Bi8940 Developmental Biology
Lesson 7

Plant Embryogenesis

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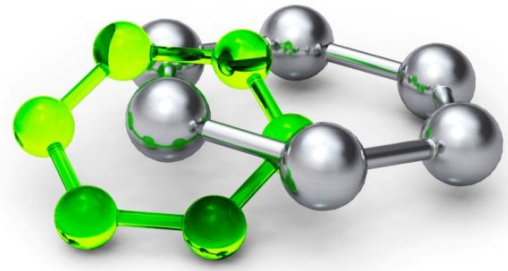
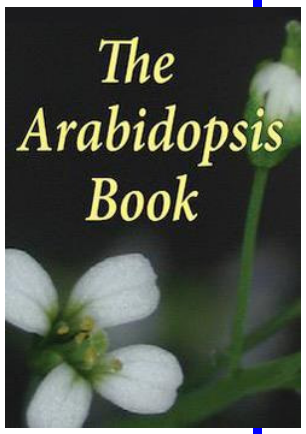


Literature



- **Capron A, Chatfield S, Provart N, Berleth T 2009**. Embryogenesis: Pattern Formation from a Single Cell. *The Arabidopsis Book*. Rockville, MD: American Society of Plant Biologists, doi: 10.1199/tab.0126, http://www.aspb.org/publications/arabidopsis/.
- Dubová J., Hejátko J., Friml J. (2005) Reproduction of Plants, in Encyclopedia of Molecular Cell Biology and Molecular Medicine (ed, R. A. Meyers), pp. 249 – 295. Wiley-VCH, Weinheim, Germany
- Selected original papers in scientific journals

Outline of Lesson 7

Plant Embryogenesis

- Overview of the embryo formation in *Arabidopsis*
- Mechanism of the apical-basal axis formation
  - female gametophyte prespecification, invariant cell division or positional information?
  - differential gene expression
  - auxin gradients formation
  - the role of auxin signalling
- Roor meristem formation
  - auxin and hypophysis identity
  - differential gene expression and root meristem patterning
  - auxin-cytokinin interaction and the root meristem organization centre formation

Outline of Lesson 7

Plant Embryogenesis

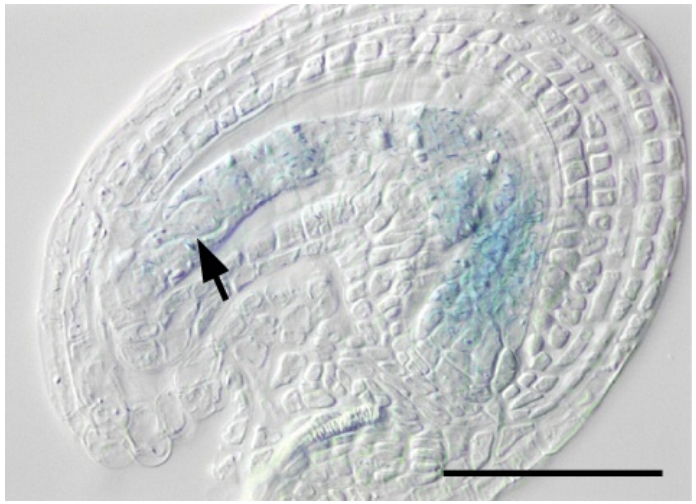
- Patterning of the apical embryo pole
  - generation of cotyledons and shoot apical meristem
  - proper spacing of lateral organs
  - adaxial-abaxial axis formation
- Radial embryo patterning
  - epidermal layer specification
  - separating vascular and ground tissue

Outline of Lesson 7

Plant Embryogenesis

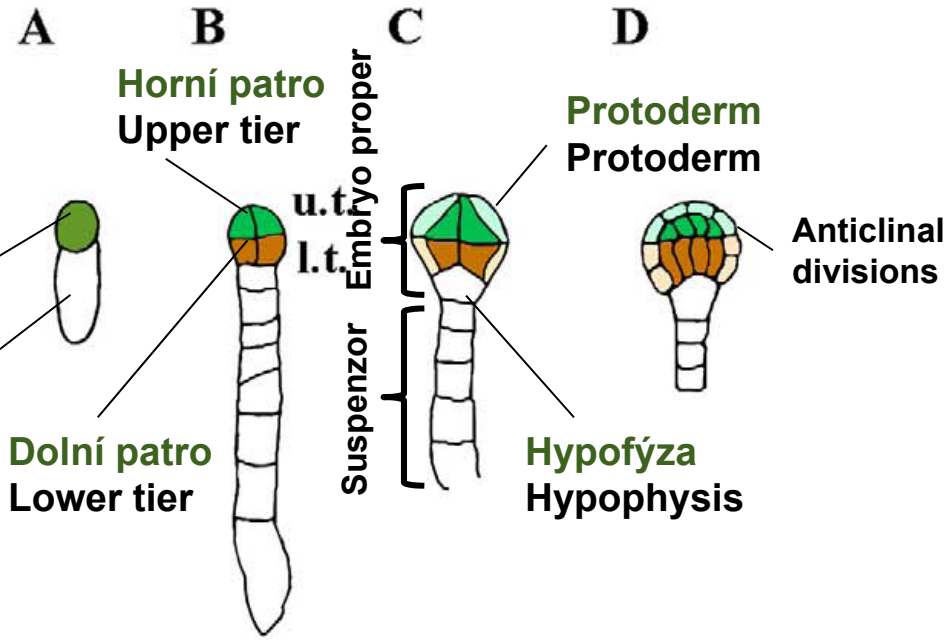
- Overview of the embryo formation in *Arabidopsis*

Hejátko et al., *Mol Genet Genomics* (2003)

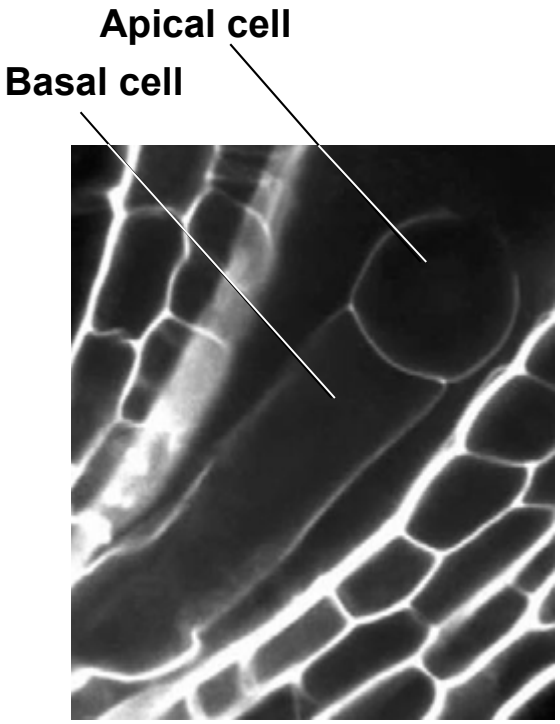


Apical cell-active protein biosynthesis

Basal cell-highly vacuolated



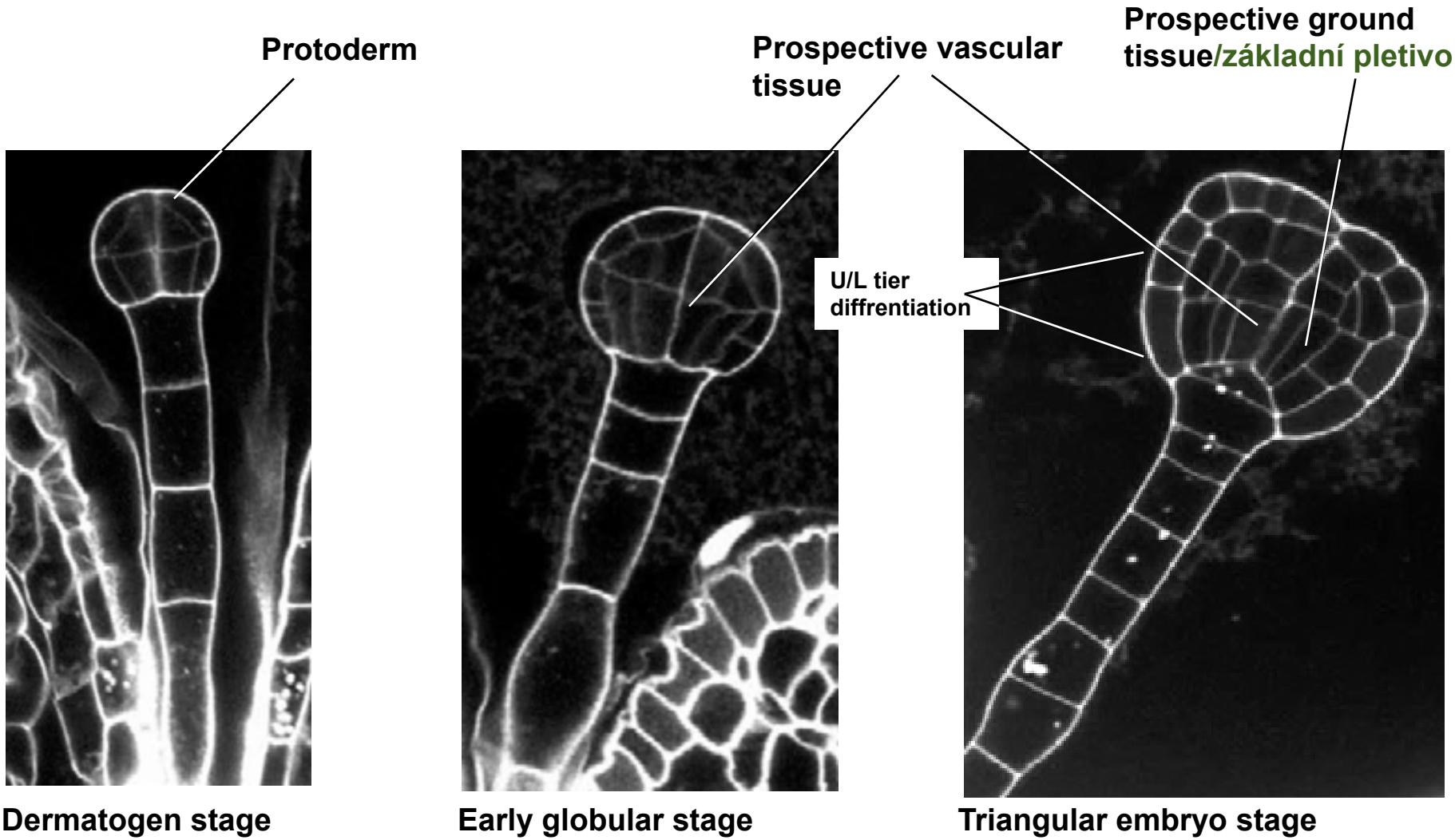
Capron et al., *Arabidopsis Book* (2009)



Capron et al., *Arabidopsis Book* (2009)

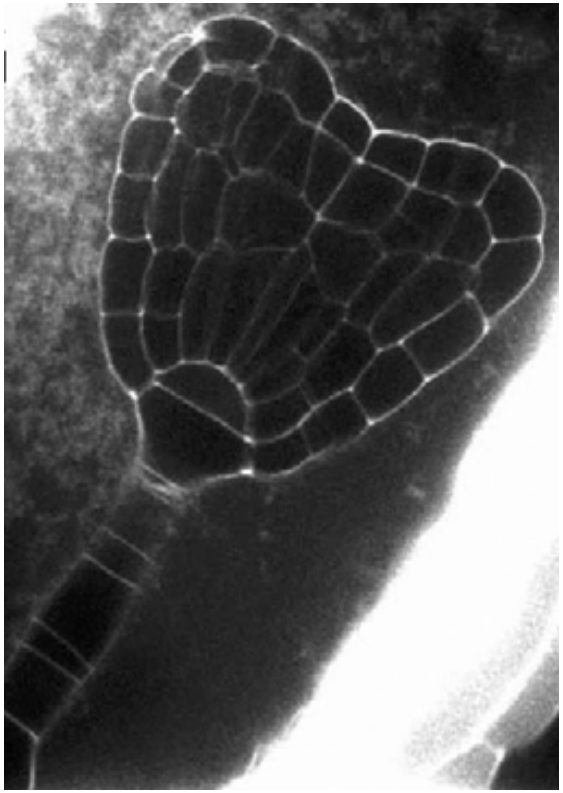
Proembryo stage

Octant stage



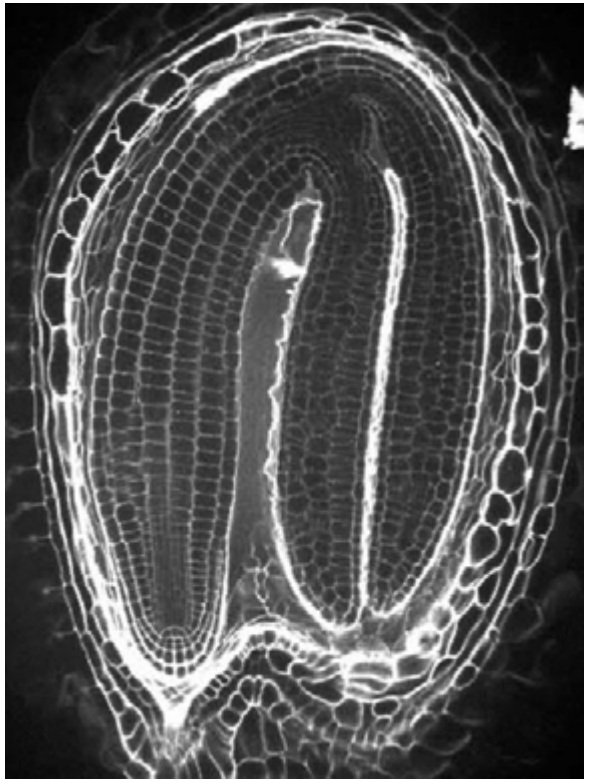
Dermatogen stage **Early globular stage** **Triangular embryo stage**

Capron et al., *Arabidopsis Book* (2009)



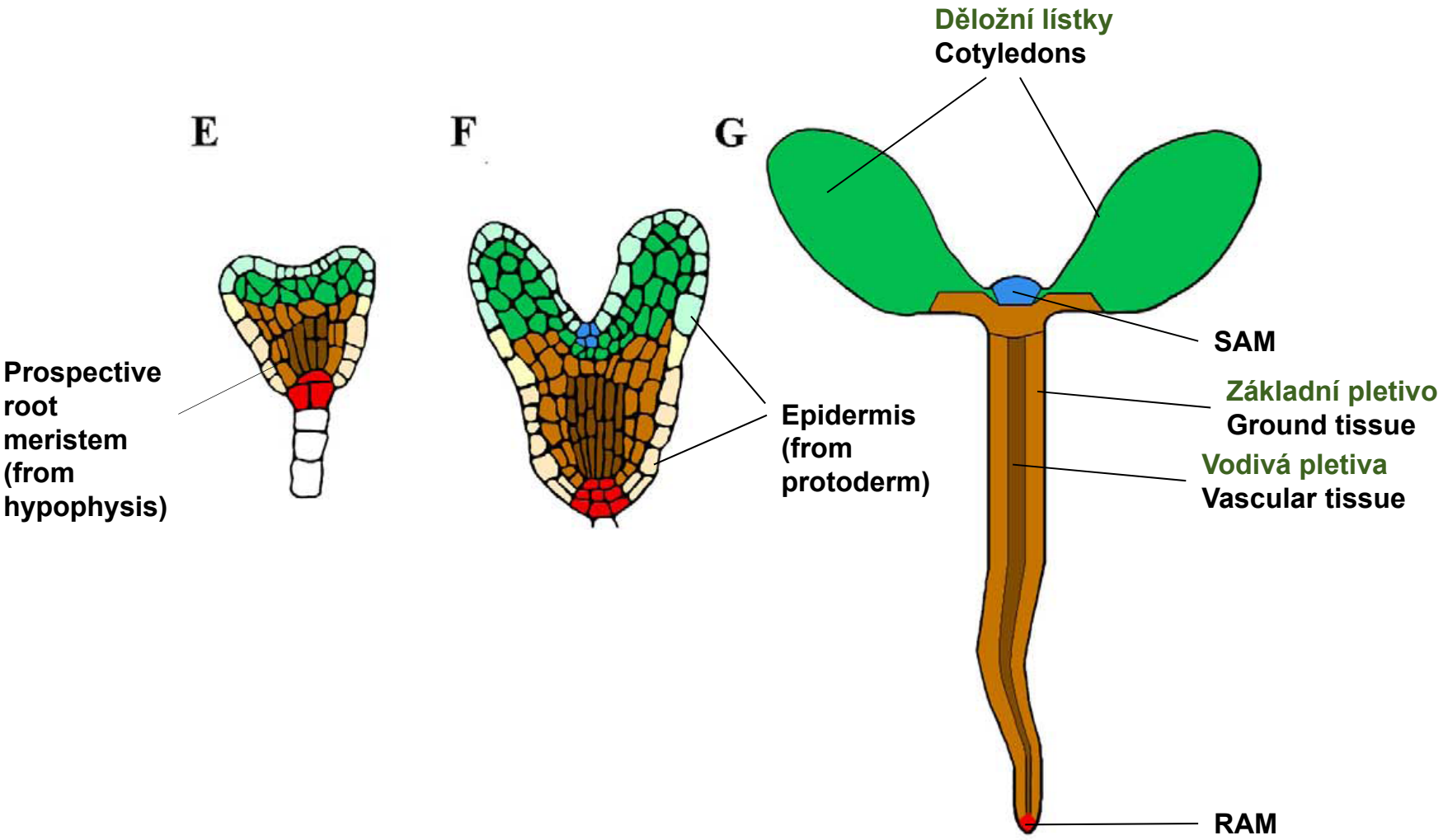
Heart stage

Topedo stage



Bended cotyledon stage

Capron et al., *Arabidopsis Book* (2009)



Capron et al., *Arabidopsis Book* (2009)

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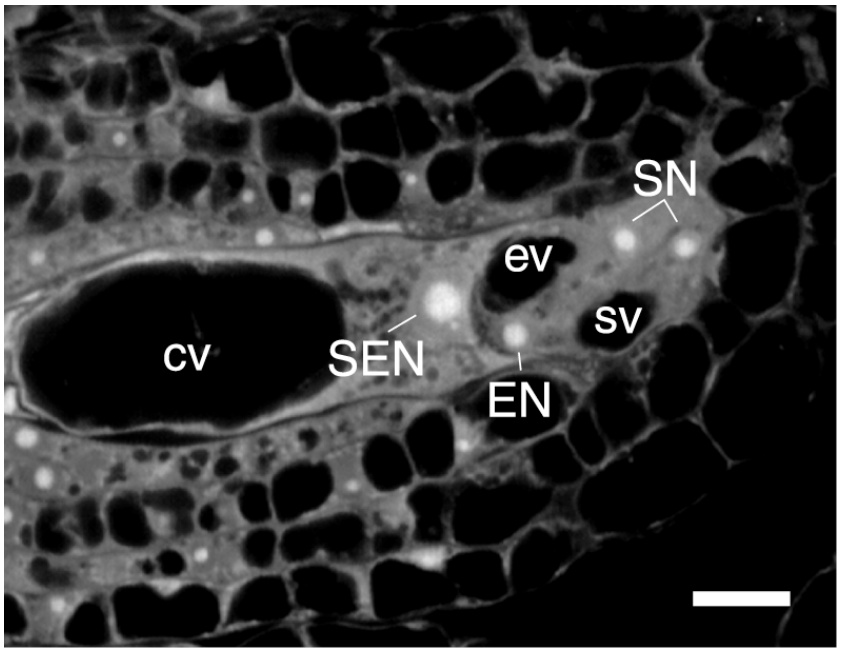
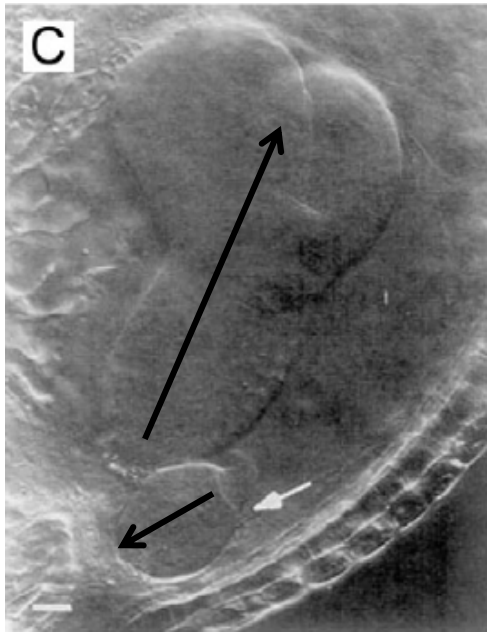
Proximal ← ***Distal***

