

Fusion of plant histology information obtained from different imaging modalities

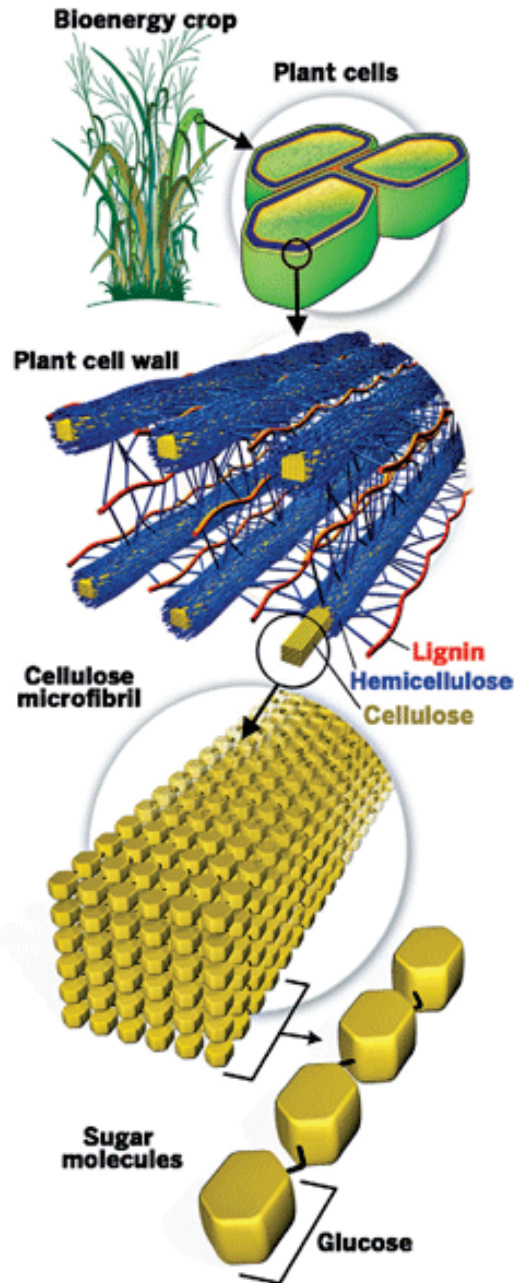
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INRA Versailles – IJPB

SSIAB, Rennes, 25-27 May 2016

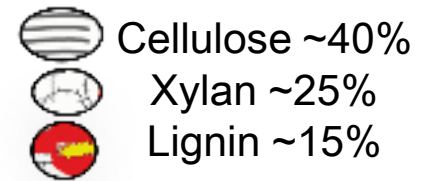
Context: valorisation of agro-resources



Plant cell wall

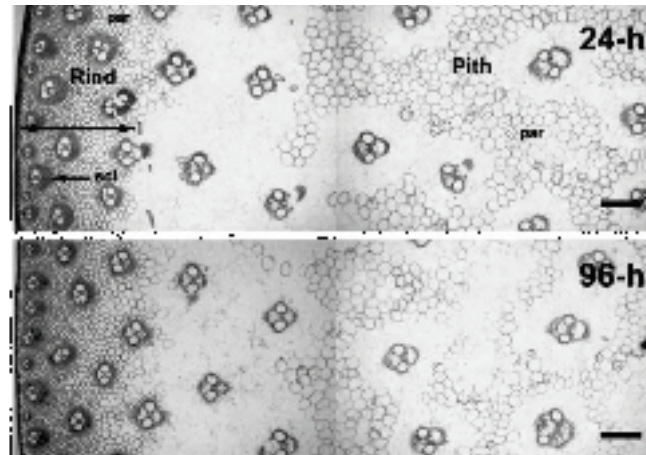


Cell wall = Polysaccharides
+ lignins



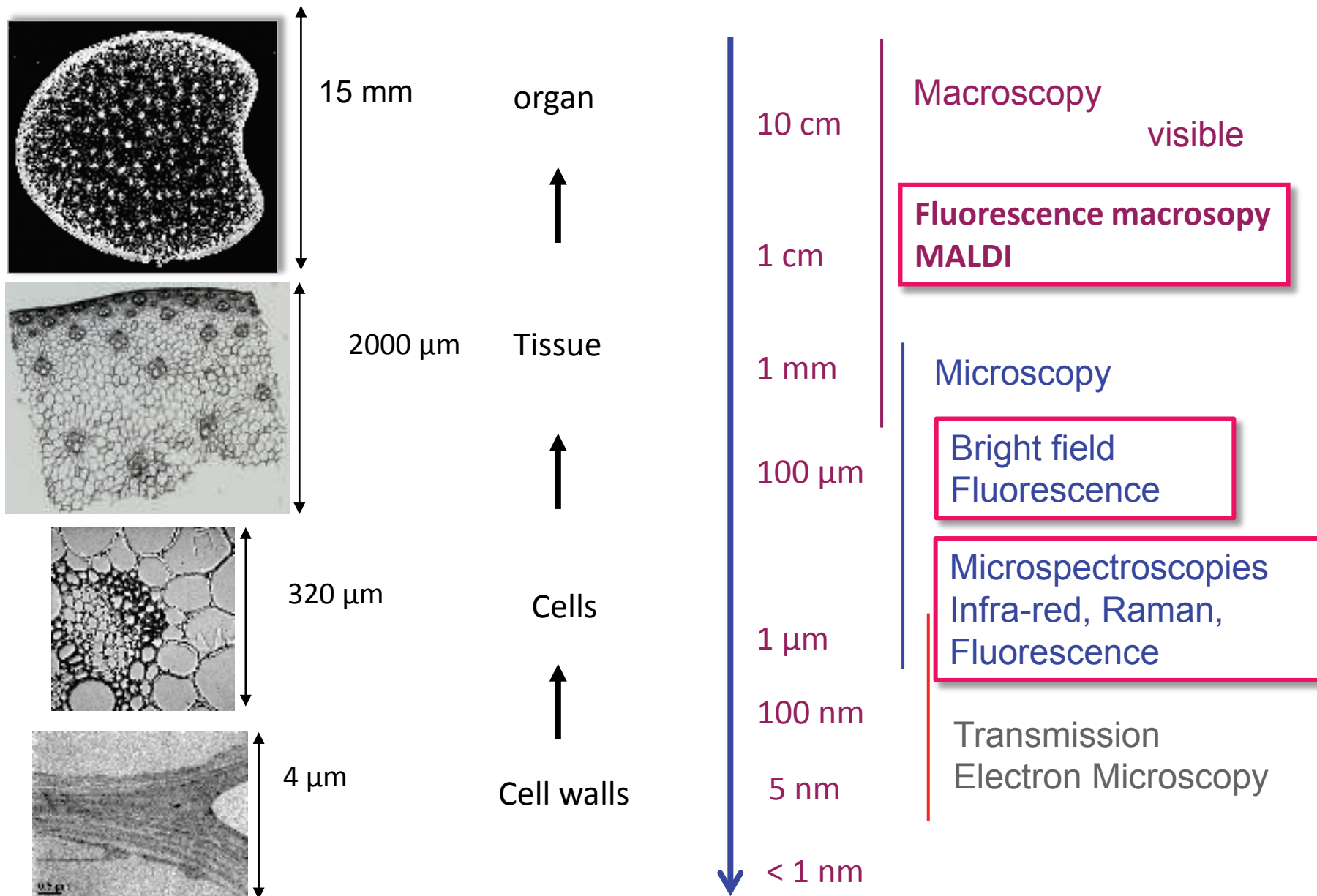
(in maize stems)

- Polysaccharide: needed for feed and biofuel
- Lignins limit the degradability of cell walls
- **Anatomical structure** of tissues could help explain the degradability



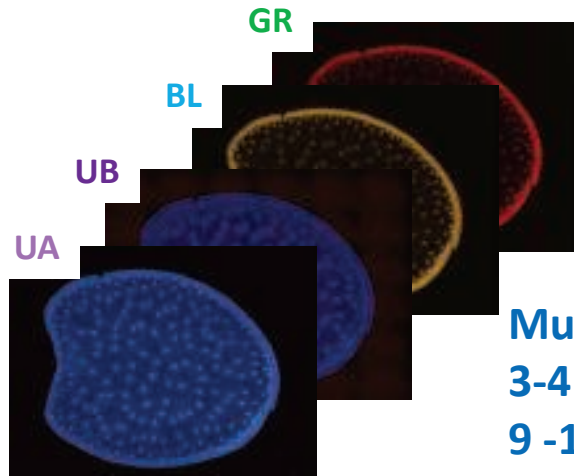
- Need methods for quantification of histology and local degradability

Multiscale imaging of plant tissues



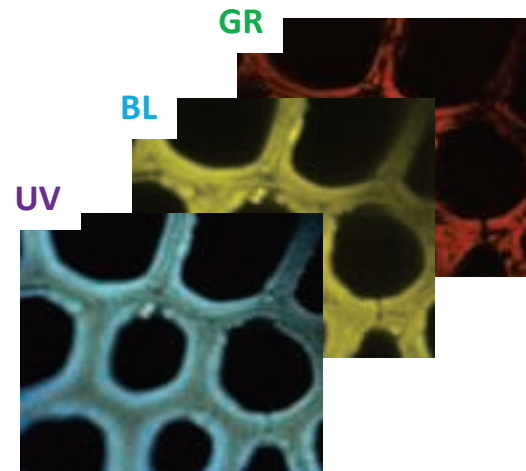
Multiscale mapping of cell walls composition

