

Forward-time Individual-based Simulations in Ecology and Evolution

Module 6: Genotype-phenotype map of complex traits

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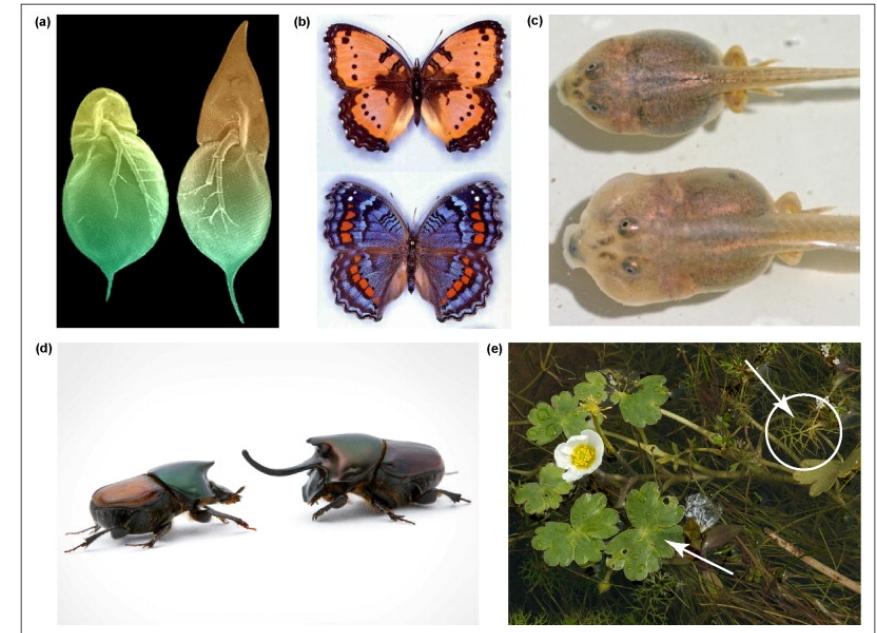
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Phenotypic plasticity

= environment-dependent phenotype expression

(a single genotype can express multiple phenotypes as response to environmental variation)

Phenotype expression can vary with
→ abiotic environment
→ resource availability
→ presence or absence of predators
→ ...

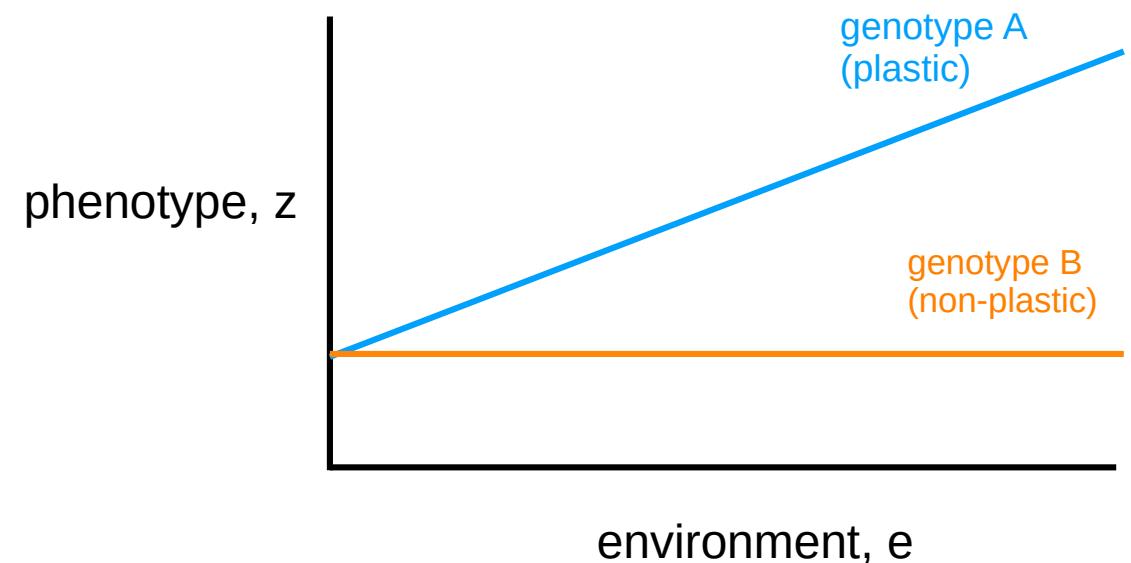


Pfennig et al. (2010), TREE, 25: 459-467

Phenotypic plasticity

= best illustrated by a *reaction norm*

A reaction norm plots
the expressed phenotypes
of a single genotype
across a range of environments



Phenotypic plasticity

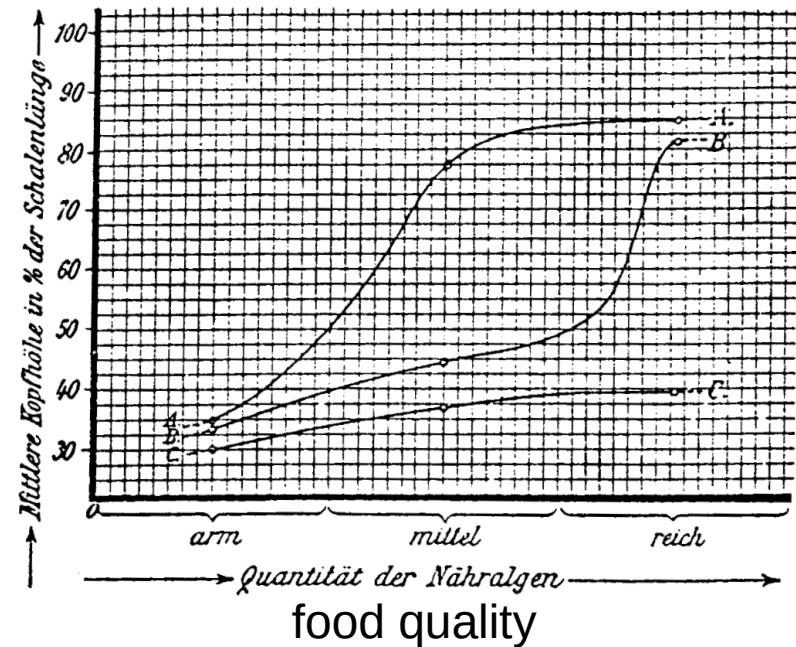
= best illustrated by a reaction norm

→ an old concept !



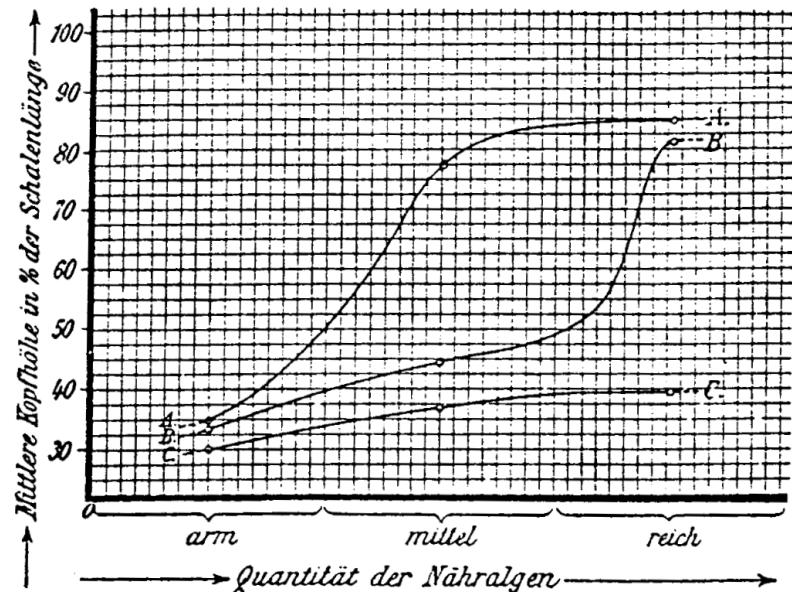
Head height in Daphnia

*“The genotype of a quantitative trait
is its inherited reaction norm”* (Woltareck 1909)



Phenotypic plasticity

- = best illustrated by a *reaction norm*
- an old concept !
- initially mostly ignored in Europe and N. America
- an important conceptual tool in Soviet Union
- „rediscovered“ after WW II in the „west“



Phenotypic plasticity

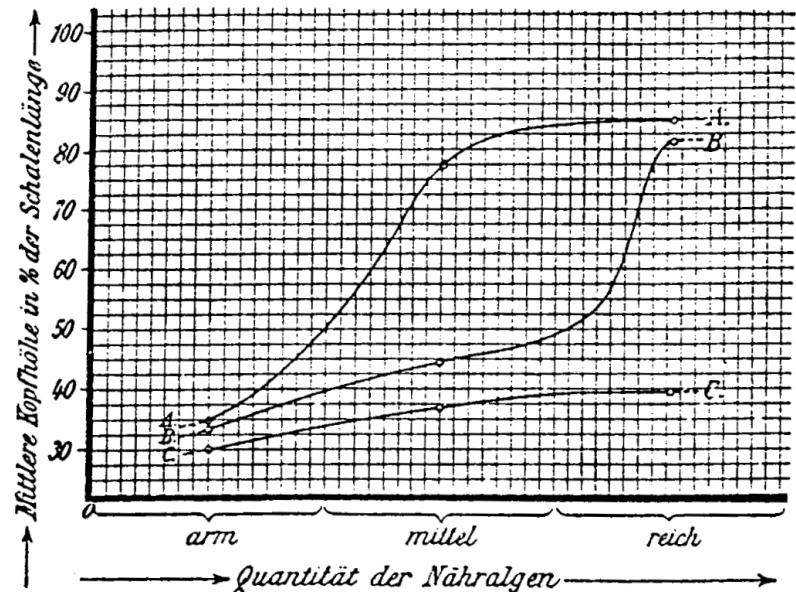
= best illustrated by a reaction norm

„The ability of a genotype to change its phenotype was once considered rather a nuisance - making it difficult to define a genotype.“

(Bradshaw 2006, New Phytologist 170: 644-648)

↓
„How populations and species respond to modified environmental conditions is critical to their persistence“

(Fox et al. 2019, Phil. Trans. R. Soc. B 374: 20180174)



