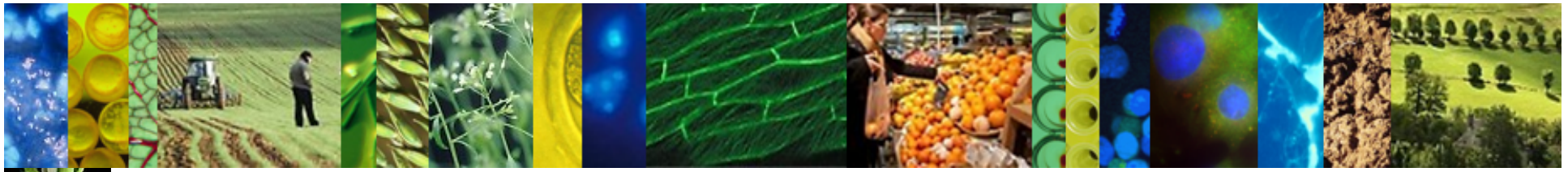
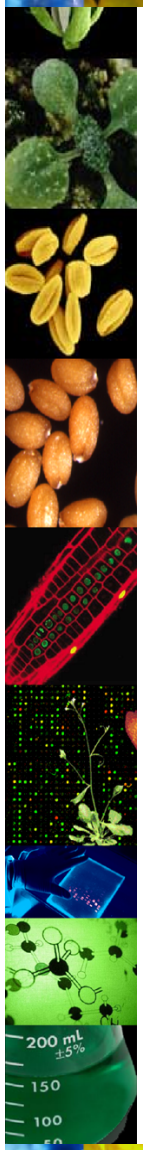




Saclay Plant Sciences LabEx
Kick-Off meeting

Projet 4 :
Modelling developmental mechanisms

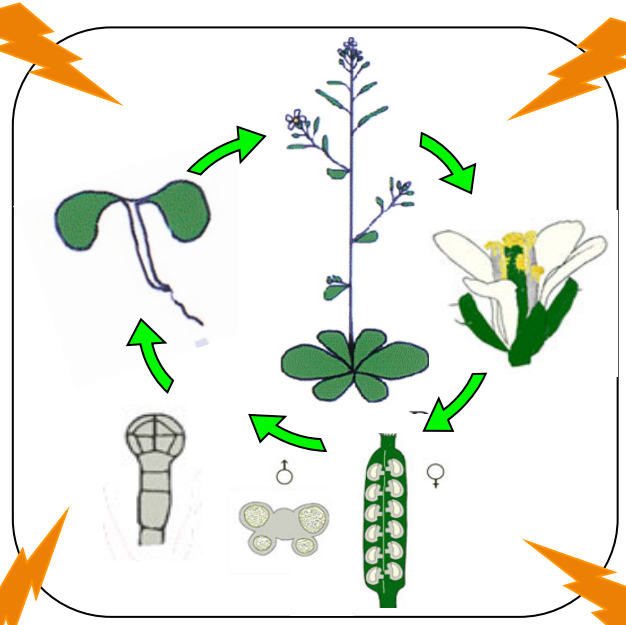
Coord : P Andrey and P Laufs

October 13, 2011

Plant development
is a plurifactoriel and integrated process

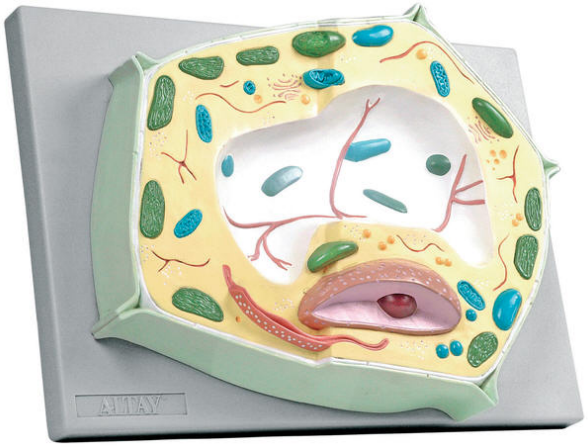
Genome

Biotic factors



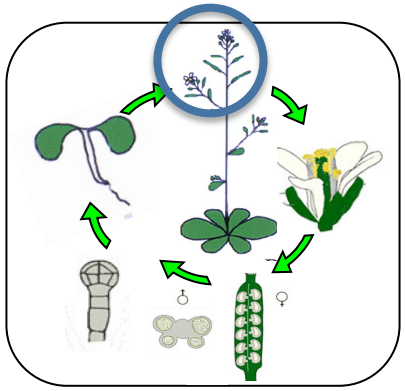
Hormones

Abiotic factors

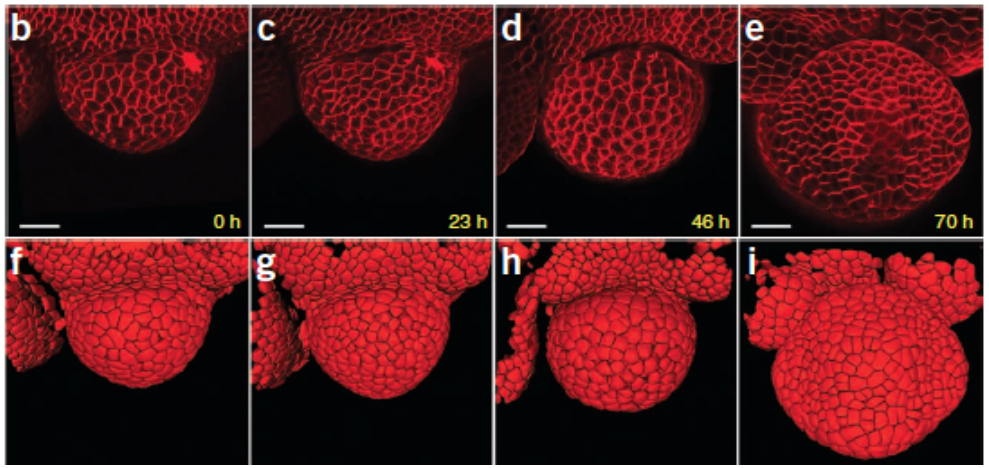


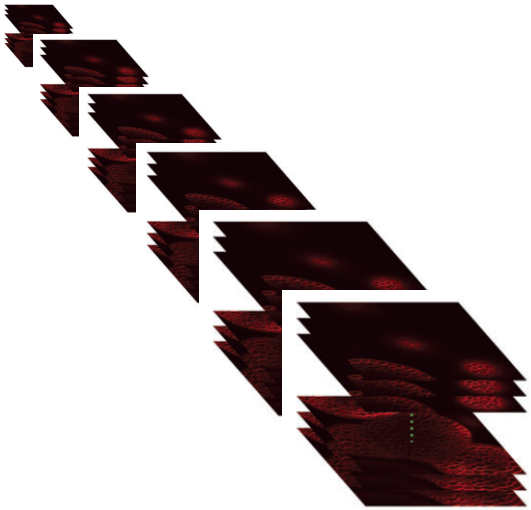
Genetic and epigenetic factors
Resources availability
and energetic status
Cell-to-cell chemical signalling
Cell-to-cell mechanical interaction
Environmental factors
....

How can modelling contribute to plant biology ?



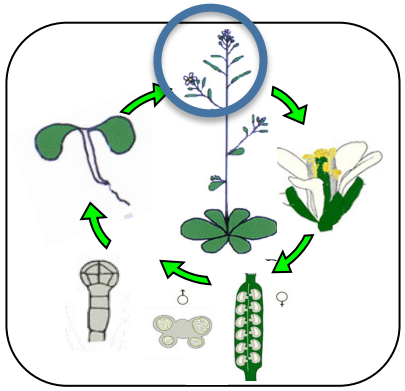
- Extraction of data, representation and quantification

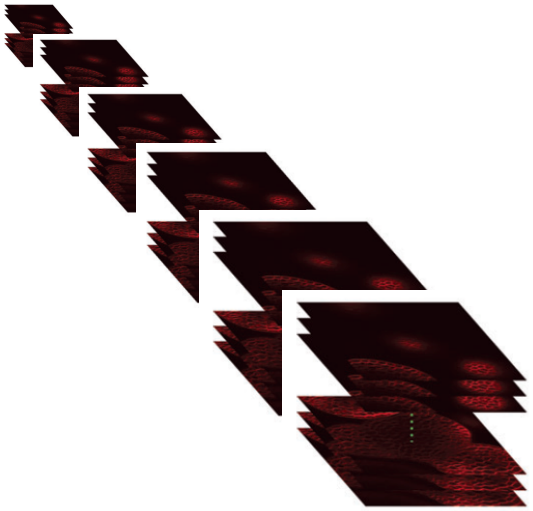




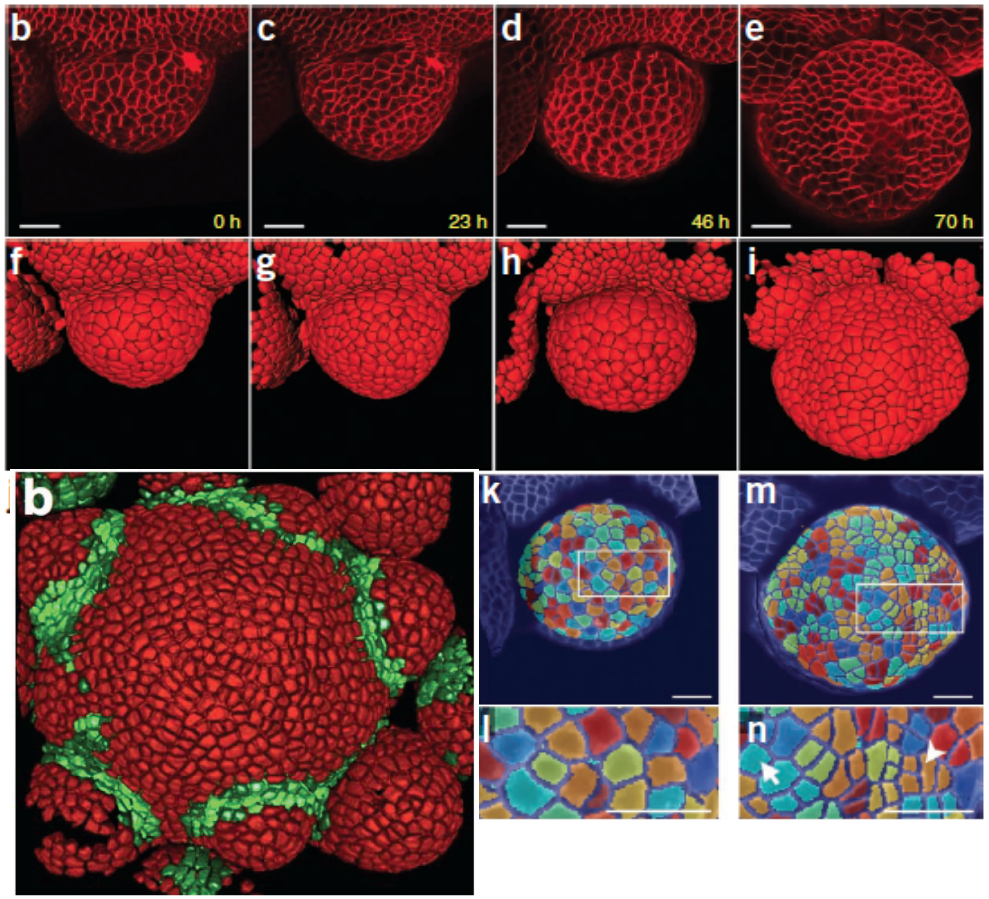
Fernandez et al., (2010) Nat Methods

How can modelling contribute to plant biology ?





