

Bi8940 Developmental Biology

Lesson 7

Plant Embryogenesis

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INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Tato prezentace je spolufinancována
Evropským sociálním fondem
a státním rozpočtem České republiky



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
- Root 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

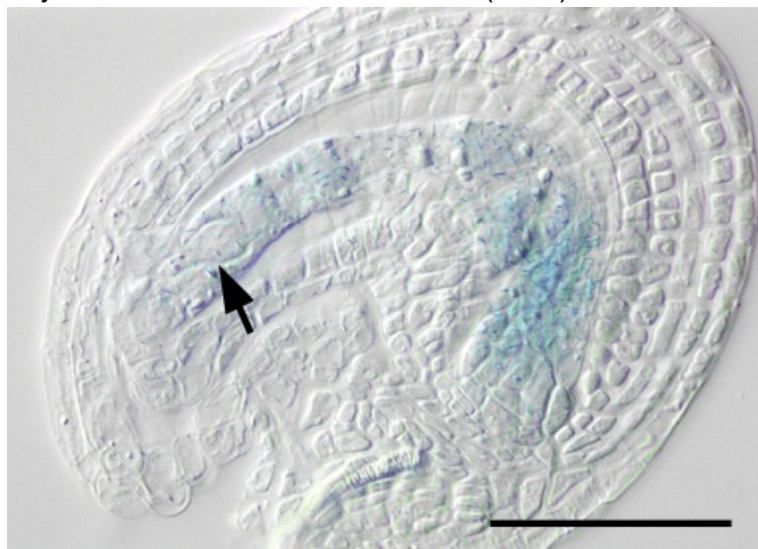
Plant Embryogenesis

- Overview of the embryo formation in *Arabidopsis*



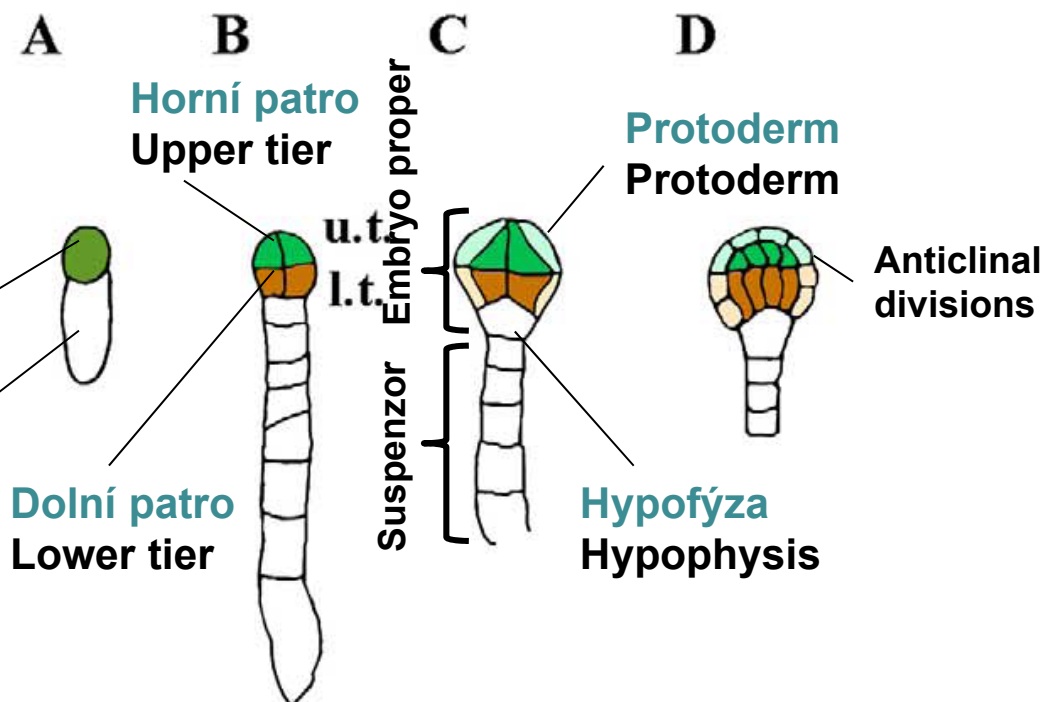
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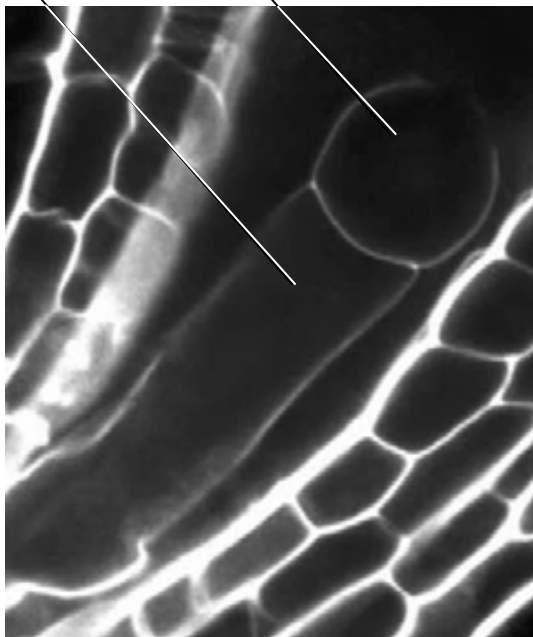
Apical cell-active protein biosynthesis

Basal cell-highly vacuolated

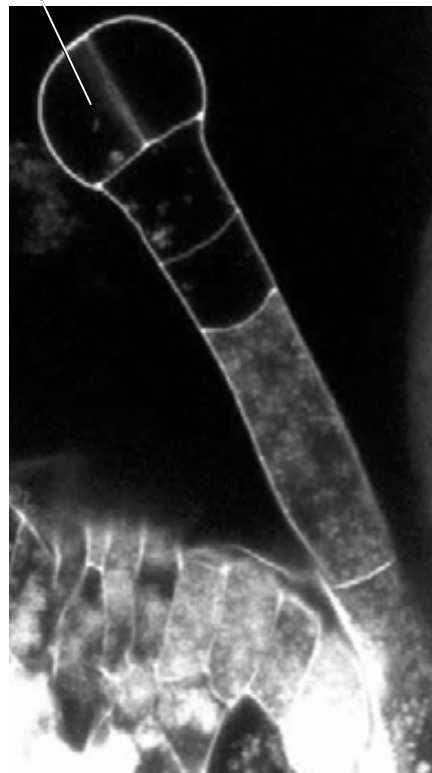


Capron et al., *Arabidopsis Book* (2009)

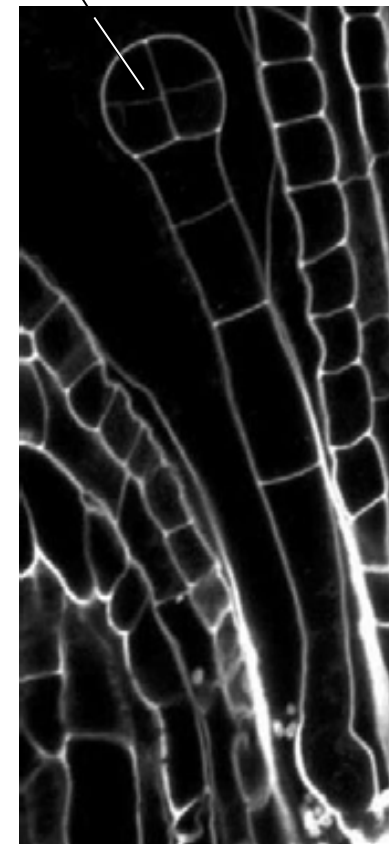
Apical cell
Basal cell



Proembryo



Four out of eight
cells of the embryo
proper



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

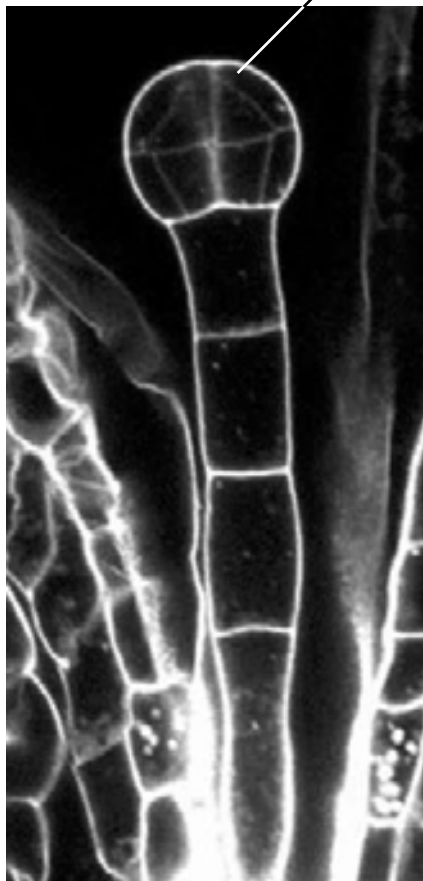
Proembryo stage

Octant stage

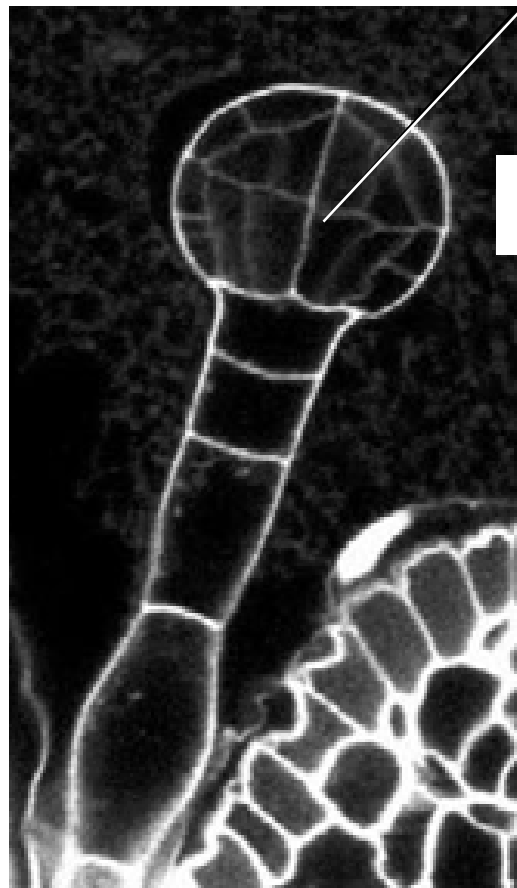
Protoderm

Prospective vascular
tissue

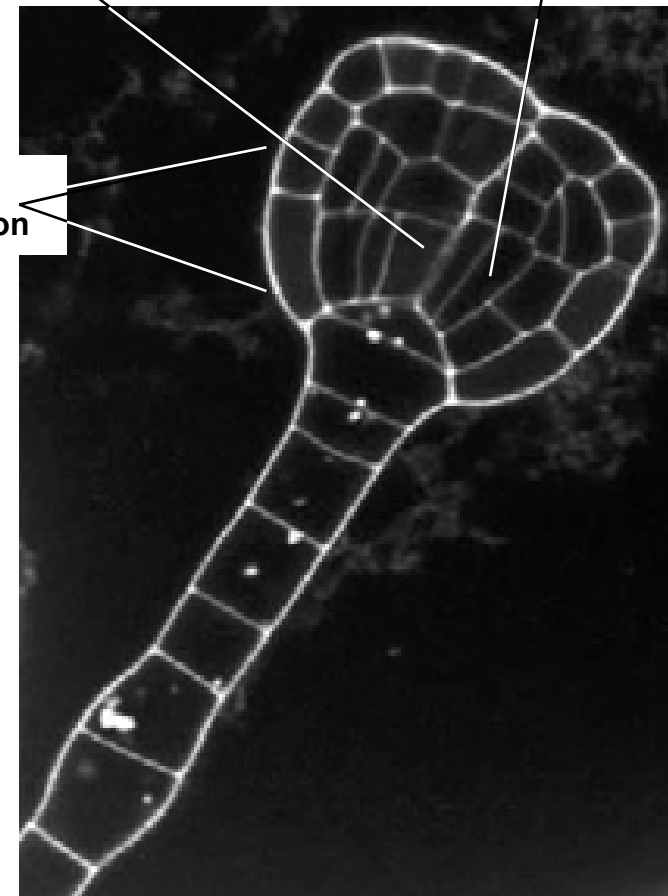
Prospective ground
tissue/základní pletivo



Dermatogen stage

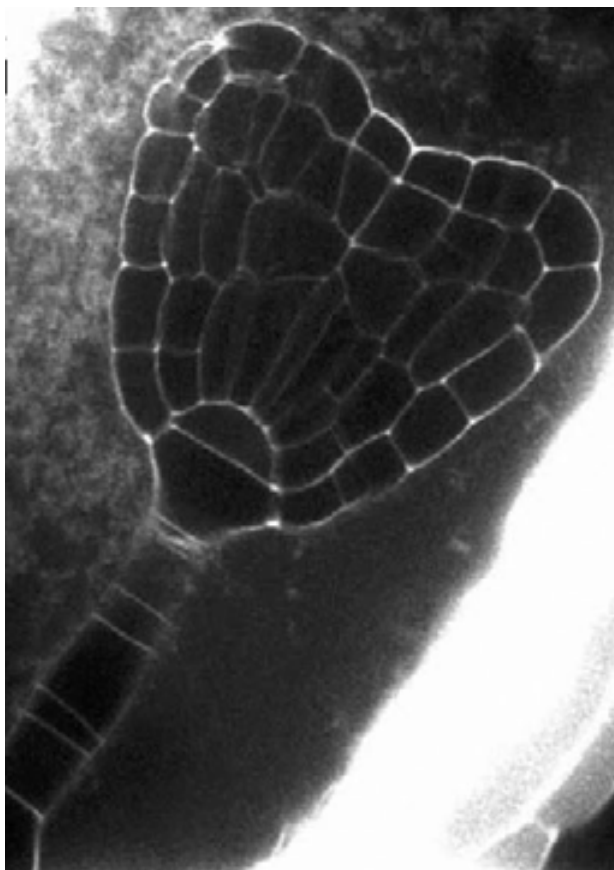


Early globular stage



Triangular embryo stage

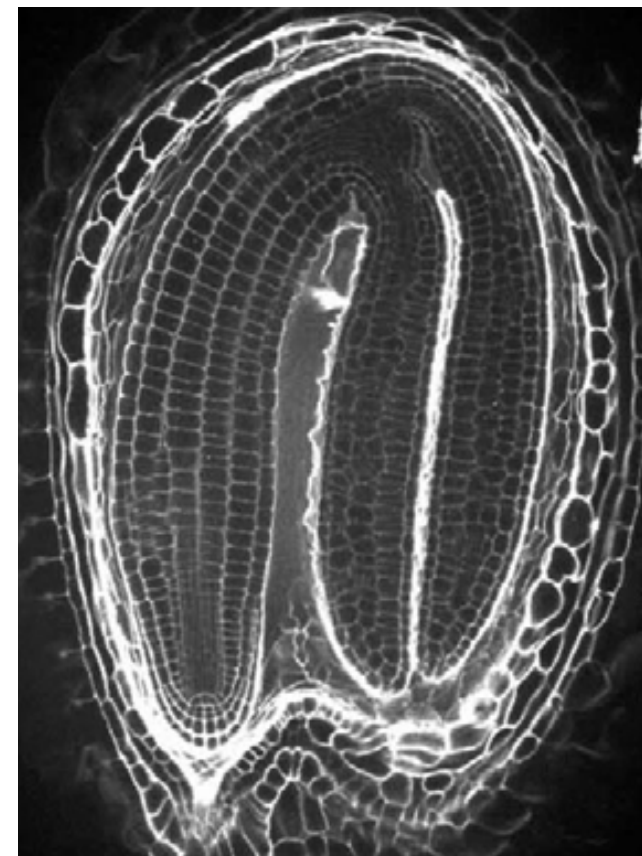
Capron et al., *Arabidopsis Book* (2009)



Heart stage

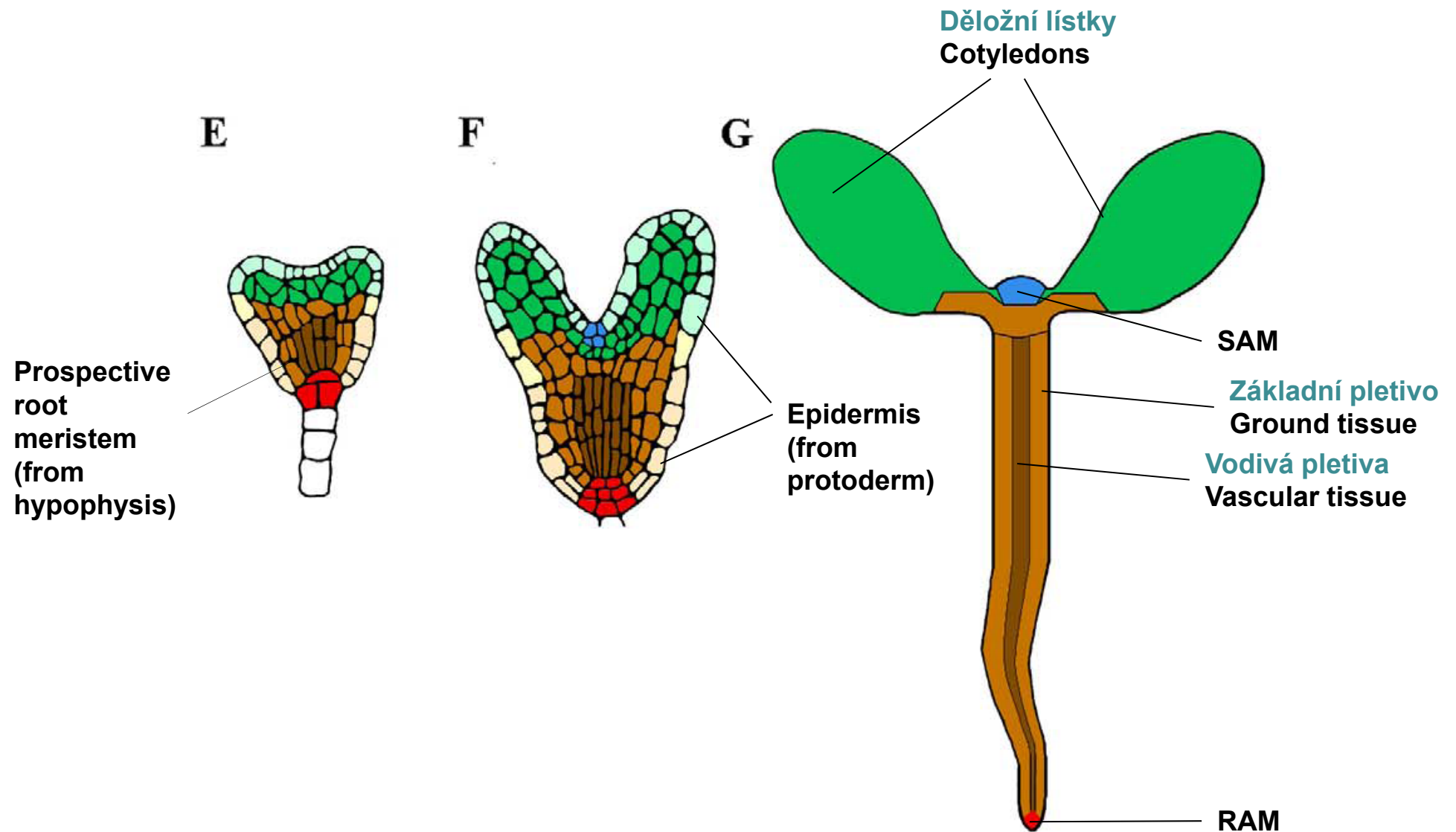


Topedo stage



Bended cotyledon stage

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



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



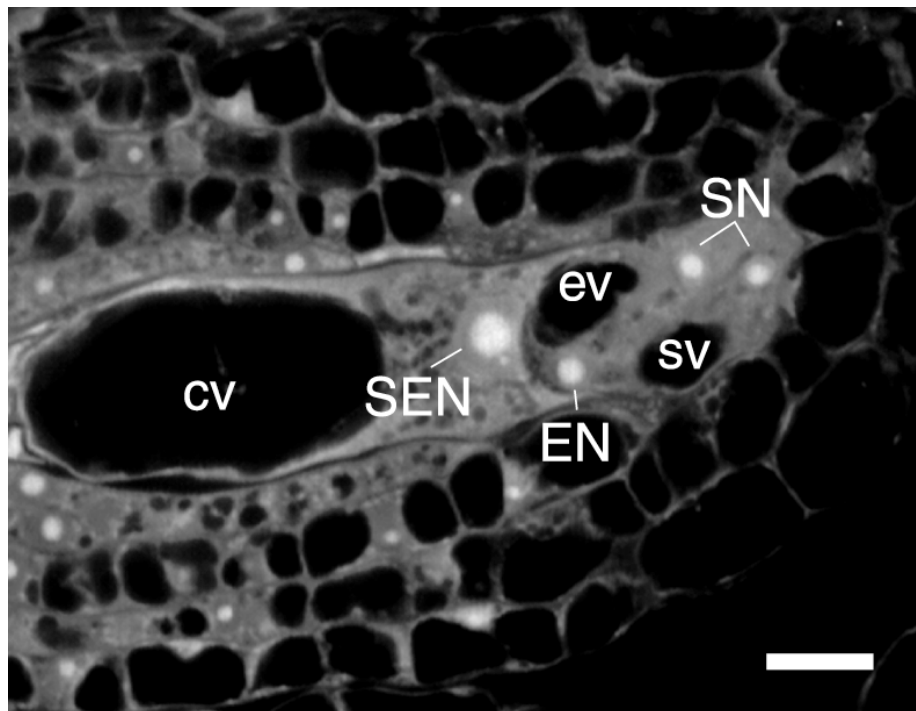
Outline of Lesson 7

Plant Embryogenesis

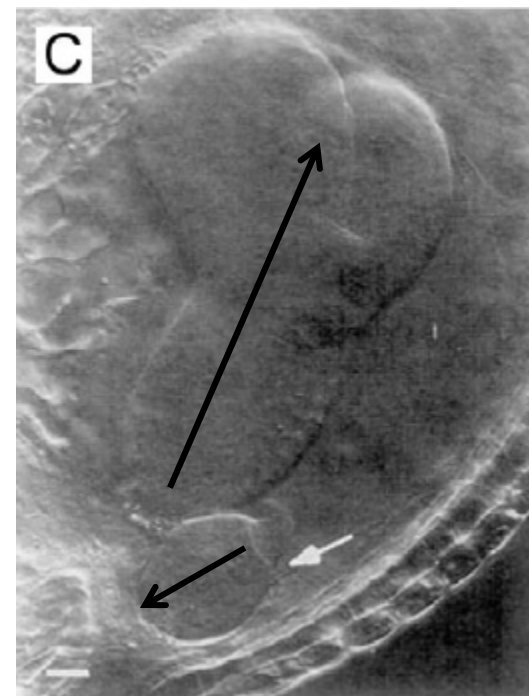
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Proximal ← *Distal*

