A model of allocation resource in plant growth



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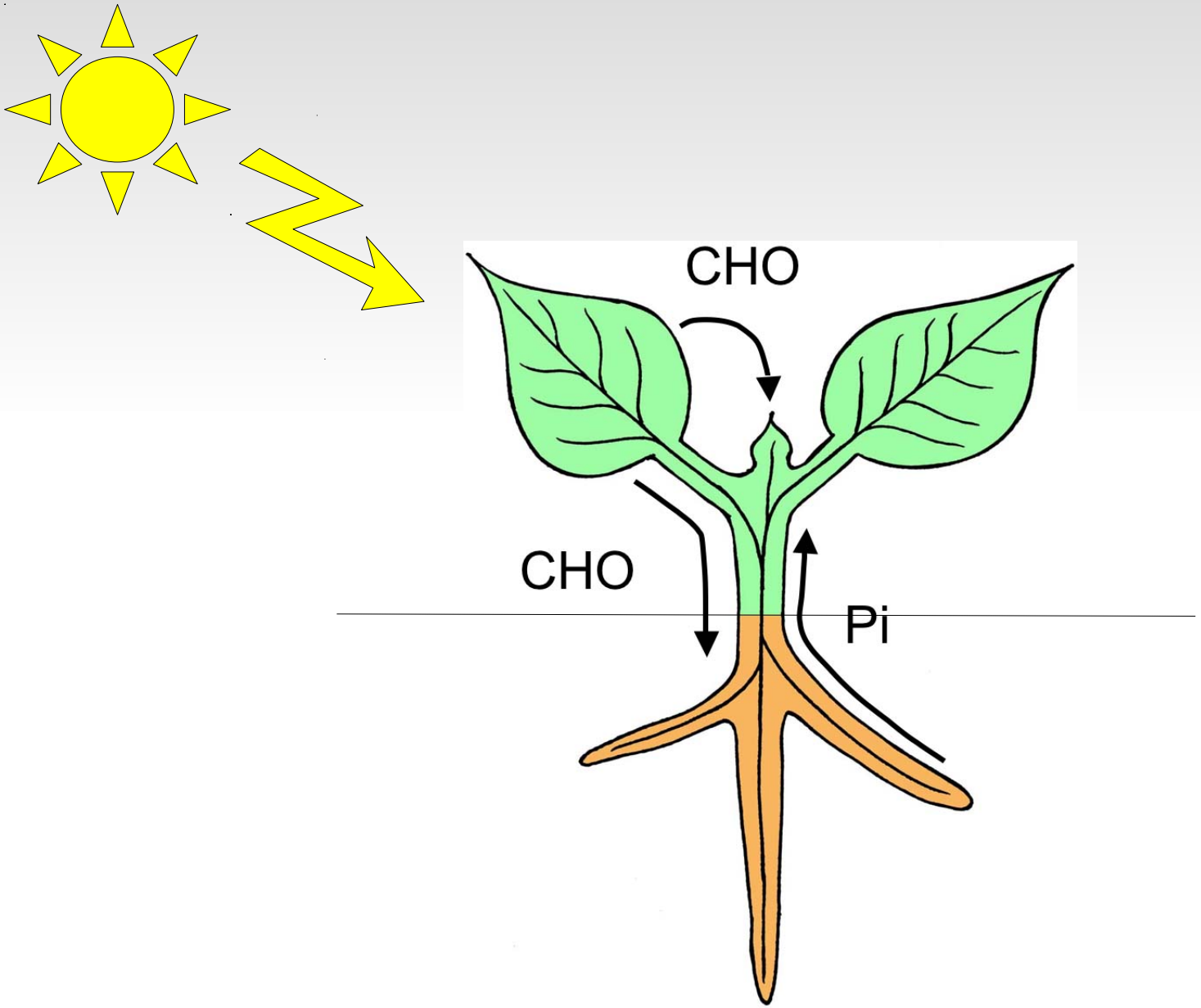
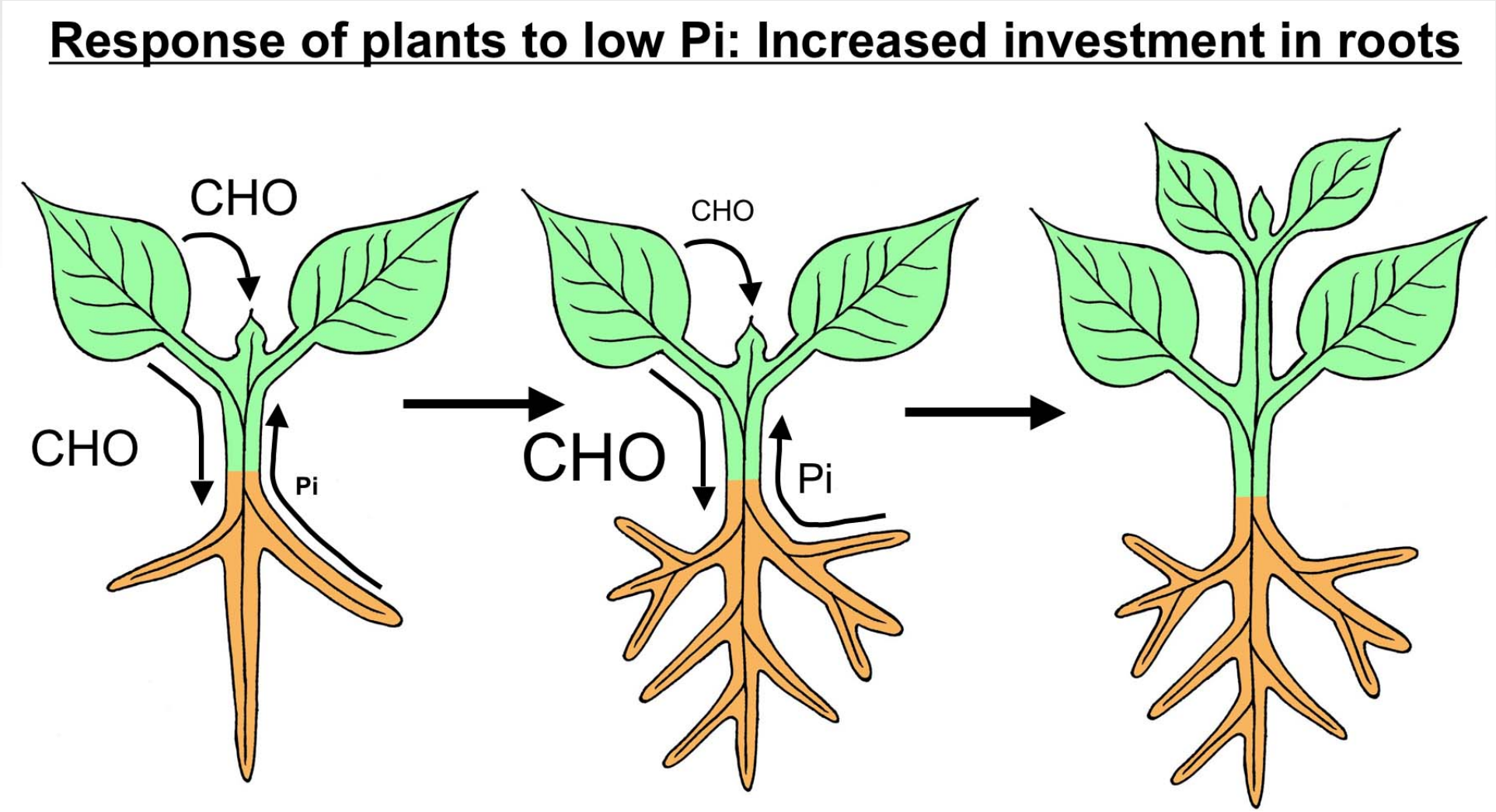
Plant growth regulation

general introduction



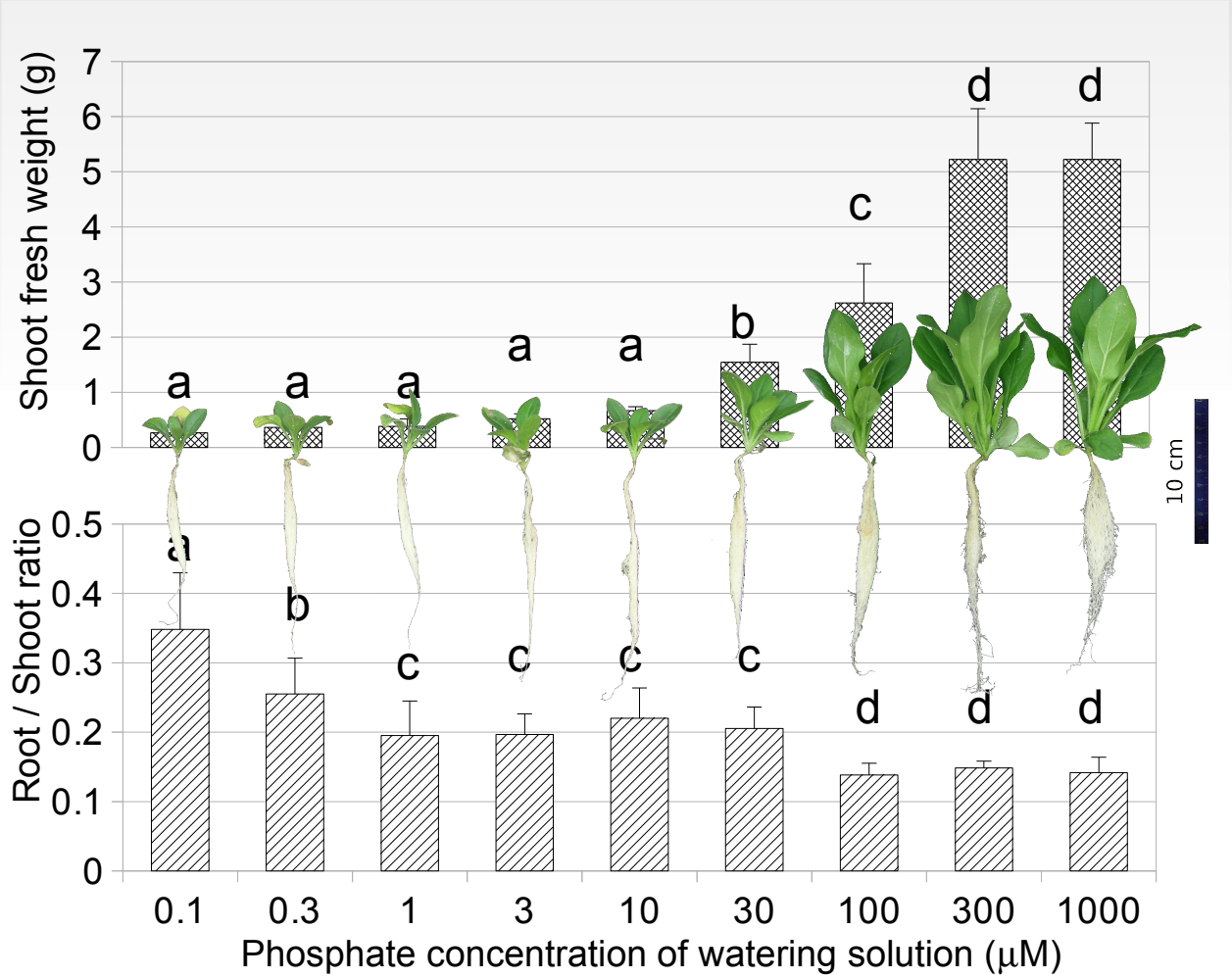
http://www.unifr.ch/plantbio/new/didier/project4.html

