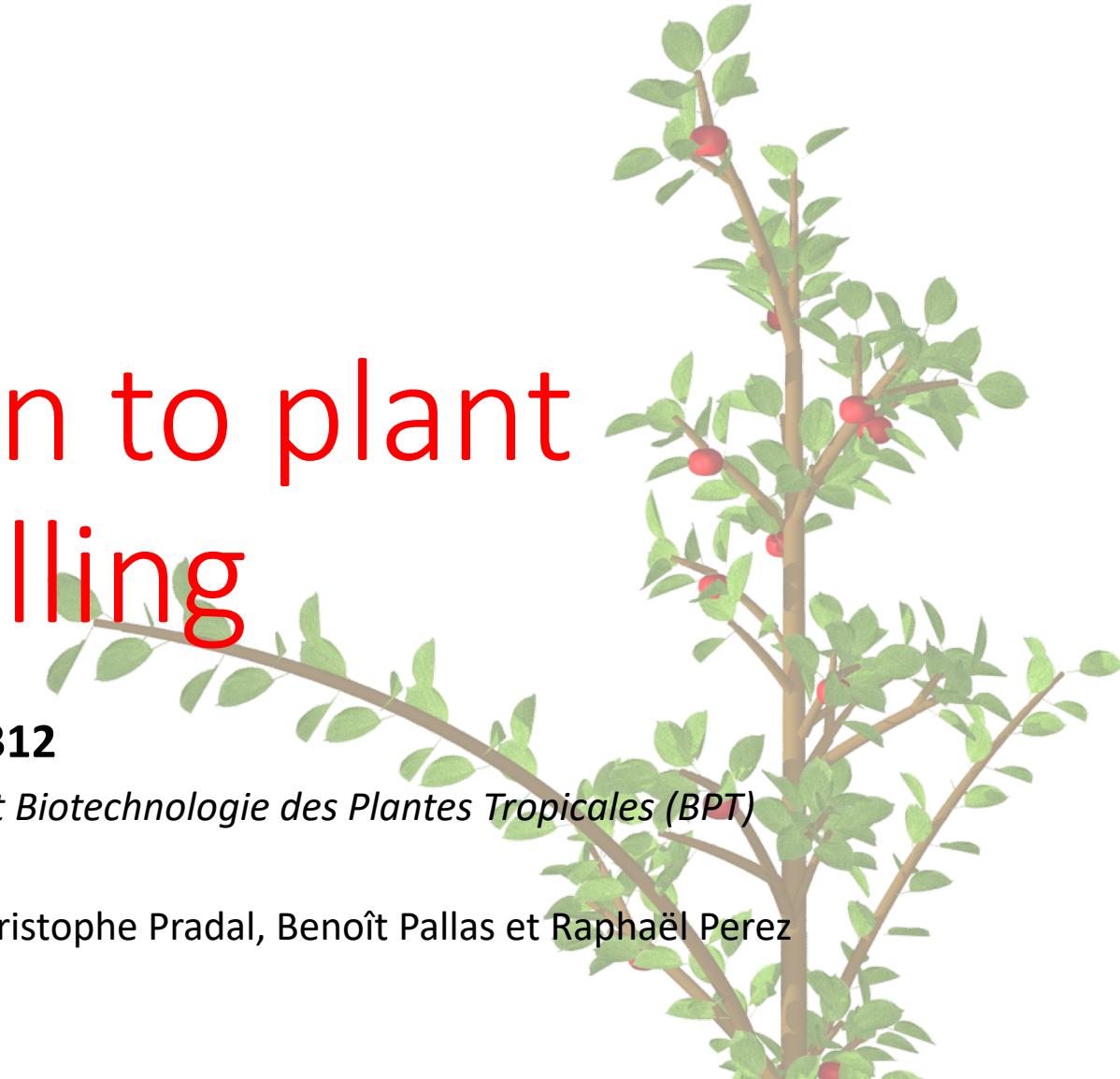


Introduction to plant modelling

HMBA312

Master Biologie Fonctionnelle des Plantes (BFP) et Biotechnologie des Plantes Tropicales (BPT)

Fred Boudon, Christian Fournier, Evelyne Costes, Christophe Pradal, Benoît Pallas et Raphaël Perez



Modelling = Conceptualize and Simplify

Reality



Question

Hypothesis



Conceptualisation
Formalisation

$$J_x = -D \frac{dN}{dx}$$

une « vue de l'esprit » analytique ou algorithmique (avec ou sans mathématiques) représentant des phénomènes et leurs relations

