

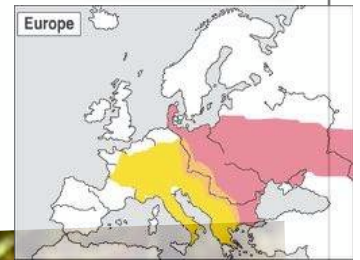


Walter Salzburger
Zoological Institute



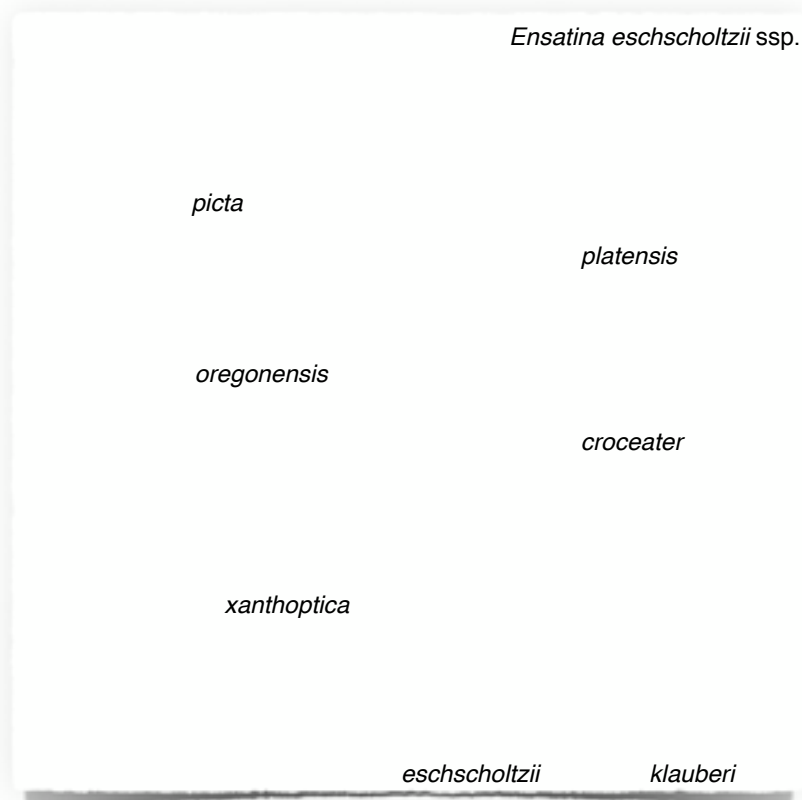
① Charles R. Darwin (1809-1882)

distribution map



① Hybrid zone between yellow- and fire-bellied toad

ring species



Stebbins (1994)

① *Ensantina eschscholtzii* inhabits the western part of the USA

Individuals within a species are variable and there is usually no “ideal” or “typical” individual.



image: www.heliconius.org

① Heliconius erato and H. melpomene are morphologically similar because of mimicry

The category species is defined according to a species concept

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 sets 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).

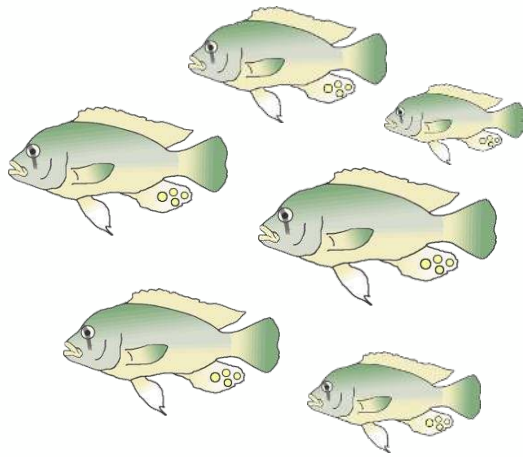
evolutionary species concept

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).

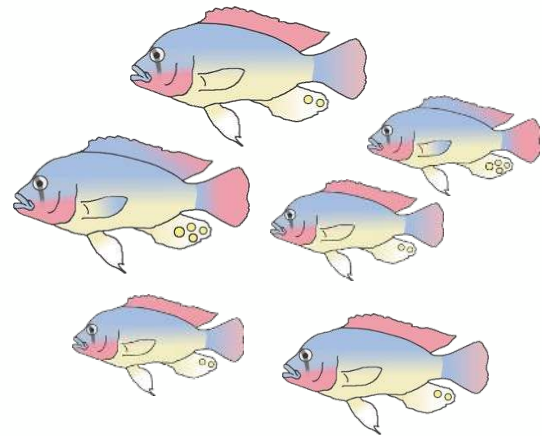
phylogenetic species concepts

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)

Members of a species share a gene pool; selection and drift operate within species.



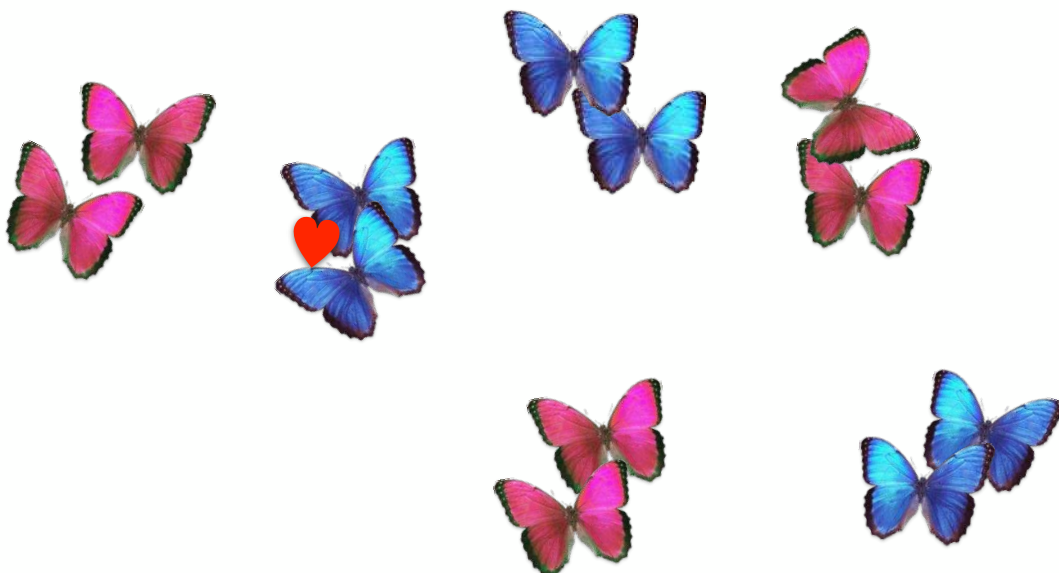
species X



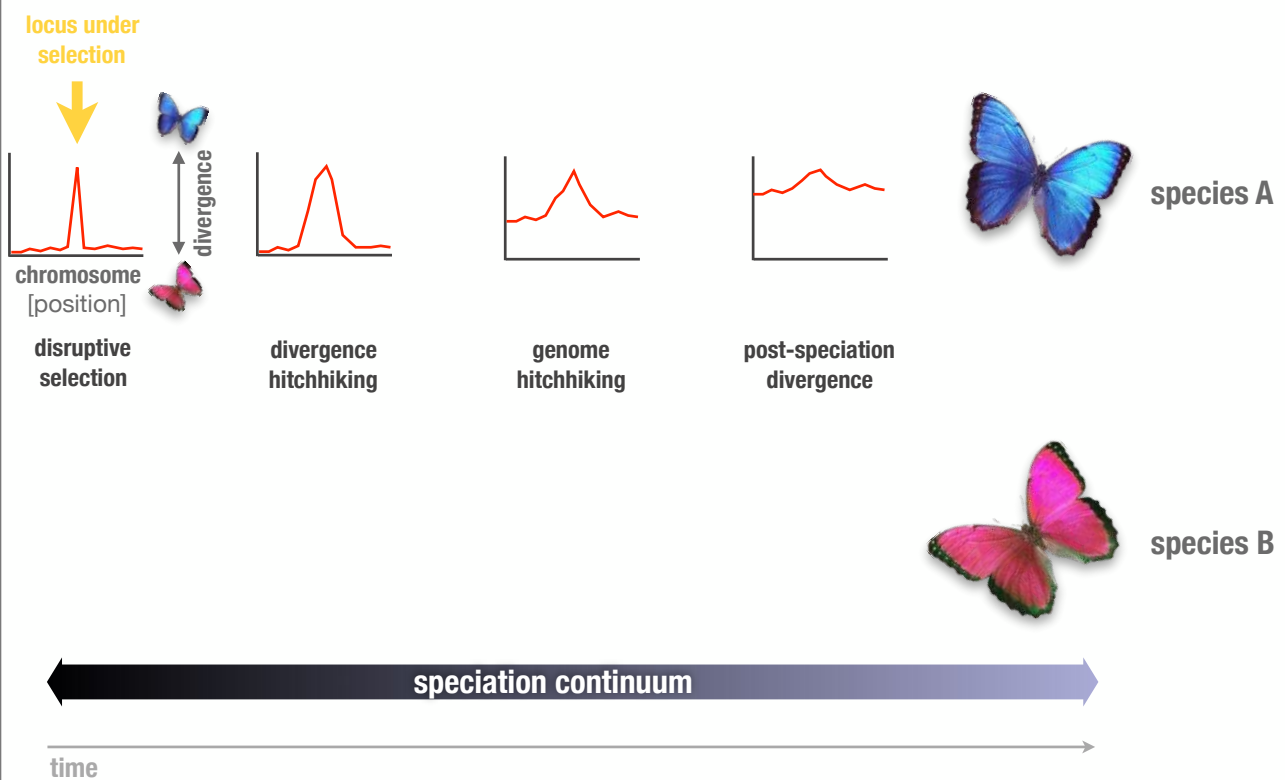
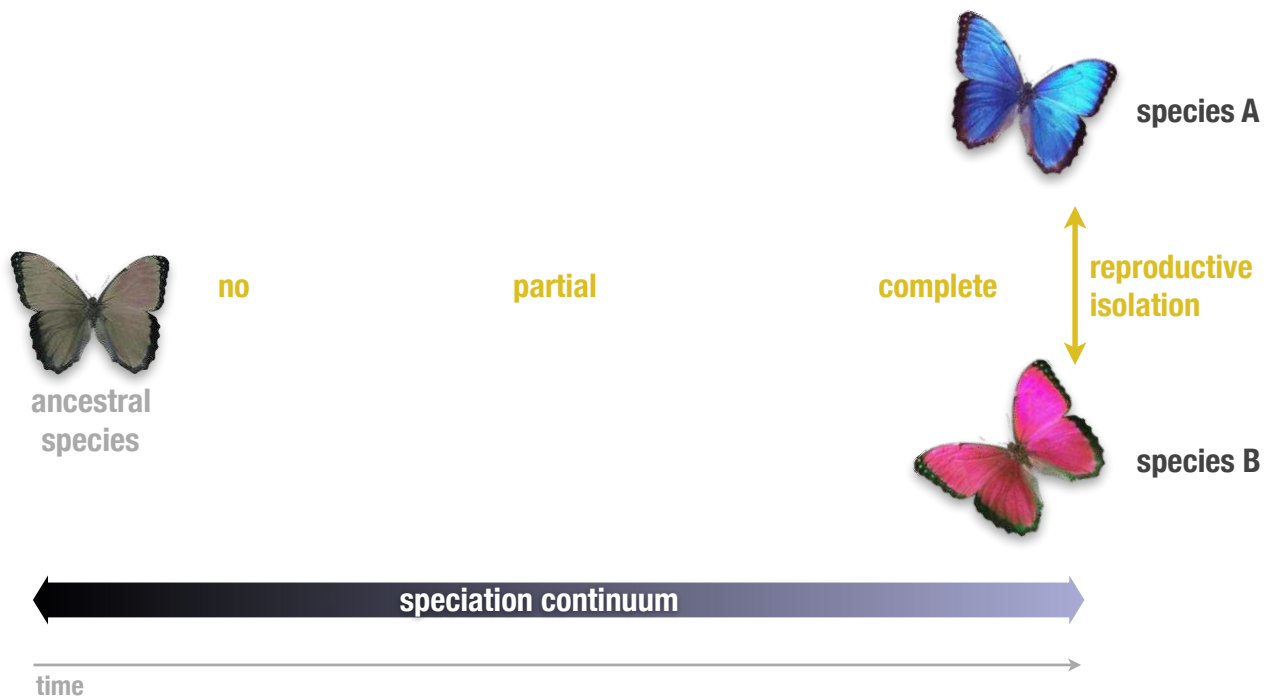
species Y

