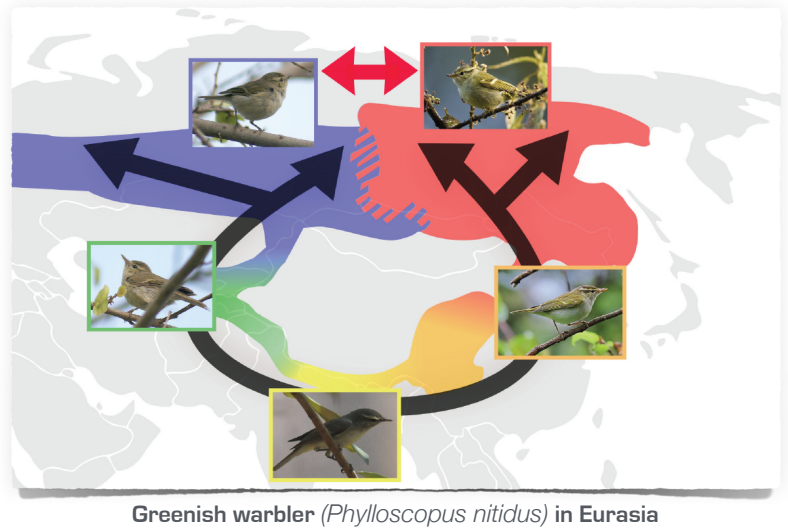
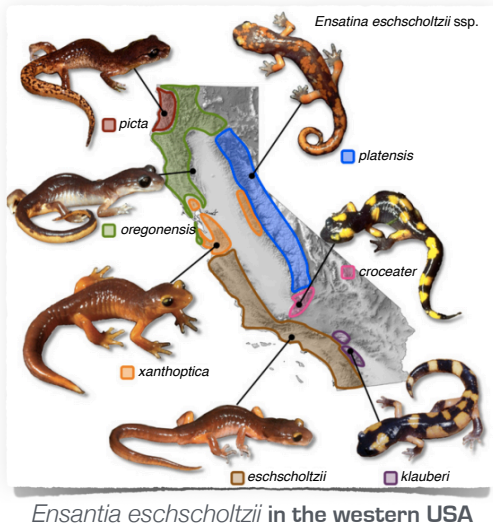
What is a Species?

- ▶ According to the **biological species concept**, a species is a group of interbreeding natural populations that is reproductively isolated from other such groups (Mayr 1963).



What is a Species?

► Conceptual problems with species definitions: ring species.

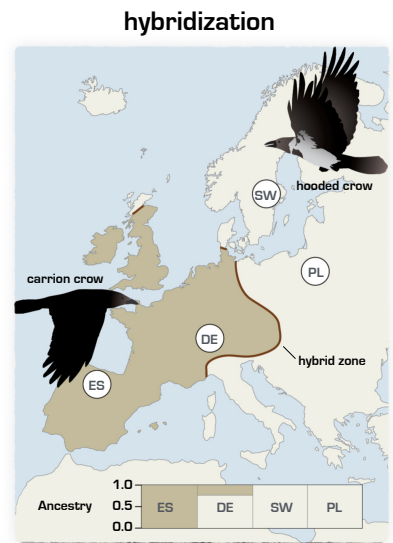
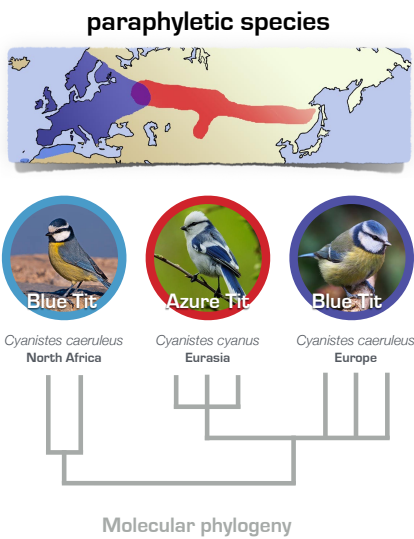


Images: Stobbins (1994), Wikimedia.org

① In a “ring species” two reproductively isolated populations are connected by a geographic ring of interbreeding populations

What is a Species?