Kinds of plasticity

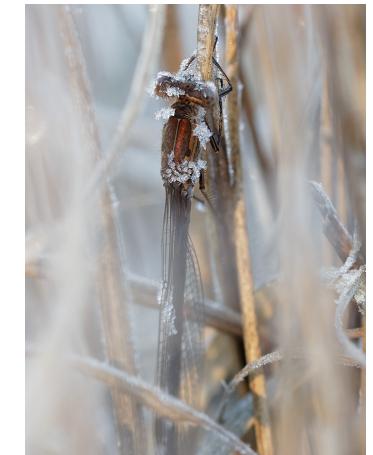
active response

„active plastic responses require a specific signal perception-transduction system allowing plants to respond by changing their development.“



passive response

„Many phenotypic responses to environmental stress, however, may be the consequence of passive reductions in growth due to resource limitation“



Kinds of plasticity

labile plasticity

„Physiological and behavioural characters typically display reversible development producing labile phenotypes that change continually during an individual lifetime“



developmental plasticity

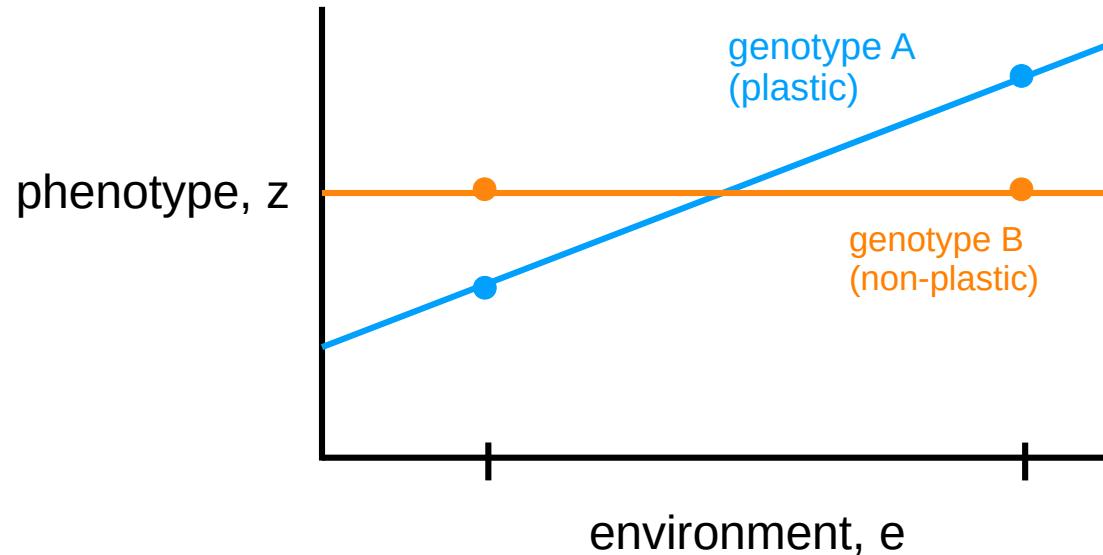
„During a brief critical stage of early development, the environment experienced by an individual influences its subsequent development. ...

(also called fixed or one-shot plasticity)