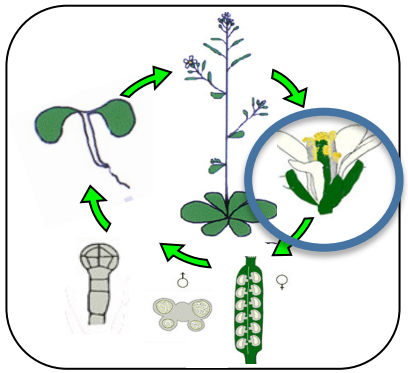
- Extraction of data, representation and quantification

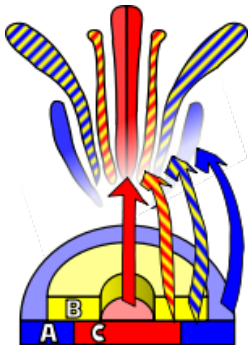


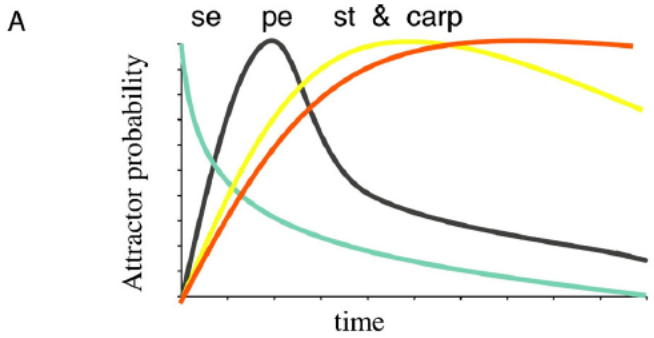
Fernandez et al., (2010) Nat Methods

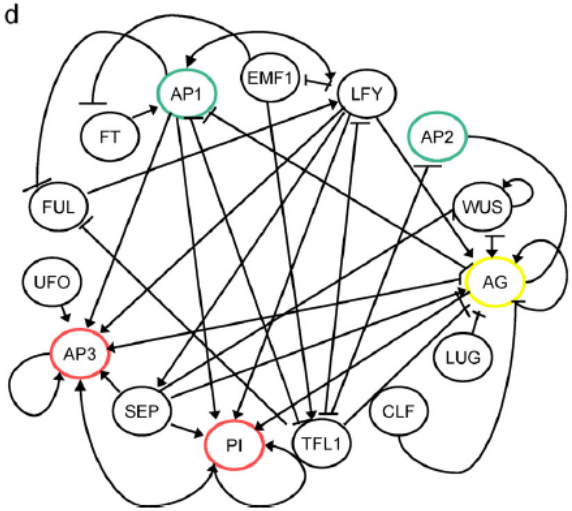
How can modelling contribute to plant biology ?

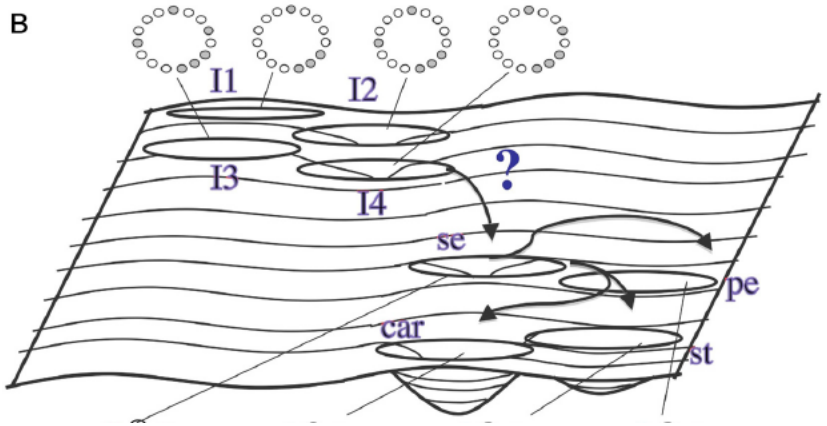
- Extraction of data, representation and quantification
- Analysis of the behaviour of complex systems





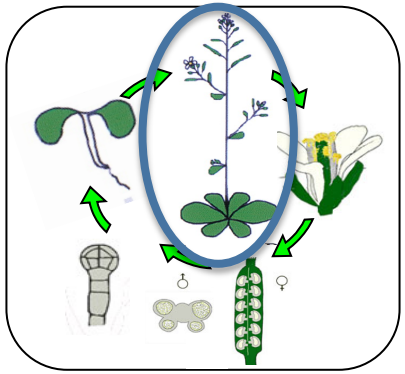




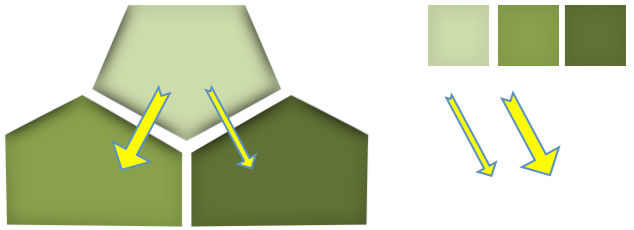


Alvarez-Buylla et al., (2010) Sem. Cell Dev. Biol.

How can modelling contribute to plant biology ?



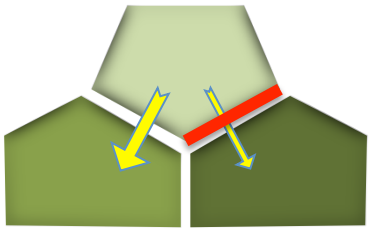
- Extraction of data, representation and quantification
- Analysis of the behaviour of complex systems
- Test the plausibility of different biological hypothesis



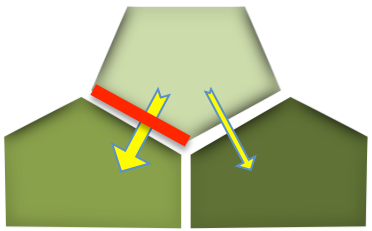
Increasing auxin concentrations

Increasing auxin fluxes

Hypothesis 1:
concentration based
"up the gradient"



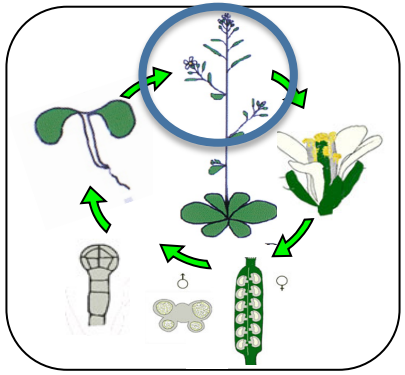
Hypothesis 2:
flux based
"canalisation"



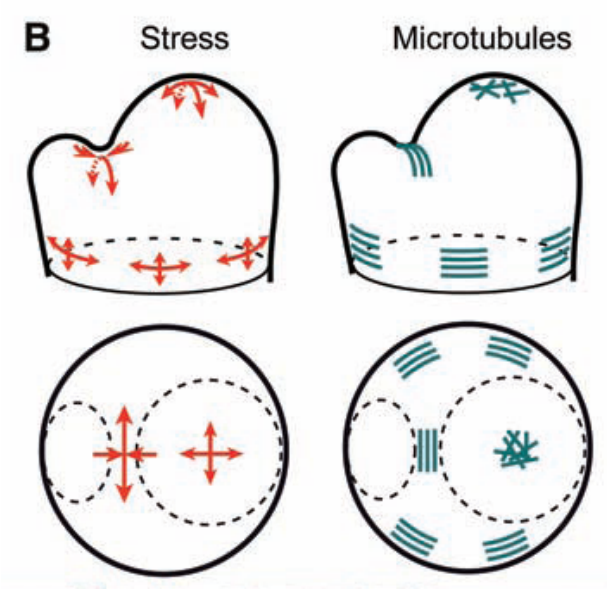
PIN deposition

Stoma et al., (2008). PLOS Comput. Biol.

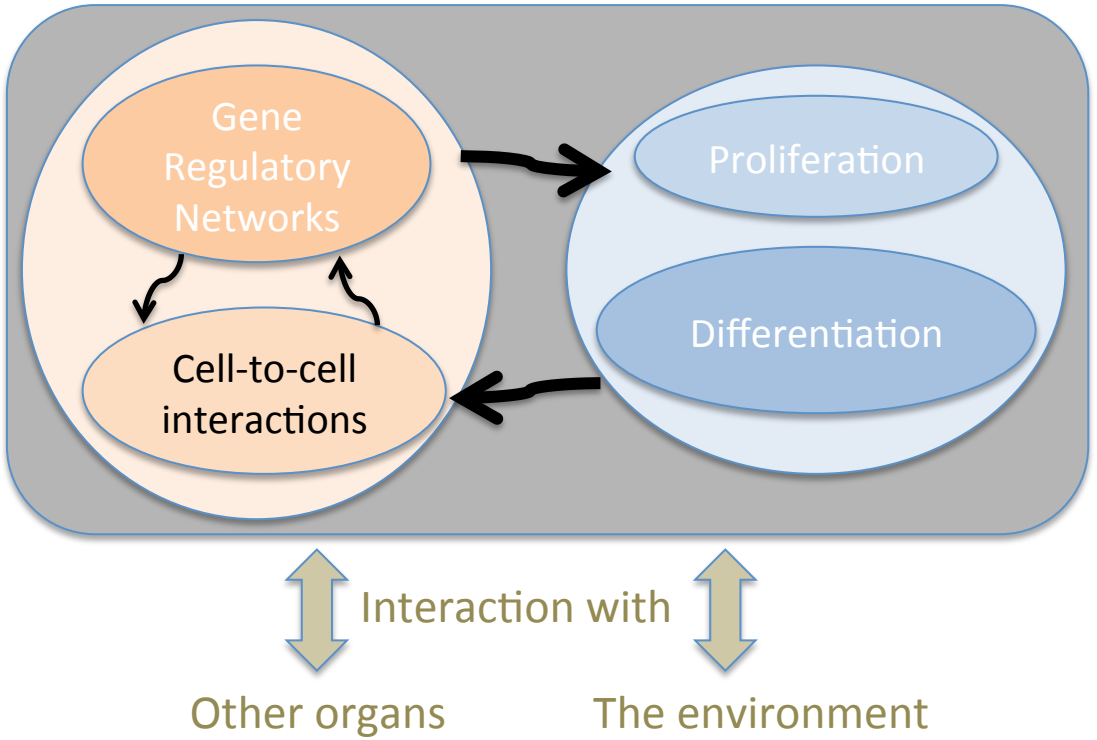
How can modelling contribute to plant biology ?



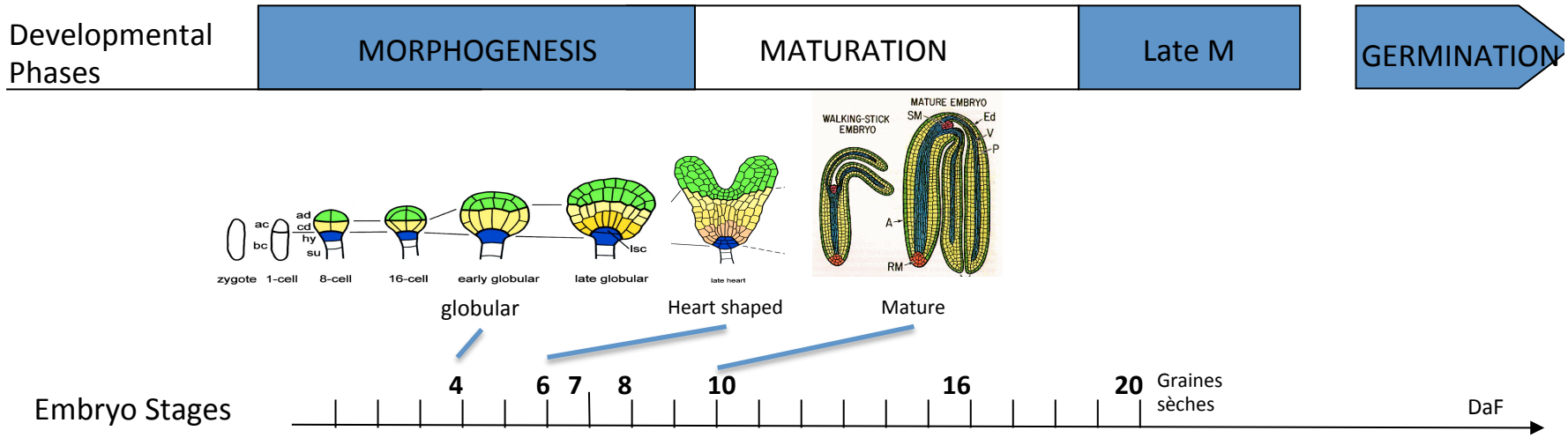
- Extraction of data, representation and quantification
- Analysis of the behaviour of complex systems
- Test the plausibility of different biological hypothesis
- Integrate multiple scales



