

# Kořenový meristém a vývoj kořenů

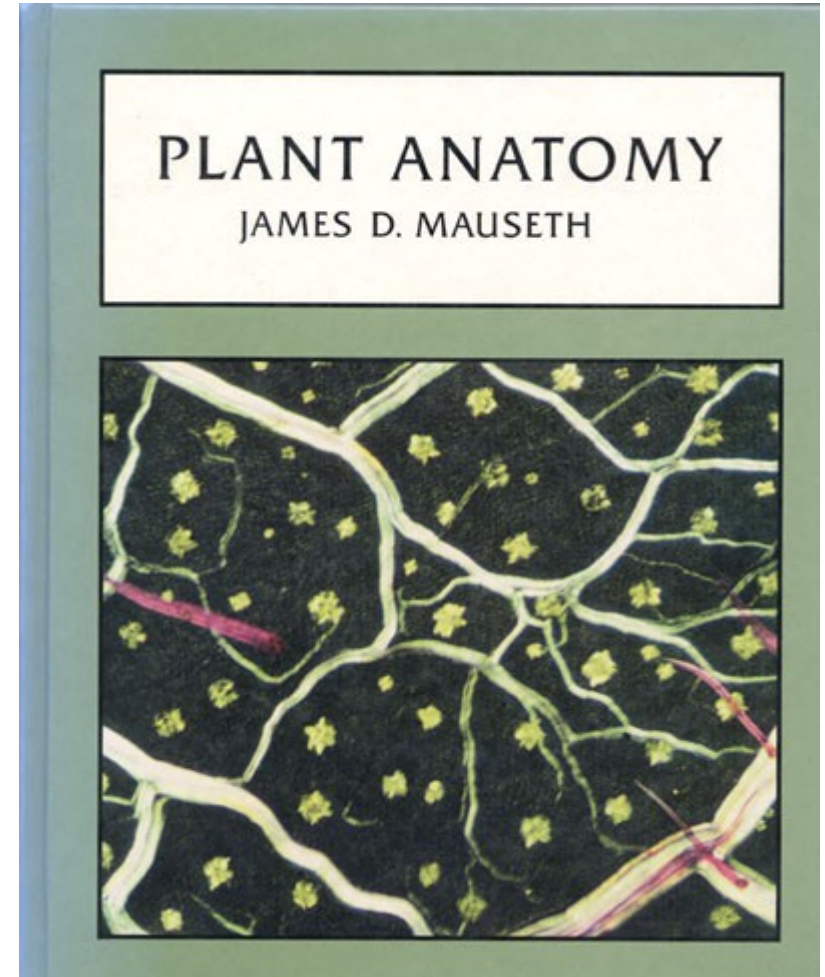
# Plant Anatomy Laboratory

Micrographs of plant cells and tissues,  
with explanatory text.

**James D. Mauseth**  
Integrative Biology  
University of Texas

## Objective:

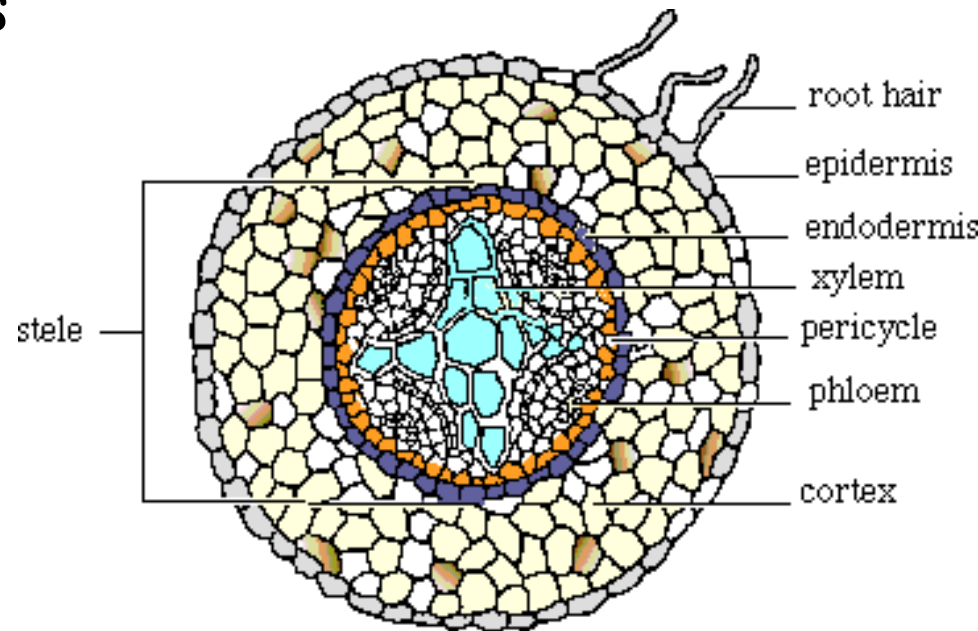
This web site is being developed as supplemental material for people studying plant anatomy. Its objective is to provide light micrographs of the types of cells and tissues that students typically examine in a plant anatomy course. All micrographs are accompanied by figure legends to help the viewer interpret and understand the structures presented.



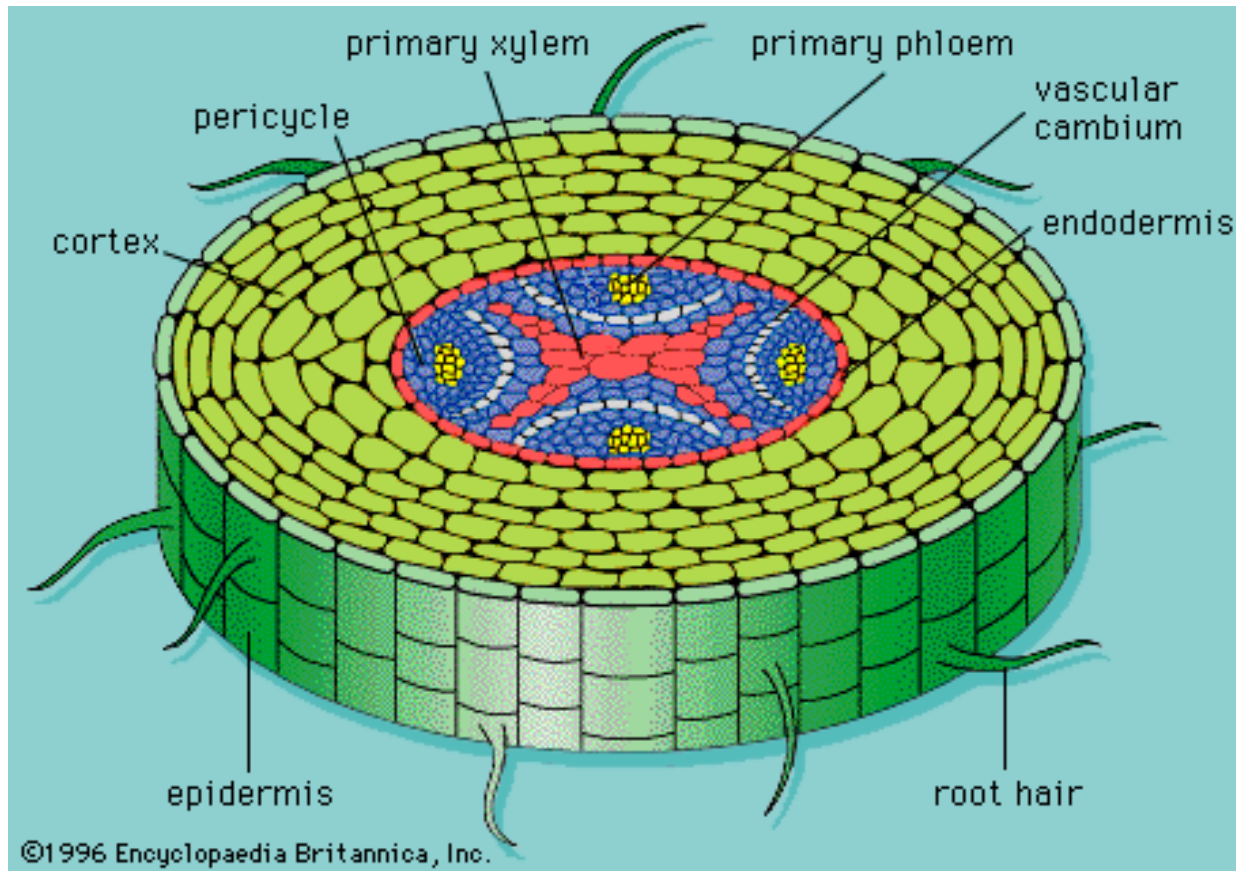
<http://www.sbs.utexas.edu/mauseth/weblab/>

# Struktura kořene

- podobná jako u stonku, ale jednodušší - kořen netvoří internodia a listy
- **primární stavba kořene na příčném řezu**
  - rhizodermis
  - primární kůra, endodermis
  - střední válec
    - pericykl
    - cévní svazky (radiální)
    - ve středu někdy dřeň

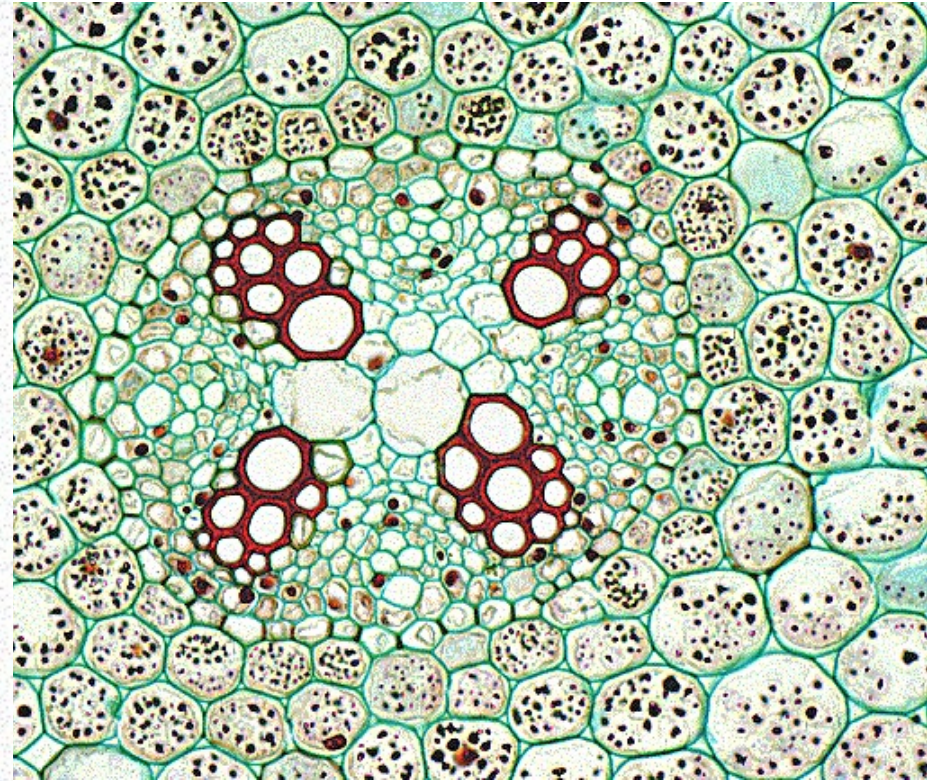
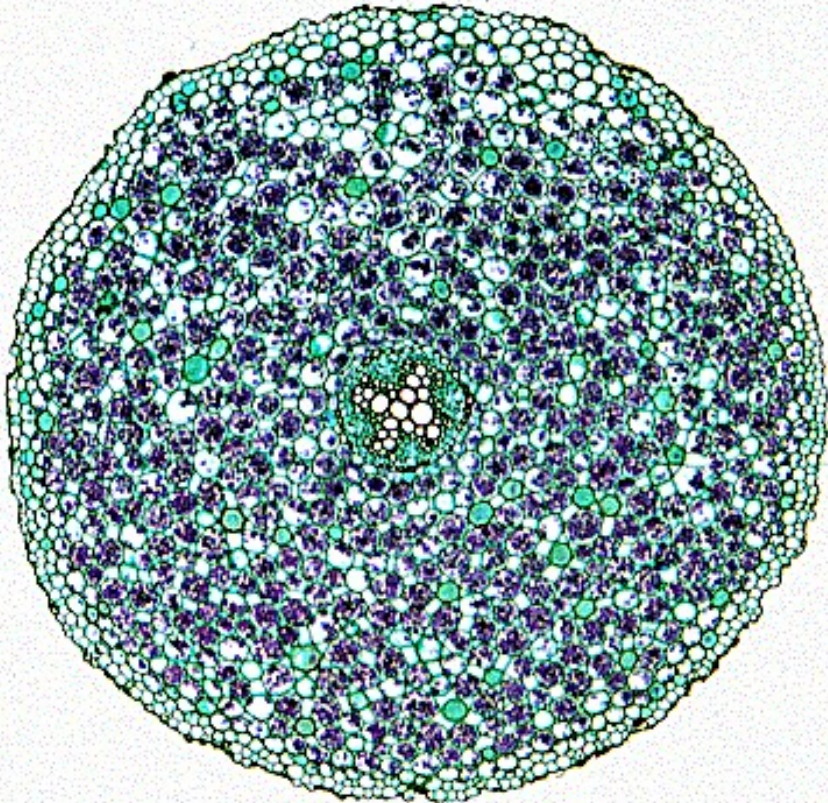


