

Kořenový meristém a vývoj kořenů

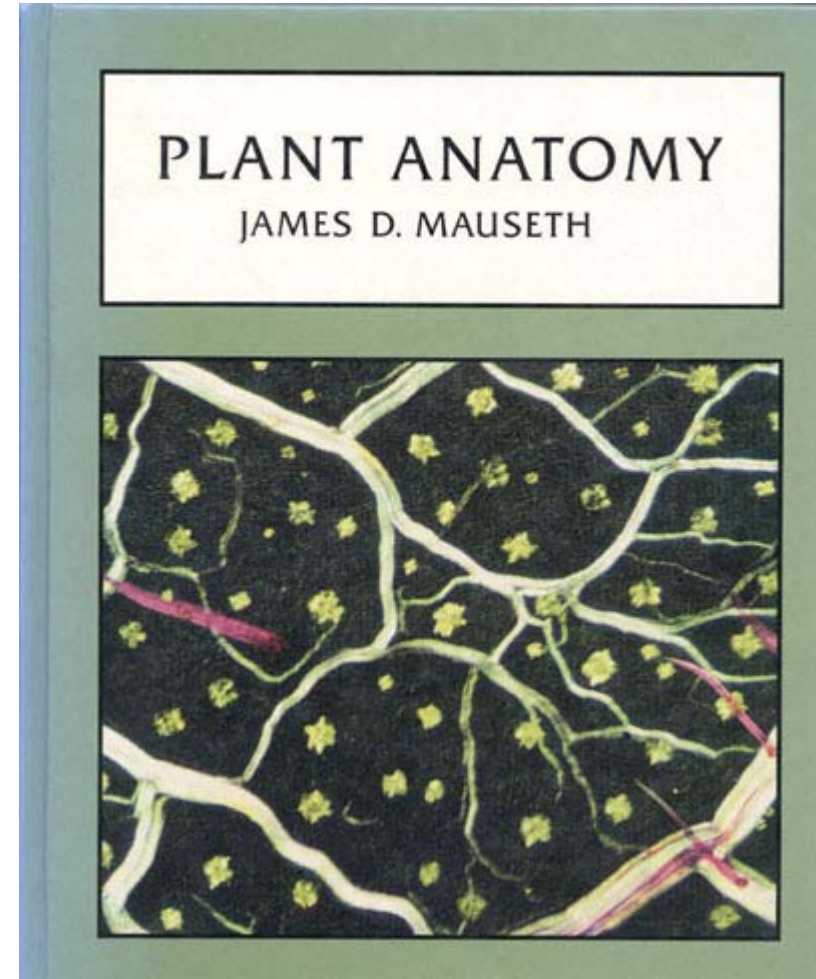
Plant Anatomy Laboratory

Micrographs of plant cells and tissues,
with explanatory text.

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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/>

Funkce kořene

Kořen zajišťuje:

- **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)
- **upevnění rostliny v půdě**

Struktura kořene - radiální

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

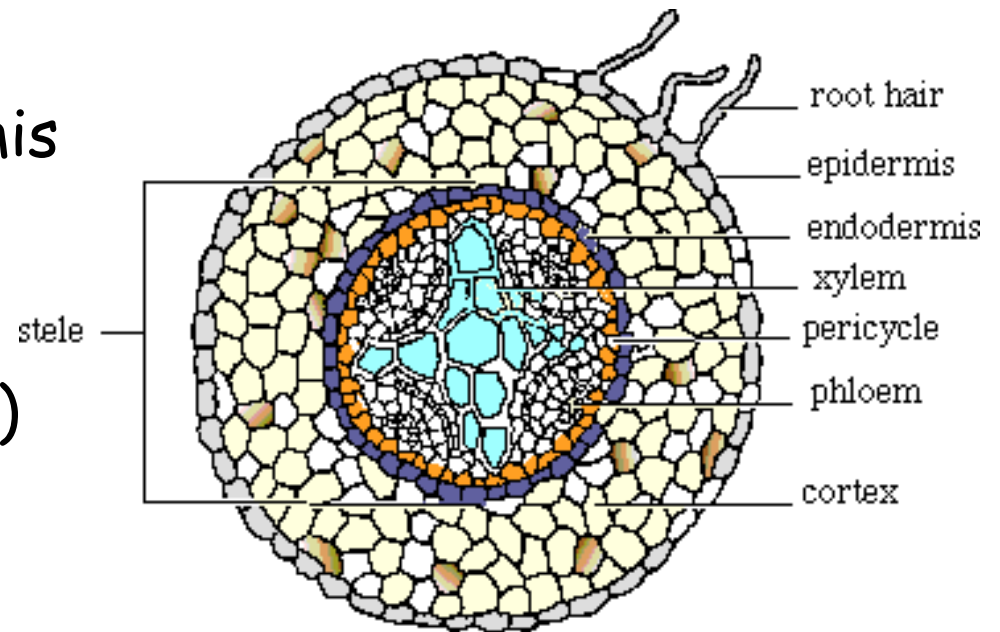
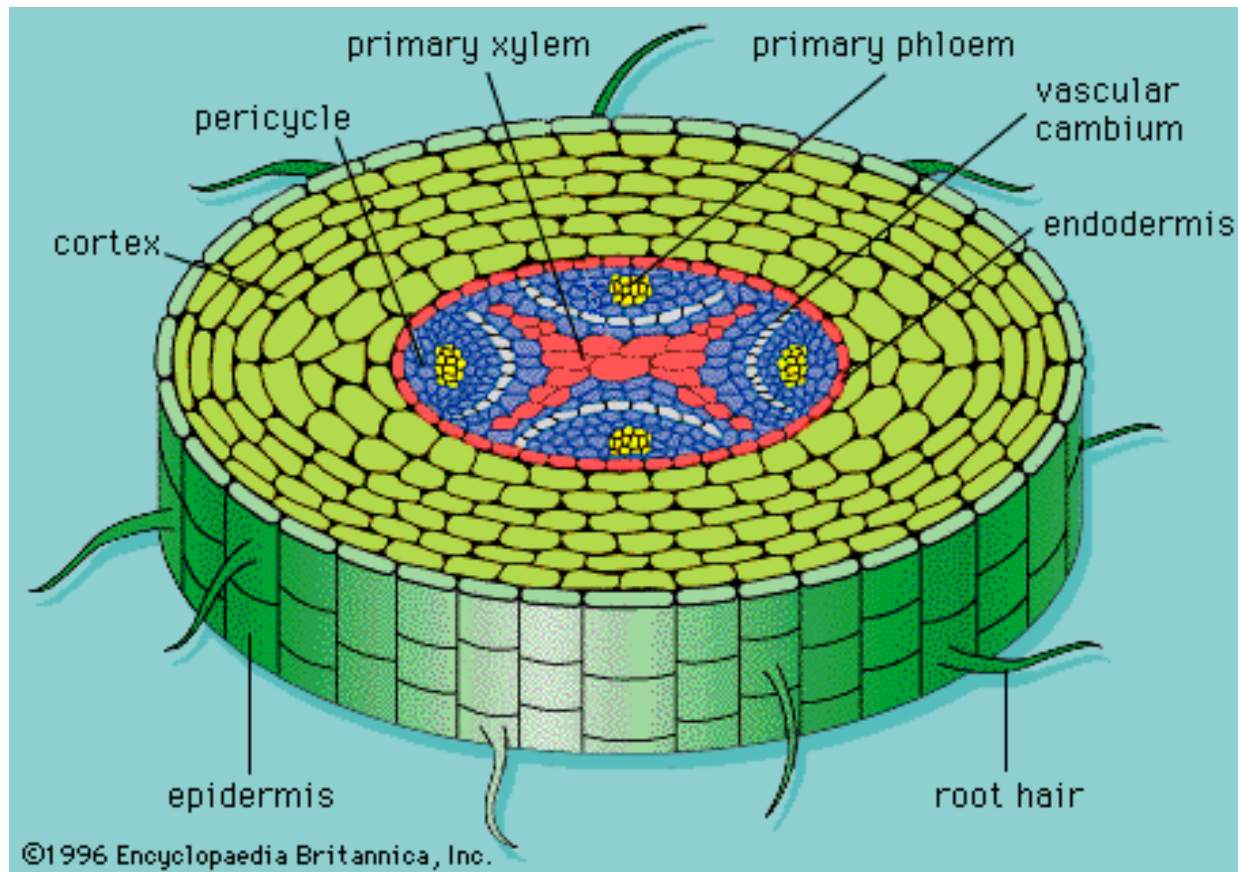
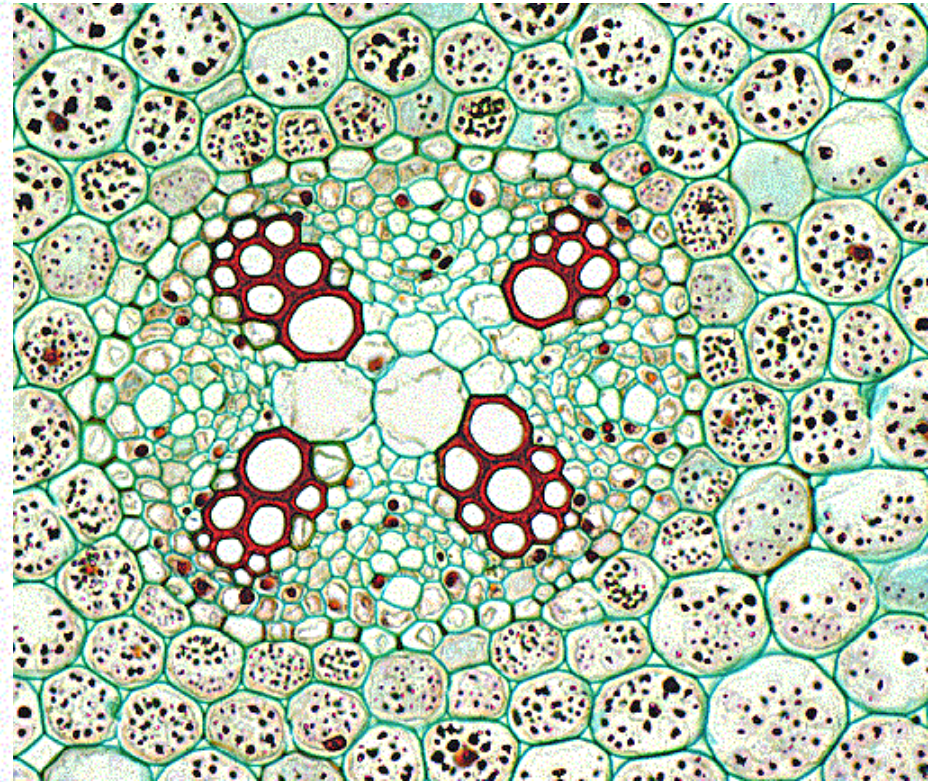
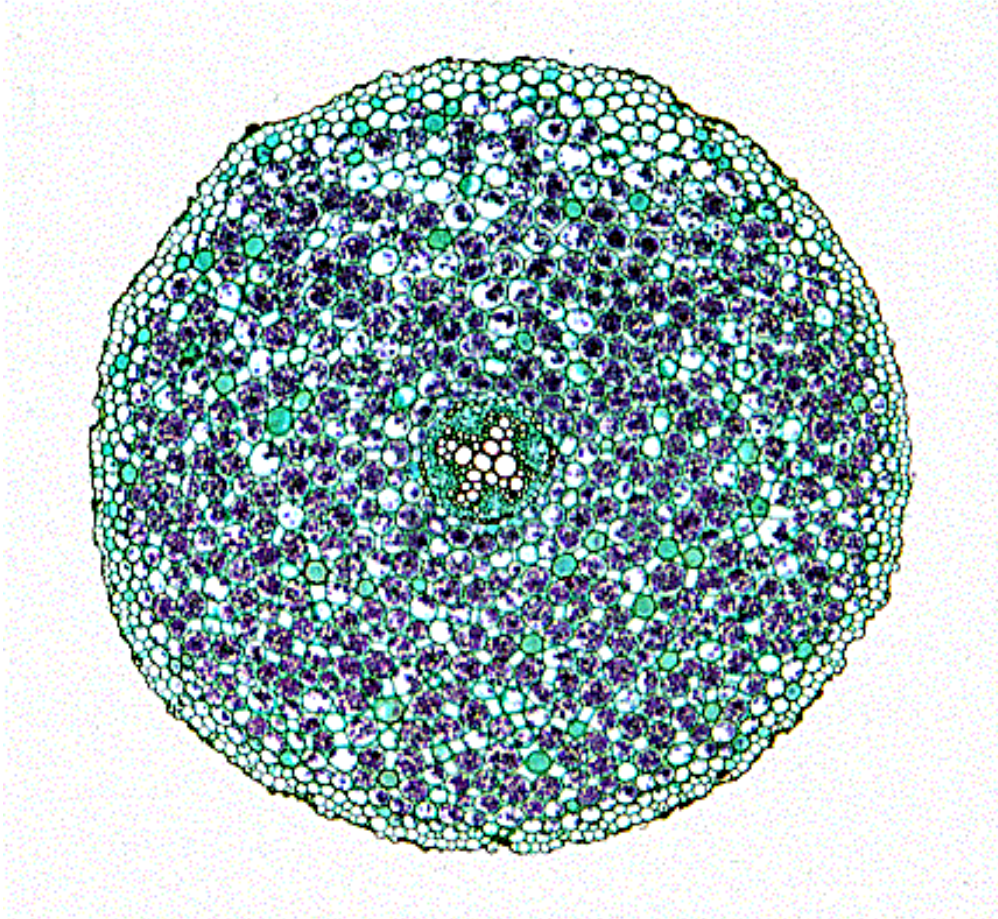


