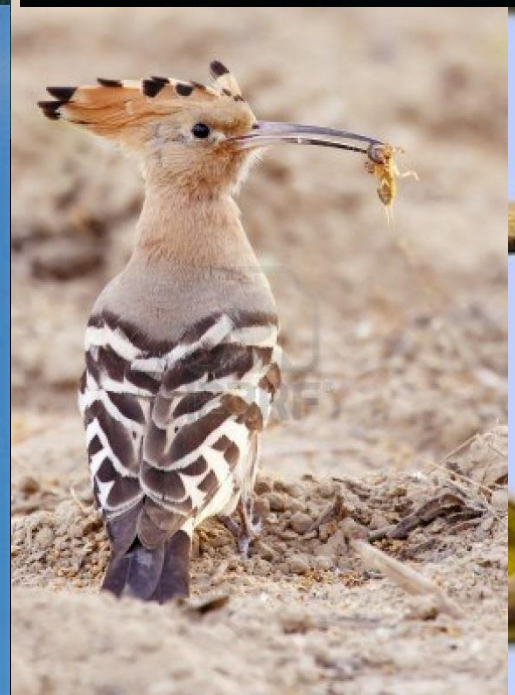
Ecologie et diversification de papillons mimétiques d'Amazonie et des Andes

Marianne Elias
Institute de Systematique, Evolution, Biodiversité
CNRS, MNHN



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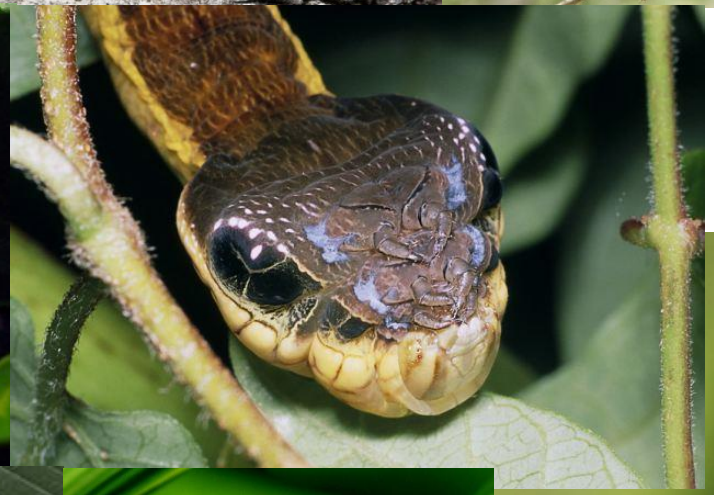

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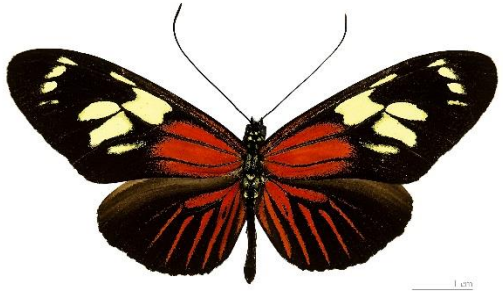
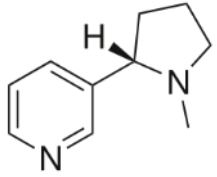
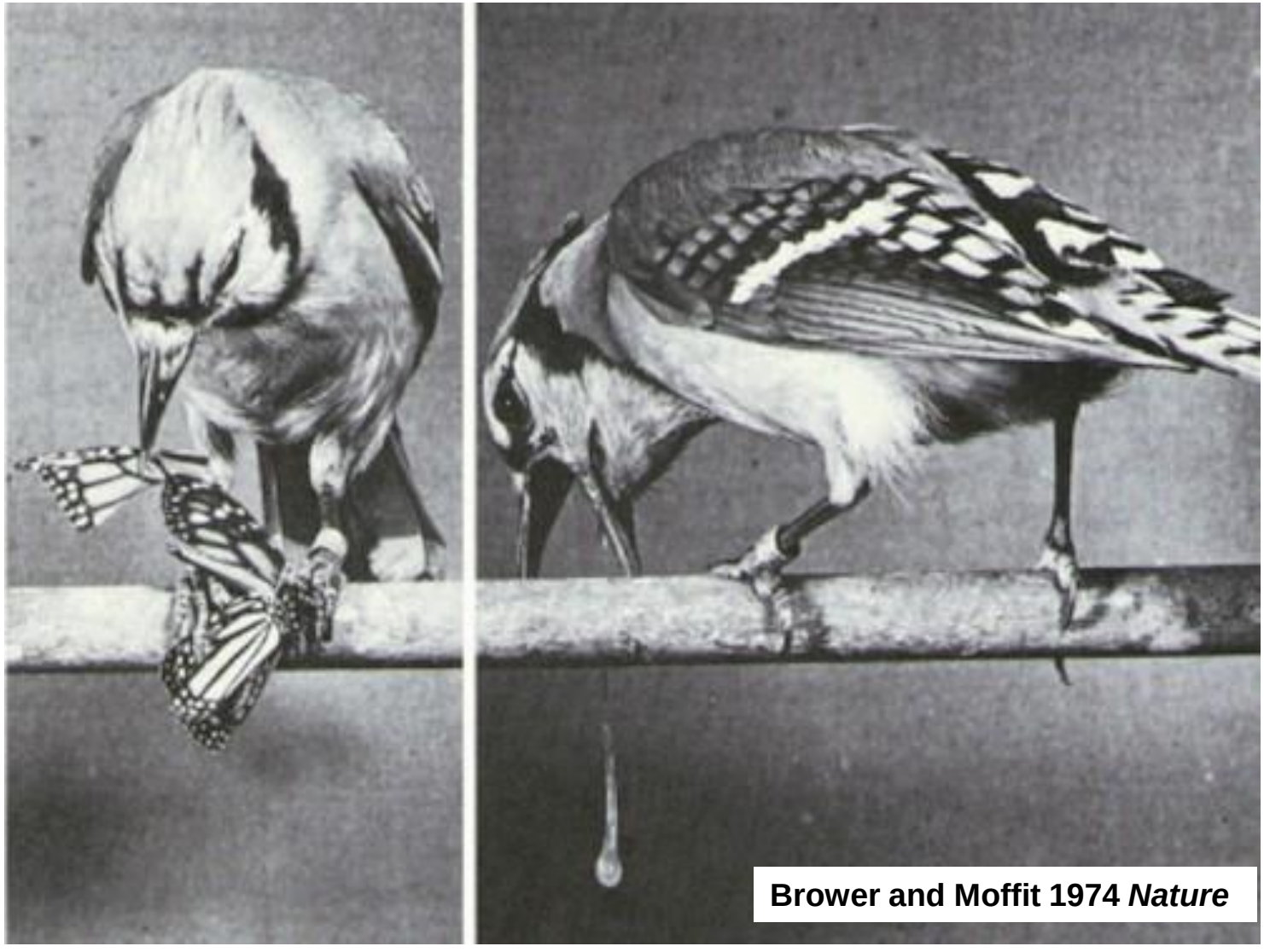


DEFENSES + SIGNAL = APOSEMATISM

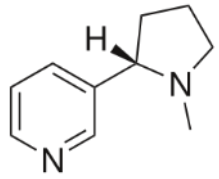
APOSEMATISM AND MIMICRY

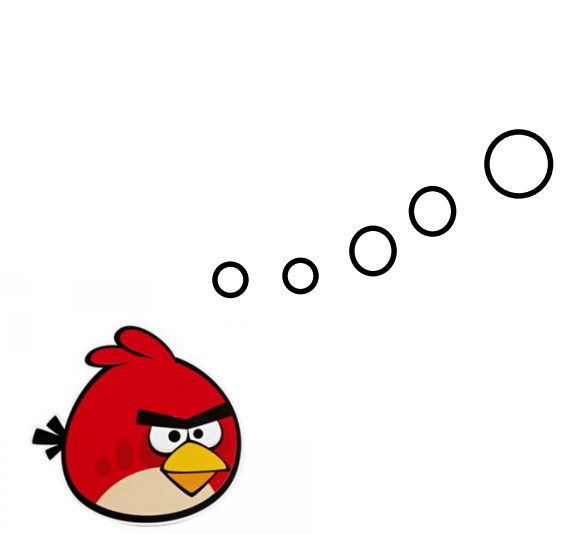




Brower and Moffit 1974 *Nature*

APOSEMATISM AND MIMICRY



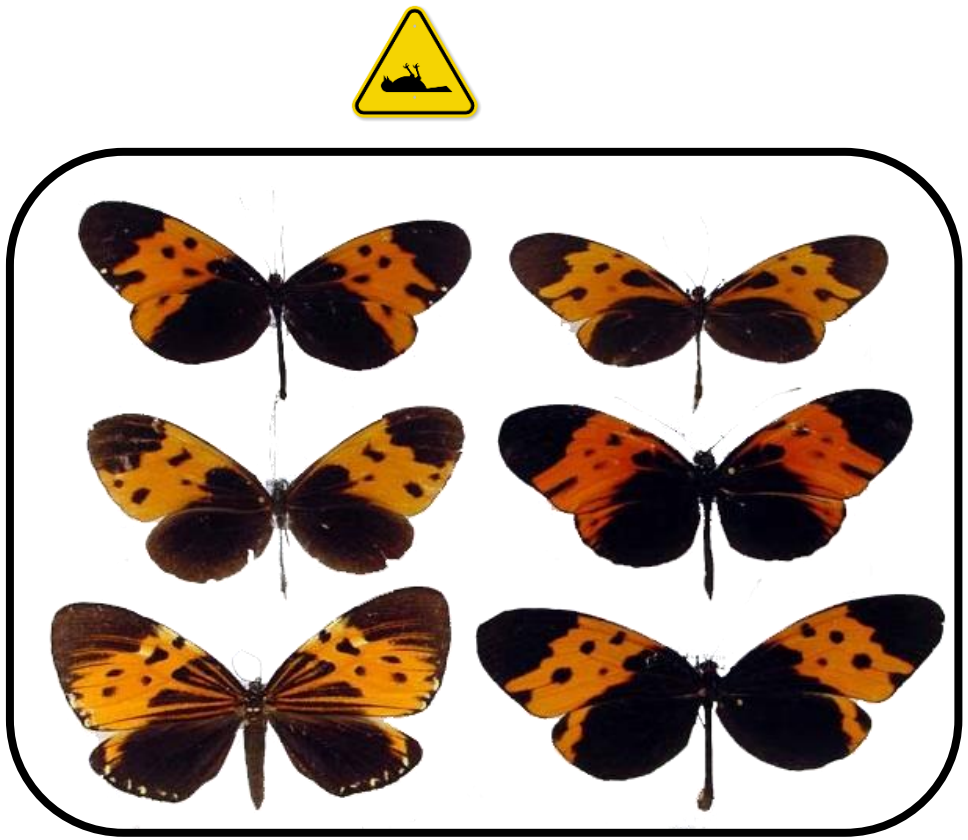


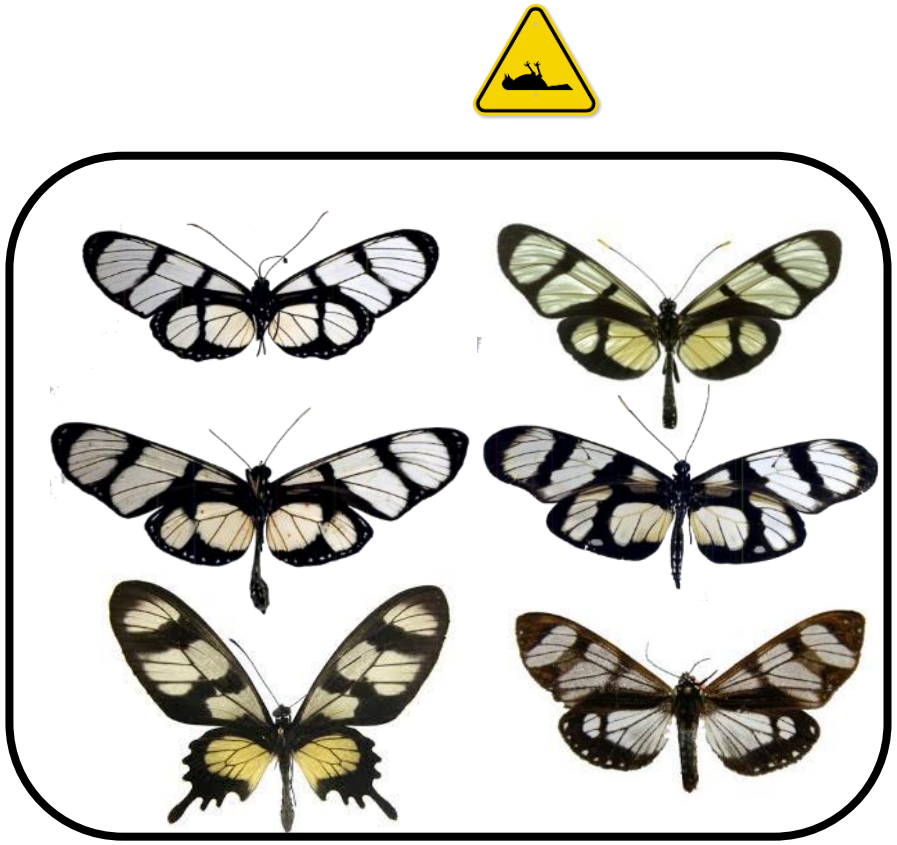
Hungry bird

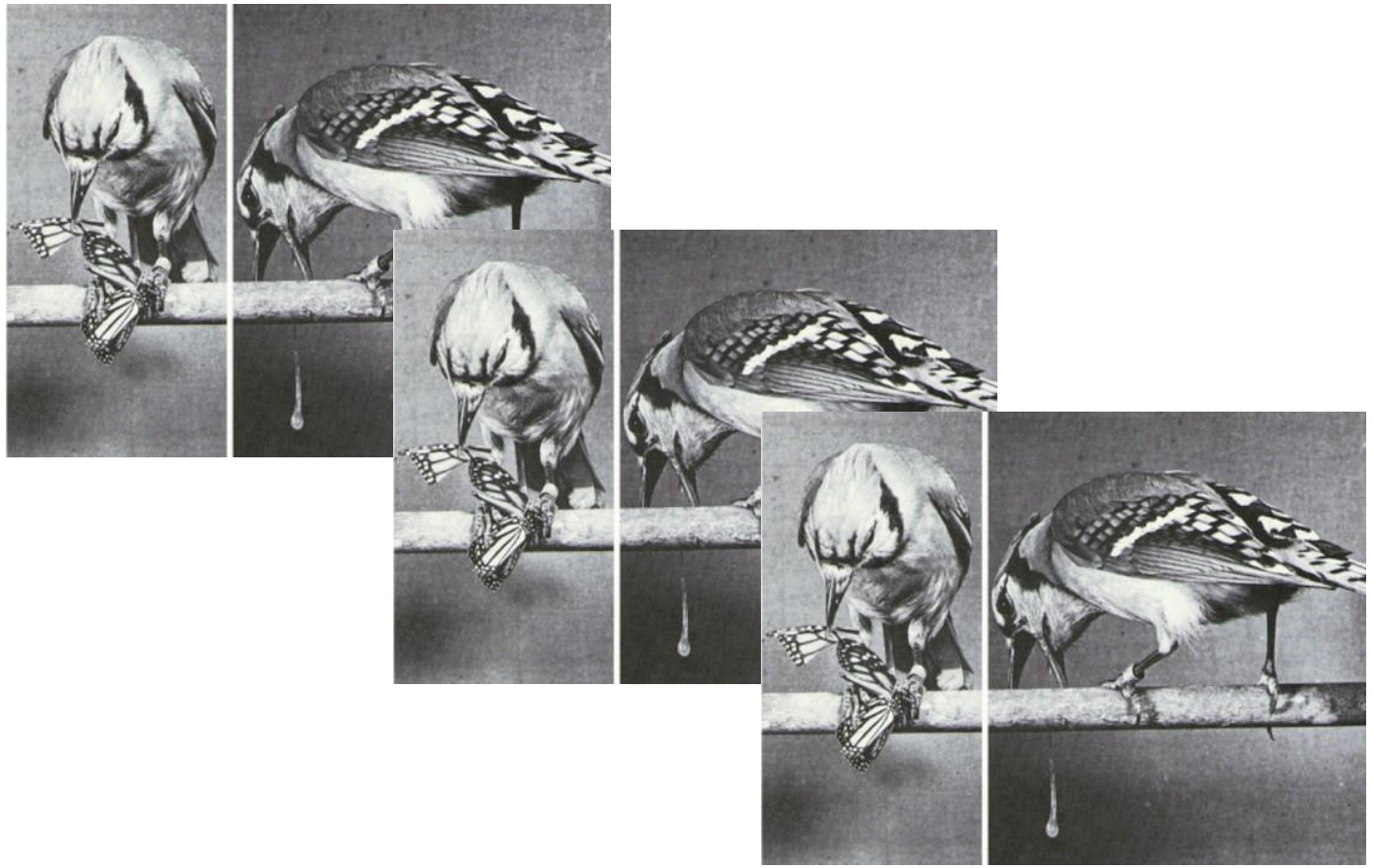
=

yuck!

APOSEMATISM AND MIMICRY

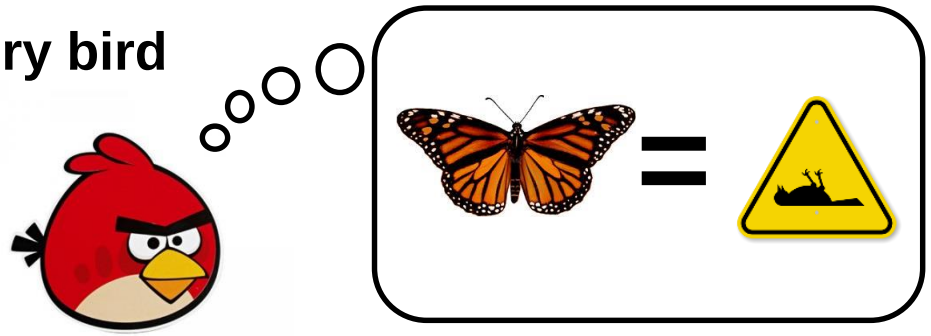






Fritz Müller

Hungry bird

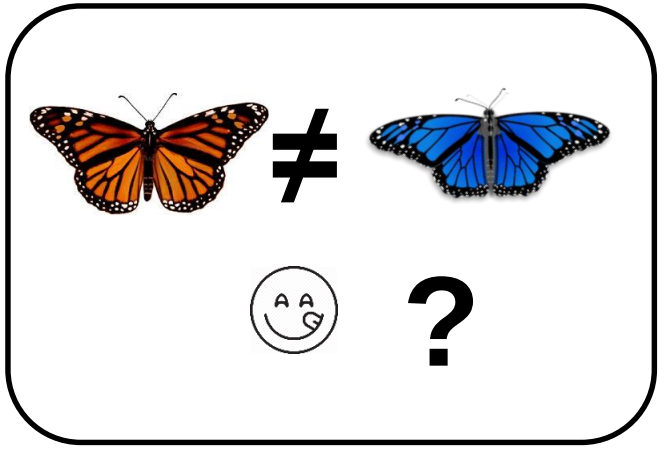


...