WT



twin



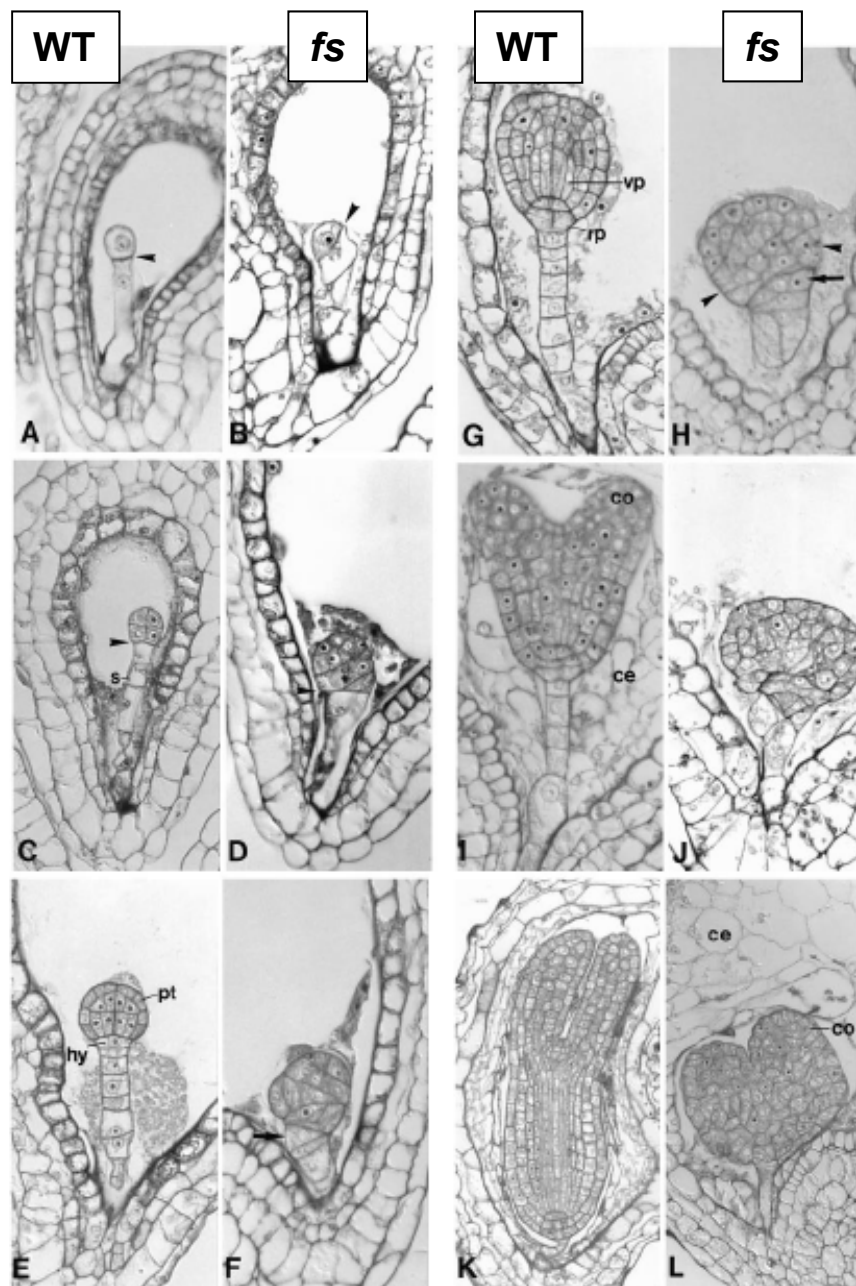
Proximal



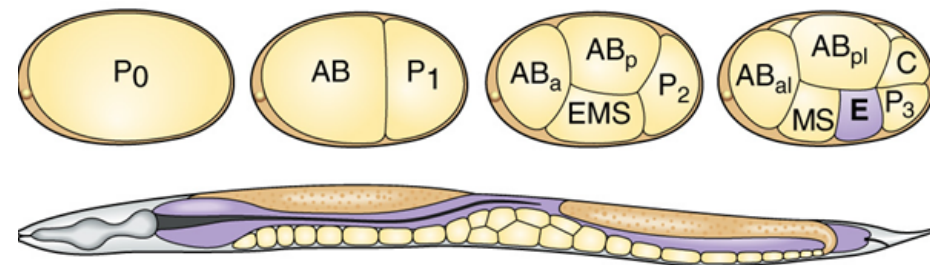
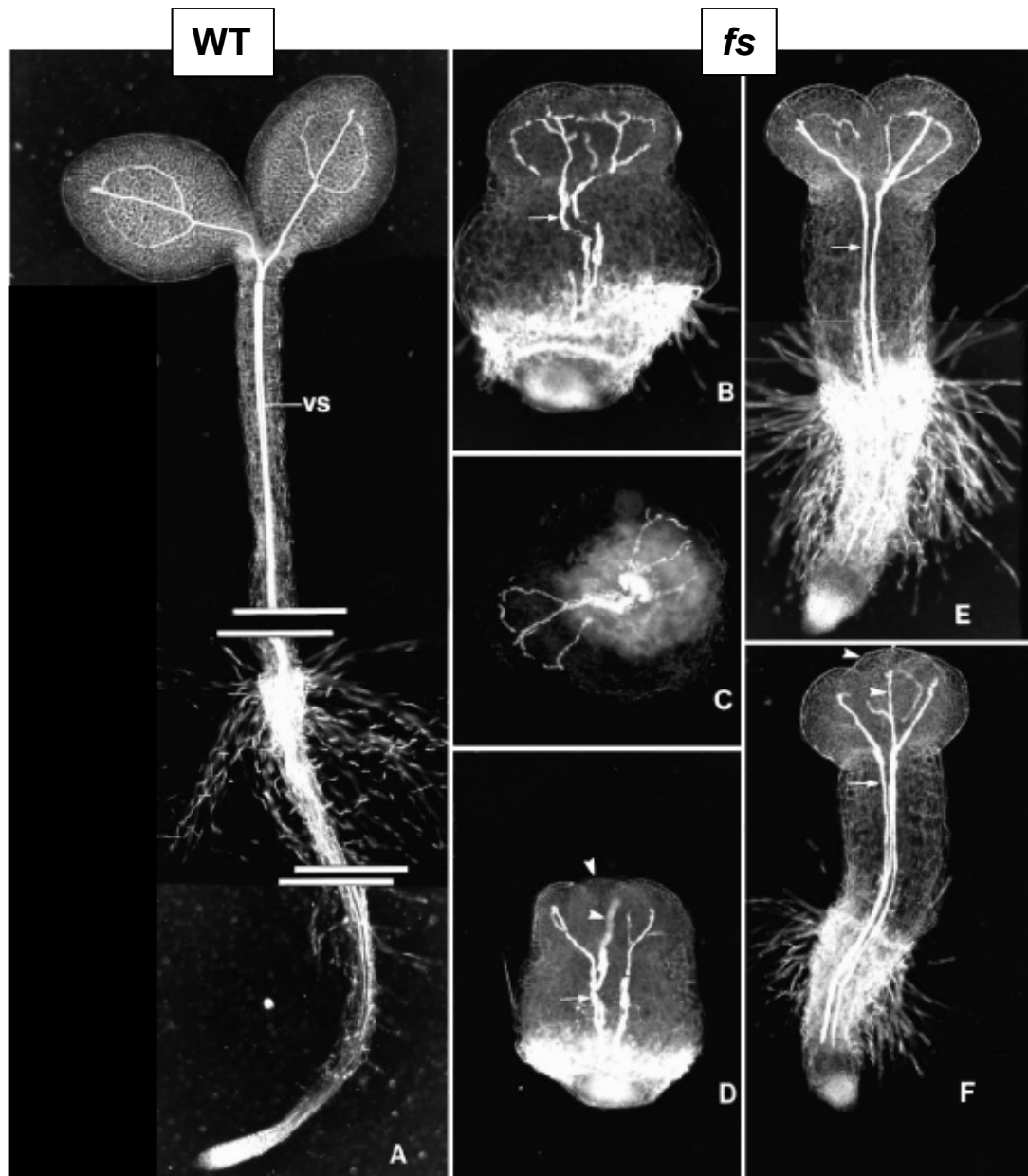
Distal

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

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



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



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

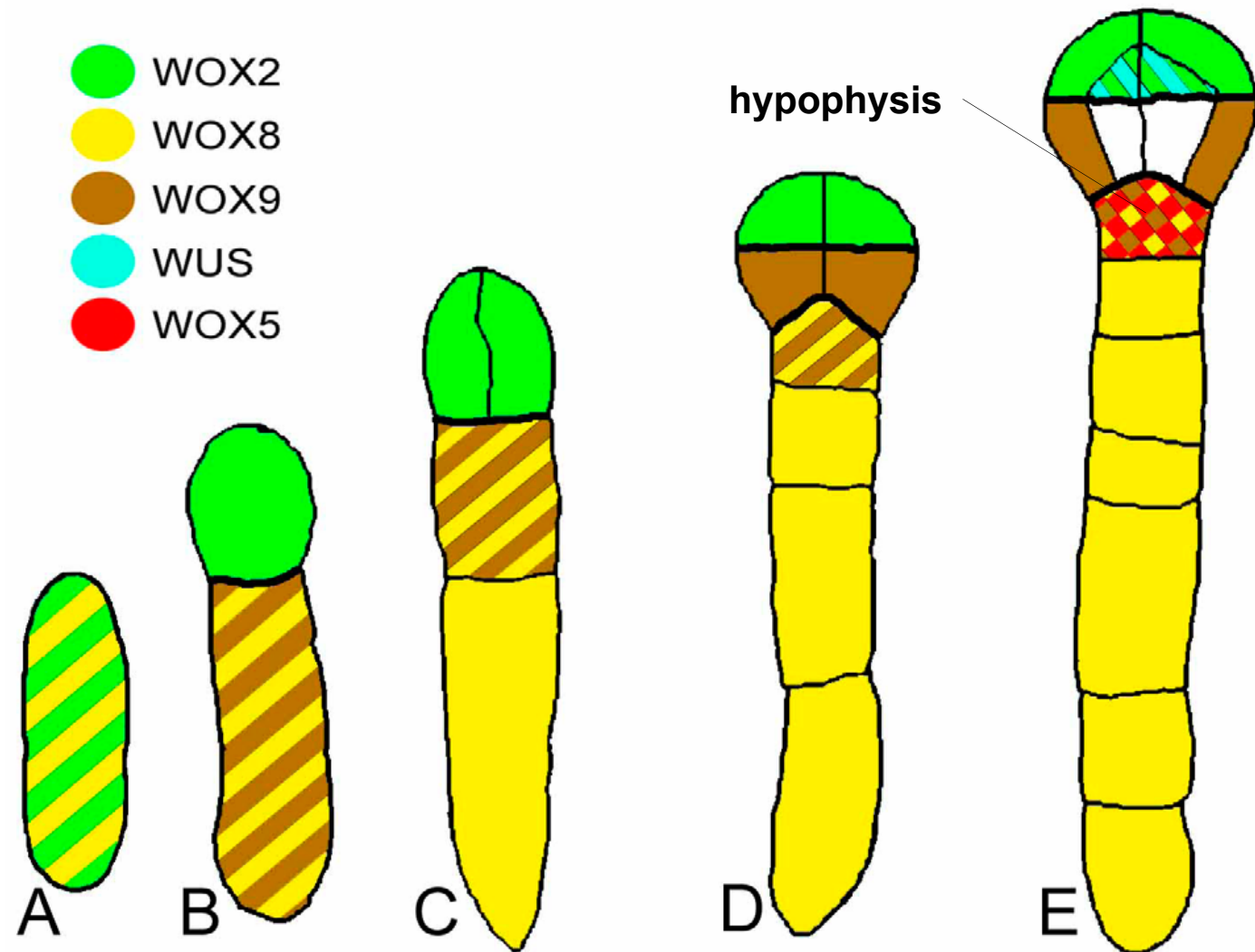


Outline of Lesson 7

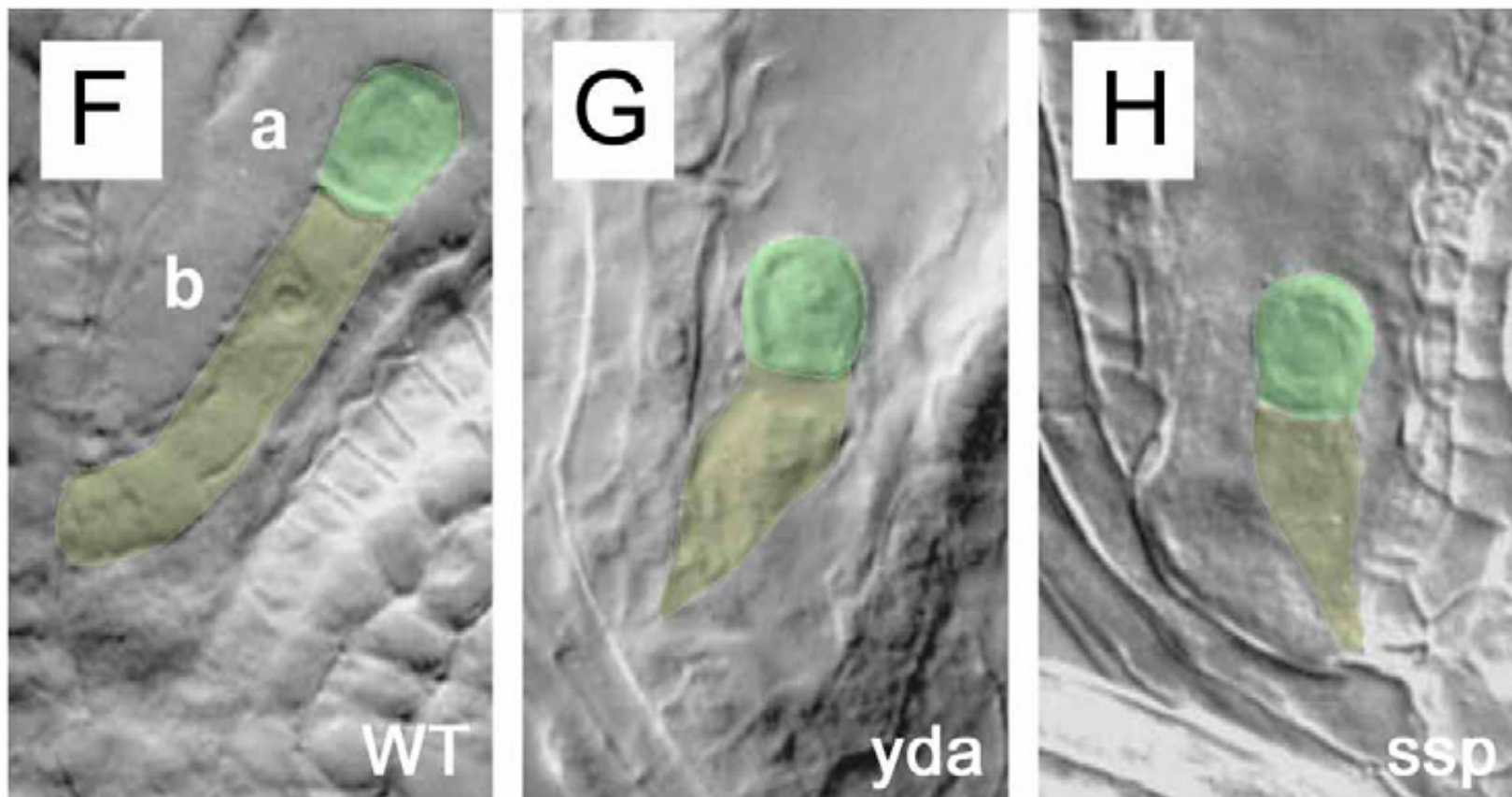
Plant Embryogenesis

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



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



YODA (YDA)

mitogen-activated protein
kinase kinase (MAPKK)

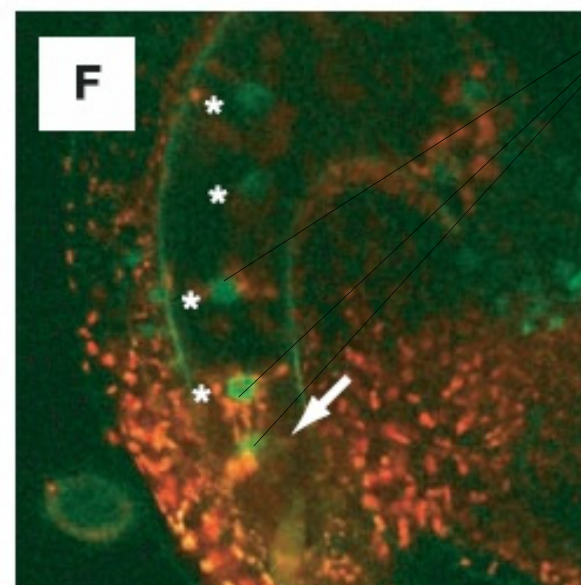
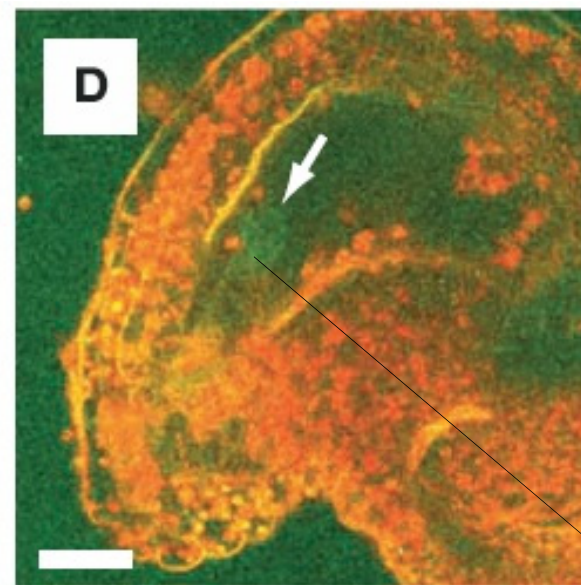
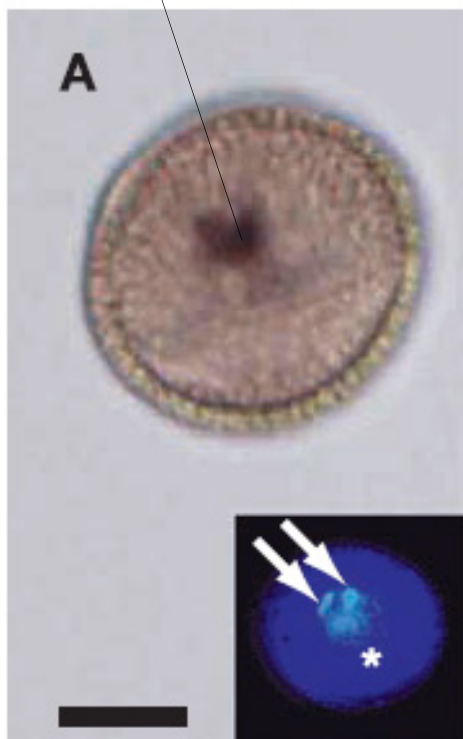


SHORT SUSPENSOR (SSP)

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

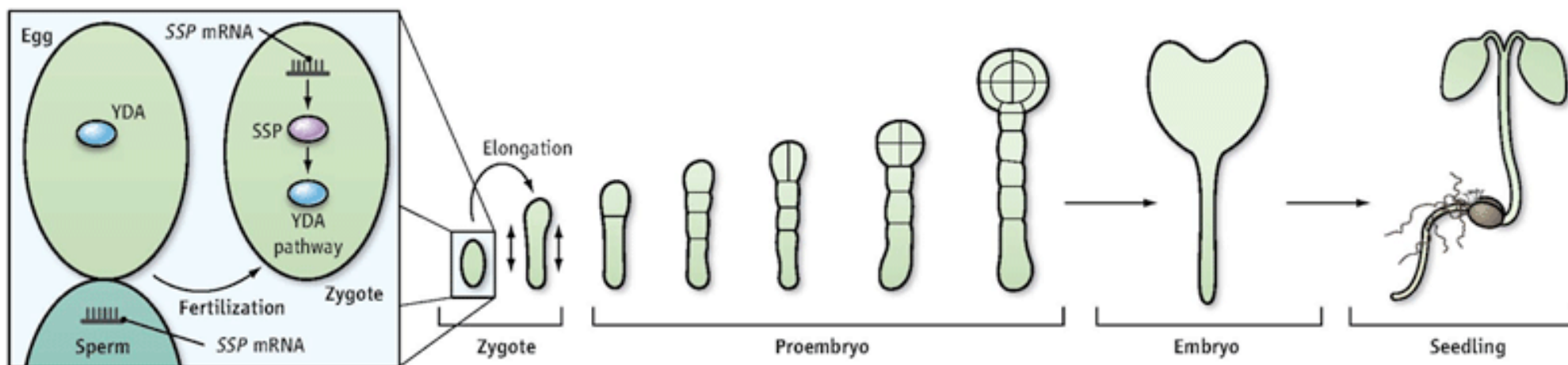
Capron et al., *Arabidopsis Book* (2009),

SSP mRNA *in situ* localization



SSP-YFP

Bayer et al., *Science* (2009)



