Intraspecific variation in a DEB framework

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University of Crete, Heraklion, Greece

deb2025.sciencesconf.org

A domestic dog

wirestock/freepik C0

An Atlantic salmon

© Anna Löf

A wall lizard

Javier Abalos/flickr CC BY-SA 2.0
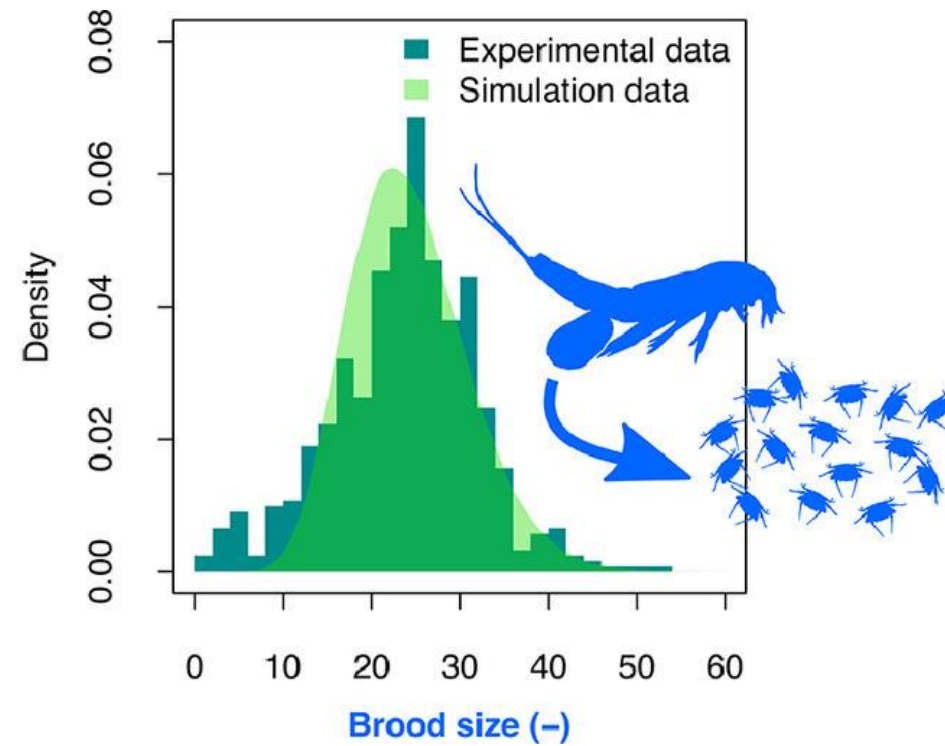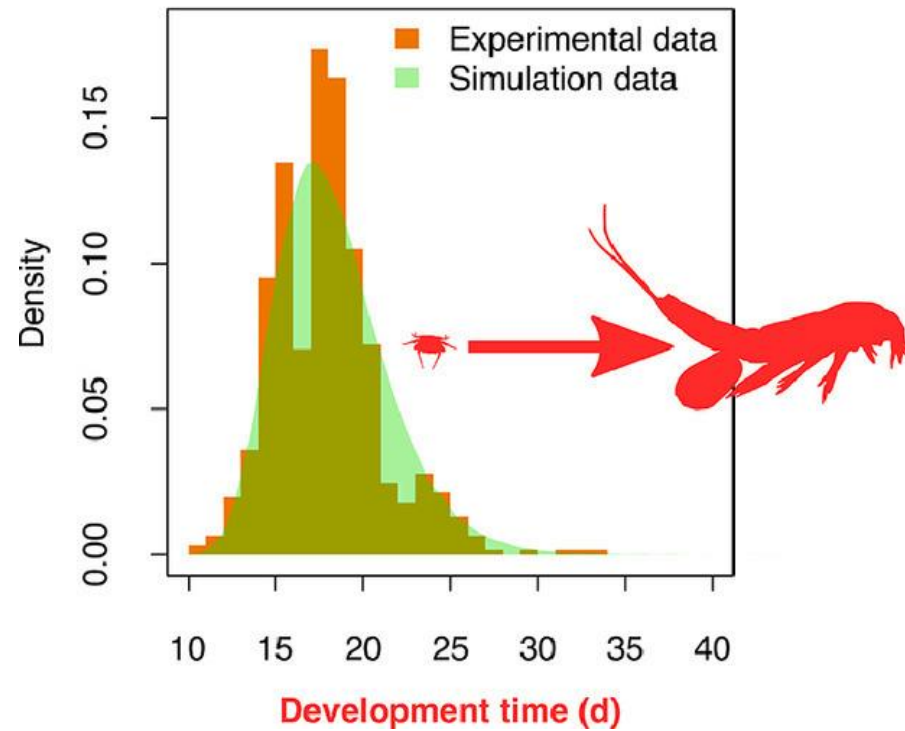
A grove snail

Angus Davison/Wikimedia CC BY-SA 4.0

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1.

Why bother about intraspecific variation?

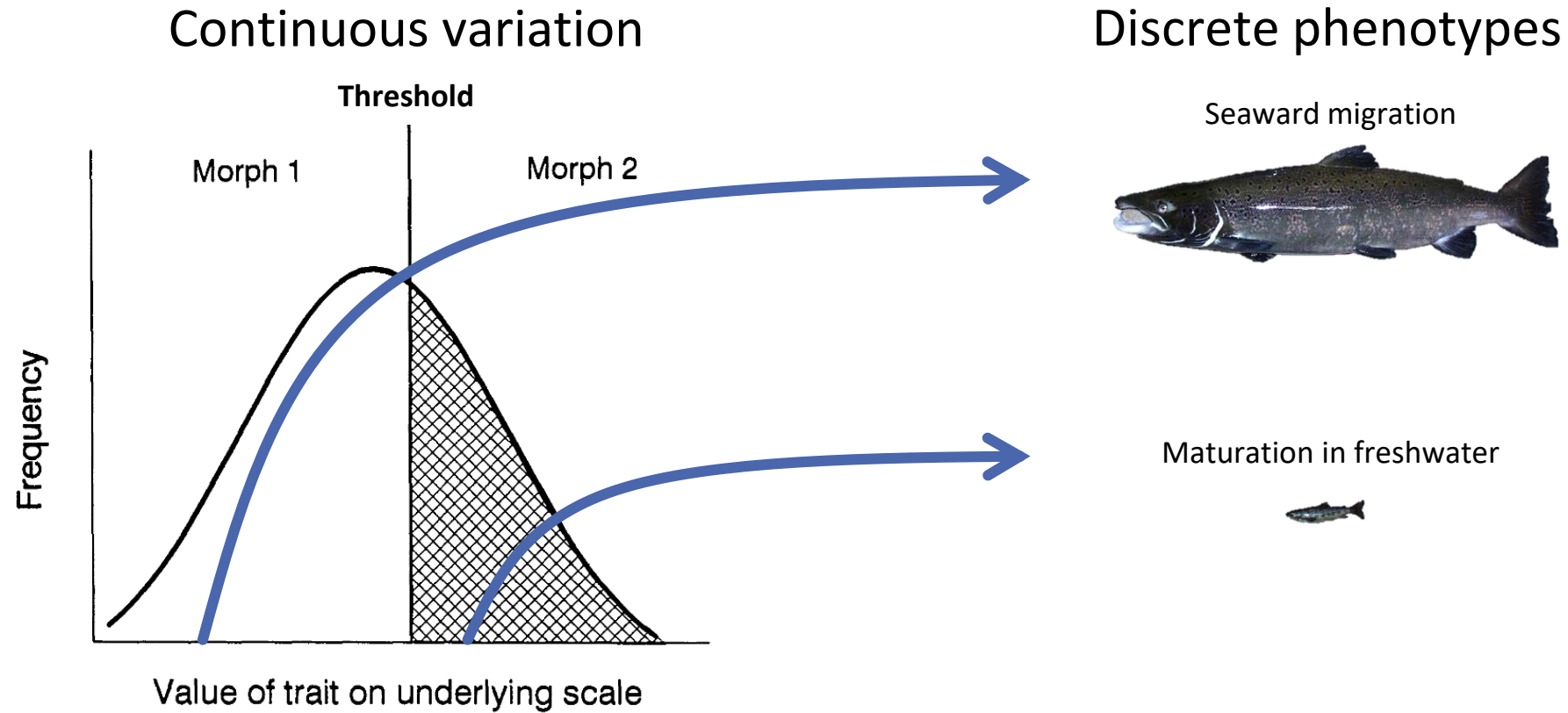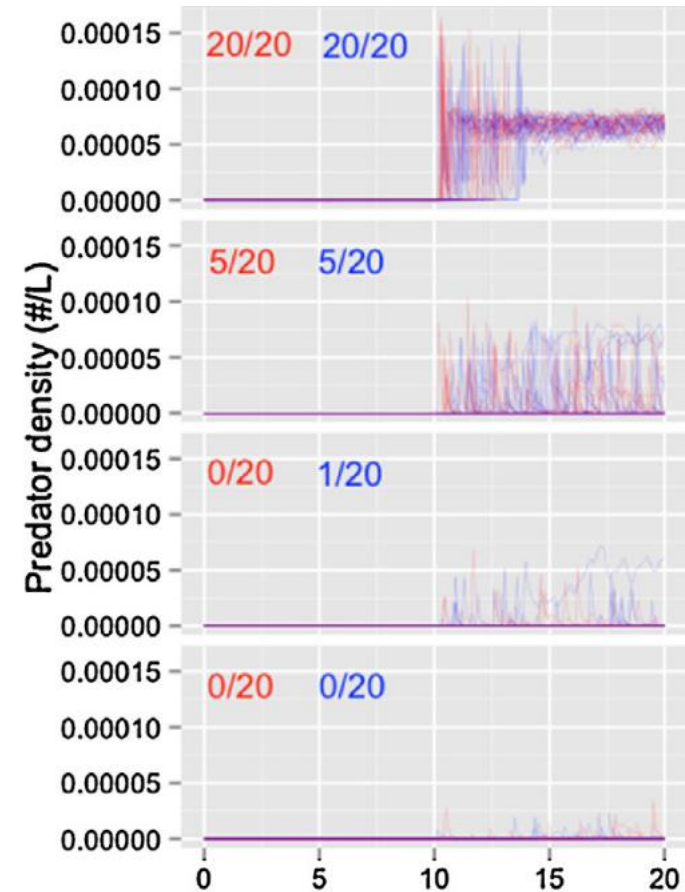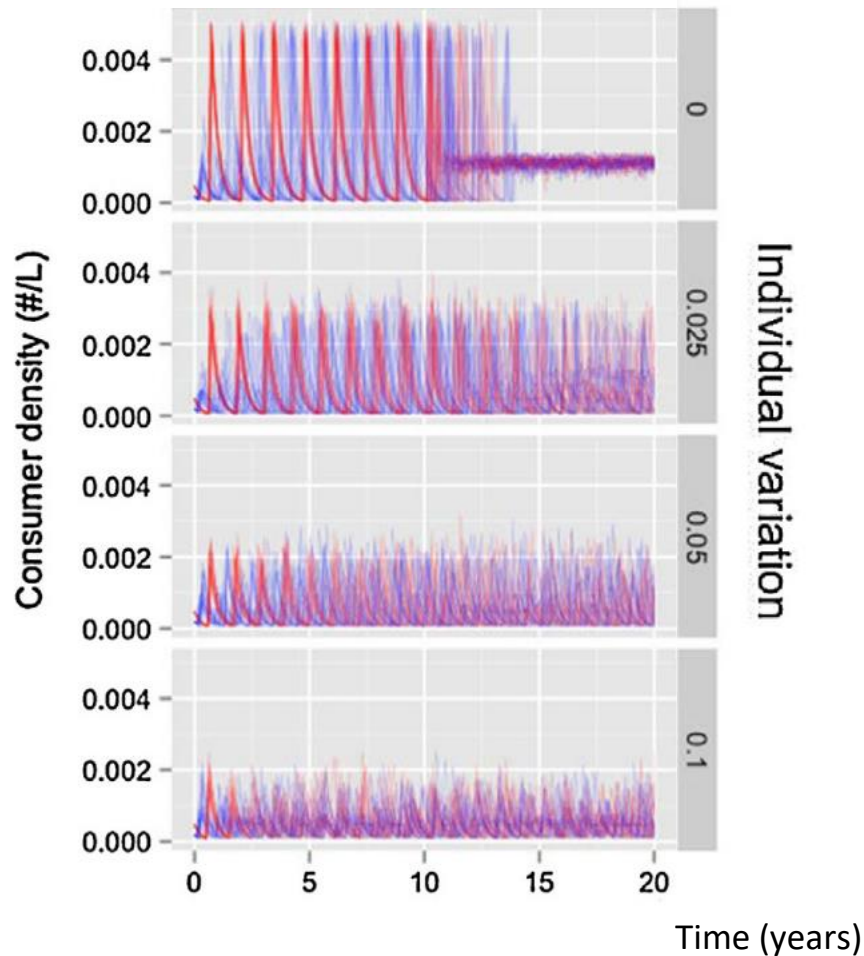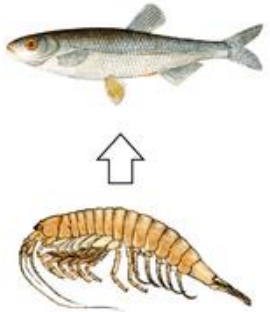# Impact on individual traits