WT



Hejátko et al., *Mol Genet Genomics* (2003)

twin

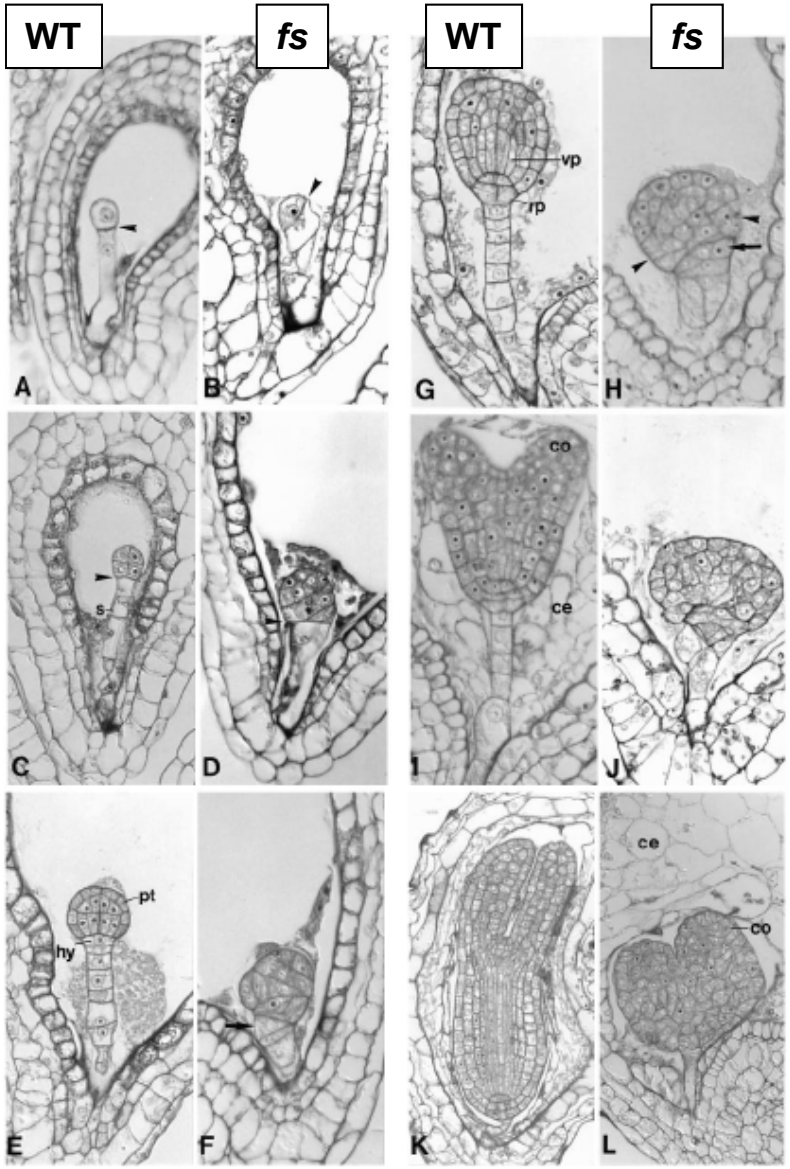


Proximal

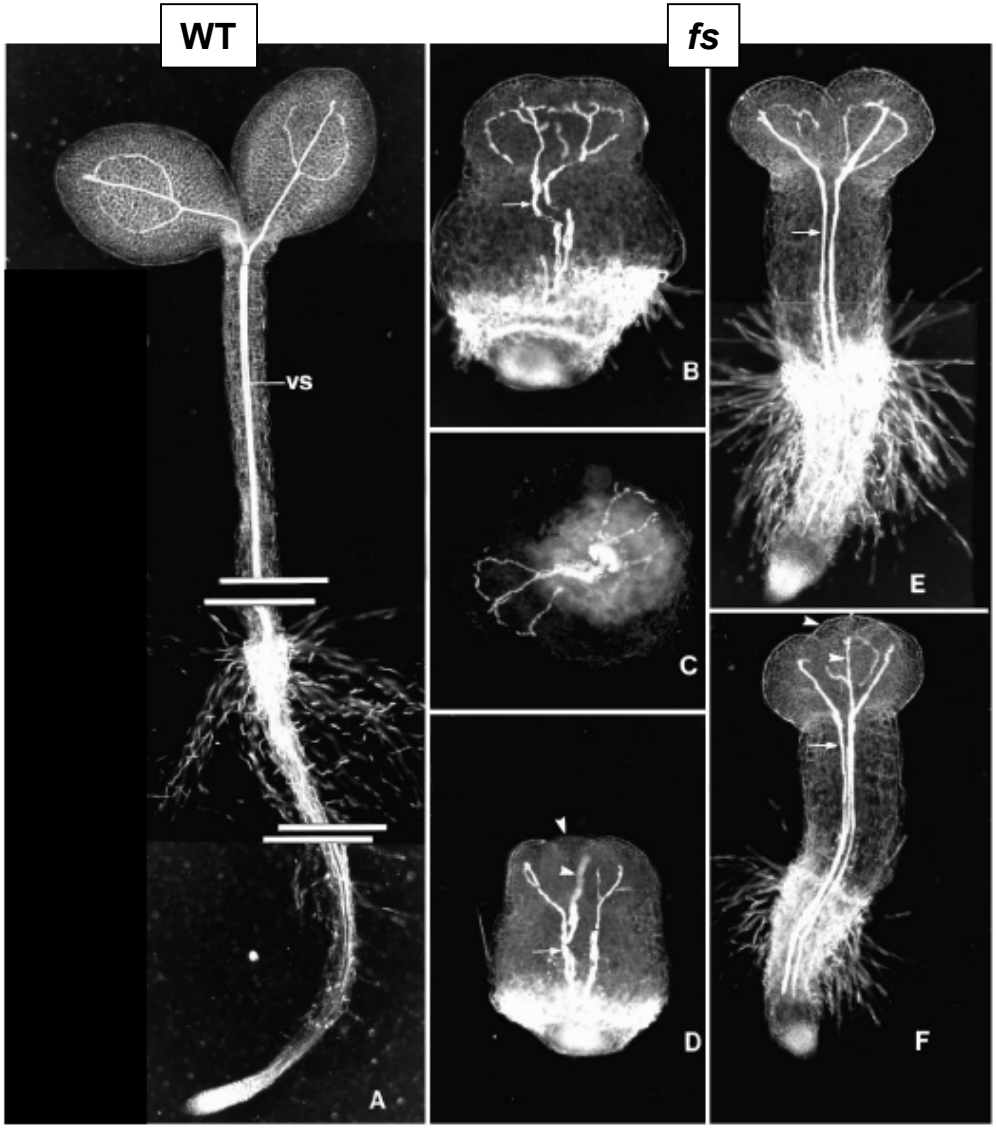
Distal

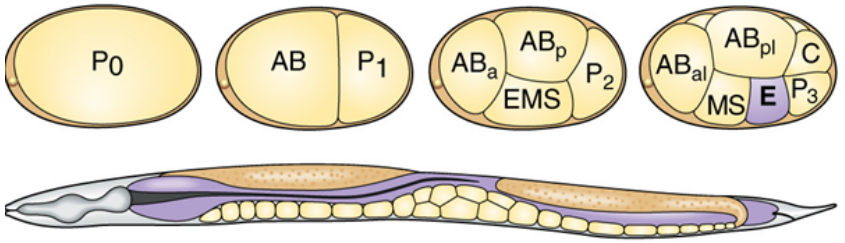
Capron et al., *Arabidopsis Book* (2009)

CEITEC



Torres-Ruiz and Jurgens, *Development* (1994)





Torres-Ruiz and Jurgens, *Development* (1994)

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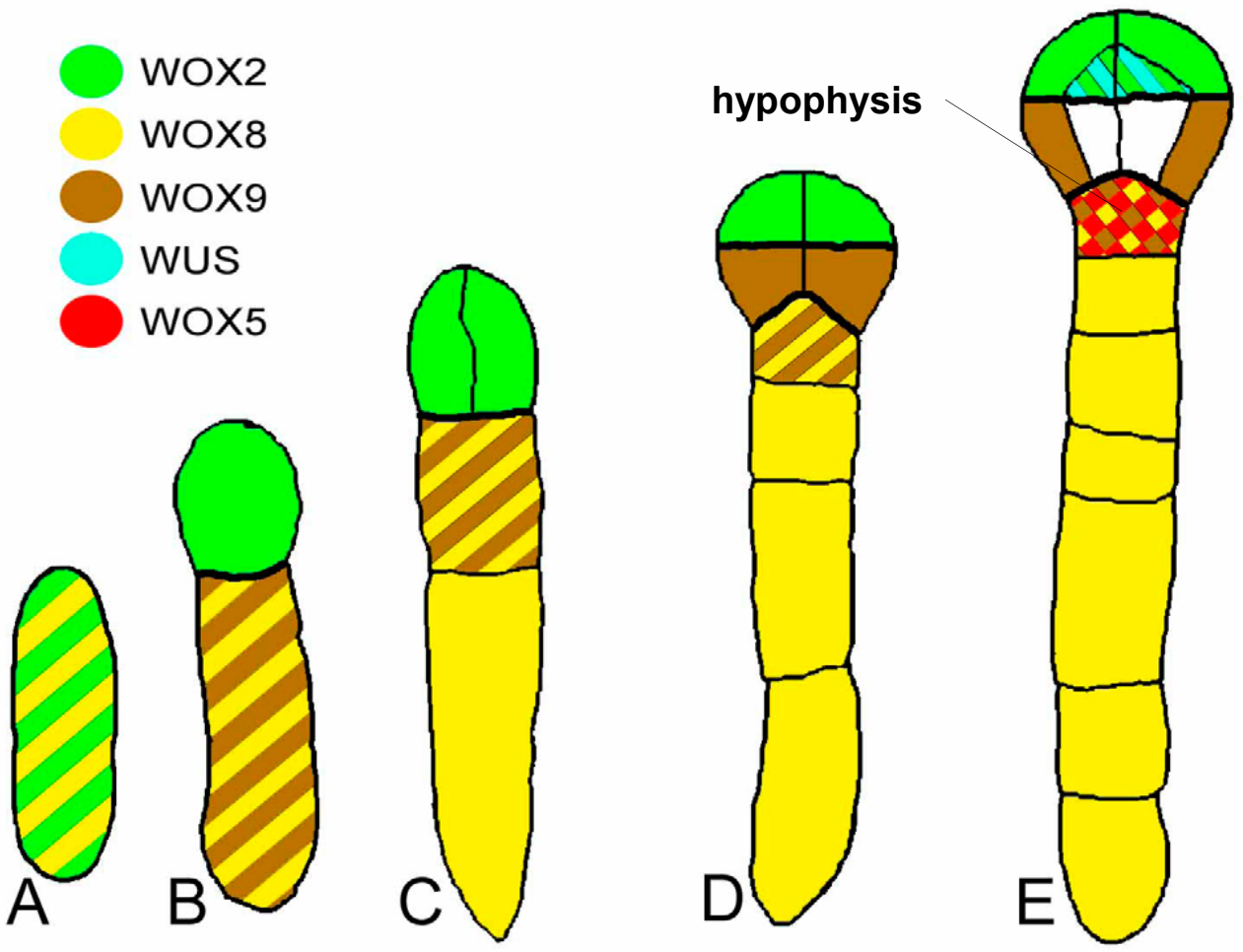
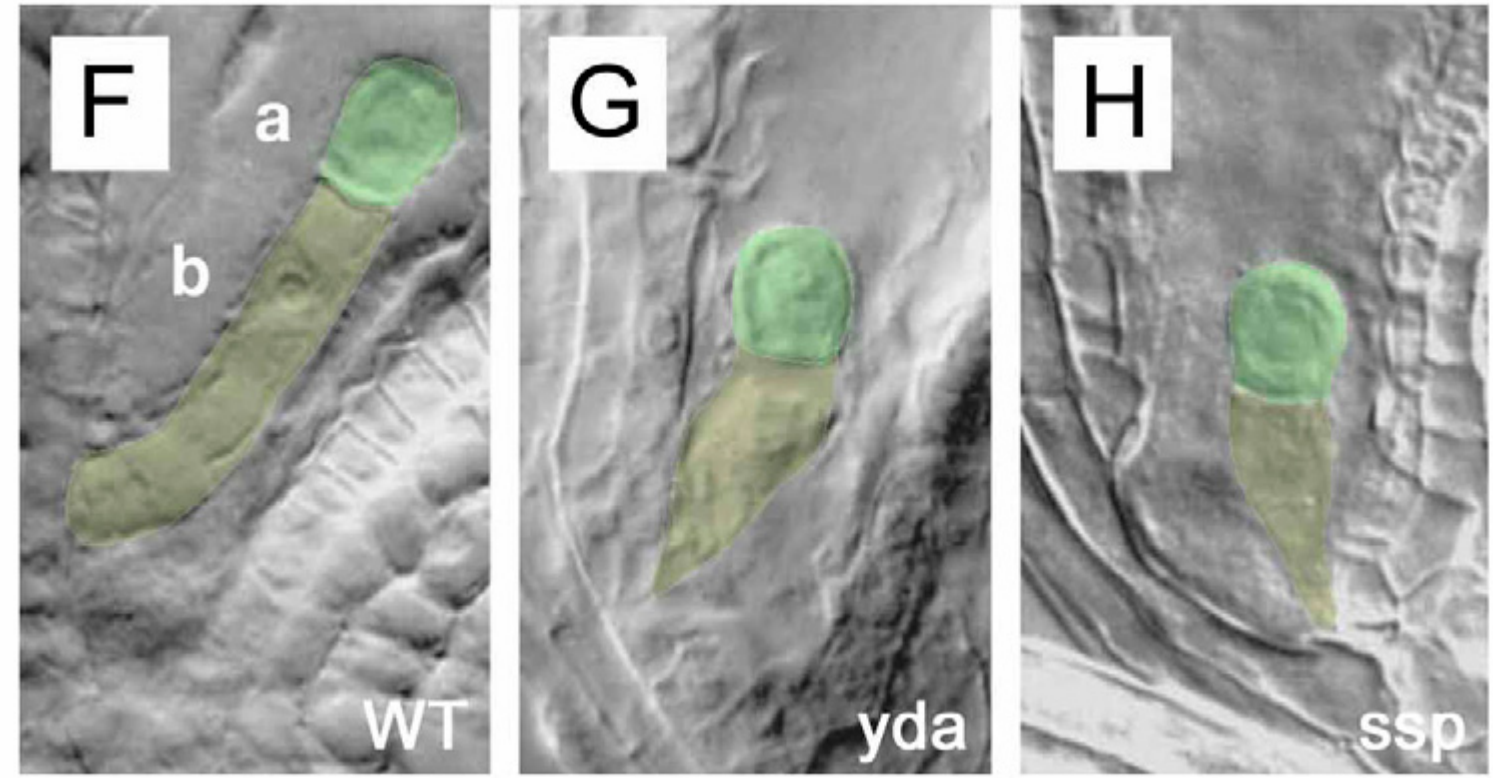
  - differential gene expression

*Differential expression of **WUSCHEL-RELATED HOMEOBOX** (**WOX**) gene family*



Capron et al., *Arabidopsis Book* (2009)

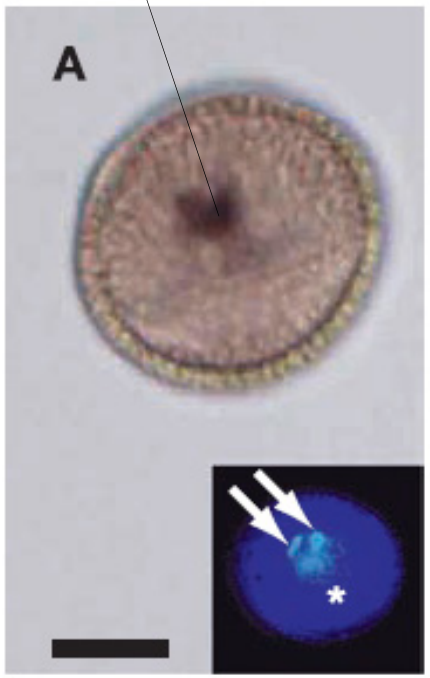


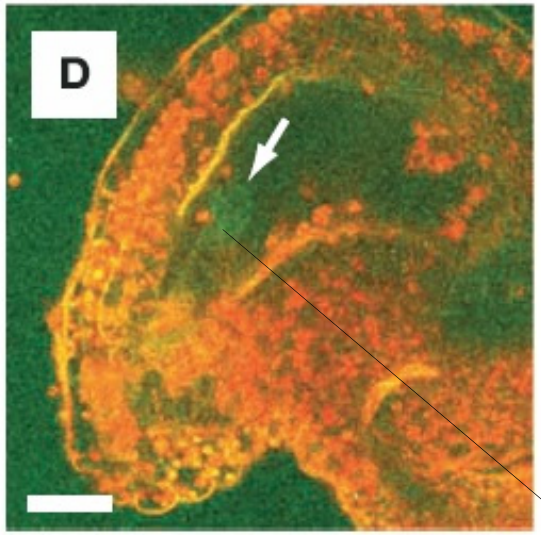
YODA (YDA)
mitogen-activated protein kinase kinase (MAPKK)

SHORT SUSPENSOR (SSP)
interleukin-1 receptor–associated kinase (IRAK)/Pelle-like kinase

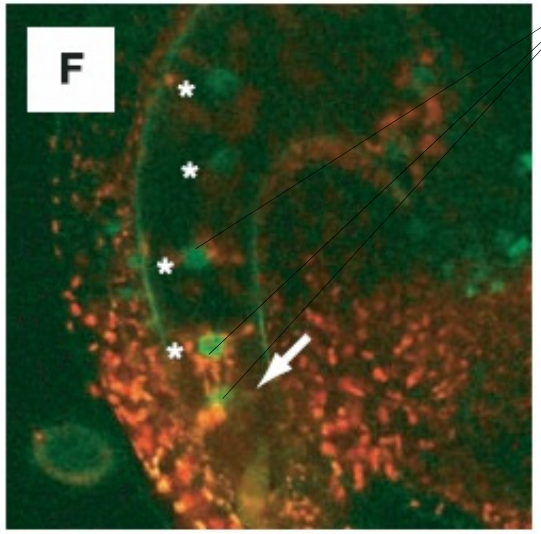
Capron et al., *Arabidopsis Book* (2009),

***SSP* mRNA *in situ* localization**

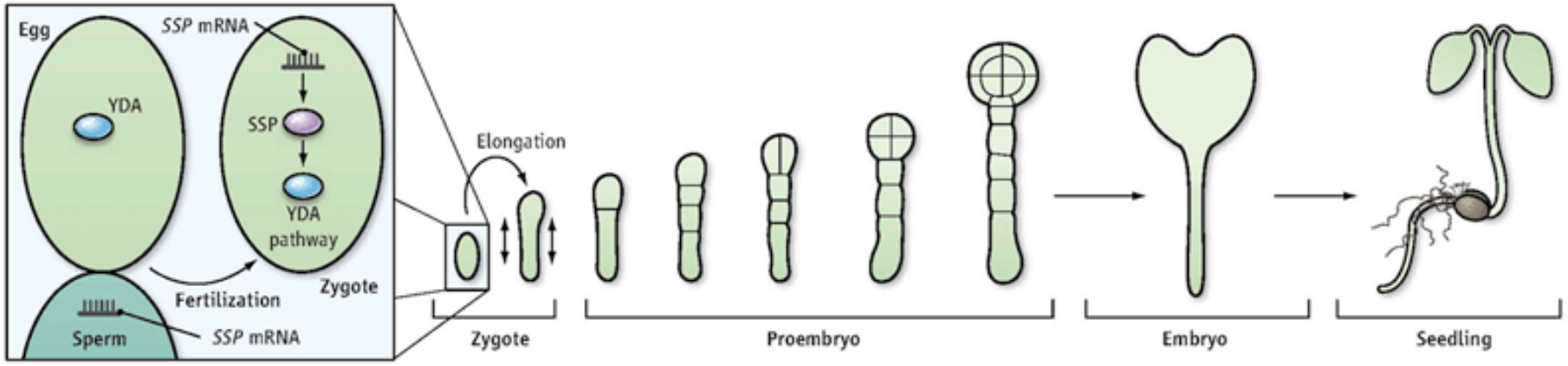




SSP-YFP



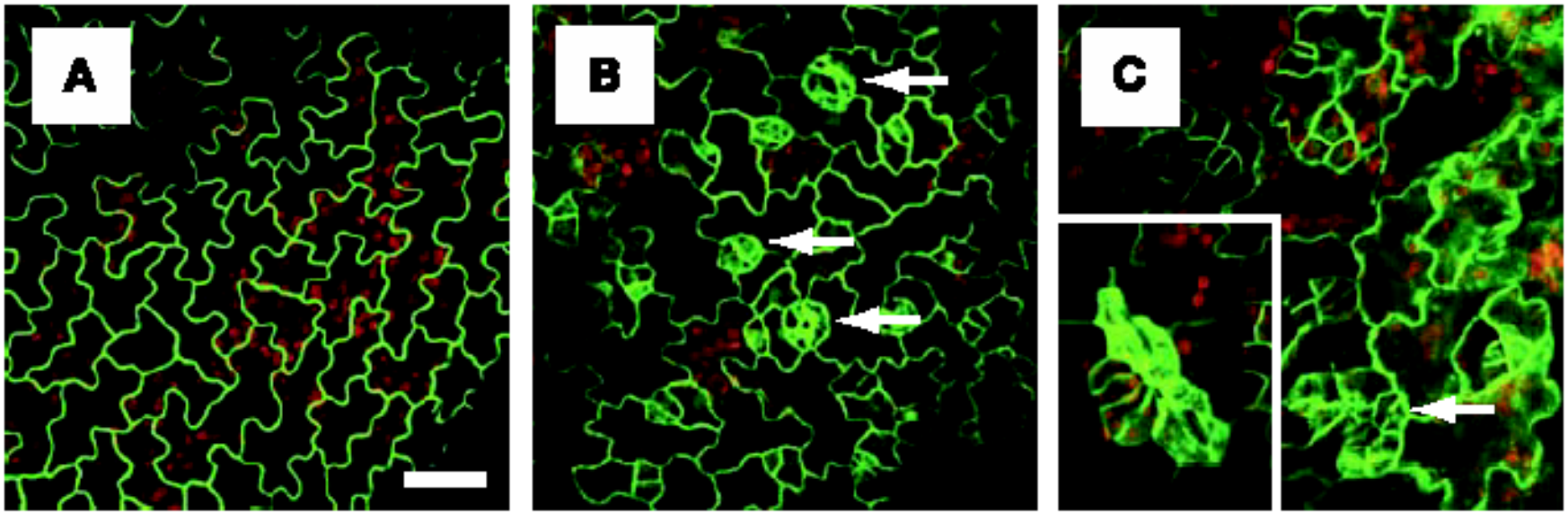
Bayer et al., *Science* (2009)