Schéma příčného řezu kořenem



Příčný řez kořenem dvouděložné rostliny

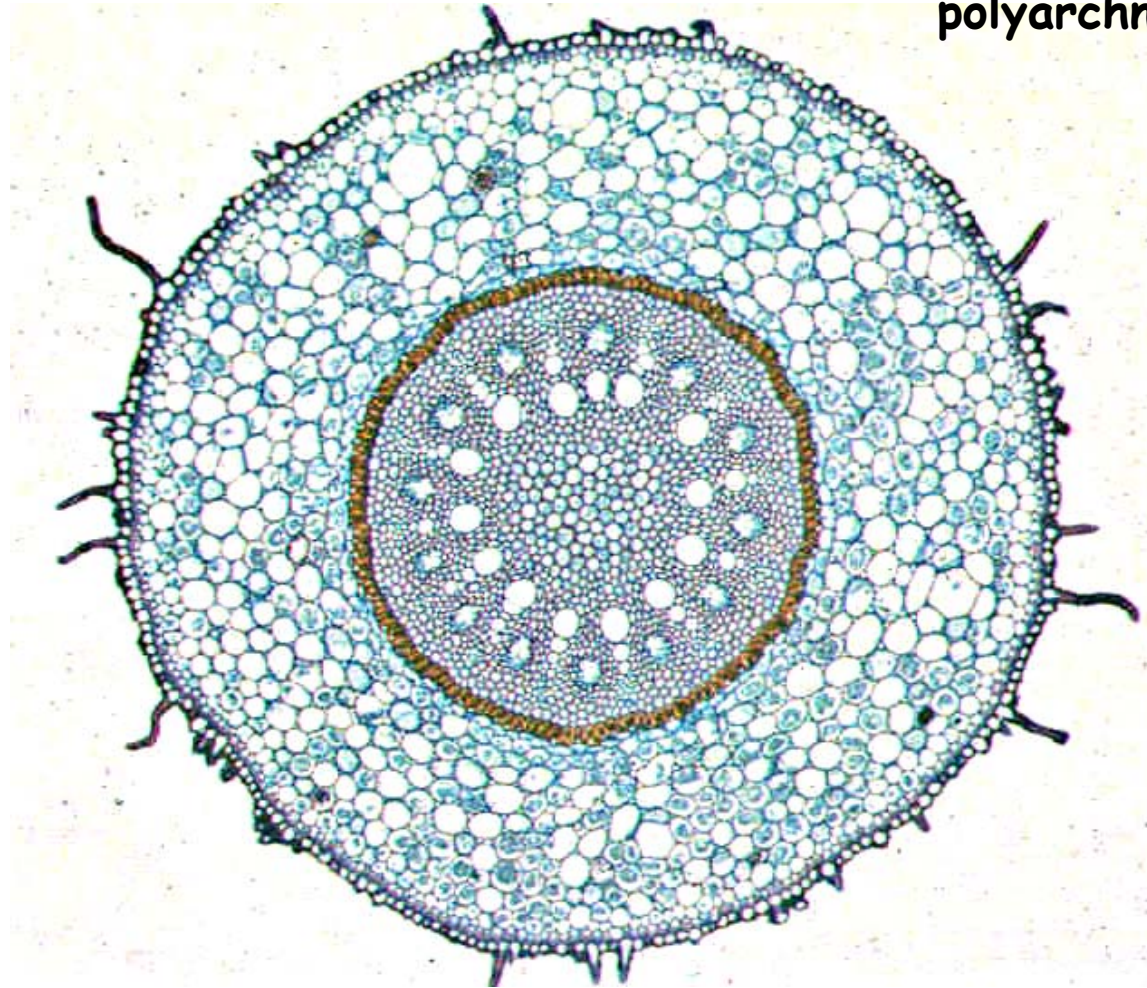


detail středního válce

tetrarchní CS, *Ranunculus*

Příčný řez kořenem jednoděložné rostliny

polyarchní CS



<http://schoolnet.gov.mt/liceohamrun/resources/TransportinPlants.pps>

Terminologie

apikální část kořene

- kořenová čepička
- vlastní kořen

kořenový (sub)apikální meristém

- vnitřní část čepičky
- vrchol vlastního kořene

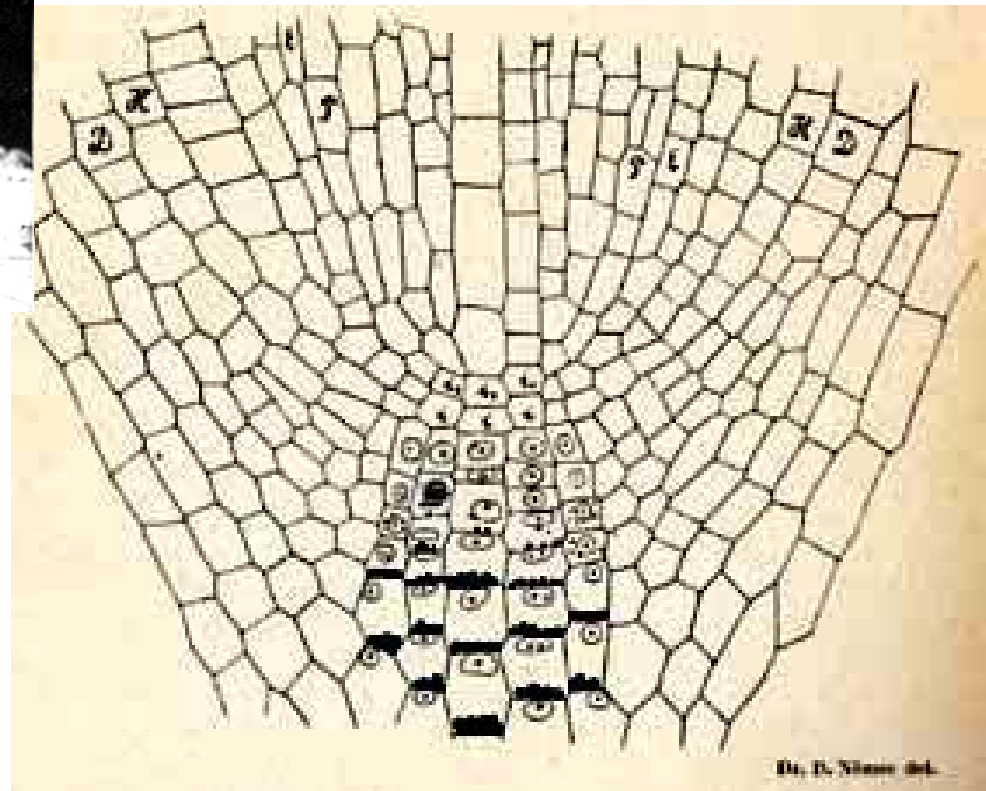
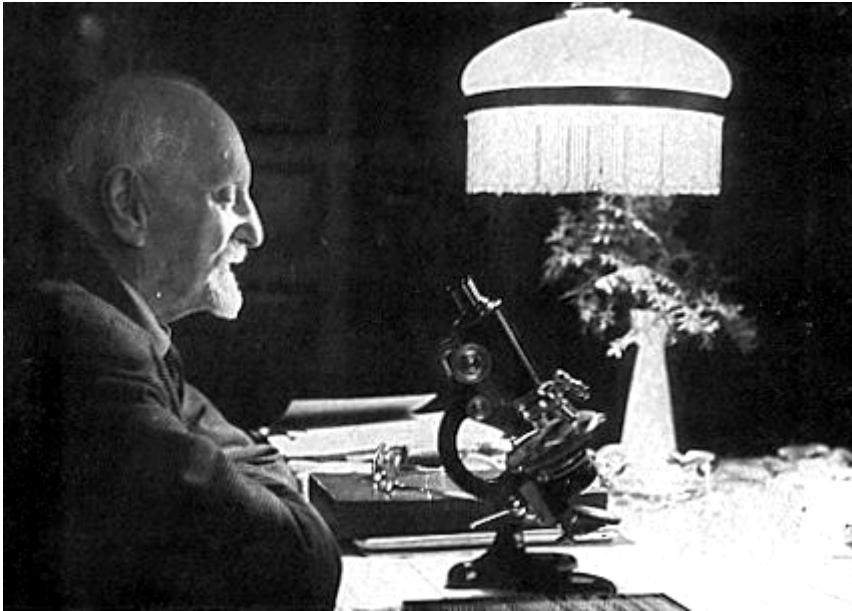
vnější část kořenové čepičky tvoří buňky dozrálé

Primární růst kořene a stavba kořene - na podélném řezu

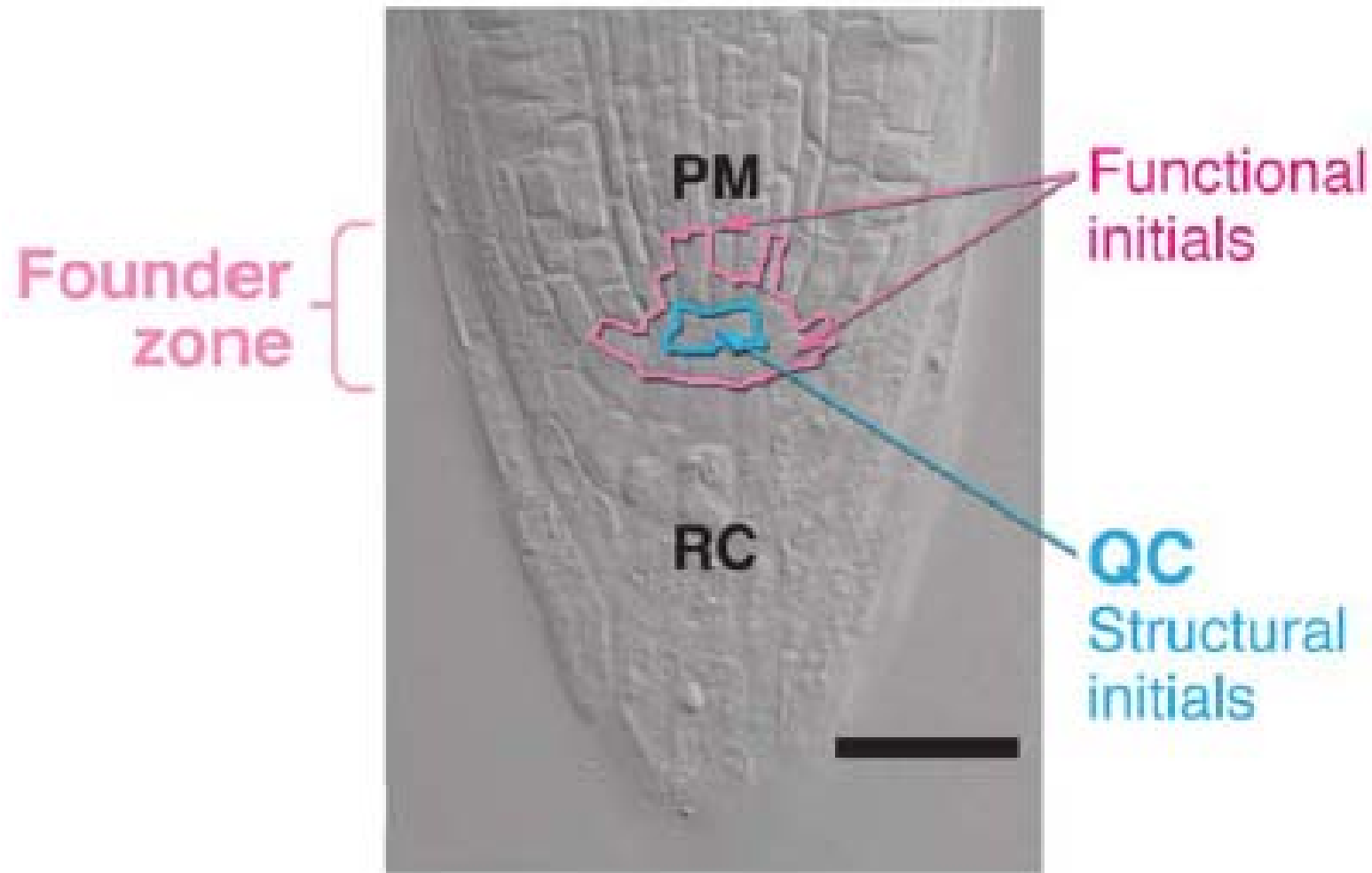
zóny:

- meristematická
- přechodná
- zóna elongace buněk (prodlužovací)
- zóna diferenciacce buněk