# Schéma příčného řezu kořenem





# Příčný řez kořenem dvouděložné rostliny



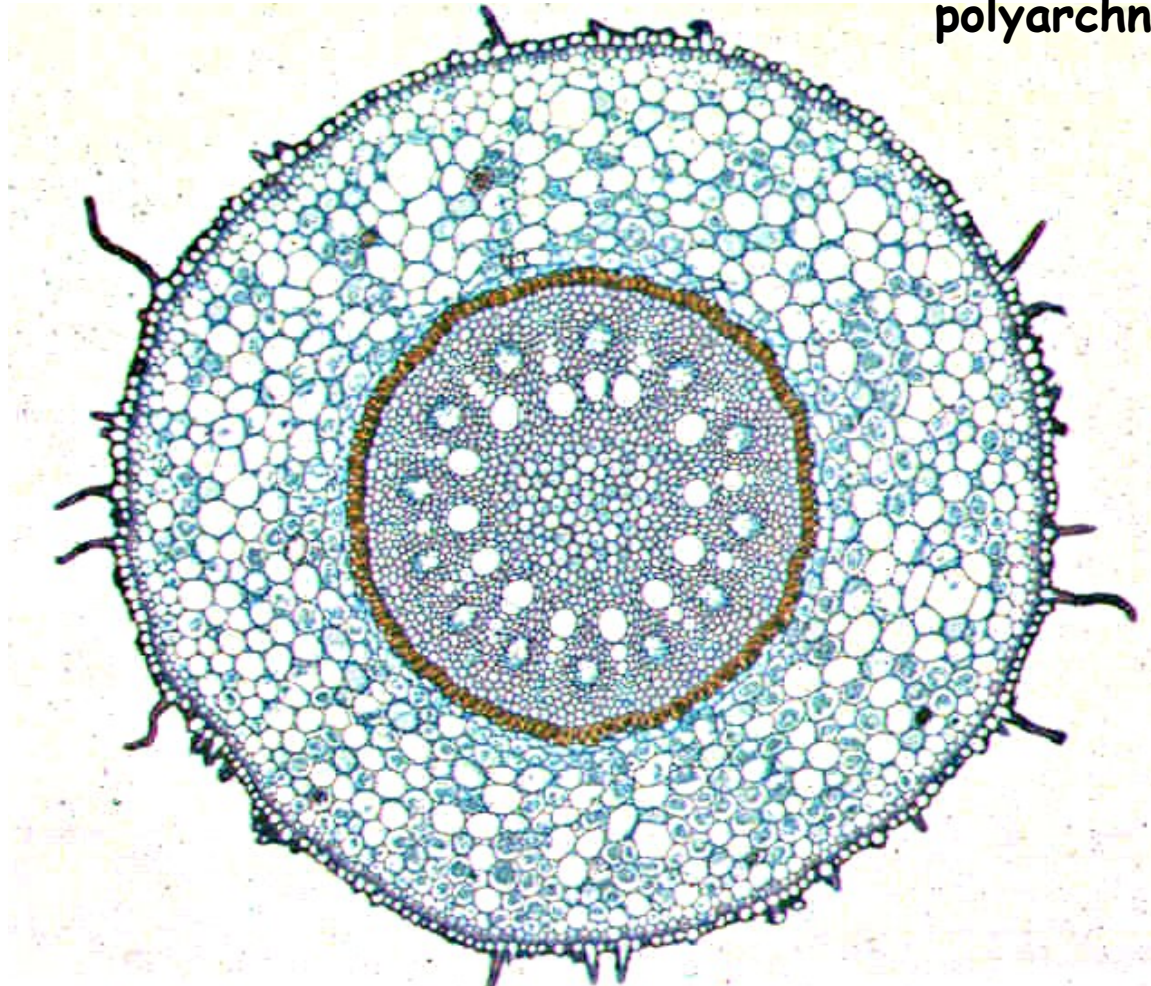
detail středního válce

tetrarchní CS, *Ranunculus*

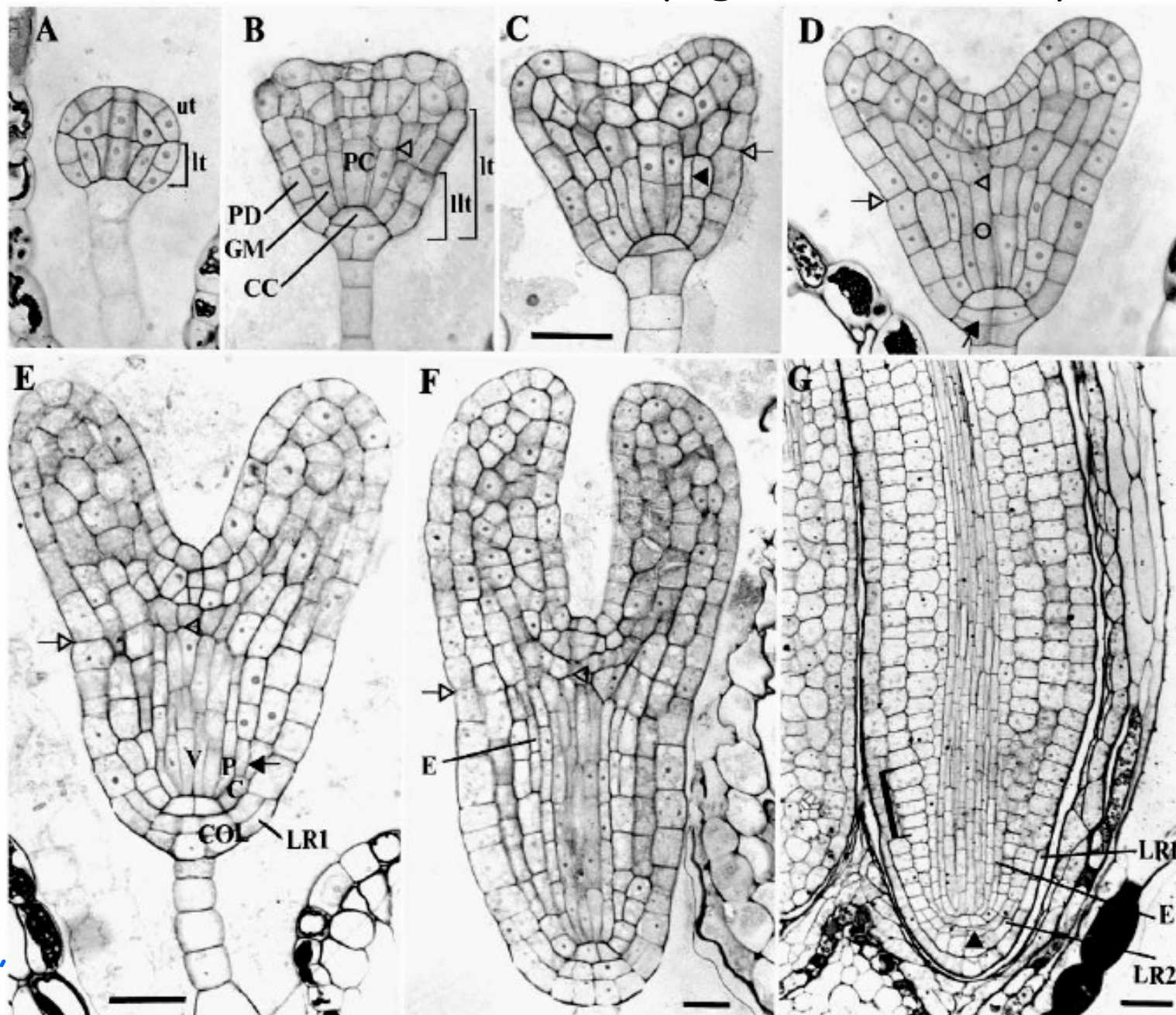


# Příčný řez kořenem jednoděložné rostliny

polyarchní CS



# Zakládání kořenového meristému v embryogenezi *Arabidopsis*



Scheres *et al.*  
Development 120,  
1994

# Primární růst kořene a stavba kořene

## - na podélném řezu

Kořen zajišťuje 3 úkoly:

- **růst** (kořenový apikální meristém)
- **penetraci do půdy** (kořenová čepička a oblast elongace kořene)
- **absorpci vody** a minerálních látek (kořenové vlášení v zóně diferenciacce a mykorrhiza)

### zóny kořene

- meristemická
- zóna elongace
- zóna diferenciacce

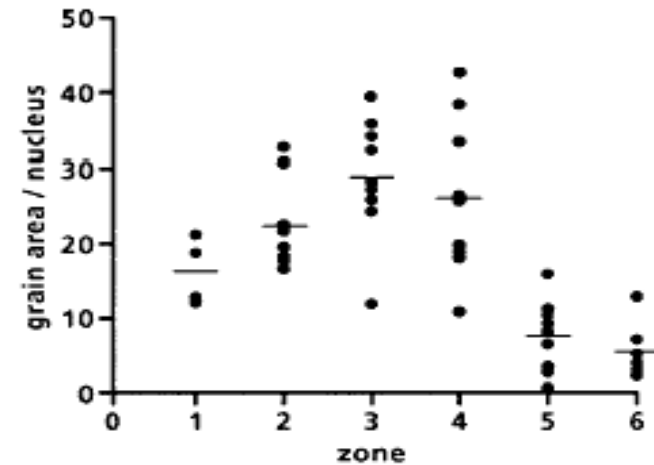
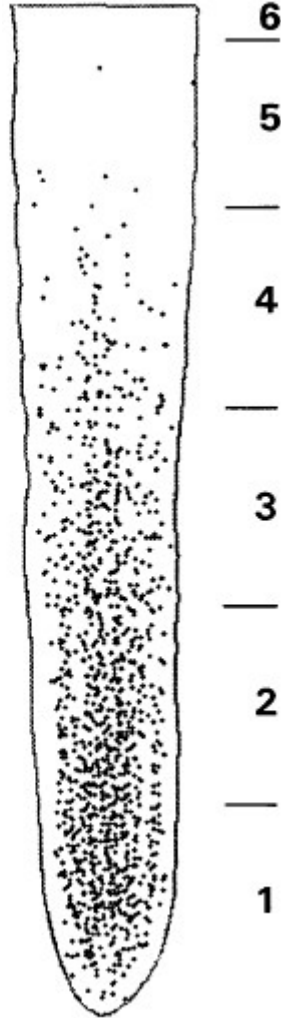
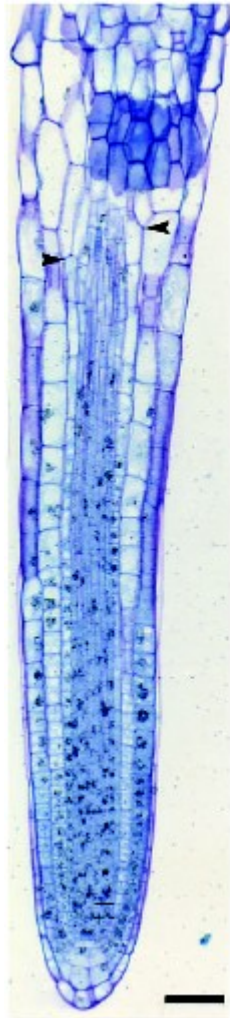


# Terminologie

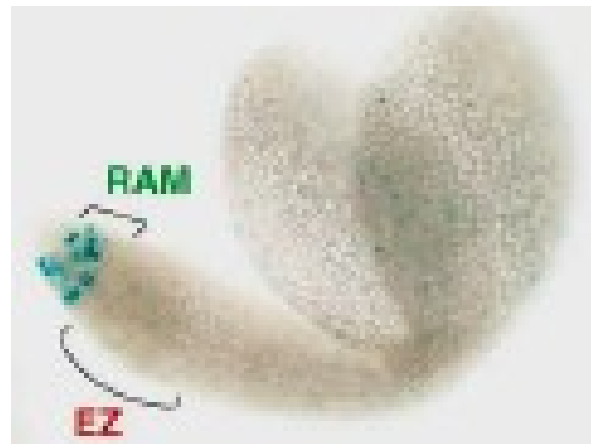
- **Apikální část kořene**
  - Kořenová čepička
  - Vlastní kořen
  
  - **Kořenový apikální meristém**
  - vnitřní část čepičky
  - vrchol vlastního kořene
  
  - Vnější část čepičky tvoří buňky dozrálé

# Vizualizace jaderného dělení v kořeni *Arabidopsis*

[3H]thymidine-labelled root 3 days after germination. Silver grains marking labelled nuclei are visible as black dots.

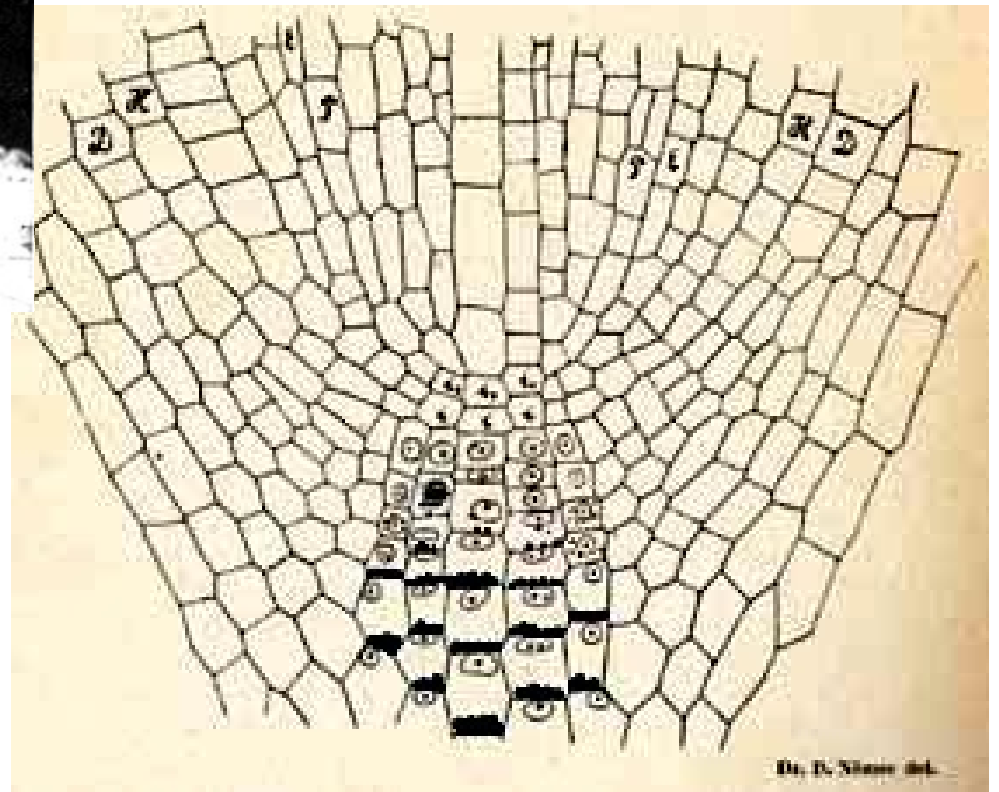
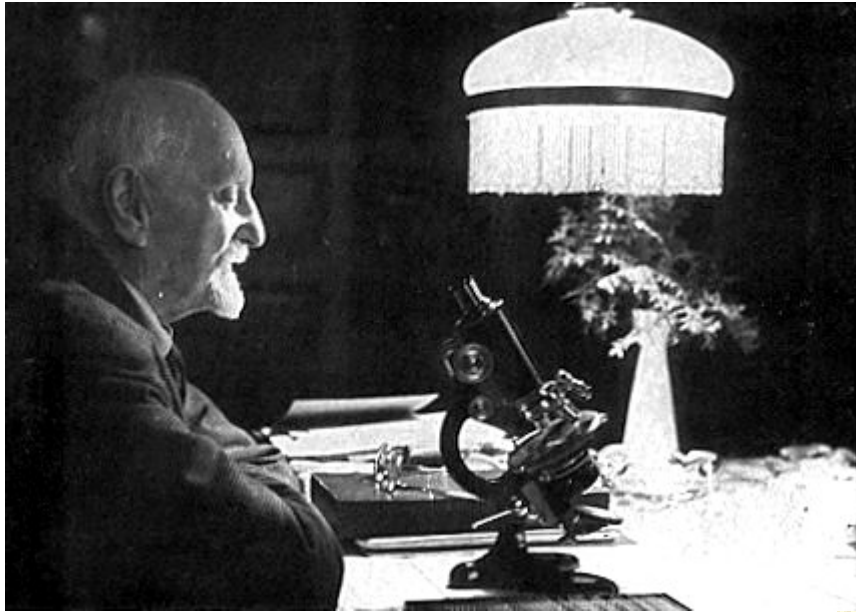