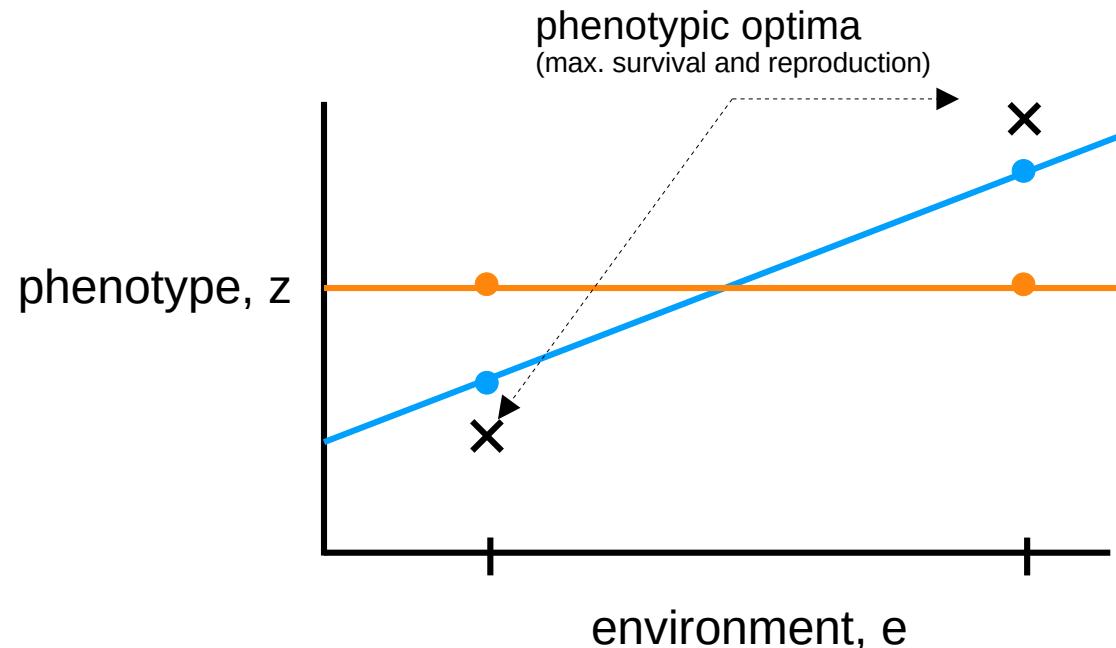


Lande (2015) Molecular Ecology 24: 2038-2045

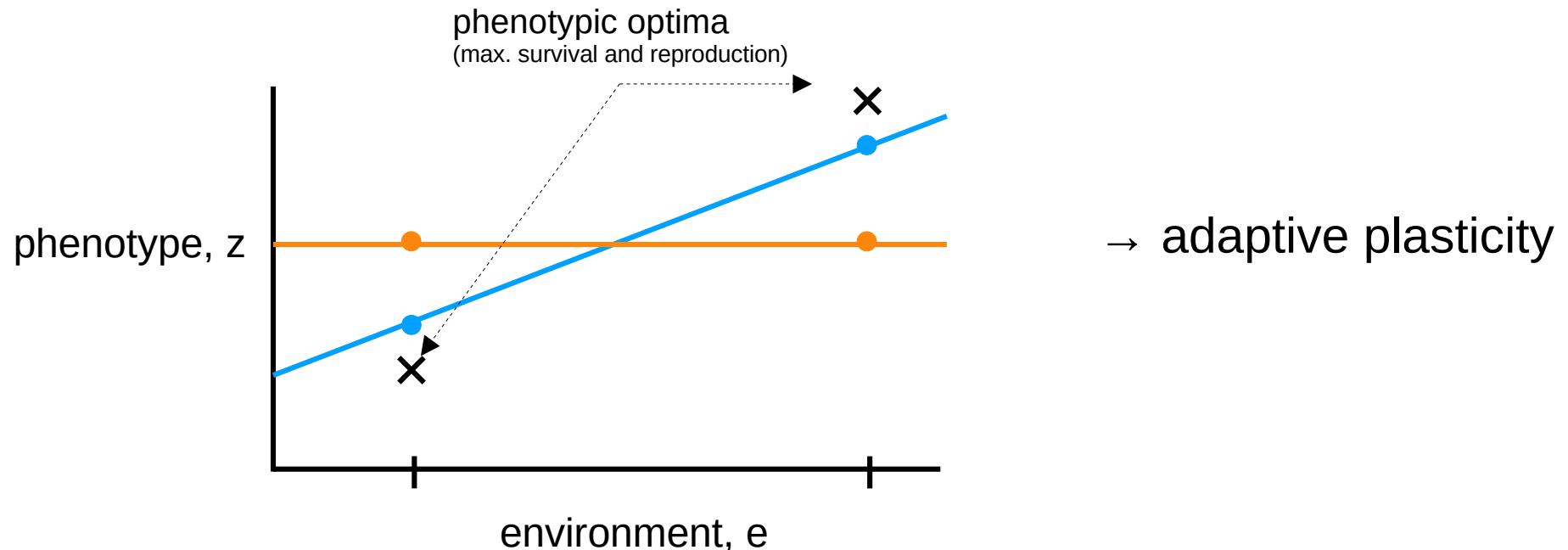
Fitness consequences of plasticity



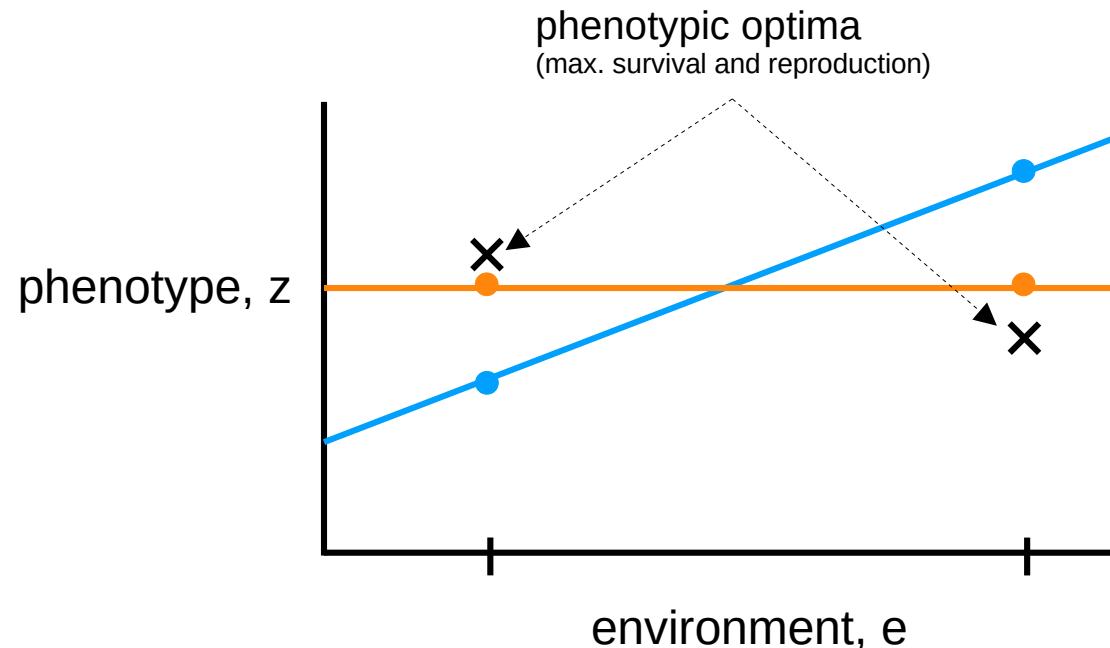
Fitness consequences of plasticity



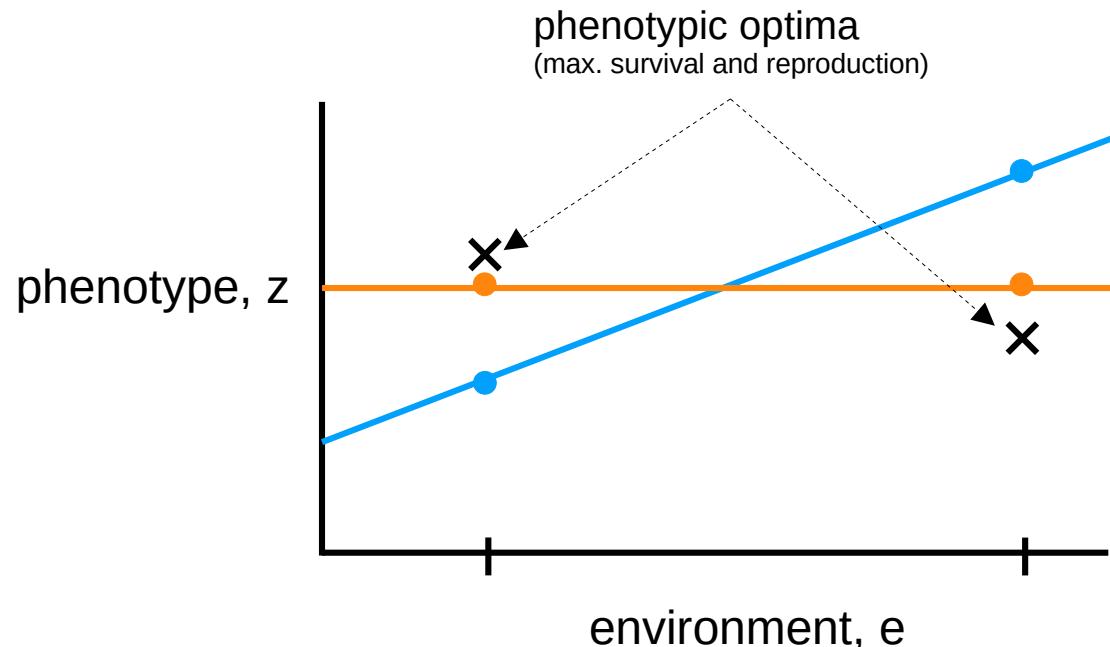
Fitness consequences of plasticity



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Fitness consequences of plasticity

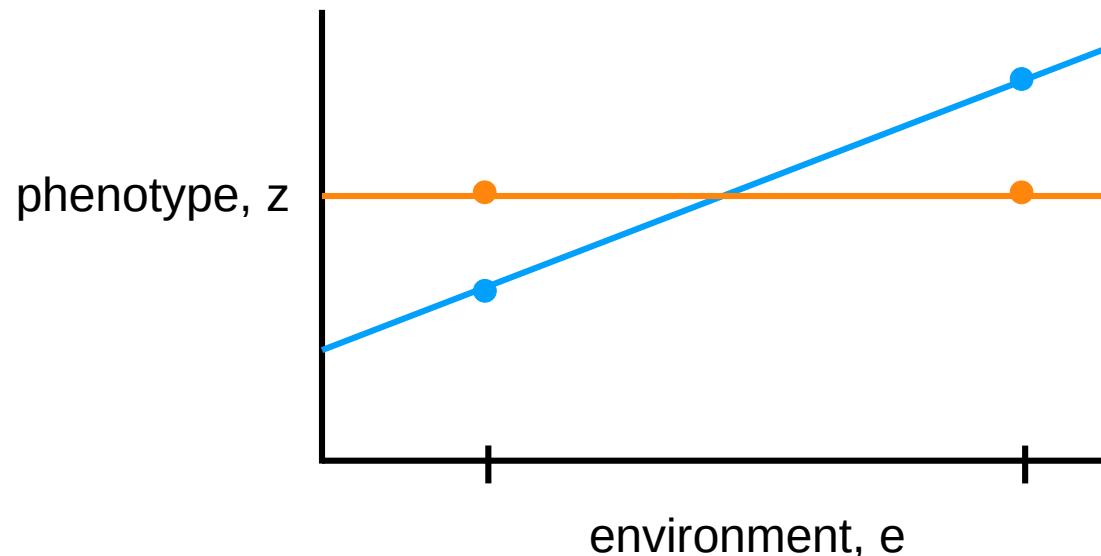


→ **maladaptive plasticity**

often:

- passive (unavoidable) response
- in novel environments
- arises from genetic correlations

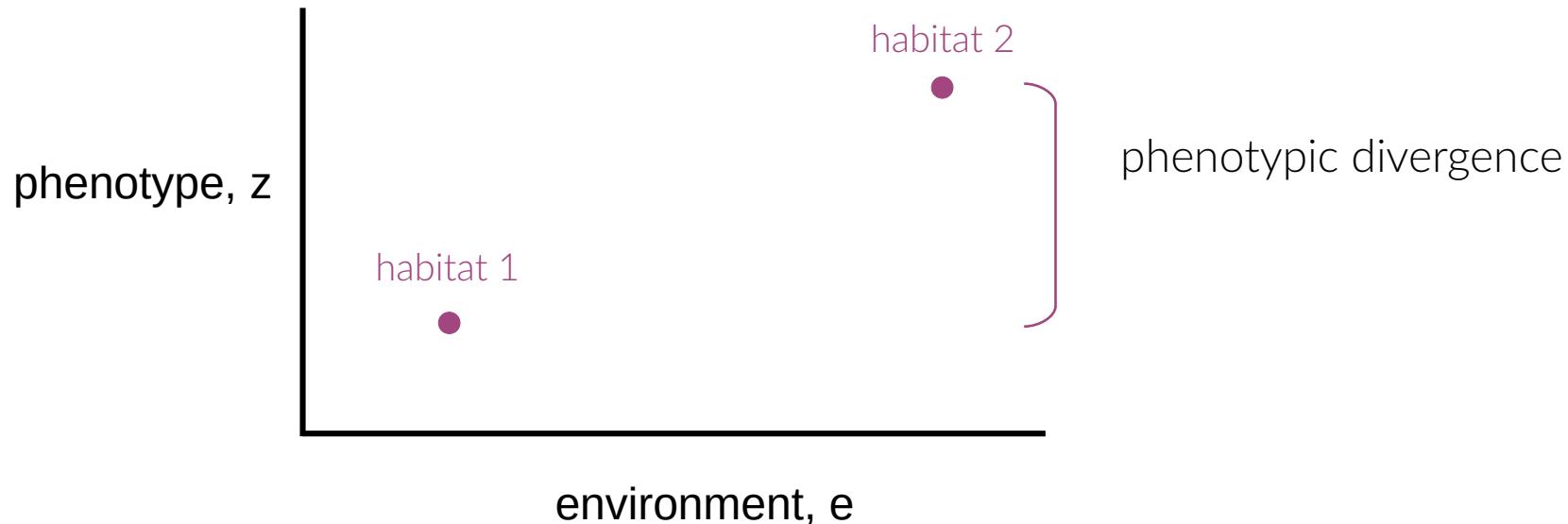
Fitness consequences of plasticity



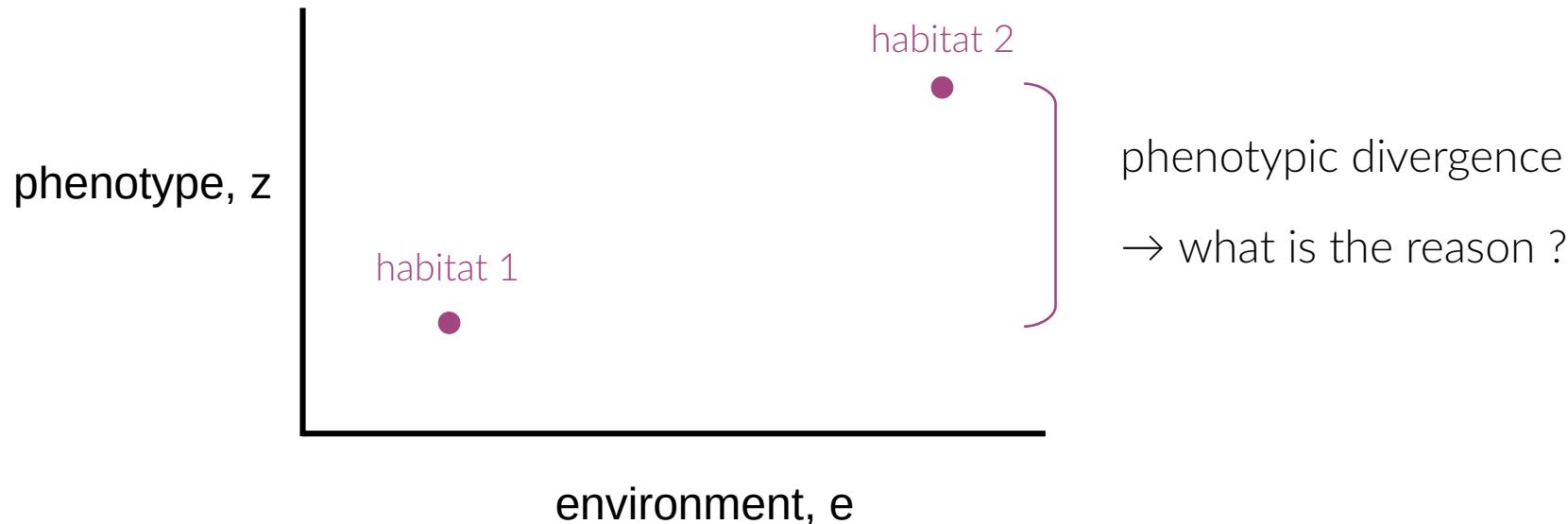
→ neutral
(non-adaptive)