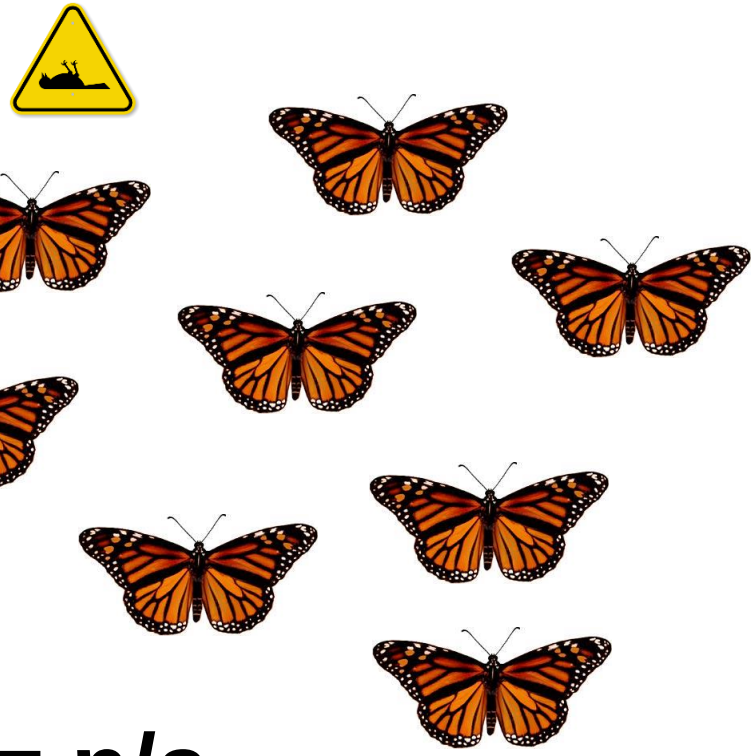
n trials

Müller 1879 *Proc Entomol Soc London*

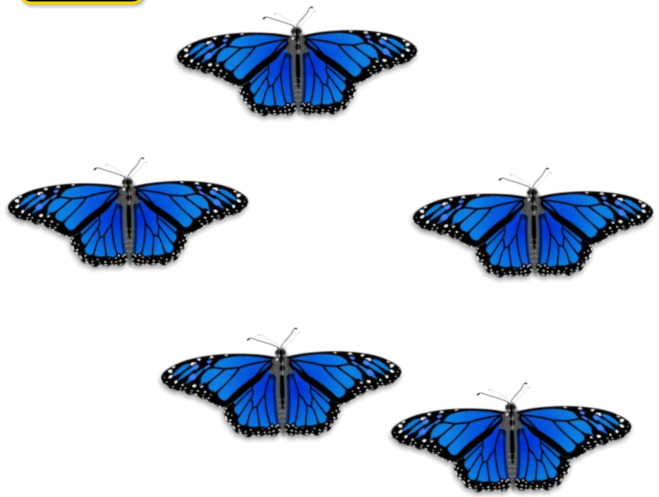
Hungry (naive) bird



Population size = a_1



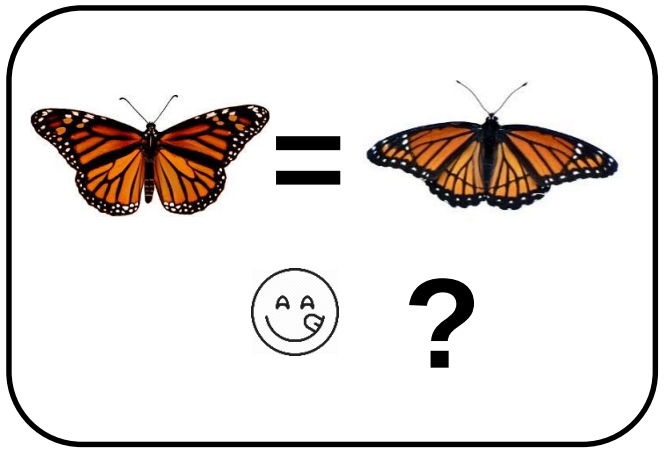
Population size = a_2



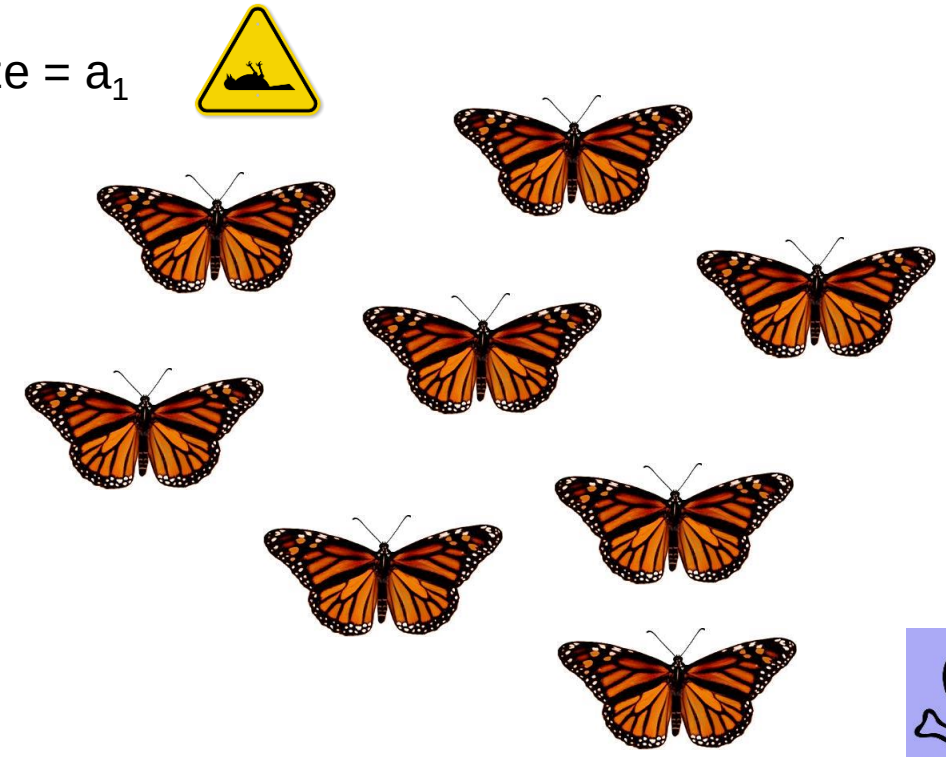
$= n/a_1$

$= n/a_2$

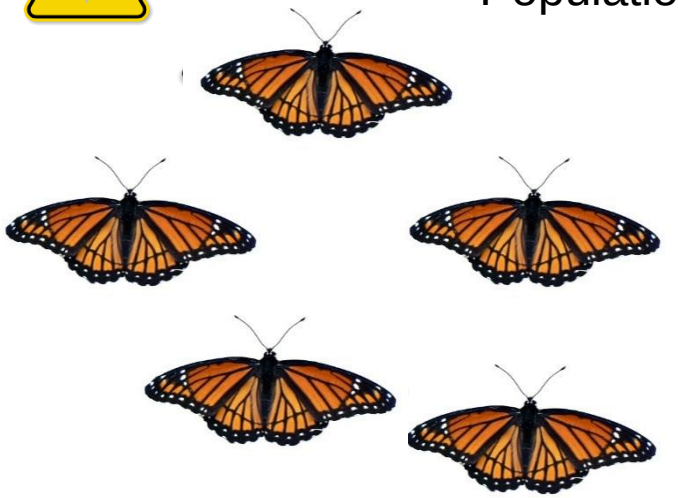
Hungry (naive) bird



Population size = a_1



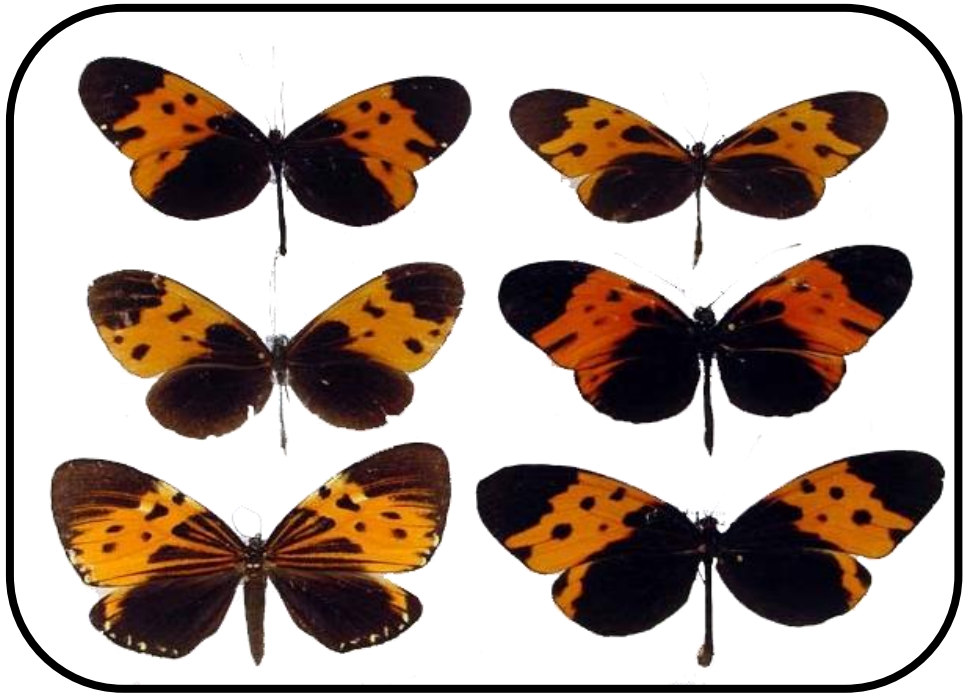
Population size = a_2

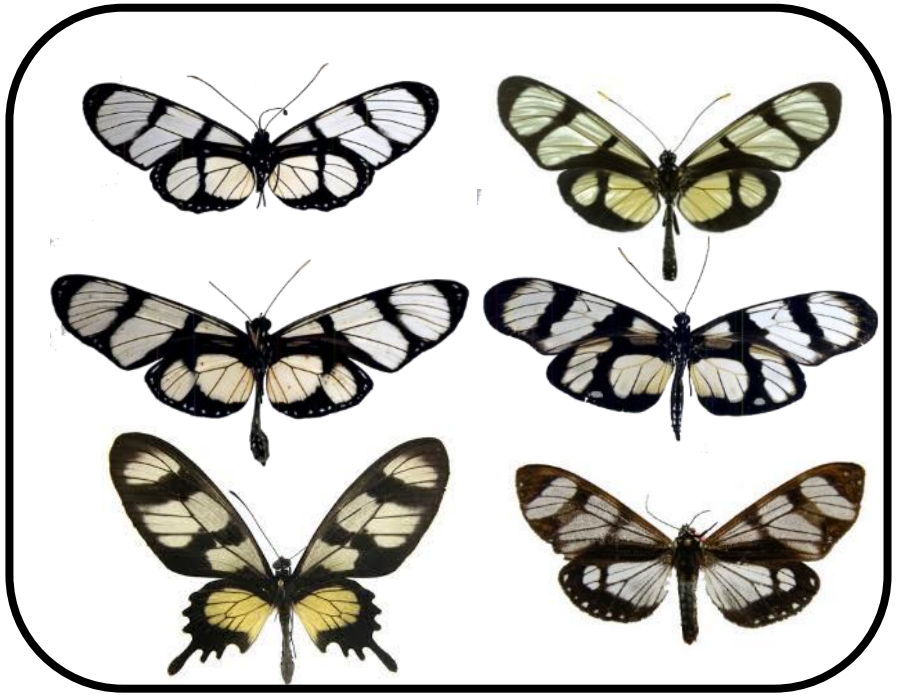


$= n/(a_1+a_2) < n/a_i$

MULLERIAN MIMICRY

Mimicry rings





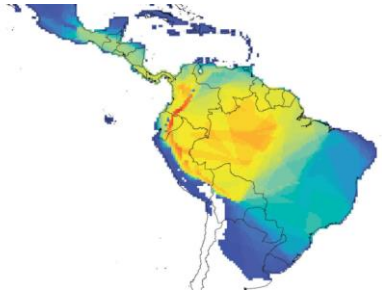
co-mimics

co-mimics

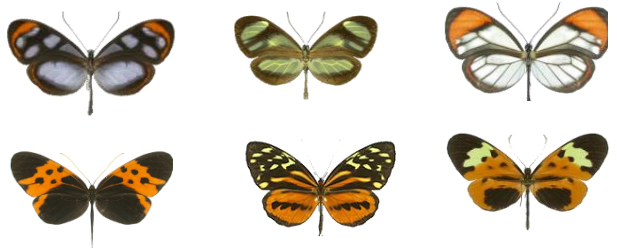
‘strength in number’ → positive interactions!

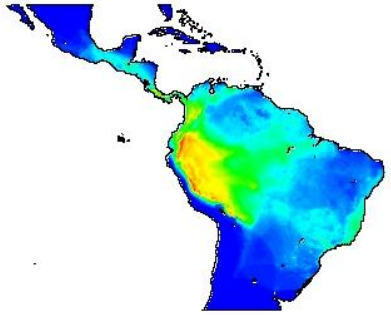
MIMETIC BUTTERFLIES

Heliconiini (77 species)



Ithomiini (393 species)