Prof. B. Němec - autor statolithové teorie

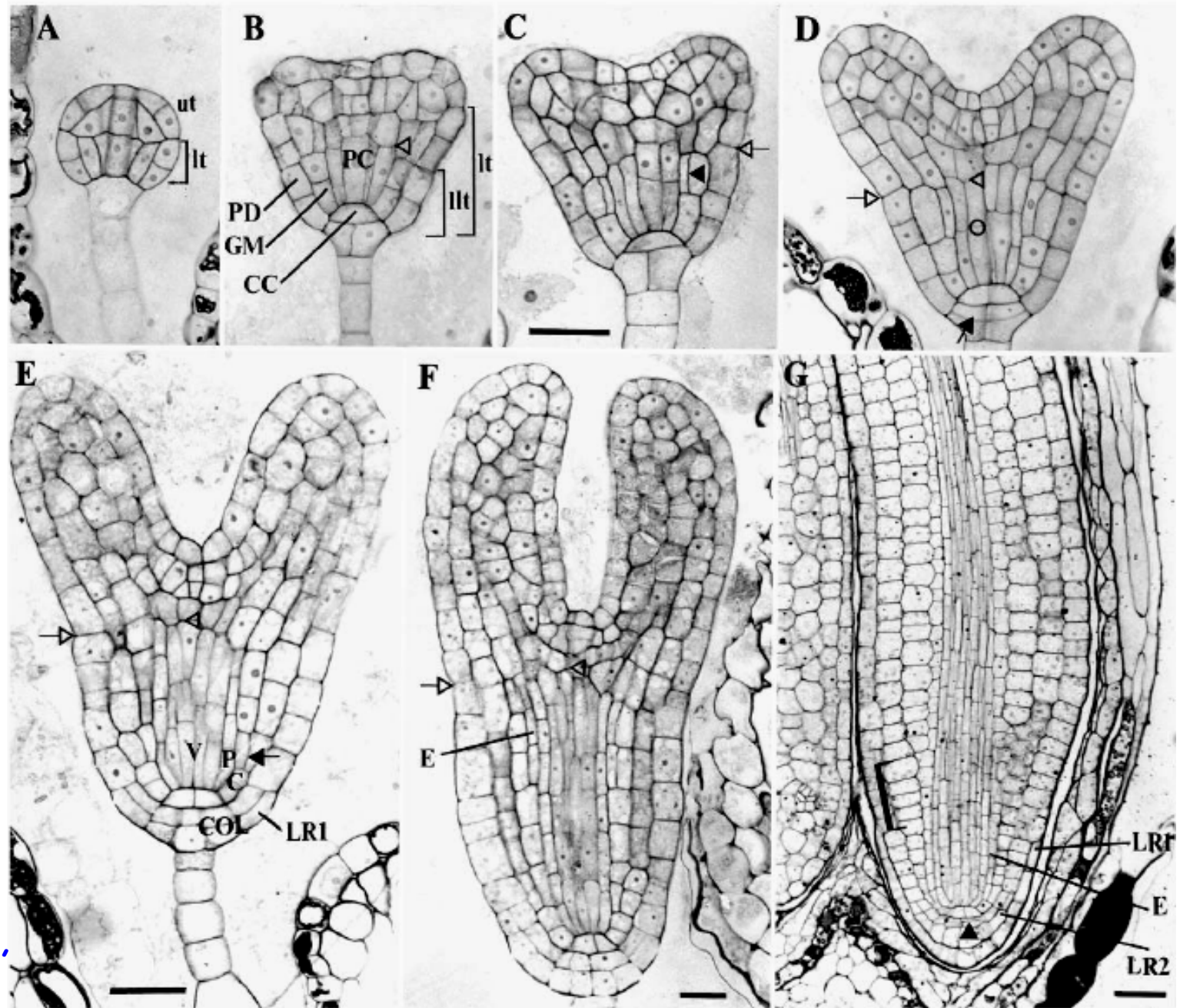


Struktura kořene *Arabidopsis*



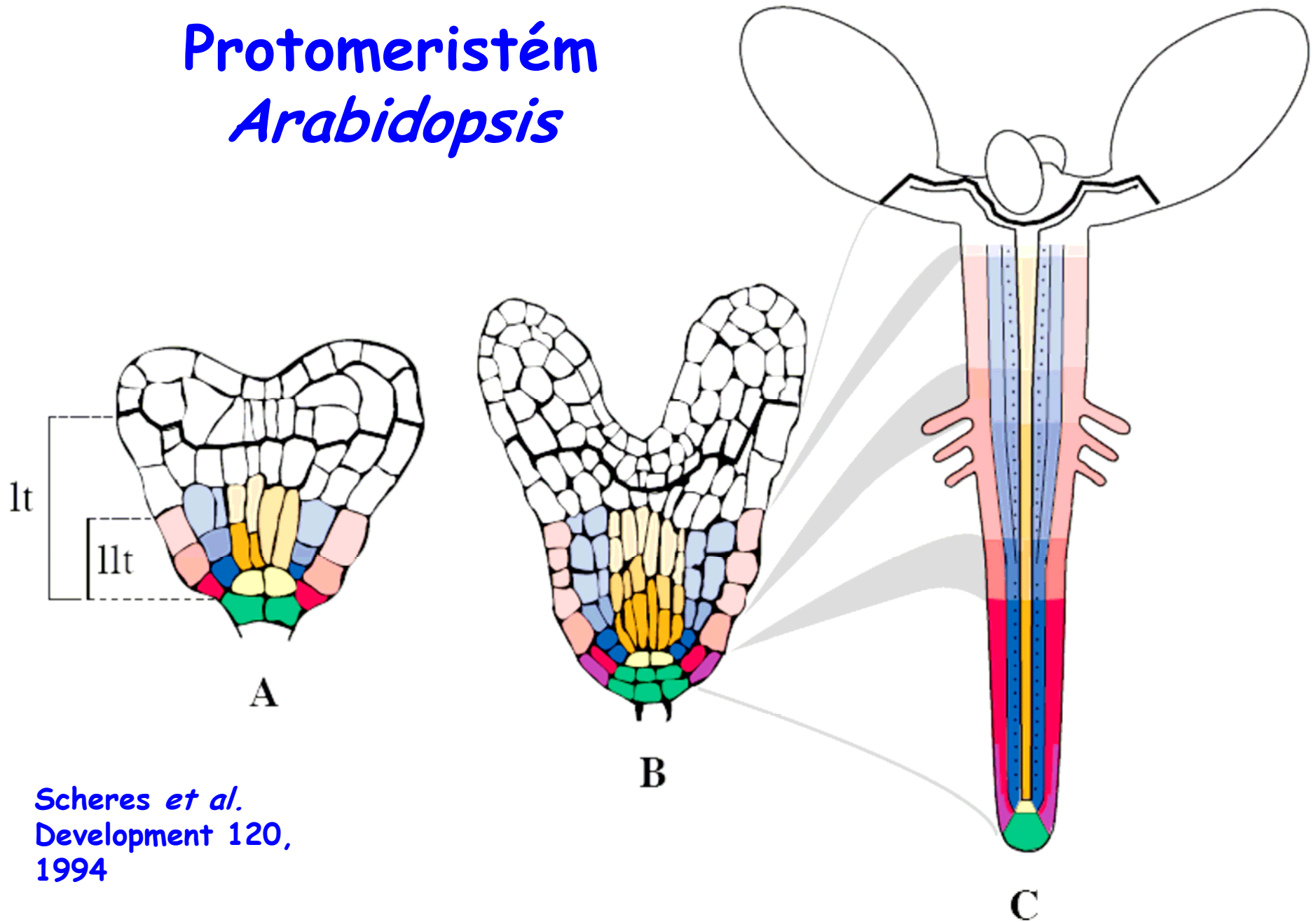
Jiang *et* Feldman 2005

Zakládání kořenového meristému v embryogenezi *Arabidopsis*



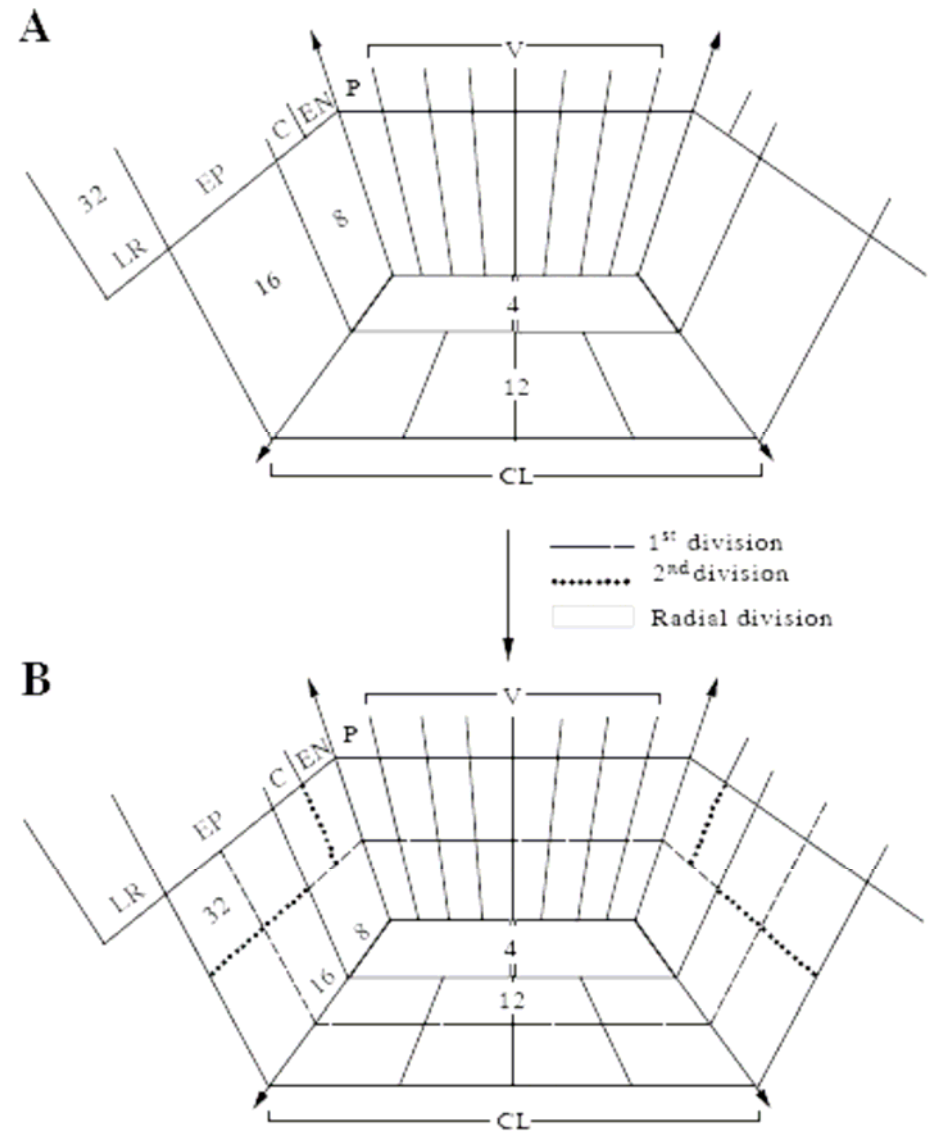
Scheres *et al.*
Development 120,
1994

Protomeristém *Arabidopsis*



Scheres *et al.*
Development 120,
1994

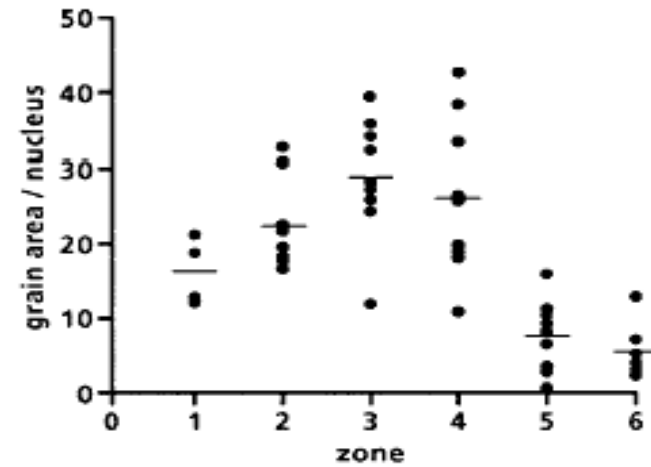
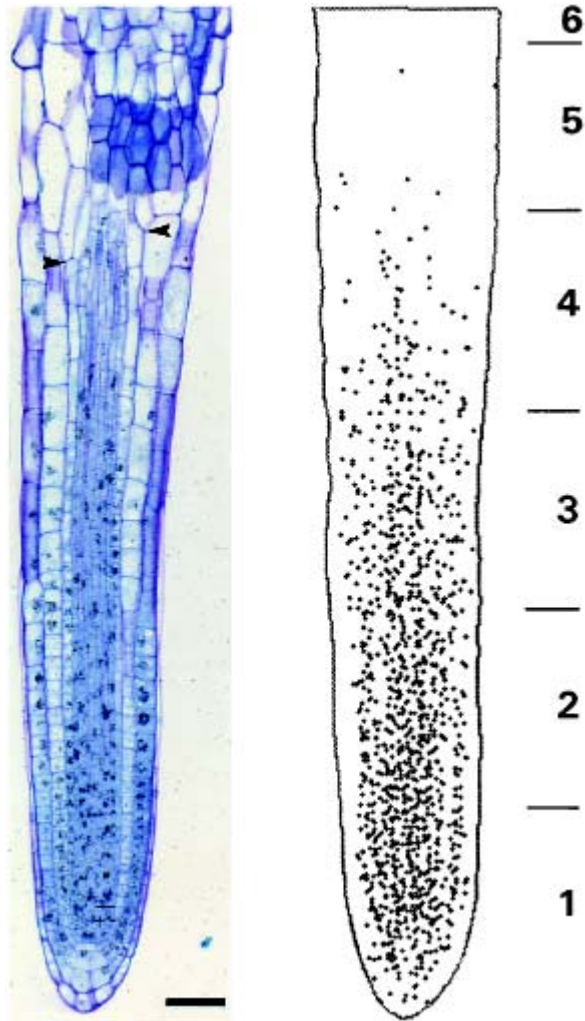
Protomeristém *Arabidopsis*



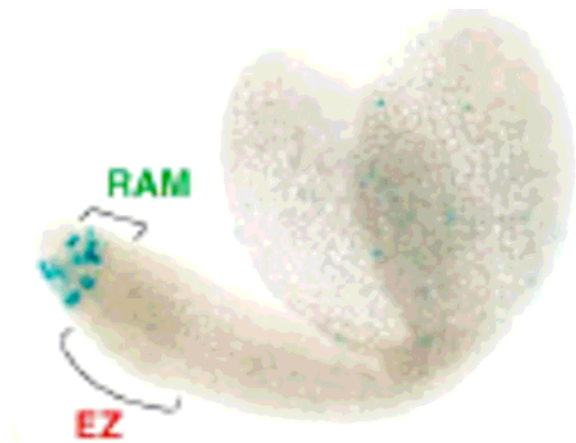
Scheres *et al.*
Development 120,
1994

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



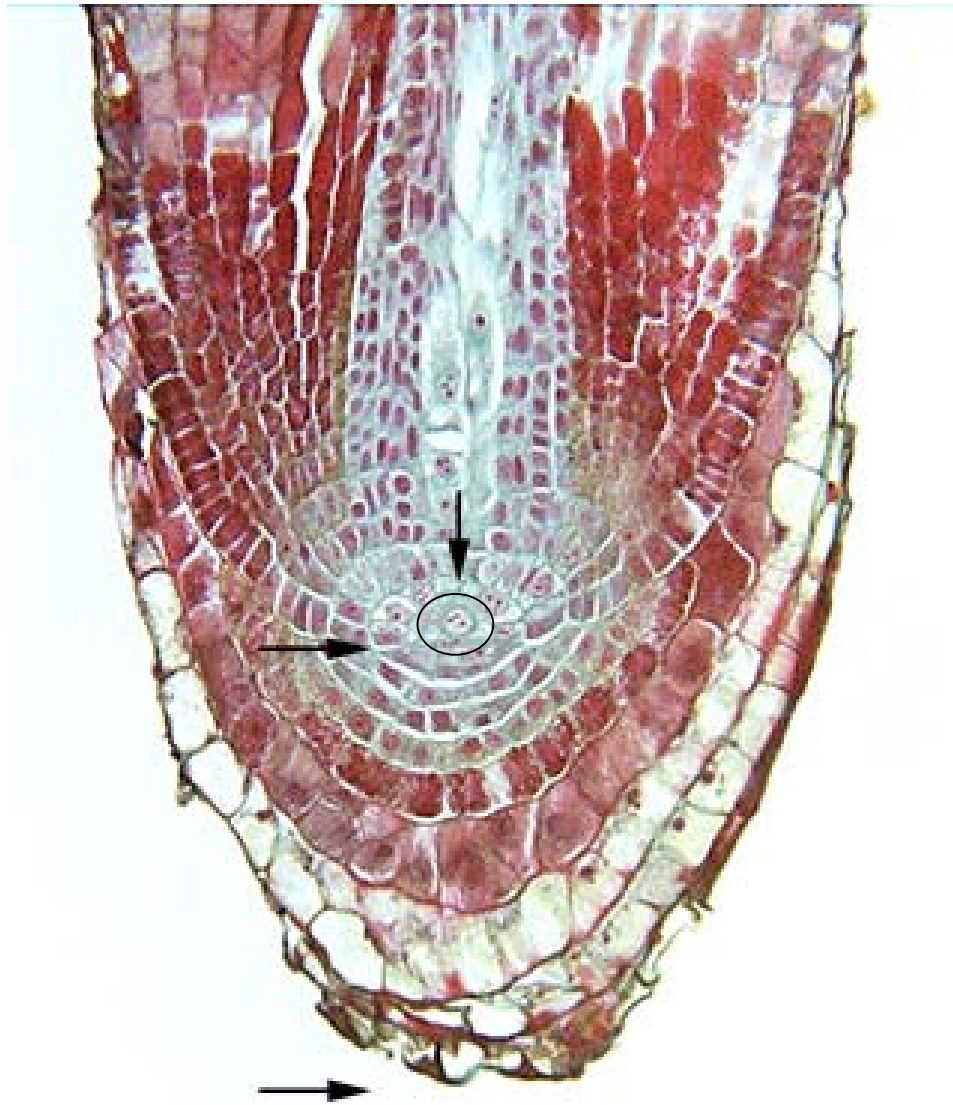
Indigogenní
vizualizace
cyklinu B
CYCB::uidA

Typy kořenových meristémů

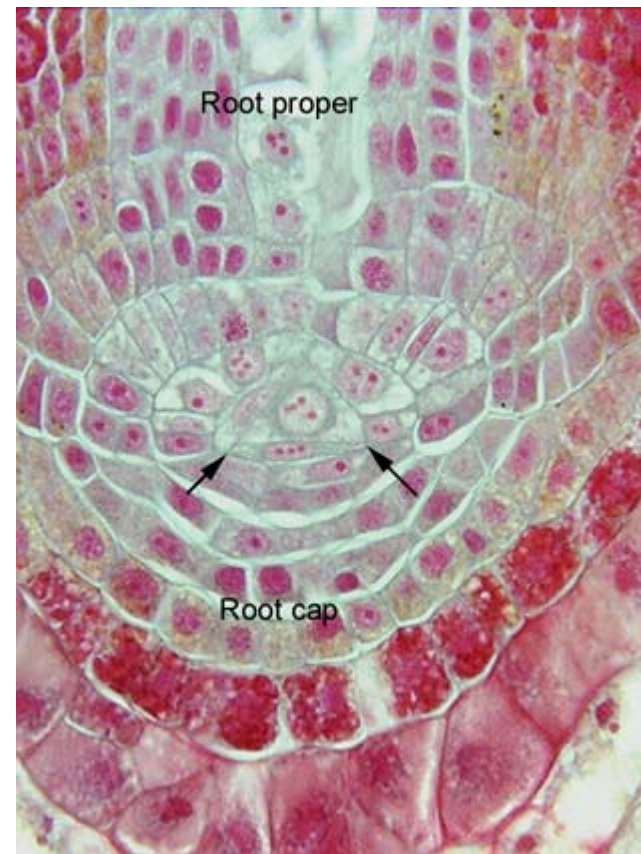
Guttenberg

- **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*)

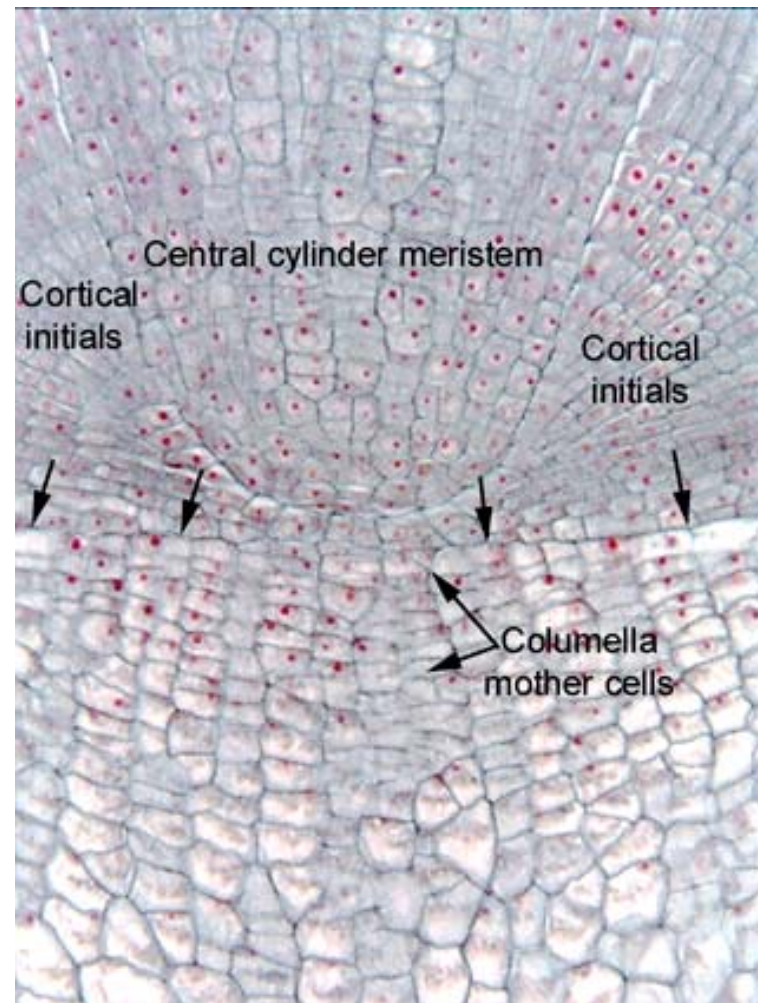
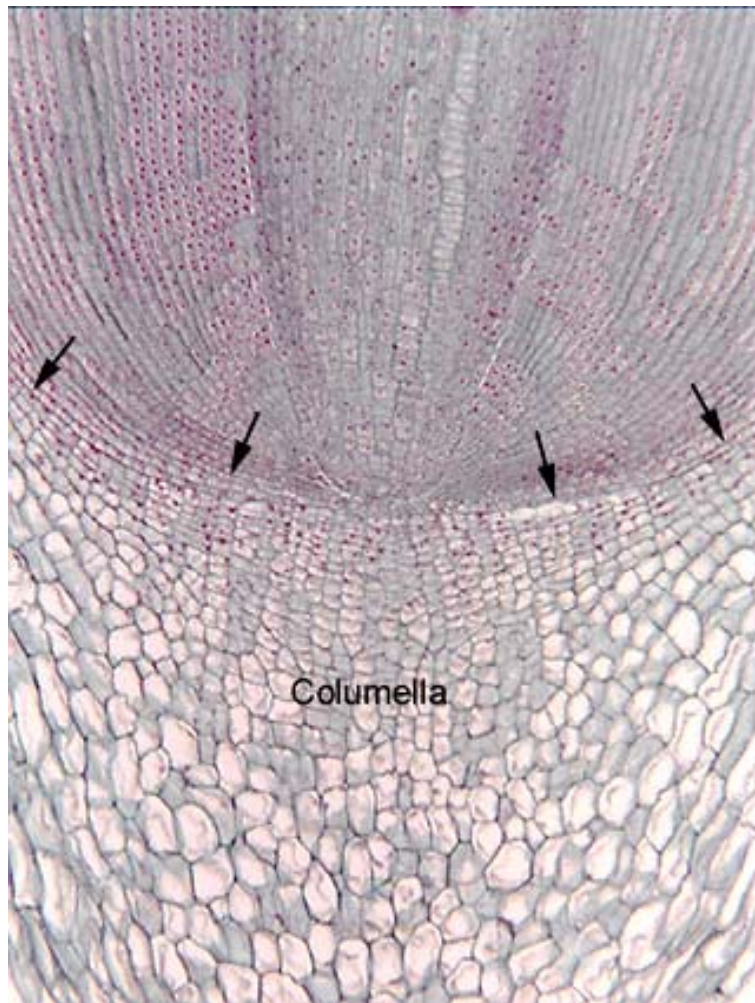
Podélný řez kořenovou špičkou kapradiny