- wikipedia

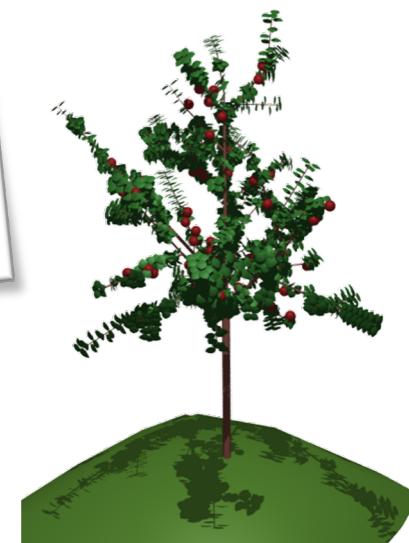
an analytical or algorithmic "view of mind" (with or without mathematics) representing phenomena and their relationships

Measurement
Calibration

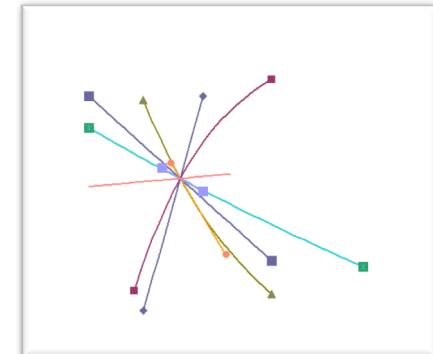
A screenshot of a Microsoft Excel spreadsheet titled 'Fonction et centre'. The table contains data points for 'x' and 'y' coordinates, along with some descriptive text at the top right. The data is as follows:

x	y	Centre
0,0000	3,95E-04	2,00E-05
0,0001	3,95E-04	2,00E-05
0,0002	3,95E-04	2,00E-05
0,0003	3,95E-04	2,00E-05
0,0004	3,95E-04	2,00E-05
0,0005	3,95E-04	2,00E-05
0,0006	3,95E-04	2,00E-05
0,0007	3,95E-04	2,00E-05
0,0008	3,95E-04	2,00E-05
0,0009	3,95E-04	2,00E-05
0,0010	3,95E-04	2,00E-05
0,0011	3,95E-04	2,00E-05
0,0012	3,95E-04	2,00E-05
0,0013	3,95E-04	2,00E-05
0,0014	3,95E-04	2,00E-05
0,0015	3,95E-04	2,00E-05
0,0016	3,95E-04	2,00E-05
0,0017	3,95E-04	2,00E-05
0,0018	3,95E-04	2,00E-05
0,0019	3,95E-04	2,00E-05
0,0020	3,95E-04	2,00E-05
0,0021	3,95E-04	2,00E-05
0,0022	3,95E-04	2,00E-05
0,0023	3,95E-04	2,00E-05
0,0024	3,95E-04	2,00E-05
0,0025	3,95E-04	2,00E-05
0,0026	3,95E-04	2,00E-05
0,0027	3,95E-04	2,00E-05
0,0028	3,95E-04	2,00E-05
0,0029	3,95E-04	2,00E-05
0,0030	3,95E-04	2,00E-05
0,0031	3,95E-04	2,00E-05
0,0032	3,95E-04	2,00E-05
0,0033	3,95E-04	2,00E-05
0,0034	3,95E-04	2,00E-05
0,0035	3,95E-04	2,00E-05
0,0036	3,95E-04	2,00E-05
0,0037	3,95E-04	2,00E-05
0,0038	3,95E-04	2,00E-05
0,0039	3,95E-04	2,00E-05
0,0040	3,95E-04	2,00E-05
0,0041	3,95E-04	2,00E-05
0,0042	3,95E-04	2,00E-05
0,0043	3,95E-04	2,00E-05
0,0044	3,95E-04	2,00E-05
0,0045	3,95E-04	2,00E-05
0,0046	3,95E-04	2,00E-05
0,0047	3,95E-04	2,00E-05
0,0048	3,95E-04	2,00E-05
0,0049	3,95E-04	2,00E-05
0,0050	3,95E-04	2,00E-05
0,0051	3,95E-04	2,00E-05
0,0052	3,95E-04	2,00E-05
0,0053	3,95E-04	2,00E-05
0,0054	3,95E-04	2,00E-05
0,0055	3,95E-04	2,00E-05
0,0056	3,95E-04	2,00E-05
0,0057	3,95E-04	2,00E-05
0,0058	3,95E-04	2,00E-05
0,0059	3,95E-04	2,00E-05
0,0060	3,95E-04	2,00E-05
0,0061	3,95E-04	2,00E-05
0,0062	3,95E-04	2,00E-05
0,0063	3,95E-04	2,00E-05
0,0064	3,95E-04	2,00E-05
0,0065	3,95E-04	2,00E-05
0,0066	3,95E-04	2,00E-05
0,0067	3,95E-04	2,00E-05
0,0068	3,95E-04	2,00E-05
0,0069	3,95E-04	2,00E-05
0,0070	3,95E-04	2,00E-05
0,0071	3,95E-04	2,00E-05
0,0072	3,95E-04	2,00E-05
0,0073	3,95E-04	2,00E-05
0,0074	3,95E-04	2,00E-05
0,0075	3,95E-04	2,00E-05
0,0076	3,95E-04	2,00E-05
0,0077	3,95E-04	2,00E-05
0,0078	3,95E-04	2,00E-05
0,0079	3,95E-04	2,00E-05
0,0080	3,95E-04	2,00E-05
0,0081	3,95E-04	2,00E-05
0,0082	3,95E-04	2,00E-05
0,0083	3,95E-04	2,00E-05
0,0084	3,95E-04	2,00E-05
0,0085	3,95E-04	2,00E-05
0,0086	3,95E-04	2,00E-05
0,0087	3,95E-04	2,00E-05
0,0088	3,95E-04	2,00E-05
0,0089	3,95E-04	2,00E-05
0,0090	3,95E-04	2,00E-05
0,0091	3,95E-04	2,00E-05
0,0092	3,95E-04	2,00E-05
0,0093	3,95E-04	2,00E-05
0,0094	3,95E-04	2,00E-05
0,0095	3,95E-04	2,00E-05
0,0096	3,95E-04	2,00E-05
0,0097	3,95E-04	2,00E-05
0,0098	3,95E-04	2,00E-05
0,0099	3,95E-04	2,00E-05
0,0100	3,95E-04	2,00E-05

