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

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Wed, 22 August
S-69 Evolutionary Physiology

Trade-offs between growth and reproduction

Example with a long-lived plant

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Francois LEFÈVRE, Sylvie ODDOU-MURATORIO, Julien PAPAÏX

Acknowledgements

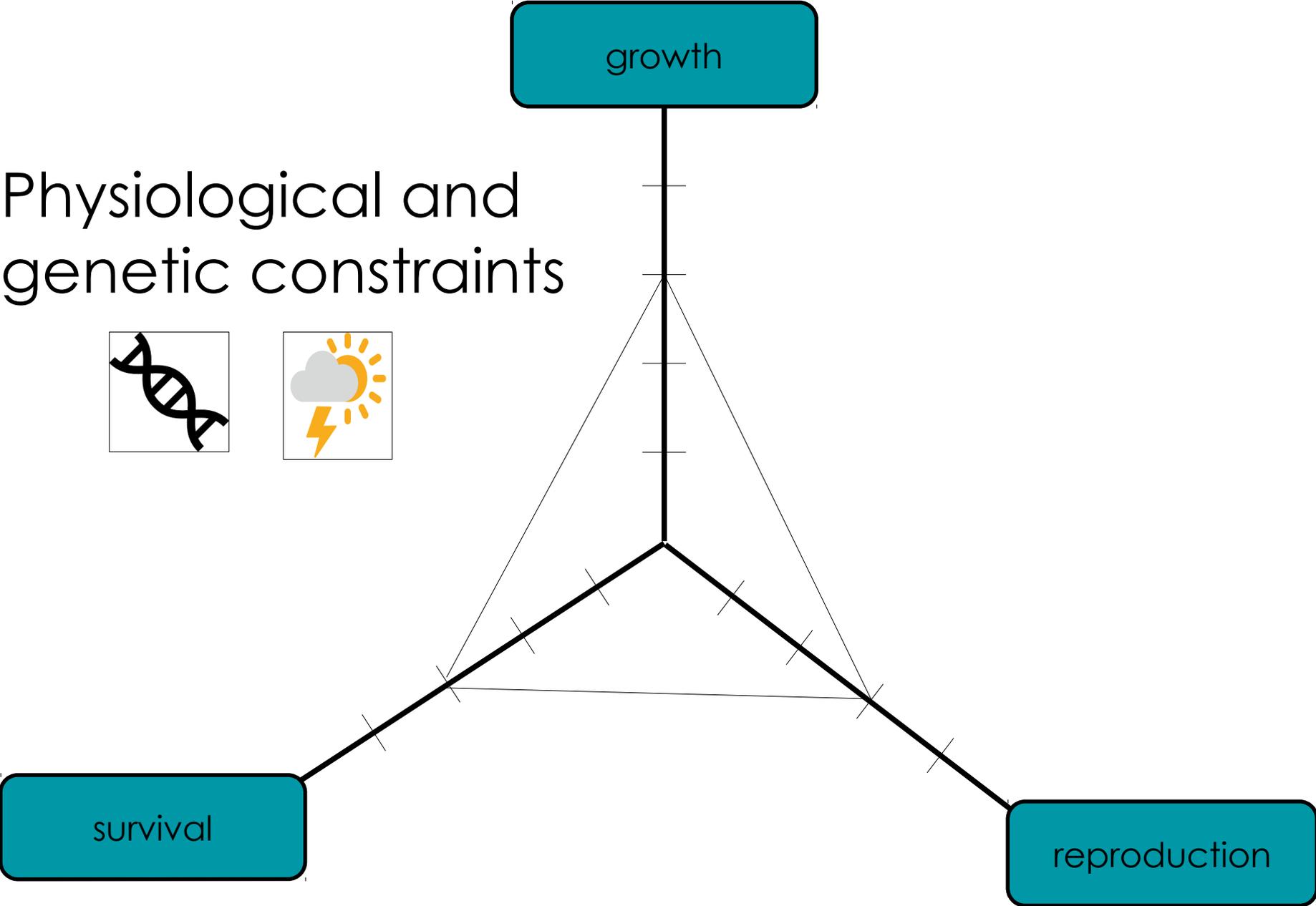
Funding:



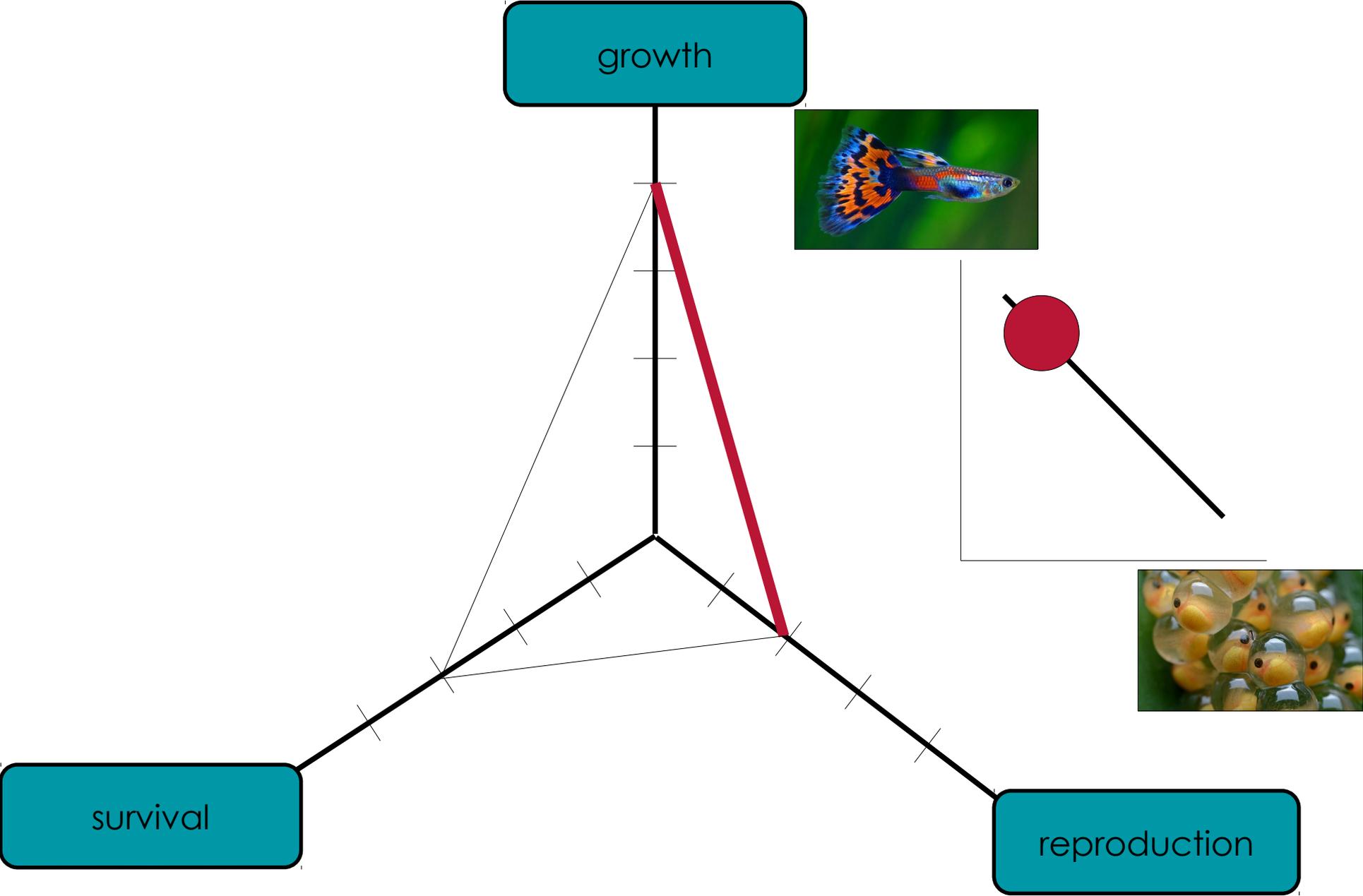
Collaborators:



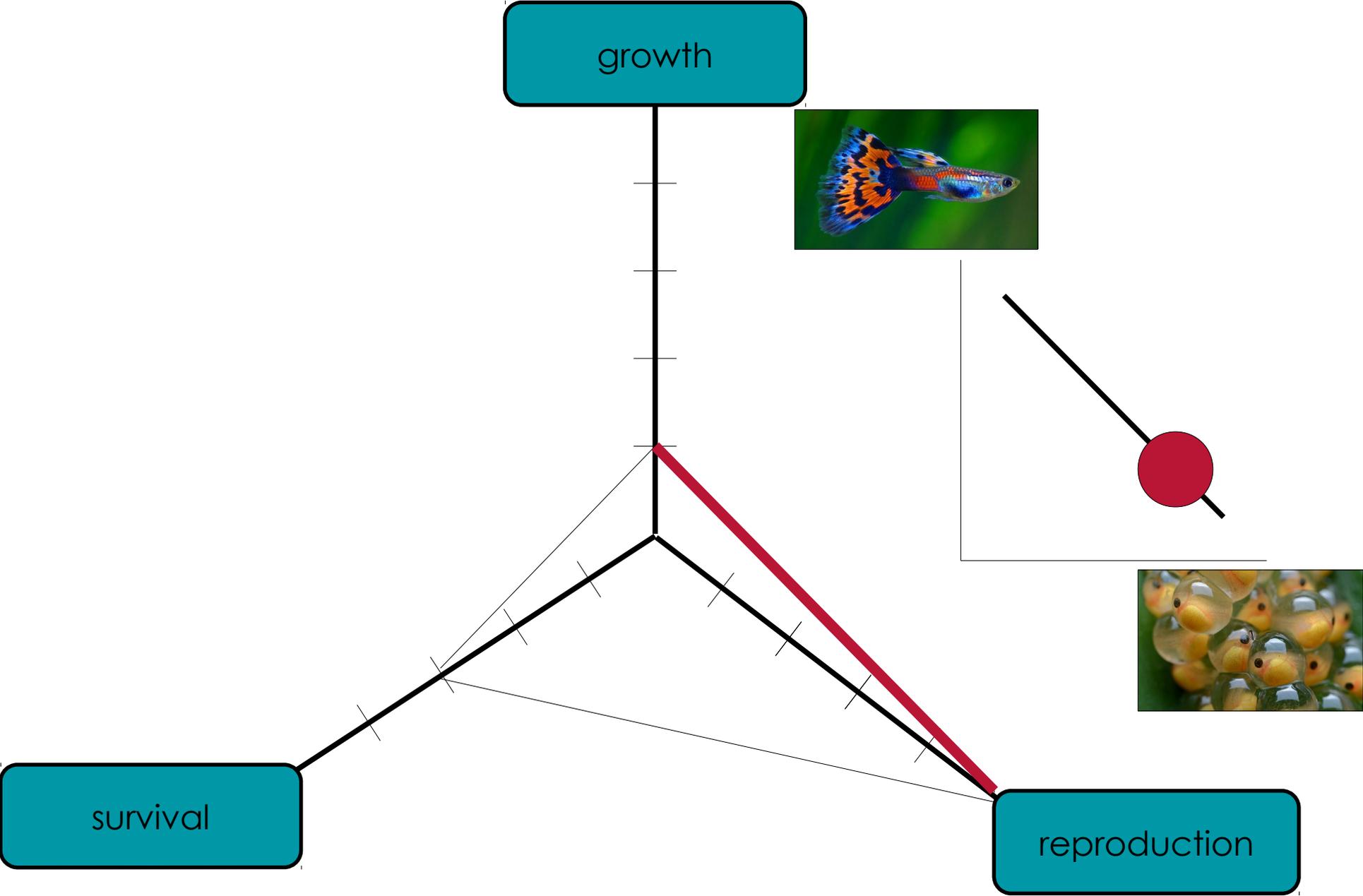
Physiological and genetic constraints



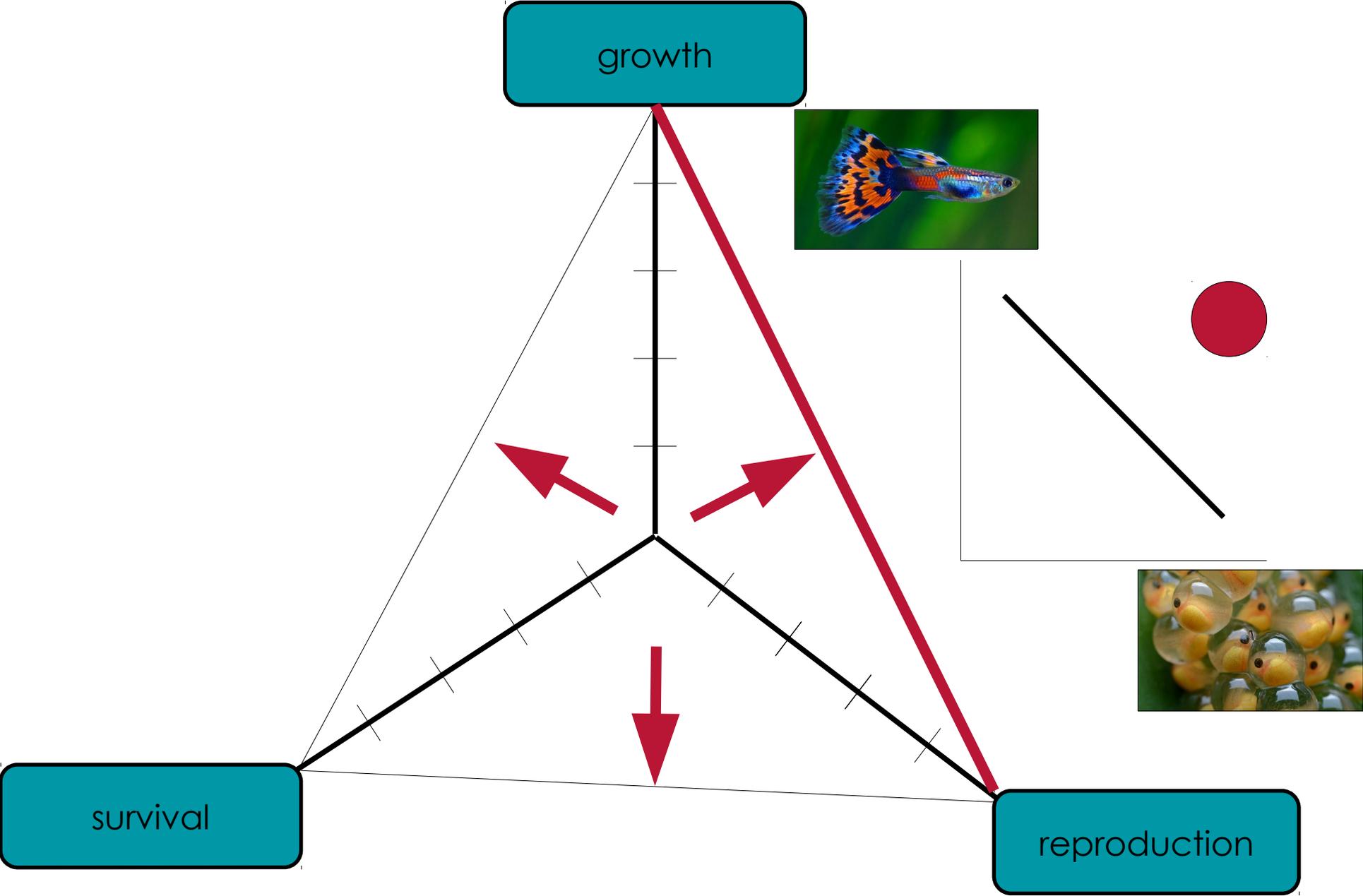
Context



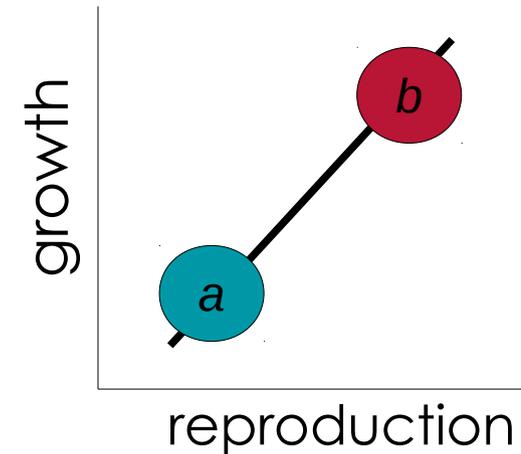
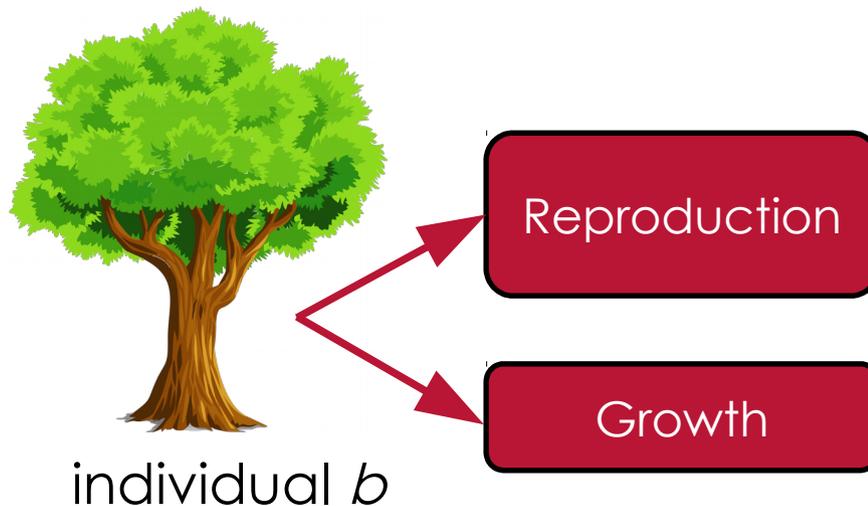
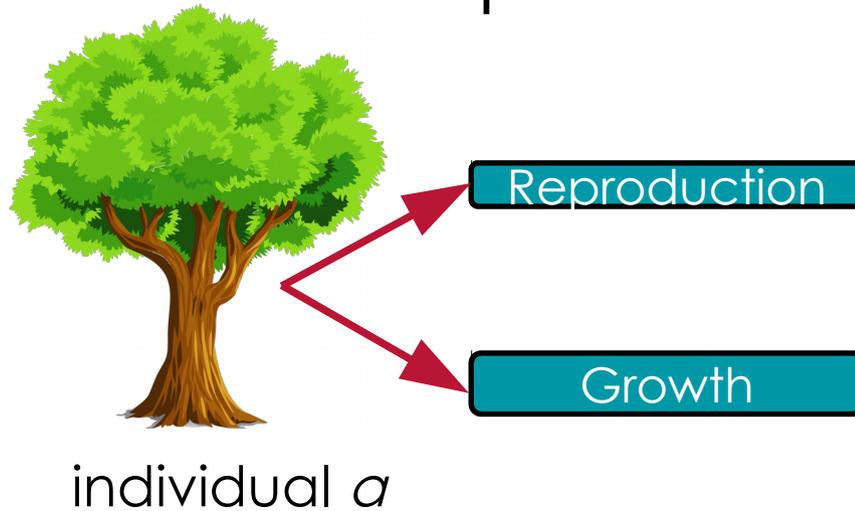
Context



Context

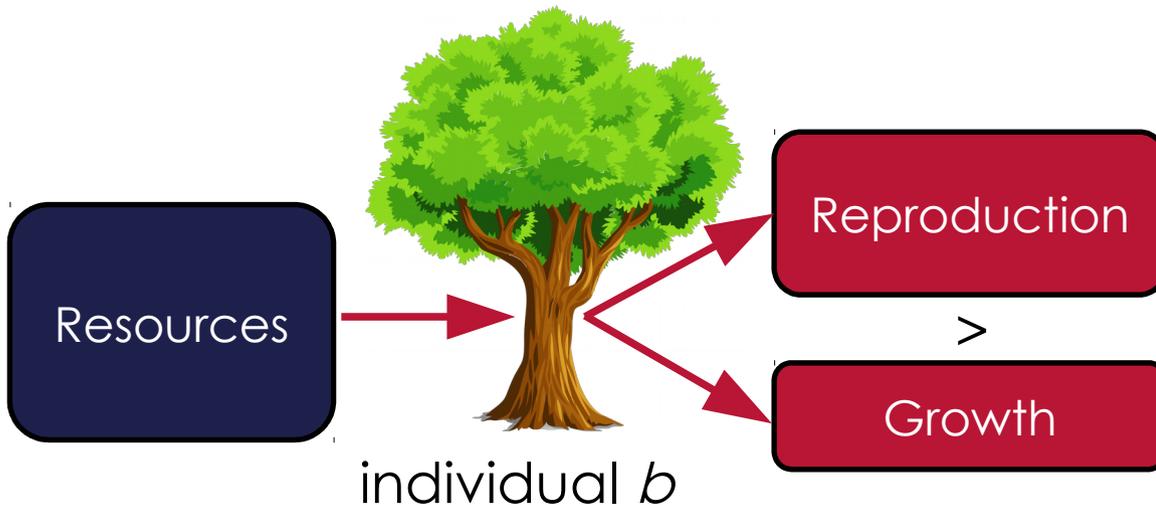
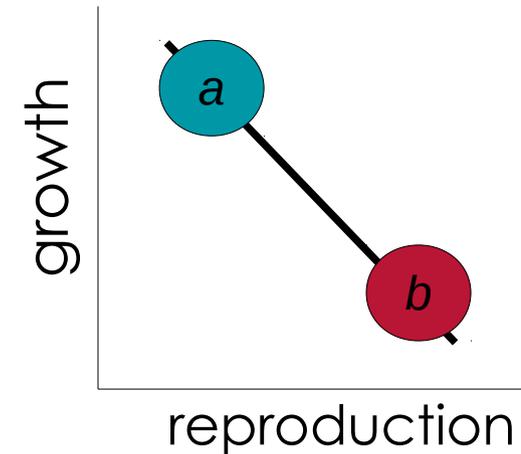
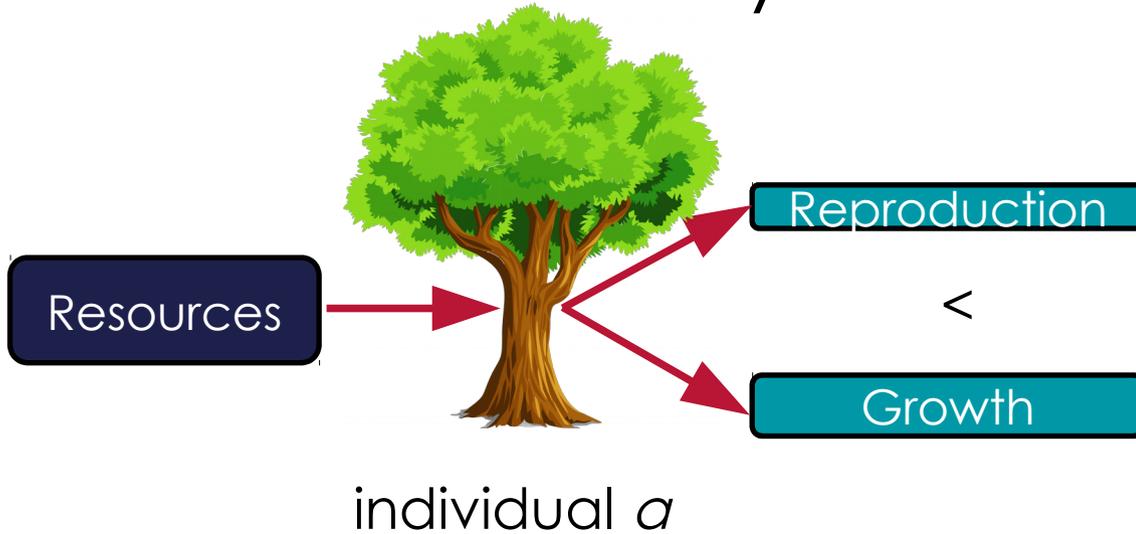


How to measure trade-off between growth and reproduction ?