Plant growth regulation
general introduction



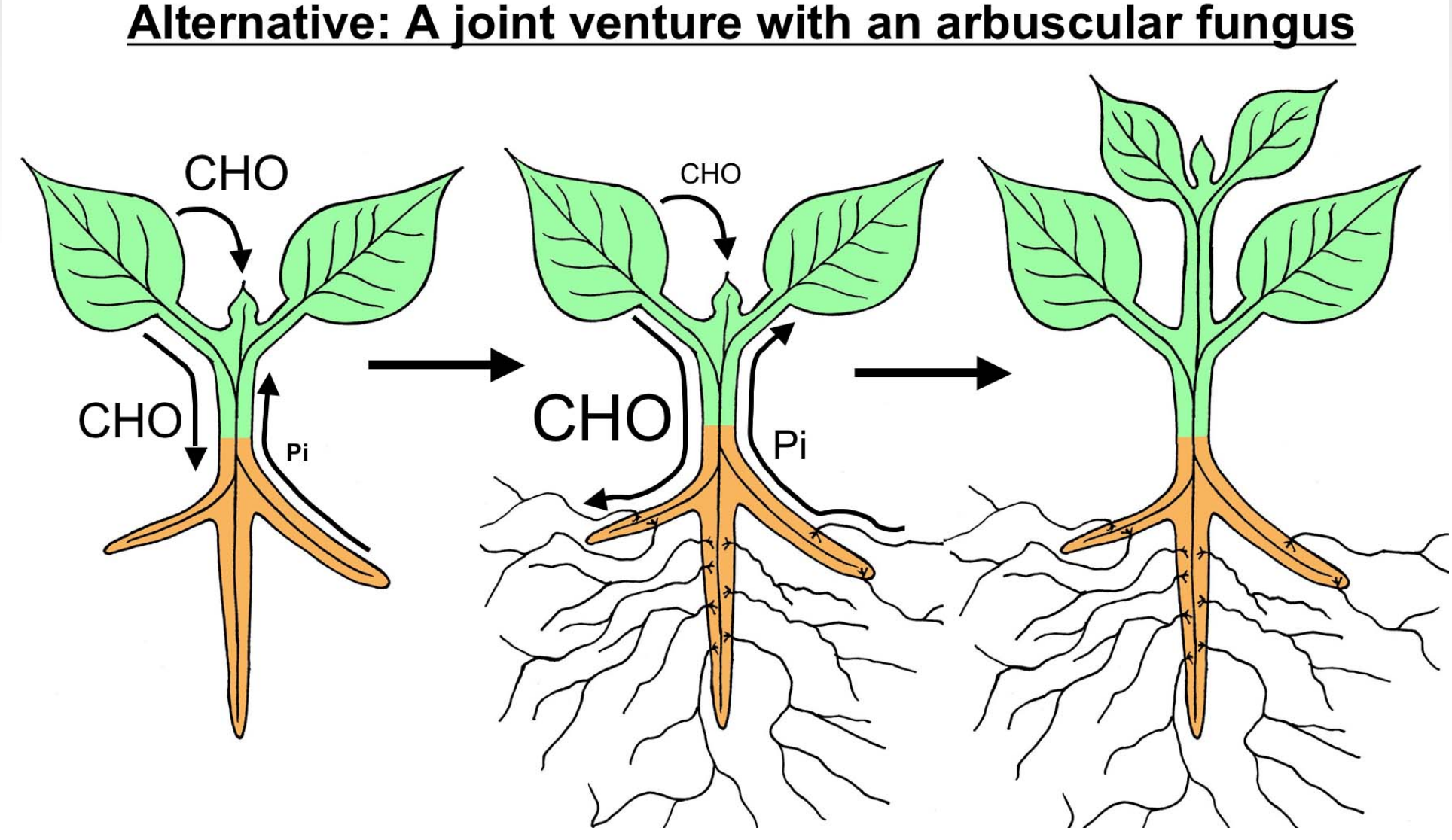
Plant growth regulation

general introduction



Plant growth regulation

general introduction

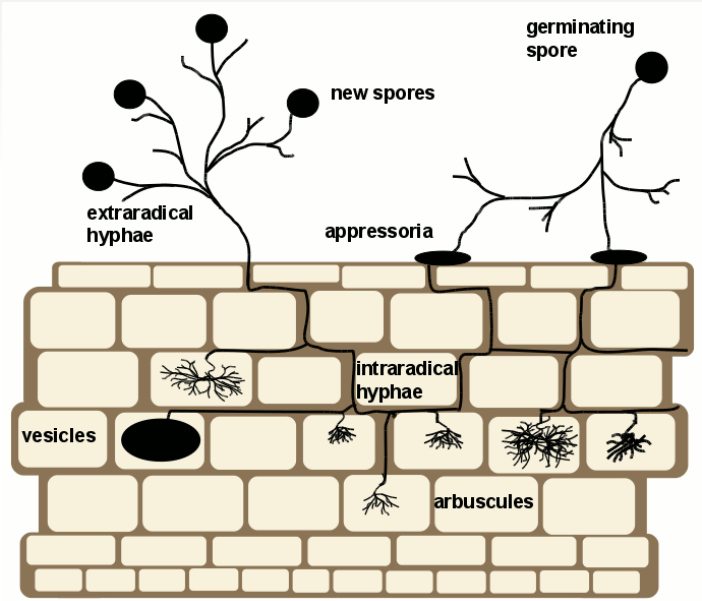


Plant growth regulation
general introduction

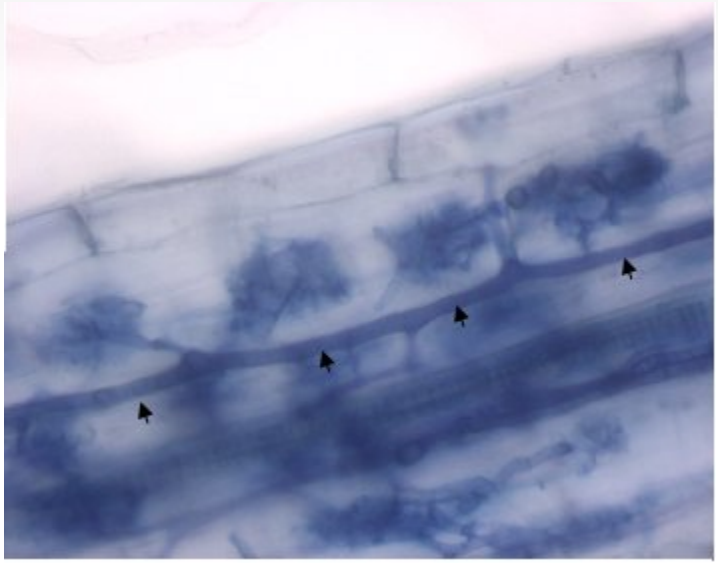
Arbuscular Mycorrhiza.



Germinating spore



Fungal life cycle



Reddy et al., 2002, Plant Journal

Plant growth modelling
general introduction

Two complementary methods are used to model the plant growth:



The M-Model or Mathematical model uses Matlab (Mathworks)
and displays results of differential equations during time.

That allows compilation program (fast computing) and parameters optimisation.

That allows mathematical conclusion (stable points, asymptotic behaviours...).



The L-Model or L-system model uses GroImp (L-system interpreter) and displays a virtual plant that integrates the M-model equations.

