

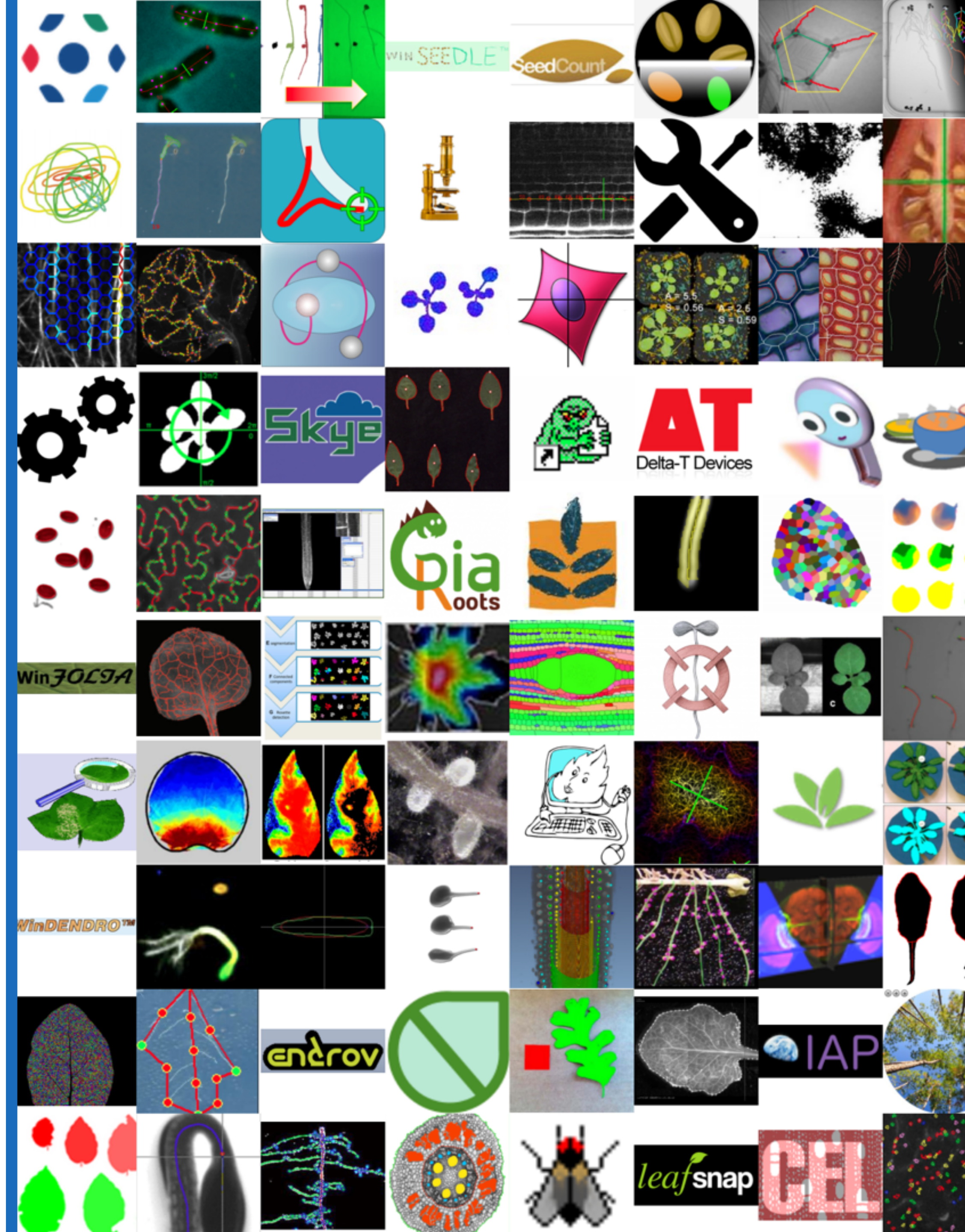
PLANT IMAGE ANALYSIS TOOLS: CURRENT TRENDS AND ~~LIMITATIONS~~ FUTURE CHALLENGES

GUILLAUME LOBET, XAVIER DRAYE & CLAIRE PÉRILLEUX

PLANT IMAGE ANALYSIS AND SOLUTIONS
15TH OF APRIL 2015, MADISON

guillaume.lobet@ulg.ac.be

@guillaumelobet 





CURRENT TRENDS



THE PHENOTYPING CHALLENGE



PHENOTYPIC VARIATION

PHENOTYPING
PLATFORMS



Image
analysis

GENETIC VARIATION

NEXT GENERATION
SEQUENCING



Plant Image Analysis

[Software](#) [References](#) [Related websites](#) [Submit](#) [About](#)



Search...

Search

Choose...

Plant organ

any

Measurements

any

[MORE OPTIONS +](#)

Operating system

any

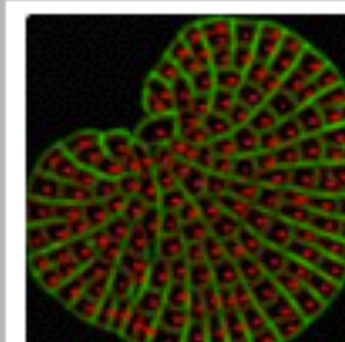
All **114** plant image analysis software solutions:



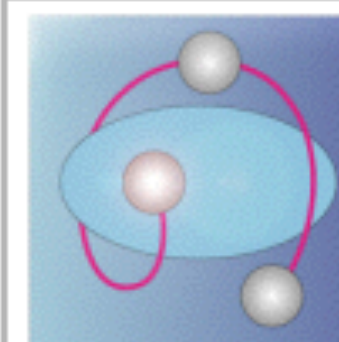
Assess



ARTT



Balloon
Plugin



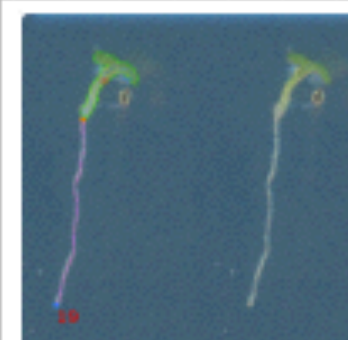
BioImageXD



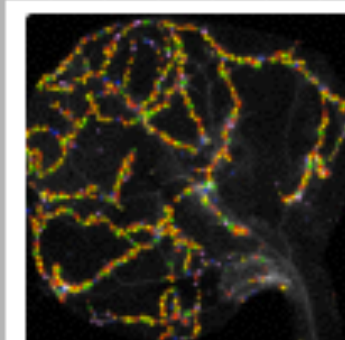
Bisque



Black Spot



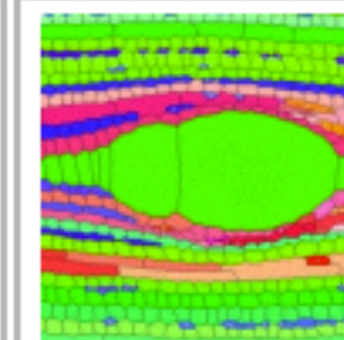
BRAT



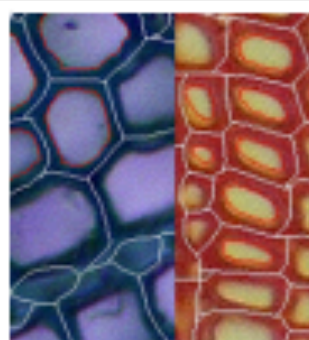
Callose
Measurer



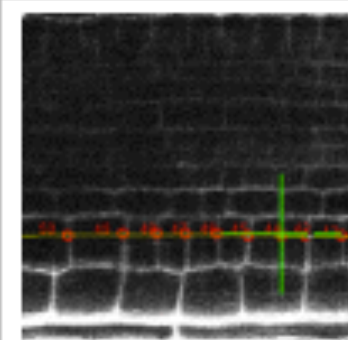
Canopy
Analysis



Cefiler



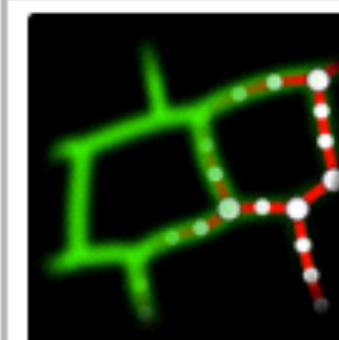
Celer



Cell-o-Tape



CellProfiler

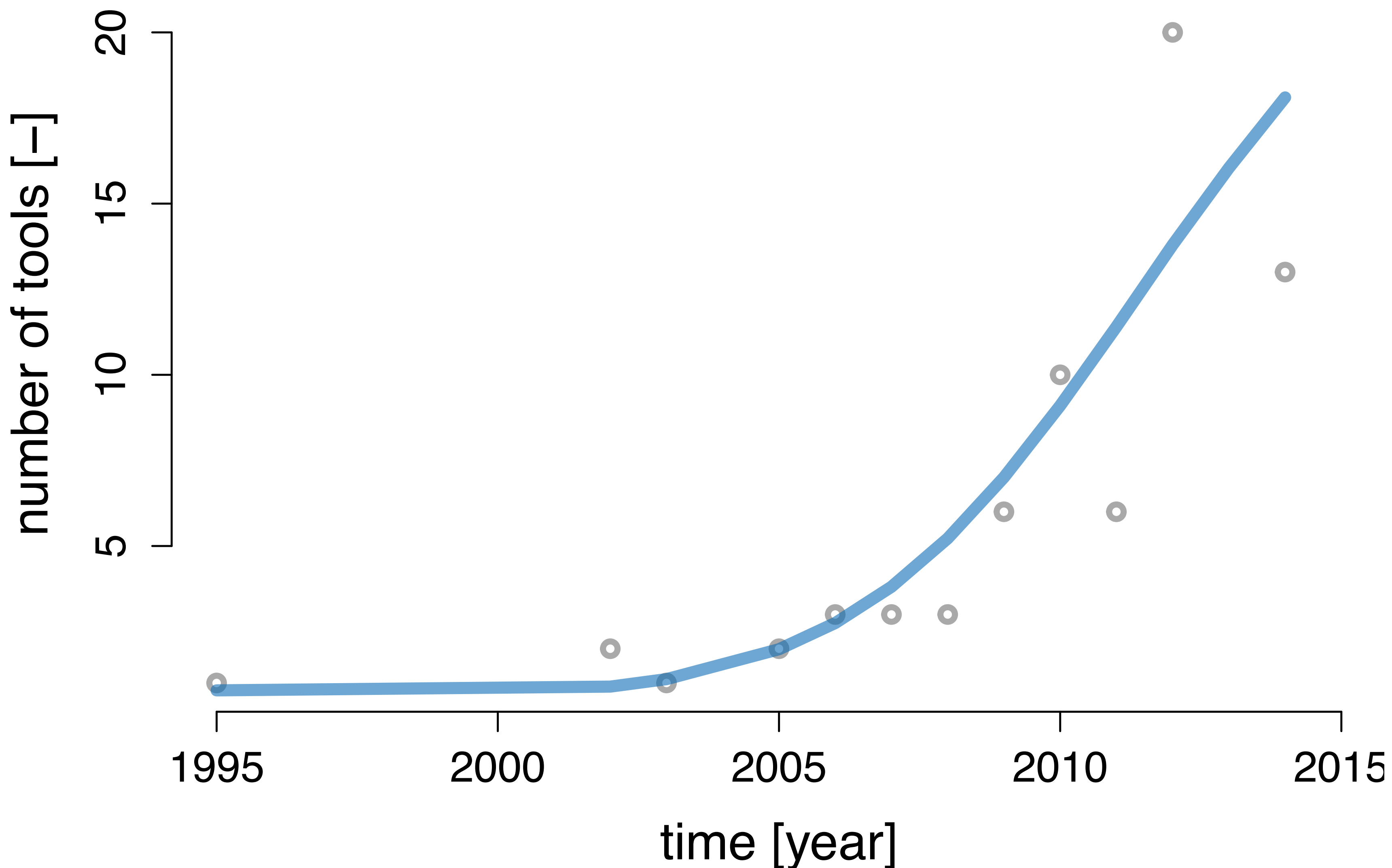


CellSeT



Circumnutation
Tracker

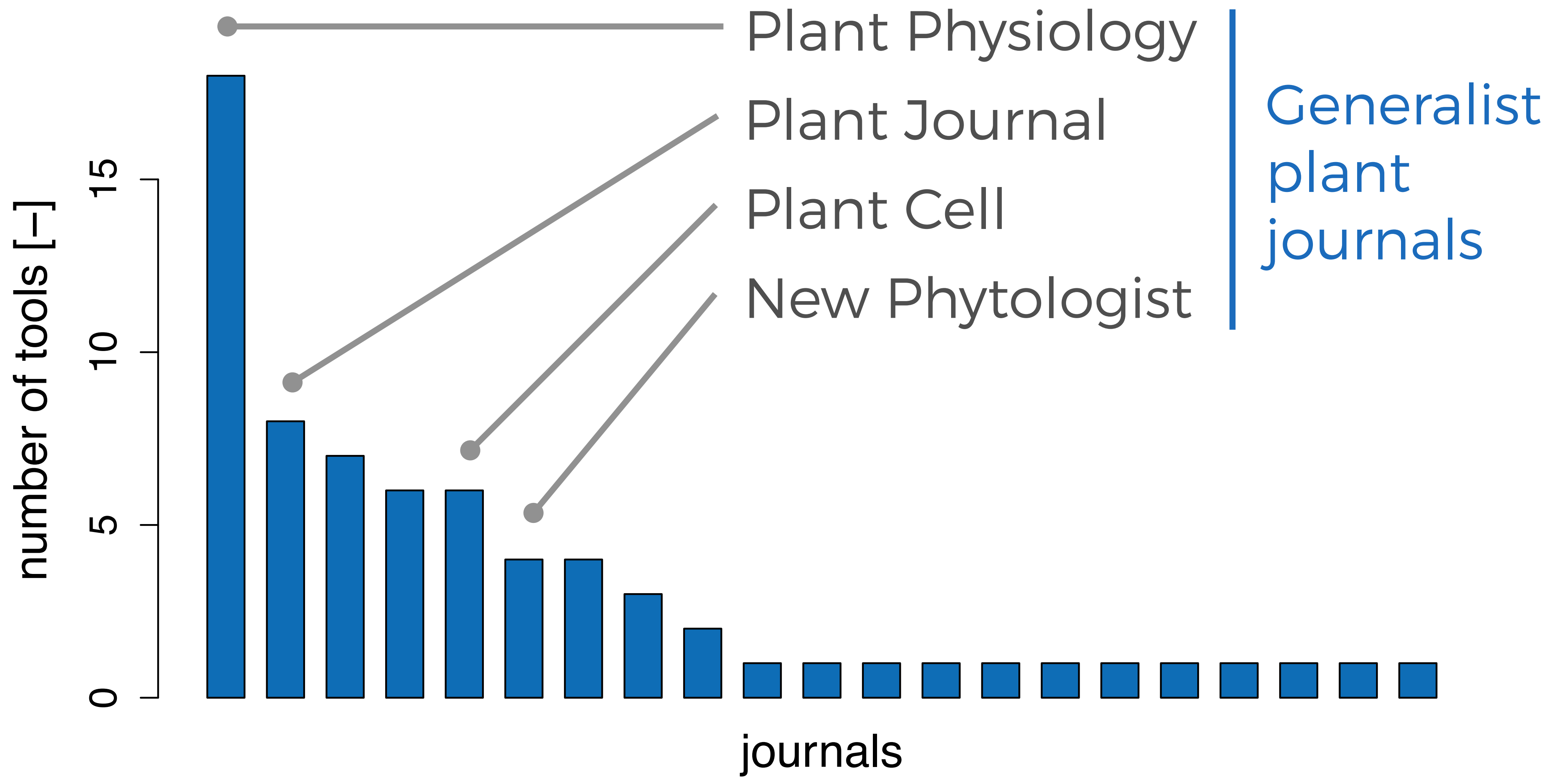
INCREASING NUMBER OF PUBLISHED TOOLS



Average
citations / year
5,6
[Scopus]