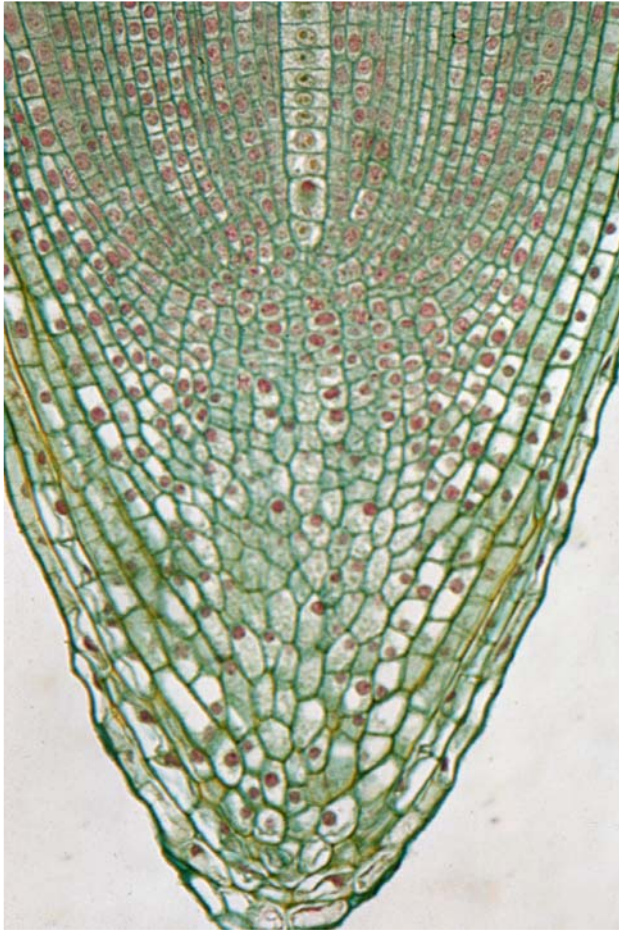
otevřený typ s jednou
iniciální buňkou (šipky)



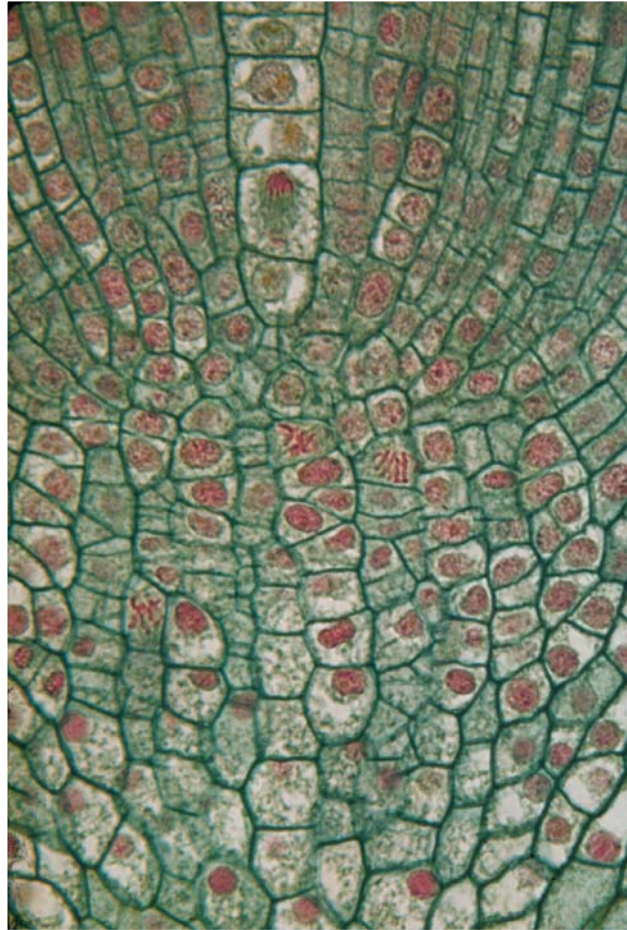
Uzavřený kořenový apikální meristém



Uzavřený kořenový apikální meristém

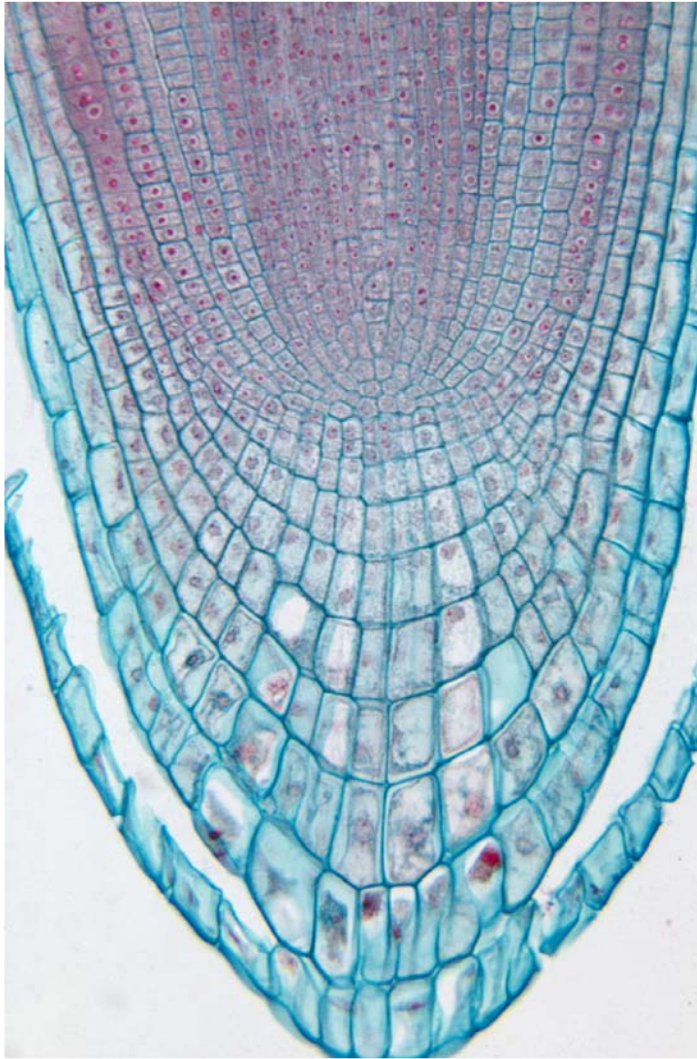


Brassica



Arabidopsis

Kořenový apikální meristém

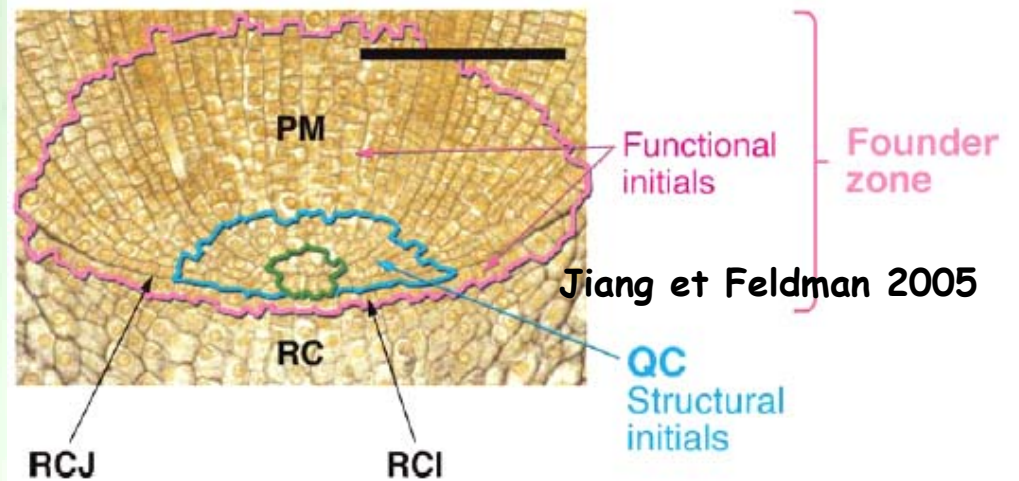
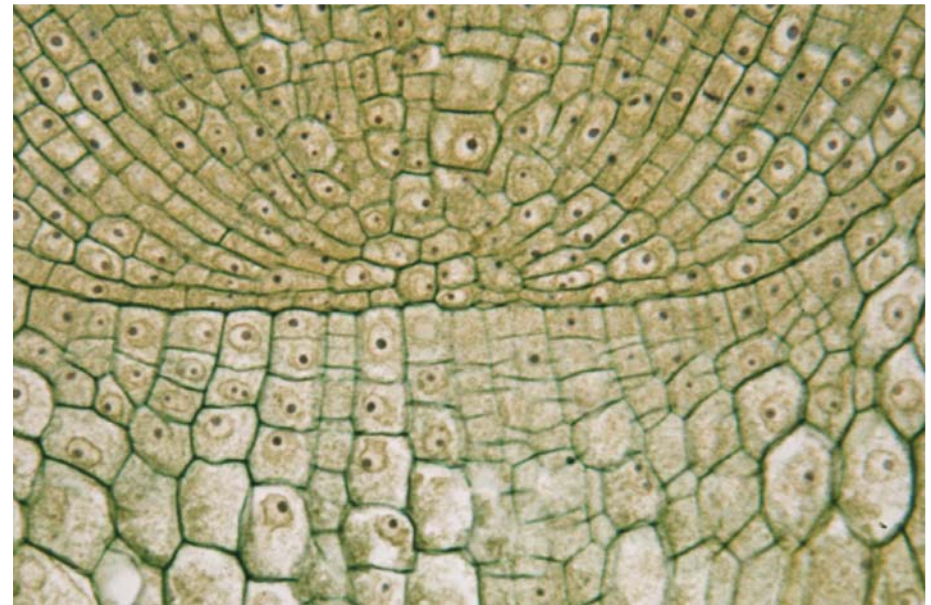
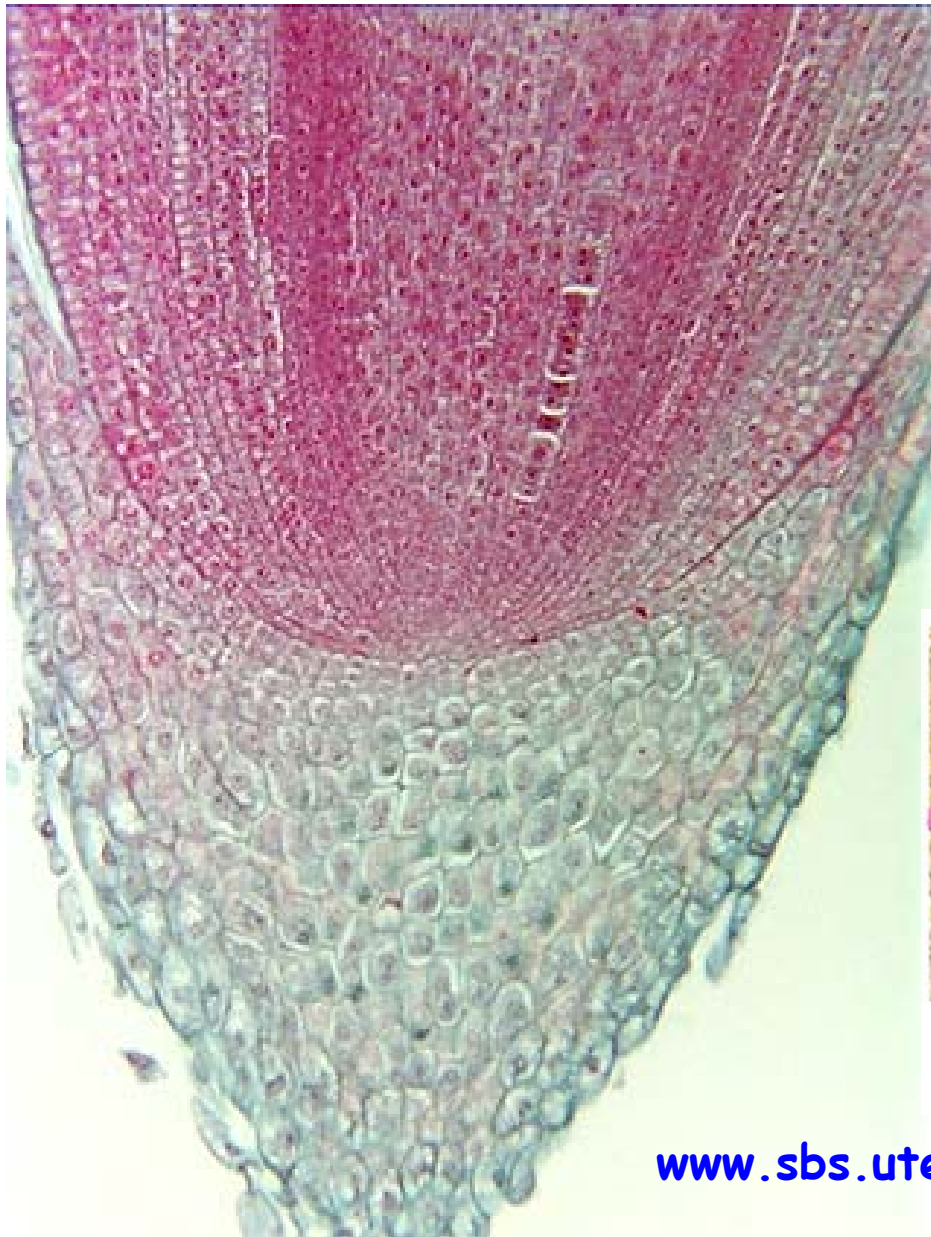