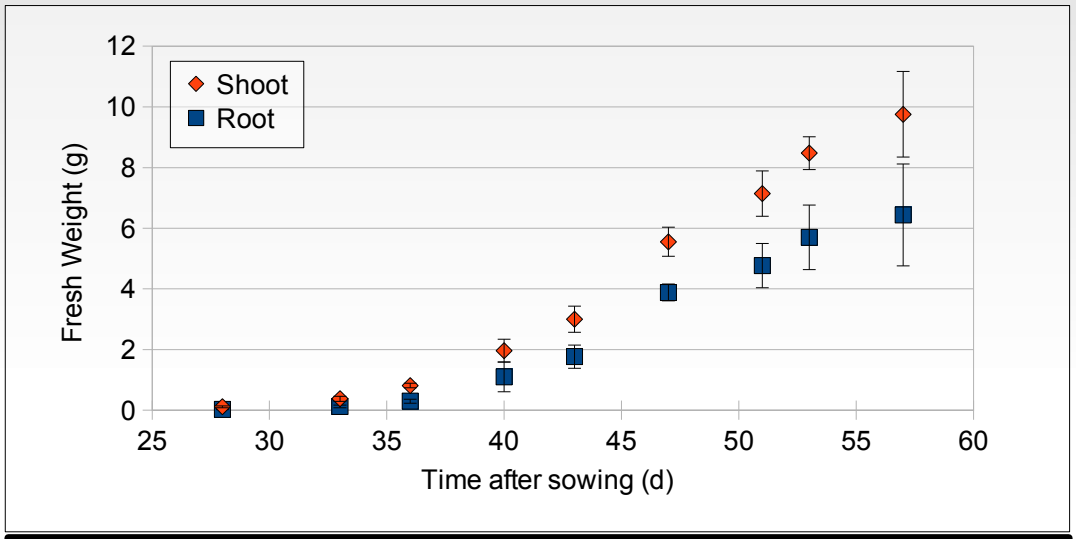
That allows to test and validate equations in multi-compartmented system (organs or unit organs).

Plant growth modelling

M-model

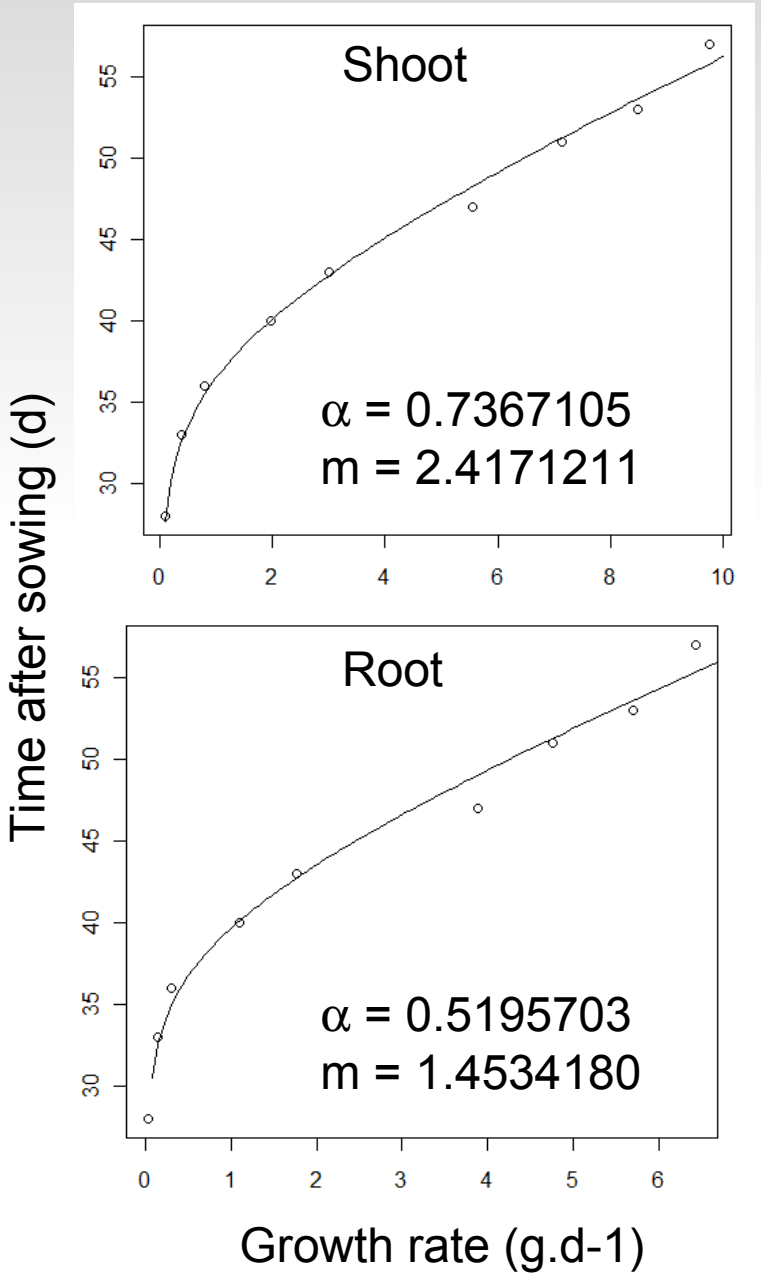
Plant growth modelling
Estimation of biological parameters

Maximum growth rate



Plant growth measurements in not limited factors (nutritive solution with 300 µM P) and maximum light intensity available in plant chambers (230 µE, T=23°C).

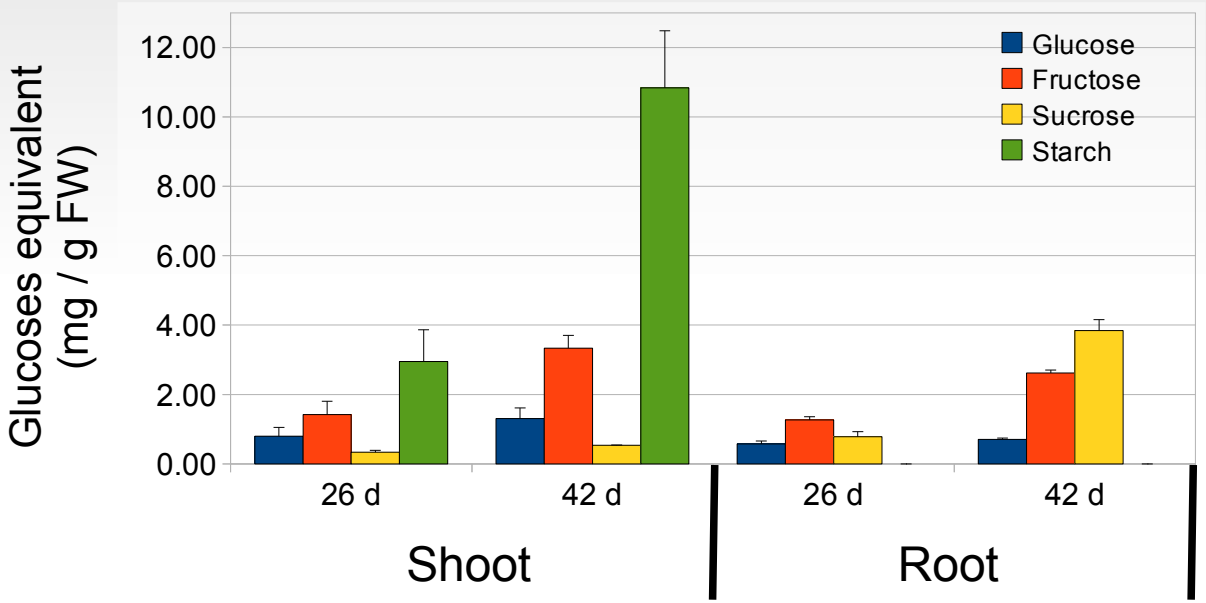
$$dV=\alpha.M(m,V).f(Cph,Csu)$$



Plant growth modelling
Estimation of biological parameters

Sugar in the plant

Starch and soluble sugars:



Glucose equivalent in shoot structure:

Density (µg DW.cm^{-3} FW) Carbohydrate prop (% DW)

$\theta^{l}_{su} = d^{l} \cdot \gamma = 5.18 * 10^{4}$ µg.cm^{-3} FW

Glucose equivalent in root structure:

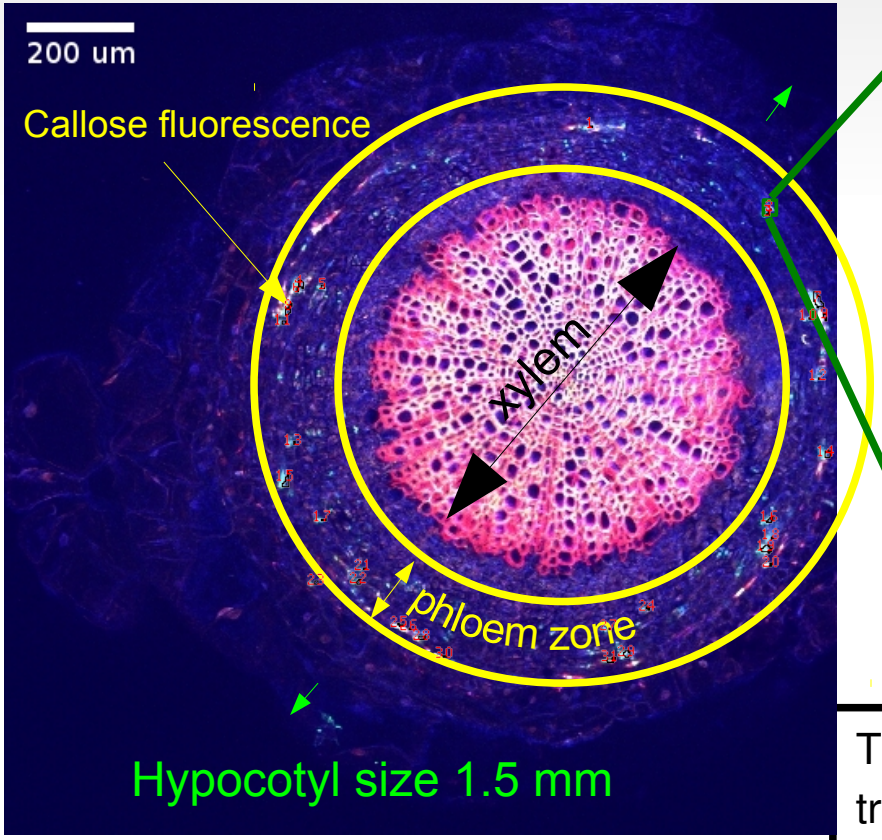
$\theta^{r}_{su} = d^{r} \cdot \gamma = 8.2 * 10^{4}$ µg.cm^{-3} FW