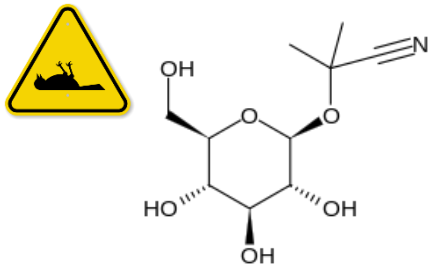




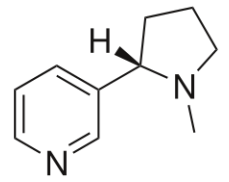
-82 ma

- tropical America

- cyanogenic glucosides

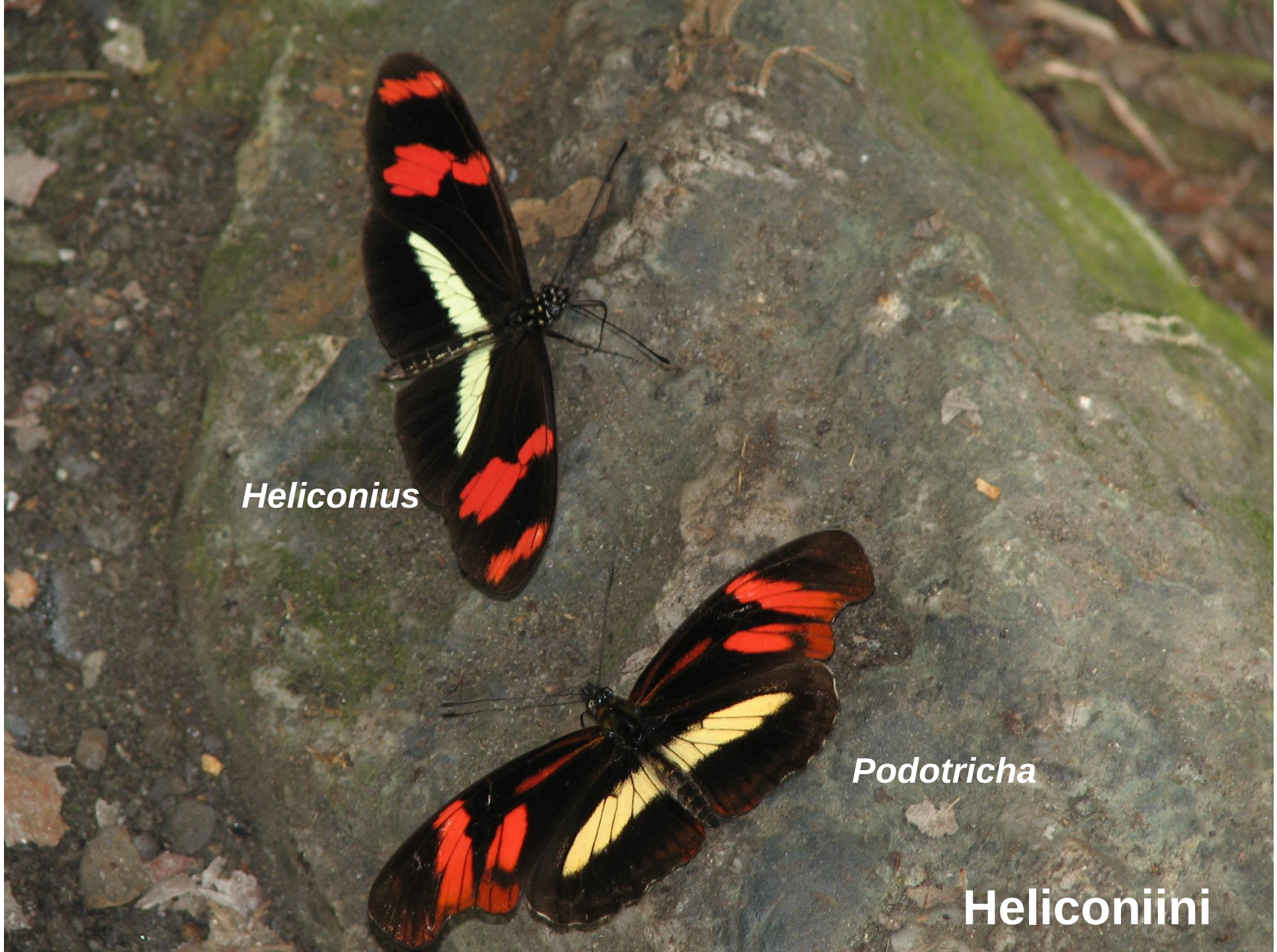


- pyrrolizidine alcaloids

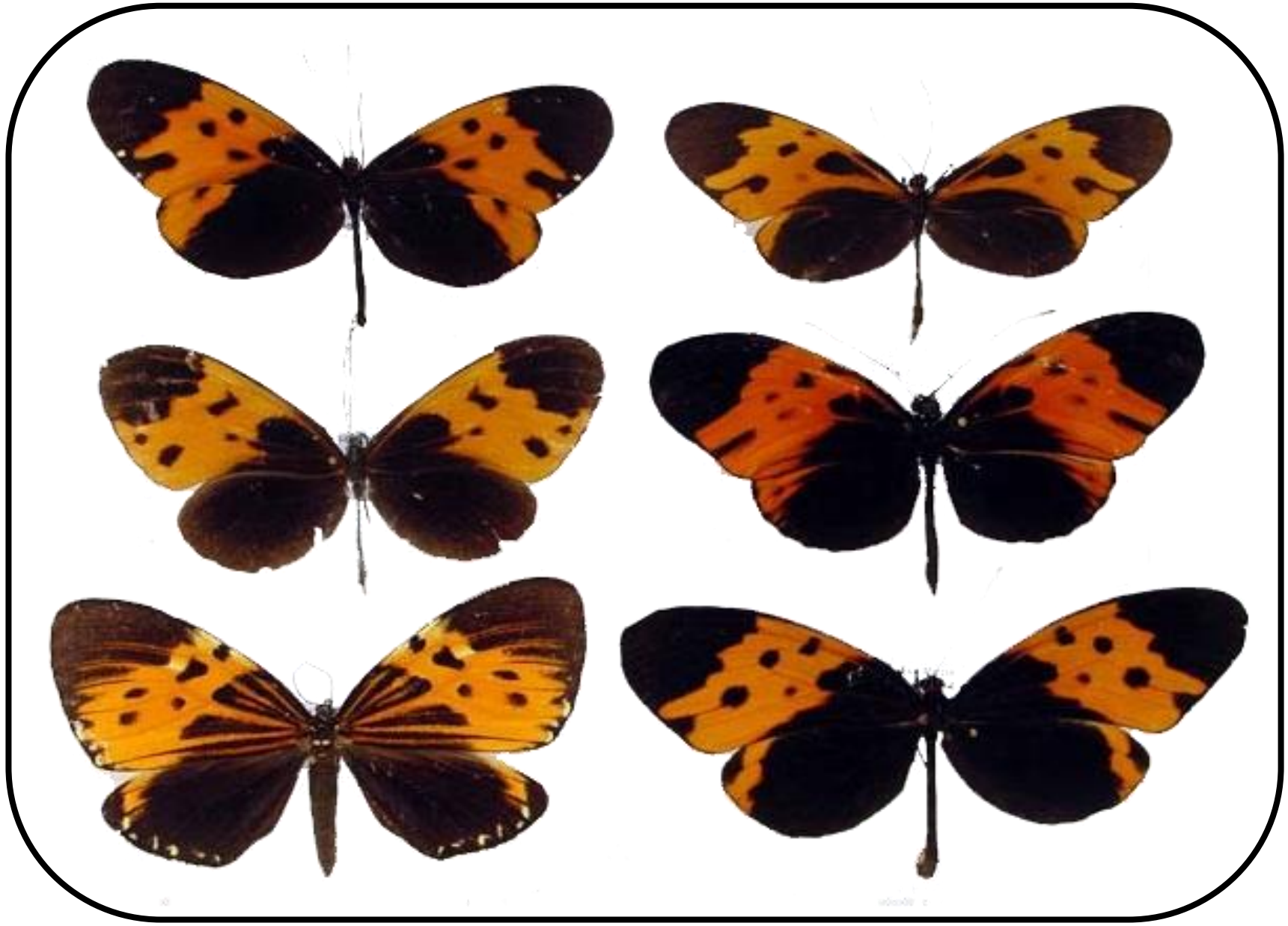


Ithomiini

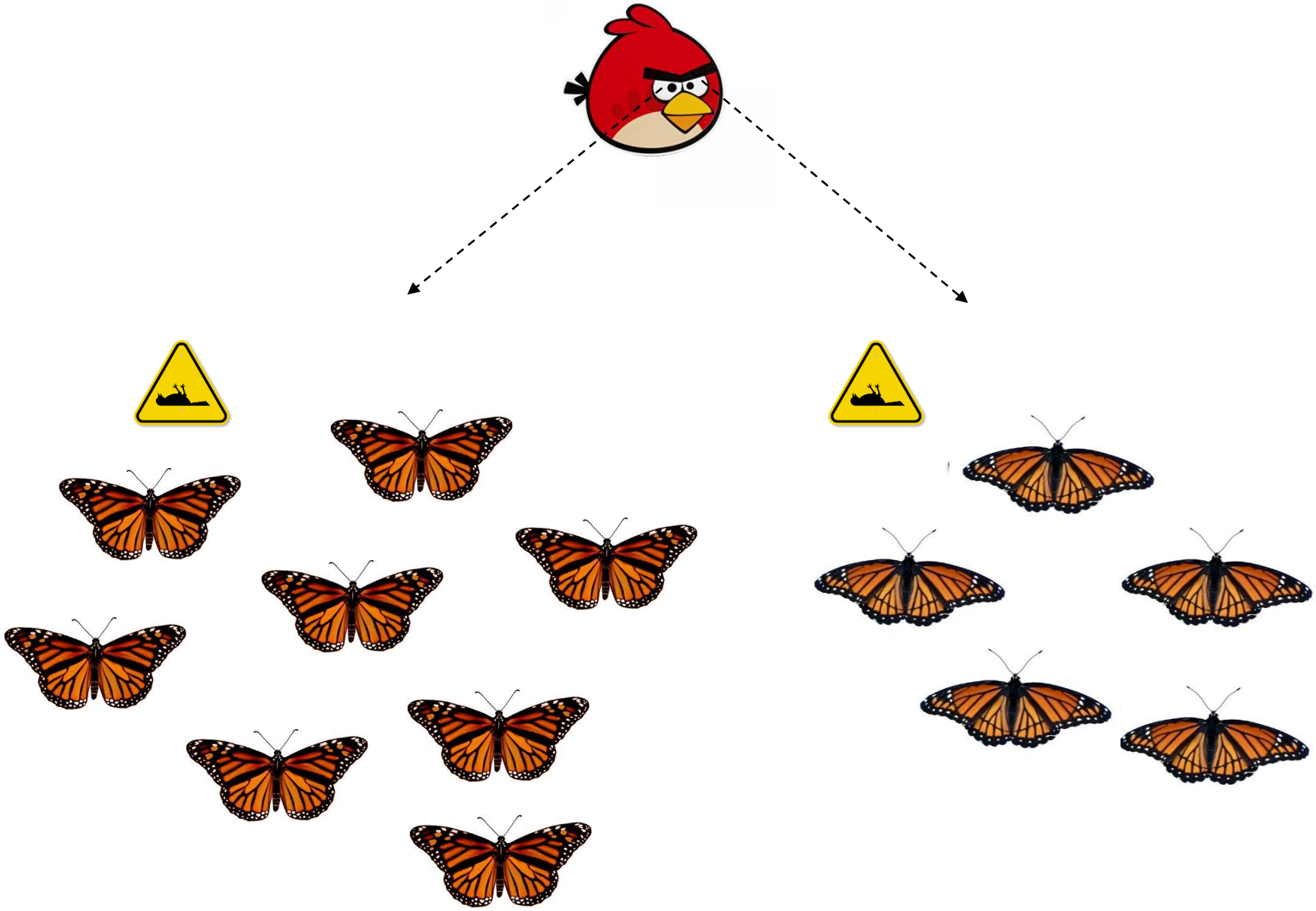
© reserva Bigal Sumacmuyu

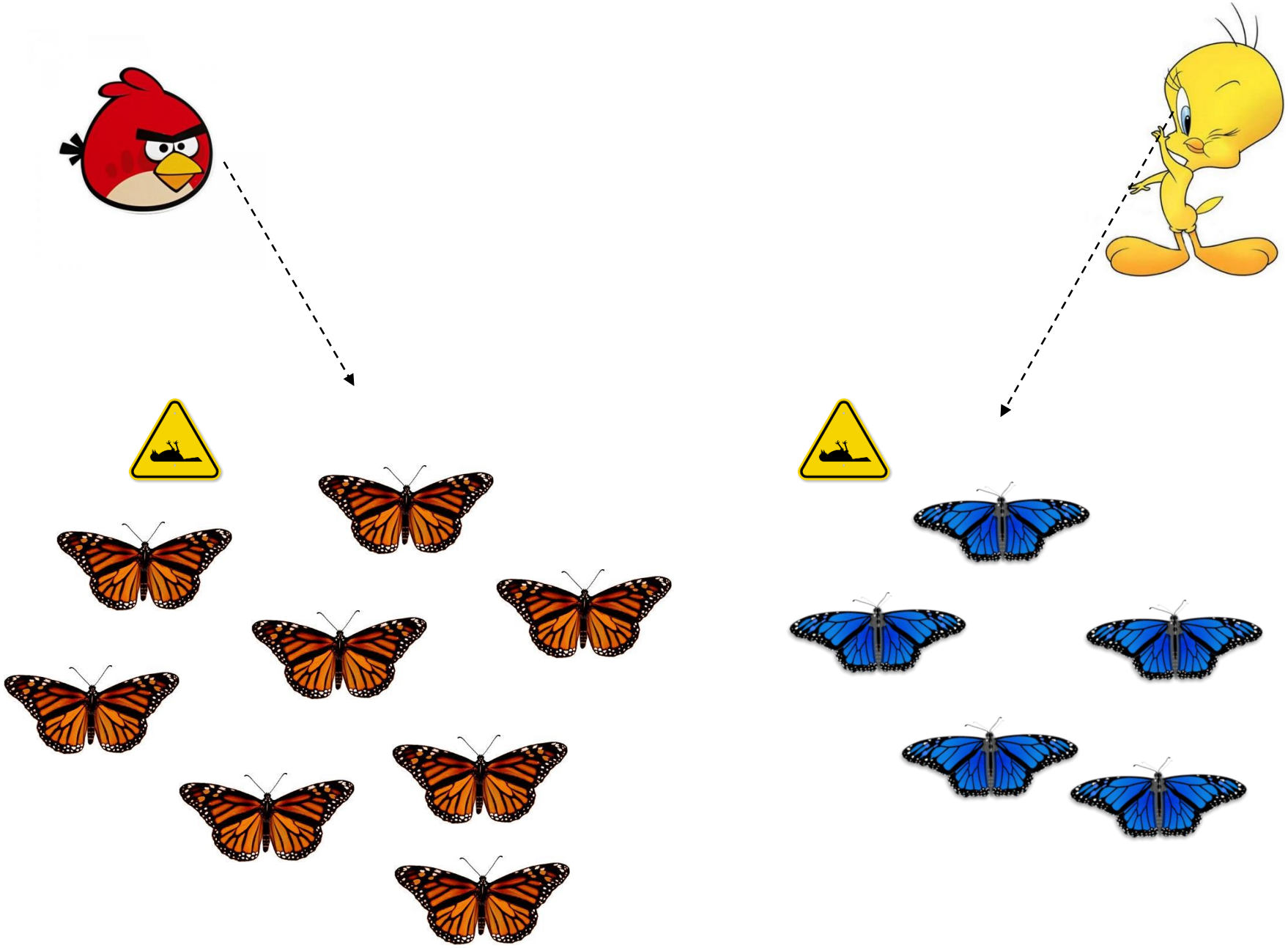

Heliconius
Podotricha
Heliconiini

© Mathieu Chouteau

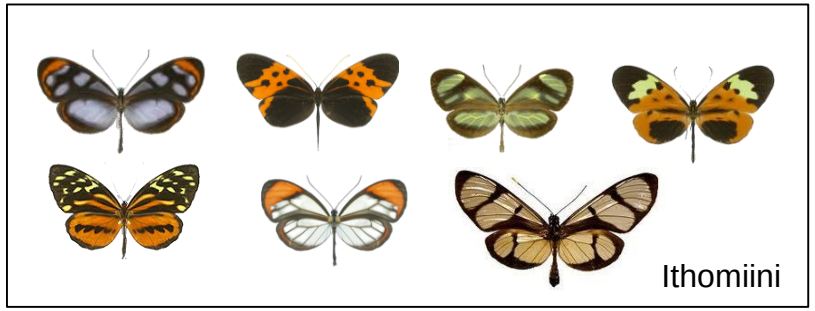


1 cm

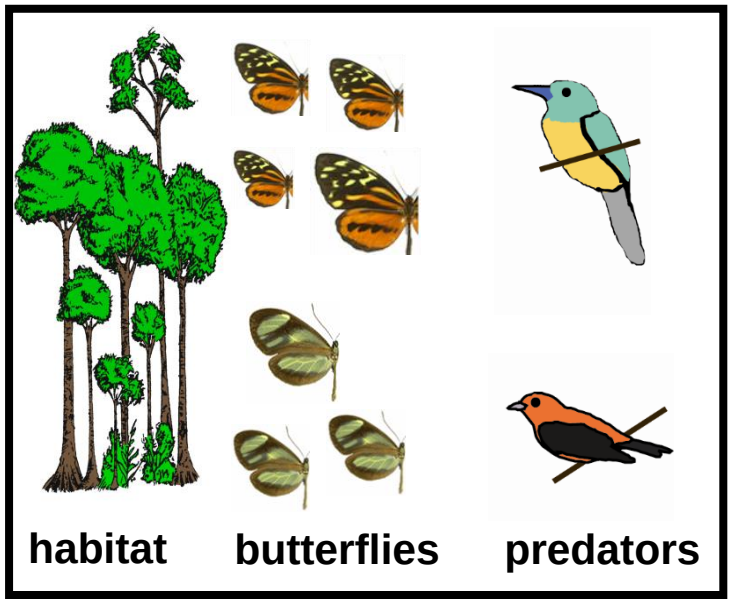




LOCAL MIMICRY DIVERSITY



Ecological segregation



Beccaloni 1997, *Biol J Lin Soc*
De Vries et al. 1999, *Biol J Lin Soc*

→ ecological segregation of mimicry rings
→ stable mimicry diversity

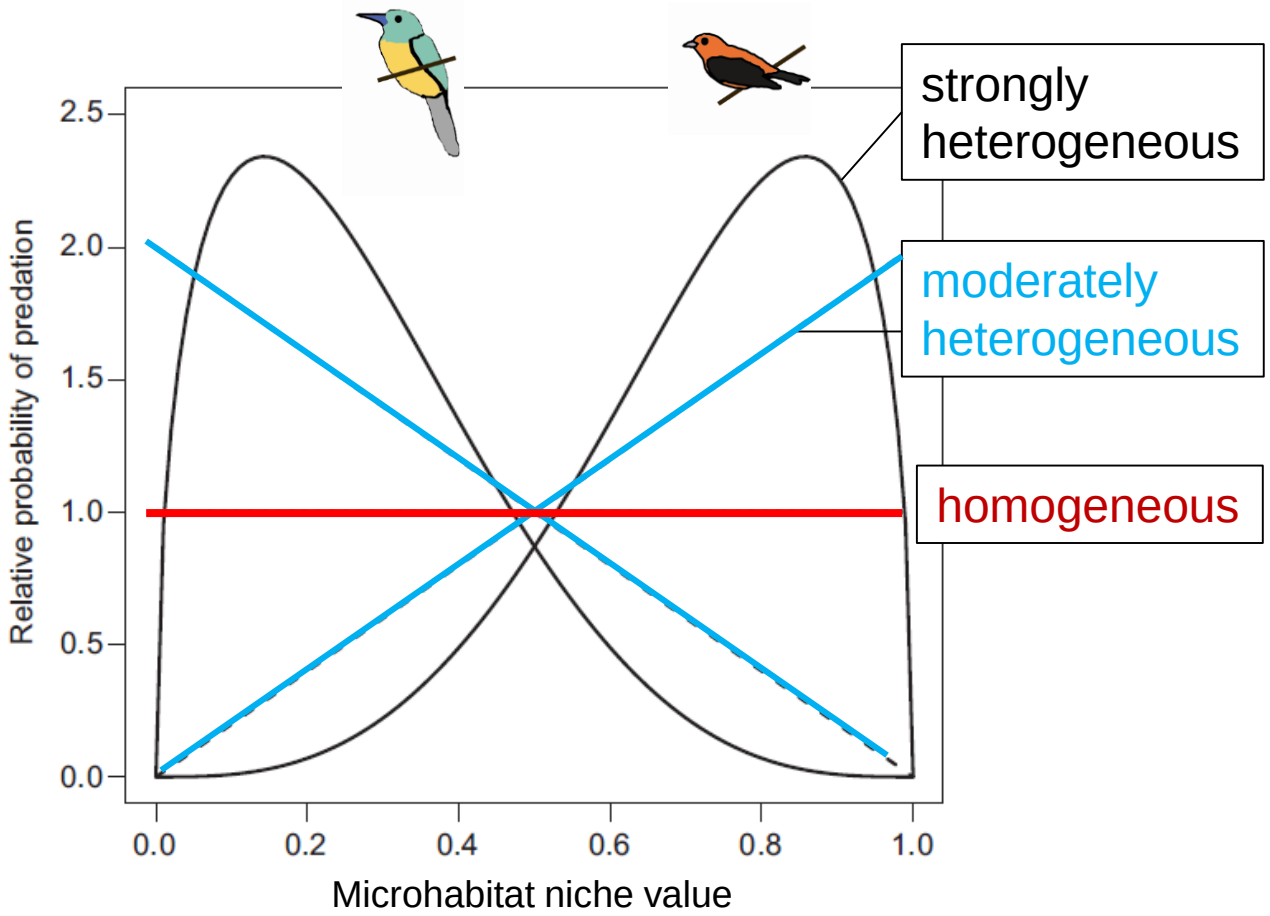
LOCAL MIMICRY DIVERSITY

Stochastic individual-based model

2-dimension ecological space. 10 species, 5 mimicry patterns

- Heterogeneous predation

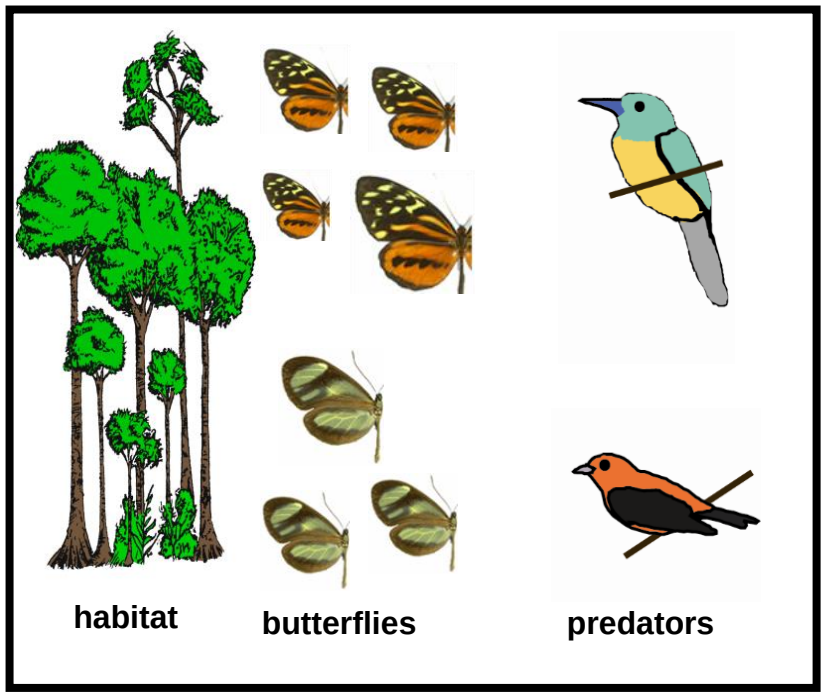
- Reproduction
  - mimicry pattern
  - niche