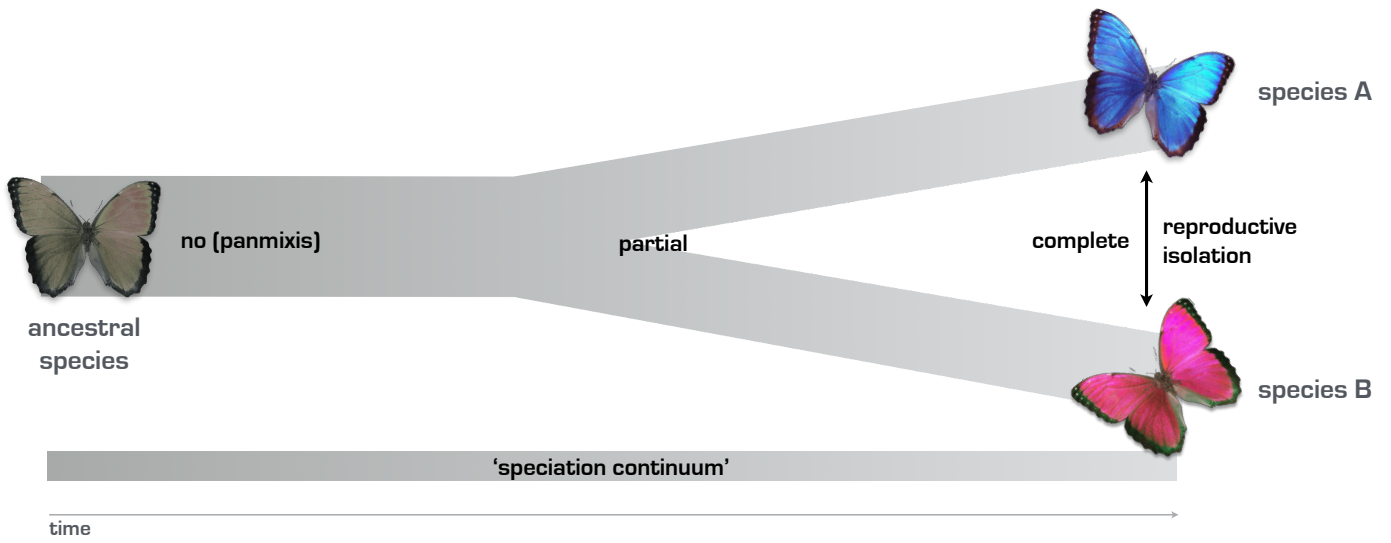
► Conceptual problems with species definitions:



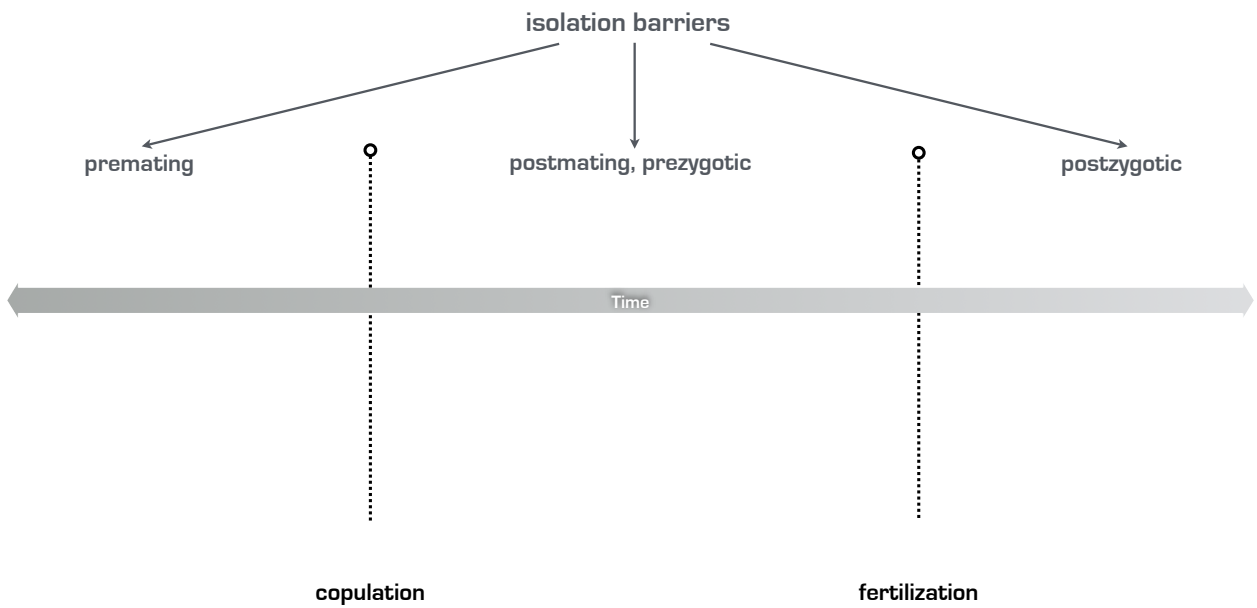
modified from Salzburger et al. (2002), de Knijff (2014)

