



THE 1ST INTERNATIONAL SUMMER SCHOOL ON ADVANCED SOIL PHYSICS

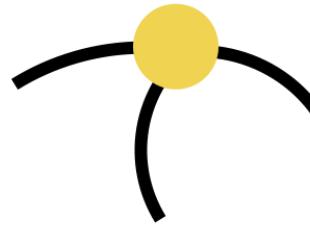
MODELING WATER FLUXES IN THE SOIL-PLANT SYSTEM

MODELLING ROOT ARCHITECTURE

GUILLAUME LOBET

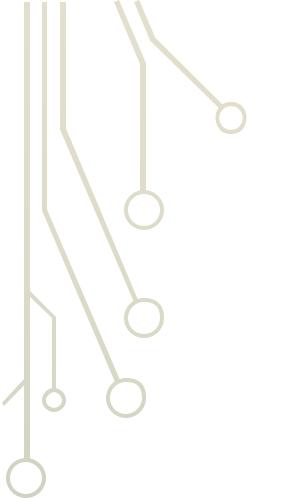
ROOT SYSTEM DEVELOPMENT

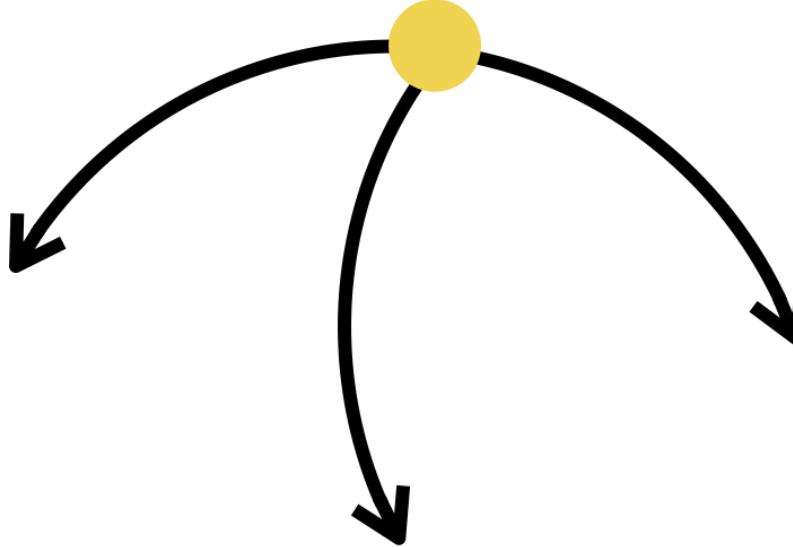


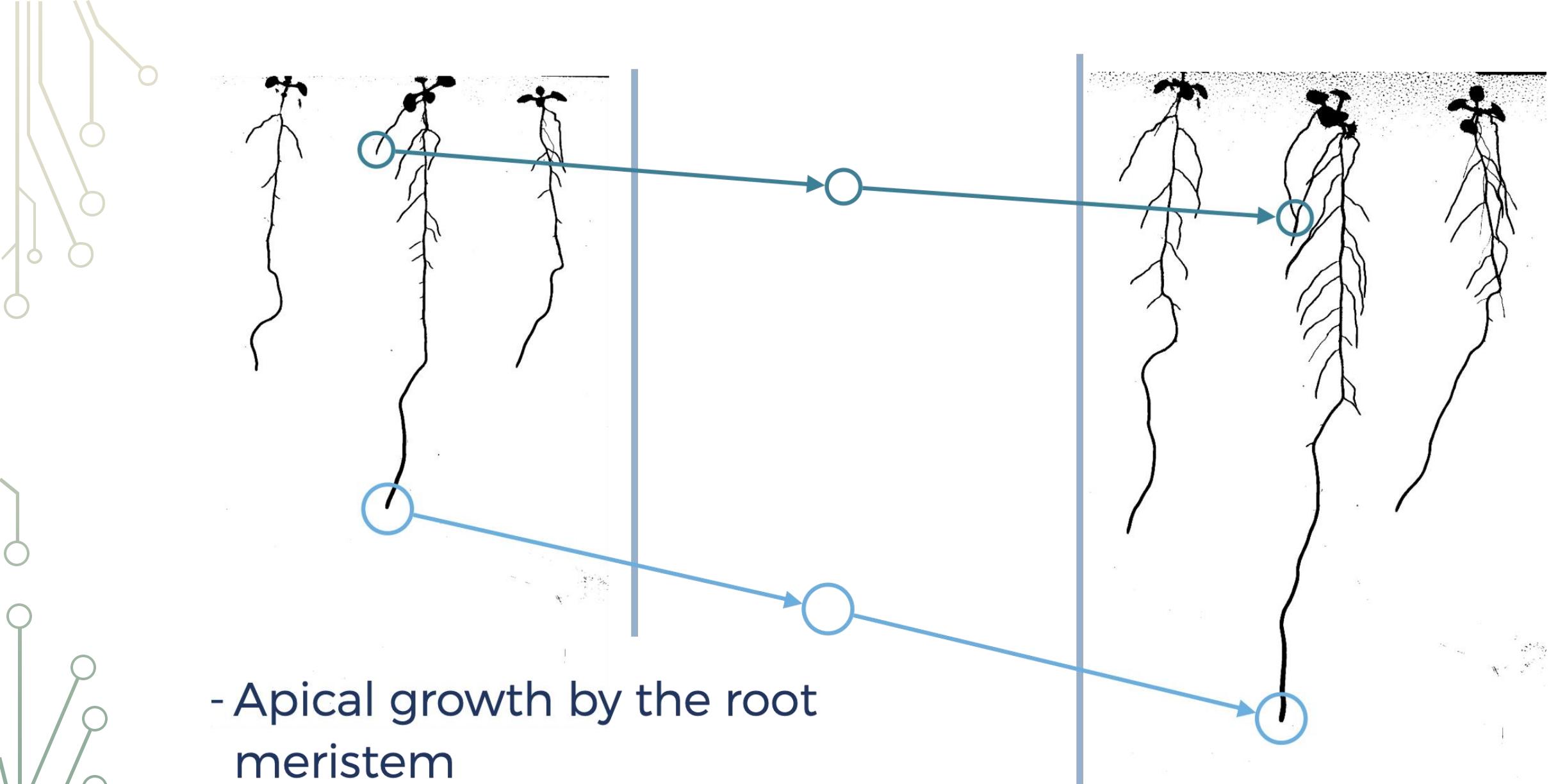


1. Axes formations

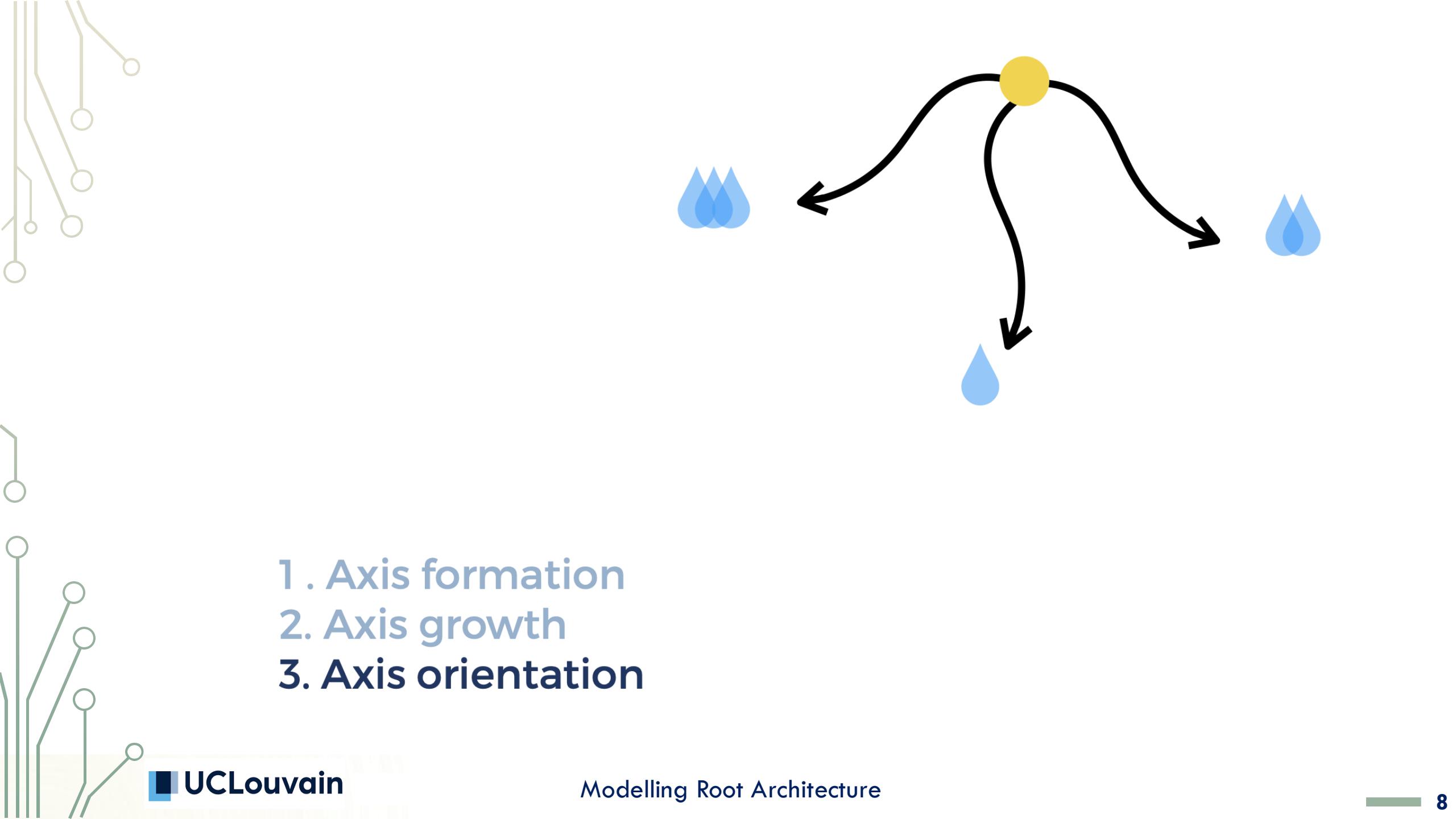