No selection
→ no phenotypic optima

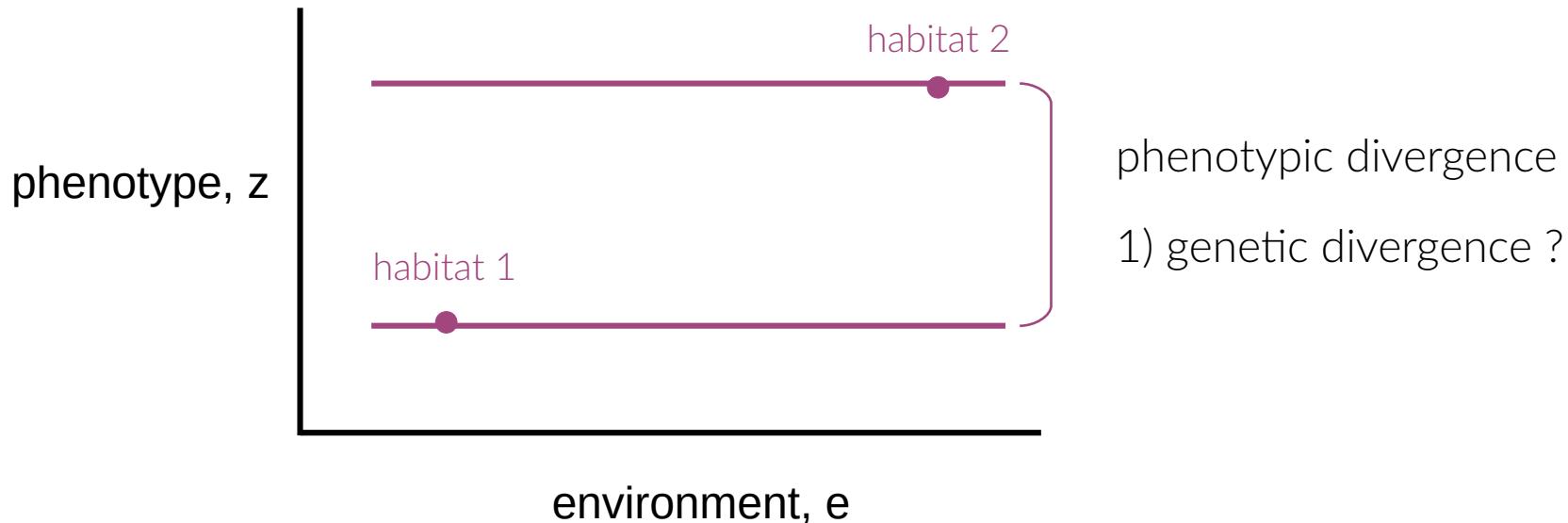
Plasticity: A “problem” for biologists



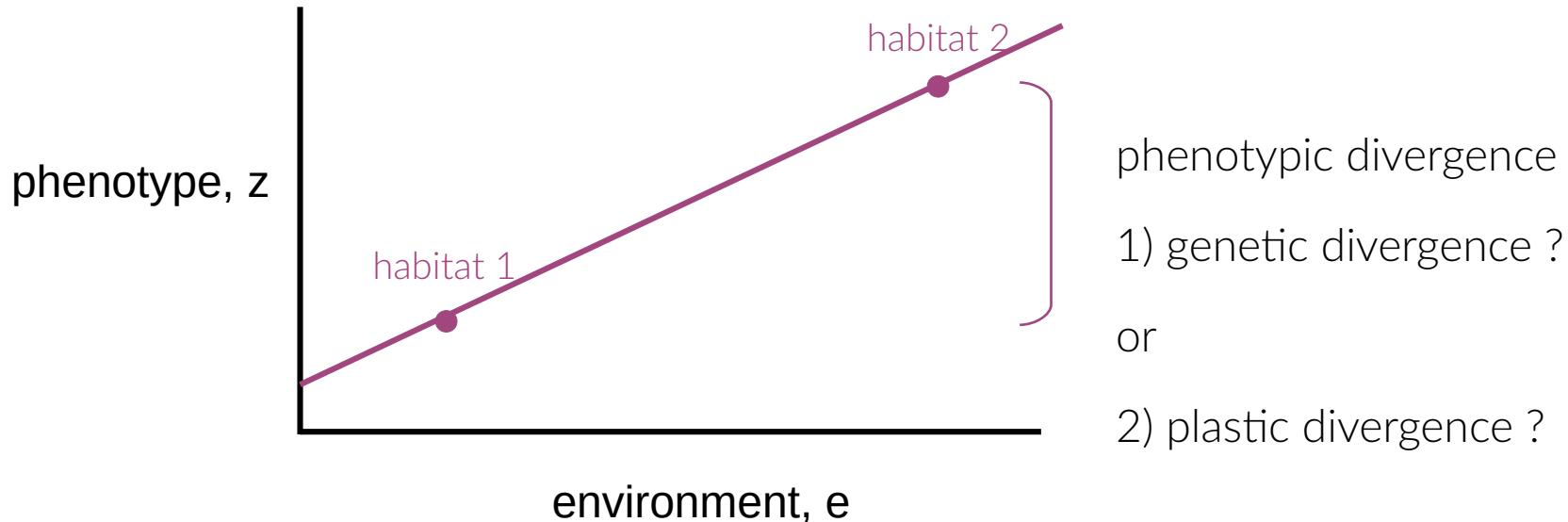
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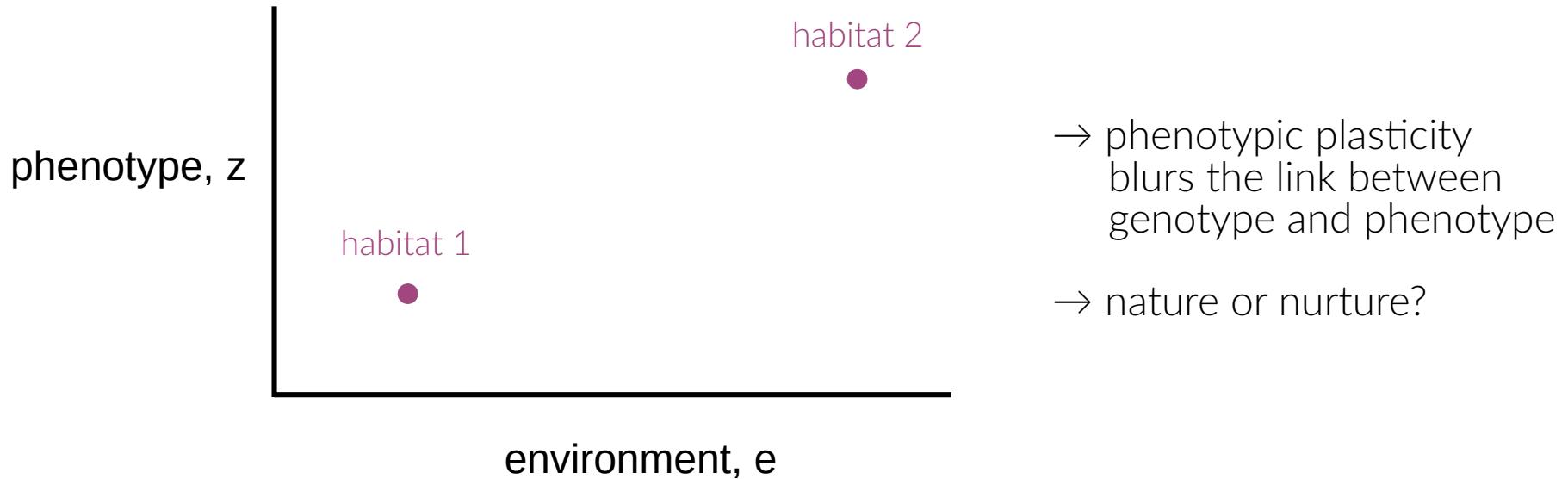
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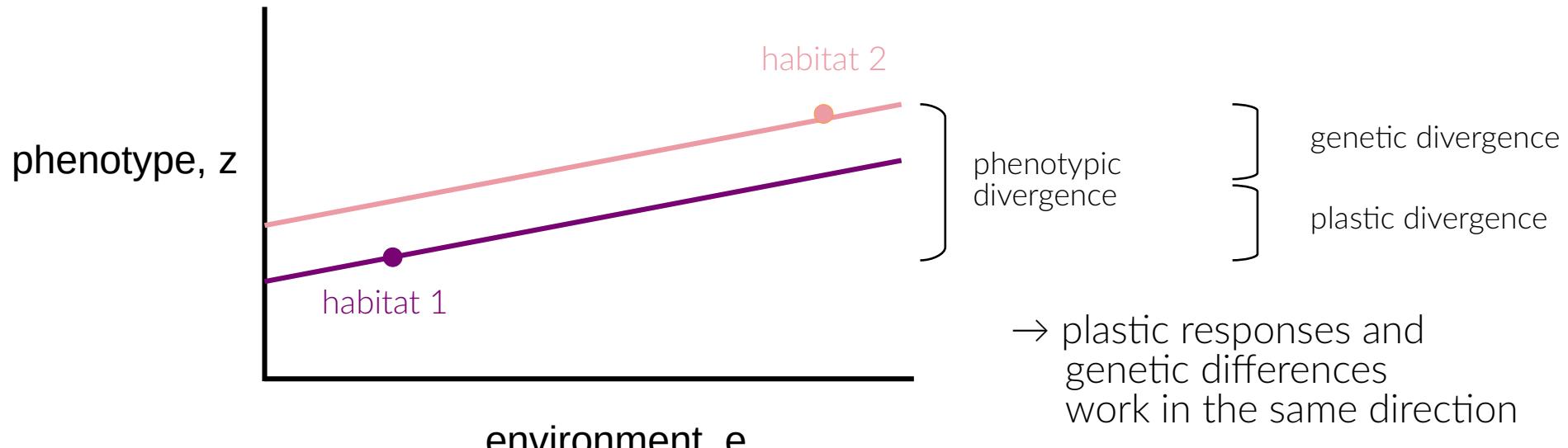