① The African Blue Tit (*C. teneriffae*) has meanwhile been given species rank, “solving” the paraphyly situation

Reproductive Isolation

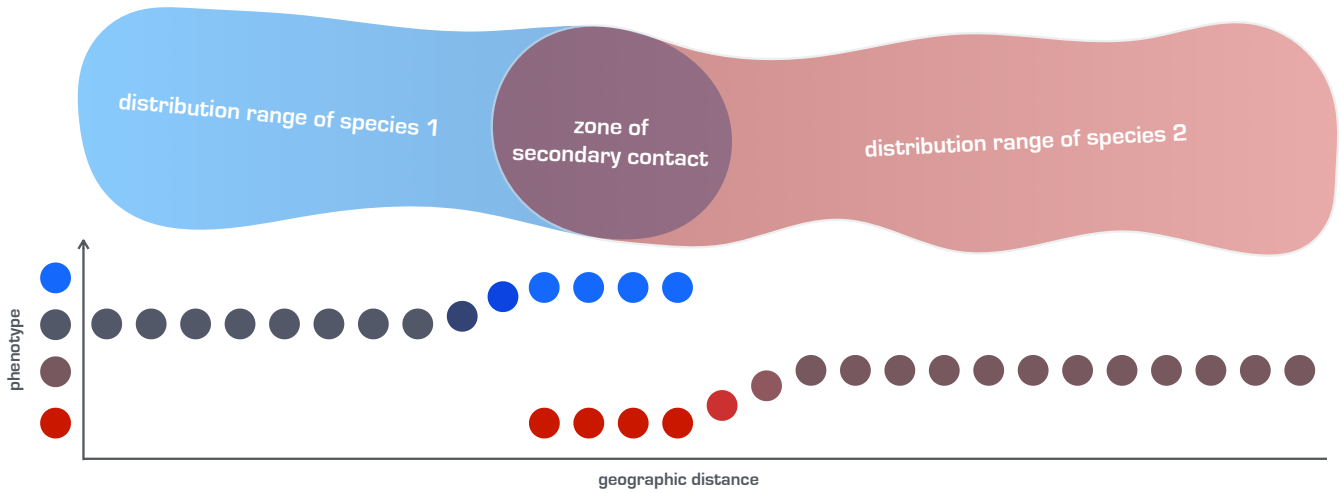


Reproductive Isolation



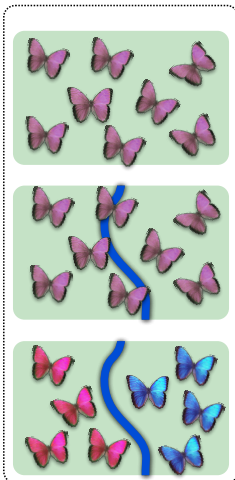
Isolation Barriers

► **Reinforcement:** Increase of reproductive isolation as a result of selection against the production of hybrids.