Simulation



Sensitivity
Analysis



Typology of models

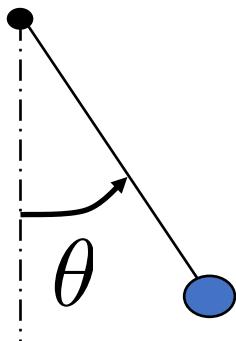
- Descriptive models:
 - Direct link (correlation) between input and output.
 - Regression, empirical laws.
 - Do not or poorly reflect underlying mechanisms of the modelled phenomena
- Mechanistical models:
 - Based on the causality principle.
 - Can use concepts pf physic, biology, chemistry, etc.

Typology of models

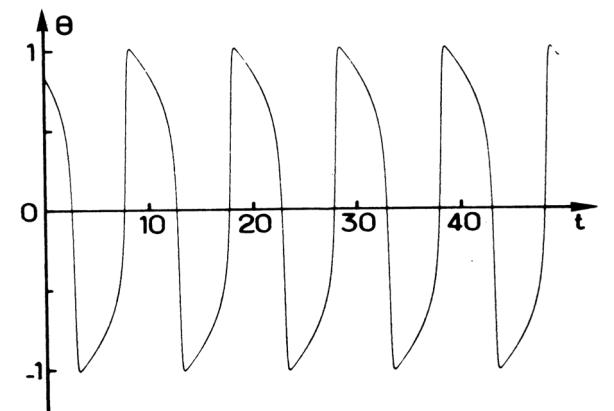
- Example of descriptive models :
 - Allometric relationship such as WBE (West, Brown, Enquist, 1998) that links Q_0 the xylem transport rate and the mass of the plant.