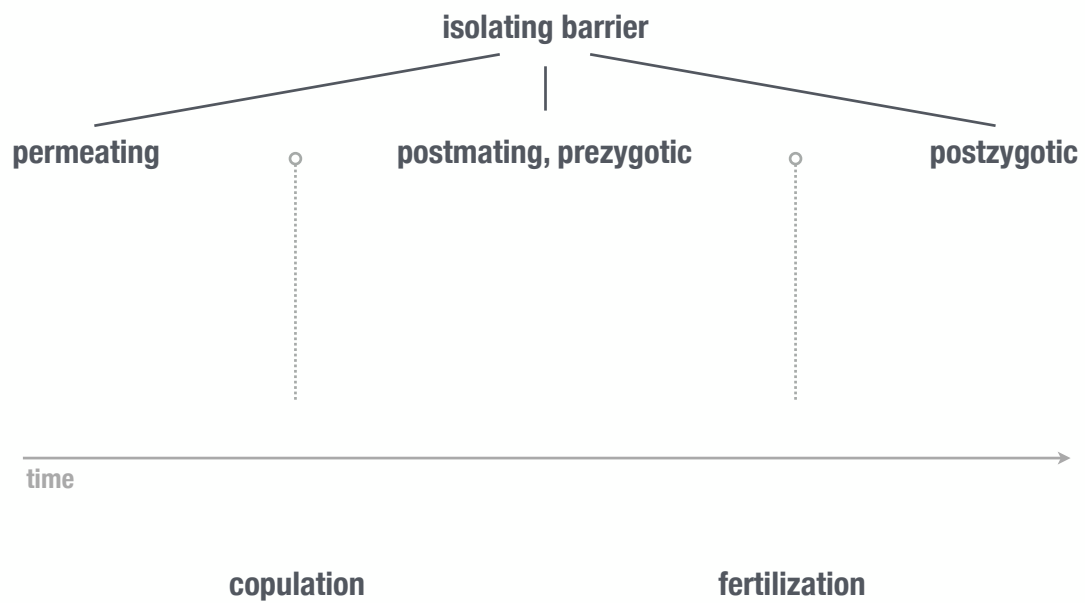
① Evolutionary biologists interpret species as independent evolutionary units

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

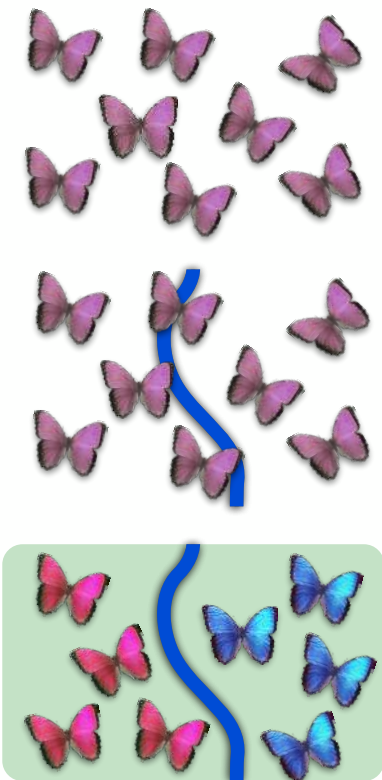


① The biological species concept places the category species within the framework of population genetics





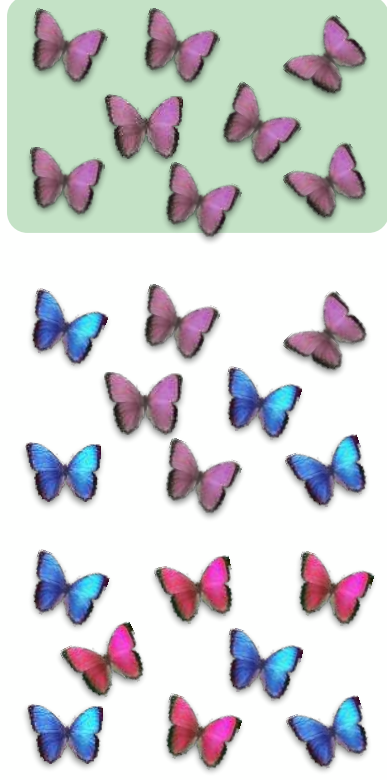
allopatric speciation



parapatric speciation



sympatric speciation



time

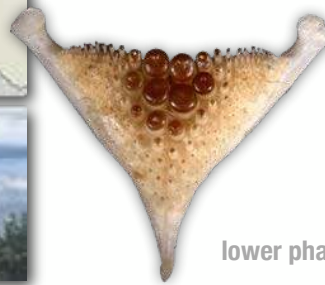


Bariuenga et al. (2006) Nature

Amphilophus citrinellus



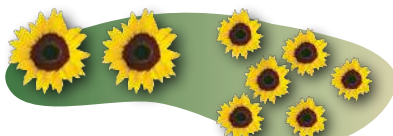
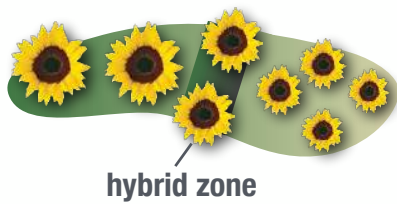
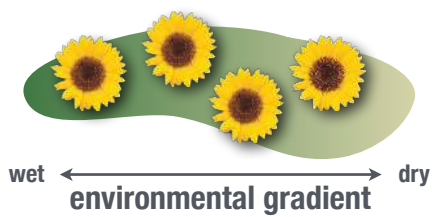
Amphilophus zaliosus



lower pharyngeal jaw bone

① The Laguna de Apoyo is a small volcanic crater lake in Nicaragua

Clinal models



colonization

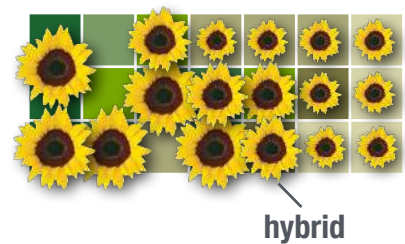


local adaptation



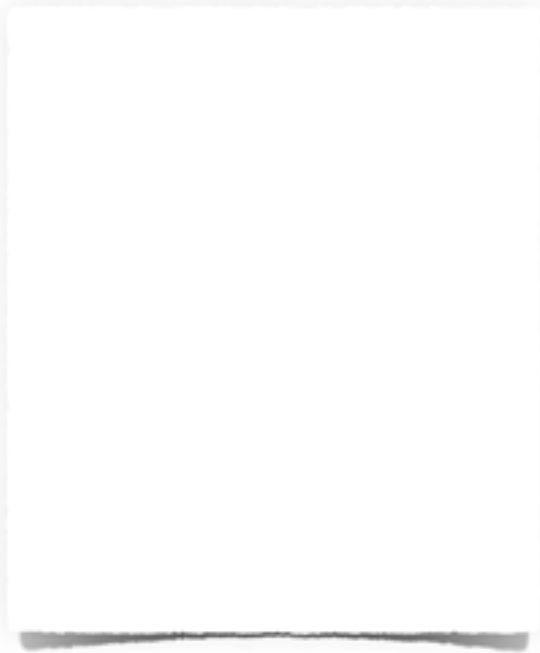
reproductive isolation

"Stepping-stone" models



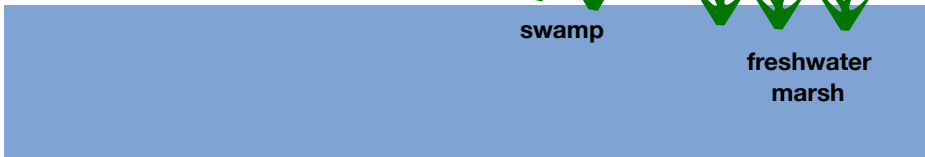
The evolution of reproductive isolation between populations by adaptation to different environments.