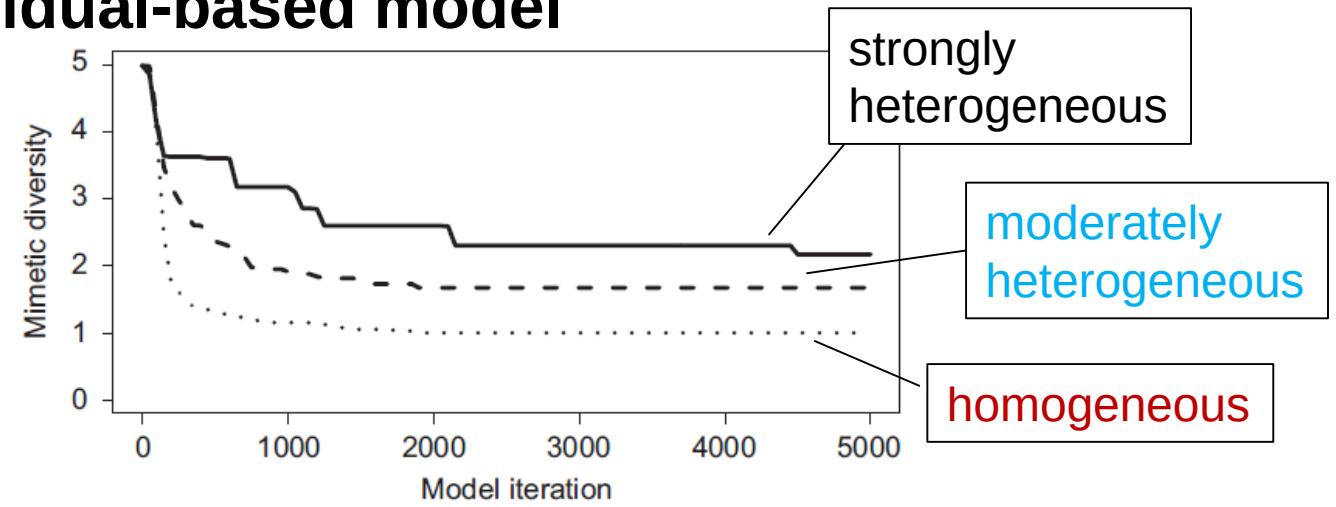


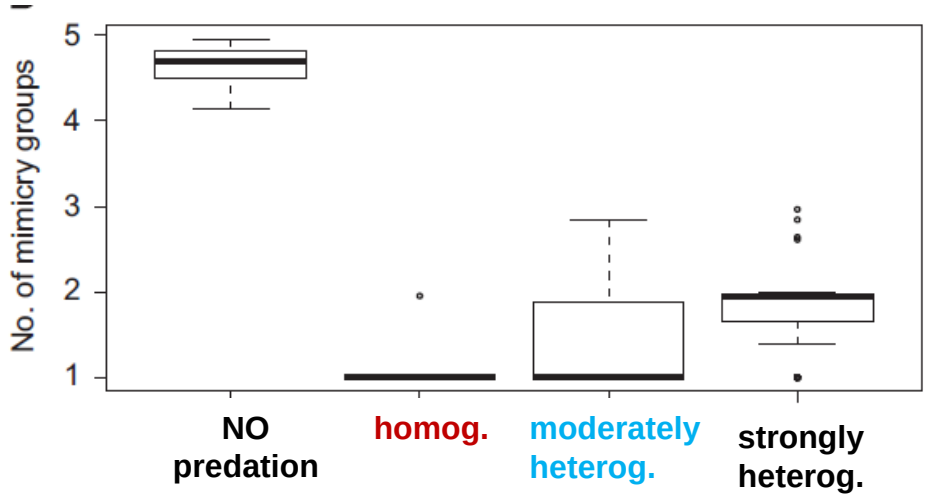
Gompert et al. 2011, *J Theor Biol*

LOCAL MIMICRY DIVERSITY

Stochastic individual-based model





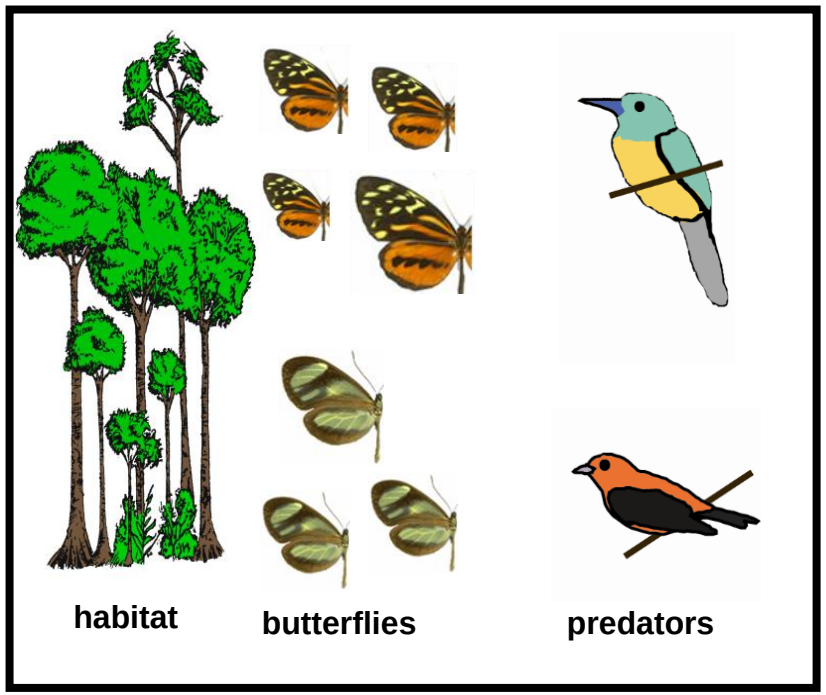


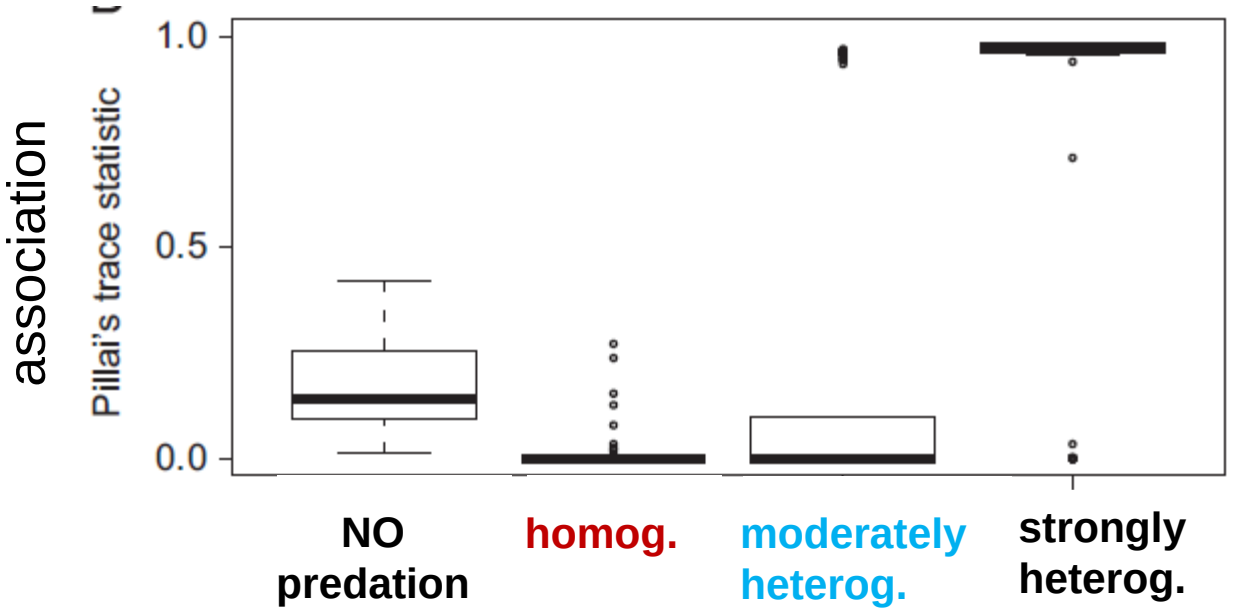
→ Heterogeneous predation promotes diversity

Gompert et al. 2011, *J Theor Biol*

LOCAL MIMICRY DIVERSITY

Stochastic individual-based model



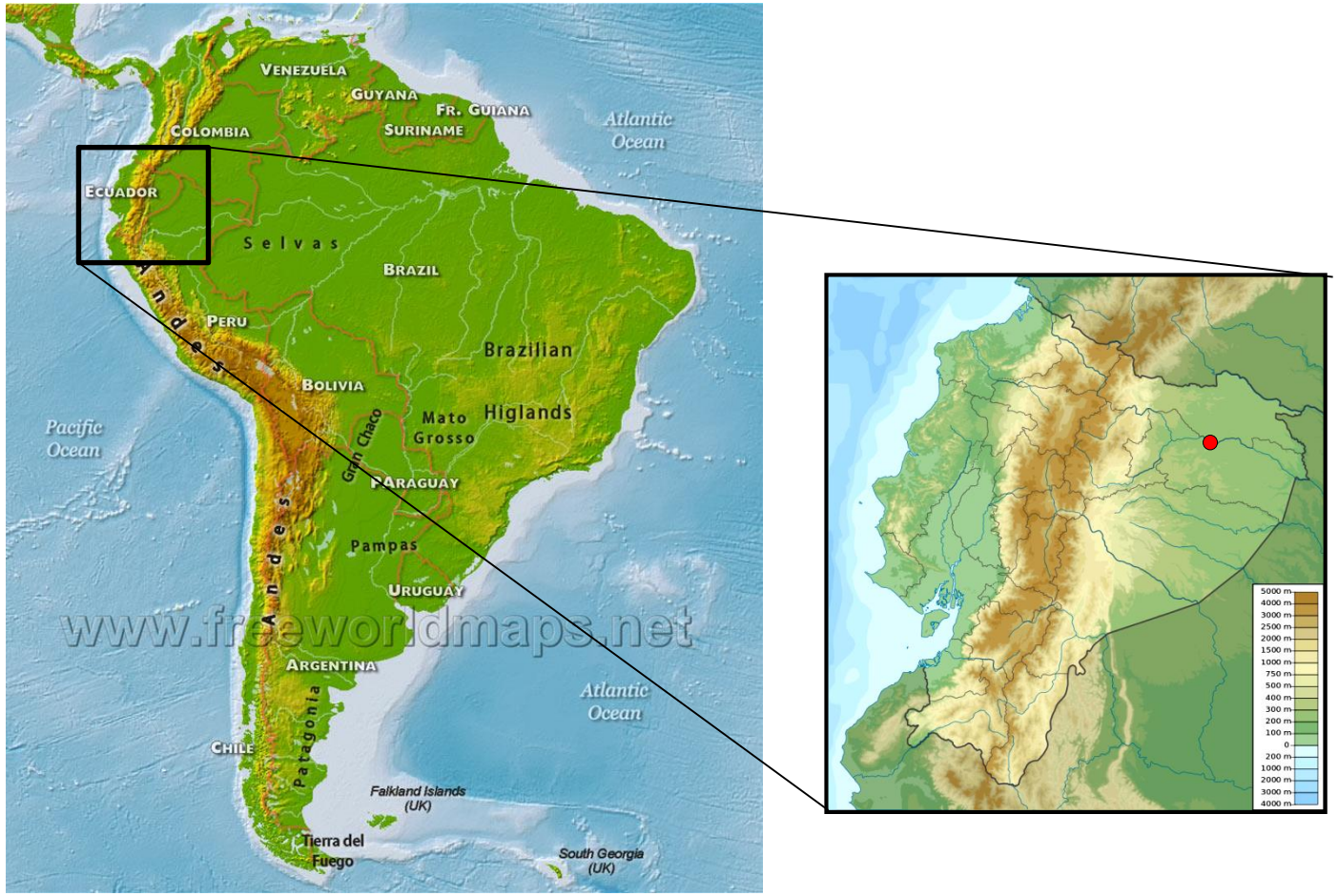


→ **Heterogeneous predation promotes association of mimicry pattern with ecological niche**

Gompert et al. 2011, *J Theor Biol*

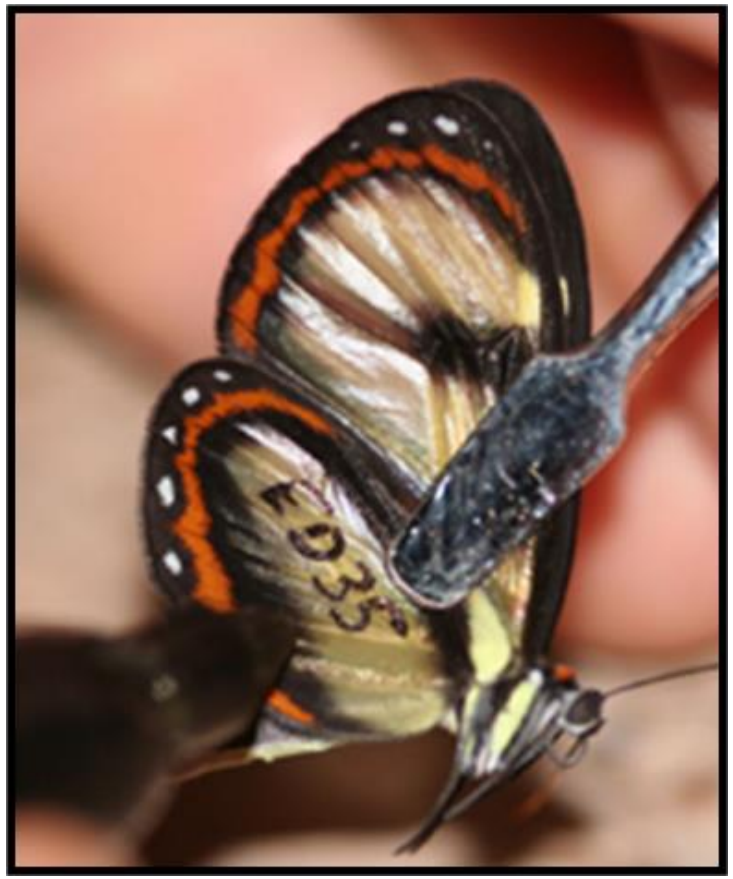
LOCAL MIMICRY DIVERSITY

Community Anangu in lowland Ecuador



- Butterflies (Ithomiini)
- Insectivorous birds
- Microhabitat
  - flight height
  - topography
  - forest structure

F113


ED35

436

- **1231 Ithomiini butterflies**
- **58 species**
- **8 mimicry rings**
- **176 bird species**

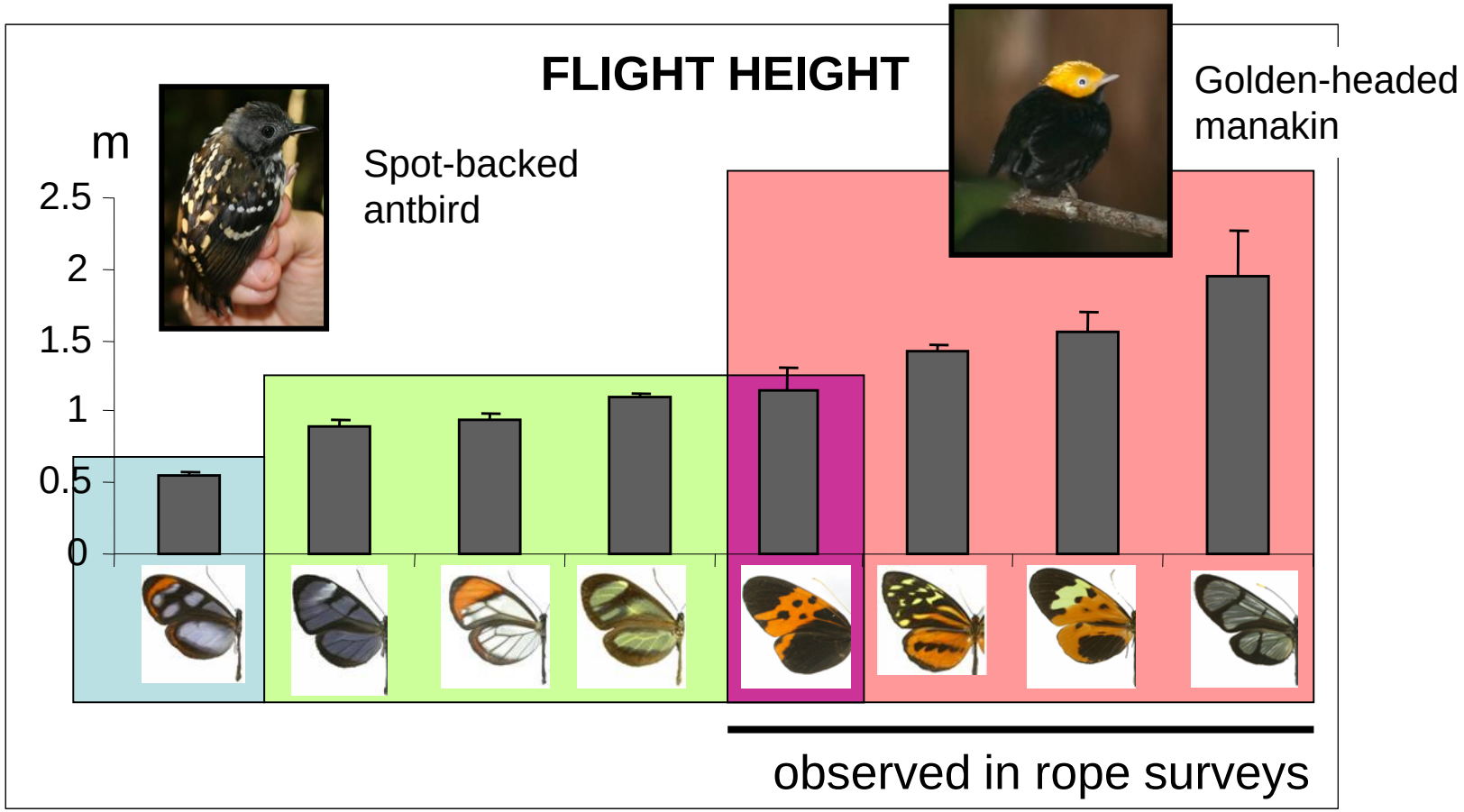
- **Flight height, topography, forest structure**

Elias et al. 2008, *PLoS biol*, Willmott et al. 2017 *PRSB*

LOCAL MIMICRY DIVERSITY

→ **Mimicry rings are segregated by flight height, topography and forest structure**

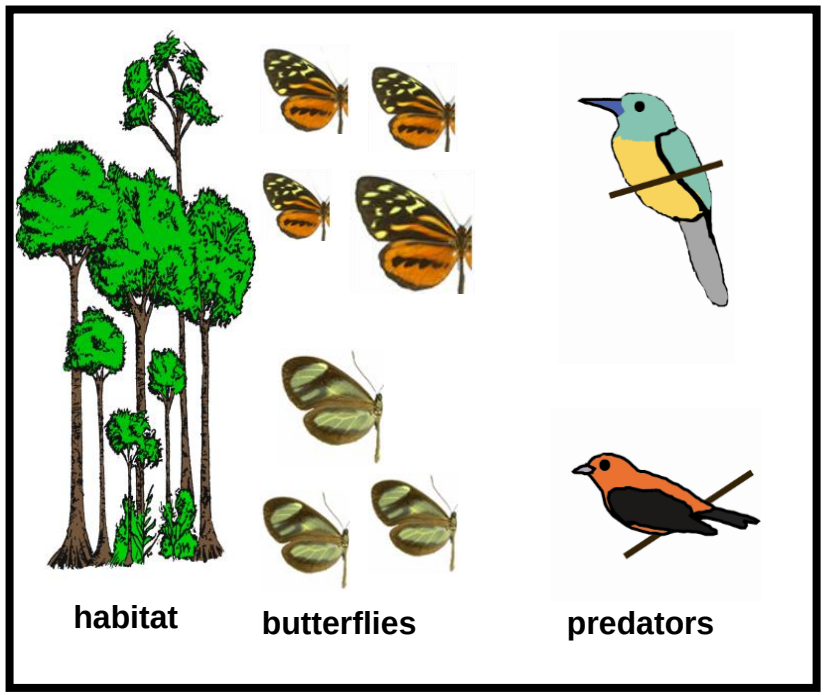
→ **Predators are segregated by flight height and topography**