$$Q_0 \alpha M^{\frac{3}{4}}$$

- Example of mechanistical models:
 - Oscillation of a pendulum



$$\dot{\theta}^2 + 2\omega_0^2(\cos \theta_0 - \cos \theta) = 0$$



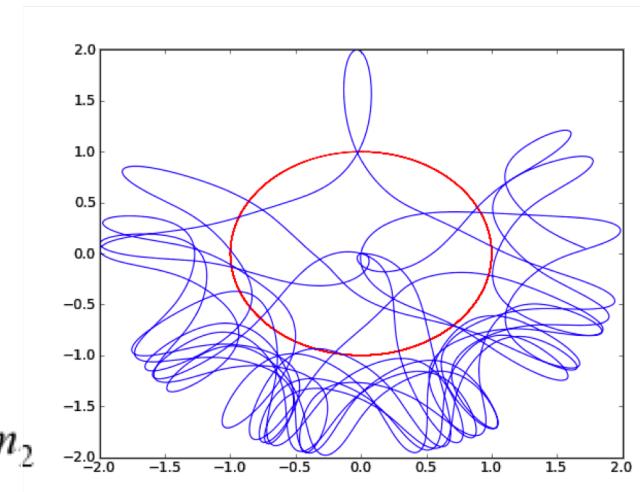
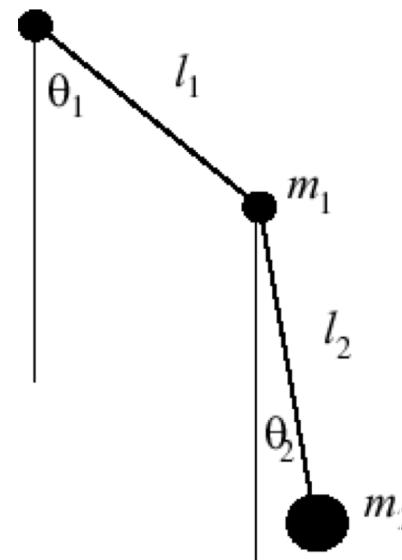
Advantages and Disadvantages

- Descriptive models:

- Easy to calibrate and analyze

- Limited prediction

- Do not explain



- Mechanistical models:

- Predictive

- Give access to difficult-to-measure indicators on underlying mechanisms

- Difficult to calibrate and analyze

- Complex development that often requires a variety of disciplines

Chaotic behaviour
the double pendulum

Interest of a model

- For science,
 - Testing hypothesis
 - Testing the completeness and coherence of a body of knowledge
 - Synthesize knowledge
 - Support for exchanges and communication between disciplines
 - ...
- Applicative interest
 - Computer-aided design
 - ...
- Pedagogical tools
- Communication tools

Plants are complex objects to model



Different levels of organisation



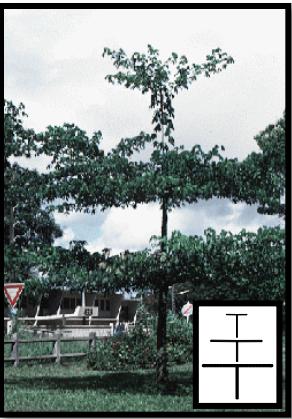
Tropical forest (Ghats, India)

(Y. Caraglio)

Ghat sholas (Y. Caraglio)



Alepo pine (Y. Caraglio)



(Y. Caraglio)



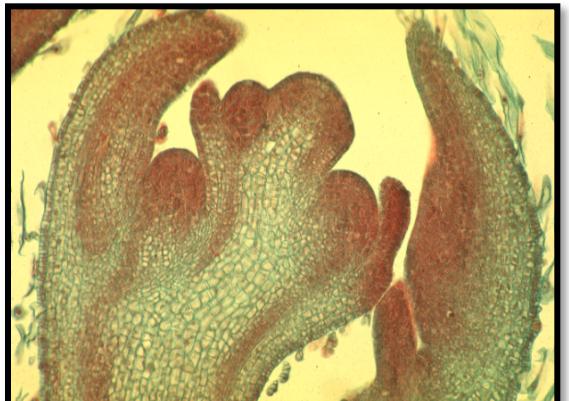
(Y. Caraglio)



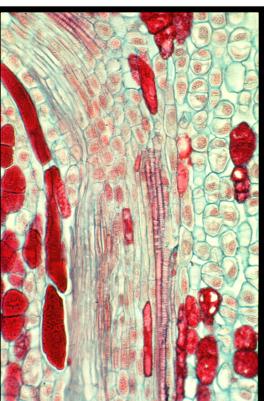
Nauclea sp. (Y. Caraglio)



Abies sp. (Y. Caraglio)

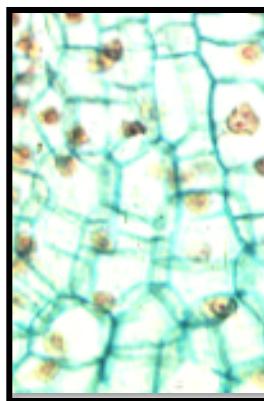


Phaseolus sp.