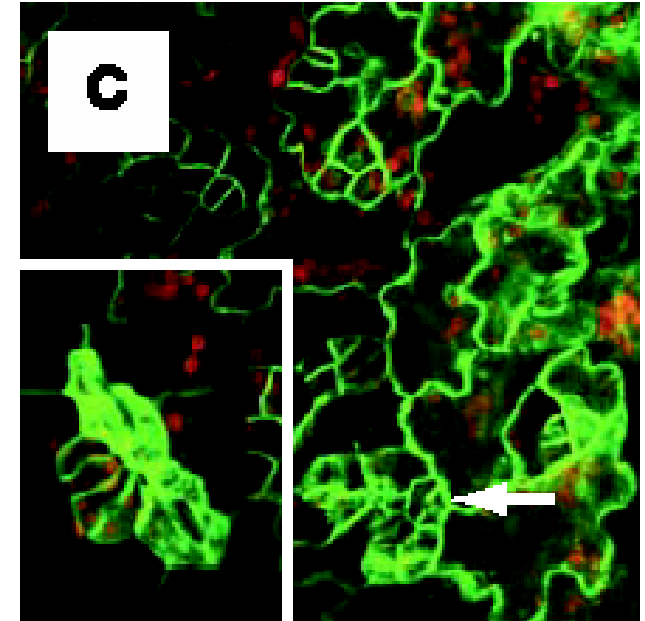
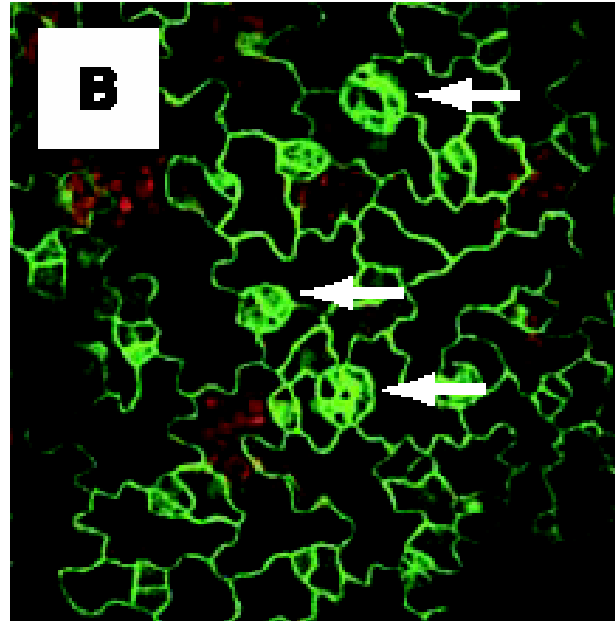
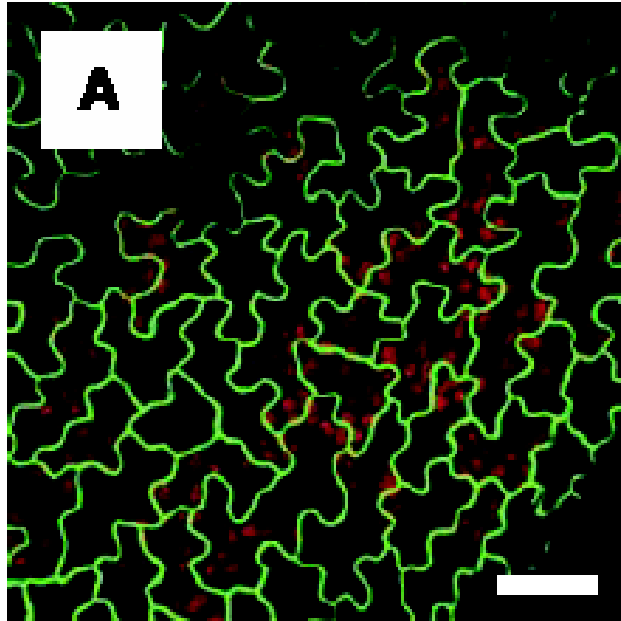
Grossniklaus, *Science* (2009)

myristoylation-deficient variant

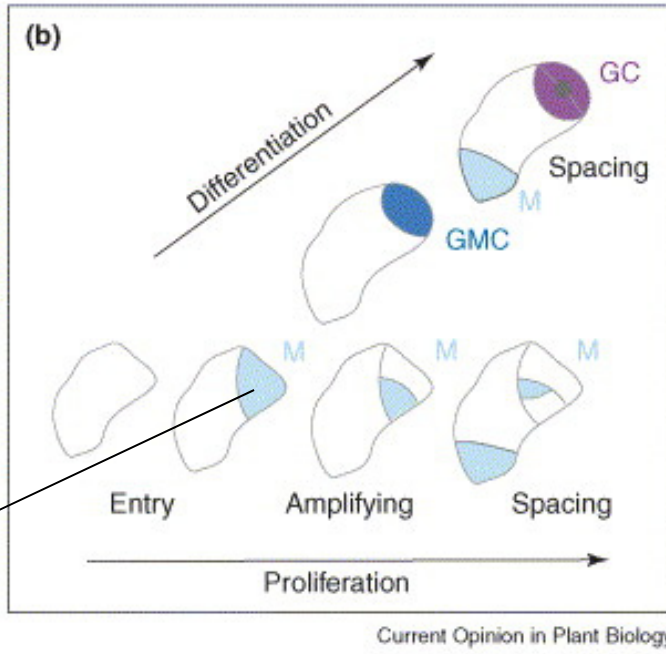
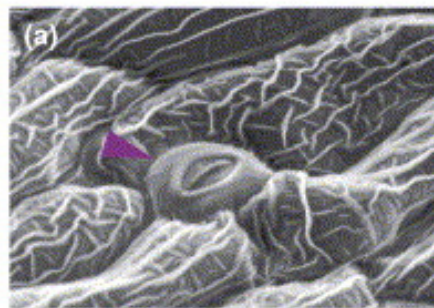
Pro35S:SSP-YFP/WT

Pro35S:ssp-YFP/WT

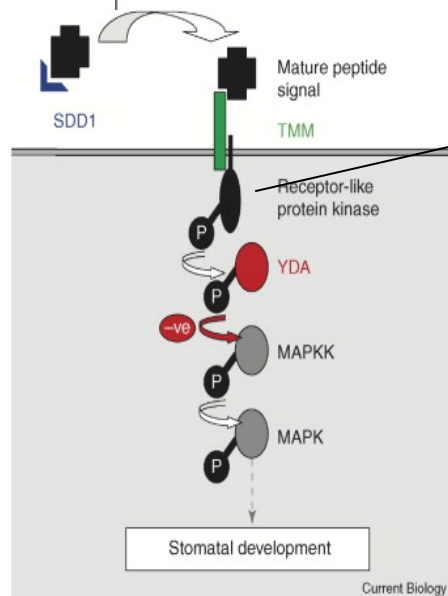
Pro35S:SSP-YFP/yda



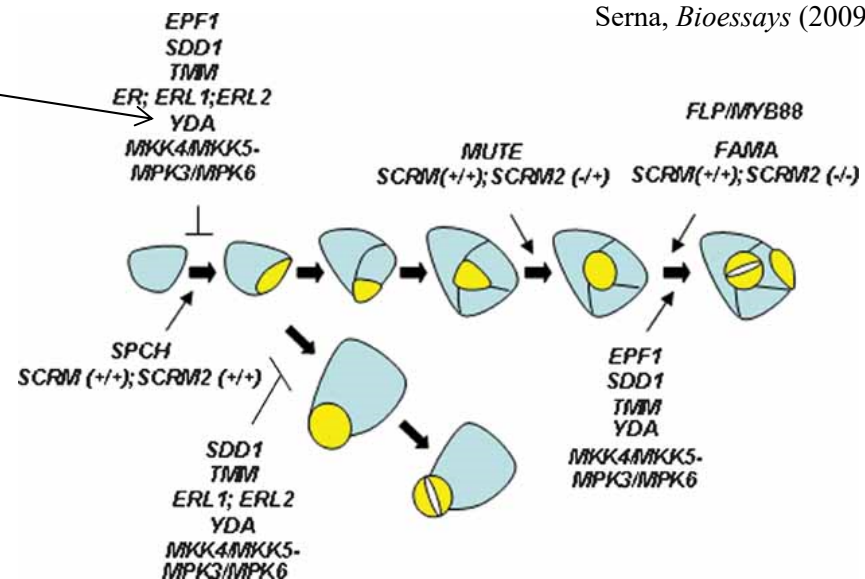
Bayer et al., *Science* (2009)



Meristemoid



SSP



Bergmann, *Curr Opin Plant Biol* (2006)

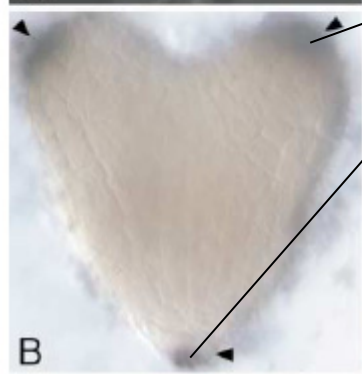
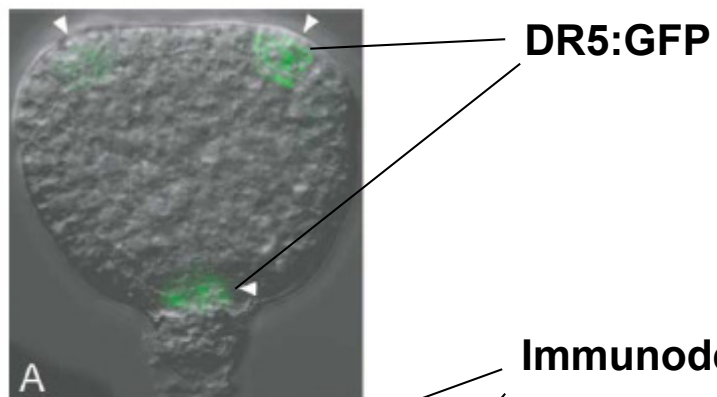
Gray and Hetherington, *Curr Biol* (2004)



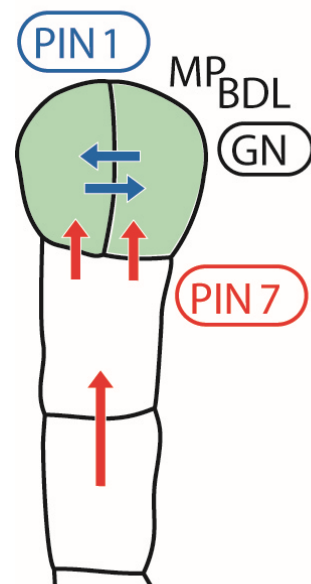
Outline of Lesson 7

Plant Embryogenesis

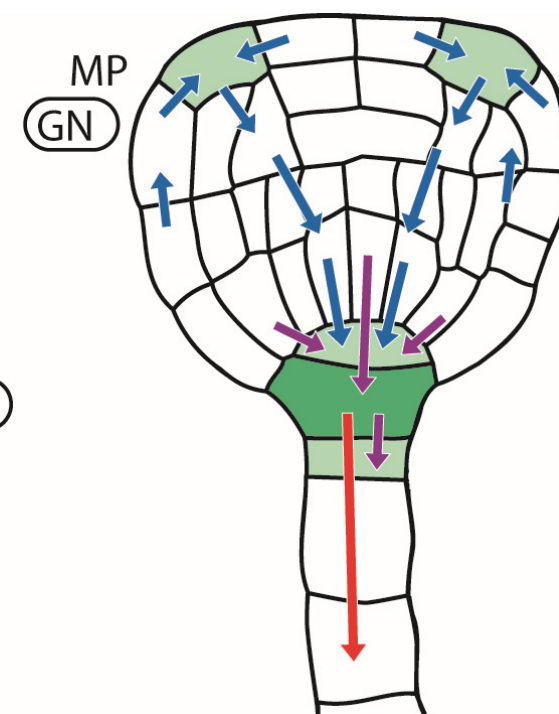
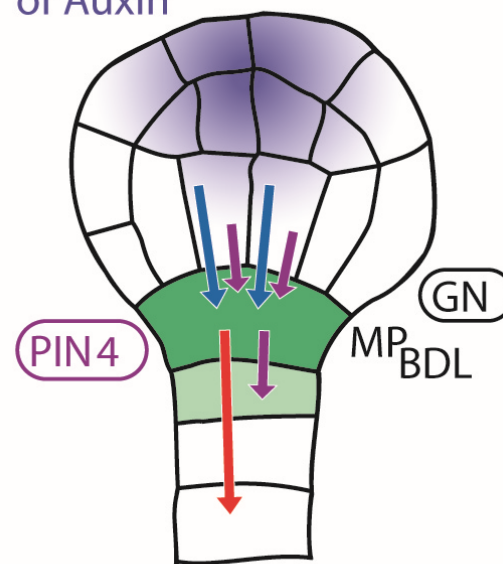
- Overview of the embryo formation in *Arabidopsis*
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 - differential gene expression
 - auxin gradients formation



Immunodetecction of IAA

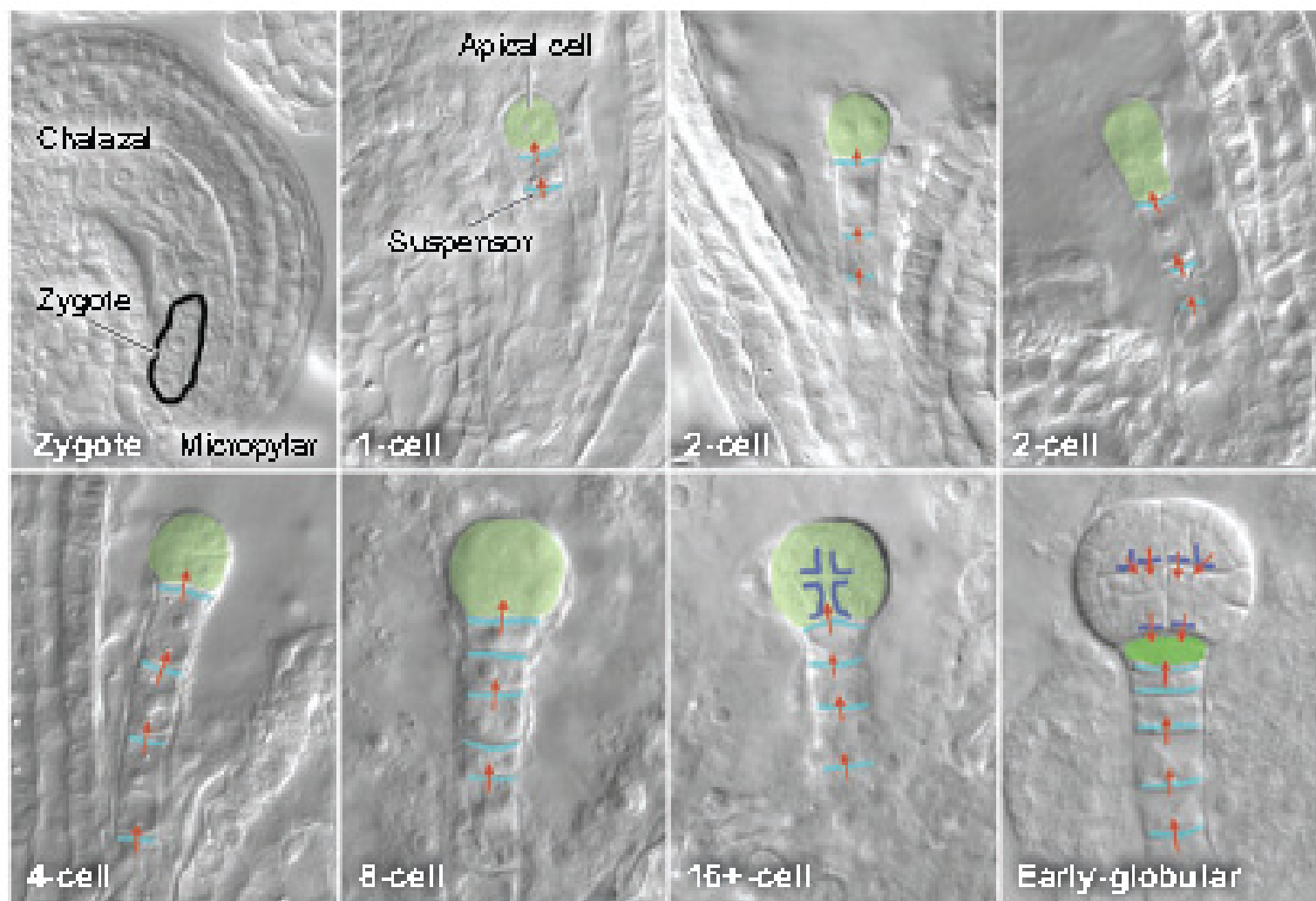


Production of Auxin

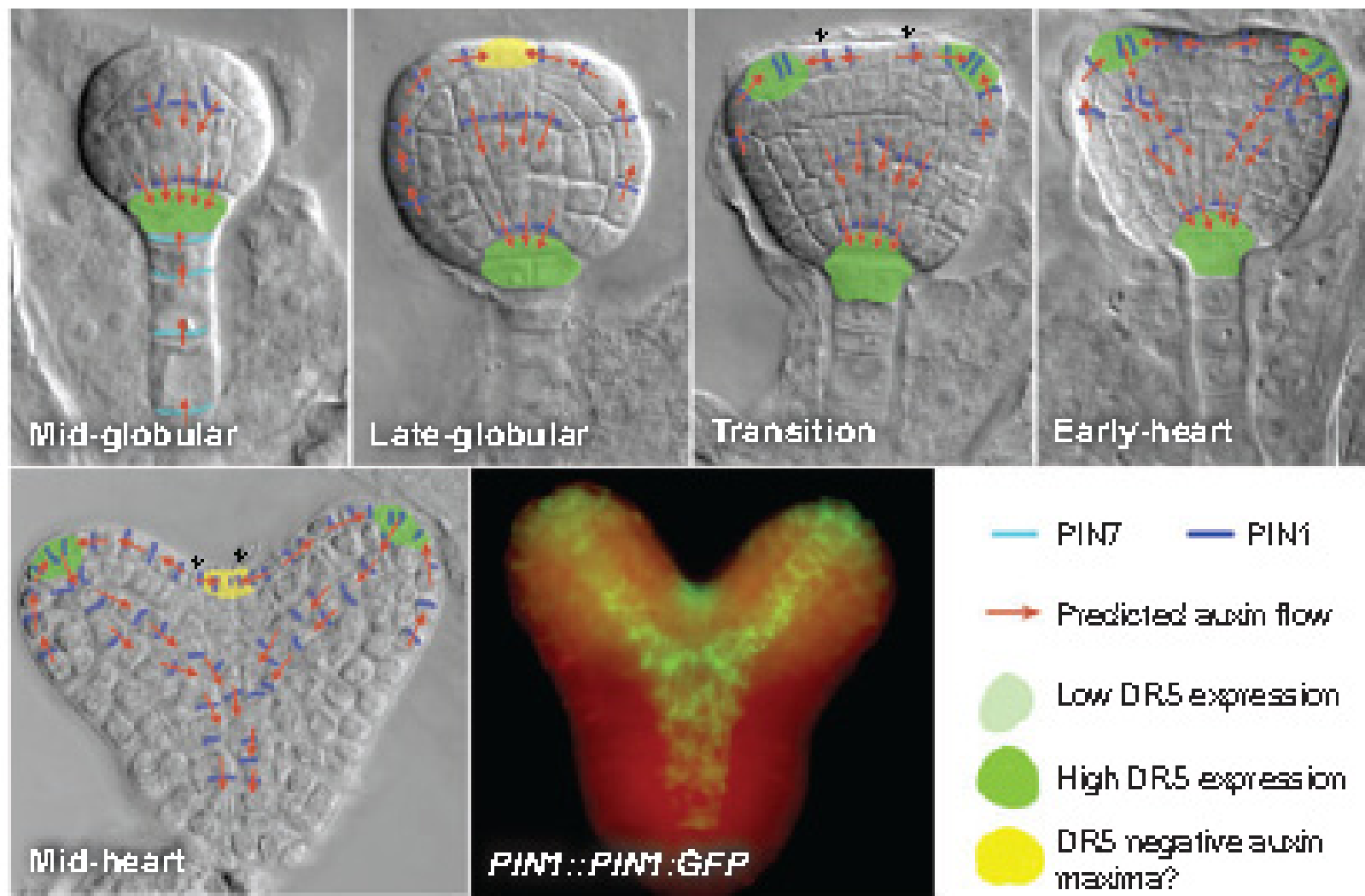


Benkova et al., *Cell* (2003)

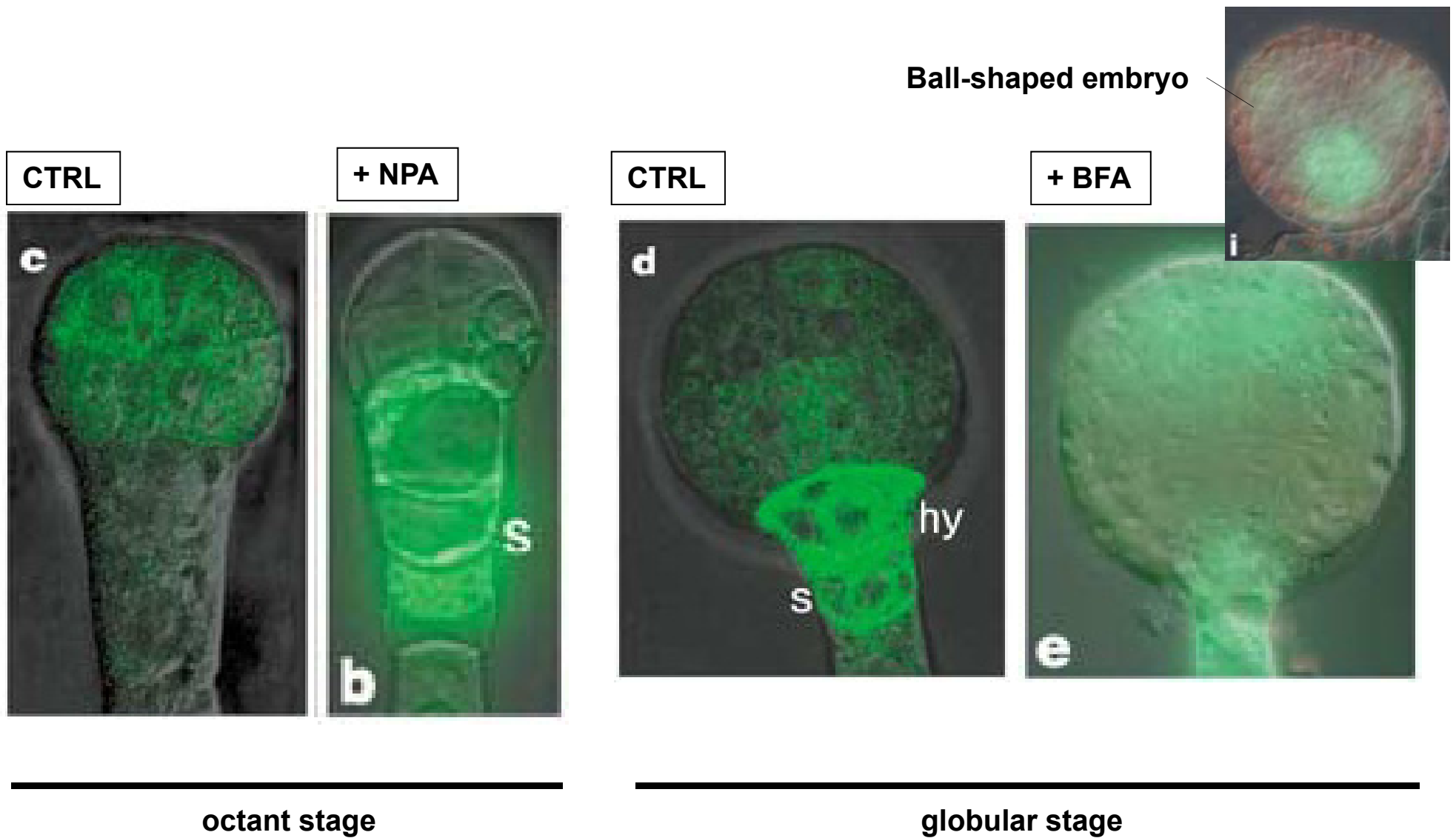
Dubova, Hejatko, Friml (2005)