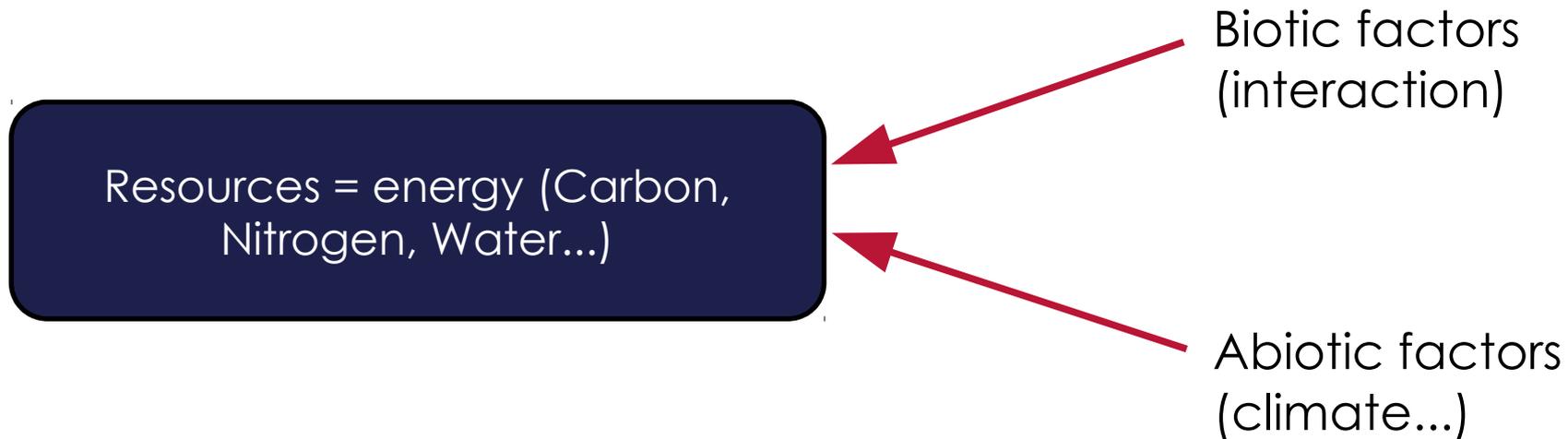


(Reznick, 1985; Reznick et al., 2000; Roff, 2000)

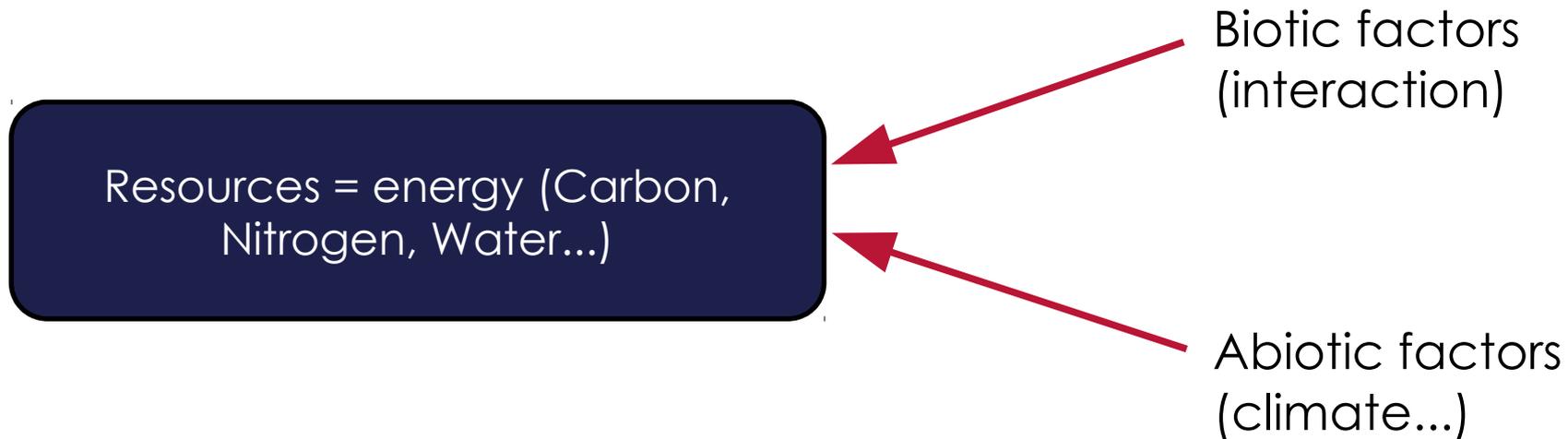
Difficulties to estimate resources ... variation between years and individuals