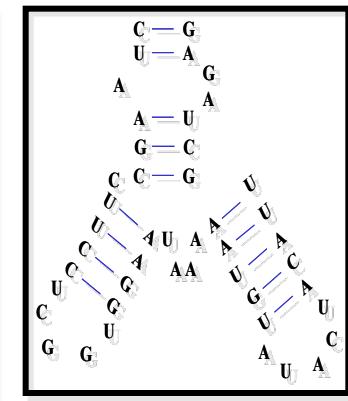


(J.L Bompard)

Pinus sp., Y. Caraglio

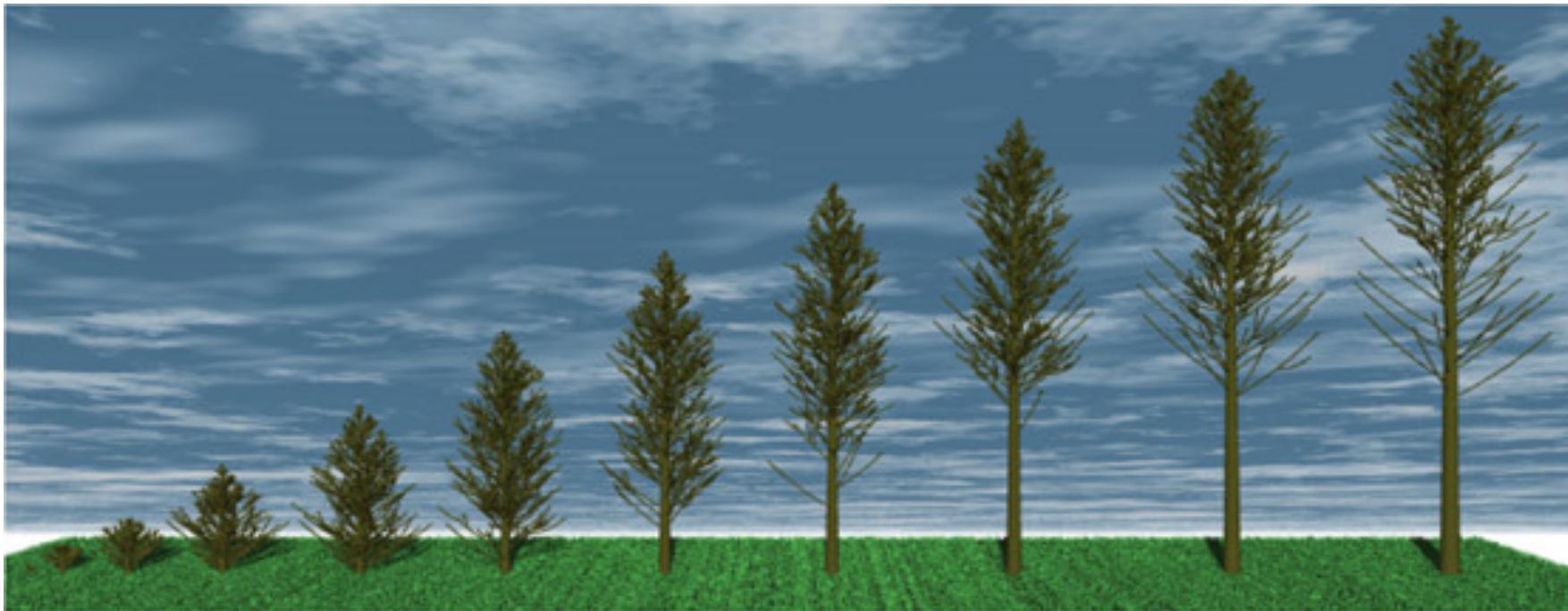


Coleus sp. (J.L Bompard)



A set of growing organs in interaction

- A variable number of organs through time
- Competition and cooperation between organs phenomena