Linum



Pisum

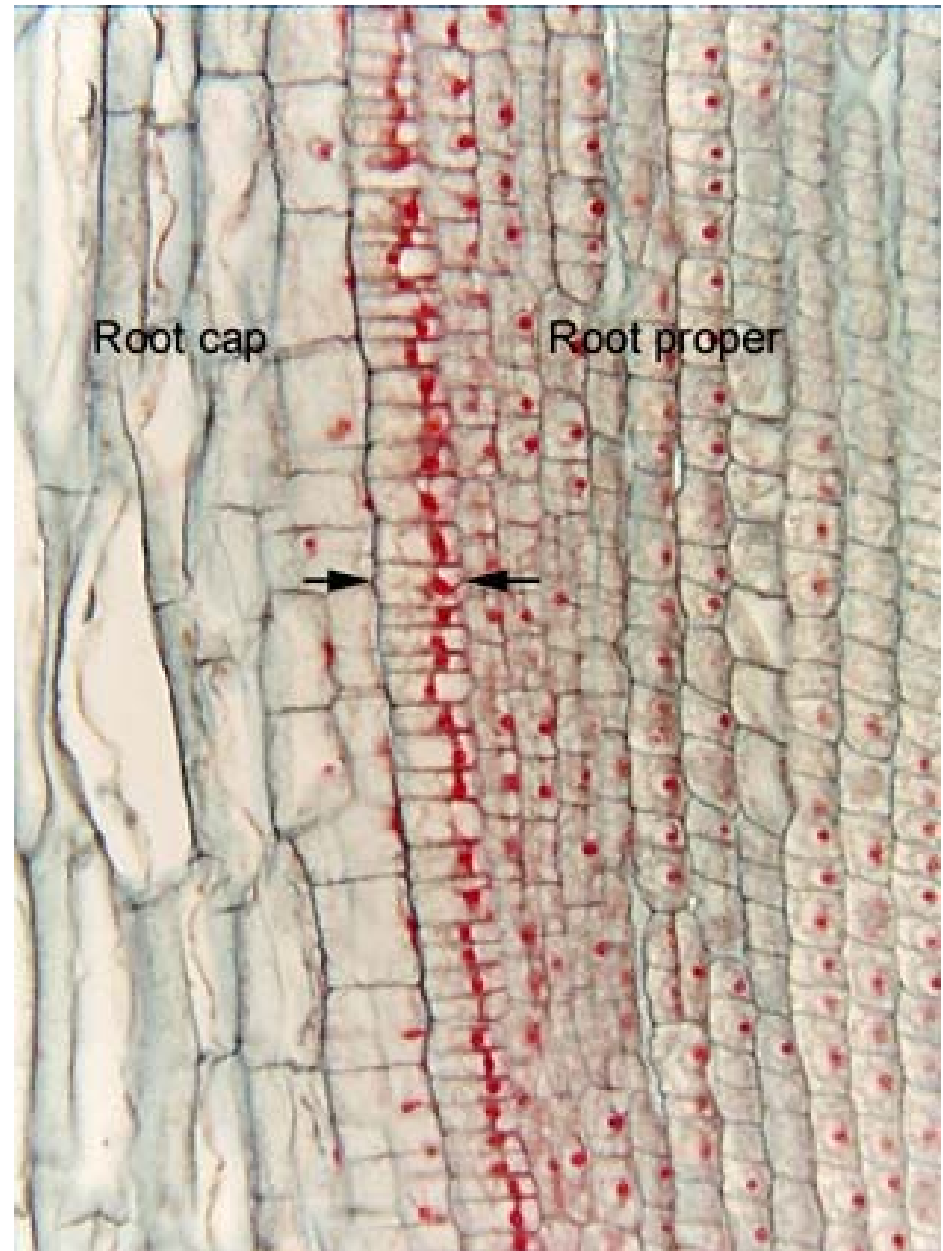
Uzavřený kořenový apikální meristém



Protoderm *Typha*

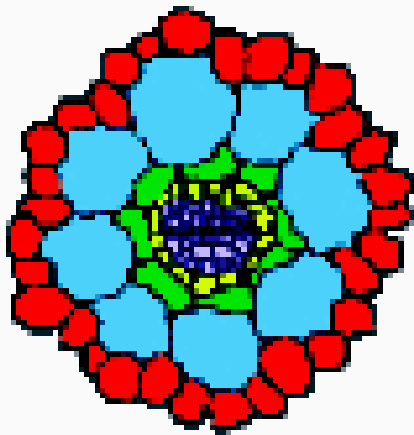
The prominent row of flat, brick-shaped cells is the **protoderm** (between arrows), and for the entire distance here, it is a uniform layer, distinct from the root cap.

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.