Scheres *et al.* Development 120, 1994



Indigogenní  
vizualizace  
cyklinu B  
CYCB::uidA

# Prof. B. Němec - autor statolithové teorie



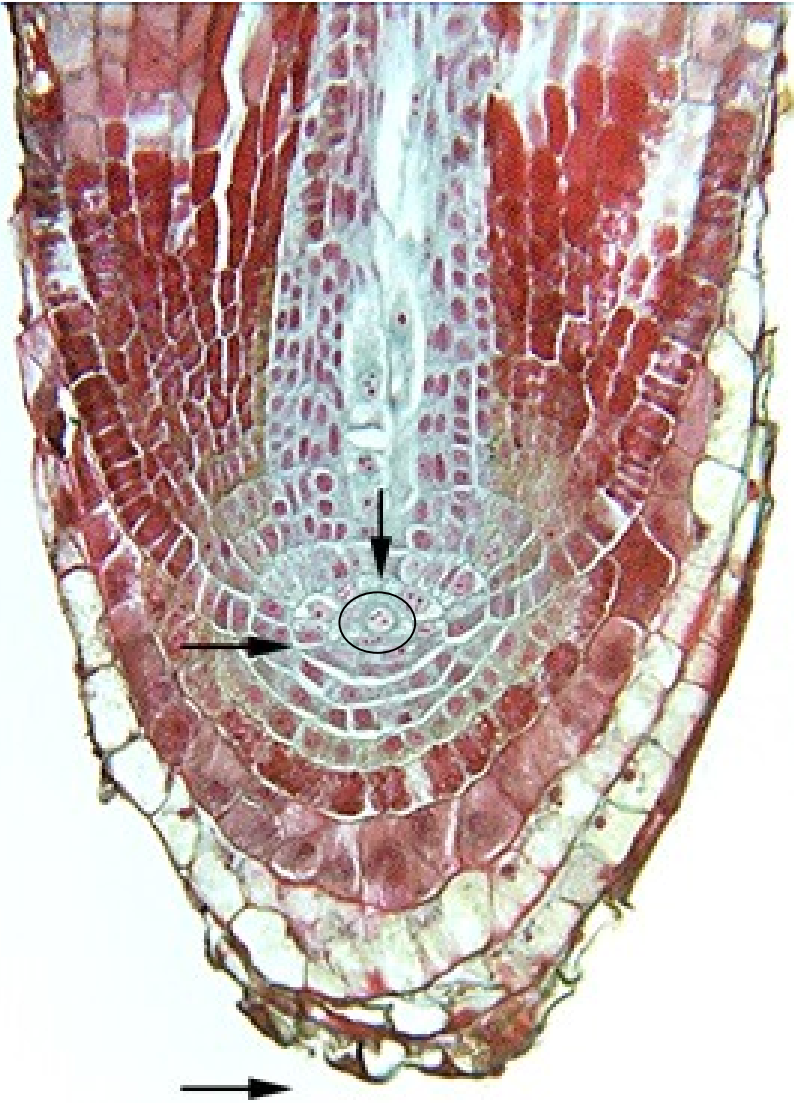


# Typy kořenových meristémů

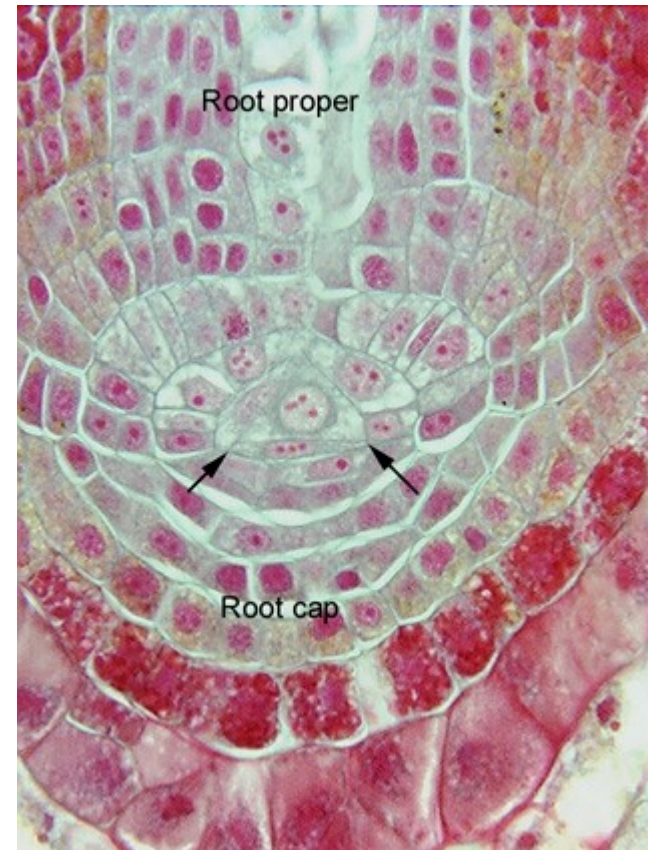
## Guttenberg

- **otevřený** (opened) - všechna pletiva kořenové špičky mají společné iniciály (kapradiny, *Pinus*, *Picea*, *Elodea*)
- **uzavřený** (closed) - všechna pletiva mají příslušné iniciály a kořenová čepička je jednoznačně oddělena od vlastního kořene (*Brassicaceae*, *Solanaceae*, *Cyperaceae*, *Poaceae*)

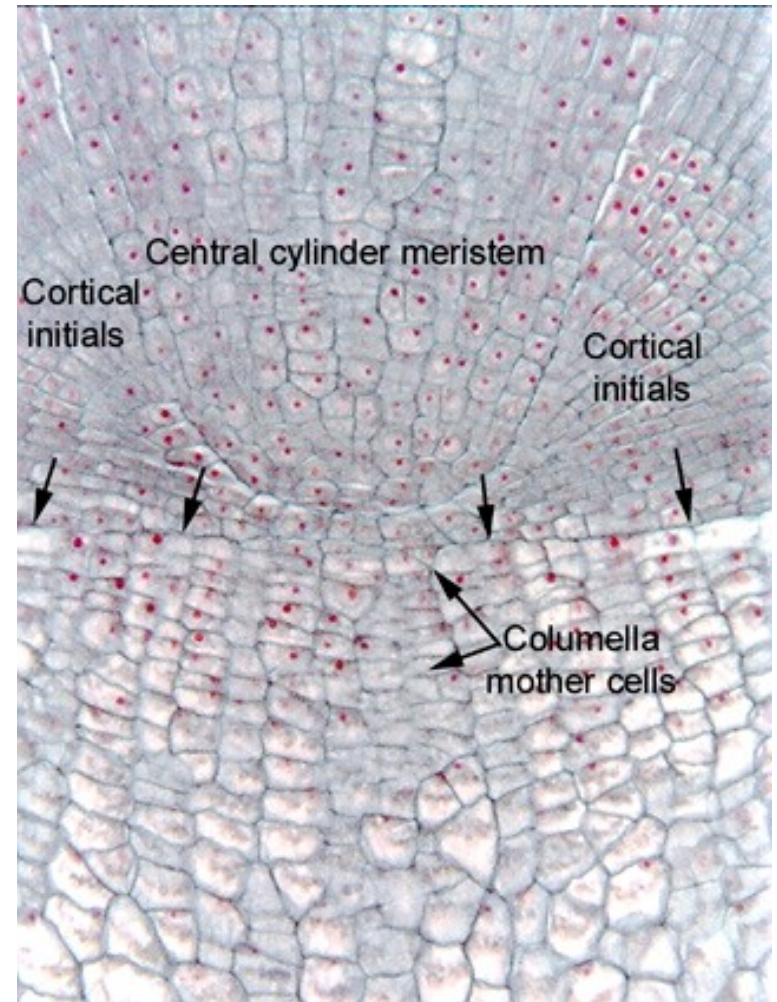
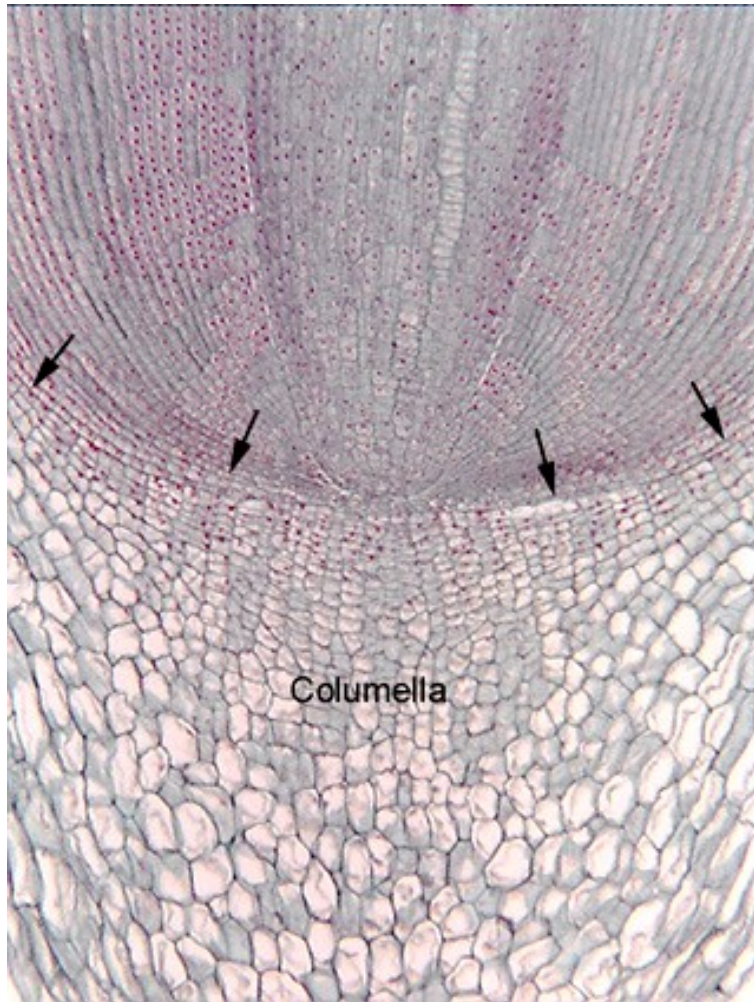
# Podélný řez kořenovou špičkou kapradiny



otevřený typ s jednou  
iniciální buňkou (šipky)