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

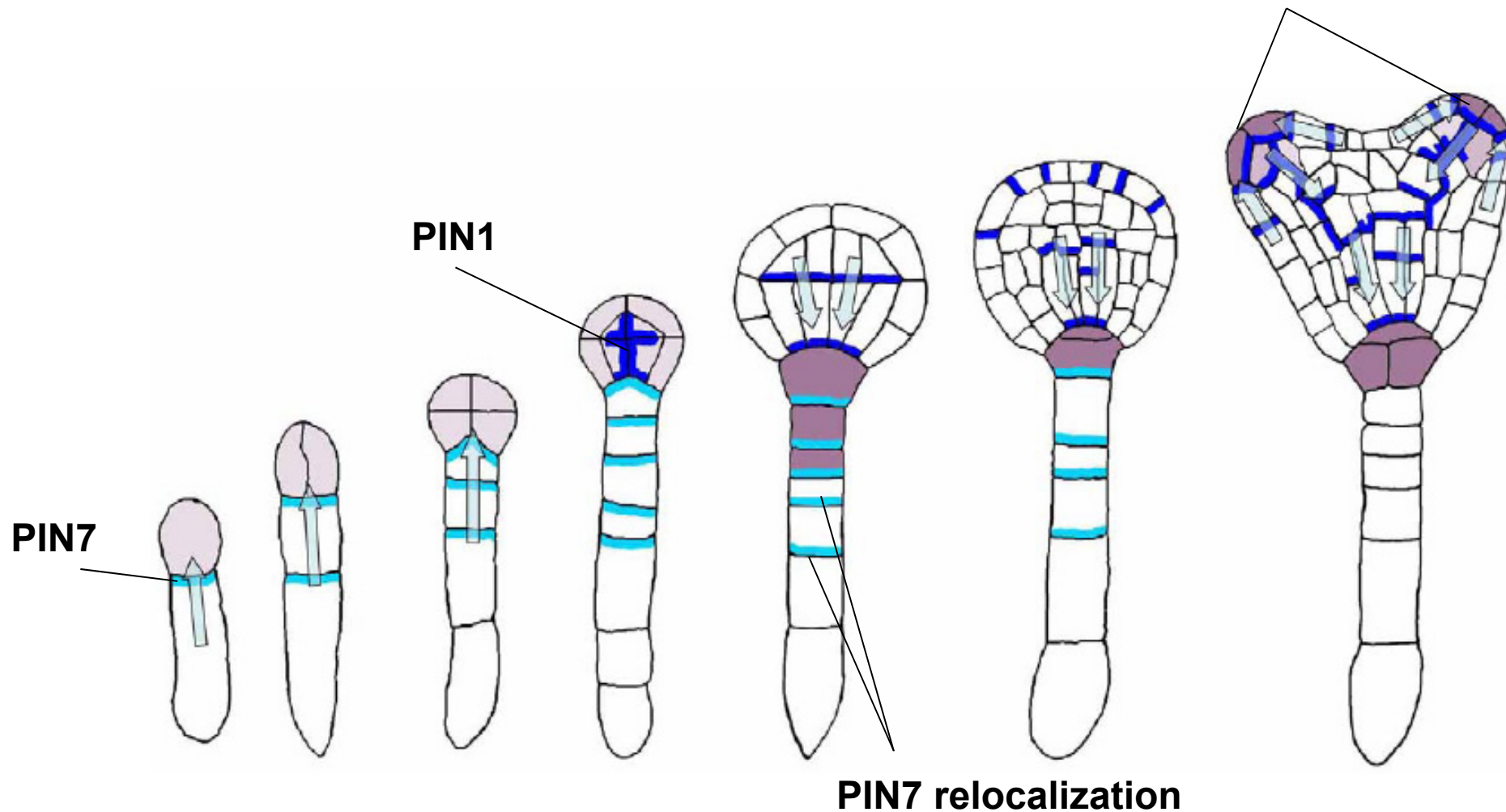


Bowman et al., *Annu. Rev. Plant. Biol.* (2008)



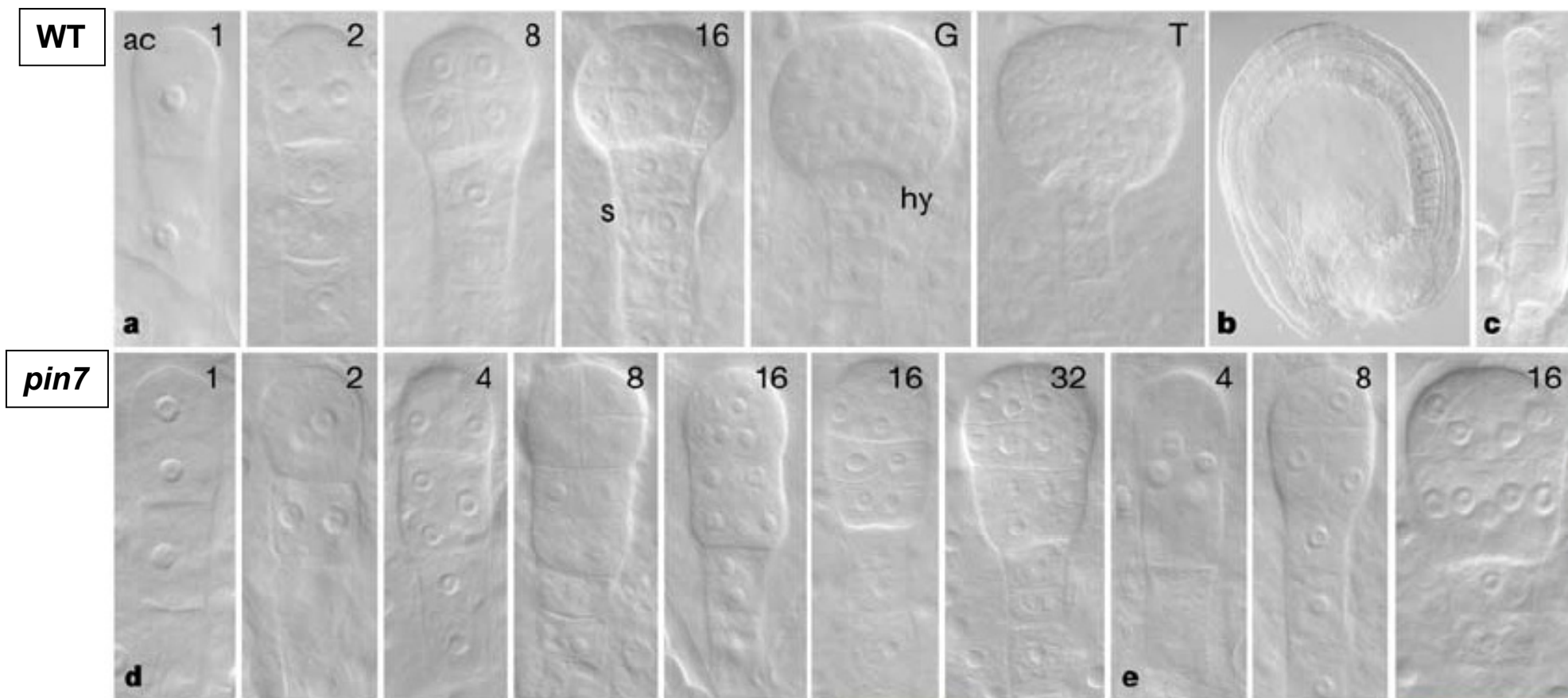
Friml, *Nature* (2003)

Bilateral symmetry via PIN1 localization

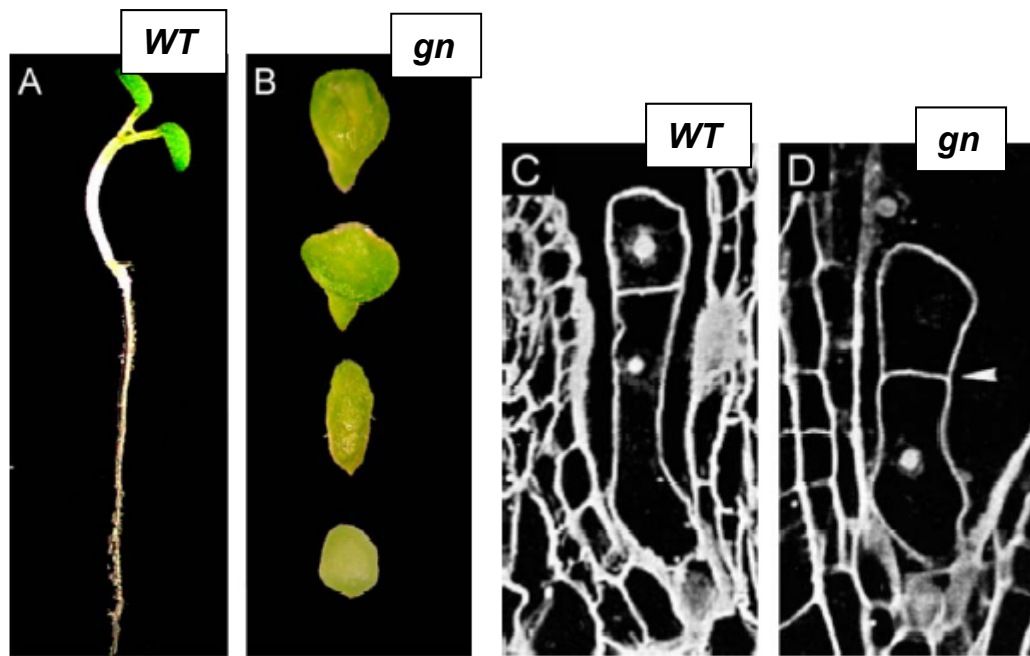


Capron et al., *Arabidopsis Book* (2009)

Dermatogen stage

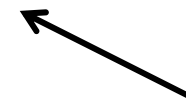


Friml et al., *Nature* (2003)

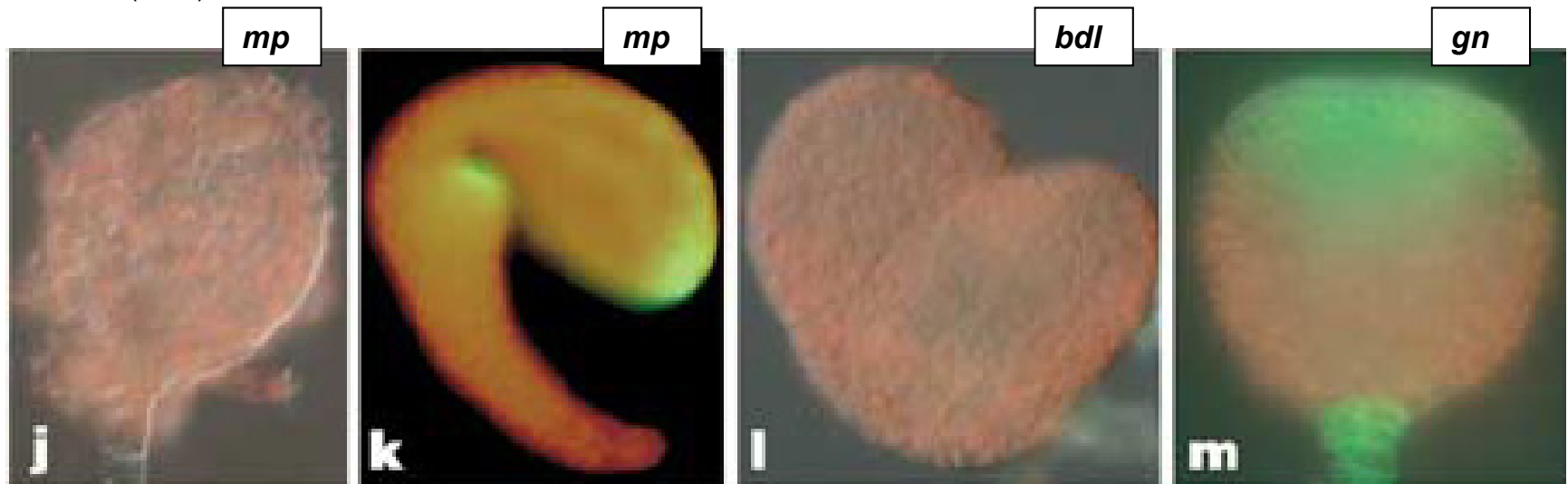


Mutations affecting embryo patterning are associated with changes in the auxin maxima formation

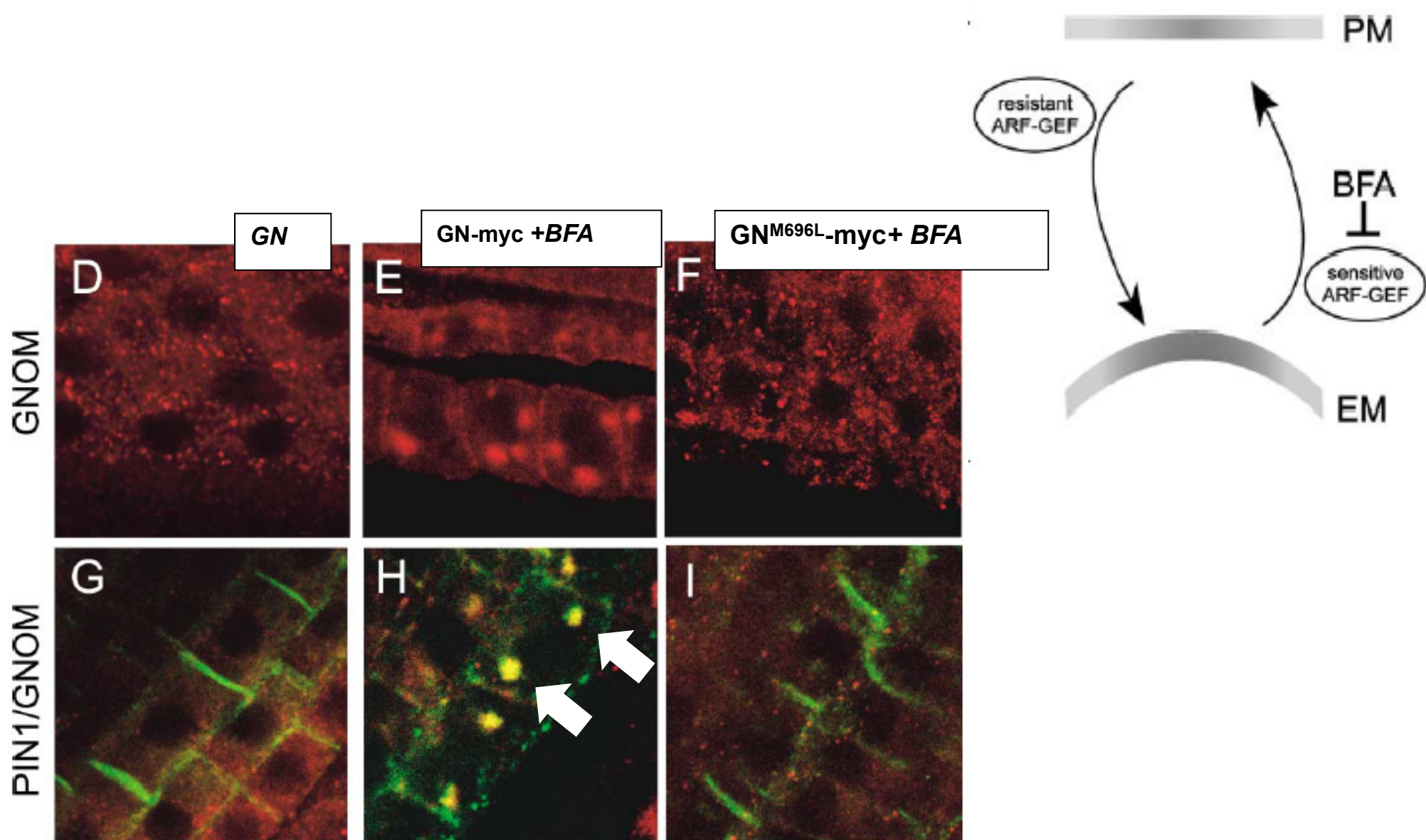
Adenosyl ribosylation factor
Guanine nucleotide Exchange
Factor (ARF GEF),



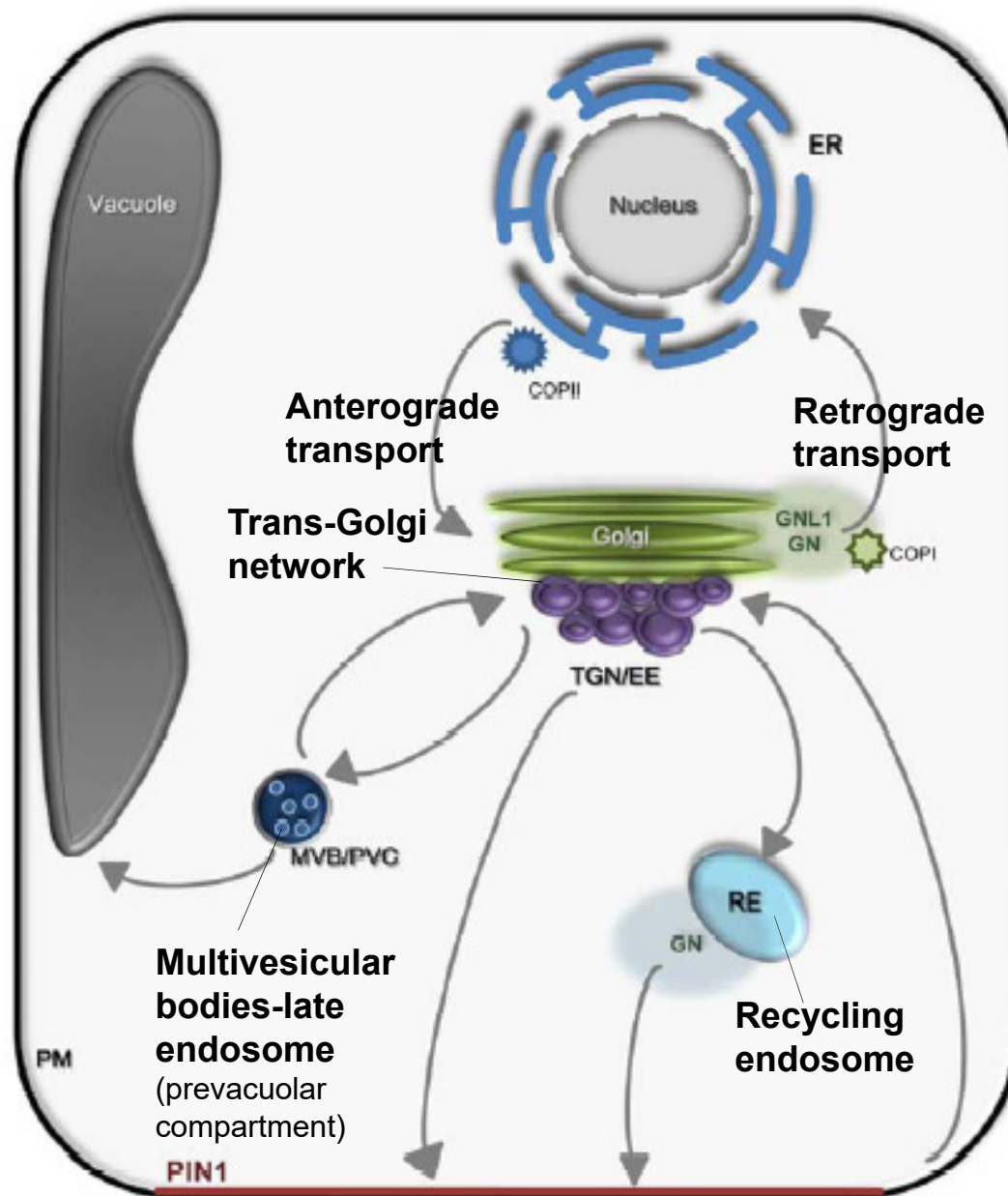
Richter et al., *E J Cell Biol* (2010)



Friml et al., *Nature* (2003)



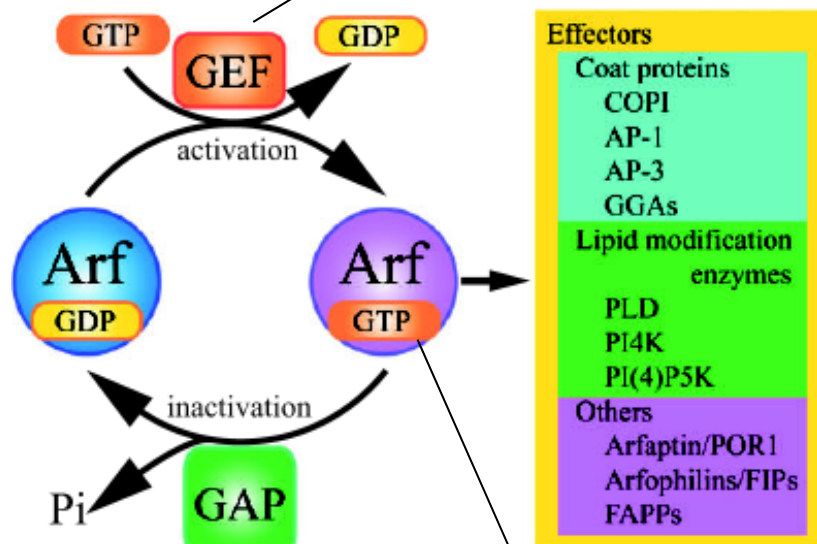
Geldner et al., *Cell* (2003)



