

ROOT SYSTEM MARKUP LANGUAGE

A NEW TOOLBOX TO LINK
EXPERIMENTAL DATA WITH
SIMULATION.

G LOBET, MP POUND, J DIENER, C PRADAL,
X DRAYE, C GODIN, M JAVAUX, D LEITNER,
F MEUNIER⁵, P NACRY, TP PRIDMORE, A SCHNEPF.



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guillaume.lobet@ulg.ac.be
[@guillaumelobet](https://twitter.com/guillaumelobet)



ROOT SYSTEM ARCHITECTURE



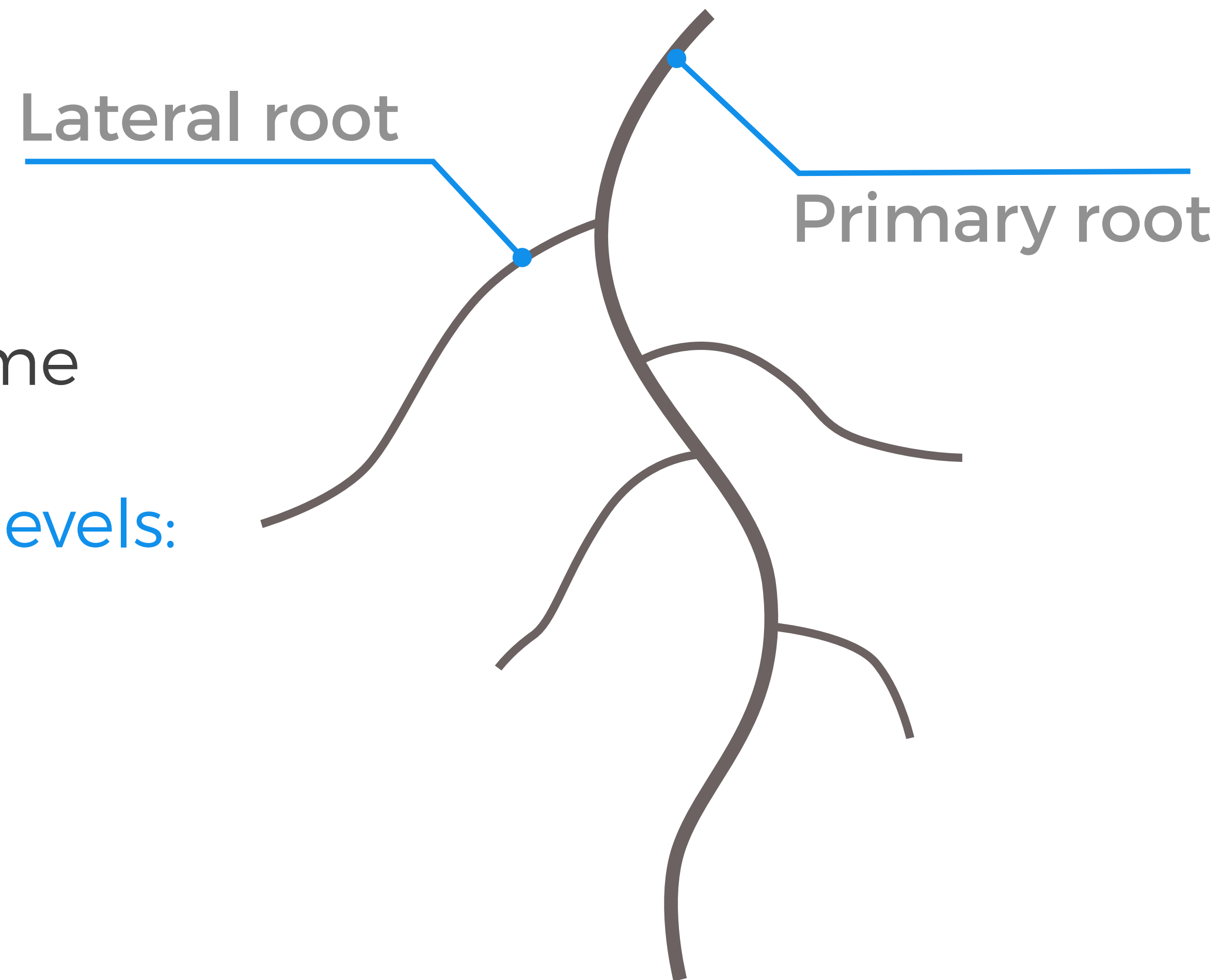
ROOT SYSTEM ARCHITECTURE

Root systems are:

Complex branched structure
Heterogenous in space and time

Can be described at different levels:

- Morphology
- Geometry
- Topology
- Dynamics



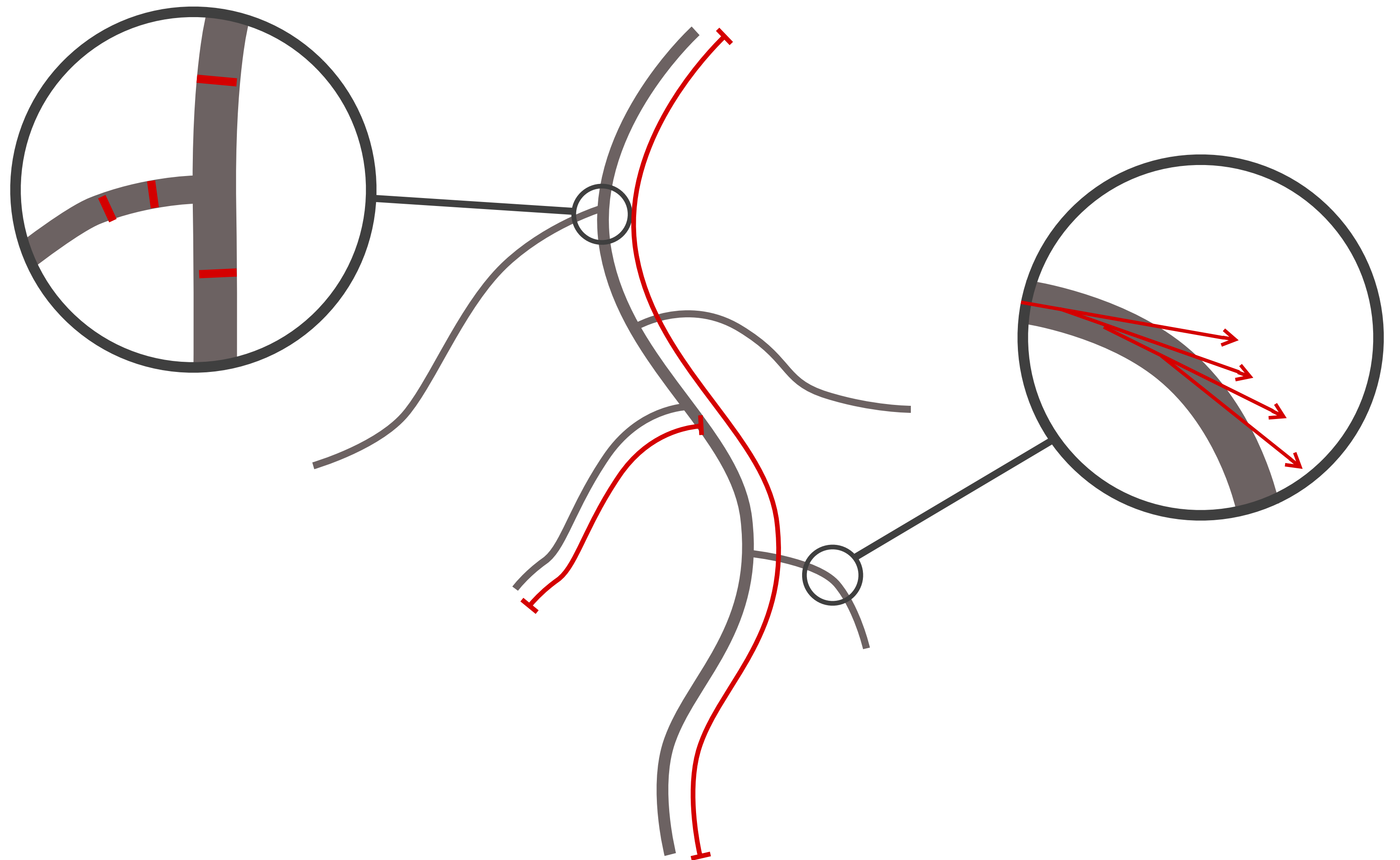
RSA DESCRIPTION > MORPHOLOGY

Measurements

- Diameter
- Length
- Tortuosity

Requirement

Tracing of a sample of the roots



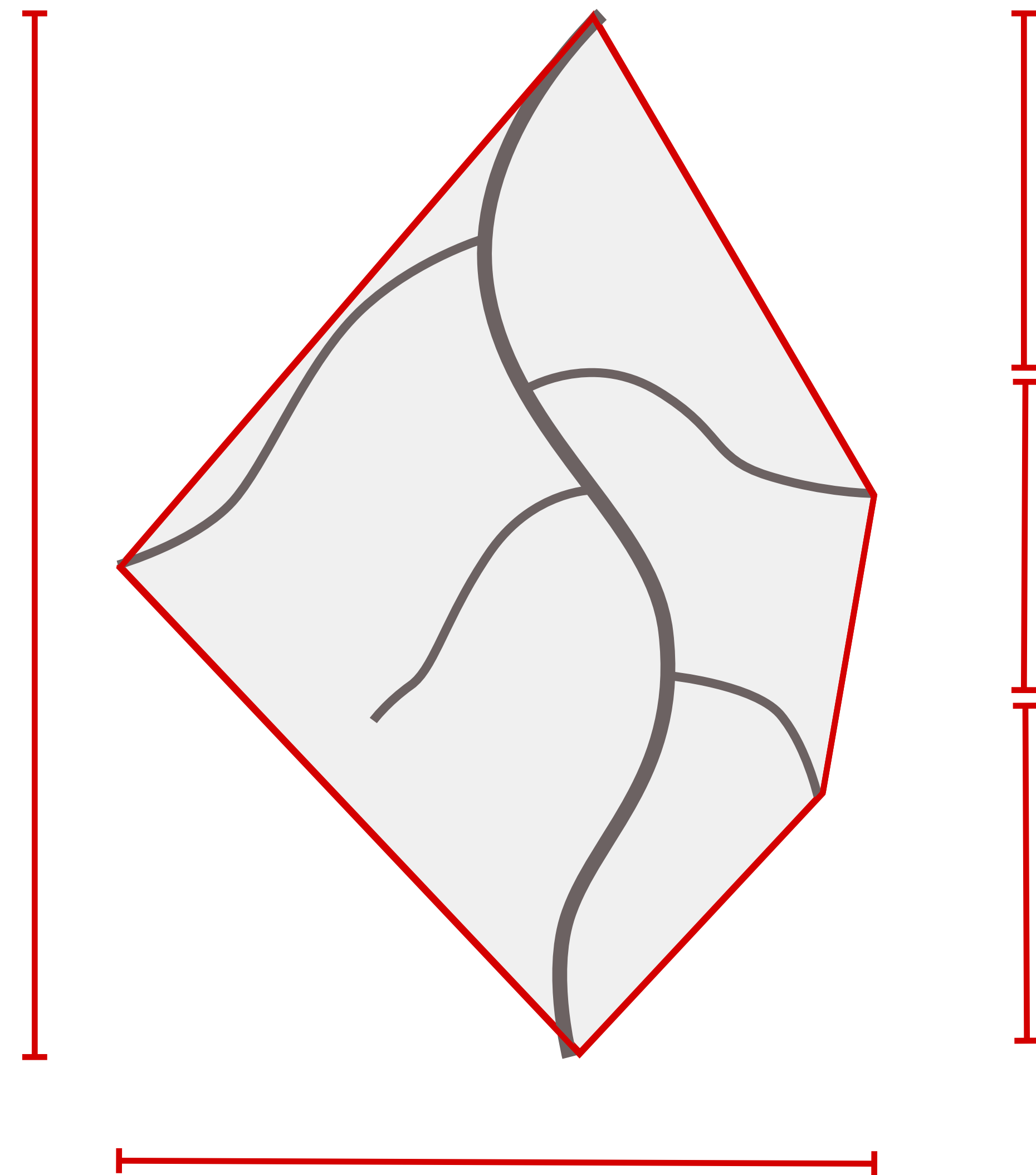
RSA DESCRIPTION > GEOMETRY

Measurements

- Depth
- Width
- Convex hull area
- Length Profile

Requirement

Position in space of every root segment



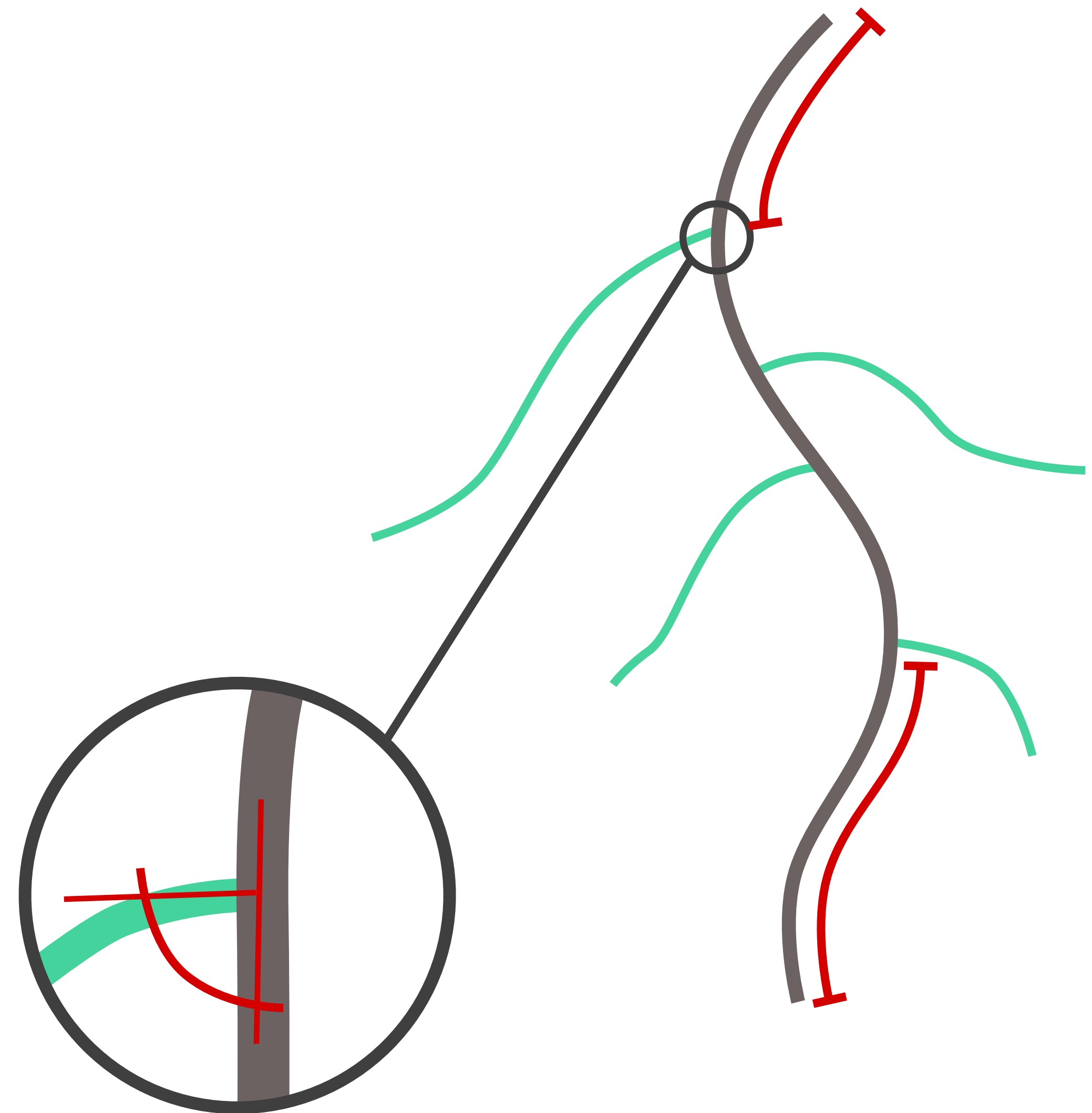
RSA DESCRIPTION > TOPOLOGY

Measurements

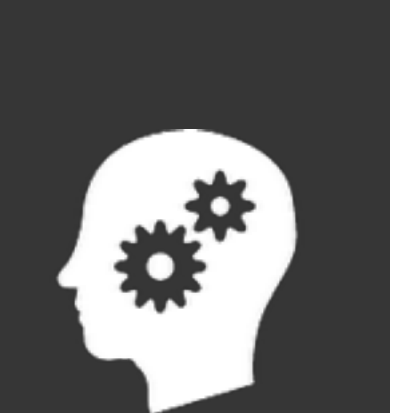
- Lateral number
- Lateral density
- Insertion angle
- LAUZ