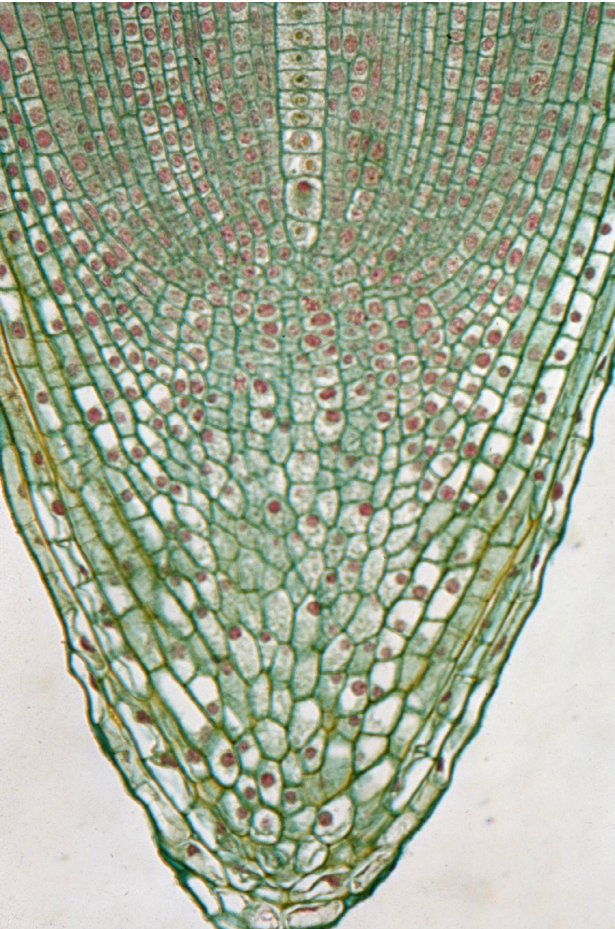


# Uzavřený kořenový apikální meristém

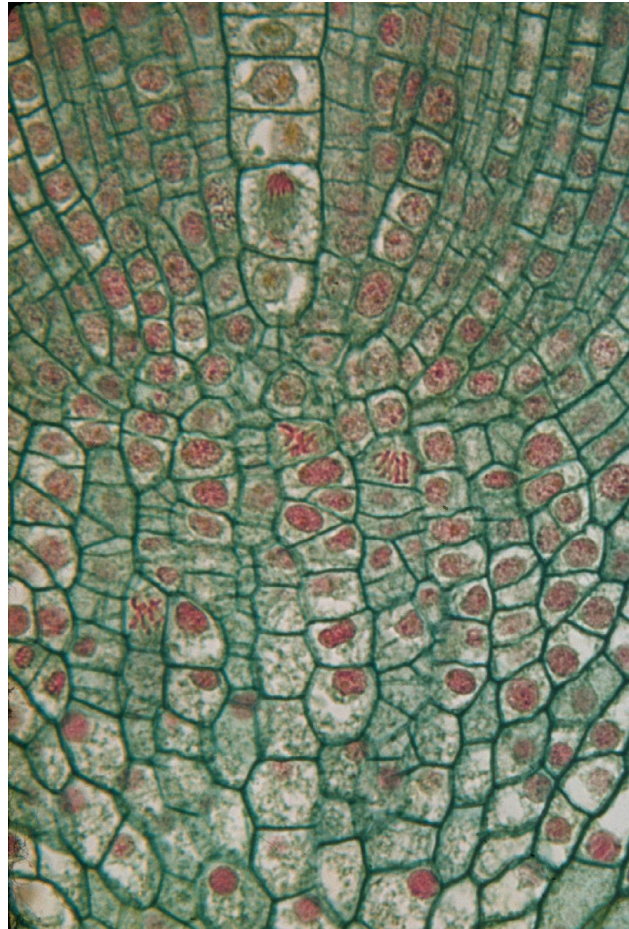




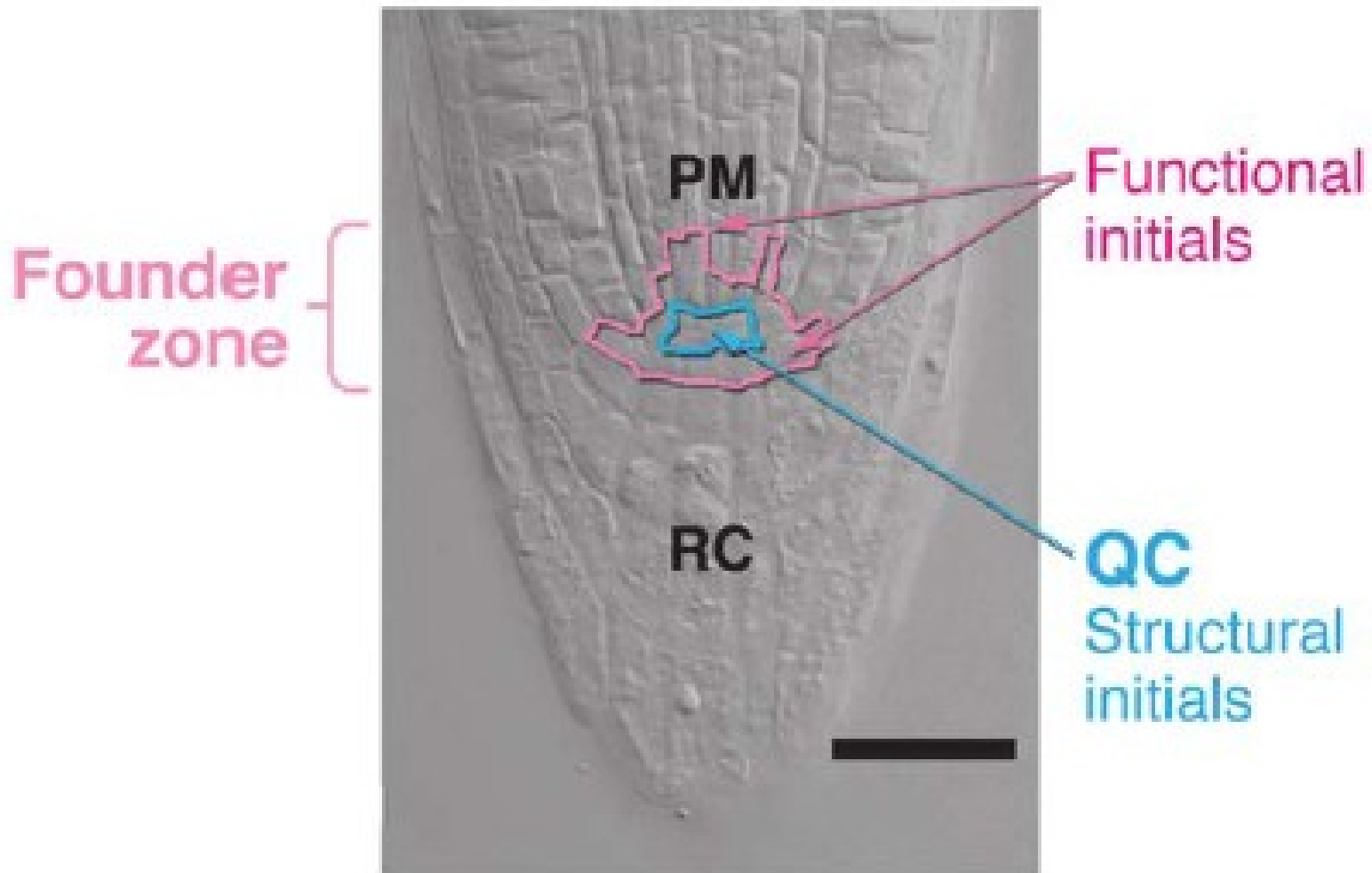
# Uzavřený kořenový apikální meristém



*Brassica*



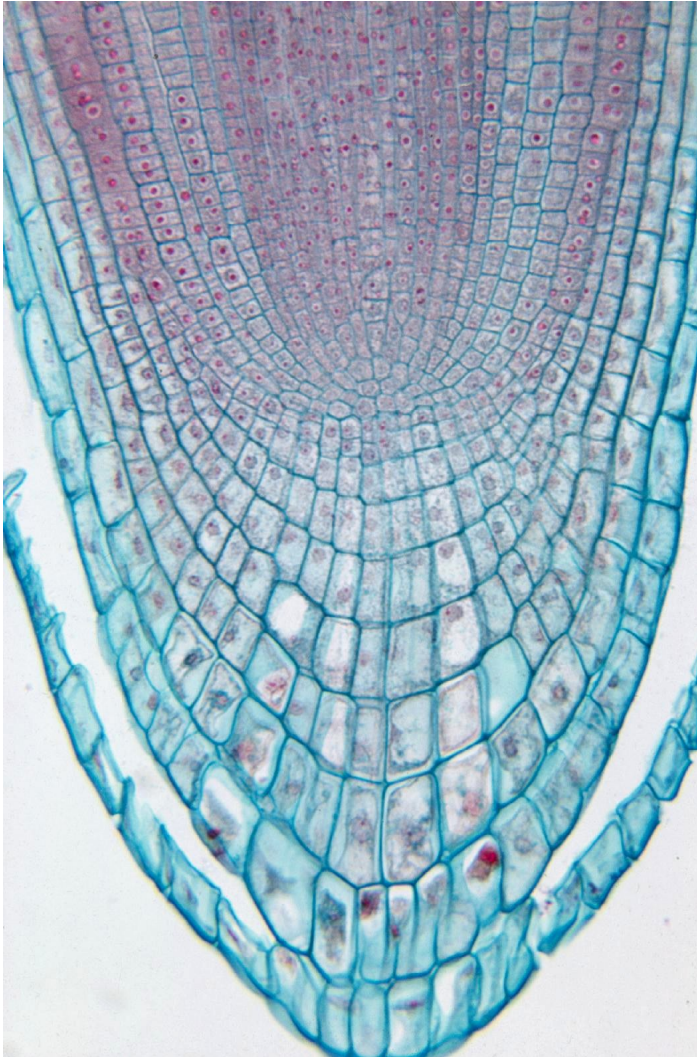
*Arabidopsis*



Jiang et Feldman 2005



# Kořenový apikální meristém



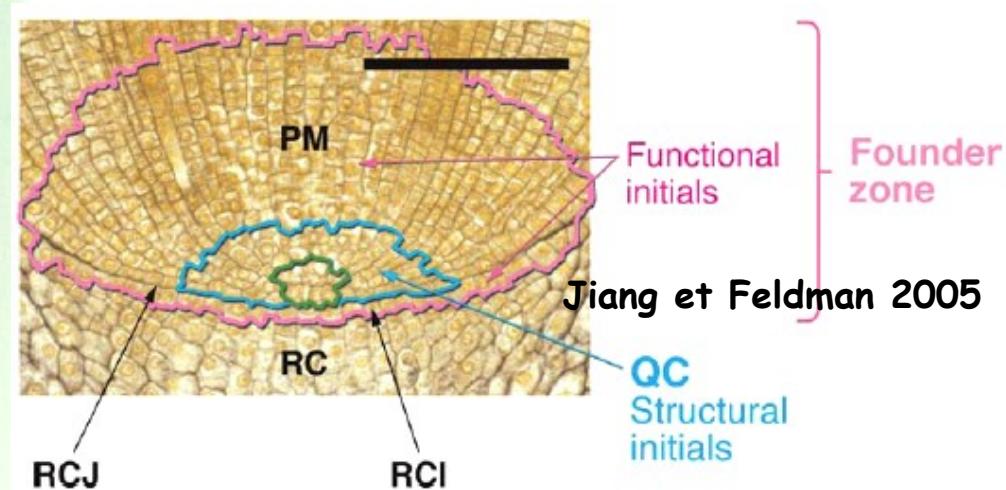
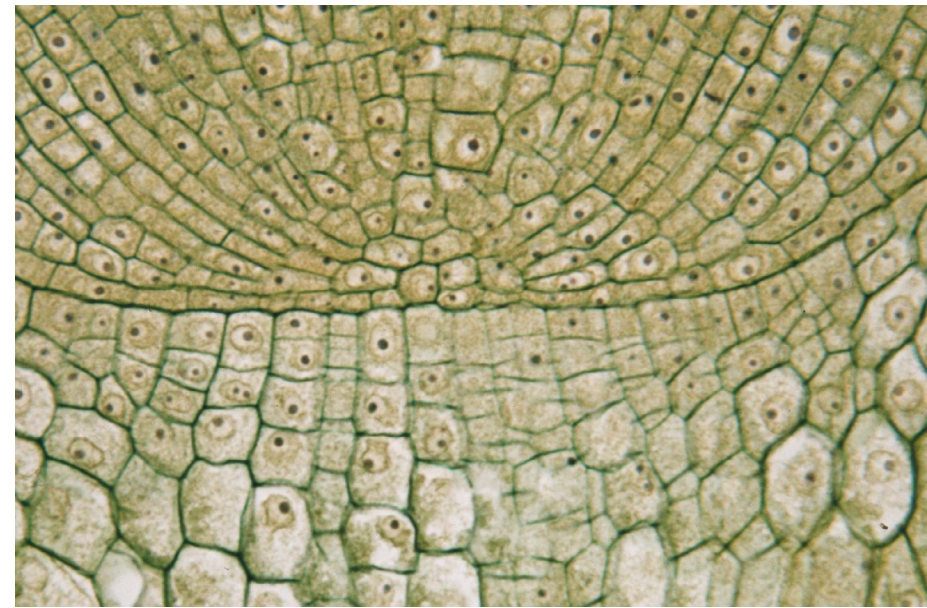
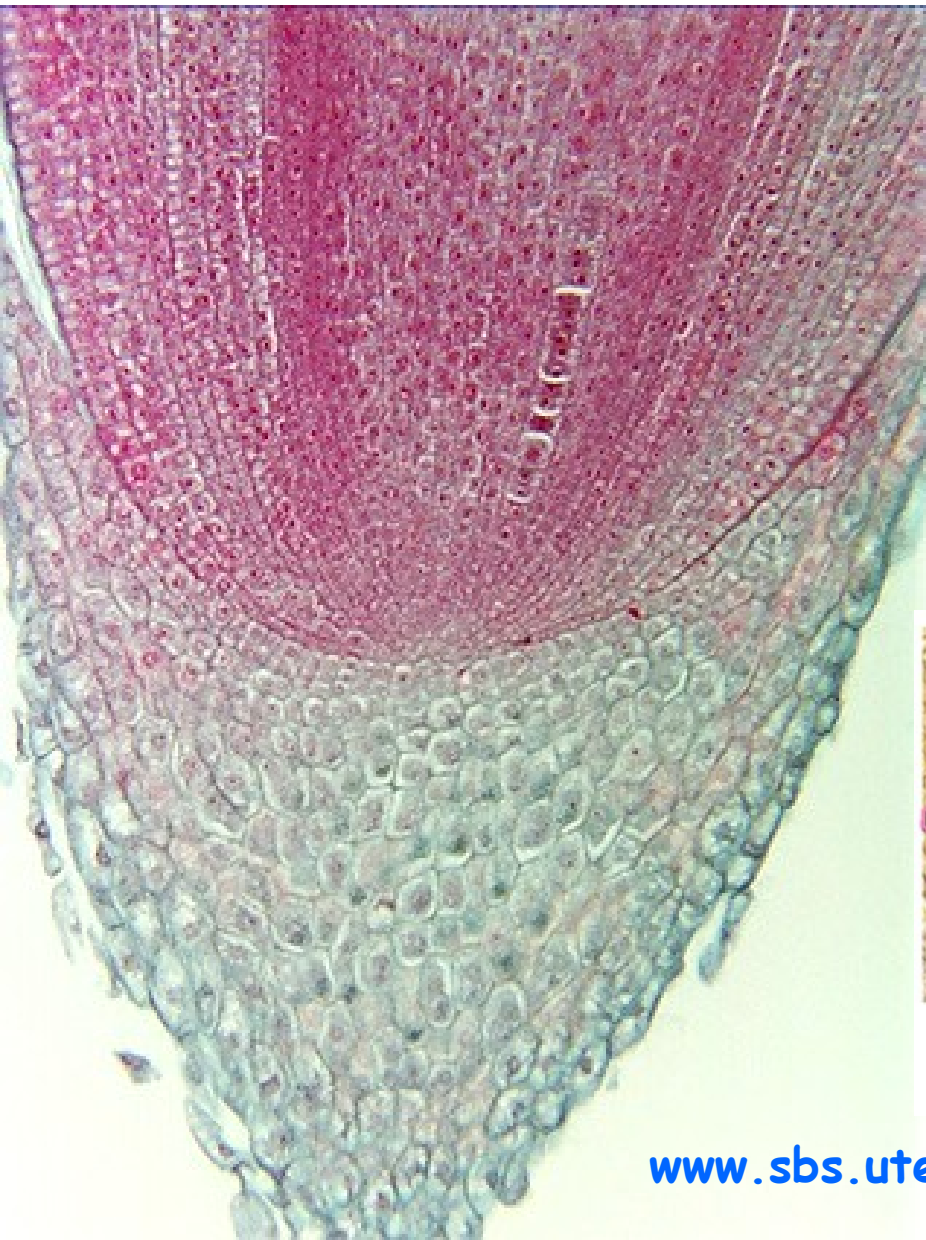
*Linum*