Multi & hyperspectral imaging



Multispectral image:
3-4 colour images
9 -12 spectral
channels

Fluorescence macroscopy

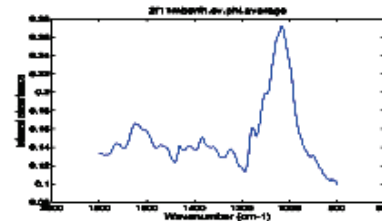
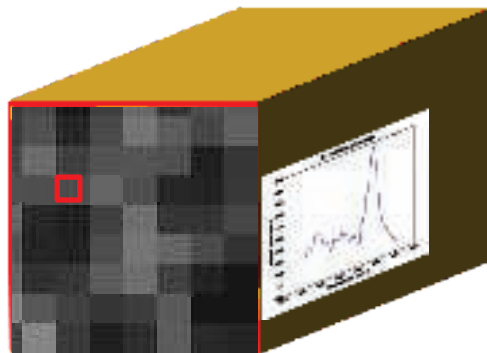


**Multispectral
image :**
32 measures
50-100 spectral
channels

Fluorescence confocal microscopy



pixels



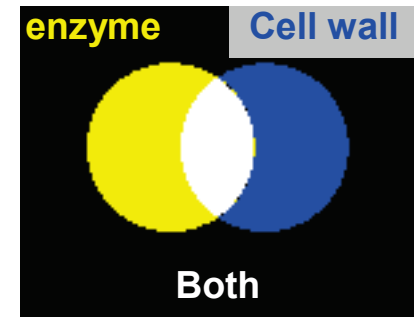
a full spectrum
per pixel

Microspectroscopies
Infrared,
Fluorescence
Raman

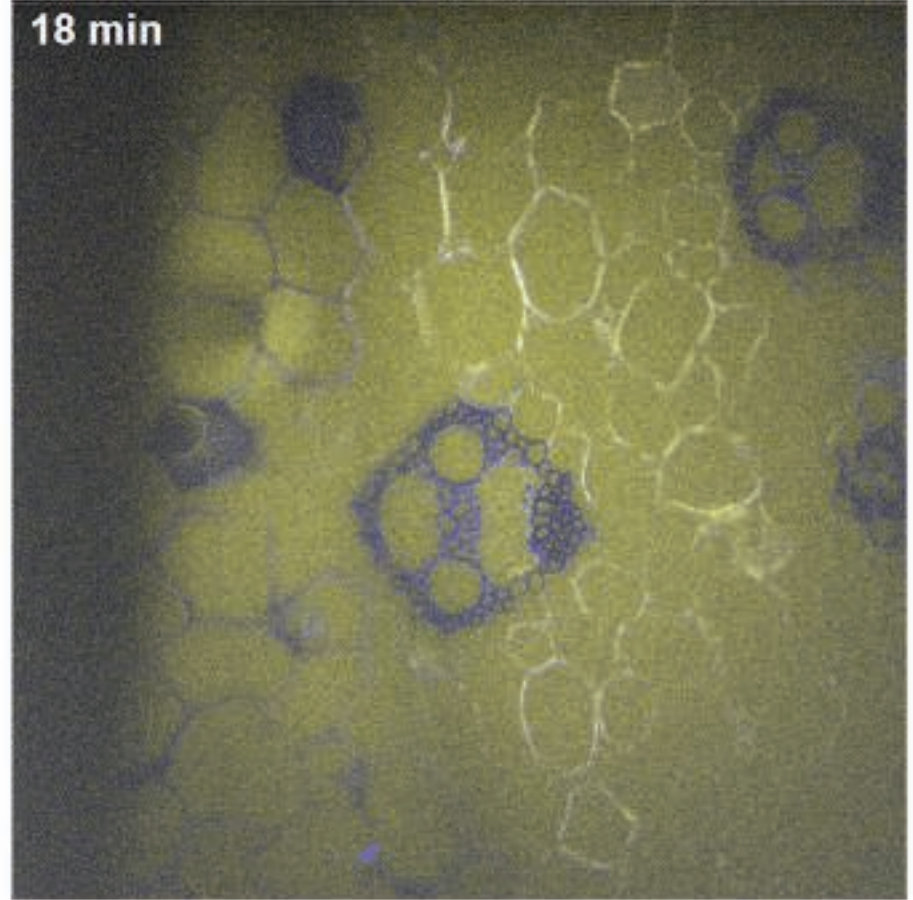
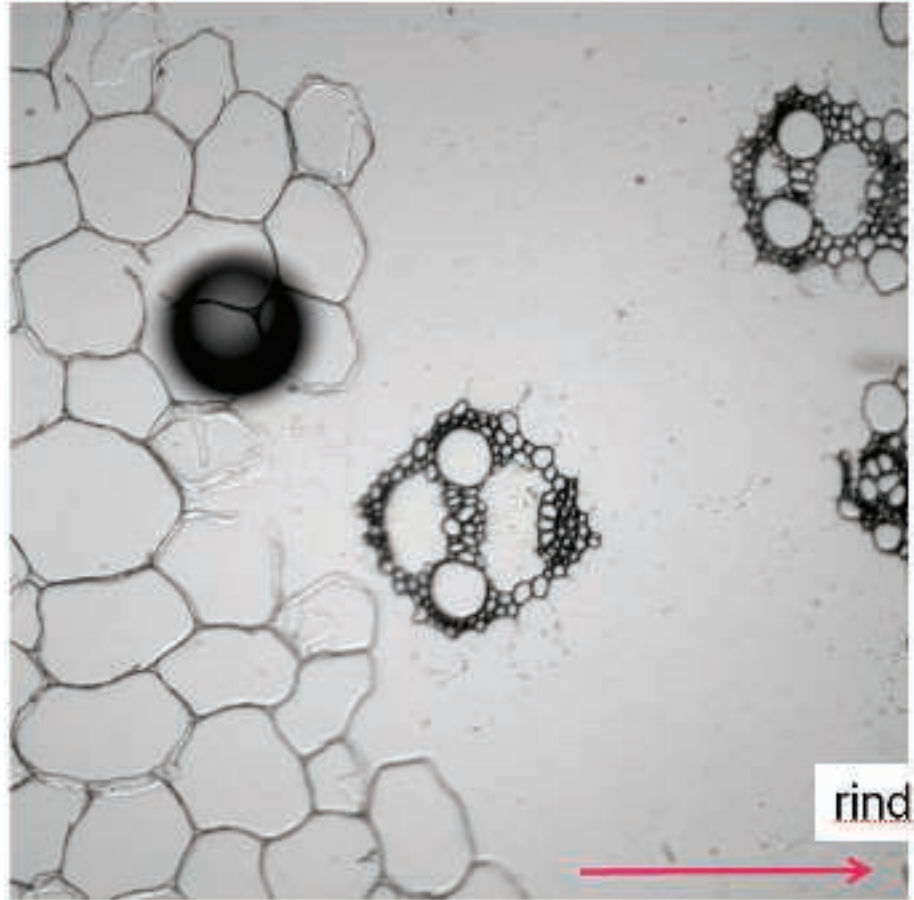


