Trade-offs between growth and reproduction in a long-lived plant

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▶ **To cite this version:**

Julien Papaix, Valentin Journé, Hendrik Davi, Emily Walker, Etienne Klein, et al.. Trade-offs between growth and reproduction in a long-lived plant. Journées du GDR Ecologie Statistique EcoStat, May 2019, Avignon, France. hal-02786260

HAL Id: hal-02786260
https://hal.inrae.fr/hal-02786260v1

Submitted on 4 Jun 2020

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evolution MONTPELLIER 2018
August 19-22, 2018
Montpellier, France

Wed, 22 August
S-69 Evolutionary Physiology

Trade-offs between growth and reproduction

Example with a long-lived plant

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INRA SCIENCE & IMPACT

Acknowledgements

Funding:

RÉGION SUD PROVENCE ALPES CÔTE D'AZUR

INRA SCIENCE & IMPACT

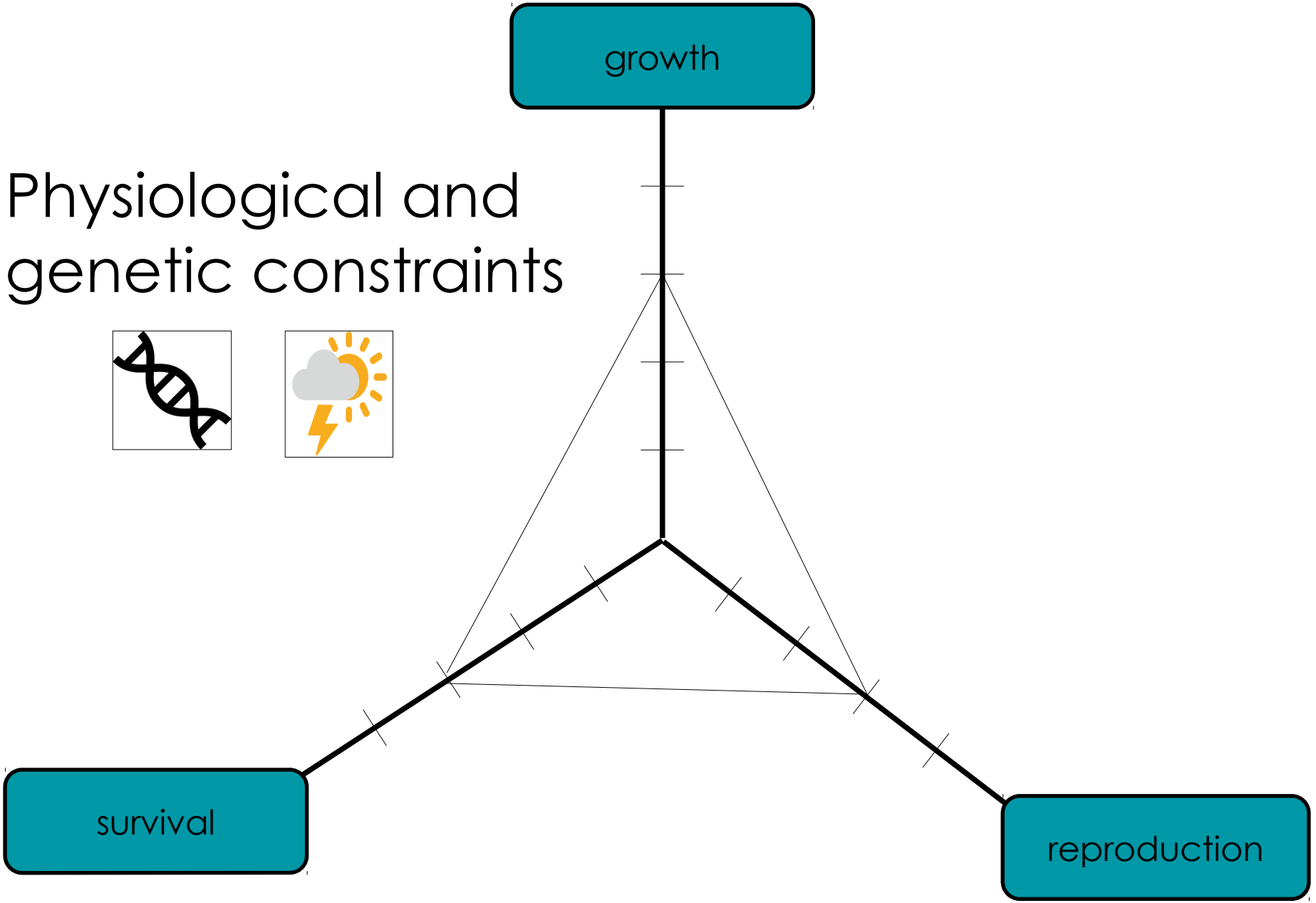
Collaborators:





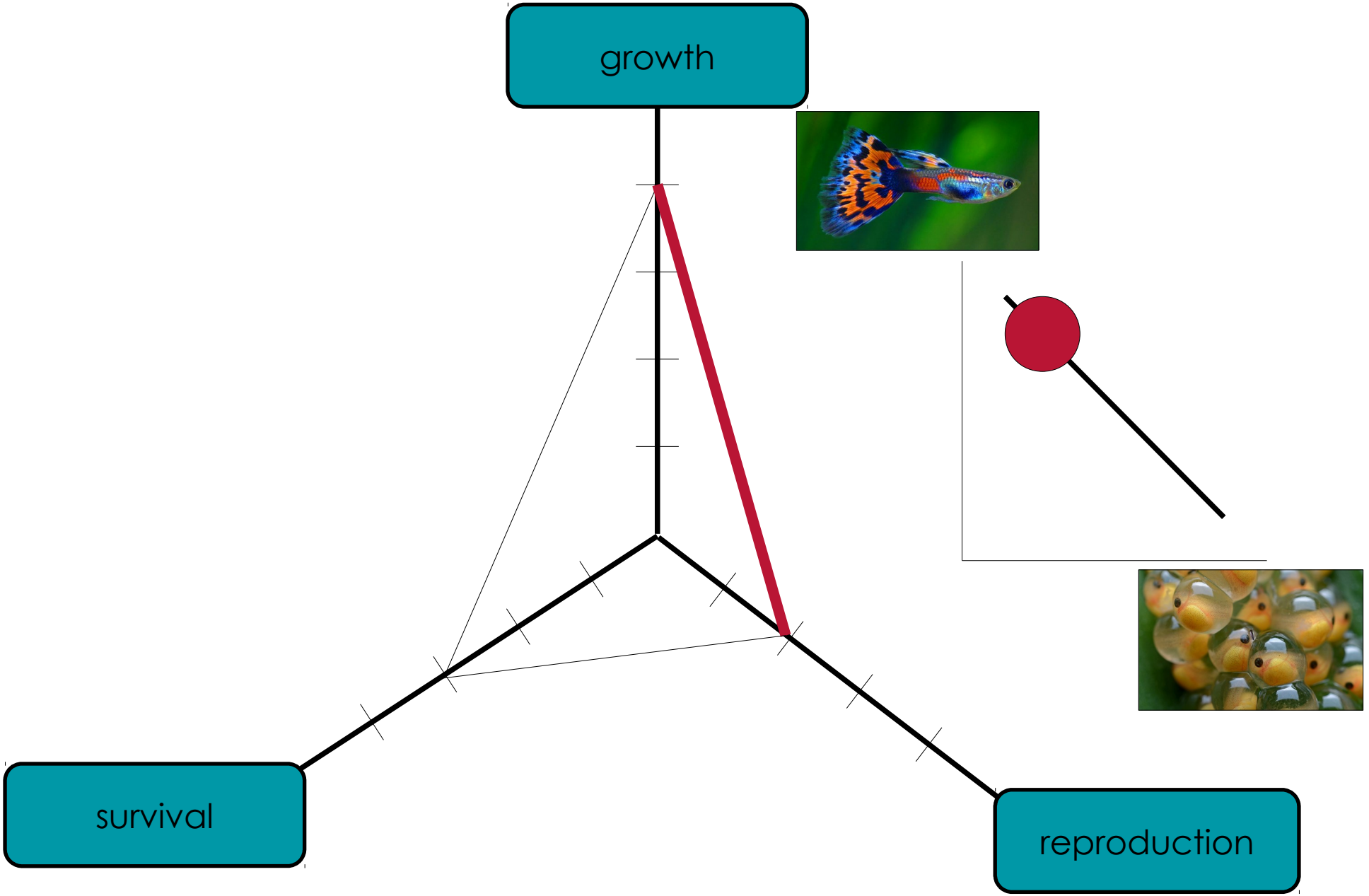


Context



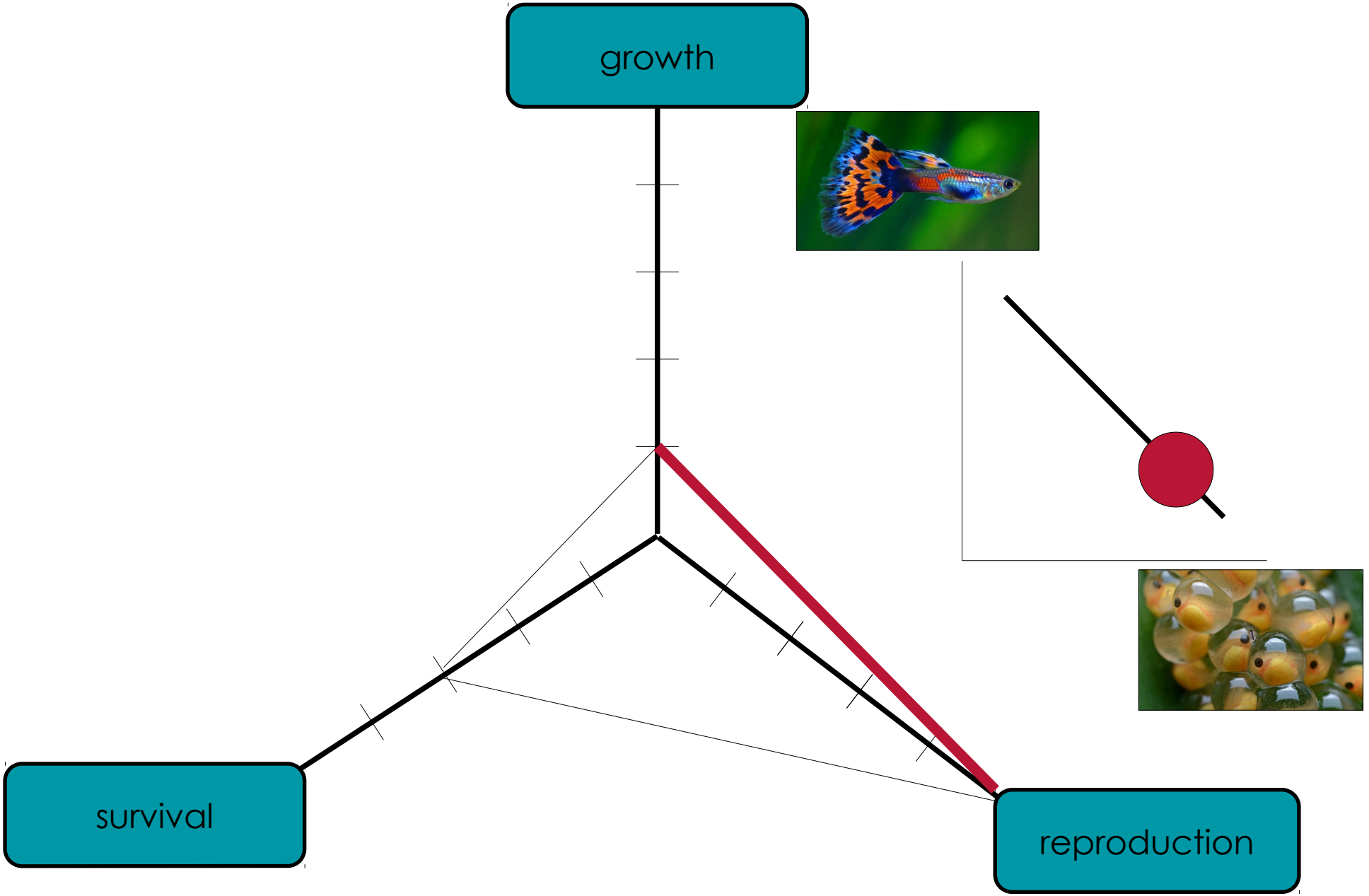
Adapted from Cody 1966

Context



Reznick, 1983
Adapted from Cody 1966

Context



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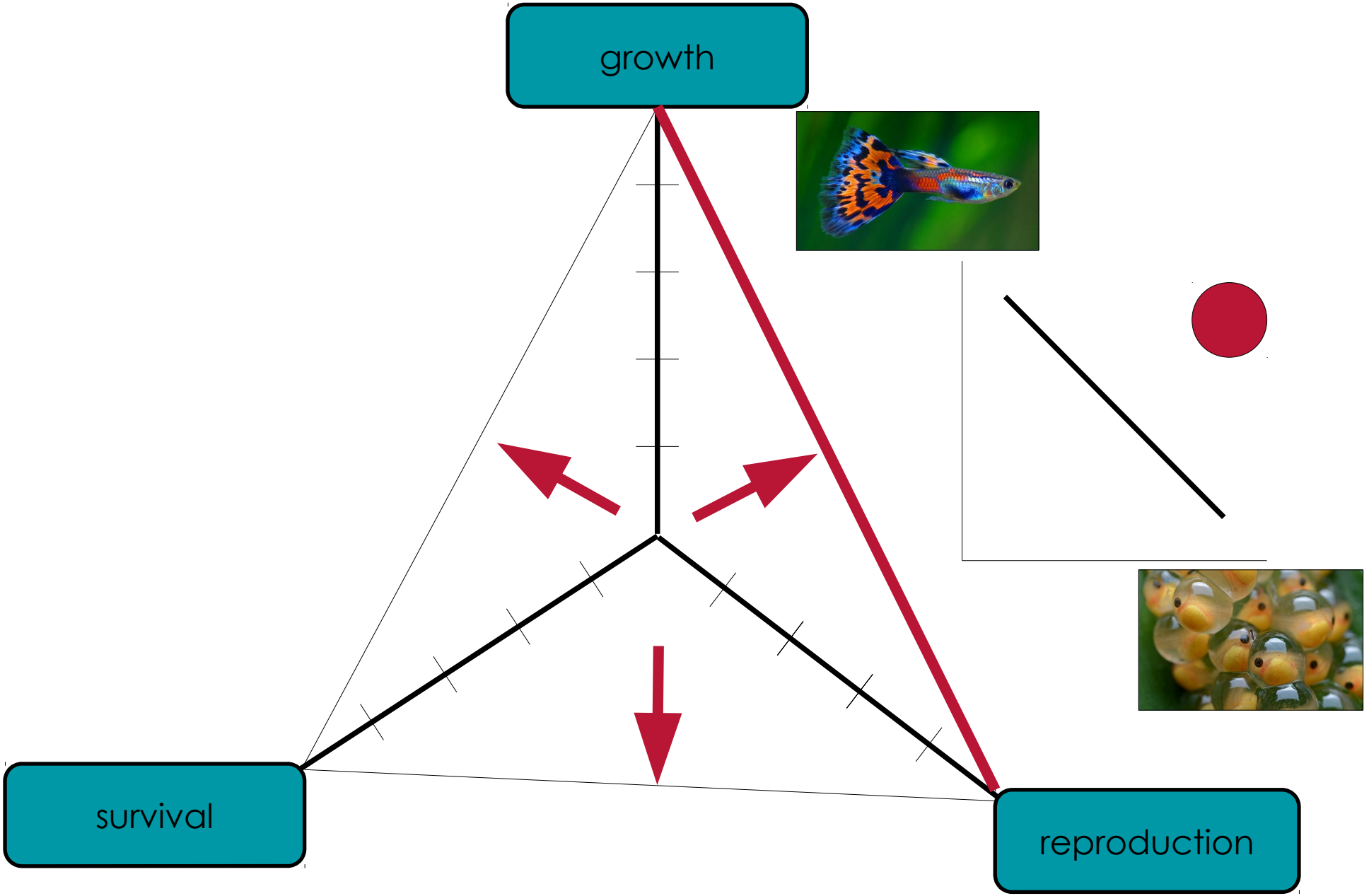
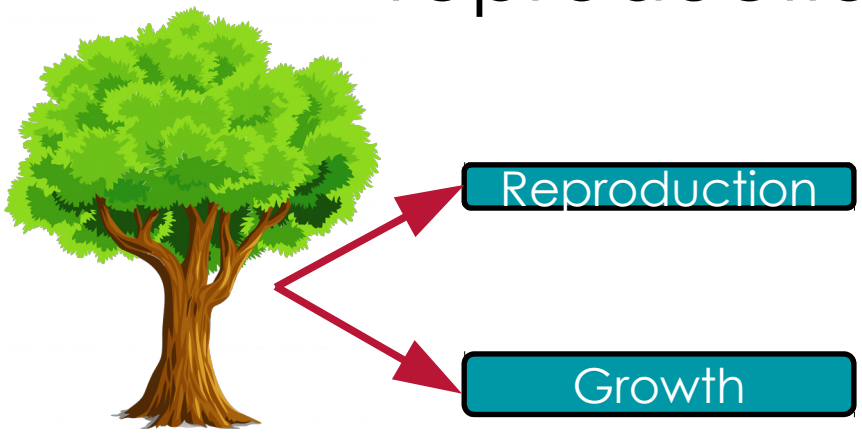
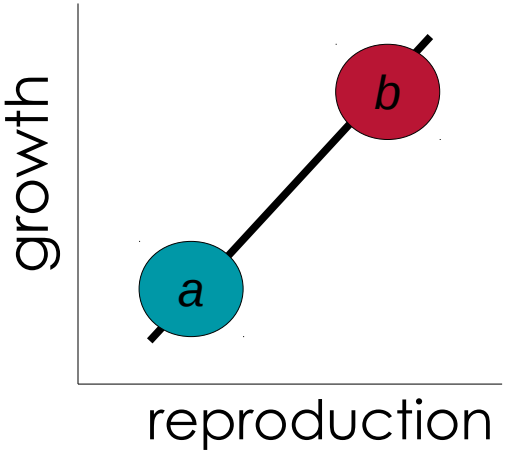


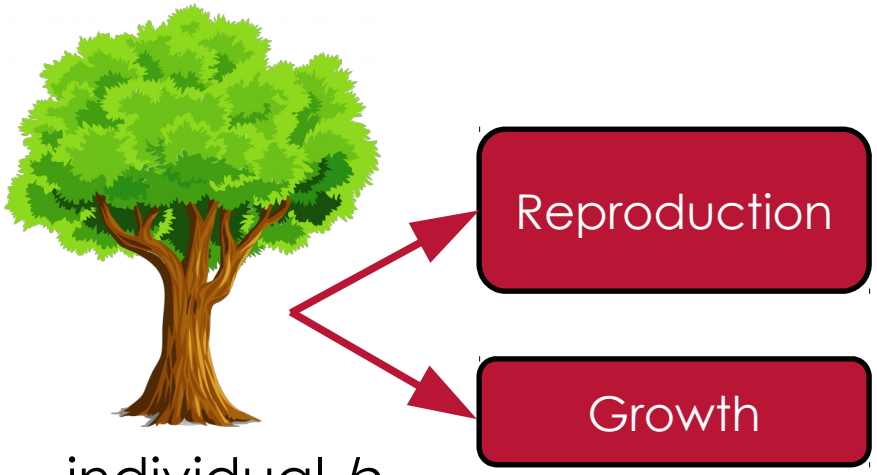
Reznick, 1983
Adapted from Cody 1966

How to measure trade-off between growth and reproduction ?



individual *a*

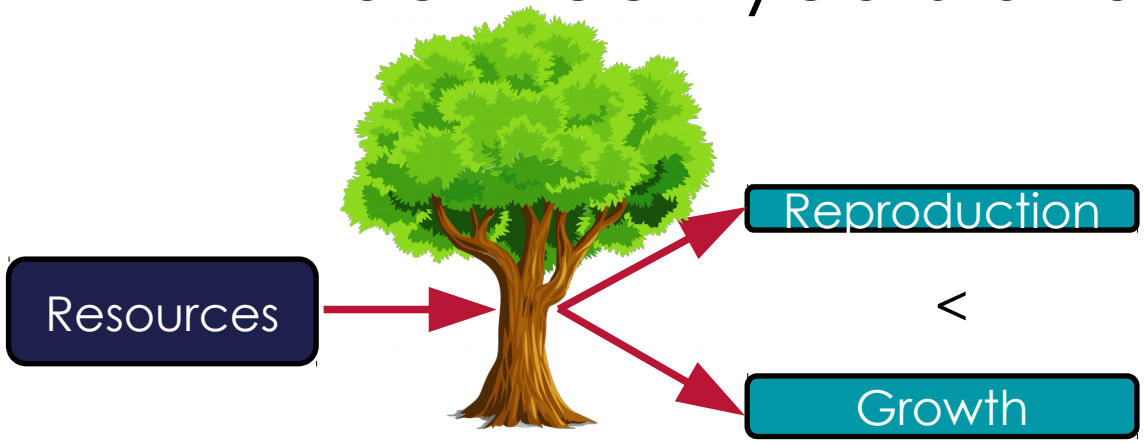




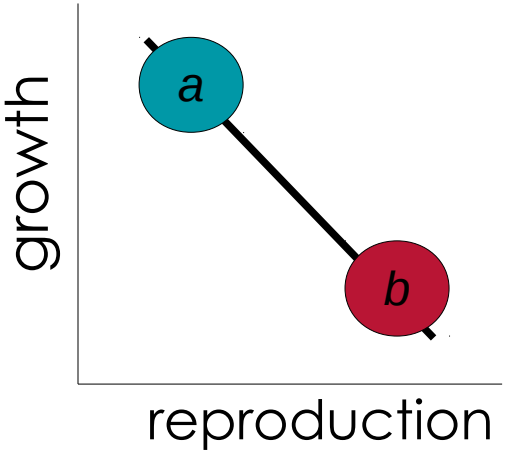
individual *b*

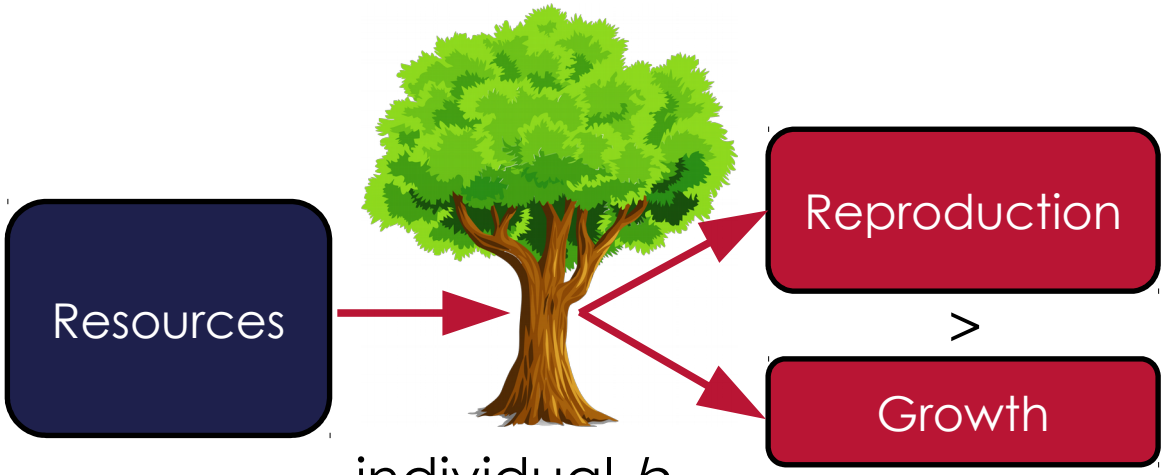
(Reznick, 1985; Reznick et al., 2000; Roff, 2000)