threespine
stickleback



Jones et al. (2012) Nature

① Ecological speciation can happen in allopatry, parapatry and sympatry



swamp

freshwater
marsh

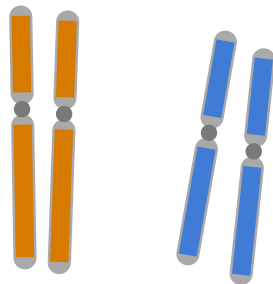
 *Iris fulva*

hybrid 

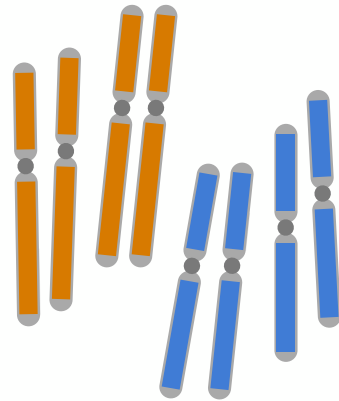
 *Iris hexagona*

from: Arnold & Bennett (1993)

① Luisiana irises

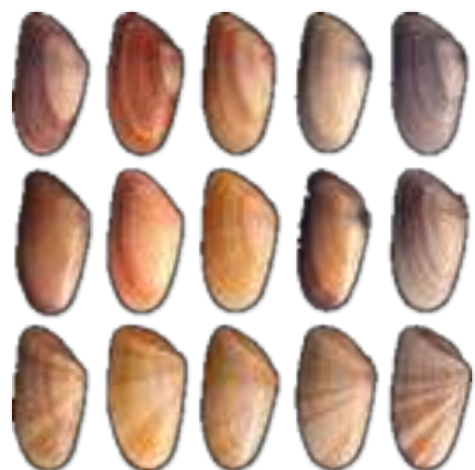


diploid
($2n=4$)



tetraploid
($4n=8$)

- ... 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)



- ▶ ... 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 through
choice by members of one sex (usually females) for certain members of the other sex
(Ridley 1996)



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’)

There are fundamental difference between natural and sexual selection:

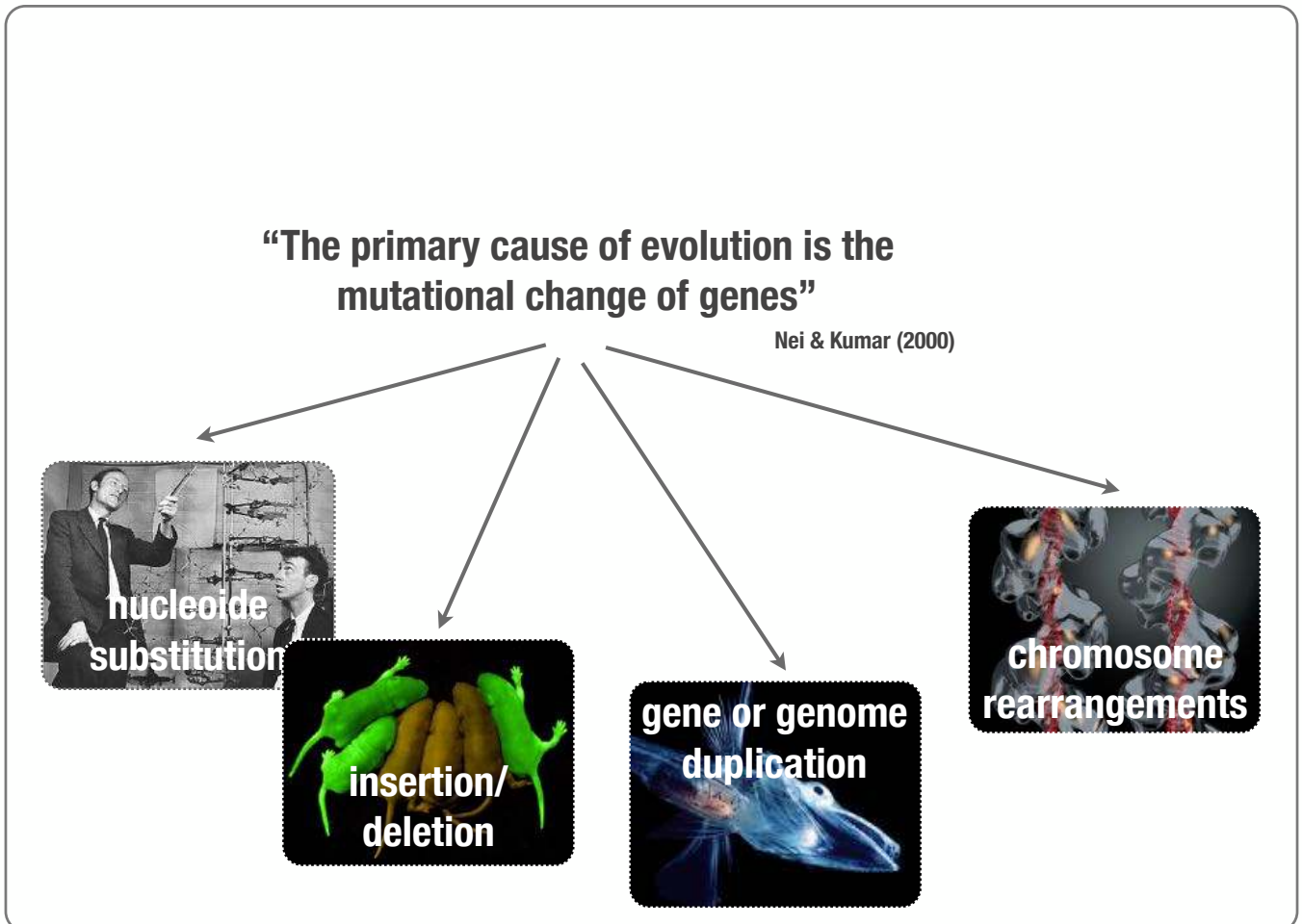
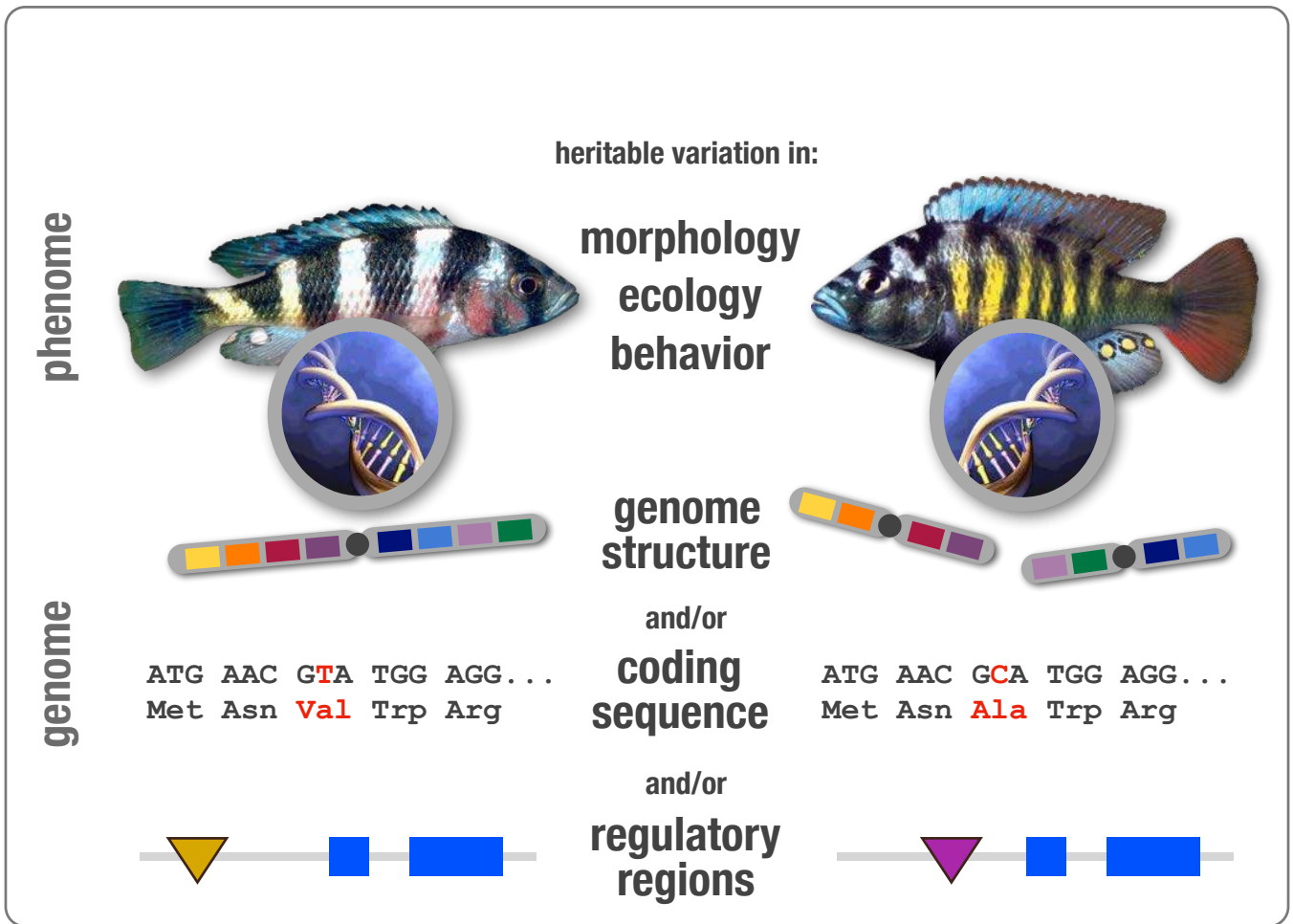
	fitness	competitors
sexual selection	individual fitness	other members of the same sex
natural selection	fitness of the genotype	other individuals in the same population

Natural populations show variation at all levels, from gross morphology to DNA sequences. Selection can only operate, if heritable variation exists.