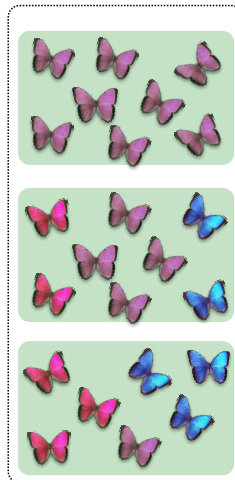


Geographic Conditions of Speciation

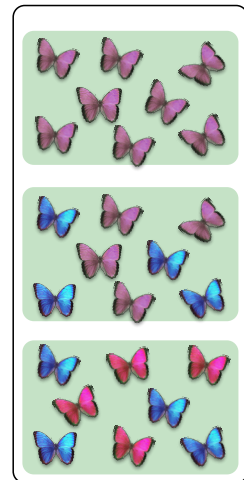
allopatric speciation



parapatric speciation



sympatric speciation



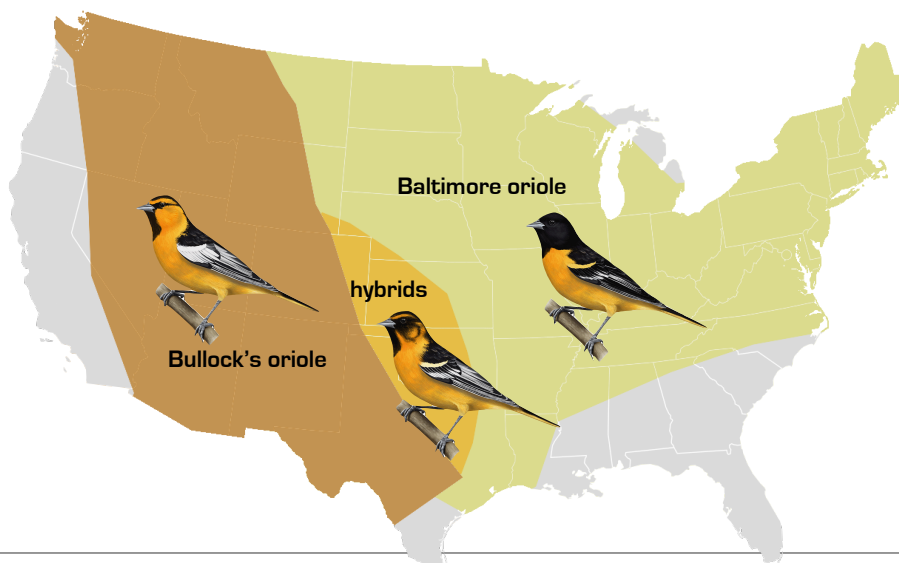
Allopatric Speciation



① The Isthmus of Panama formed between 3.5-10 million years ago, establishing a land-bridge between the Americas