Difficulties to estimate resources … variation between years and individuals



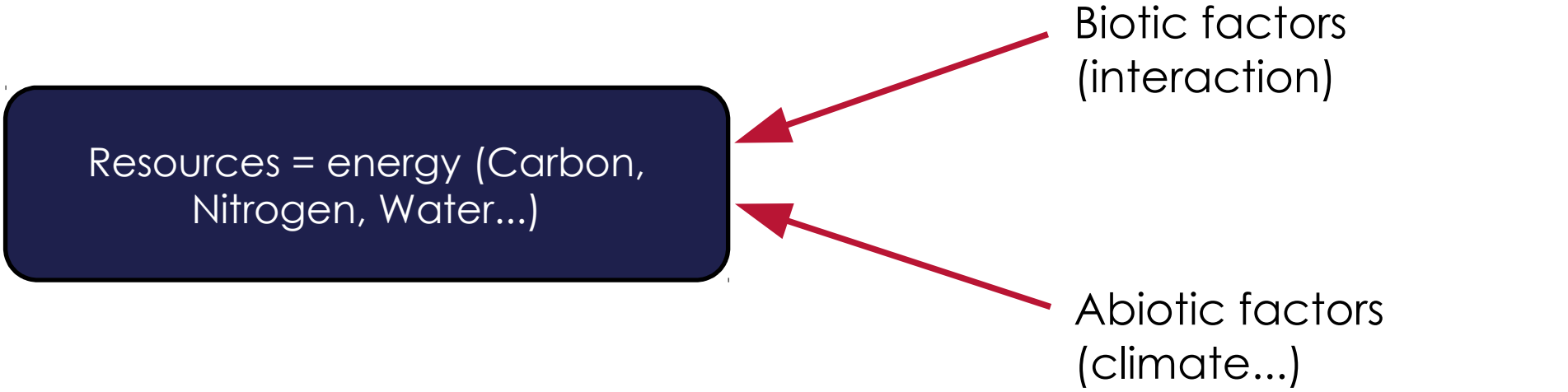
individual *a*





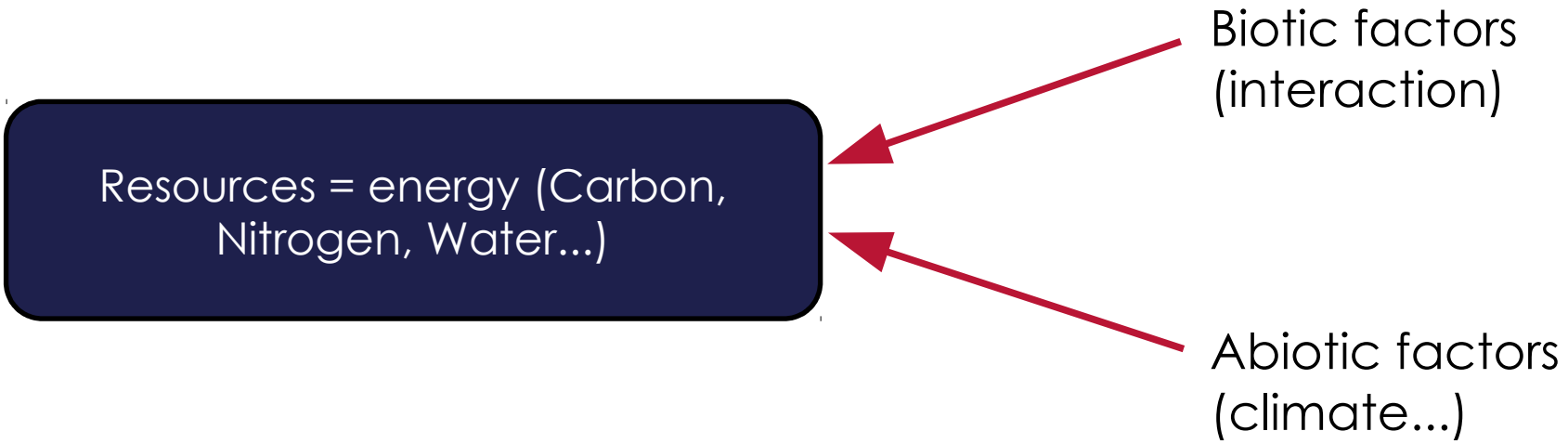
individual *b*

Need to integrate physiology

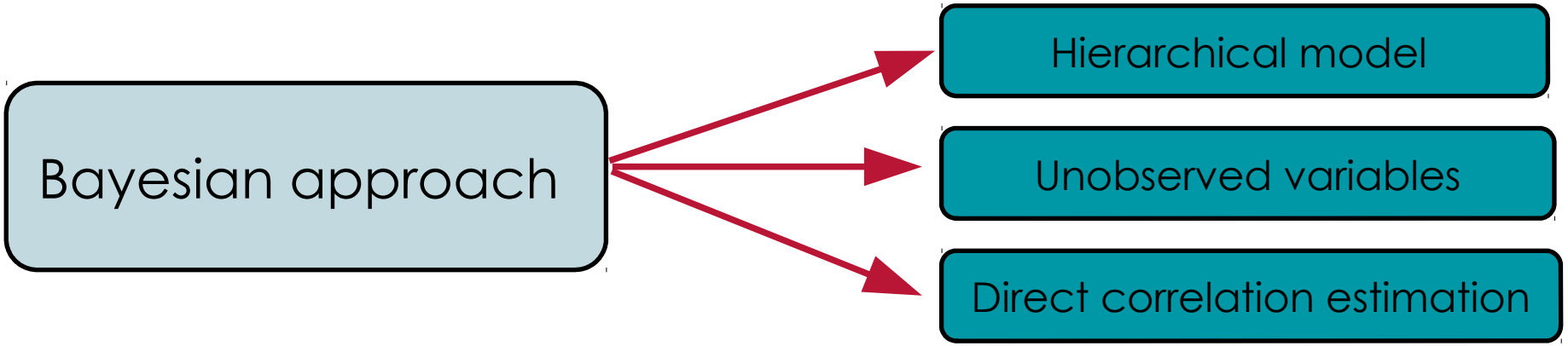


Stearns, 1989; Zera & Harshman, 2001

Context



Stearns, 1989; Zera & Harshman, 2001



Roff & Fairbairn, 2007; Worley et al., 2003

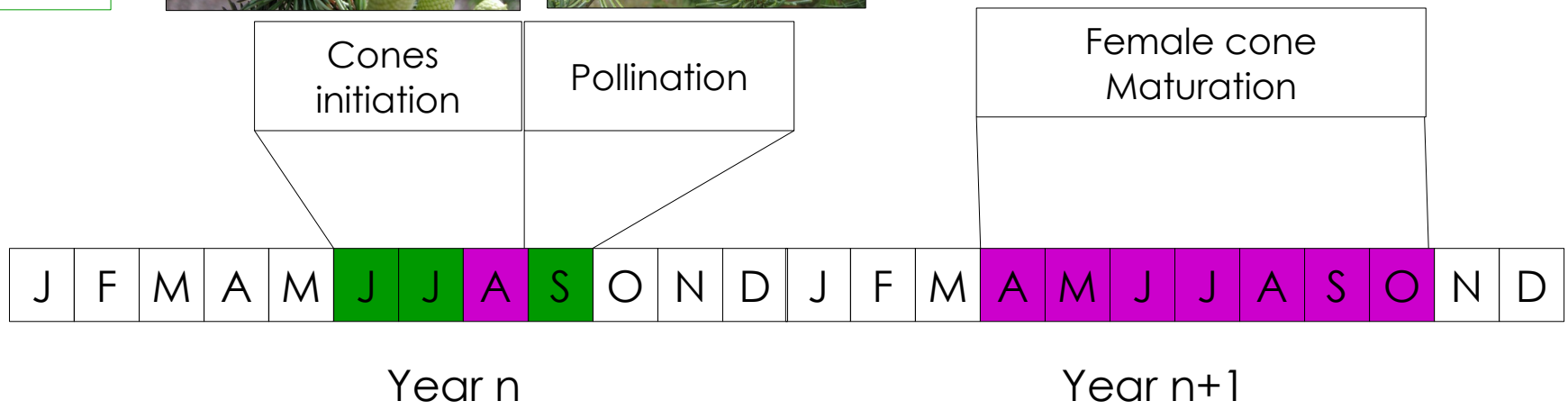
Material and Methods

- The species : *Cedrus atlantica*
- Conifer

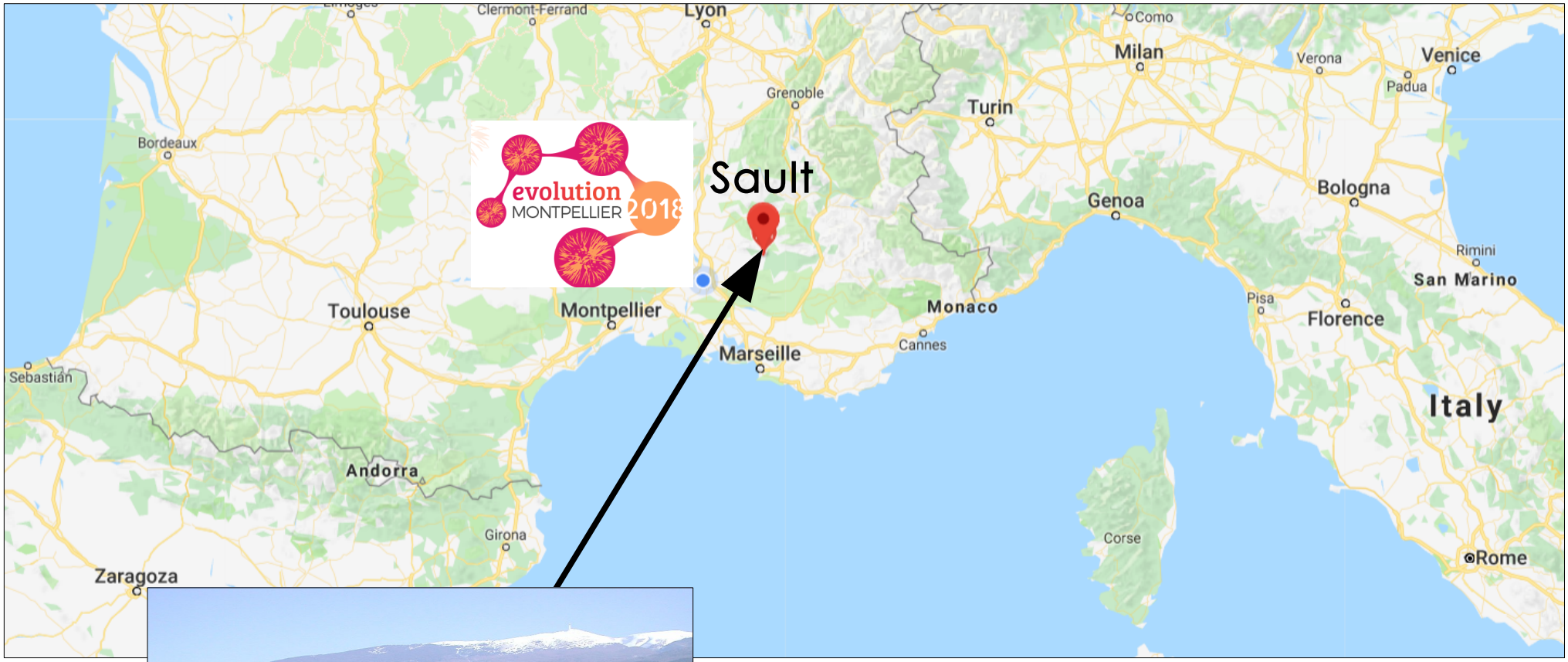
Patterns of resource allocation during reproduction