Hamant et al., (2008). Science

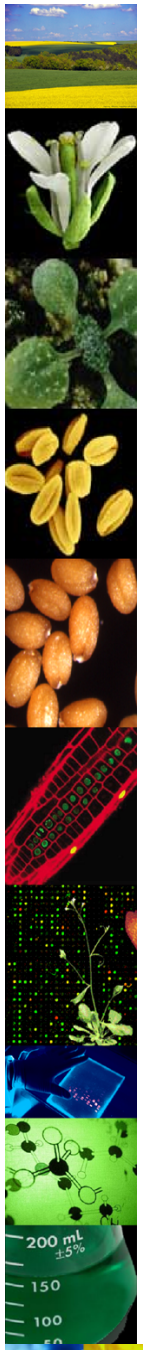


The embryo : a complex structure



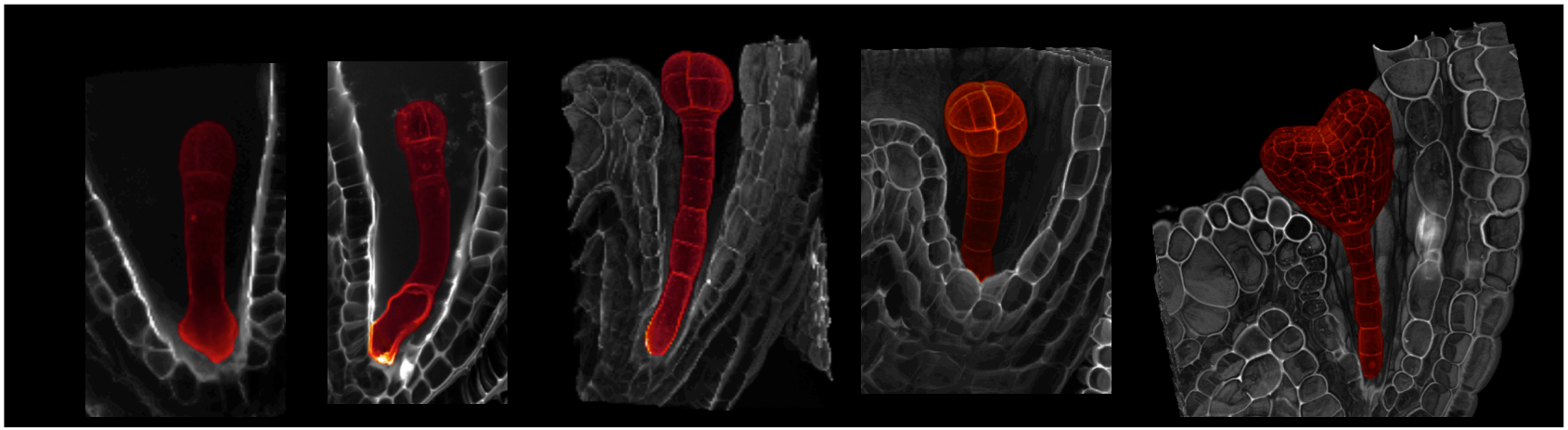
- A single cell generates a complex structure organised into different tissues
- A well-defined developmetal framework
- Numerous ressources available : mutants, expression patterns, transcriptomes….

- Economical importance

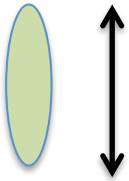


Subject 1: spatio-temporal patterning of early embryogenesis

The questions :
Cellular basis of embryo morphogenesis

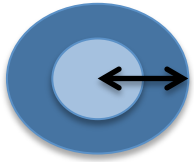


Longitudinal



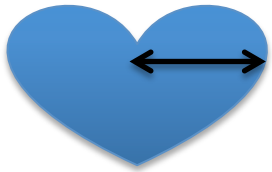
Apical-Basal

Radial



Inside-Outside

Bilateral



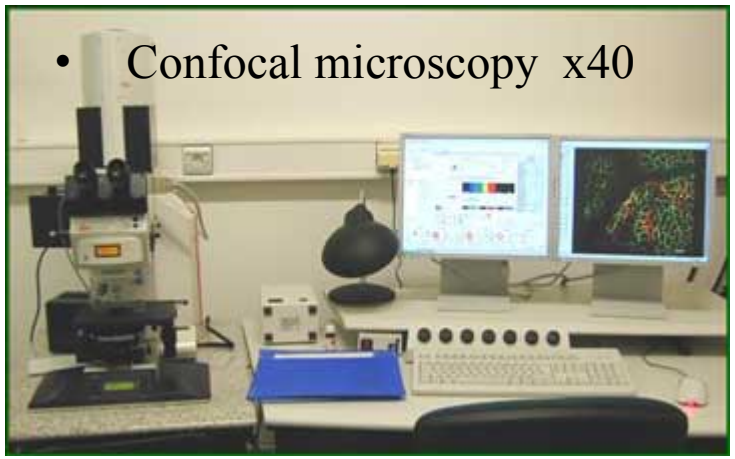
Medio-Lateral

How are the cell divisions specified ?

How are the embryo axis determined ?

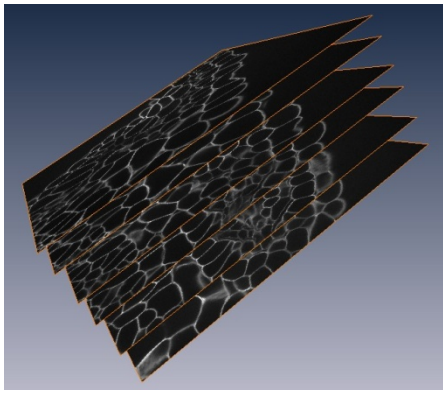
Pictures : K Belcram, JC Palauqui, B Dubreucq

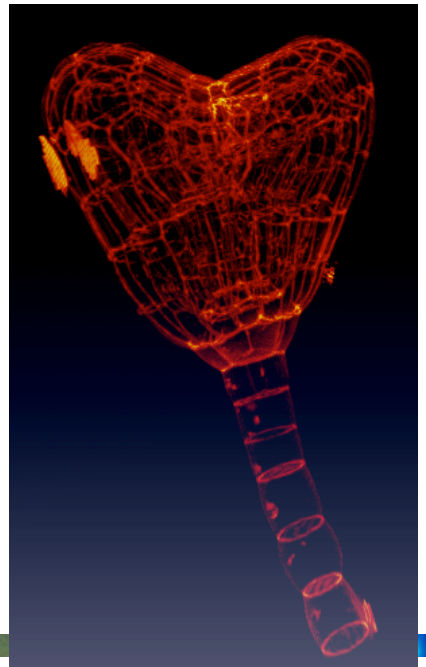
Image data



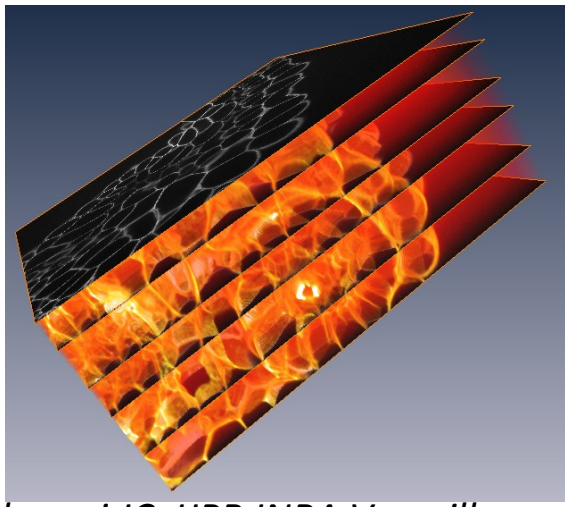
Fixed samples

Cell wall marker : IP





Volume rendering

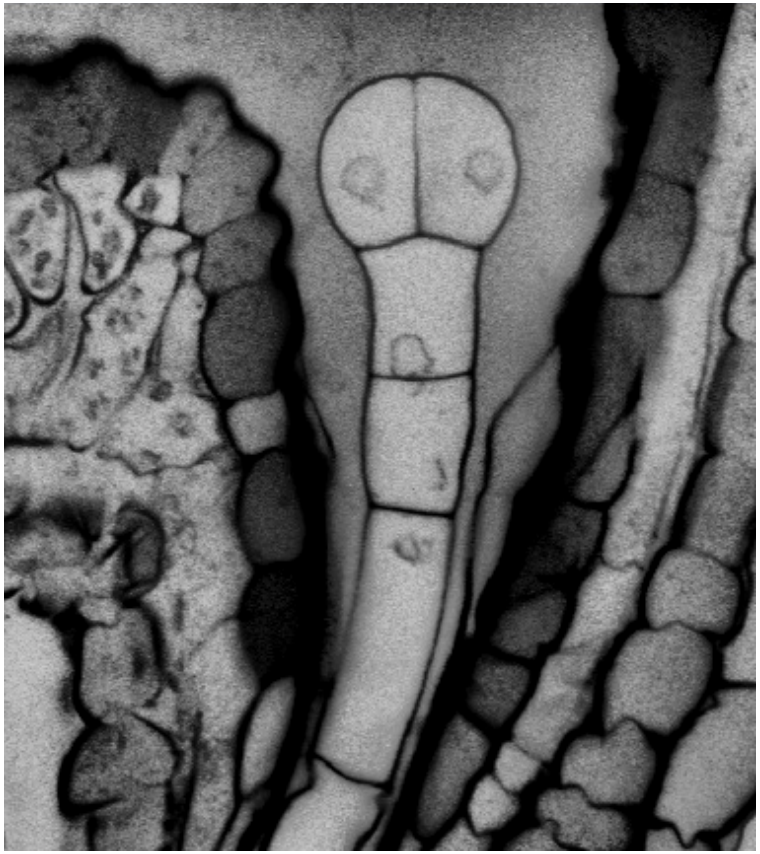


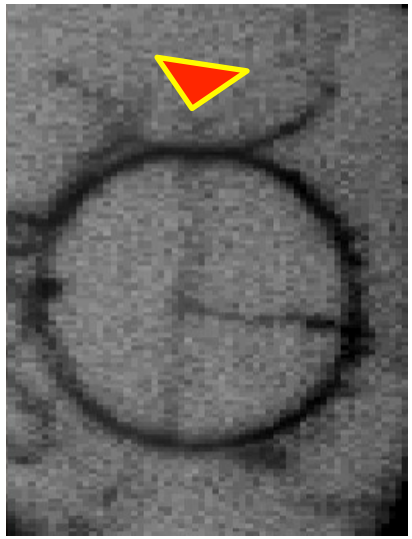
Belcram K., Palauqui JC. IJPB INRA Versailles