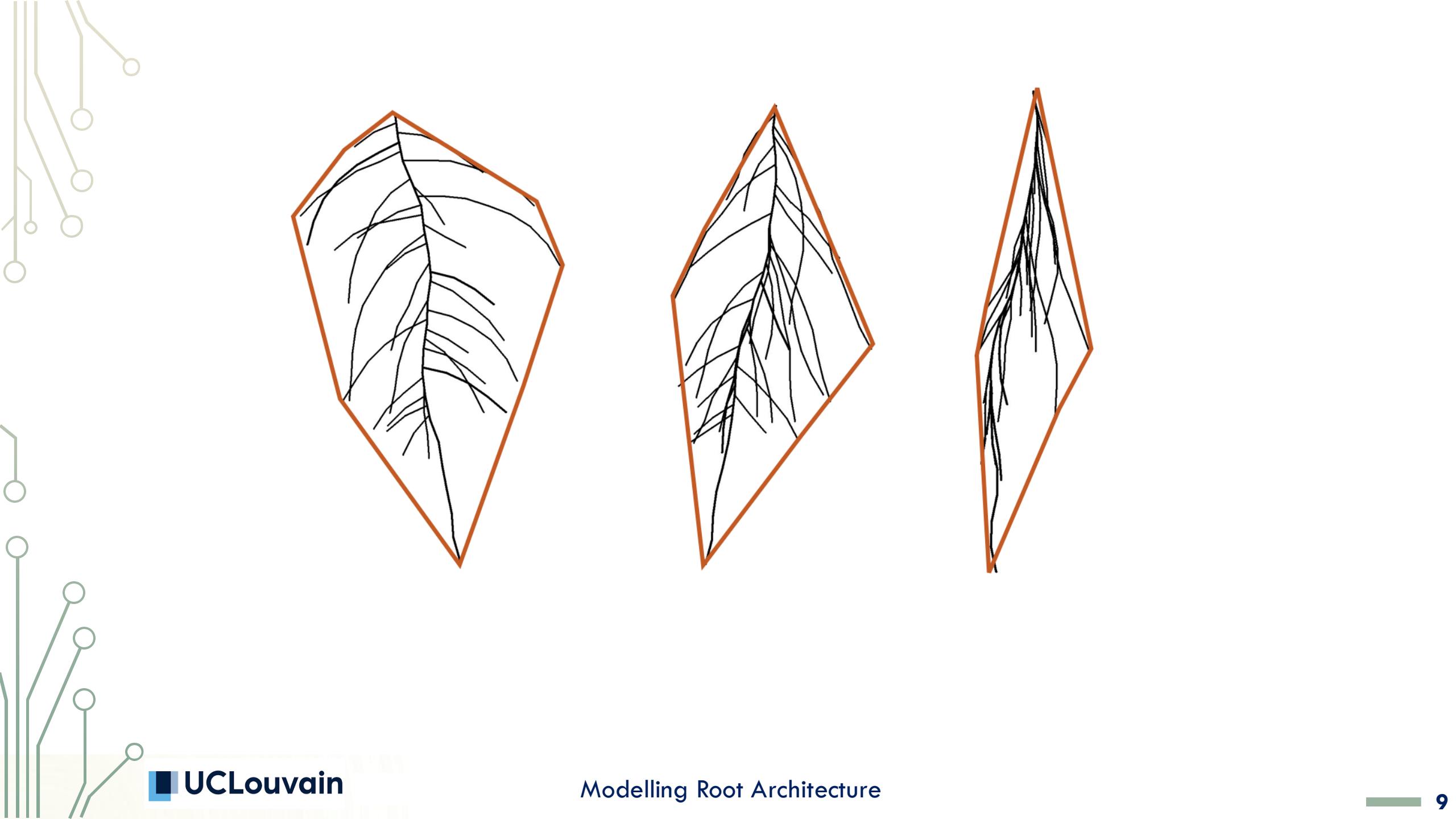
- 
1. Axis formation
 2. Axis growth

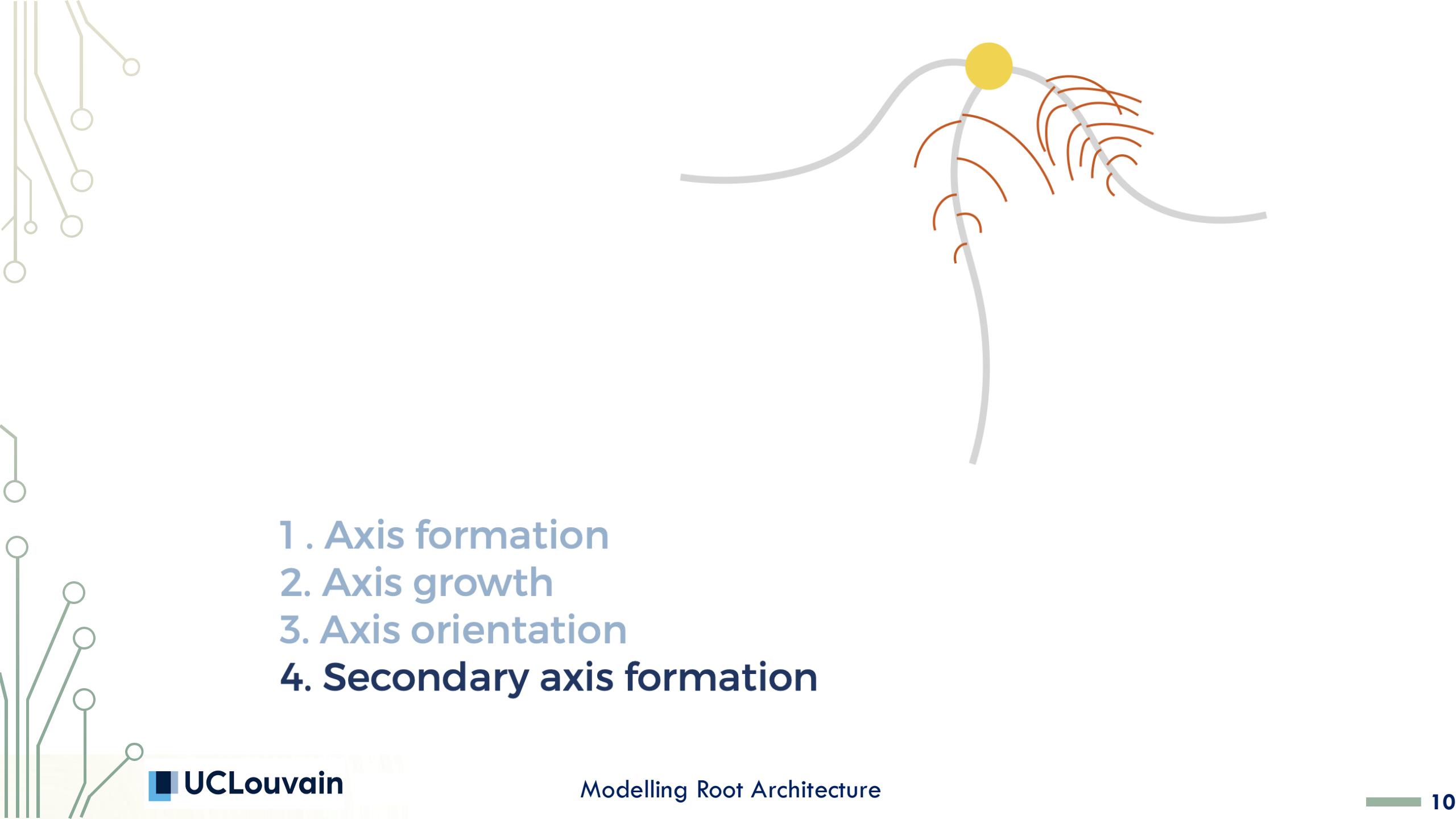


- Apical growth by the root
meristem

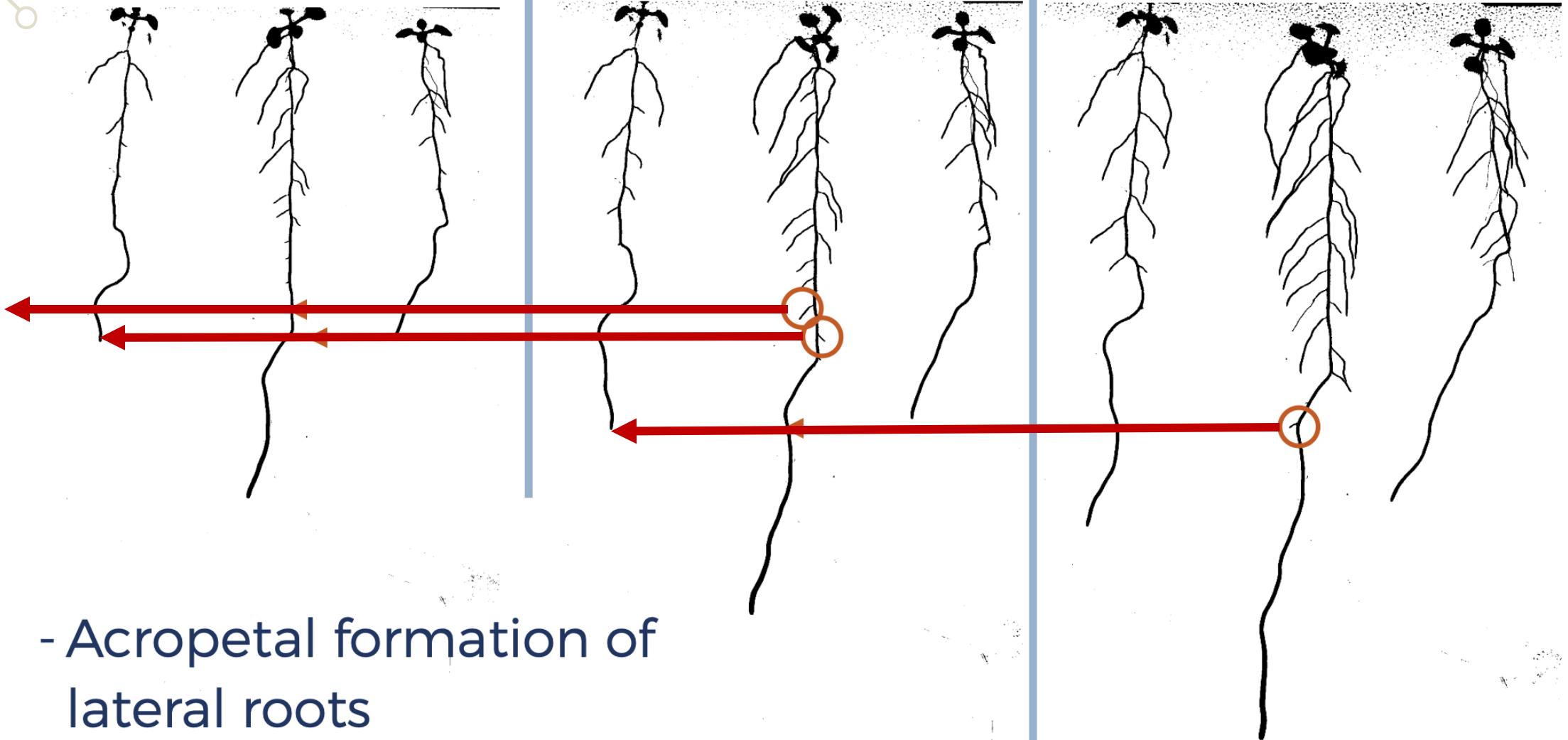


1. Axis formation
2. Axis growth
3. Axis orientation



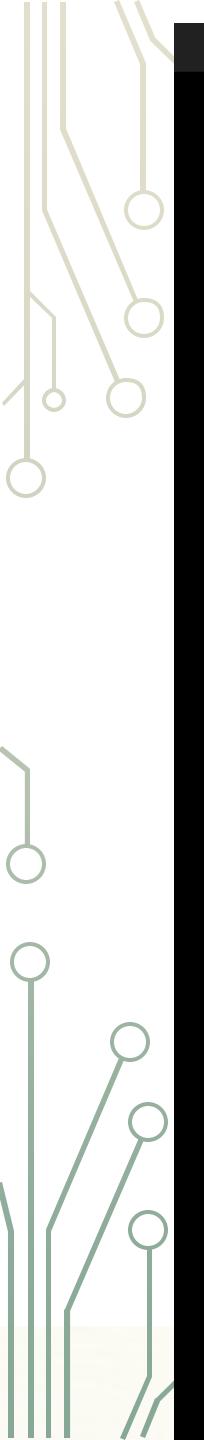
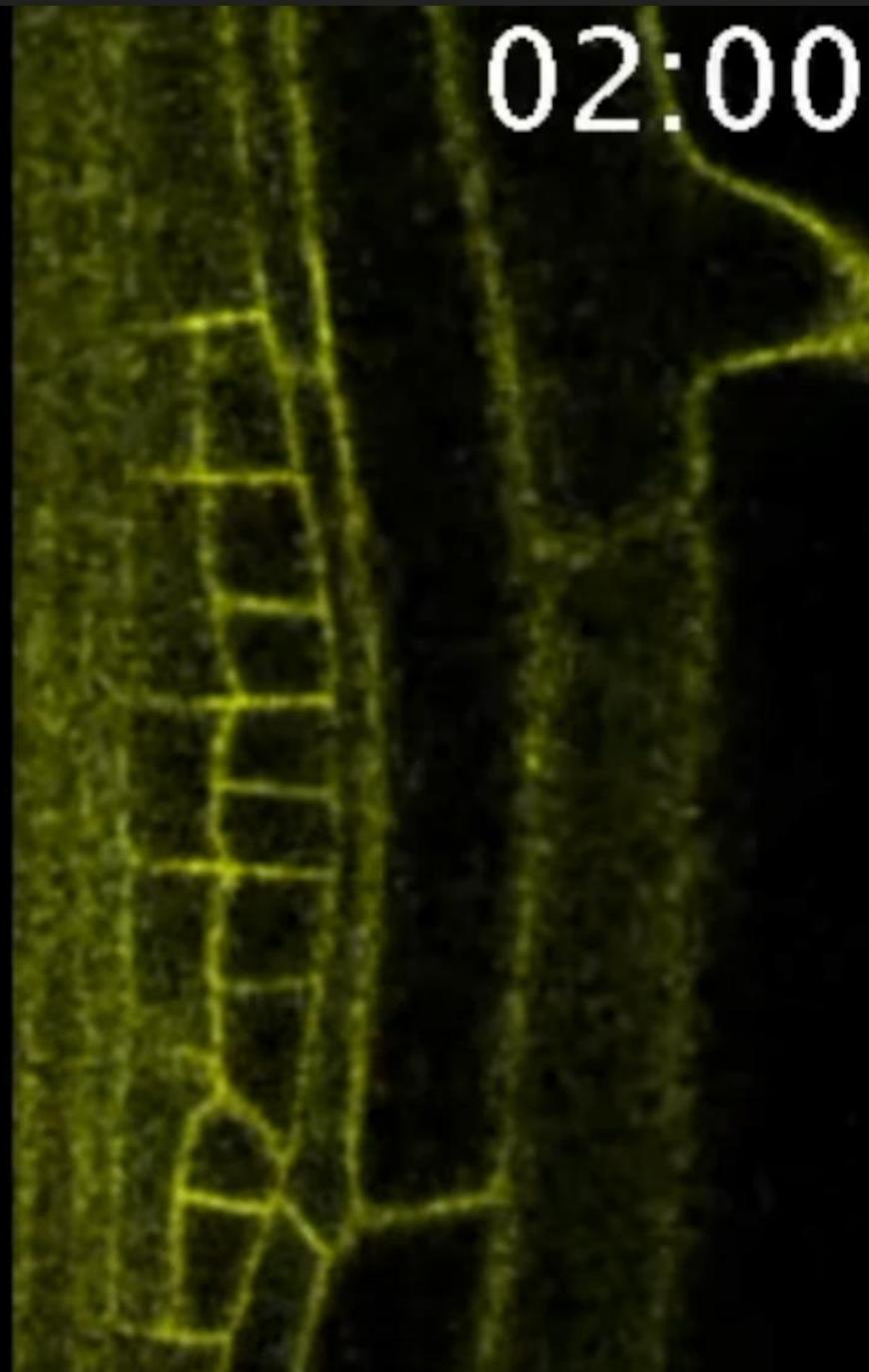


- 1. Axis formation**
- 2. Axis growth**
- 3. Axis orientation**
- 4. Secondary axis formation**