Simulated variation in $\{\dot{p}_{Am}\}$

Koch & De Schamphelaere 2020. *Ecol. Model.* 431, 109091

Threshold traits

Continuous variation

Threshold

Morph 1   Morph 2

Frequency

Value of trait on underlying scale

Discrete phenotypes

Seaward migration

Maturation in freshwater

Roff 1996. *Q. Rev. Biol.* 71(1), 3-35

Impact on demographic processes

planktivorous fish

piscivorous fish

Nisbet *et al.* 2016. *Ecol. Model.* 326, 101-112

Poor prediction across populations

Monaco 2019. *Marine Biol.* 166, 14
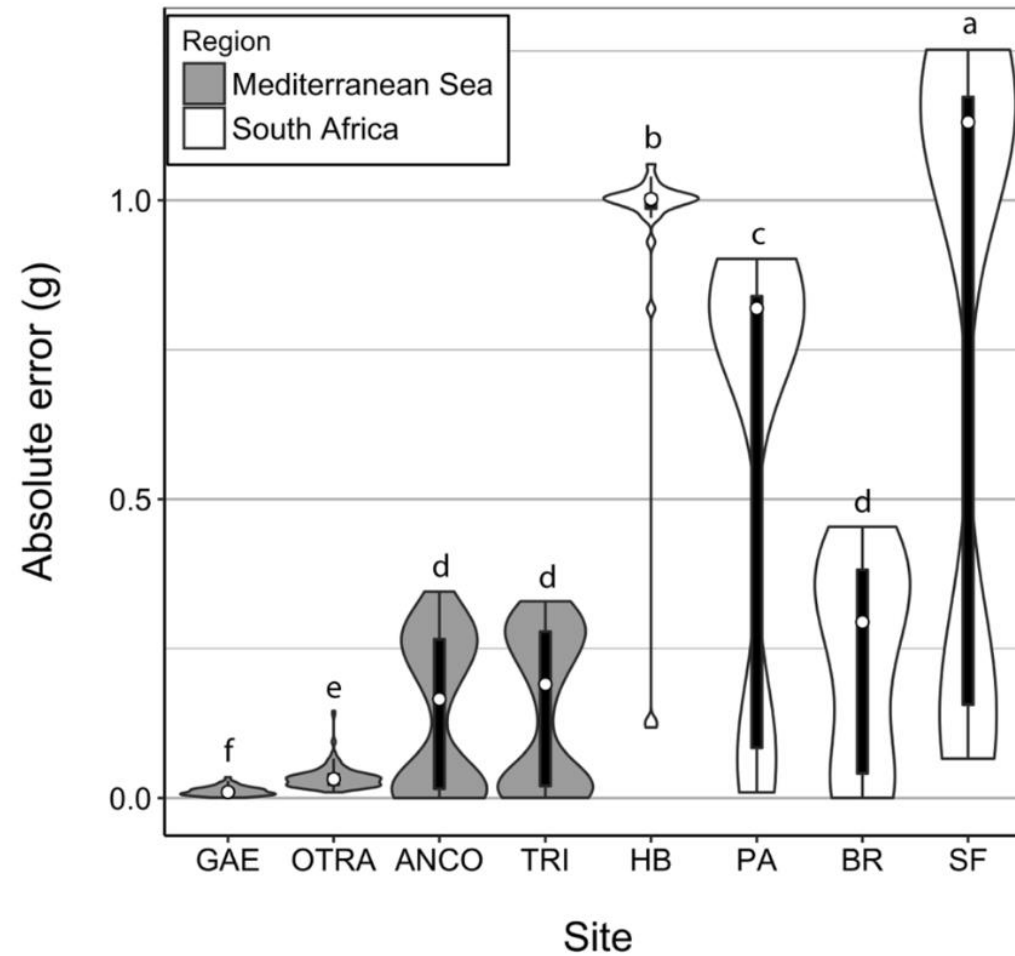
Bias in species parameter estimates

Ryszard Szczygieł/flickr
CC BY-NC 2.0

$_{48}$Cd

Group fit

Legend:
- □ 0 mg/kg
- ○ 64 mg/kg
- △ 139 mg/kg
- ✦ 300 mg/kg
- ☆ 646 mg/kg
- ◇ 1392 mg/kg
- ▷ 3000 mg/kg

Individual fit

Conc. 64 mg/kg food — Conc. 139 mg/kg food — Conc. 300 mg/kg food
Conc. 646 mg/kg food — Conc. 1392 mg/kg food — Conc. 3000 mg/kg food
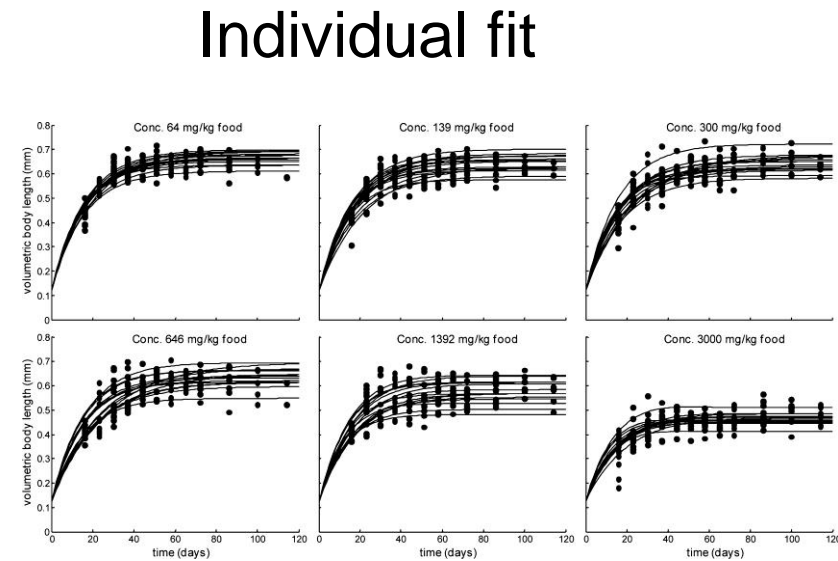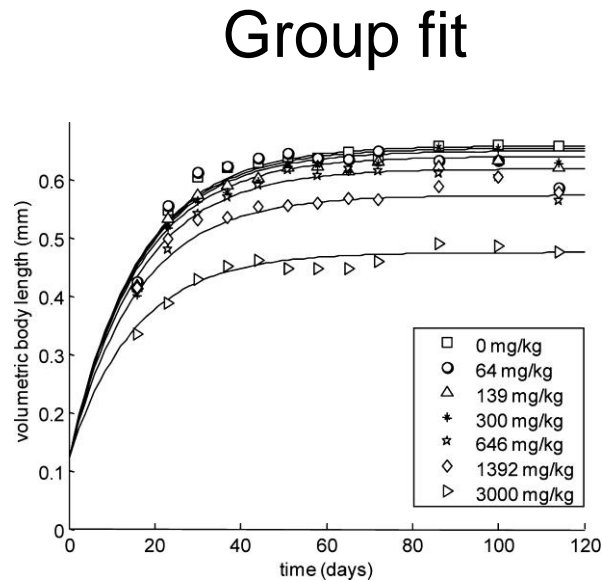
	Group fit		Individual fit
Elimination rate (d^{-1})	1.62 (>0.310)	≠	0.139 (0.100–0.235)
Tolerance (mg/kg food)	10.8 (10.0–11.5) 10^3	≠	8.99 (8.41–9.69) 10^3