Visualization of enzymes and cell wall without staining

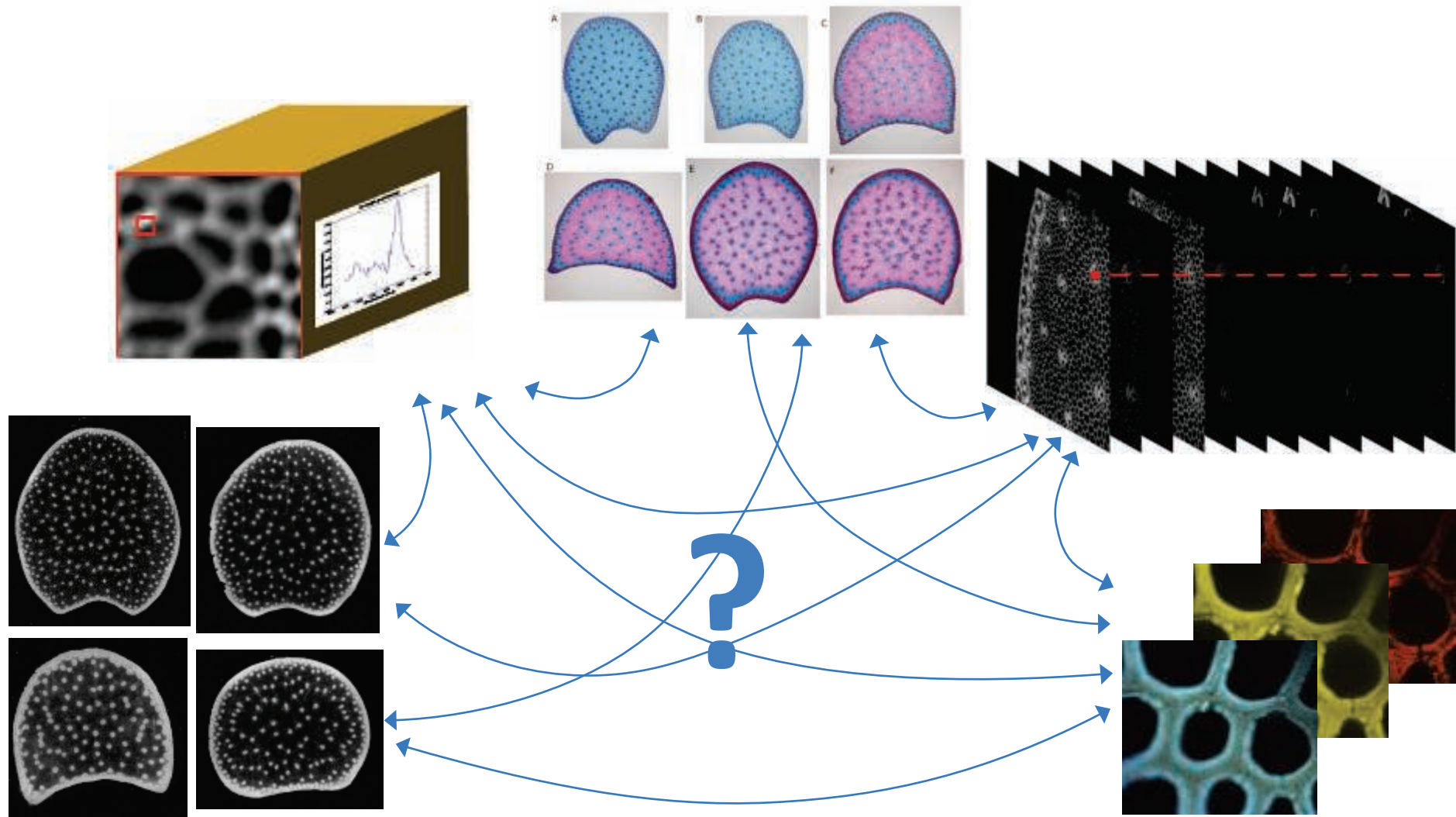
Full field imagery - X10 objective



1230 μm

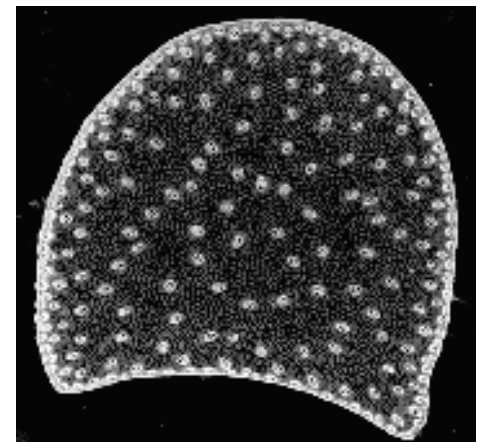
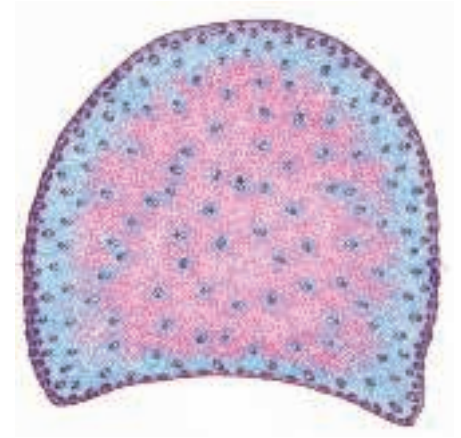


Question: how to relate information
obtained from various modalities and
various individuals?



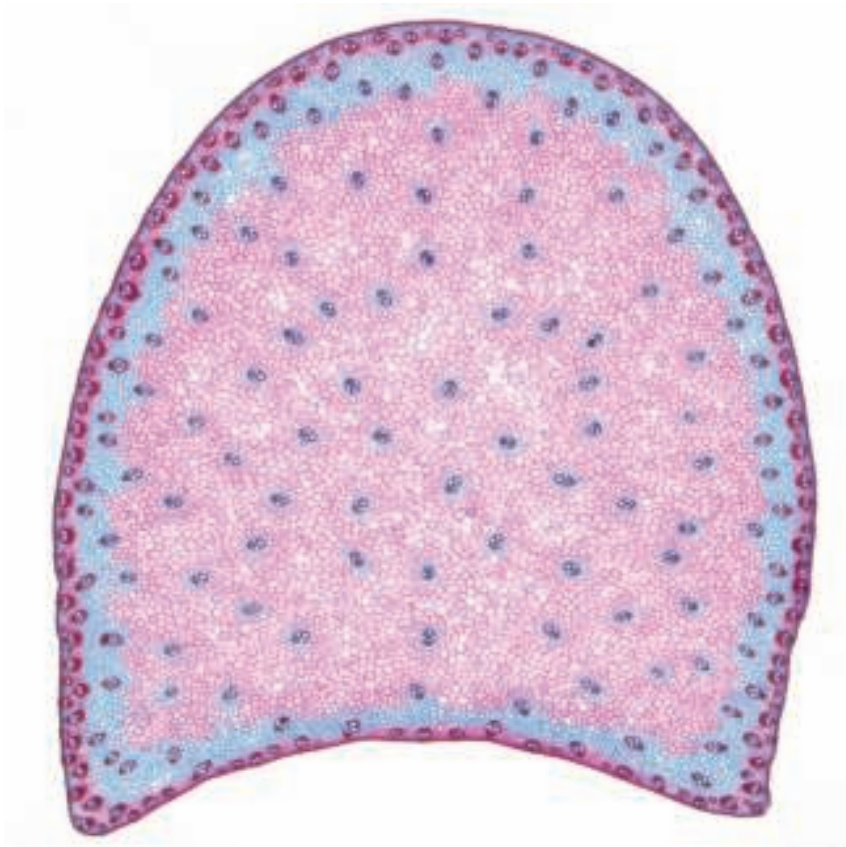
Talk outline

- Focus multi-modal image fusion
- Two imagery modalities:
 - FASGA staining
 - Color quantification
 - Macroscopy
 - Granulometry analyses
 - Parametric mapping
- Data fusion
 - Image registration
 - Multivariate histograms

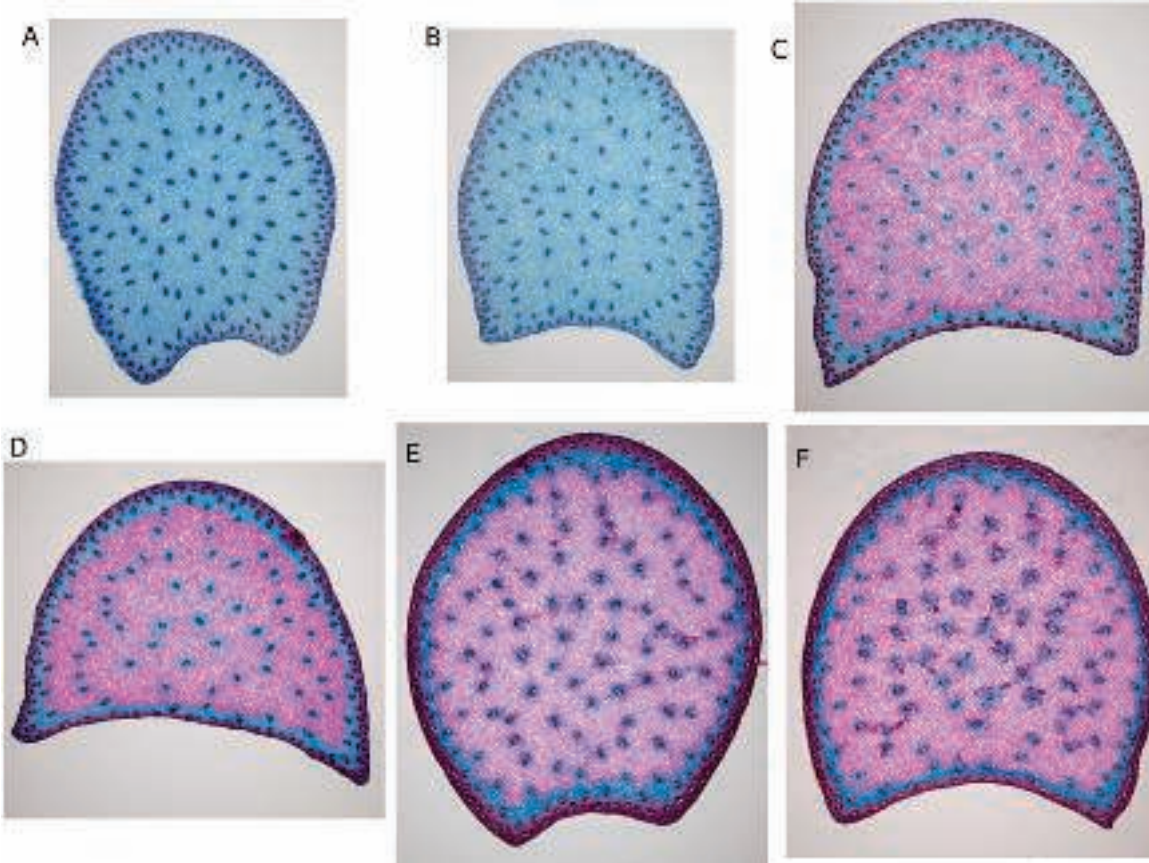


Fasga staining

- Histological staining
 - reveals specific tissue components within section
- Fasga staining
 - Blue -> cellulose
 - Red -> lignified tissues
 - Magenta -> both of them