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

A

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

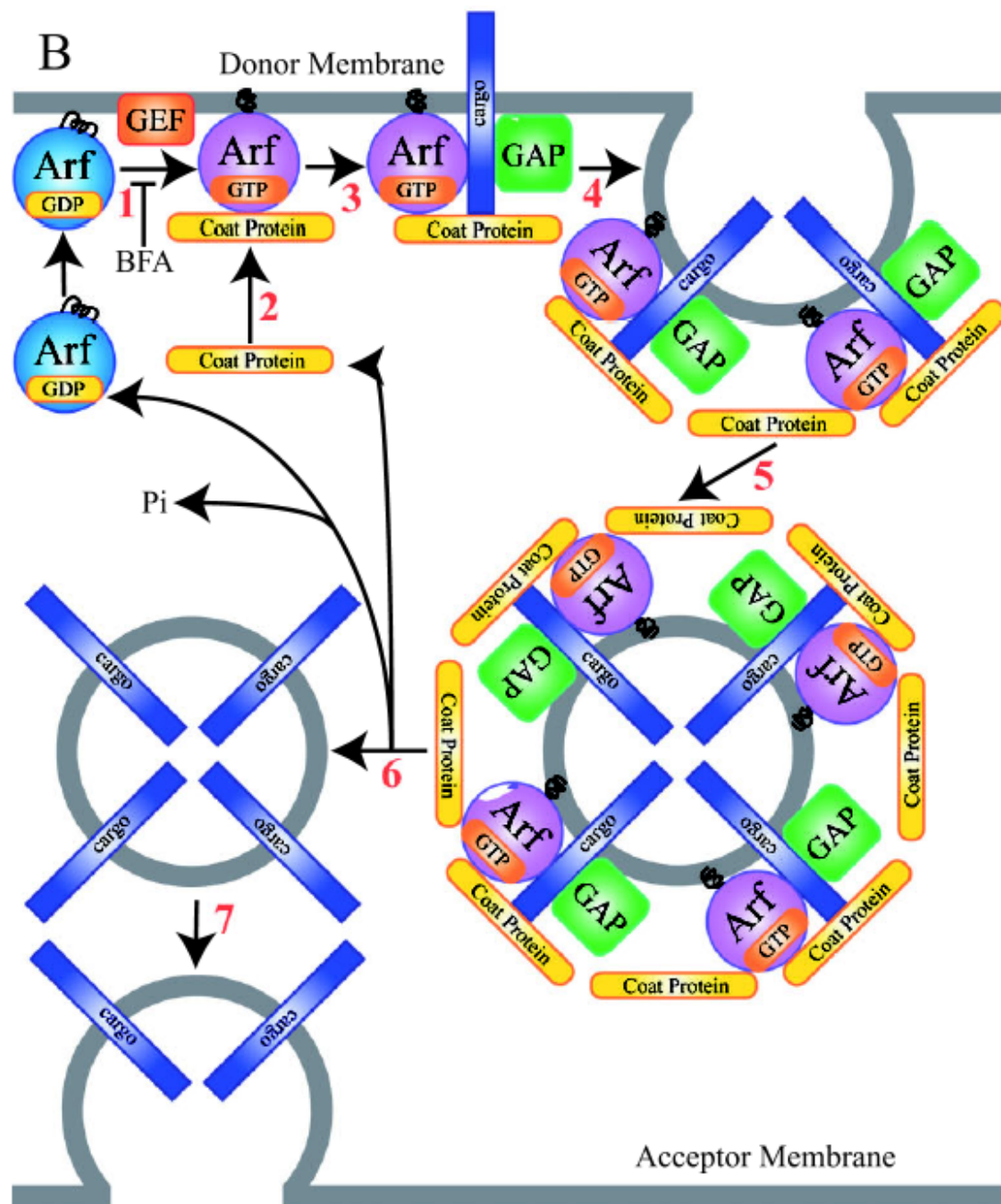


Adenosyl ribosylation factor

GTPase-activating
protein

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

B



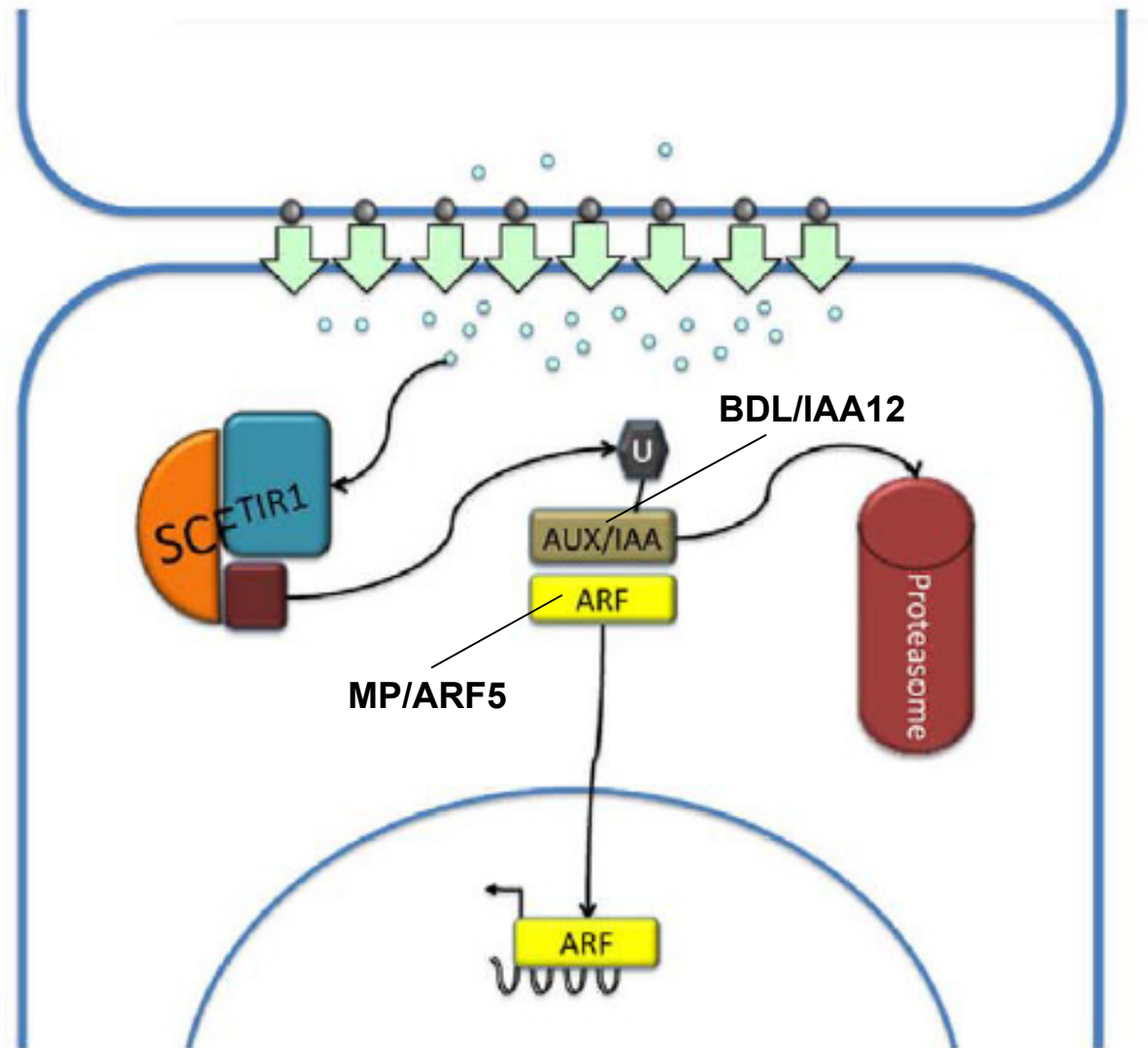


Outline of Lesson 7

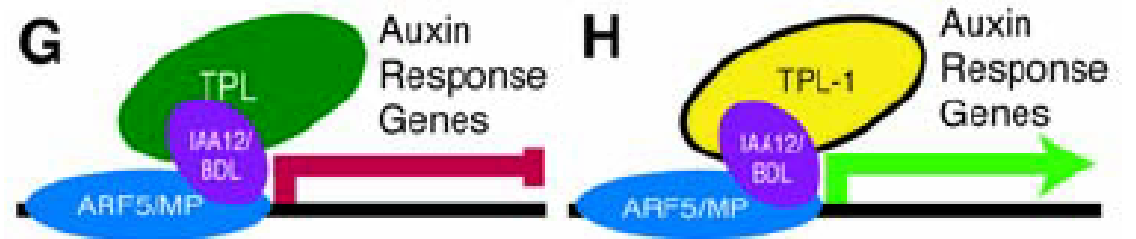
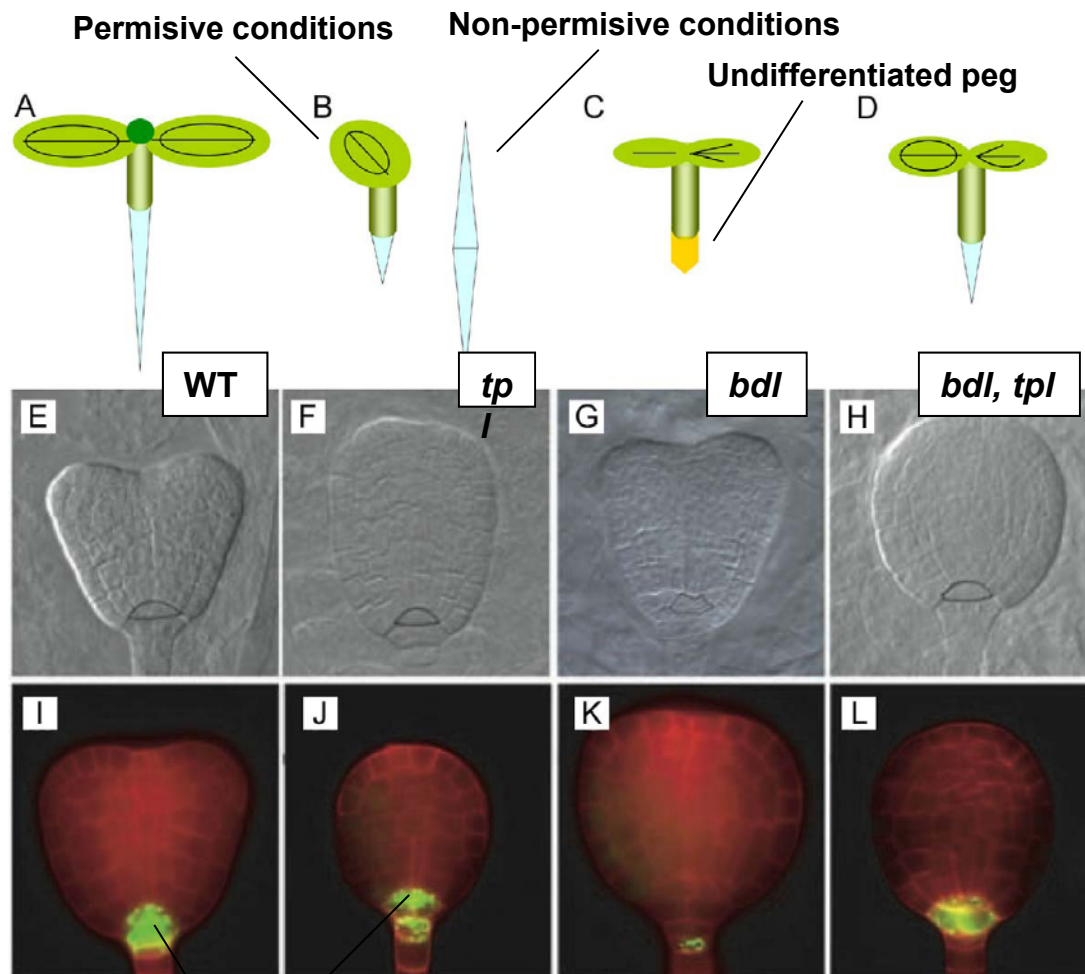
Plant Embryogenesis

- Overview of the embryo formation in *Arabidopsis*
- Mechanism of the apical-basal axis formation
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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)



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

Szemenyei et al., *Science* (2008)

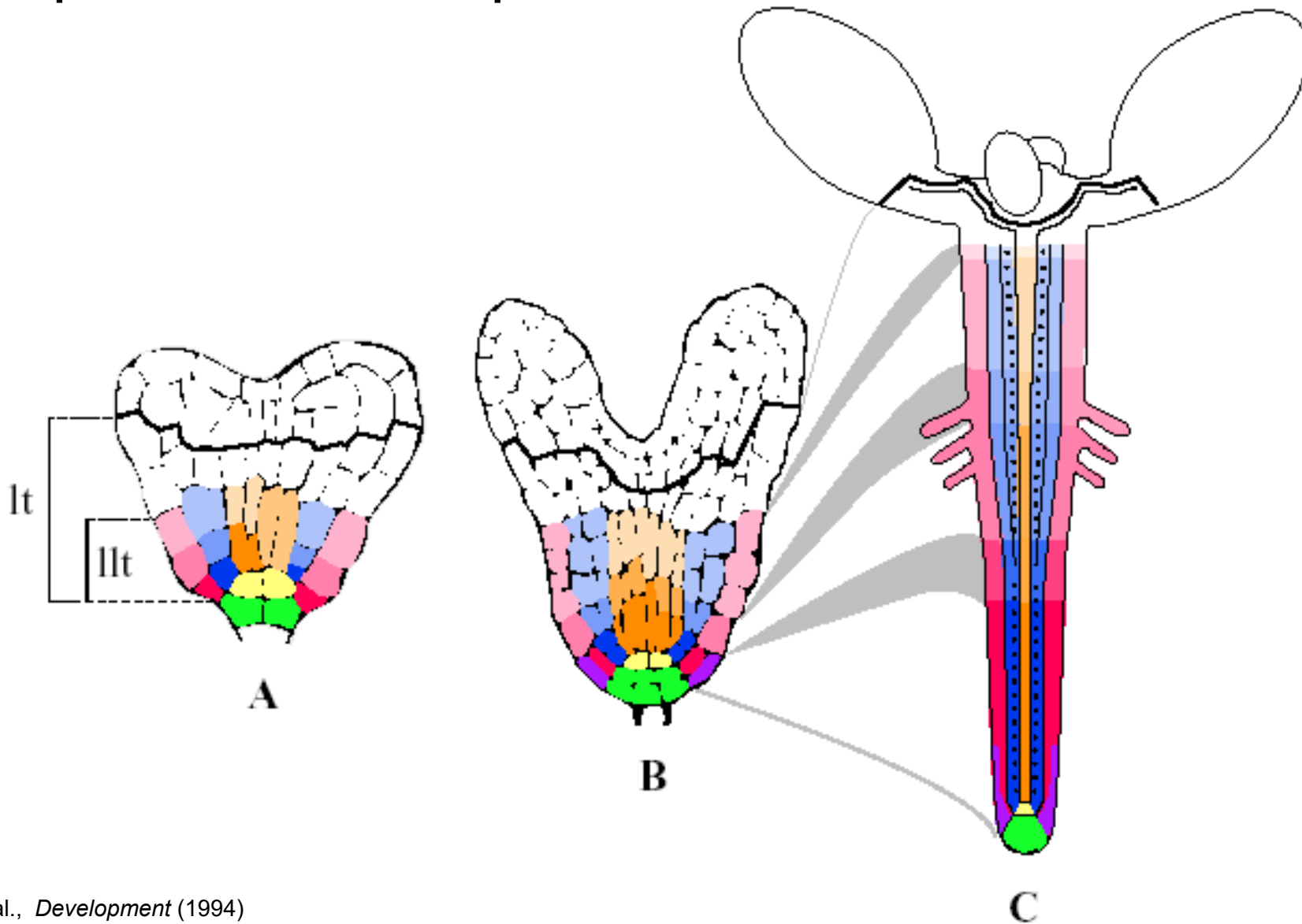


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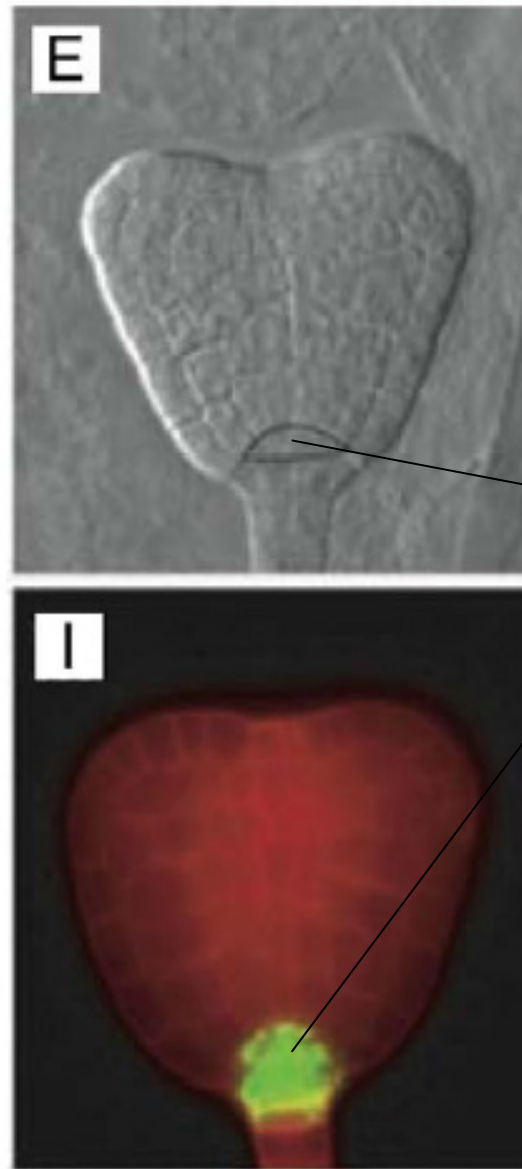
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- Root meristem formation
 - auxin and hypophysis identity

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

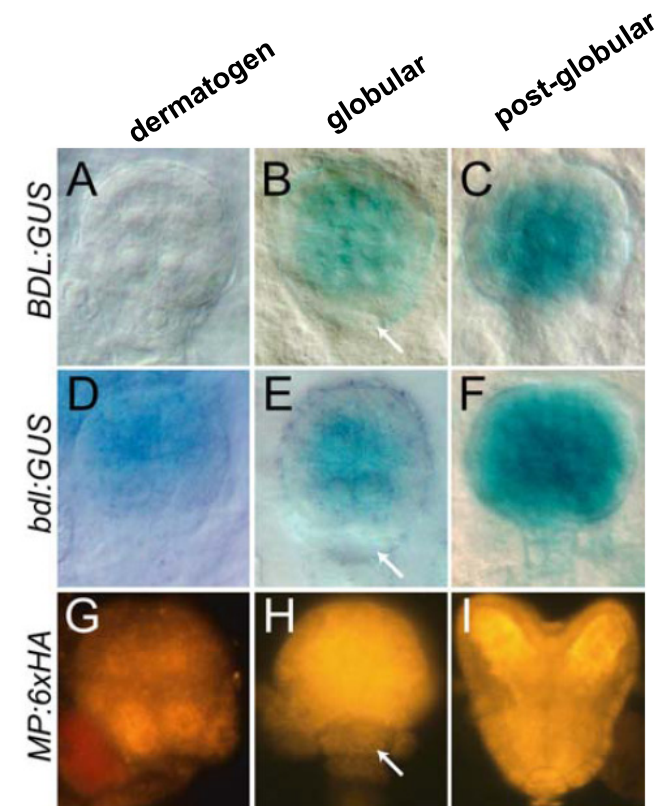
Auxin flow from
the UT

Hypophysis

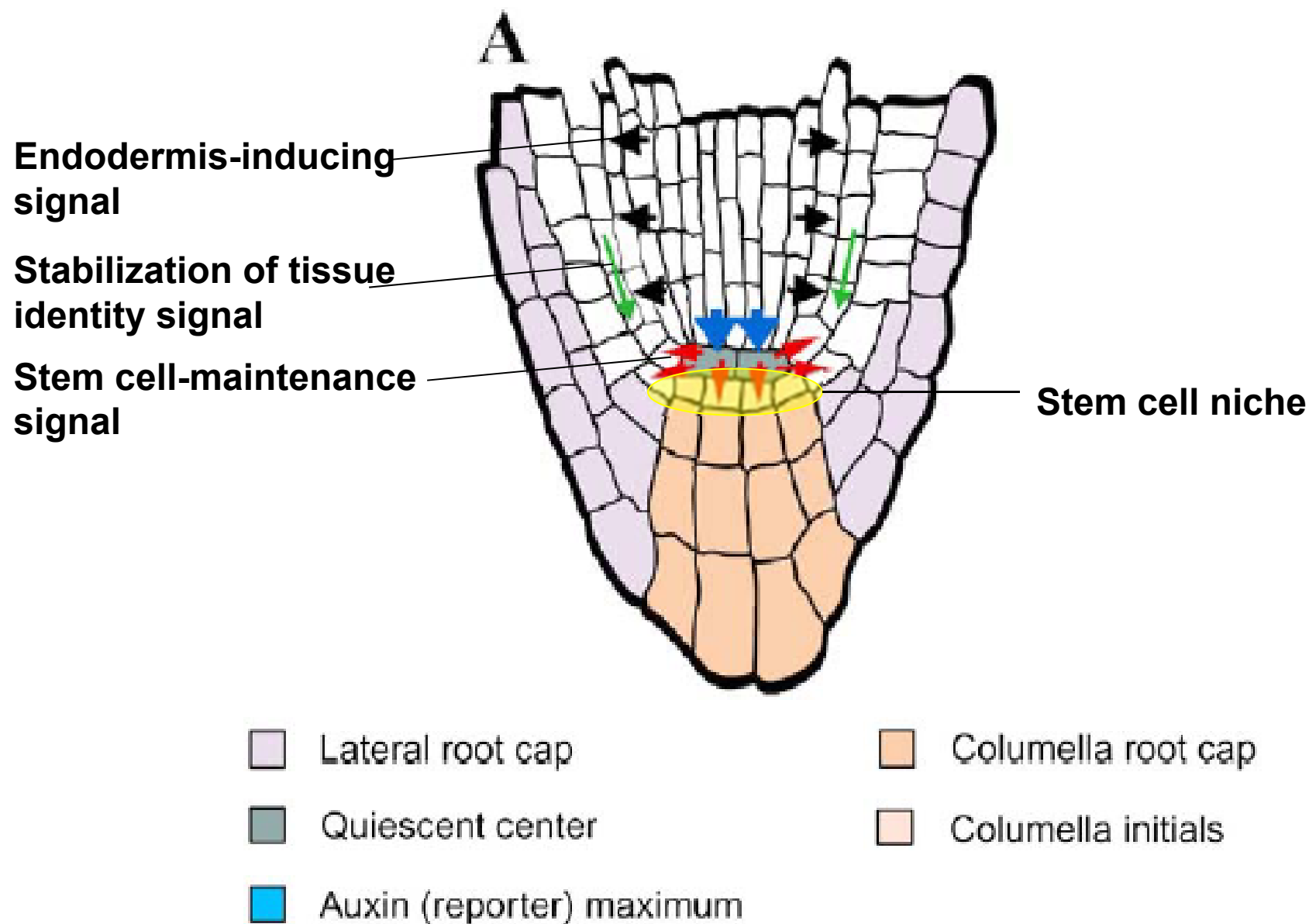
Lens shaped cell

Globular stage Late globular-early triangular embryo stage

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

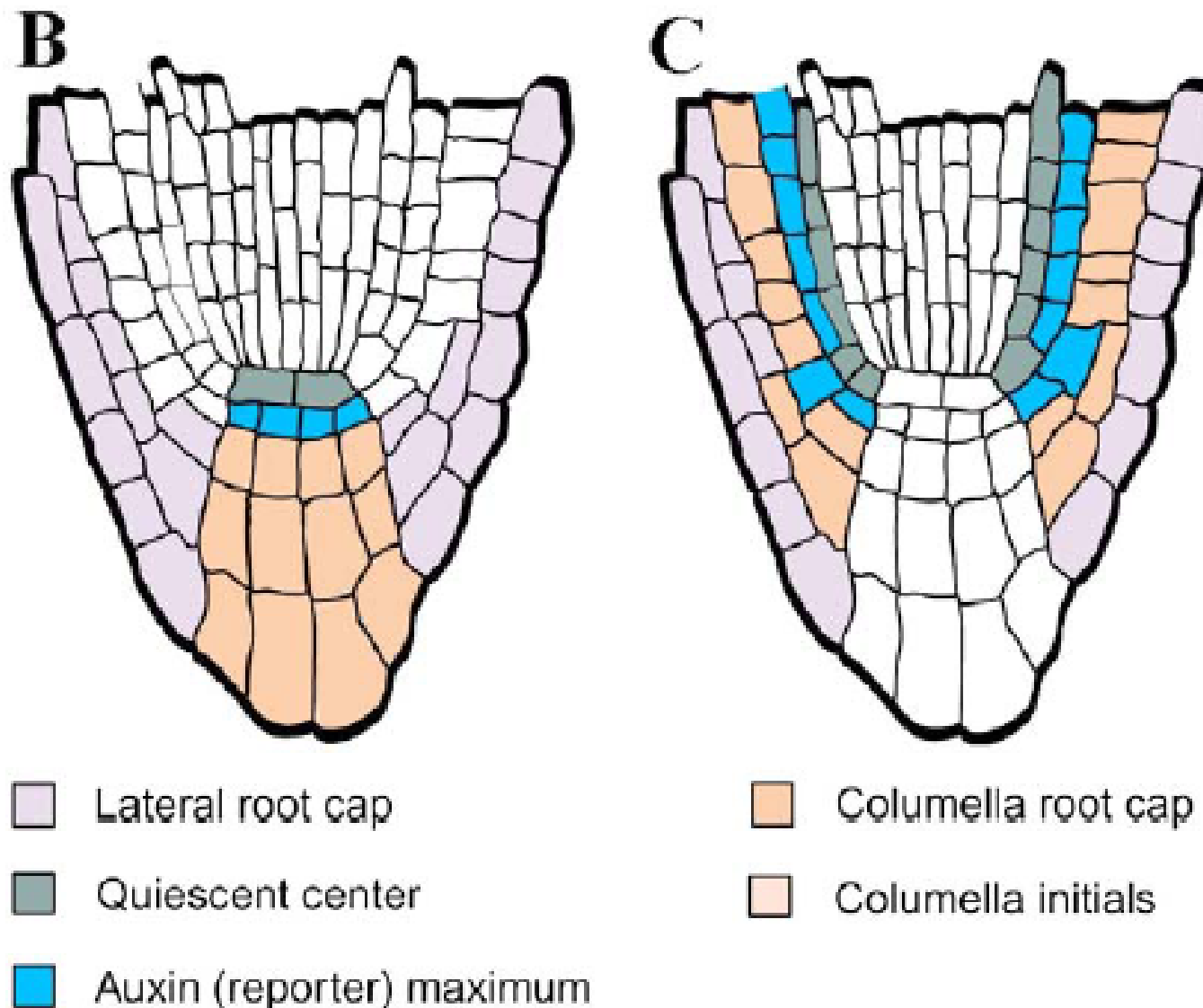


Weijers et al., *Dev Cell* (2006)