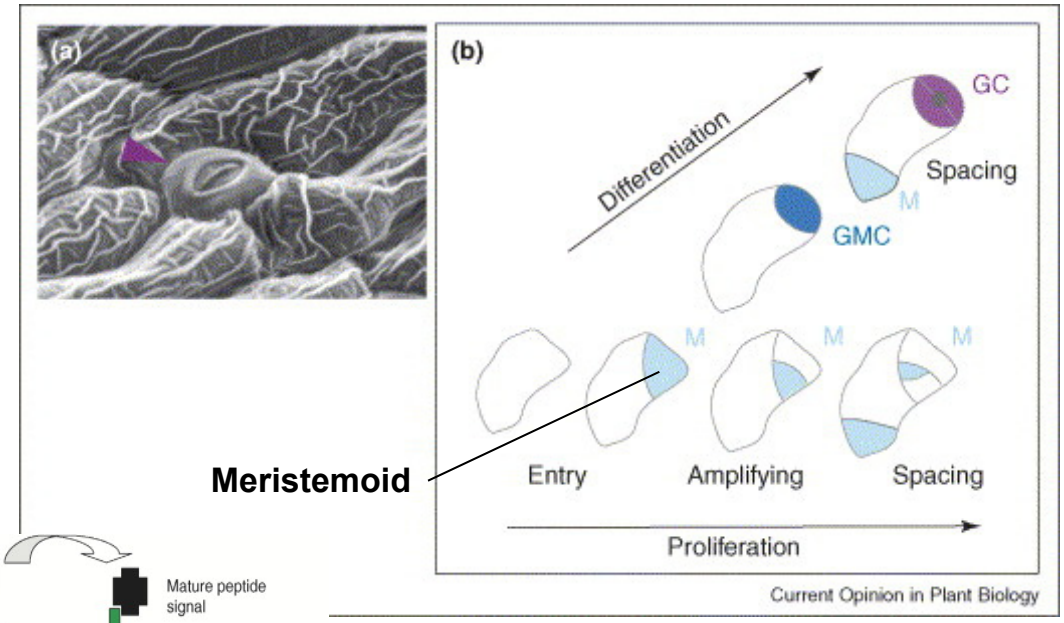
Grossniklaus, *Science* (2009)

myristoylation-deficient variant

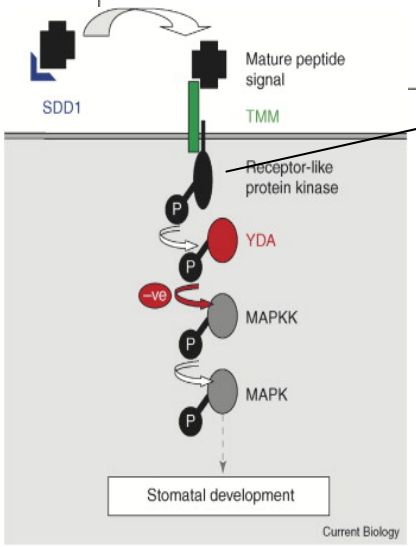
Pro35S:SSP-YFP/WT ***Pro35S:ssp-YFP/WT*** ***Pro35S:SSP-YFP/yda***



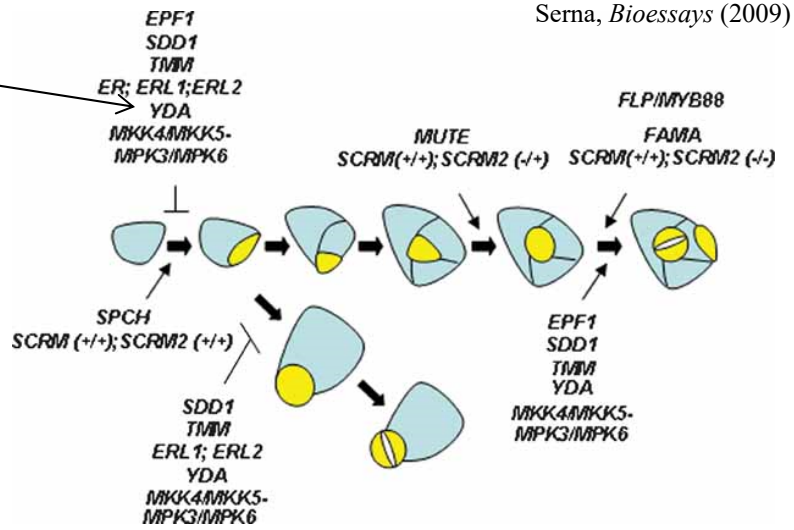
Bayer et al., *Science* (2009)



Meristemoid



SSP



Serna, *Bioessays* (2009)

Bergmann, *Curr Opin Plant Biol* (2006)

Gray and Hetherington, *Curr Biol* (2004)

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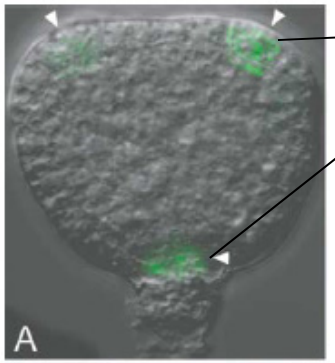
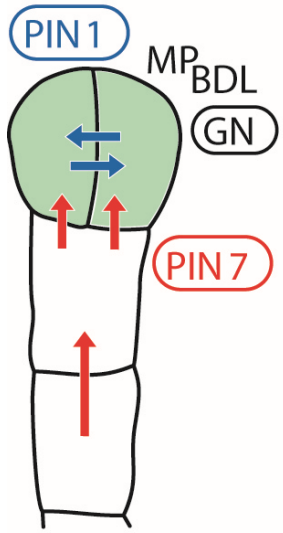
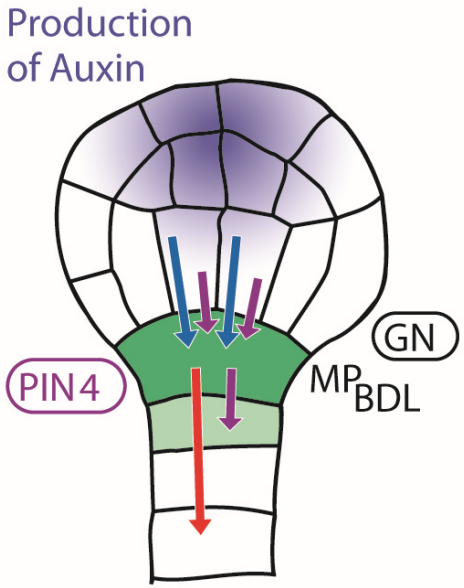
  - differential gene expression
  - auxin gradients formation

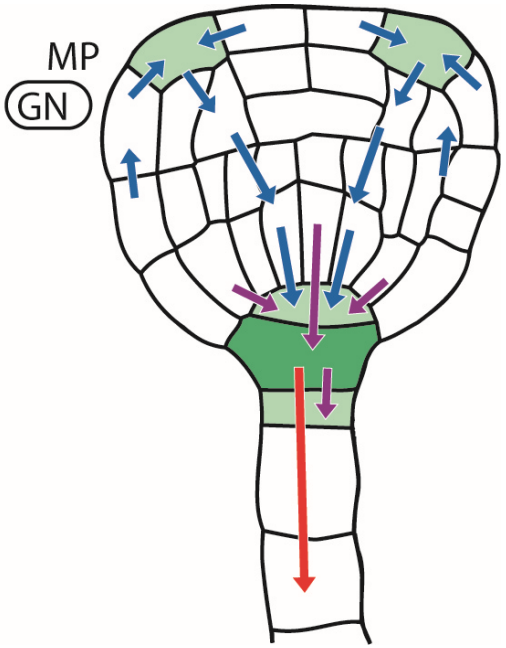


DR5:GFP

Immunodetetcion of IAA

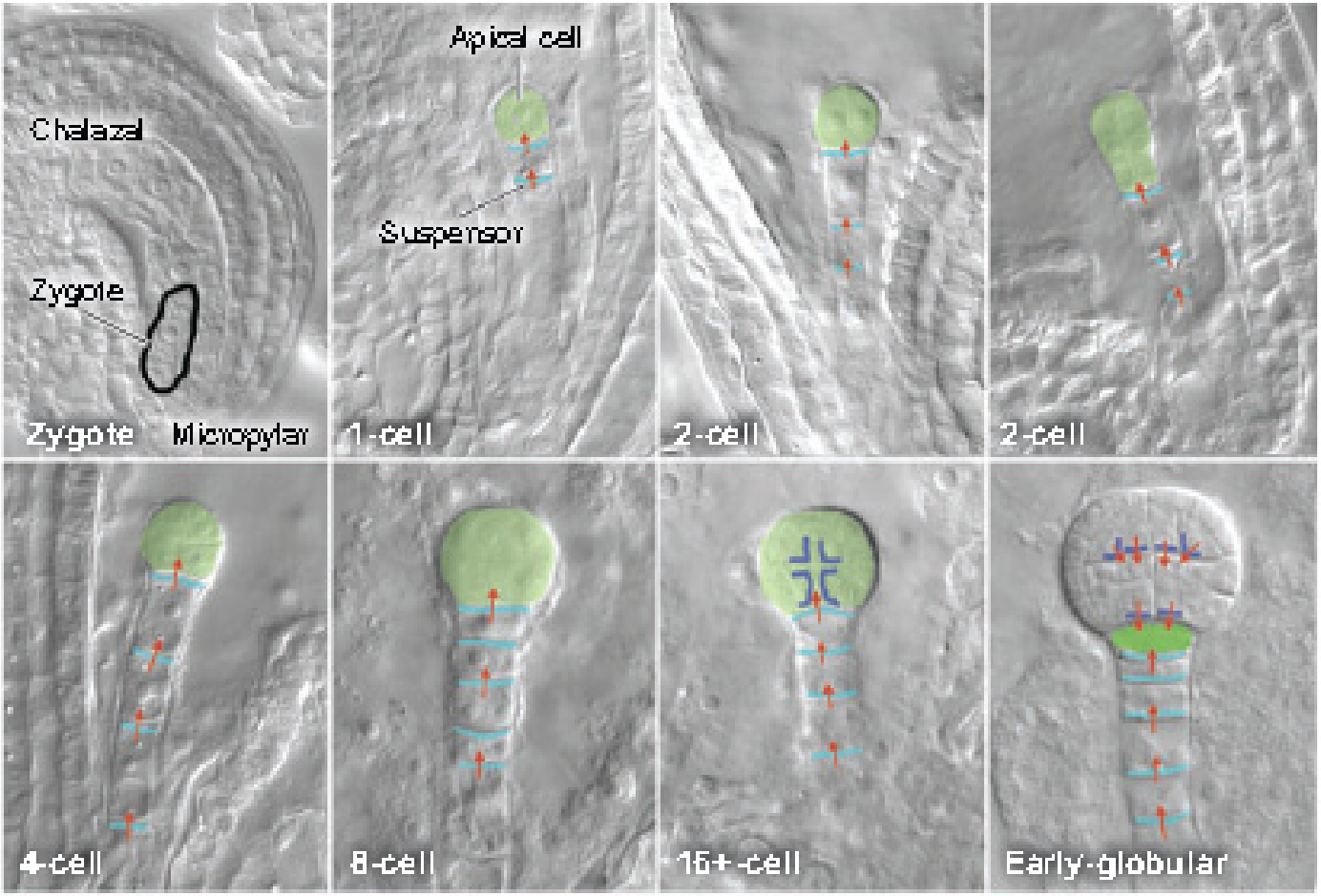




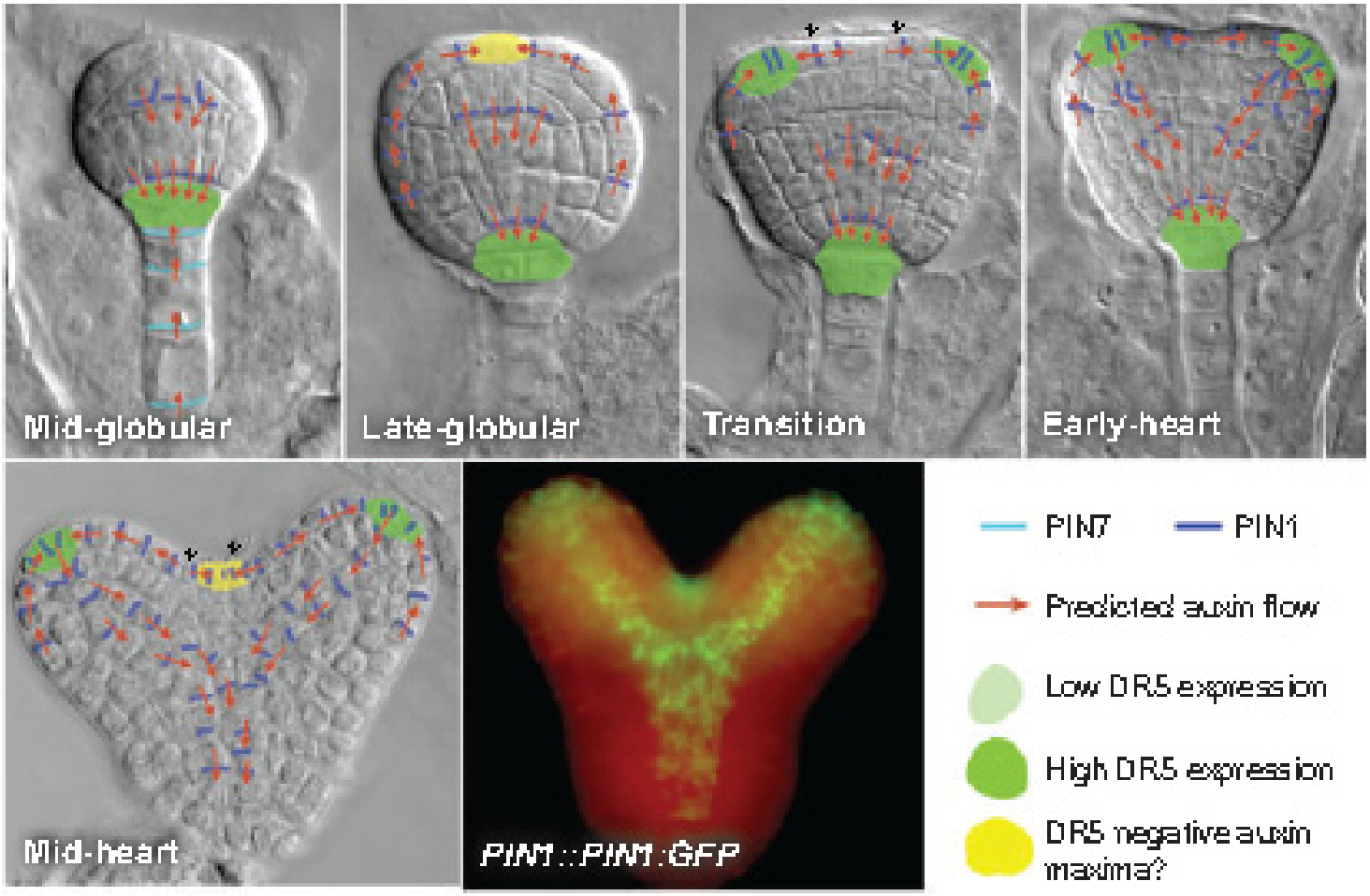


Benkova et al., *Cell* (2003)

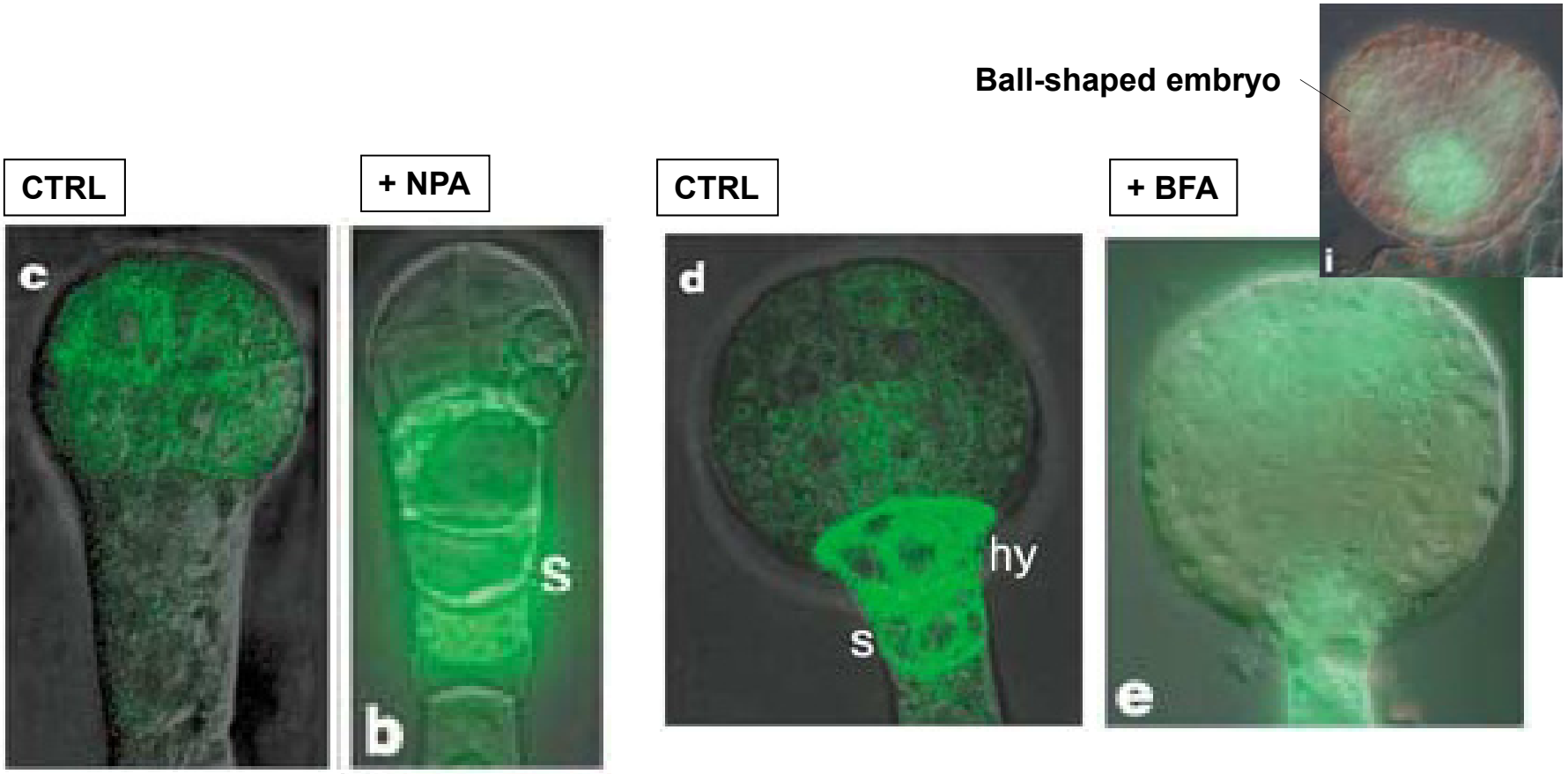
Dubova, Hejatko, Friml (2005)



Bowman et al., *Annu. Rev. Plant. Biol* (2008)



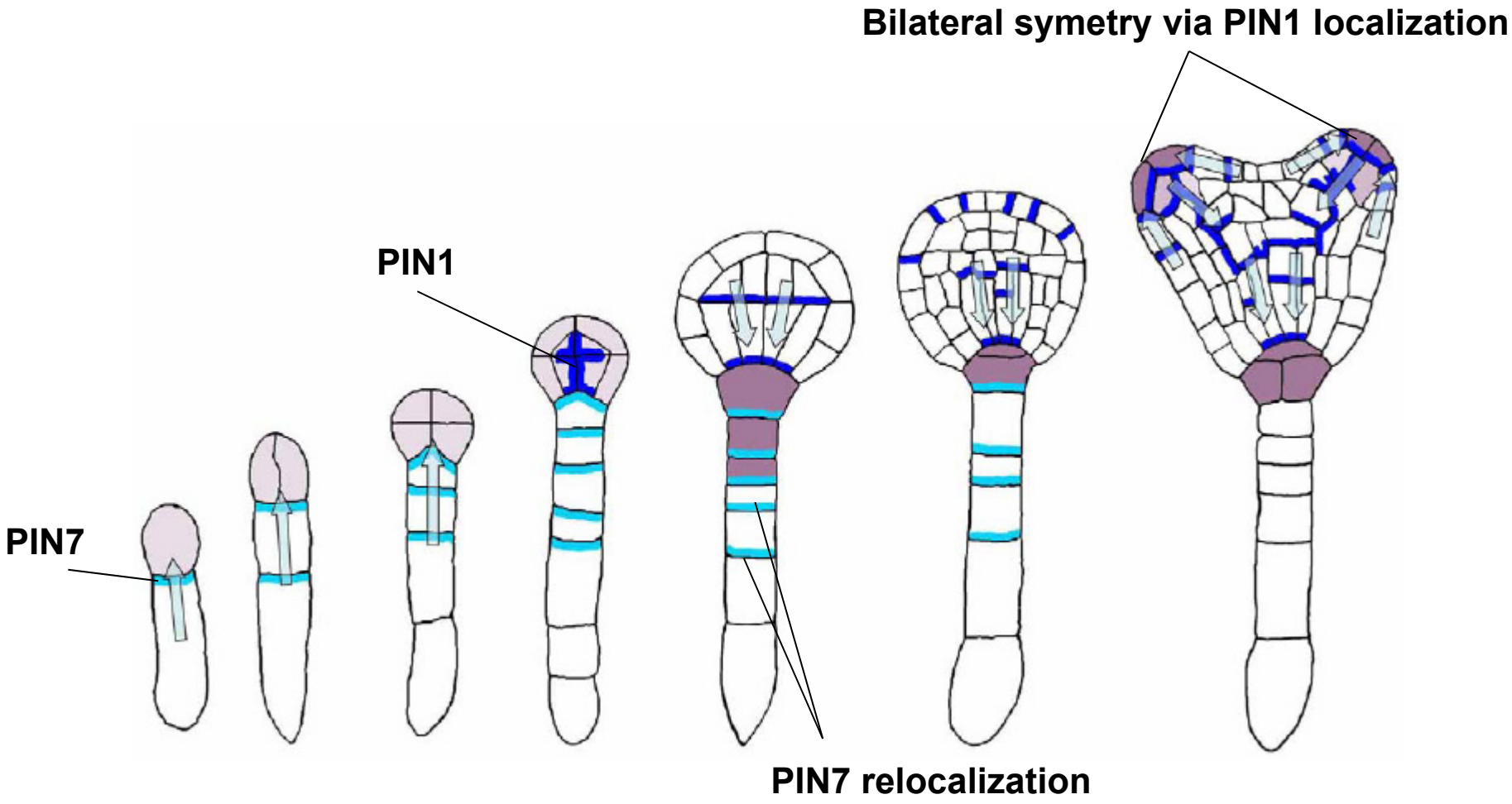
Bowman et al., *Annu. Rev. Plant. Biol* (2008)