Plasticity: A “problem” for biologists



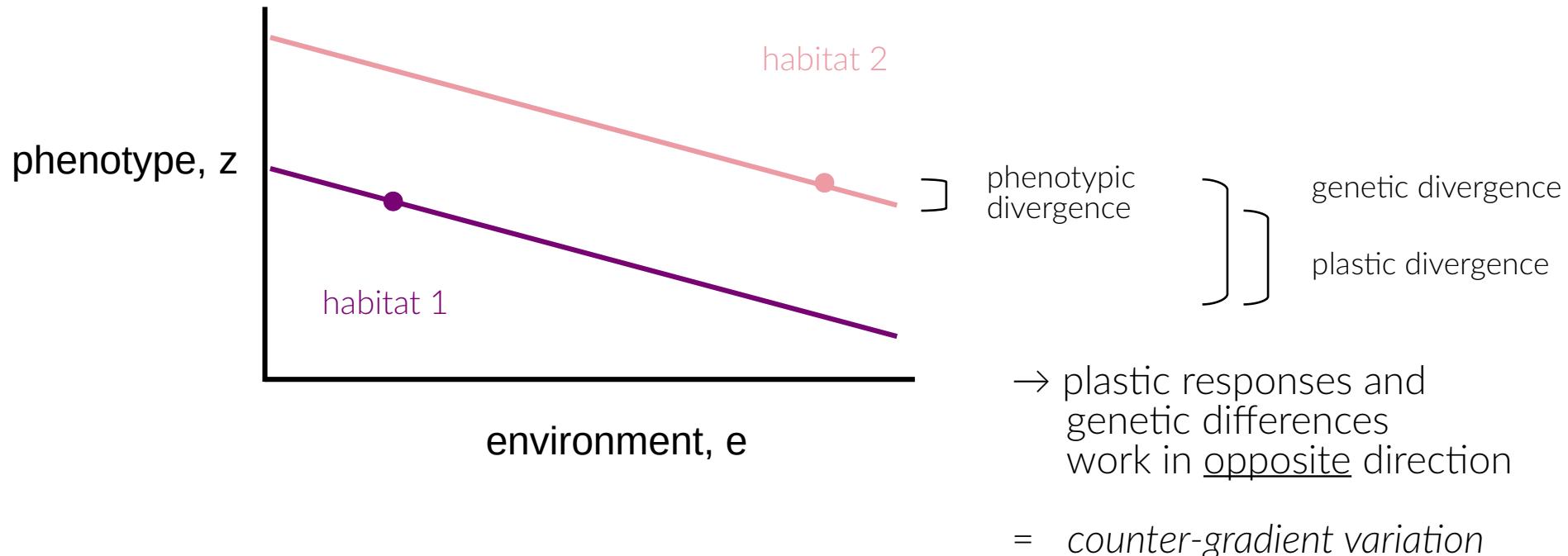
Plasticity: A “problem” for biologists

→ most often, they shape phenotype expression in concert

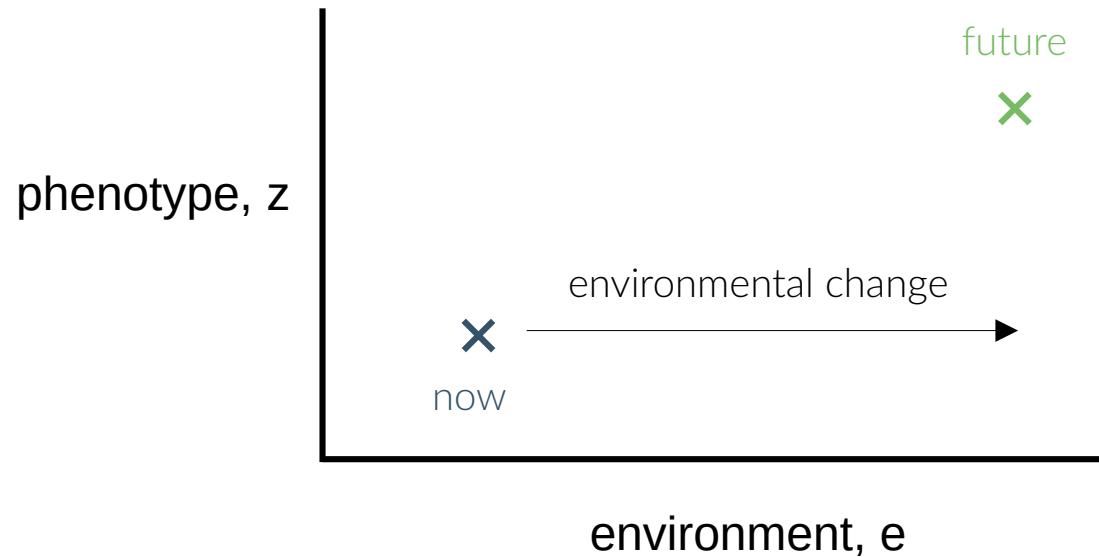


Plasticity: A “problem” for biologists

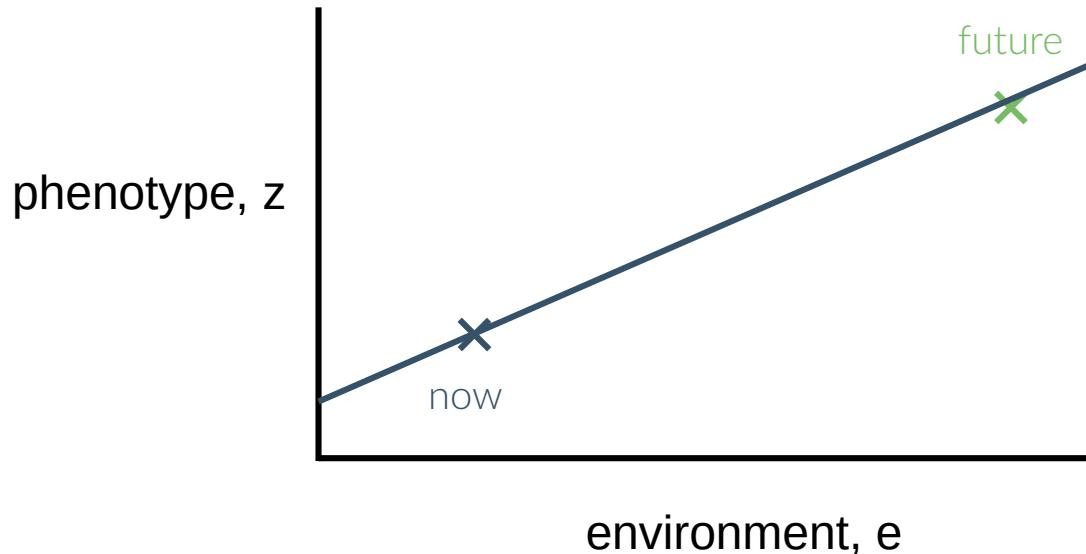
→ most often, they shape phenotype expression in concert



Plasticity feeds back on genetic evolution



Plasticity feeds back on genetic evolution



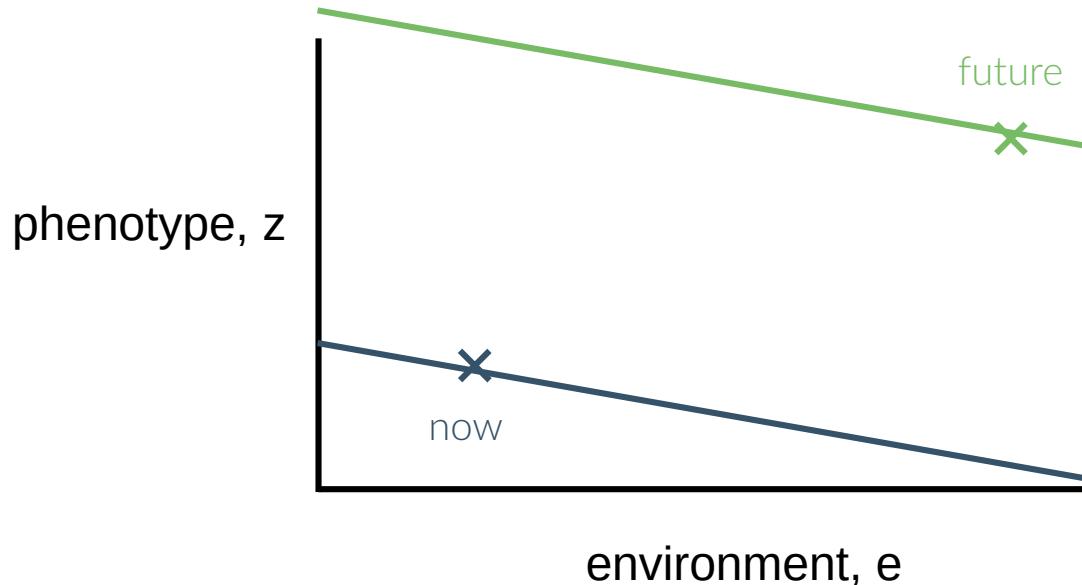
With (perfectly) adaptive plasticity
genetic change is redundant.