LARGE INTEREST BY THE PLANT COMMUNITY



DISTRIBUTION OF PLANT IMAGE ANALYSIS TOOLS



All [114]



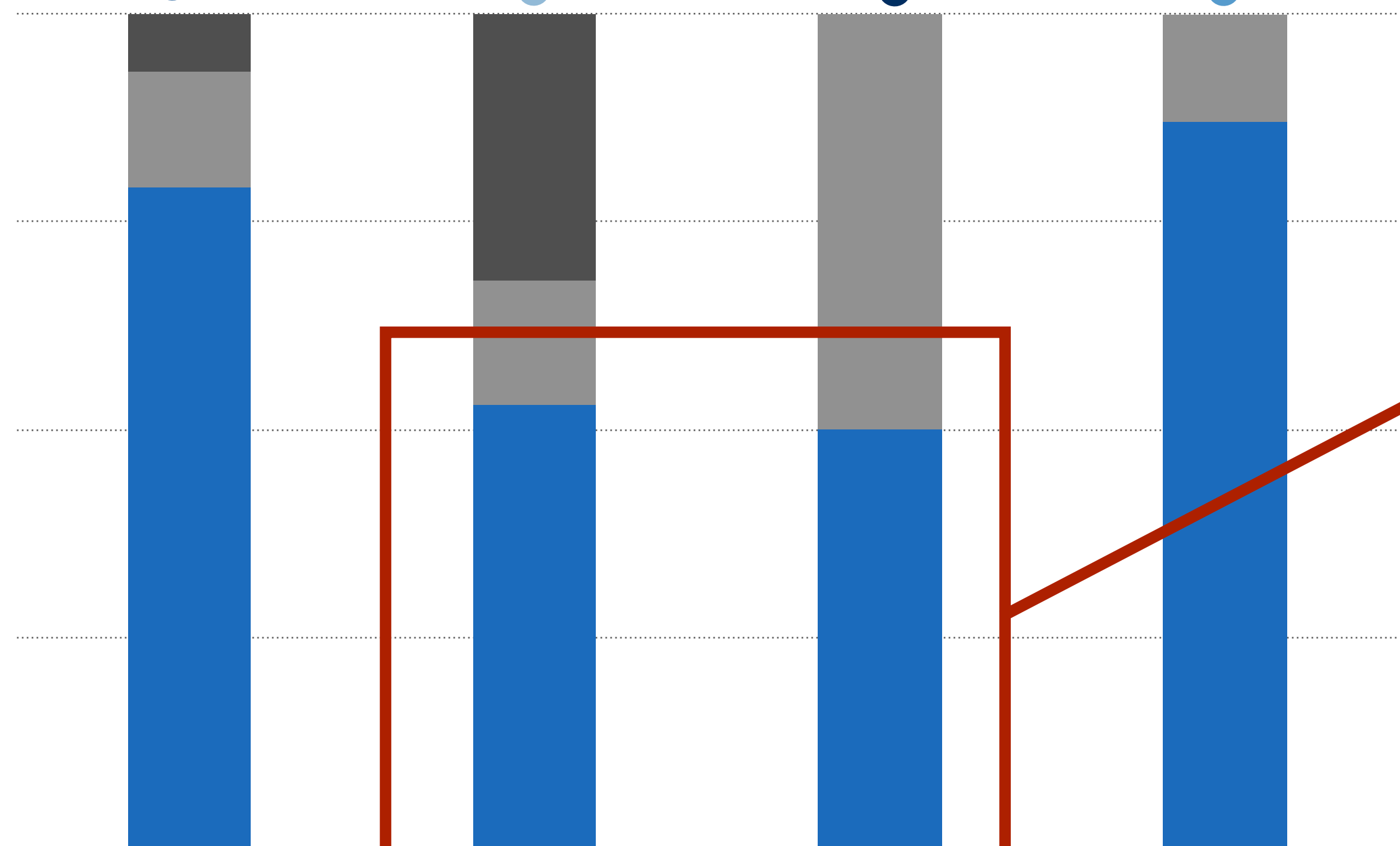
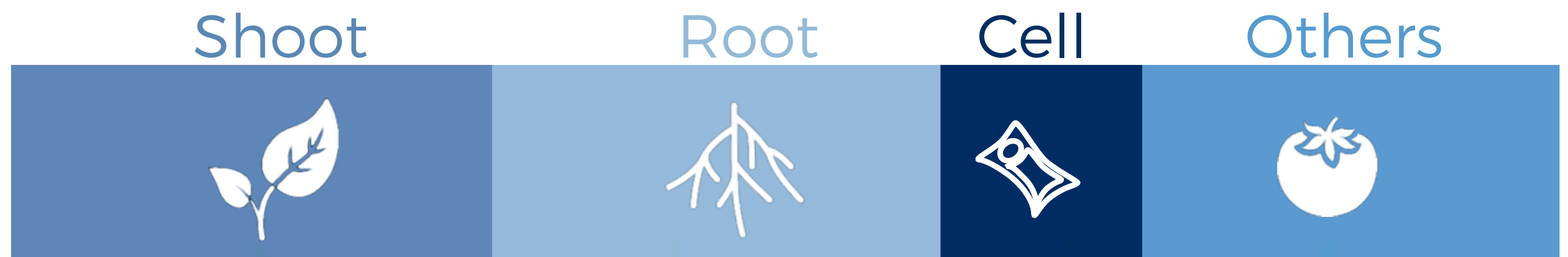
Shoot
[14]

Root
[16]

Cell
[8]

Others
[15]