Elias et al. 2008, *PLoS biol*, Willmott et al. 2017 *PRSB*

LOCAL MIMICRY DIVERSITY

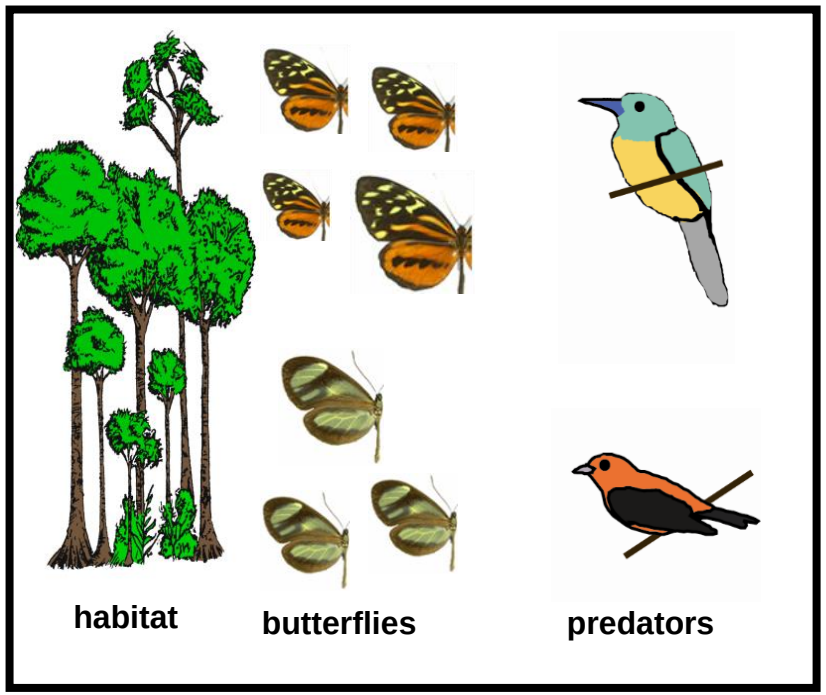
Ecological segregation



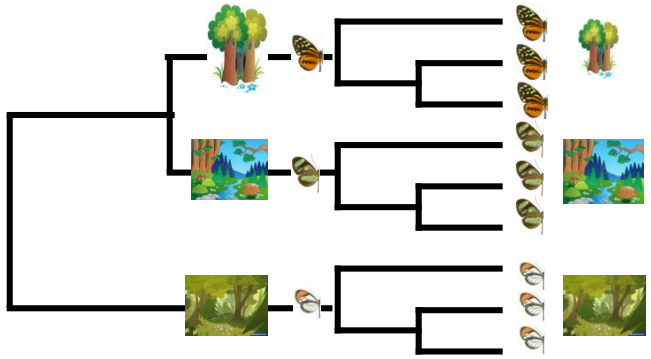
Willmott et al. 2017 *PRSB*

MIMICRY AND THE EVOLUTION OF THE ECOLOGICAL NICHE

Ecological segregation

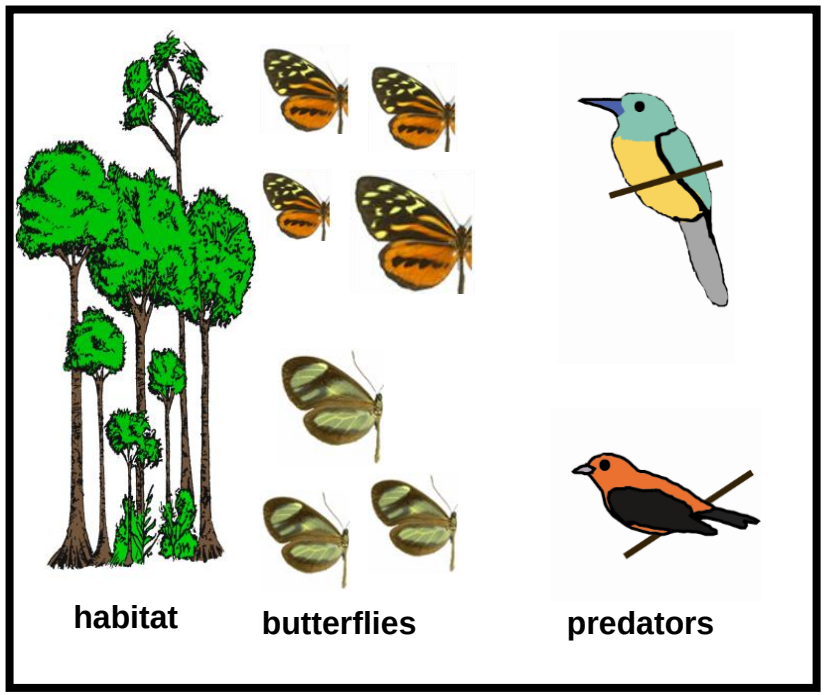


Common ancestry…

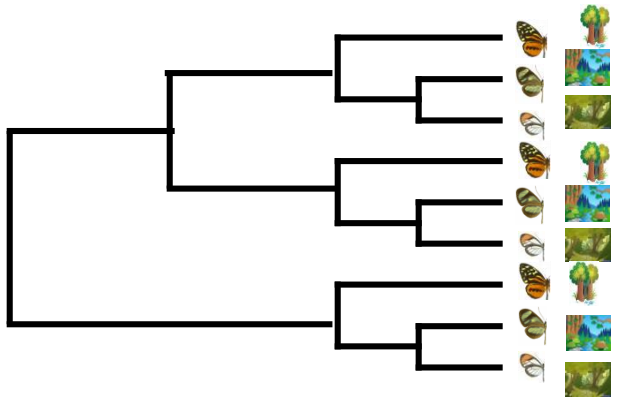


MIMICRY AND THE EVOLUTION OF THE ECOLOGICAL NICHE

Ecological segregation

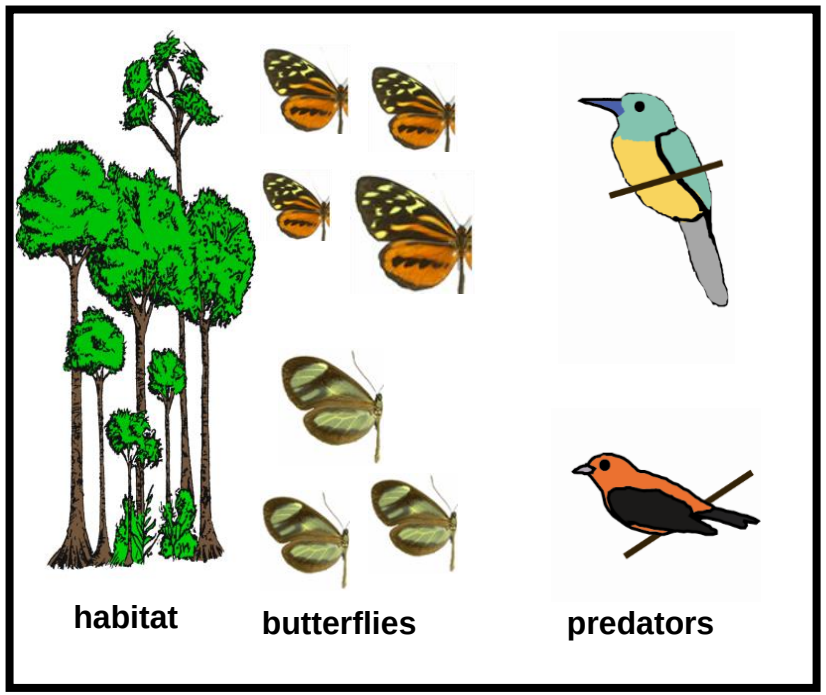


… or selection?

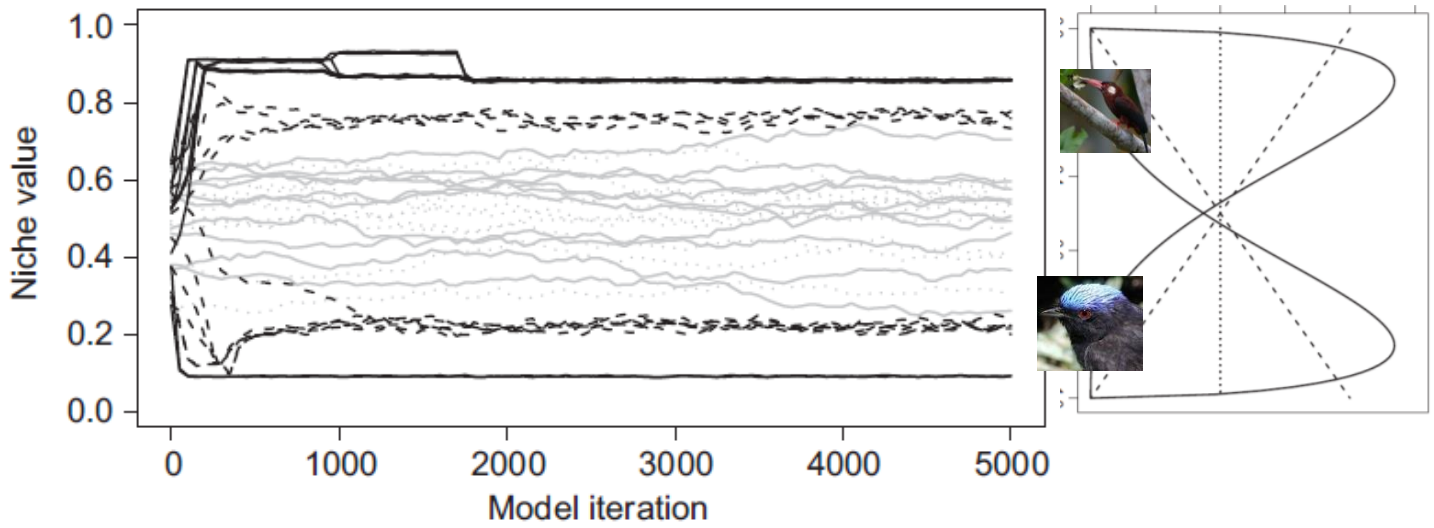


MIMICRY AND THE EVOLUTION OF THE ECOLOGICAL NICHE

Ecological segregation



Theoretical model

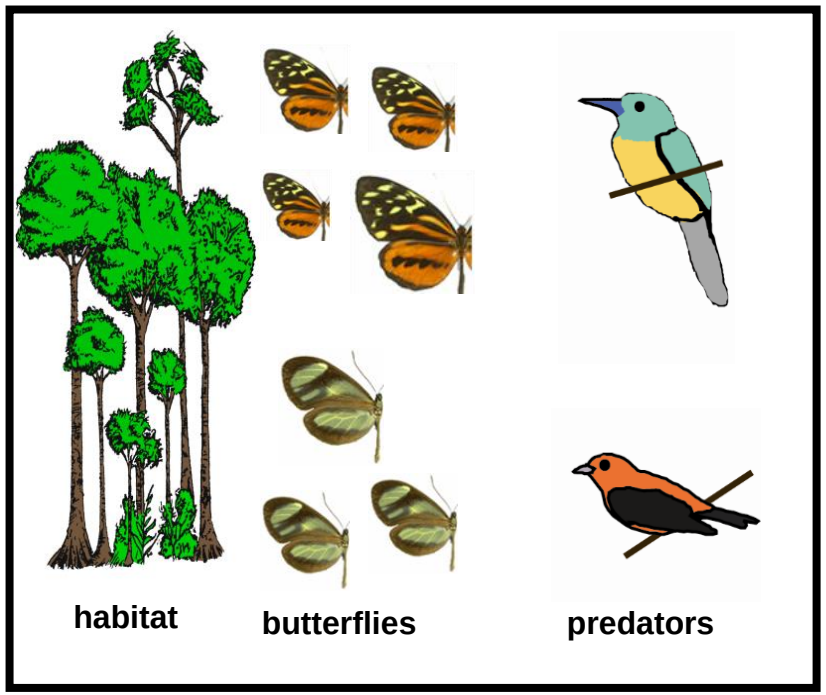


→ heterogeneous predation drives
adaptive microhabitat niche convergence

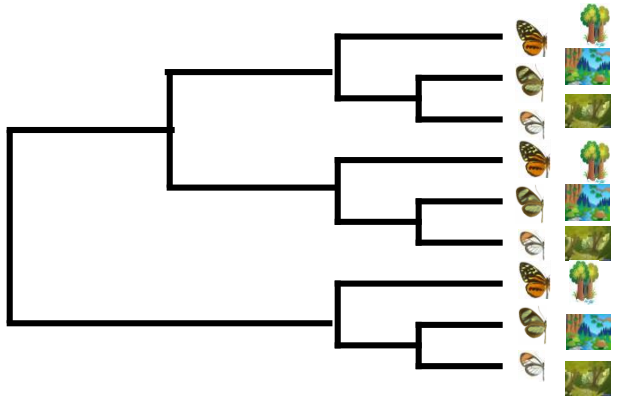
Gompert et al. 2011 *JTB*

MIMICRY AND THE EVOLUTION OF THE ECOLOGICAL NICHE

Ecological segregation



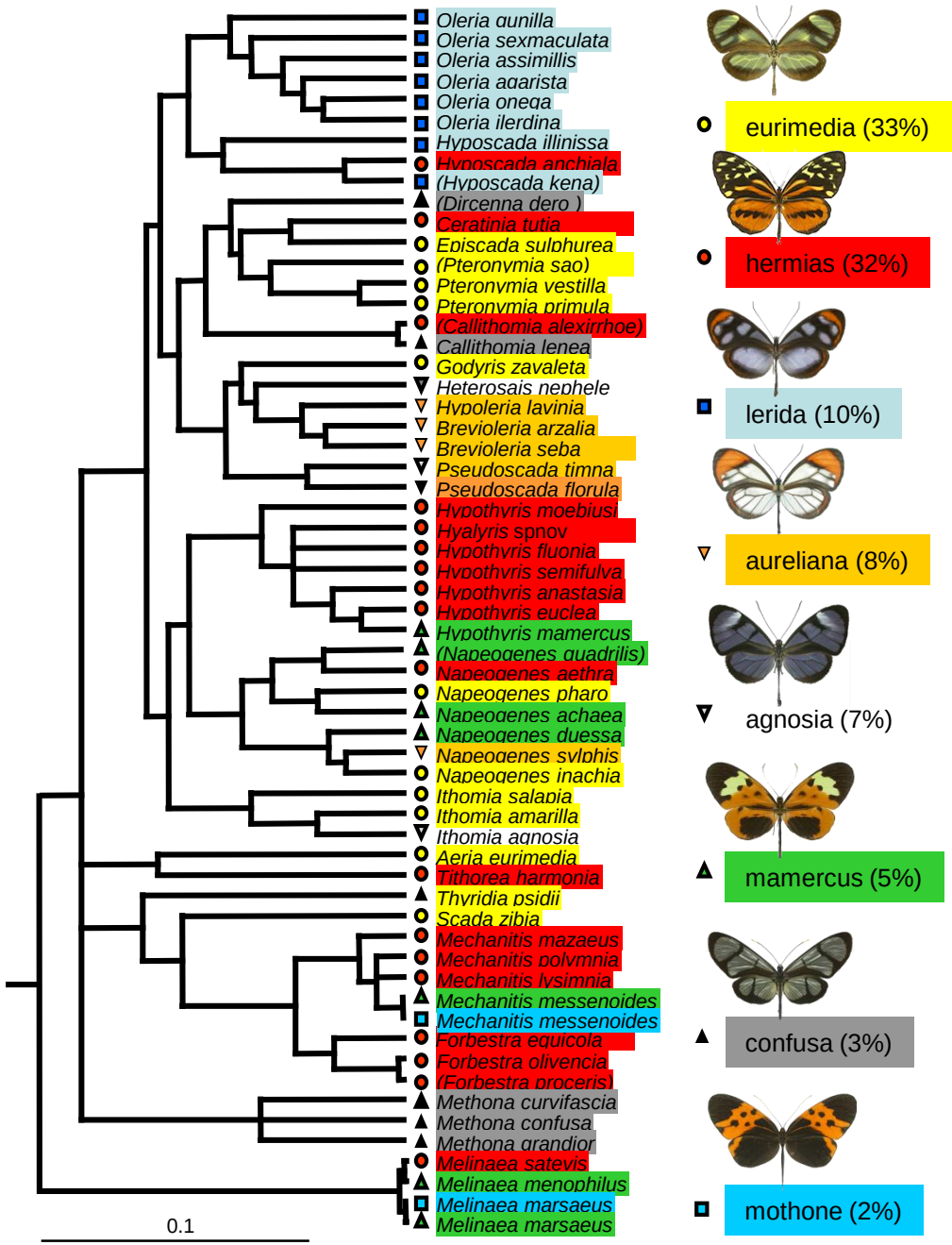
Theoretical model



selection

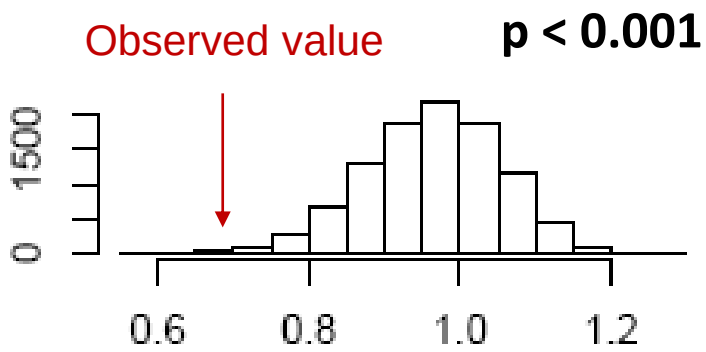
→ heterogeneous predation drives
adaptive microhabitat niche convergence

Gompert et al. 2011 *JTB*



Are co-mimics ecologically *more similar* than expected given the phylogeny?

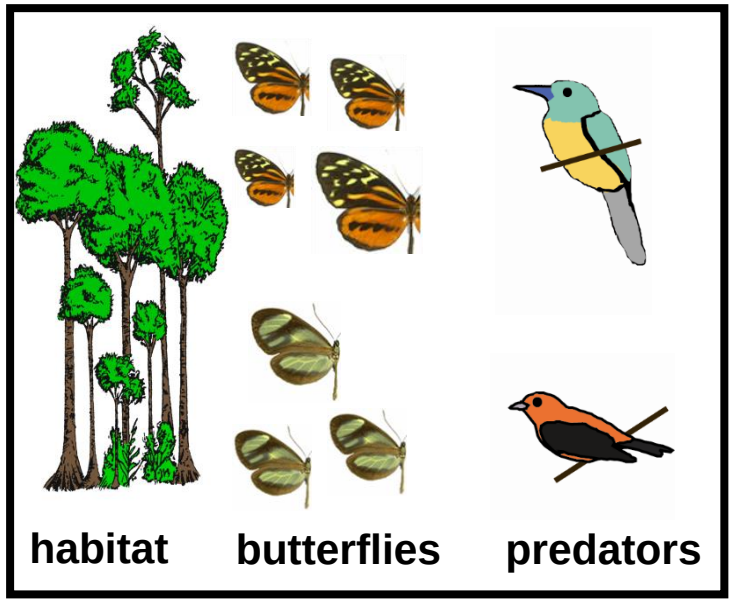
→ simulations of microhabitat niche evolution