→ adaptive plasticity limits genetic
adaptations

→ because they are alternative
solutions to the same problem

Plasticity feeds back on genetic evolution

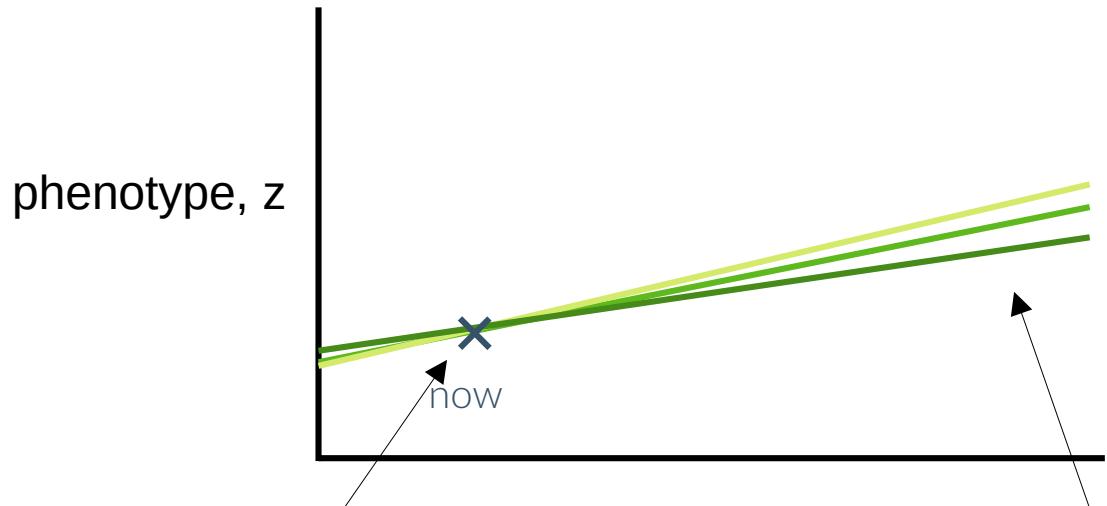
→ because they are alternative solutions to the same problem



With maladaptive plasticity
large genetic changes are
necessary to adapt

→ genetic compensation

Phenotypic plasticity can evolve



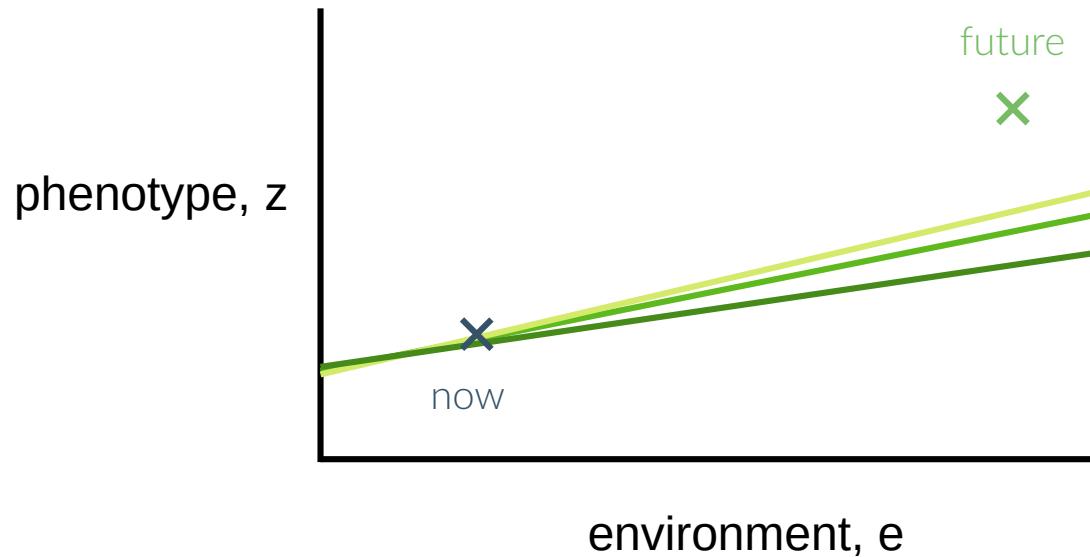
Small phenotypic variance in
mean environment (*canalization*)
from stabilizing selection

... but large (*cryptic*) variation
under novel conditions

Genetic variance in plasticity
(GxE interaction)

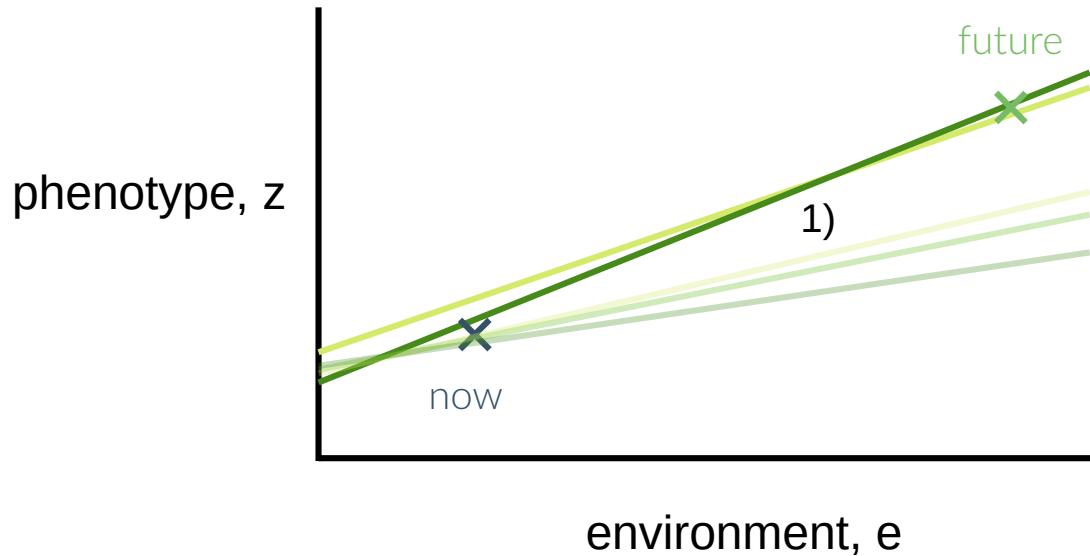
= precondition for evolution of
plasticity

Phenotypic plasticity can evolve



Plasticity evolution occurs in 2 steps:

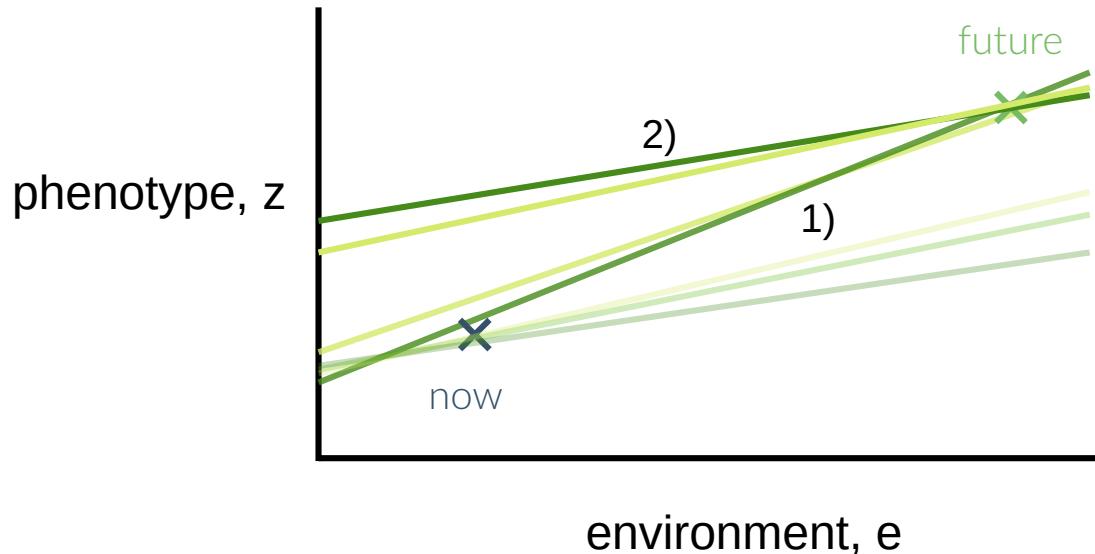
Phenotypic plasticity can evolve



Plasticity evolution occurs in 2 steps:

- 1) evolution of larger plasticity

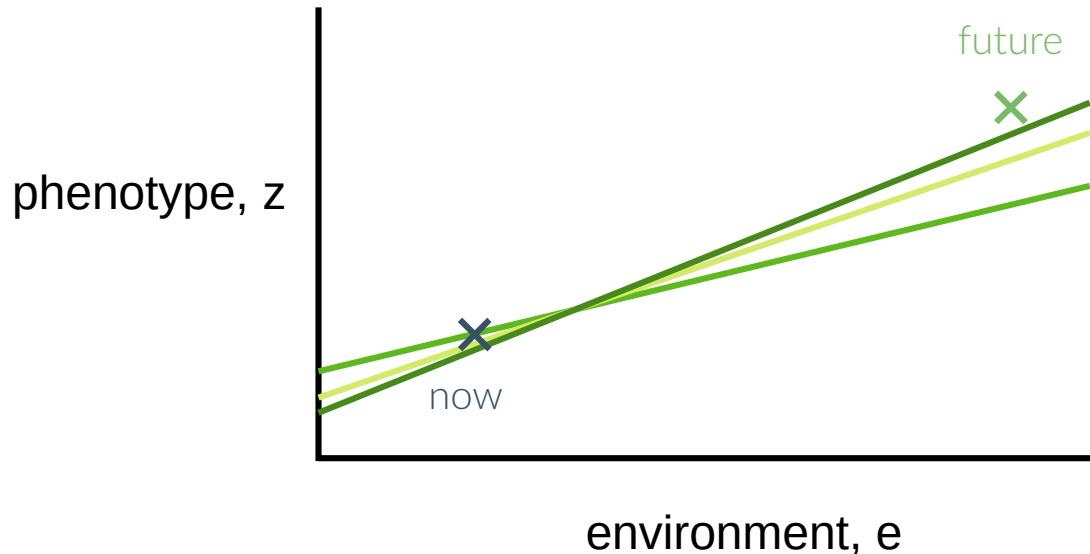
Phenotypic plasticity can evolve



Plasticity evolution occurs in 2 steps:

- 1) evolution of larger plasticity
- 2) genetic assimilation
(return to smaller plasticity)

Phenotypic plasticity can evolve

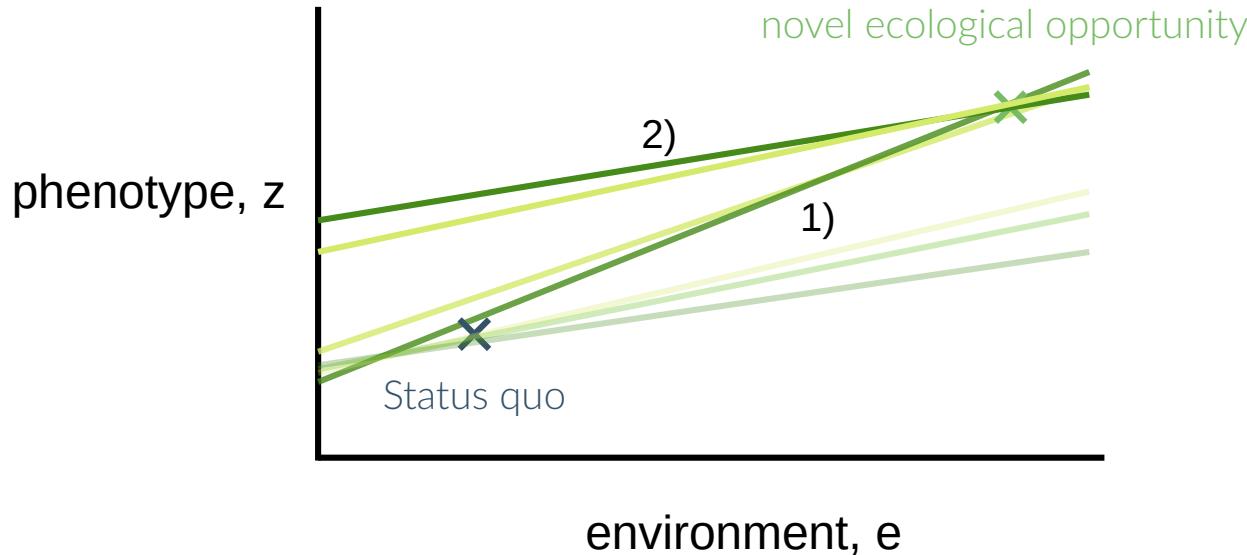


But ...

plasticity rarely evolves
to be perfect
because of

- costs of plasticity
- limited cue reliability
- time lag in phenotypic response
- ...