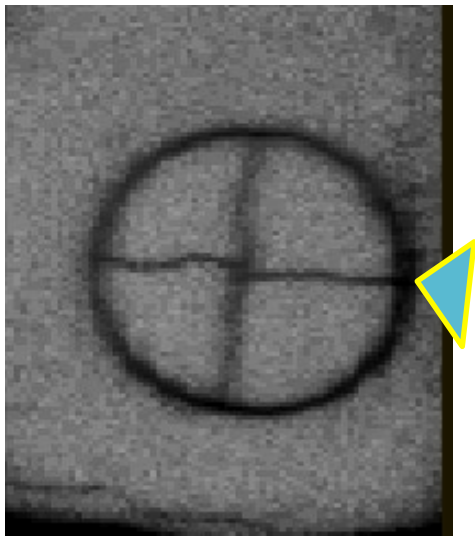
First division of the apical cell

-> sagittal plane

Second division -> frontal plane

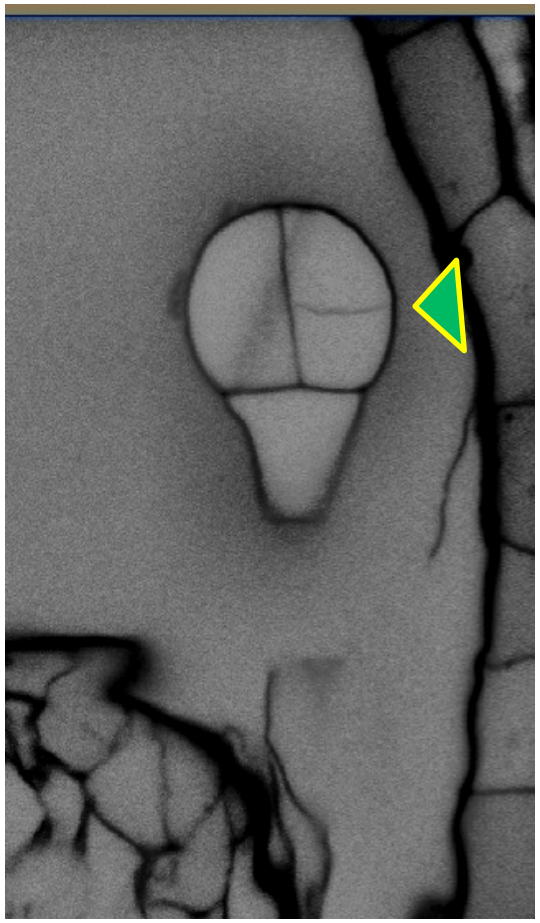


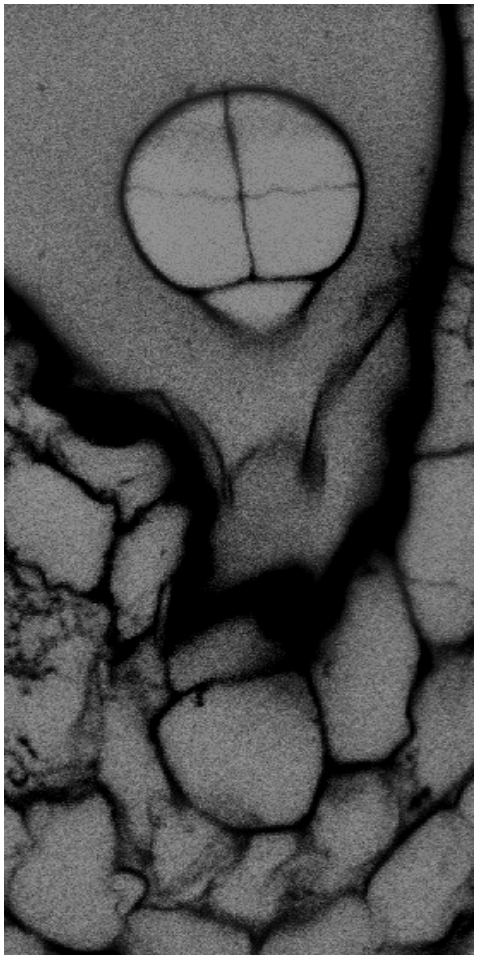


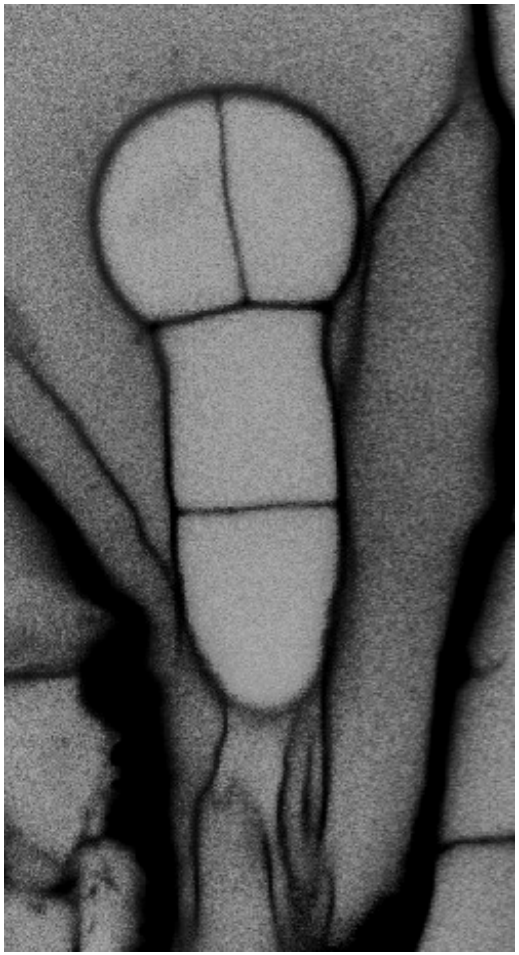


Asynchronous, shifted division

Third division -> transversal plane





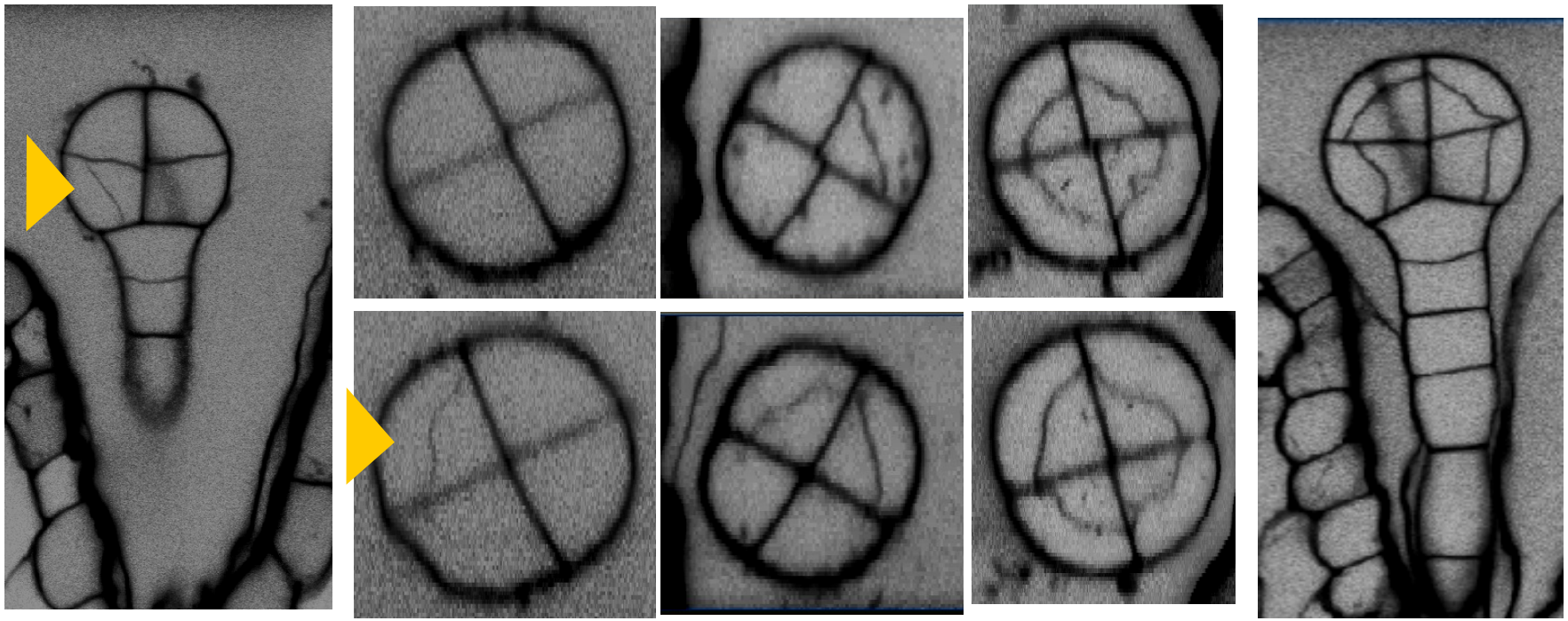


Front

Back

Fourth division -> protoderm

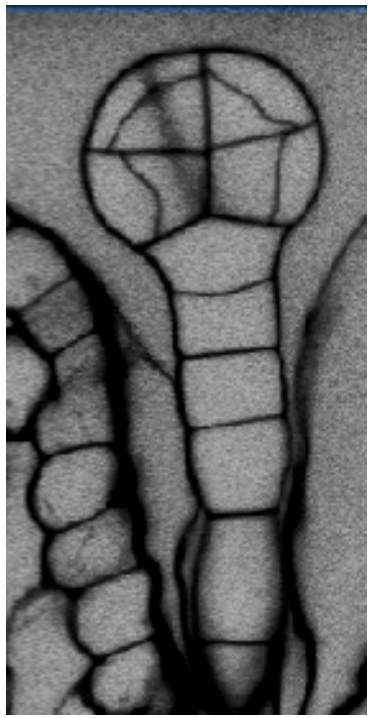
Apical domain

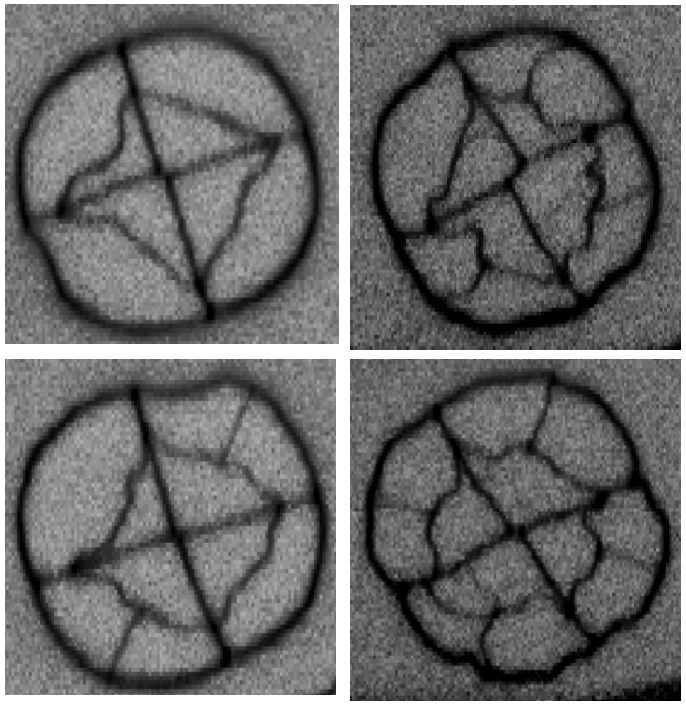


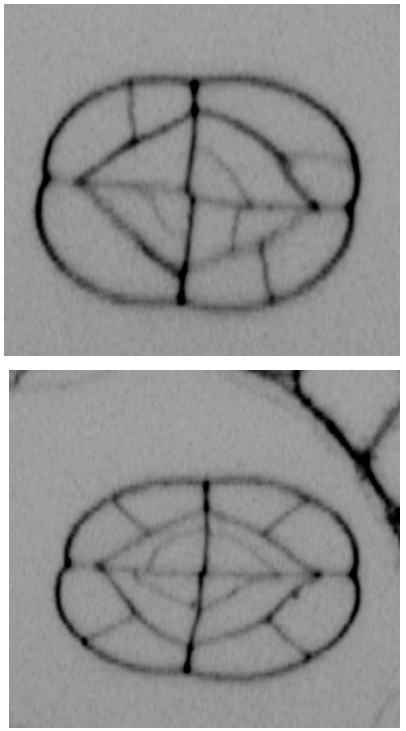
Basal domain

Fifth (protoderm) divisions : first in basal domain and opposed divisions

Apical domain



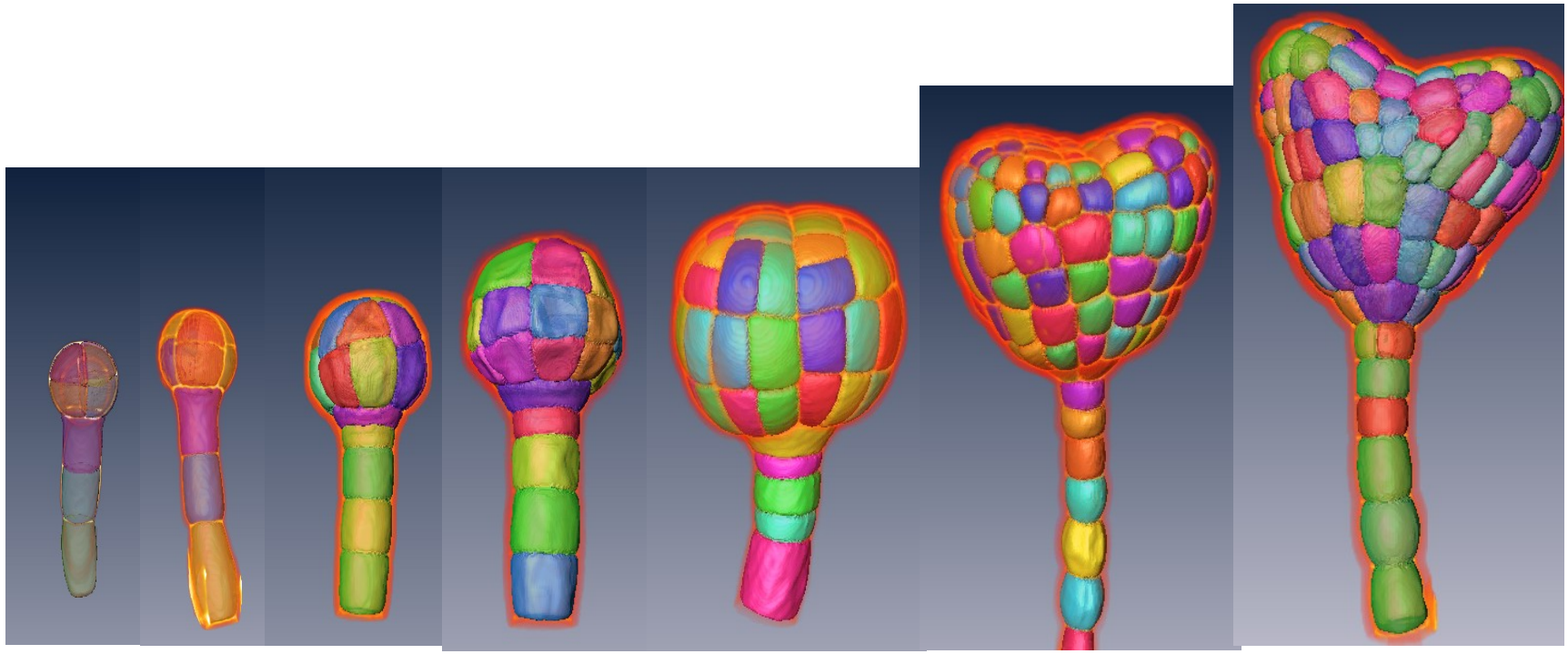




Basal domain

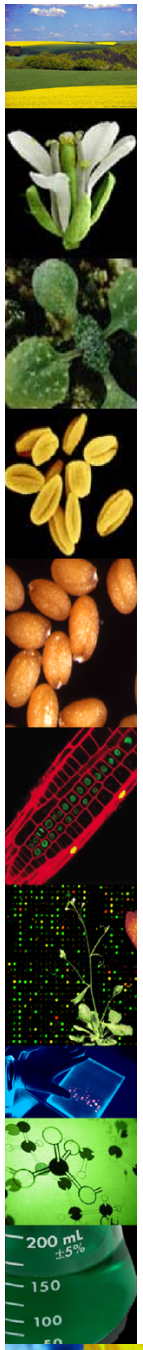
Loss of symmetry beyond 24 cells

Image segmentation and 3D reconstructions



8 **12** **25** **32** **103** **278** **294**

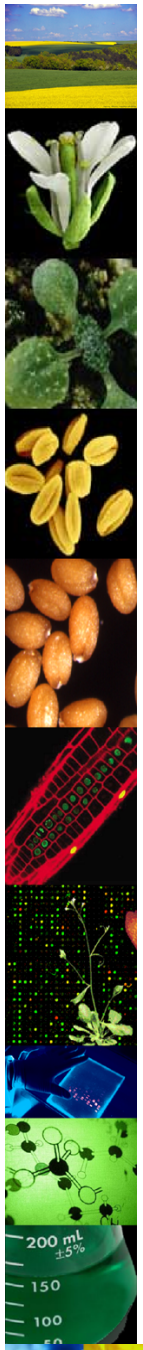
A. Urbain and A. Trubuil



Subject 1: spatio-temporal patterning of early embryogenesis