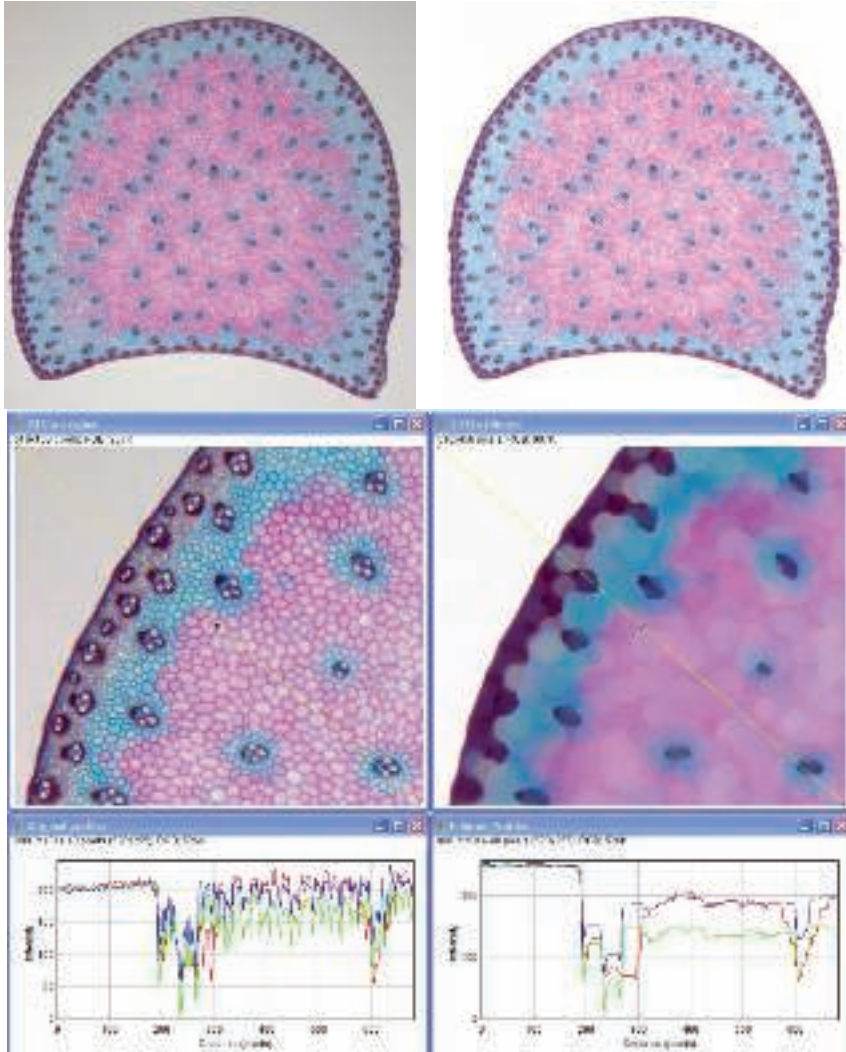


Experimental data



- Three genotypes
- Six development stages
 - Various lignification patterns
- 4-5 repetitions

Fasga images processing & analysis

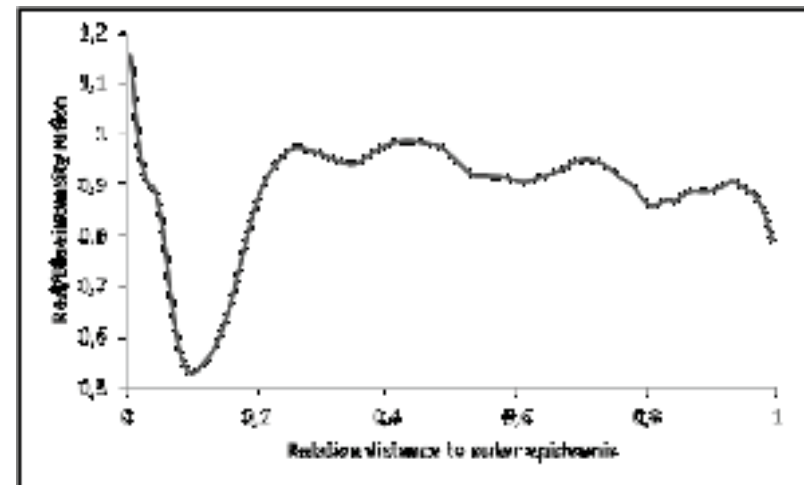
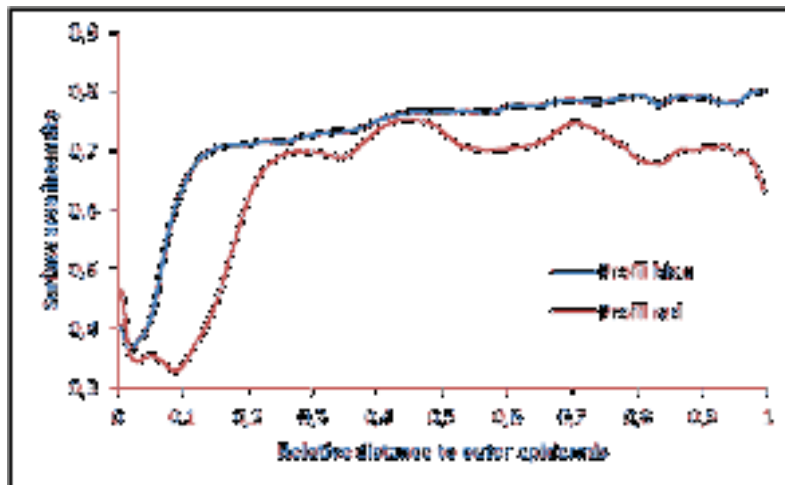


- Correction of background inhomogeneity
 - Normalisation of colors
- Morphological filtering
 - Keep colorimetric information
 - while removing non informative details

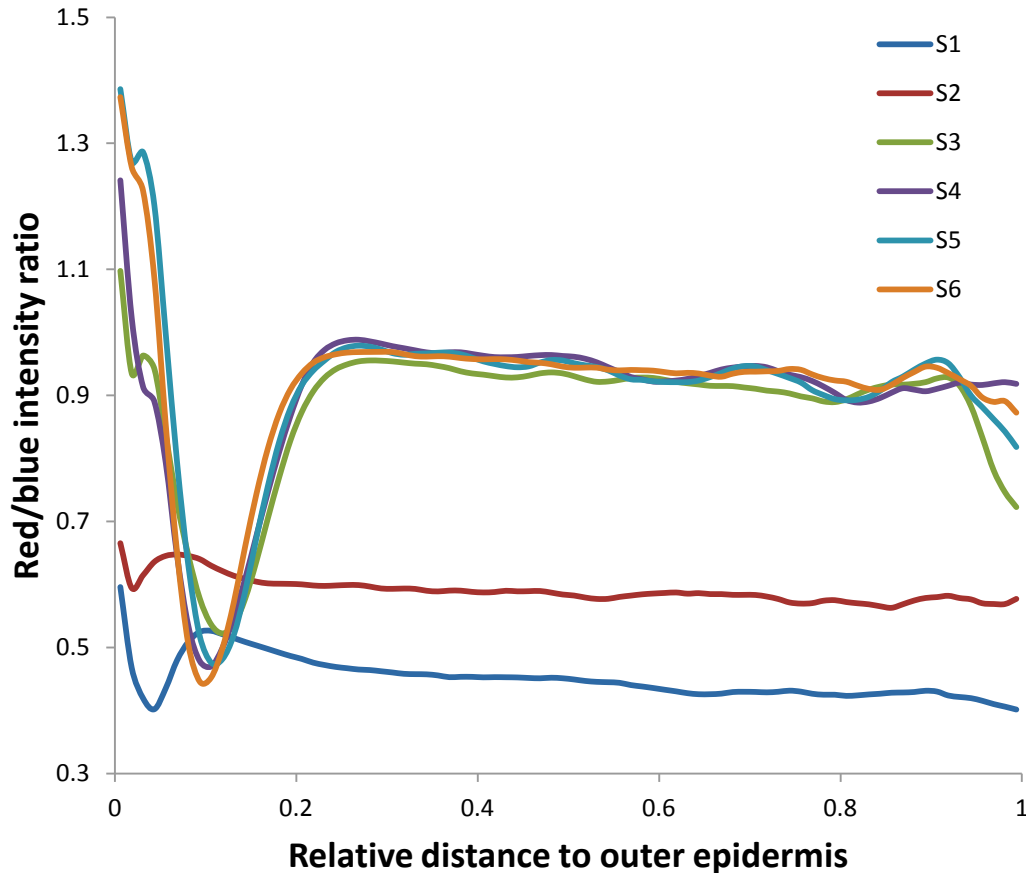
Computation of lignification profiles



- Identify concentric regions
- Average intensity of each band in each region
- Lignification assessed as ratio of blue over red