DEGREE OF AUTOMATION DEPENDS ON THE ORGAN



images tend to be more complex/noisy

■ automated ■ semi-automated ■ manual

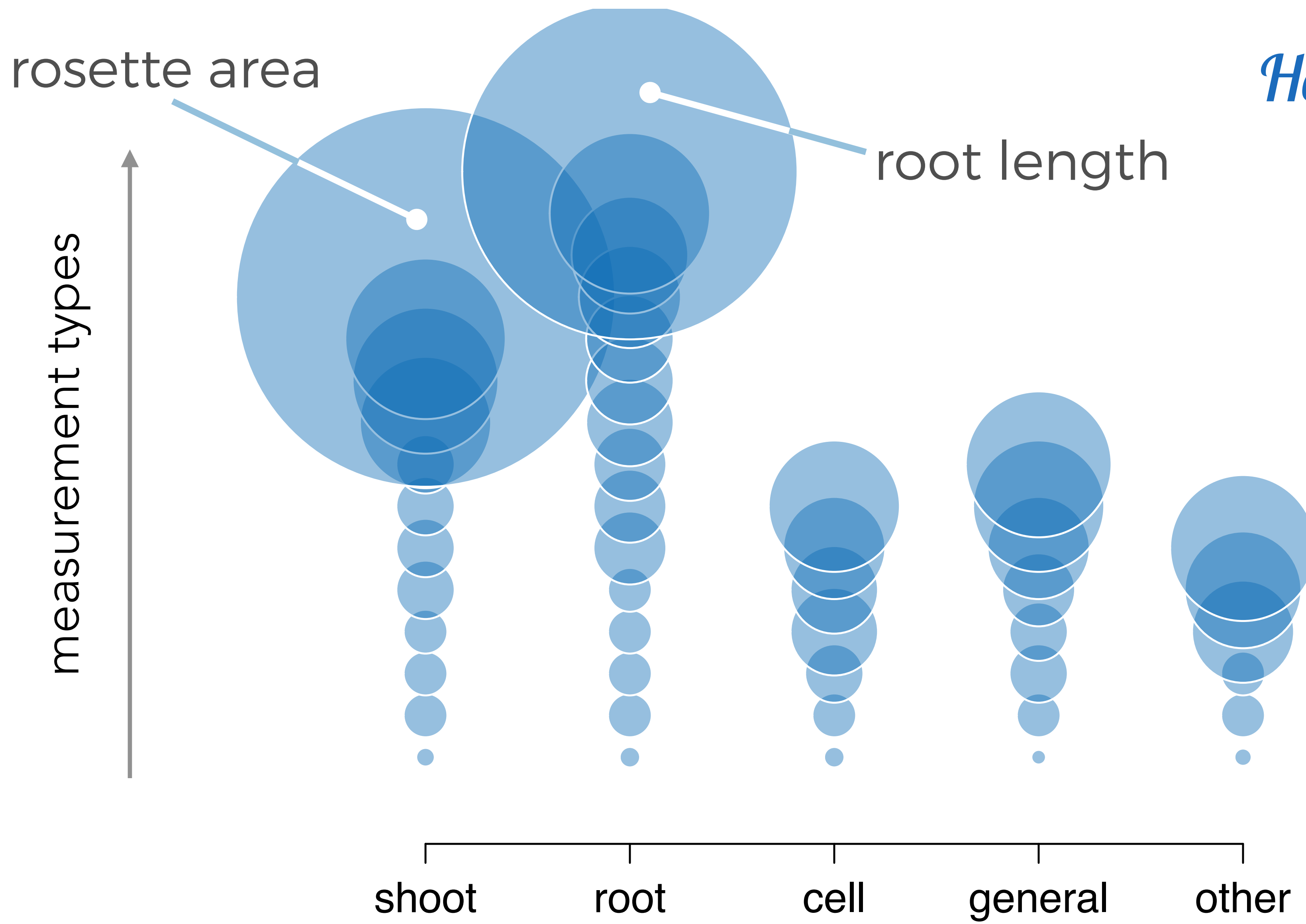




BENCHMARK DATASETS



MEASUREMENT OVERLAP BETWEEN TOOLS



How can we choose between them?