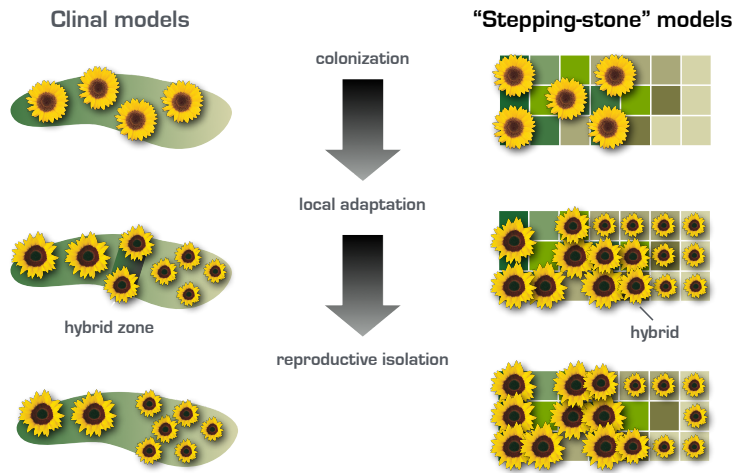
Parapatric Speciation

▶ Example: Bullock's oriole and Baltimore oriole in the United States of America



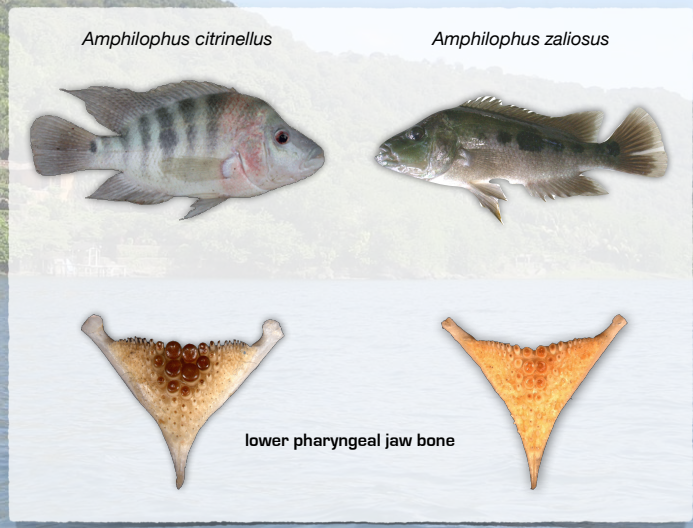
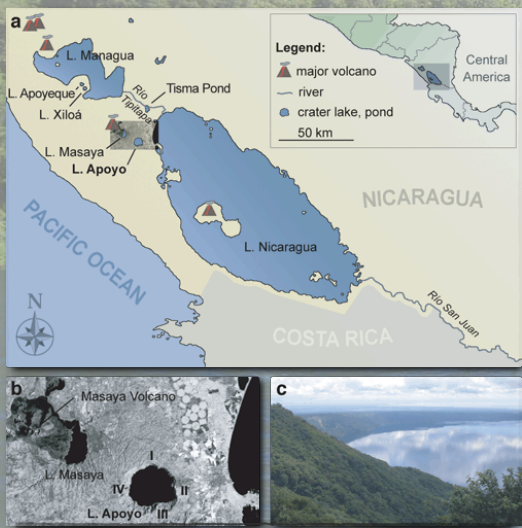
Parapatric Speciation

► Models of parapatric speciation typically involve a gradient (ecological, geographic) and occasional hybridization



Sympatric Speciation

► Example: Cichlid fishes in Crater Lake Apoyo in Nicaragua



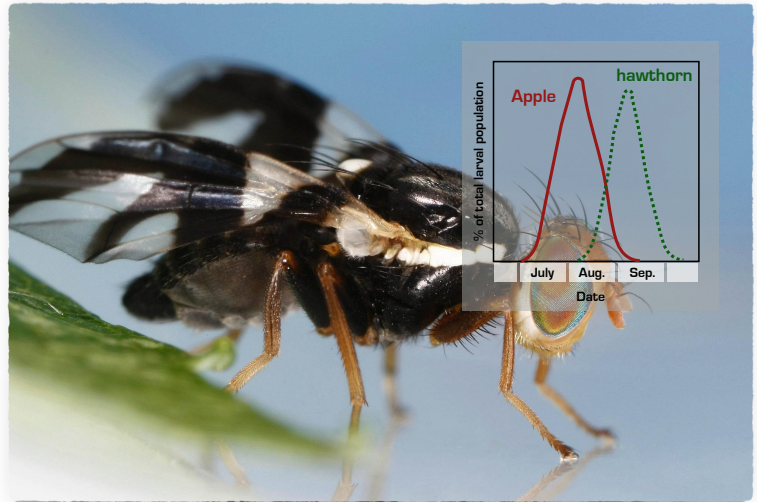
① The 'Laguna de Apoyo' is a small but deep volcanic crater lake

Sympatric Speciation

- ▶ Examples: Palm trees on Lord Howe Island and apple maggot flies in North America