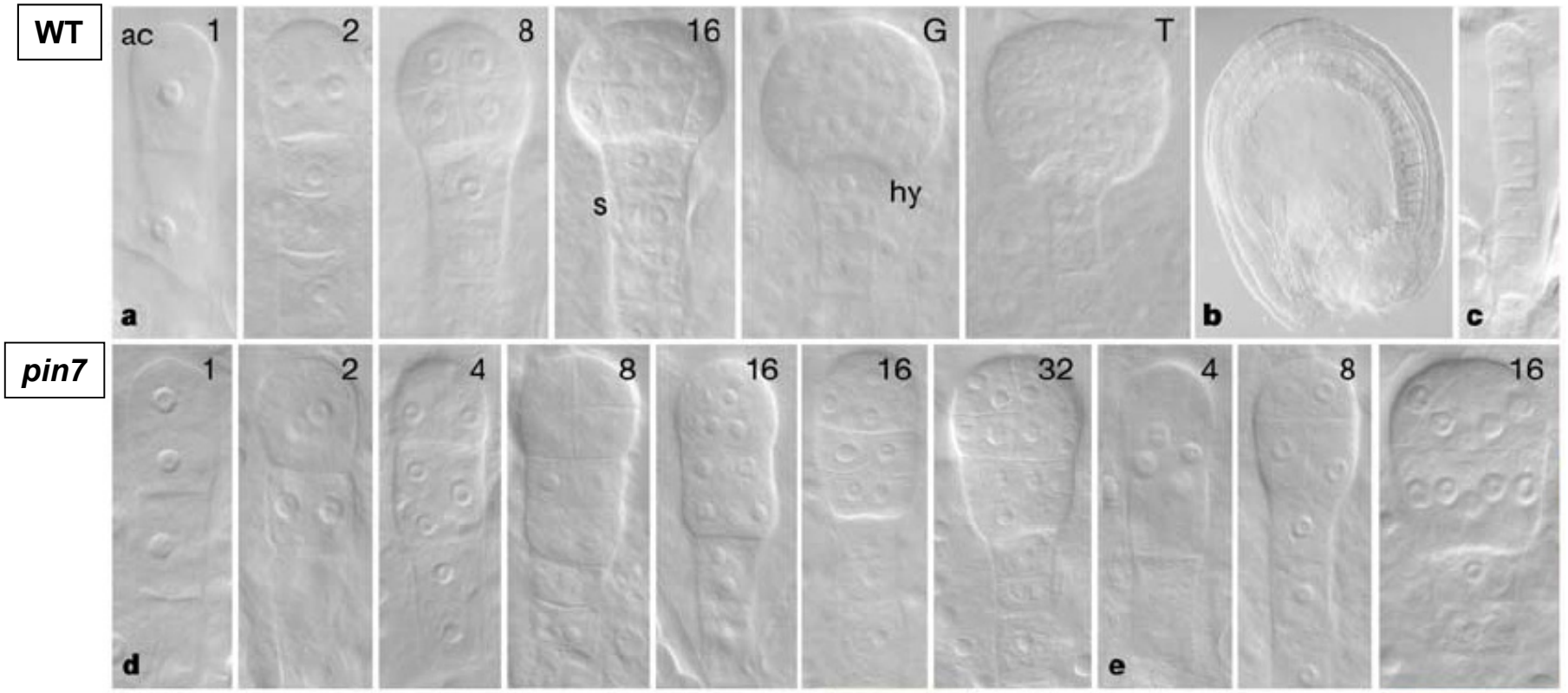
octant stage

globular stage

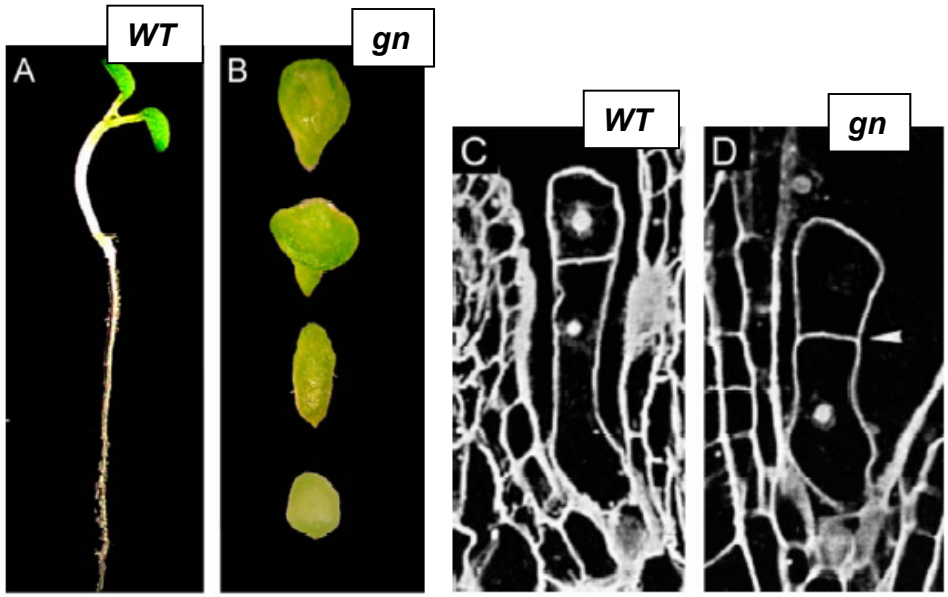
Friml, *Nature* (2003)



Capron et al., *Arabidopsis Book* (2009)



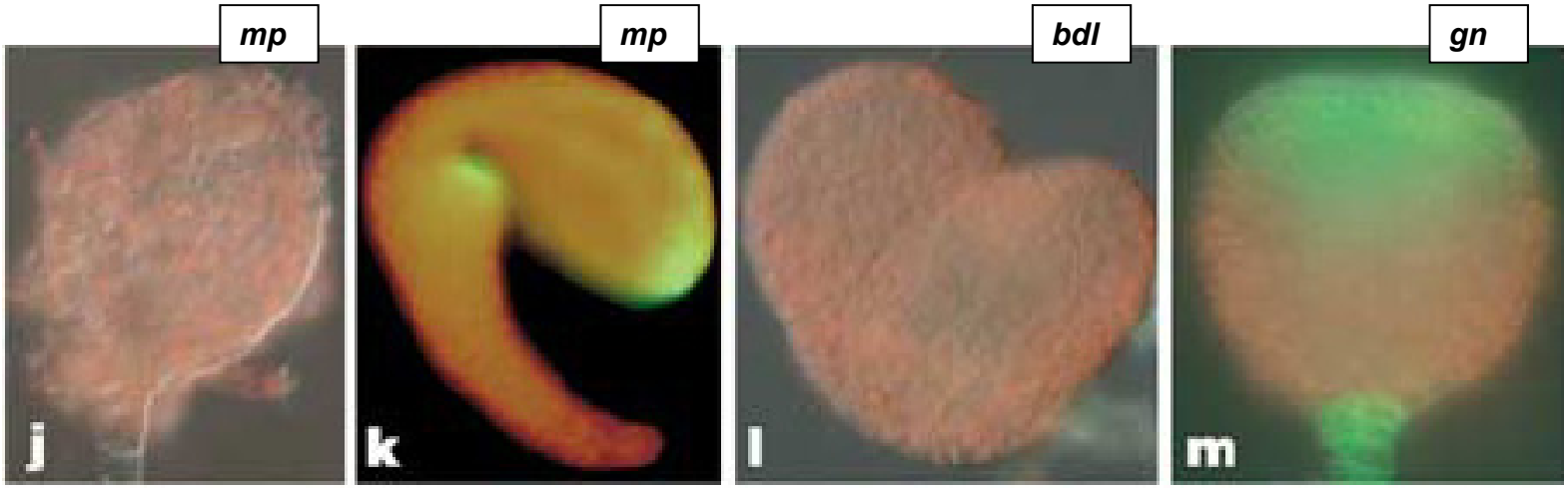
Friml et al., *Nature* (2003)



Richter et al., *E J Cell Biol* (2010)

Mutations affecting embryo patterning are associated with changes in the auxin maxima formation

Adenosyl ribosylation factor Guanine nucleotide Exchange Factor (ARF GEF),



Friml et al., *Nature* (2003)

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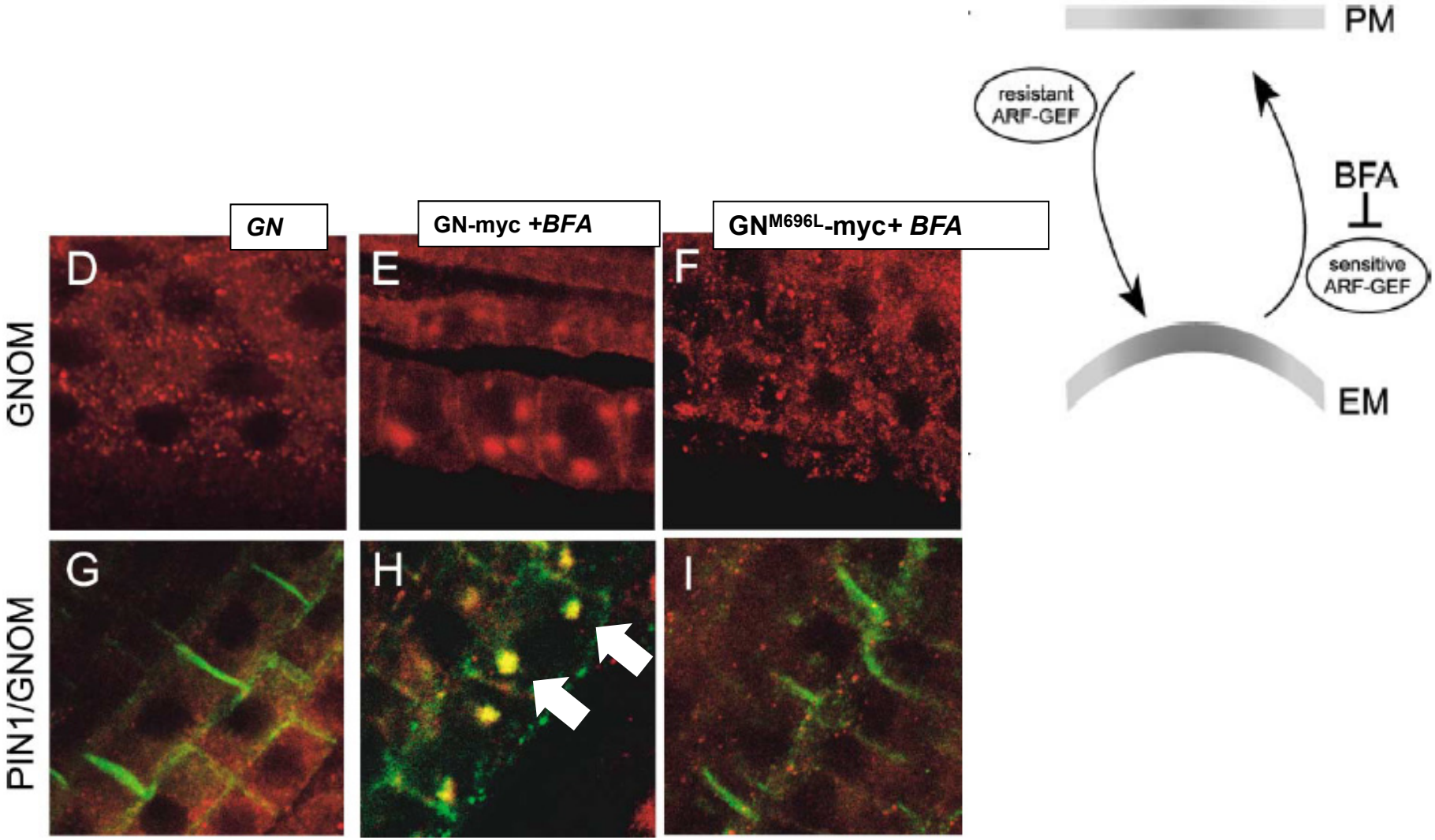
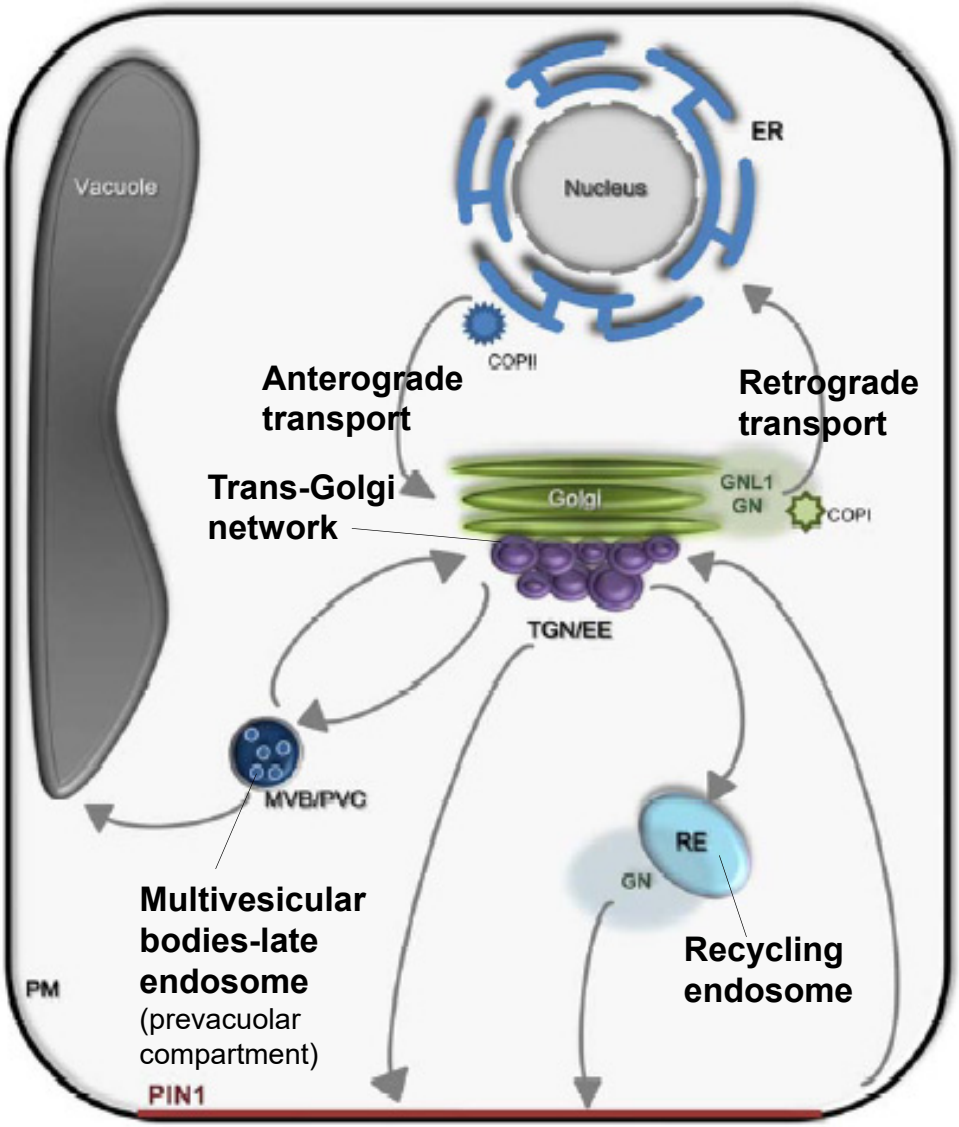
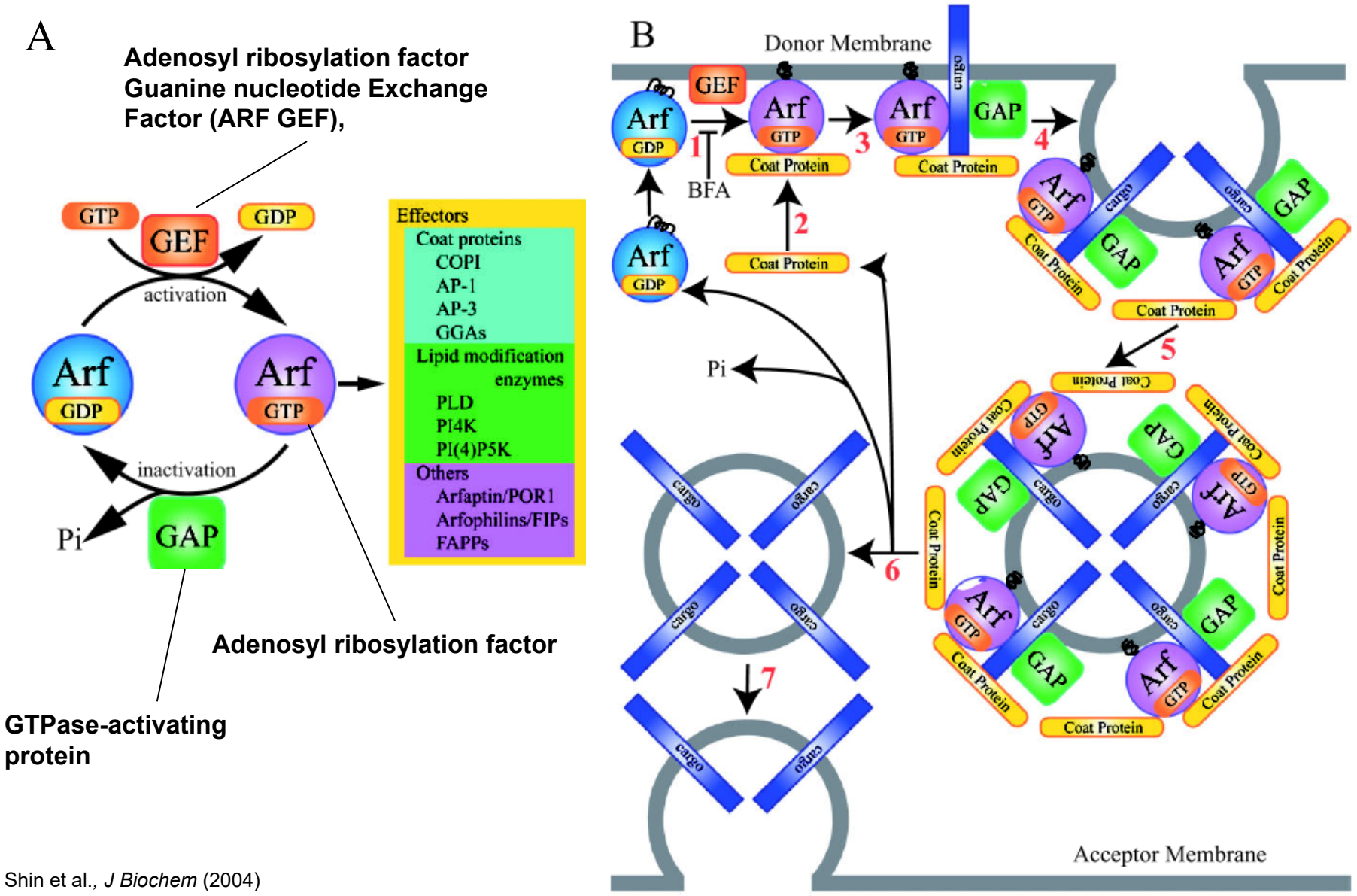


Geldner et al., *Cell* (2003)



Richter et al., *E J Cell Biol* (2010)



Shin et al., *J Biochem* (2004)