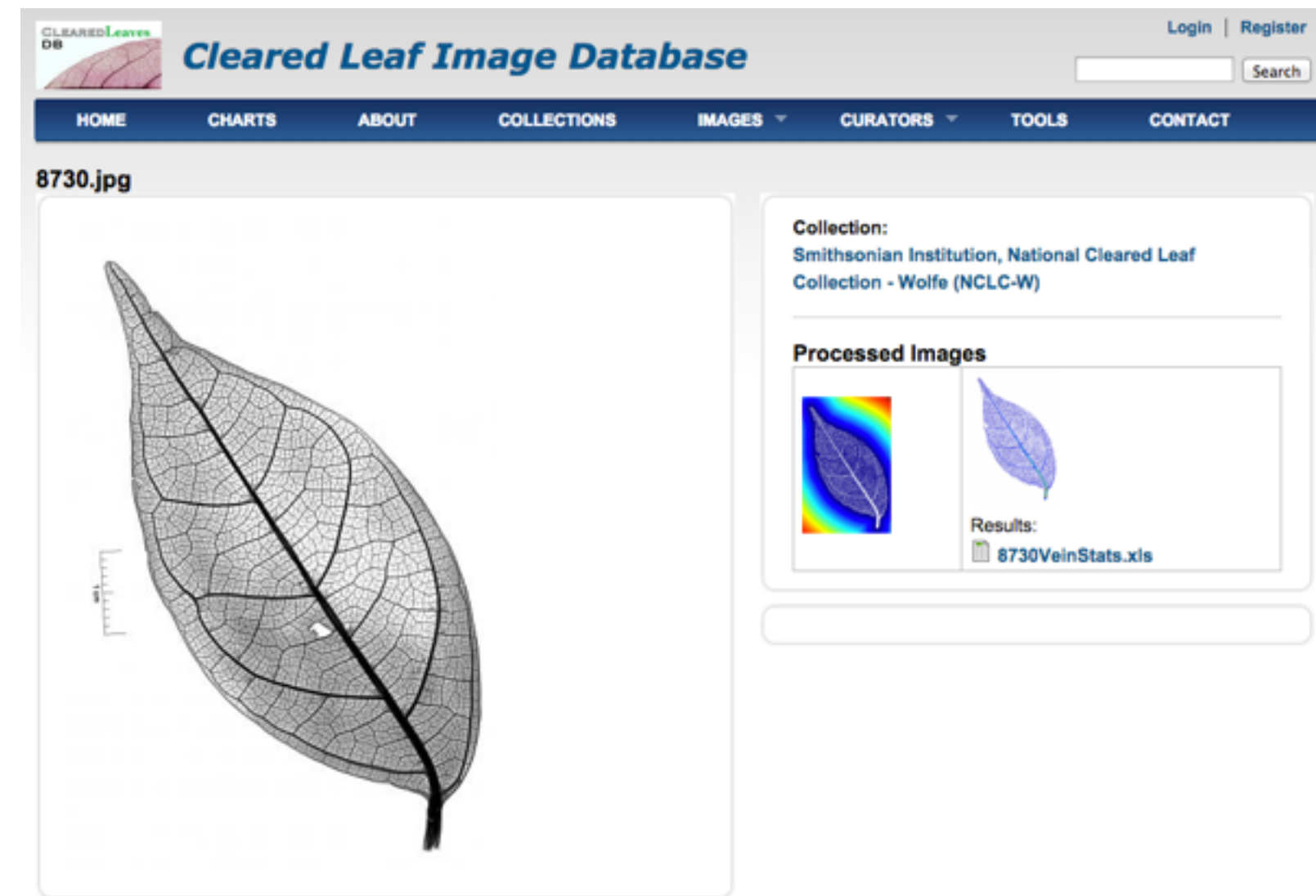
● measurement type

○ # tools



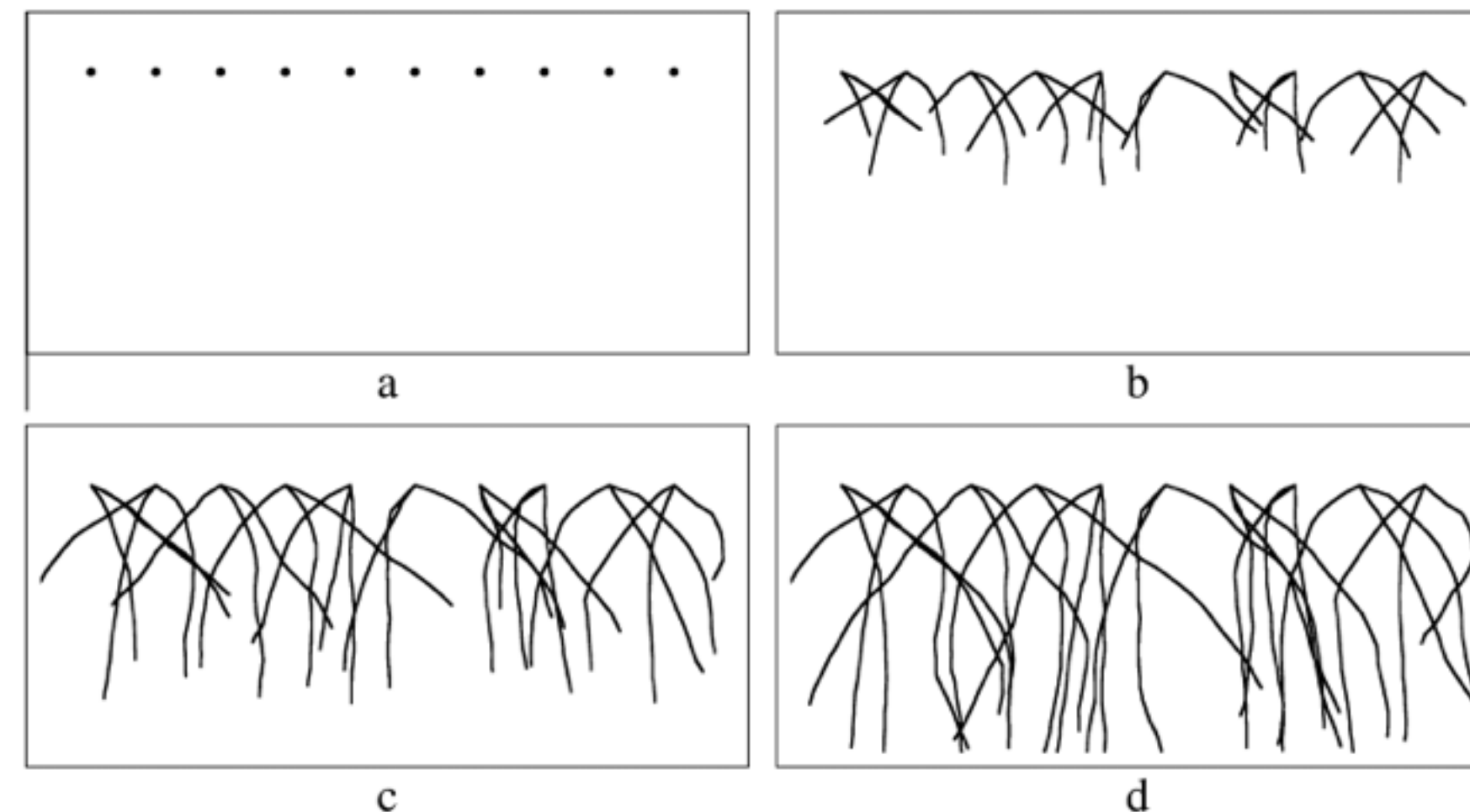
NEED OF BENCHMARK DATASETS

Online repository
- [ClearedLeafDB](#)



Das et al, 2014

Simulated images
- [ElonSim](#)
- ground truth

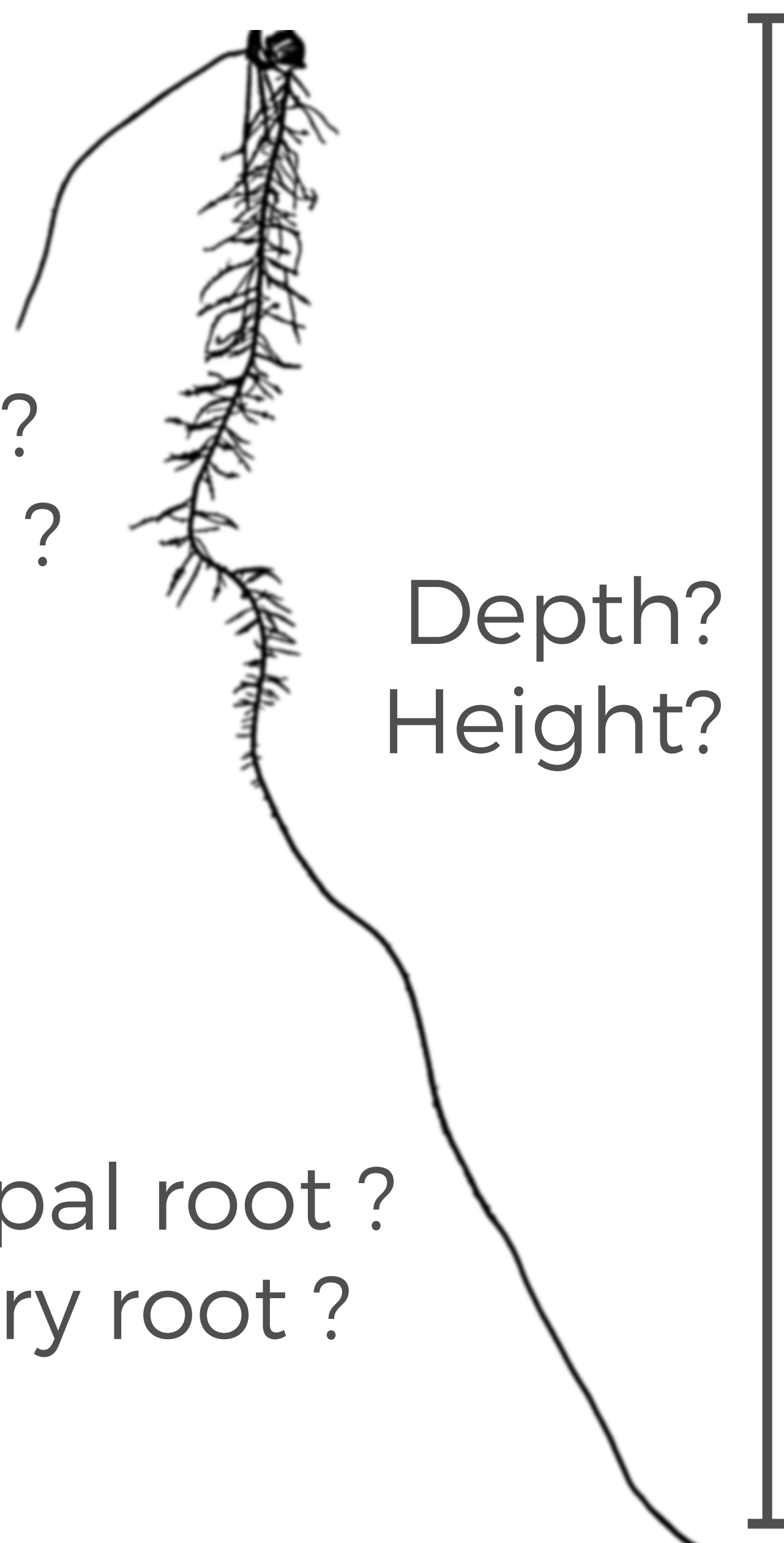


Benoit et al, 2014

CONSISTENCY BETWEEN DATASETS



Nodal root ?
Crown root ?



Depth?
Height?

Principal root ?
Primary root ?

m?
cm?
mm?

- [Plant Ontology](http://www.plantontology.org)
[www.plantontology.org]
- [Trait Ontology](http://www.gramene.org)
[www.gramene.org]

COMMON FORMALISMS

- Multi Tree Graph [MTG]