Howea forsteriana *Howea belmoreana*



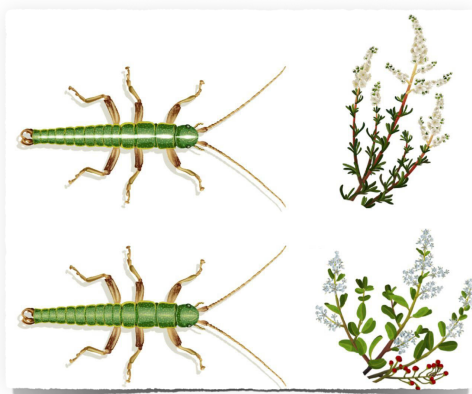
Rhagoletis pomonella

modified from Savolainen et al. (2006), Fitchak et al. (2000), image: wikimedia.org

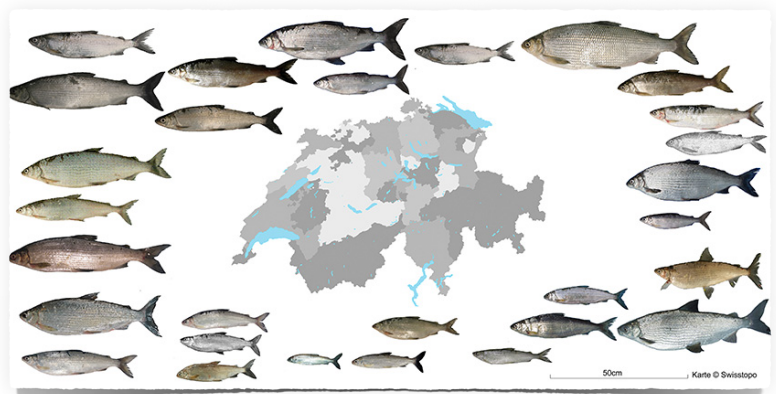
Ecological Speciation

- ▶ Ecological speciation is the evolution of reproductive isolation between populations by adaptation to different environments or ecological niches

Timema stick insects



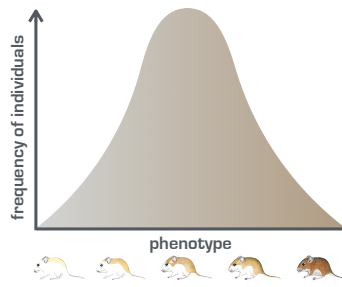
Lake whitefish



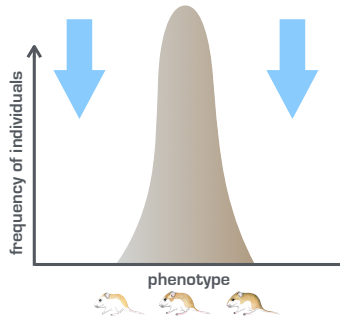
① Ecological speciation can occur in allopatry, parapatry and sympatry

Selection

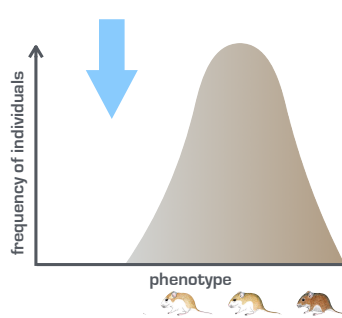
original population



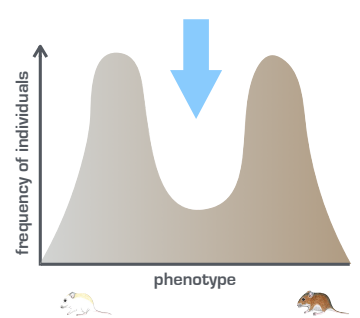
stabilizing selection



directional selection



disruptive selection



Selection

- **Natural selection** is the process by which the forms of organisms in a population that are best adapted to the environment increase in frequency relative to less well-adapted forms over a number of generations (Ridley 2004)



Selection

- ▶ **Sexual selection** is the selection on mating behavior, either through competition among members of one sex (usually males) for access to members of the other sex, or choice by members of one sex (usually females) for certain members of the other sex (Ridley 1996)