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

auxin response maximum displaced



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

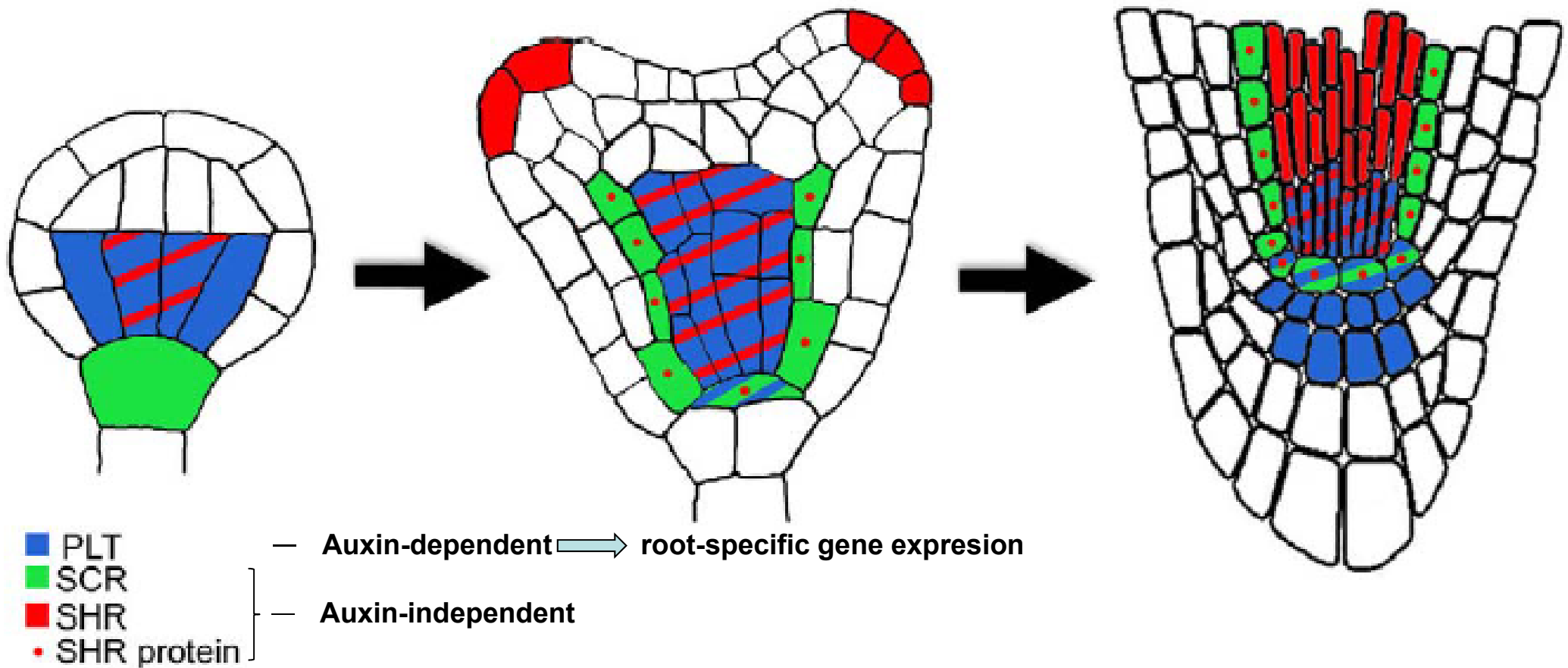


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Auxin-dependent and auxin-independent differential gene expression patterns root meristem



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



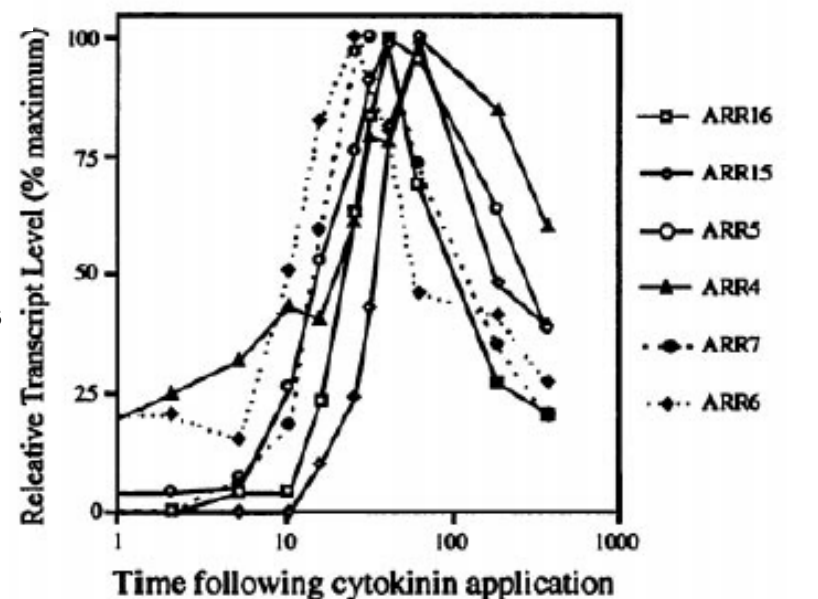
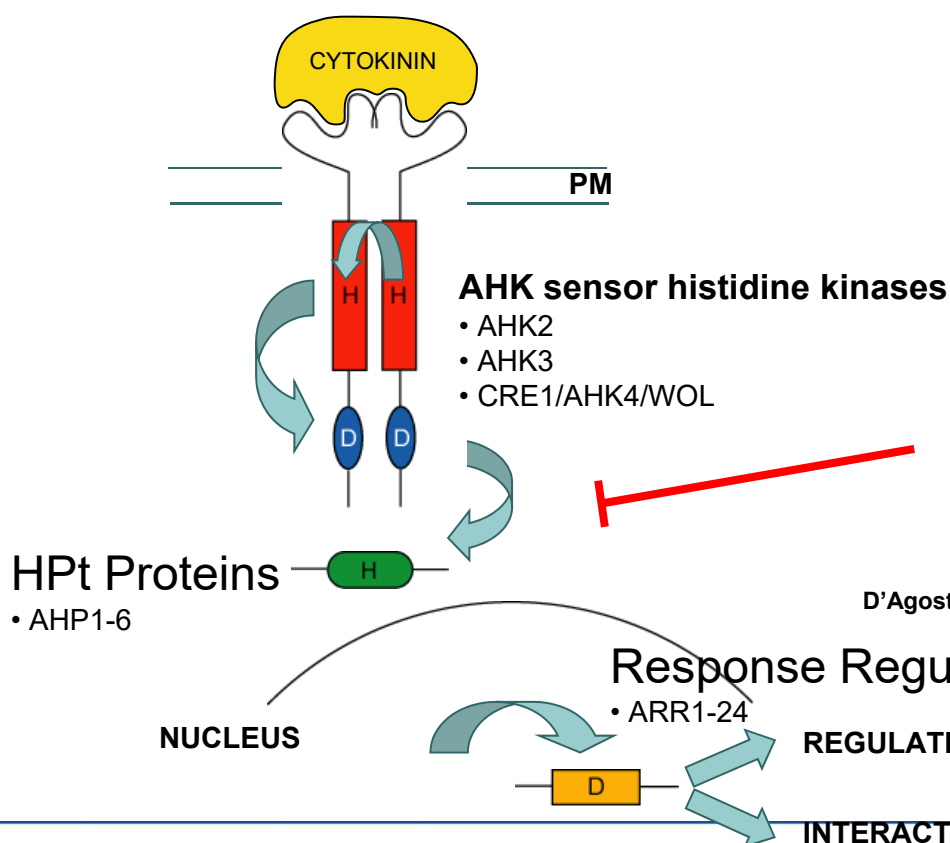
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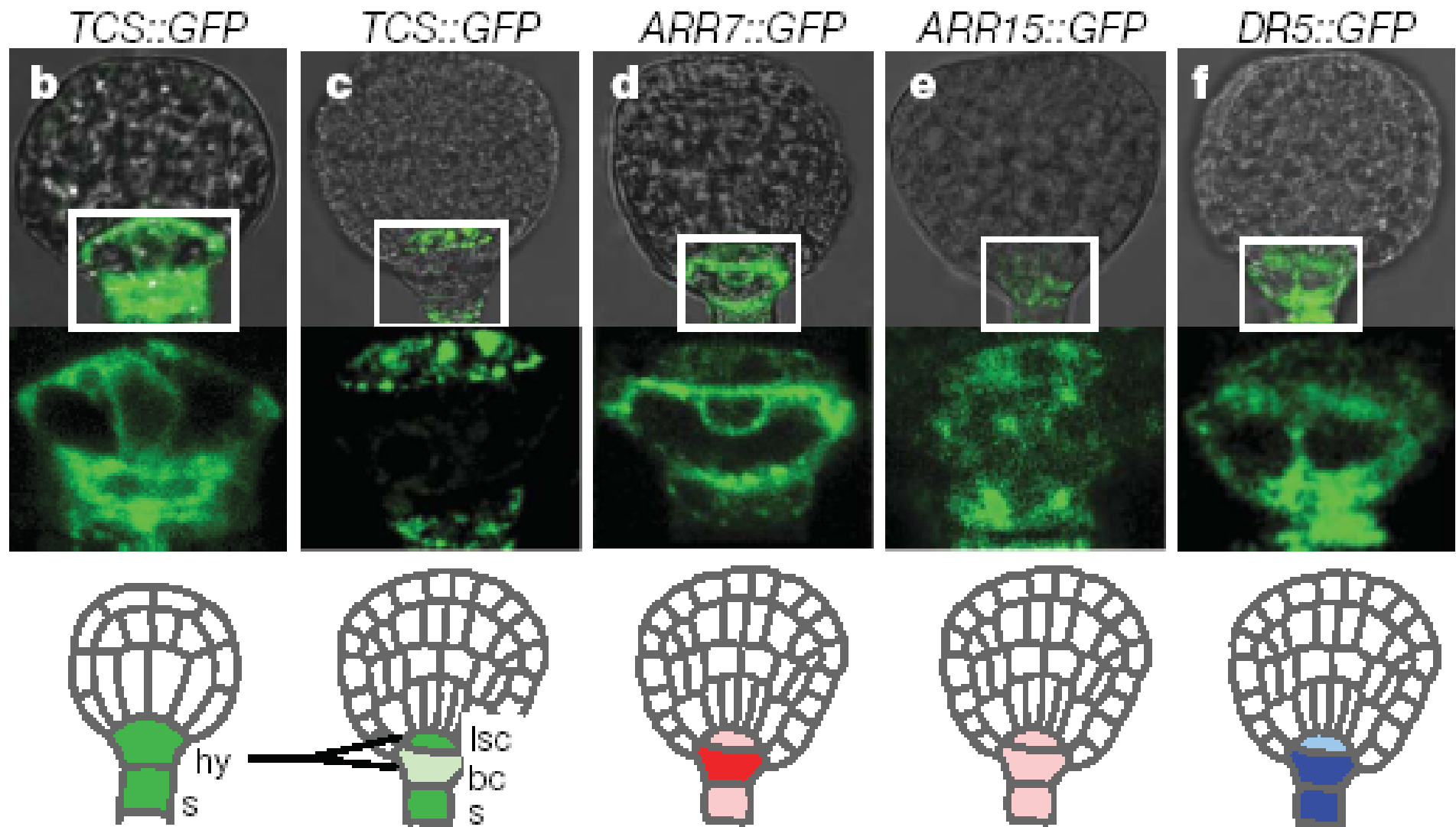
Signal Transduction via TCS

Recent Model of the CK Signaling via TCS Pathway

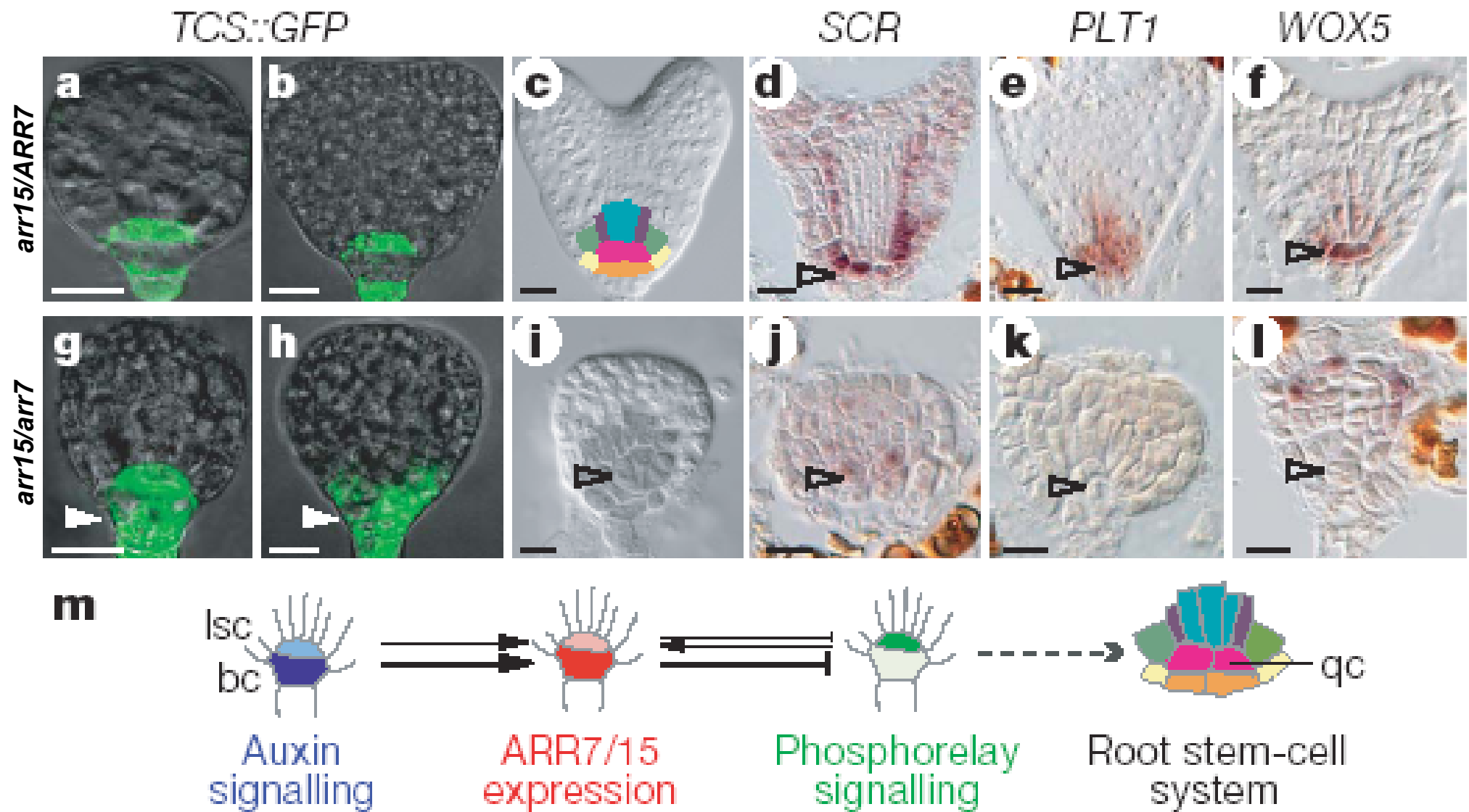


D'Agostino et al., Plant Physiol, 2000

CK primary response genes
- Type-A ARR expression



Muller and Sheen., *Nature* (2008)



Muller and Sheen., *Nature* (2008)

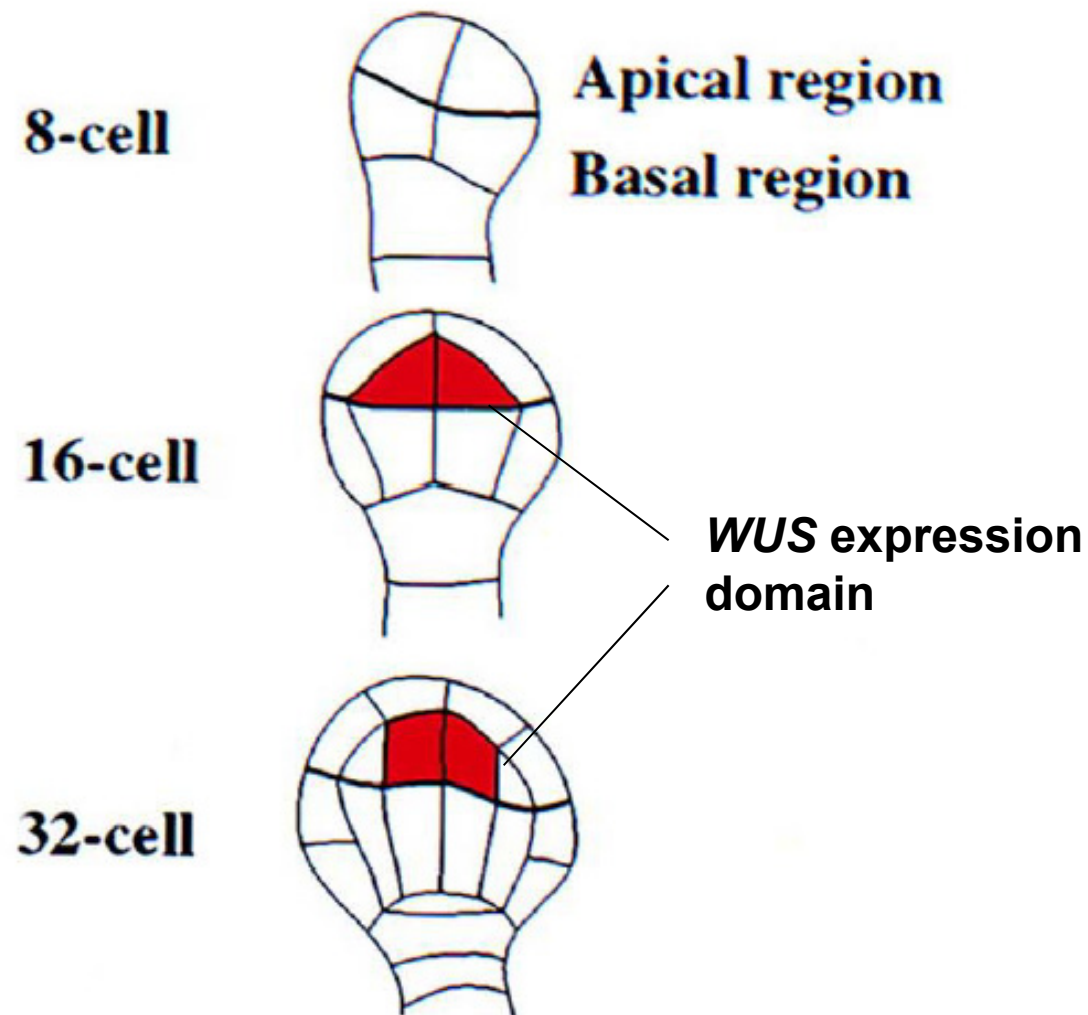


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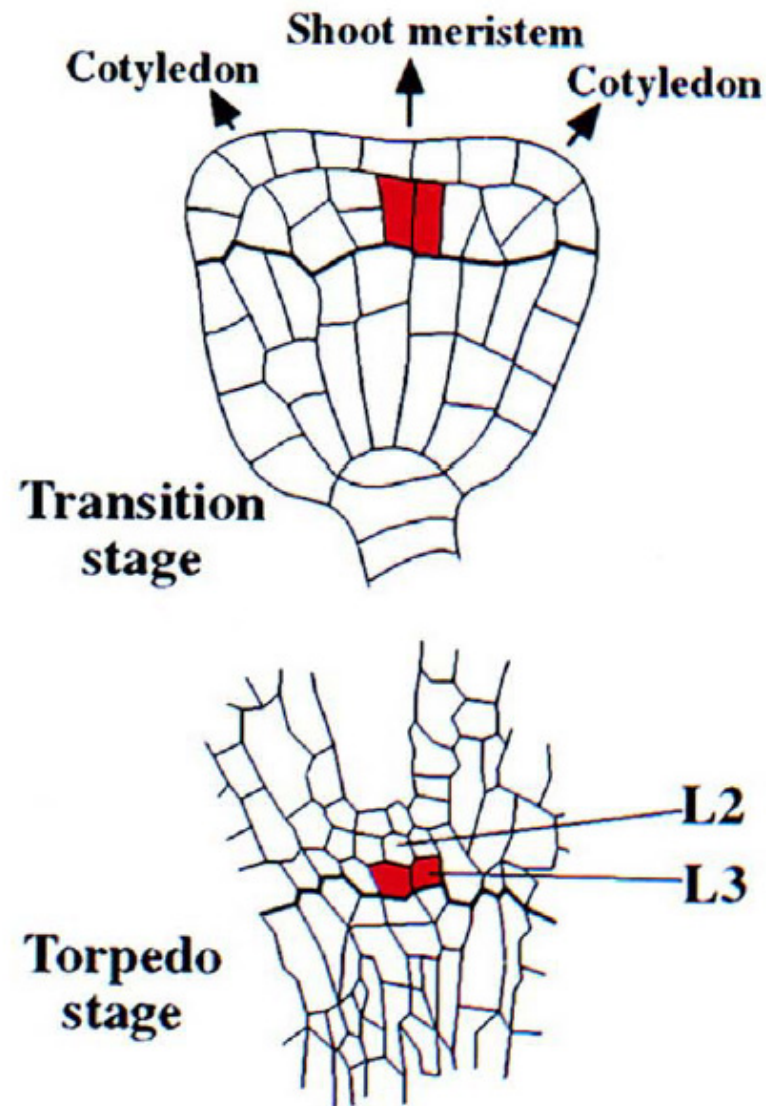
Plant Embryogenesis