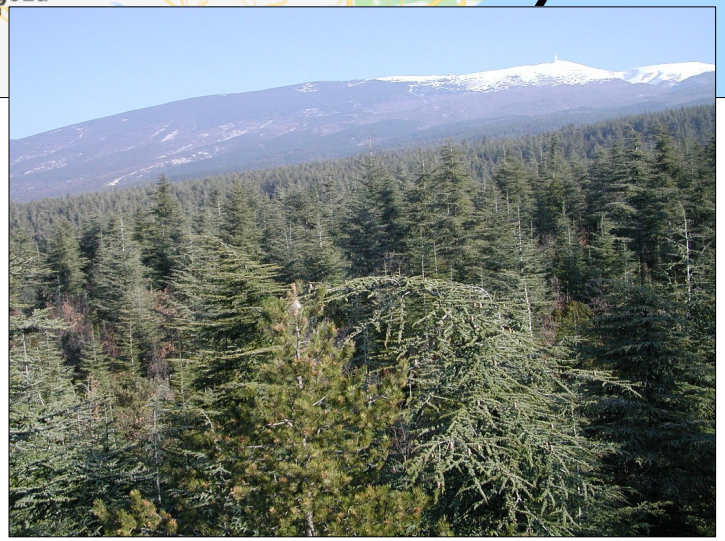
Female reproduction ♀

Male reproduction ♂

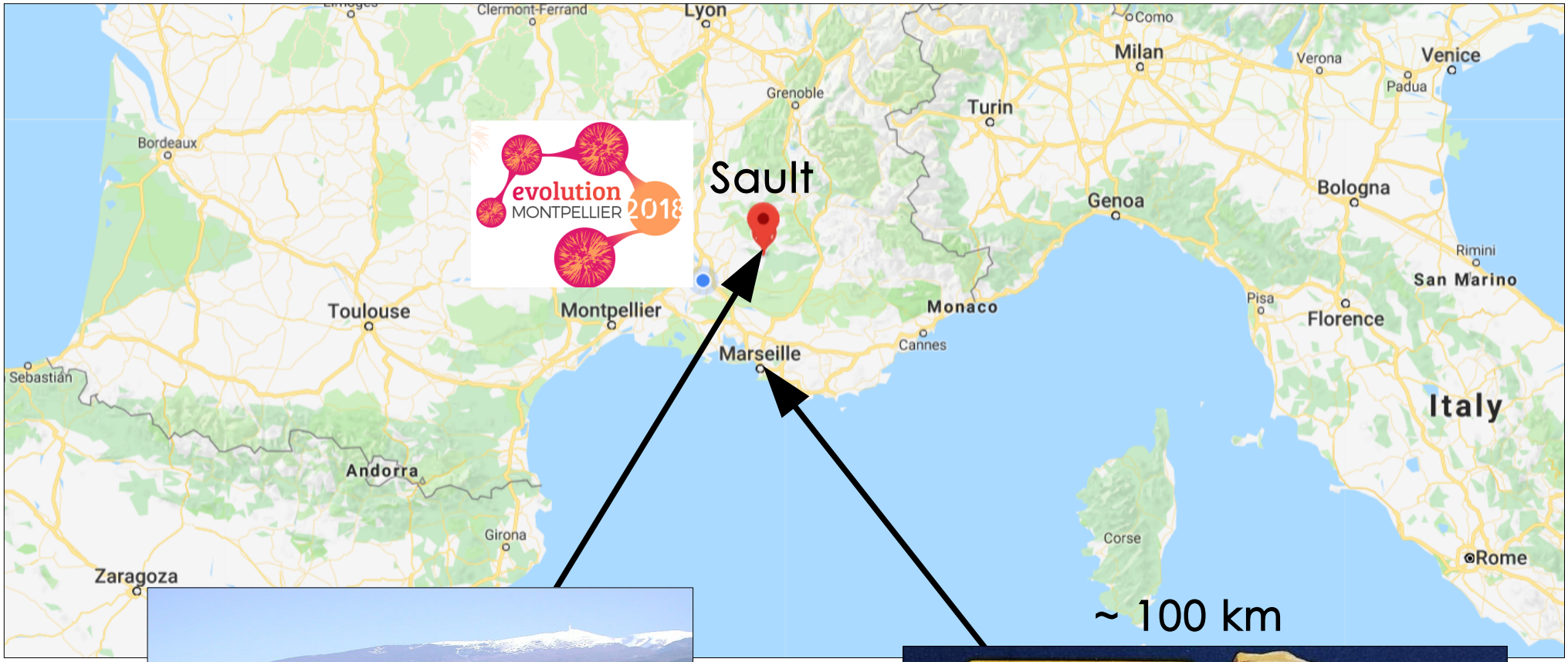


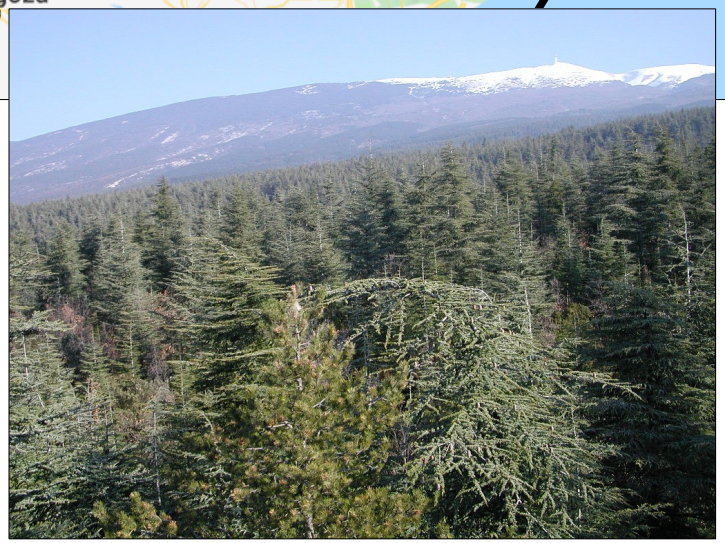
Material and Methods





Material and Methods





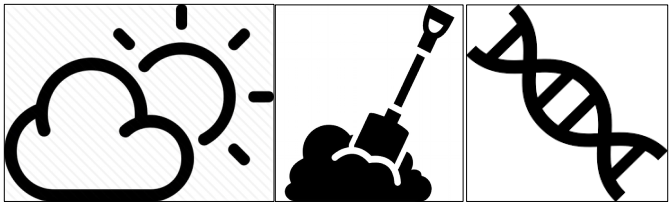
*Boy ! A Marseillaise-style RICARD

Material and Methods

Plantation with two density populations

250 stems/ha = low density

1200 stems/ha = high density



Even aged populations !