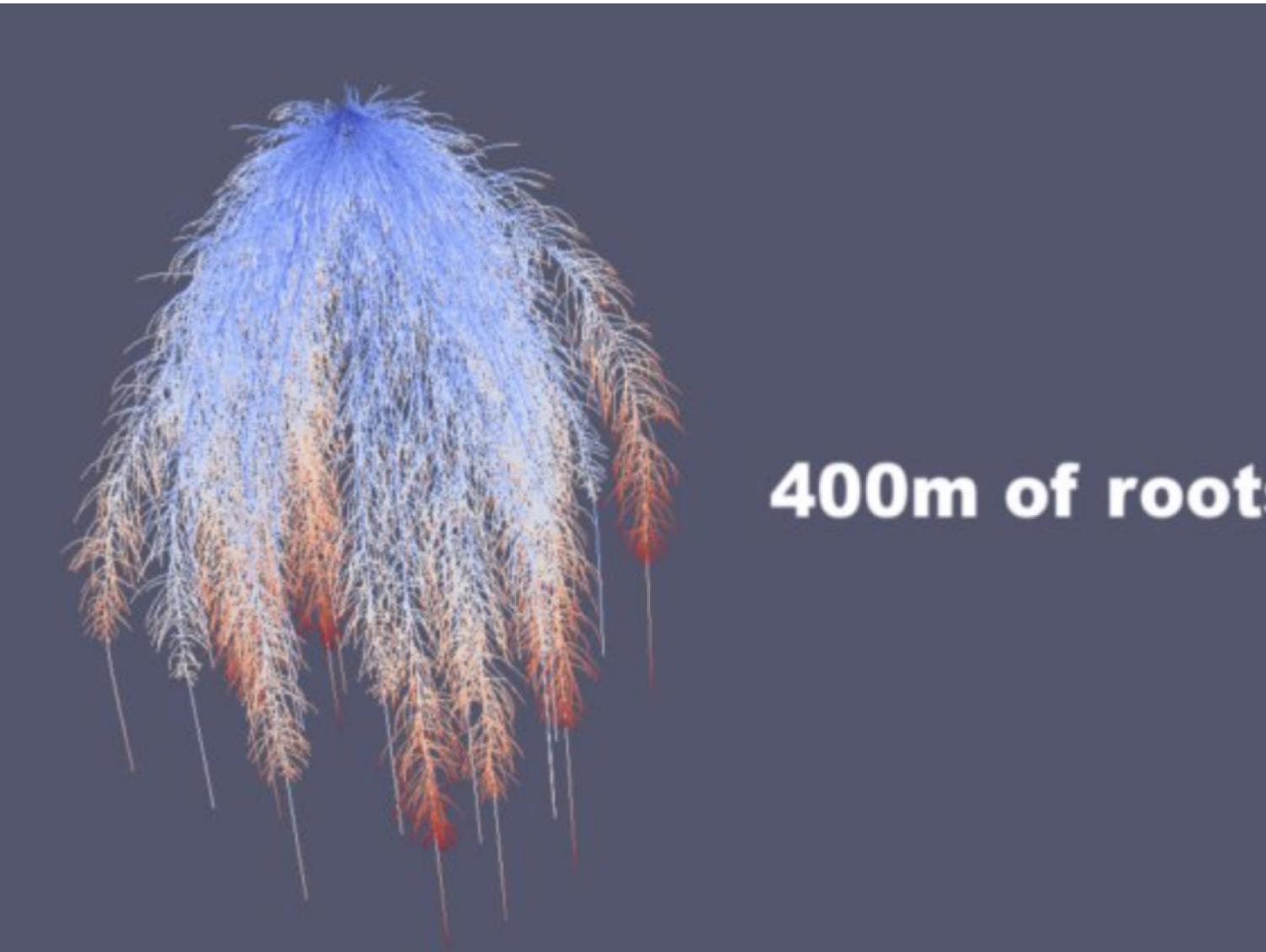


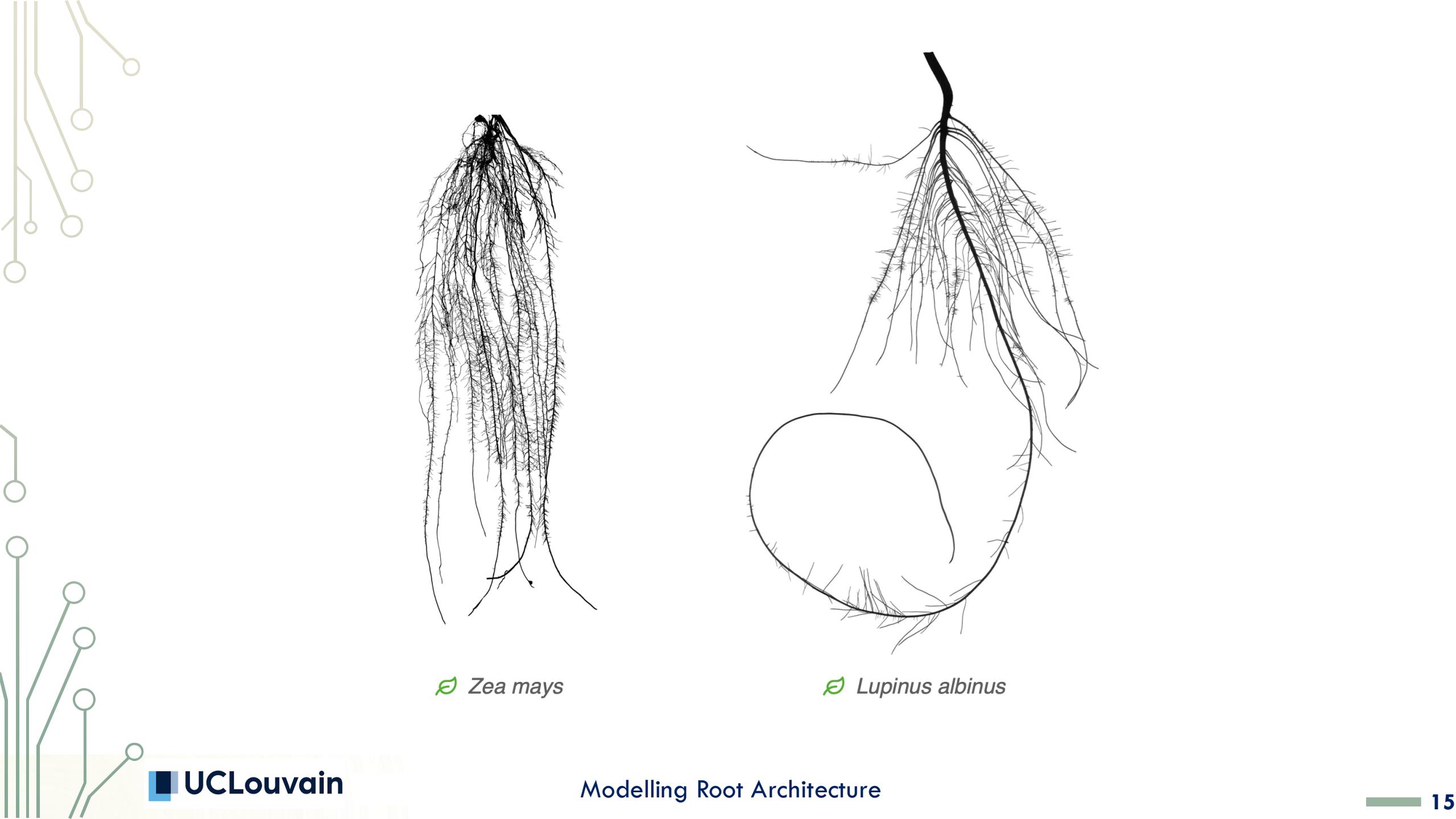
- Acropetal formation of
lateral roots

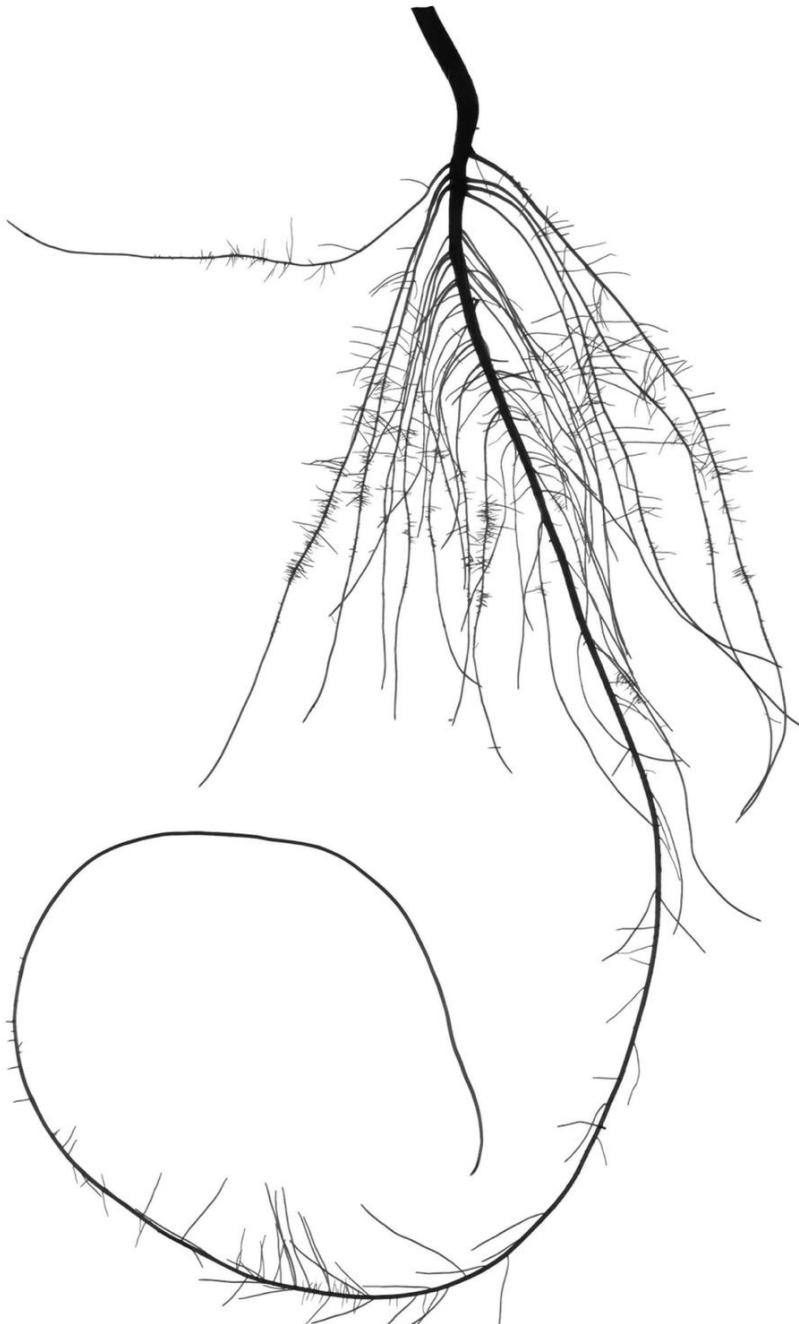
02:00



WOOLAP

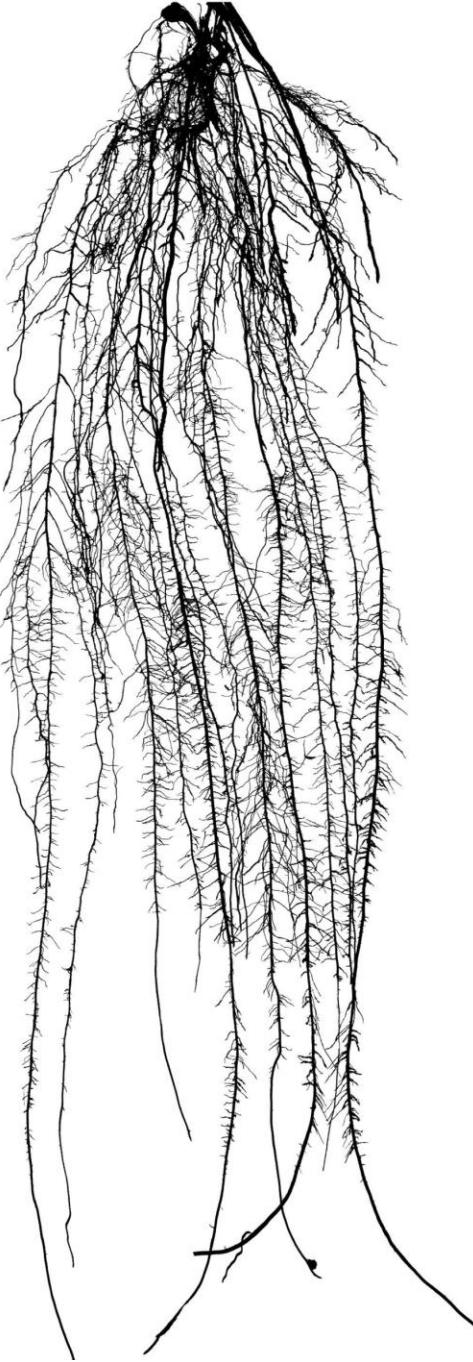
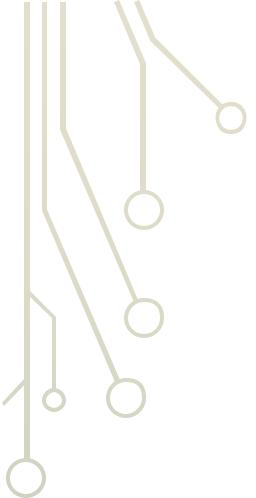