Requirement

Explicit relation
between different
root orders



RSA DESCRIPTION > DYNAMICS

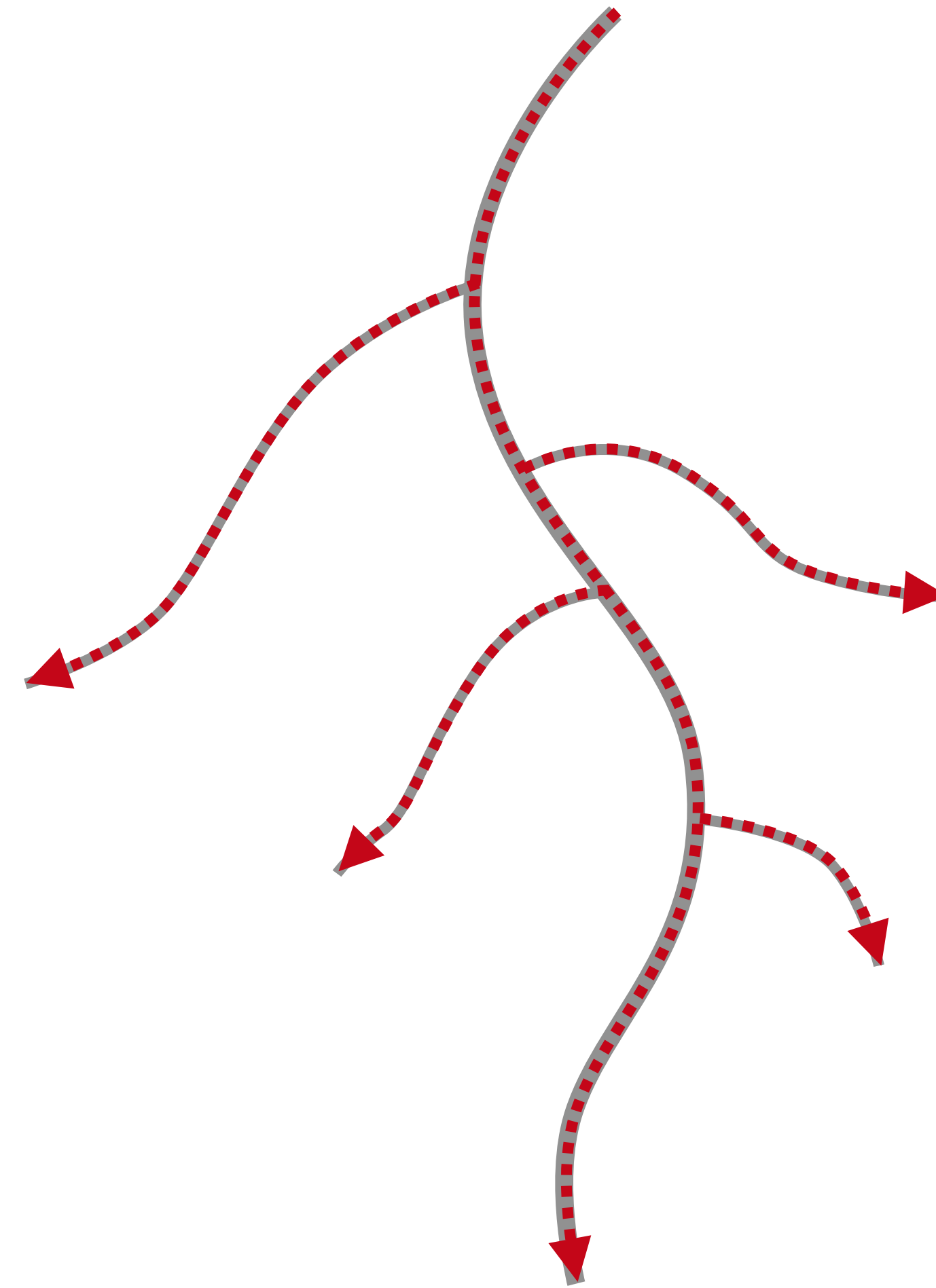


Measurements

- Growth rates
- Lateral apparitions rate

Requirements

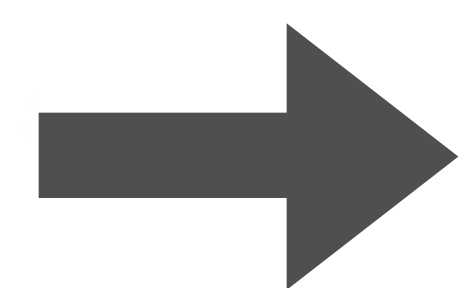
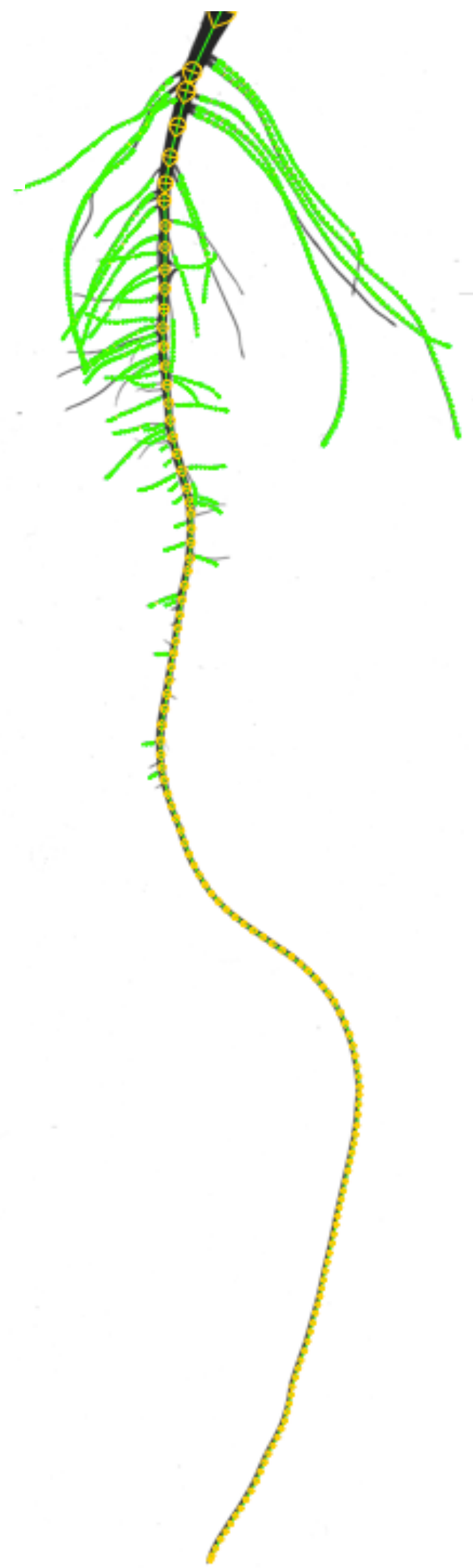
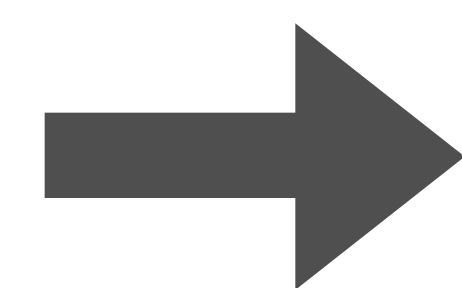
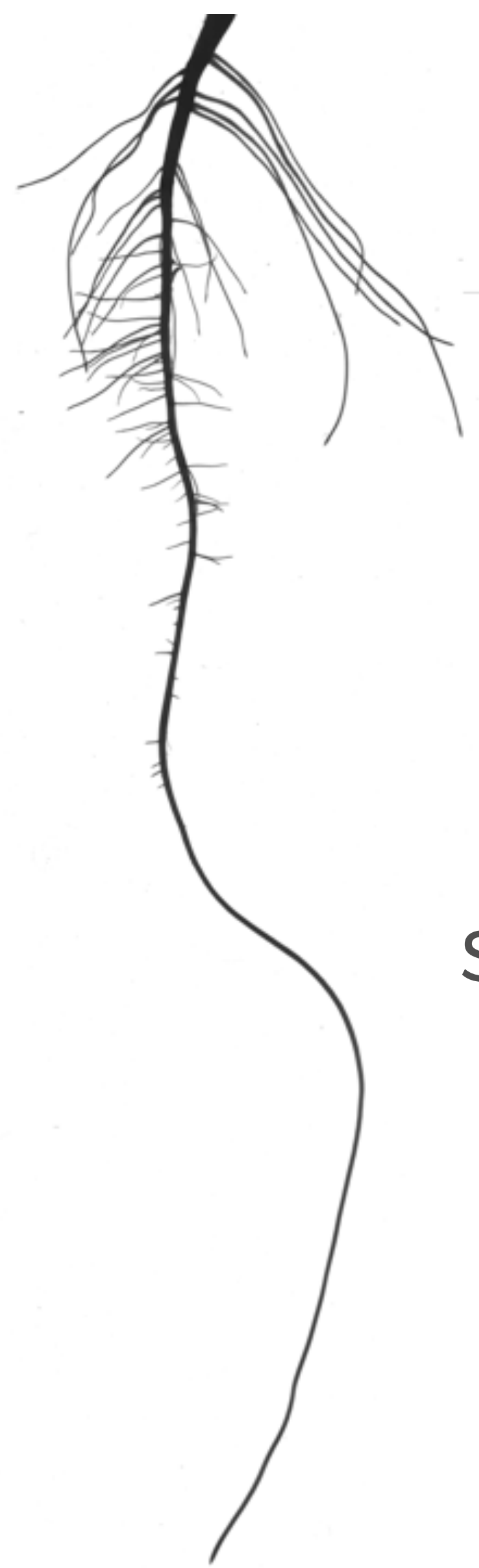
Time series images
Follow the roots individually



WHEN THINGS GET COMPLICATED..

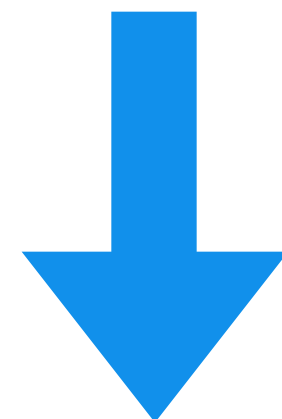
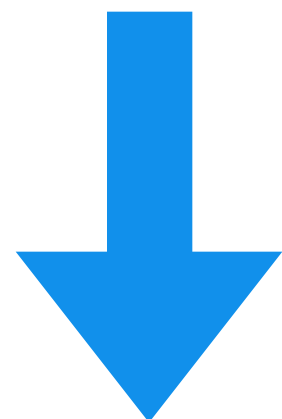


RSA ANALYSIS IS TIME CONSUMING



semi-automated

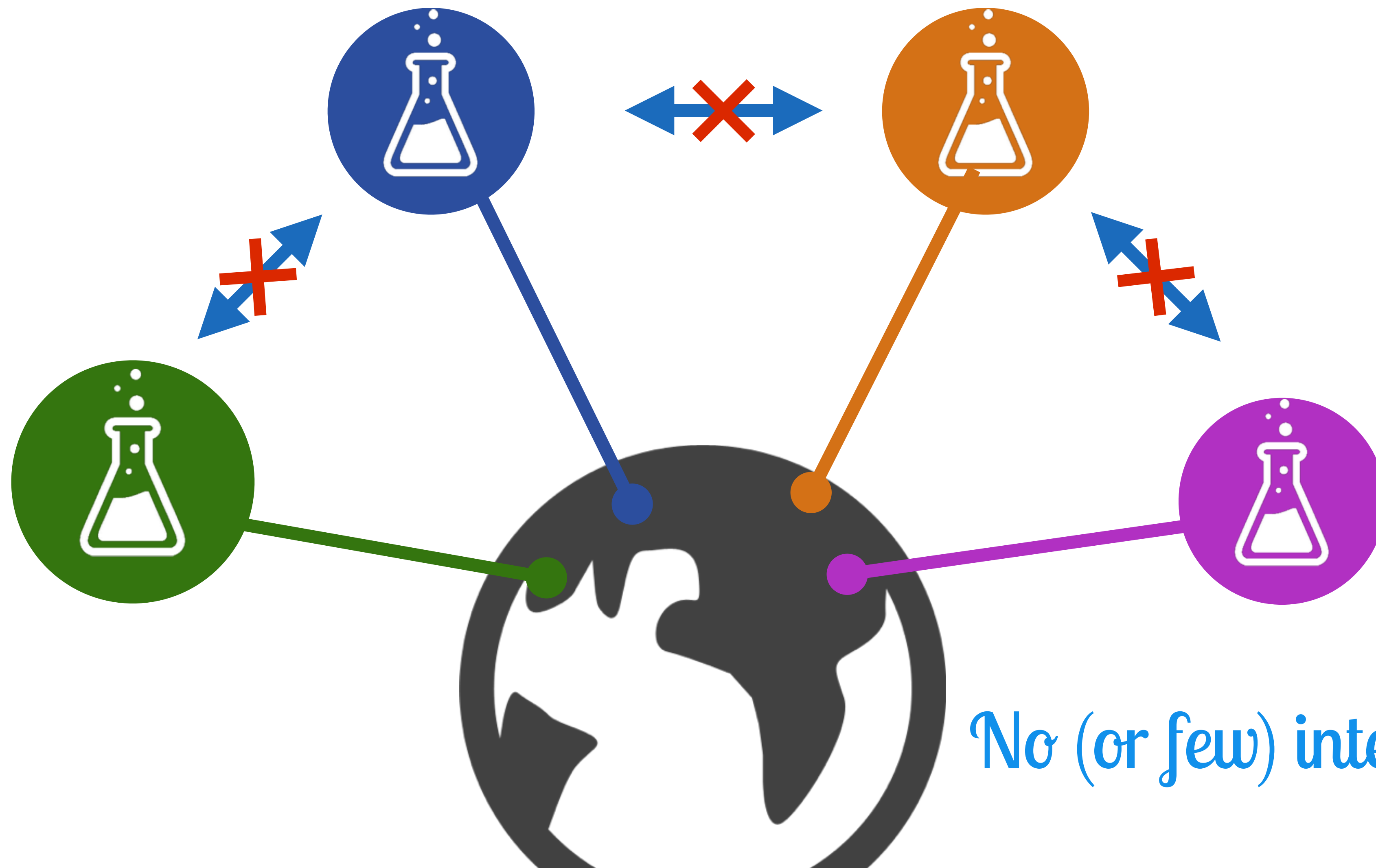
data selection



Time consuming

Many unexploited data

RSA ANALYSIS IS DIVERSE



No (or few) inter-compatibility



</> ROOT SYSTEM MARKUP LANGUAGE



WHERE IT STARTED

Image Analysis

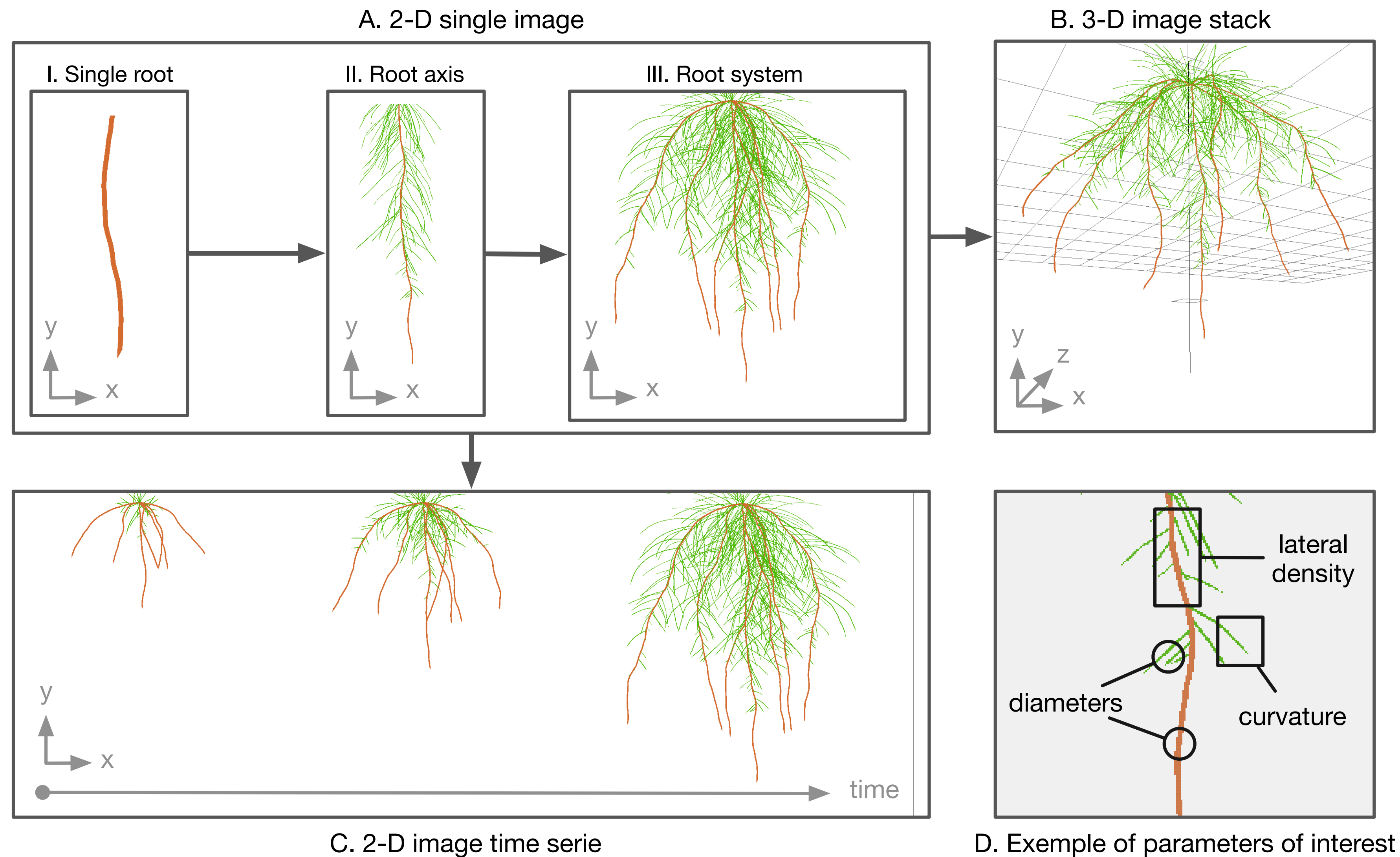
RootNav
SmartRoot
RSA Analyser
RhizoScan
RootTrace
RooTrak