*Pisum*



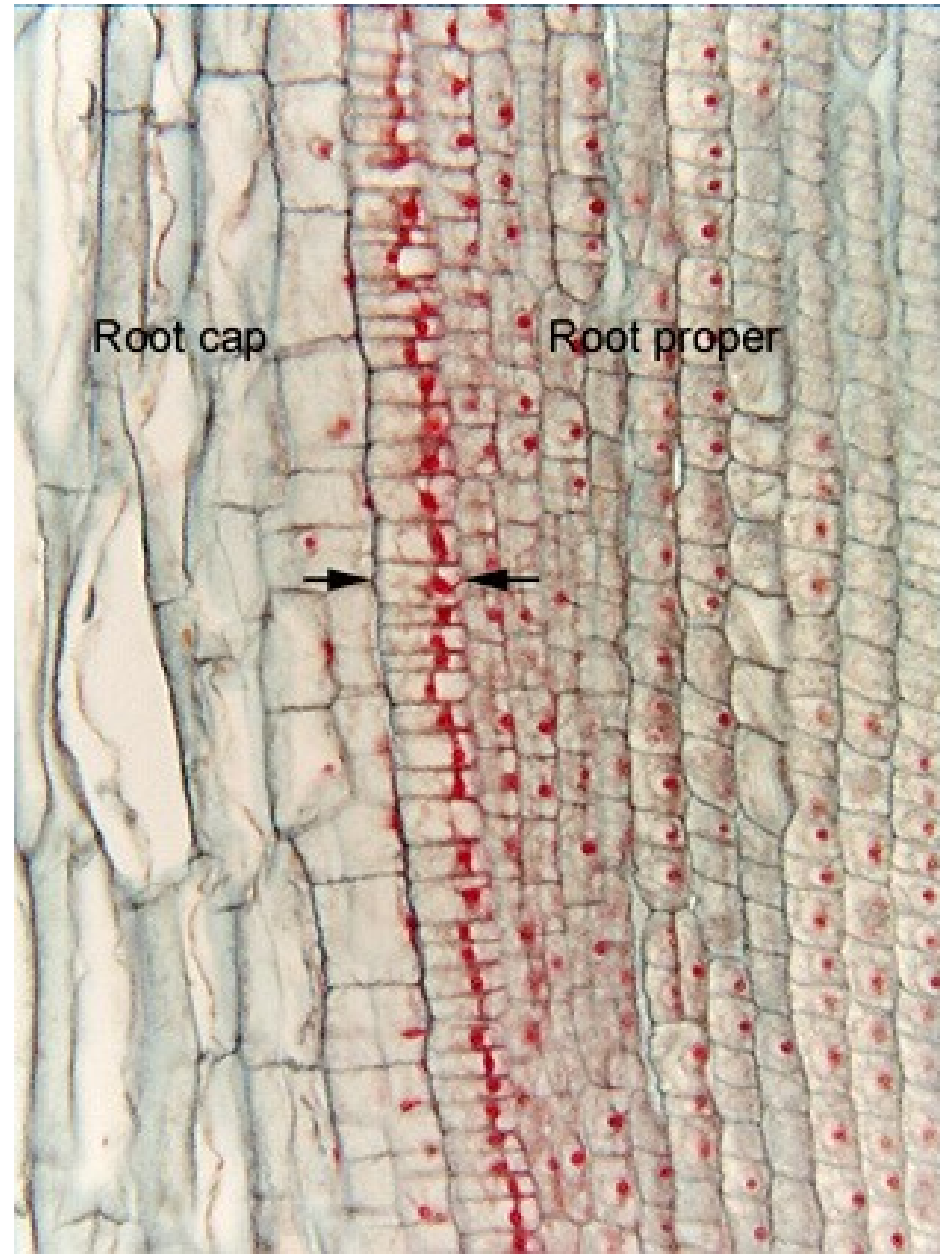
# Uzavřený kořenový apikální meristém



# Protoderm *Typha*

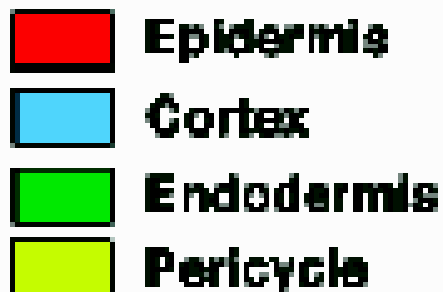
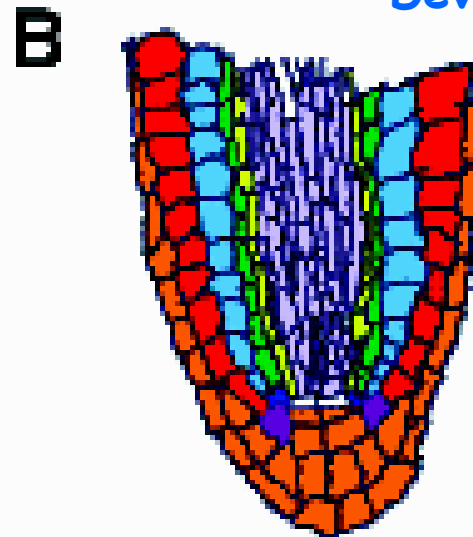
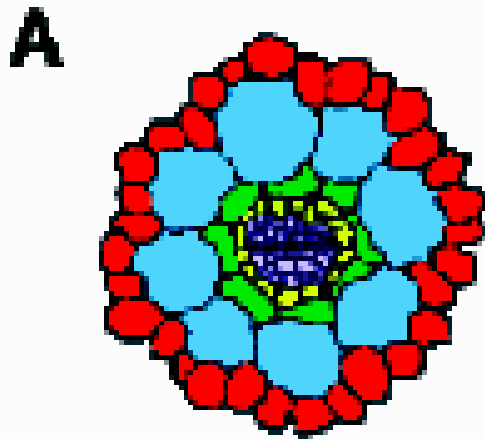
The prominent row of flat, brick-shaped cells is the **protoderm** (between arrows), and for the entire distance here, it is a uniform layer, distinct from the root cap.

Because it is so distinct, this is a **closed root apical meristem**. The cells of the root proper have been dividing so much that they are still small, despite the fact that they have also been enlarging, whereas the cells in the root cap have undergone many fewer divisions, so they are much larger.



# Schéma stavby kořene Arabidopsis

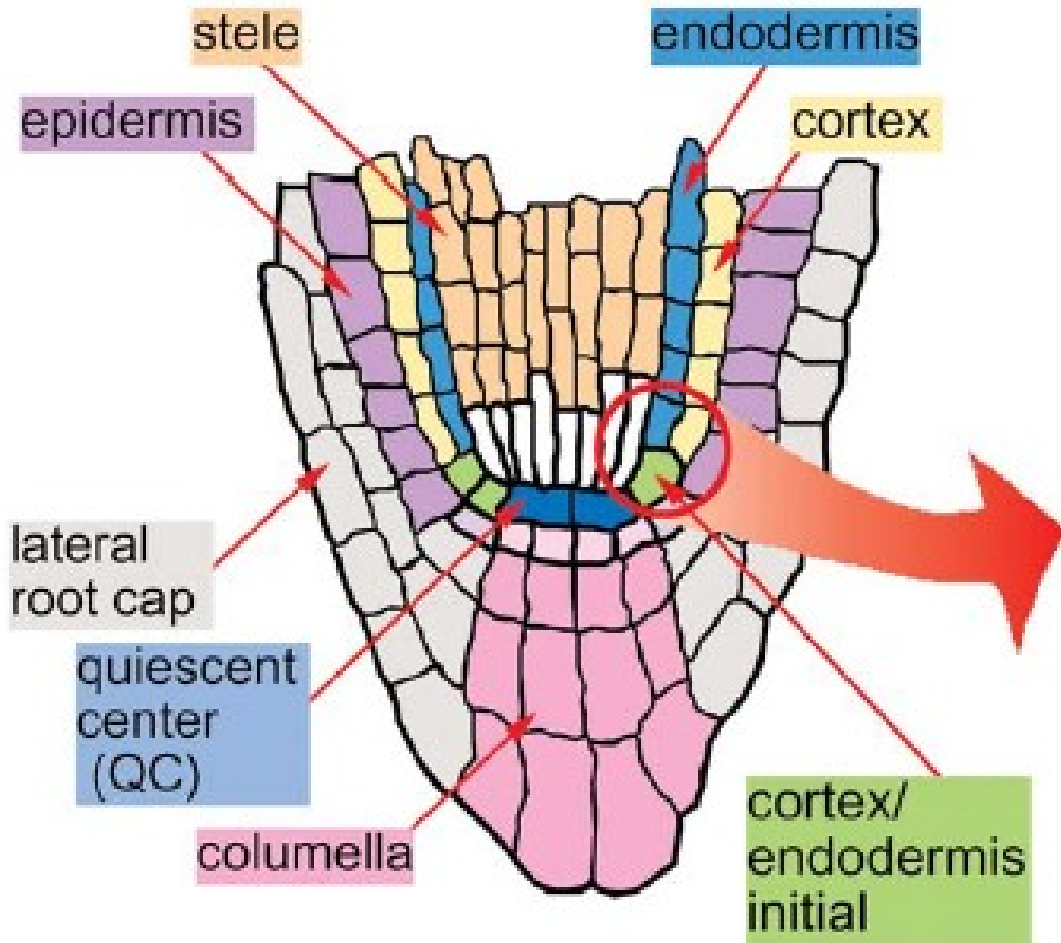
Malamy and Benfey  
Development, 124, 1997



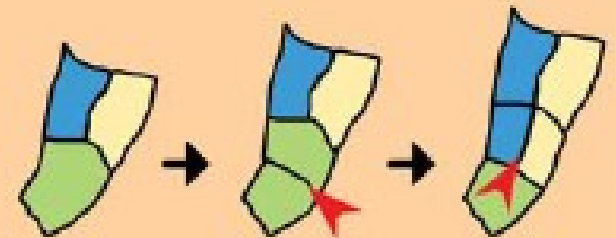


# Buněčné typy v RAM Arabidopsis

Scheres et al. 2002  
The Arabidopsis Book

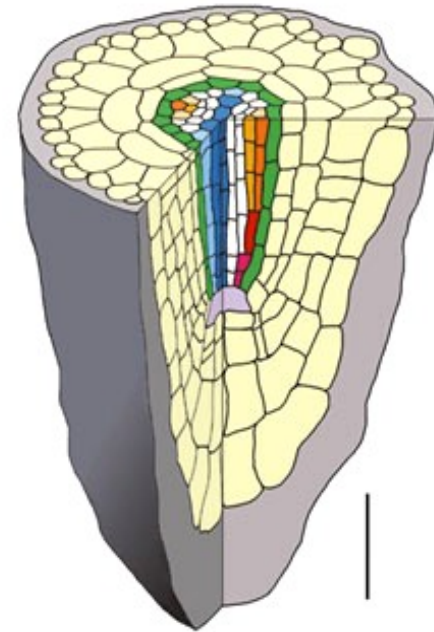
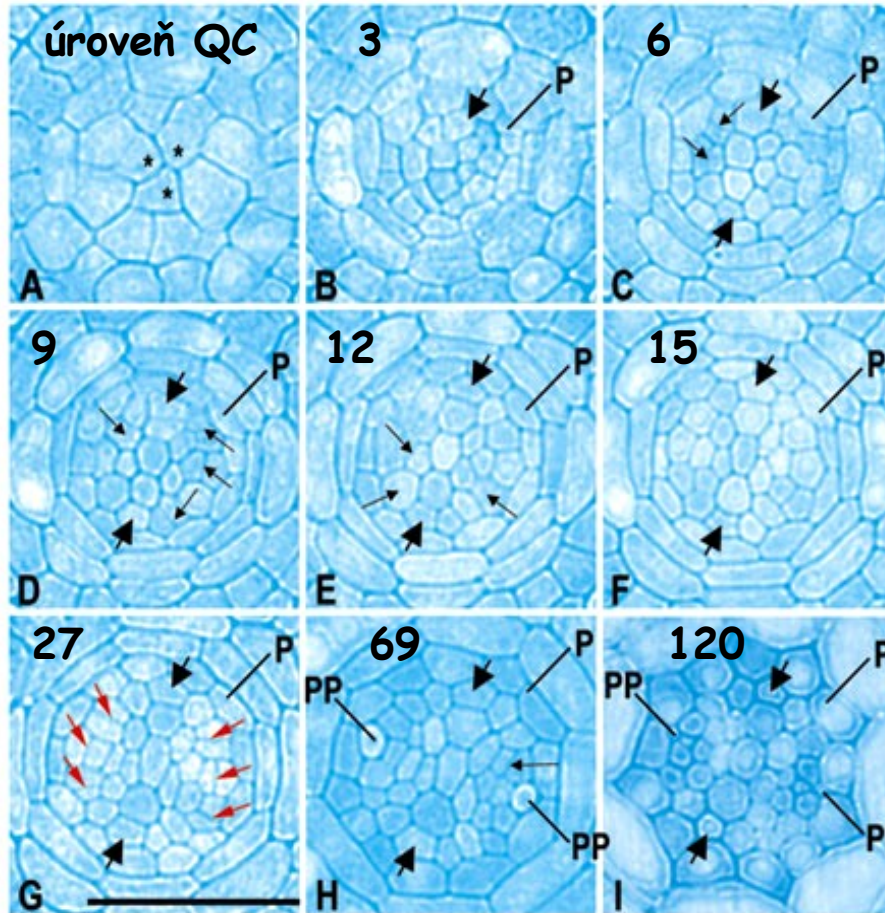


Pattern formation relies on consistent division of initial cells



# Stavba RAM u Arabidopsis

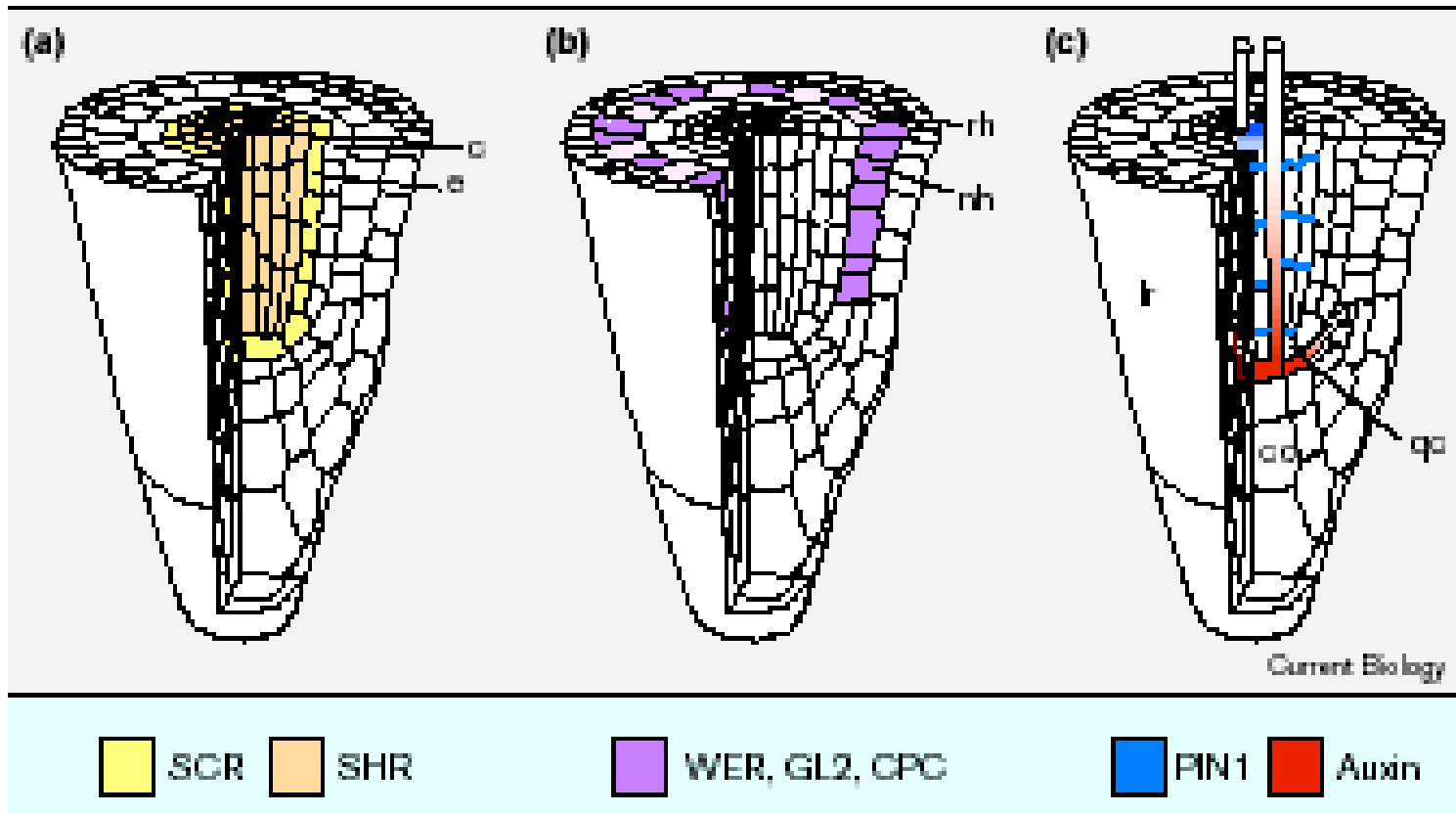
p - pericykl  
pp – protofloém



- |  |                              |  |                    |
|--|------------------------------|--|--------------------|
|  | Protoxylem                   |  | Companion cells    |
|  | Metaxylem                    |  | Procambium cells   |
|  | Protophloem                  |  | Pericycle          |
|  | Metaphloem                   |  | Quiescent center   |
|  | } Phloem/procambium initials |  | Outer cell layers  |
|  |                              |  | Peripheral rootcap |