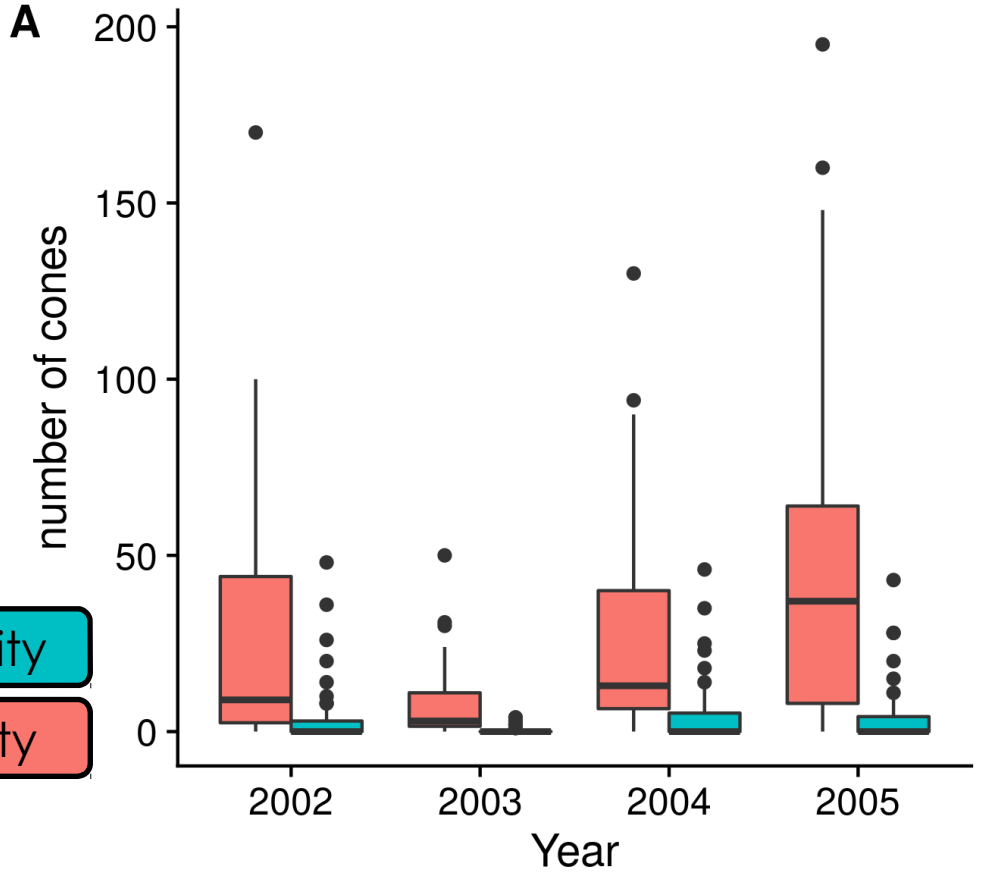
Material and Methods

Observation during 4 years

Female cones quantity

high density

low density



Material and Methods

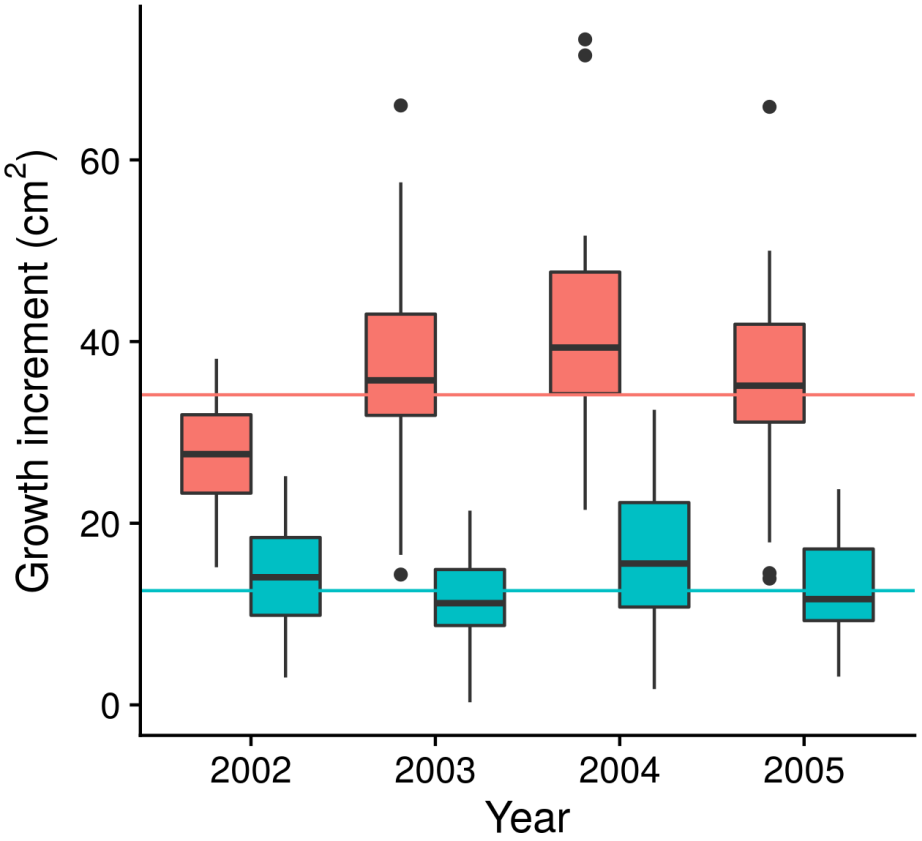
Observation during 4 years

Female cones quantity

Male pollen index

Material and Methods

Observation during 4 years



Growth increment

high density

low density

Material and Methods

Observation during 4 years

Female cones quantity

Male pollen index

Growth increment

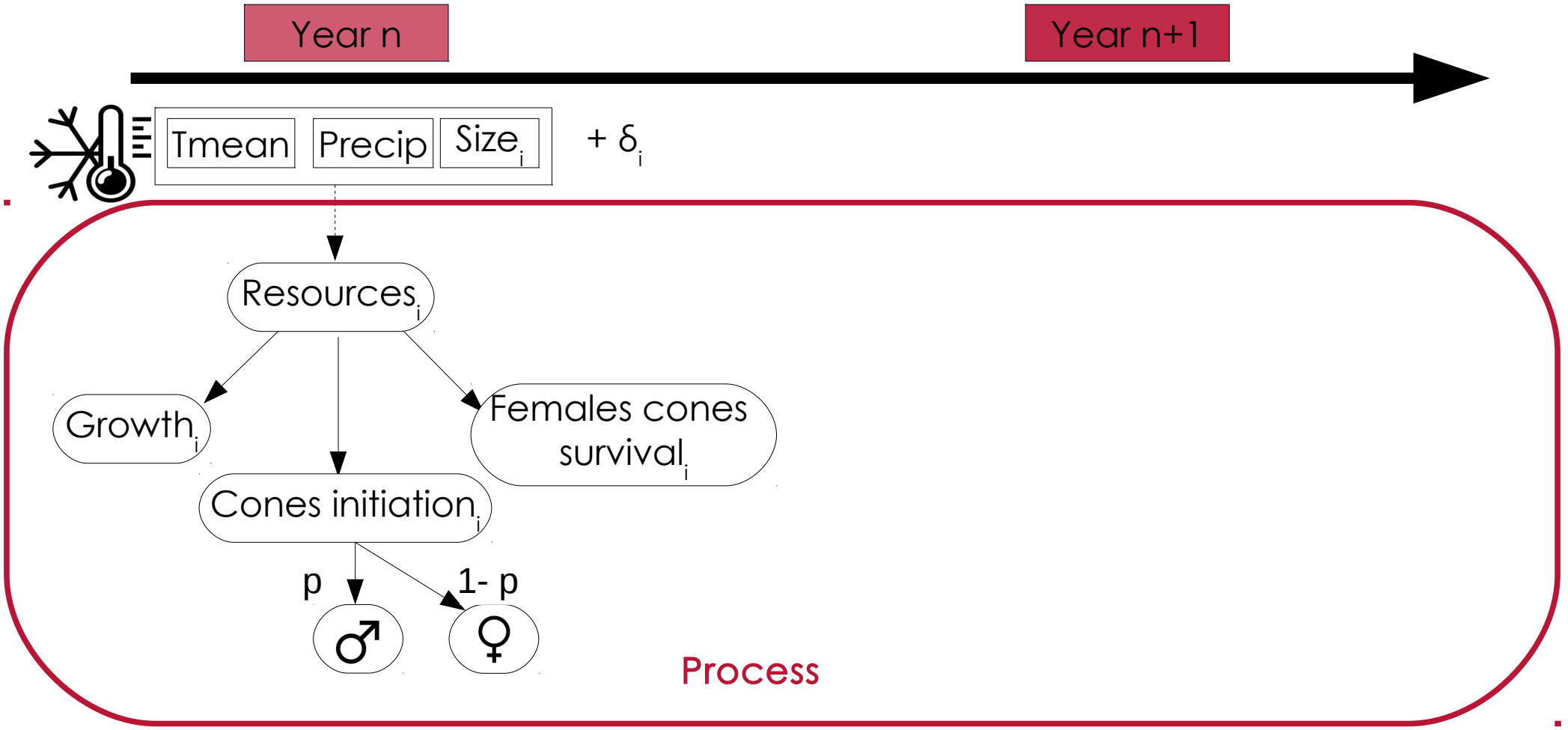
Reproduction

Growth

Material and Methods

Process

Material and Methods



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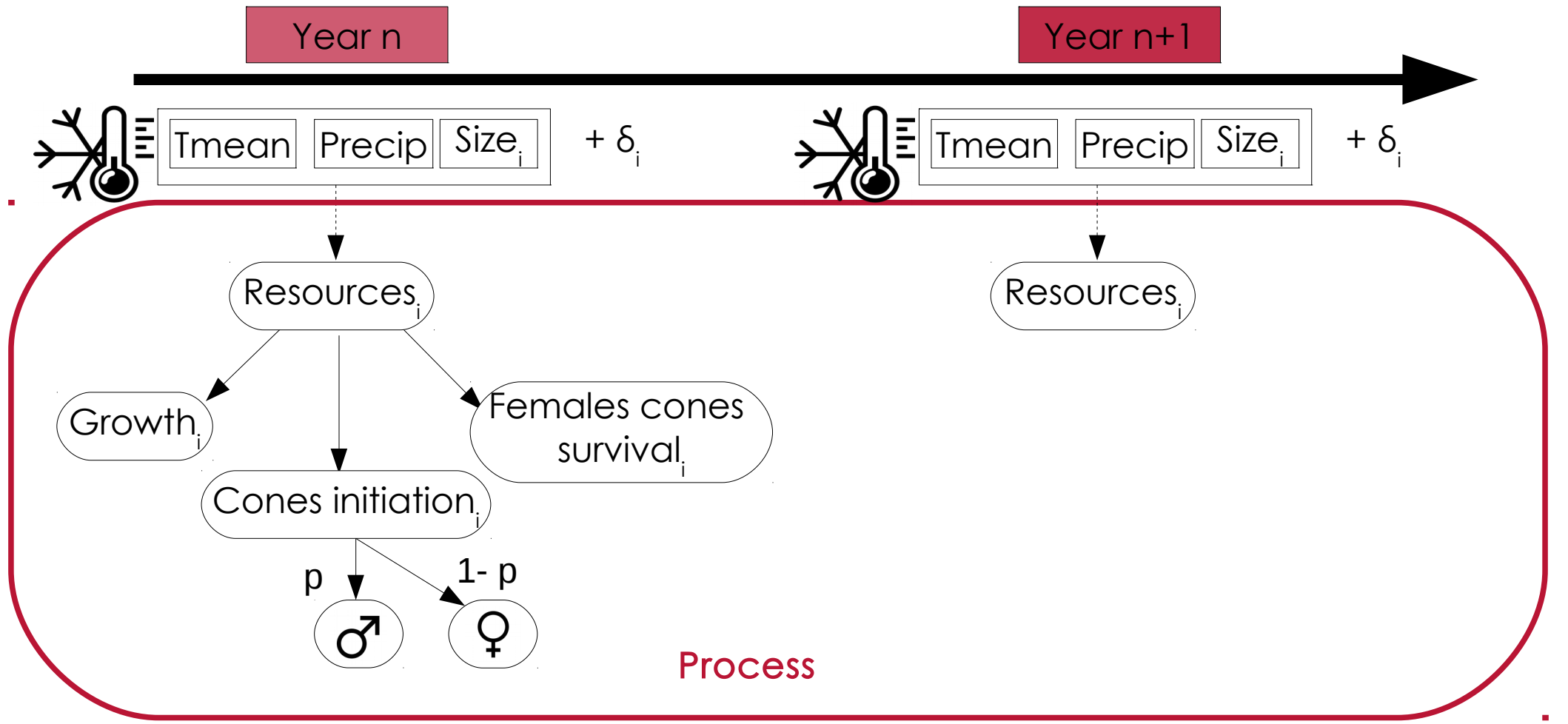
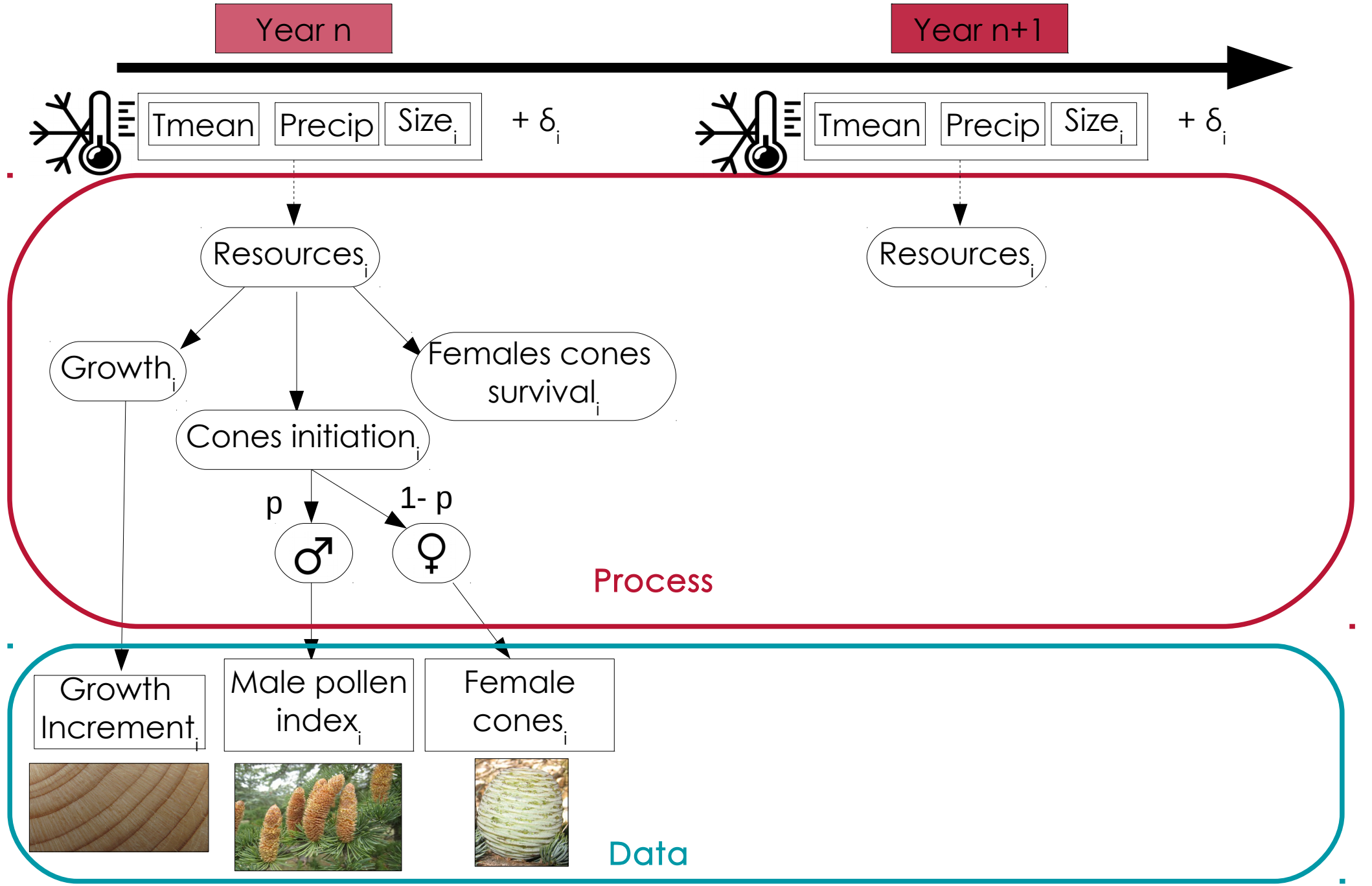
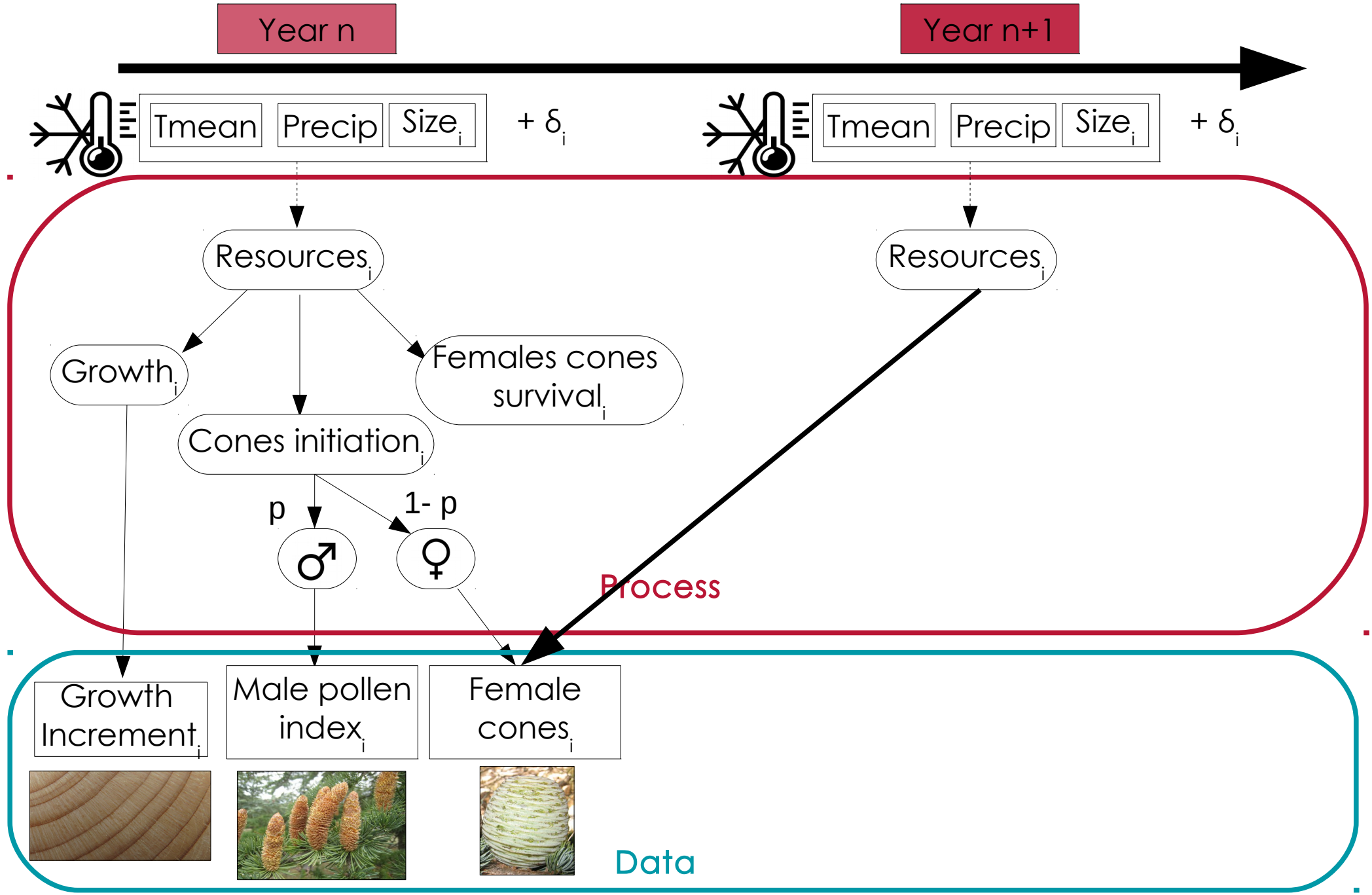