- What are the determinants of the spatio-temporal pattern of cell divisions in the early plant embryo?

-> Geometrical and physical principles explaining the observed division planes?



Phenomenological division rules

Division in two equal volumes according to

- **Hofmeister's rule**

  Division orthogonally to cell elongation axis

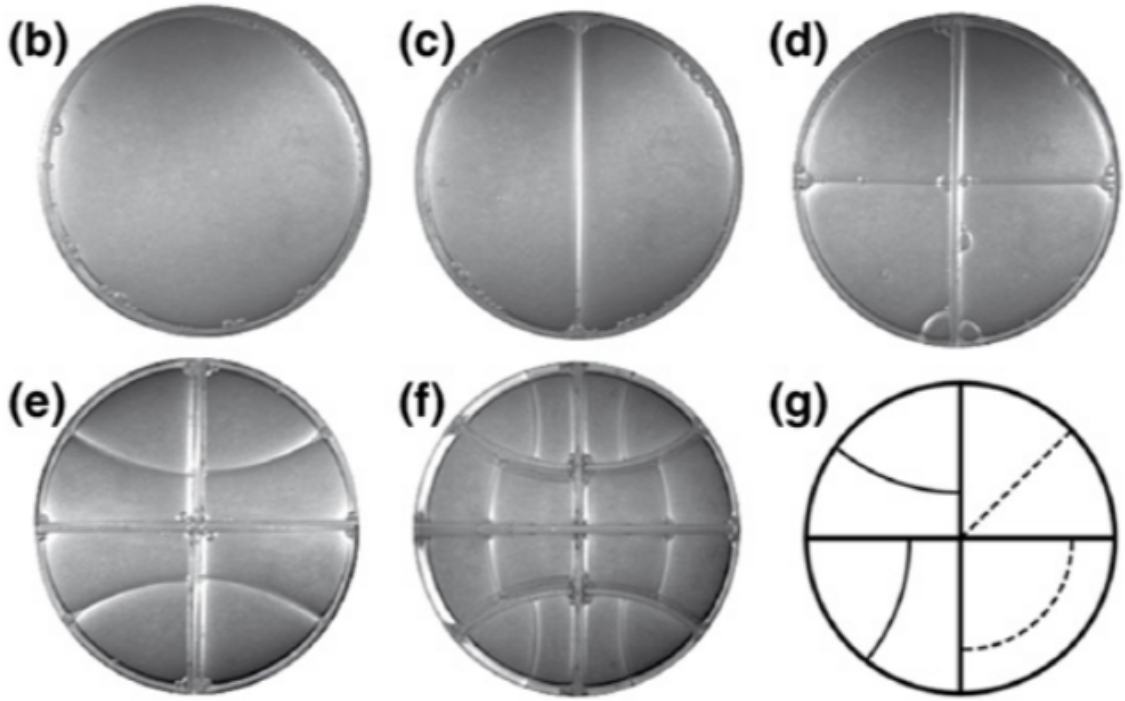
- **Sachs' rule**

  Division orthogonally to parent division plane

- **Errera's rule**

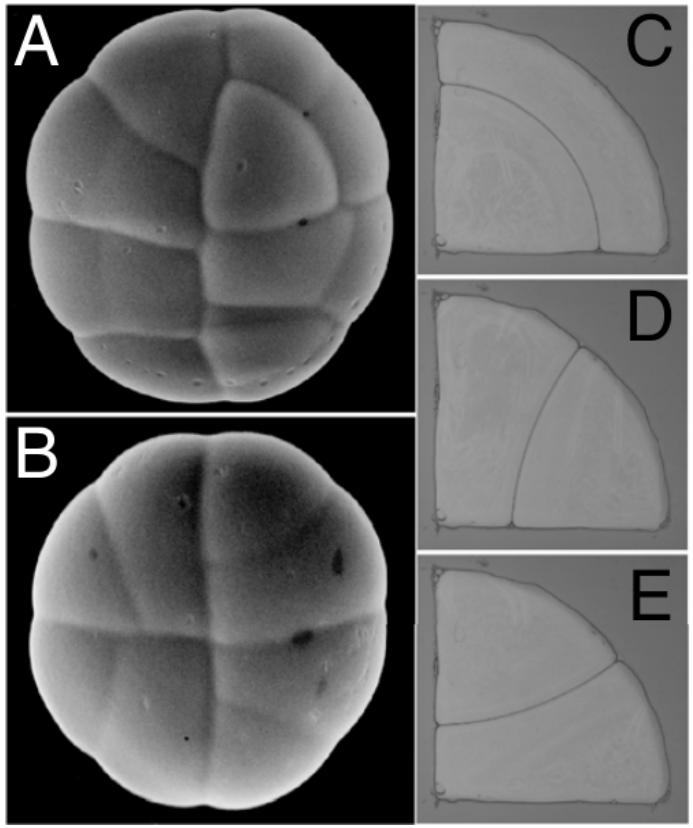
  Division so as to minimize plane area

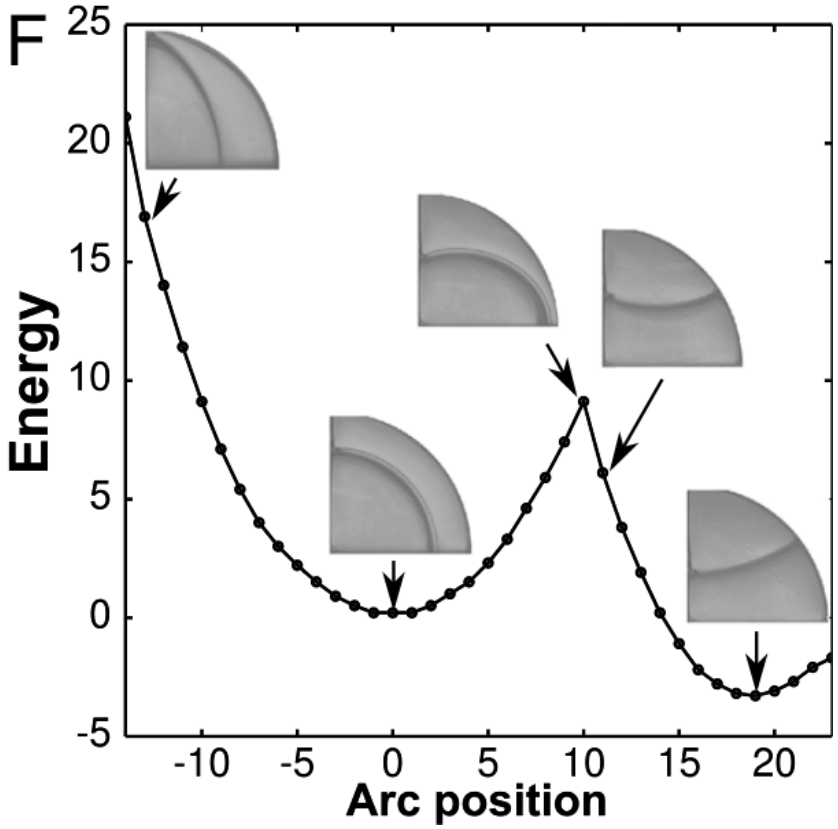
Errera's division rule



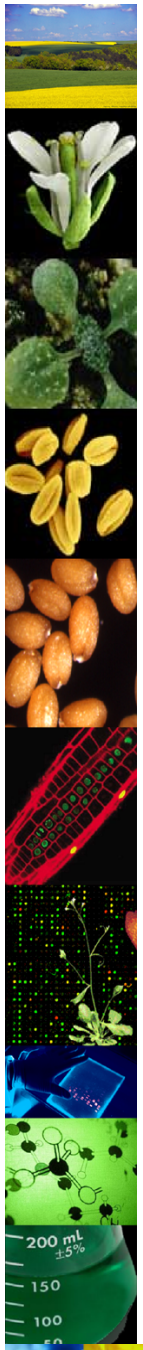
(Dumais, 2007)

Local minima of division plane area probability distribution



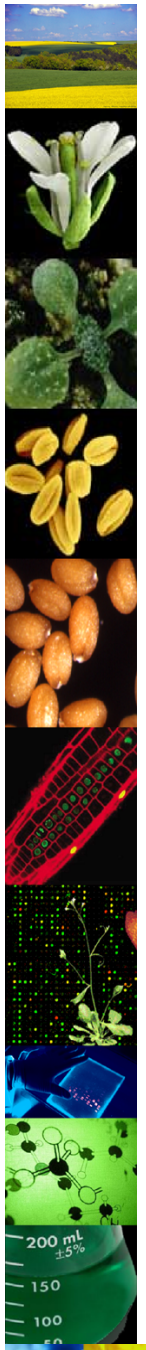


(Besson & Dumais, 2010)



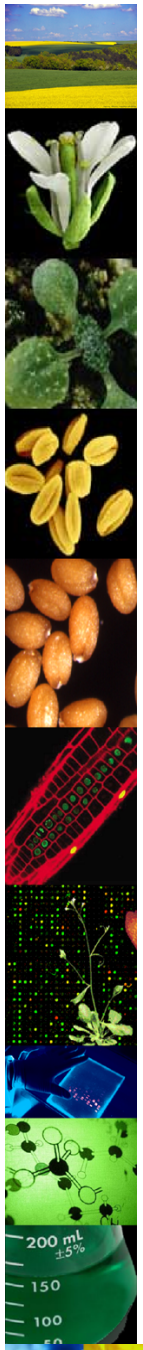
Subject 1: spatio-temporal patterning of early embryogenesis

- From 2D to 3D probabilistic division rules
- Influence of cell morphological constraints
- Sources of variability/robustness
- Origin of basal/apical asymmetry
- Identification of other factors/mechanisms