Phenotypic plasticity can evolve



→ Plasticity might benefit genetic diversity and speciation

"genes are probably more often followers than leaders in evolutionary change"

(Mary Jane West-Eberhard)

Exercise

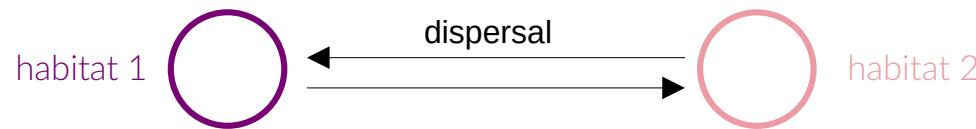
Exercise: The evolution of local adaptation in face of phenotypic plasticity

Largely following
Schmid & Guillaume (2017), Heredity 119: 214–225

You could also check out a shiny app:

<https://maxschmid.shinyapps.io/plasticityandpopulationdifferentiation/>

Exercise: The evolution of local adaptation in face of phenotypic plasticity



A single species

2 patches

dispersal between patches

Patches differ in environmental factor

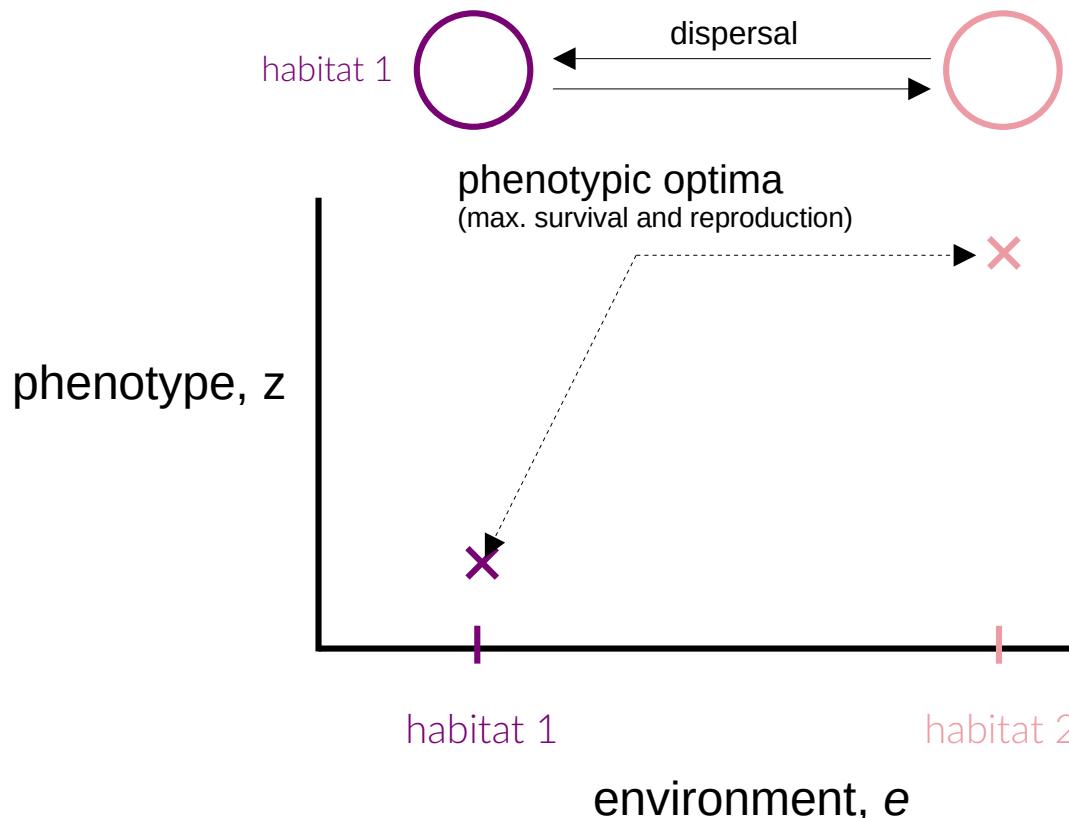


habitat 1

habitat 2

environment, e

Exercise: The evolution of local adaptation in face of phenotypic plasticity



A single species

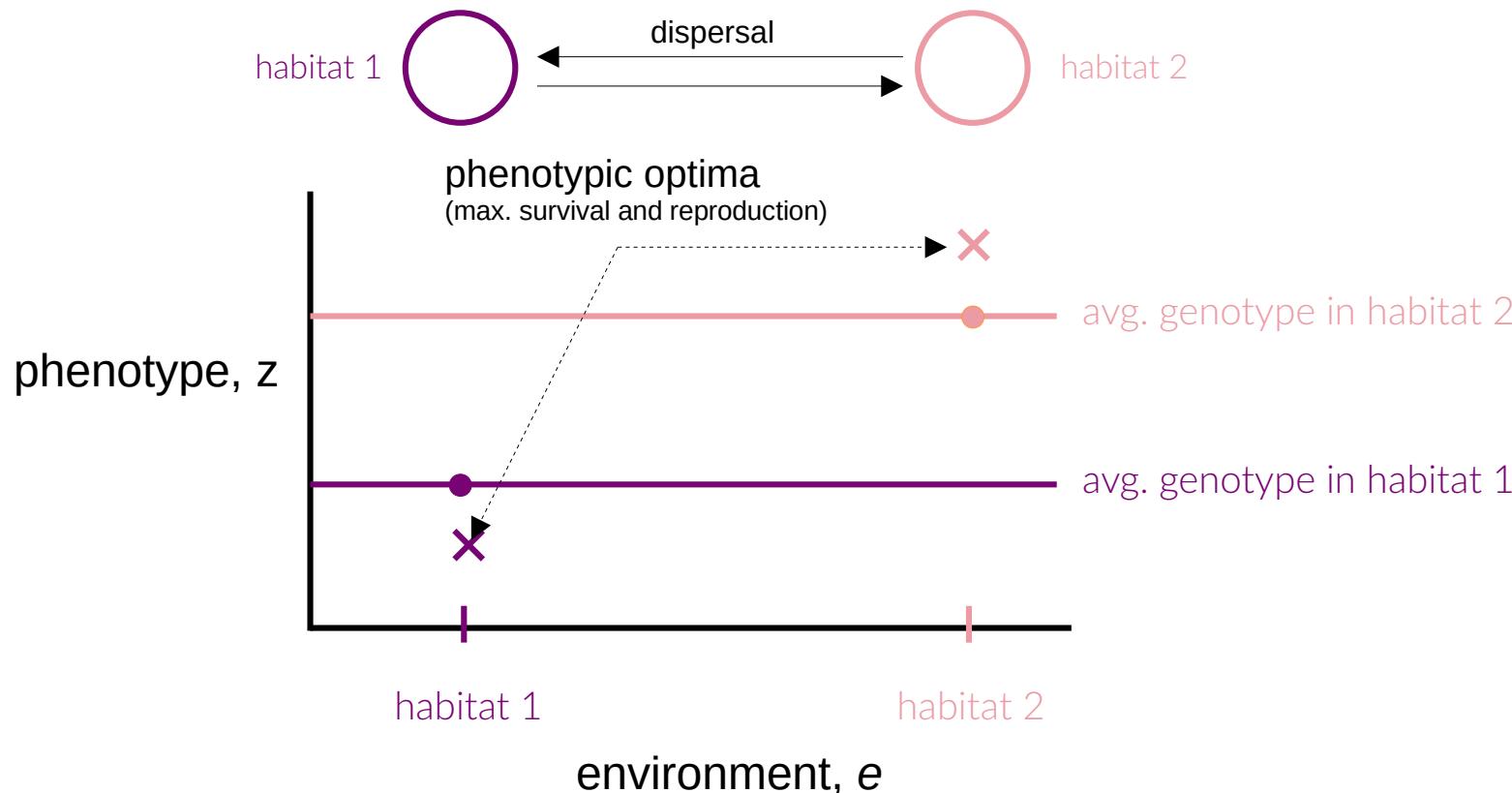
2 patches