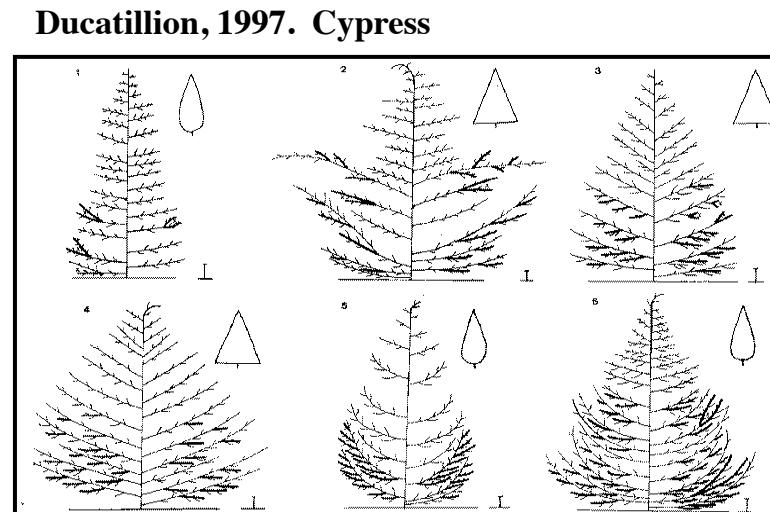


(Caraglio et al., 2000)

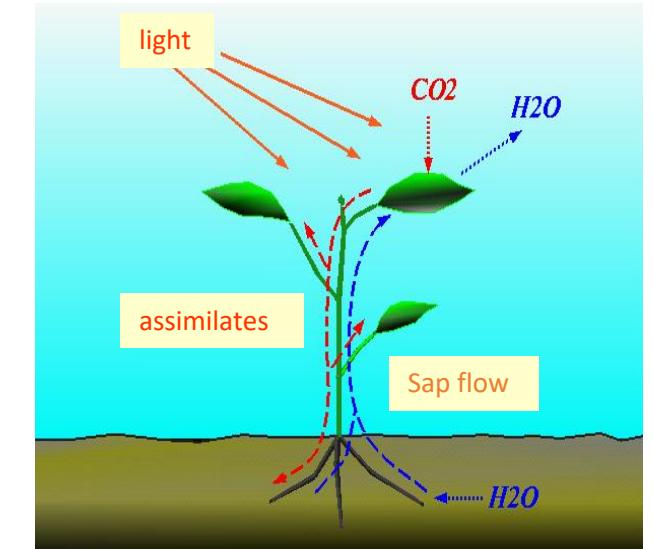
A diversity of factors that modulate their developments

- Plant development depends ...

- Genomes
- Temperature
- Resources availability (Water, nutrient, light, space, etc.)
- Mechanical constraints
- etc.