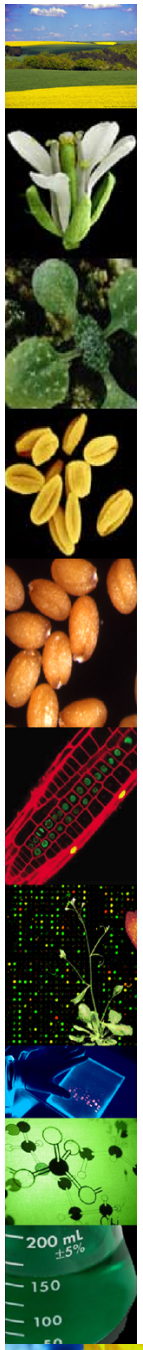


Participants

- Différenciation et polarité cellulaire
  - JC Palauqui
- Modélisation et imagerie numérique
  - P Andrey, E Biot, 1 CDD (post-doc 24 months)
- Plateforme de cytologie et d'imagerie végétale
  - K Belcram



Subject 2: nuclear organization and transcriptional regulation of seed maturation



The questions :
Gene network and nuclear organisation

ALF genes activate an embryo-specific program

Developmental Phases

MORPHOGENESIS | MATURATION | Late M | GERMINATION

FUS3

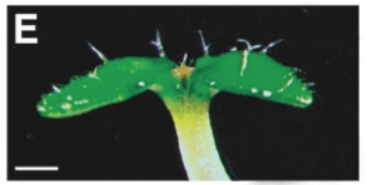
LEC1

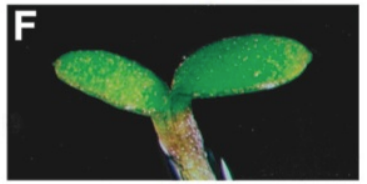
LEC2

Morphogenesis

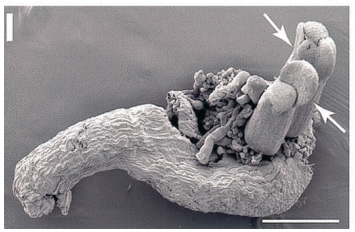
Cell expansion
Differentiation
Storage

Dessication



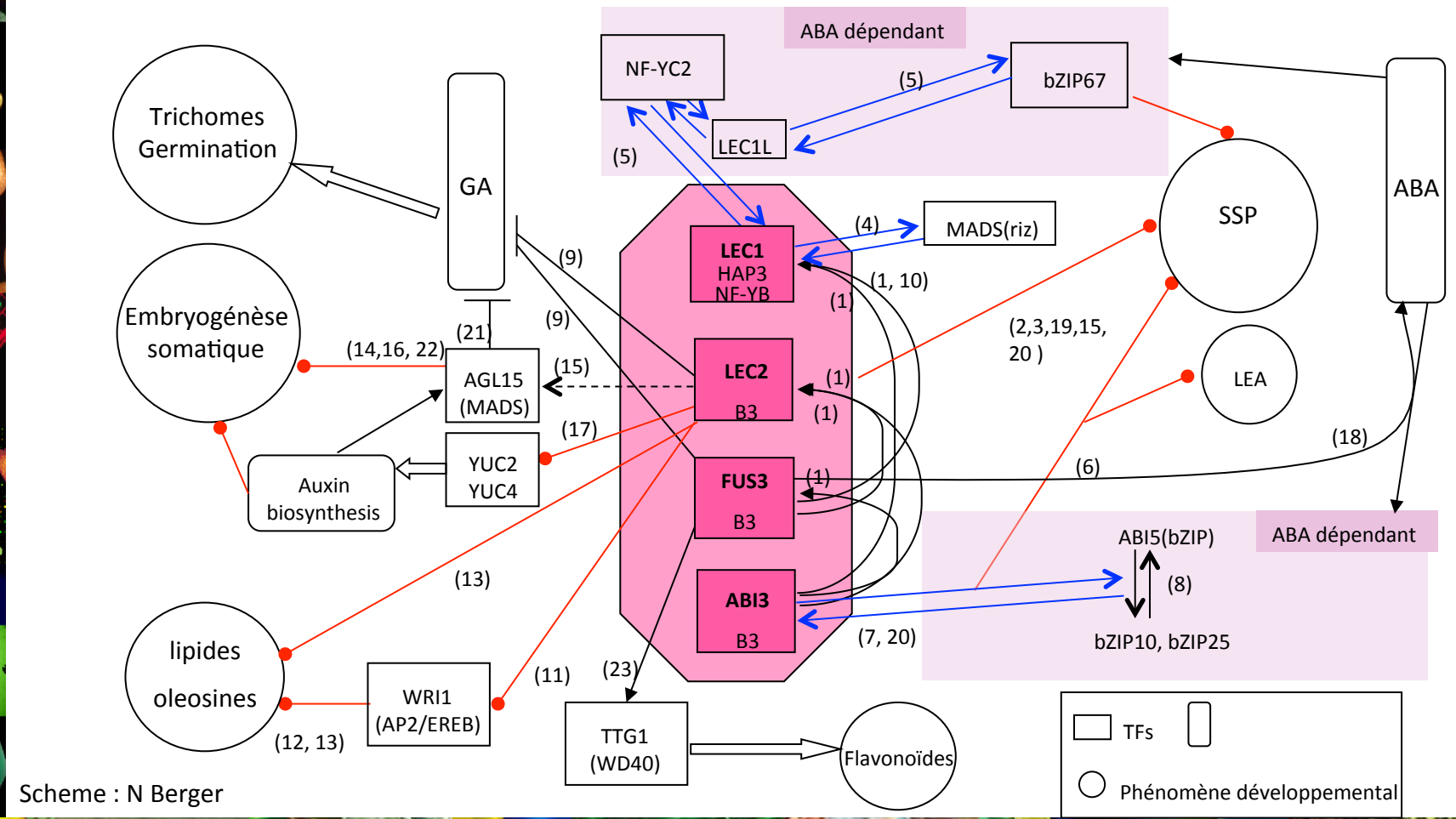


WT

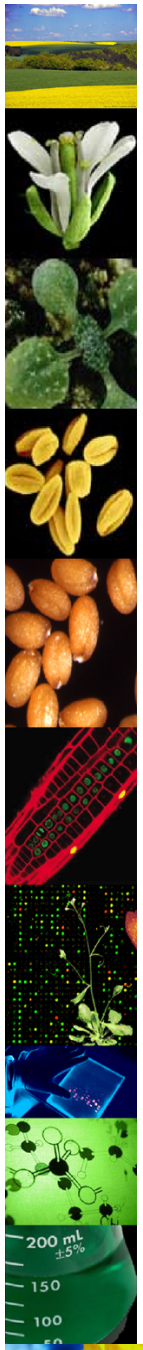


The questions :
Gene network and nuclear organisation

ALF genes are at the nexus of a regulatory network controlling embryo development

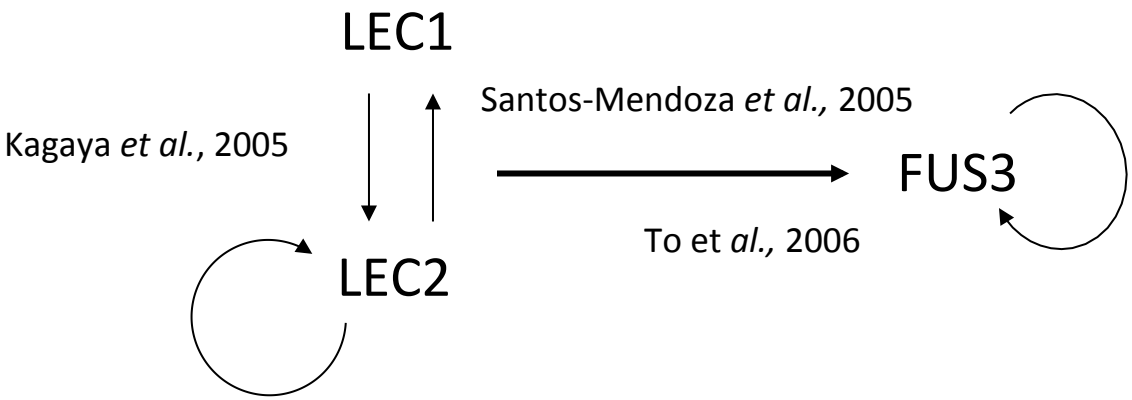


Scheme : N Berger



The questions :
Gene network and nuclear organisation

ALF genes form a core regulatory network subjected to external regulations



The questions :
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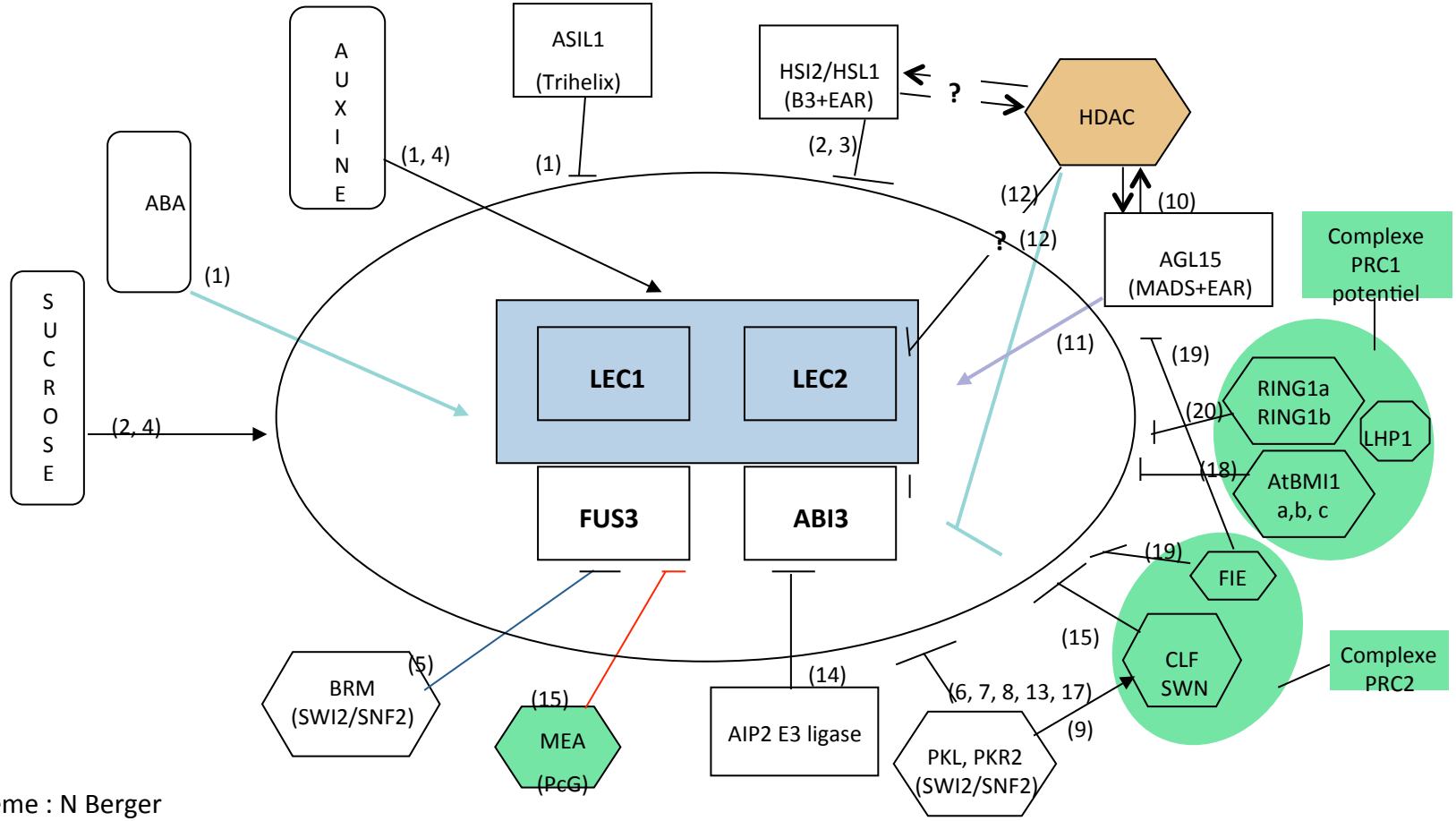
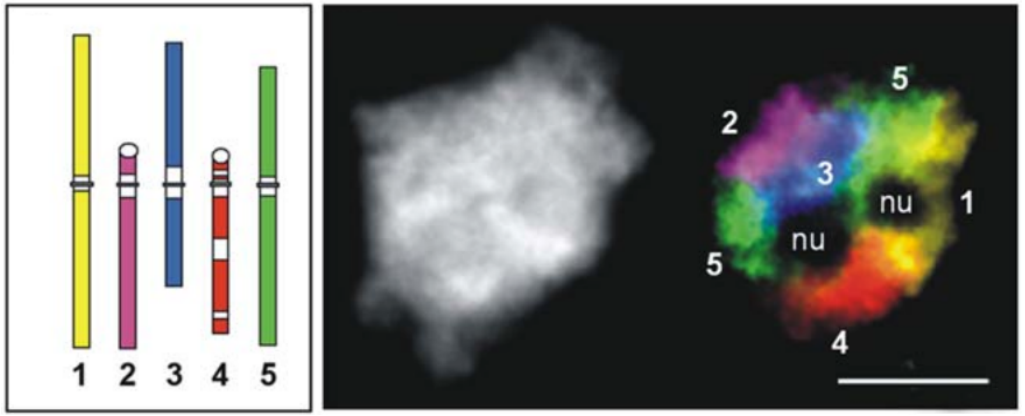
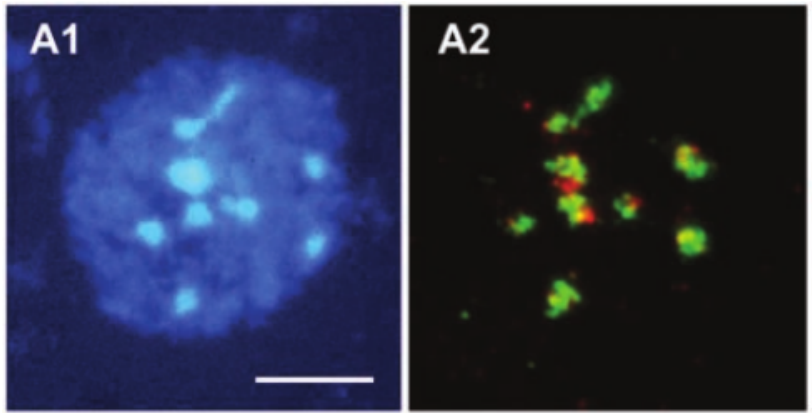