Helariutta et al. 2000

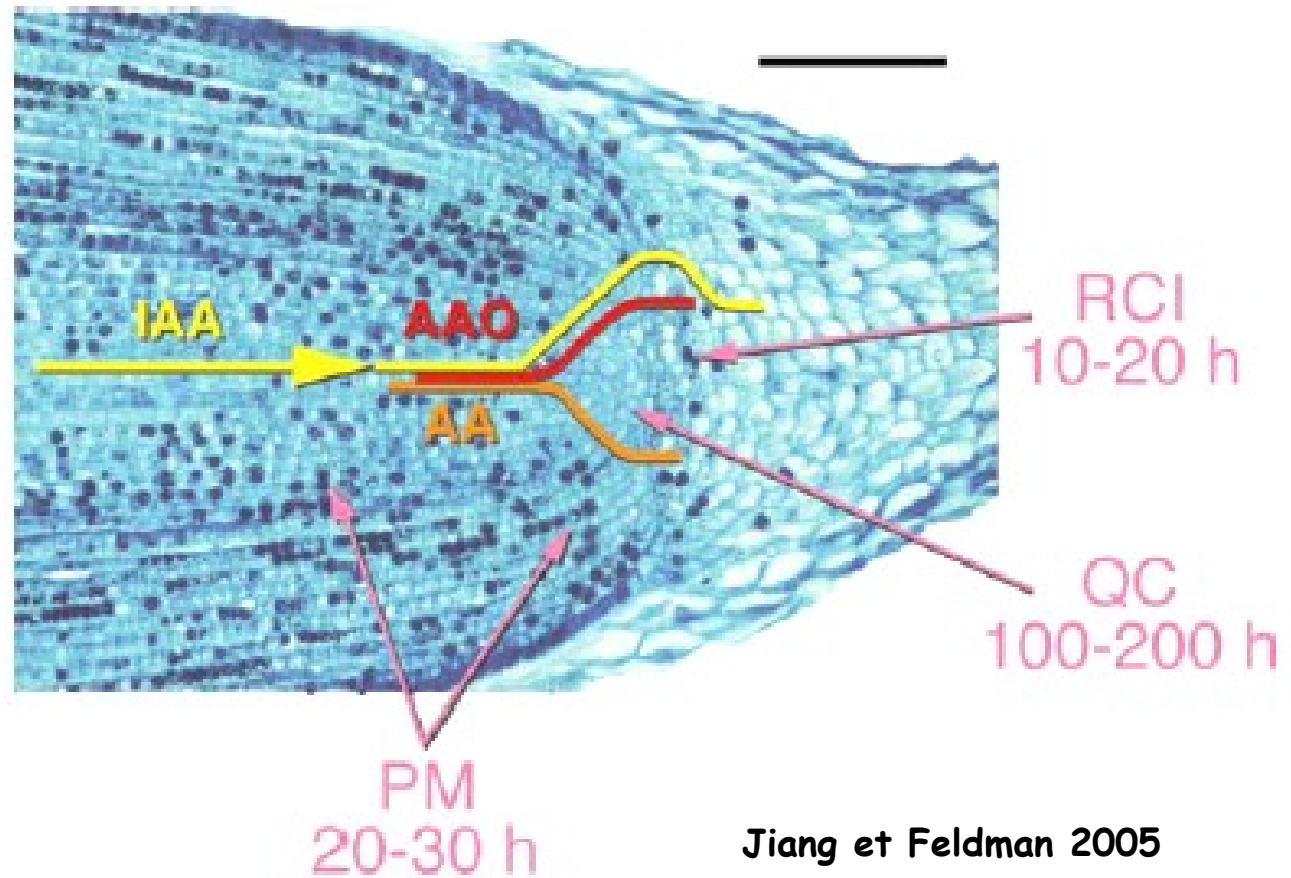
# Formování RAM u Arabidopsis



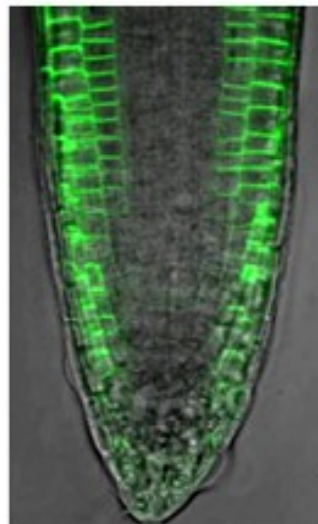
Benfey et Scheres



# Gradient auxinu a rychlost dělení buněk



# Polární lokalizace PIN proteinů

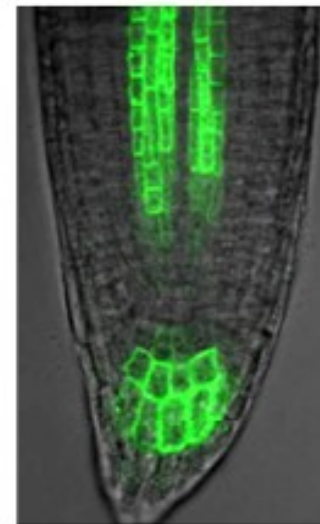


PIN2:GFP

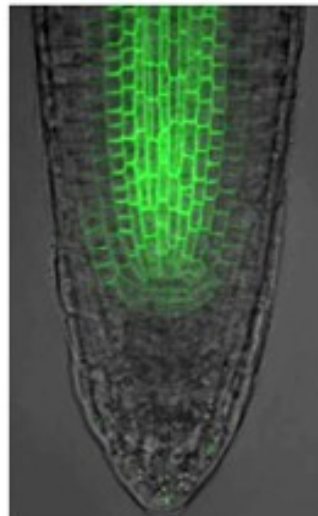


ROP2

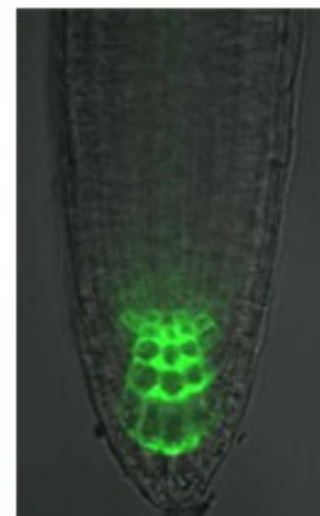
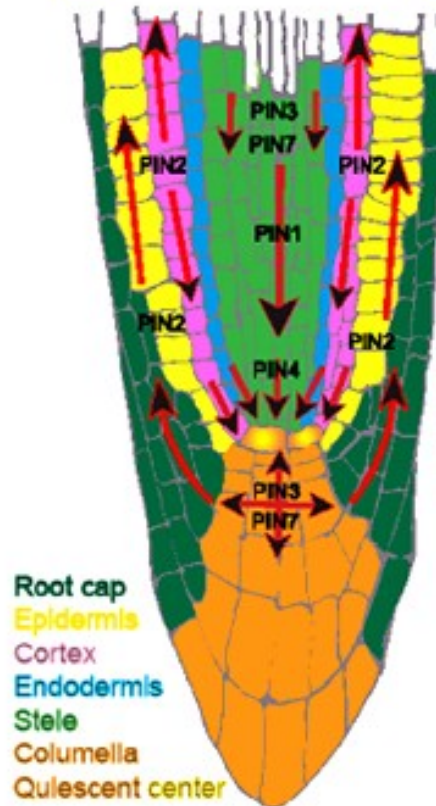
ROP2



PIN7:GFP



PIN1:GFP



PIN4:GFP

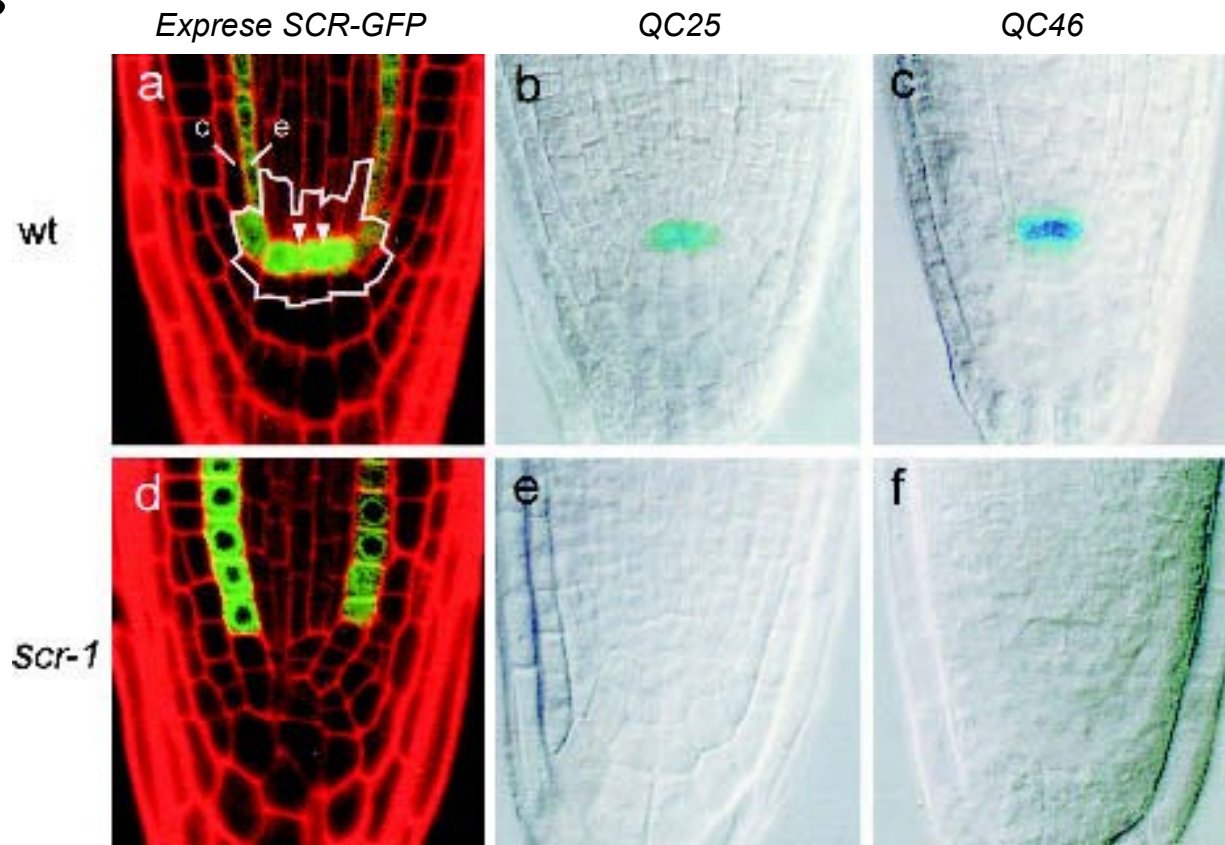
Feraru et Friml  
2008

# Transkripční faktor SCARECROW (SCR)

je součástí informace o pozici kmenových buněk u kořenového meristému *Arabidopsis*

Sabatini et al. 2003

Defects in QC identity and columella stem cell activity in the *scr-1* mutant

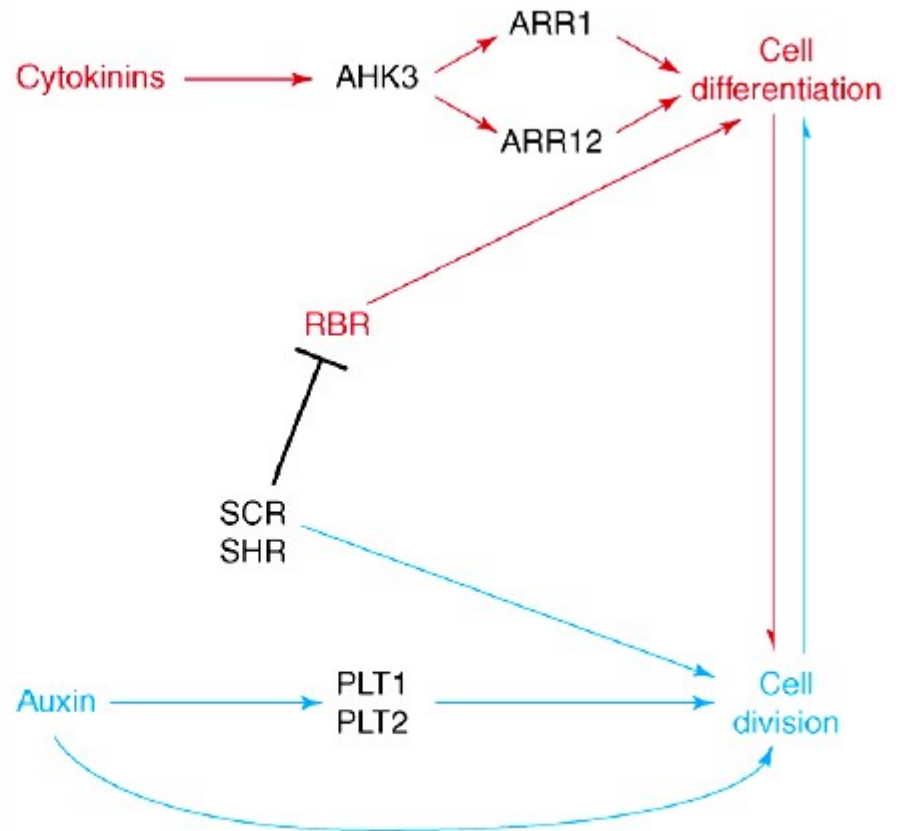


SCR poprvé identifikován díky jeho roli při radiálním utváření kořene („radial patterning“), je nutný pro distální specifikaci QC, jež naopak reguluje osud kmenových buněk obklopujících QC