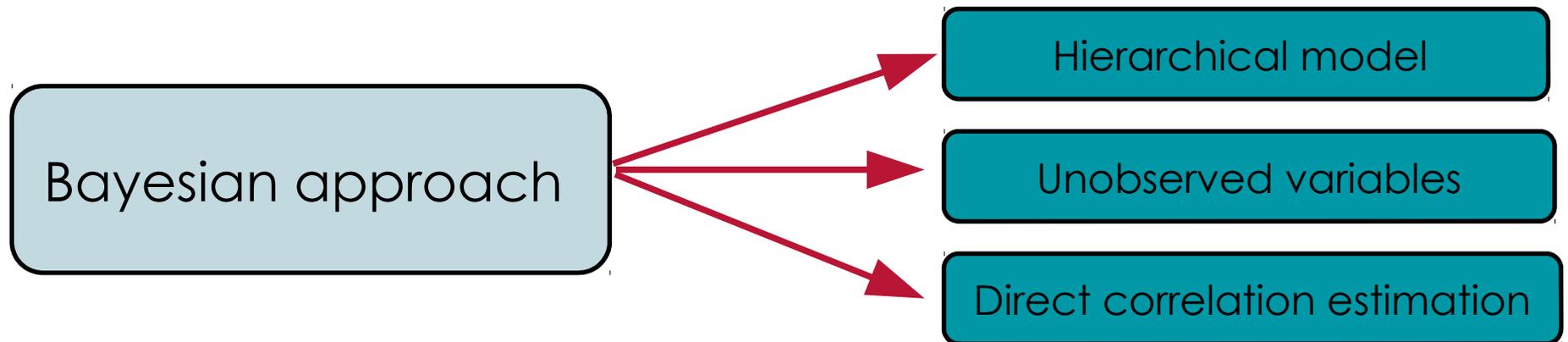
Need to integrate physiology



Stearns, 1989; Zera & Harshman, 2001



Stearns, 1989; Zera & Harshman, 2001



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

- The species :
Cedrus atlantica
- Conifer



Material and Methods

Patterns of resource allocation during reproduction

Female ♀
reproduction



Male ♂
reproduction



Cones initiation Pollination

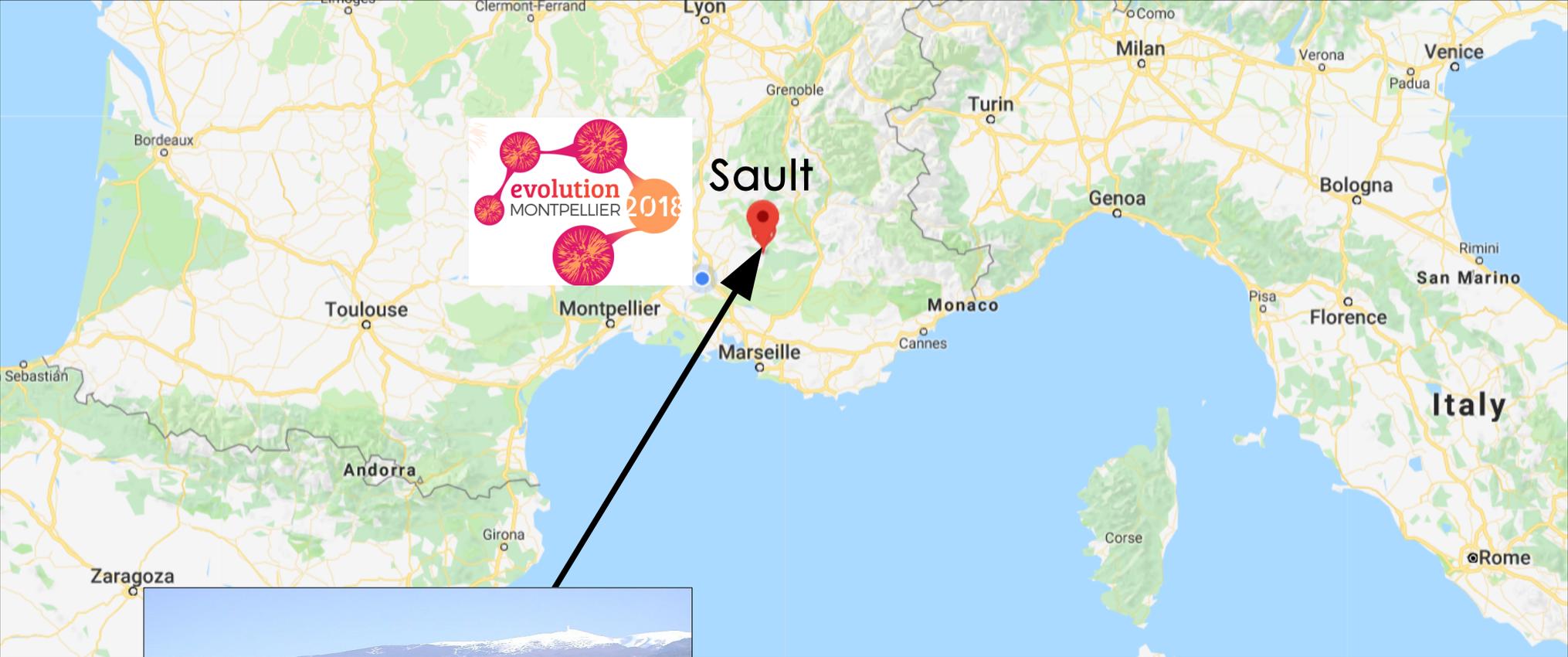
Female cone
Maturation



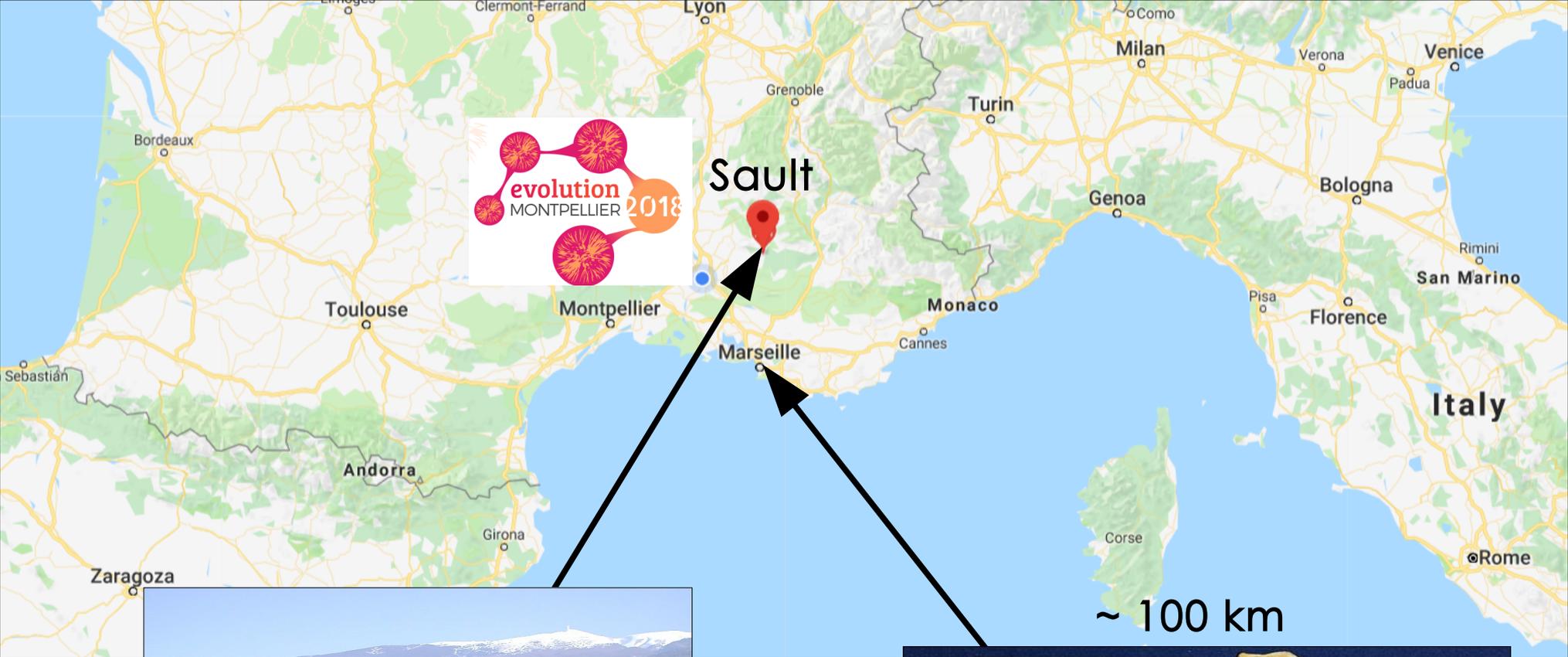
Year n

Year n+1

Material and Methods



Material and Methods



*Boy ! A Marseillaise-style RICARD

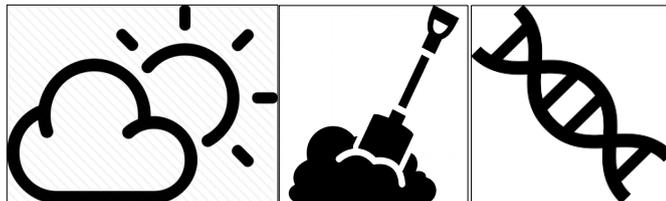
Plantation with two density populations



250 stems/ha = low density



1200 stems/ha = high density



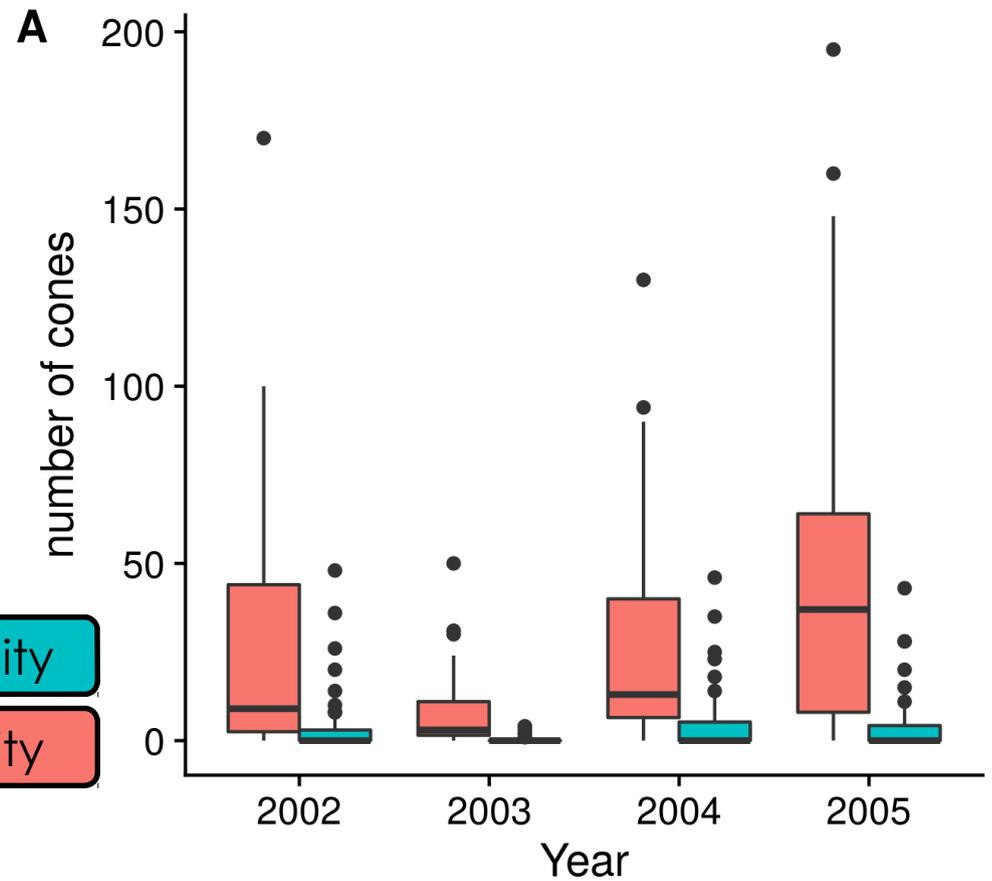
Even aged populations !