Images: National Geographic, www.smh.com.au

Selection

- ▶ **Both natural and sexual selection** operate if the following conditions are met:

reproduction

organisms must reproduce to form new generations

heredity

offspring resemble parents ("like must produce like")

trait variation

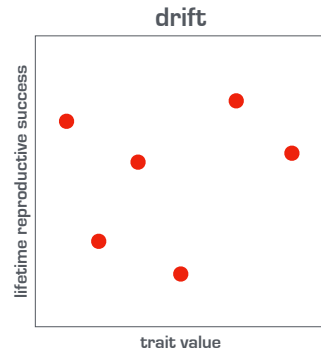
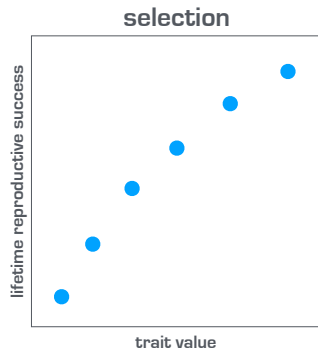
individuals in natural populations vary in (adaptive) traits

variation in fitness

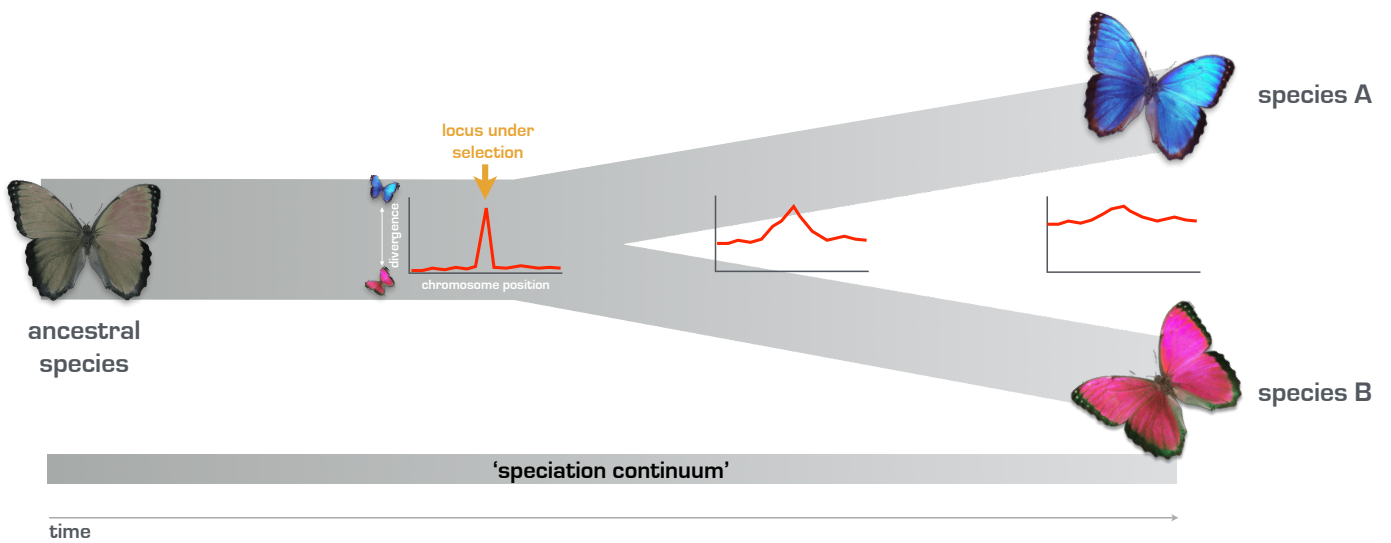
individuals in natural populations vary in the number of their offspring that survive to reproduce ('lifetime reproductive success')

Selection

► (Natural) selection versus drift:



Speciation Continuum | Genomics



Speciation Continuum | Genomics

► Cichlid fishes (*Astatotilapia sp.*) in crater lake Massoko (Malinsky et al. 2015, Science)