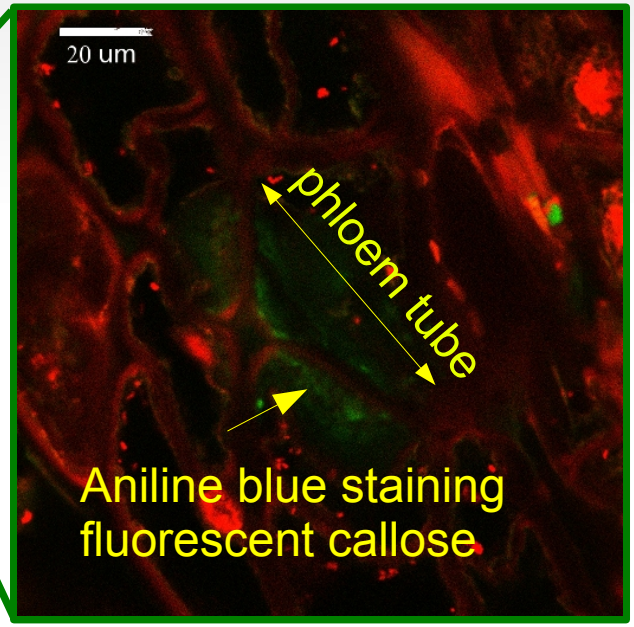
Plant growth modelling
Estimation of biological parameters

Sugar transport



Phloem tubes in the hypocotyl

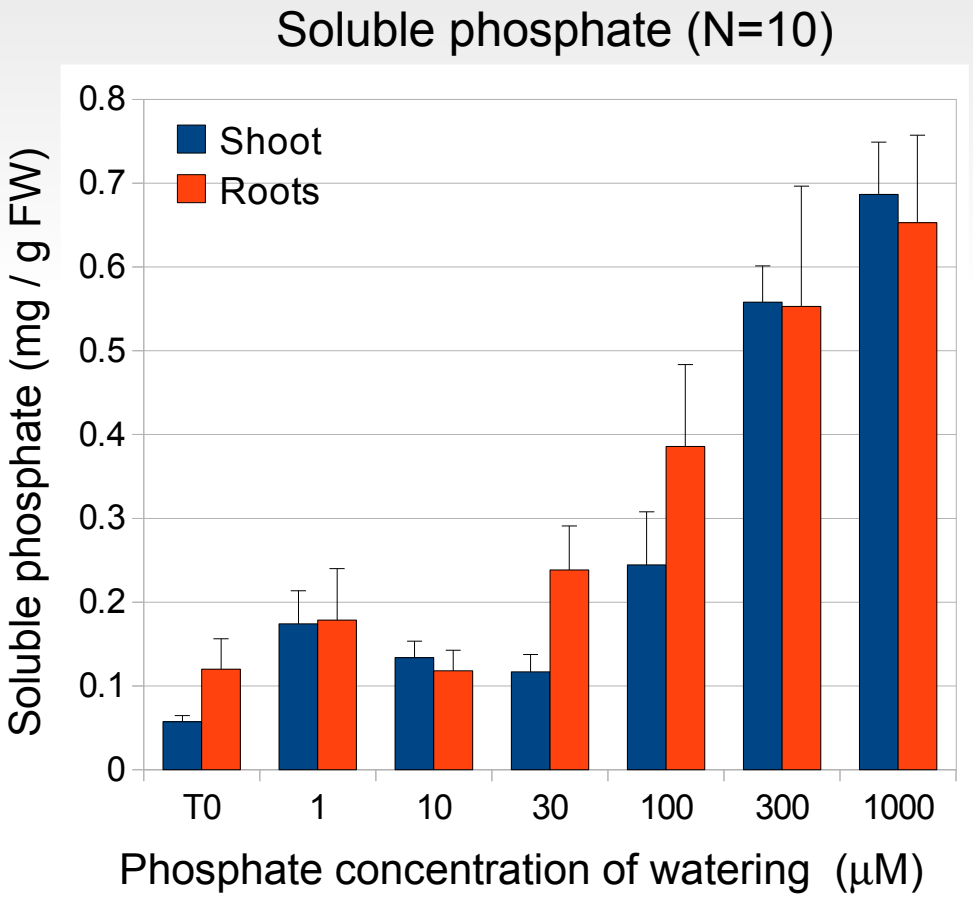


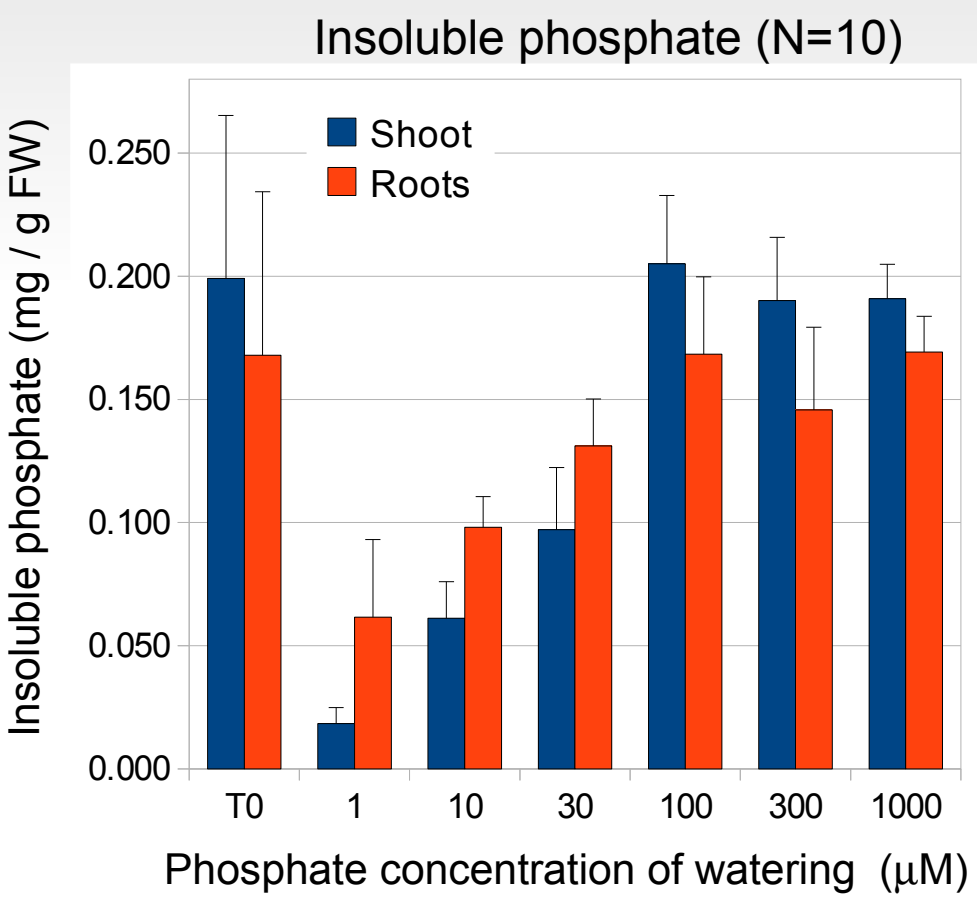


The law of Hagen-Poiseuille is applied to calculate the transport in the phloem tubes. The number of phloem tubes is identified by fluorescence microscopy of callose. More data are required for statistical cues.