Observation during 4 years



Female cones quantity

high density
low density



Observation during 4 years

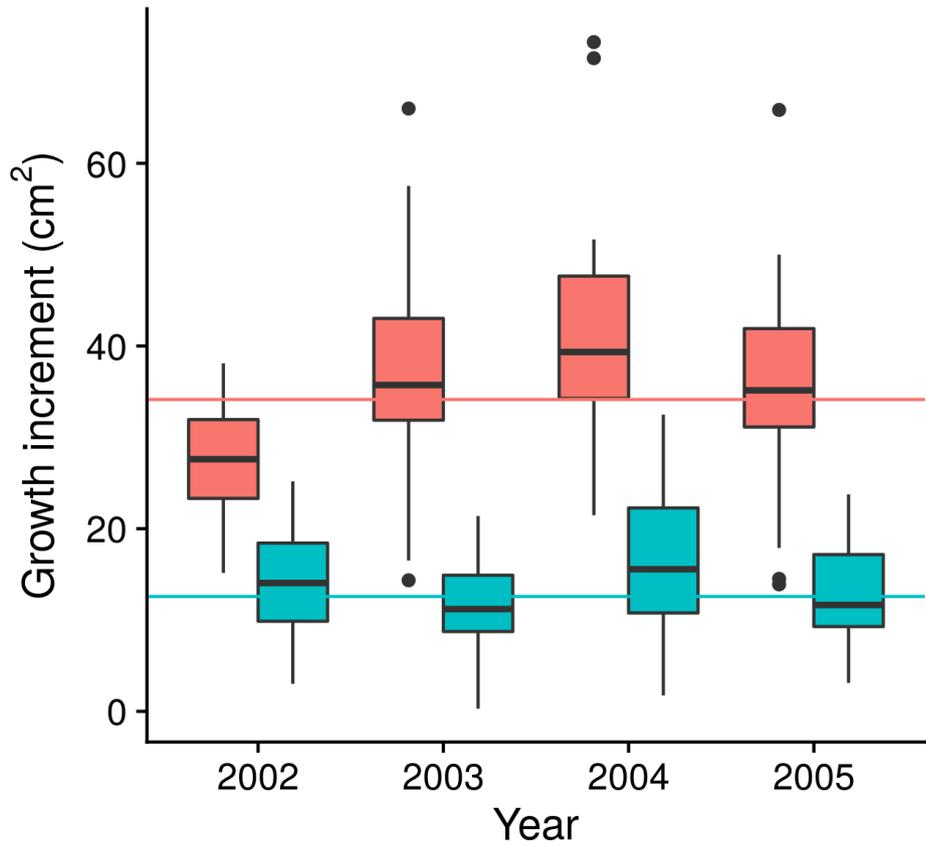


Female cones quantity



Male pollen index

Observation during 4 years



Growth increment

high density

low density

Observation during 4 years



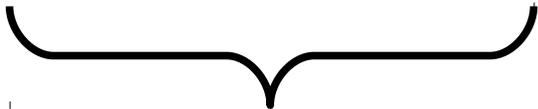
Female cones quantity

Male pollen index

Growth increment



Reproduction



Growth

Material and Methods

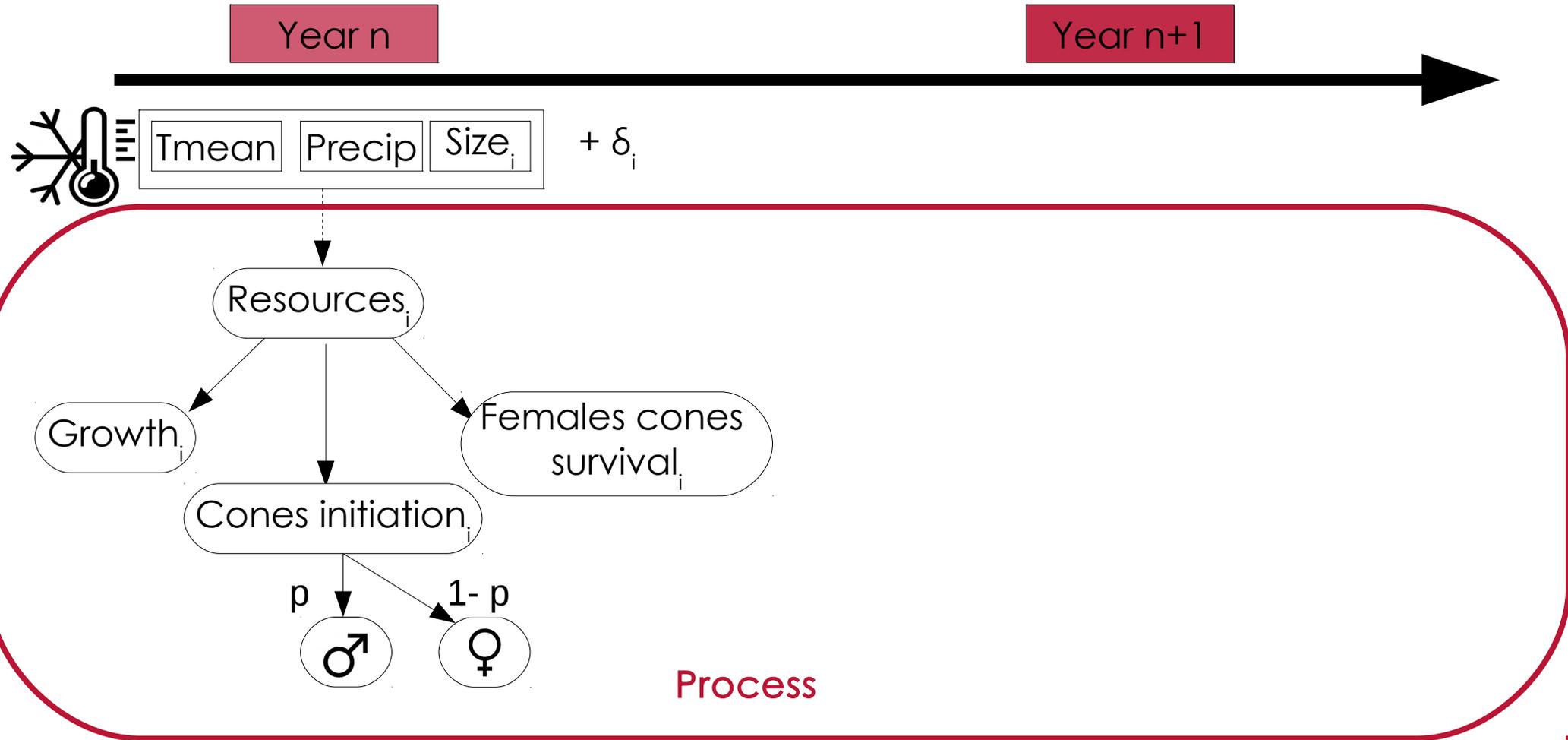
Year n

Year n+1

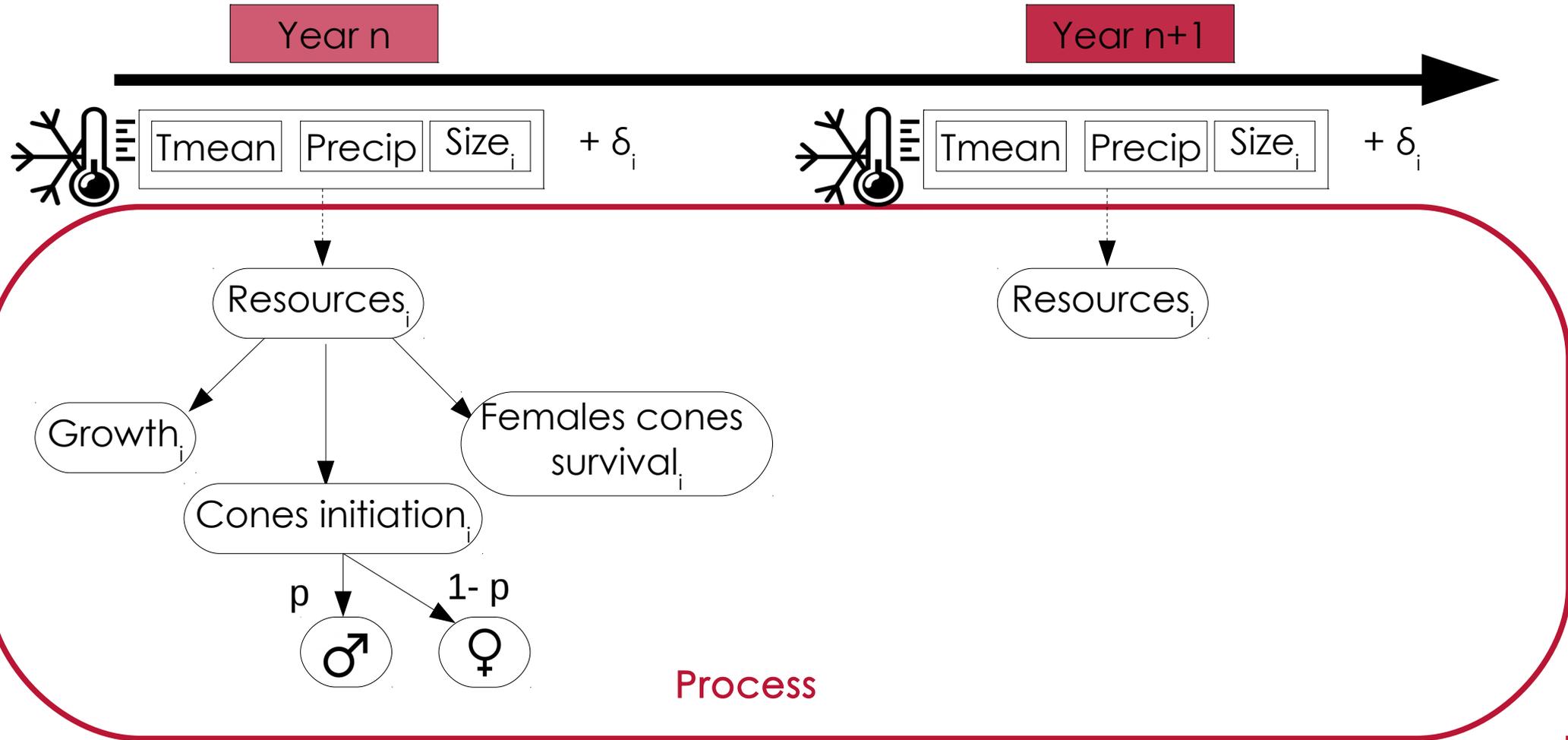
Process

The diagram consists of a horizontal black arrow pointing to the right, representing a timeline. Two red rectangular boxes are positioned above the arrow: one on the left labeled 'Year n' and one on the right labeled 'Year n+1'. Below the arrow is a large, horizontally-oriented rounded rectangle with a red border. The word 'Process' is centered within this rounded rectangle.