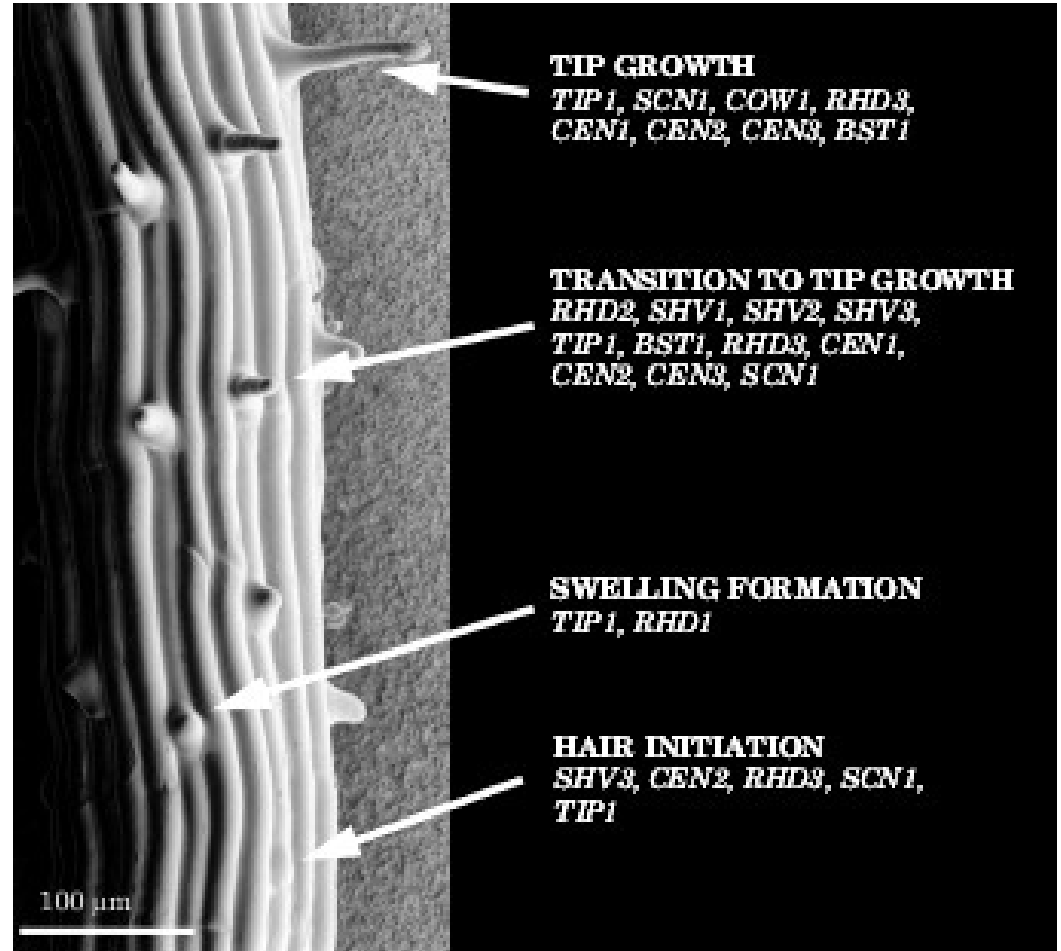
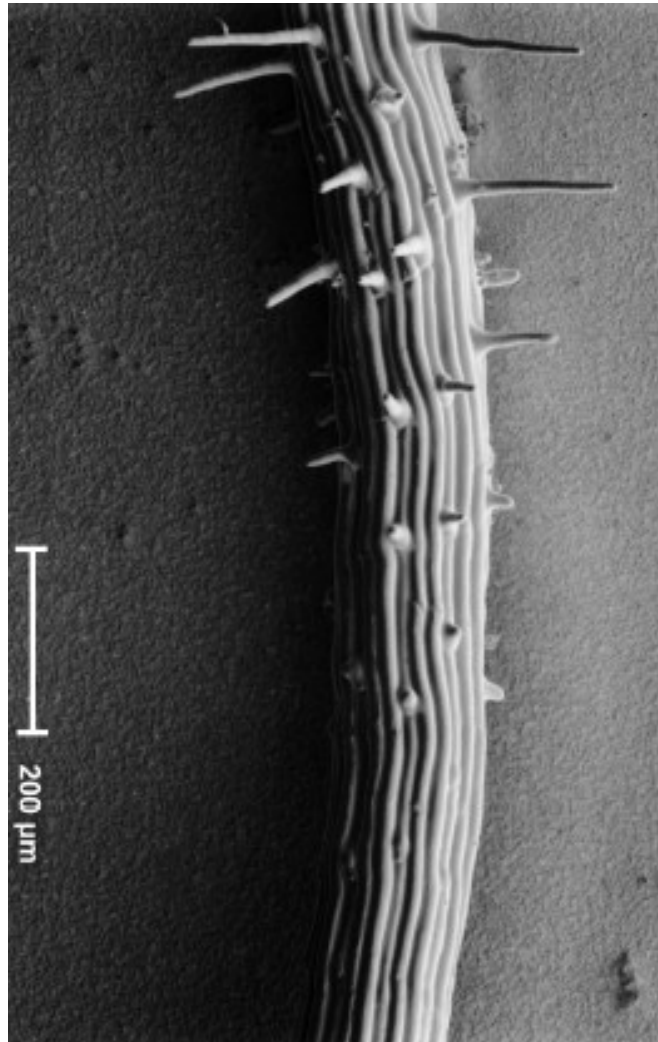
# Regulace kořenového meristému

polární transport auxinu



Ioio et al. 2008

# Vývoj kořenového vlášení



Foreman a Dolan 2001

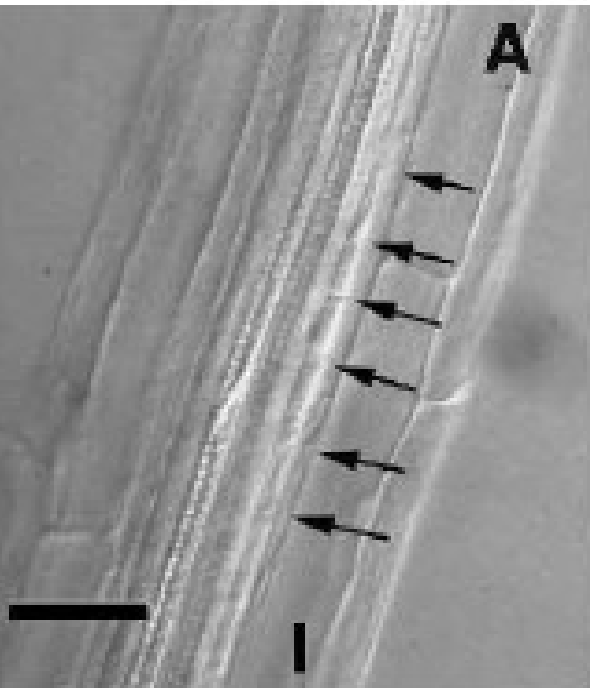
# Zakládání laterálních kořenů

- U kořenů neexistují nějaké základy laterálních orgánů (na rozdíl od axilárních meristémů prýtlů)
- Laterální kořeny se musí vyvíjet z meristémů aktivovaných v diferencovaném pletivu - **pericyklu** (latentní meristém)



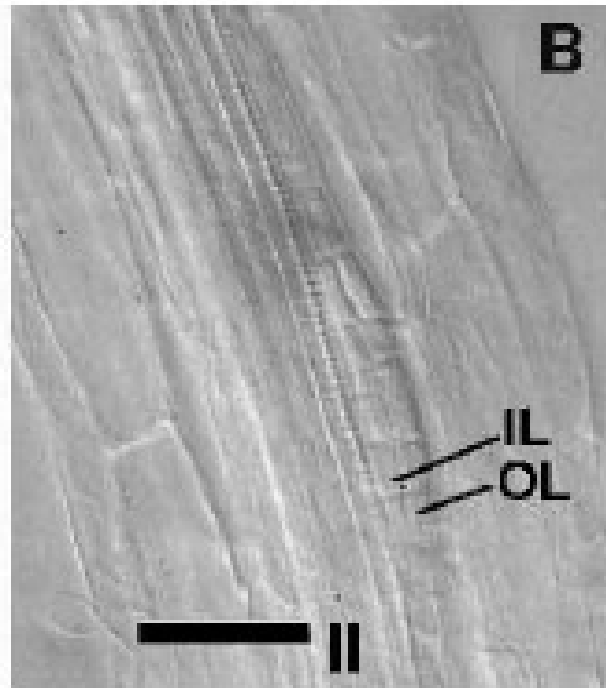
# Stadia vývoje laterálního kořene u *Arabidopsis*

Stage I.



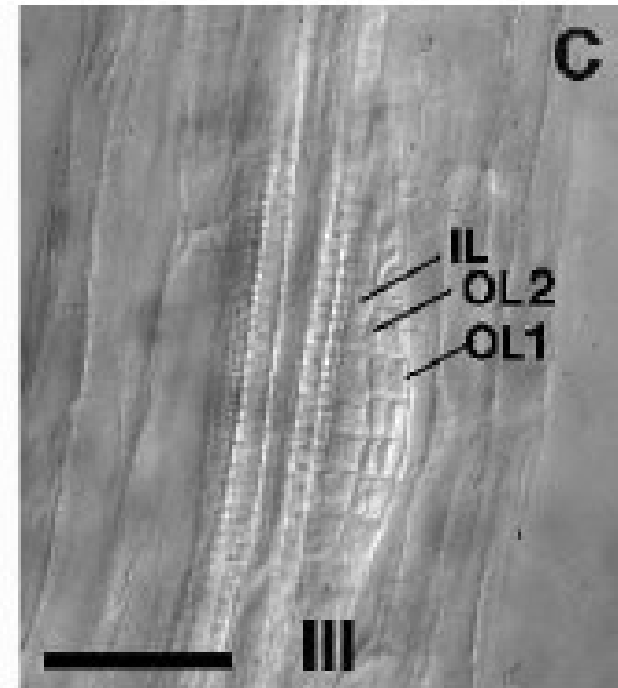
Arrows point to new cell walls indicating anticlinal divisions in the pericycle.

Stage II.



A periclinal division has divided the LRP into two layers, outer layer (OL) and inner layer (IL).

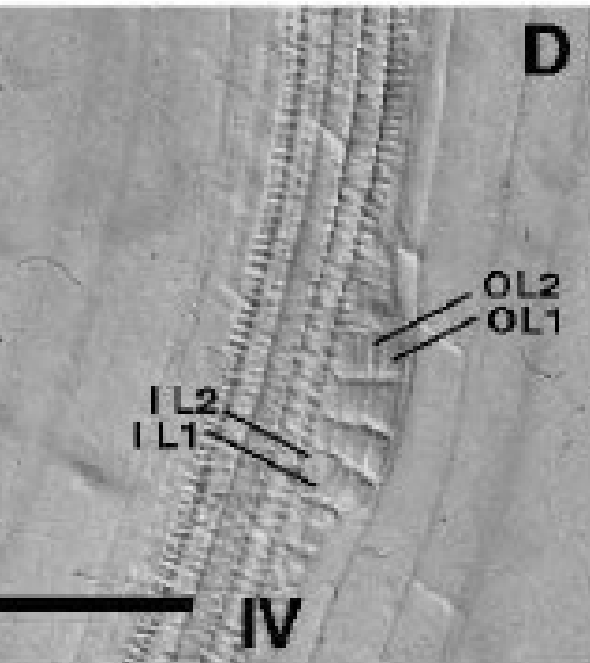
Stage III.



A periclinal division in OL has created a total of three layers.

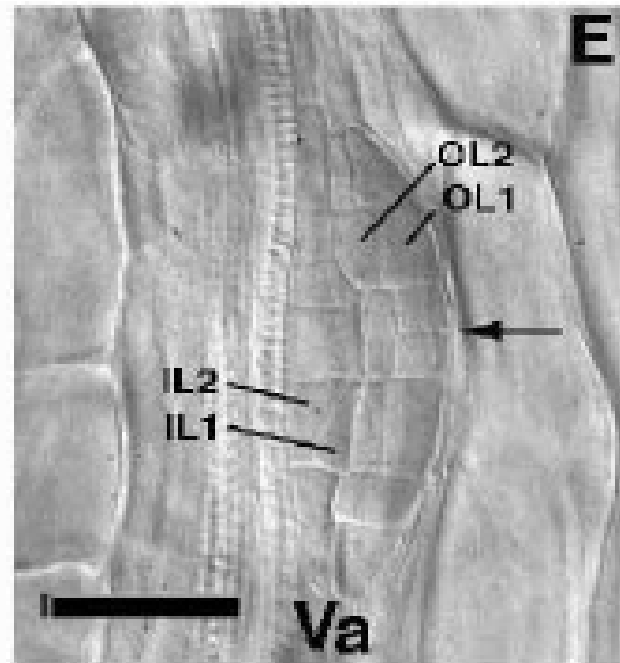
# Stadia vývoje laterálního kořene u *Arabidopsis*

Stage IV.



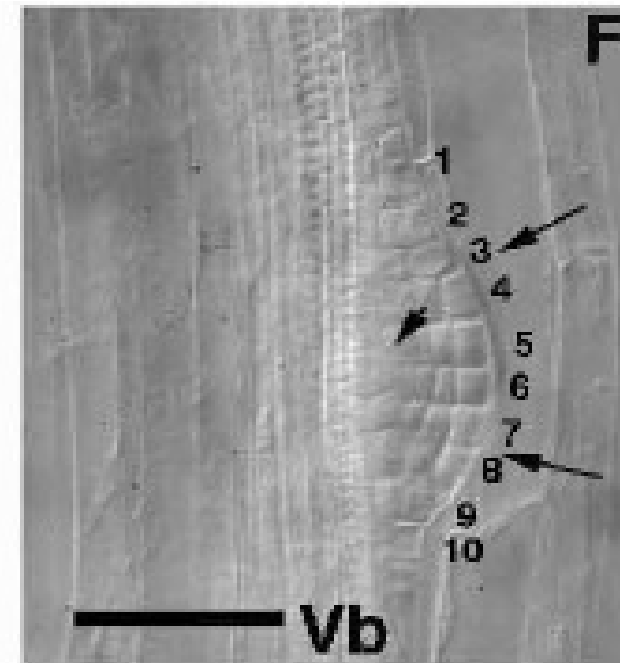
A periclinal division in IL creates a fourth layer.

Stage Va.



Arrow indicates a single anticlinal division in the center cells of OL1 and OL2.

Stage Vb.

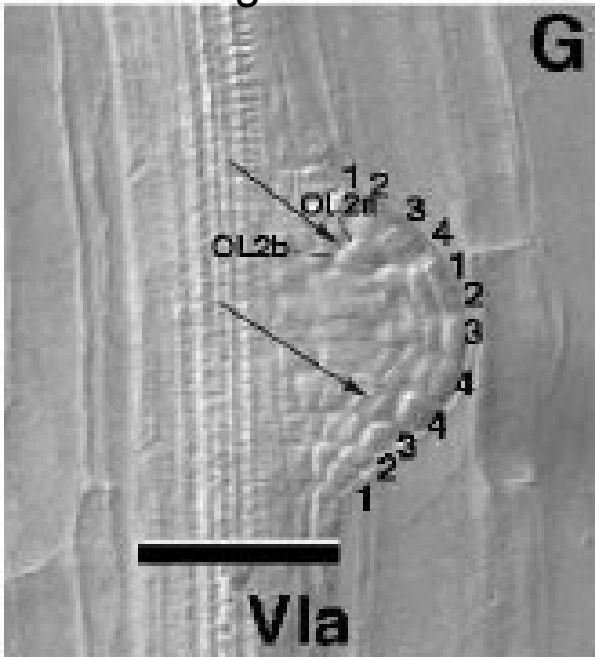


Arrows indicate two **additional anticlinal divisions** in OL1 and OL2.