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- Overview of the embryo formation in *Arabidopsis*
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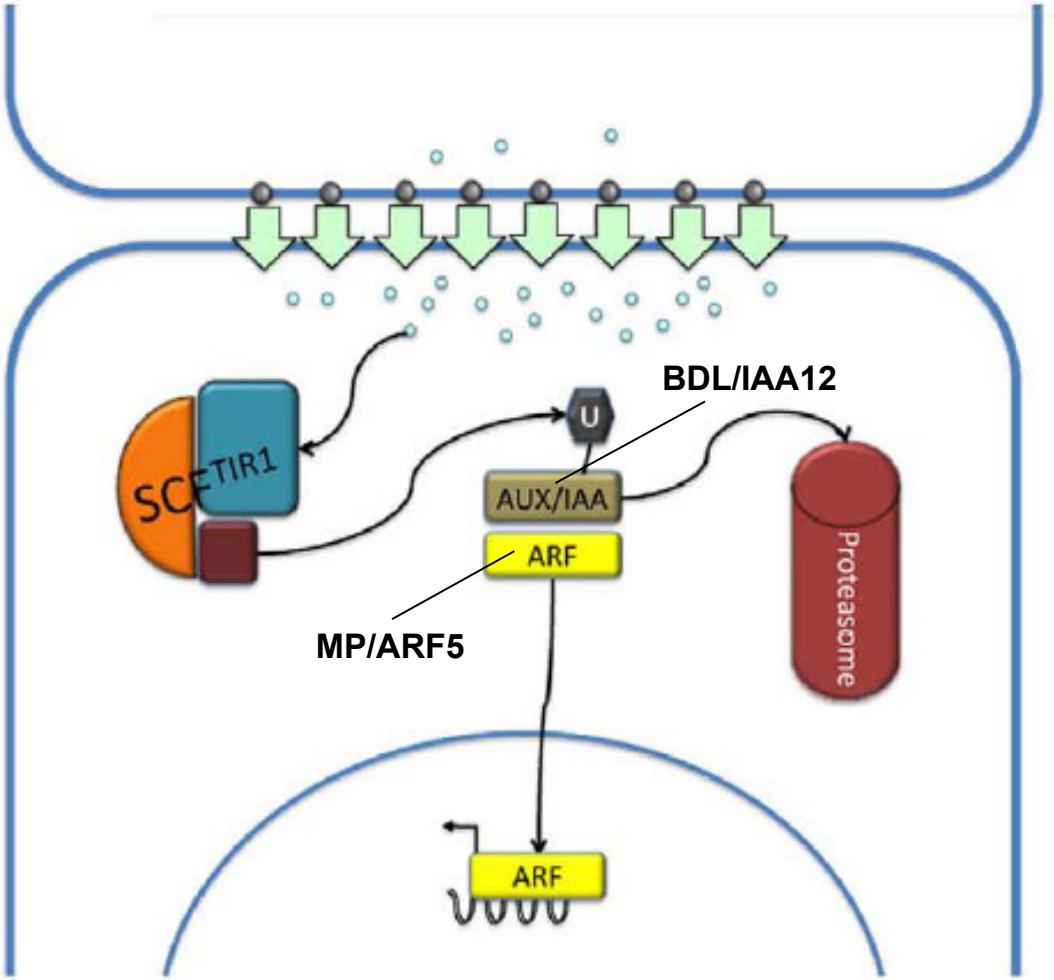
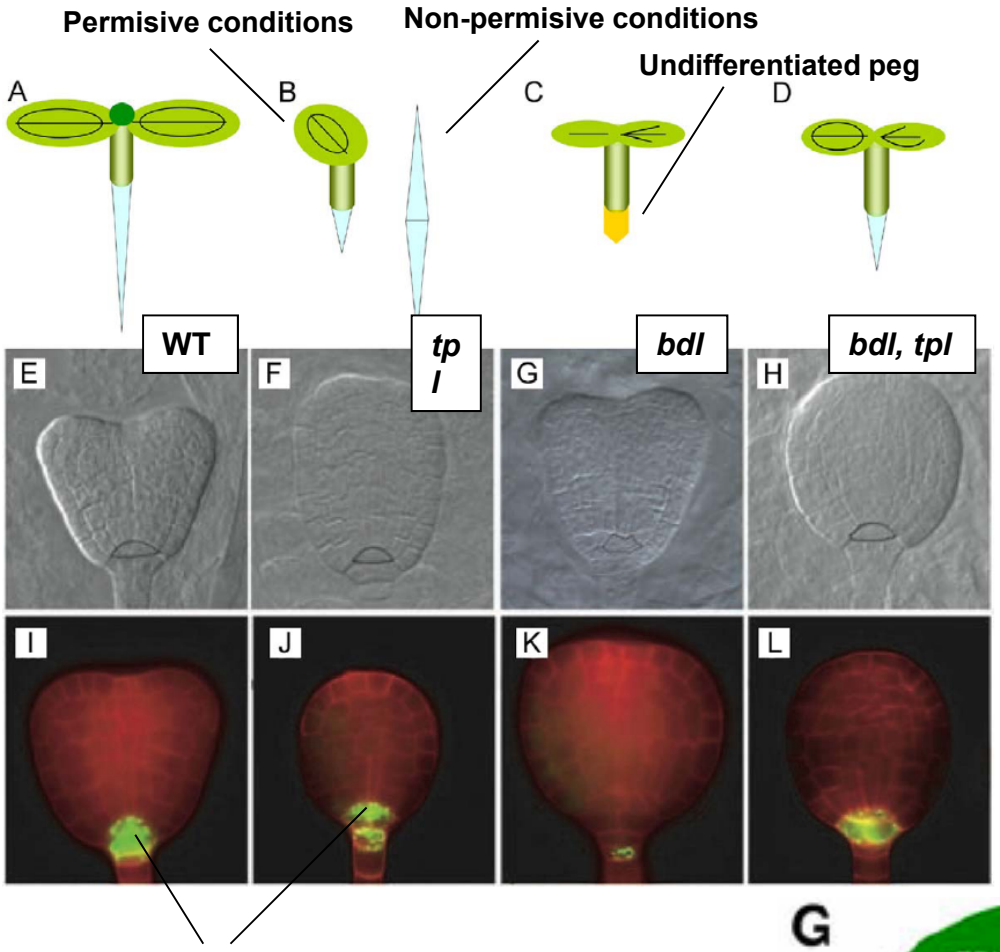
  - differential gene expression
  - auxin gradients formation
  - the role of auxin signalling

Auxin signalling and its role in the embryo patterning

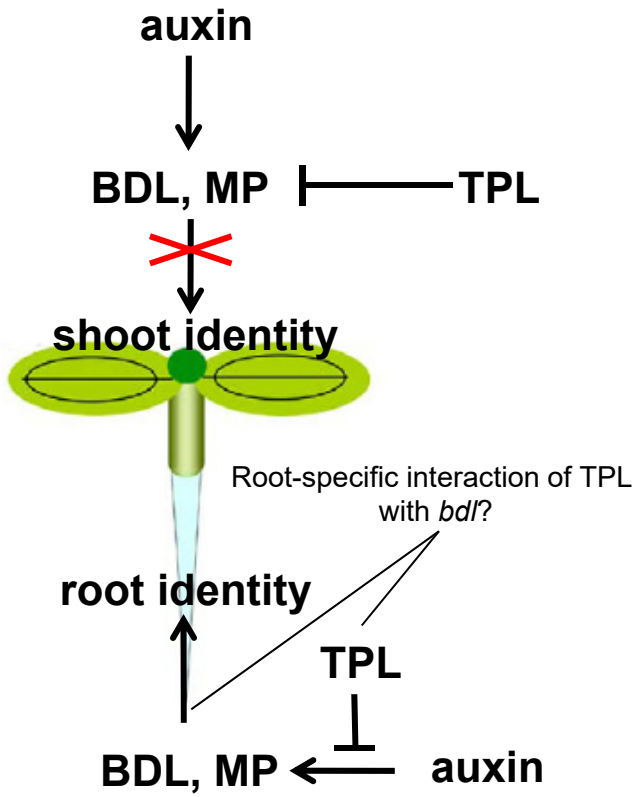


Capron et al., *Arabidopsis Book* (2009)



Auxin maxima in lens shaped cell

Capron et al., *Arabidopsis Book* (2009)



Szemenyei et al., *Science* (2008)

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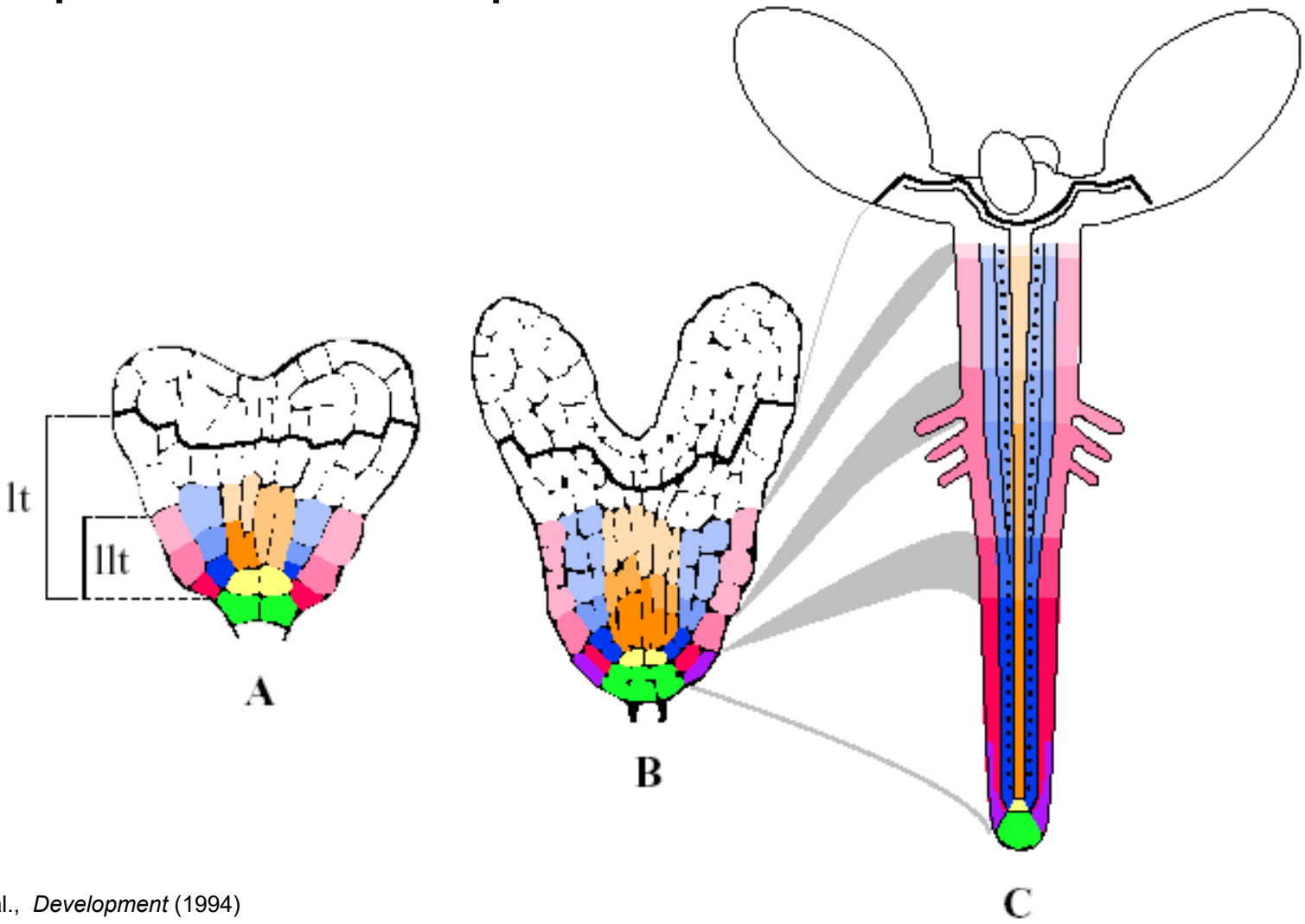
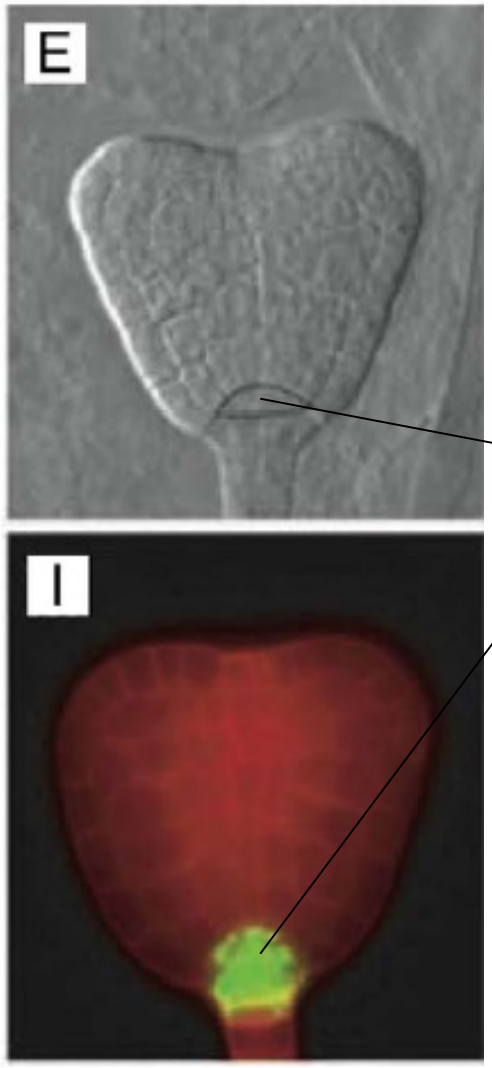
  - auxin gradients formation
  - the role of auxin signalling
- Root meristem formation
  - auxin and hypophysis identity

Root apical meristem develops from the LT descendants



Sheres et al., *Development* (1994)



Lens shaped cell

↓

Klidové centrum
Quiscent centre

↓

Organizational centre for the RAM formation

Capron et al., *Arabidopsis Book* (2009)

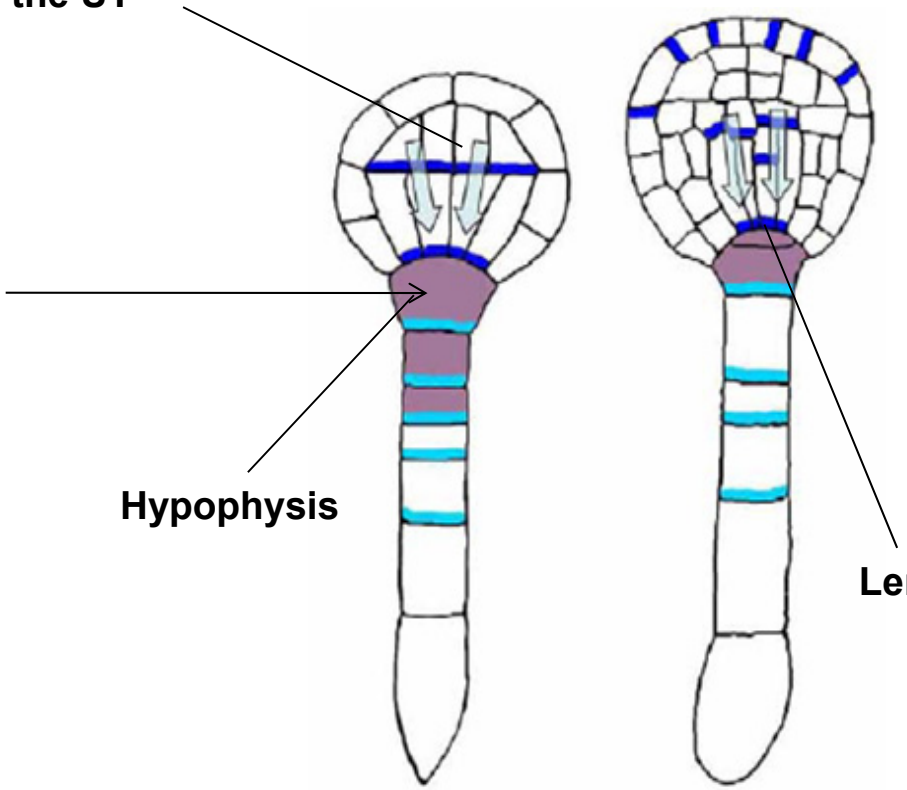
auxin

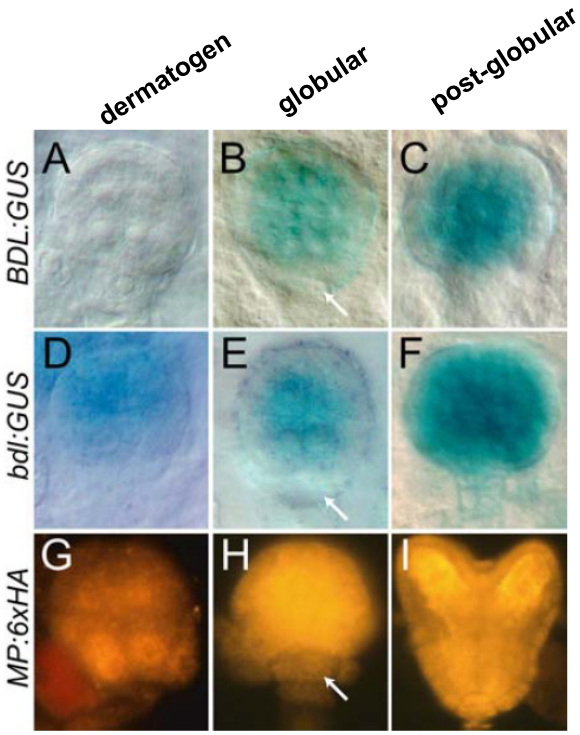
↓

BDL, MP

↓

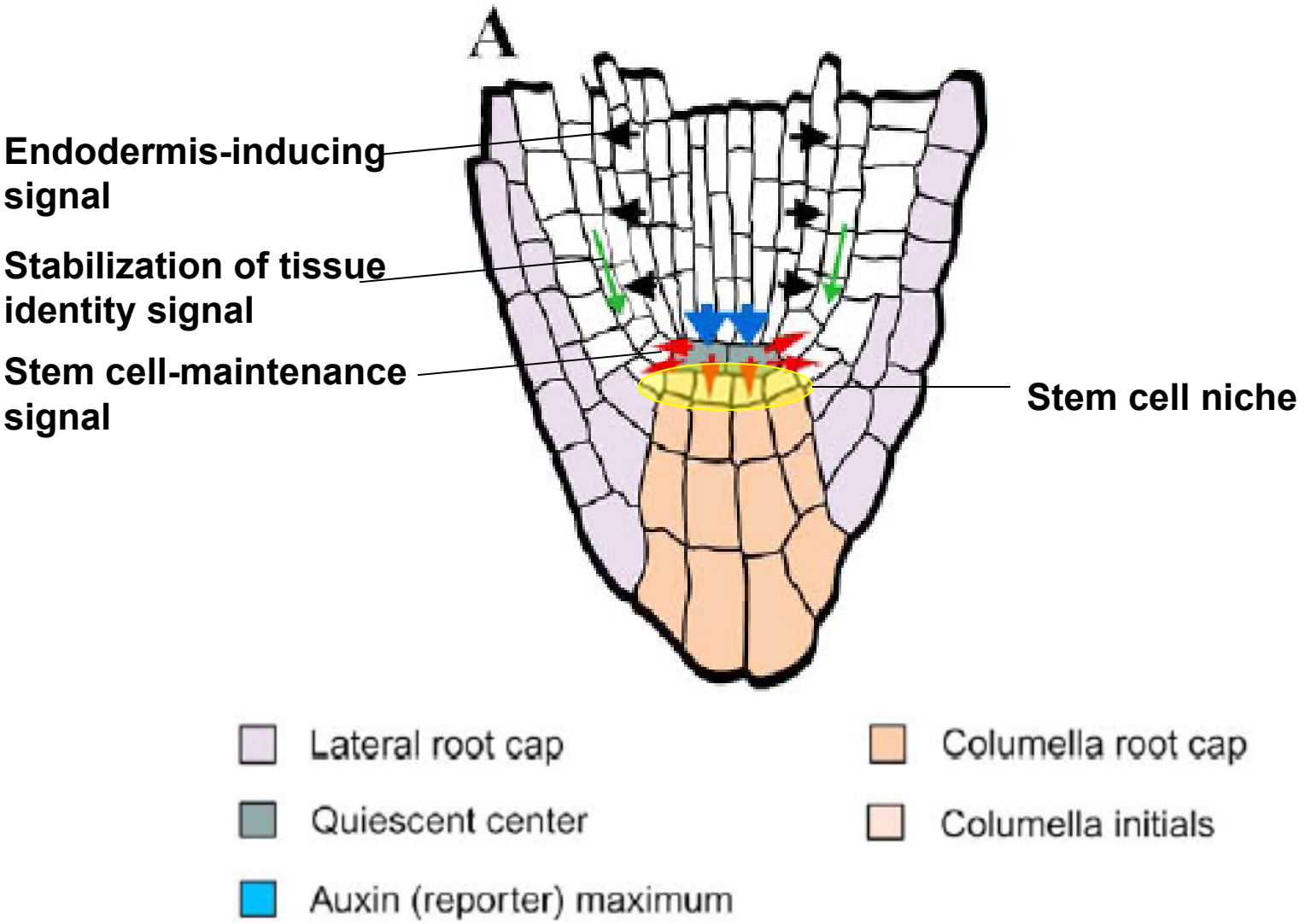
TOM TF





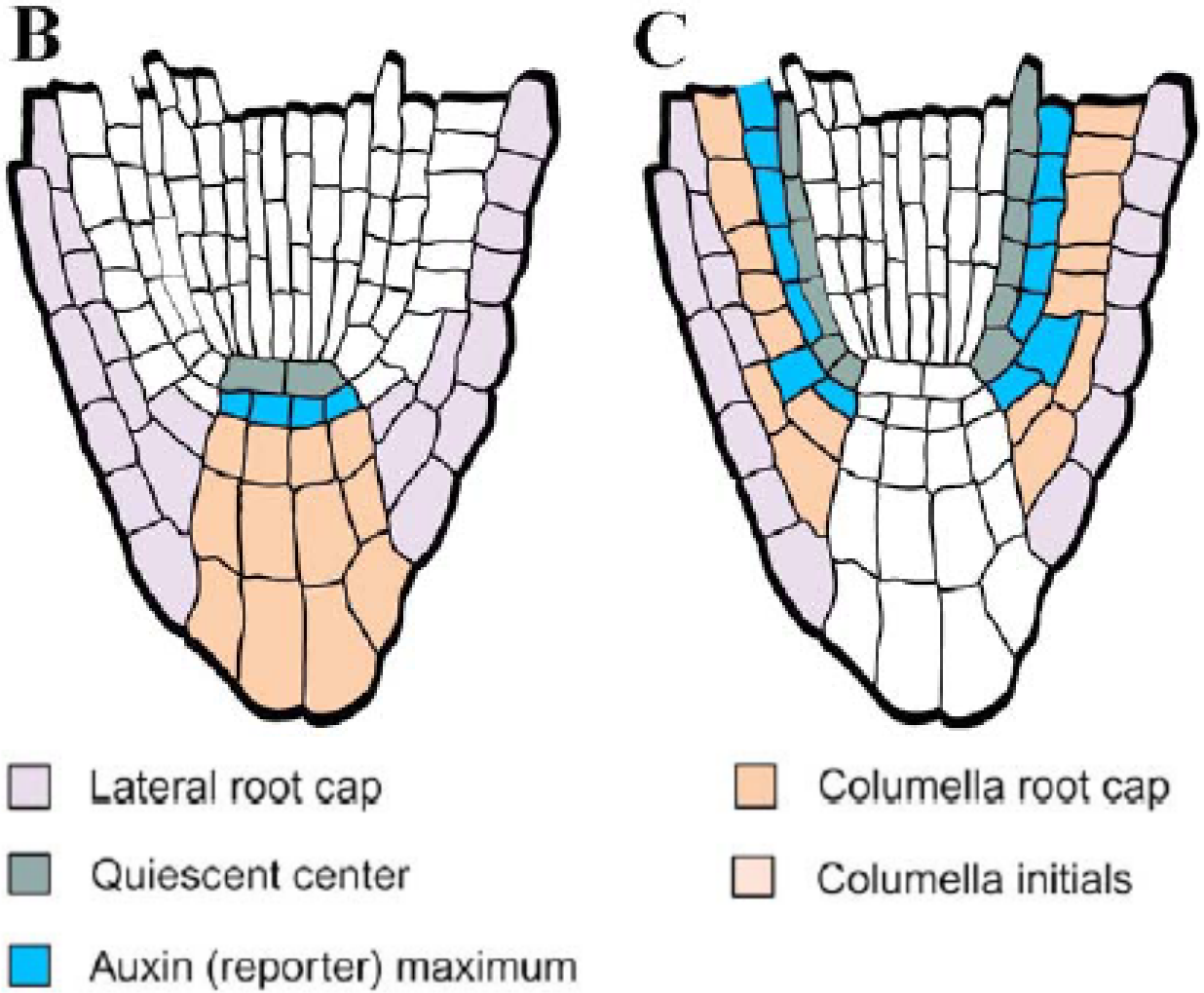
Weijers et al., *Dev Cell* (2006)