Material and Methods



Material and Methods



Material and Methods

Allocation of resources to 3 energetic sinks

- $Growth_{i,n} = \gamma * Resources_{i,n} + \varepsilon_{1,i}$
- $Cones\ Initiated_{i,n} = X_{i,n} * (\beta_1 * Resources_{i,n} + \varepsilon_{2,i})$
- $Females\ cones\ survival_{i,n} = \beta_0 + \beta_2 * Resources_{i,n} + \varepsilon_{3,i}$

X: Probability to reproduce

ε: Residual term

Estimation of trade-off

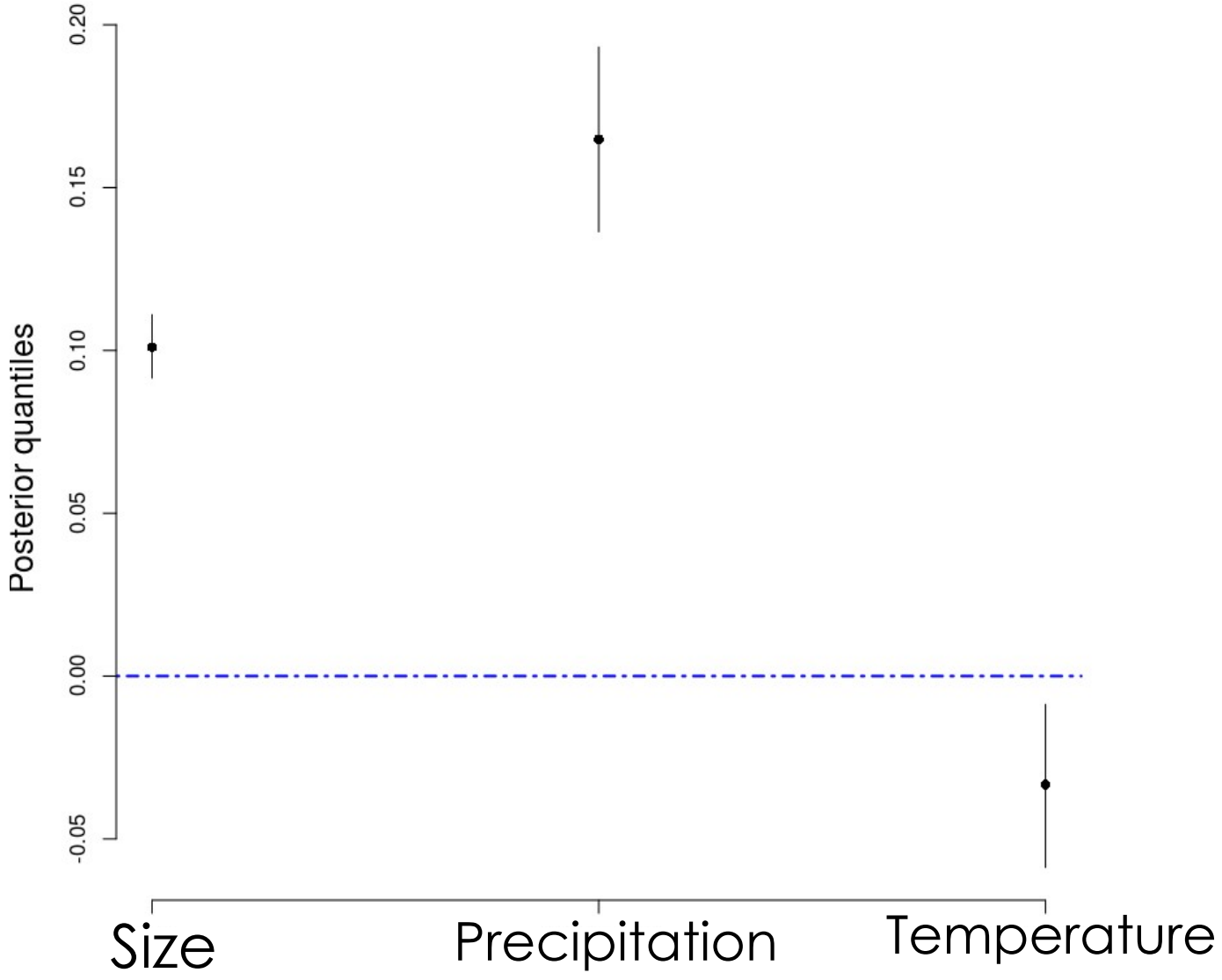
$$\begin{pmatrix} \varepsilon_{1,i} \\ \varepsilon_{2,i} \\ \varepsilon_{3,i} \end{pmatrix} \sim \text{Multivariate Normal } (0, \Sigma)$$

$$\begin{pmatrix} \sigma_{1,1} & \cdots & \cdots \\ \sigma_{1,2} & \sigma_{2,2} & \cdots \\ \sigma_{1,3} & \sigma_{2,3} & \sigma_{3,3} \end{pmatrix}$$

Define correlation coefficient

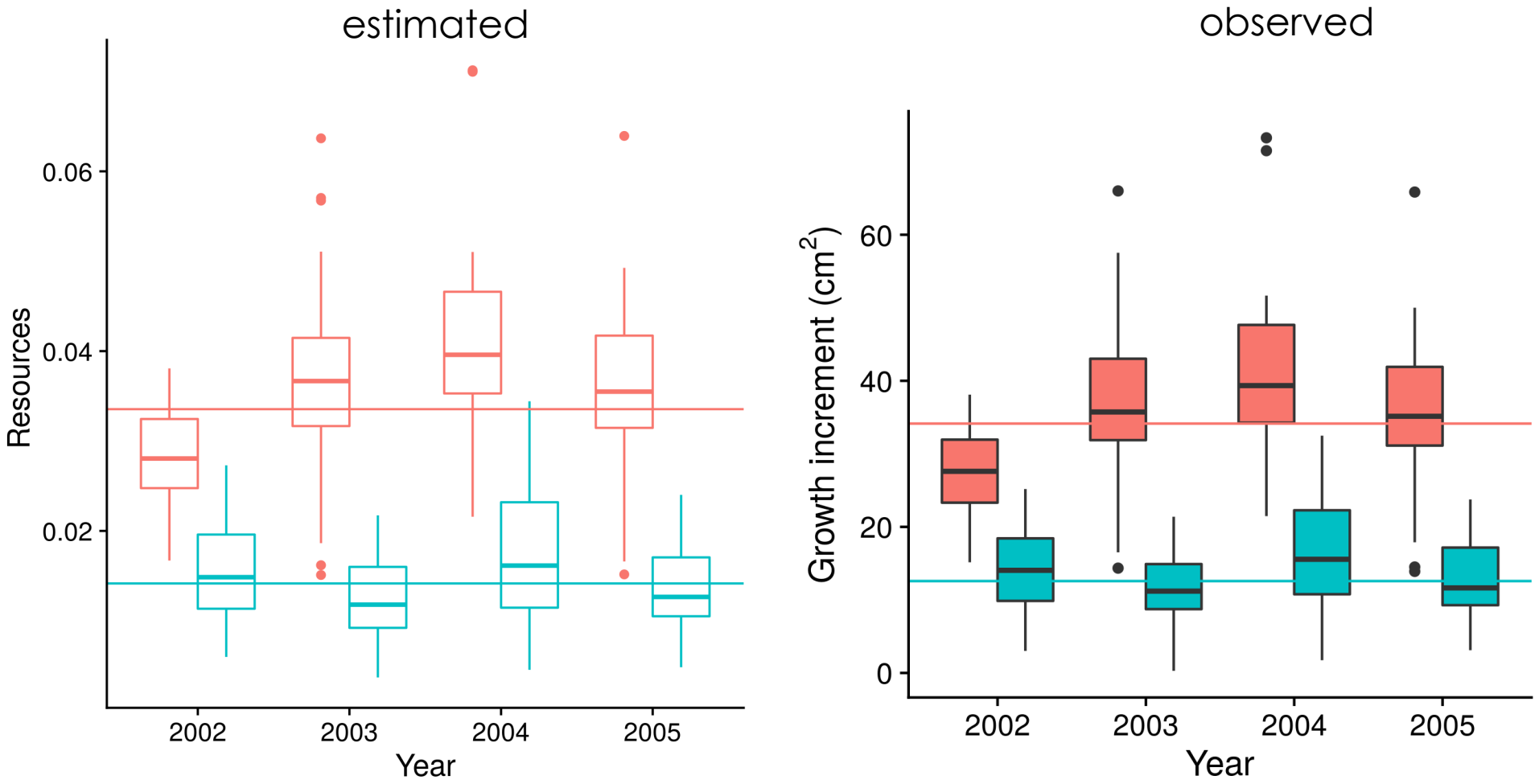
$$\rho_{x,y} = \frac{\sigma_{x,y}}{\sigma_{x,x} * \sigma_{y,x}}$$