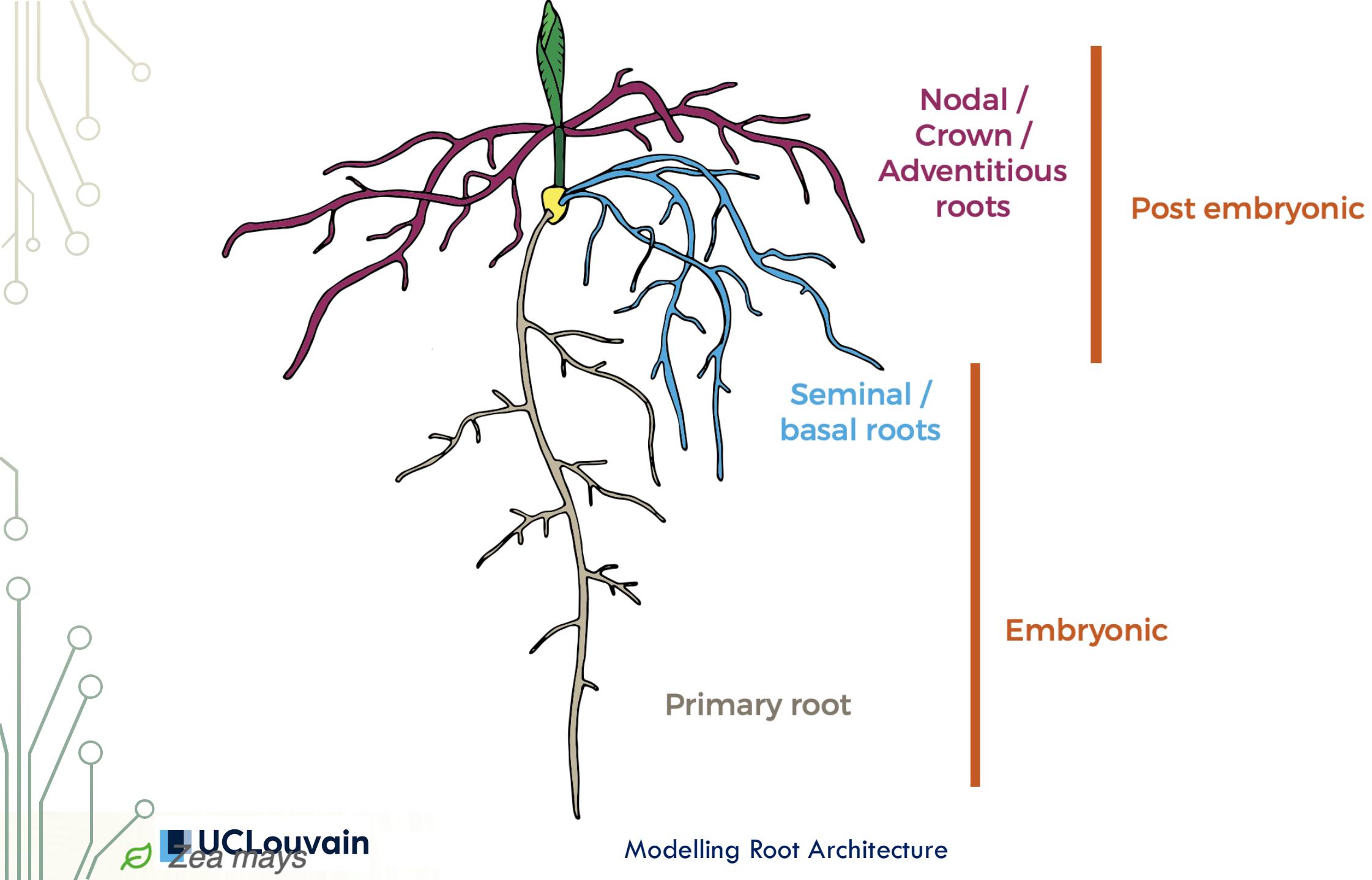
Modelling Root Architecture

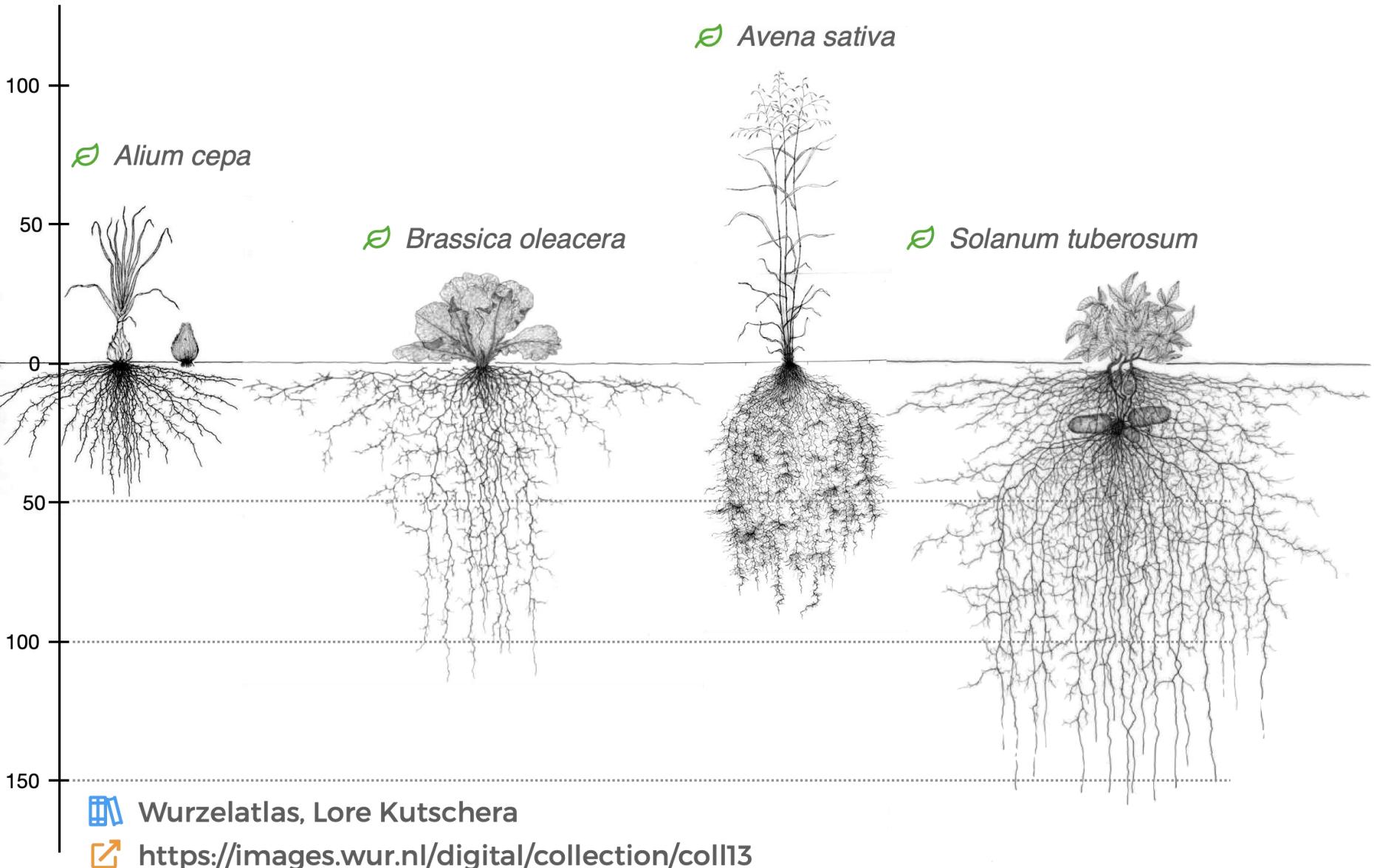
- Secondary growth
- One primary axis
- Dicots

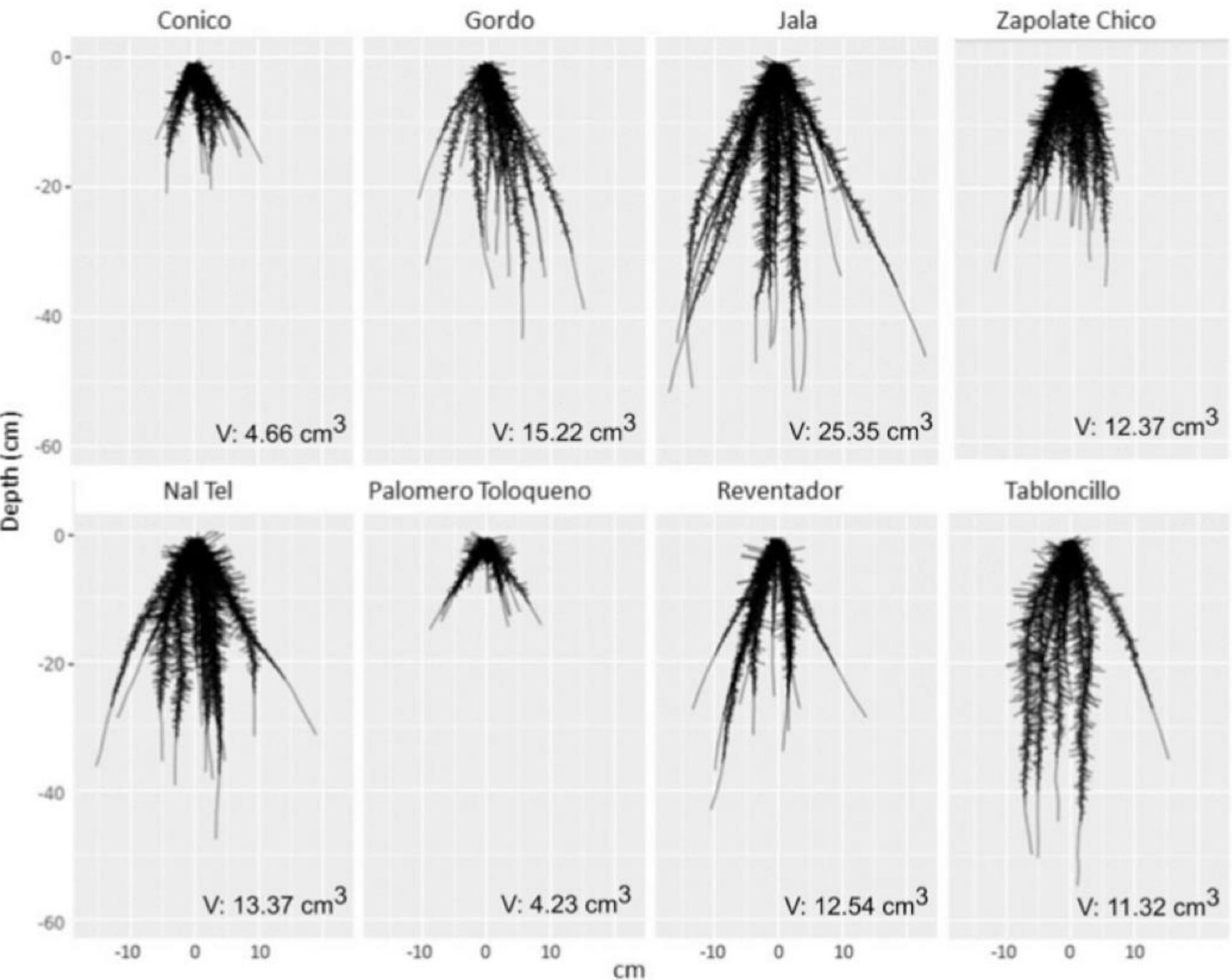


Modelling Root Architecture

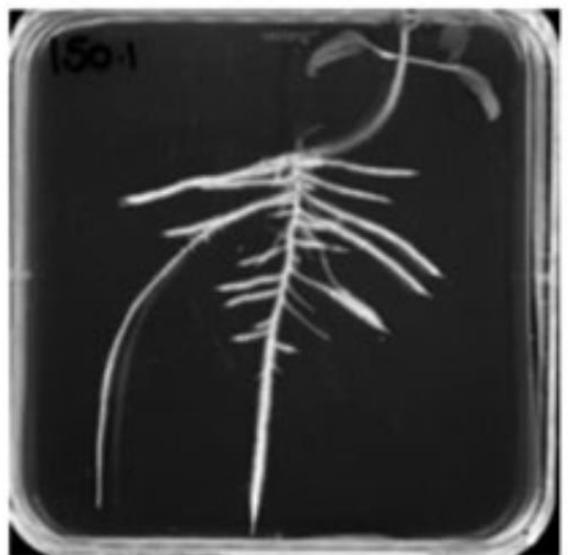
- No secondary growth
- Several primary axis
- Monocots