Plant growth modelling
Estimation of biological parameters

Phosphate in the plant

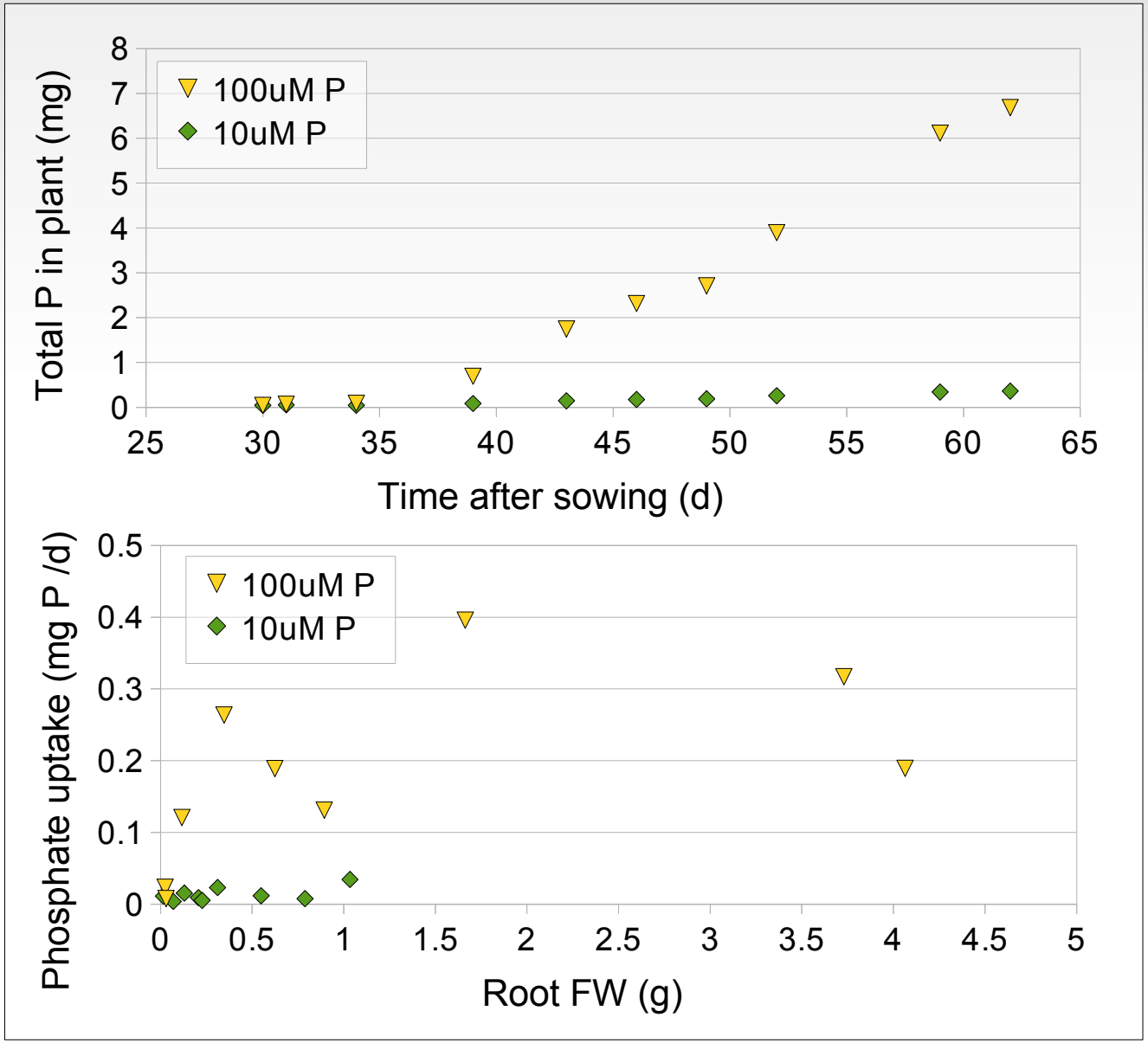




Plant growth modelling

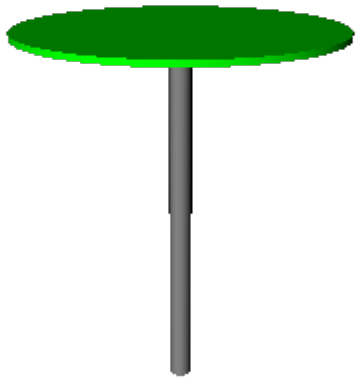
Estimation of biological parameters

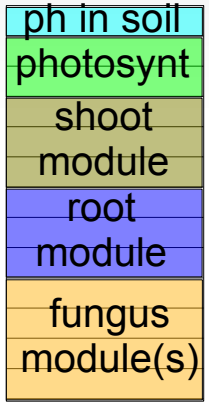
Phosphate uptake



Plant growth modelling using GroImp software

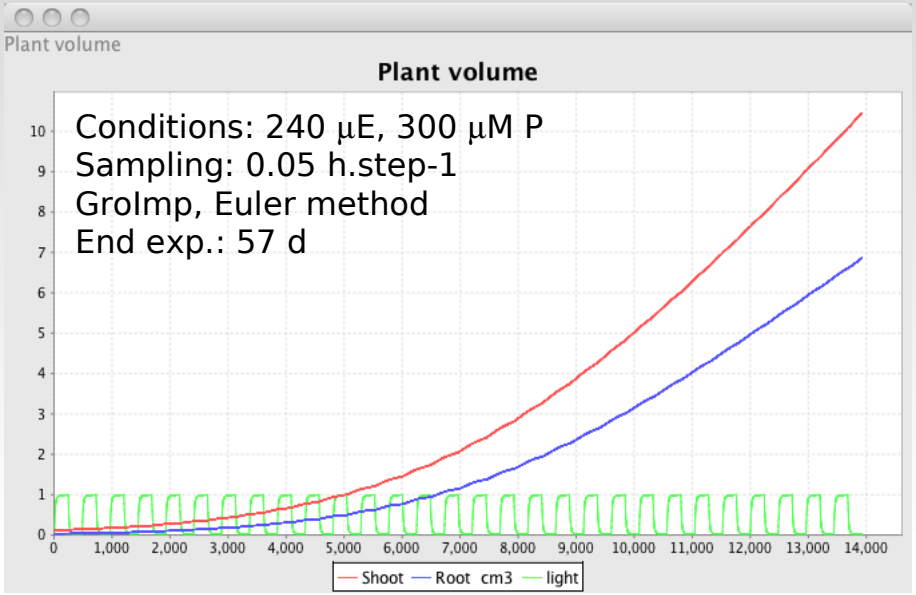
2 compartments (shoot and root)

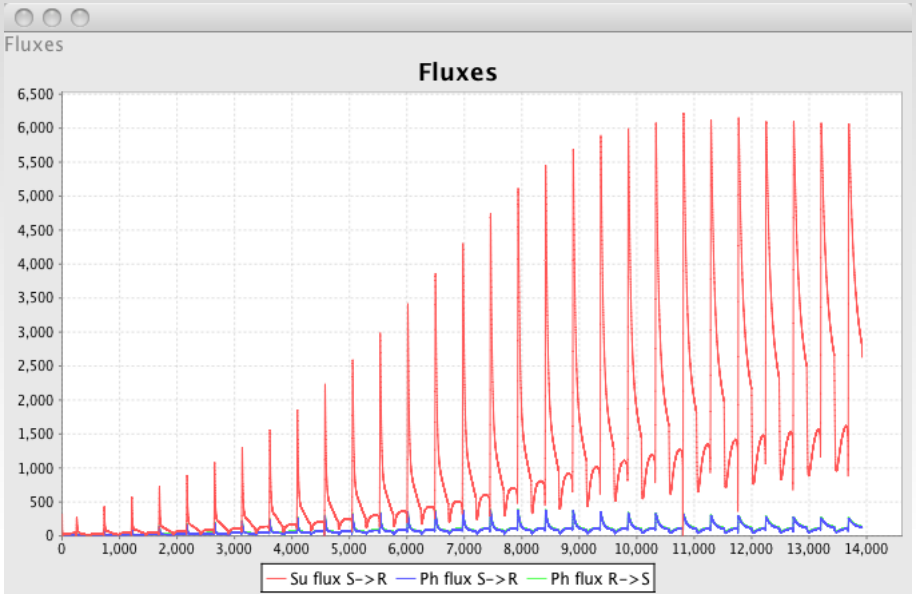




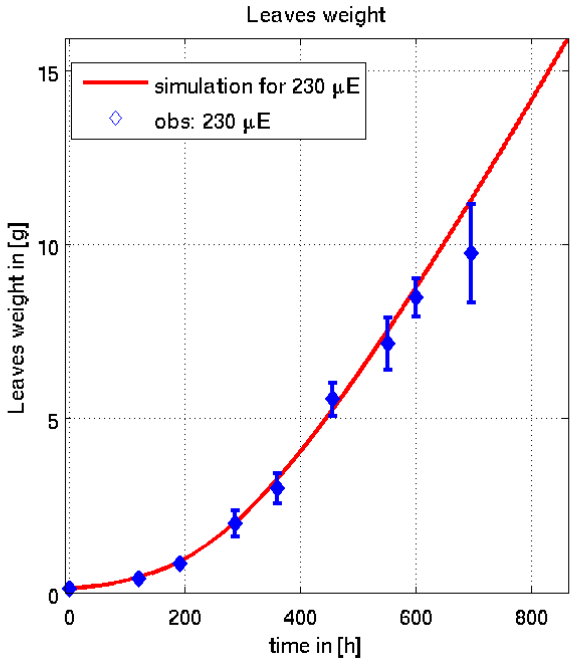
Plant growth modelling using GroImp

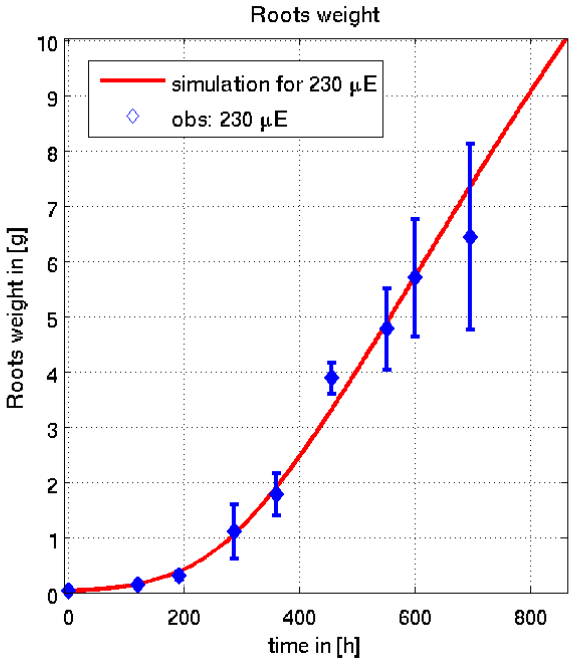
2 compartments (shoot and root)



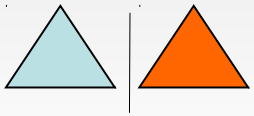


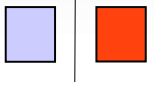
Conditions: 240 µE, 300 µM P
Sampling: 0.005 h.step-1
Mathlab, Rugue Kutta method
End exp.: 57 days after sowing