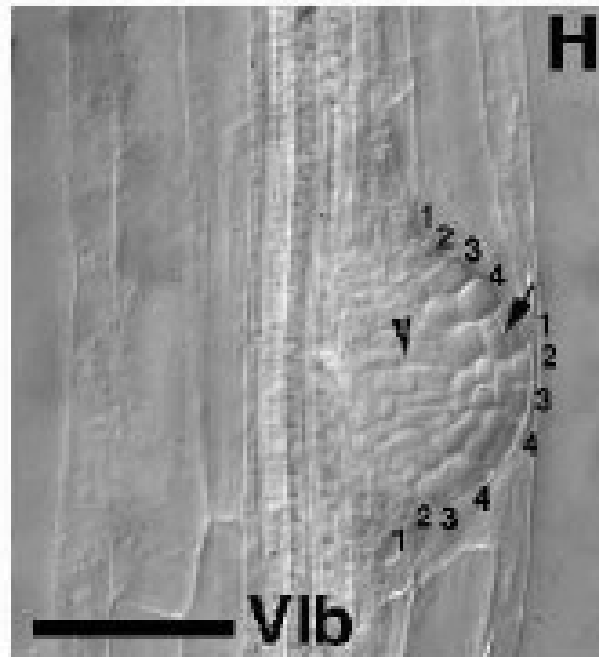
The short arrow indicates the region in which cells of the IL2 undergo expansion and division, distorting the shape of IL1 and OL2. Cells in the outermost layer are numbered to indicate the constant organization at this stage.

# Stadia vývoje laterálního kořene u *Arabidopsis*

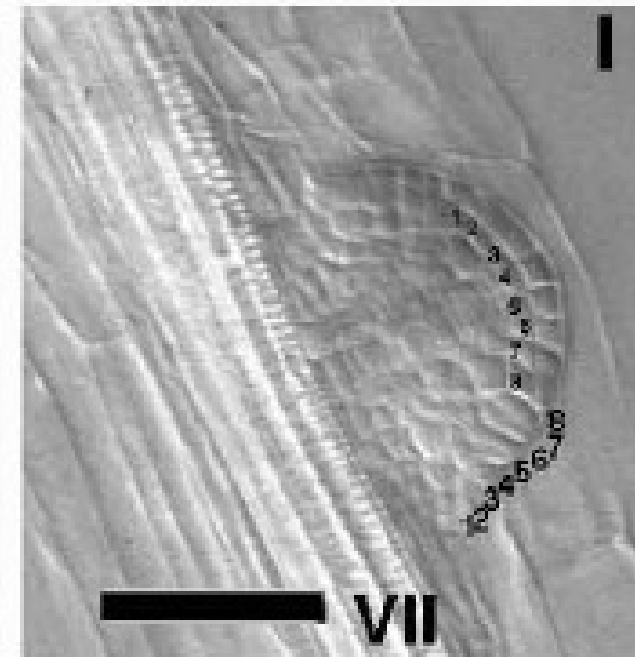
Stage VIa.



Stage VIb.



Stage VII.



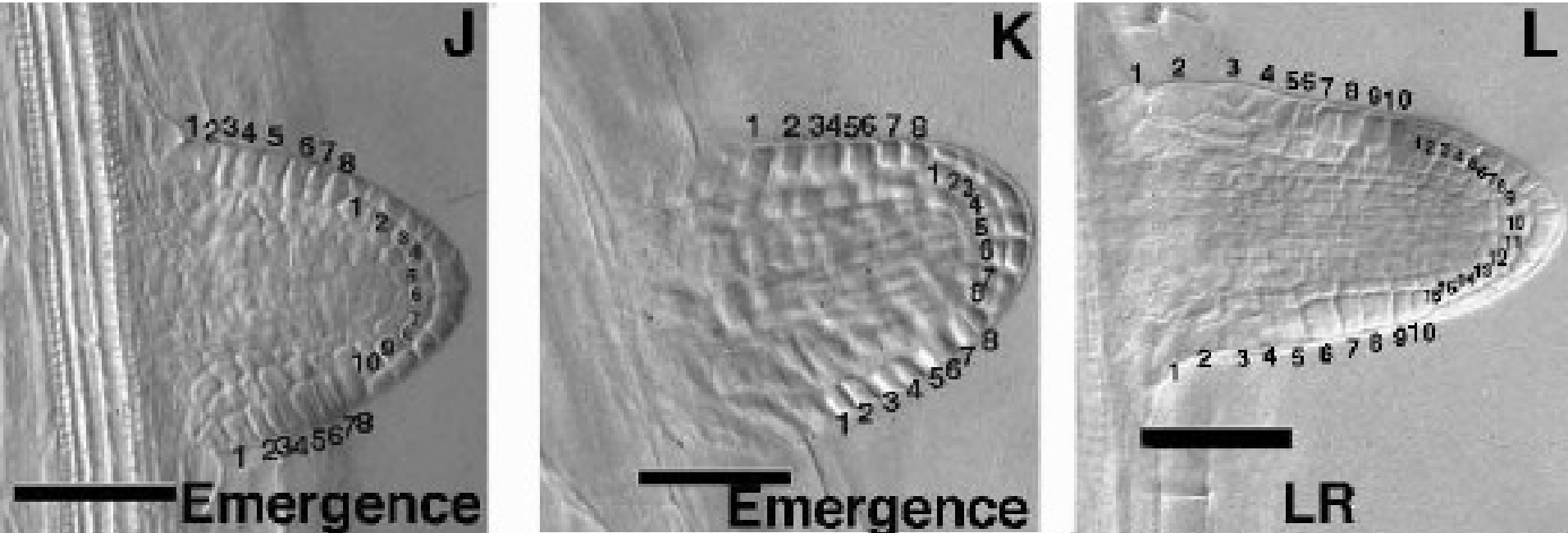
A **periclinal division** in all but the center cells of OL2 creates a new tier of cells (arrows). The two tiers are designated OL2a and OL2b.

Four central cells in OL1 divide **periclinally** to create another new tier at the tip of the primordium (arrow). Numbering shows that there are now four cells in OL1 on either side of four divided central cells. The OL1 is considered to be the inner of these two layers of divided central cells.

All the cells in the OL1 have undergone **anticlinal divisions**, as evidenced by the cell shape and the increased number of cells in this layer. This gives the characteristic 8-8-8 cell pattern, as indicated by cell numbering.

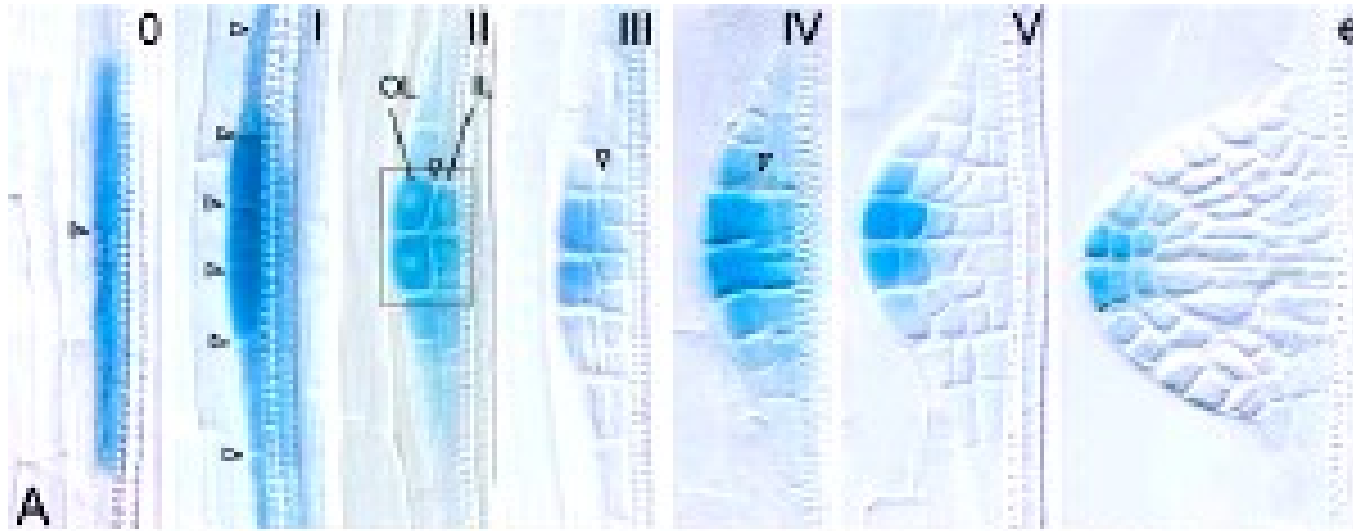


# Stadia vývoje laterálního kořene u *Arabidopsis*

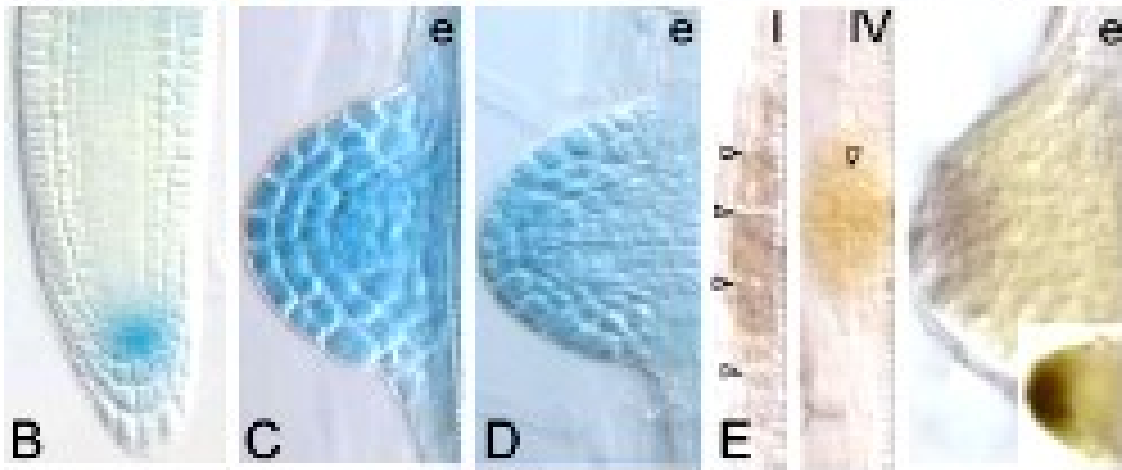


(J,K) Emerging LRP. Note that the cells in the OL1 are **enlarged**. The number of cells near the apex has increased slightly, potentially indicating the first divisions of meristematic initials. (L) Fully emerged LR. Note the gross increase in size that has occurred in the basal cells of the OL1. Cell numbering indicates that there are now more cells in this layer near the root tip, consistent with the presence of an **active lateral root apical meristem**.

# Distribuce auxinu a vývoj primordia laterálního kořene u *Arabidopsis*



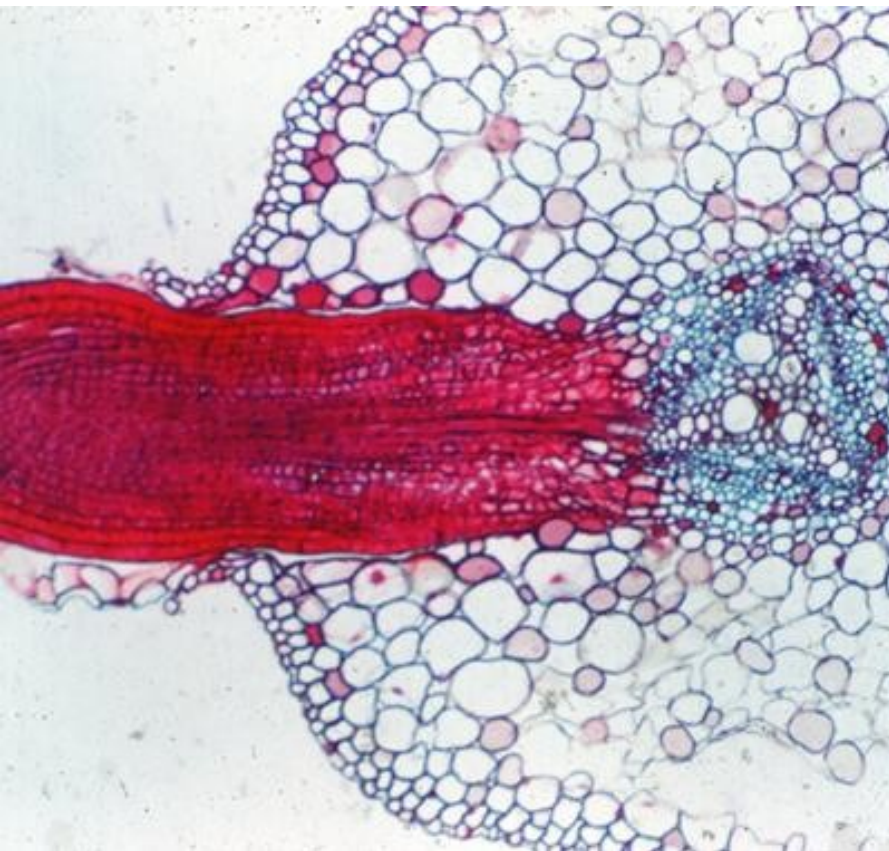
expresse  
DR5::*GUS*



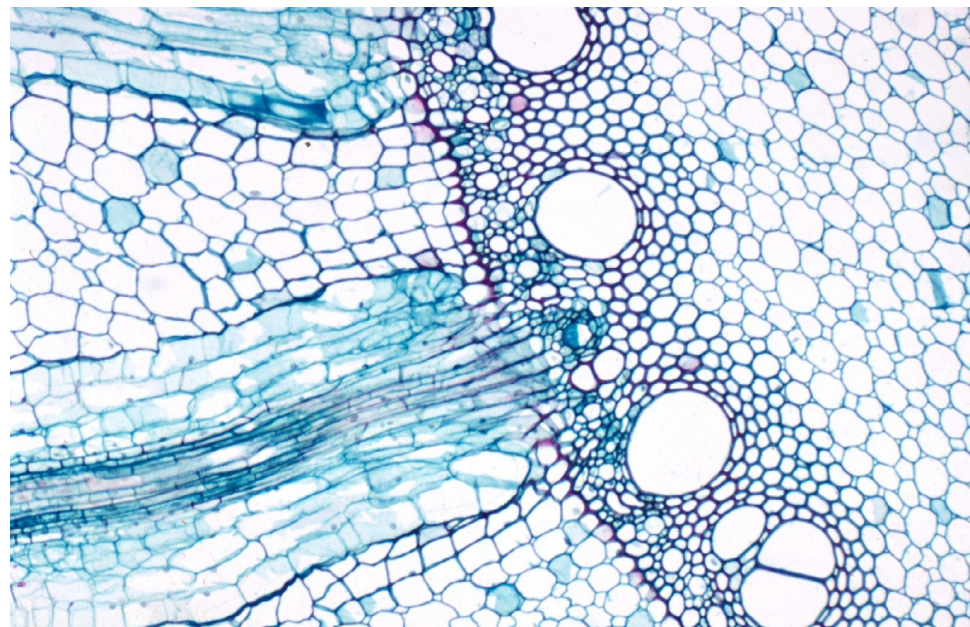
Benková *et al.*,  
Cell, 2003

Vliv 2,4-D    NPA    Imunolokalizace IAA

# laterální kořen



**Salix**



**Zea mays**