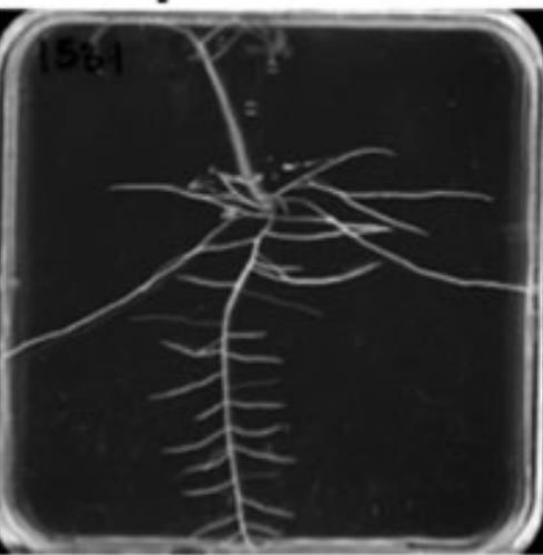




A Christmas Tree



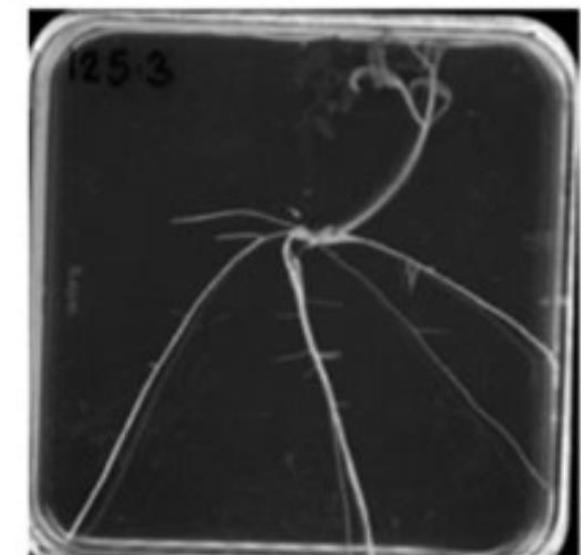
Telephone Pole

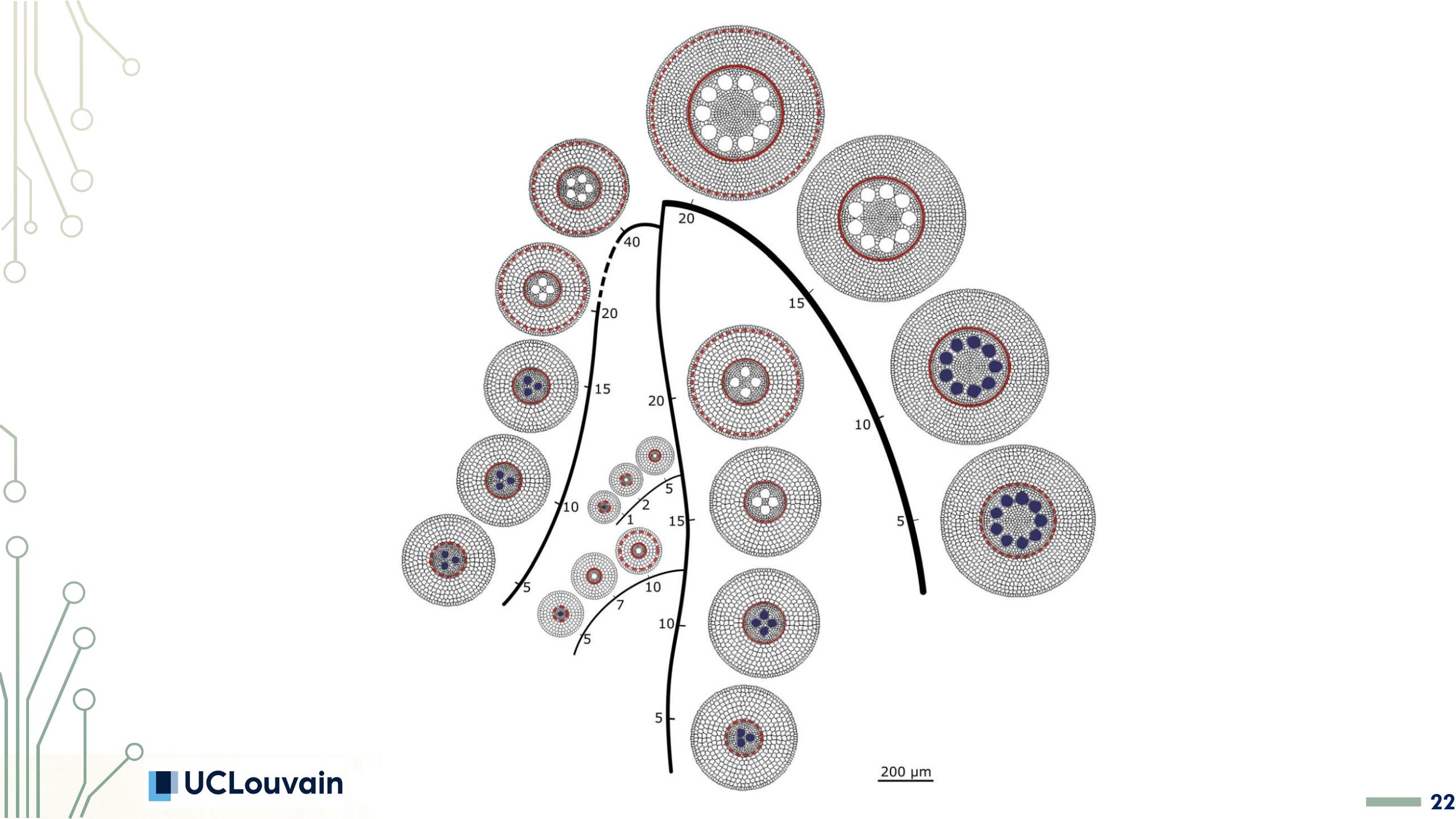


Droopy Telephone Pole



Broomstick





ROOT SYSTEM DESCRIPTION

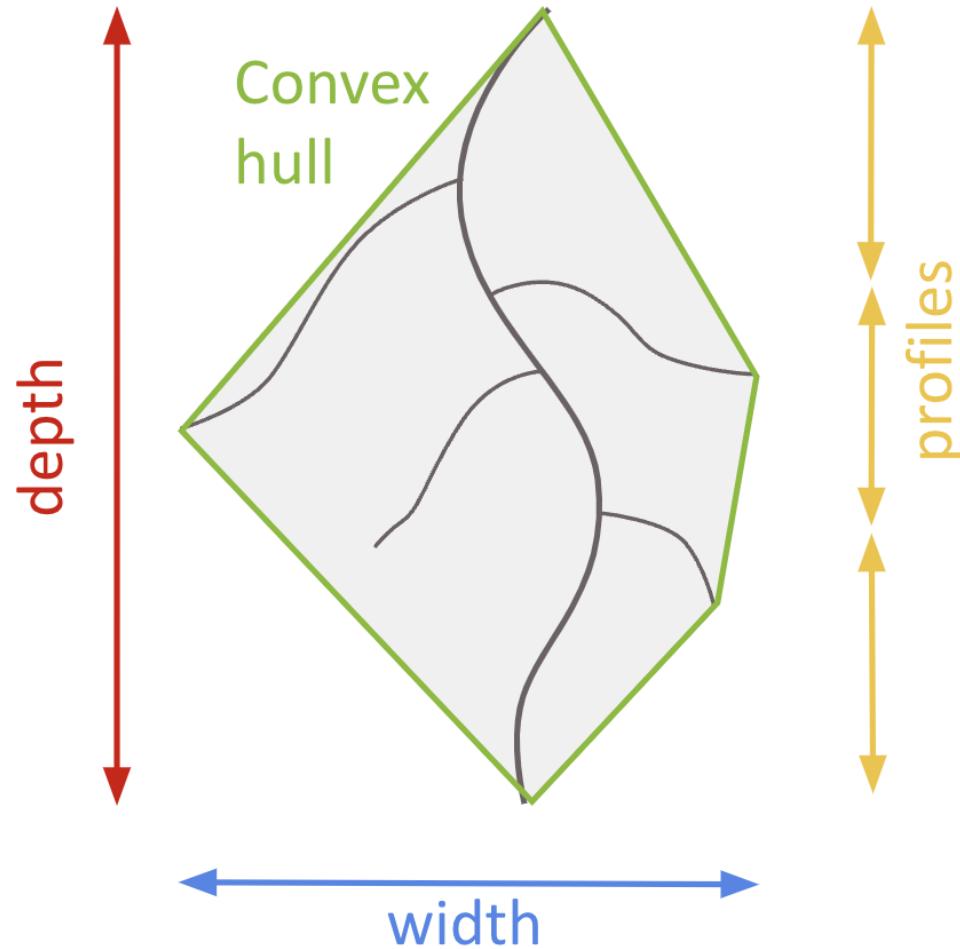
Geometrical information

What you need

Position in space of every root segment

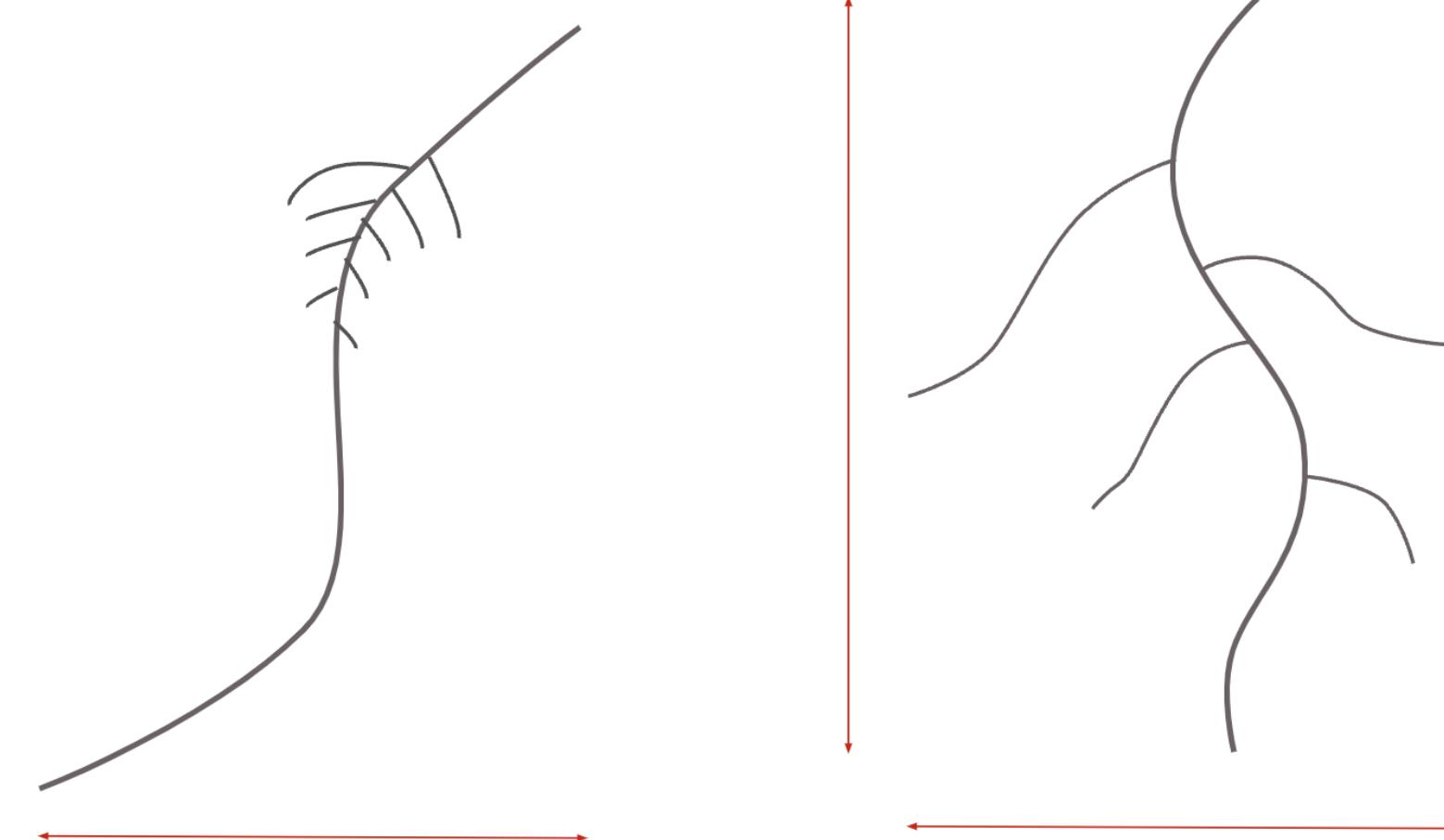
What you get

Depth
Width
Convex hull area
Length Profile
...





Identical width and depth, but very different root systems



Morphological information

What you need

Tracing of a sample of the roots

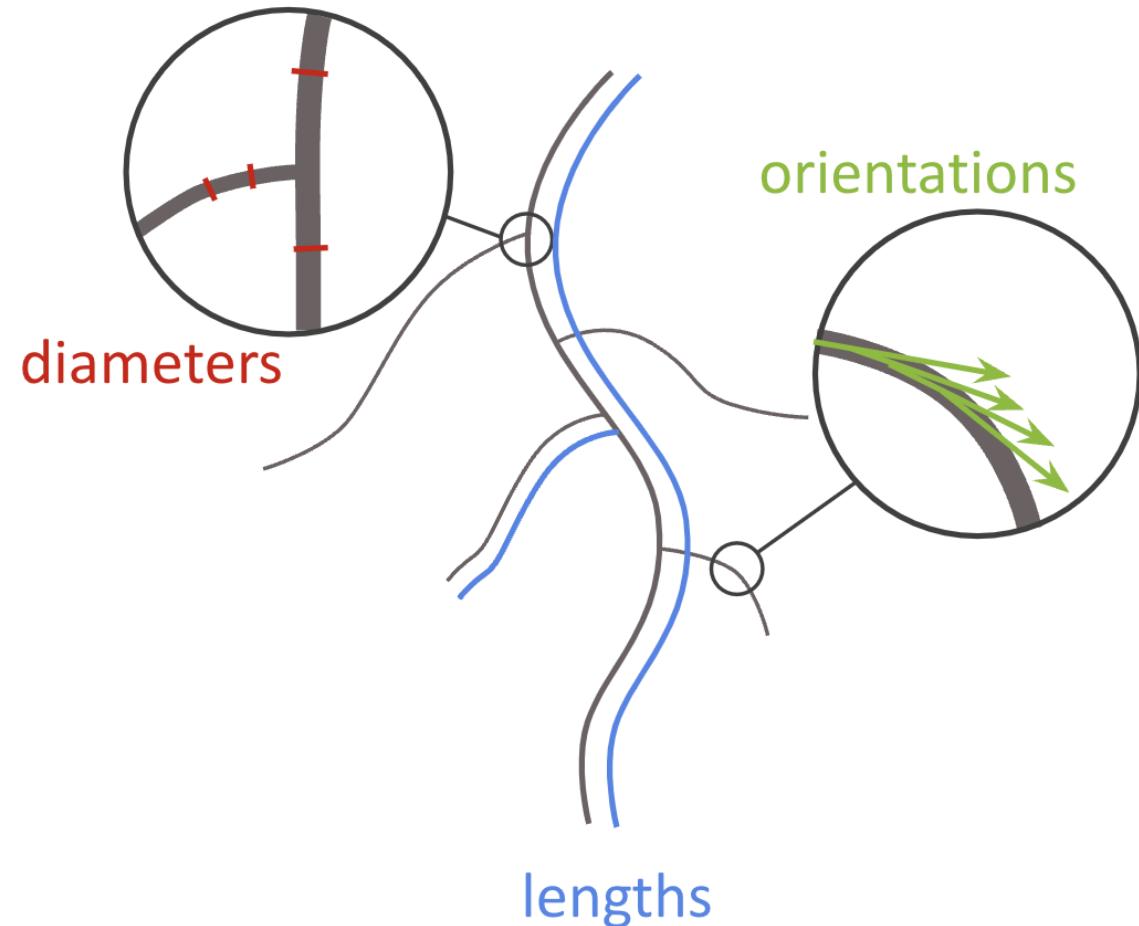
What you get

Diameter

Length

Orientations

...