Heritable natural variation is generated by two processes, mutation and recombination.

New mutations are only transmitted to the next generation, if they occur in germinal tissue.





The rate of non-synonymous (dN) to synonymous (dS) substitution informs about the selective pressure that has acted on a protein coding gene:

$dN/dS \ll 1$: purifying selection

$dN/dS = 1$: neutrality

$dN/dS > 1$: positive selection (adaptive sequence evolution)

$Ka/Ks = 4.026$

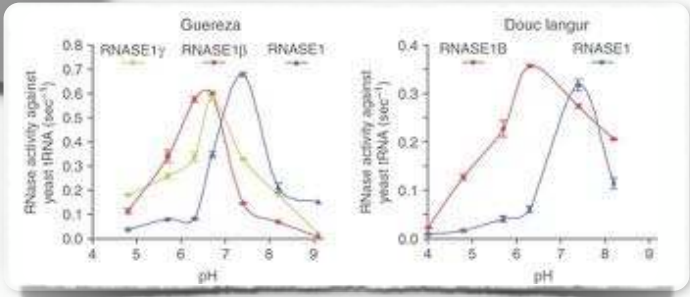
Pancreatic ribonuclease in colobine monkeys



Pancreatic ribonuclease in leaf-eating monkeys

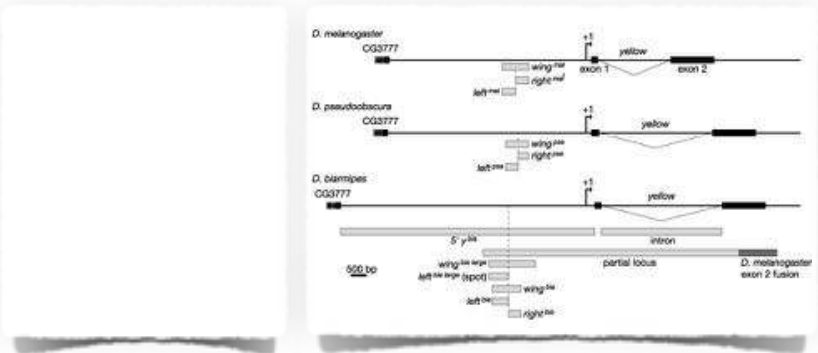


Prud'homme & Carroll (2006)



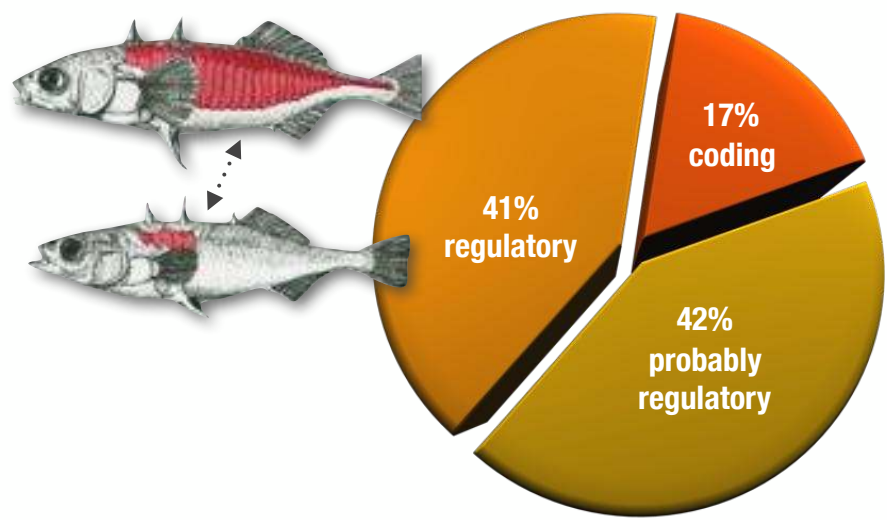
Zhang (2006)

cis-regulatory evolution in fruitless

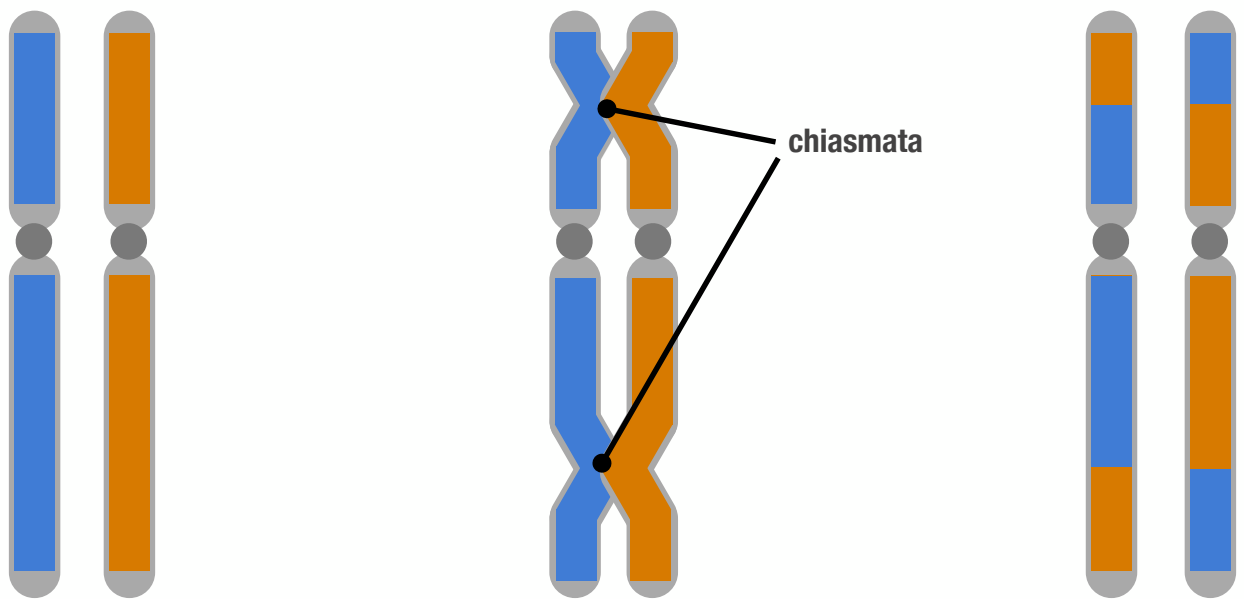


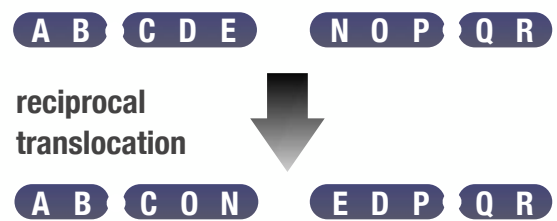
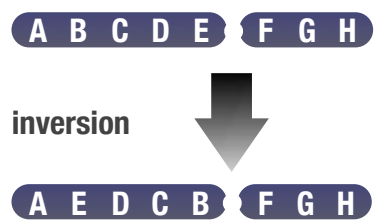
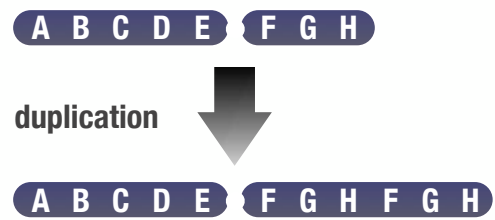
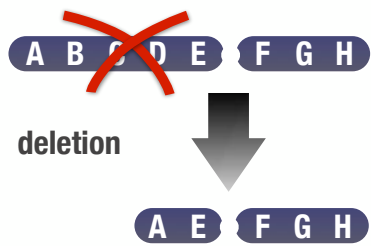
Gompel et al. (2005)