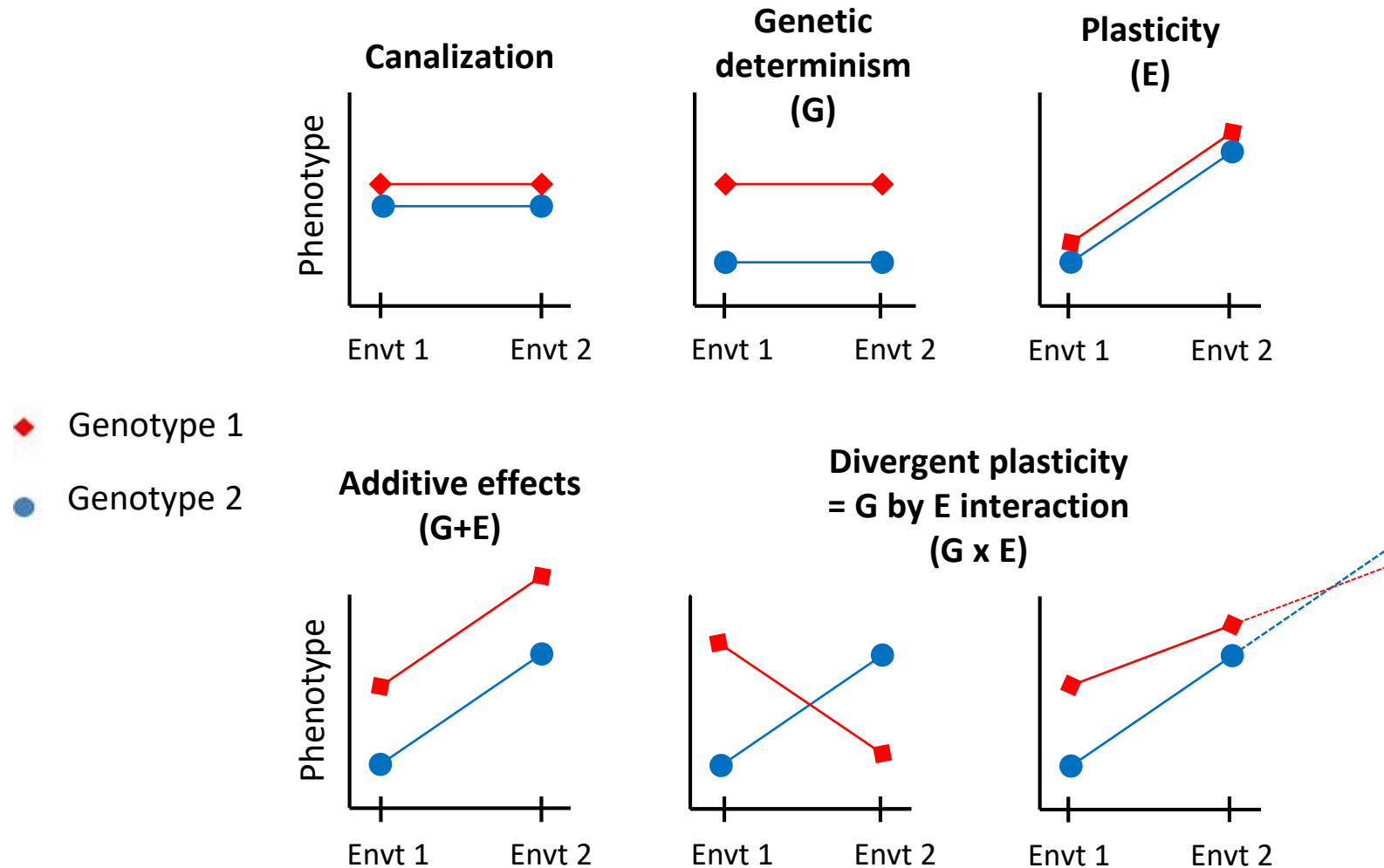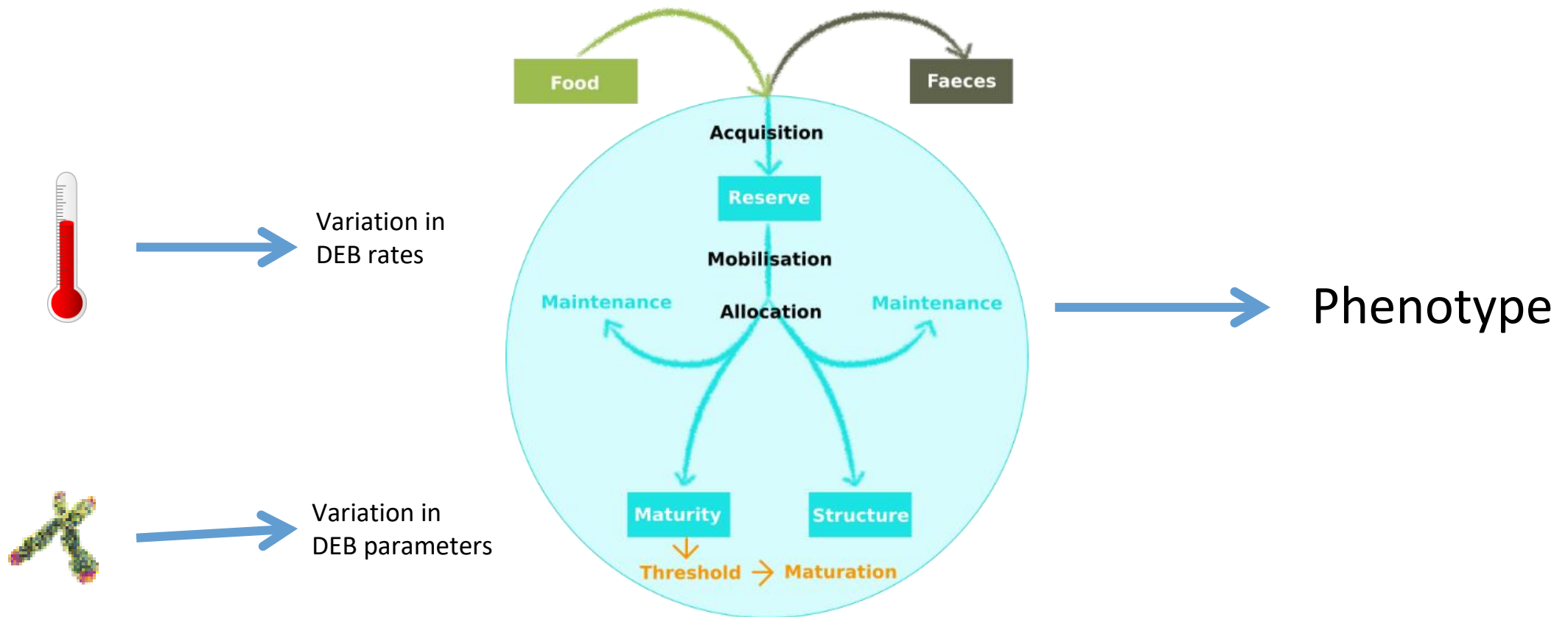Jager 2013. *Environ. Sci. Technol.* 47, 3, 1664-1669

2.

Physiology integrates genes and the environment

Sources of individual variation

But not genetic variation, yet…

Variation in DEB rates
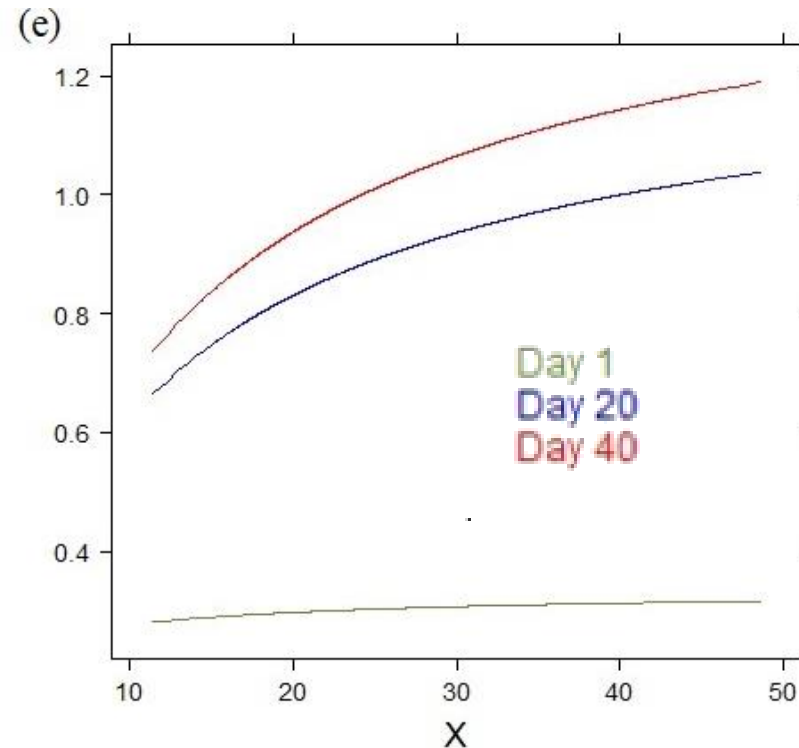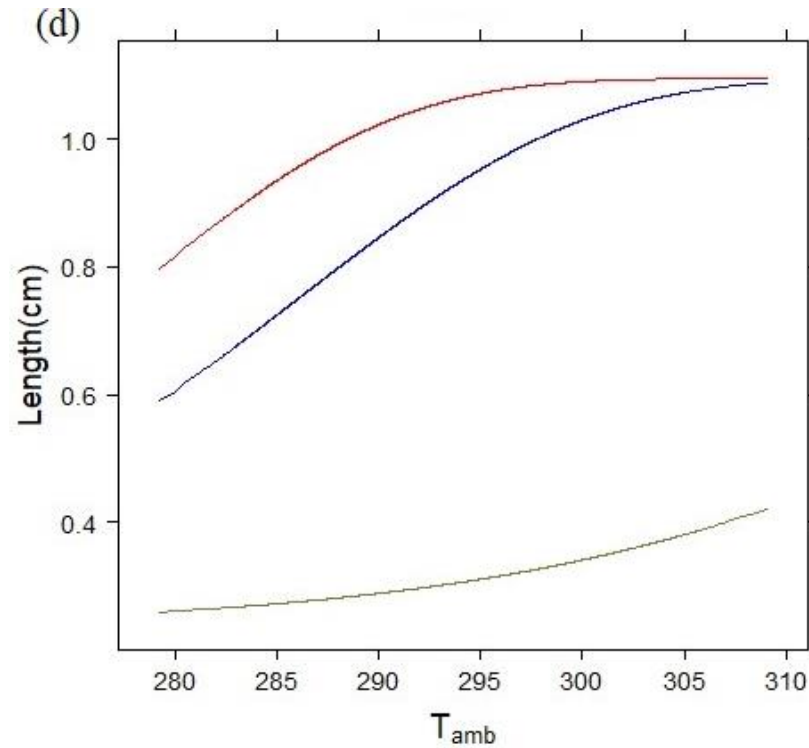
Variation in DEB parameters

Food

Faeces

Acquisition

Reserve

Mobilisation

Maintenance

Allocation

Maintenance

Maturity

Structure

Threshold → Maturation

Phenotype

Plasticity is built within DEB models.

Ryszard Szczygieł/flickr CC BY-NC 2.0

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Plasticity is built within DEB models.