Elias et al. 2008 *PLoS Biol*

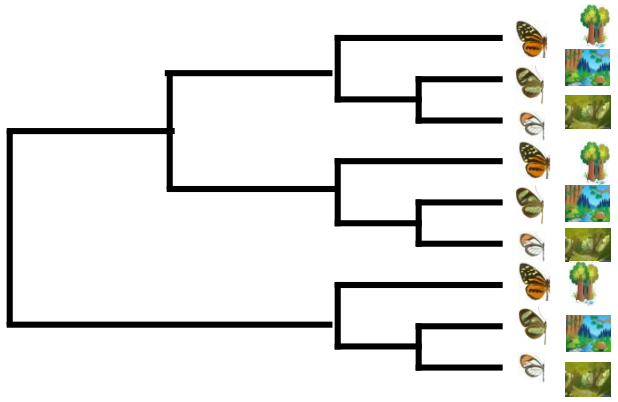
MIMICRY AND THE EVOLUTION OF THE ECOLOGICAL NICHE

Ecological segregation



Willmott et al. in 2017 *PRSB*

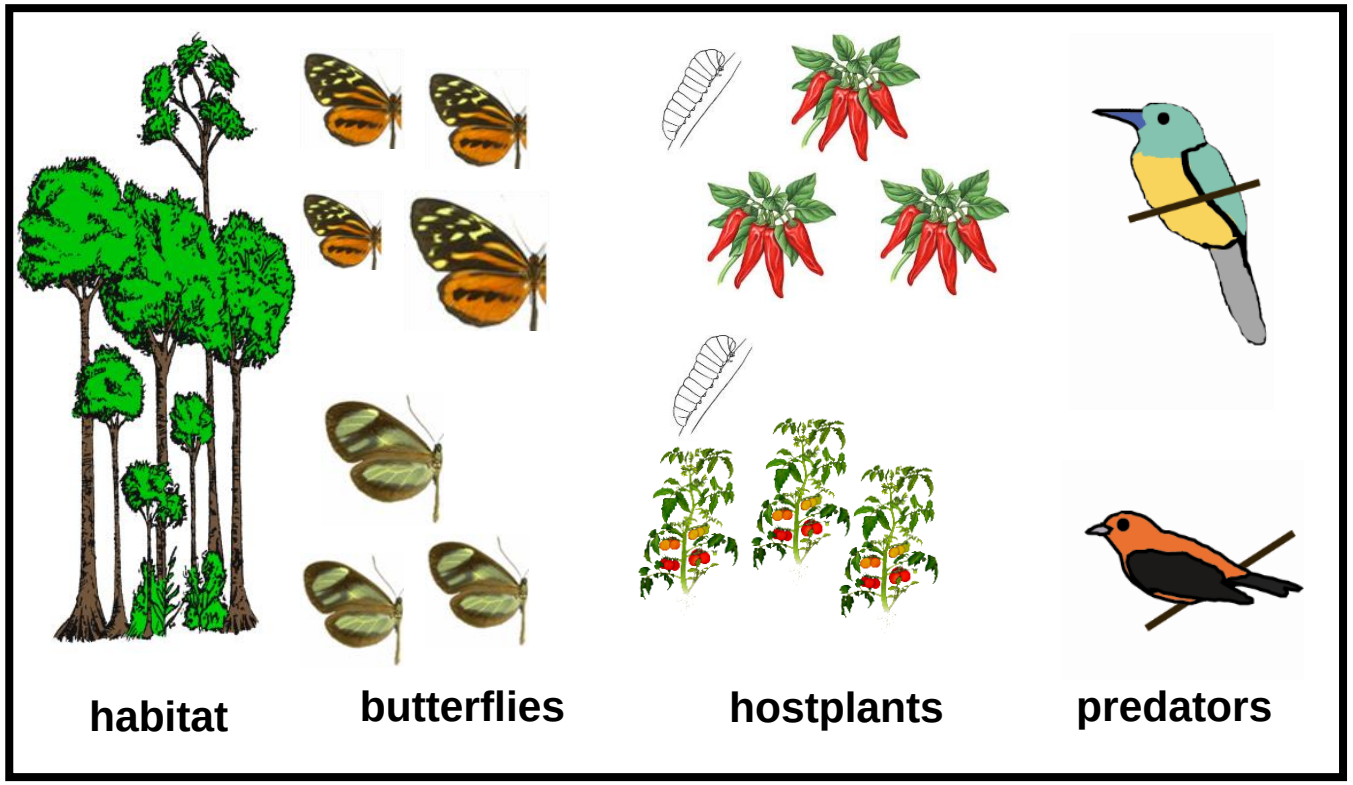
selection



Elias et al. 2008 *PLoS Biol*

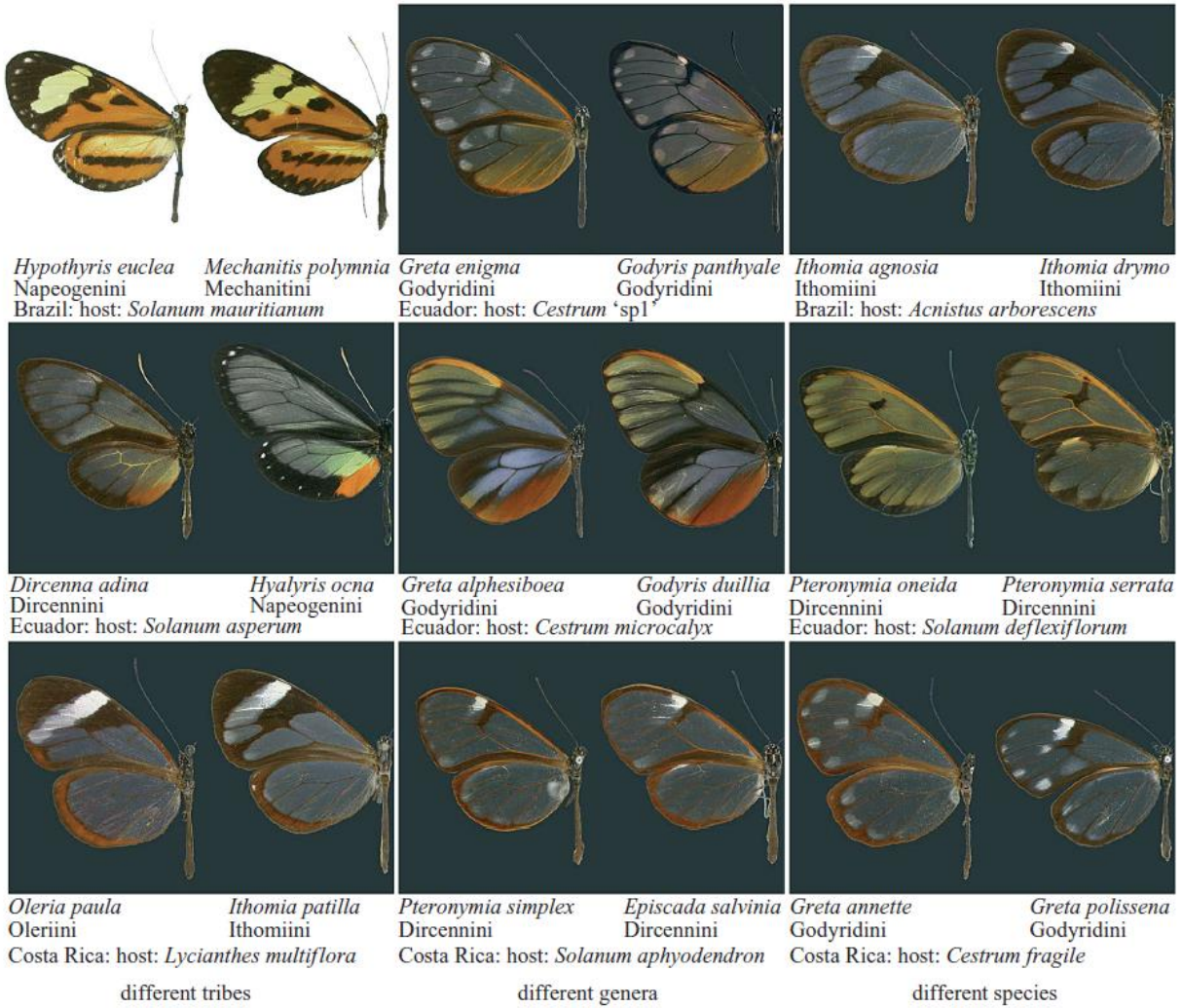
→ **adaptive microhabitat niche convergence**

MIMICRY, HABITAT AND HOSTPLANT



hostplants segregation by microhabitat
→ co-mimics expected to share hostplants more often than at random

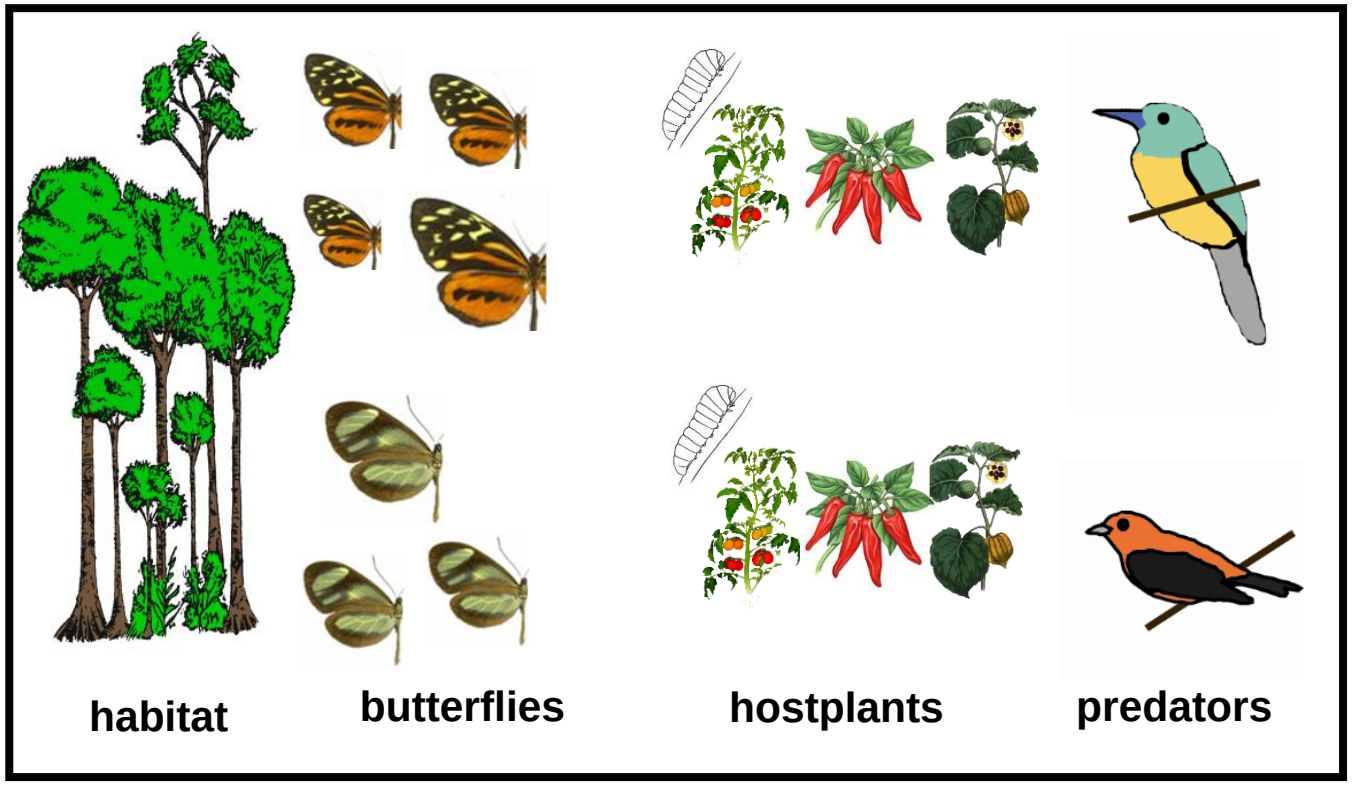
MIMICRY, HABITAT AND HOSTPLANT



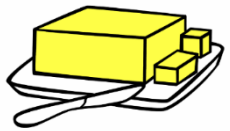
→ hostplant sharing
in 2 out of 5 communities

Willmott and Mallet 2004 *Biol Let*

MIMICRY, HABITAT AND HOSTPLANT

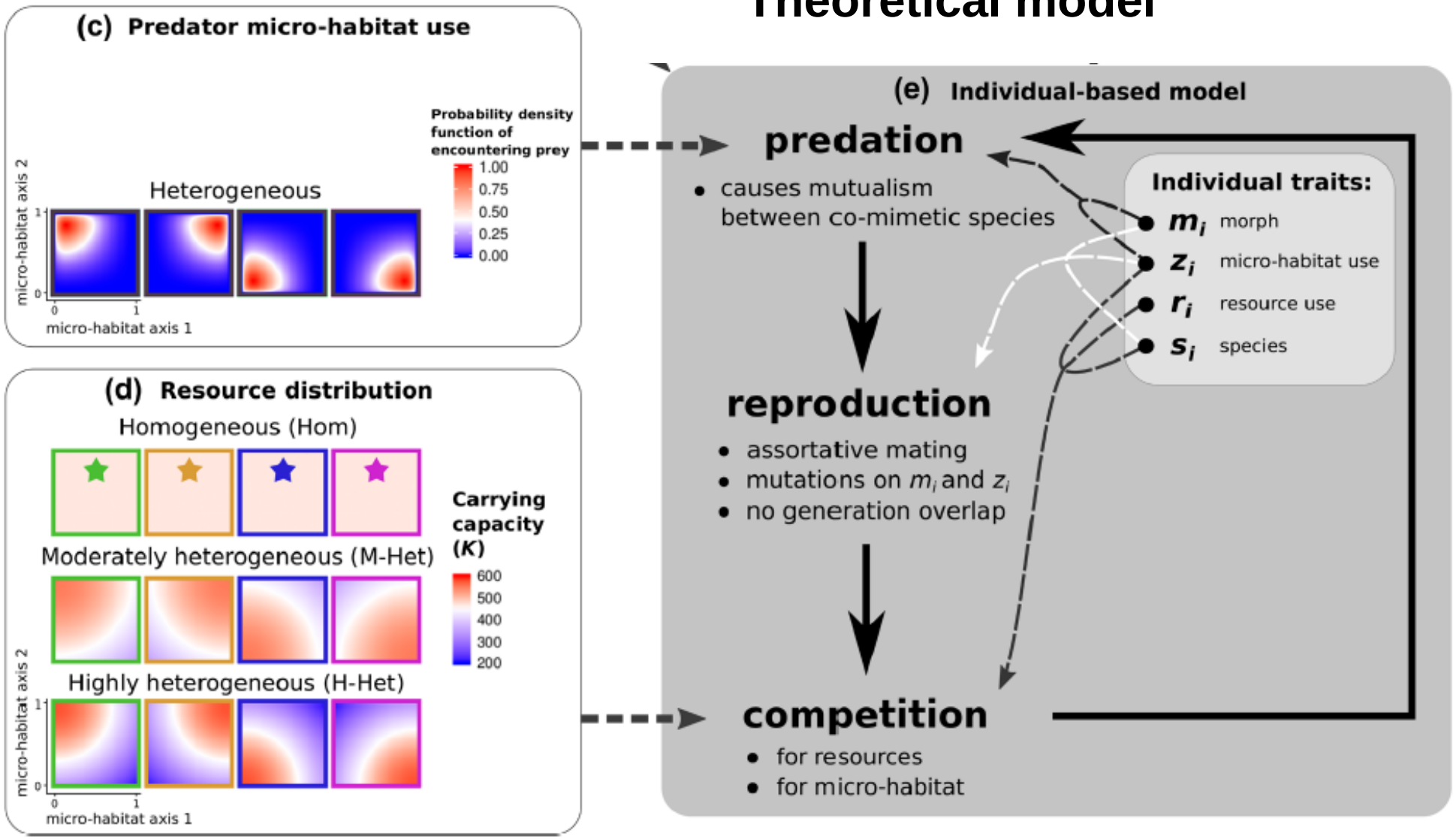


No hostplants segregation by microhabitat
→ co-mimics expected to share hostplants **less** often than at random



MIMICRY, HABITAT AND HOSTPLANT

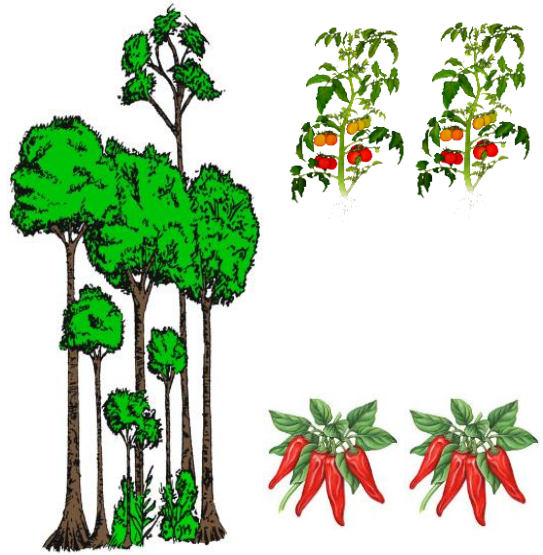
Theoretical model



Aubier and Elias 2020 *Oikos*

MIMICRY, HABITAT AND HOSTPLANT

Heterogeneous hotsplant distribution
(= hostplant segregation by microhabitat)

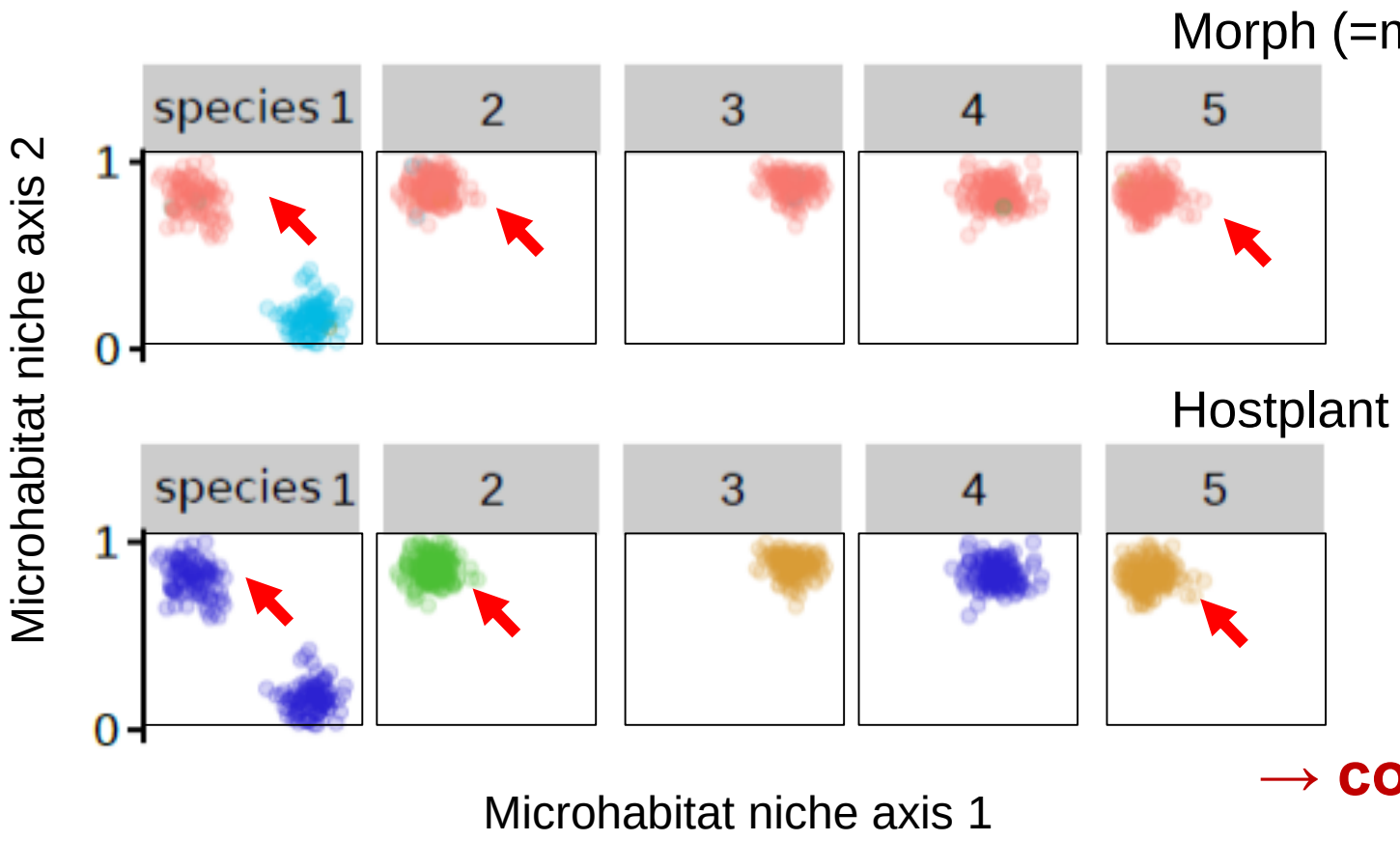


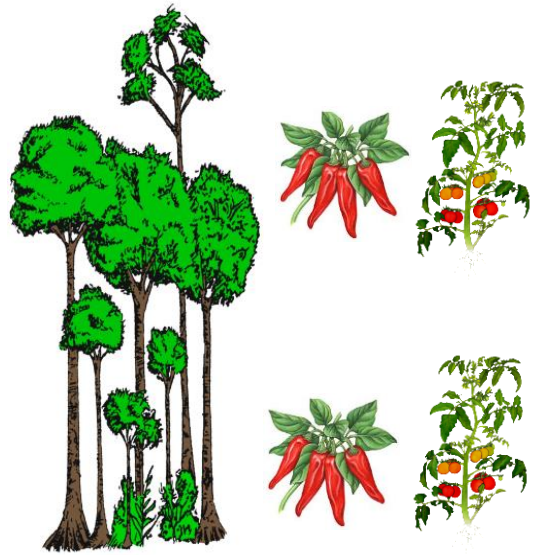
→ co-mimics use the same hostplant

Aubier and Elias 2020 *Oikos*

MIMICRY, HABITAT AND HOSTPLANT

Homogeneous hotsplant distribution
(= no hostplant segregation by microhabitat)





→ co-mimics use <u>different</u> hostplant

Aubier and Elias 2020 *Oikos*

MIMICRY, HABITAT AND HOSTPLANT

Field study

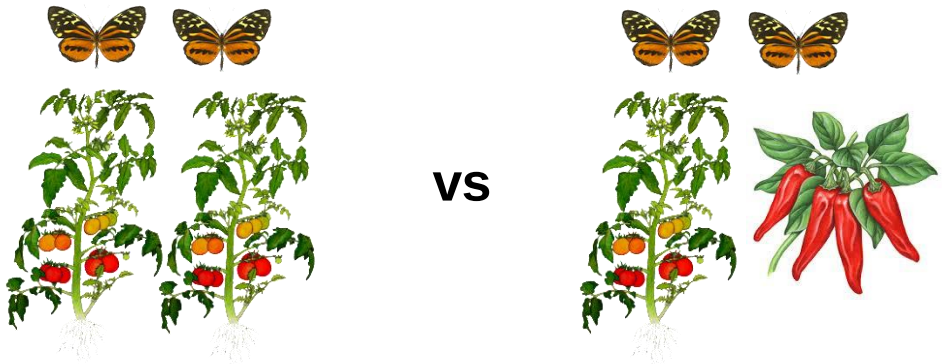
- 4 community-level networks
  - ~ 30 Ithomiini species/site
  - ~ 30 hostplant species/site

Solanaceae

Elias et al. in prep.

???
I am your father!

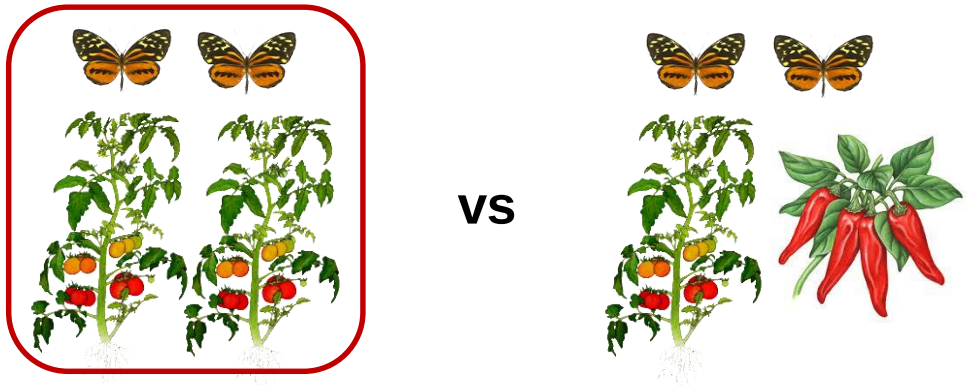
- **Do co-mimics share more (or less) plants than expected at random?**



vs

Elias et al. in prep.