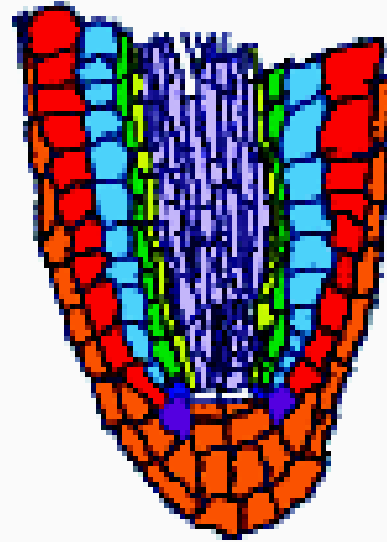


Buněčné typy v RAM *Arabidopsis*

A



B



Malamy *et* Benfey
Development, 124, 1997



Epidermis



Cortex



Endodermis



Pericycle



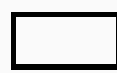
Vasculature



Cortex/Endodermal Initial



Epidermal/Root Cap Initial



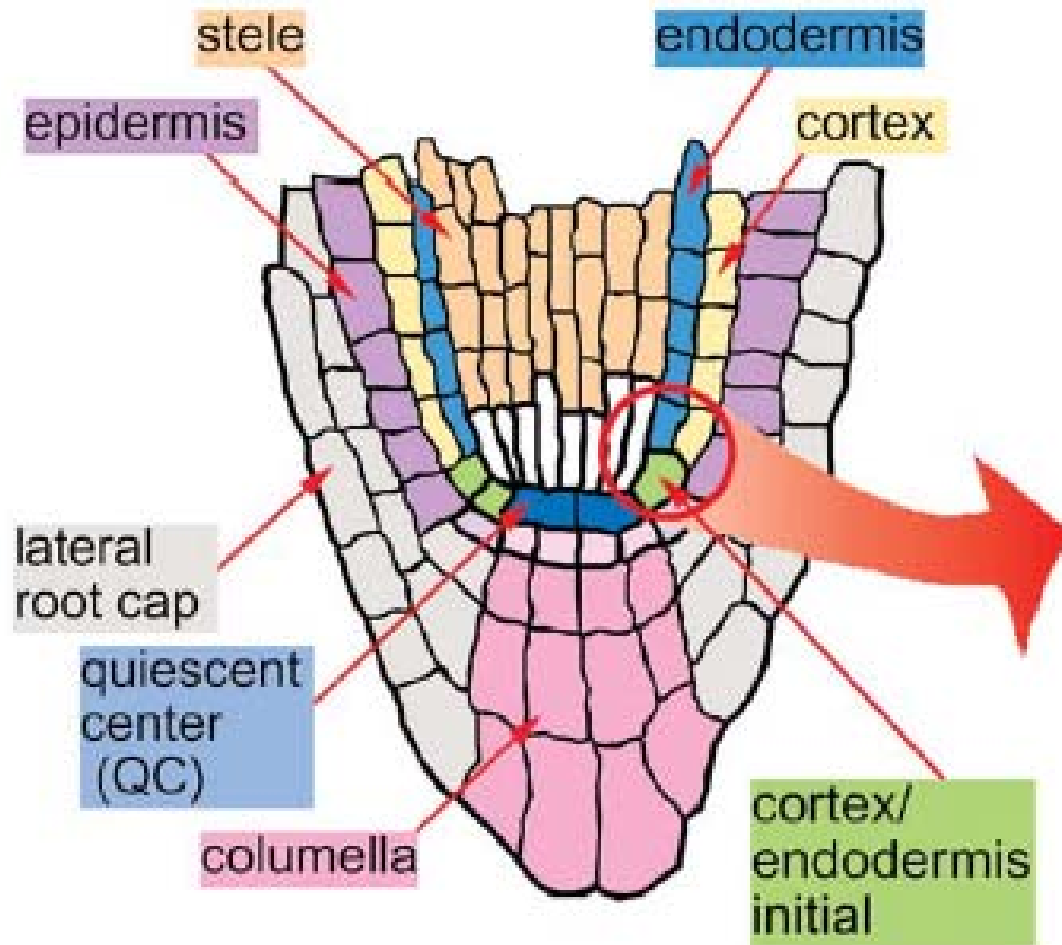
Quiescent Center



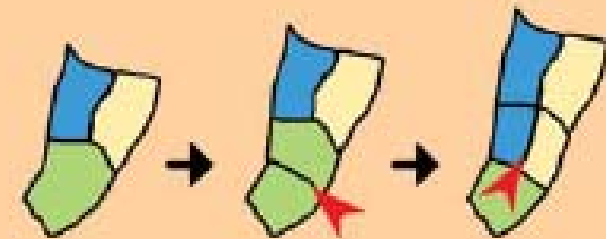
Root Cap

Buněčné typy v RAM *Arabidopsis*

Scheres *et al.* 2002
The Arabidopsis Book

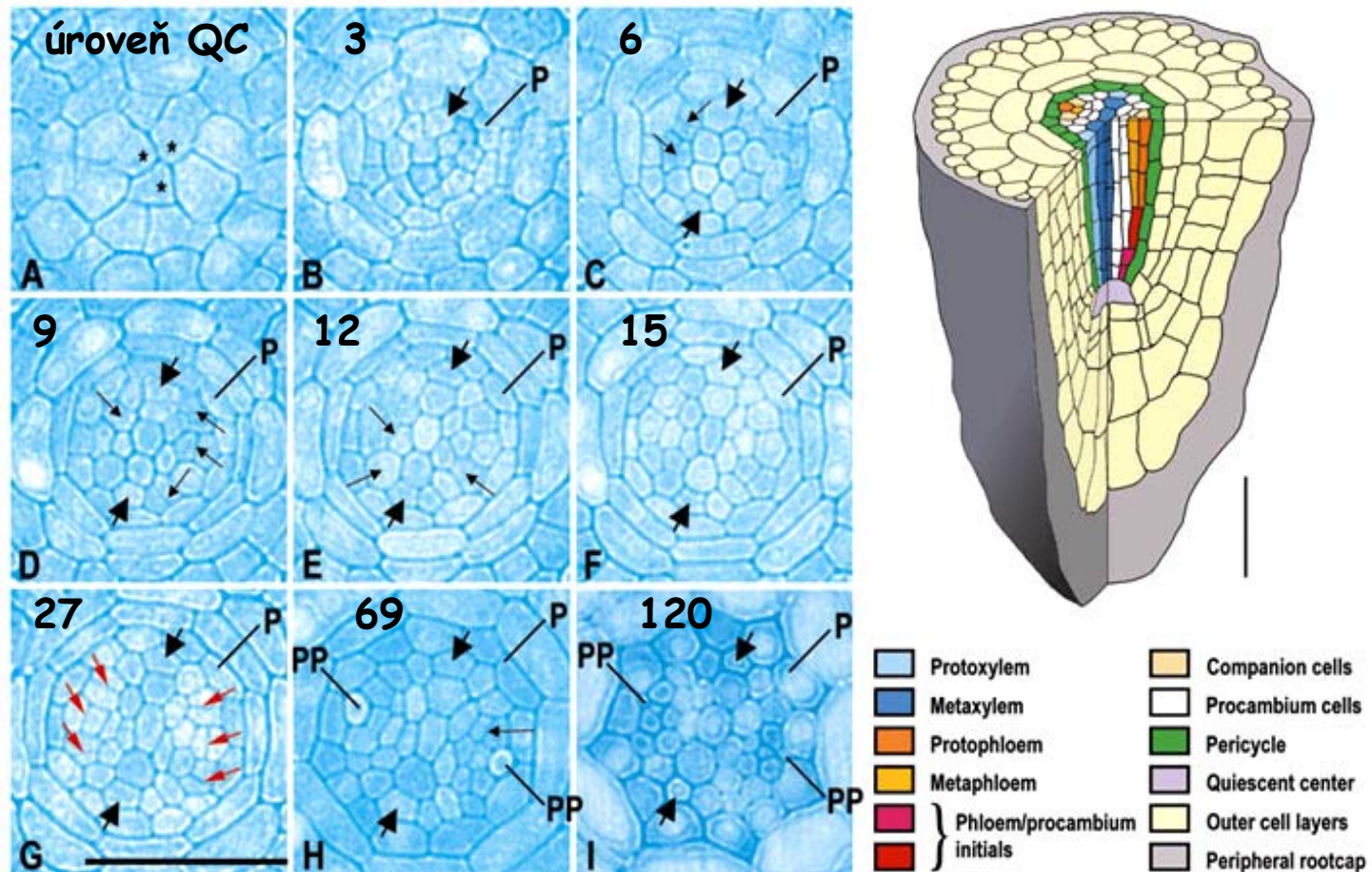


Pattern formation relies on consistent division of initial cells



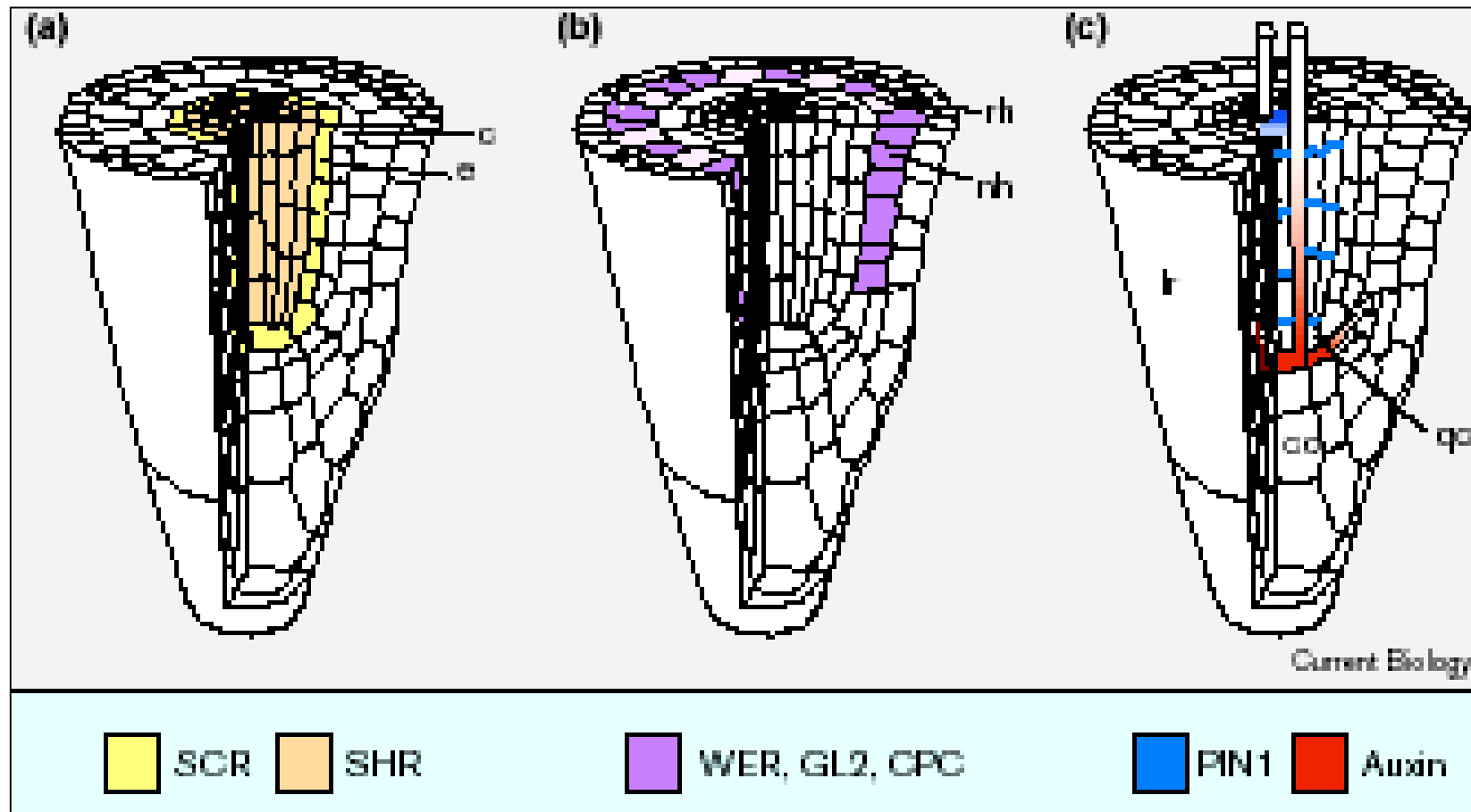
Stavba RAM u *Arabidopsis*

p - pericykl
pp – protofloém



Helariutta *et al.* 2000

Formování RAM u *Arabidopsis*



transkripční faktory
SCARECROW
SHORT-ROOT

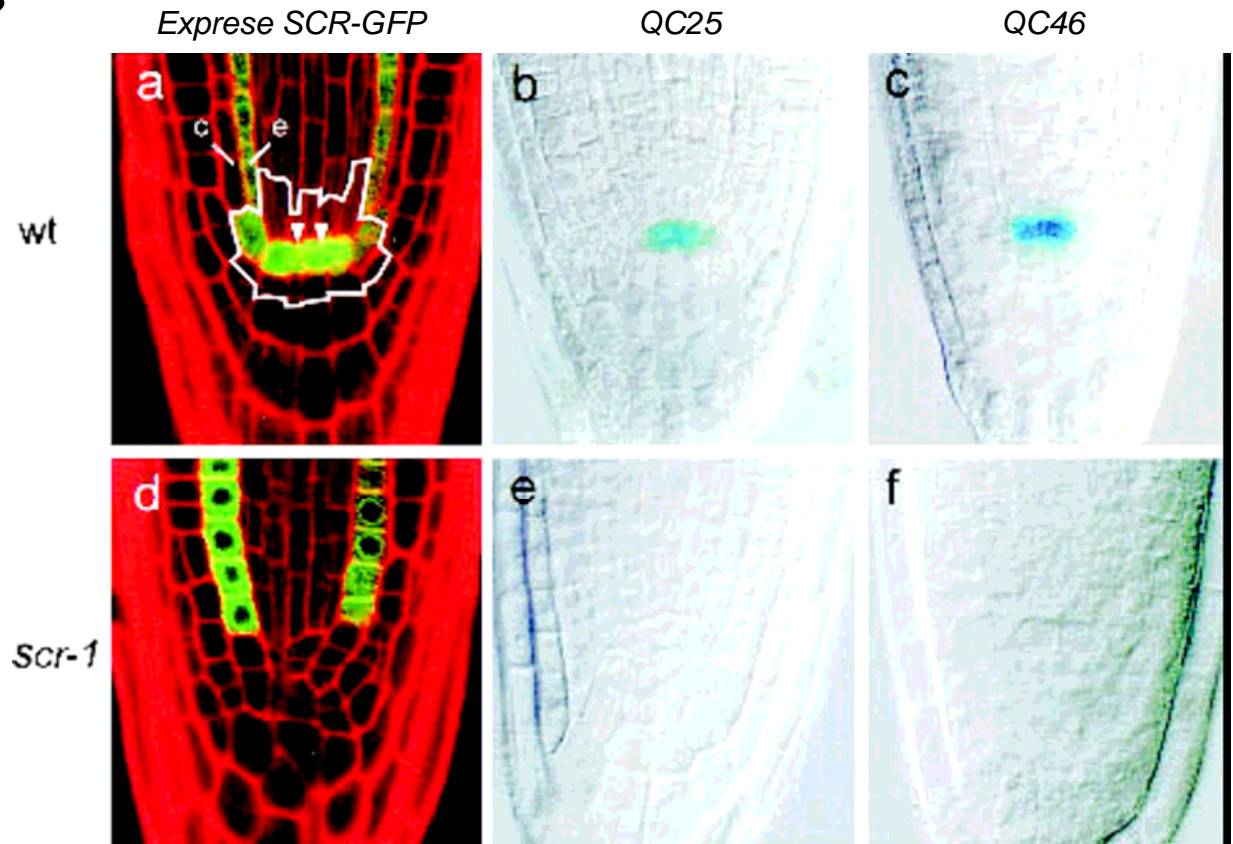
Benfey et Scheres

Transkripční faktor SCARECROW (SCR)

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

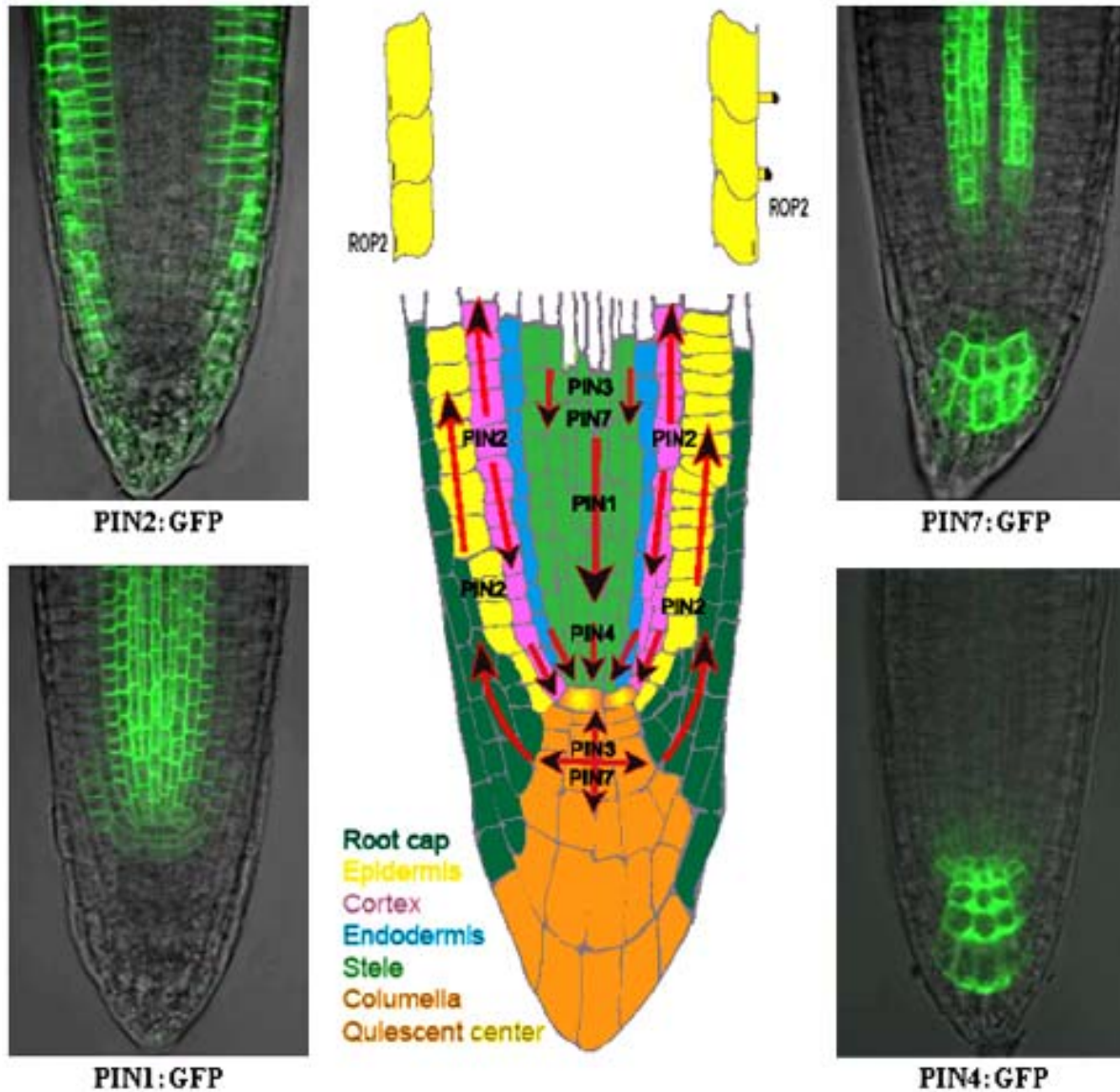
Sabatini *et al.* 2003

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



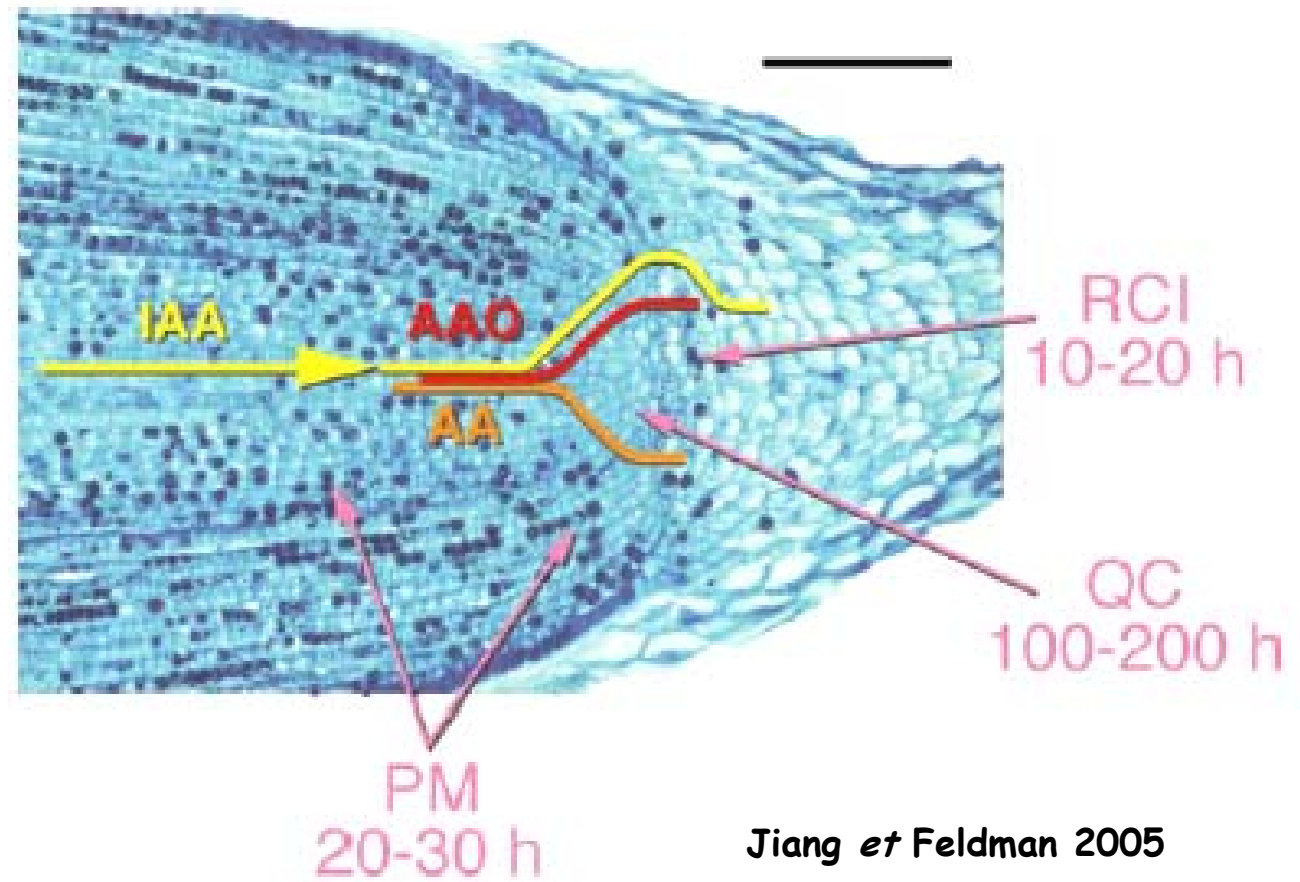
SCR poprvé identifikován díky jeho roli při radiálním utváření kořene („radial patterning“), je nutný pro distální specifikaci QC, jež naopak reguluje osud kmenových buněk obklopujících QC

Polární lokalizace PIN proteinů

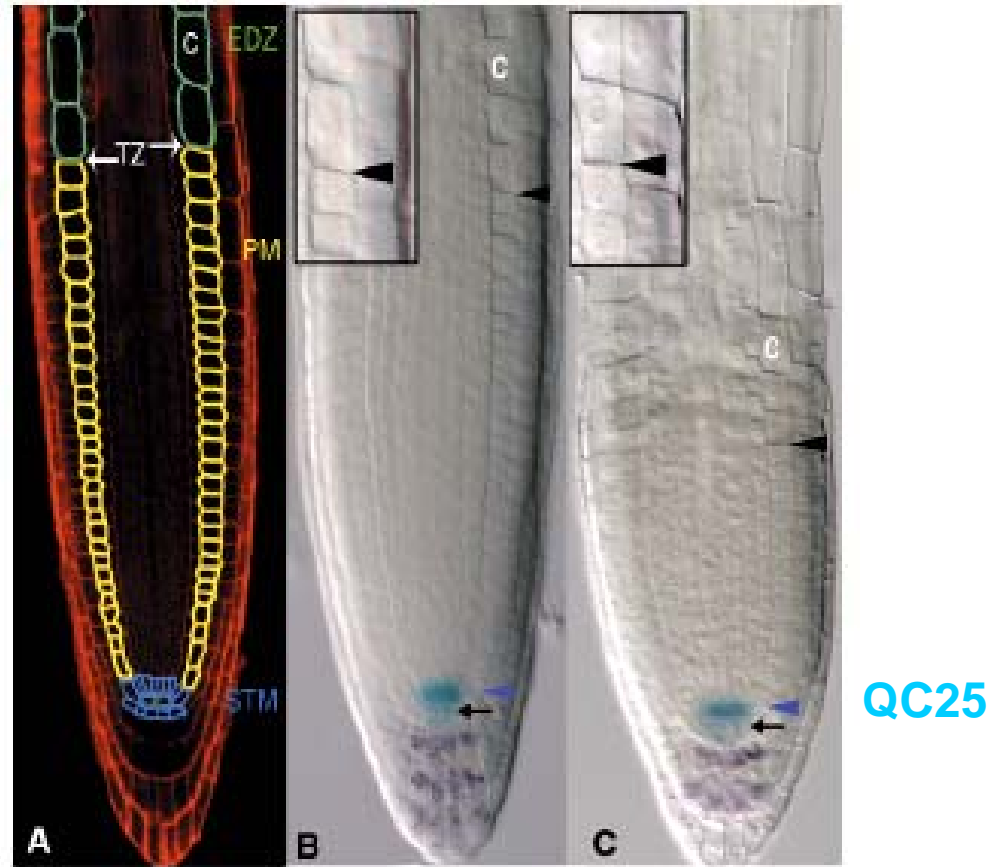


Feraru *et* Friml
2008

Gradient auxinu a rychlost dělení buněk

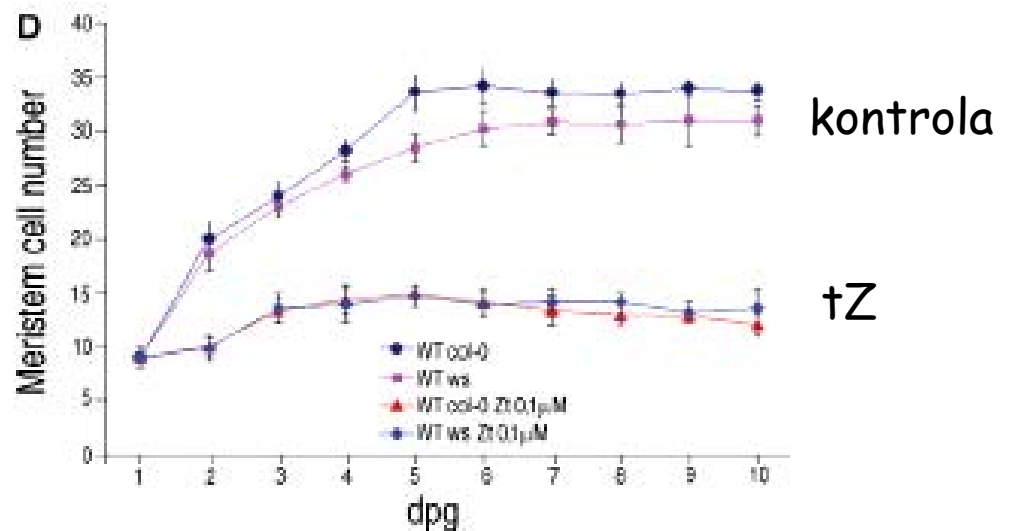


Regulace kořenového meristému *Arabidopsis*



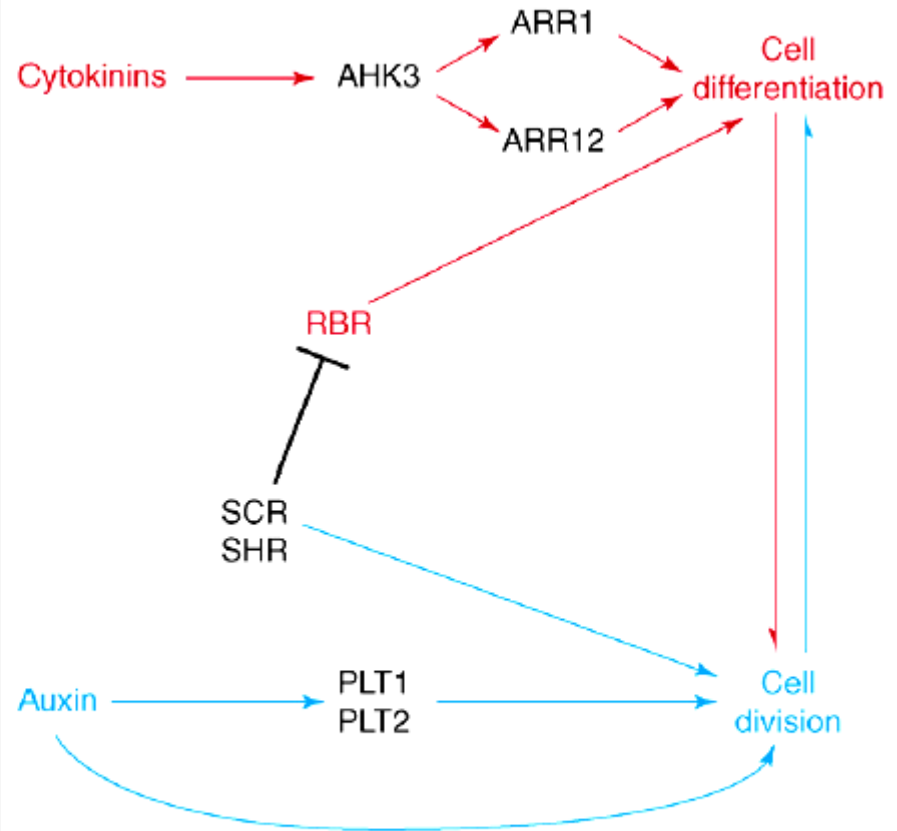
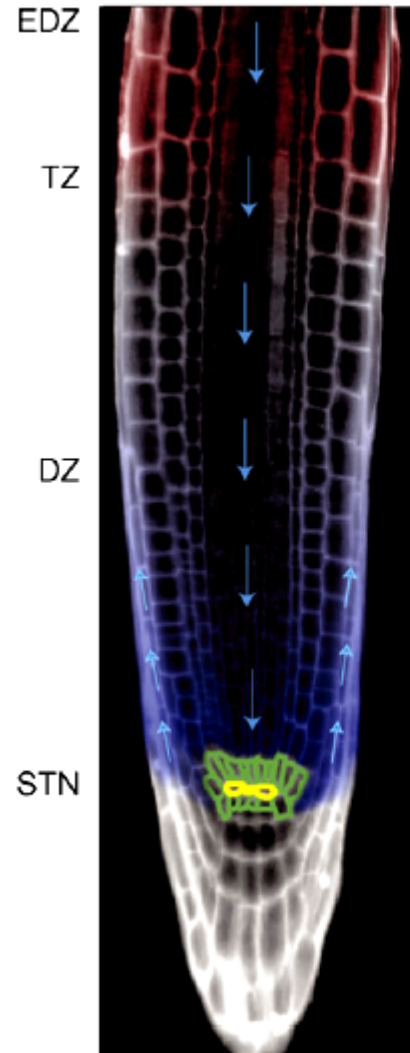
exogenní aplikace cytokininů
snižovala počet buněk meristému