Genetic variability

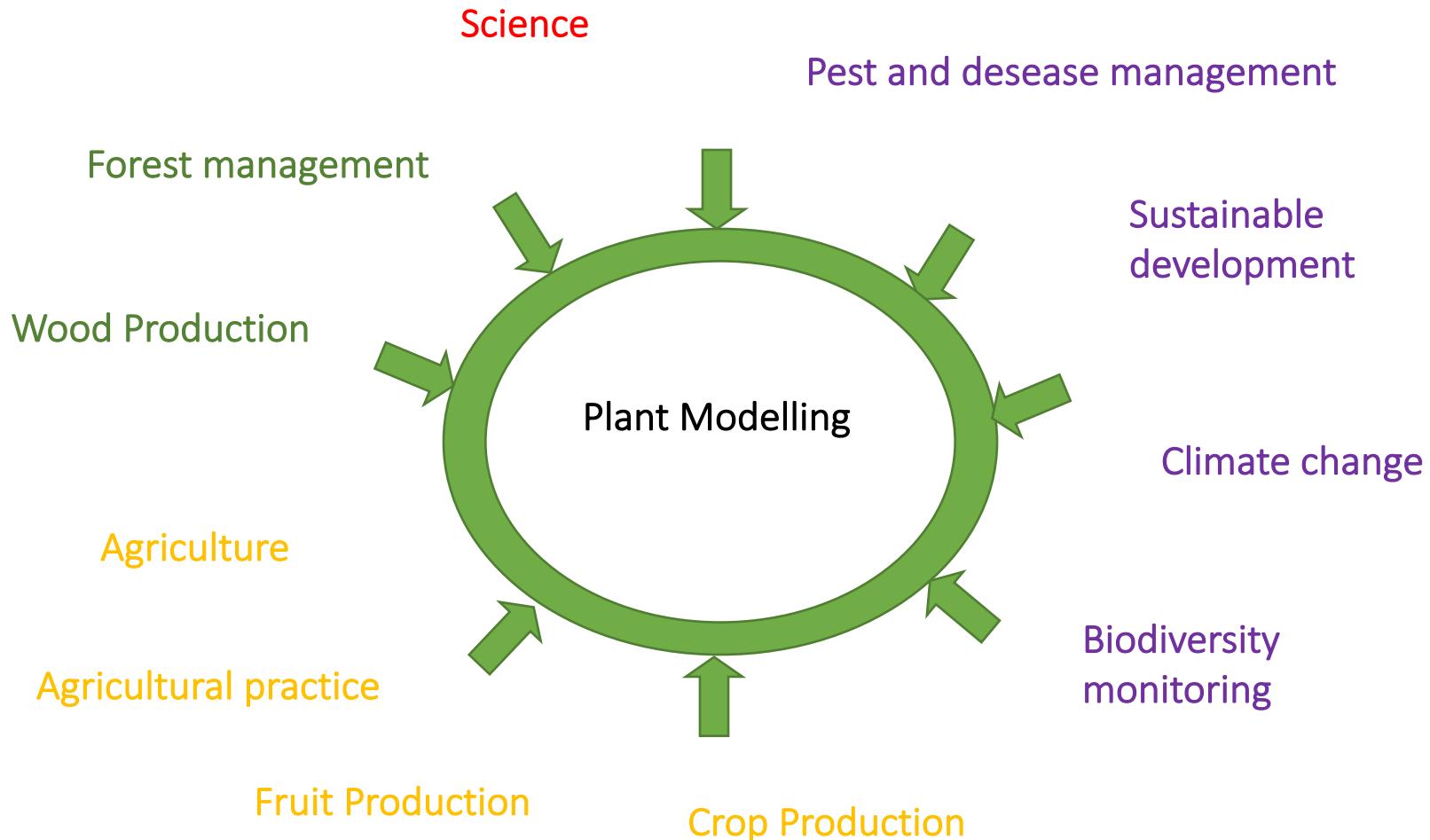


Grosfeld, 1999. Araucaria



Environmental factors

A variety of questions



A focus on plant architecture and functioning



- Modelling of plant 3D structure 3D and their organs
 - Modelling of ecophysiological processes
 - Spatialisation of processes in the plants
- Formalism of structural-fonctional plant models (FSPM).

Program

- **Monday**

- 9h - 9h30 : Introduction – *F. Boudon*
- 9h30 - 10h : Modelling approach– *C. Pradal*
- 10h - 12h : Introduction to programming– *C. Pradal*
- 14h - 15h : Plant Architecture – *E. Costes*
- 15h - 17h : Architecture phenotyping – *F. Boudon*

- **Tuesday**

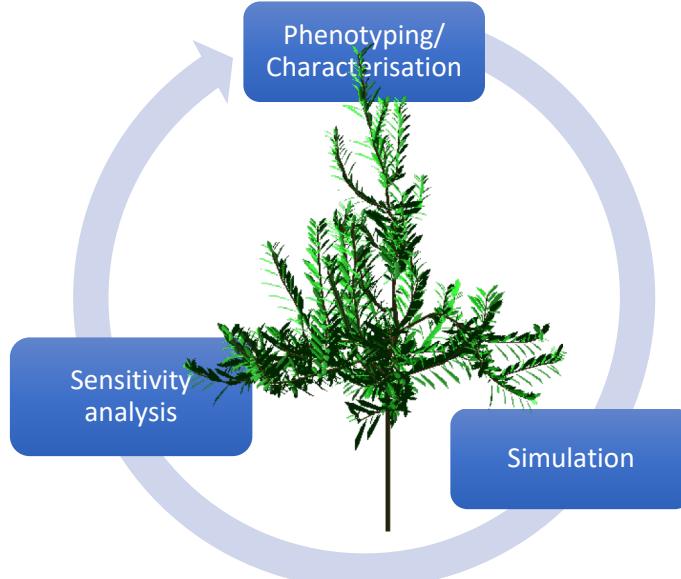
- 9h - 12h : The L-System formalism – *F. Boudon*
- 14h - 16h : Simulating plants with L-systems - *F. Boudon*
- 16h - 17h : Modelling projects

- **Wednesday**

- 9h - 10h : Ecophysiological processes. From crop model to FSPM – *B. Pallas*
- 10h - 12h : Light modelling, RUE and photosynthesis – *C. Fournier*
- 14h - 16h : Recent work on carbon allocation model / signalling – *B. Pallas*
- 16h - 17h : Modelling projects