regulatory evolution in three spine sticklebacks

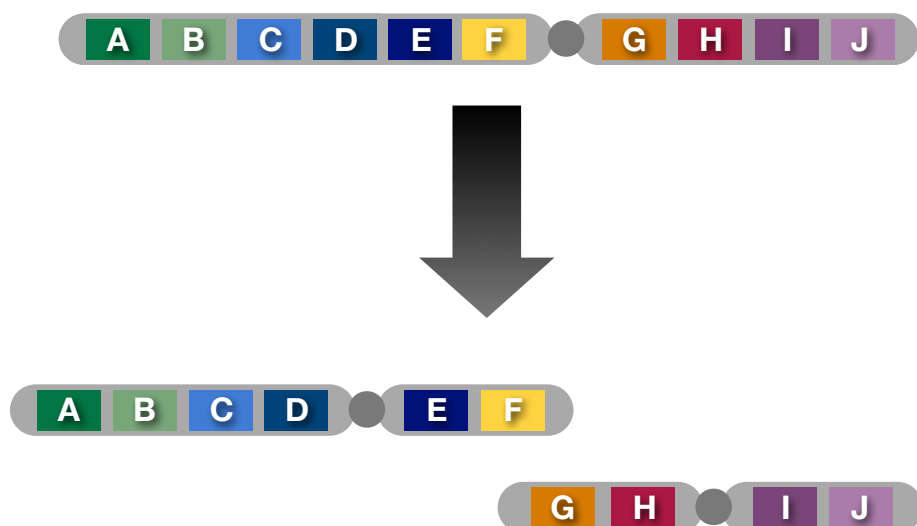


Recombination

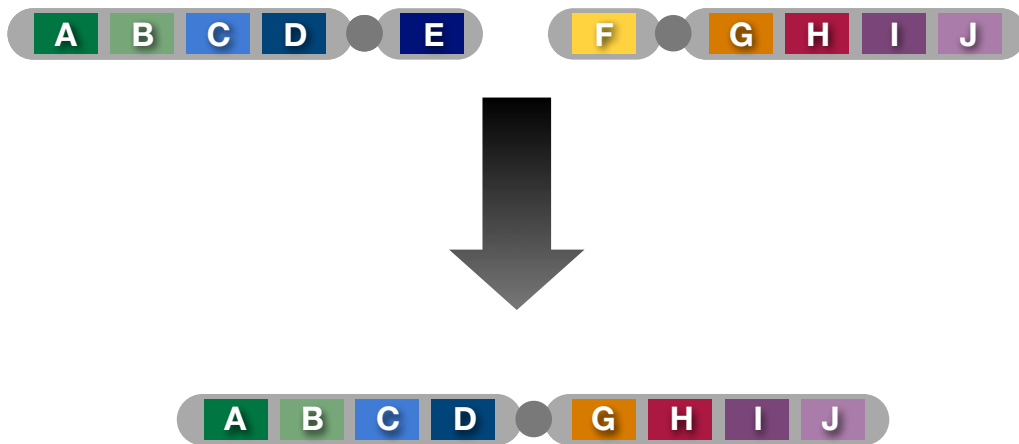




Chromosomal fission



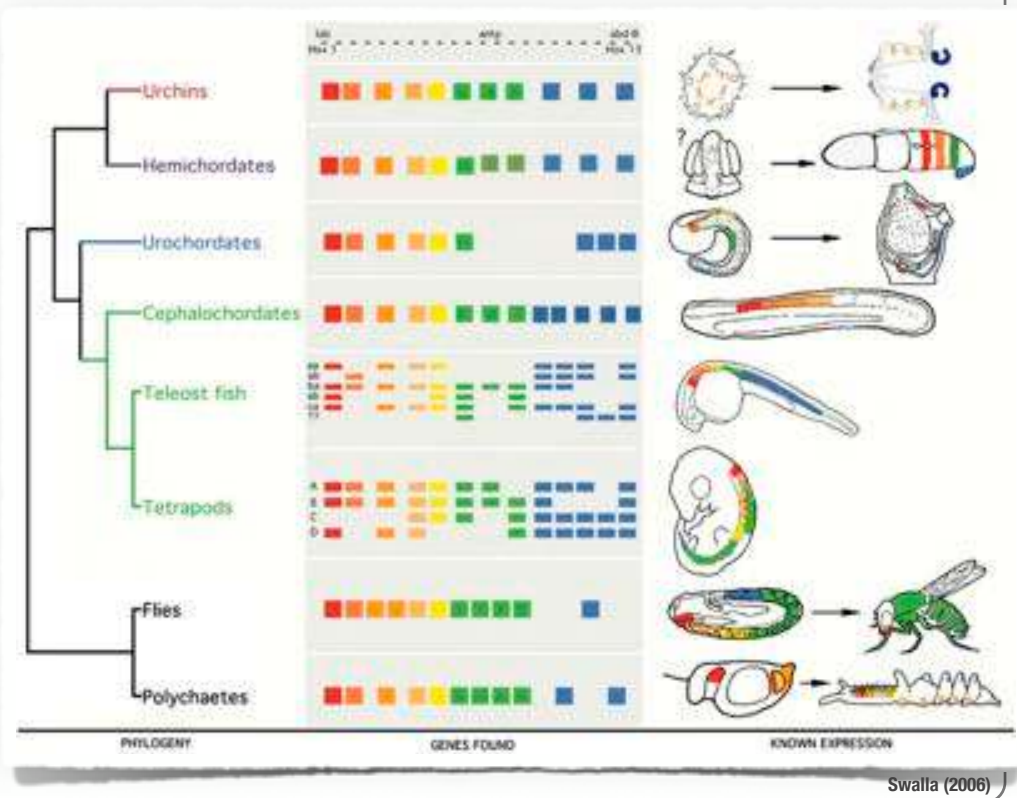
Chromosomal fusion



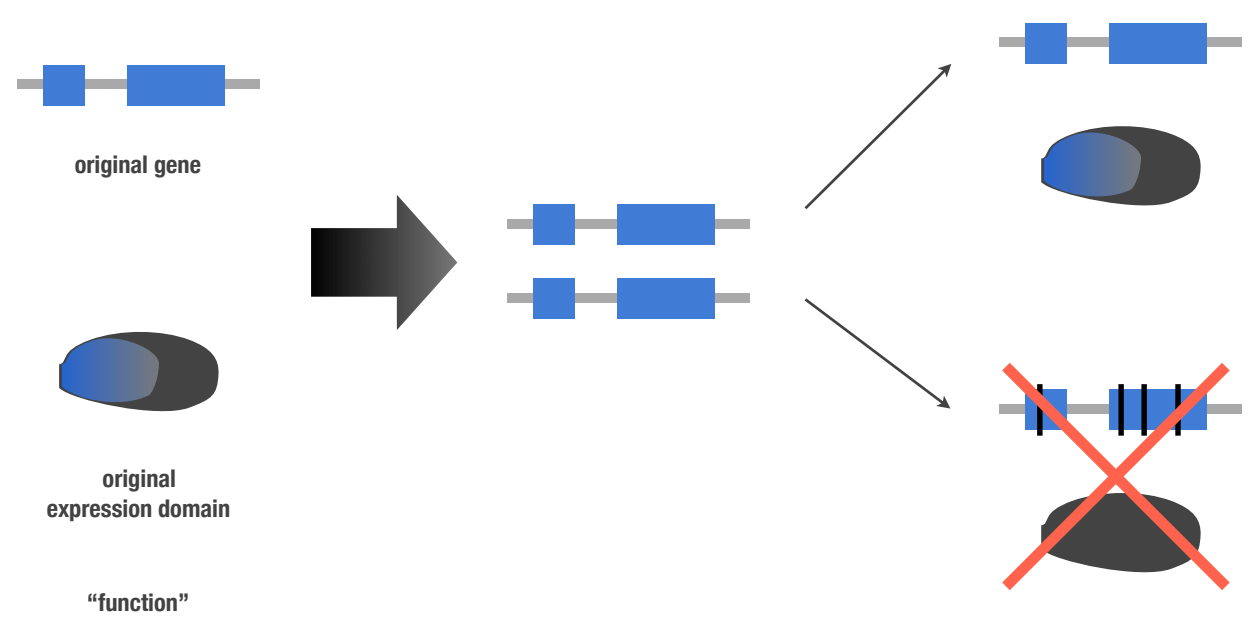
Chromosomal rearrangements in muntjac deers