Day 1
Day 20
Day 40

Ryszard Szczygieł/flickr CC BY-NC 2.0

13
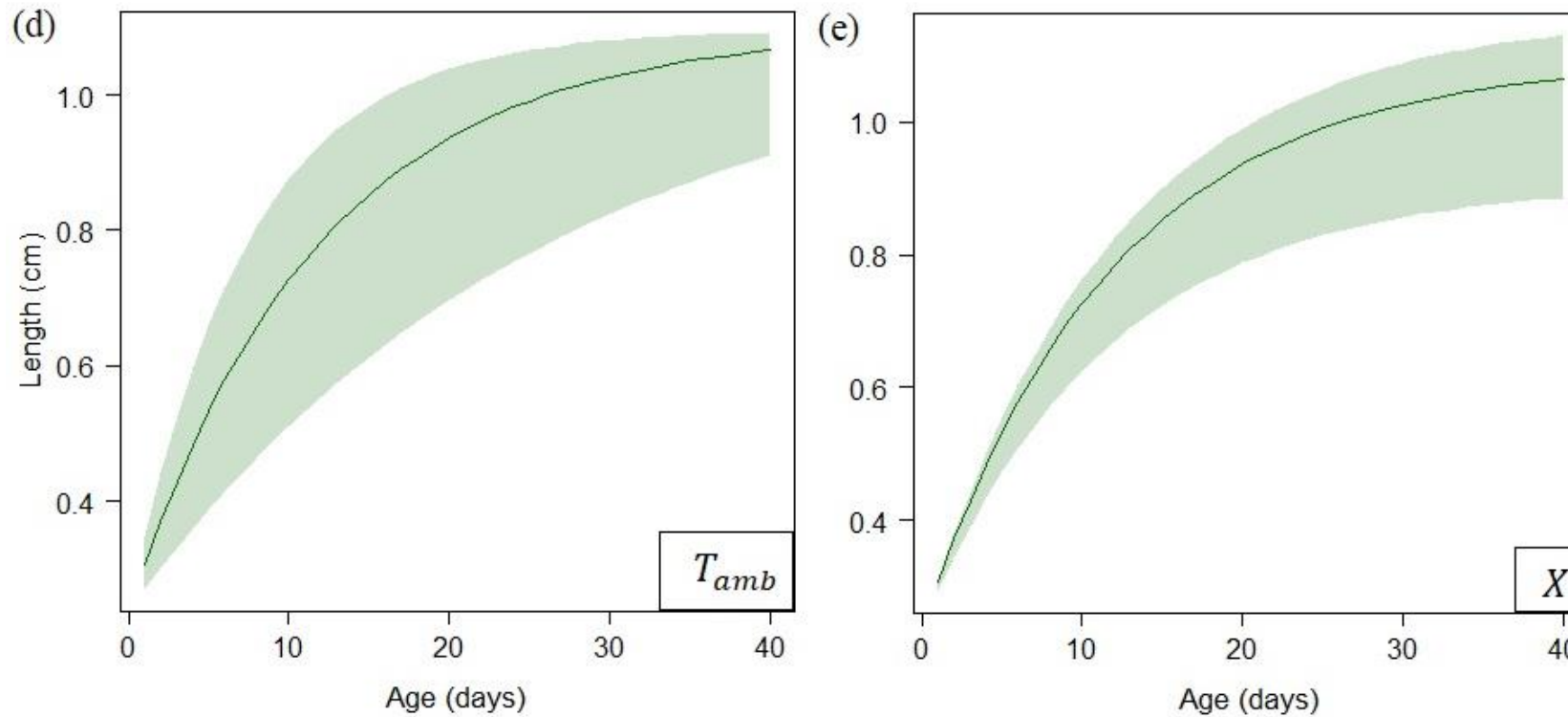
Exercise: Guess the reaction norms
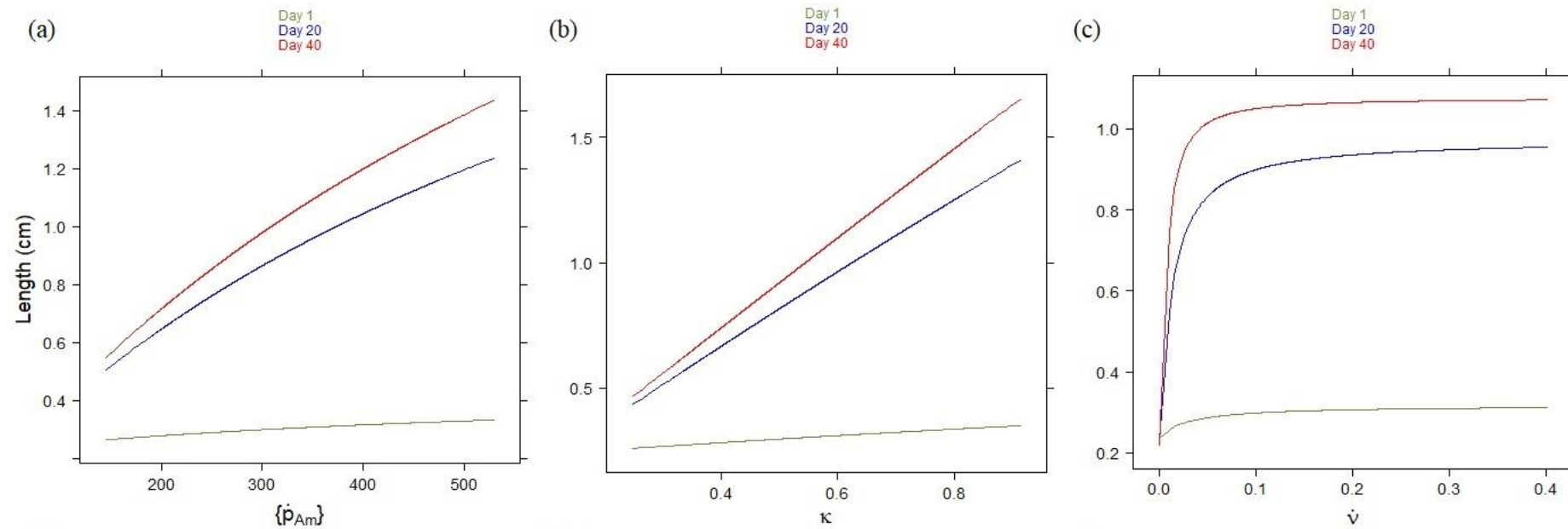

Traits
Size (length)
Reproductive output
Developmental time
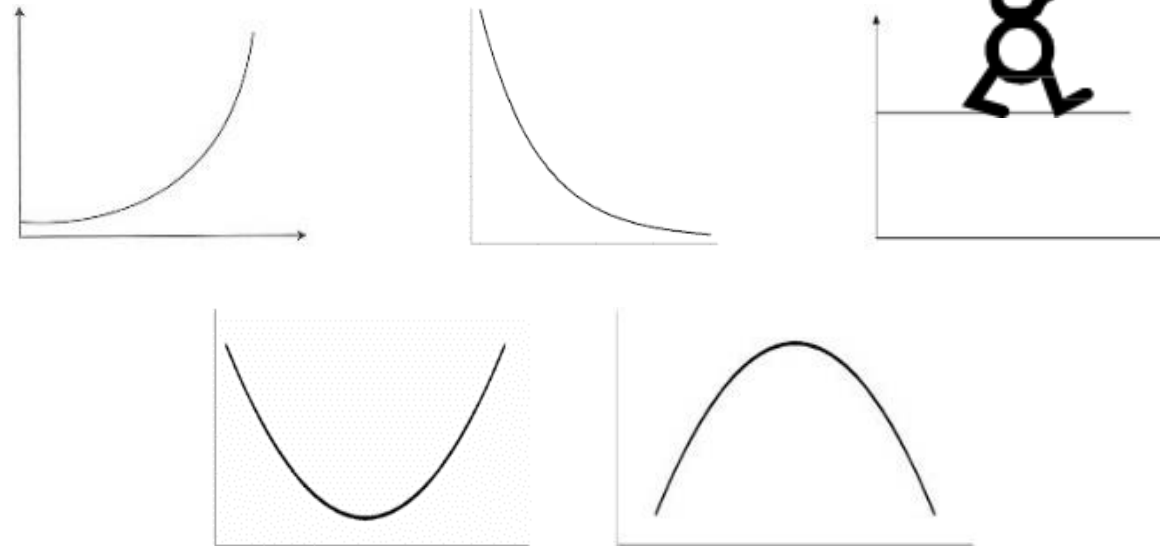
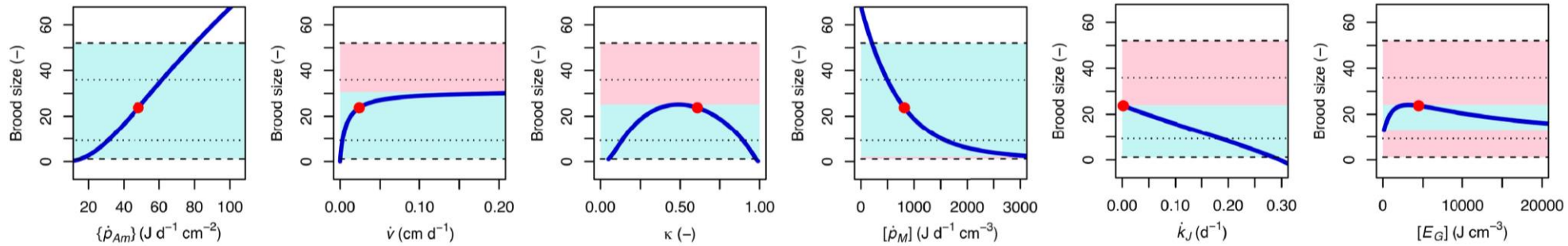**Parameters**
$\{\dot{p}_{Am}\}, \dot{v}$
κ, E_H^b, E_H^p
$[\dot{p}_M], \dot{k}_J$
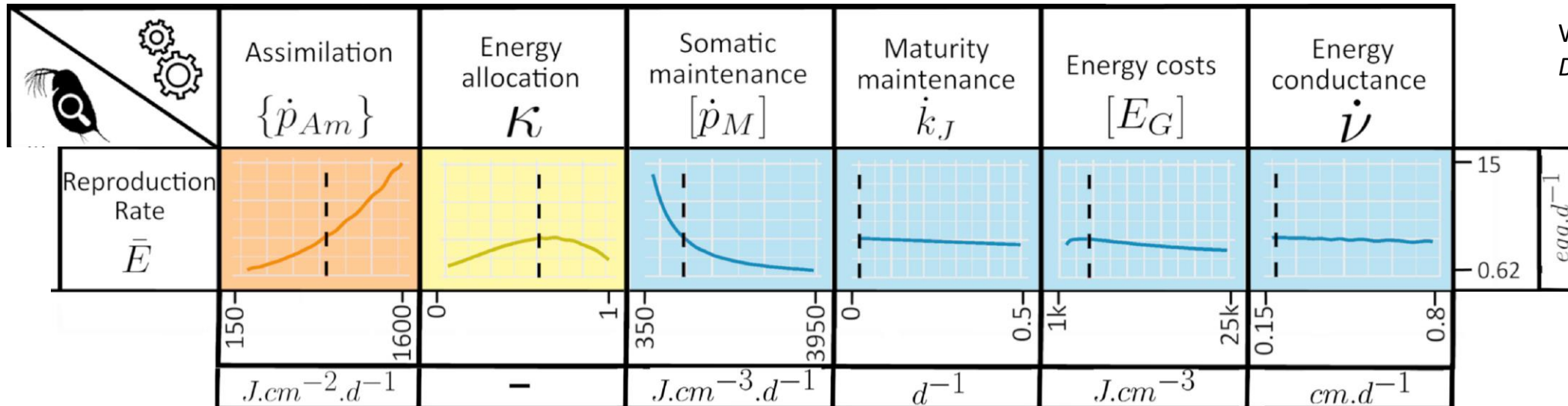
Size (physical length)