Root systems can be seen as **populations** of roots



Similarly as you sample plants into a field, you can sample roots within a root system to acquire morphological informations

Apical diameter is a proxy for root growth rate

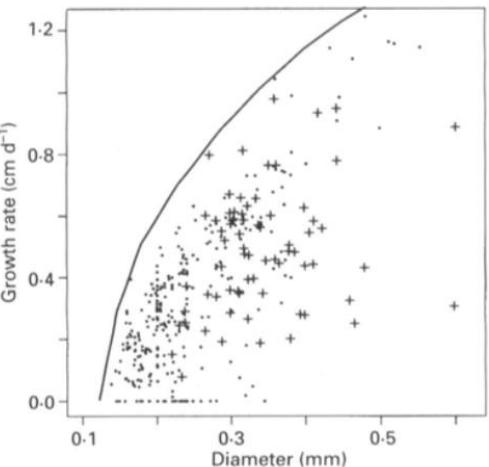
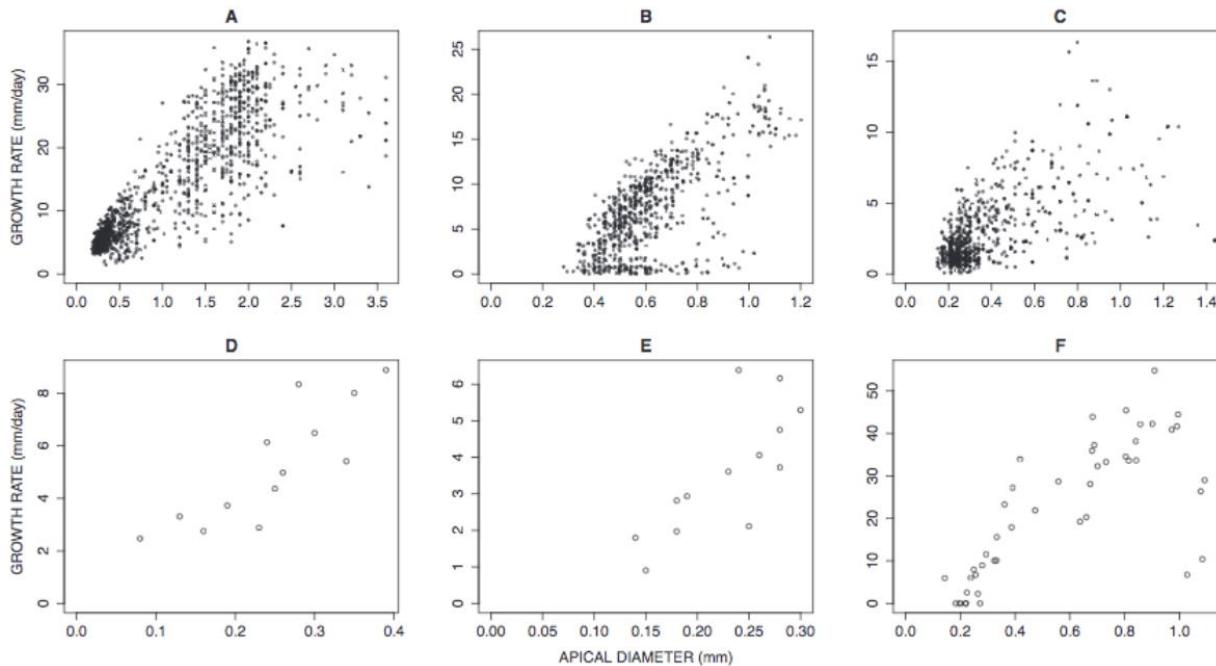


Figure 4. Relationship between apical diameter and growth rate. The hand-drawn line (upper limit of the scatter plot) illustrates a potential growth rate allowed by a given diameter (see the text). Young roots are highlighted (+). These points present the growth during the first 2 d after emergence.



Pages, L. (1995). Growth patterns of the lateral roots of young oak (*Quercus robur*) tree seedlings Relationship with apical diameter. *New Phytol.* **130**: 503–509.

Pages, L., Bécel, C., Boukrim, H., Moreau, D., Nguyen, C., and Voisin, A.-S. (2013). Calibration and evaluation of ArchiSimple, a simple model of root system architecture. *Ecol. Modell.* **290**: 76–84.

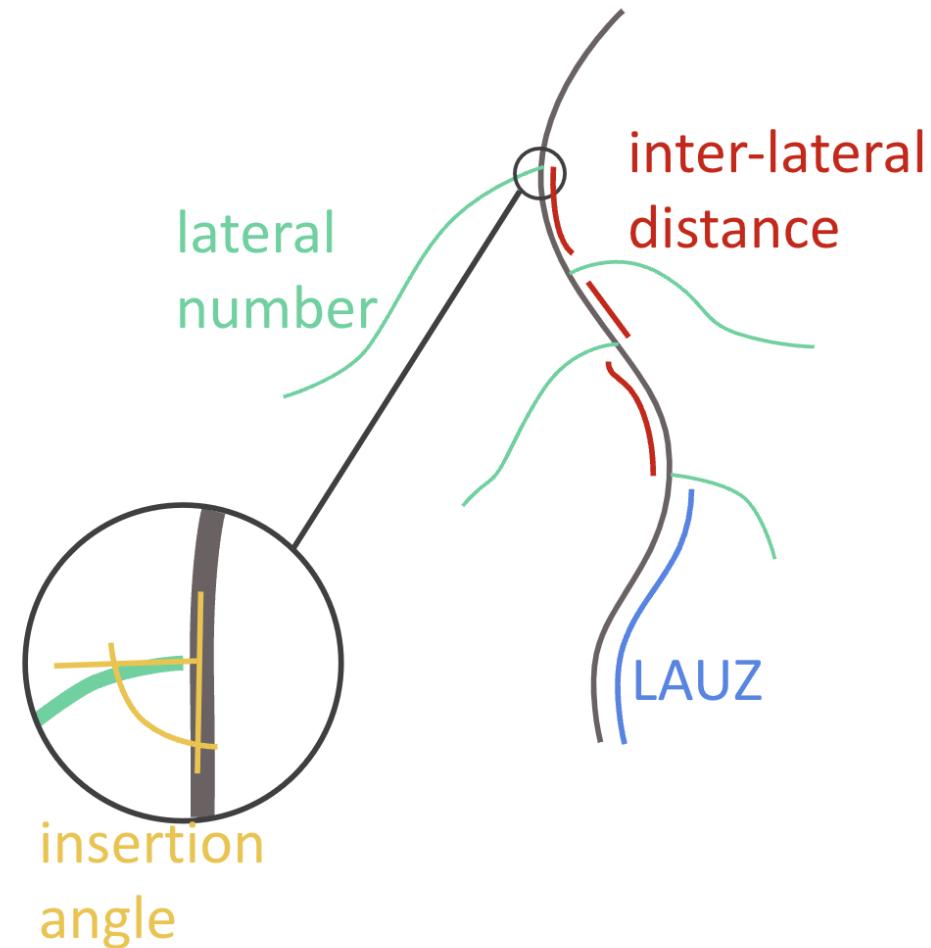
Topological information

What you need

Explicit relation between different root orders

What you get

Lateral number
Inter-lateral distance
Insertion angle
Length of
Unbranched Apical
Zone (LAUZ)
...



Dynamic information

What you need

Time series images

Follow the roots individually

What you get

Growth rates

Root emergence rates

...

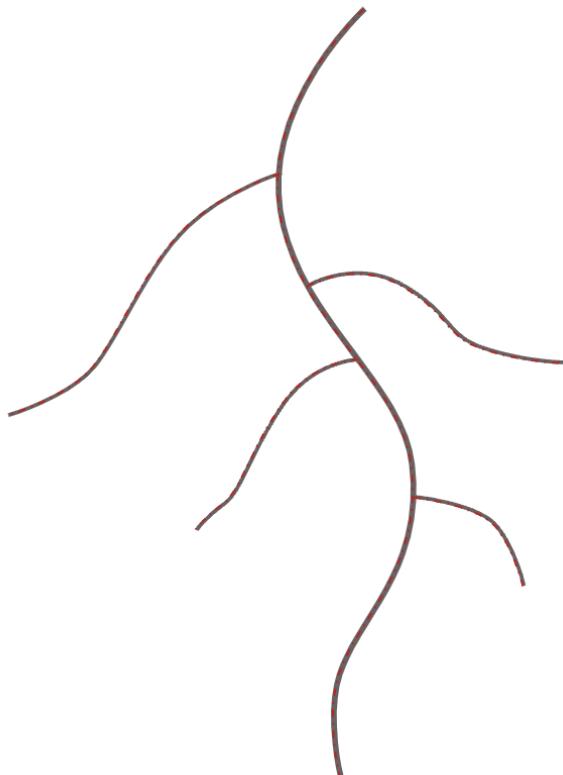
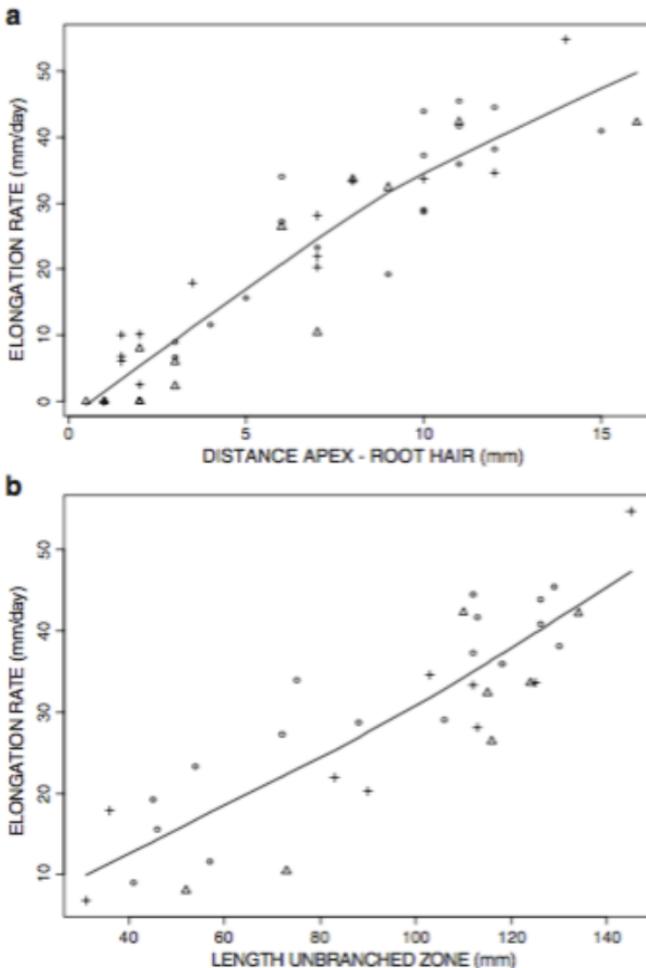


Fig. 2 Relationships between indicators and elongation rate, presented in two examples. **a** Elongation rate versus distance from the apex to the nearest root hair at least 0.2 mm long (L_{hair}); **b** Elongation rate versus length of the unbranched zone (L_{unb}). Each point represents a root measured in a root box. Symbols indicate substrates (circles: nylon mesh; triangles: peat/vermiculite; plus: peat/sand). The curves represent the trends, as evaluated by a local regression smoother (lowess).

Pagès, L., Serra, V., Draye, X., Doussan, C., and Pierret, A. (2010). Estimating root elongation rates from morphological measurements of the root tip. *Plant Soil* **328**: 35–44.