Modelling

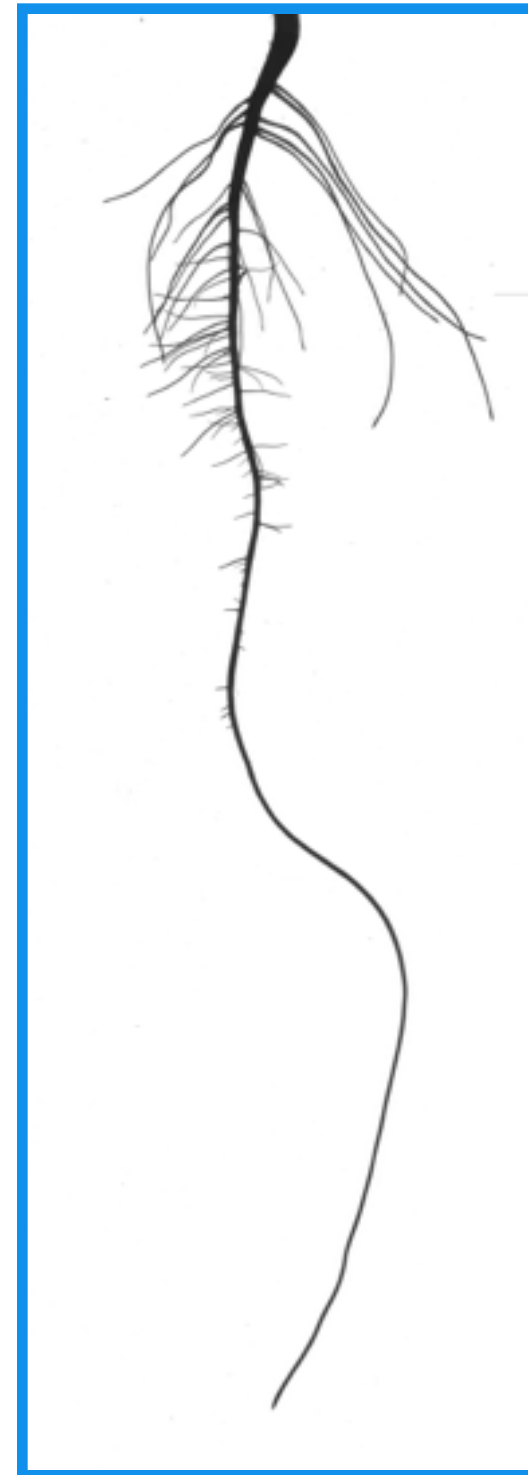
RootBox
ArchiSimple
OpenAlea
R-SWMS



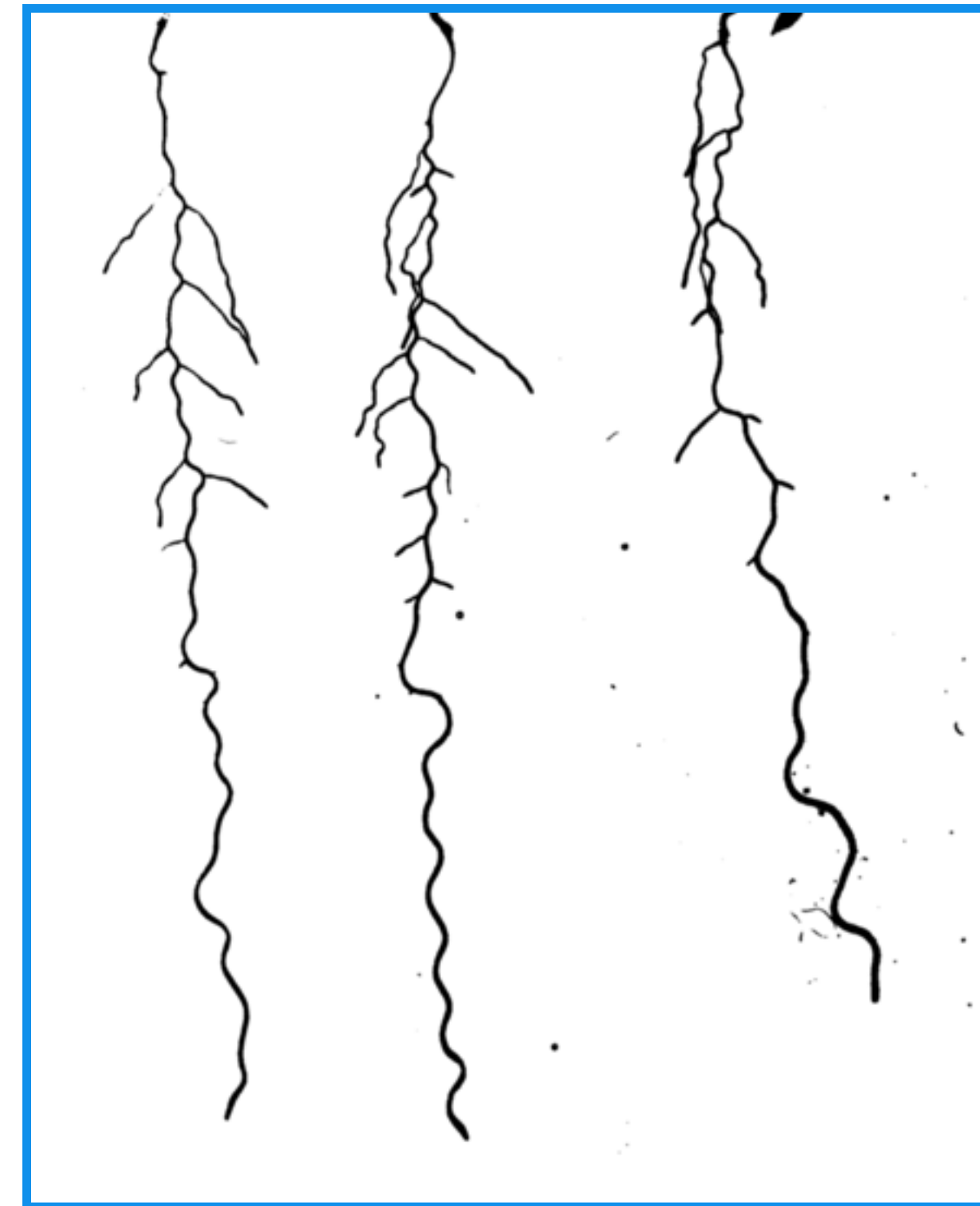
DEALING WITH ANY TYPE OF ROOT SYSTEMS



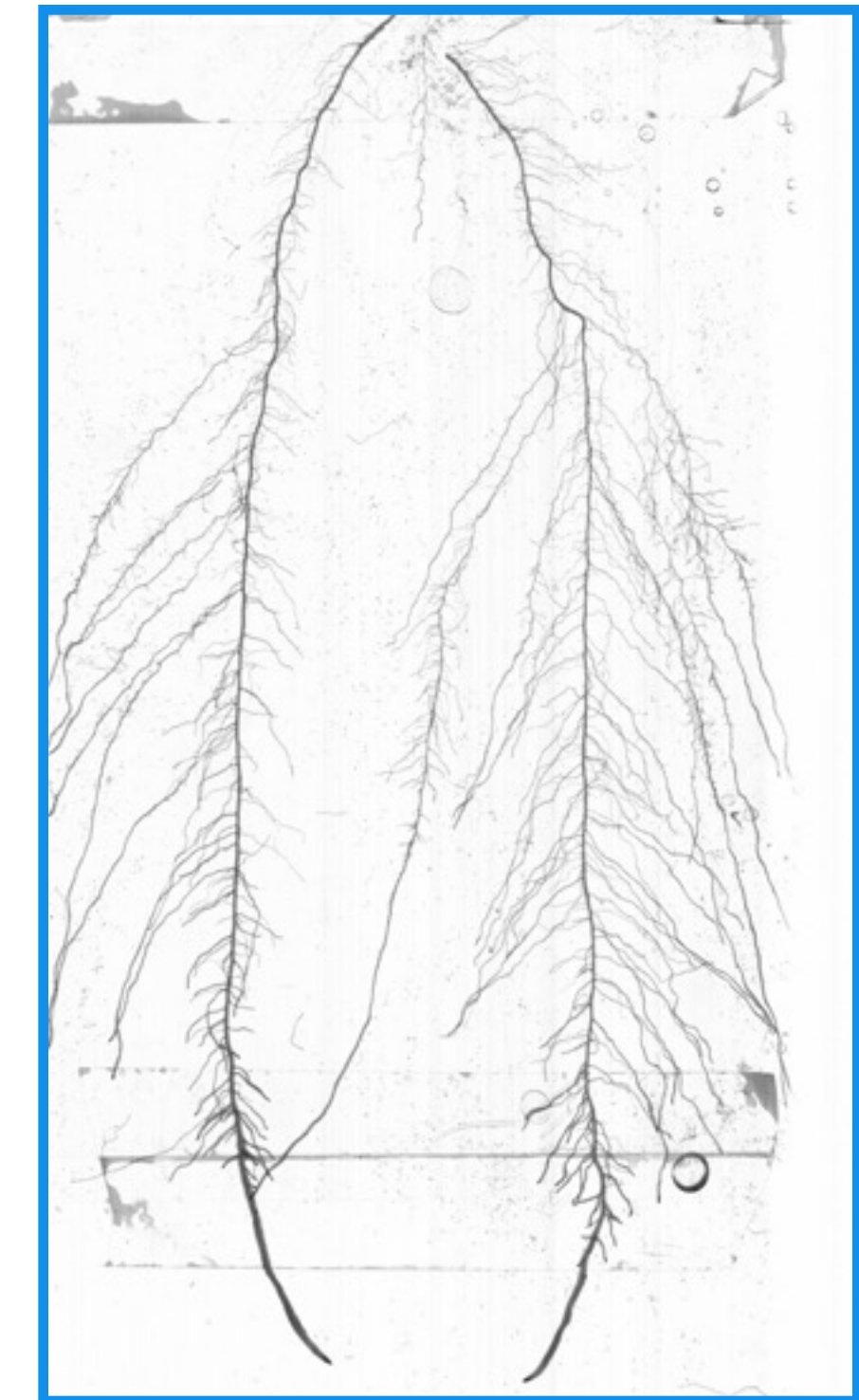
DEALING WITH ANY TYPE OF ROOT IMAGES



single plants



multiple plants



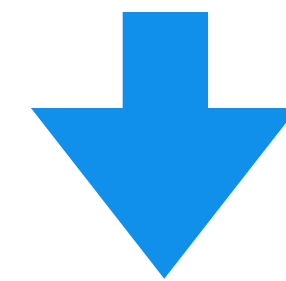
detached roots



DEFINING A NEW STANDARD

XML

- strong standard
 - many tools to read and write
 - versatile and flexible
-
- many existing declinations (“just another XML scheme”)
 - Systems Biology Markup Language [Hucka et al 2003]
 - RealTime PCR Data Markup Language [Lefever et al 2009]

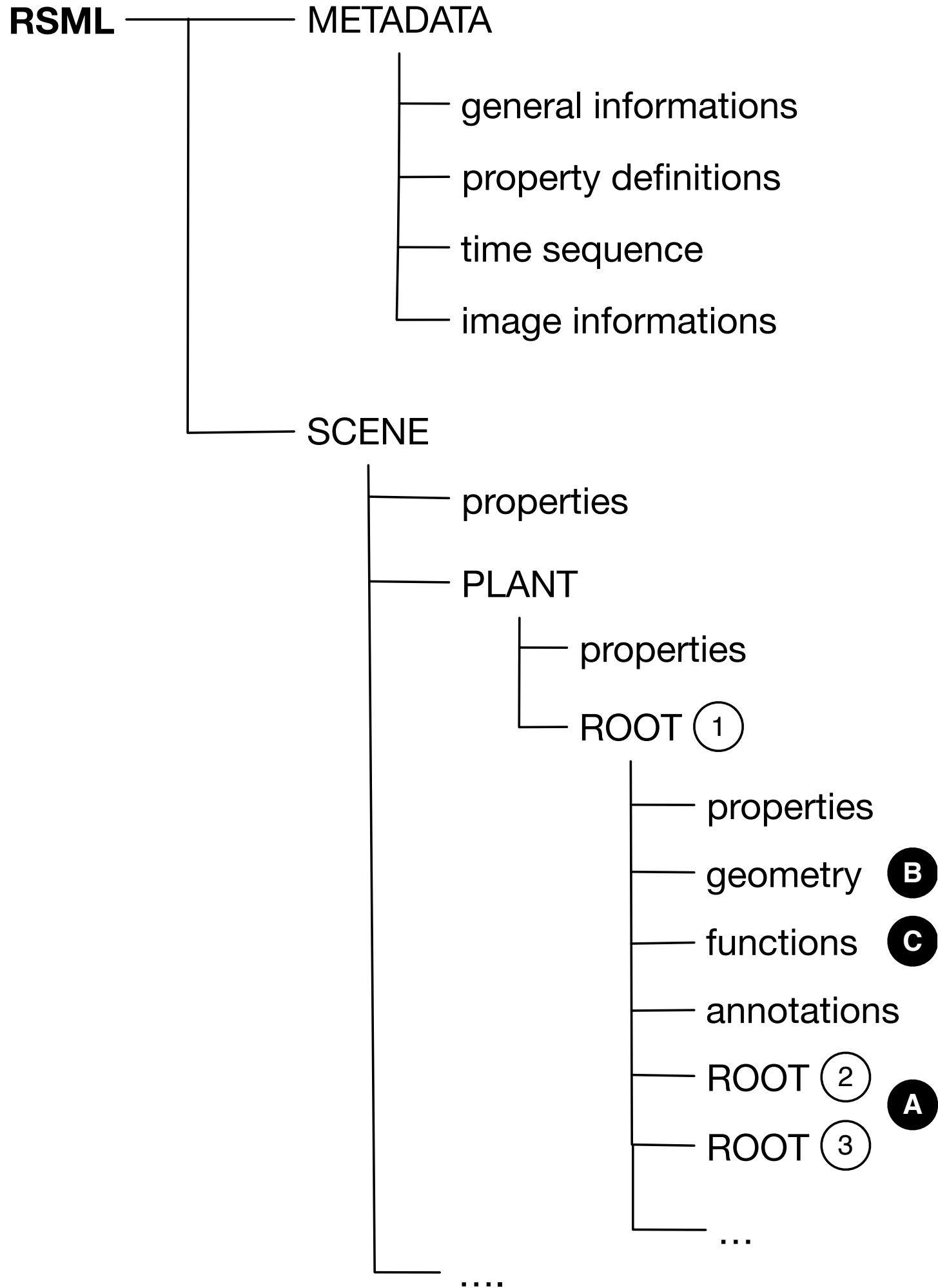
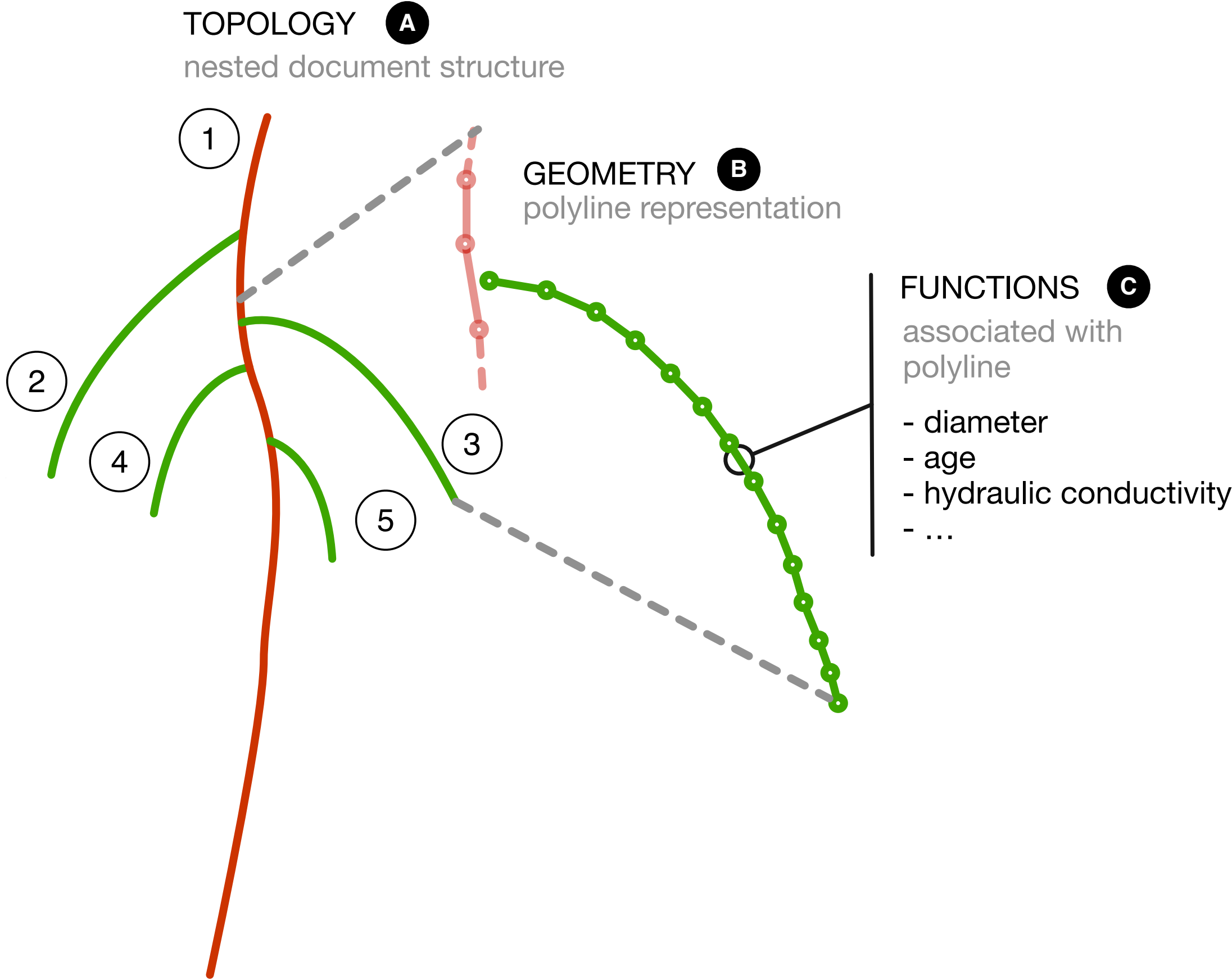