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

SAM specification

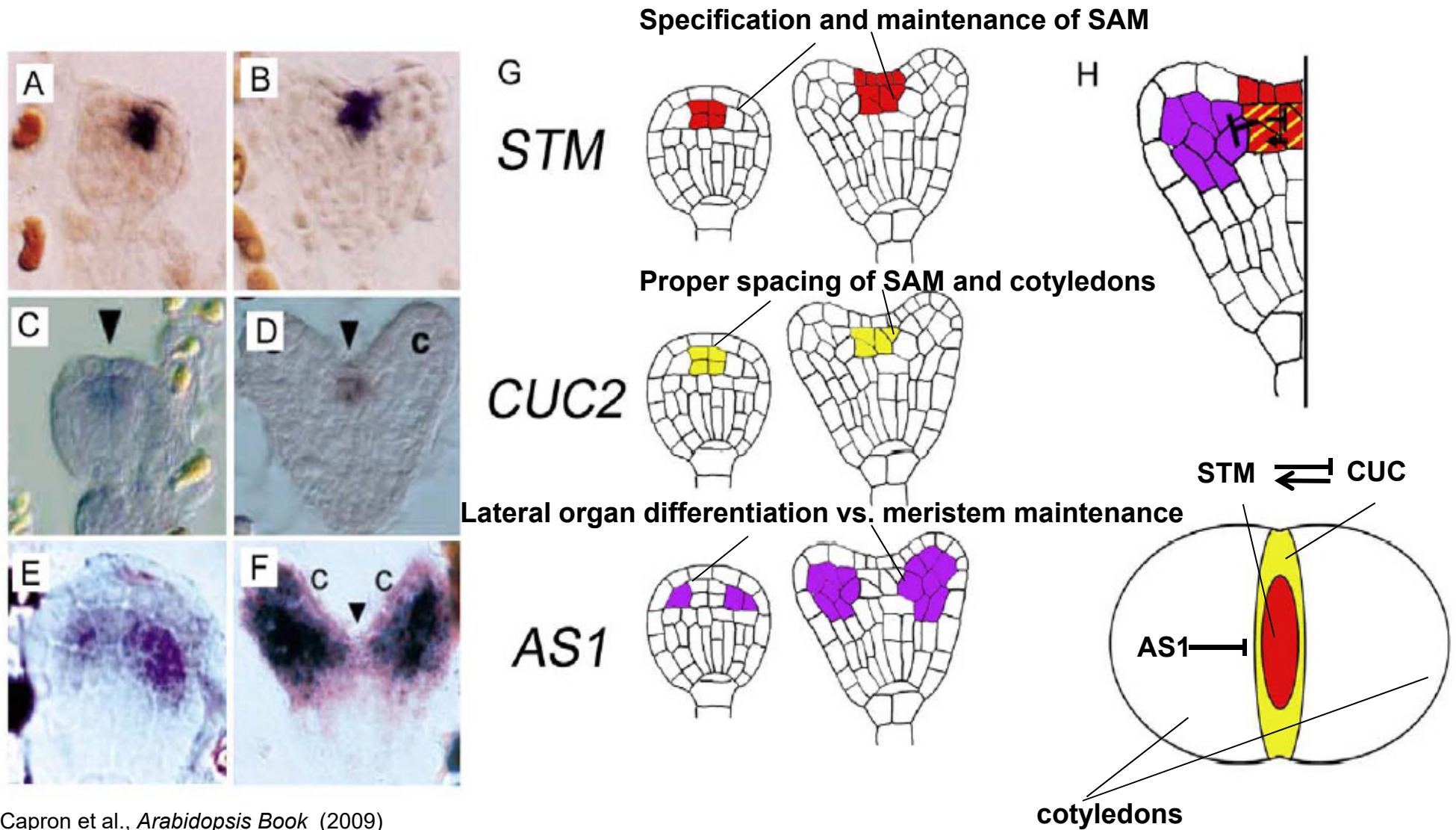


Capron et al., *Arabidopsis Book* (2009)



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

Gene interactions during apical embryo pole patterning



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

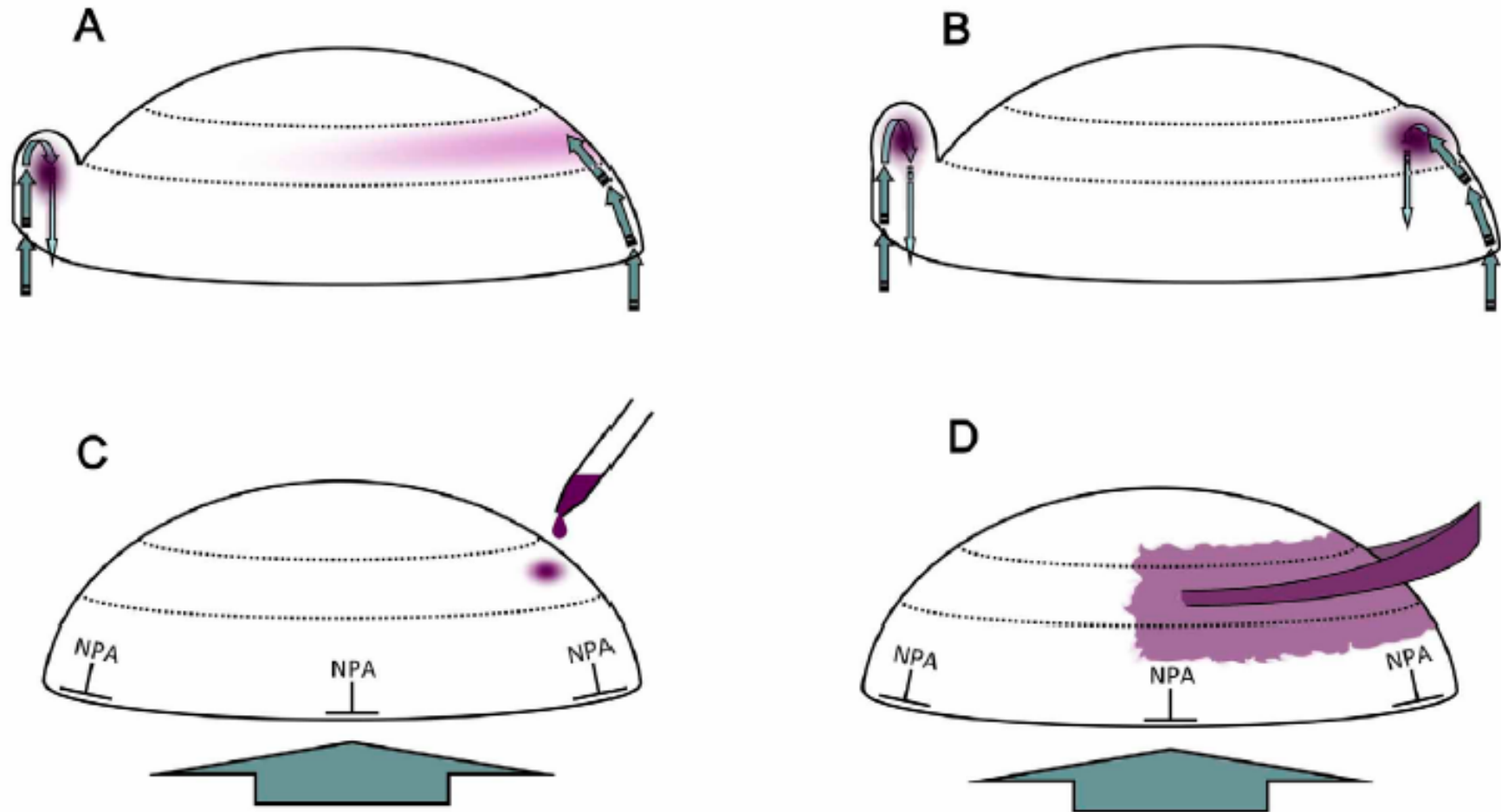


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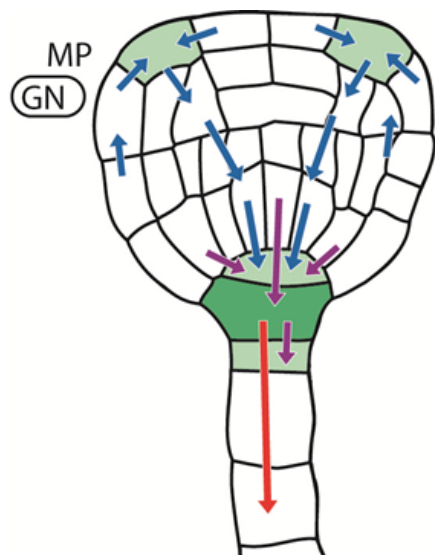
Plant Embryogenesis

- Patterning of the apical pole of the plant embryo
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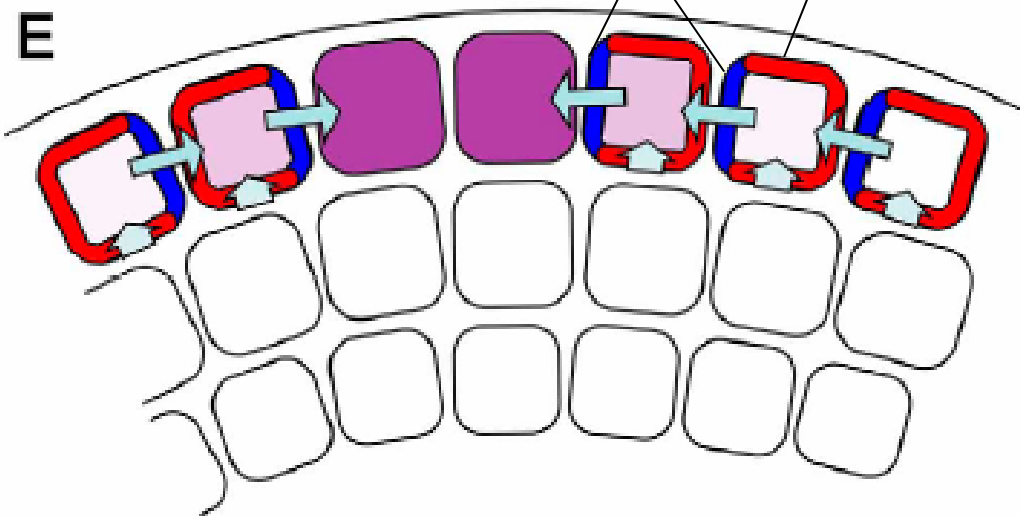
Auxin maxima are involved in lateral organ formation and acquiring of bilateral symmetry



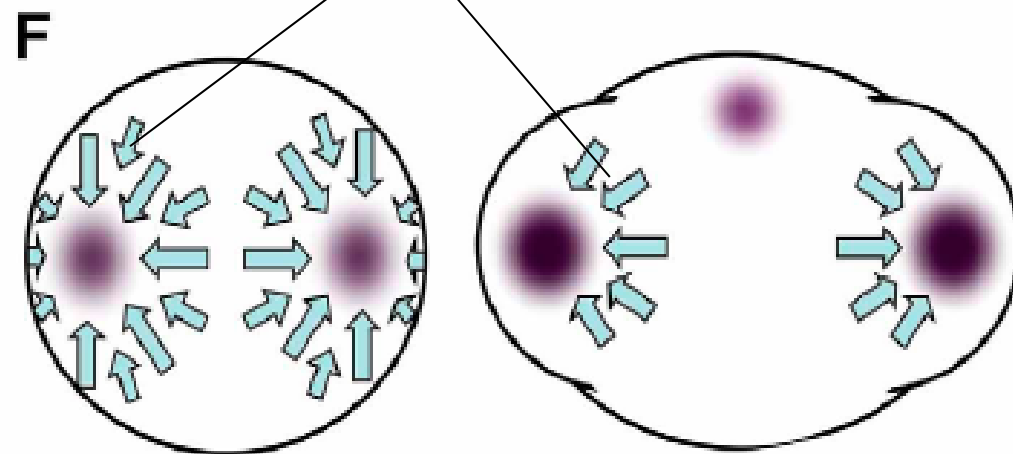
Capron et al., *Arabidopsis Book* (2009)



PINs
AUX1 and LAX1



Concerted action of auxin transporters
(influx and efflux carriers)



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

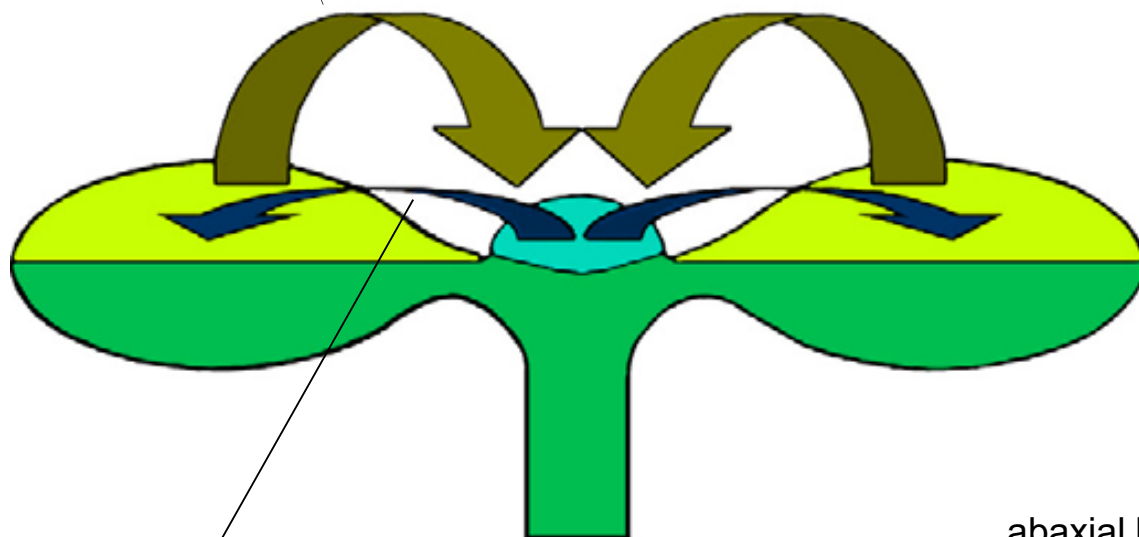


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Plant Embryogenesis

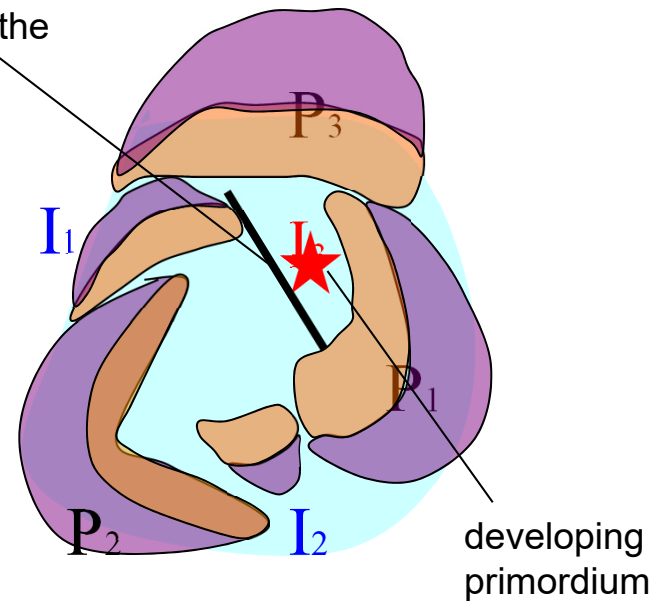
- Patterning of the apical pole of the plant embryo
 - generation of cotyledons and shoot apical meristem
 - proper spacing of lateral organs
 - adaxial-abaxial axis formation

SAM-inducing positive feedback from the adaxial pole



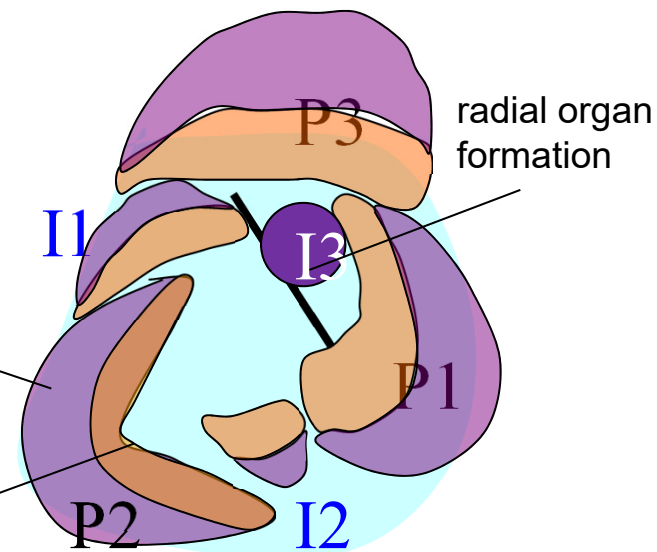
SAM-derived signals induce adaxial-abaxial diversification

Incision in the meristem



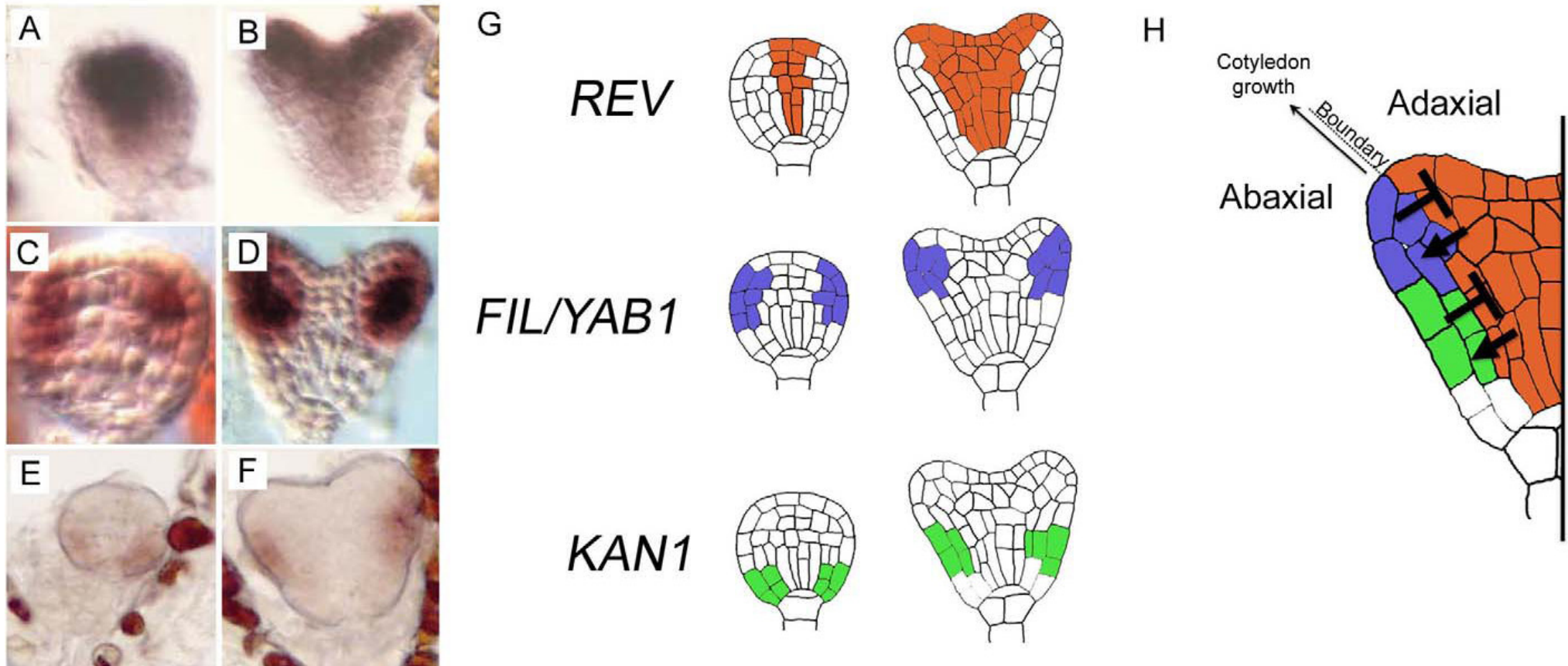
abaxial leaf side

adaxial leaf side

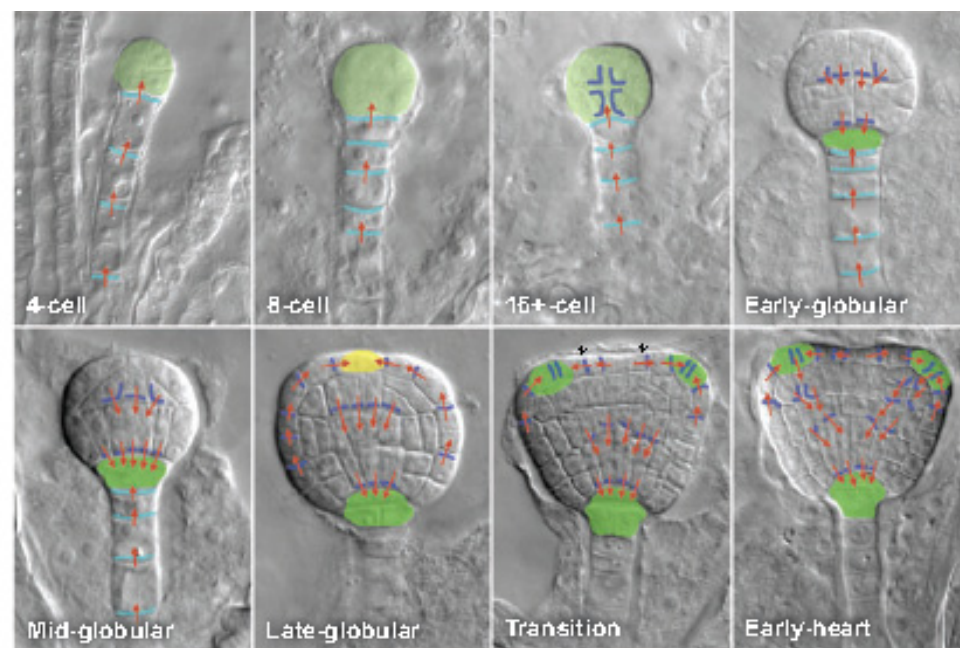
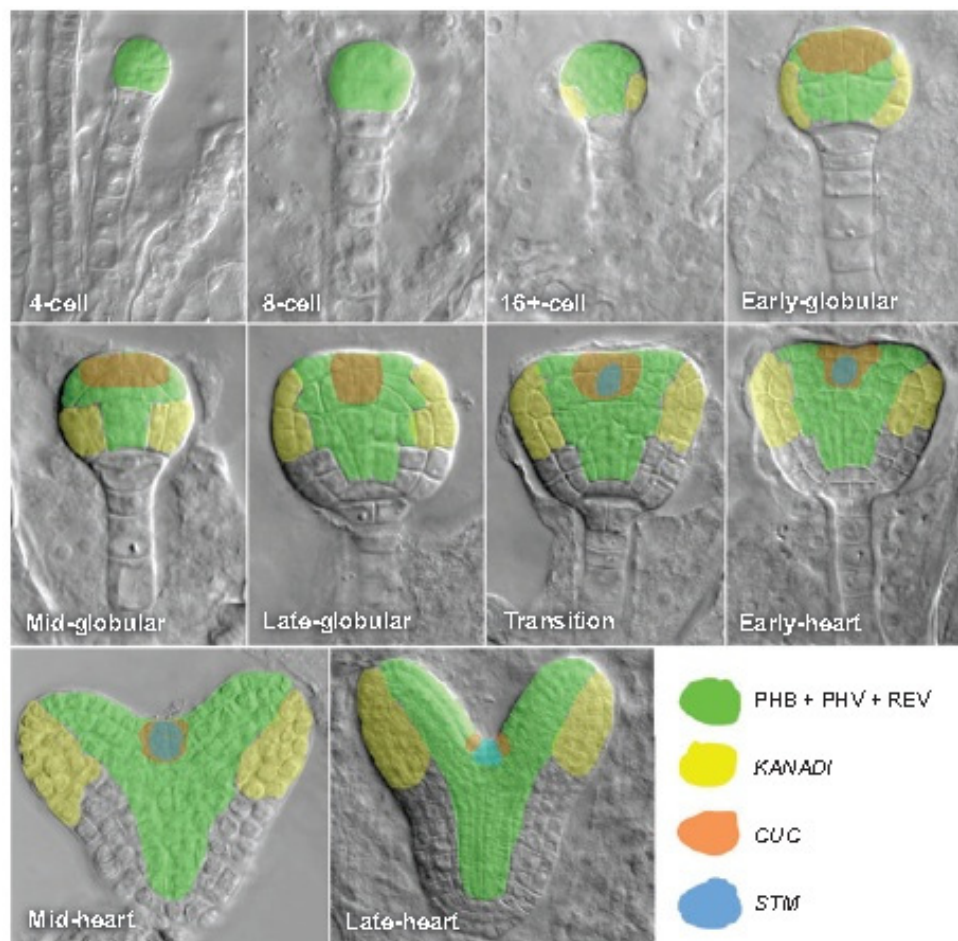