Root elongation
can also be linked to
morphological /
topological phenes
such as the
length of the apical
unbranched zone
(LAUZ)

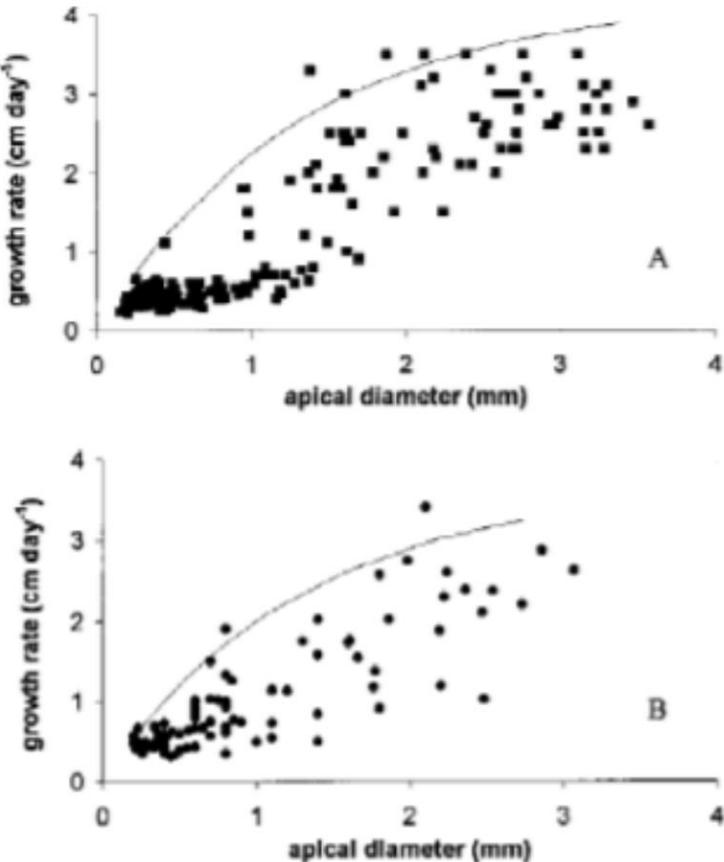
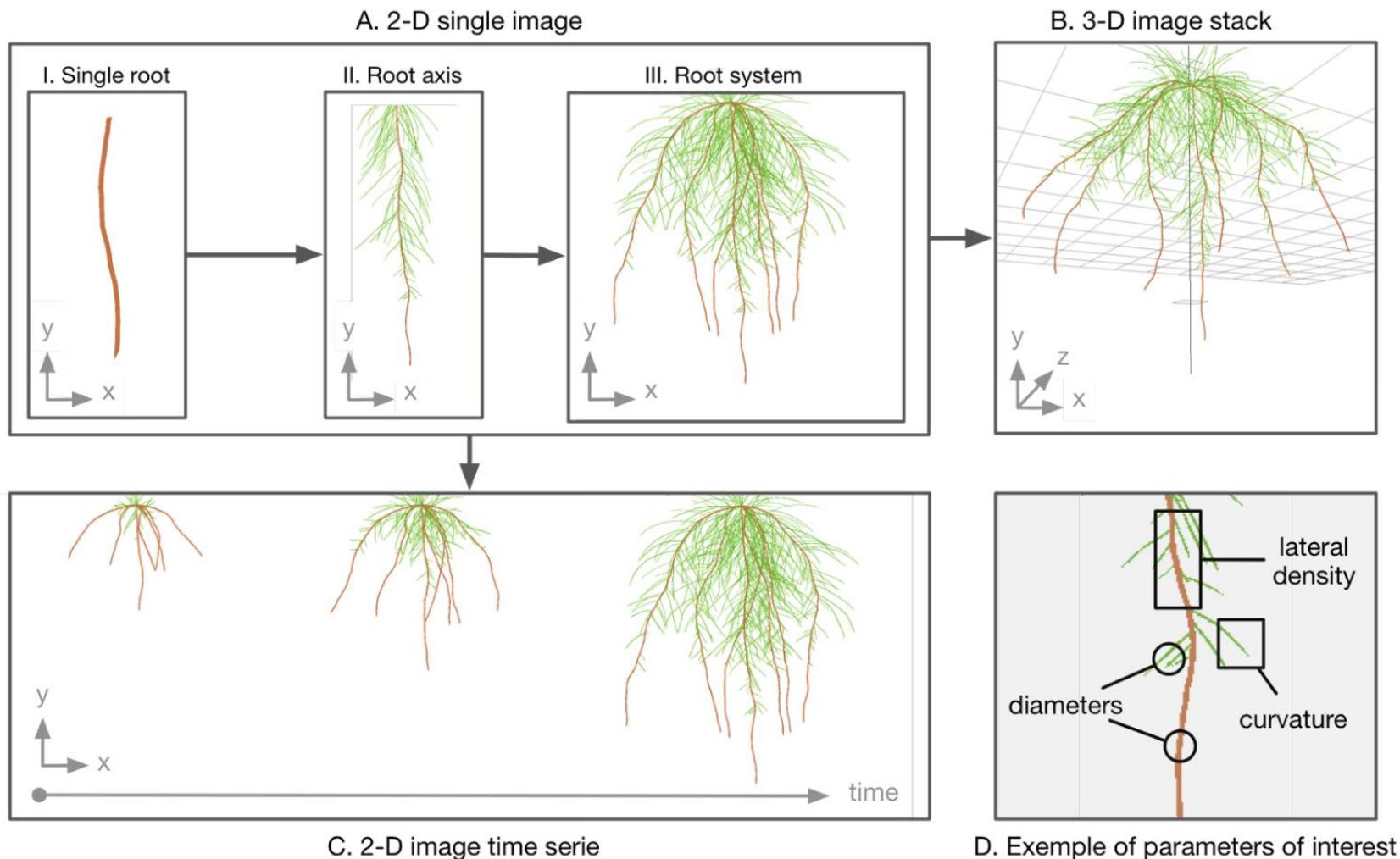


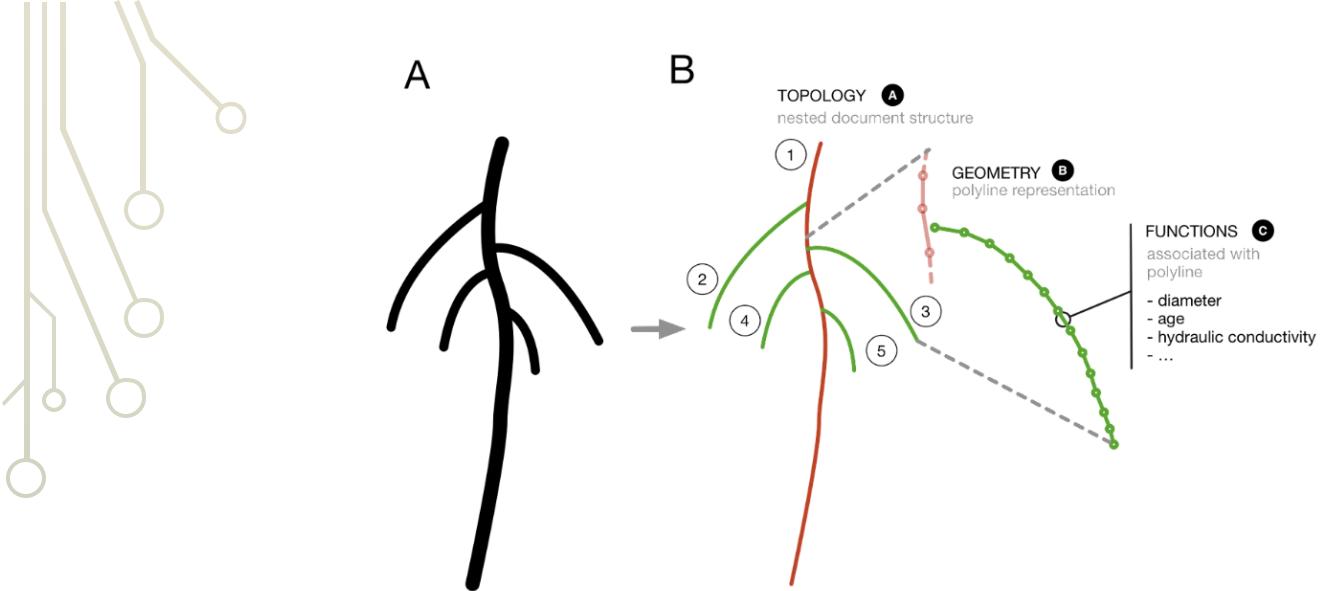
Figure 6. Plot of root growth rates *versus* apical diameter in rhizotron (A) and in the field (B), for all root orders. Root growth rates in rhizotron were measured while they were estimated from root LAUZ in the field. Curves are monomolecular functions fitted on the maximum observed growth rates for respectively 14 (A) and 10 (B) series of apical diameter classes (see Thaler and Pagès, 1998 for details).

Root elongation
can also be linked to
morphological /
topological phenes
such as the
apical diameter of the
root

Lecompte, F., Ozier-Lafontaine, H., and Pagès, L. (2001). The relationships between static and dynamic variables in the description of root growth. Consequences for field interpretation of rooting variability. *Plant Soil* 236: 19–31.

Root system architecture is **complex** and **multidimensional**





Any root system architecture
can be stored into a
Root System Markup Language
format (RSML)

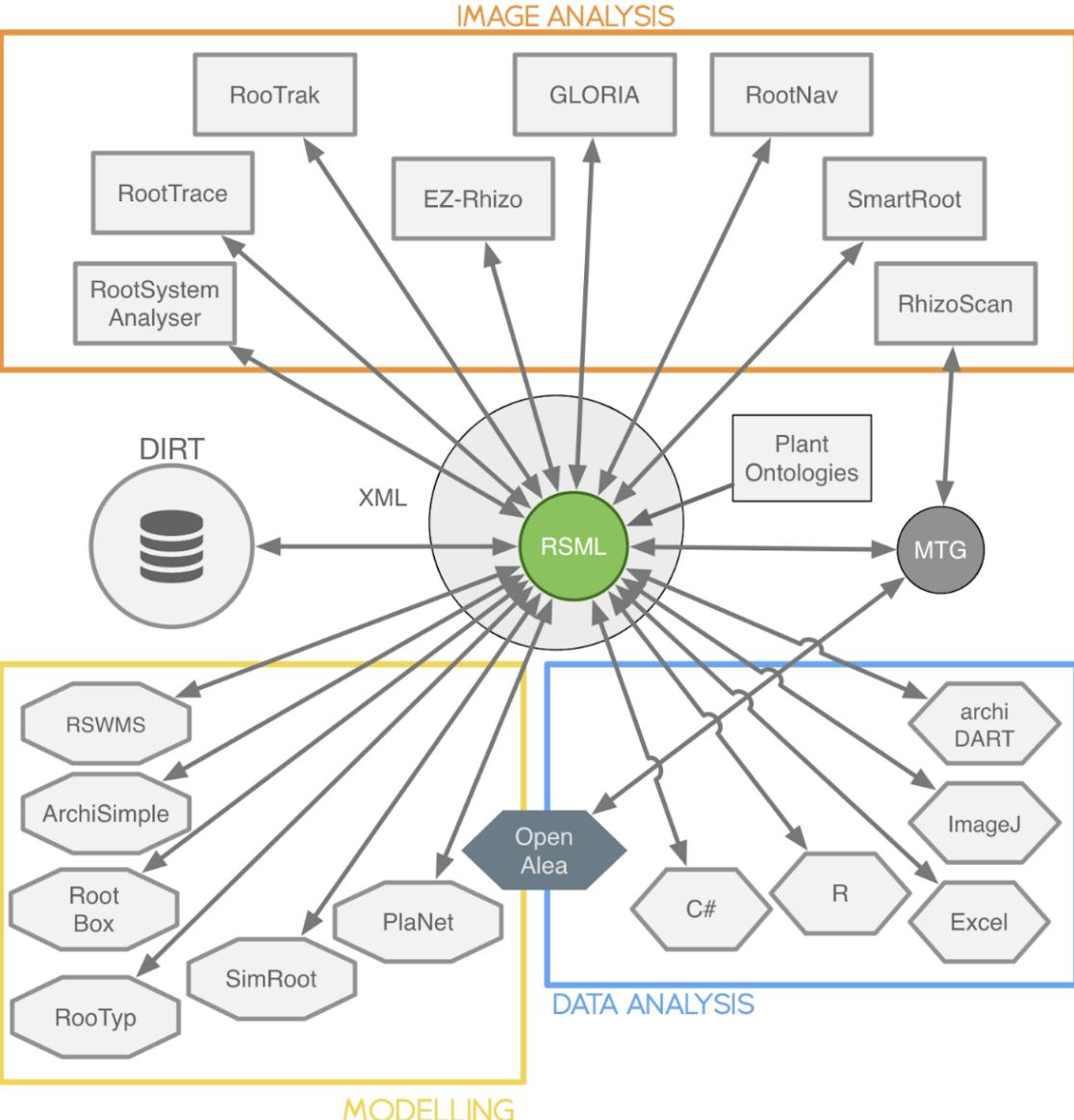
Figure 2: visual representation of the RSML structure. A. Original image B. Graphical representation of the structure. Topology (primary root in red and lateral roots in green), geometry and properties are represented at different levels. C. Schematic representation of an RSML file structure. D. Representation of the coupling between the root geometry and its associated functions (here the diameter). Dotted lines represent data from the same point in a polyline.

Lobet, G., Pound, M.P., Diener, J., Pradal, C., Draye, X., Godin, C., Javaux, M., Leitner, D., Meunier, F., Nacry, P., Pridmore, T.P., and Schnepf, A. (2015). Root System Markup Language: Toward a Unified Root Architecture Description Language. *Plant Physiol.* **167**: 617–627.