15

Reproductive output

Koch & De Schamphelaere 2020. *Ecol. Model.* 431, 109091
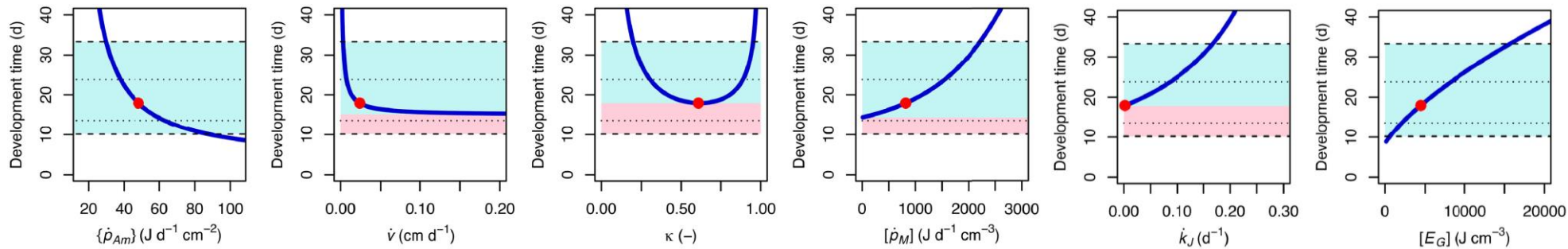
Copepod
Nitocra spinipes

Water flea
Daphnia magna

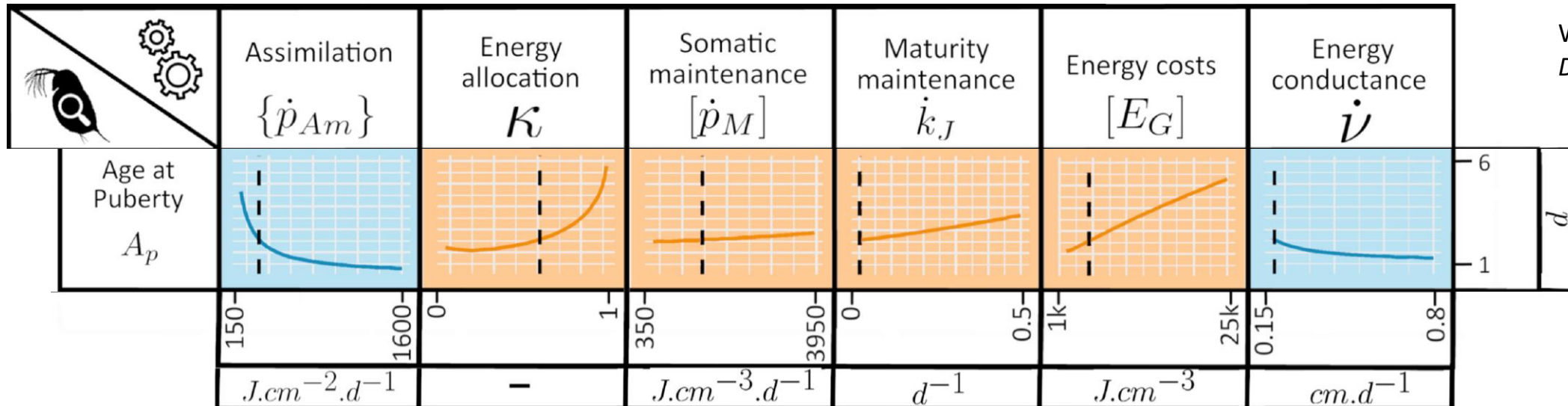Debelgarric & Récapet 2025. *Ecol. Model.* 501, 110993

Development time (hatching → puberty)

Copepod
Nitocra spinipes

Koch & De Schamphelaere 2020. *Ecol. Model.* 431, 109091
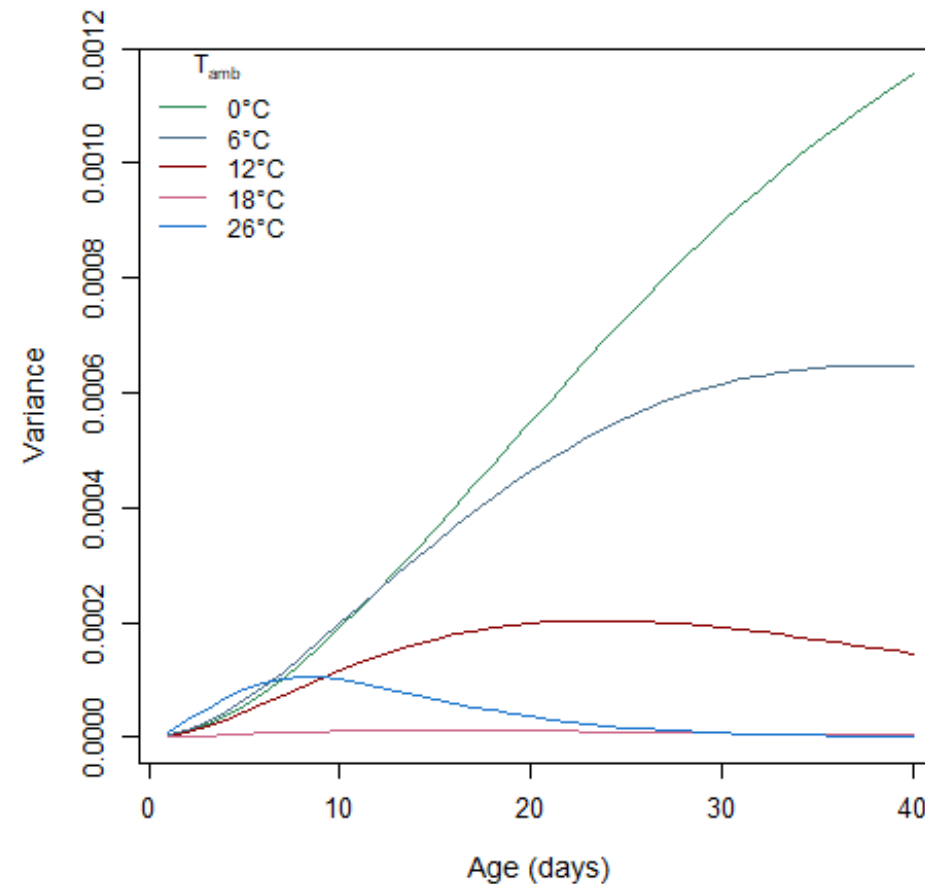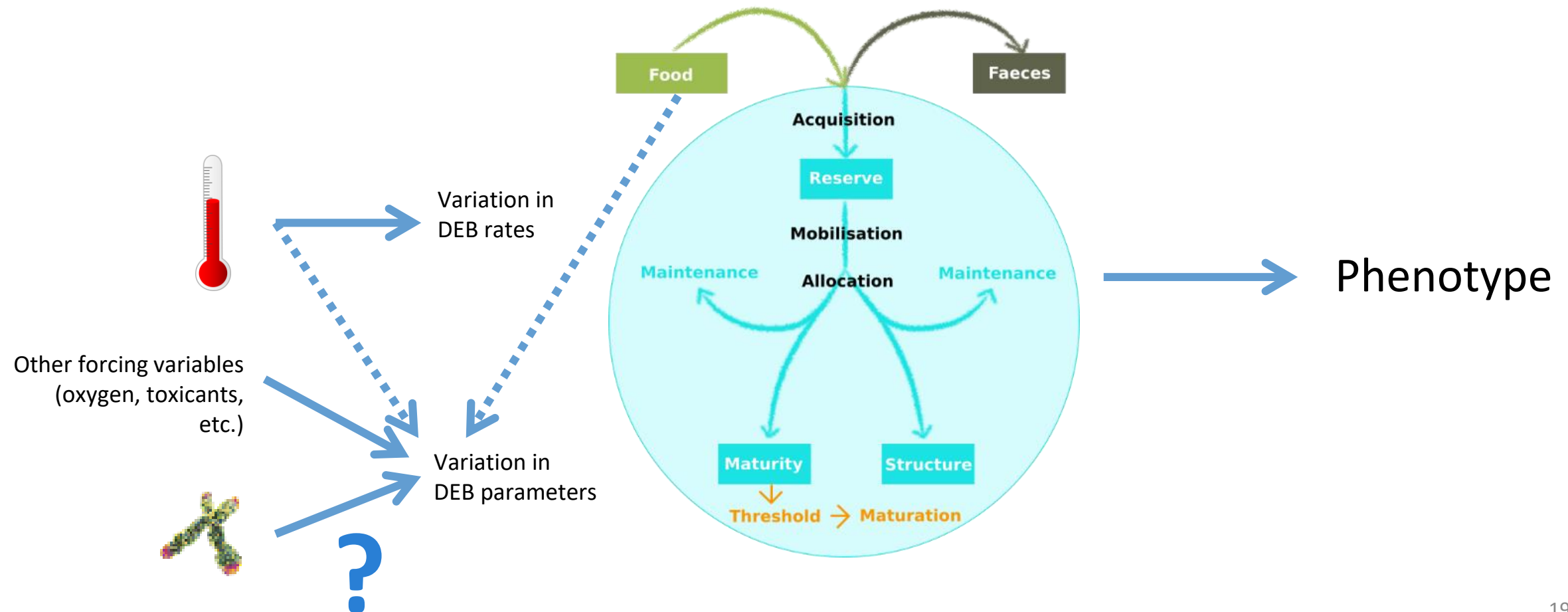

Water flea
Daphnia magna

Interaction between G and E

Inherent to the model

Variance in body size due to variation in T_A at different T

Ryszard Szczygieł/flickr CC BY-NC 2.0

G x E interactions on DEB parameters?