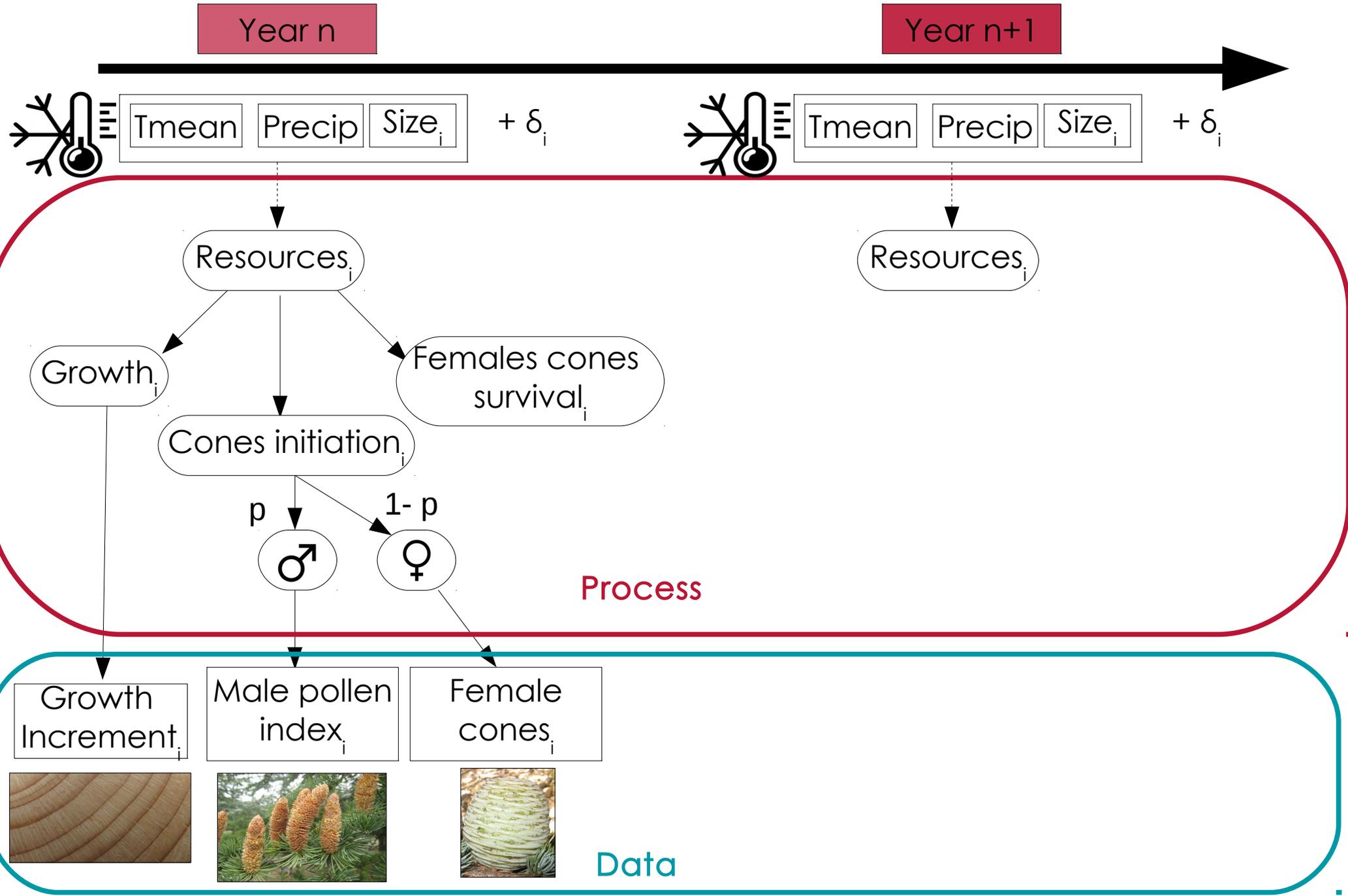
Material and Methods



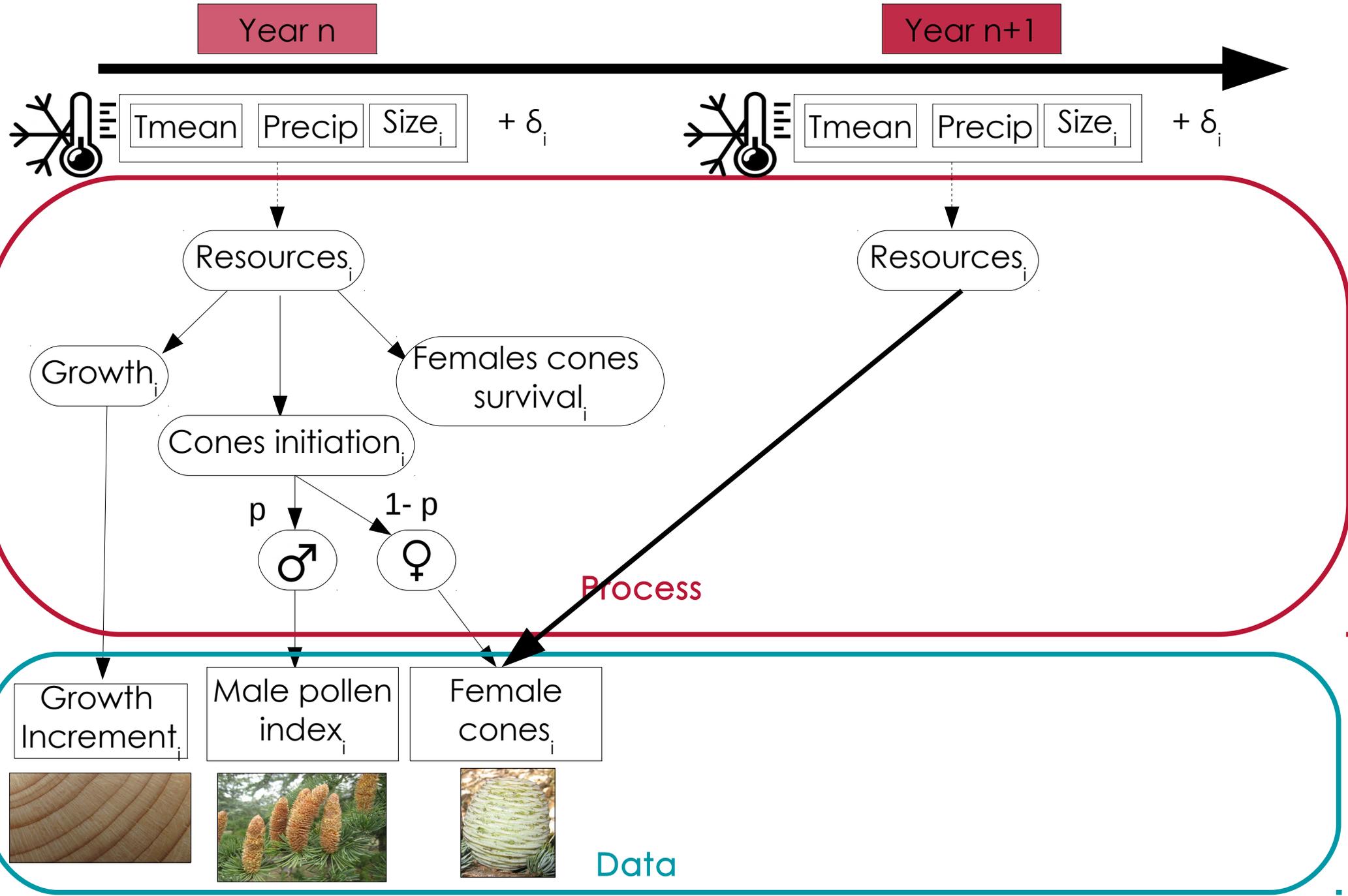
Material and Methods



Material and Methods



Material and Methods



Allocation of resources to 3 energetic sinks

- $\text{Growth}_{i,n} = \gamma * \text{Resources}_{i,n} + \epsilon_{1,i}$
- $\text{Cones Initiated}_{i,n} = X_{i,n} * (\beta_1 * \text{Resources}_{i,n} + \epsilon_{2,i})$
- $\text{Females cones survival}_{i,n} = \beta_0 + \beta_2 * \text{Resources}_{i,n} + \epsilon_{3,i}$

X: Probability to reproduce

ϵ : Residual term

Estimation of trade-off

$$\begin{pmatrix} \varepsilon_{1,i} \\ \varepsilon_{2,i} \\ \varepsilon_{3,i} \end{pmatrix}$$

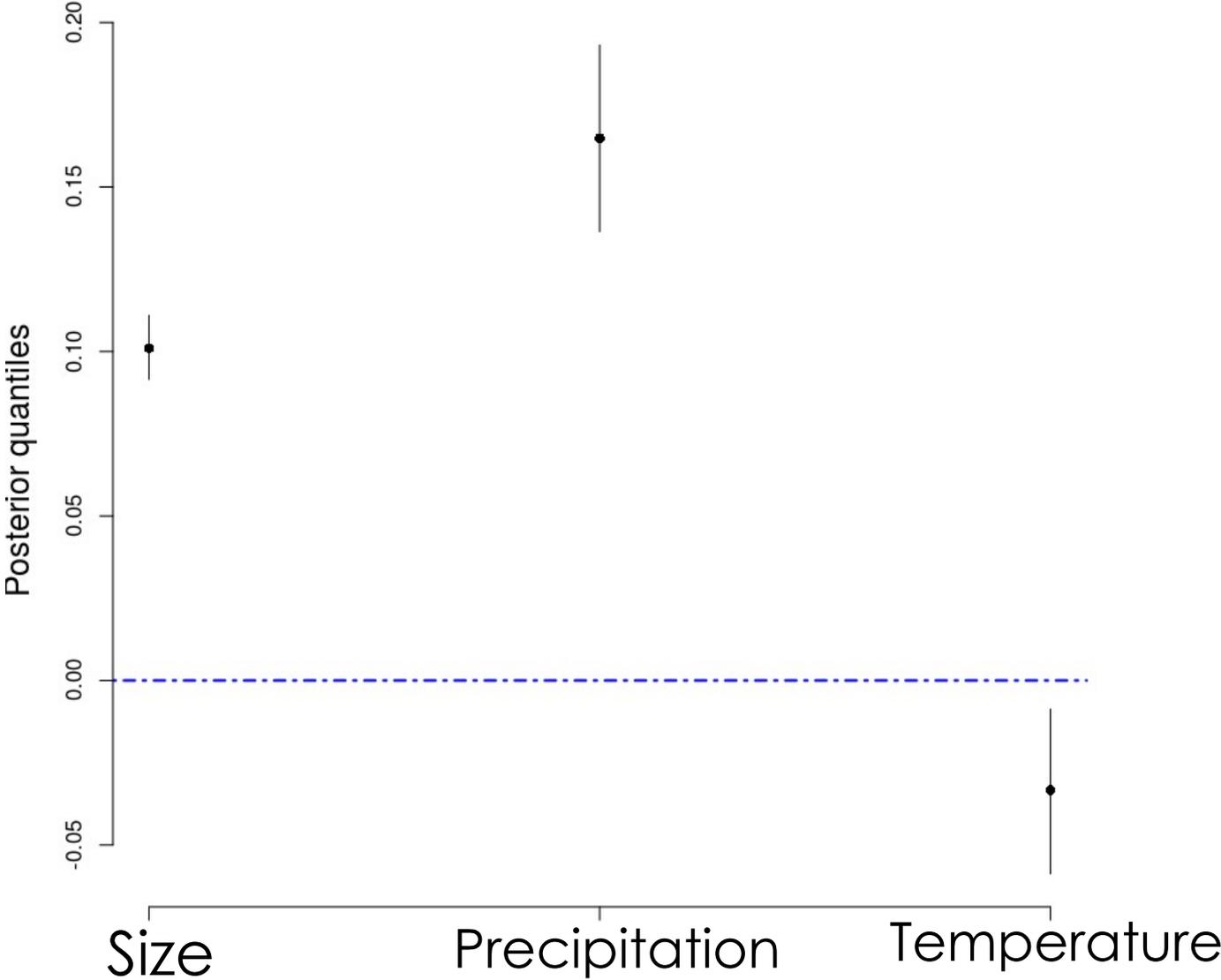
\sim Multivariate Normal $(0, \Sigma)$

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

Define correlation coefficient

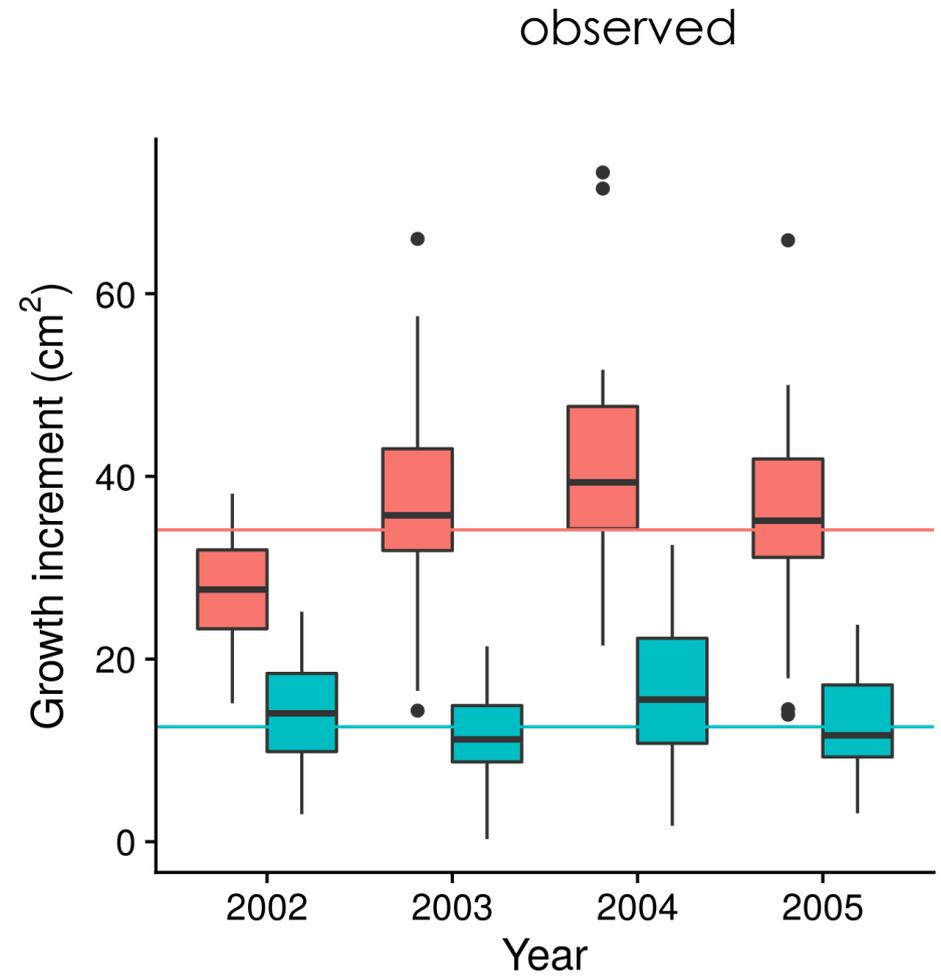
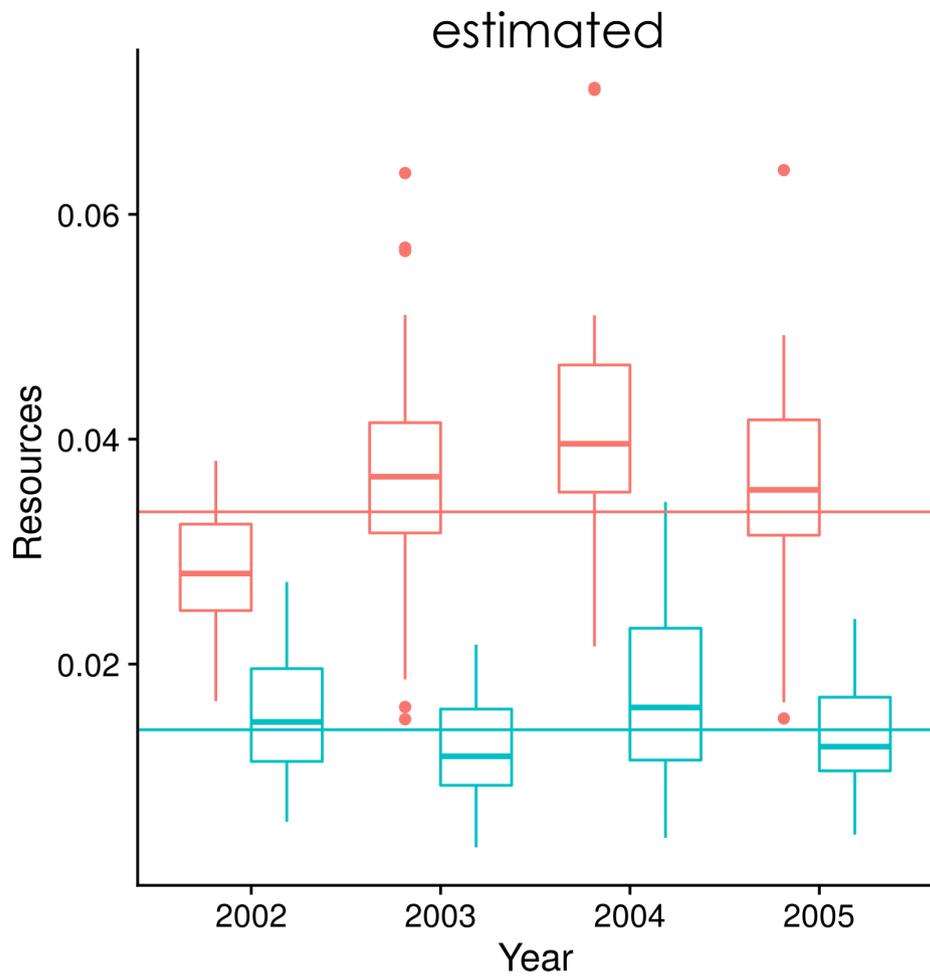
$$\rho_{x,y} = \frac{\sigma_{x,y}}{\sigma_{x,x} * \sigma_{y,x}}$$