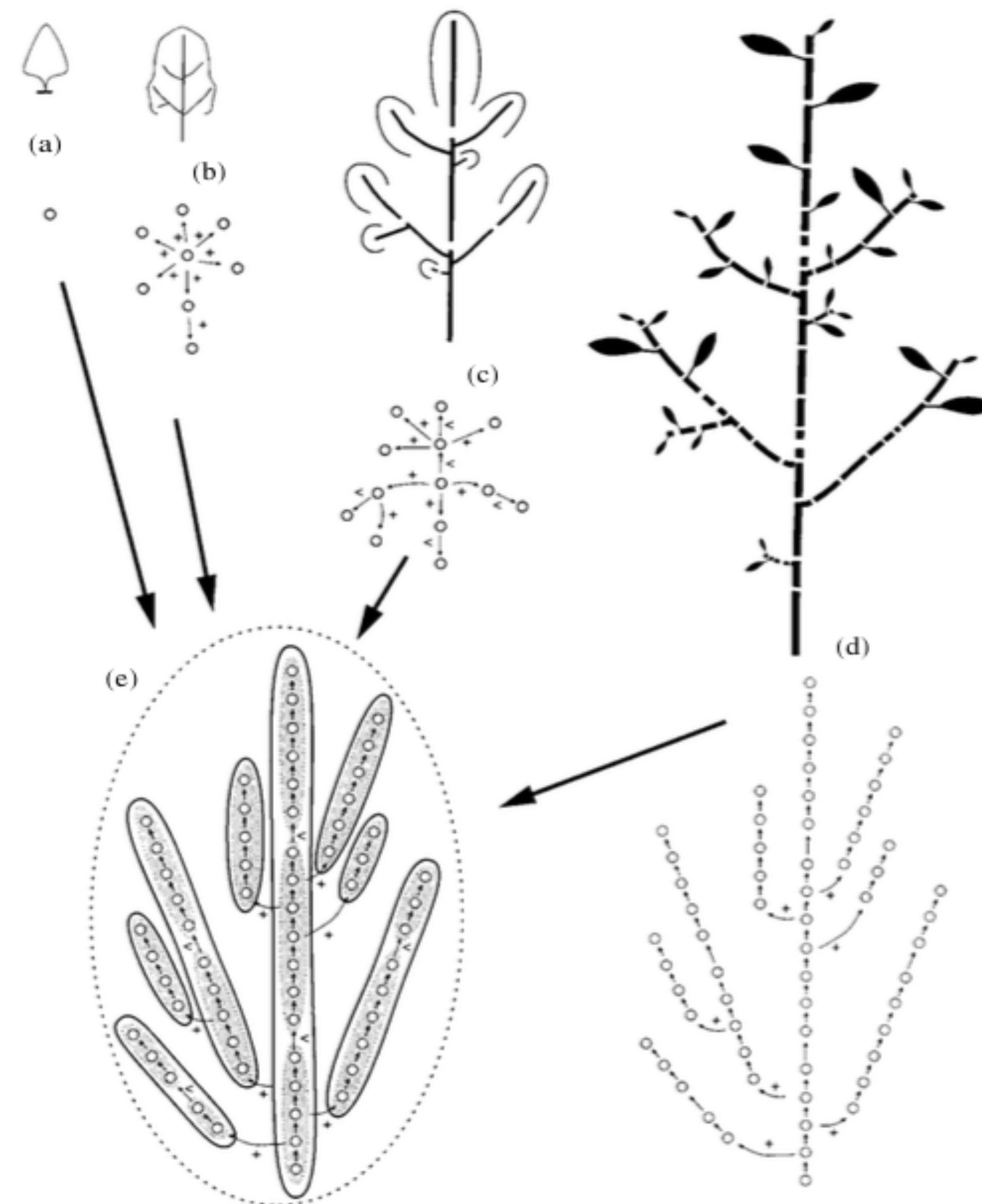
[openalea.gforge.inria.fr]

[Godin and Caralagio, 1998]

- Root System Markup Language [RSML]

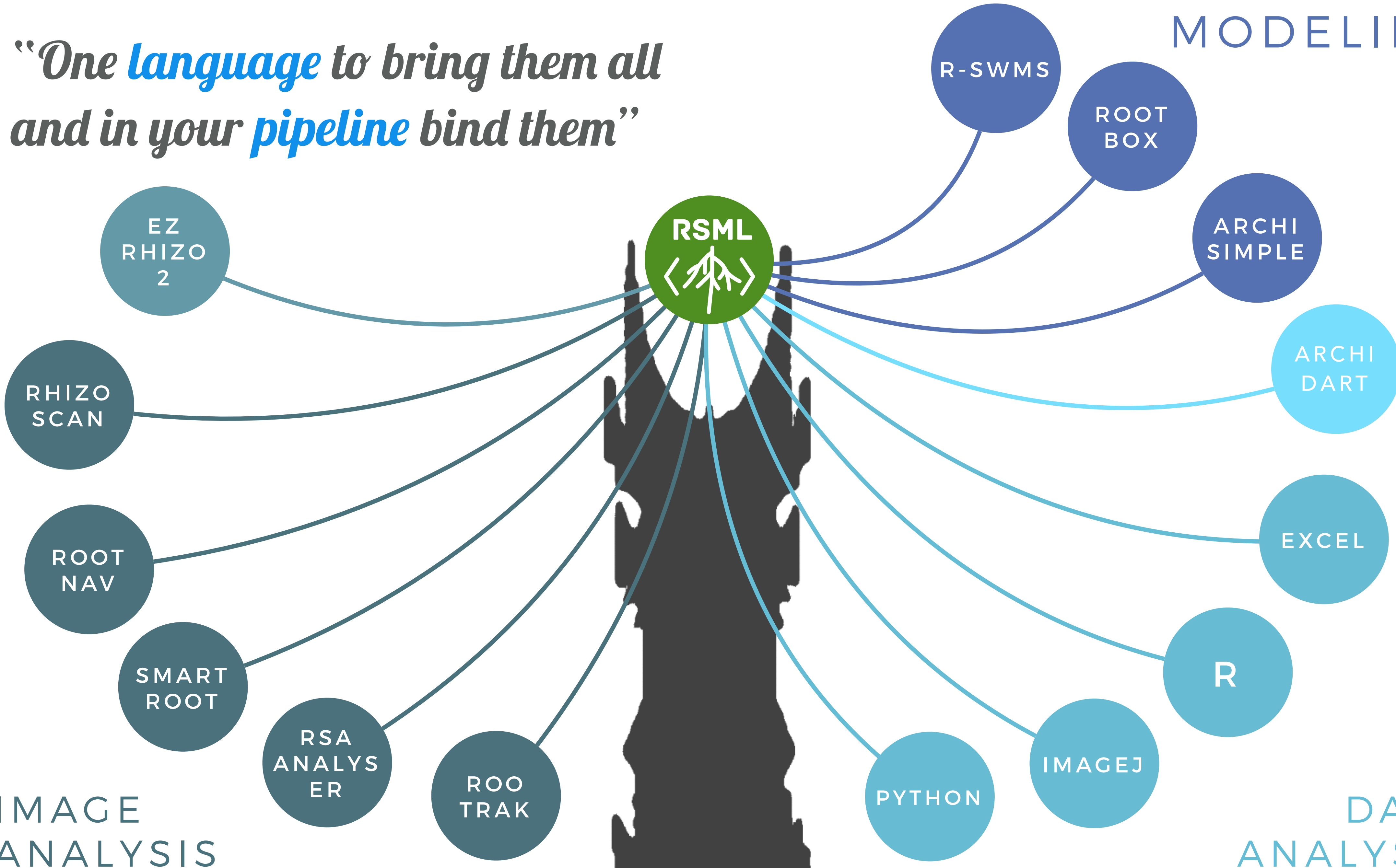
[rootssystemml.github.io]

[Lobet, Pound, Diener, Pradal et al, 2015]