Capron et al., *Arabidopsis Book* (2009)



Capron et al., *Arabidopsis Book* (2009)

auxin response maximum displaced



Capron et al., *Arabidopsis Book* (2009)

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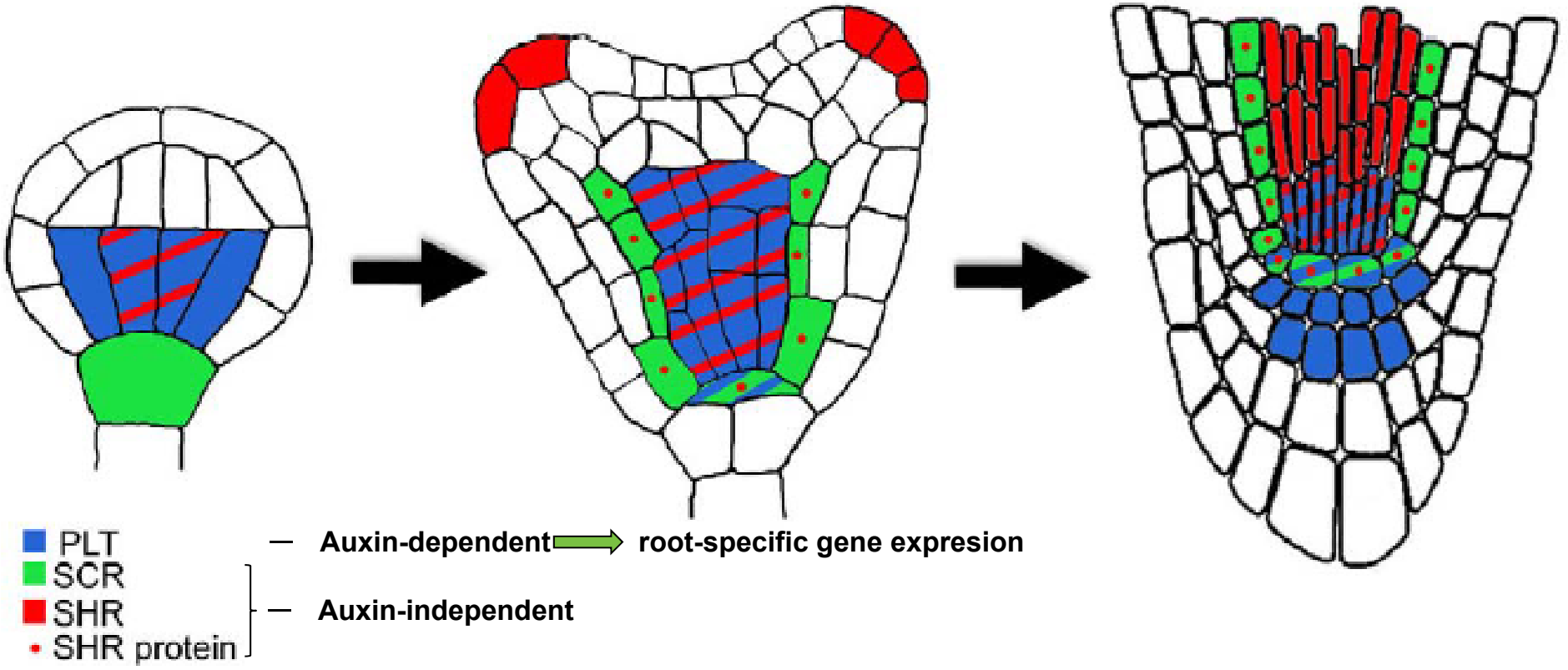
  - the role of auxin signalling
- Roor meristem formation
  - auxin and hypophysis identity
  - differential gene expression and root meristem patterning

Auxin-dependent and auxin-independent differential gene expression patterns root meristem



Capron et al., *Arabidopsis Book* (2009)

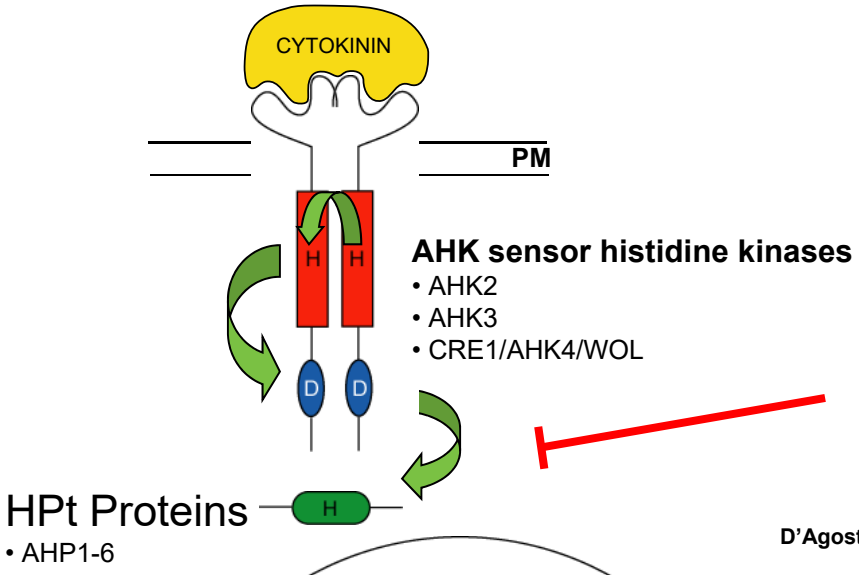
Outline of Lesson 7

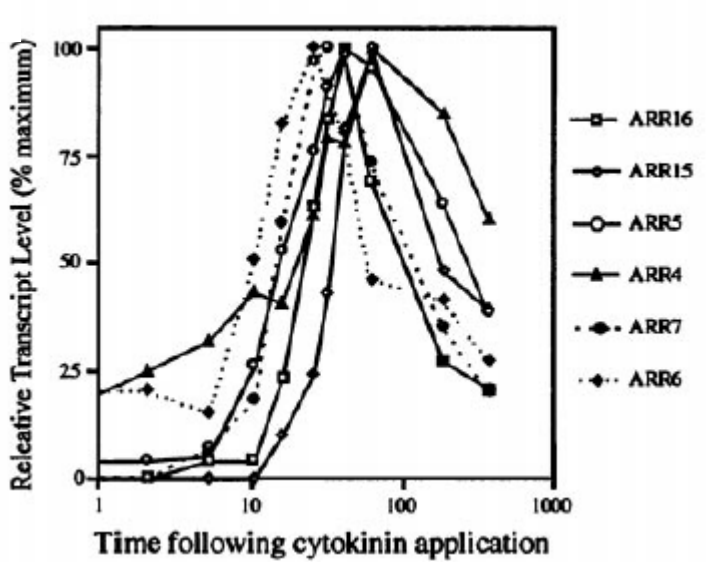
Plant Embryogenesis

- Overview of the embryo formation in *Arabidopsis*
- Mechanism of the apical-basal axis formation
  - invariant cell division or positional information?
  - differential gene expression
  - auxin gradients formation
  - the role of auxin signalling
- Roor meristem formation
  - auxin and hypophysis identity
  - differential gene expression and root meristem patterning
  - auxin-cytokinin interaction and the root meristem organization centre formation

Signal Transduction via TCS

Recent Model of the CK Signaling via TCS Pathway

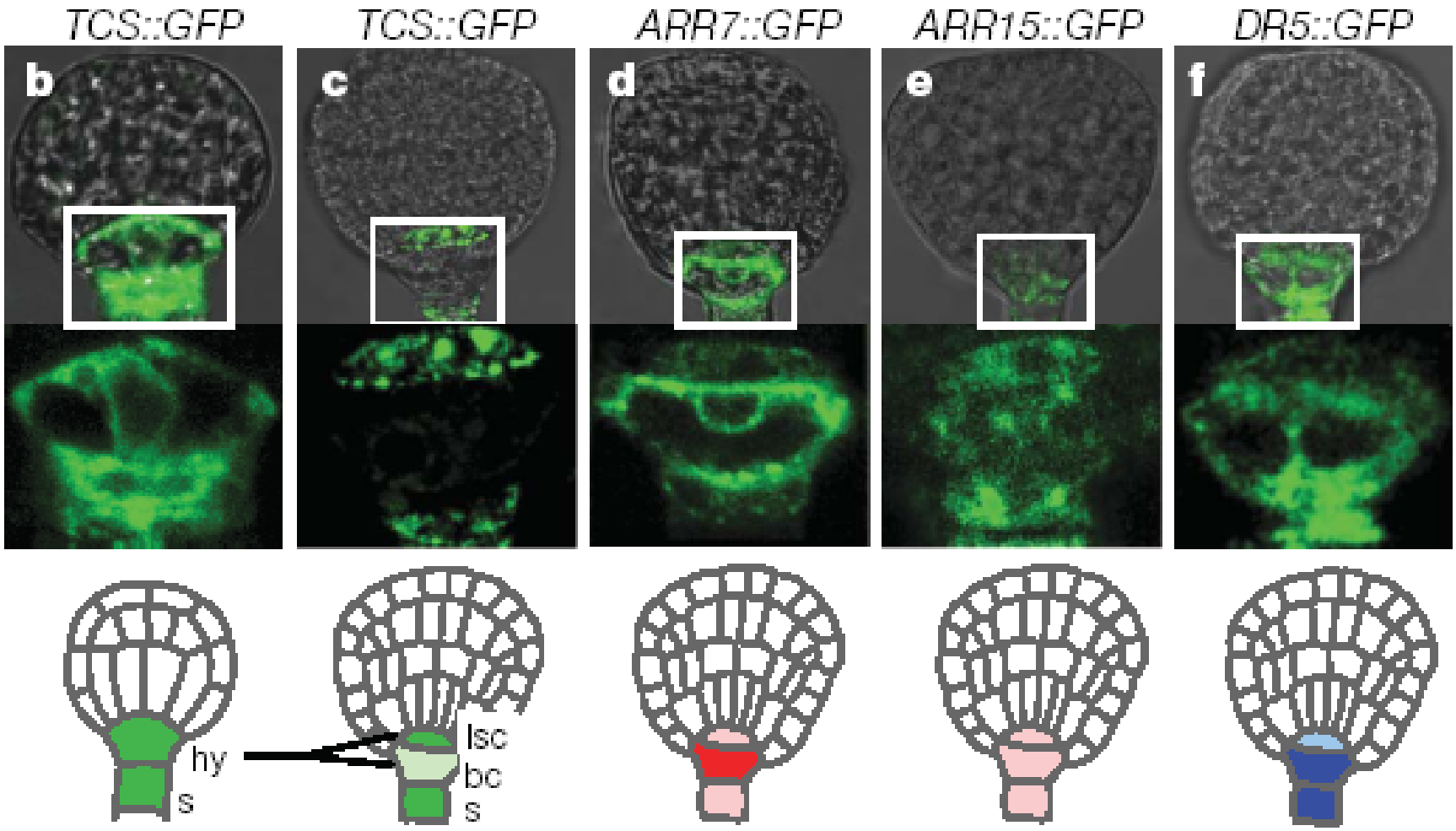




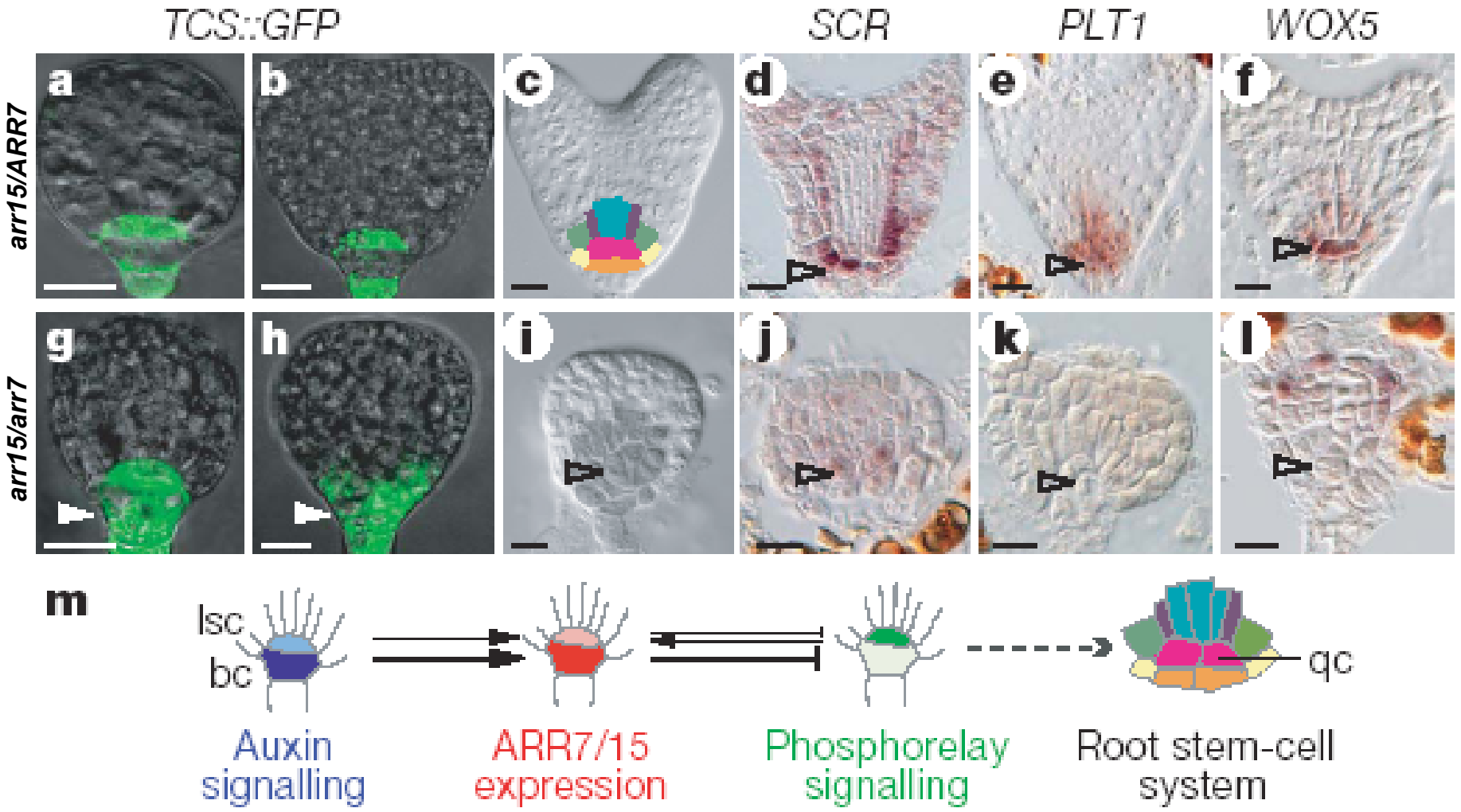
D'Agostino et al., Plant Physiol, 2000

CK primary response genes
- Type-A *ARRs* expression

CEITEC



Muller and Sheen., *Nature* (2008)



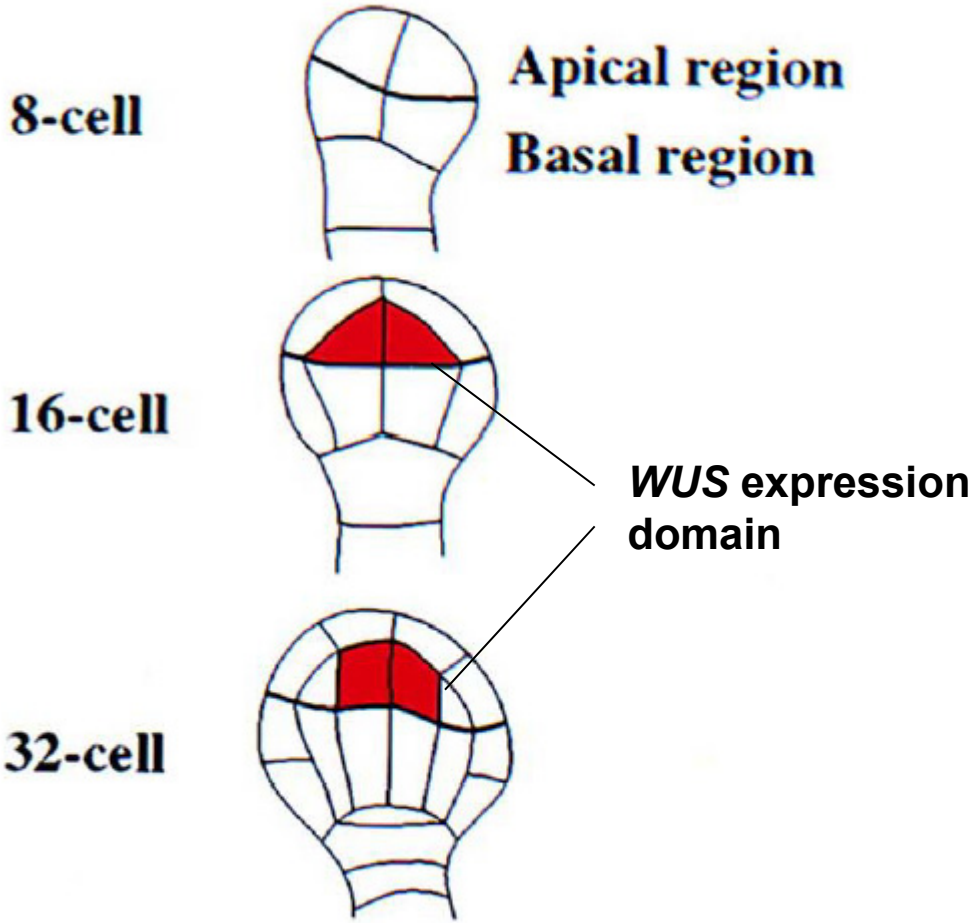
Muller and Sheen., *Nature* (2008)

Outline of Lesson 7

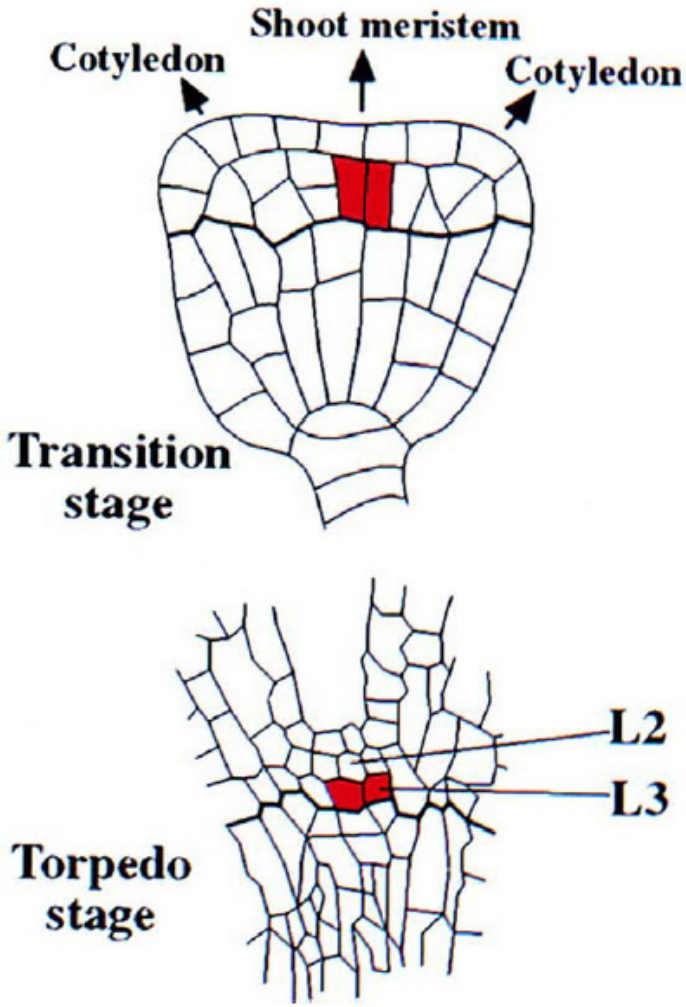
Plant Embryogenesis

- Patterning of the apical pole of the plant embryo
  - generation of cotyledons and shoot apical meristem