Root System Markup Language [RSML]



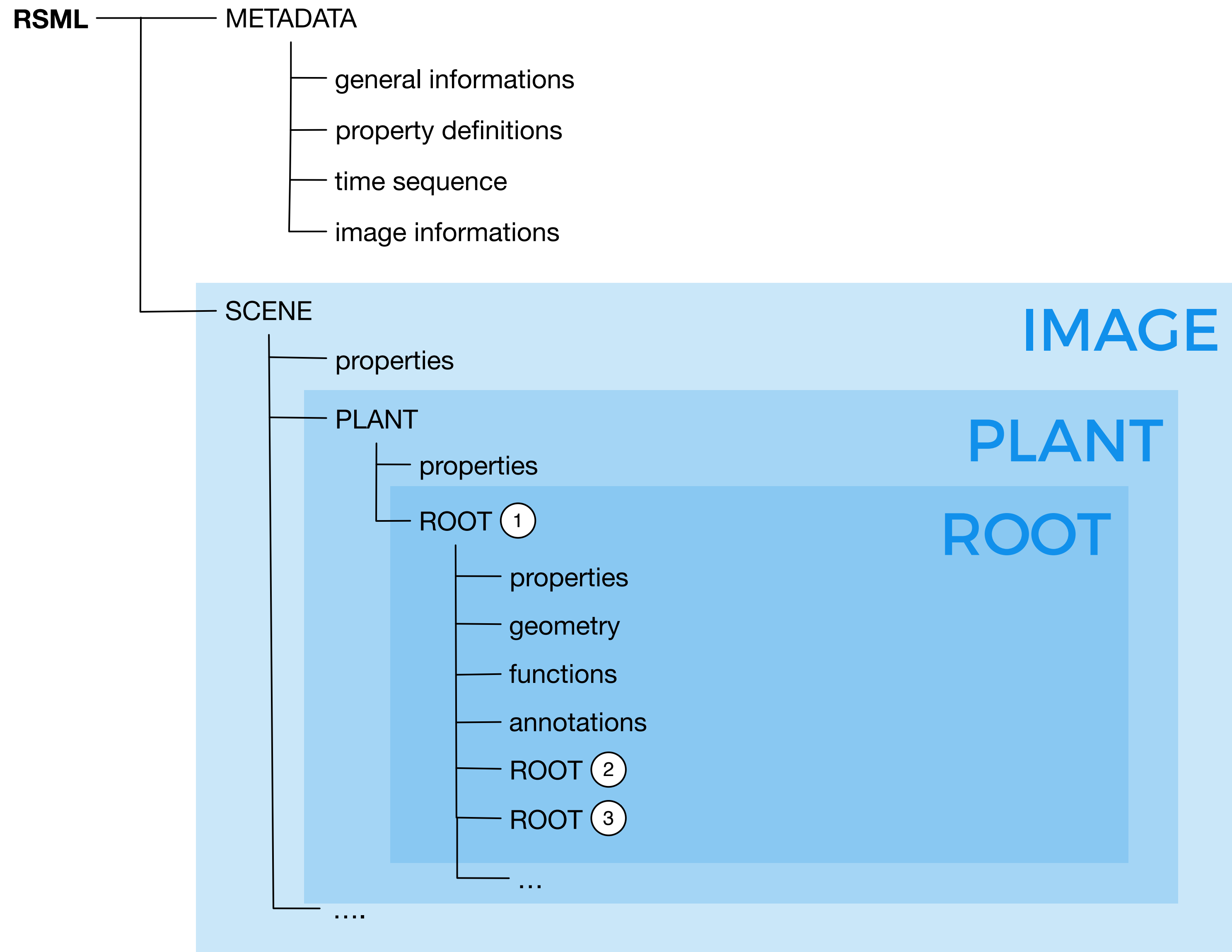


OVERVIEW OF THE RSML STRUCTURE

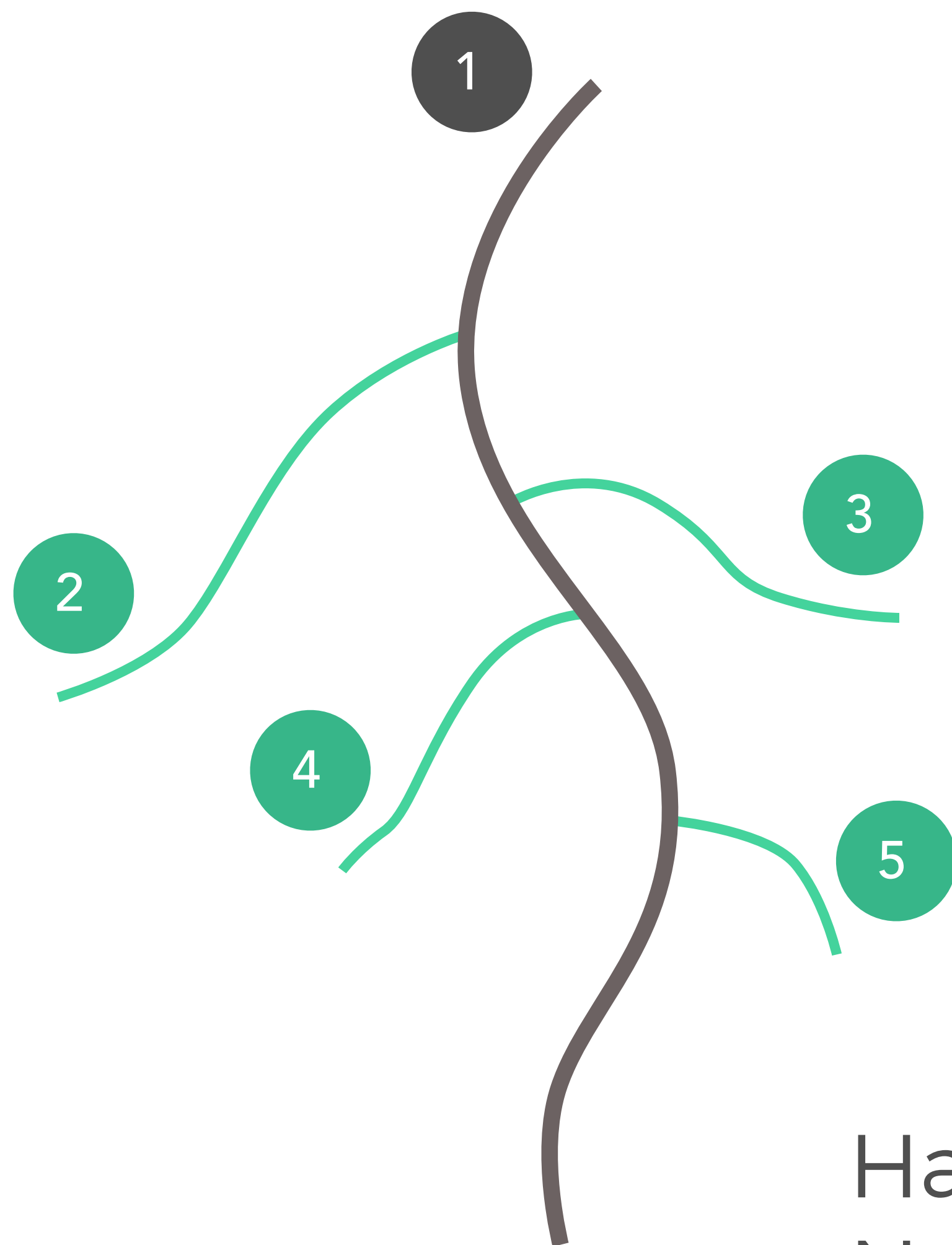




OVERVIEW OF THE RSML STRUCTURE



DEALING WITH TOPOLOGY

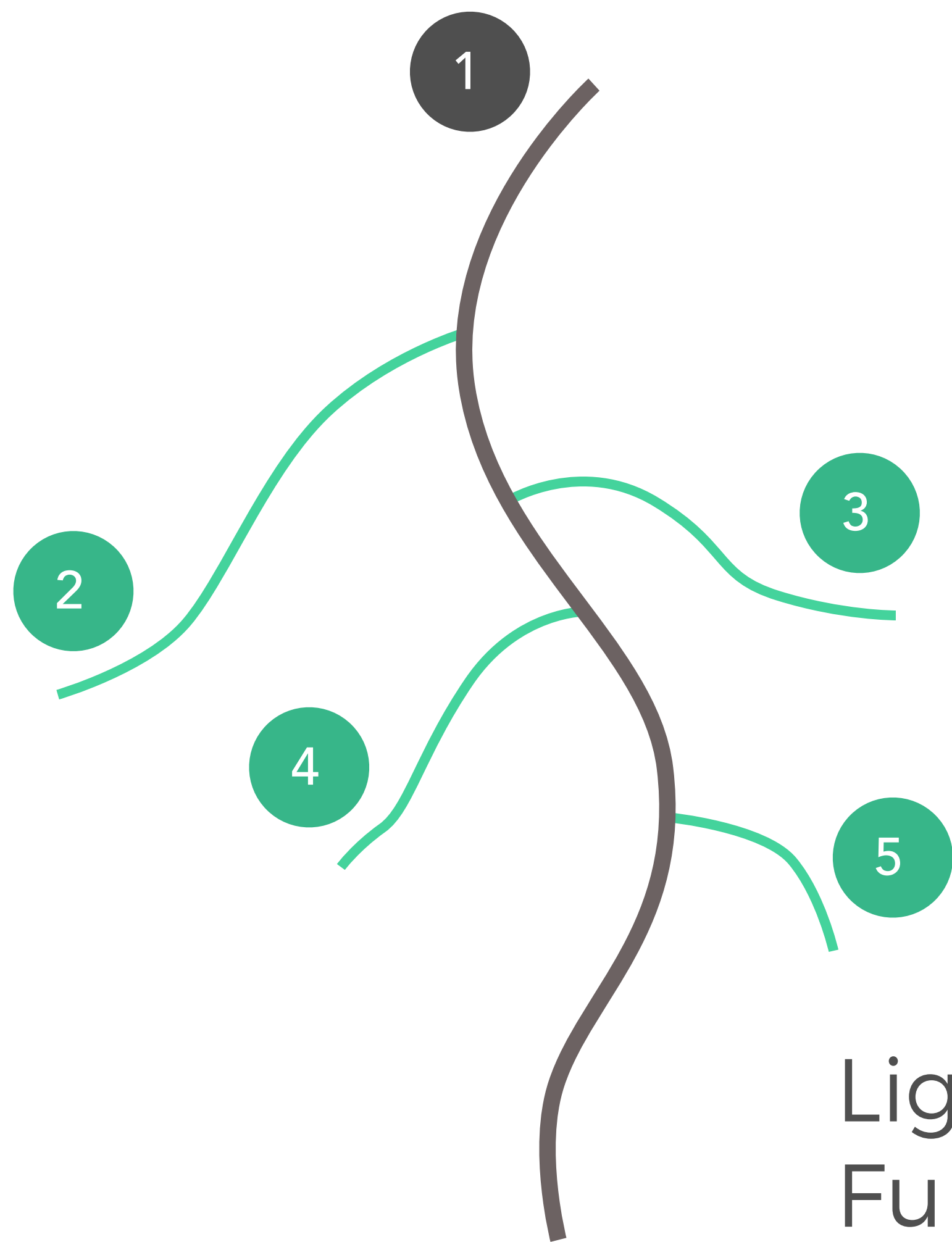


First solution: **Explicit links**

```
<root id=1 parent=0></root>
<root id=2 parent=1></root>
<root id=3 parent=1></root>
<root id=4 parent=1></root>
<root id=5 parent=1></root>
```