- **Thursday**

- 9h - 12h : Sensitivity analysis – *R. Perez*
- 14h - 17h : Modelling projects
- 14h - 17h : Presentation of the modelling projects



F. Boudon



B. Pallas



C. Pradal



E. Costes



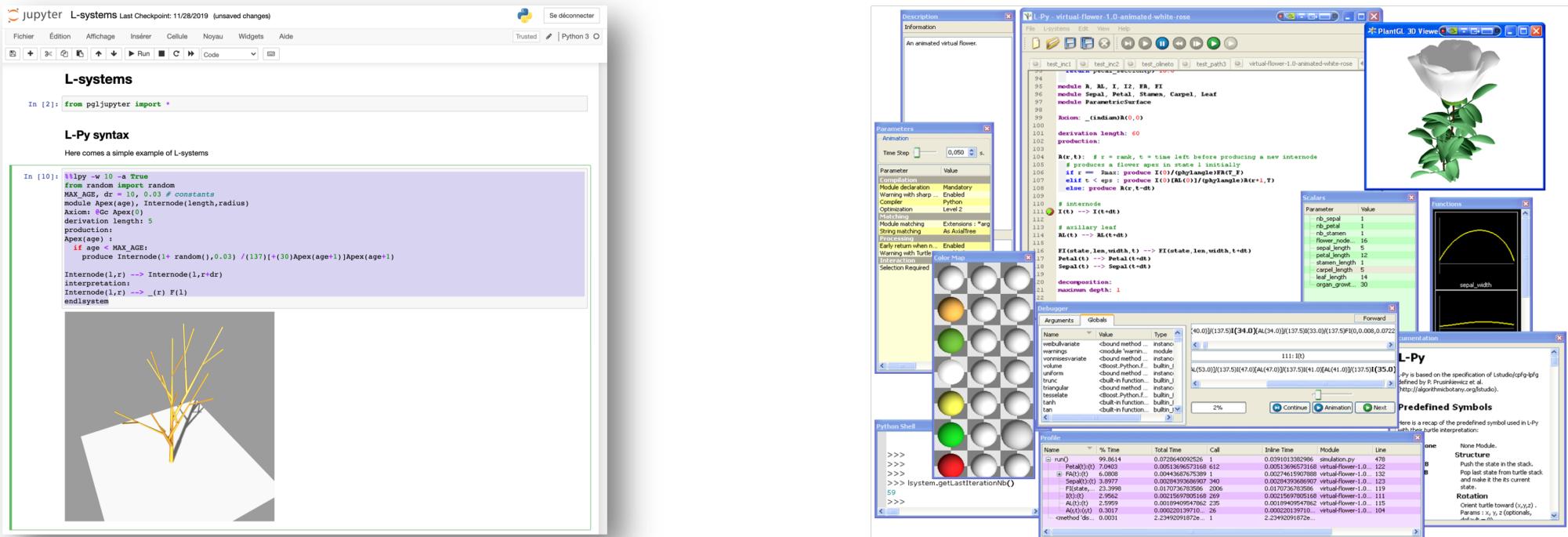
R. Perez



C. Fournier

Python as modelling language

- **Open-source** high level modelling language
- Jupyter: **web-based** interactive computational **environment** for creating notebook documents
- L-Py: a dedicated scientific module for **plant simulation with 3D visualization**.
- Sensitivity analysis made with **R** within Jupyter notebooks.



Organisation of sessions

- Organisation of remote sessions
 - Video for lectures.
 - Password : **plantmodelling**
 - Question sessions
 - Tutorials with notebooks.
- All information such as video links and tutorials on:
https://github.com/openalea-training/hbma312_training
- Use of Zoom to communicate with the group.
- Team meeting for private conversations.

Modelling projects

- Modelling a fruit tree



- Fill the form for the assignment on framasoft
- Final exam consist on presenting your models, its objectives, its analysis

➤ Wednesday 16/12 Afternoon

			Kiwi Vine	Mango Tree	Palm Tree	Peach Tree	Vine	
	Your name							
<input type="button" value="Save choices 0/5"/>								<input type="button" value="Save"/>

Practical information

- Meeting at 8h55 and 13h55 on Zoom every day.
 - Appointment for questions and tutorials
- We will stay on Zoom. Don't hesitate to ask question, interact ...

First questions ?