Analysis of lignin distribution



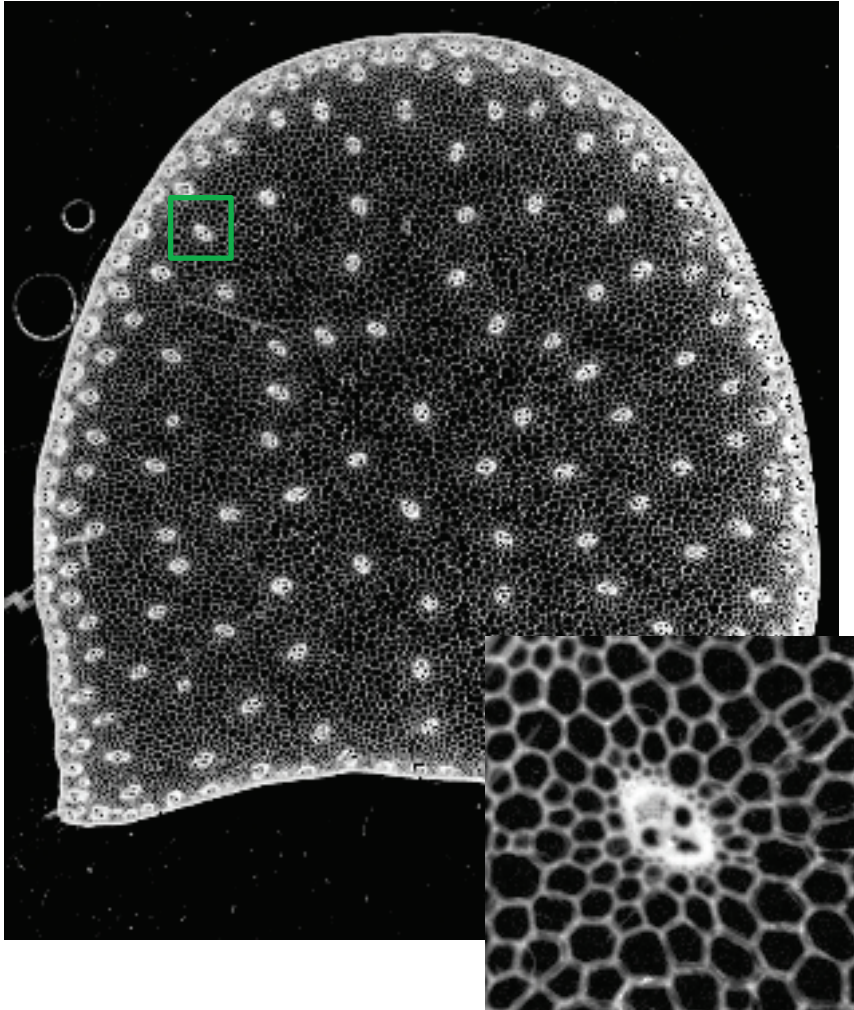
S6



S1

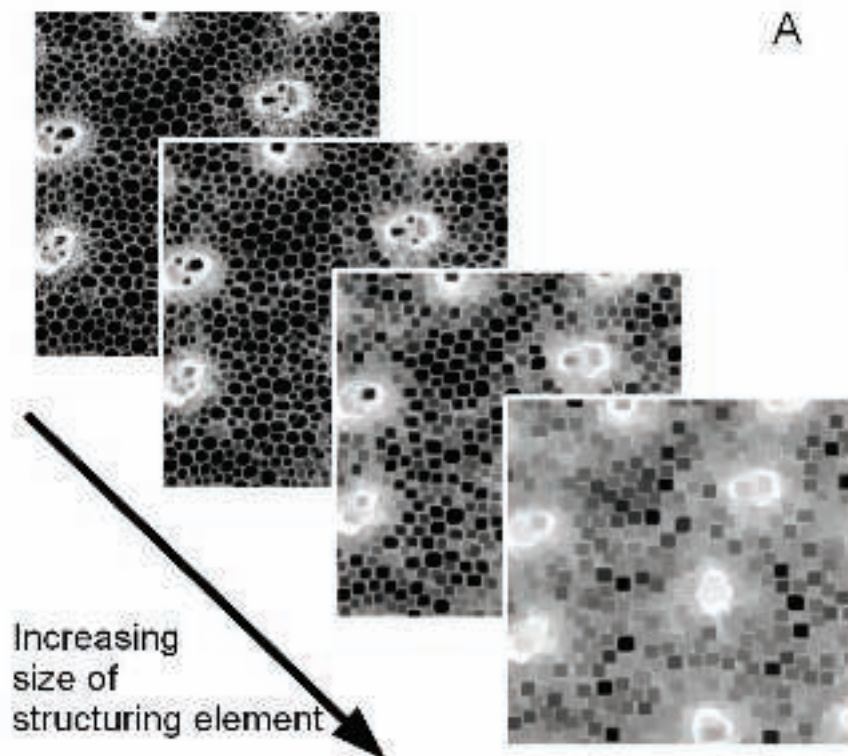
- Evolution of lignin distribution during development
 - ✓ S1-S2: low lignified, distribution homogenous
 - ✓ S3- S6: distribution heterogenous in 3 regions lignification
 - ✓ Increase of lignification in epidermis

Macroscopy imaging

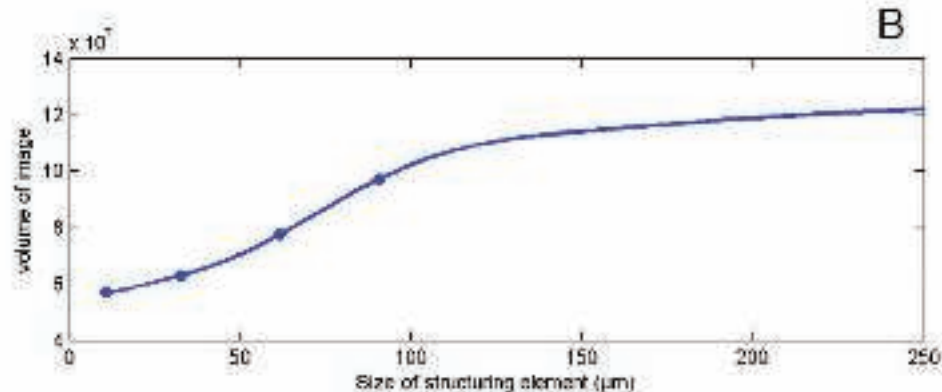


- « BlueBox » imagery
 - 4000 x 4000 pixels²
 - Resolution 3.6 $\mu\text{m}/\text{px}$
 - Field of view:
 - 1.5 x 1.5 cm²
- Information:
 - Cell morphology
 - size + shape
 - Spatial distribution
 - Size of bright structures(?)