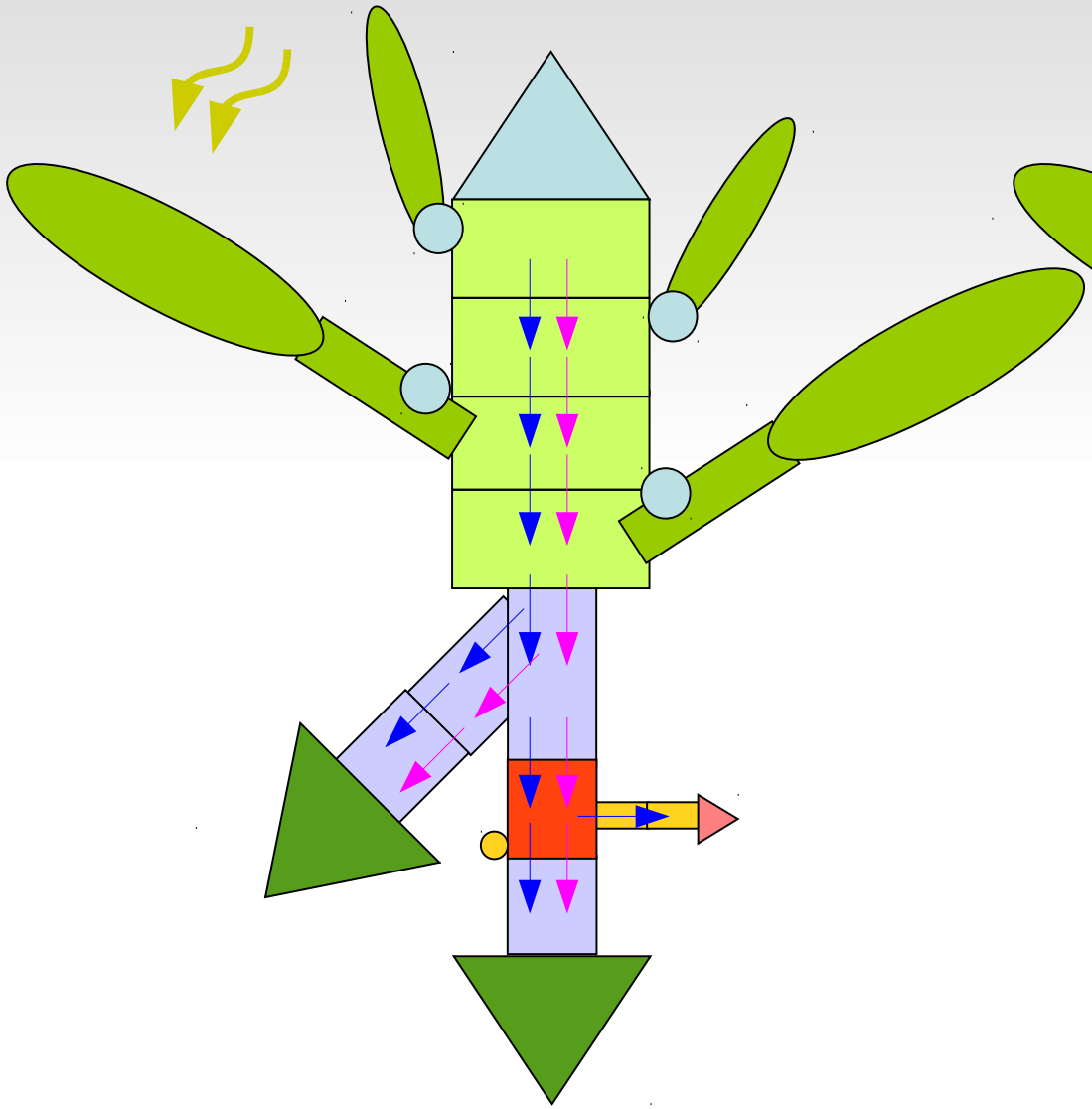
Plant modelling using L-systems
Basic modules

- Modules
  - Aerial part
    -  Apical meristem
    -  Internode
    -  Leaf
    -  Bud

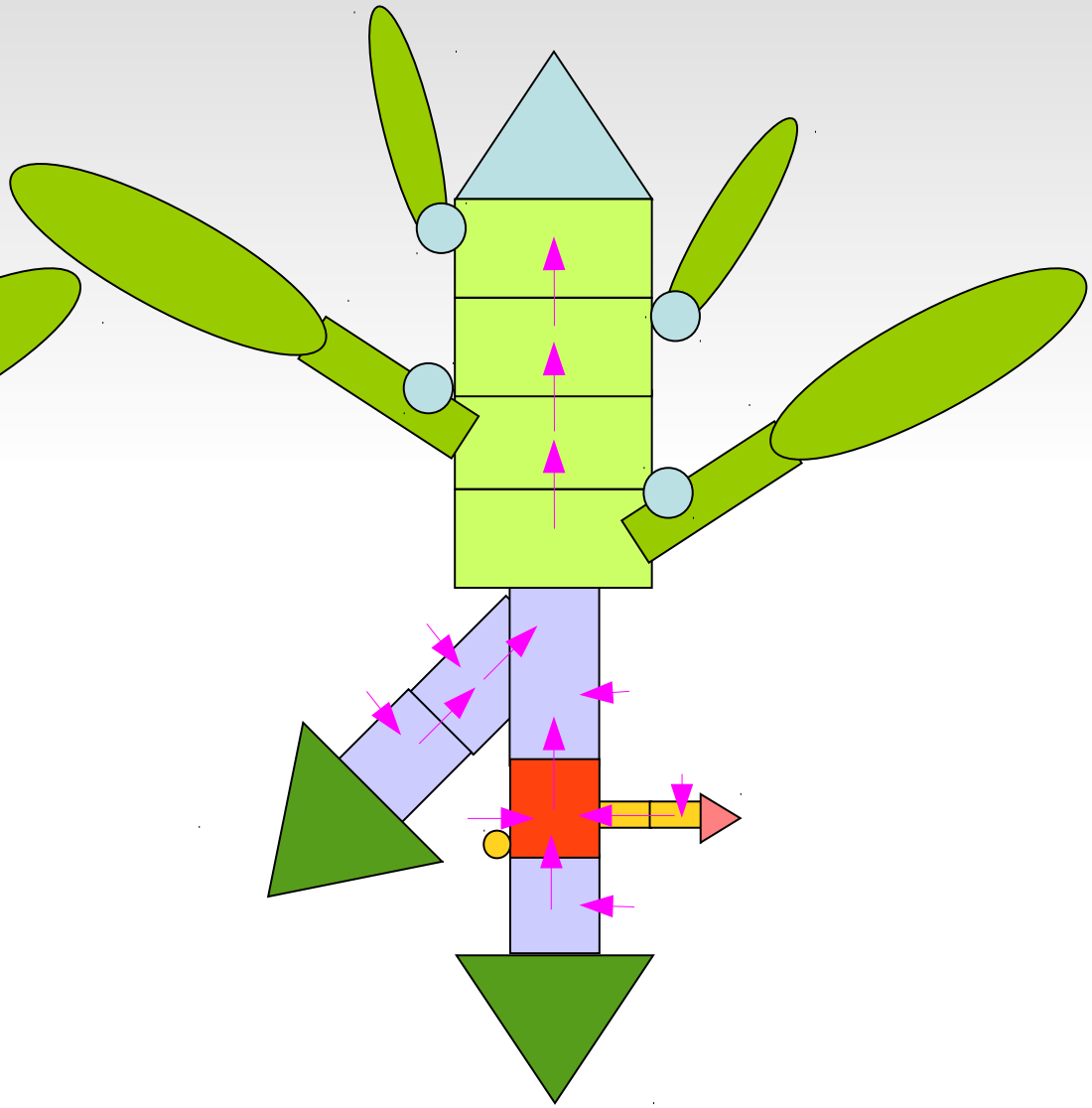
    phytomer
  - Roots
    -  Root meristem
    -  Root unit
  - Mycorrhizae
    -  Spore
    -  Hyphae tip
    -  Hyphae unit