Hard to find the lowest branching level
Not fully tacking advantage of XML

DEALING WITH TOPOLOGY

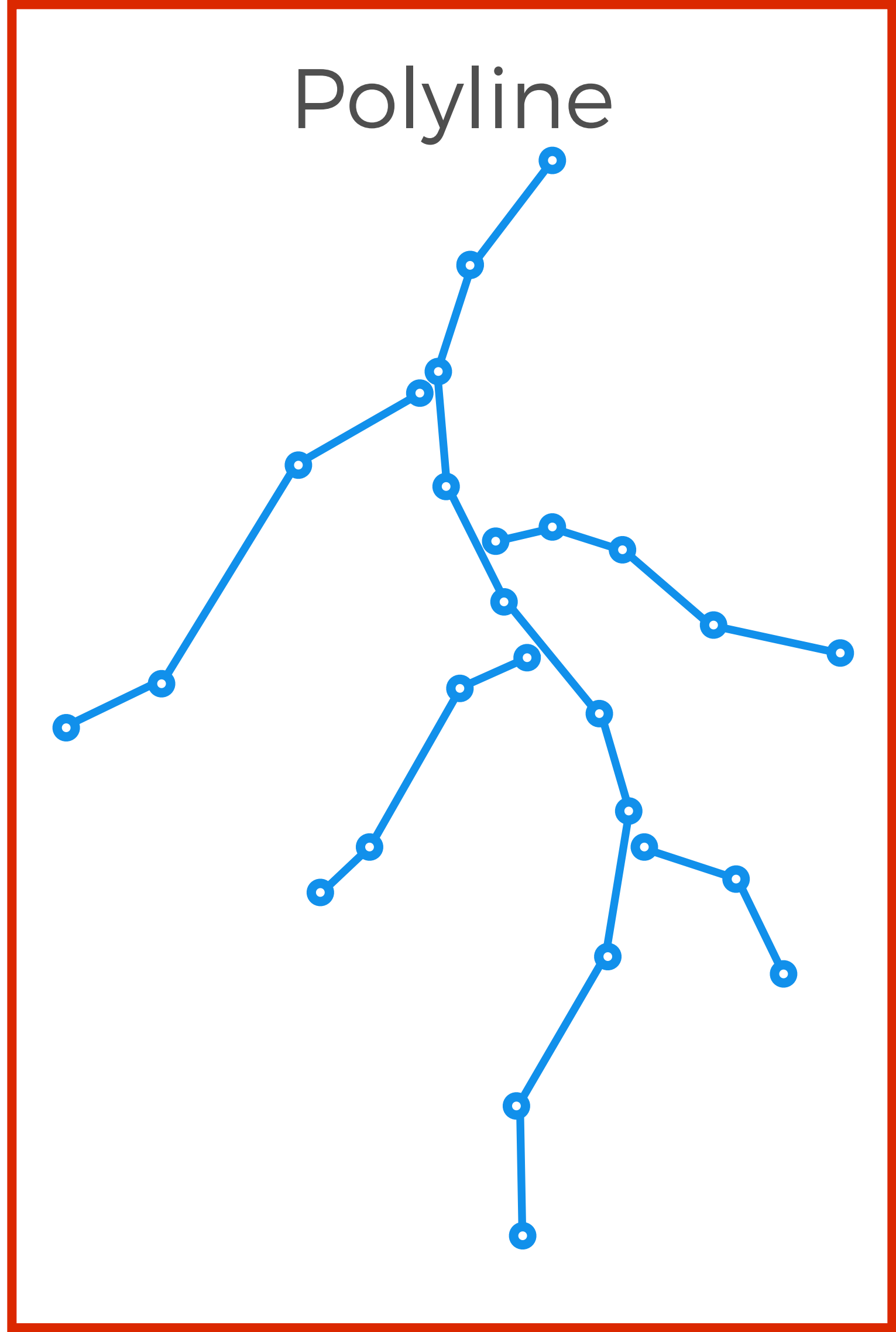
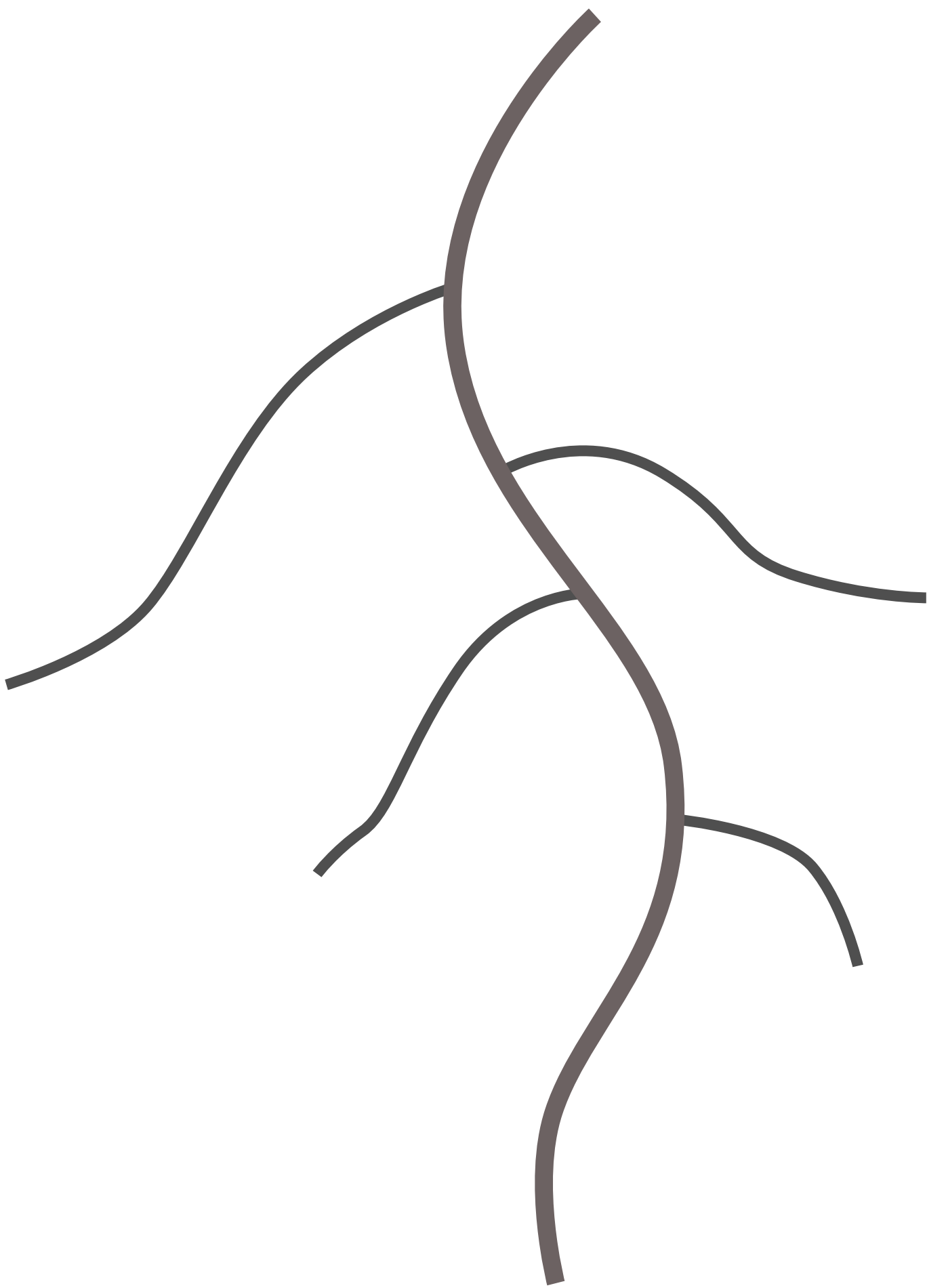
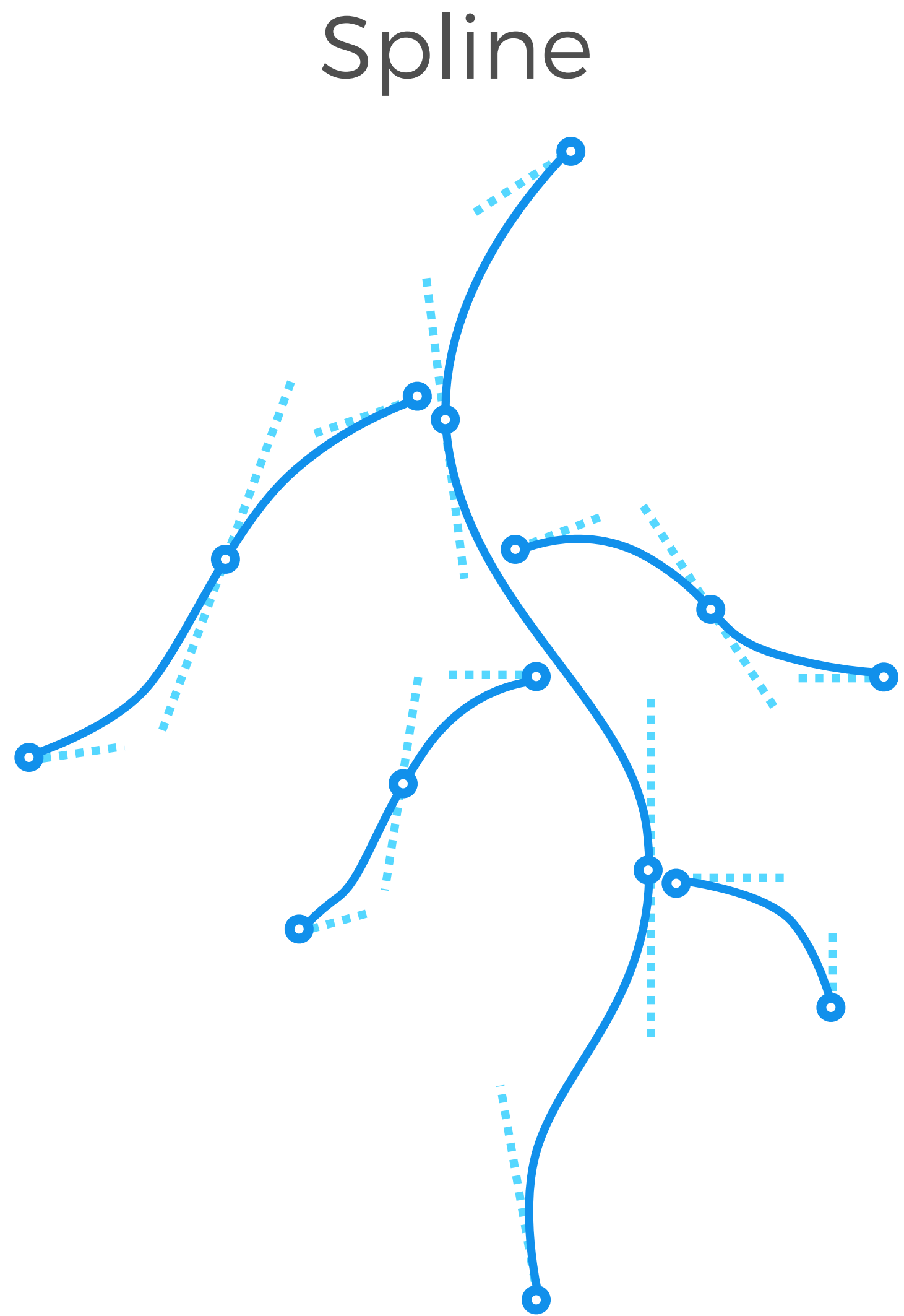


Second solution: **Implicit links**

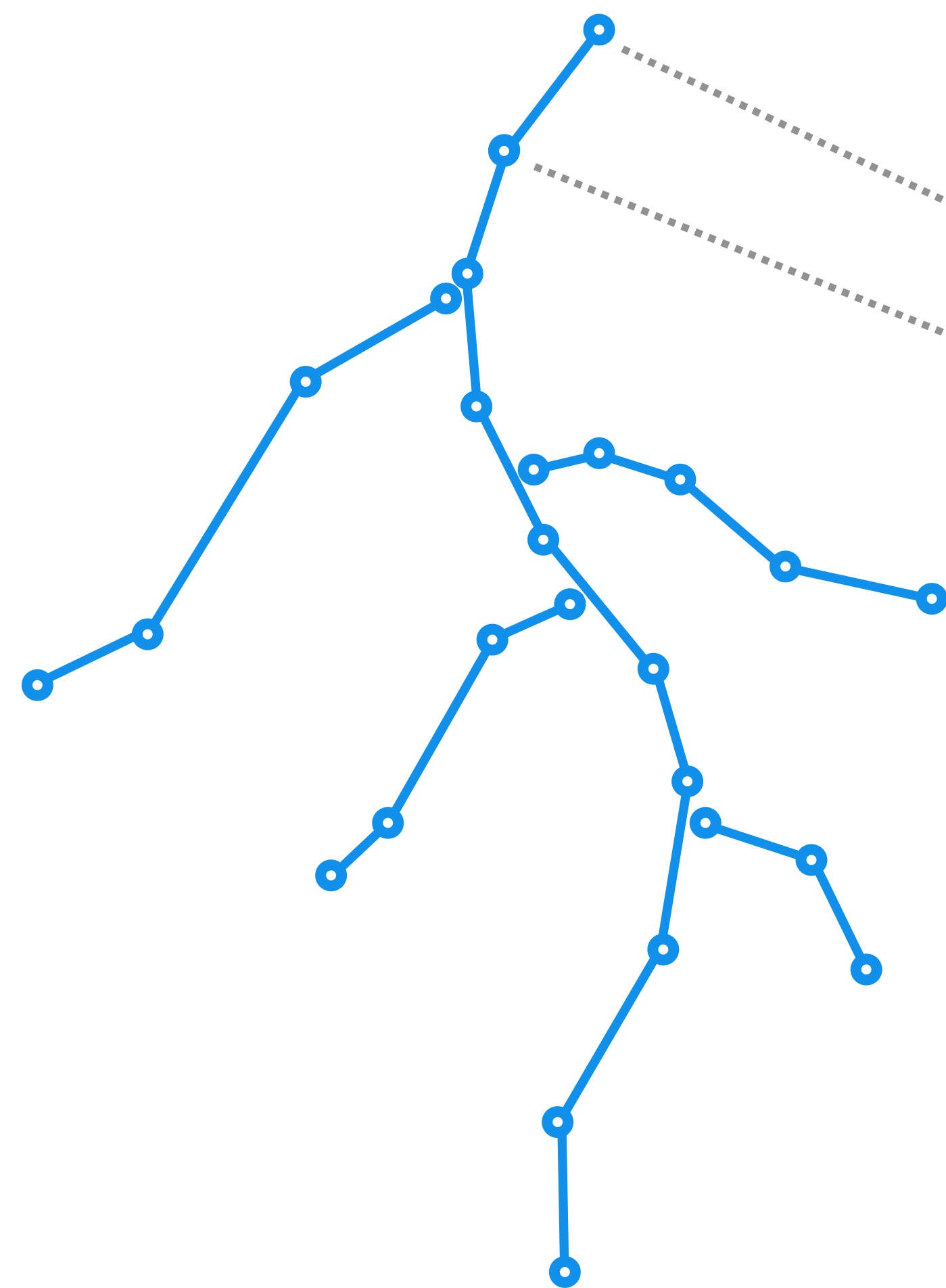
```
<root id=1>
  <root id=2></root>
  <root id=3></root>
  <root id=4></root>
  <root id=5></root>
</root>
```

Lighter
Fully tacking advantage of XML
Easy to find lowest branching level

DEALING WITH GEOMETRY



DEALING WITH GEOMETRY



```
<root id=1>
```

```
<geometry>
```

```
<polyline>
```

```
<point x=1 y=1>
```

```
<point x=1 y=2>
```

```
...
```

```
</polyline>
```

```
<spline>
```

```
</spline>
```

```
</geometry>
```

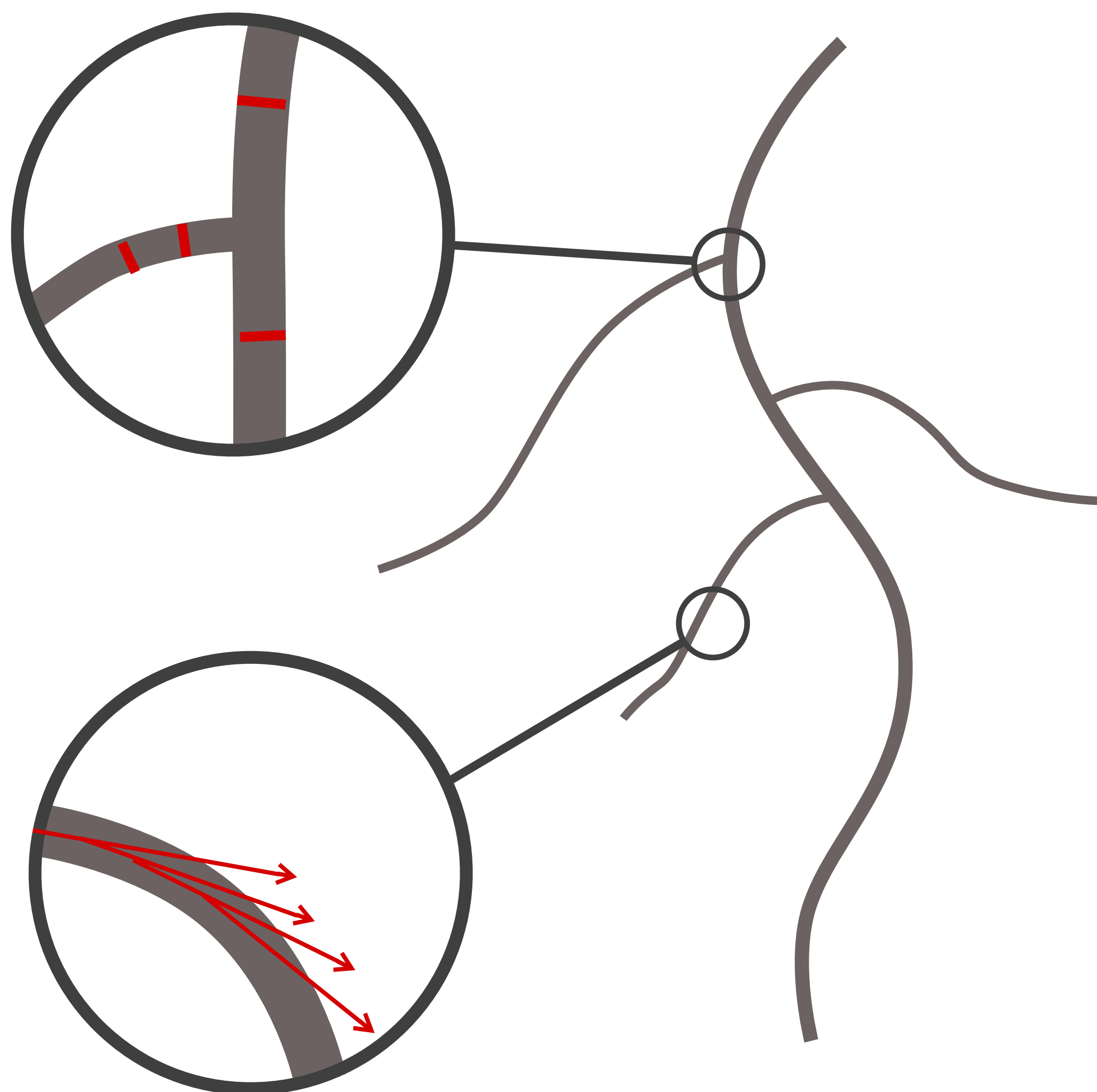
```
<root id=2></root>
```

```
</root>
```