Effects of Climate and Size on resources



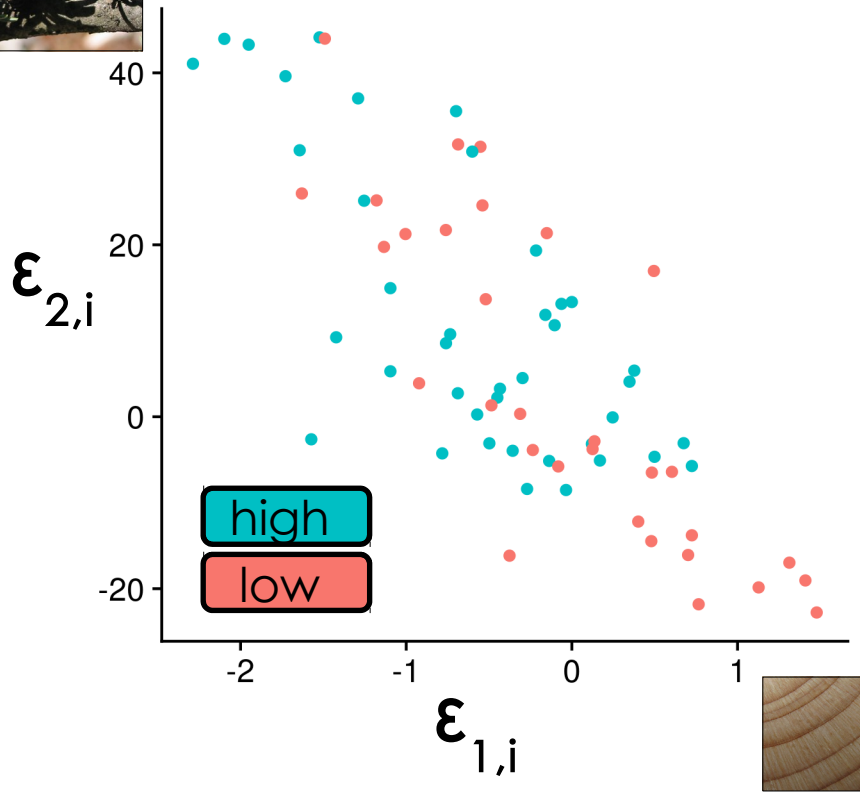
Results

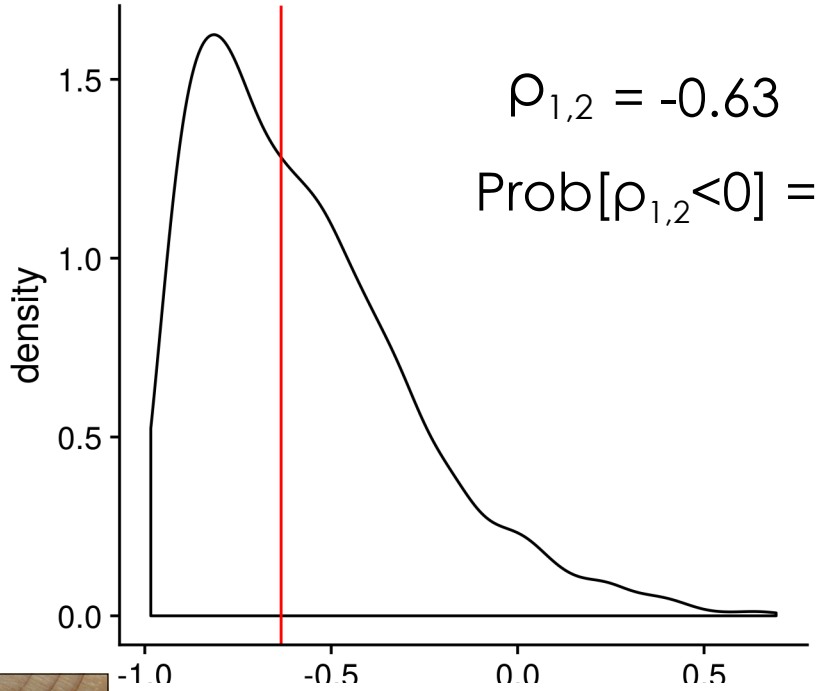
Resources vary among years and competition levels



Results

Negative correlation between Growth and Cones initiated

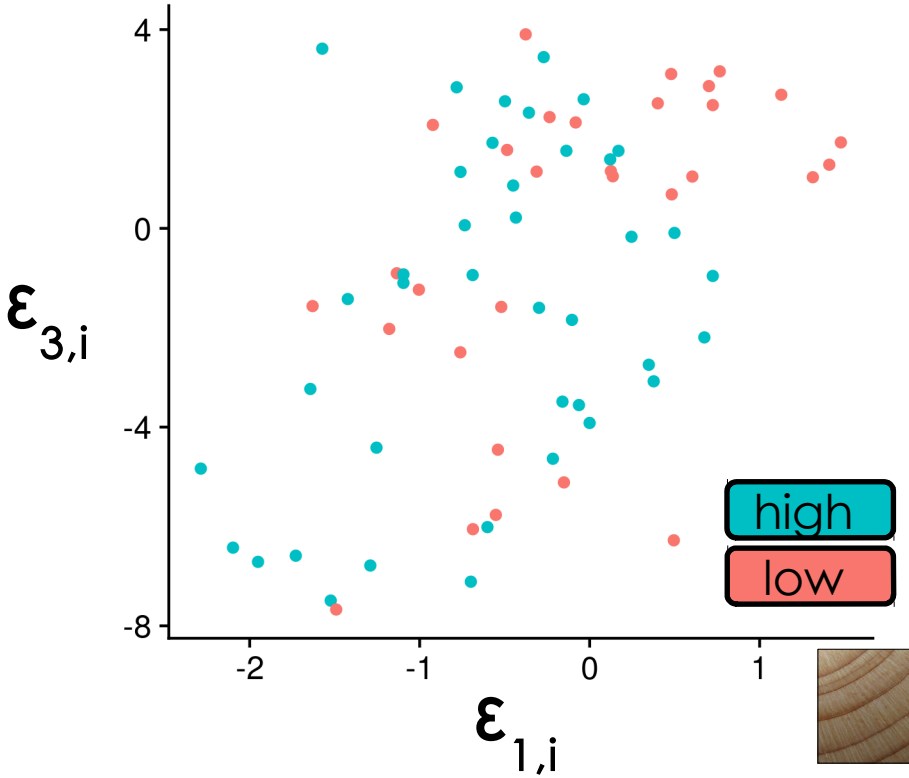


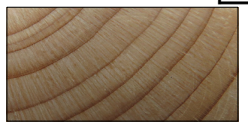


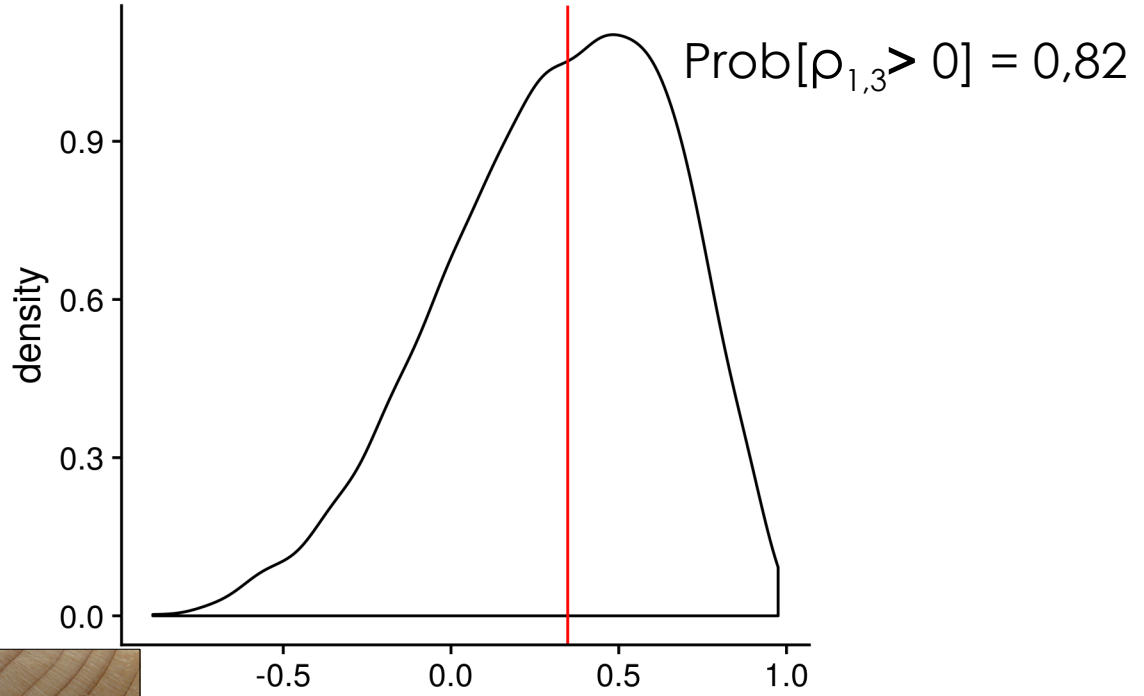
- Growth$_{i,n}$ = γ * Resources$_{i,n}$ + $\varepsilon_{1,i}$
- Cones Initiated$_{i,n}$ = X$_{i,n}$ * (β_1 * Resources$_{i,n}$ + $\varepsilon_{2,i}$)