Scheme : N Berger

The interphase nucleus, a spatially organized organelle

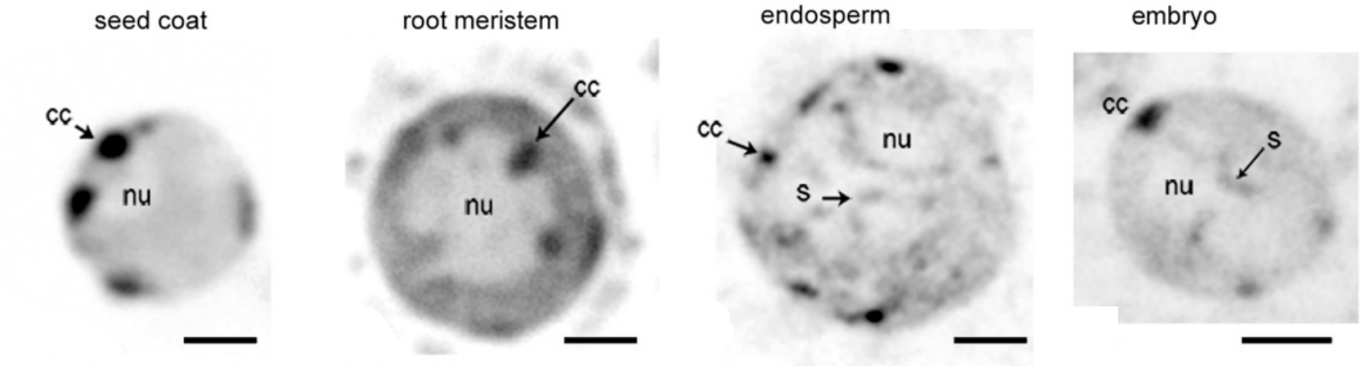


(Pecinka et al, 2004)

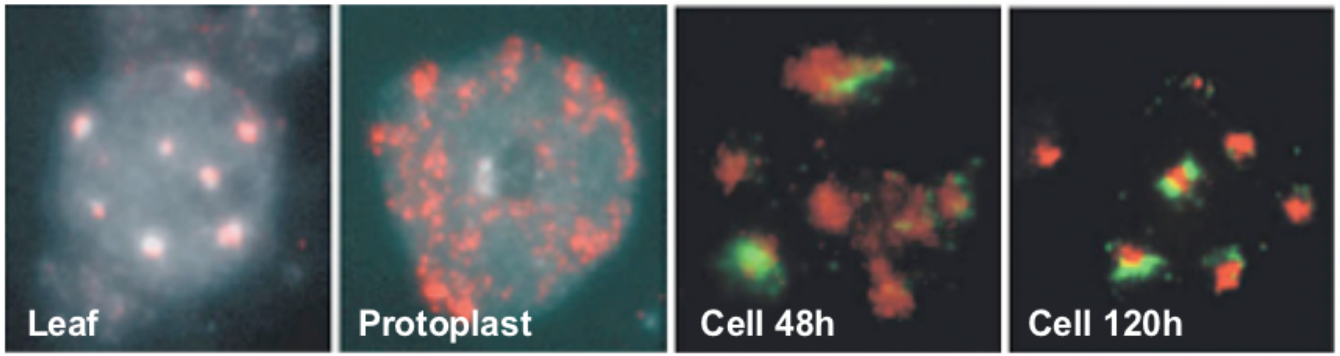


(Fransz et al, 2002)

Nuclear organization plasticity and dynamics

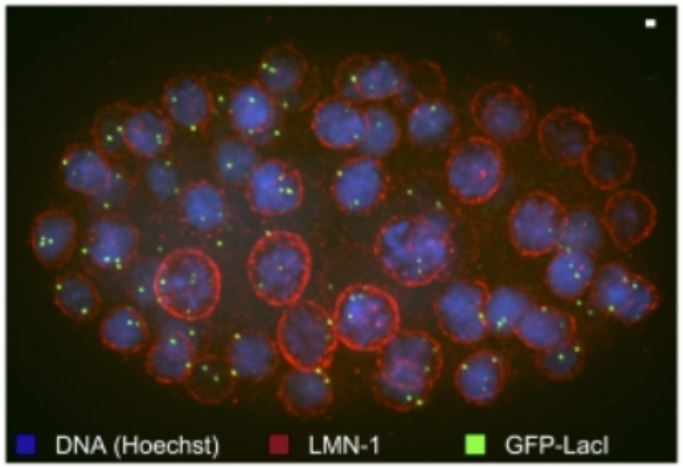


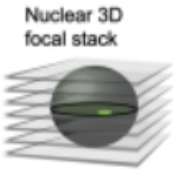
(Baroux et al, 2007)

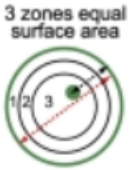


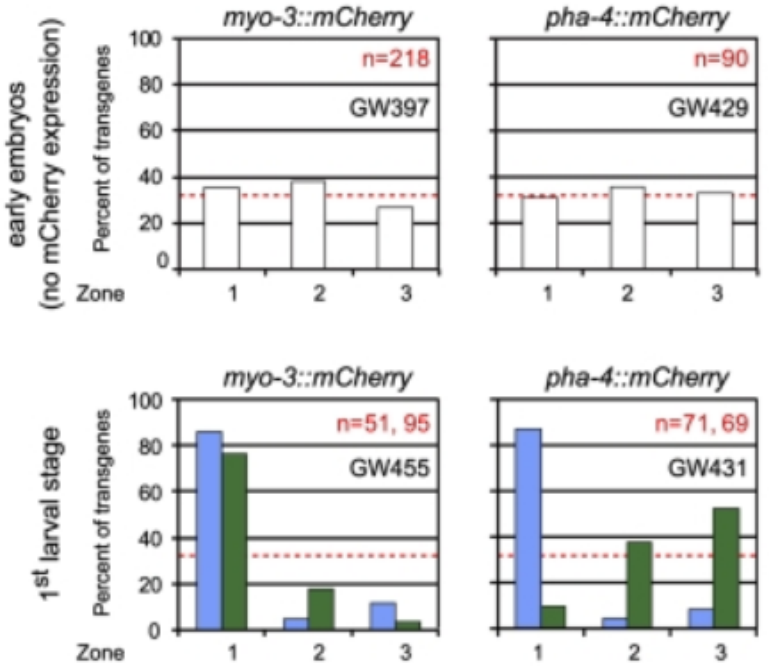
(Tessadori et al, 2007)

Gene activity and nuclear positioning









(Meister et al., 2010)

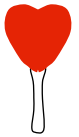
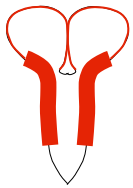
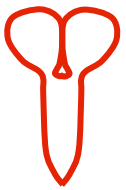
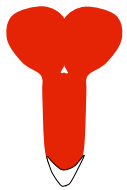
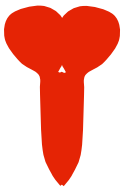
The questions :
Gene network and nuclear organisation

Is the ALF regulatory network tissue-dependant ?

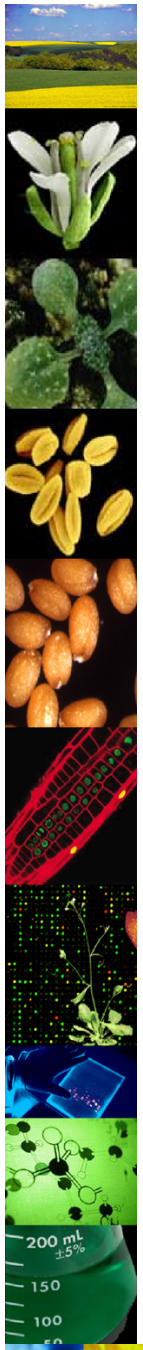
Is the nuclear organisation different in embryonic and vegetative tissues ?

Is the nuclear organisation of genes linked to their expression ?

How does nuclear organisation impinge on gene regulatory networks ?

LEC2	*FUS3*	*ABI3*	*LEC1*
pLEC2::GUS	*pFUS::FUS GFP*	ISH	ISH
			
			
			

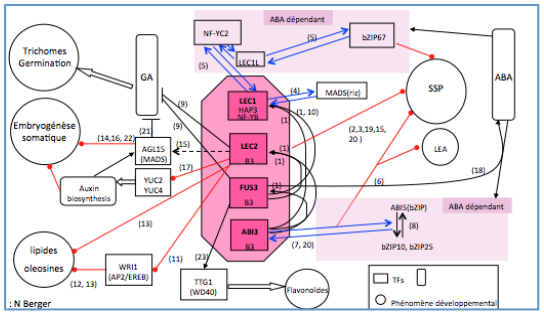
Scheme : Mendoza et al., 2008

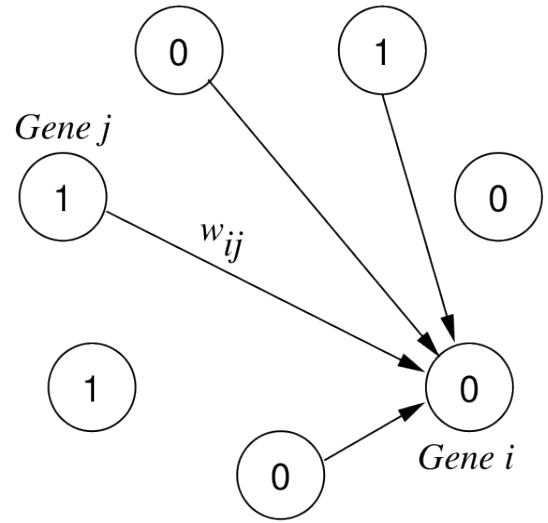


Subject 2: nuclear organization and transcriptional regulation of seed maturation

Analysis of the dynamics of gene regulatory networks and their link with nuclear organisation during seed maturation ?