Ordered
along the
root axis

Optional

DEALING WITH MORPHOLOGY



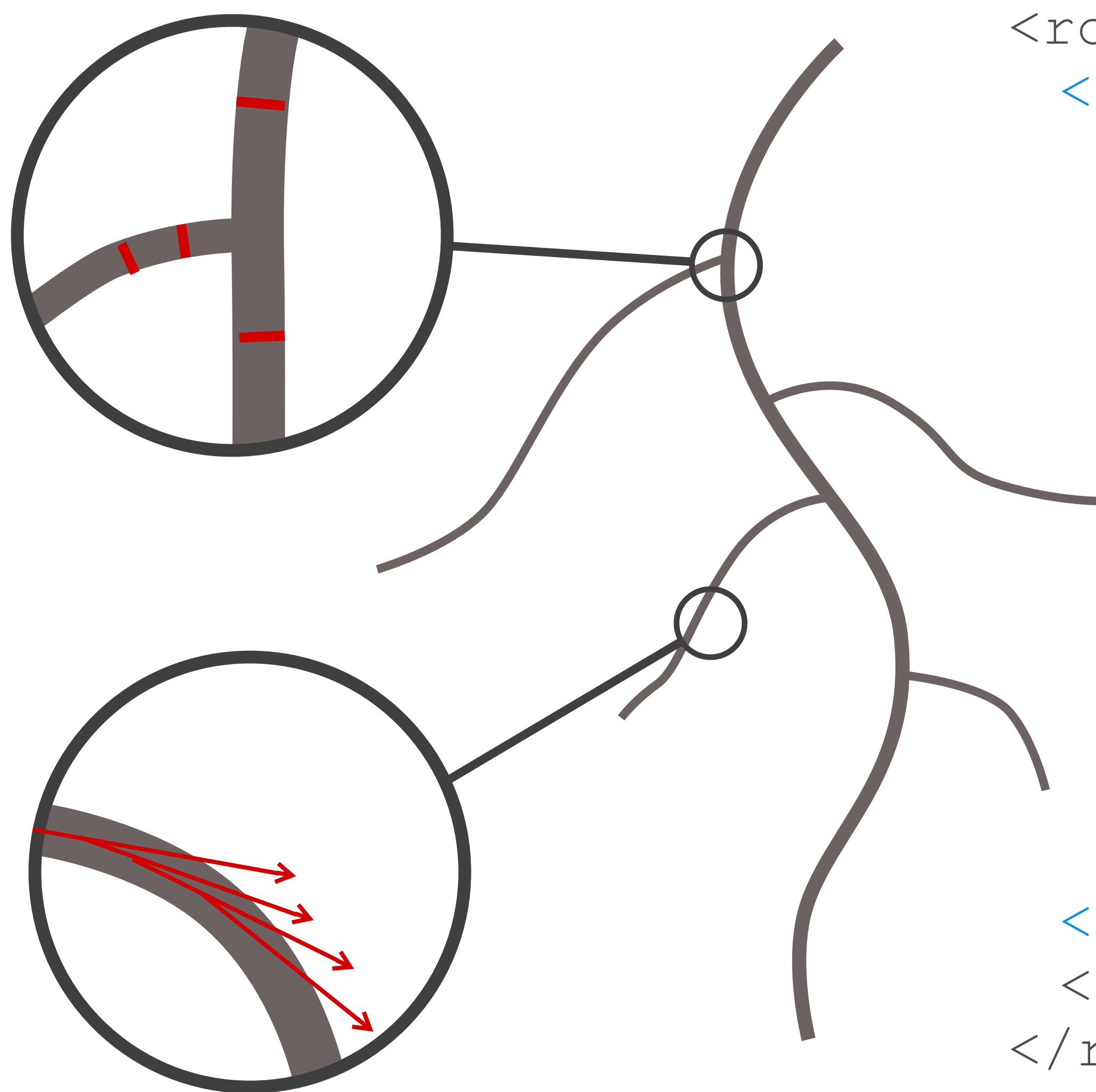
Changes between roots

→ Linked to the `<root>`

Changes along the root axis

→ Linked to the `<geometry>`

DEALING WITH MORPHOLOGY



```
<root id=1>
  <geometry>
    <polyline>
      <point x=1 y=1>
      <point x=1 y=2>
      ...
    </polyline>
    <functions>
      <function name="diameter">
        <sample value="10"/>
        <sample value="4"/>
        ...
      </function>
    </functions>
  </geometry>
  <root id=2></root>
</root>
```

Implicit link between
polyline and functions



RSML IS EXTENSIBLE

```
<metadata>
  <property-definitions>
    <property-definition>
      <label>diameter</label>
      <type>float</type>
      <unit>pixel</unit>
    </property-definition>
  </property-definitions>
</metadata>
<scene>
  <plant>
    <root id=1>
      <geometry>
        <polyline>
        </polyline>
        <functions>
          <function name="diameter"></function>
        </functions>
      </geometry>
    <root id=2></root>
    ...
```

- Any type of information can be included
- New informations are defined in header
- Quick to parse



ONE LANGUAGE - MANY TOOLS



"Piled Higher and Deeper" by Jorge Cham
www.phdcomics.com



*“One **language** to bring them all
and in your **pipeline** bind them”*

MODELING

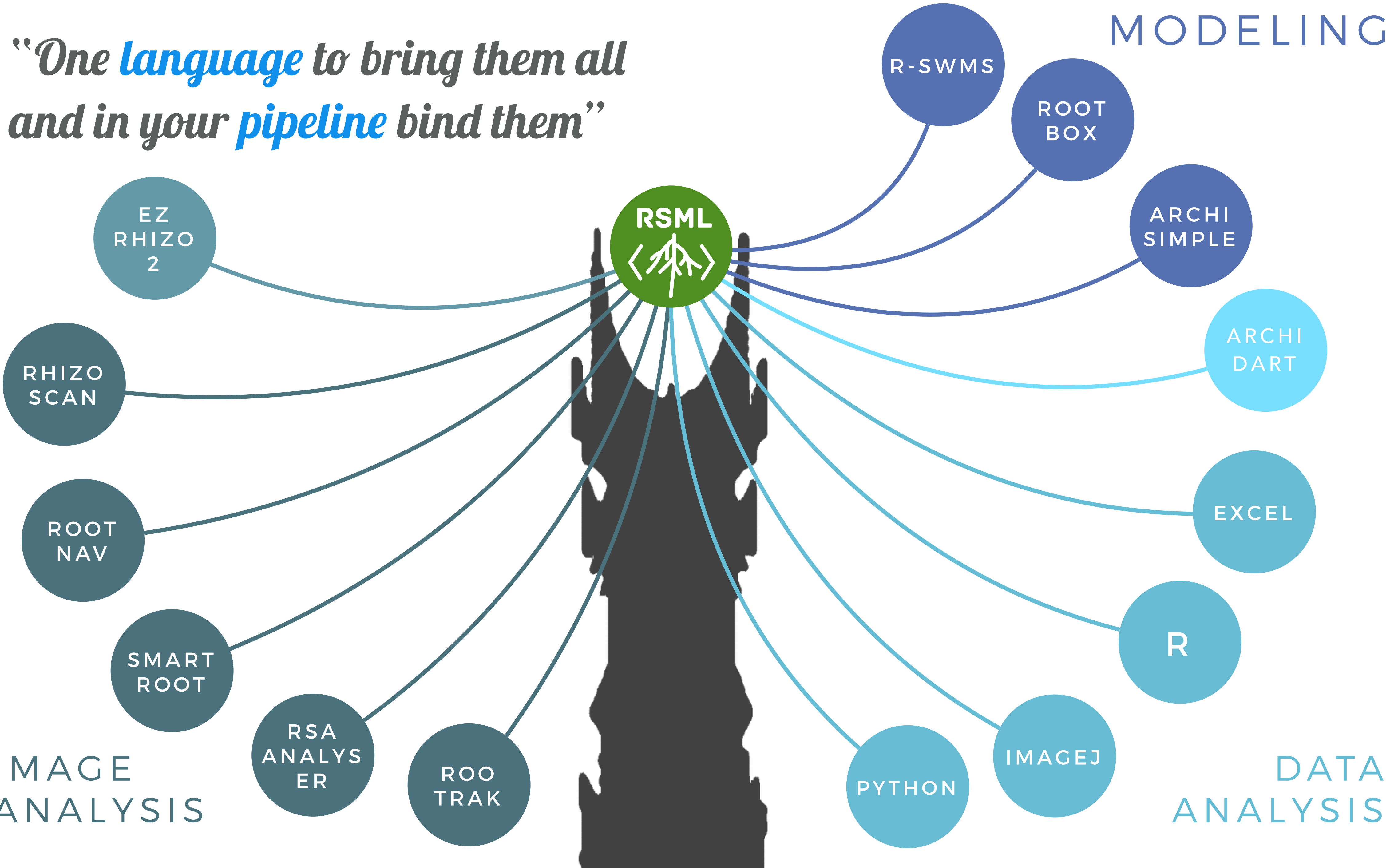
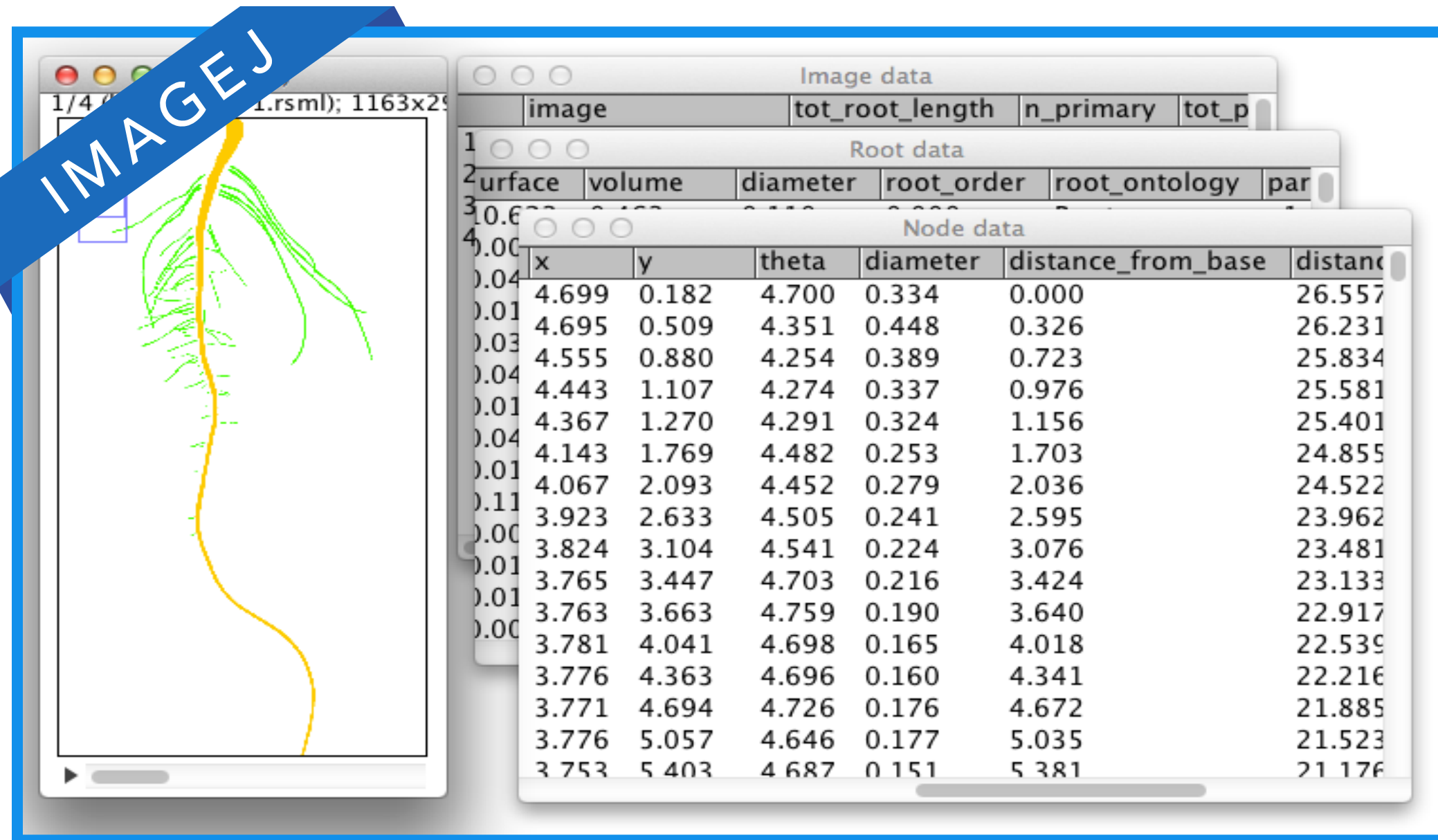


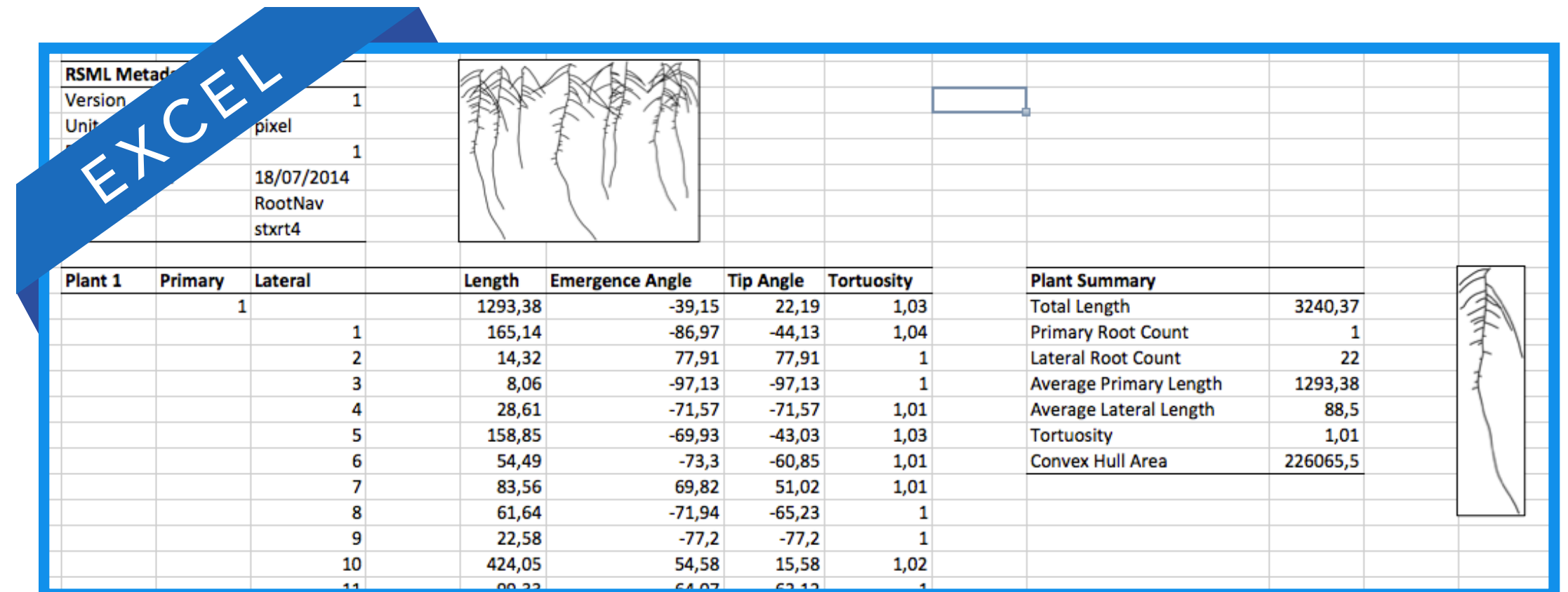
IMAGE ANALYSIS

DATA ANALYSIS

COMMON ANALYSIS PIPELINES

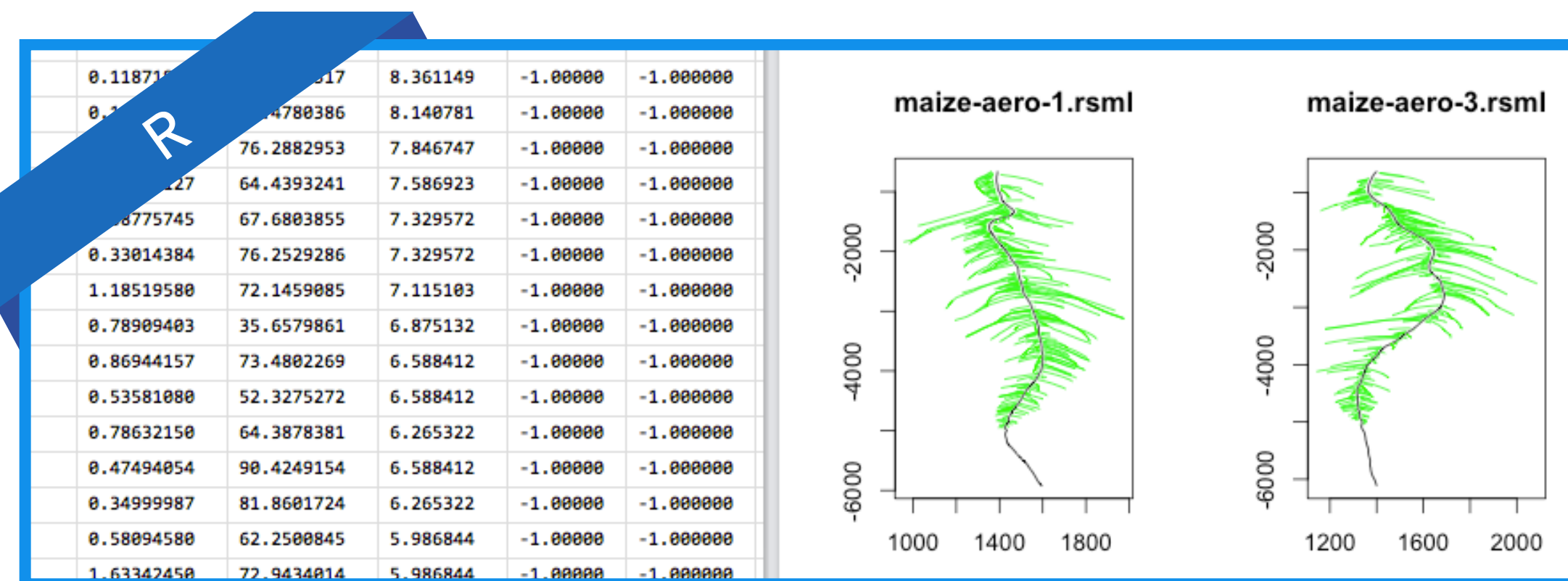


EXCEL



Plant 1	Primary	Lateral	Length	Emergence Angle	Tip Angle	Tortuosity
1	1		1293,38	-39,15	22,19	1,03
		1	165,14	-86,97	-44,13	1,04
		2	14,32	77,91	77,91	1
		3	8,06	-97,13	-97,13	1
		4	28,61	-71,57	-71,57	1,01
		5	158,85	-69,93	-43,03	1,03
		6	54,49	-73,3	-60,85	1,01
		7	83,56	69,82	51,02	1,01
		8	61,64	-71,94	-65,23	1
		9	22,58	-77,2	-77,2	1
		10	424,05	54,58	15,58	1,02
		11	88,23	64,87	62,13	1