Plant modelling using L-systems

transport substances: sugar and phosphate



Sugar fluxes



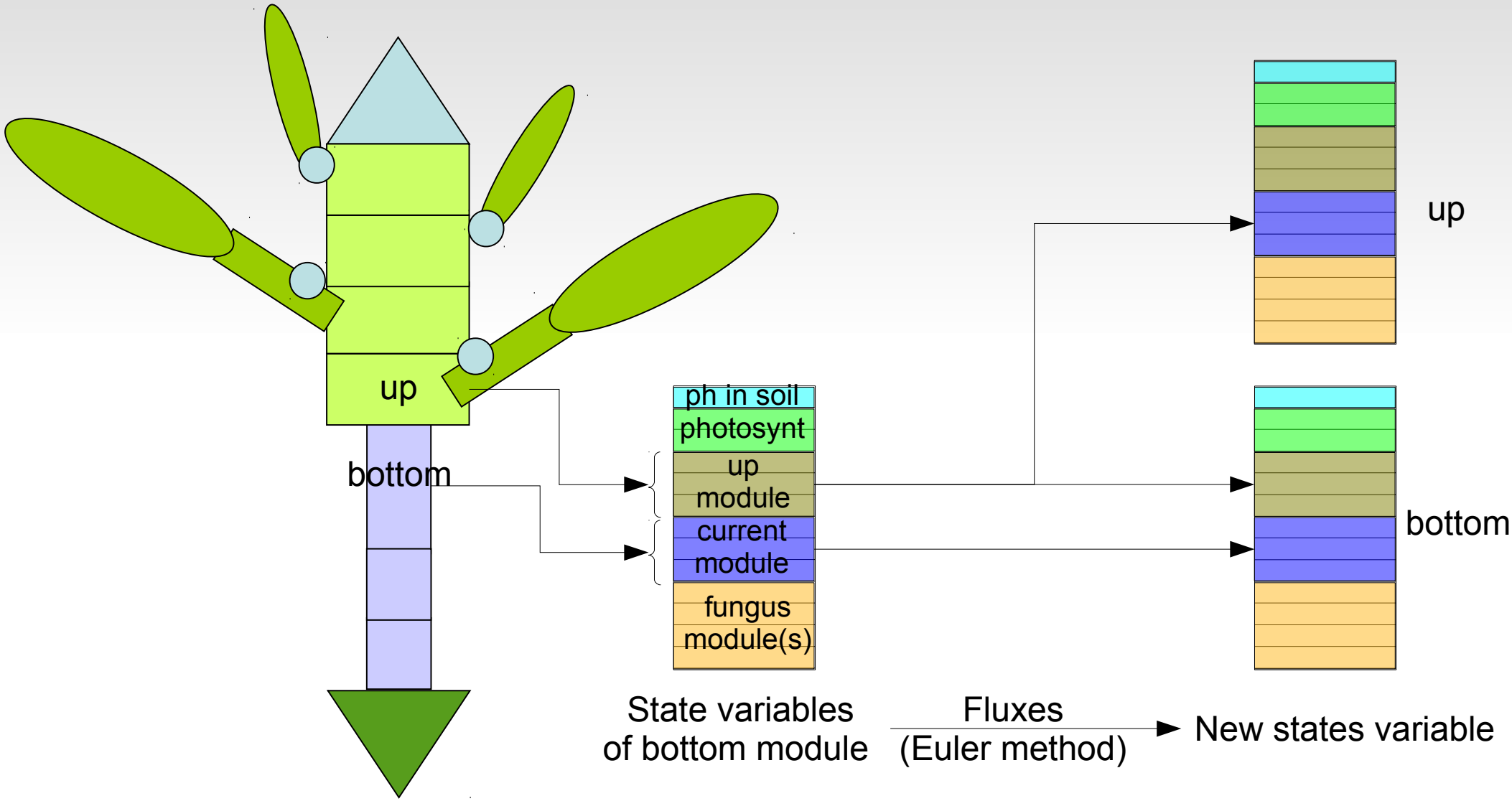
Phosphate fluxes

Plant growth modelling using GroImp software

multi-compartments: plant with fungus

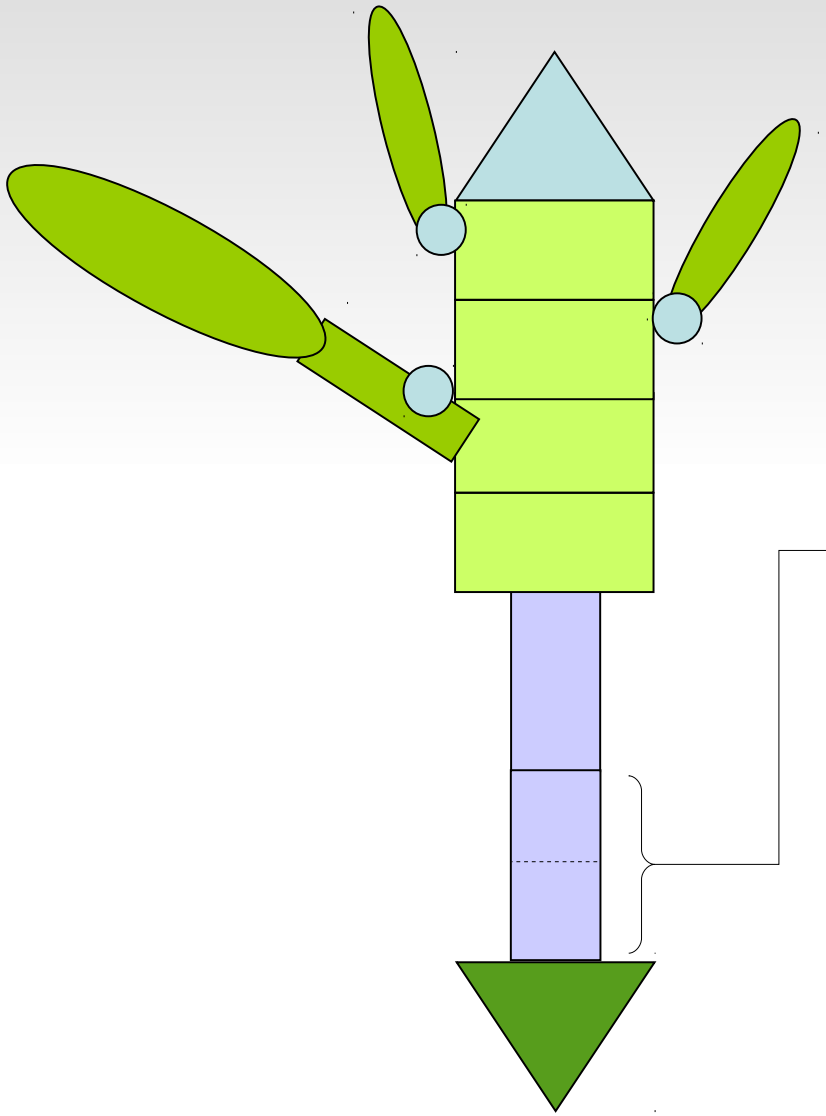
Plant modelling using L-systems

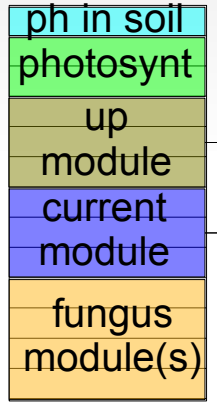
transport substances: sugar and phosphate



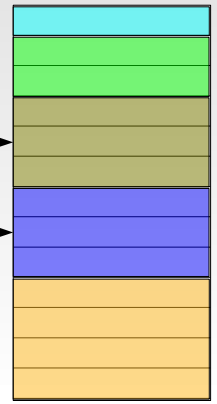
Plant modelling using L-systems

New root unit formation

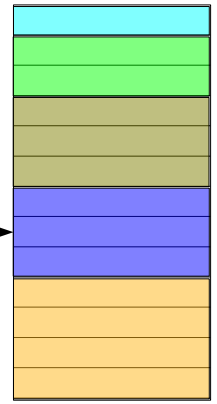




x 1/2



up



bottom

State variables of last module

Length>Lmax (split)

New state variables

Plant growth modelling using GroImp software

multi-compartments

Plant modelling
Main differences from the mathematical model

- Multi-compartmented plant (organes)
- Plant topology considered (shaded leaves, root branching...)
- Light interception possible
- Independent module properties (leaves, root unit...)
- Realistic rendering

- Compilation (?)
- Calculation increases proportionally to the complexity
- Fitting parameters very long

Plant growth modelling
Perspectives (1)

- Experiments using *Arabidopsis thaliana* cv. Col
  - Hydroponic system required (Tocquin *et al.*, 2003)
  - Phosphate and sugar related *Arabidopsis* mutants

- Modelling of *Arabidopsis thaliana*
  - Highlighting physiological mechanisms and feedbacks
  - No symbiotic association

Plant modelling
Perspective (2)

- Plant growth and symbiosis modelling
  - Mathematical equations of fungus system
    - Experimental estimation of growth parameters for the modelling of resource allocation in plant-fungus

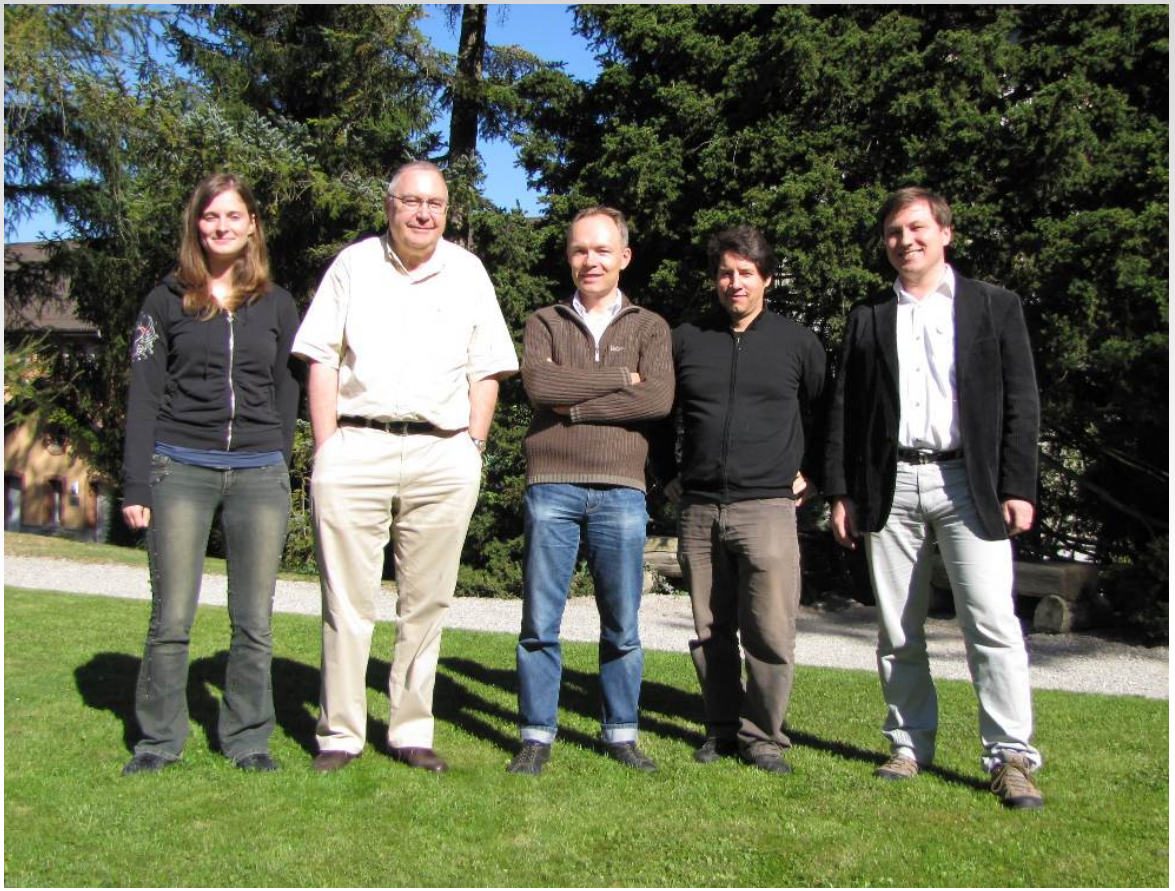
  - Refine and finalise the L-model

Conclusion

- The M-model is stable and the equations is implemented in the L-model
- Results of equations of allocation resources (su,ph) reflect the observation
- Integration of other nutrients (N,...)