- **Do co-mimics share more (or less) plants than expected at random?**



vs

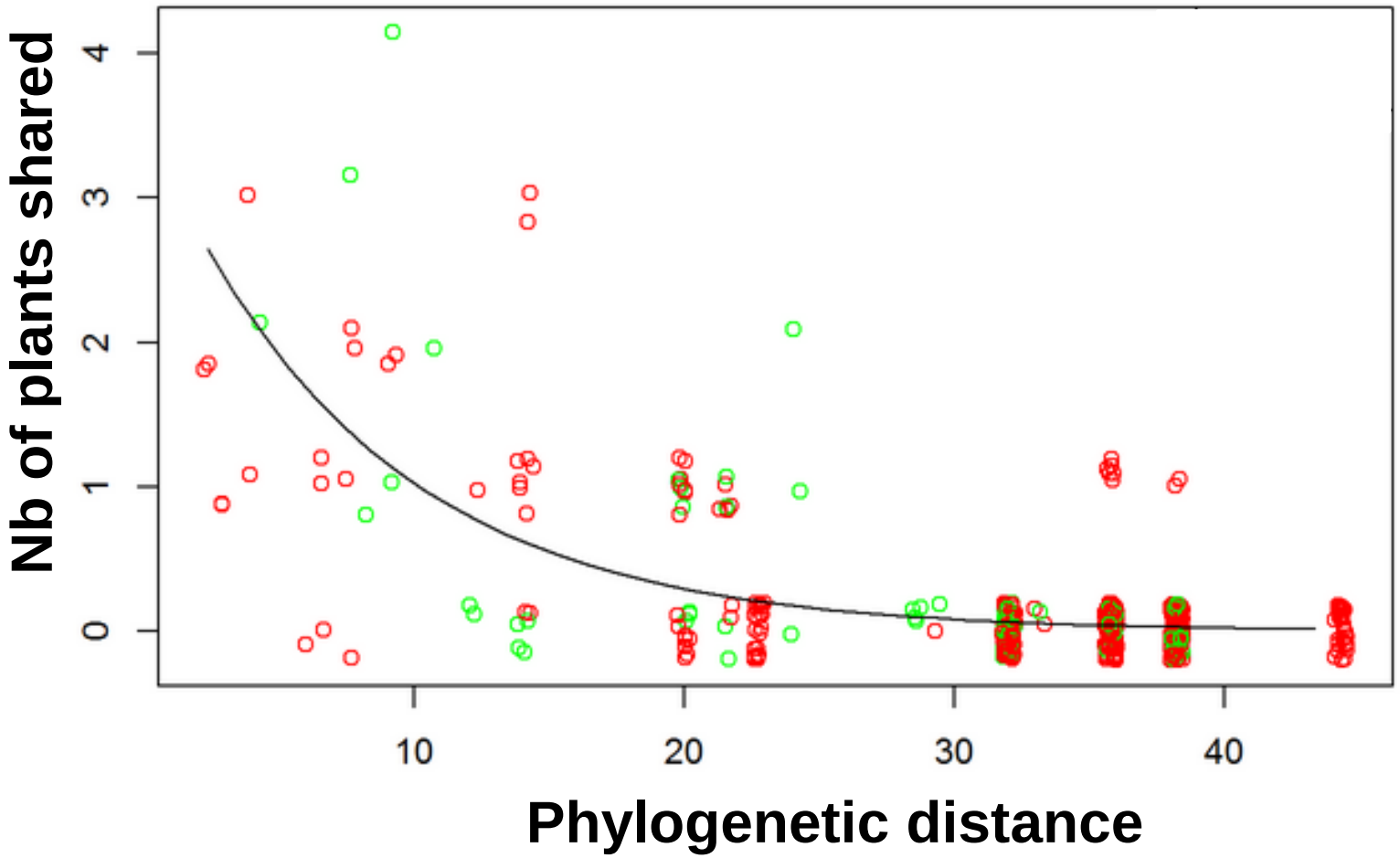
~ Willmott & Mallet 2004 *Biol Let*

Elias et al. in prep.

- **Taking phylogeny into account**

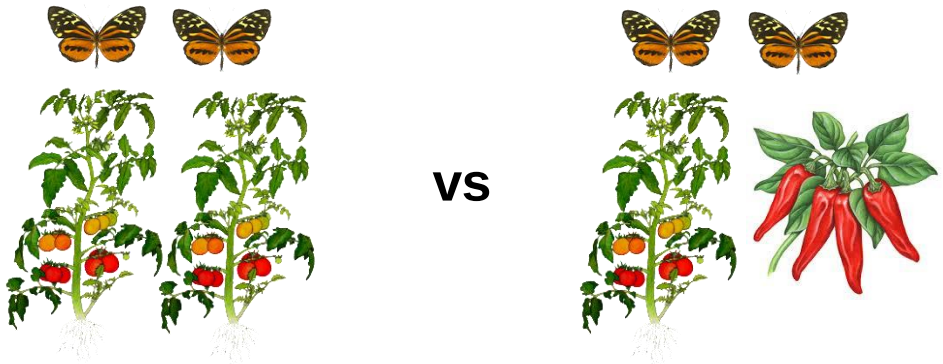
Co-mimetic species

non- co-mimetic species



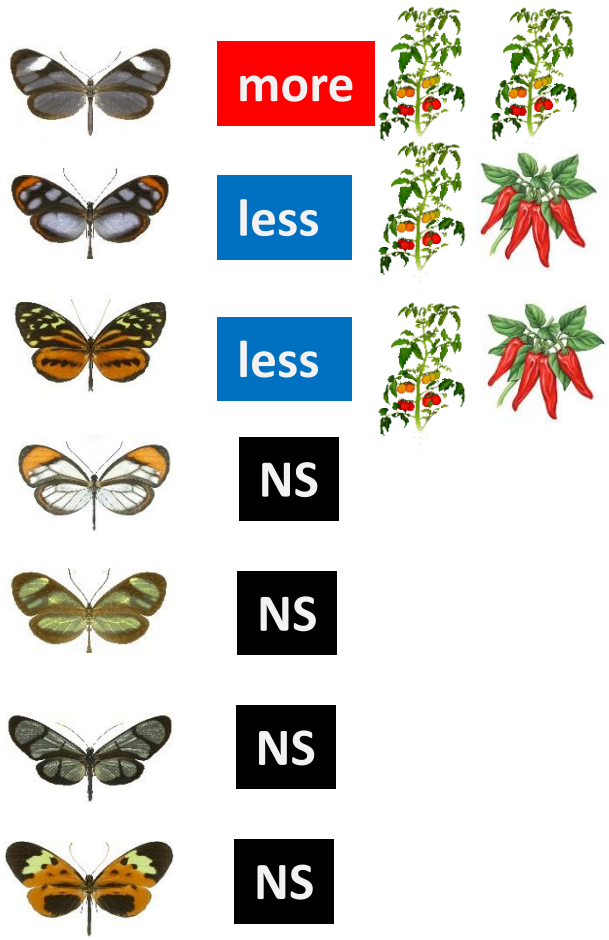
Poisson regression

- **Do co-mimics share more (or less) plants than expected given the phylogeny?**



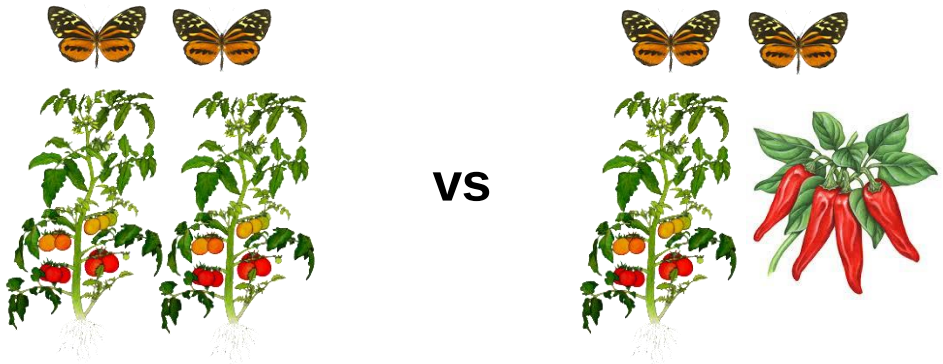
vs

Elias et al. in prep.

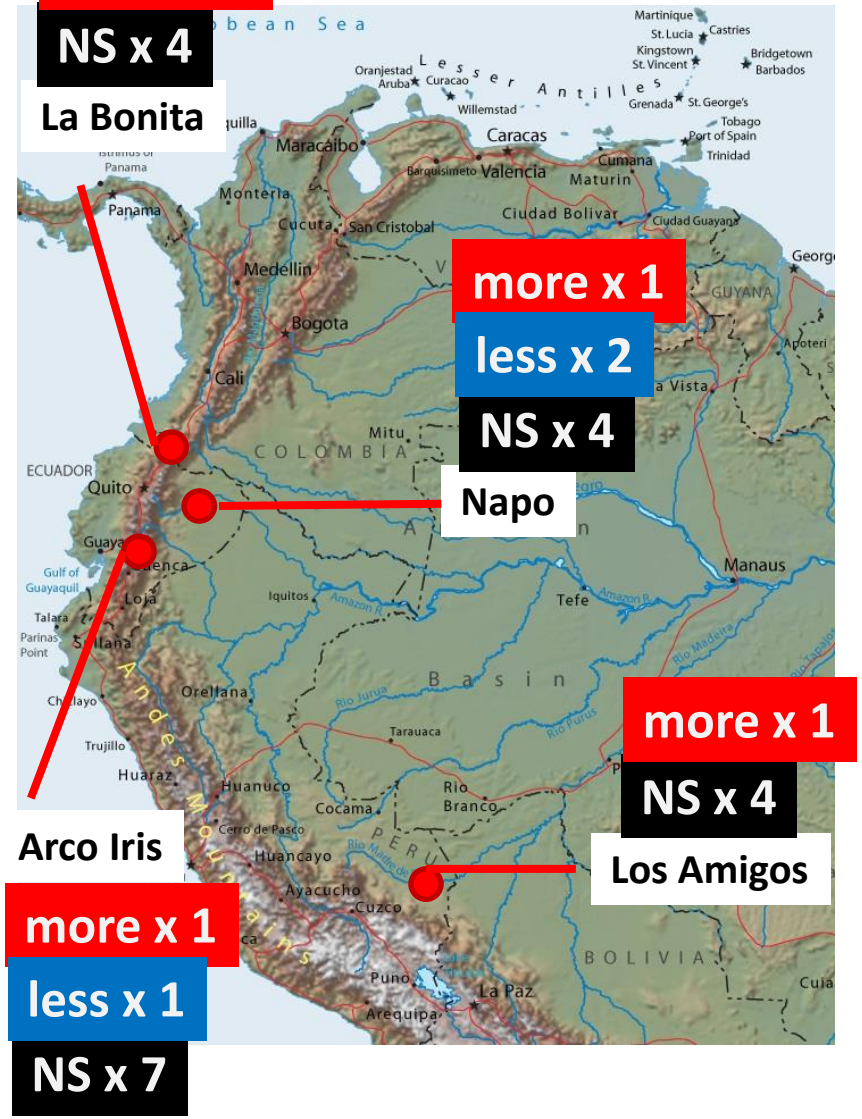


Elias et al. in prep.

- **Do co-mimics share more (or less) plants than expected given the phylogeny?**

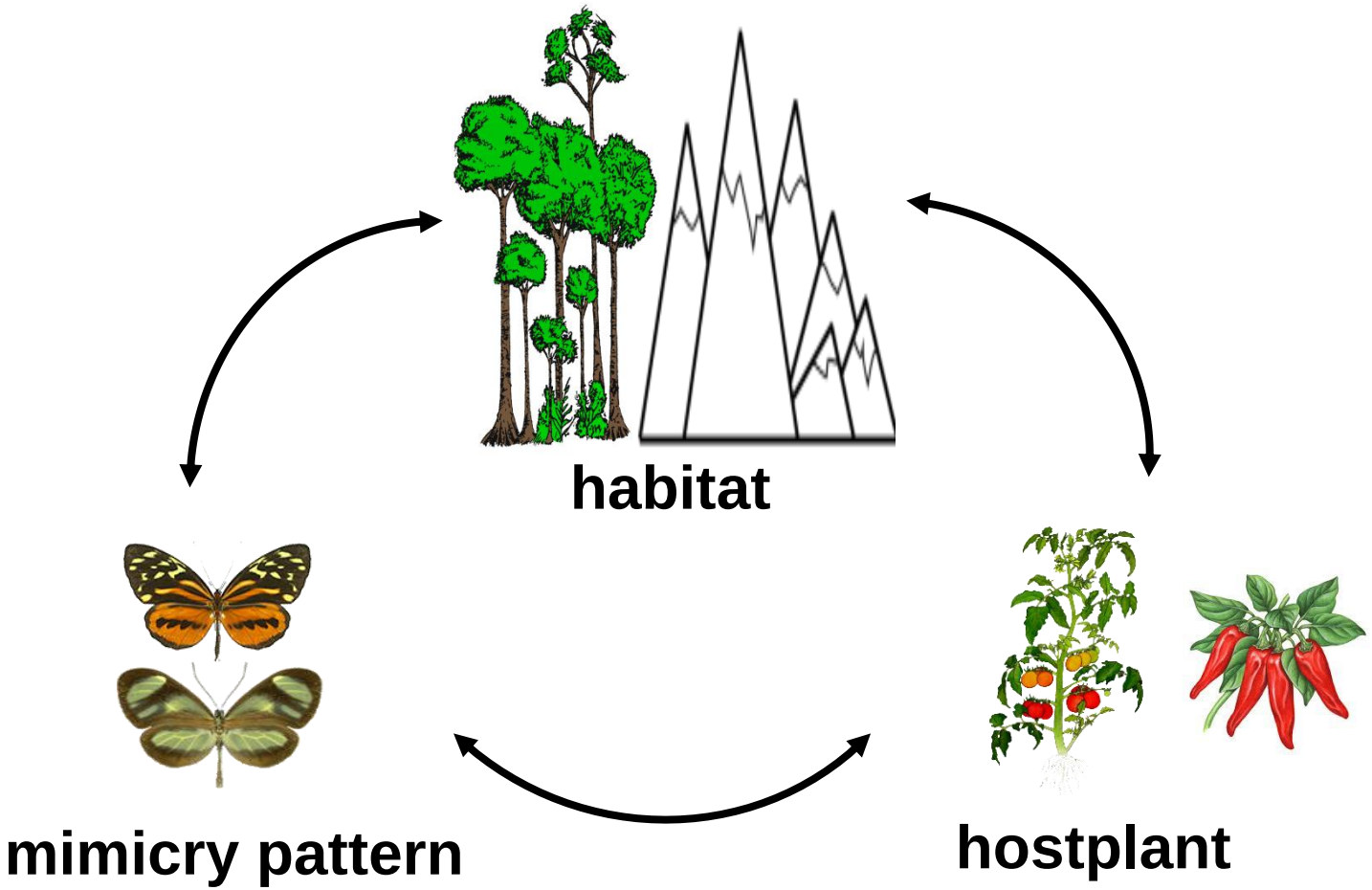


vs



Elias et al. in prep.

- **Correlated shifts along multiple ecological variables**



SHIFTS IN MIMICRY PATTERN AND SPECIATION

- **In mimetic butterflies**

→ assortative mating for wing colour pattern

Jiggins et al. 2001 *Nature*
Chamberlain et al. 2009 *Science*
Merrill et al. 2011 *Evolution*
McClure and Elias 2019 *Anim Behav*
…

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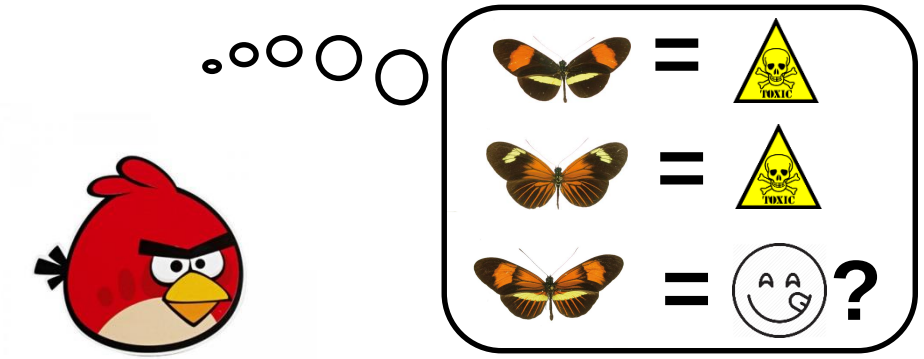
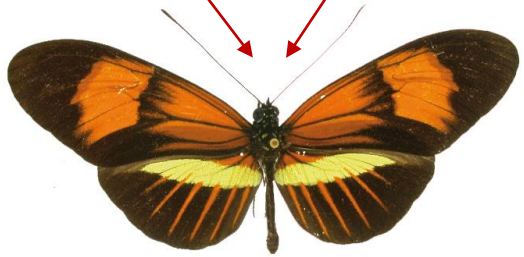
…