Results

Positive correlation between Growth and Female cones survival



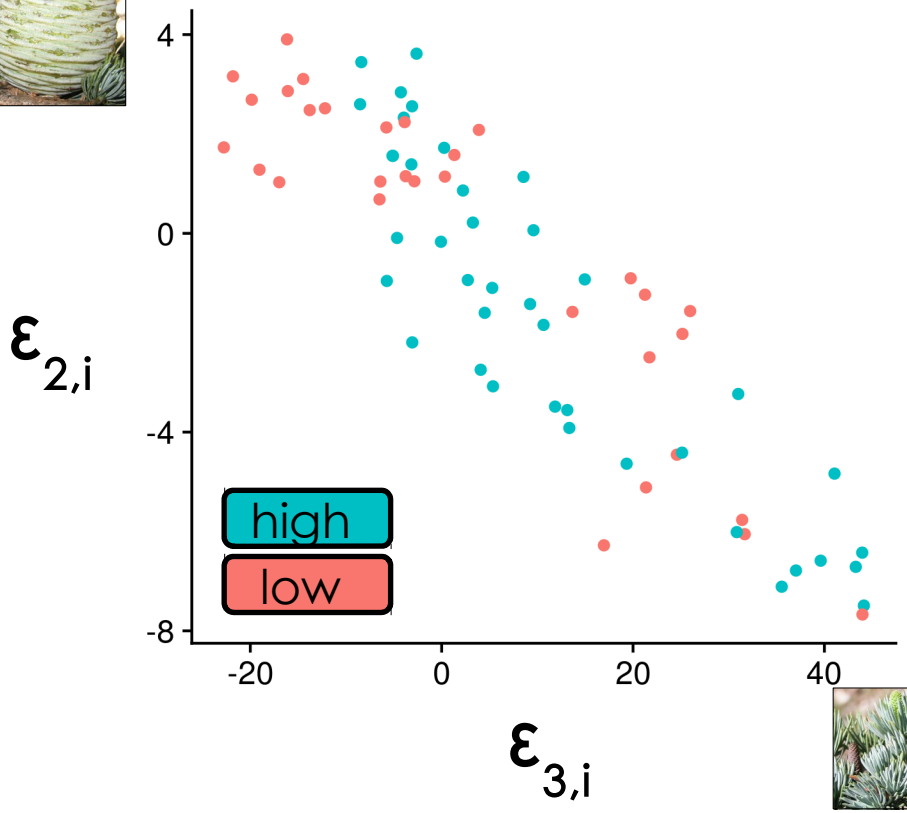


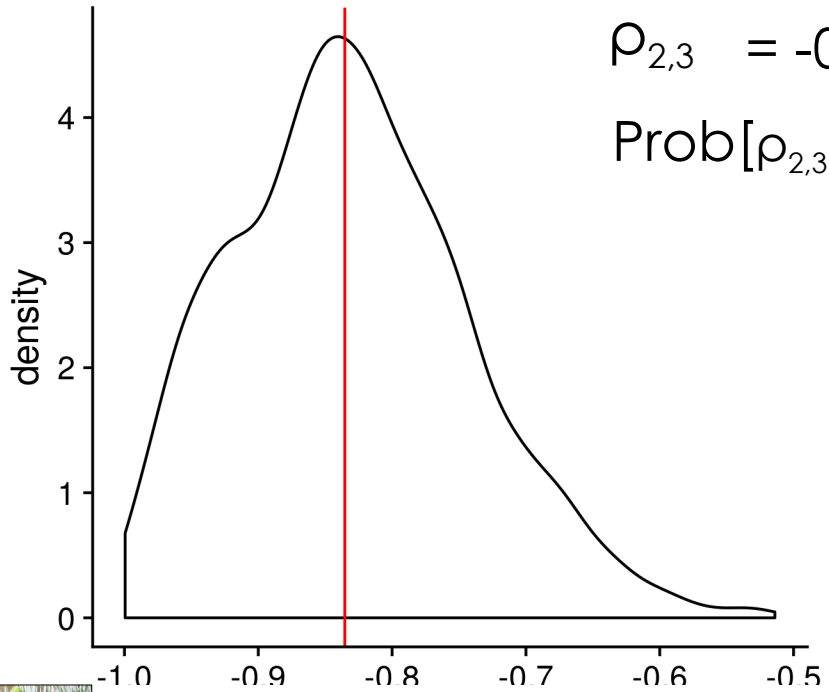


- $Growth_{i,n} = \gamma * Resources_{i,n} + \varepsilon_{1,i}$
- $Females\ cones\ survival_{i,n} = \beta_0 + \beta_2 * Resources_{i,n} + \varepsilon_{3,i}$

Results

Negative correlation between Cones initiated and Female cones survival





$\rho_{2,3} = -0.84$

$Prob[\rho_{2,3} < 0] = 1$

- $Cones\ Initiated_{i,n} = X_{i,n} * (\beta_1 * Resources_{i,n} + \varepsilon_{2,i})$
- $Females\ cones\ survival_{i,n} = \beta_0 + \beta_2 * Resources_{i,n} + \varepsilon_{3,i}$

Discussion

1) Clear trade-off between growth and reproduction at initial stage (**negative** correlation)

2) Positive variation of growth and cone survival (**positive** correlation)

3) Current year of reproduction impact future reproduction (**negative** correlation)

Discussion

1) Clear trade-off between growth and reproduction at initial stage (**negative** correlation)

2) Positive variation of growth and cone survival (**positive** correlation)

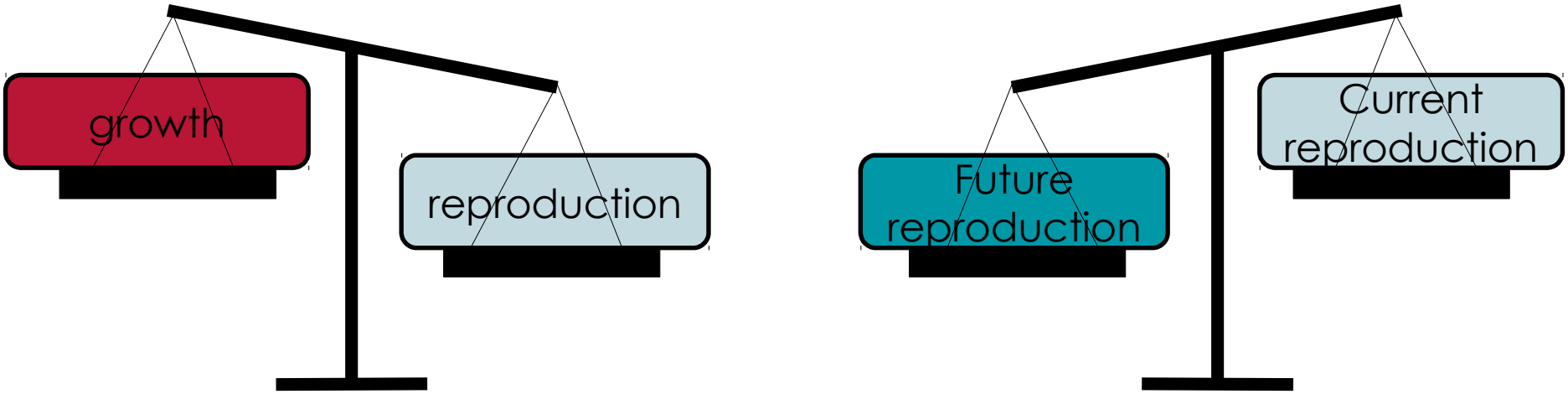
3) Current year of reproduction impact future reproduction (**negative** correlation)

- Same trend for both populations: density did not impact all three relations identified

Discussion

Why trees produces variable quantities of seeds?

Several hypothesis exists (e.g. resource matching, resources switching...) (Kelly & Sork, 2002; Pearse et al, 2016)



Not only one hypothesis

Discussion

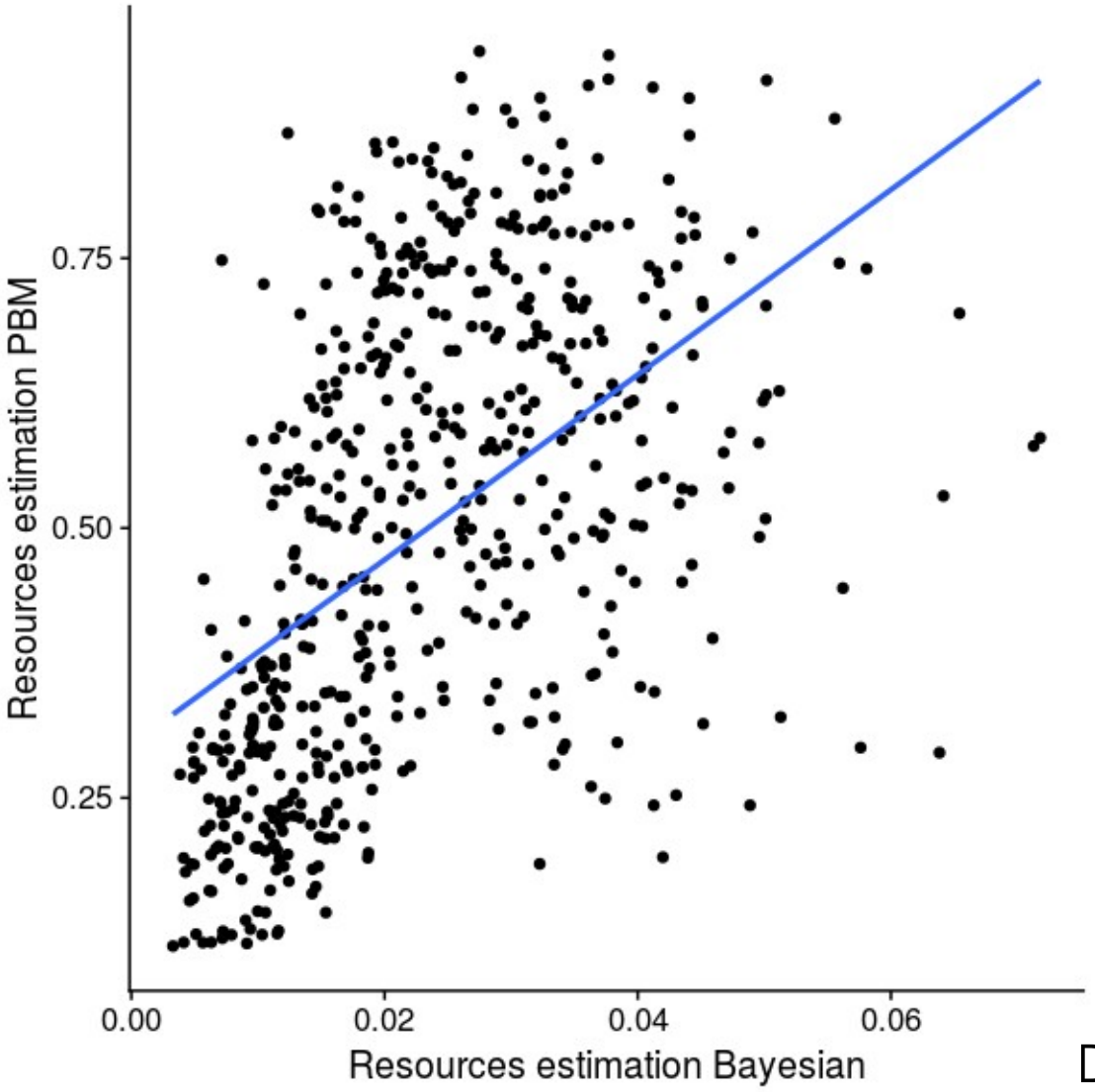
- Evolution is needed to understand ecological phenomenon : Why trees produces variable quantities of seeds ?
- Mechanistic approach for trade-off investigation : a touch of physiology allows a better understanding of evolution

Discussion

Variation of resources : depending of climate, tree size and density

- Growth Increment drives the level of resources
- How to simulate resources?
- Integration of more physiological process?

Comparison of resources estimated with an ecophysiological model



Dufrêne et al., 2005

- We combined **physiology** and **evolution**

- We found evidence for growth-reproduction **trade-offs** in trees

More information ?

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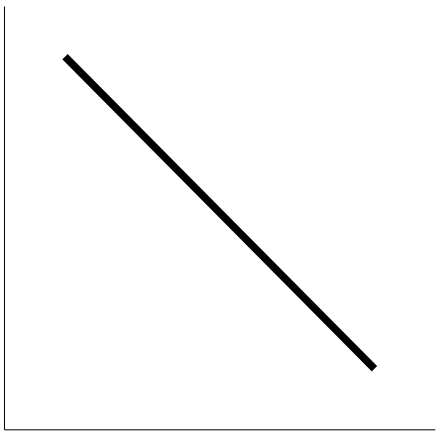

@Valentin_Journe

Supp

- Initialized Males $cones_{i,t}$ = Phenotypic $gender_{i,t}$ * Initialized $cones_{i,t}$
- Notations convert into Multinomial observation

$$\begin{cases} M_{i,t} = 0 \Rightarrow IMC_{i,t}^{\text{obs}} = [1,0,0,0,0] \\ M_{i,t} = 1 \Rightarrow IMC_{i,t}^{\text{obs}} = [0,1,0,0,0] \\ M_{i,t} = 2 \Rightarrow IMC_{i,t}^{\text{obs}} = [0,0,1,0,0] \\ M_{i,t} = 3 \Rightarrow IMC_{i,t}^{\text{obs}} = [0,0,0,1,0] \\ M_{i,t} = 4 \Rightarrow IMC_{i,t}^{\text{obs}} = [0,0,0,0,1] \end{cases}$$

Supp

- Initialized Males $cones_{i,t}$ = Phenotypic $gender_{i,t}$ * Initialized $cones_{i,t}$
- Notations convert into Multinomial observation
- Link Initialized Males cones (observed) to latent variable Initialized Males cones in the process model

Prior for correlation : inverse Wishart