Plant Summary	
Total Length	3240,37
Primary Root Count	1
Lateral Root Count	22
Average Primary Length	1293,38
Average Lateral Length	88,5
Tortuosity	1,01
Convex Hull Area	226065,5

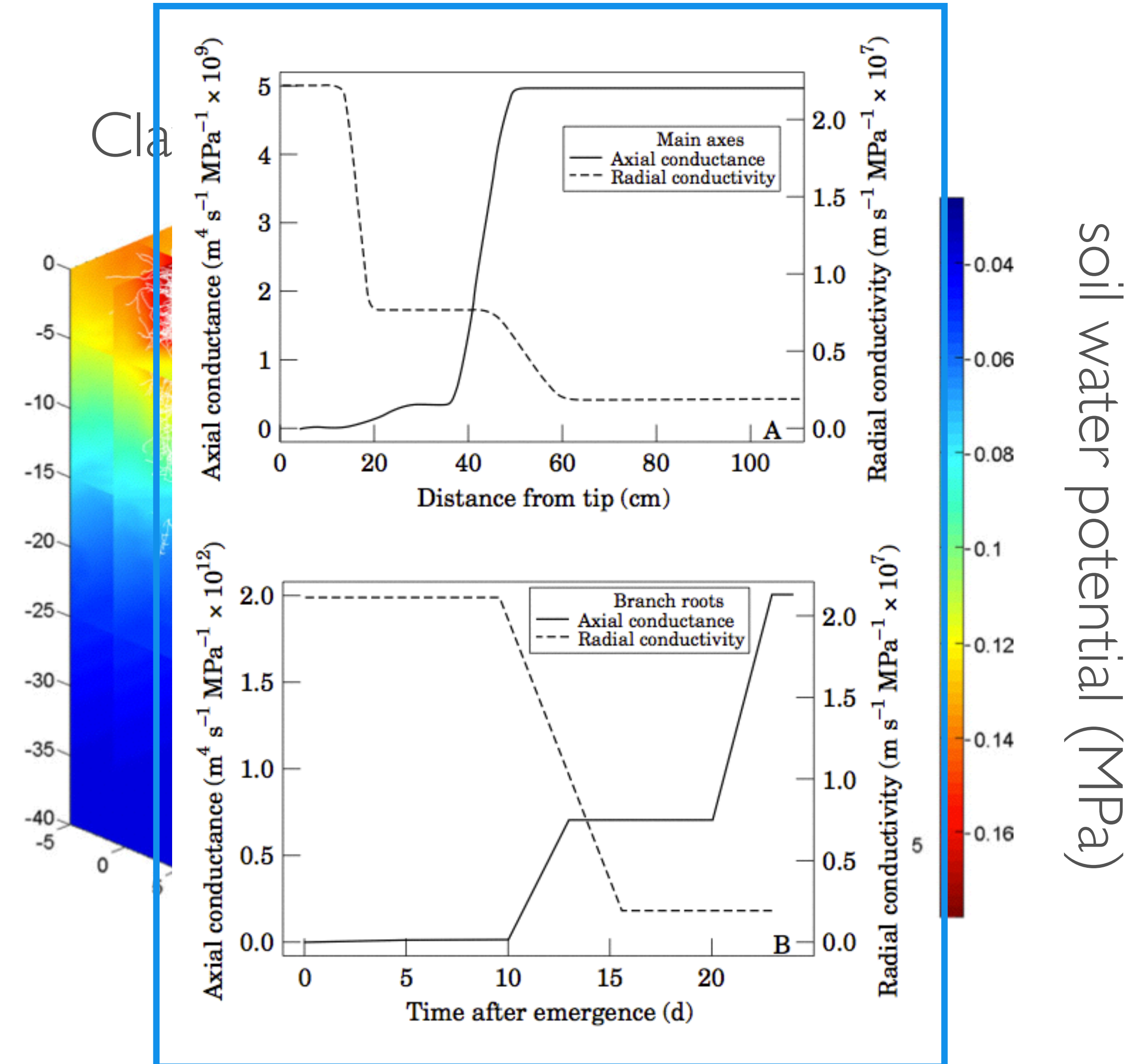
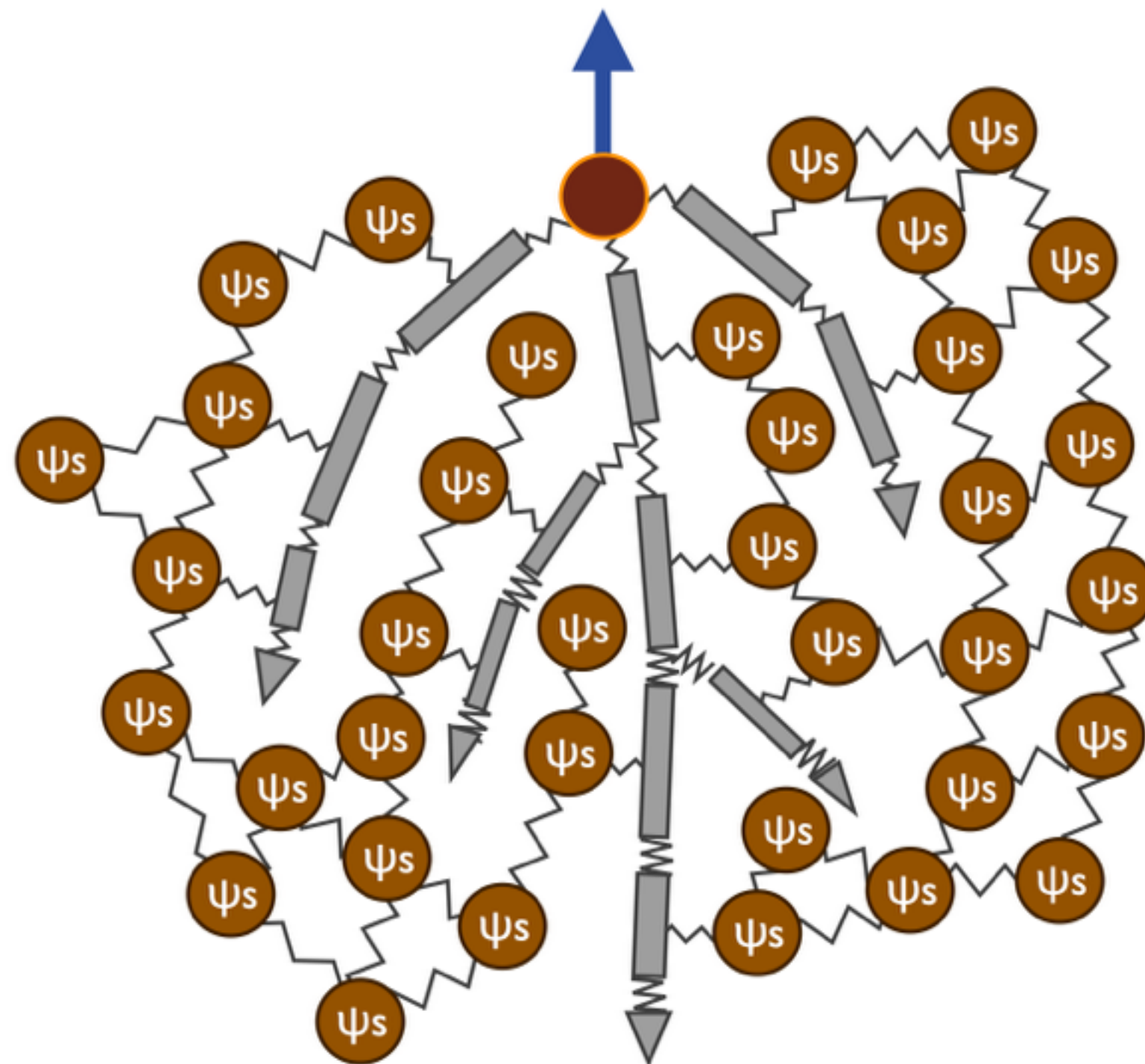


- Easily compare datasets
- Across experiments
- Across teams
- Models and experiments

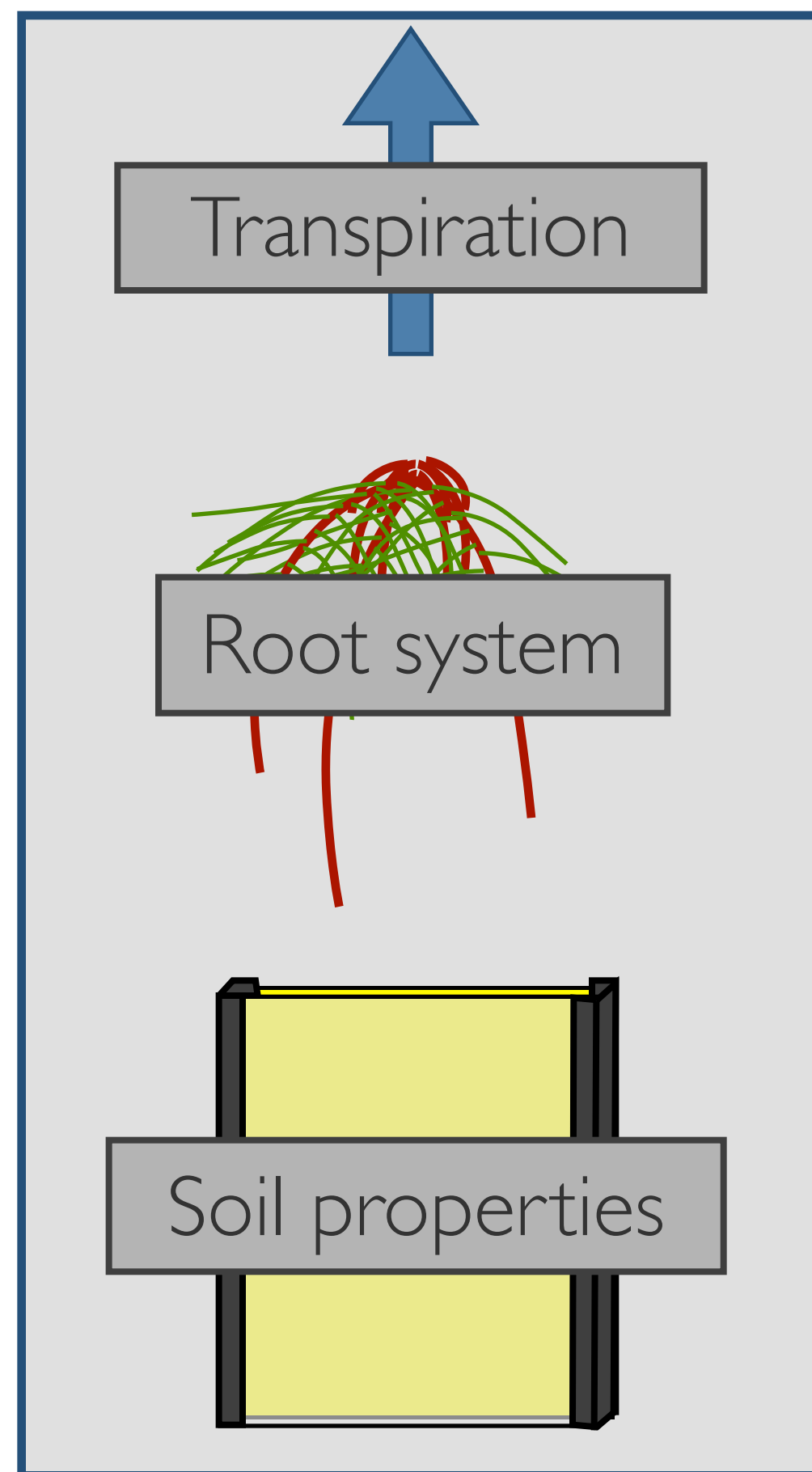
FROM IMAGES TO MODELS

R-SWMS

- functional-structural model
- 1000's of connected articles
- explicit 3D soil water movement
- no shoot (boundary condition)