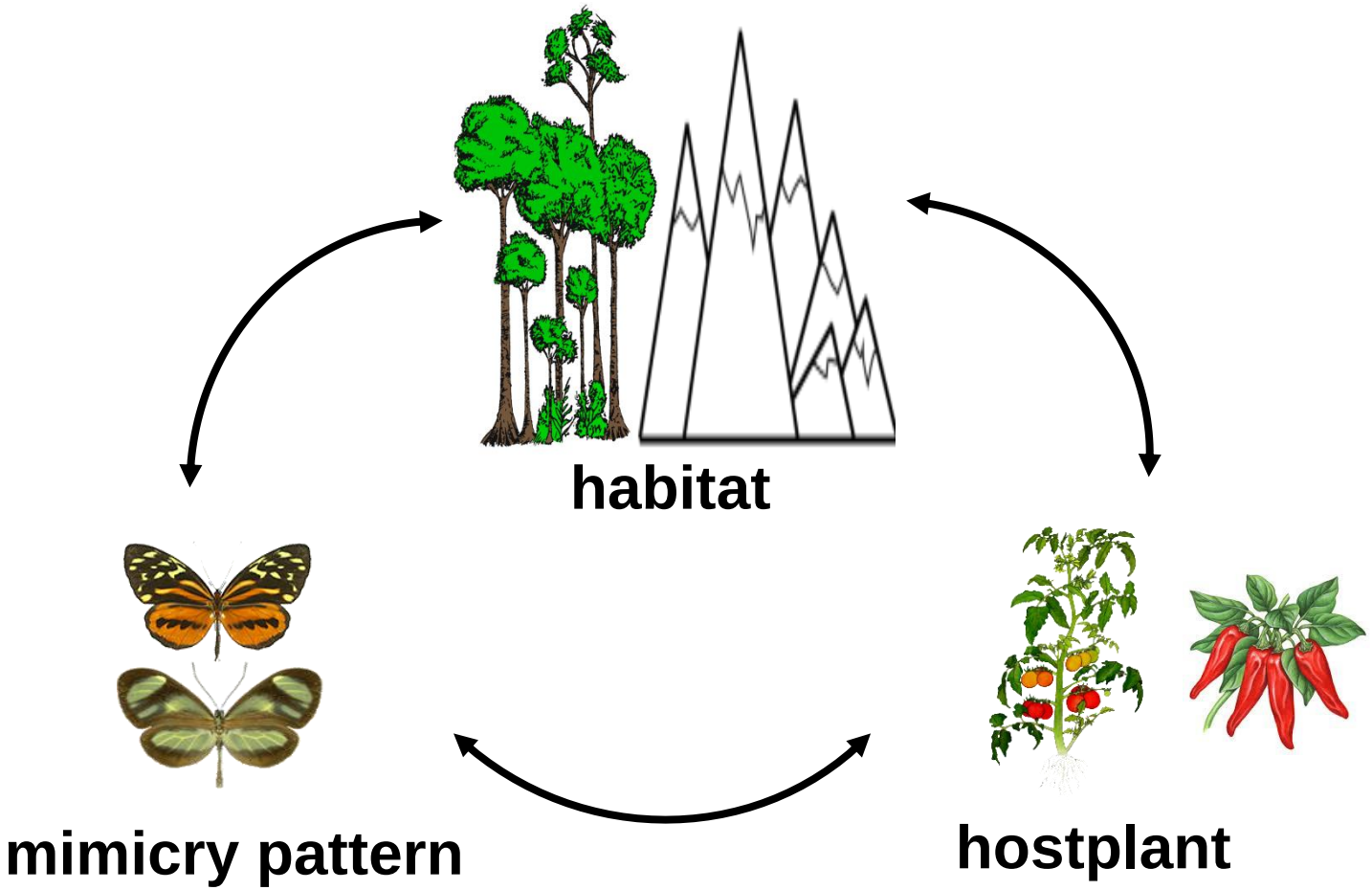
→ lower survival of hybrids





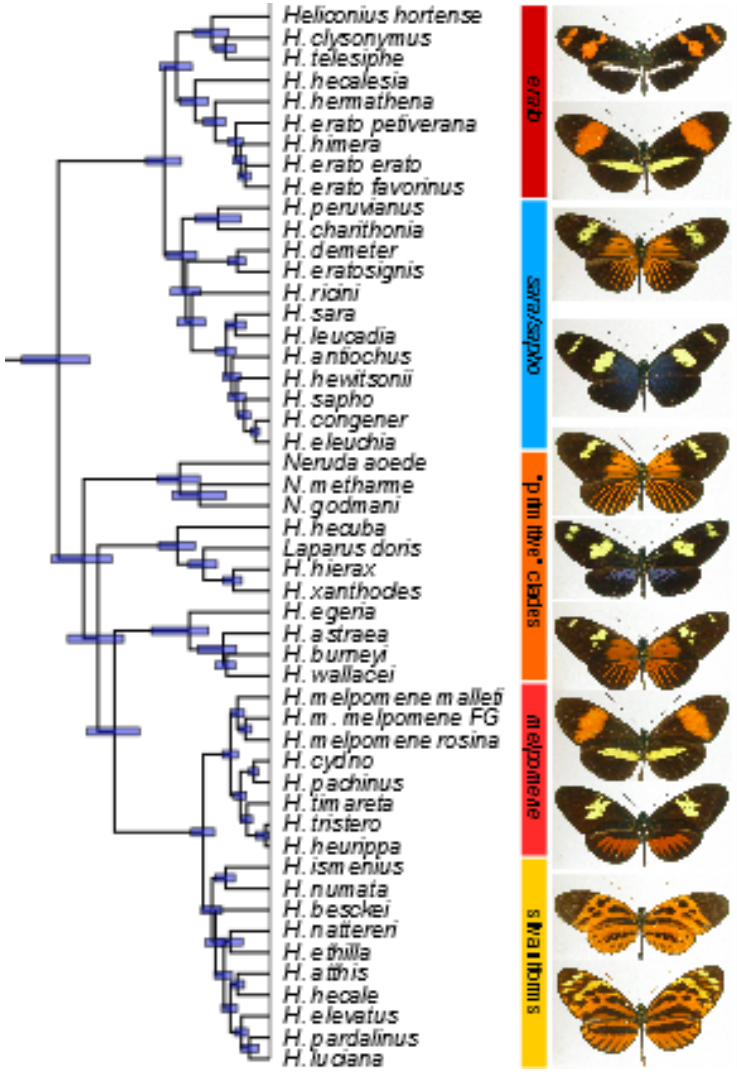
Merrill et al. 2012 *PRSB*

- **Correlated shifts along multiple ecological variables**

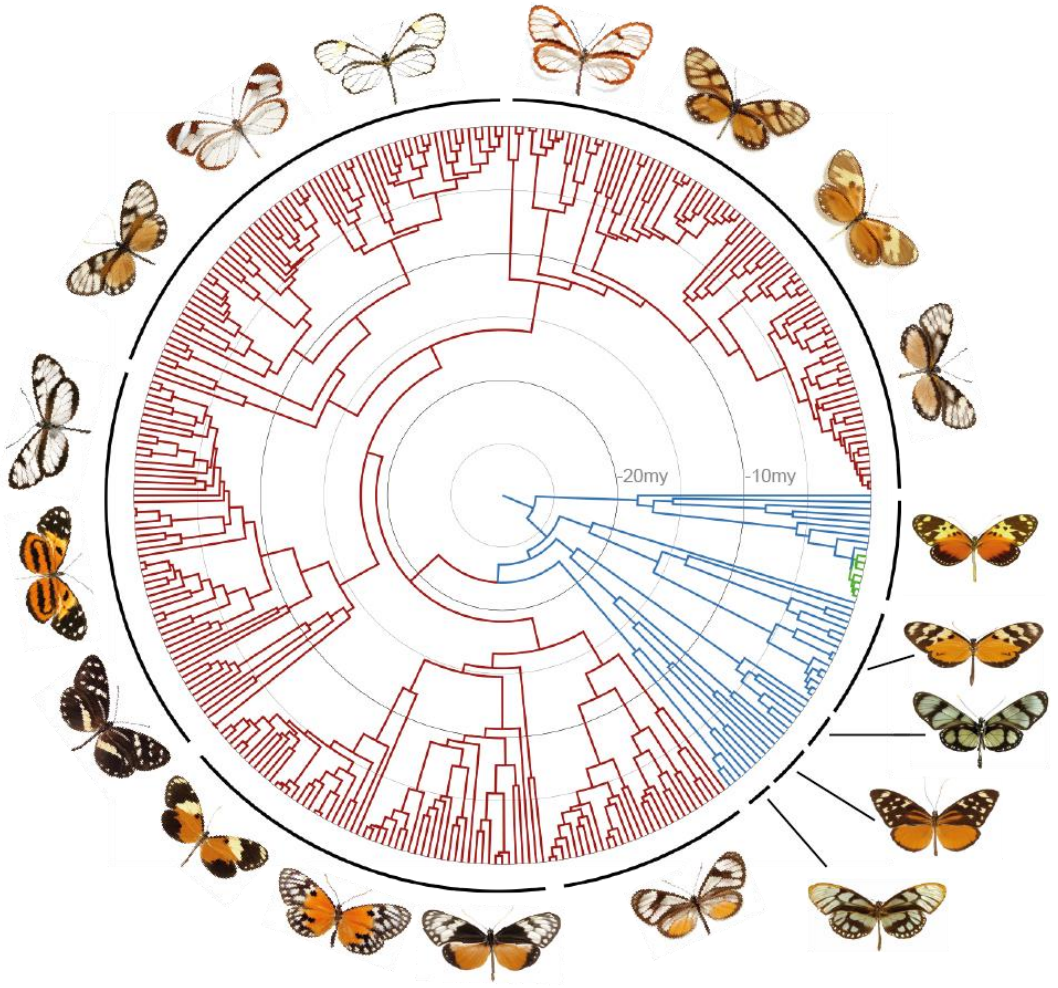


→ drivers of speciation

Heliconius
46 species in 12 million years

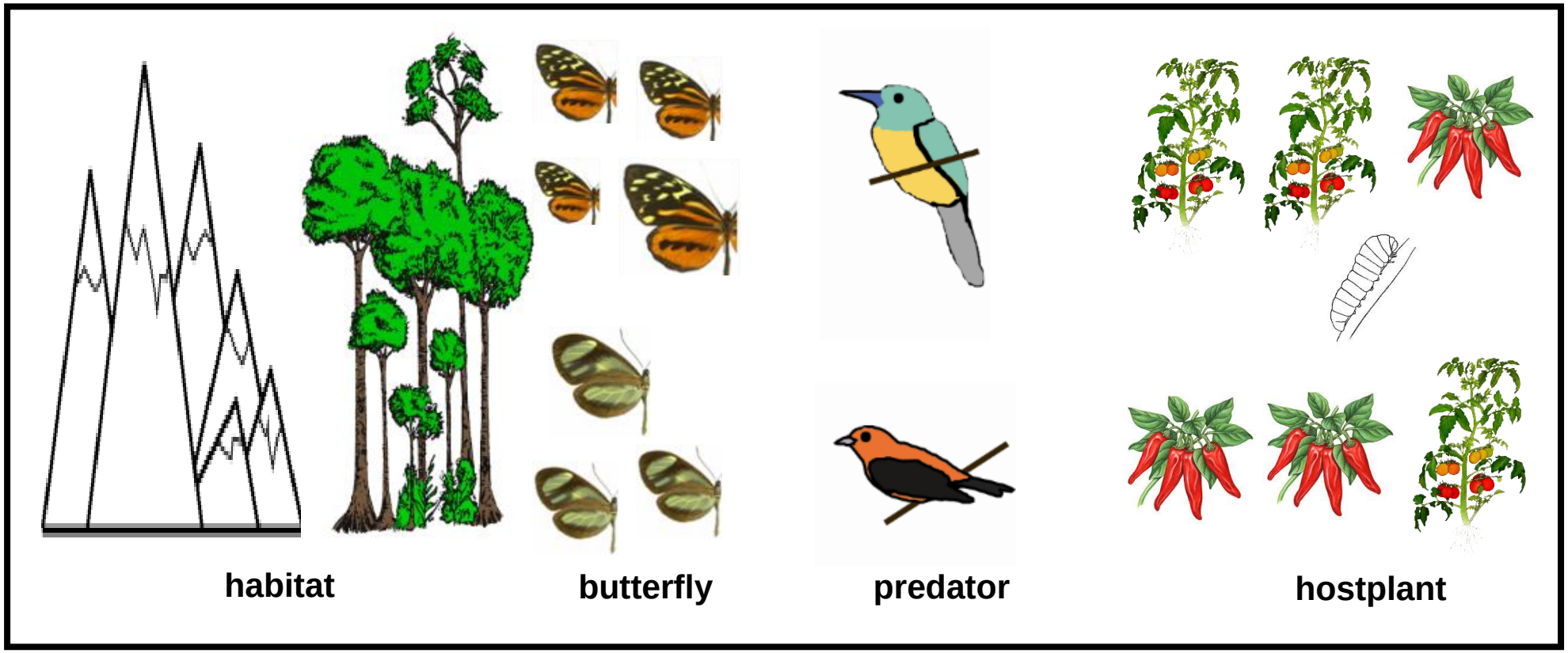


Ithomiini
393 species in 26 million years



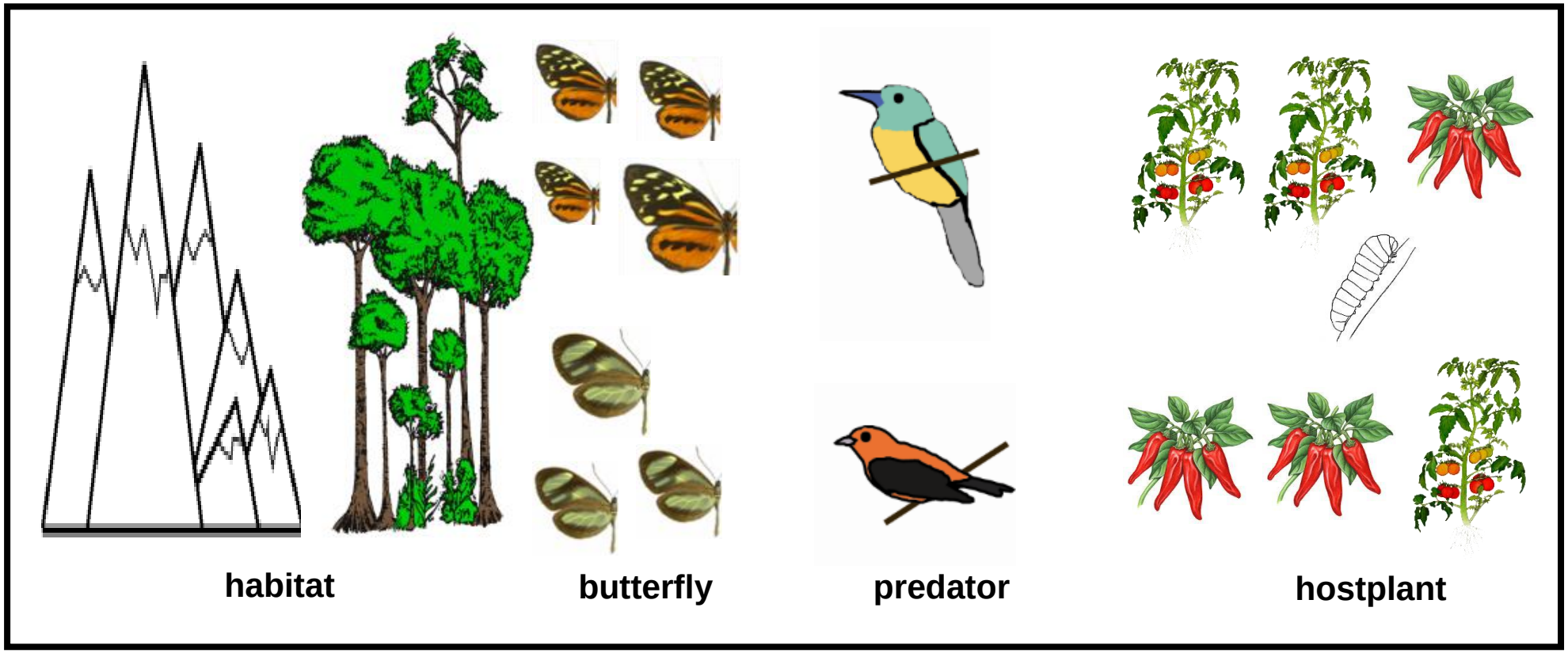
CONCLUSION

- **Ecological segregation of predators maintains local mimicry diversity**
- **Positive interactions drive ecological convergence**



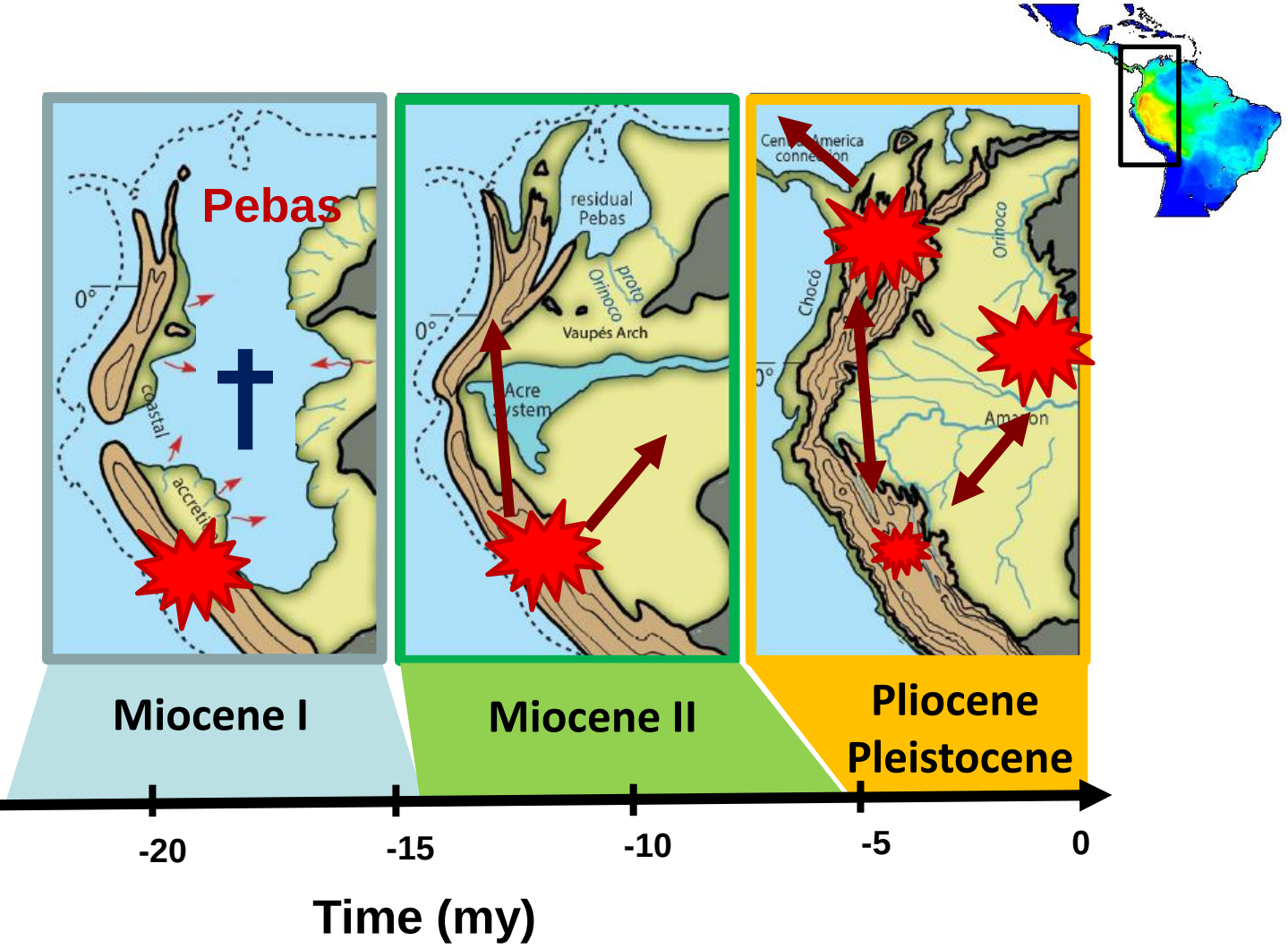
CONCLUSION

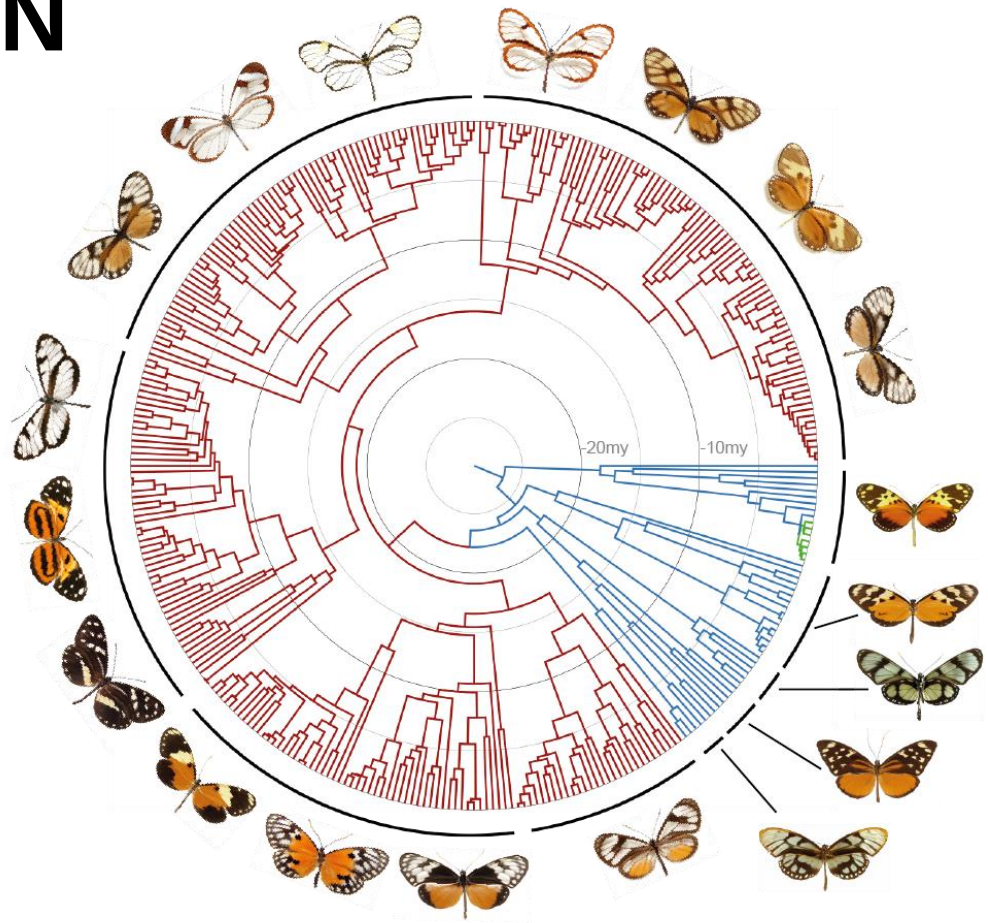
- **Complex outcome of interplay between positive and negative interactions**



CONCLUSION

- **Interactions may drive diversification**





Phylogenetic signatures of adaptive radiation

Chazot et al. 2019 *GEB*, Elias et al. in prep

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- Hostplant analysis

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U. Zurich

© Willmott

MERCI!

- Amandine et Colin
- field assistants and colleagues
- Peru: SERFOR, Proyecto Huallaga,
  Museo de Historia Natural (Lima)
- Ecuador: ministerio del ambiente,
  Museo de ciencias naturales

FUNDING

ANR

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cnrs dépasser les frontières

The Leverhulme Trust

ATIP