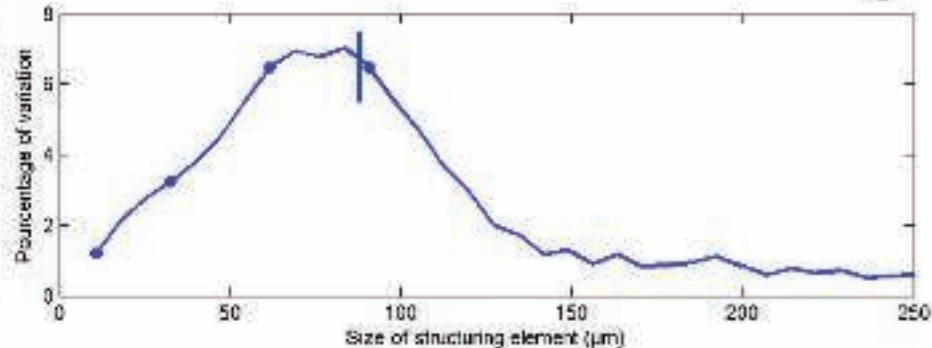
Gray level granulometry



A



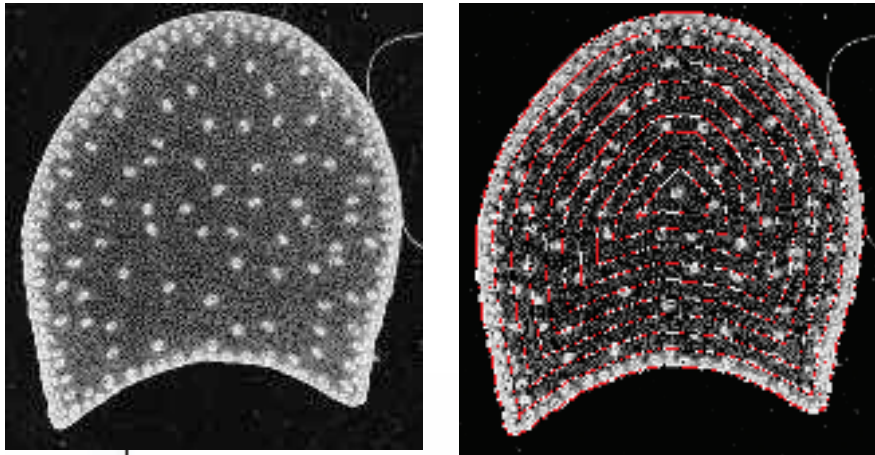
C



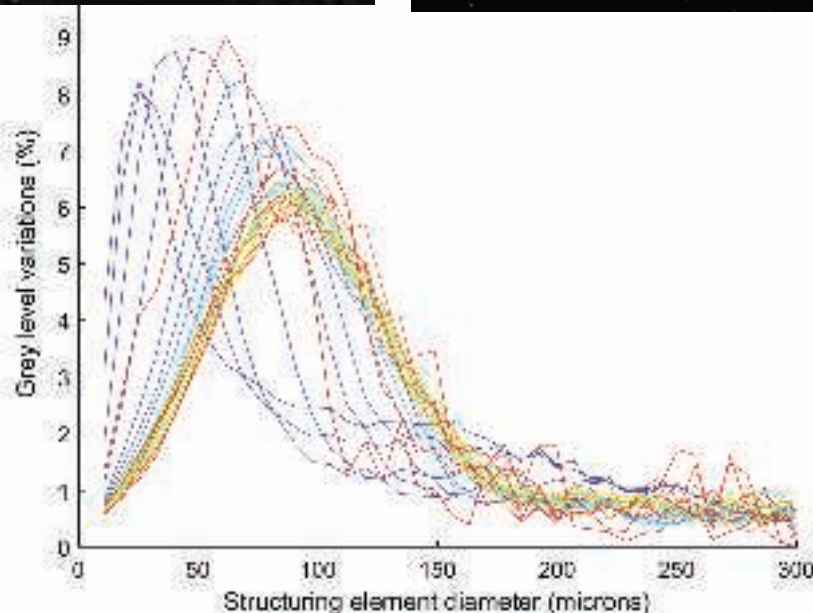
$$Gr(i) = \frac{V_{i+1} - V_i}{V_{\infty} - V_0}$$

$$m_G = \exp \left[\sum_i \log(x(i)) \cdot Gr(i) \right]$$

Parametric mapping: Concentric regions

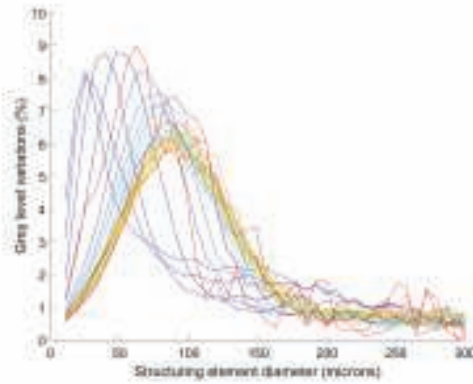
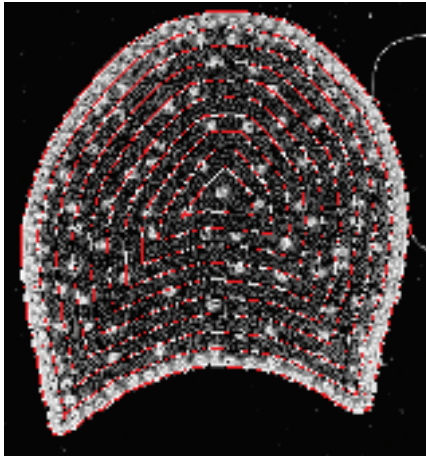


- Subdivision of each slice into concentric regions
 - Use distance map
- Compute granulometry within each region



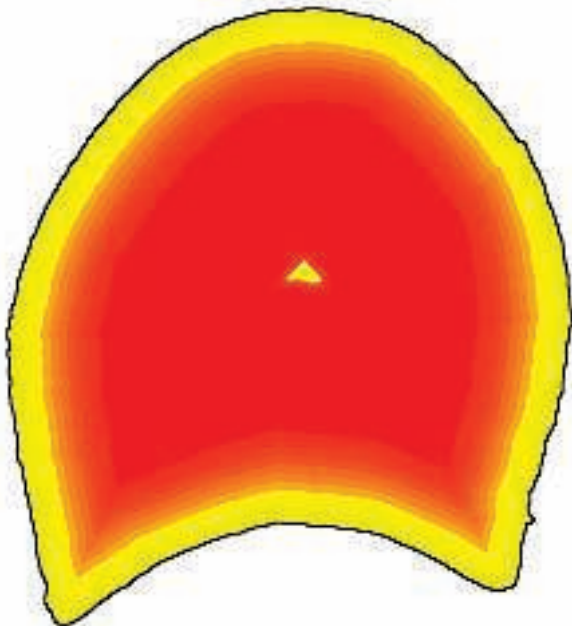
$$Gr_{R_k}(i) = \frac{V_{i+1}(R_k) - V_i(R_k)}{V_{\infty}(R_k) - V_0(R_k)}$$

Parametric mapping: Concentric regions



- Granulometry by region:

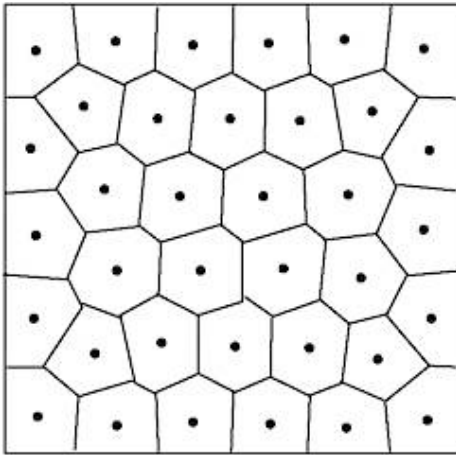
$$Gr_{R_k}(i) = \frac{V_{i+1}(R_k) - V_i(R_k)}{V_{\infty}(R_k) - V_0(R_k)}$$



- Computation of grey-level mean size from geometric mean

$$m_G(R_k) = \exp \left[\sum_i \log(x(i)) \cdot Gr_{R_k}(i) \right]$$

Parametric mapping: Centroidal Voronoi Diagram



- Centroidal Voronoi Diagram:
 - Special case of Voronoi Diagram
 - Germs $\leftrightarrow$ region centroids
- Simulation
 1. Generate random germs
 2. Compute voronoi diagram from germs
 3. Germs $\leftarrow$ centroids of regions
 4. Iterate (2) until convergence

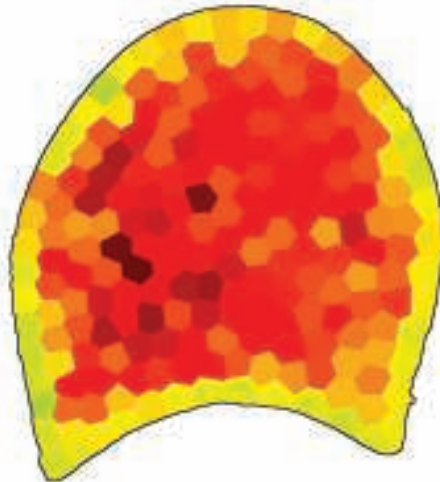
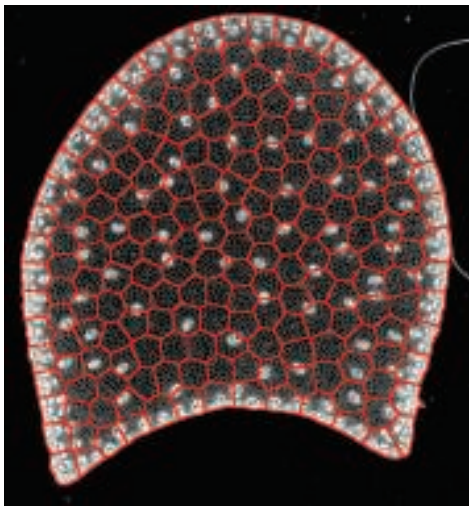
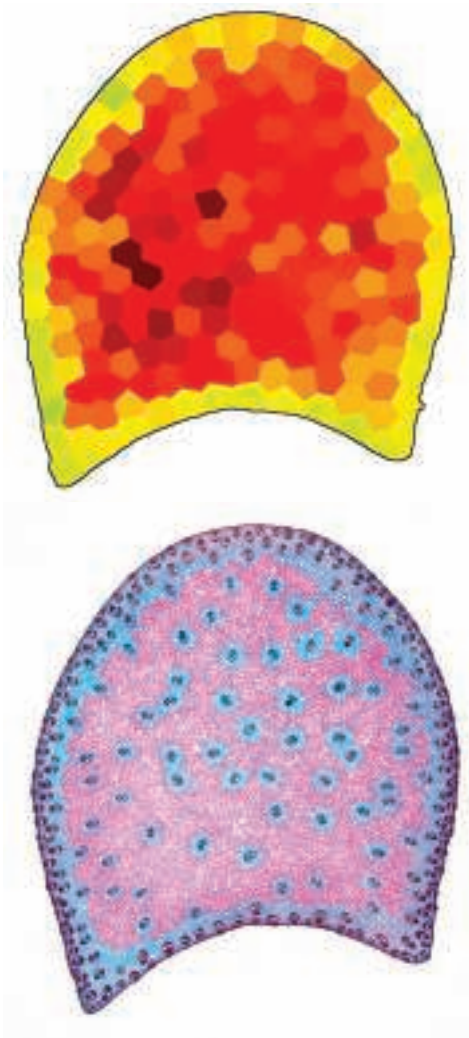