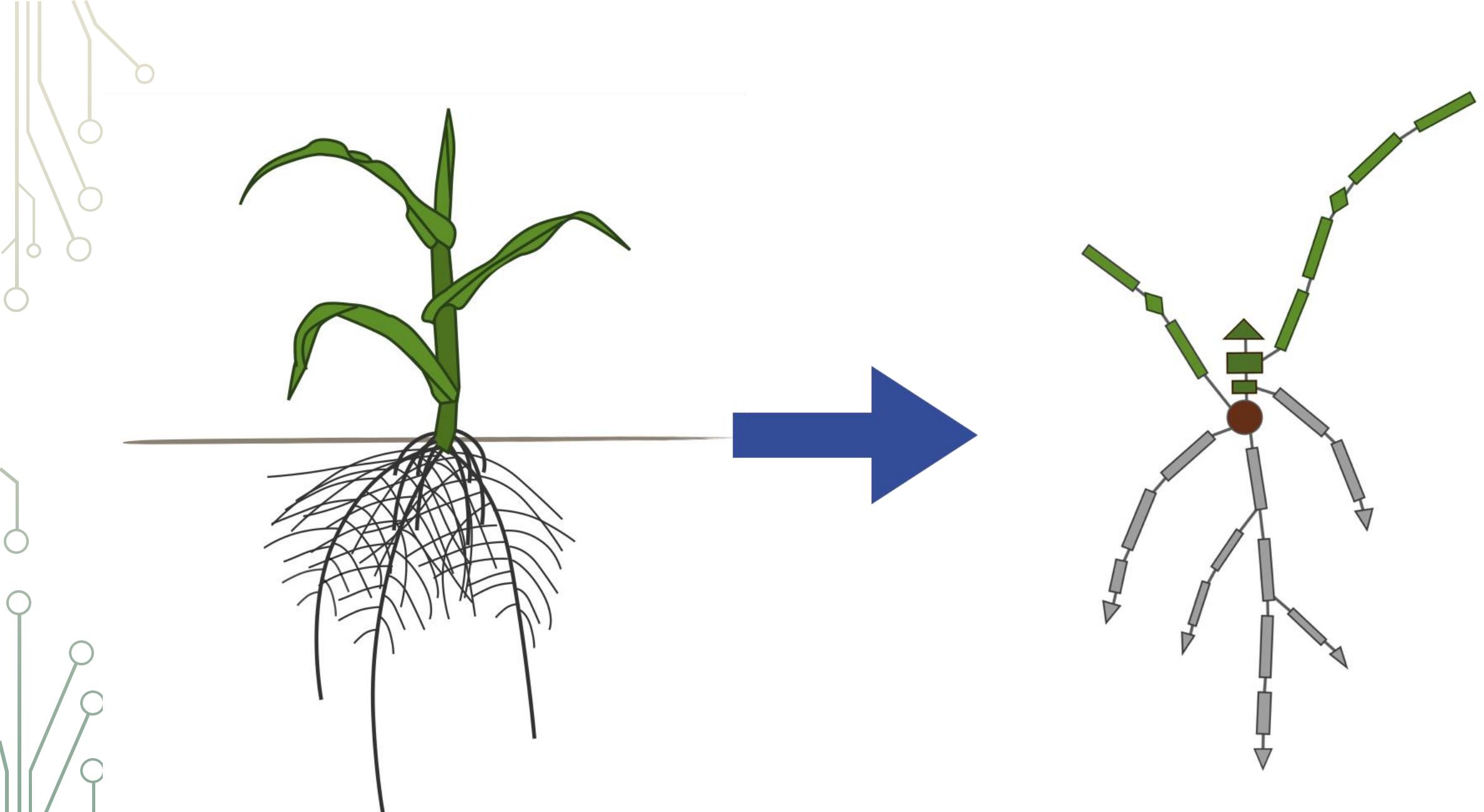
The RSML format is compatible with a wide range of tools.

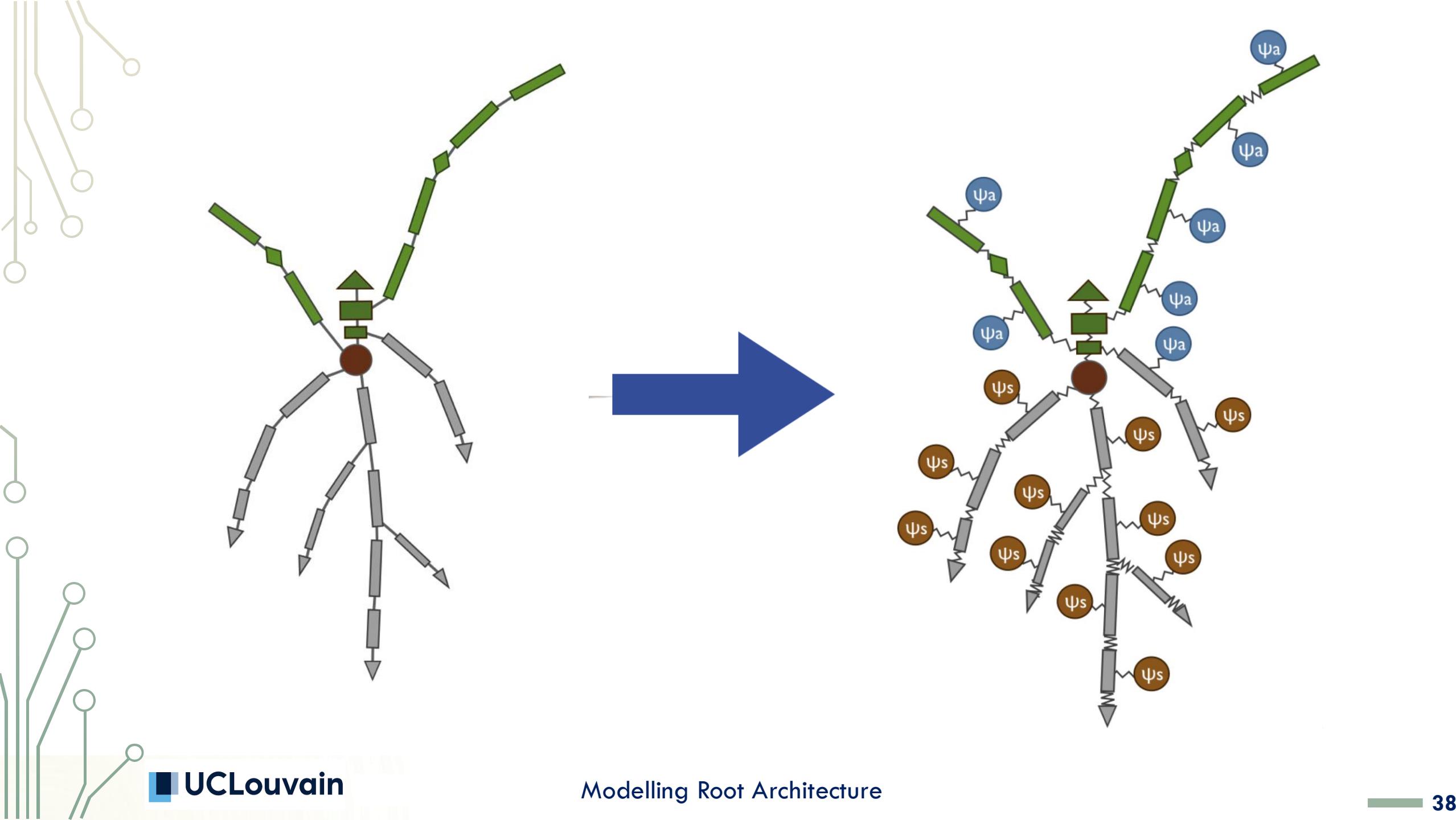
- This enables:
- Interoperability
 - Repeatability
 - Meta analysis
 - ...

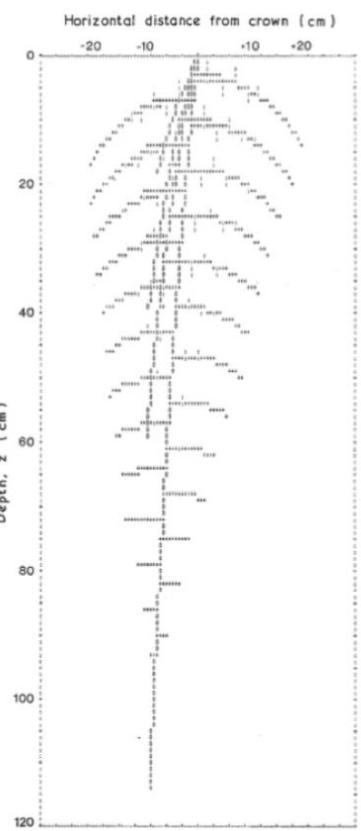


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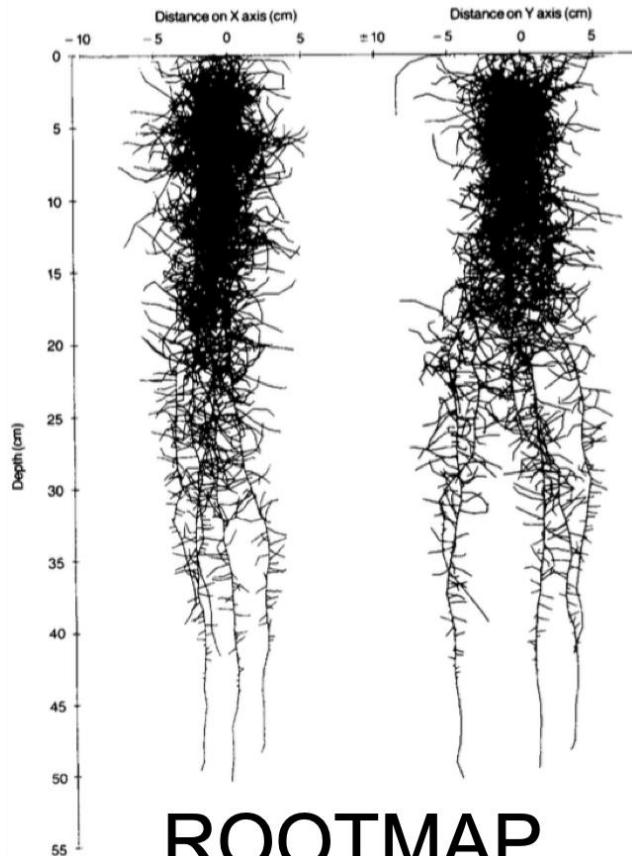
ROOT SYSTEM MODELING





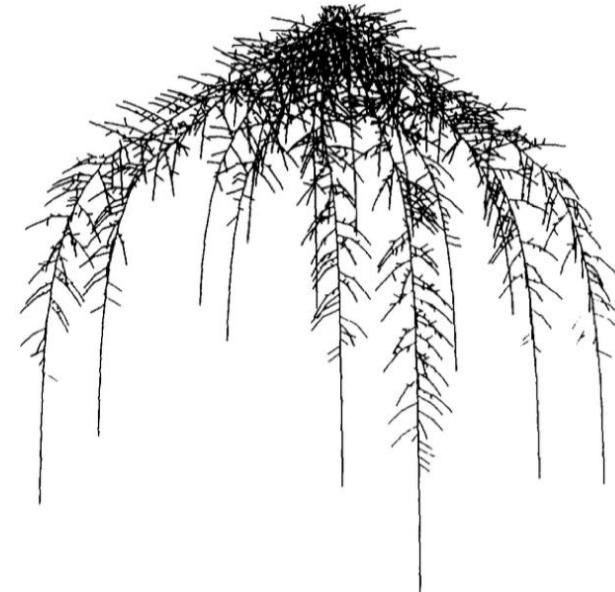


1973



ROOTMAP

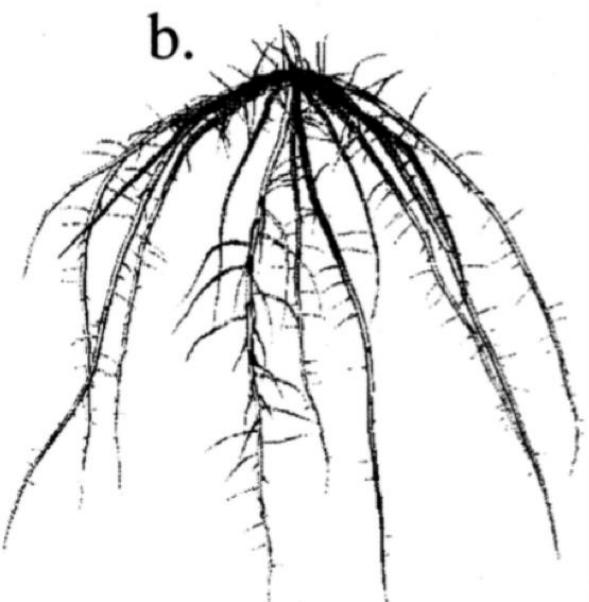
1988



1989

Modelling Root Architecture

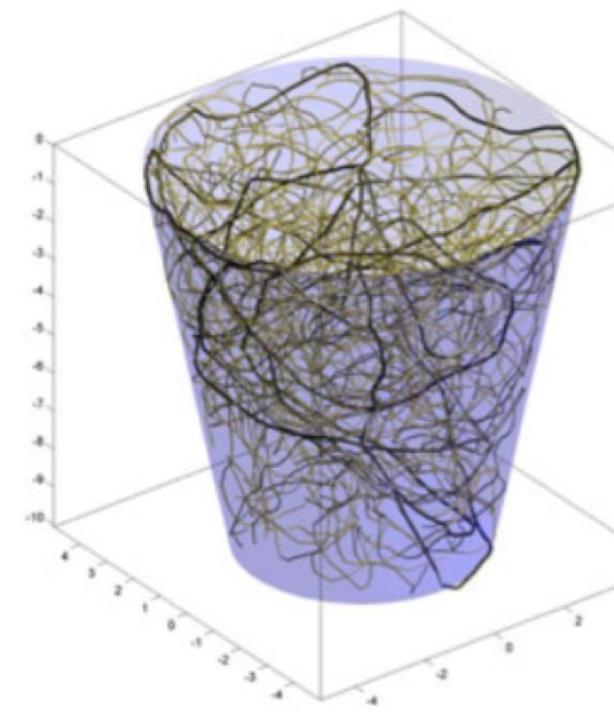
1997



2004



2010



MODELLING ROOT ARCHITECTURE