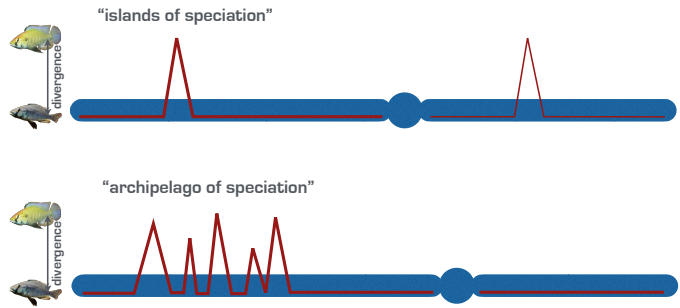
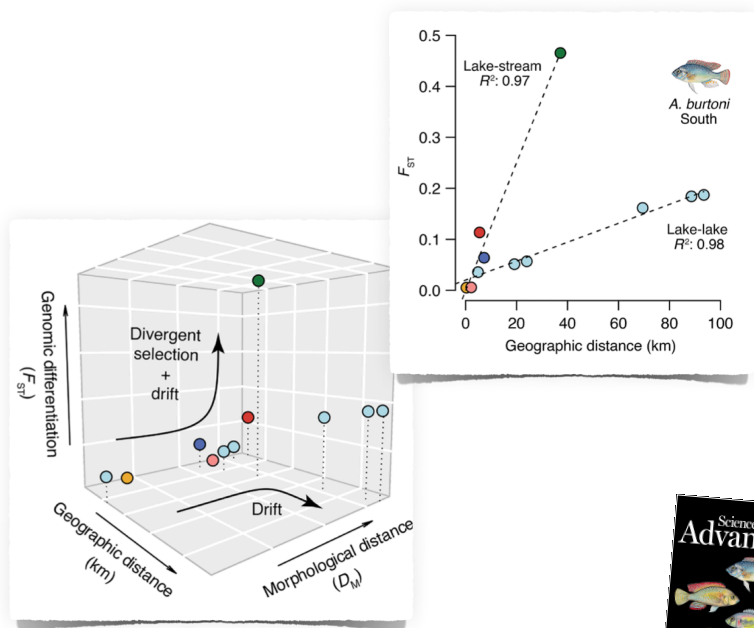
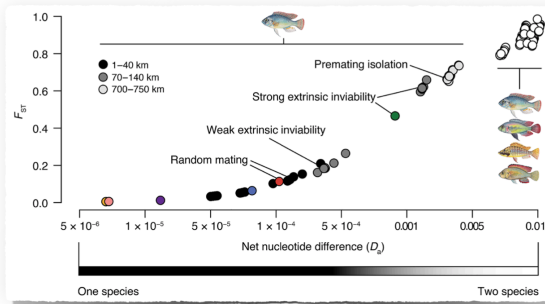
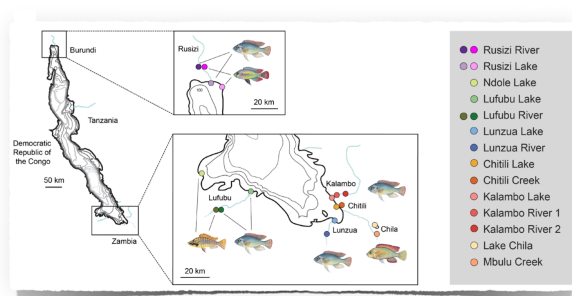


Figure: Ronco & Salzburger (2016) | Current Biology

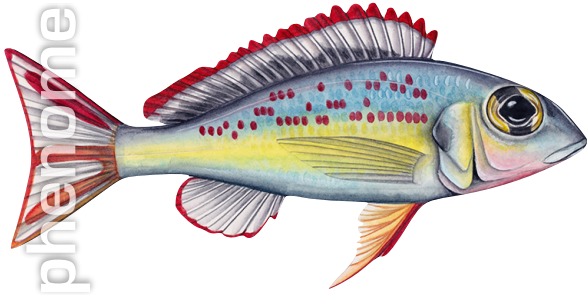
Speciation Continuum | Genomics



••• AAT Weber, J Rajkov, K Smaluis, B Egger & W Salzburger (2021) Science Advances

Speciation | Genomics

phenome



genome



genome structure

and/or



...ATG AAC **GTA** TGG AGG...
...Met Asn **Val** Trp Arg...

coding sequence

and/or

...ATG AAC **GCA** TGG AGG...
...Met Asn **Ala** Trp Arg...



regulatory elements