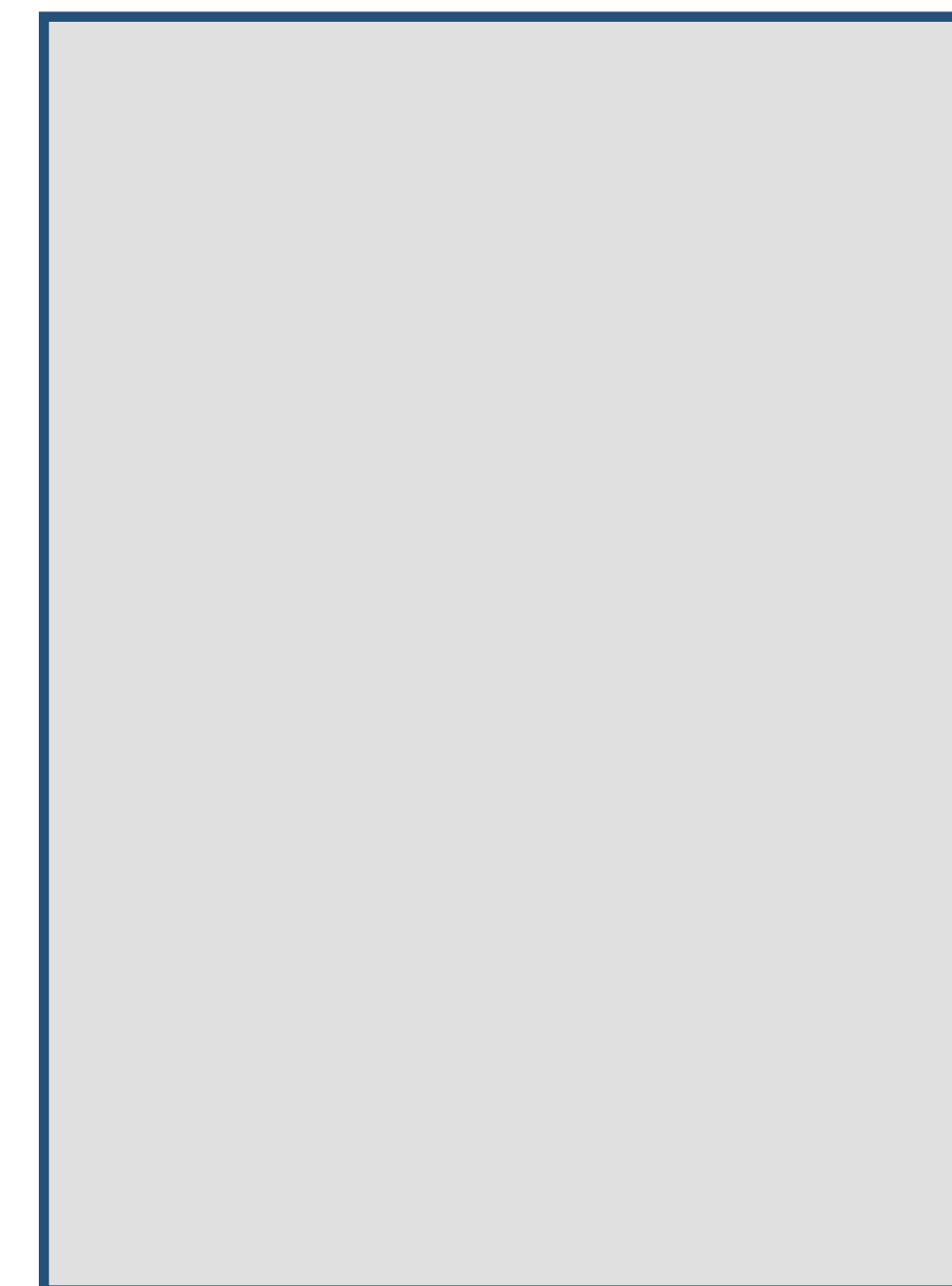
FROM IMAGES TO MODELS



3D water flow
soil-root domain

←→
VALIDATION

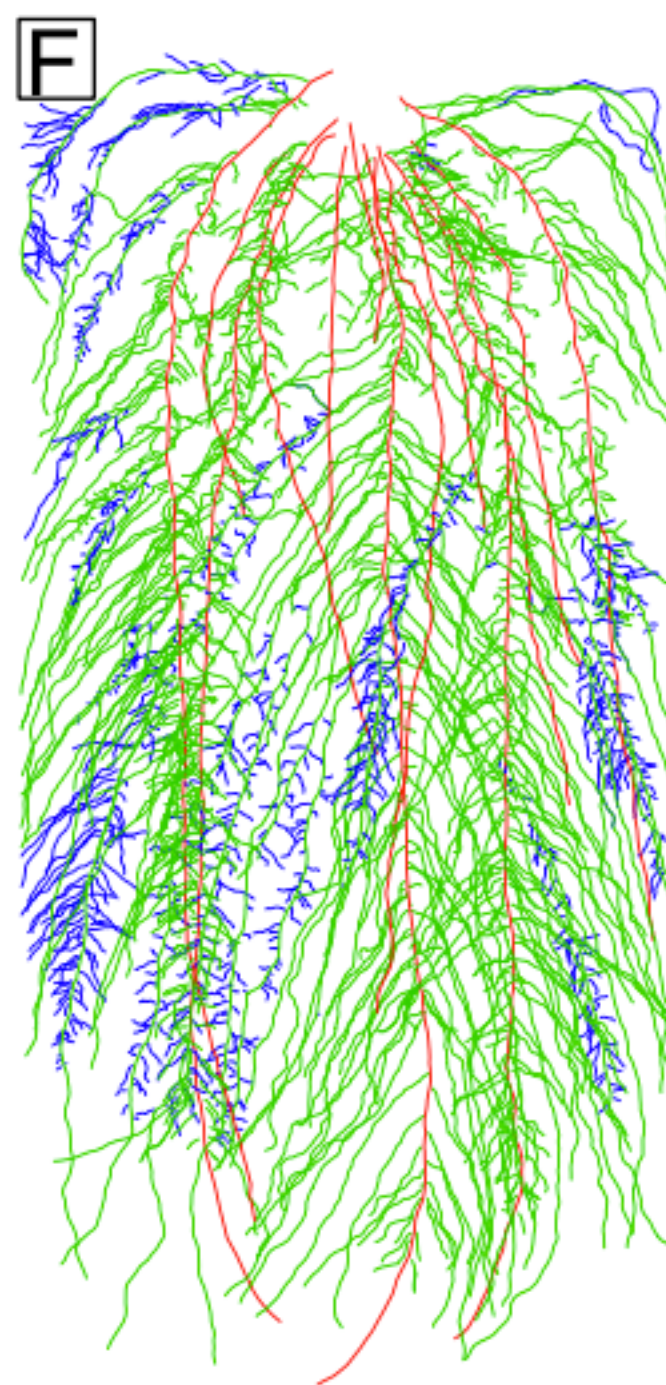
New variables



FROM IMAGES TO MODELS



SmartRoot



RSML

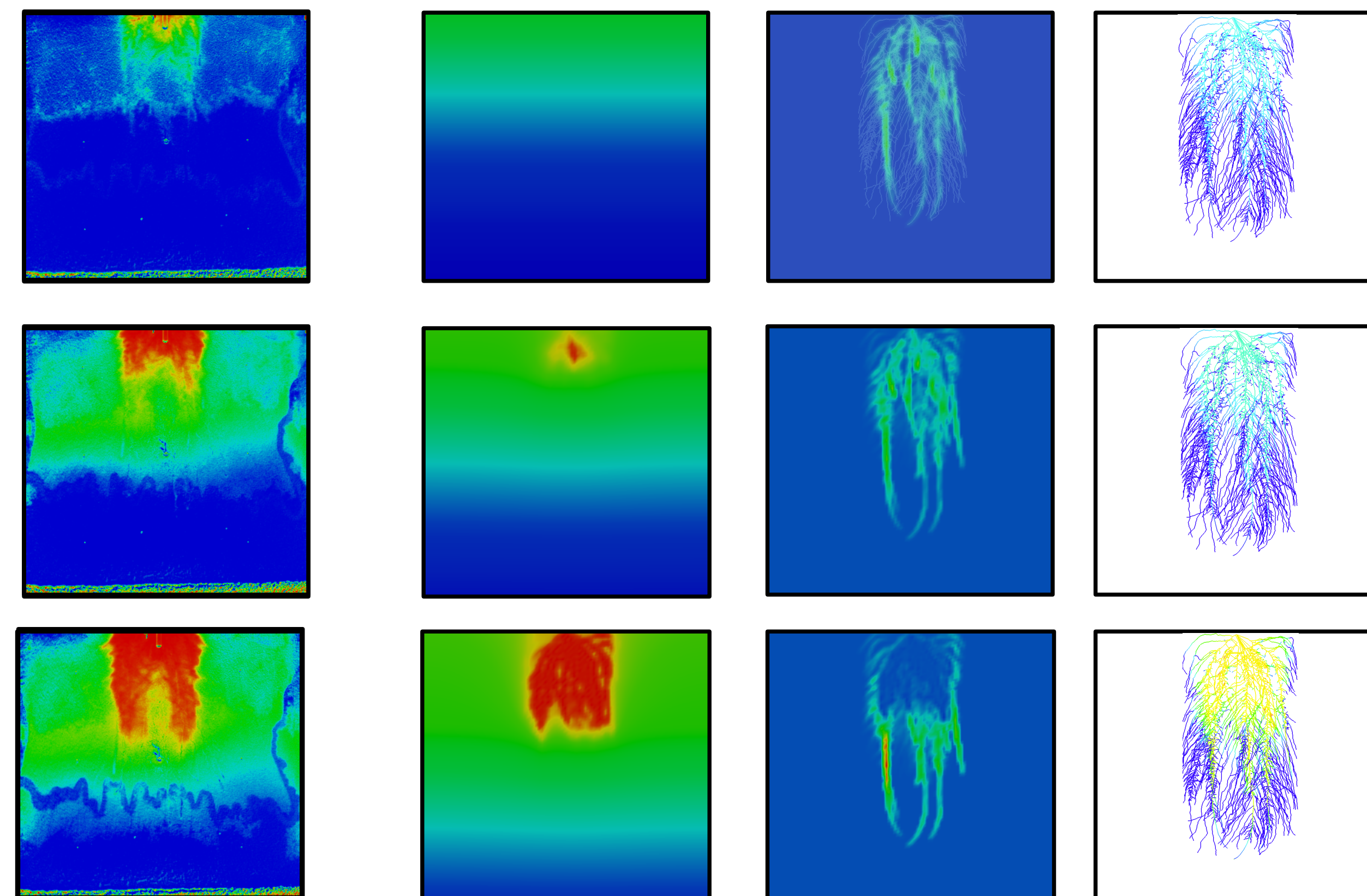


Maize root
system grown
in rhizotron

FROM IMAGES TO MODELS



→
R-SWMS



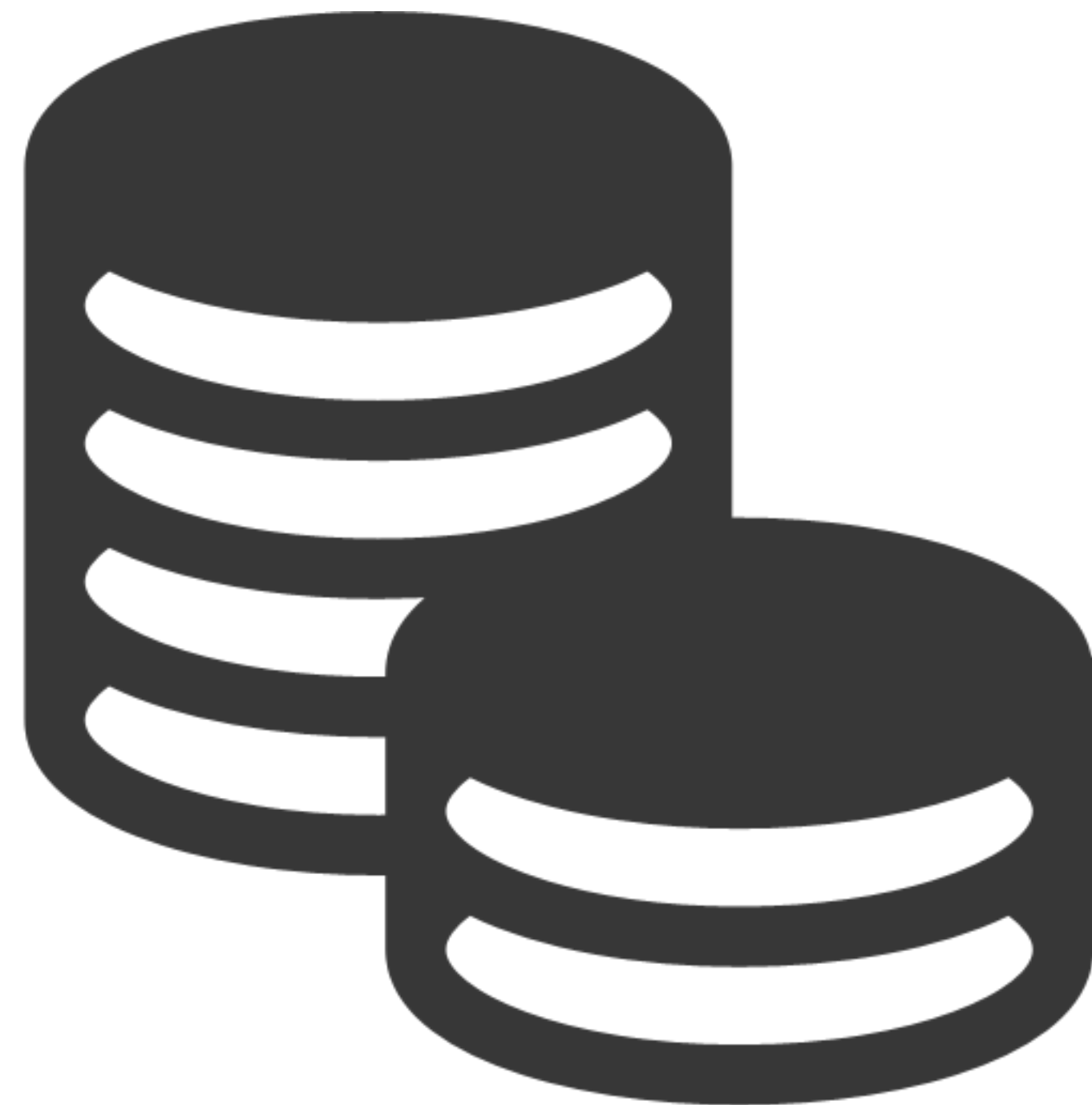
WC [%]
0 20 40

WU [cm³/cm³.d]
0 1.5 3

ψ [MPa]
0 -0.4 -0.8

Test the functional properties of
experimental root systems

ROOT ARCHITECTURE DATABASE



- online repository
- re-use existing data
- meta analysis
- valorisation of expensive datasets





WRAPPING UP



TAKE HOME MESSAGE

RSML is

- is designed to store **root architectures**
- is **flexible**
- is based on strong **standard**
- is implemented in **many tools**
- can **bridge the gaps** between
 - different tools
 - different groups
 - different disciplines





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Christophe Godin
Philippe Nacry
Christophe Pradal



Andrea Schnepf



Daniel Leitner
universität
wien





UPCOMING EVENTS:

Emerging technologies for root system scale imaging and phenotyping

Roundtable at Rhizosphere 4 Meeting - 21-25 June 2015

www.rhizo4.org

Insights into plant biological processes through phenotyping

Ghent, Belgium - 13-19 Sept 2015

<http://events.embo.org/15-plant-phenotyping/>

Workshop on Image Analysis Methods for the Plant Sciences

Louvain-la-Neuve, Belgium - 21-22 Sept 2015

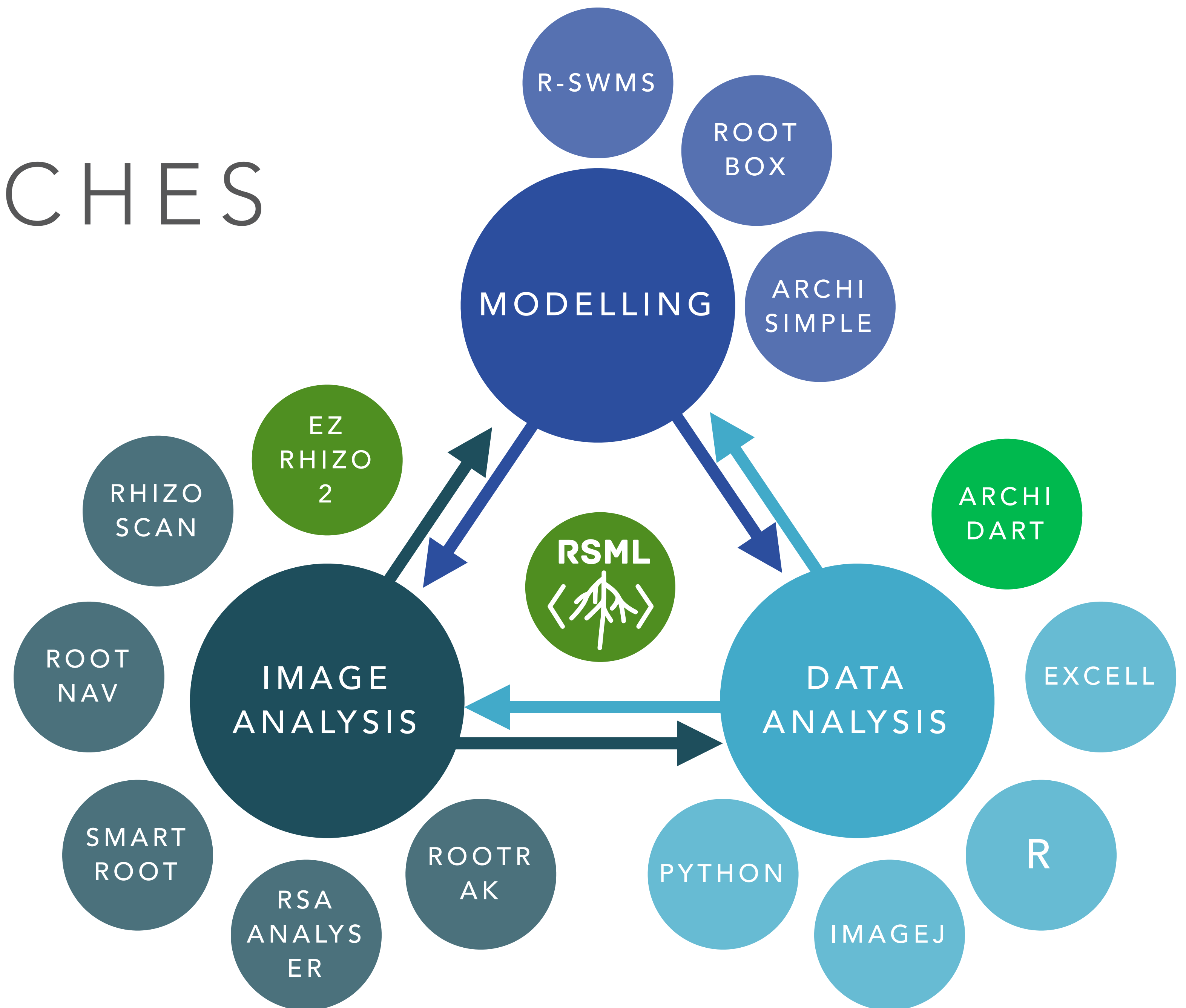
<http://www.phytosystems.ulg.ac.be/iamps15/>



**Thank you for
your attention.**

Any questions?

MANY APPROACHES



FROM MODELS TO IMAGES