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

MODELING

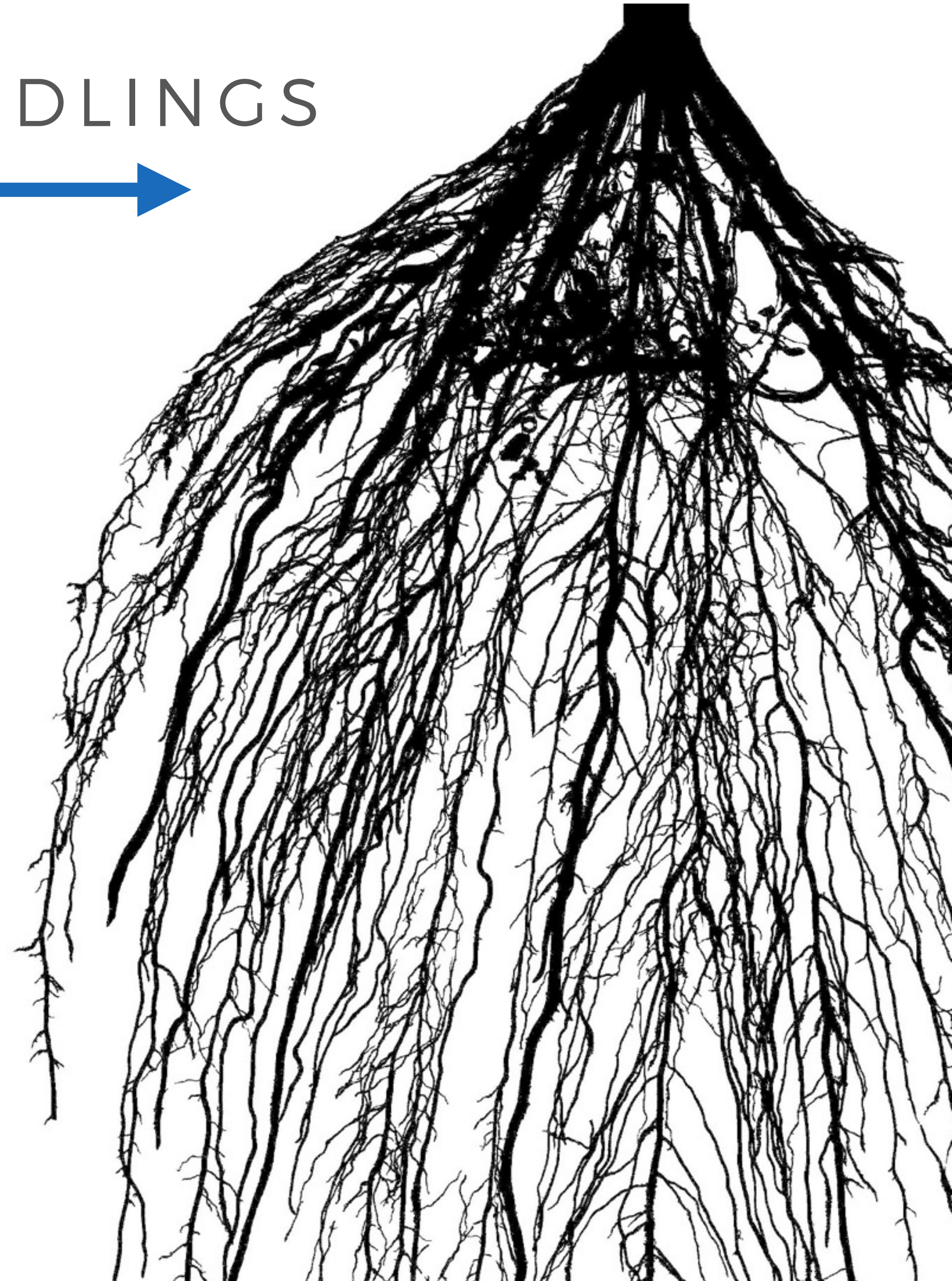




GETTING MORE OUT OF PLANT IMAGES



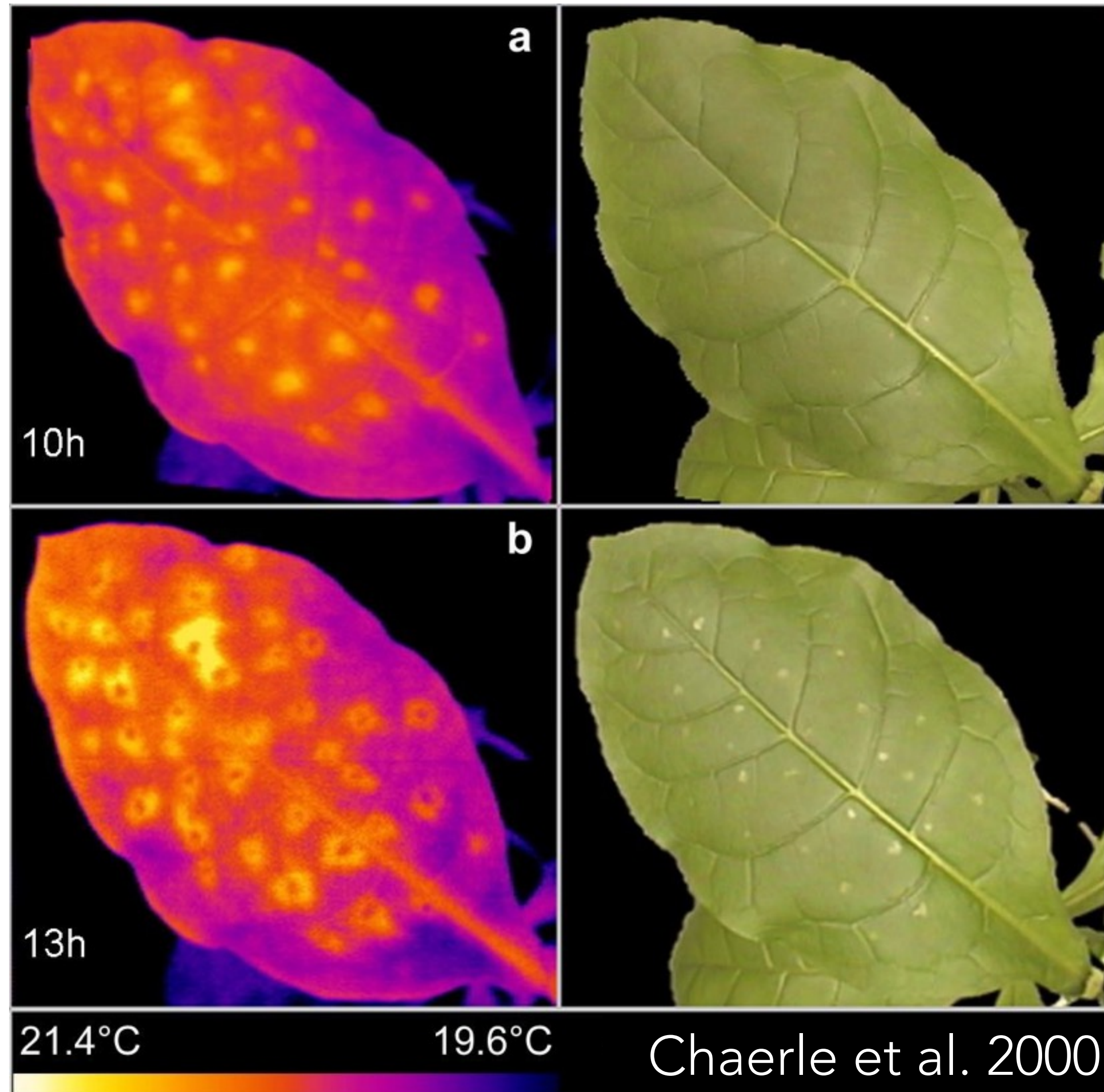
MOVING AWAY FROM SEEDLINGS



In-depth analysis of complex root systems is still missing...



MULTI-DIMENSIONAL IMAGING



- Multi-spectral imaging
 - infra-red
 - thermography
 - ...
- 3D imaging
 - reconstruction
 - segmentation
 - ...
- Combining multiple scales
 - cell
 - organ
 - ...