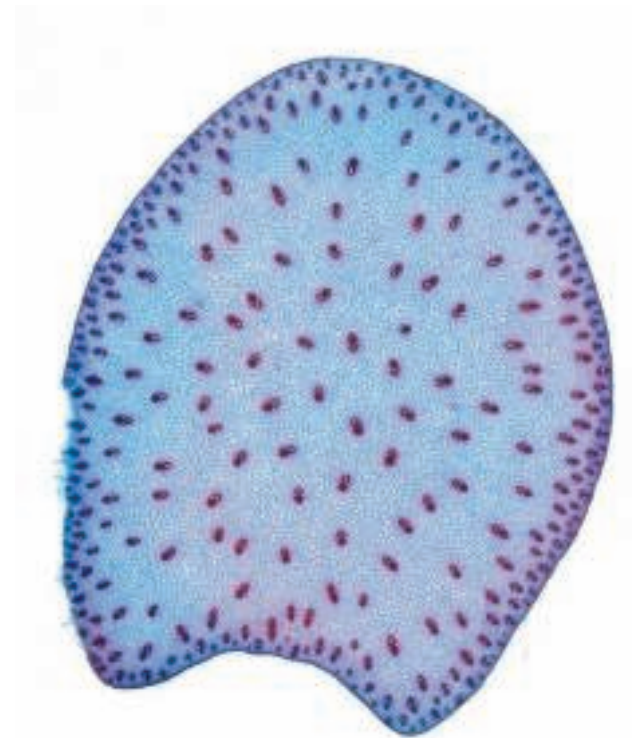
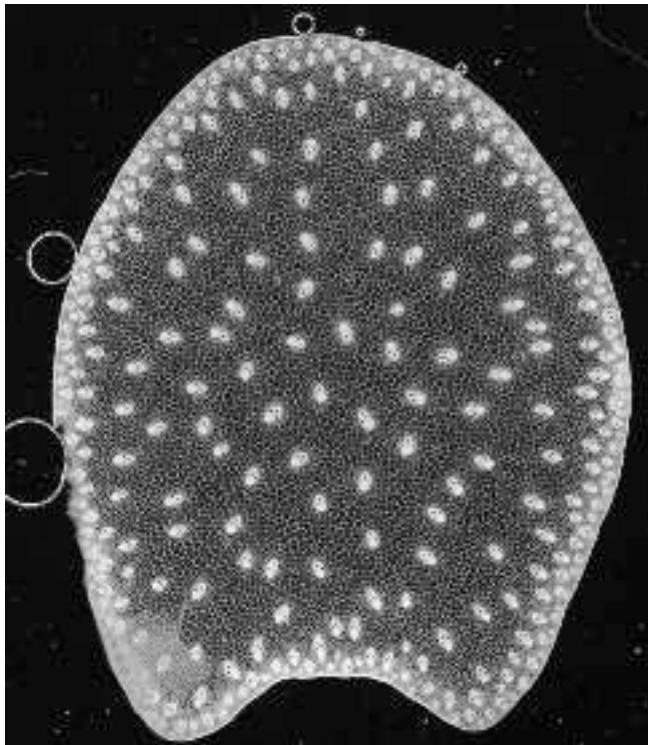
Image fusion



- How to merge information obtained from each modality?
 - Identify relationships between features
 - Identify tissue types
- Registration of images
- Joint analysis of multi-modal information

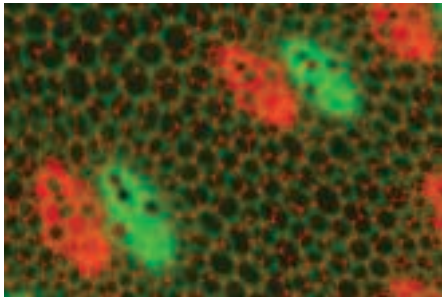
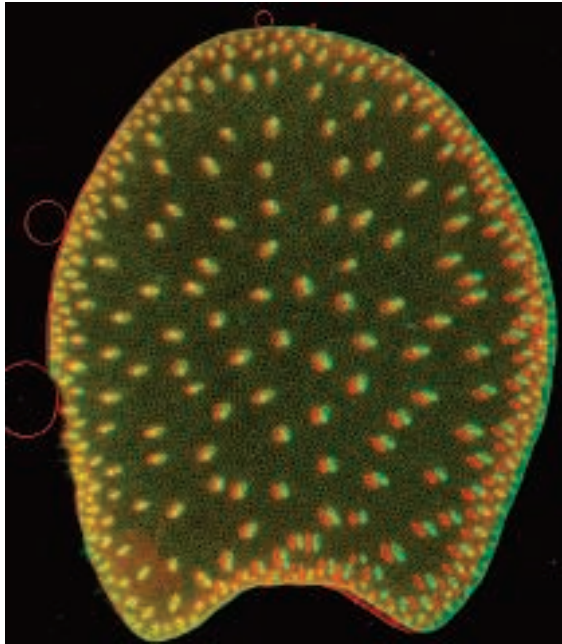
Image registration

- Need to correct: motion, scaling, slight warping

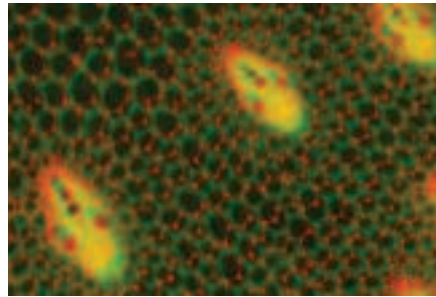
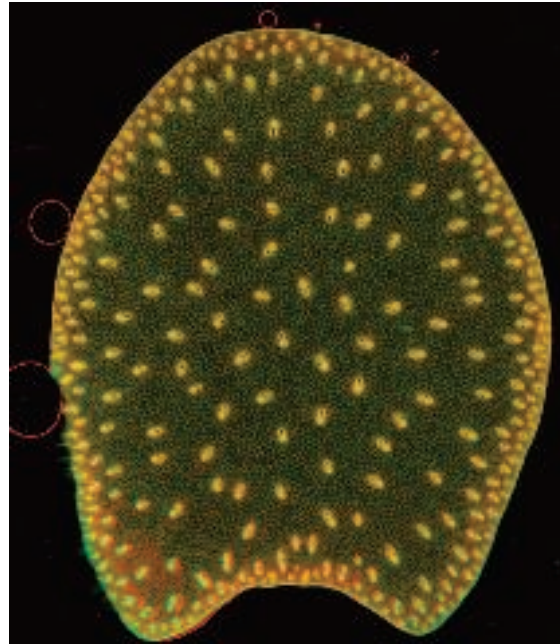


Choice of registration model

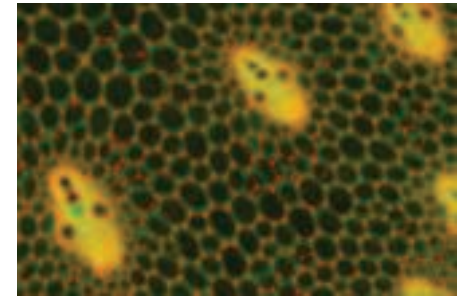
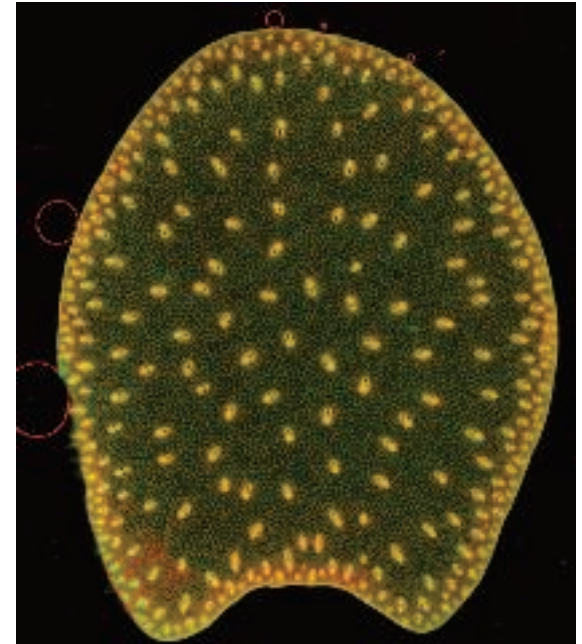
Rigid