Heritable variation in DEB parameters

E_G **Heritability** = 0.4
(40% individual variation due to genetic variation)

Genotype
Between-families
QTLs

Hans Hillewaert/wikimedia
CC BY-SA 4.0

Environment
Temperature
Food availability

DEB
Reserve
Maint.
Maint.
Structure
Maturation Reproduct.
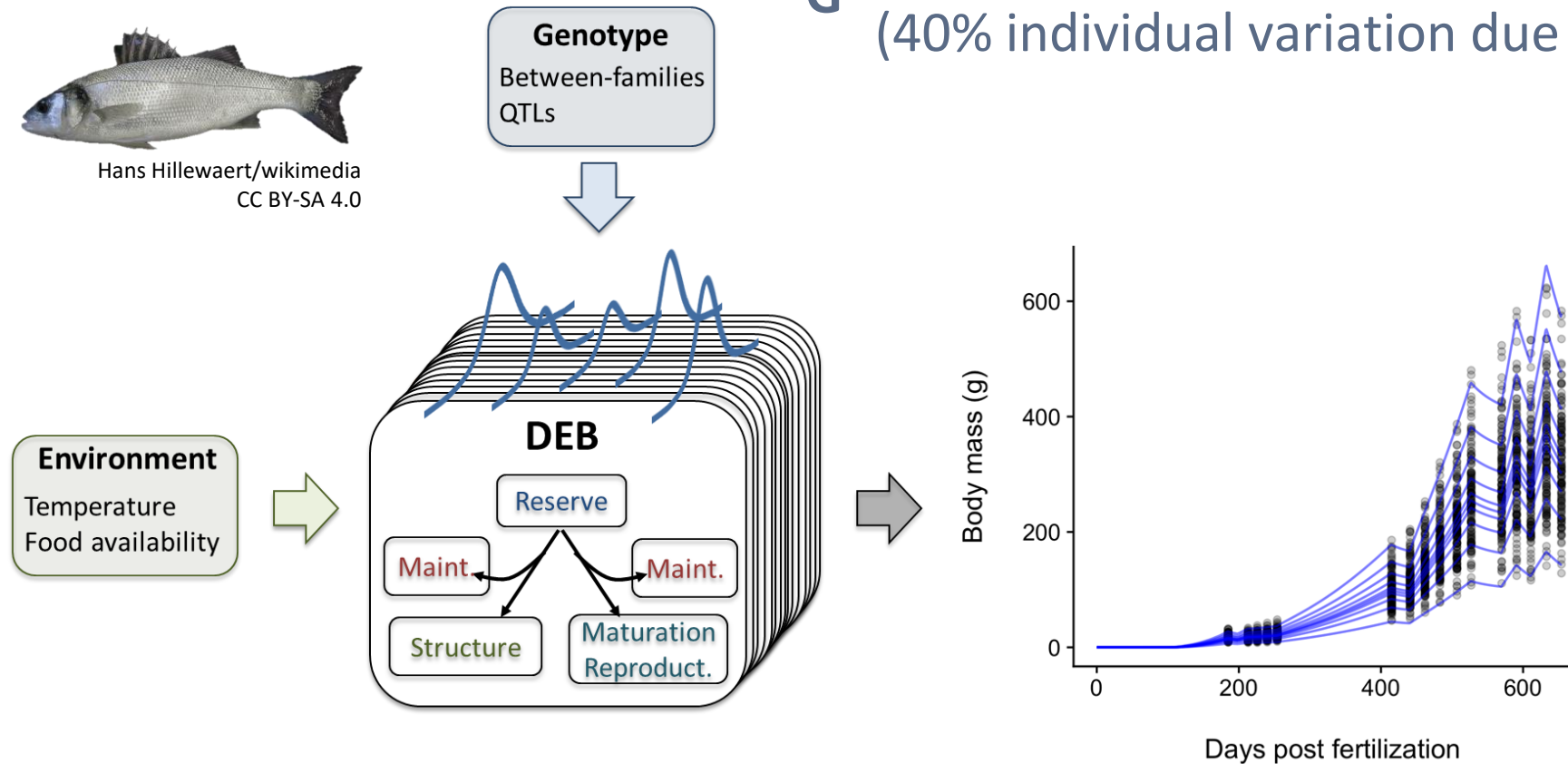
Interaction between G and E

Hans Hillewaert/wikimedia
CC BY-SA 4.0

Genotype
Between-families
QTLs

E_G **Heritability** = 0.4
(40% individual variation due to genetic variation)

The remaining 60%: Error? Plasticity?

DEB

Reserve

Maint.   Maint.

Structure   Maturation Reproduct.

Environment
Temperature
Food availability

Besson, Vandeputte, Allal, Prunet , Bégout & Sadoul 2019. Unpublished data, with permission from B. Sadoul.
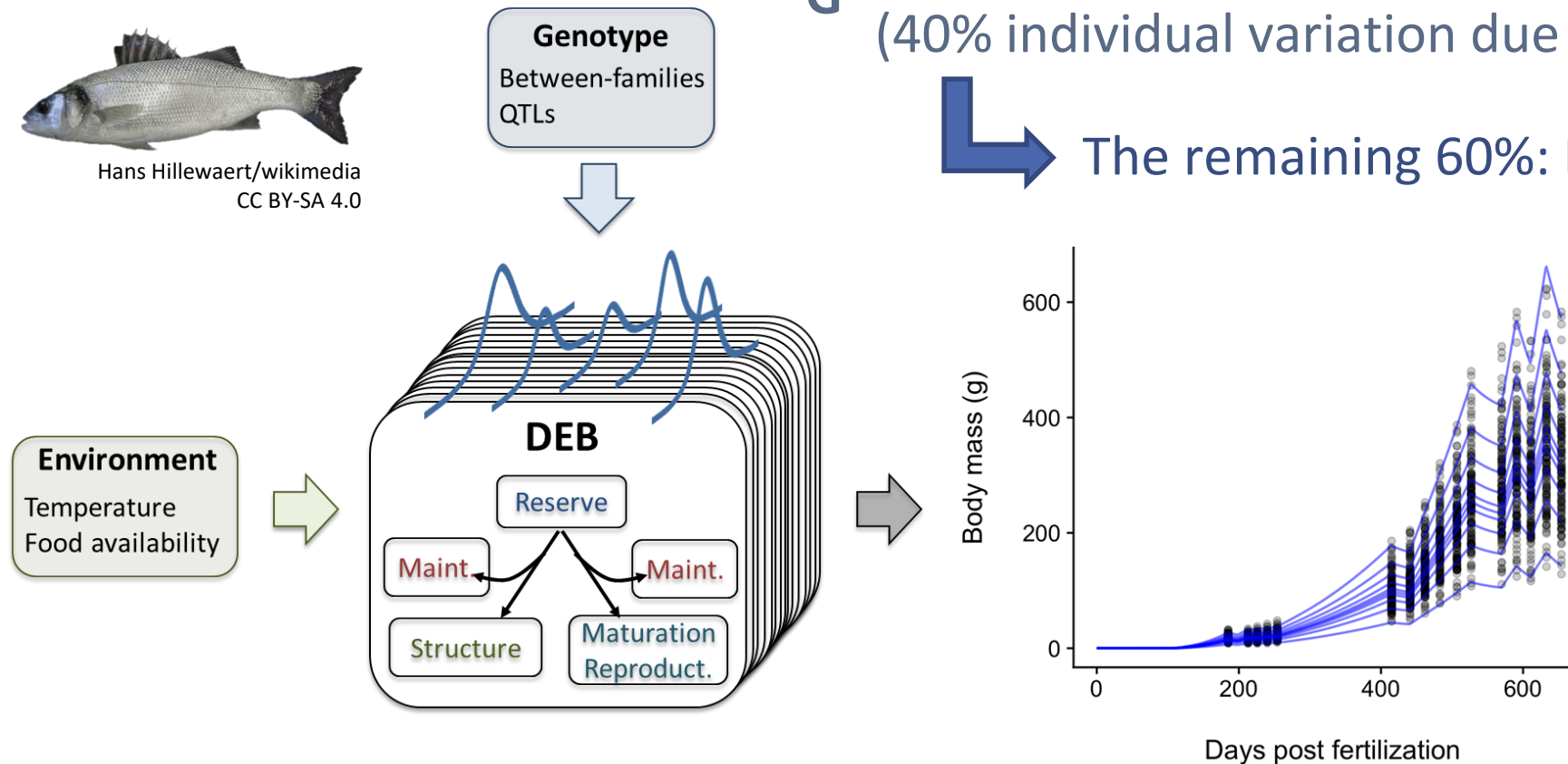
3.

Estimating subspecies variation in DEB parameters
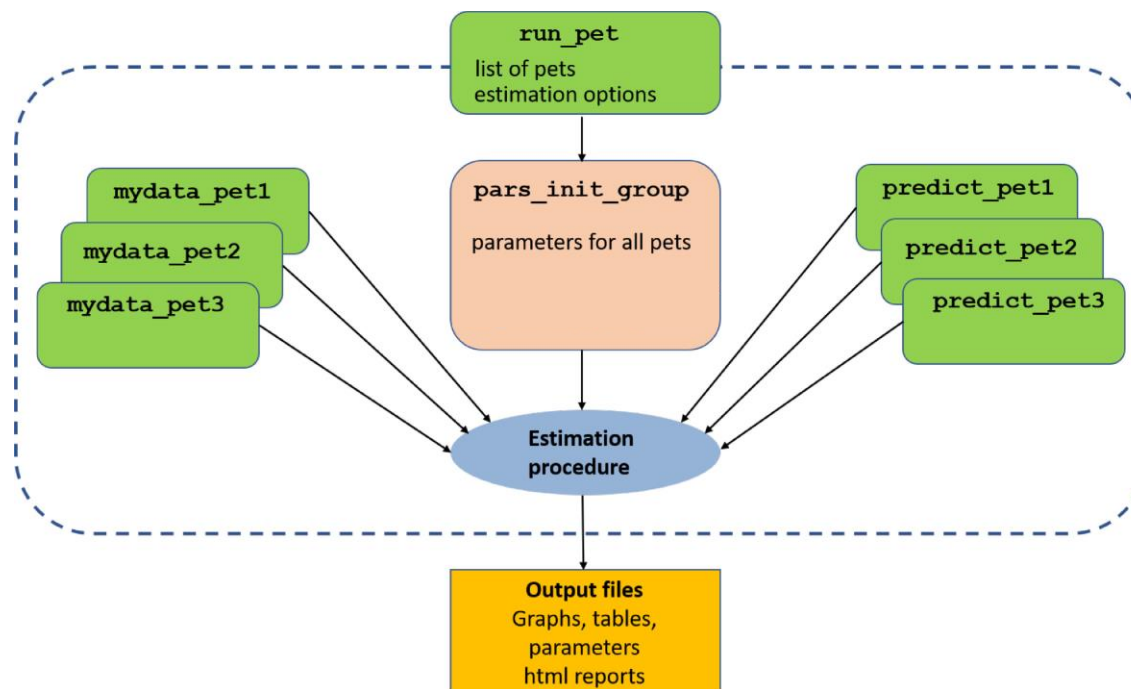
Each group separately

+
- No assumptions on constant/variable parameters

−
- Sensitive to differences in data completeness
- Difficult to identify biologically significant differences (no credibility interval for Δ)