Effects of Climate and Size on resources



Results

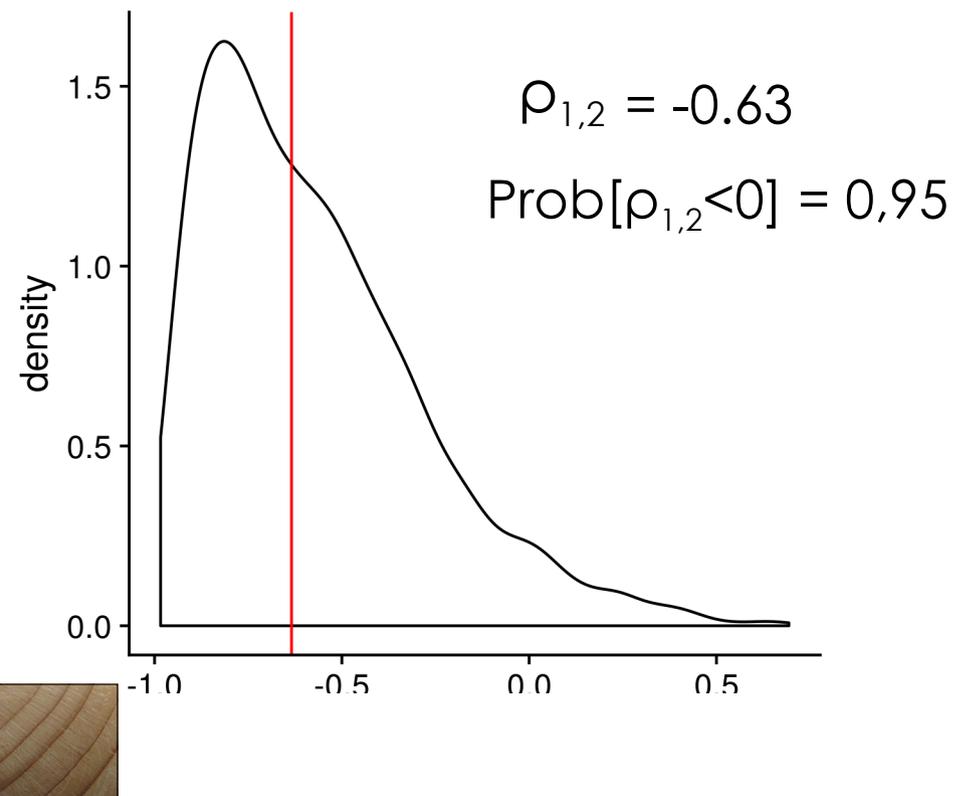
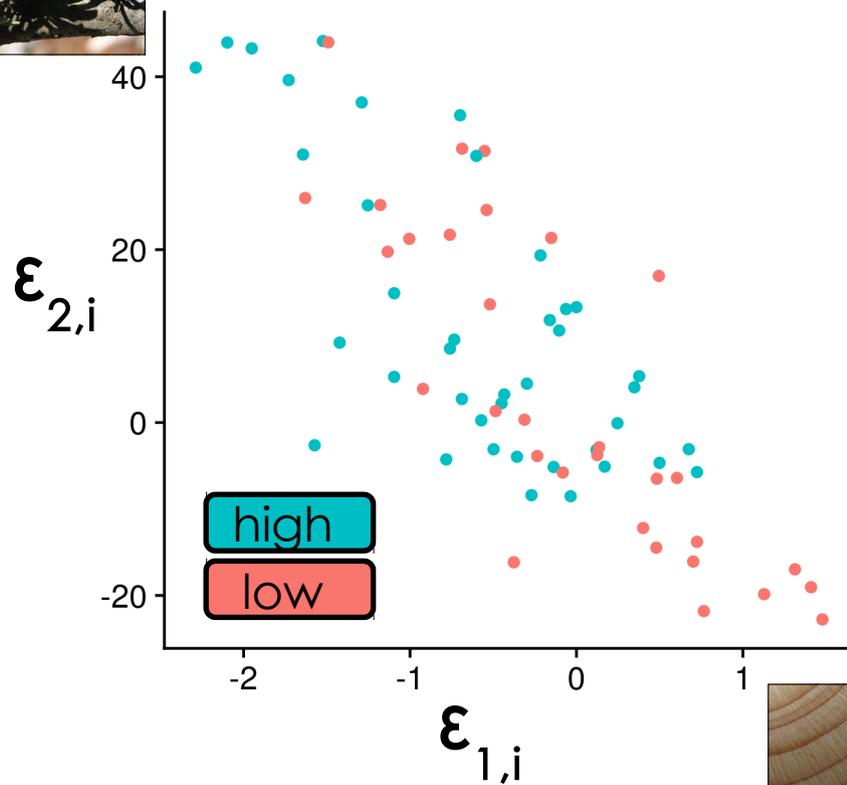
Resources vary among years and competition levels