Ioio *et al.* 2008



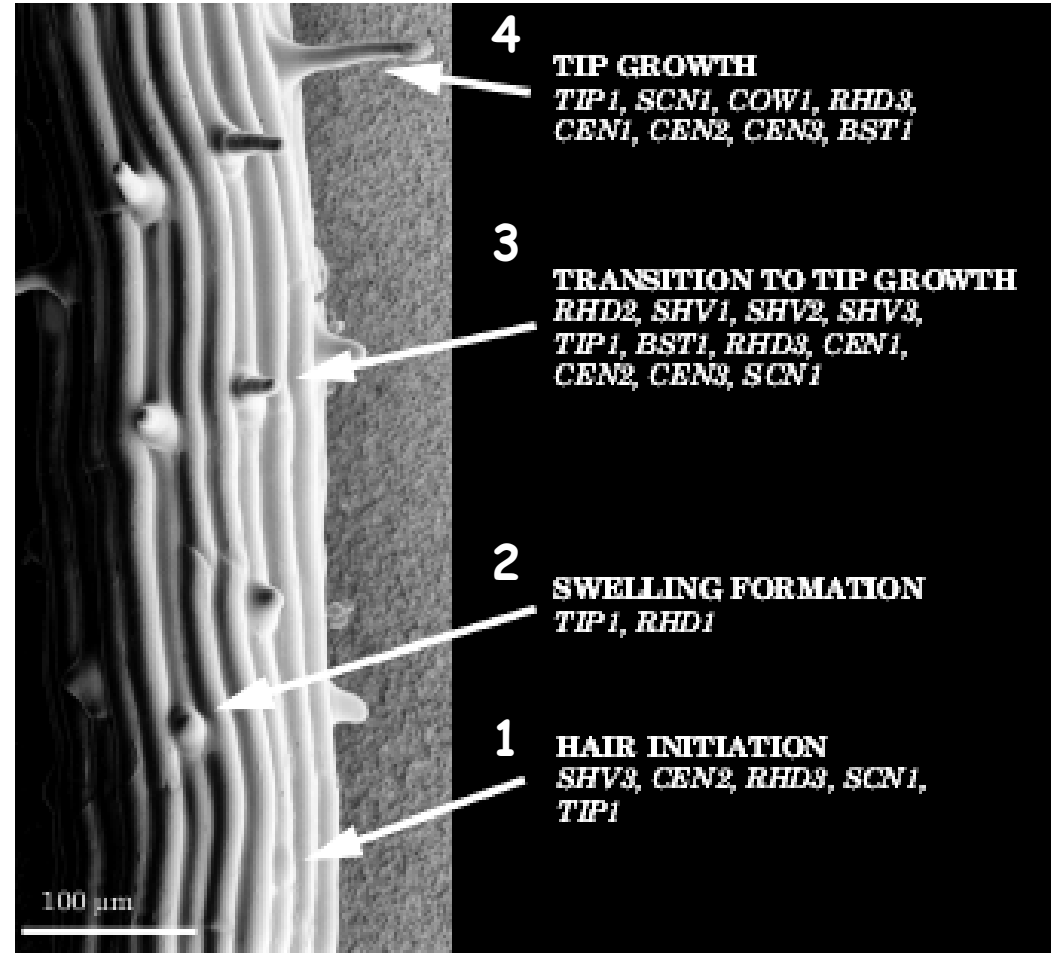
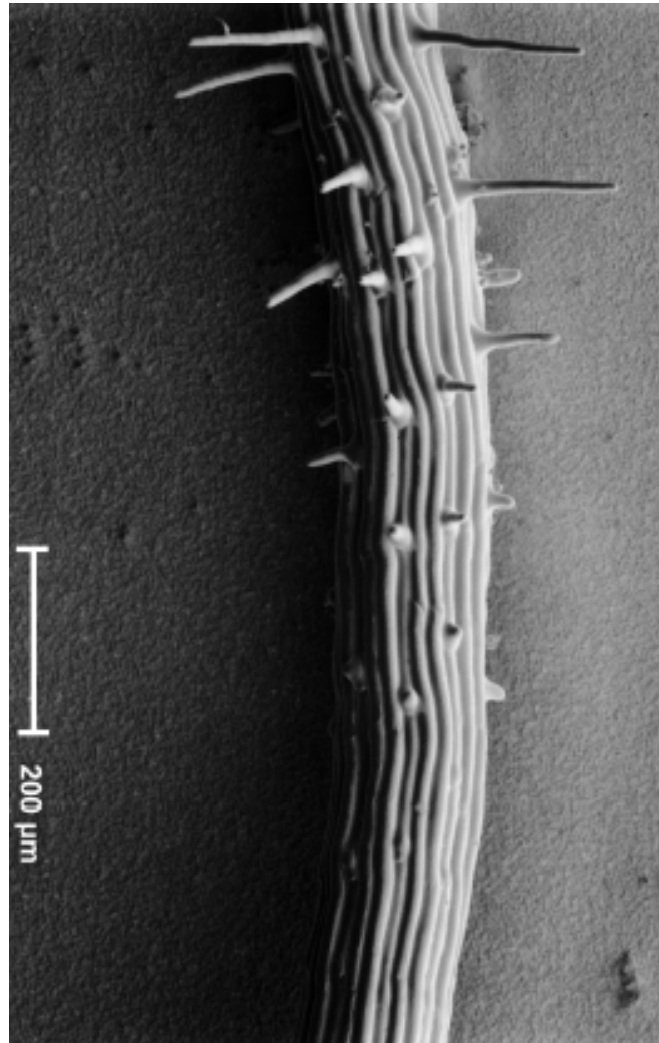
Regulace kořenového meristému

cytokininy regulují velikost kořenového meristému kontrolou diferenciace buněk



Ioio et al. 2008

Vývoj kořenového vlášení



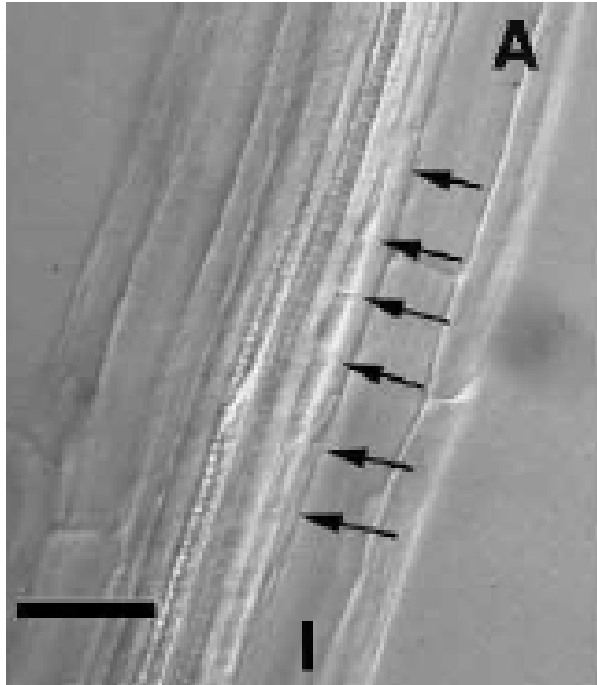
Foreman *et Dolan* 2001

Zakládání laterálních kořenů

- u kořenů neexistují základy laterálních orgánů (narozdíl od axilárních meristémů prýtlů)
- laterální kořeny se musí vyvíjet z meristémů aktivovaných v diferencovaném pletivu - **pericyklu** (latentní meristém)

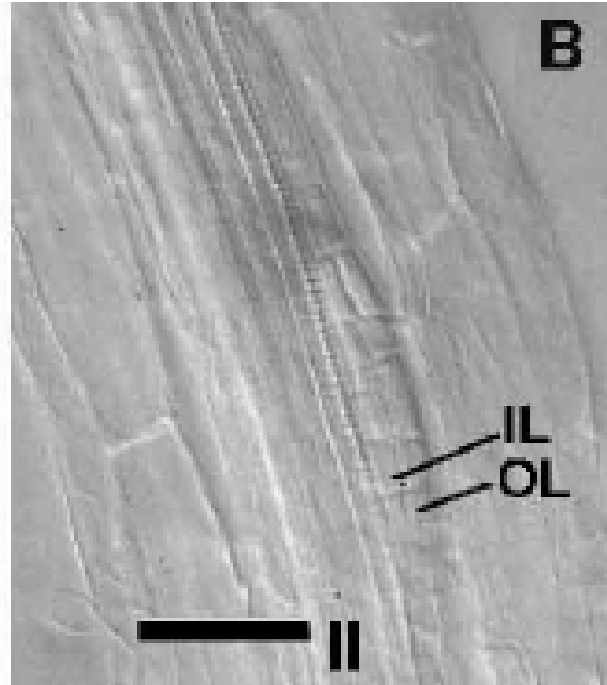
Stadia vývoje laterálního kořene u *Arabidopsis*

Stage I.



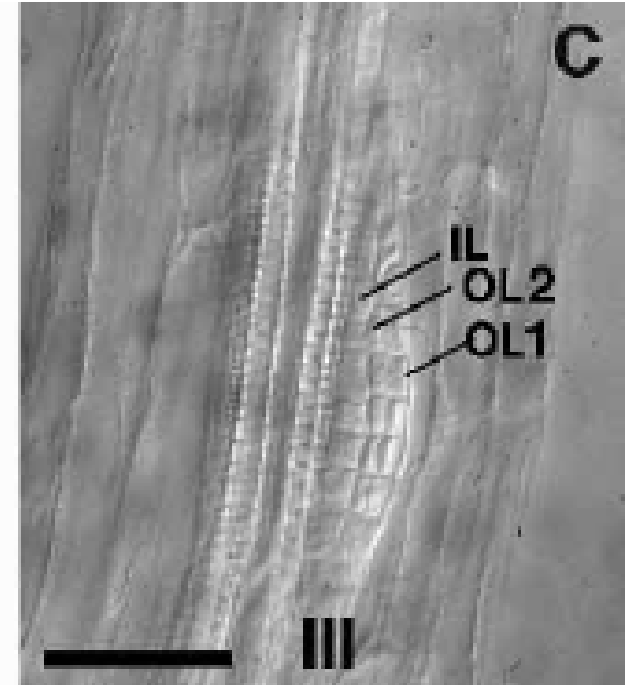
Arrows point to new cell walls indicating anticlinal divisions in the pericycle.

Stage II.



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

Stage III.

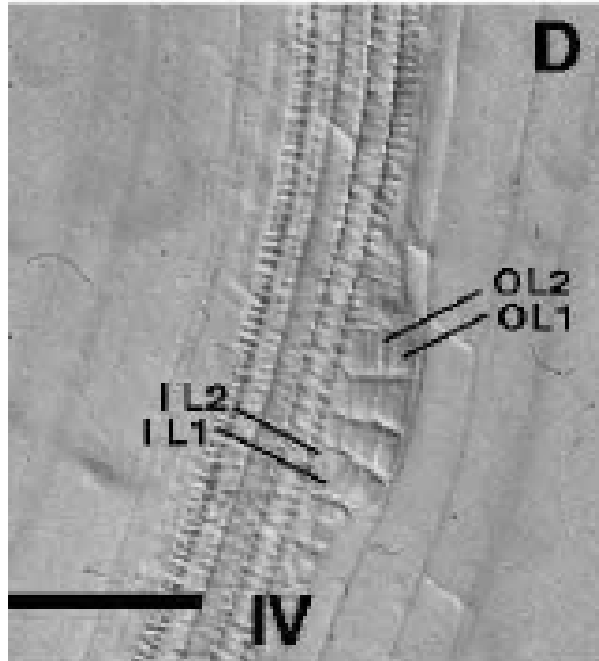


A periclinal division in OL has created a total of three layers.

Malamy et Benfey
Development, 124, 1997

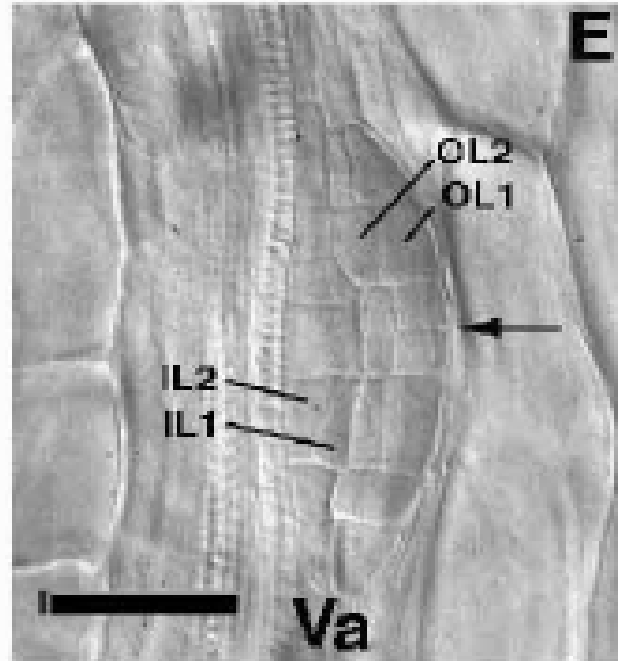
Stadia vývoje laterálního kořene u *Arabidopsis*

Stage IV.



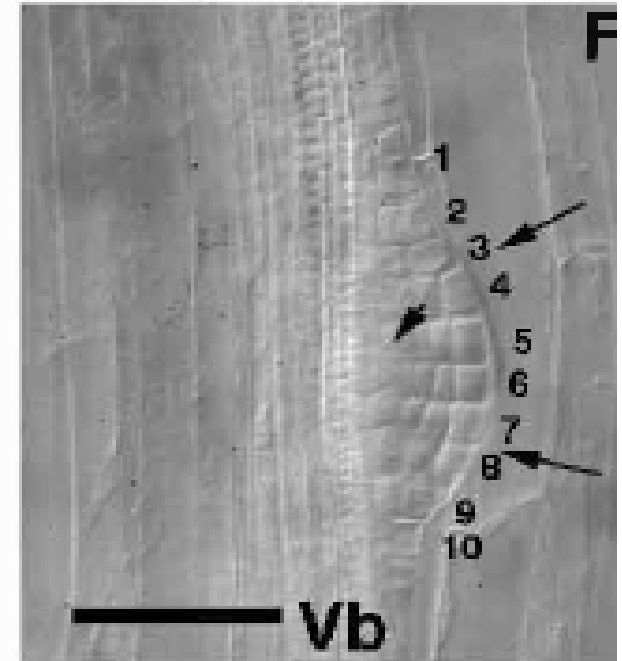
A periclinal division in IL creates a fourth layer.