Modelling network dynamics





- **System state**

$$S_i(t) = \begin{cases} 1 & \text{active} \\ 0 & \text{inactive} \end{cases}$$

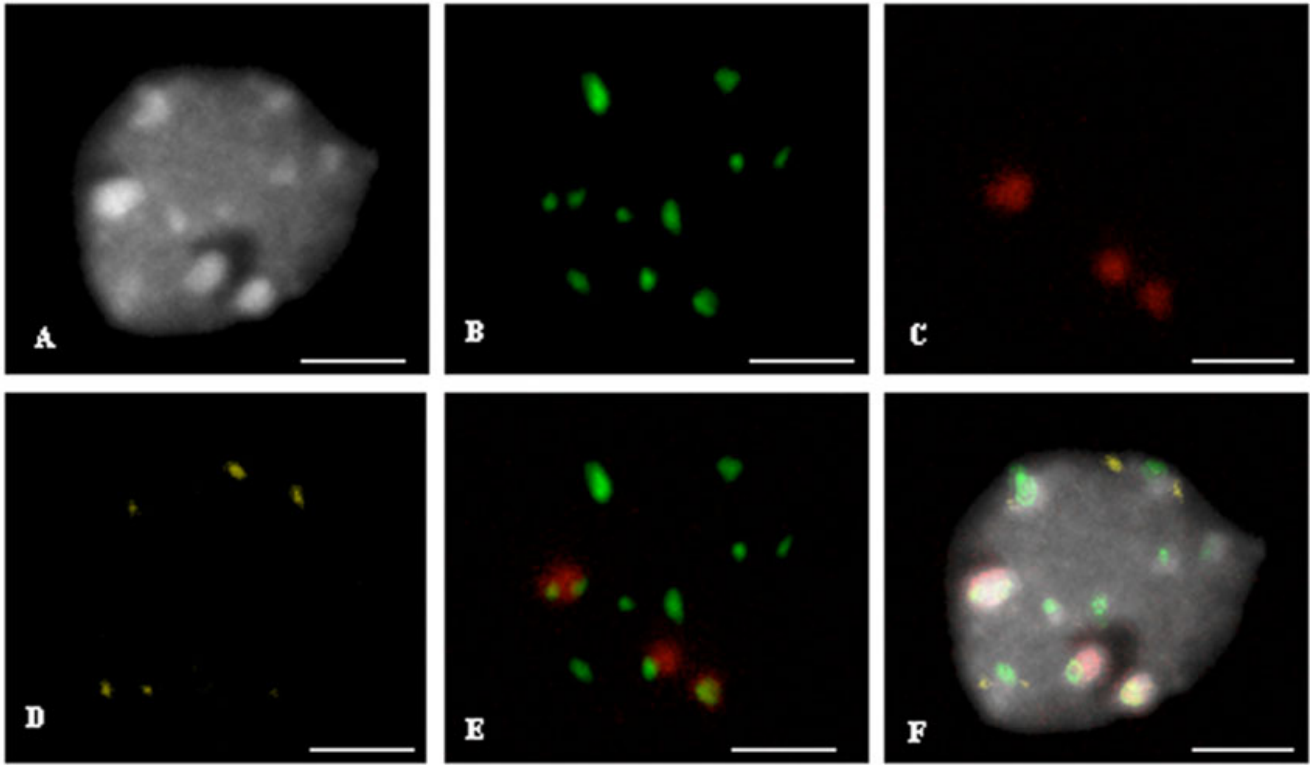
- **Interactions**

$$w_{ij} = \begin{cases} -1 & \text{repression} \\ 1 & \text{activation} \end{cases}$$

- **Dynamics**

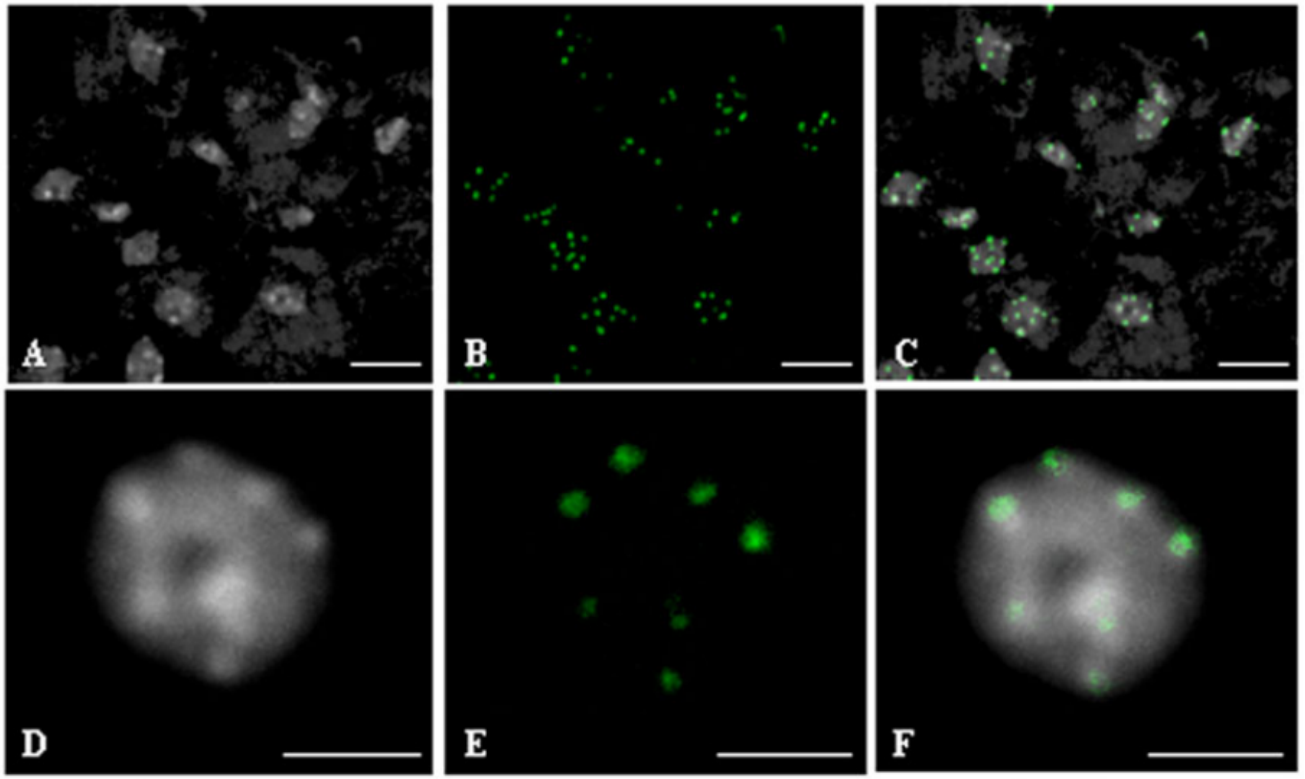
$$S_i(t+1) = \begin{cases} 1 & \text{if } \sum w_{ij} S_j(t) > 0 \\ 0 & \text{otherwise} \end{cases}$$

Imaging of nucleus and genes 3D spatial organization



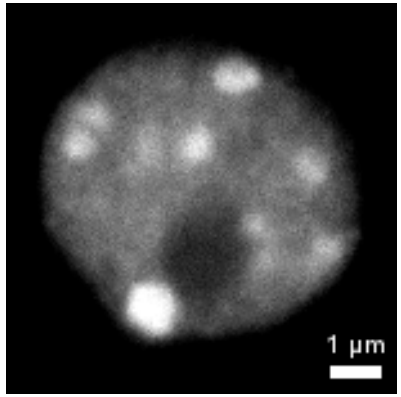
(Tirichine et al., 2009)

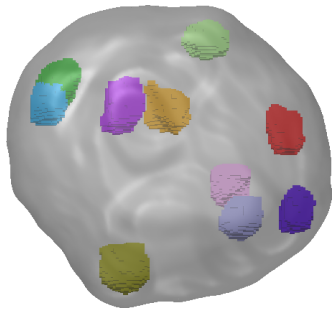
Imaging of nucleus and genes spatial organization

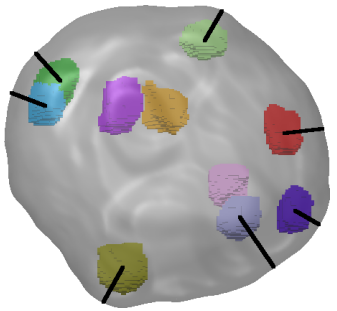


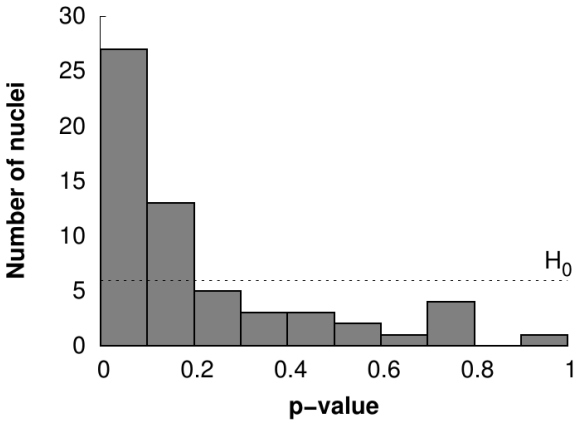
(Tirichine et al., 2009)

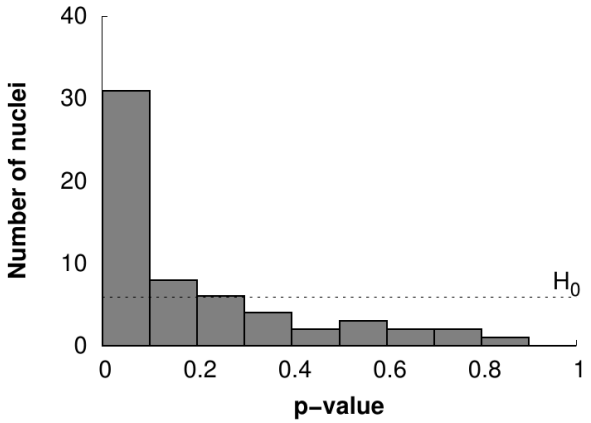
Spatial statistics and modelling of nuclear organization in 3D



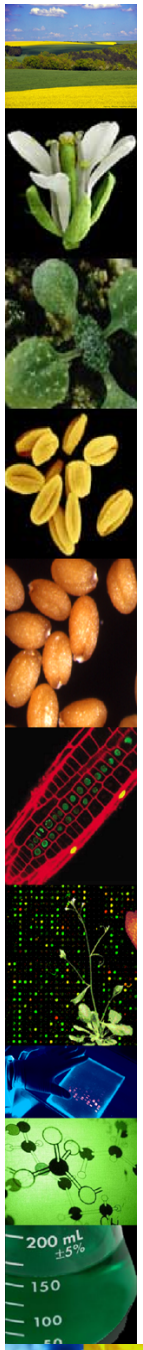






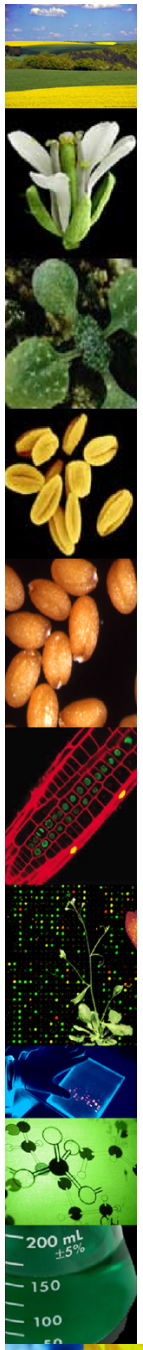


(Andrey et al., 2010)



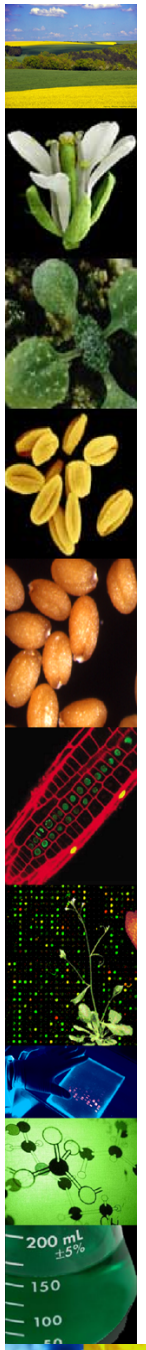
Subject 2: nuclear organization and transcriptional regulation of seed maturation

- Mathematical modelling of transcriptional regulation networks in seed maturation
- Imaging and spatial modelling of nuclear organization and nuclear gene positions
- Integrated modelling of transcriptional regulation networks and spatial dynamics



Participants

- Développement et qualité des graines
  - B Dubreucq
- Dynamique de la chromatine et expression génique
  - V Gaudin
- Modélisation et imagerie numérique
  - P Andrey, E Biot, 1 CDD (post-doc, 24 months)
- Plateforme de cytologie et d'imagerie végétale
  - 1 CDD (IE, 24 months)



Expected outcomes of the project

- A multidisciplinary approach
- Towards a seed systems biology
- Better understanding of seed development
- Innovating tools to drive seed biology

- New and generic tools for plant modelling
- Foster interdisciplinary interactions in the Labex