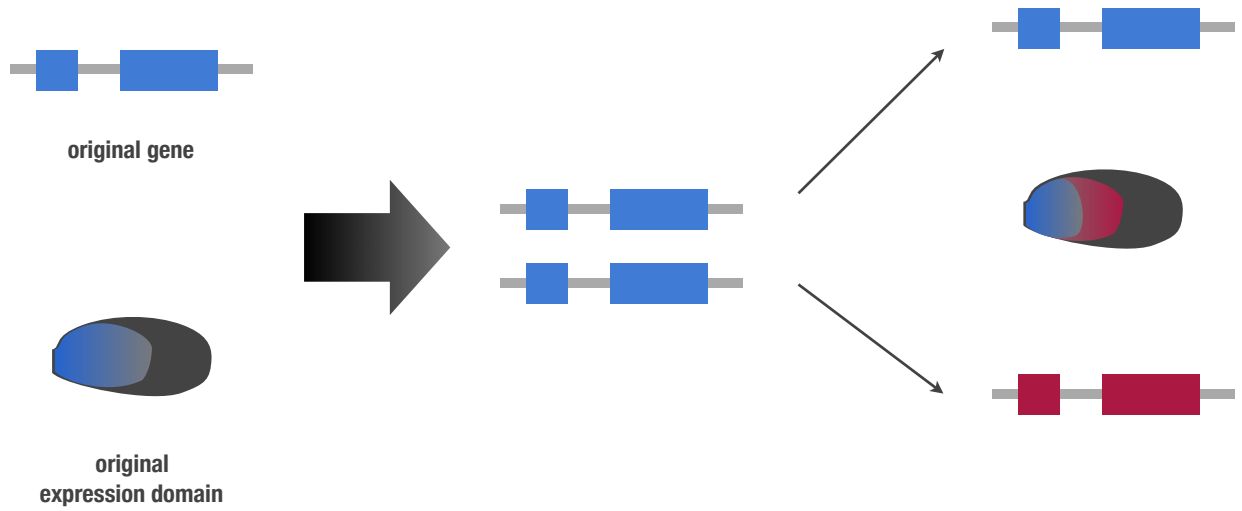
Hox gene clusters



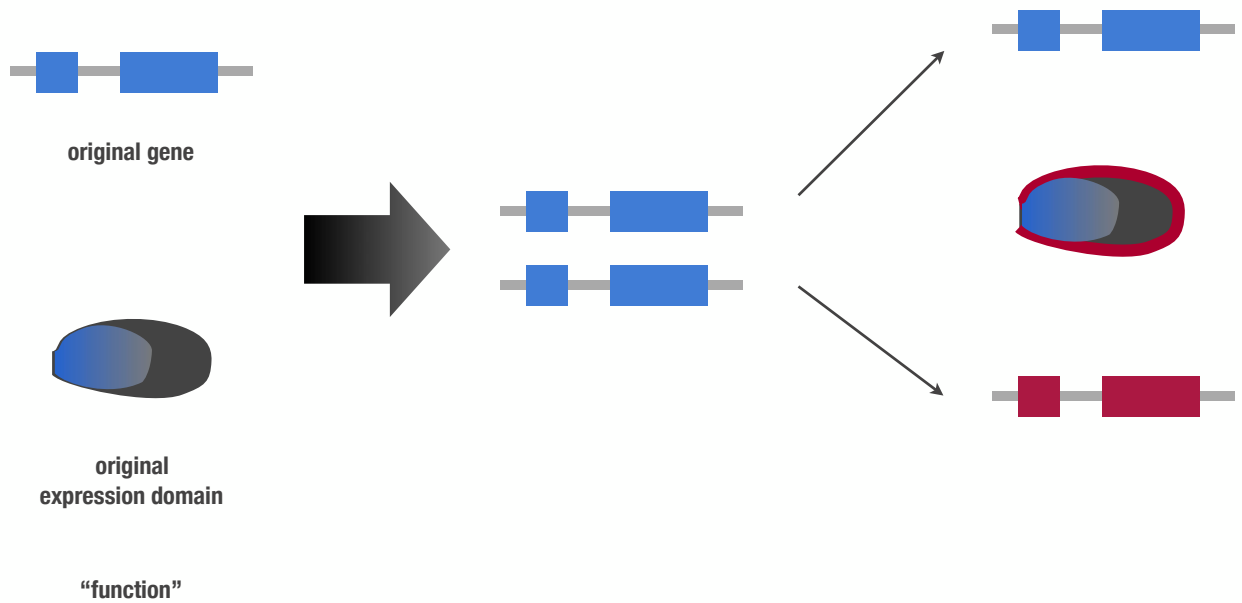
non-functionalization



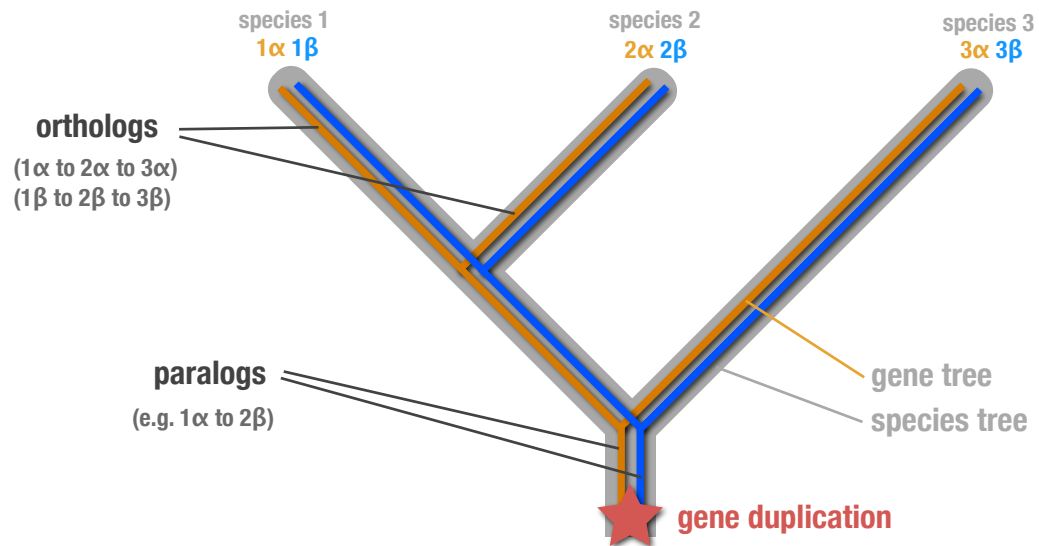
sub-functionalization

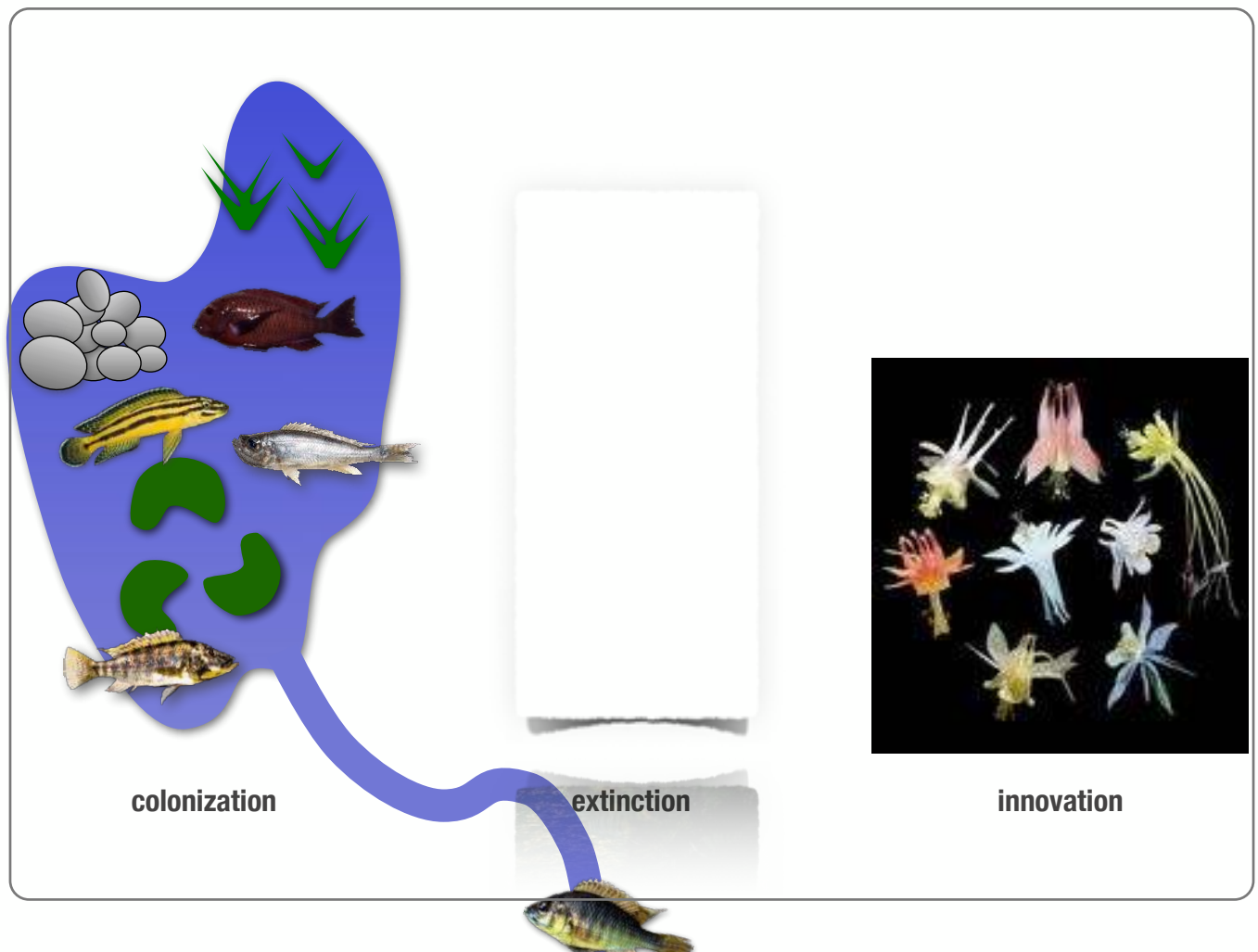


neo-functionalization



Caveats and pitfalls in phylogenetic inference: mixing paralogs with orthologs



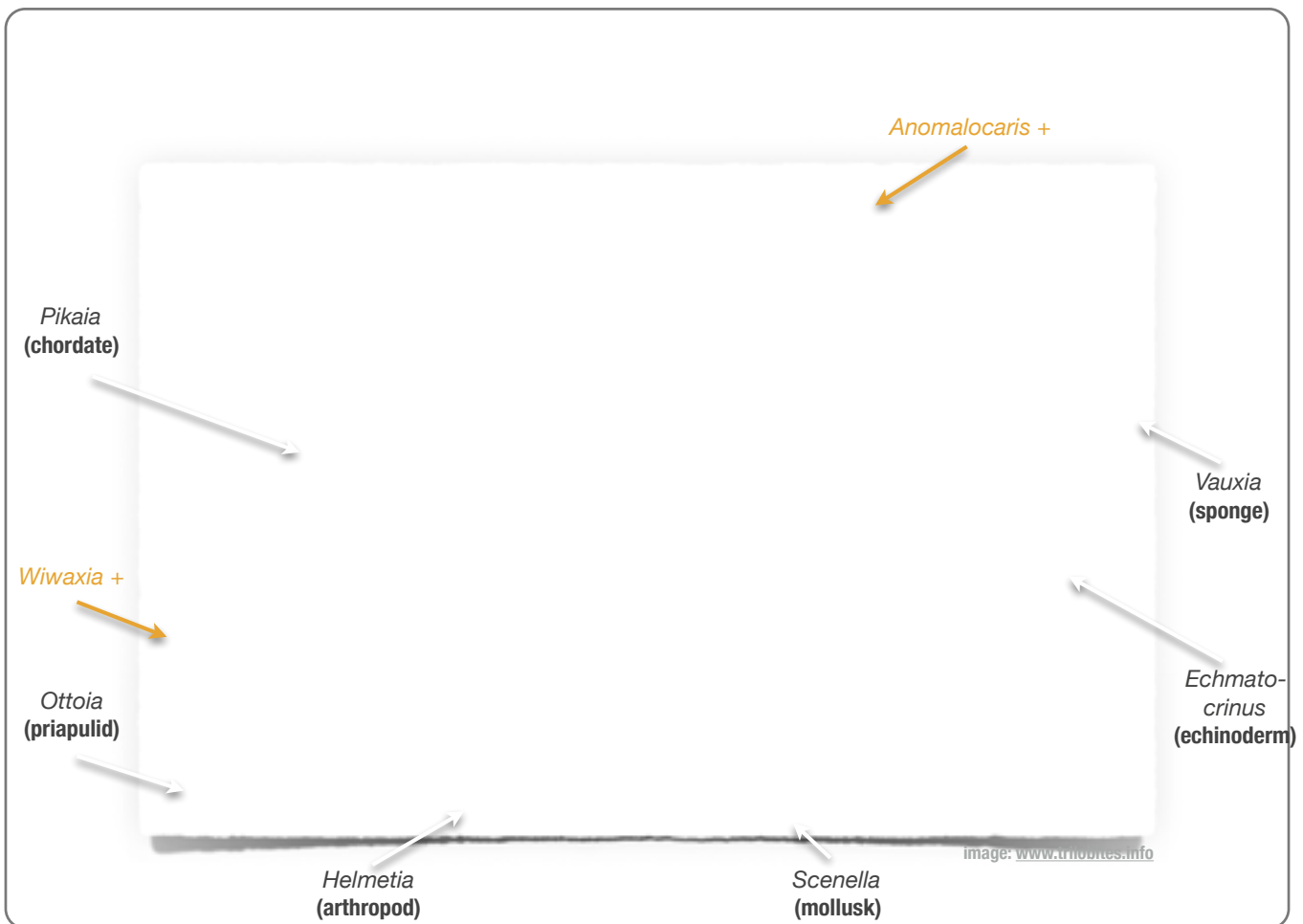


The 'Cambrian evolutionary radiation' most likely was an adaptive radiation.