SAM specification

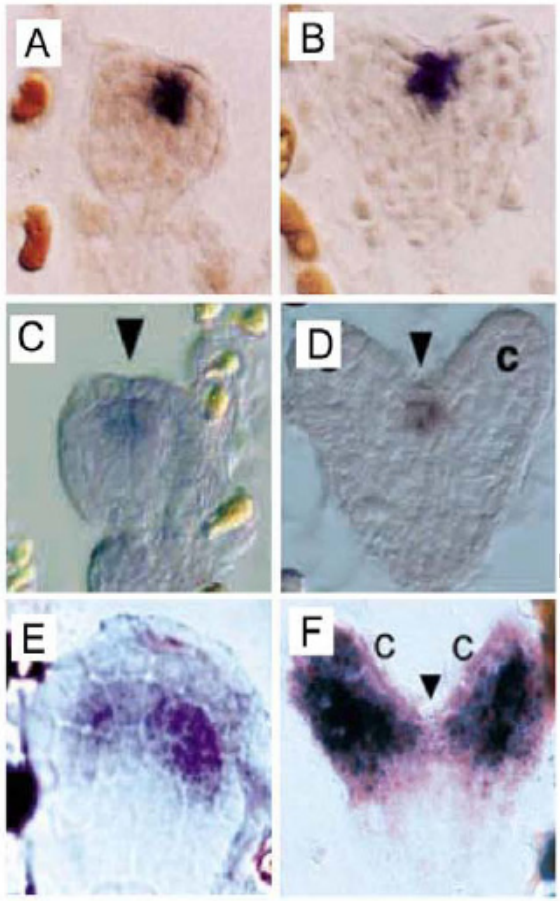


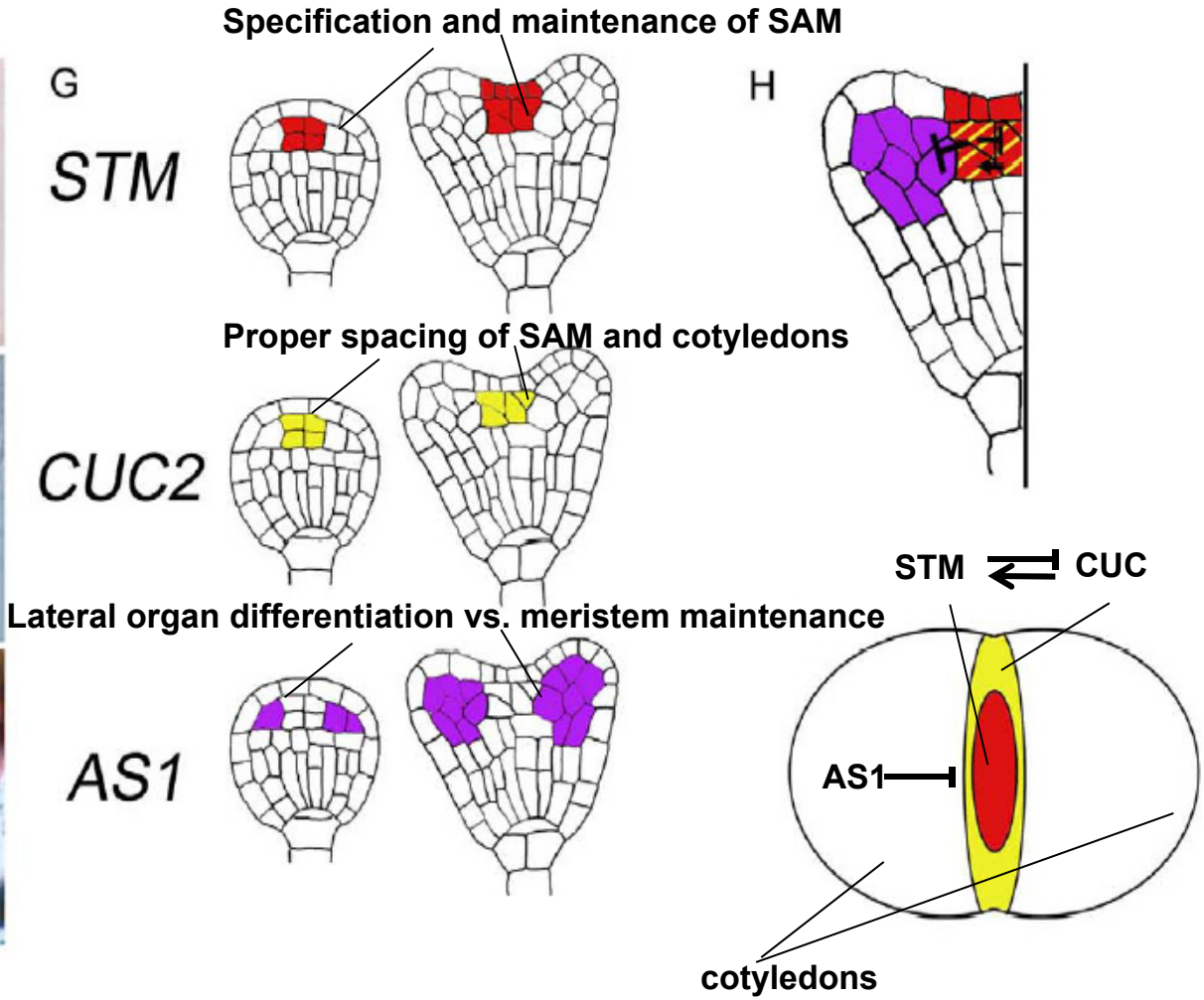
Capron et al., *Arabidopsis Book* (2009)



Capron et al., *Arabidopsis Book* (2009)

Gene interactions during apical embryo pole patterning





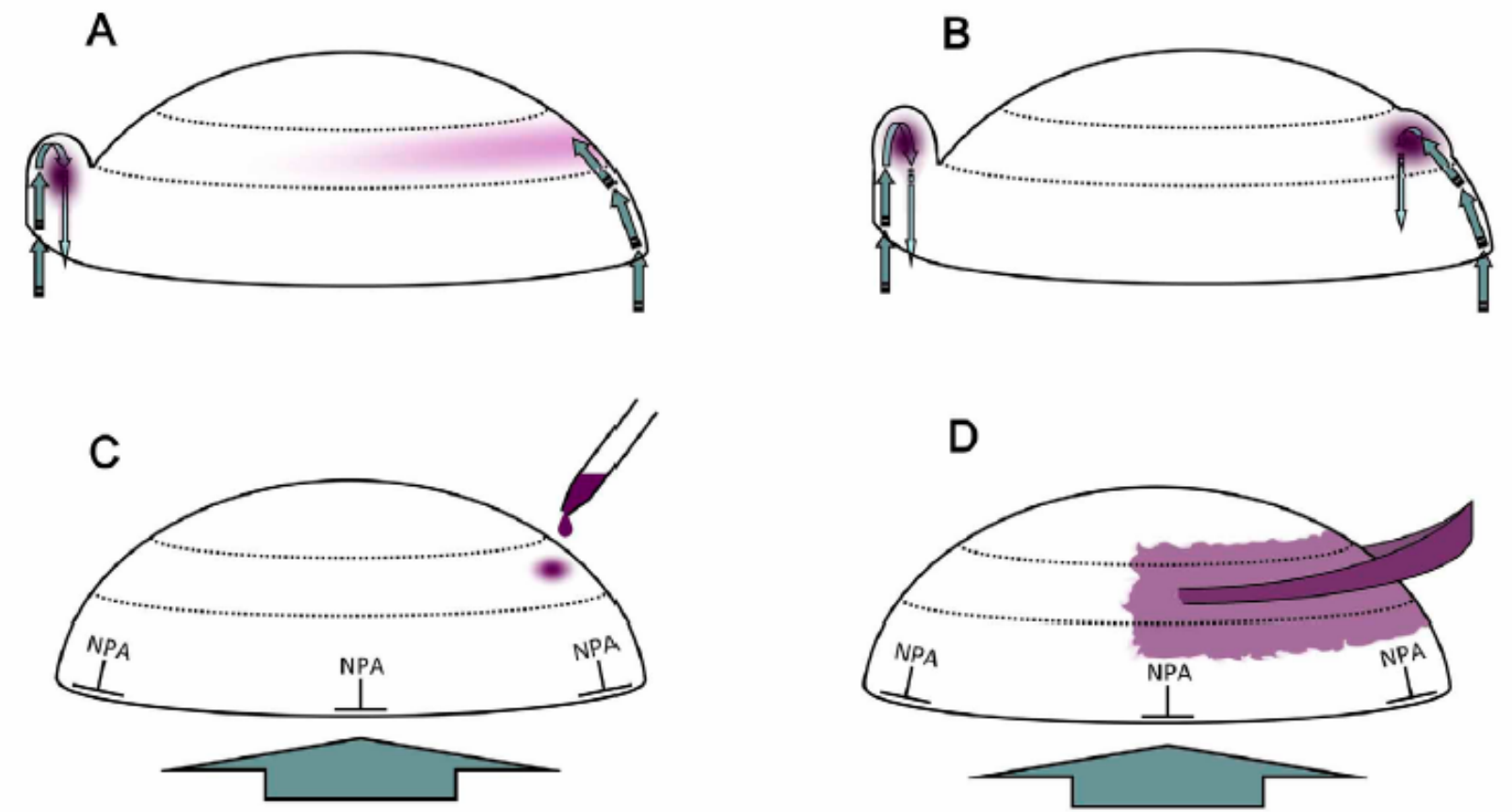
Capron et al., *Arabidopsis Book* (2009)

Outline of Lesson 7

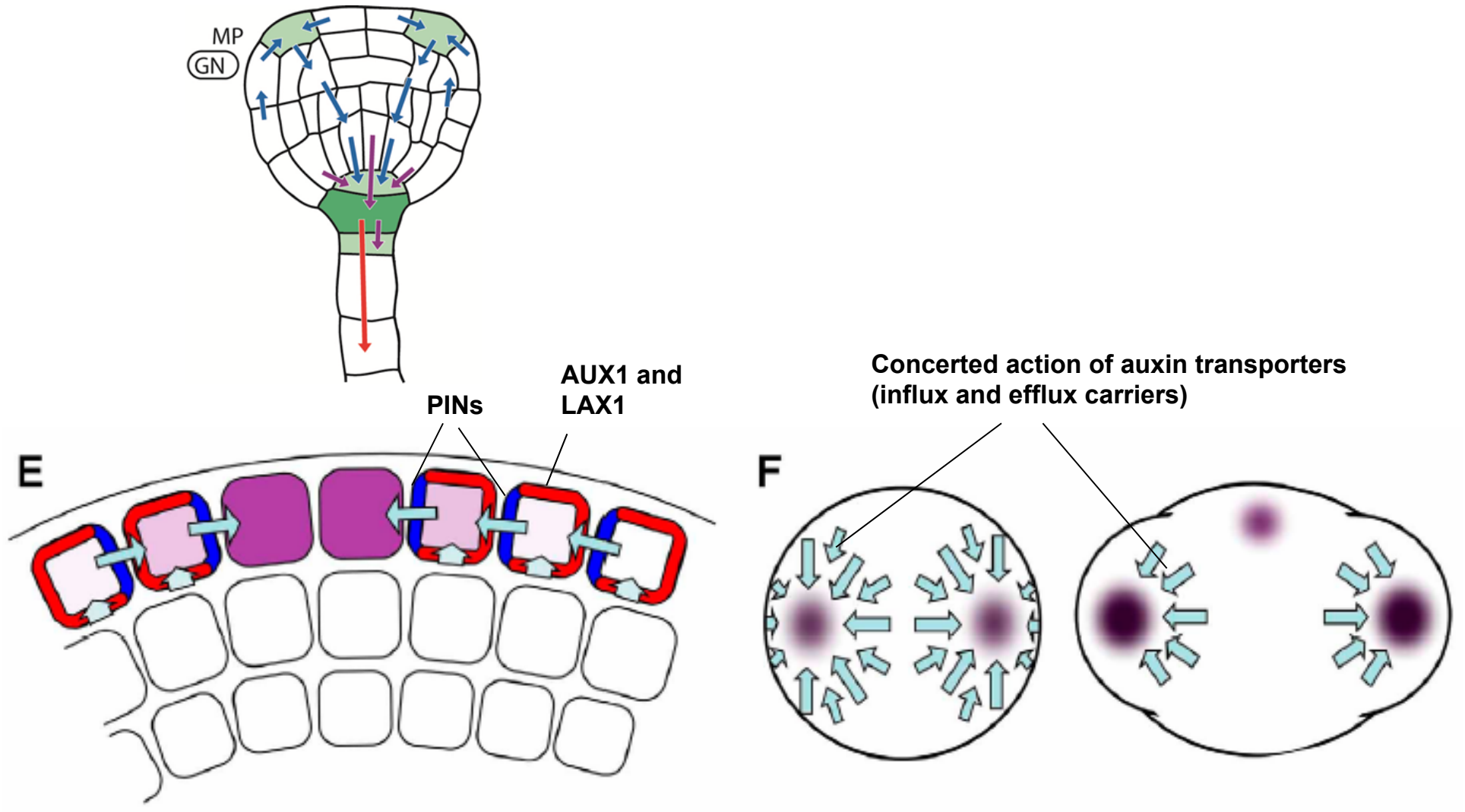
Plant Embryogenesis

- Patterning of the apical pole of the plant embryo
  - generation of cotyledons and shoot apical meristem
  - proper spacing of lateral organs

Auxin maxima are involved in lateral organ formation and acquiring of billateral symmetry



Capron et al., *Arabidopsis Book* (2009)



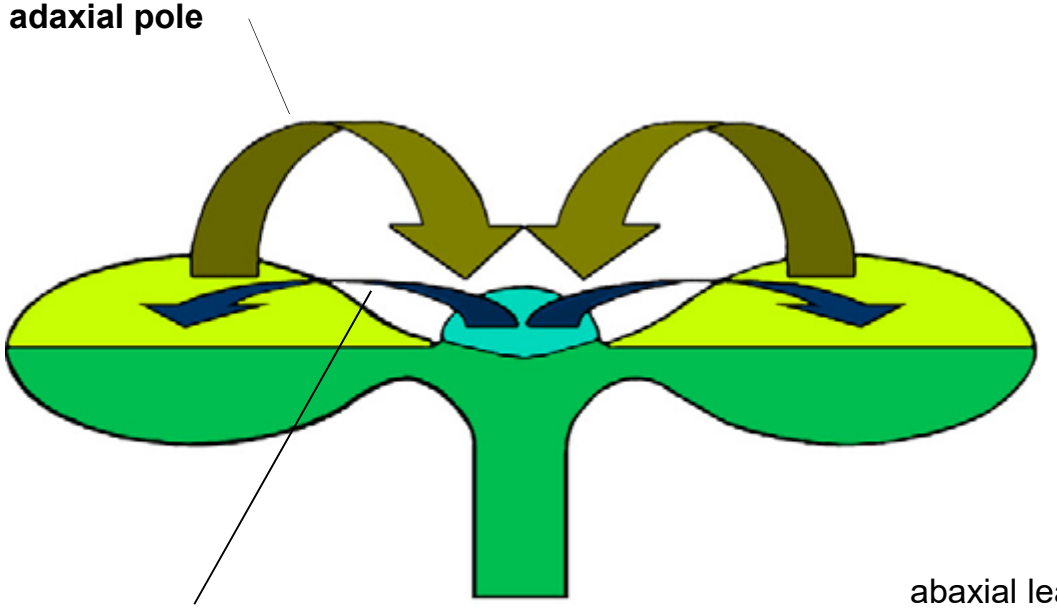
Capron et al., *Arabidopsis Book* (2009)

Outline of Lesson 7

Plant Embryogenesis

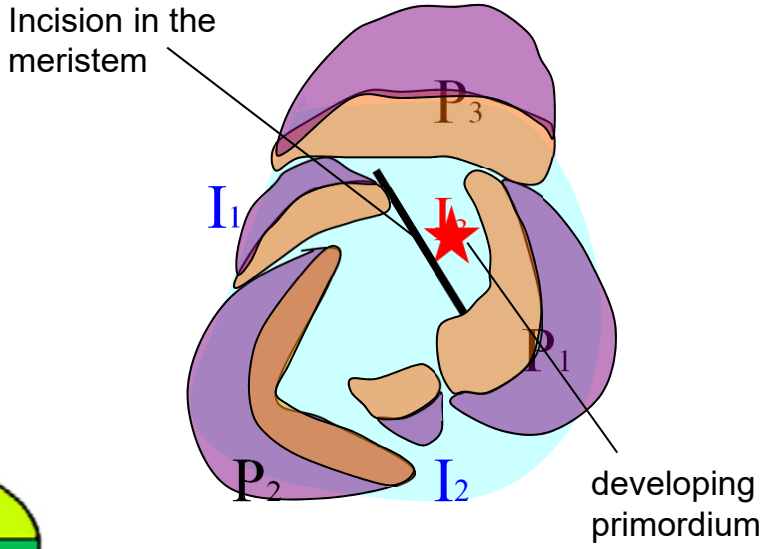
- Patterning of the apical pole of the plant embryo
  - generation of cotyledons and shoot apical meristem
  - proper spacing of lateral organs
  - adaxial-abaxial axis formation

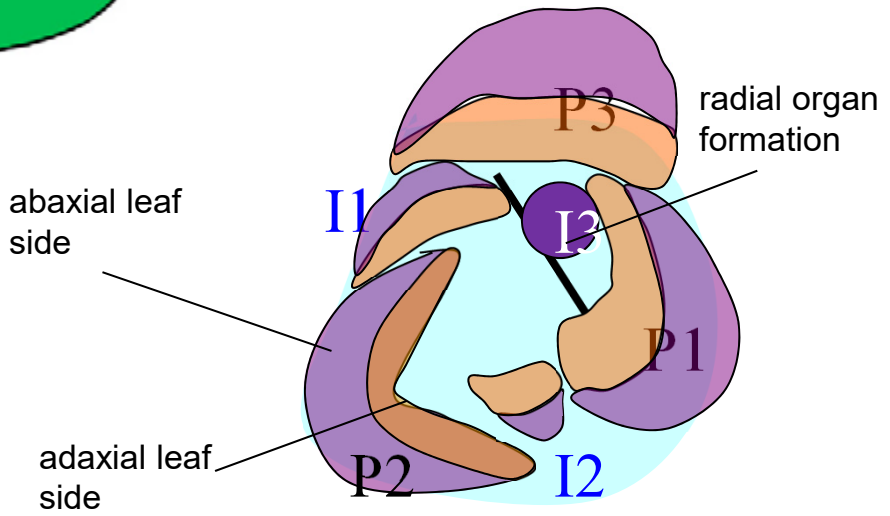
SAM-inducing positive feedback from the adaxial pole



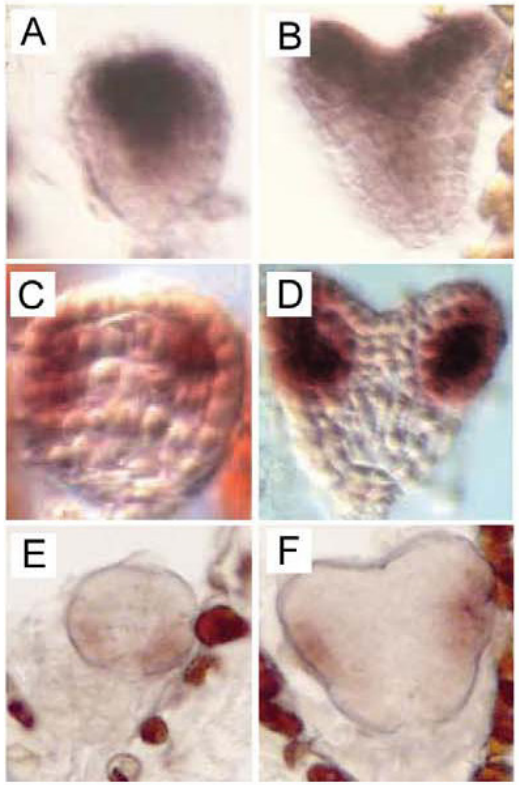
SAM-derived signals induce adaxial-abaxial diversification

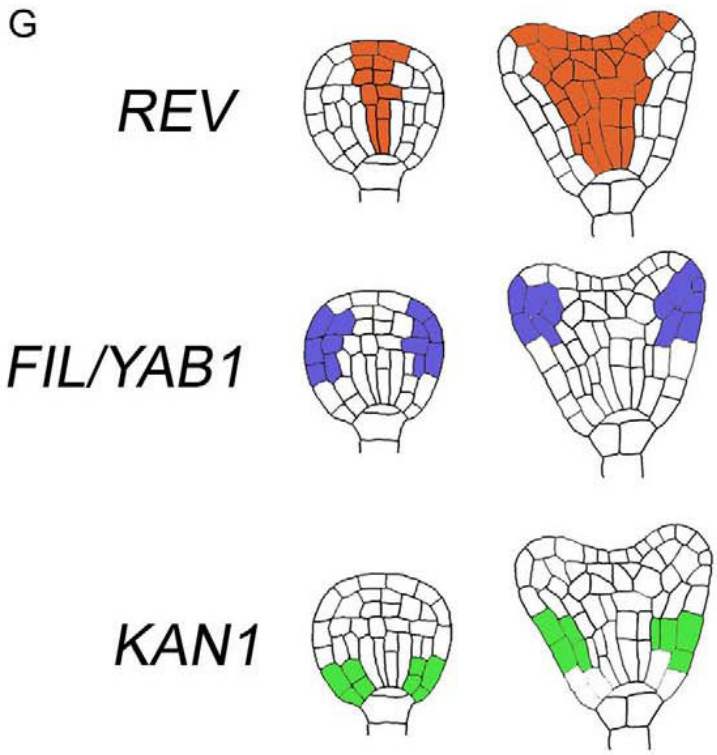
Capron et al., *Arabidopsis Book* (2009)