high density

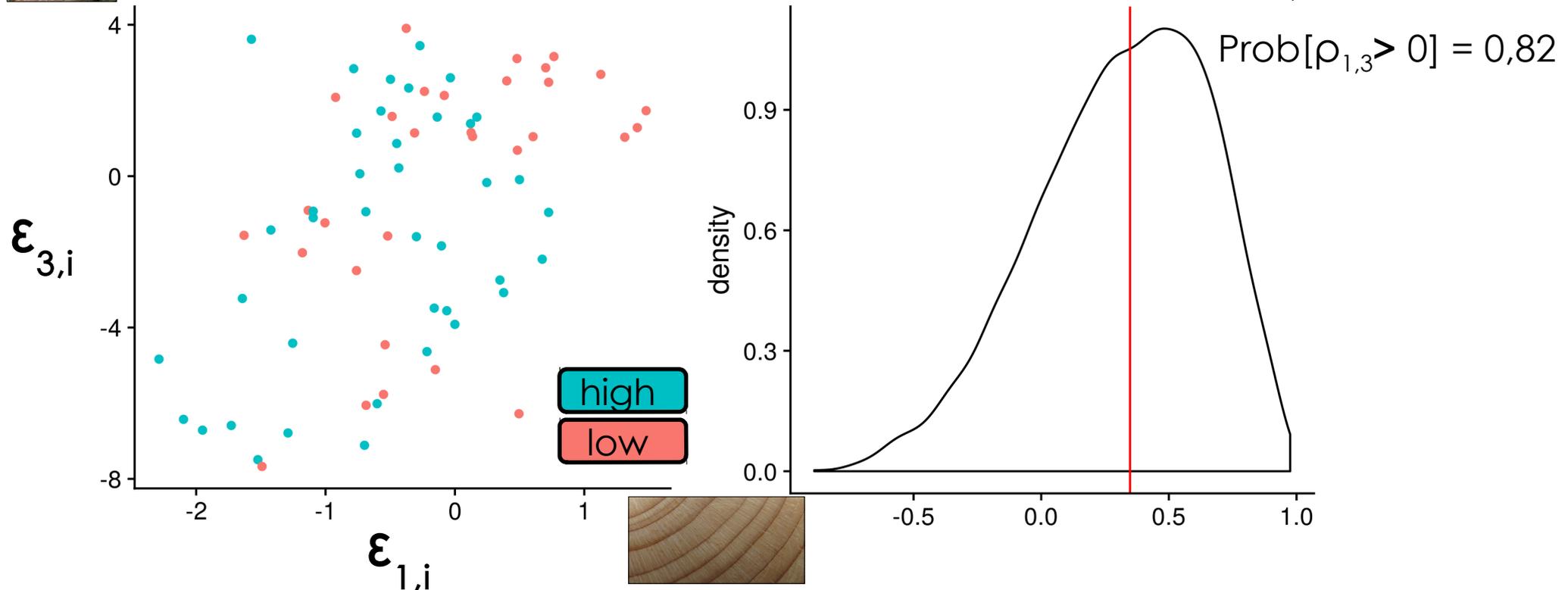
low density

Negative correlation between Growth and Cones initiated



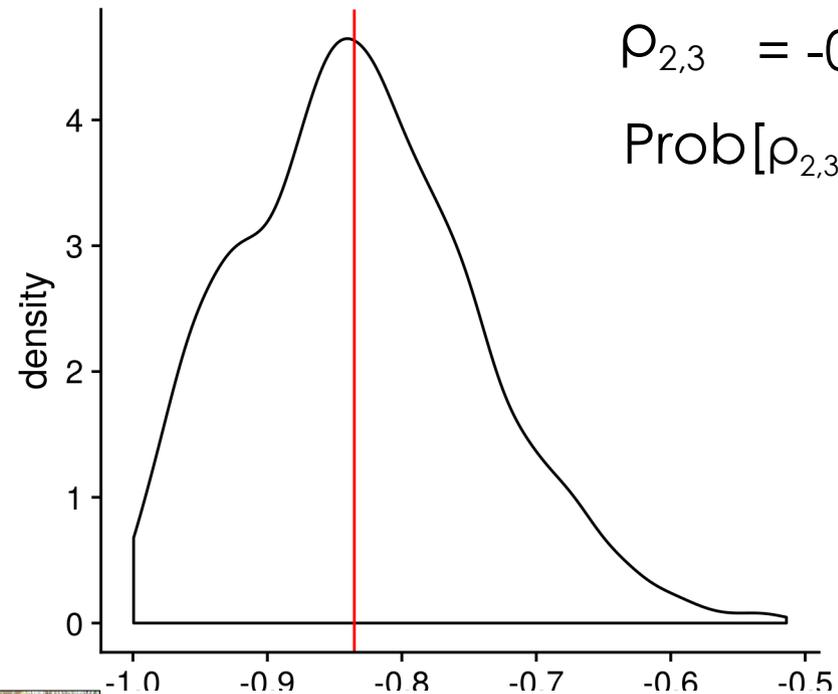
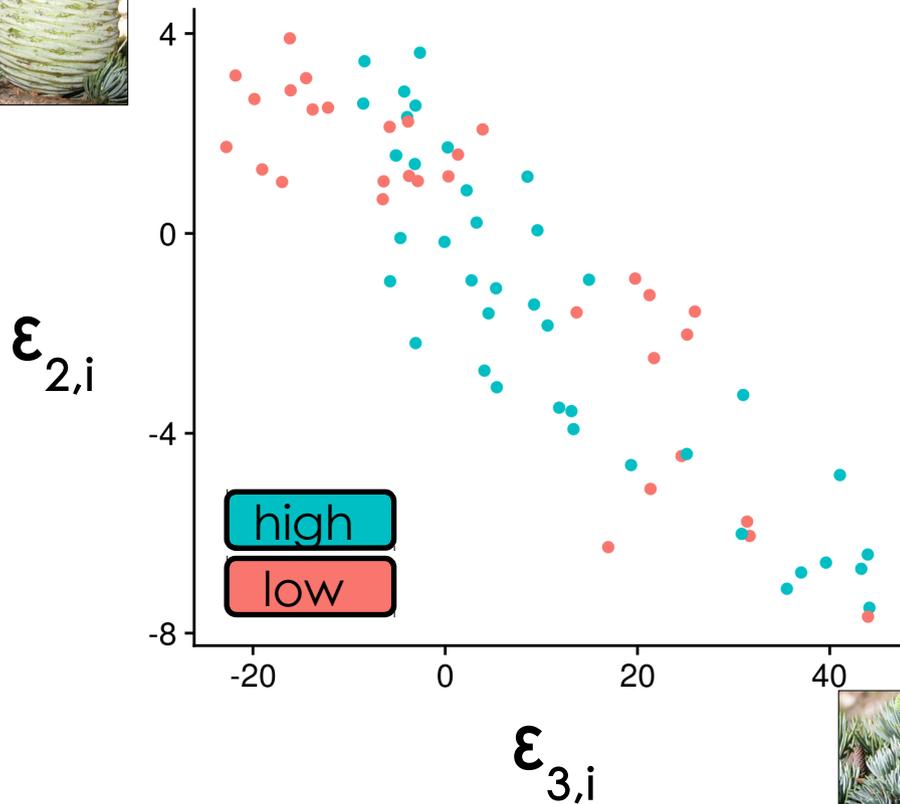
- $\text{Growth}_{i,n} = \gamma * \text{Resources}_{i,n} + \epsilon_{1,i}$
- $\text{Cones Initiated}_{i,n} = \chi_{i,n} * (\beta_1 * \text{Resources}_{i,n} + \epsilon_{2,i})$

Positive correlation between Growth and Female cones survival



- $\text{Growth}_{i,n} = \gamma * \text{Resources}_{i,n} + \epsilon_{1,i}$
- $\text{Females cones survival}_{i,n} = \beta_0 + \beta_2 * \text{Resources}_{i,n} + \epsilon_{3,i}$

Negative correlation between Cones initiated and Female cones survival



$\rho_{2,3} = -0.84$
 $\text{Prob}[\rho_{2,3} < 0] = 1$



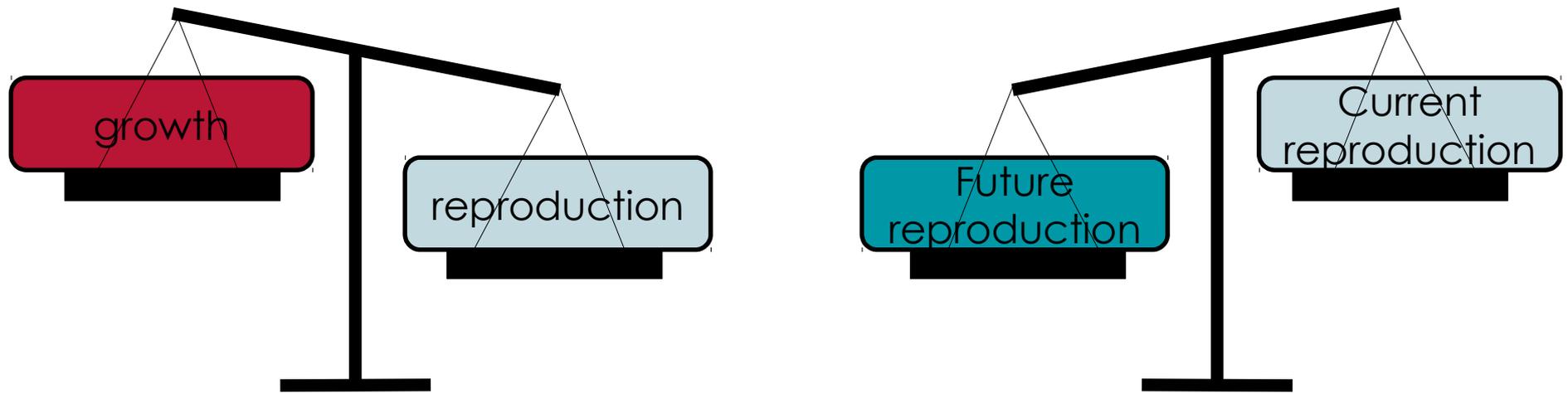
- Cones Initiated $_{i,n} = X_{i,n} * (\beta_1 * \text{Resources}_{i,n} + \epsilon_{2,i})$
- Females cones survival $_{i,n} = \beta_0 + \beta_2 * \text{Resources}_{i,n} + \epsilon_{3,i}$

- 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)

- 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

Why trees produce variable quantities of seeds?

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



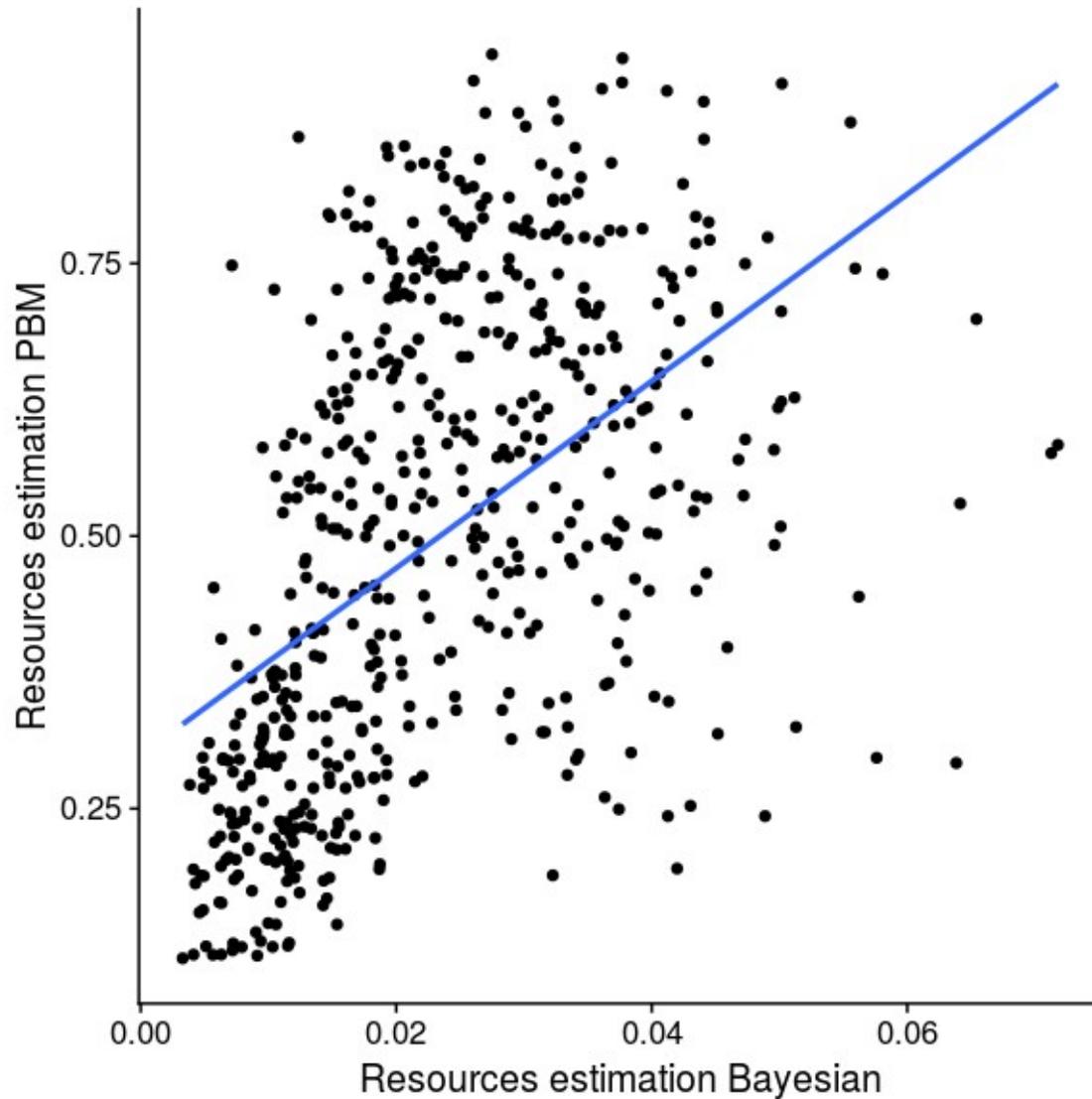
Not only one hypothesis

- 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

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



- We combined **physiology** and **evolution**
- We found evidence for growth-reproduction **trade-offs** in trees

More information ?

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[@Valentin_Journe](https://twitter.com/Valentin_Journe)

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

$$\left\{ \begin{array}{l} M_{i,t} = 0 \Rightarrow IMC_{i,t}^{\text{obs}} = [1, 0, 0, 0, 0] \\ M_{i,t} = 1 \Rightarrow IMC_{i,t}^{\text{obs}} = [0, 1, 0, 0, 0] \\ M_{i,t} = 2 \Rightarrow IMC_{i,t}^{\text{obs}} = [0, 0, 1, 0, 0] \\ M_{i,t} = 3 \Rightarrow IMC_{i,t}^{\text{obs}} = [0, 0, 0, 1, 0] \\ M_{i,t} = 4 \Rightarrow IMC_{i,t}^{\text{obs}} = [0, 0, 0, 0, 1] \end{array} \right.$$

- Initialized Males cones $_{i,t} = \text{Phenotypic gender}_{i,t}^*$
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