dispersal between patches

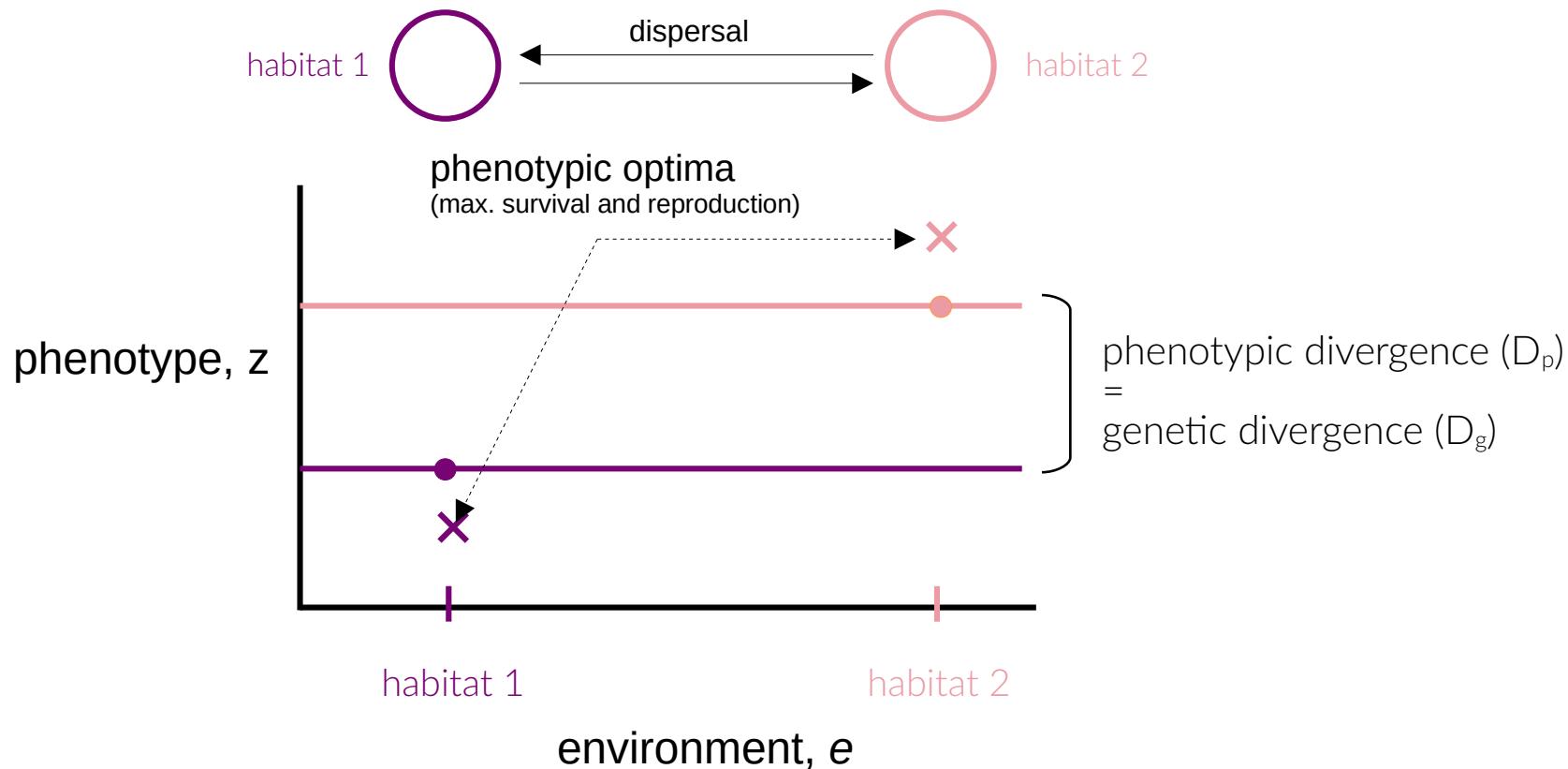
Patches differ in environmental factor

→ divergent selection
(favoring phenotypic divergence)

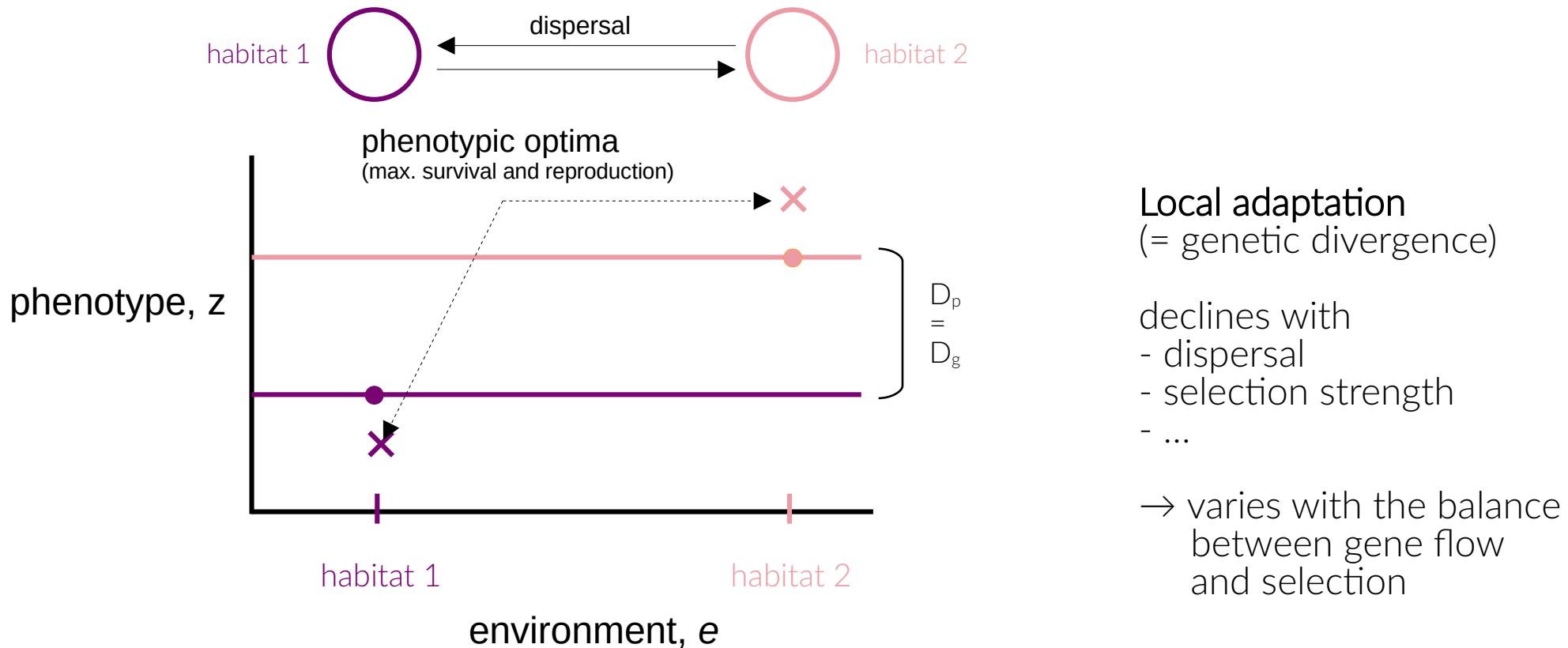
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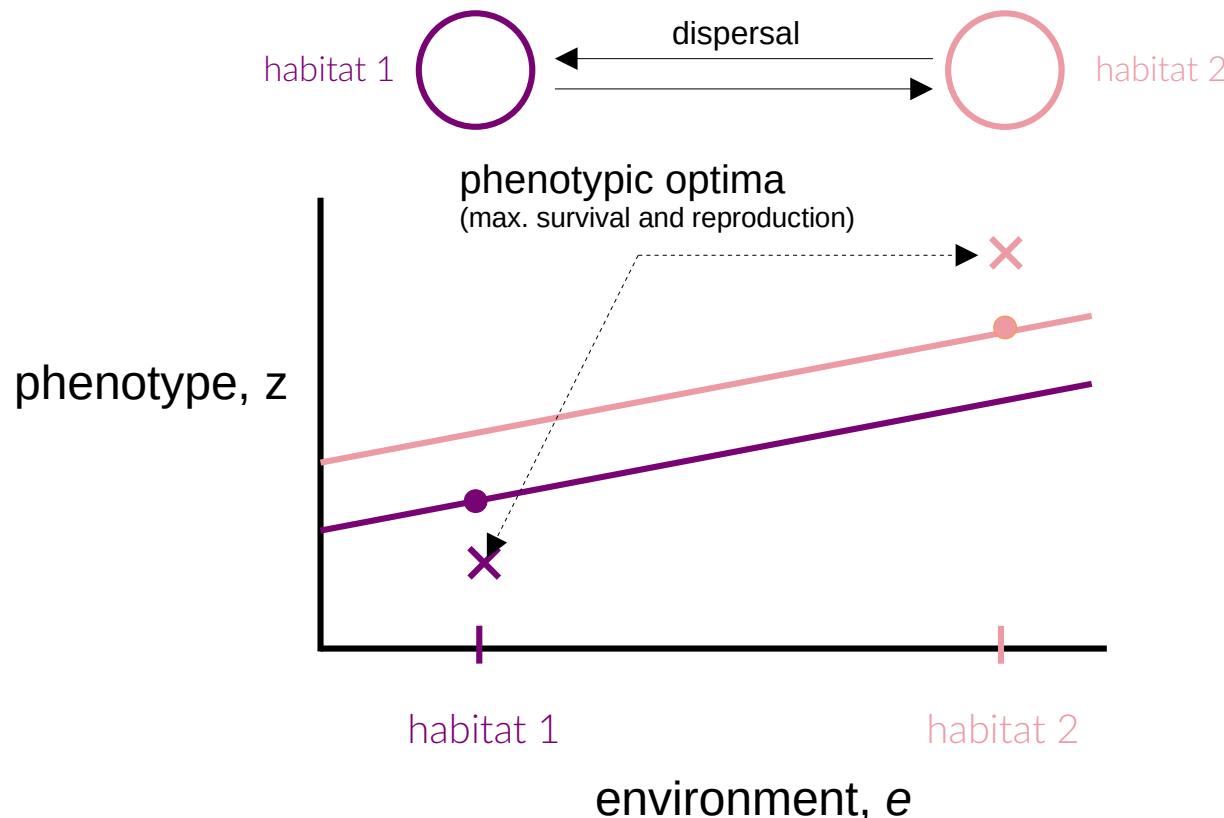
Exercise: The evolution of local adaptation in face of phenotypic plasticity



Exercise: The evolution of local adaptation in face of phenotypic plasticity



Exercise: The evolution of local adaptation in face of phenotypic plasticity



→ What is the effect of phenotypic plasticity?

Exercise: The evolution of local adaptation in face of phenotypic plasticity

1. Read exercise file *(Exercise_Phenotypic_plasticity.pdf)*
2. copy/compile new nemo-age version *(nemoage0.32.1)*
3. run the ini-file with new nemo-age *(Exercise_Phenotypic_plasticity.ini)*
4. use the R script to plot *(Exercise_Phenotypic_plasticity.R)*
5. explore the exercises