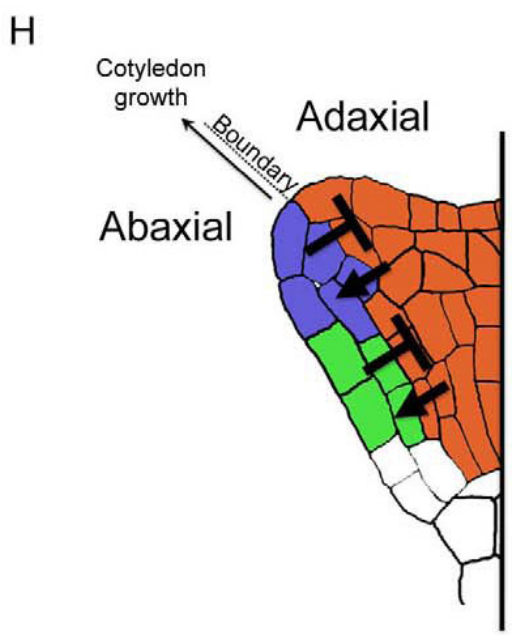




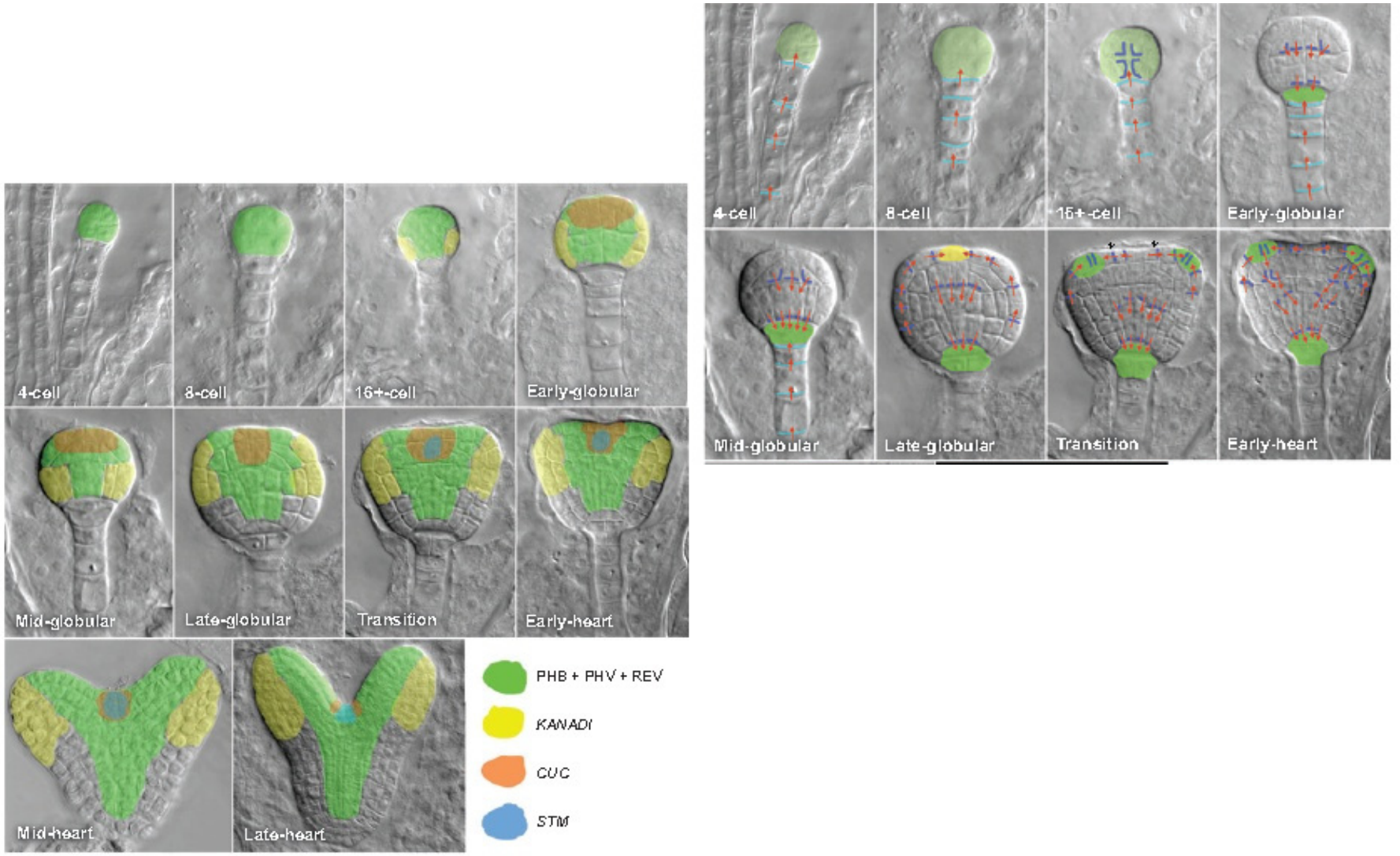
Specificity in gene expression is involved in the adaxial-abaxial patterning







Capron et al., *Arabidopsis Book* (2009)



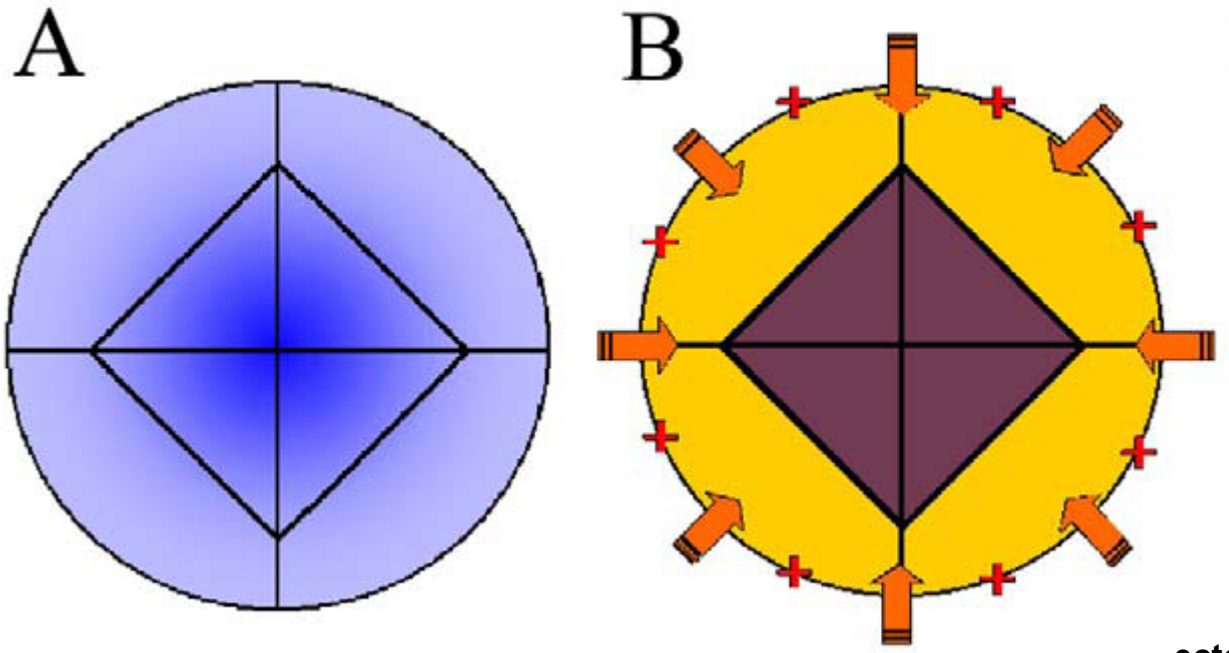
Bowman et al., *Annu. Rev. Plant. Biol* (2008)

Outline of Lesson 7

Plant Embryogenesis

- Patterning of the apical pole of the plant embryo
  - generation of cotyledons and shoot apical meristem
  - proper spacing of lateral organs
  - adaxial-abaxial axis formation
- Radial embryo patterning
  - epidermal layer specification

Epidermal layer specification



Single morphogen model

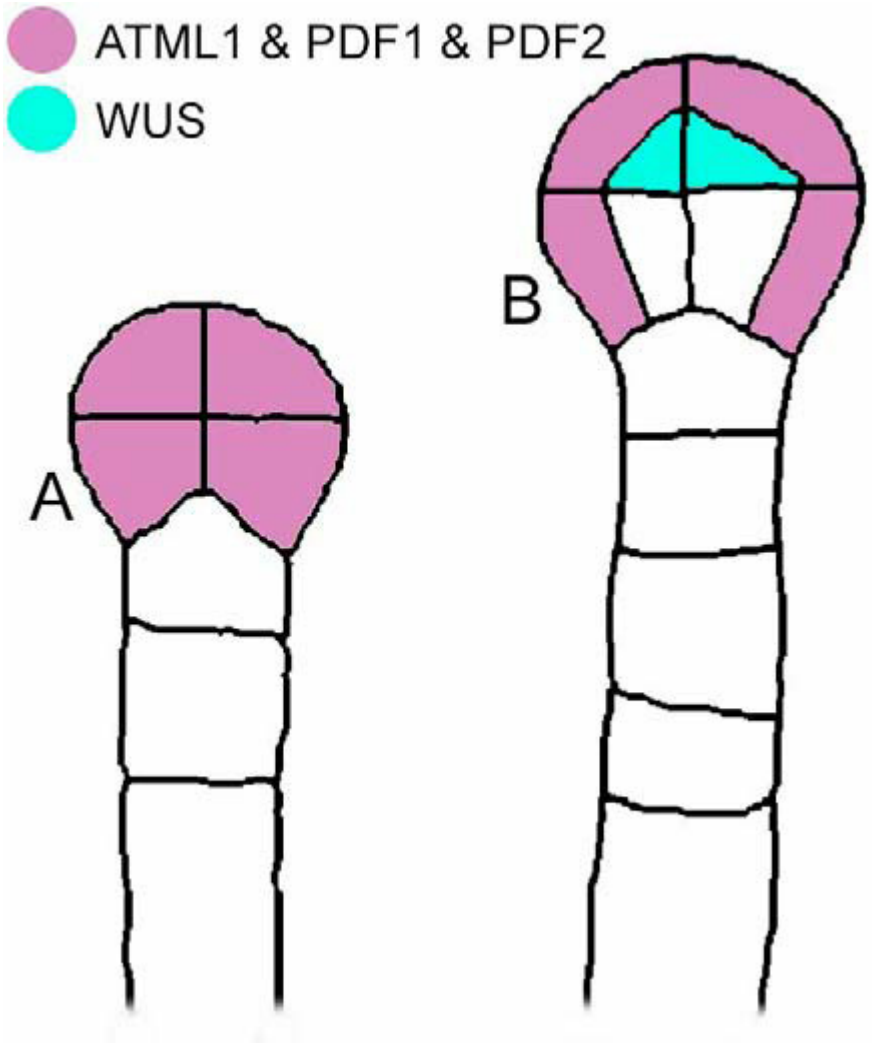
“Ouside-in” model

ectopic expression of epidermal markers

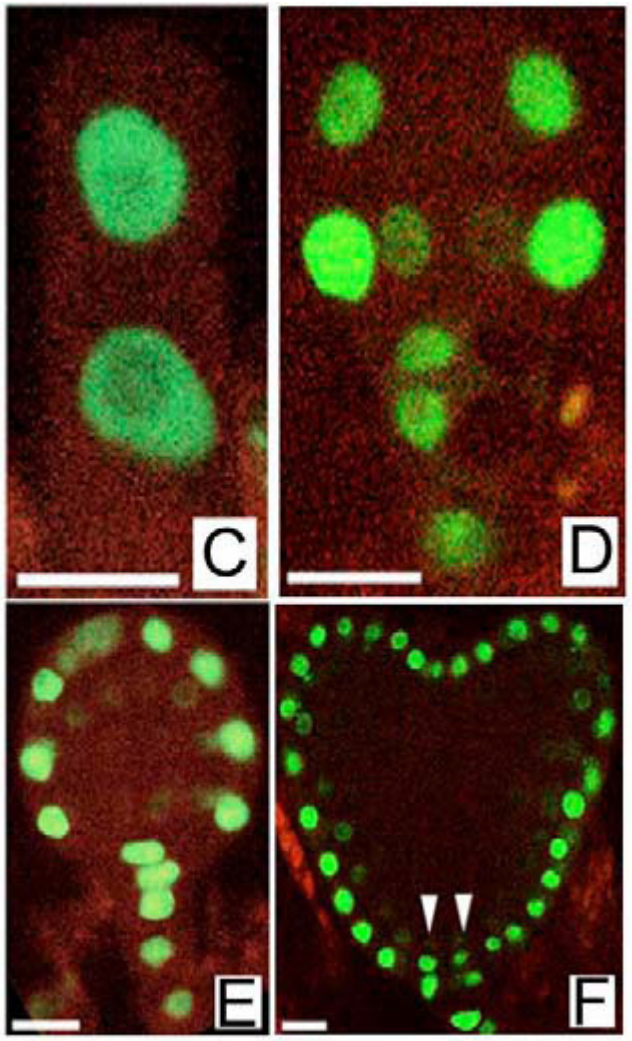
***knolle* and *keulle* cytokinesis mutants (incomplete CW)**

Capron et al., *Arabidopsis Book* (2009)

MERISTEM LAYER1 (AtML1) and PROTODERMAL FACTOR 1* and *2



ProATML1:NLS-3xeGFP

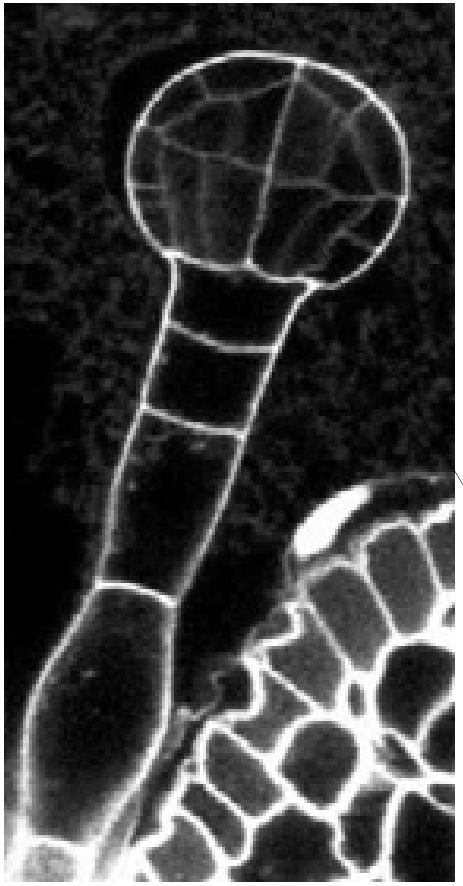


Outline of Lesson 7

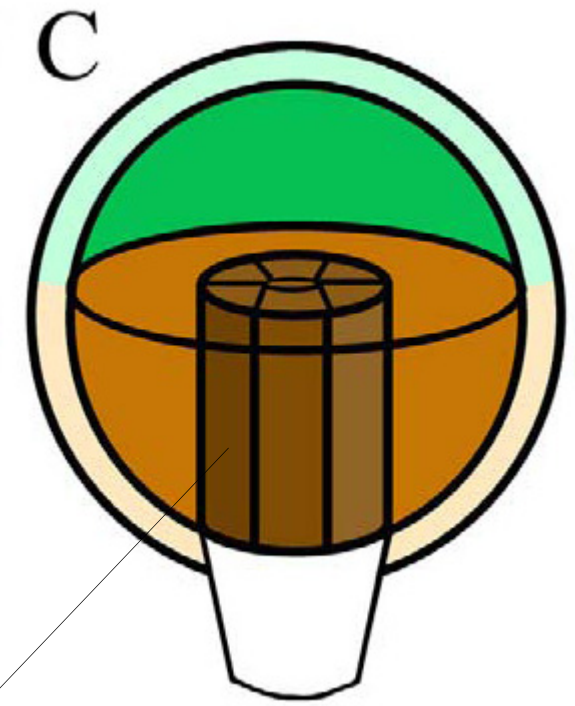
Plant Embryogenesis

- Patterning of the apical pole of the plant embryo
  - generation of cotyledons and shoot apical meristem
  - proper spacing of lateral organs
  - adaxial-abaxial axis formation
- Radial embryo patterning
  - epidermal layer specification
  - separating vascular and ground tissue

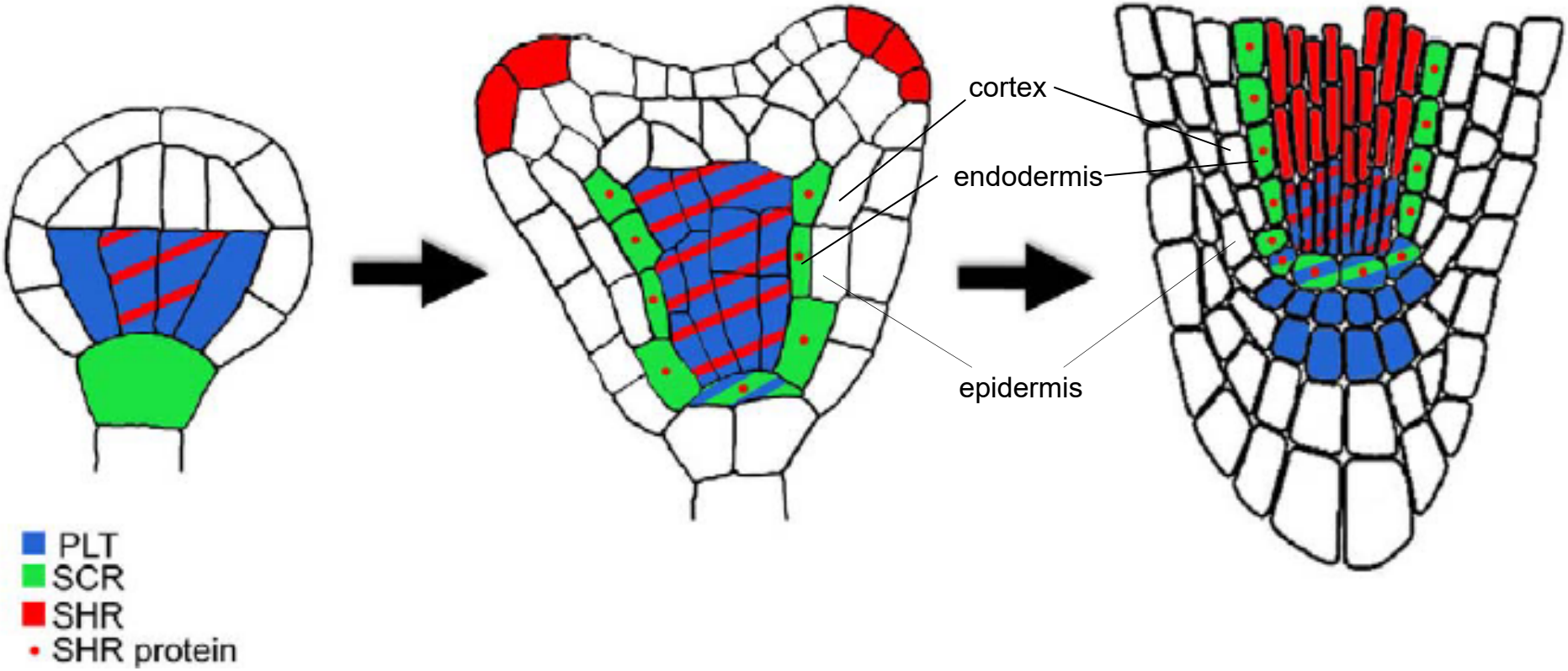
Separation of vascular and ground tissue

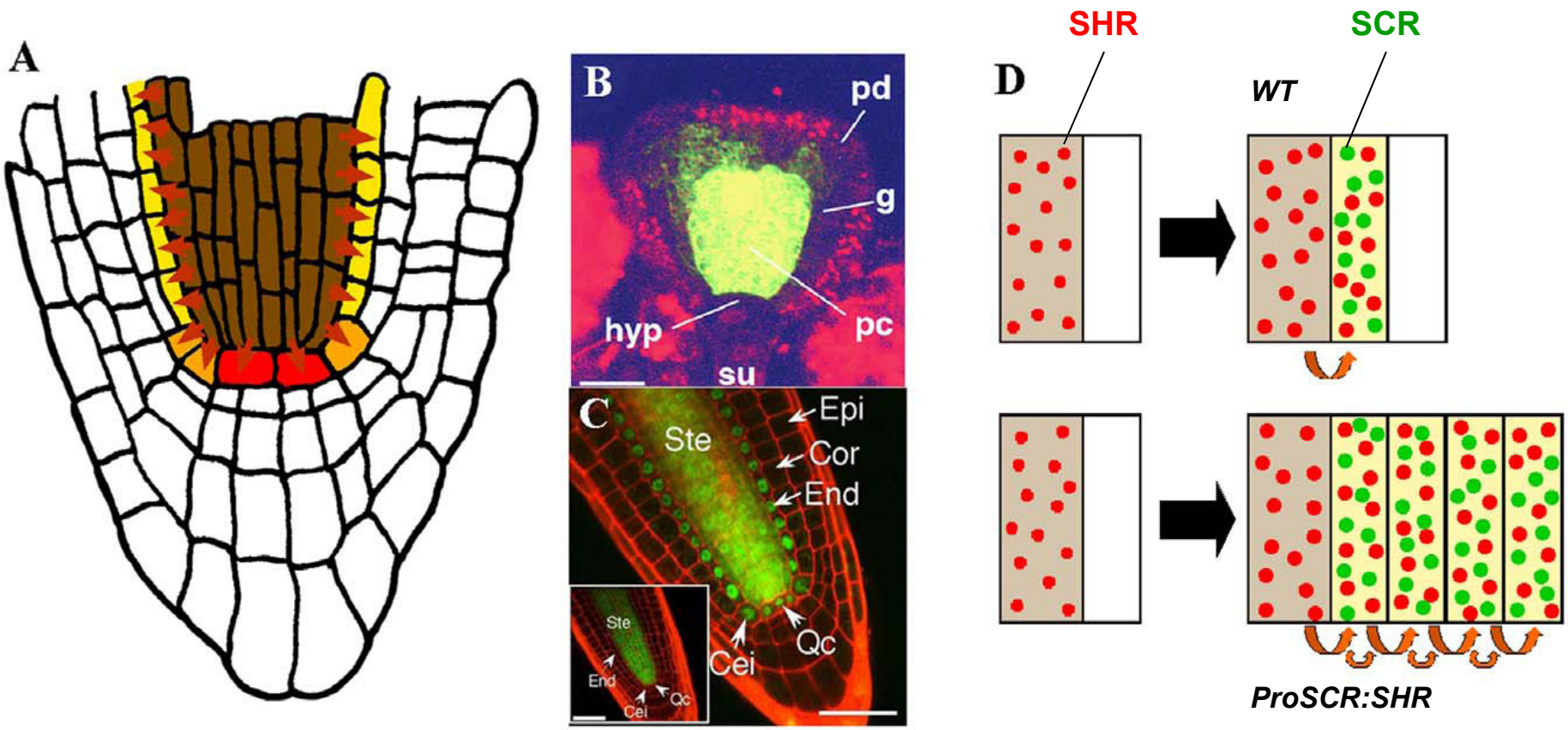


Early globular stage



Cell divisons predominantly along the apical-basal axis


cortex
endodermis
epidermis
PLT
SCR
SHR
SHR protein



Key Concepts

Plant Embryogenesis

- Similarly to animals, both **embryonic and extraembryonic tissue** forms during plant embryogenesis
- In plant embryogenesis, **positional information** rather than invariant cell division is decisive for the proper embryo patterning
- **Auxin gradient formation provides positional information** that together with **differential gene expression** directs downstream developmental events during plant embryogenesis
- **Auxin transport machinery** and **auxin signalling** are critical for the proper embryo development
- **Interaction of auxin with other growth regulators**, e.g. **cytokinins** emerges as a crucial regulatory factor for many developmental processes during plant embryo formation
- **Gene** and **protein interactions** allow formation of **distinct cell and tissue spatial patterns** and allow proper organogenesis

Discussion