Capron et al., *Arabidopsis Book* (2009)

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)

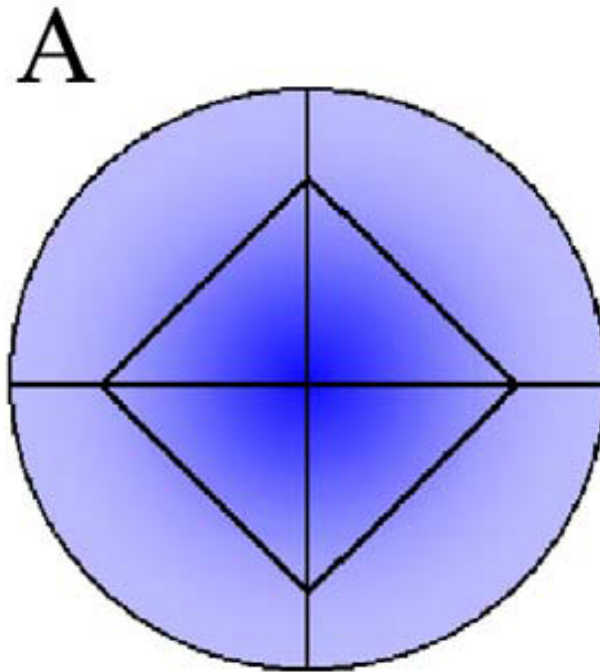


Outline of Lesson 7

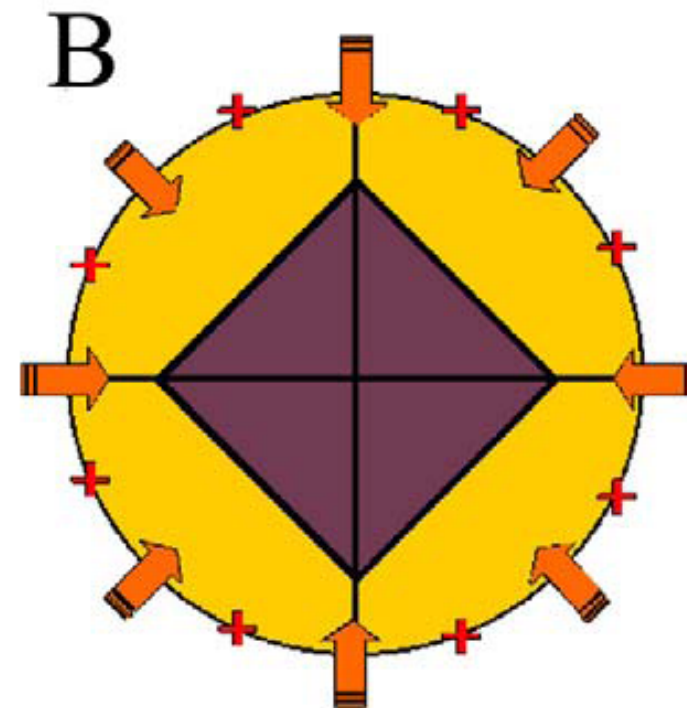
Plant Embryogenesis

- 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



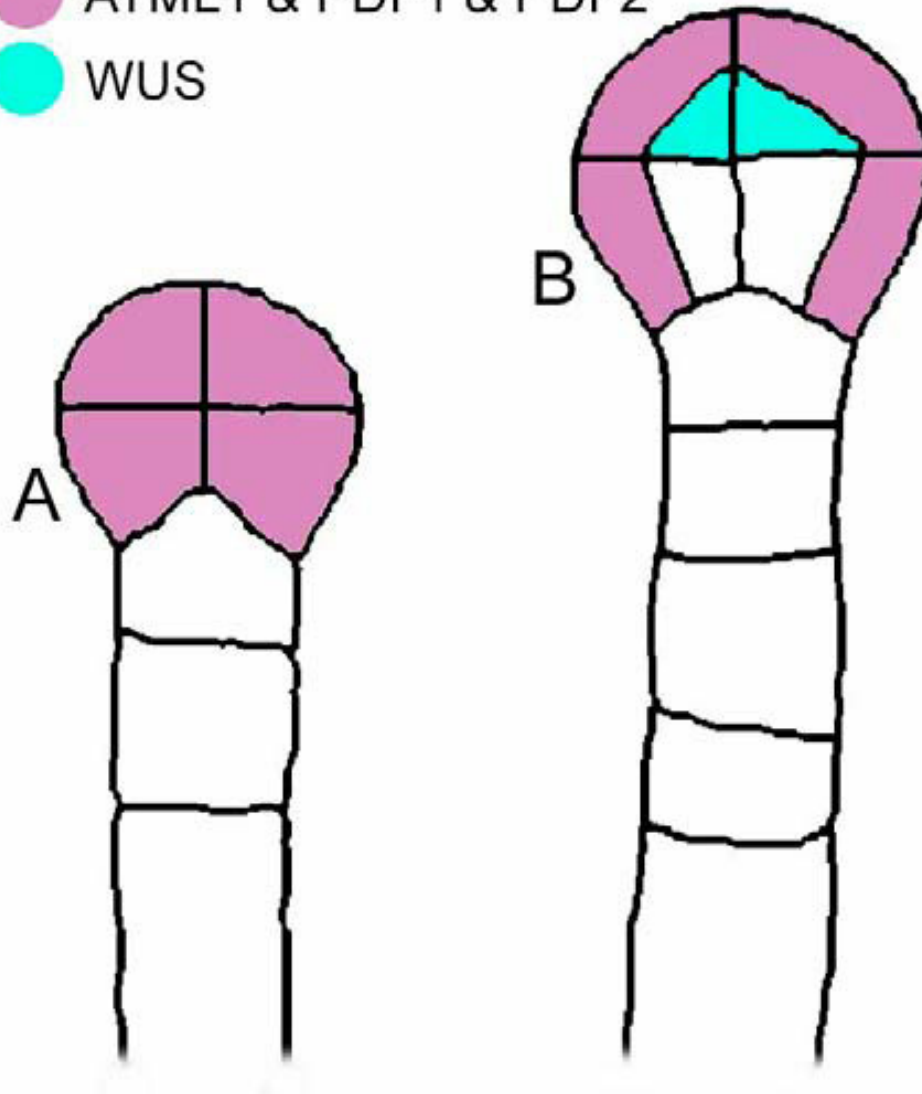
“Outside-in” model

ectopic expression of
epidermal markers

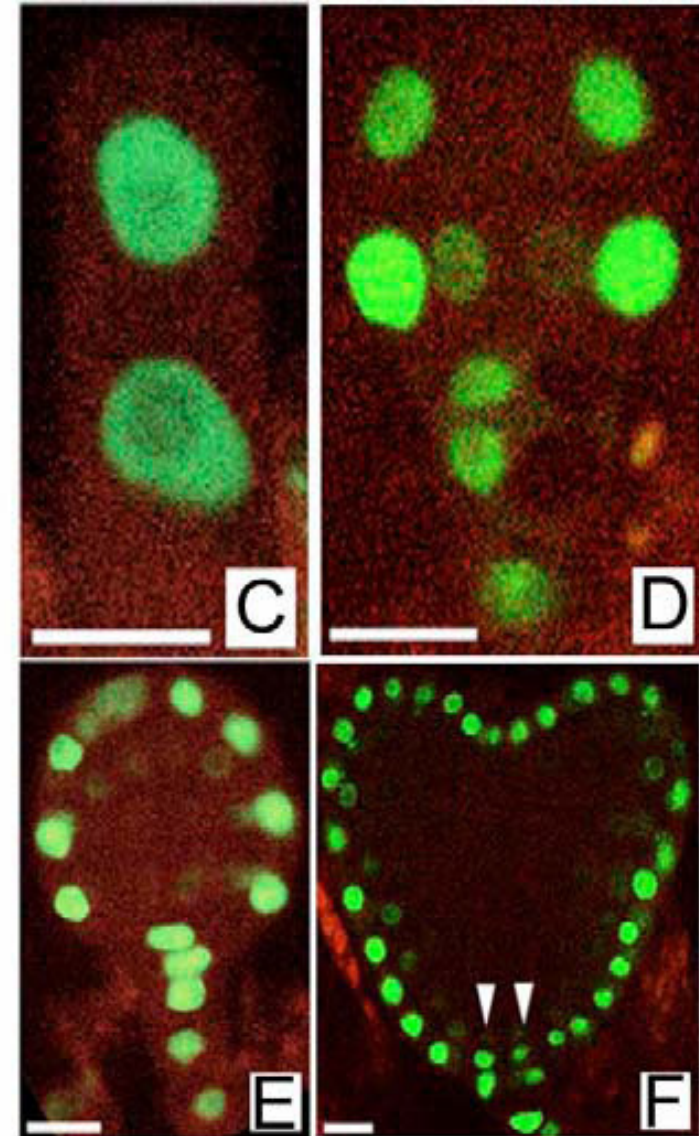
↓
knolle and *keulle* cytokinesis mutants
(incomplete CW)

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

MERISTEM LAYER1 (AtML1) and PROTODERMAL FACTOR 1 and 2



ProATML1:NLS-3xeGFP



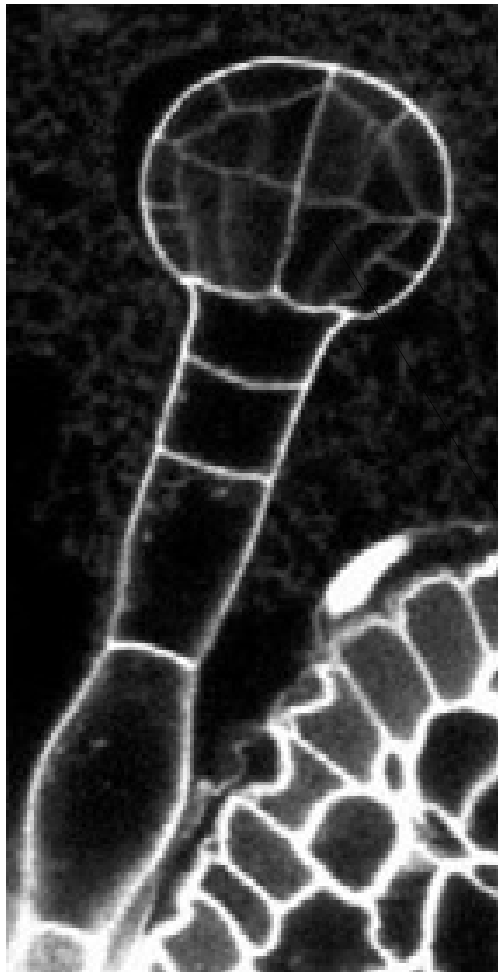


Outline of Lesson 7

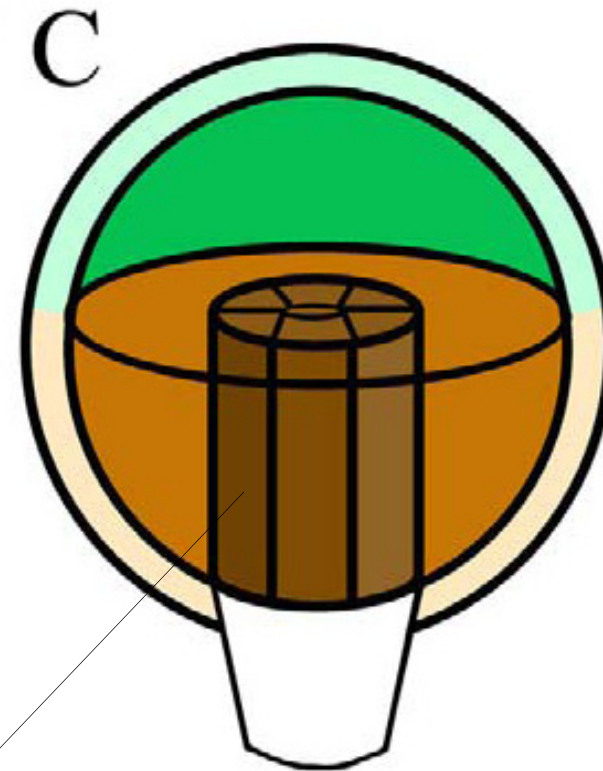
Plant Embryogenesis

- 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

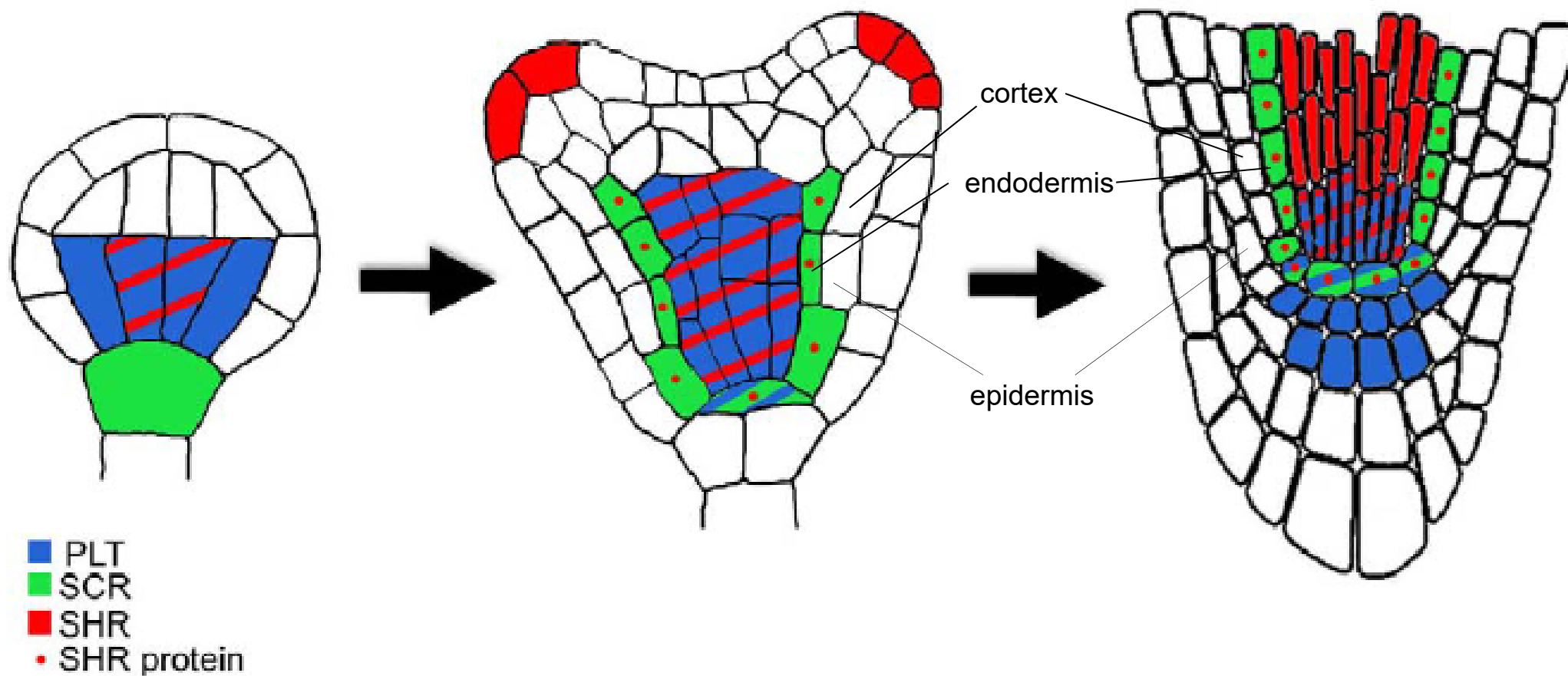
Separation of vascular and ground tissue

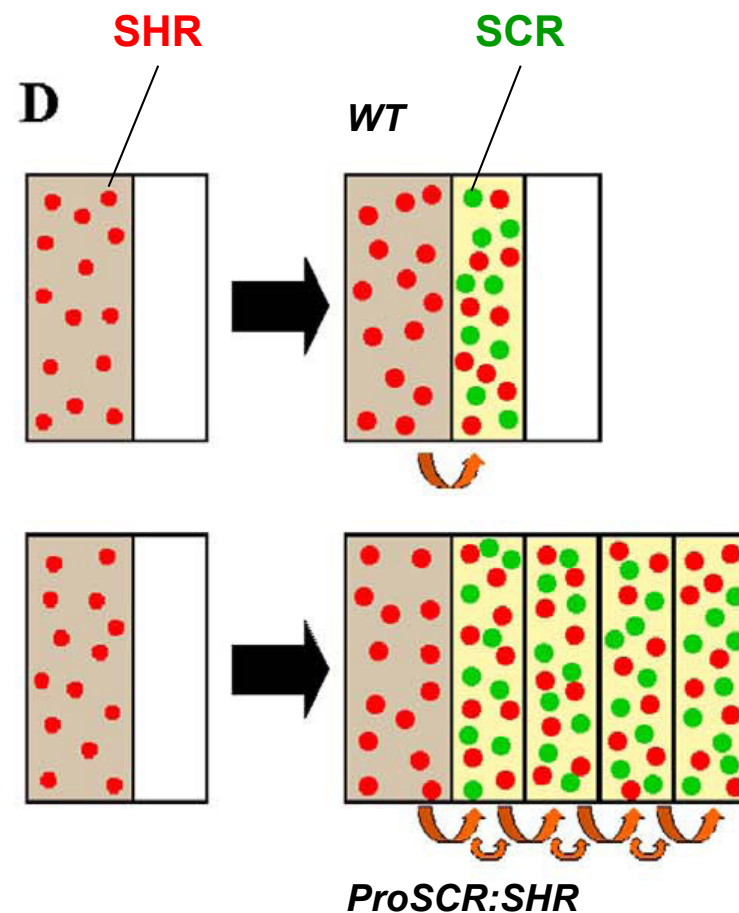
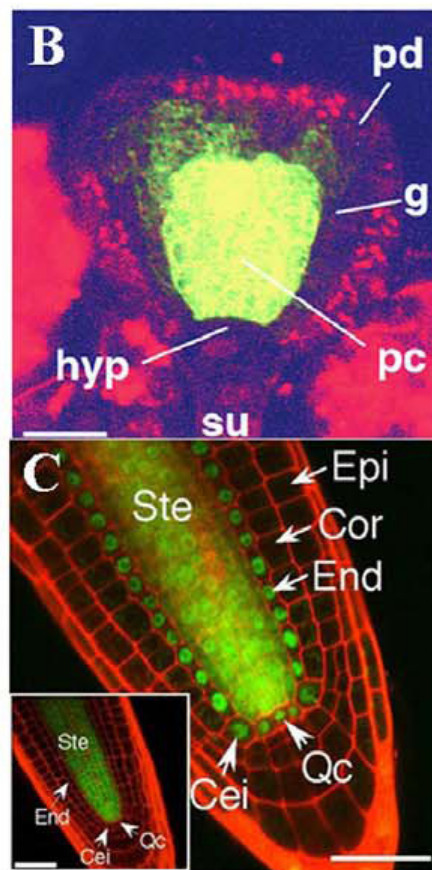
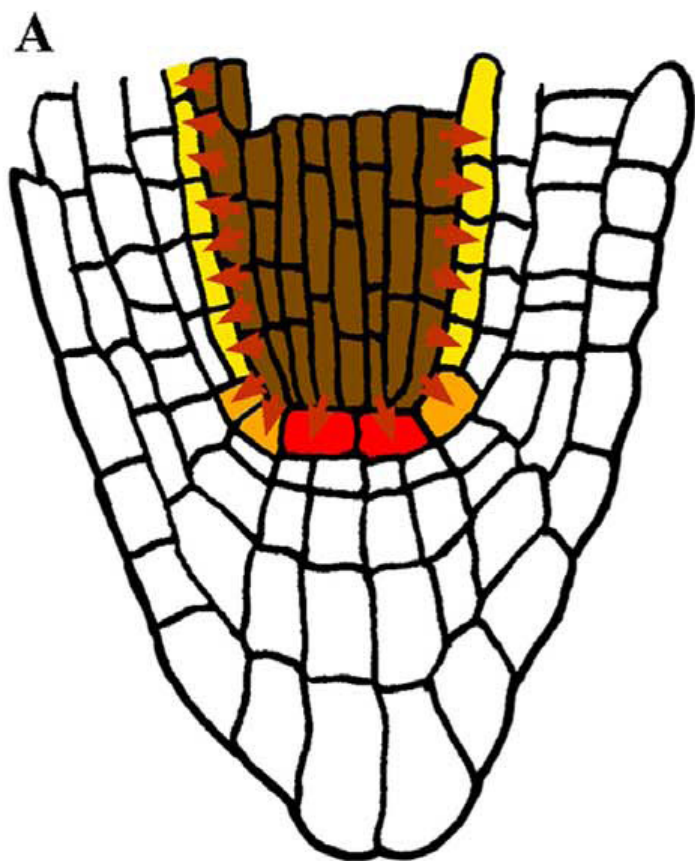


Early globular stage



Cell divisions predominantly along the apical-basal axis







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