Stage Va.



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

Stage Vb.

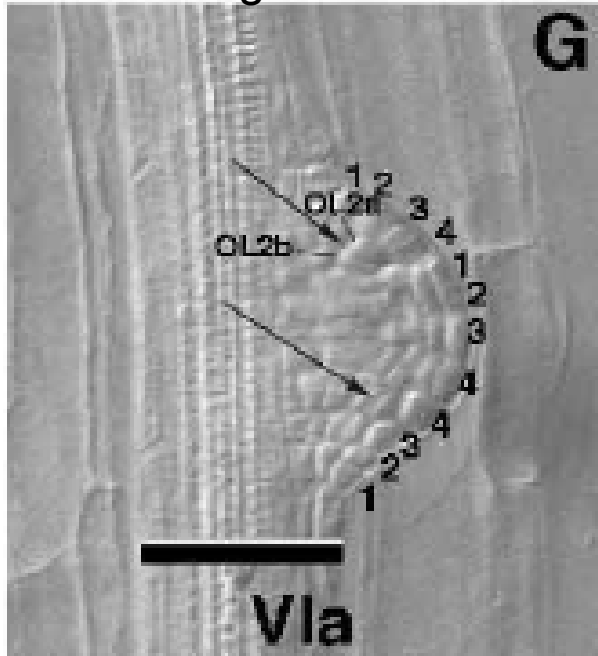


Arrows indicate two additional anticlinal divisions in OL1 and OL2.

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.

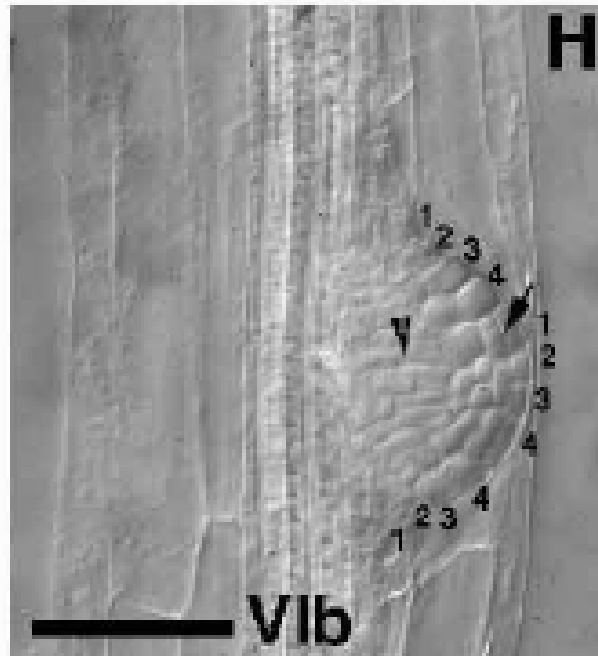
Stadia vývoje laterálního kořene u *Arabidopsis*

Stage VIa.



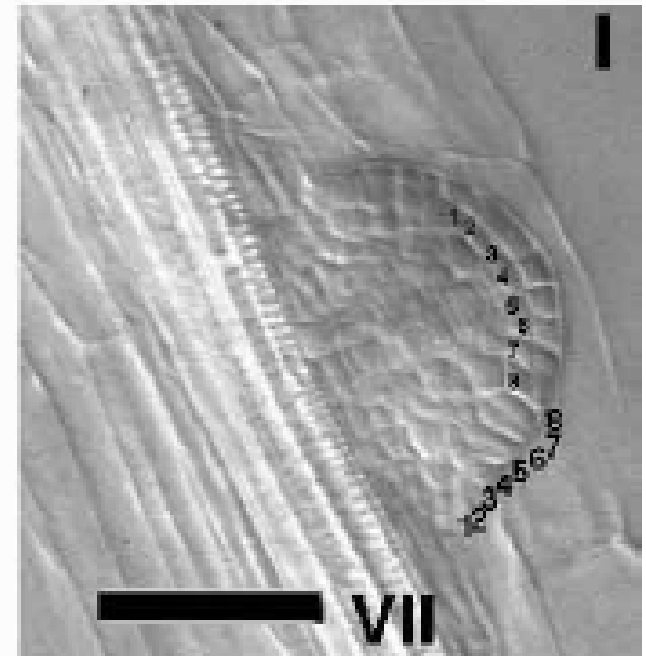
A **periclinal division** in all but the center cells of OL2 creates a new tier of cells (arrows). The two tiers are designated OL2a and OL2b.

Stage VIb.



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.

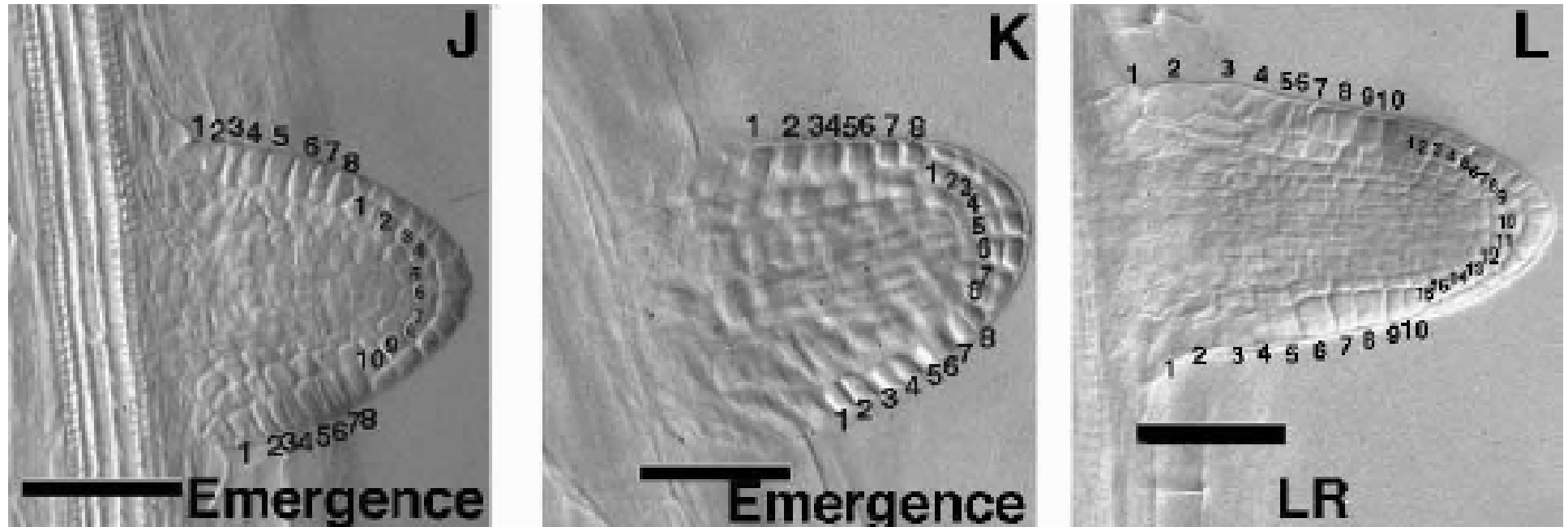
Stage VII.



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.

Malamy et Benfey
Development, 124, 1997

Stadia vývoje laterálního kořene u *Arabidopsis*

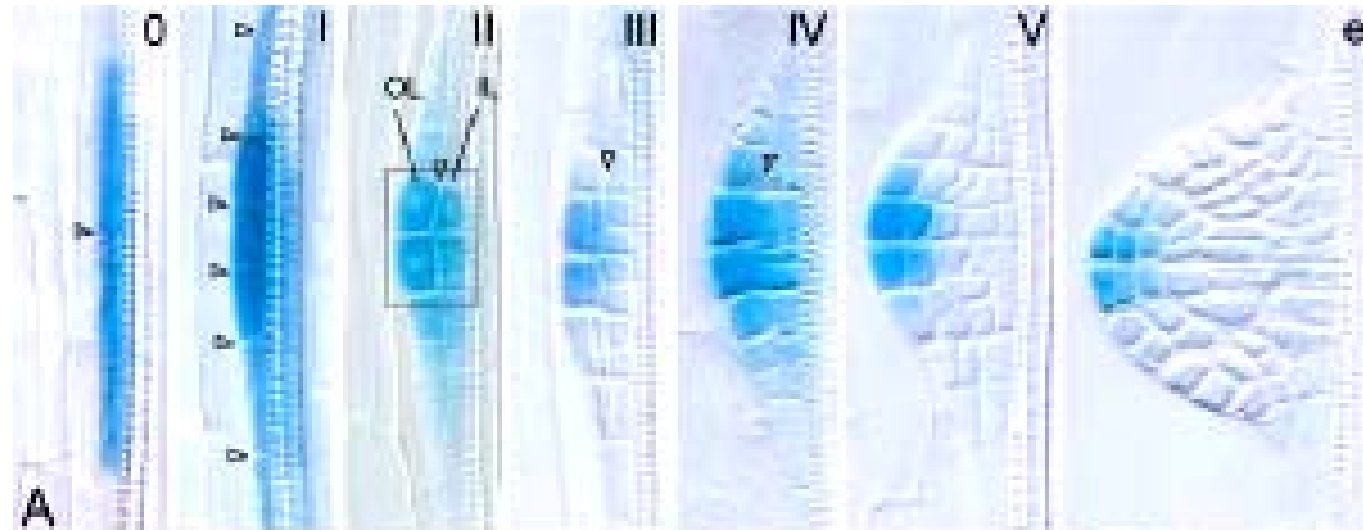


(J,K) Emerging LRP. Note that the cells in the OL1 are **enlarged**. The number of cells near the apex has increased slightly, potentially indicating the first divisions of meristematic initials. (L) Fully emerged LR. Note the gross increase in size that has occurred in the basal cells of the OL1. Cell 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**.

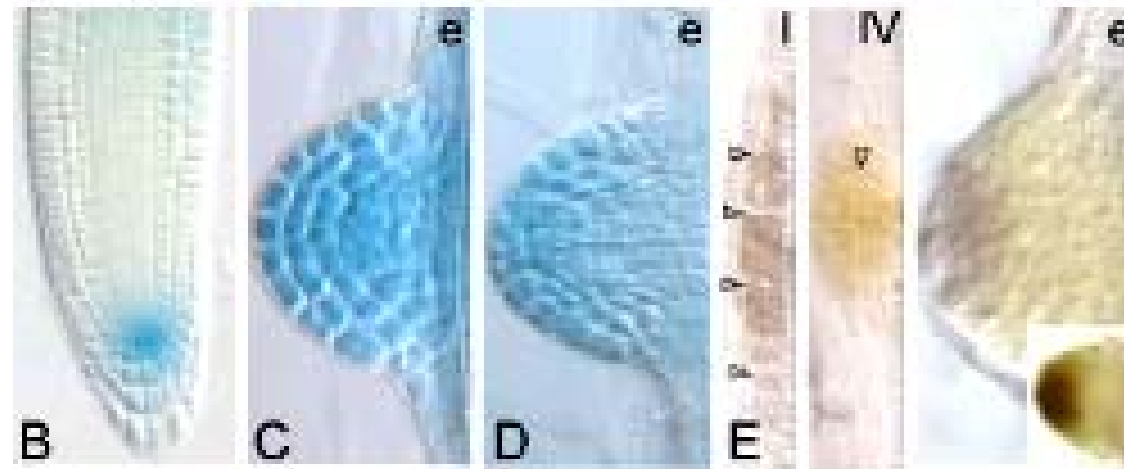
Malamy et Benfey
Development, 124, 1997

Bar= 50 μ m.

Distribuce auxinu a vývoj primordia laterálního kořene u *Arabidopsis*



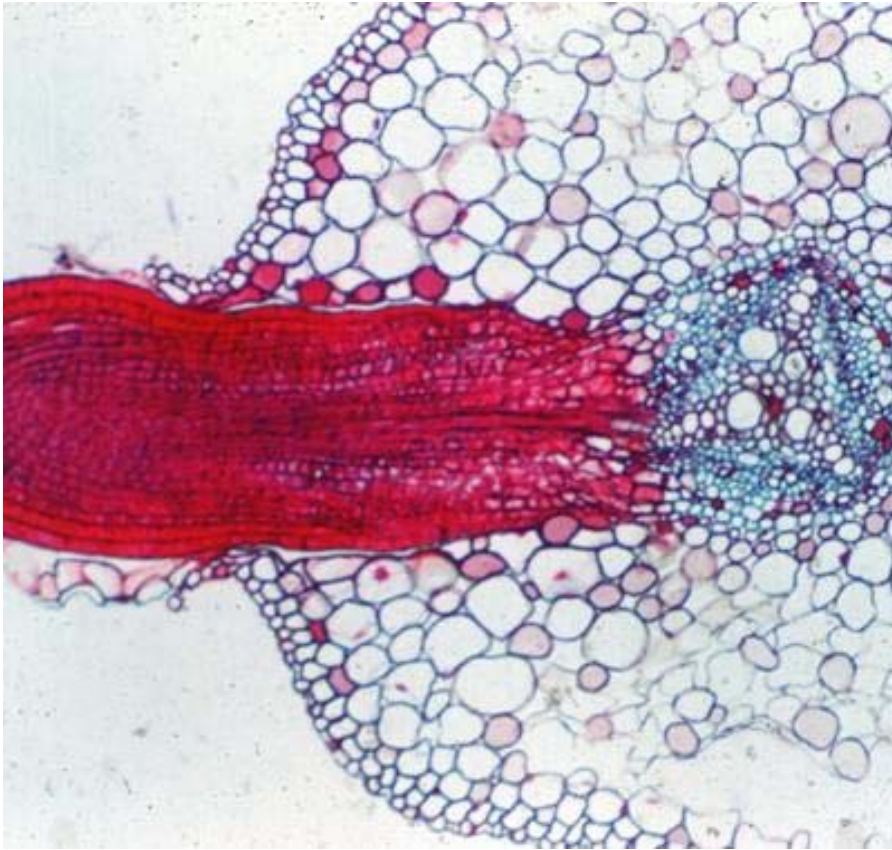
expresse
DR5::GUS



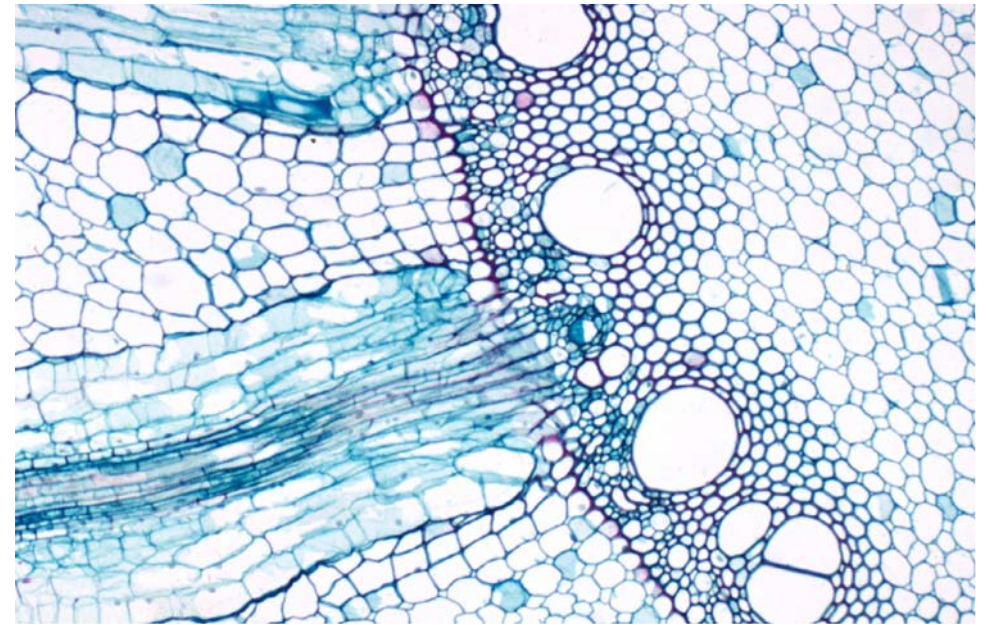
Benková *et al.*,
Cell, 2003

Vliv 2,4-D NPA Imunolokalizace IAA

Laterální kořen



Salix



Zea mays