Joint estimation

All-or-nothing parameter differences

- Parameters are either equals or different between groups.
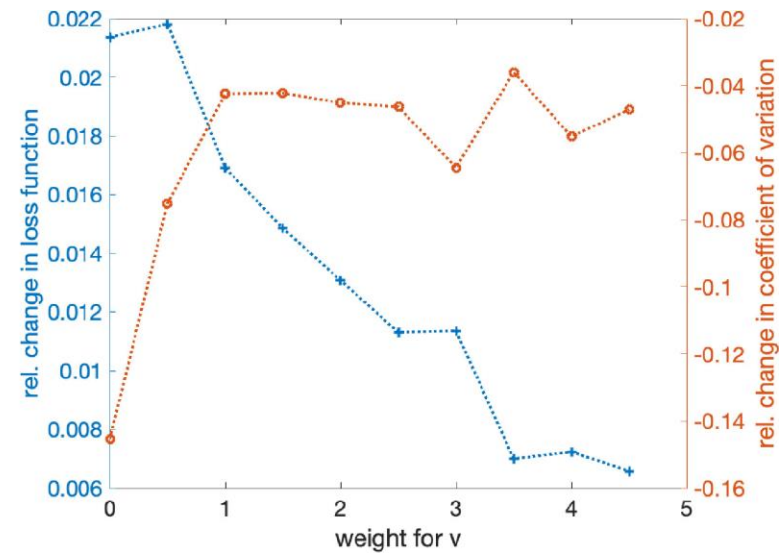- Covariation rules may constrain the parameter space (e.g. between maturity levels and zoom factor).
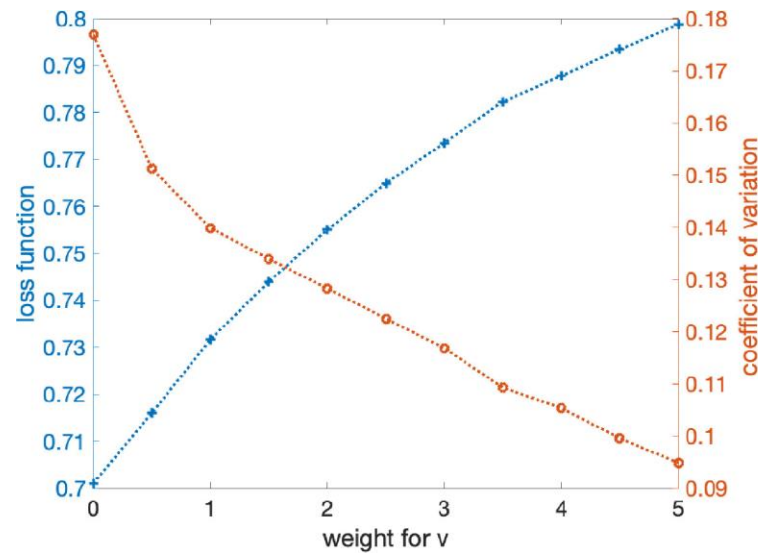

Adapted from Lika et al. 2020. *Ecol. Model.* 428, 109110

Joint estimation

Using an augmented loss function

Variation between groups
not penalized

Variation between groups
increasingly penalized

Lika et al. 2020. *Ecol. Model.* 428, 109110

Joint estimation

+

- Possibility to estimate Δ as a parameter → credibility interval
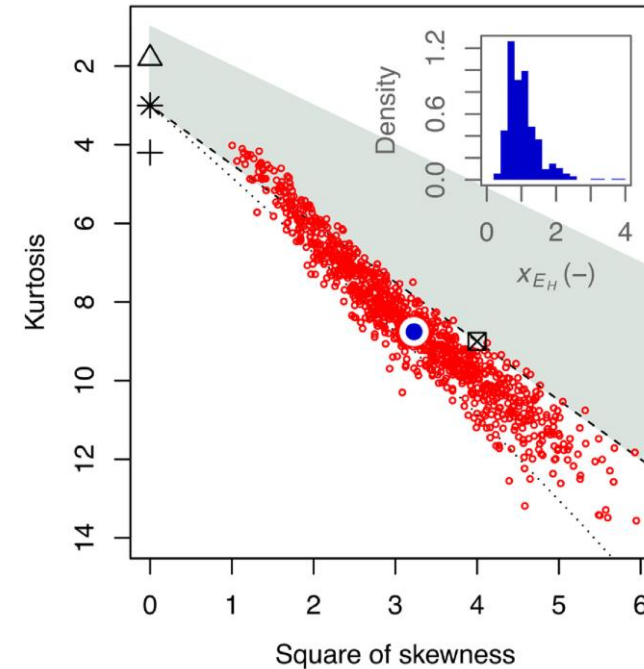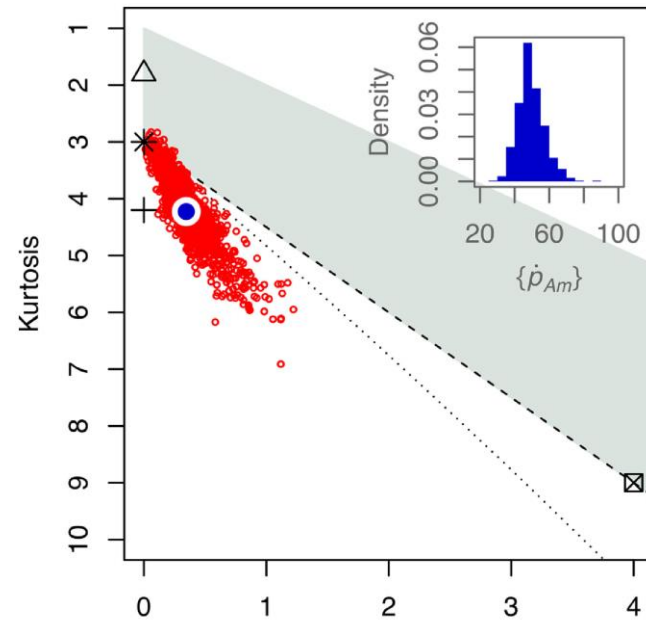- Use information from data-rich groups to improve estimation in data-poor groups

-

- Requires assumptions on constant/variable parameters

4.

Estimating individual variation in DEB parameters

Distribution of one trait (OAT)

Theoretical distributions

- ✳ Normal
- △ Uniform
- ⊠ Exponential
- + Logistic
- ▢ Beta
- ⋯ Log-normal
- - - Gamma

(Weibull is close to gamma and log-normal)

- ● Observation
- ○ Bootstrapping

Koch & De Schamphelaere 2020. *Ecol. Model.* 431, 109091
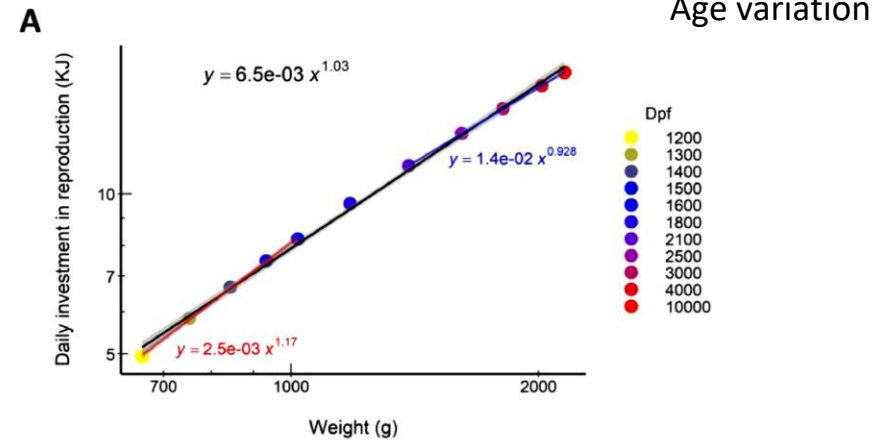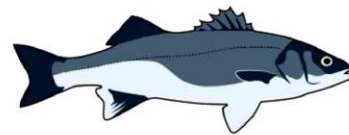
28

Distribution of one trait (OAT)

+

- Possible without longitudinal data (distribution only)
- Help identify most relevant parameters

–
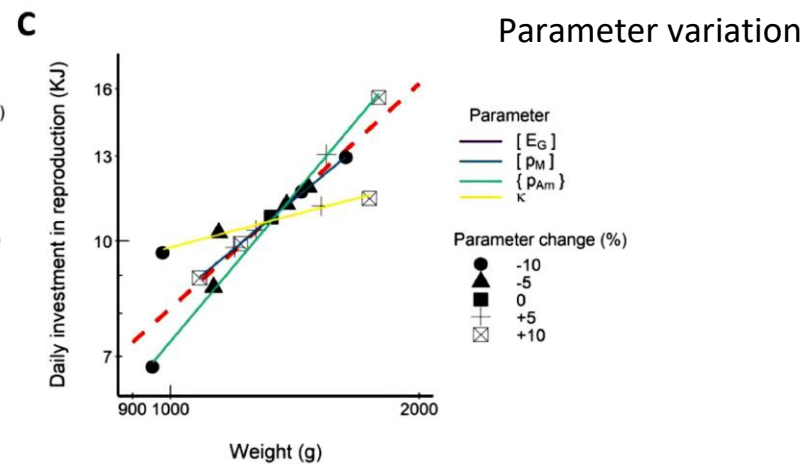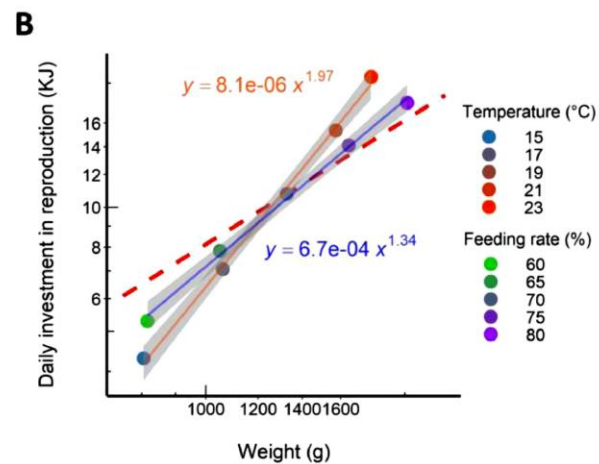
- Assumes one parameter explains all variation
- Rely on only one source of information (trait)

Relationship between traits (OAT)

Age variation

Environmental variation

Parameter variation

Sadoul *et al.* 2020. *Ecol. Model.* 433, 109228

Relationship between traits (OAT)