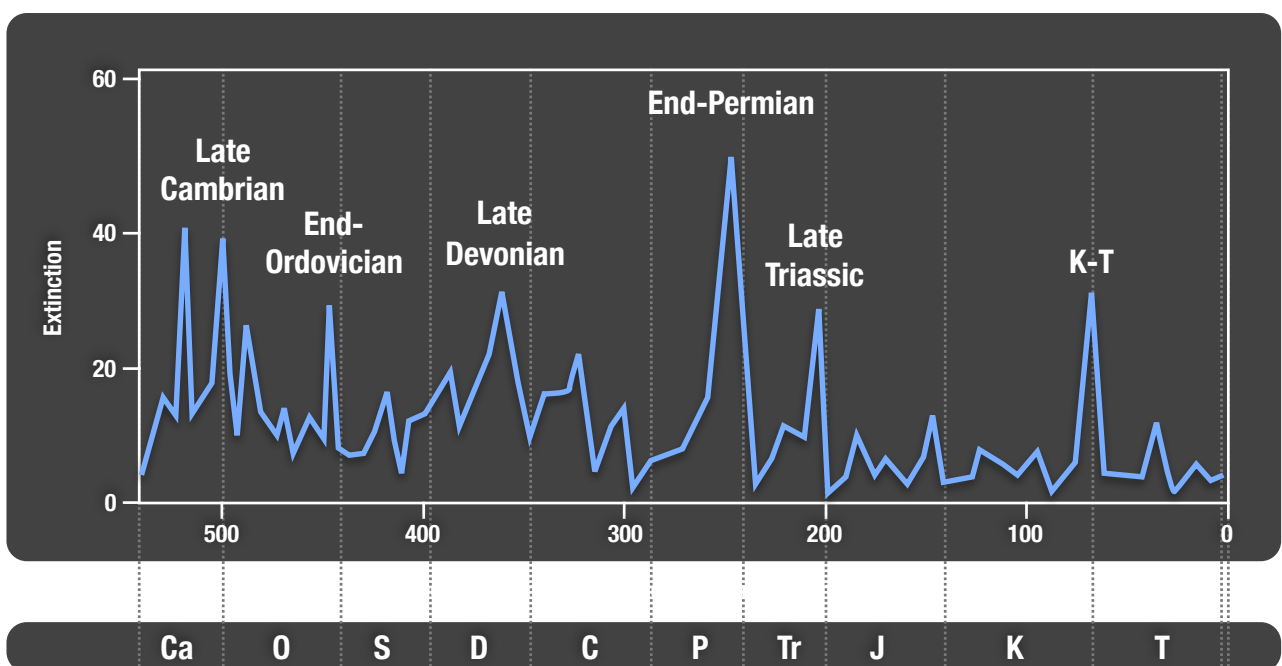


image: www.field.ca

trilobite

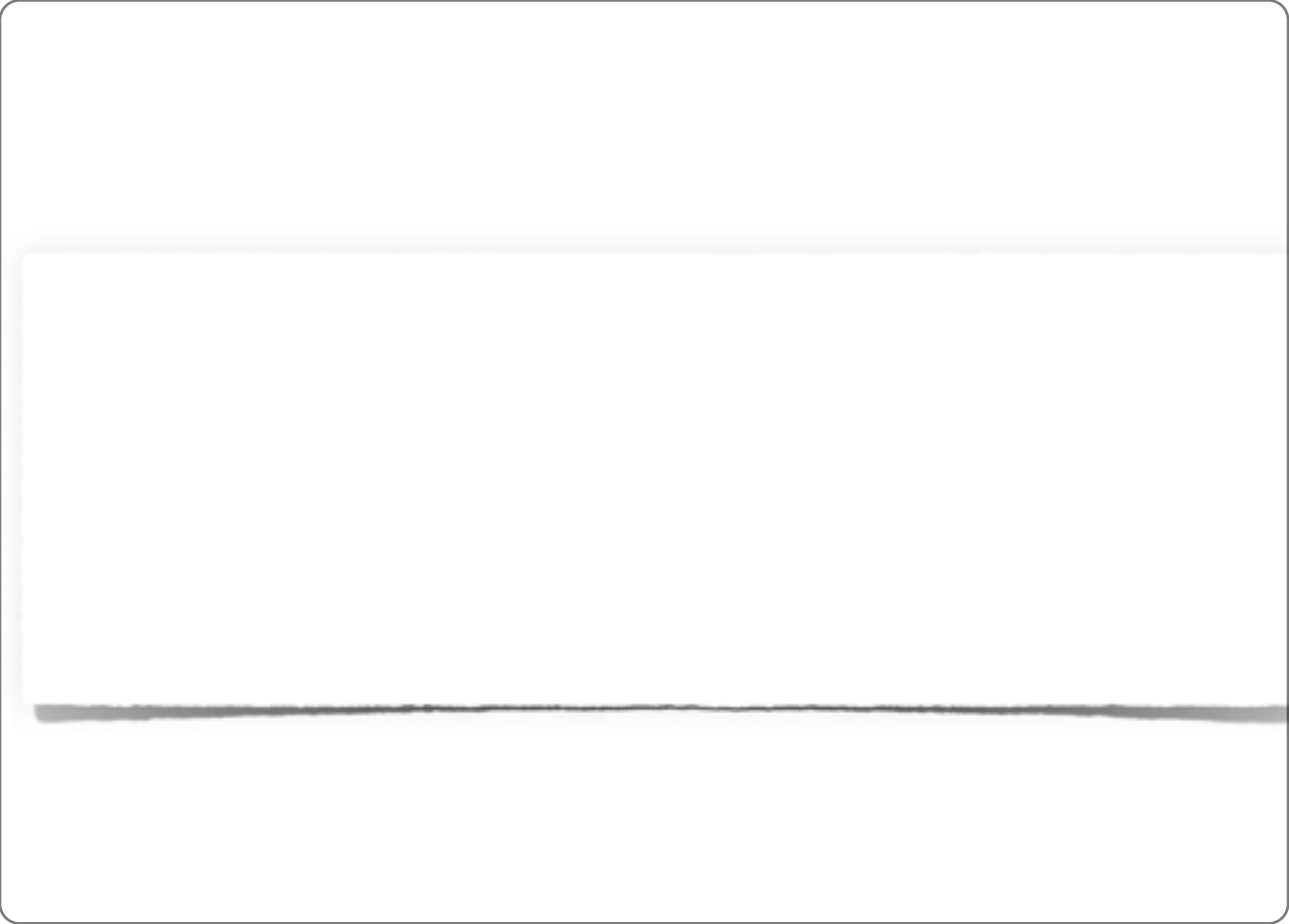


The 'big five' mass extinctions (based on marine fossils)