MOVING TO THE FIELD

Bucksch et al, 2014, Plant Physiology



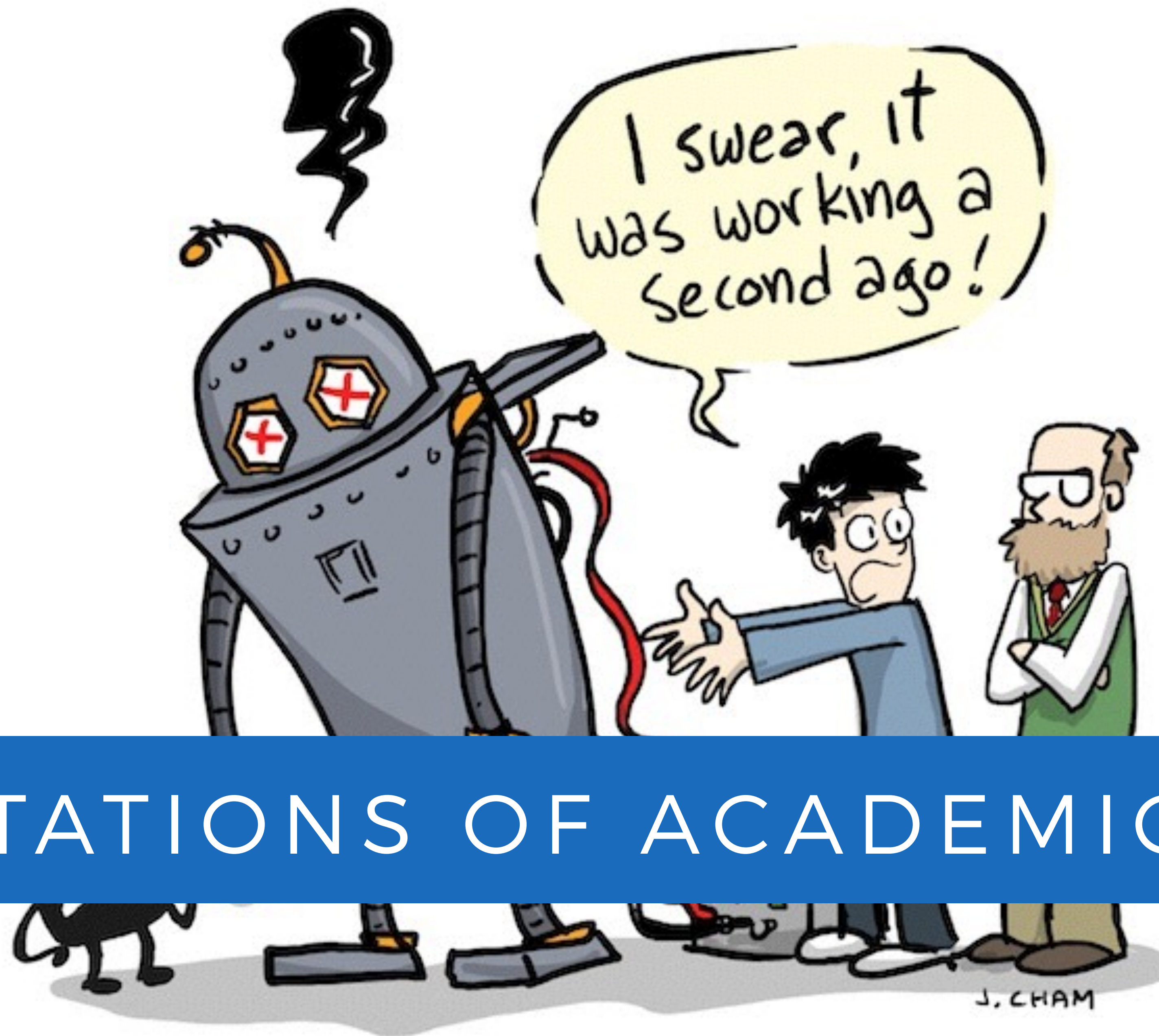
DATA STORAGE AND BACKUPS



- Aeroponics robot in LLN
 - 250 000 images
 - 4000 x 15000 px
 - 2Mb / images (in jpeg)
 - 500Gb / experiment

*Need for specific storage
and backup solution*





LIMITATIONS OF ACADEMIC TOOLS

"Piled Higher and Deeper" by Jorge Cham

www.phdcomics.com

LONG TERM MAINTENANCE IS NOT ENSURED

WE TRY
WHAT'S OUT
THERE AND IT
DOESN'T
WORK...

WE SHOULD
DEVELOP AN IMAGE
ANALYSIS TOOL!

*Maintaining academic
tools is not profitable on
the short term*



publication



funding for an in-house
image analysis specialist



WRITING ALGORITHM ≠ DEVELOPING TOOLS

```

SR.log("pre-threshold " + threshold);
if ((float)(pct - min) / (float)(max - min) < 0.20f)
  threshold = (1.2f * threshold + 0.8f * pct) / 2f;
  // threshold = min + 3.5f * (pct - min);

SR.log("threshold at: " + x + " " + y + " radius " + r + " -> value:" + ip.getPixel(x, y)
      + " max: " + max + " pct: " + pct + " threshold: " + threshold);
}

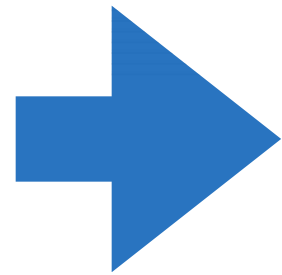
public void clearThresholdMemory() {lastThreshold = 0.0f; }

/** Automatically recenters a root node using the behavior defined by flag. ThetaStep and rSt
    respectively the angle and radius step for border search. Narrow = false forces the search
    to be done on a 360 degrees circle around the node, while narrow = true forces the search
    a 180 degrees arc around the direction of the line joining the previous/next node to the
@SuppressWarnings("unused")
public int reCenter (Node n, float thetaStep, float rStep, boolean narrow, int flag) {
  boolean snapBorder = ((flag & RootModel.SNAP_TO_BORDER) != 0);
  boolean freezeDiameter = ((flag & RootModel.FREEZE_DIAMETER) != 0);
  boolean autoTrace = ((flag & RootModel.AUTO_TRACE) != 0);
  boolean probablyCrossing = false;

  int returnCode = 0;

  int nTheta;
  float likelyRadius = 0.0f;
  SR.log("reCenter on " + n.x + " " + n.y);
  if (n.parent == null && n.child == null) {
    theta = 0;
    nTheta = (int) Math.round(Math.PI / thetaStep);
    narrow = false;
    calcAdaptiveThreshold((int) n.x, (int) n.y, DEFAULT_ADAPTIVE_THRESHOLD_RADIUS);
  }
  else {
    if (n.parent != null) {
      x = n.x - n.parent.x;
      y = n.y - n.parent.y;
      likelyRadius = n.parent.diameter / 2.0f;
      // if (n.parent.threshold == 0.0f) calcAdaptiveThreshold(n.parent);
      calcAdaptiveThreshold((int) n.x, (int) n.y, (int) Math.ceil(ADAPTIVE_THRESHOLD_RADIUS));
      // if (Math.abs(threshold - n.parent.threshold) > 15.0) threshold = n.parent.threshold;
    }
  }
}

```



The screenshot shows the SmartRoot software interface. On the left, a 'Root List' panel displays a tree structure with nodes labeled 'prim_1' through 'sec_16'. On the right, a detailed view for 'Root = prim_1' shows the following statistics:

- Order = 0
- Parent root = -1
- Length [cm] = 35.559635
- Surface [cm²] = 17.45974
- Volume [cm³] = 1.0763079
- Mean diameter [cm] = 0.12052258
- Insertion angle [°] = 0.0
- # of laterals = 47
- Lateral density [root/cm] = 2.7600691
- Mean interbranch distance [cm] = 7.583
- # of marks = 9

Below the statistics is a table with columns: Source, Mark, Value, and LPos. The table contains 8 rows of data:

Source	Mark	Value	LPos
lupin-030619-b...	Number	1	3.4
lupin-030619-b...	Number	2	7.116
lupin-030619-b...	Number	3	9.386
lupin-030619-b...	Number	5	18.638
lupin-030619-b...	Number	6	22.428
lupin-030619-b...	Number	7	23.4
lupin-030619-b...	Number	8	24.025
lupin-030619-b...	Number	4	12.354

At the bottom of the interface are buttons for 'Delete root(s)', 'Apply', 'Cancel', 'OK', and 'Refresh'. To the right of the interface is a window showing a root system image with colored segments corresponding to the data in the table.

User interface is of important for dissemination in the plant scientific community



SOURCE CODE IS NOT ALWAYS AVAILABLE

Making the source available is a way to ensure durability



- version control
- DOI
- ...



WRAPPING UP

TAKE HOME MESSAGE.

Current trends

- many tools available [www.plant-image-analysis.org]
- ranging from cell to canopies
- fair proportion of free, automated, cross-platform solutions

Future challenges

- need for benchmark image datasets
- getting more out complex images
- increase automation for complex problems
- moving out of the lab
- ensuring long-term maintenance of useful tools



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?



Presentation
available on **figshare**

bit.ly/plantimage-lobet