+
- Possible without longitudinal data (relationship only)
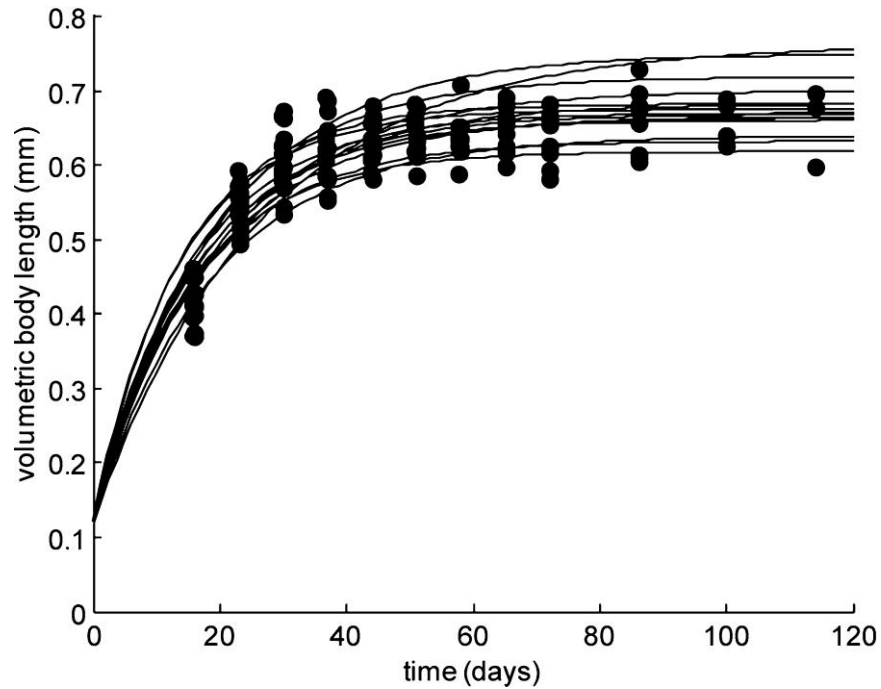- Helps identify most relevant parameters

-
- Assumes one parameter explains all variation
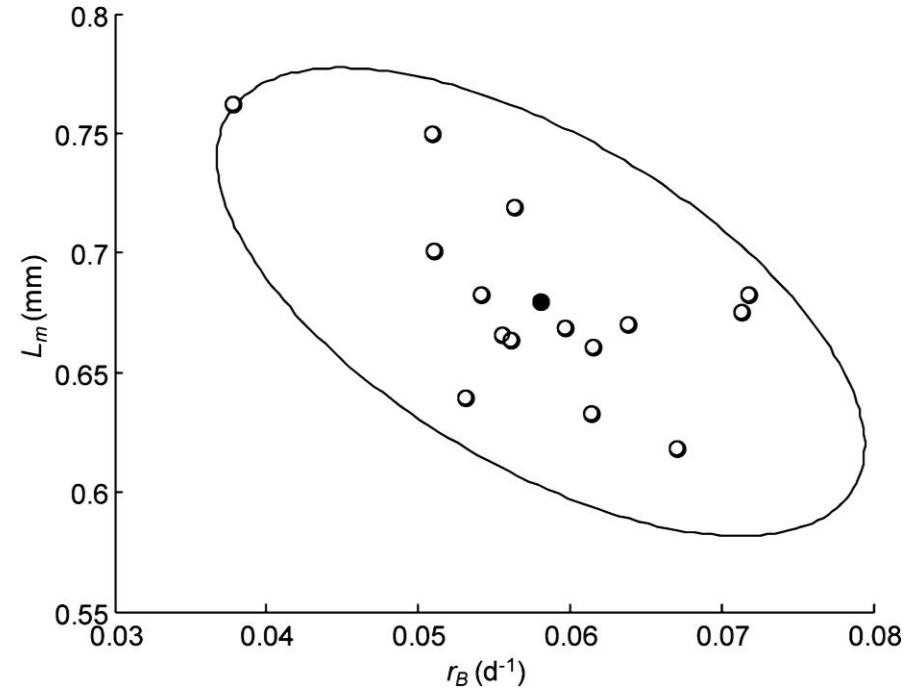- Does not estimate parameter distribution

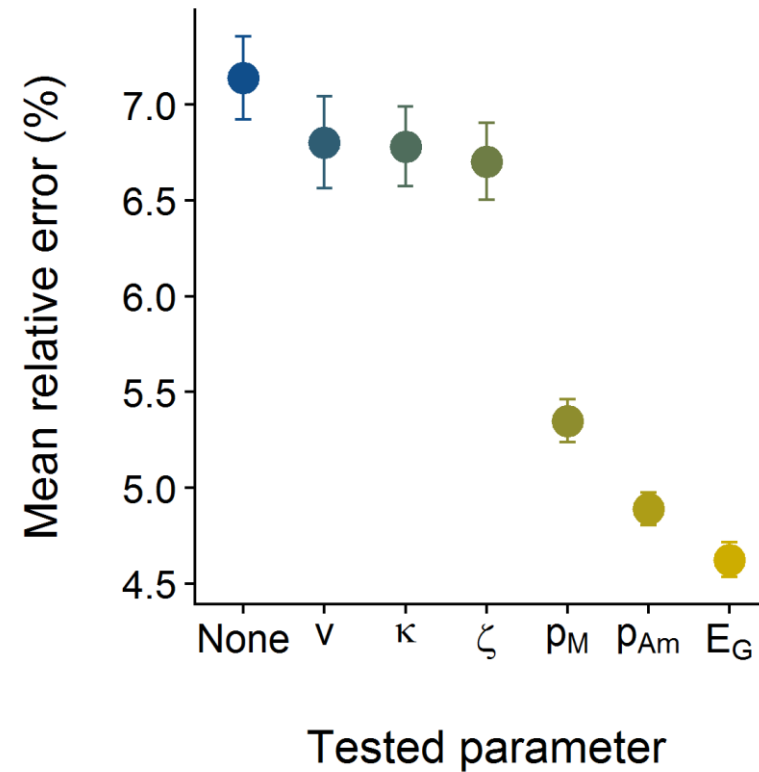# Individual fit (covariation)

Individual fit → Parameters' distribution
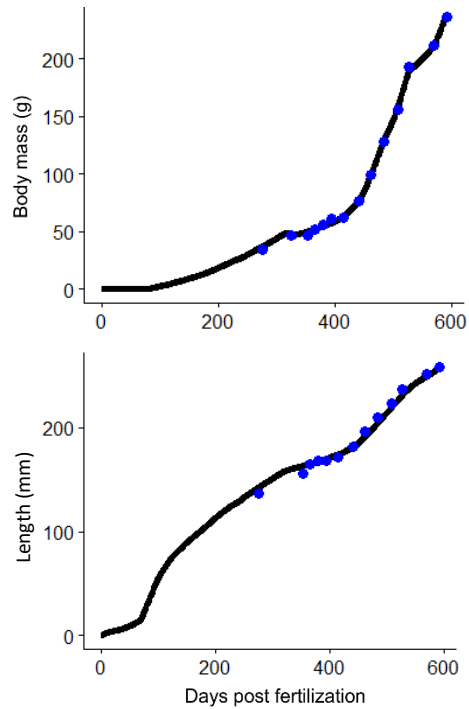
Jager 2013. *Environ. Sci. Technol.* 47, 3, 1664-1669

Individual fit (OAT)

Model fit with one variable parameter
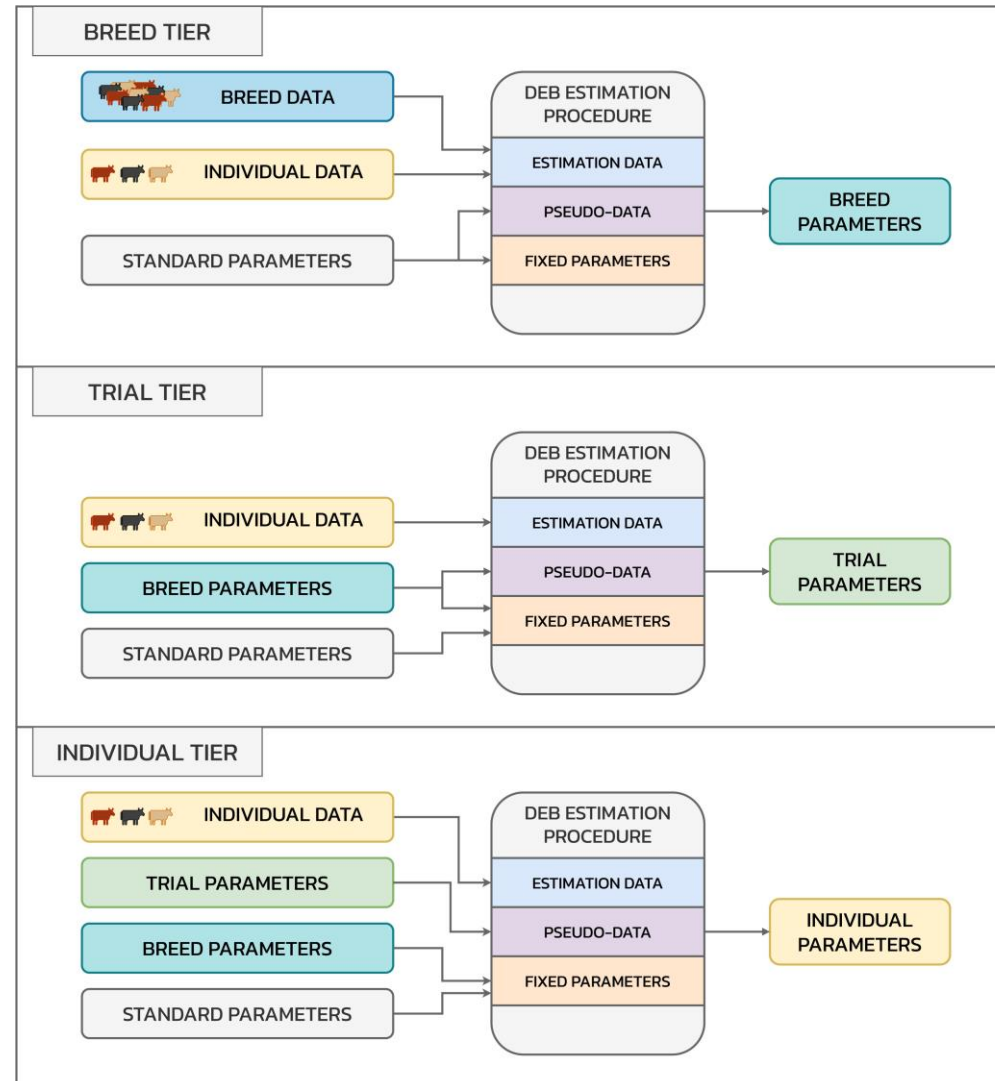
Many traits – one individual (covariation)

+

- Can estimates variation in several parameters
- Does not need any assumption on parameter or error (trait) distributions

−

- Requires longitudinal data
- Sensitive to error in individual data
- Sensitive to identifiability issues (→ OAT)

Combining estimations at several levels

Oliveira et al. 2024. *Ecol. Model.* 494, 110779

Using assumptions on parameters' distribution?

+

- Each parameter variance (and even covariance) is directly estimated as a new parameter
- Accounts for error in individual data

−

- Requires individual data on several traits
- Requires assumption on parameter and error distributions
- Number of estimated parameters may increase rapidly!
- Still sensitive to identifiability issues

Let's sum up!

What should we keep in mind?

✓ Risks of ignoring intraspecific variation :
- poor predictions for some populations
- biased species-level estimates and predictions

✓ DEB-based models can combine environmental and genetic sources of variation.

✓ Estimating intraspecific variation :
- Assumptions on variable parameters may help improve identifiability, but increase risk of error.
- Measurement errors and intraspecific variation remain difficult to tell apart.

Thank you for your attention

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