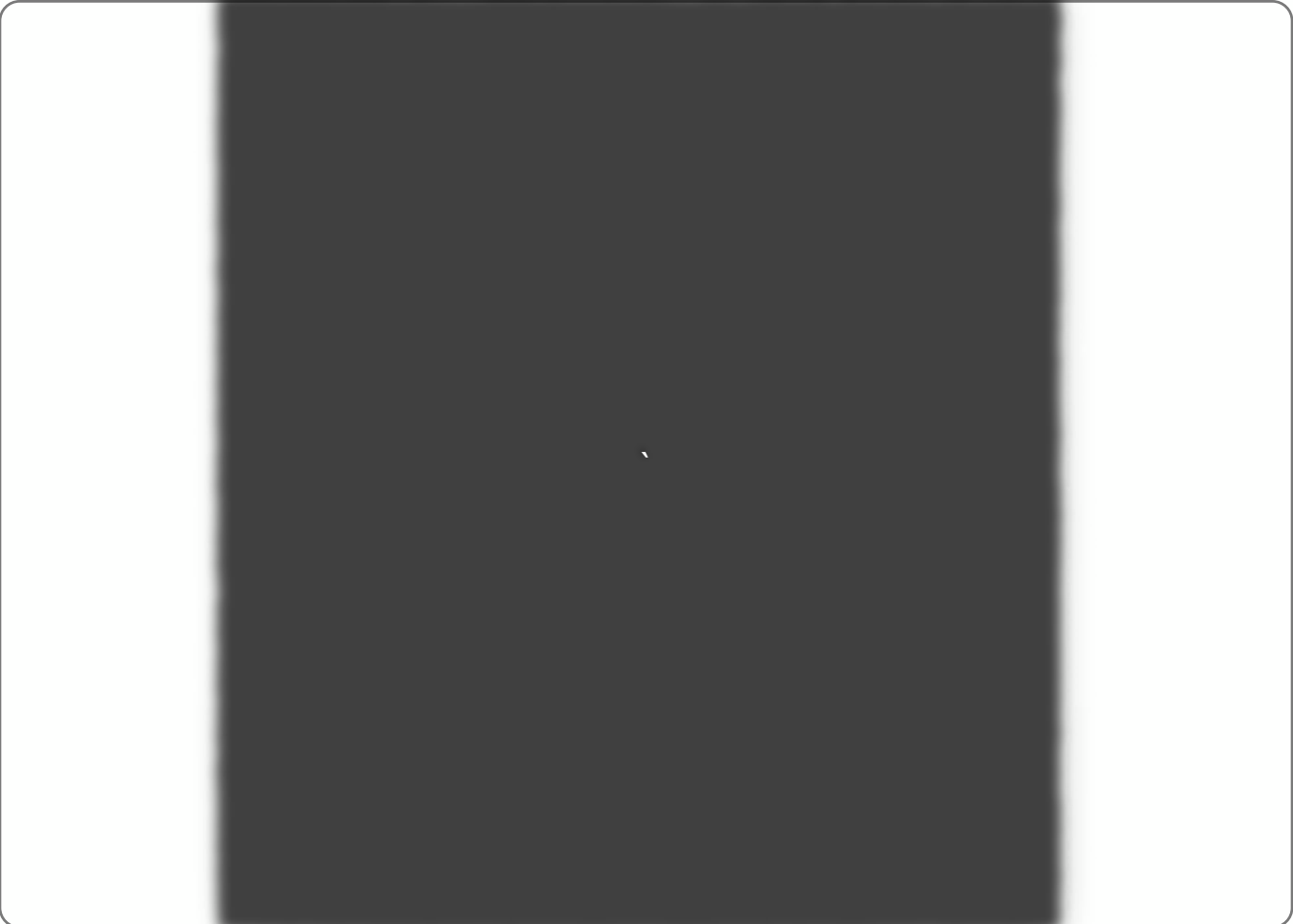


Radiating





••• R Reed et al. (2011) Science



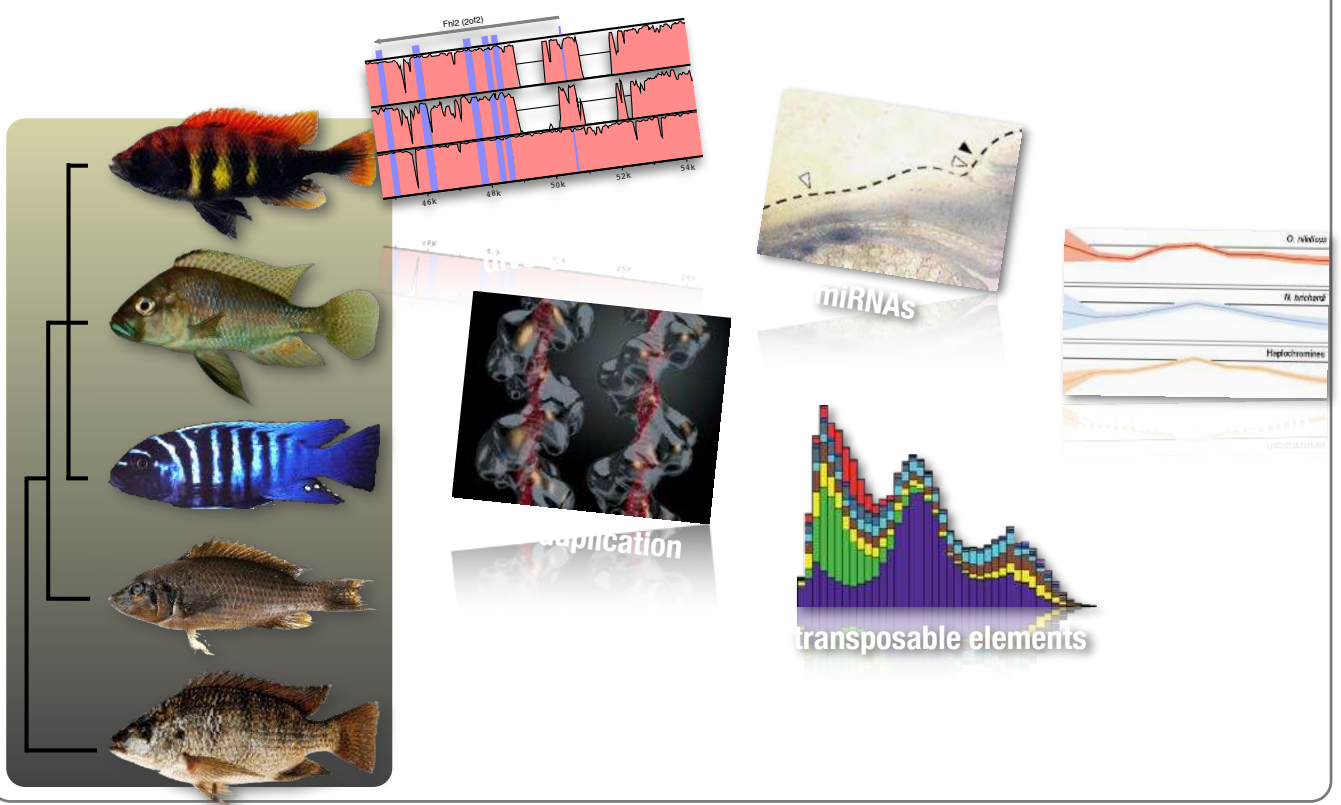
••• The Heliconius Genome Consortium (2012) Nature

... FC Jones et al. (2012) Nature

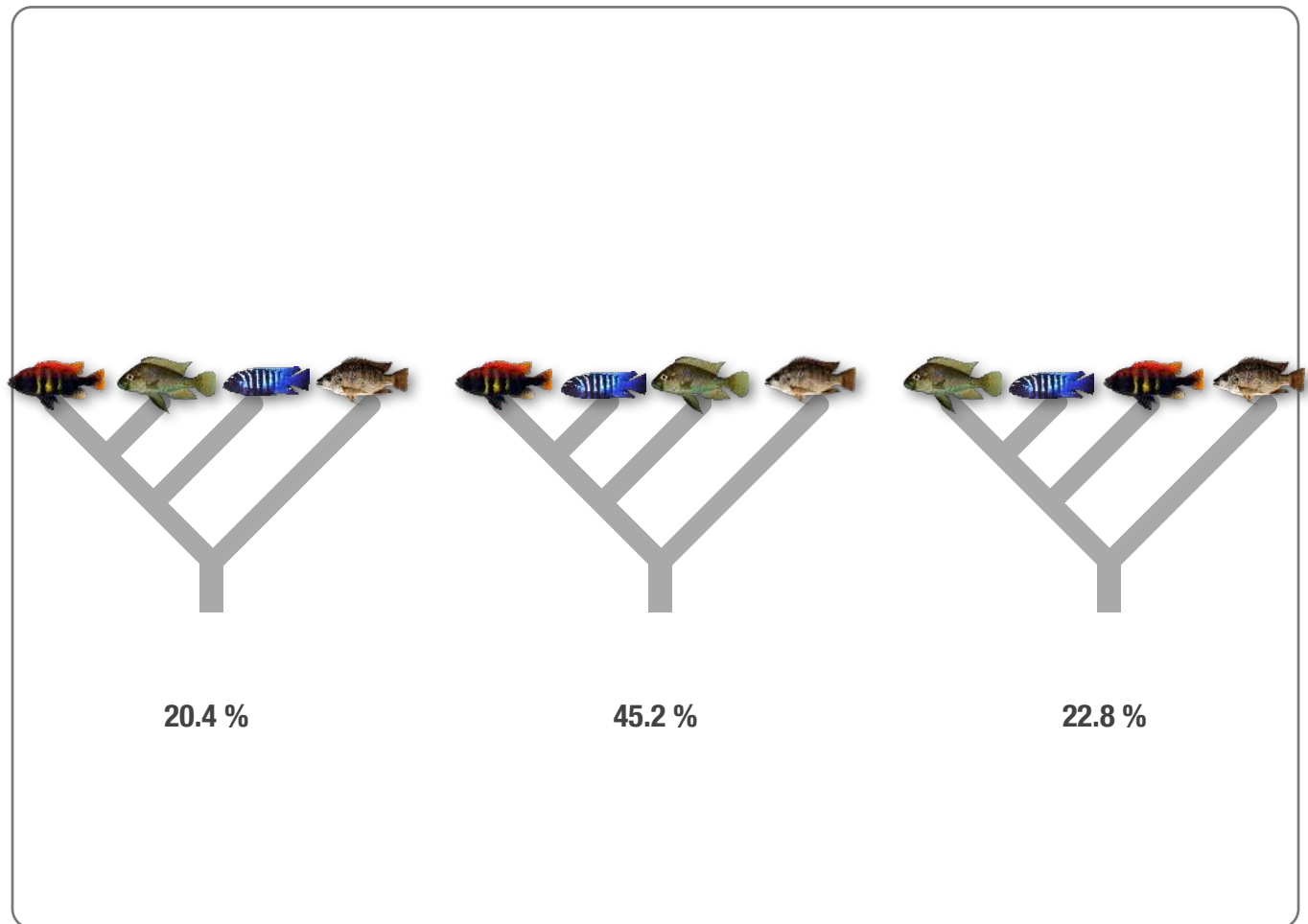
... S Lamichhaney et al. (2015) Nature



... S Lamichhaney et al. (2015) Nature



... D Brawand et al. (2014) Nature



••• D Brawand et al. (2014) Nature

	genomes	gene duplications	mobile elements	regulatory changes	accelerated coding evolution	miRNAs	inversions	hybridization introgression ILS
	1	n/r	YES	maybe	n/r	n/r	n/r	n/a
	5 (>100)	YES	YES	YES	YES	YES	n/r	YES
	1 (>100)	n/r	n/r	n/r	n/r	n/r	n/r	YES
	1 (>100)	n/r	YES	maybe	n/r	YES	n/r	YES
	1 (>100)	n/r	n/r	YES	n/r	n/r	YES	YES

••• D Berner & W Salzburger (2015) Trends in Genetics