Affine



B-splines

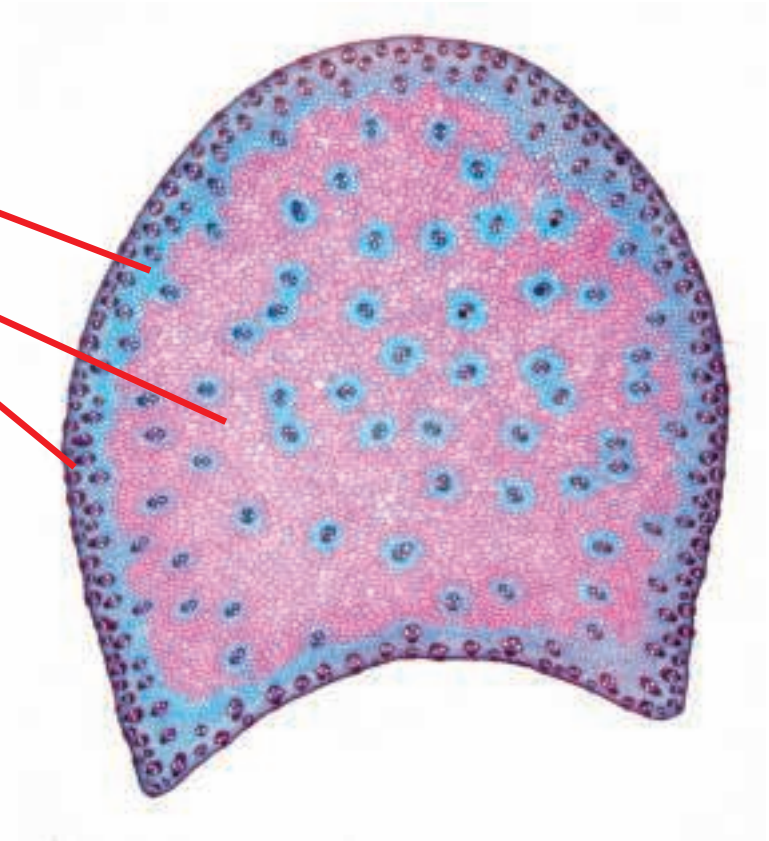
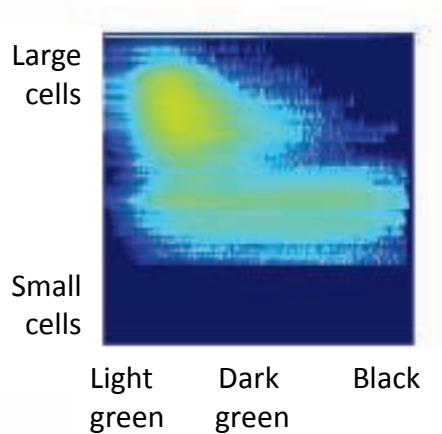
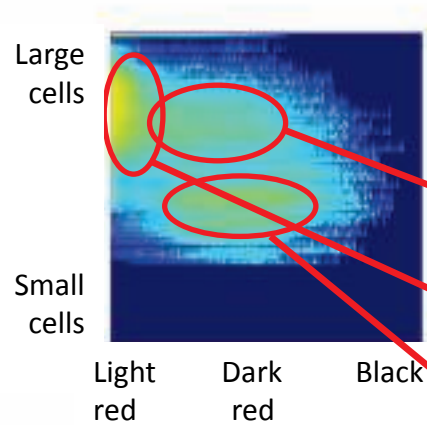
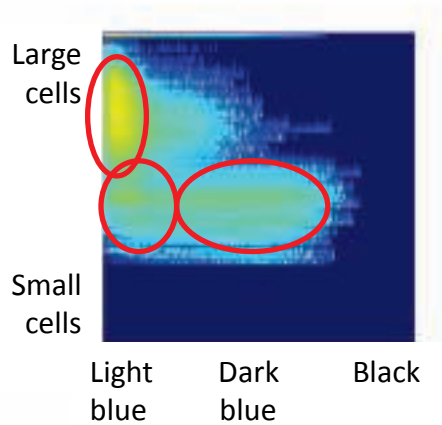


Red: macroscopy

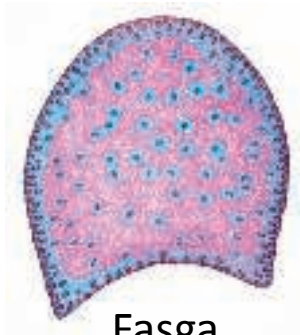
Green: inverted Fasga

Yellow: good registration

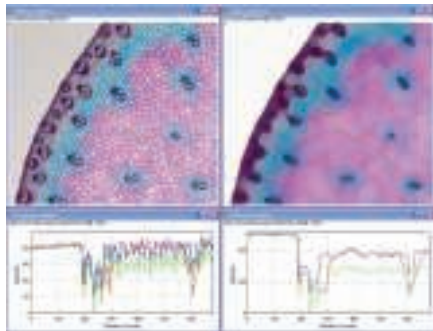
Information fusion: joint histograms



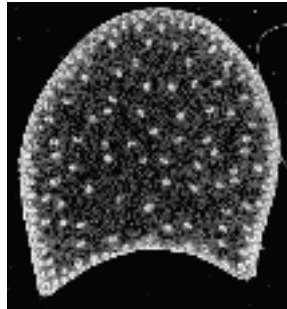
Summary



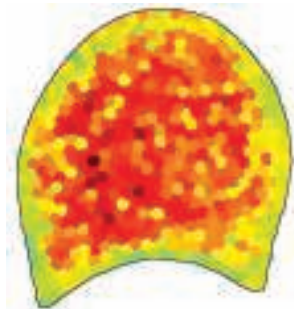
Fasga
Imagery



Color variations
quantification



Macroscopy
Imagery



Cell morphology
quantification

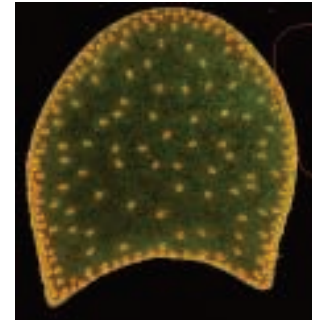
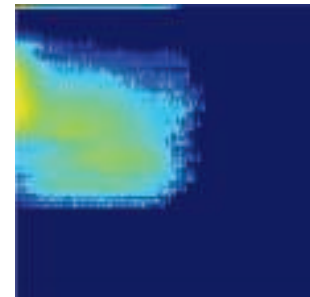


Image registration

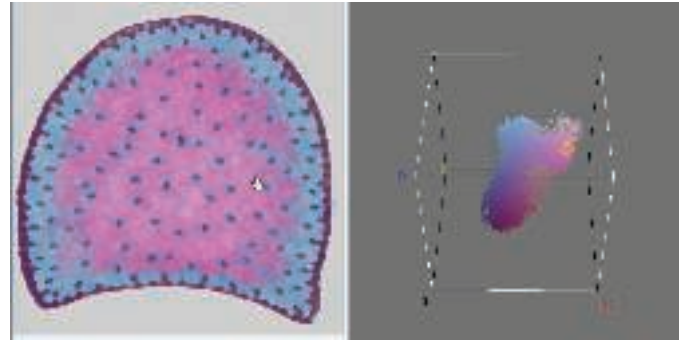


Joint histogram
analysis

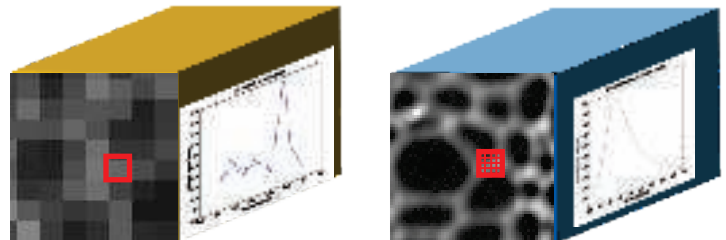


Perspectives

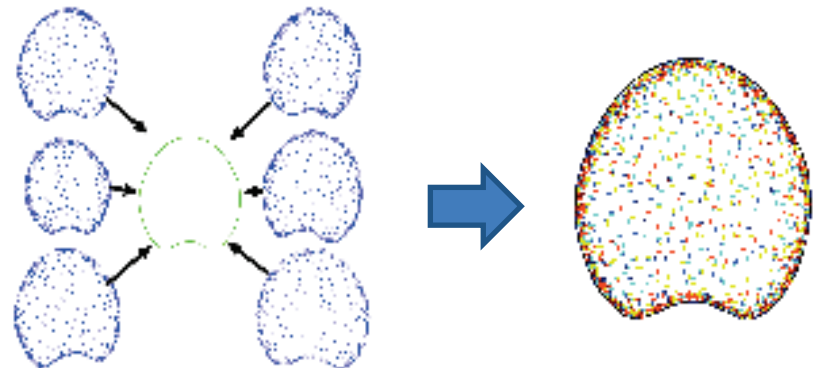
- Multidimensional data
 - Efficient representation
 - Analysis



- Management of different image resolutions and data dimensionality



- Fusion of information obtained on image collections
 - group-wise registration



Any question?

References

- **Zhang, Y.; Legay, S.; Barrière, Y.; Méchin, V. & Legland, D., 2013.** Color Quantification of Stained Maize Stem Section describes Lignin Spatial Distribution within the Whole Stem. *Journal of Agricultural and Food Chemistry*, **61**, 3186-3192
- **Legland, D.; Devaux, M.-F.; Bouchet, B.; Guillon, F. & Lahaye, M., 2012.** Cartography of cell morphology in tomato pericarp at the fruit scale. *J. Microsc.*, **247**, 78-93
- **Devaux, M.-F. & Legland, D., 2014.** Grey level granulometry for histological image analysis of plant tissues. In Microscopy: advances in scientific research and education, Méndez-Vilas, A. (Ed.), *Formatex Research Center*, 681-688
- **Du, Q.; Faber, V. & Gunzburger, M., 1999.** Centroidal Voronoi Tessellations: Applications and Algorithms. *SIAM Review*, **41**, 637-676
- **Legland, D.; Devaux, M.-F. & Guillon, F., 2014.** Statistical Mapping of Maize Bundle Intensity at the Stem Scale Using Spatial Normalisation of Replicated Images. *PLoS ONE*, **9**, e90673