Research collaborators:
Chrystel Feller[2]
Jean-Pierre Gabriel[2]
Didier Reinhardt[1]
Patrick Favre[1]
Ales Janka[2]

Other collaborators:
Samuel Zeeman[3]
Olivier Kötting[3]



[1]Department of Biology, University of Fribourg, Switzerland
[2]Department of Mathematics, University of Fribourg, Switzerland
[3]ETH Zurich, Institute of Plant Science, Zurich, Switzerland

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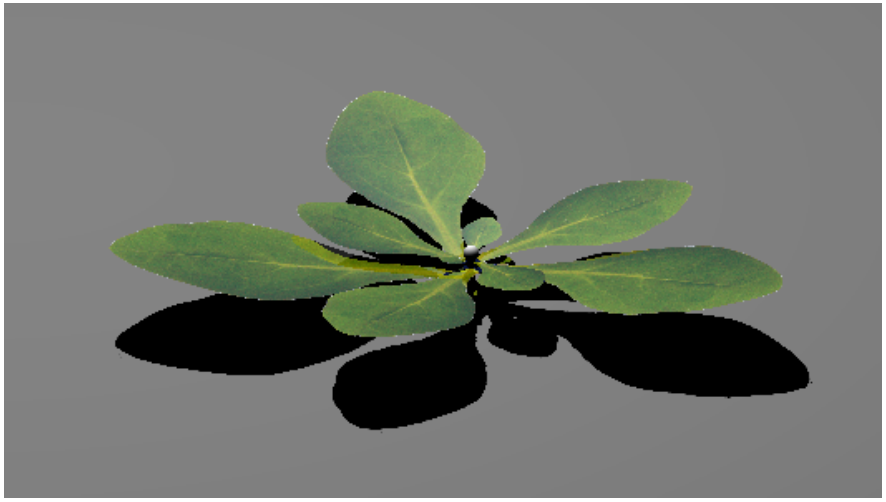
Thank you for your attention





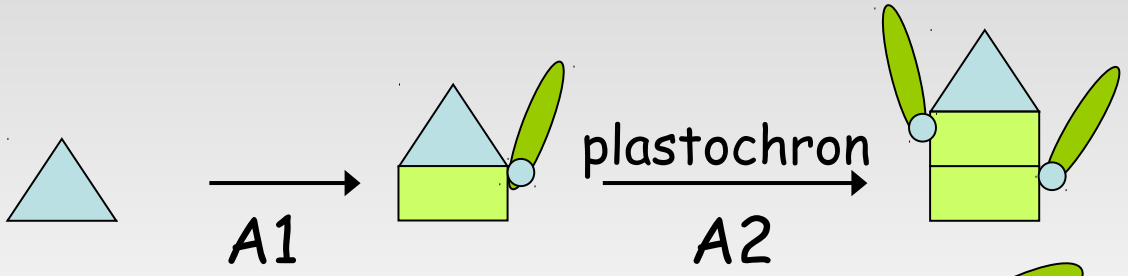


Petunia hybrida W115

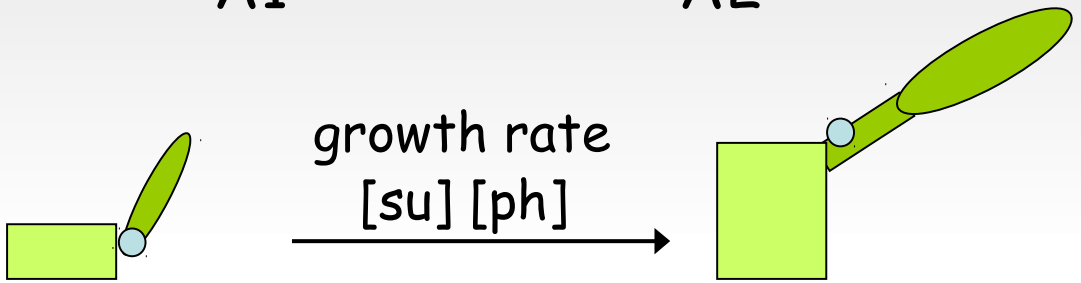
Plant modeling using L-systems

Basic production rules: aerial part

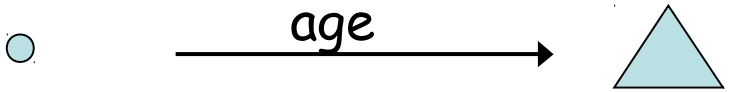
A: Phytomer production



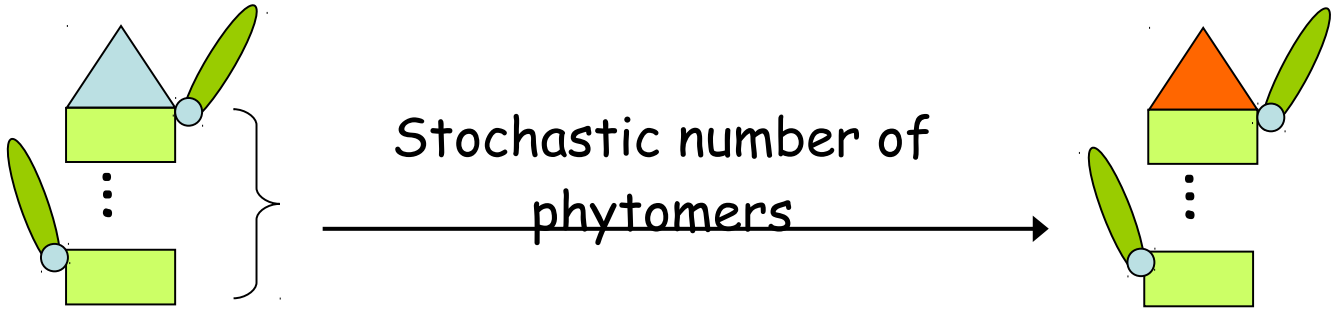
B: Phytomer development



C: Axillary bud outgrowth



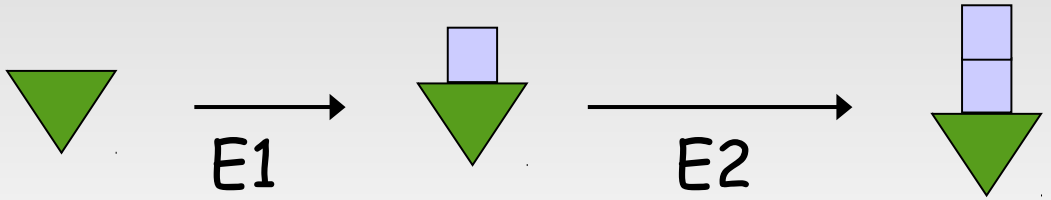
D: Floral organogenesis and phytomer numbers



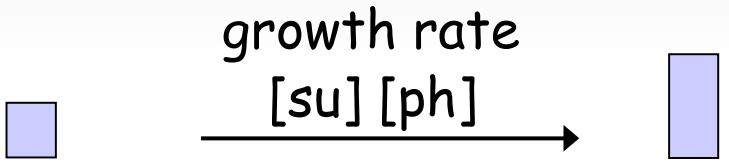
Plant modeling using L-systems

Basic production rules: roots

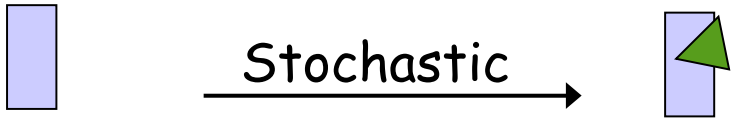
E: root unit production



F: root unit elongation



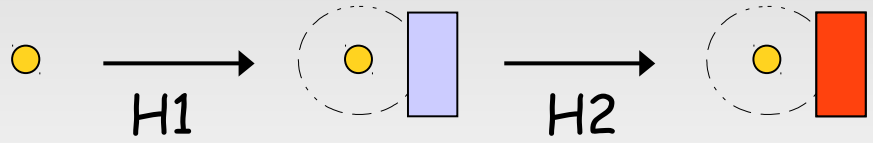
G: root ramification



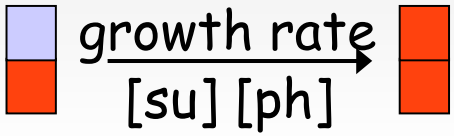
Plant modeling using L-systems

Basic production rules: mycorrize

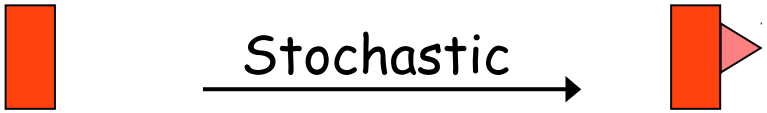
H: Spore contact and root colonisation



I: root colonisation spread (intraradical hyphae)



J: Extraradical hyphae development



K: hyphae unit production

