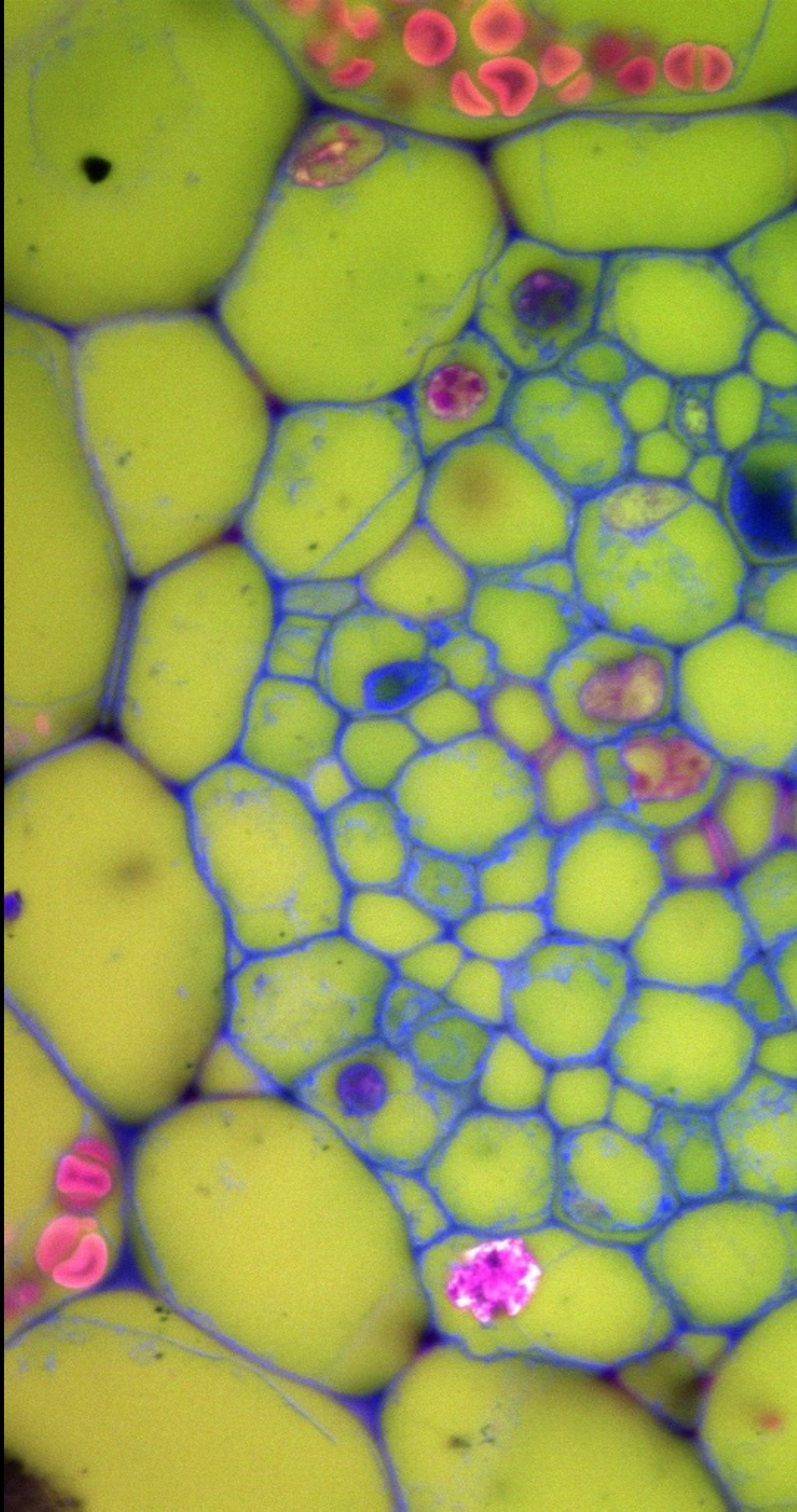
CDB Part IB
Plant Development

Lecture 3

Regulation of root initiation and growth by auxin



Jim Haseloff
Department of Plant Sciences
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Different conditions faced by algae and plants

Supportive medium (water)

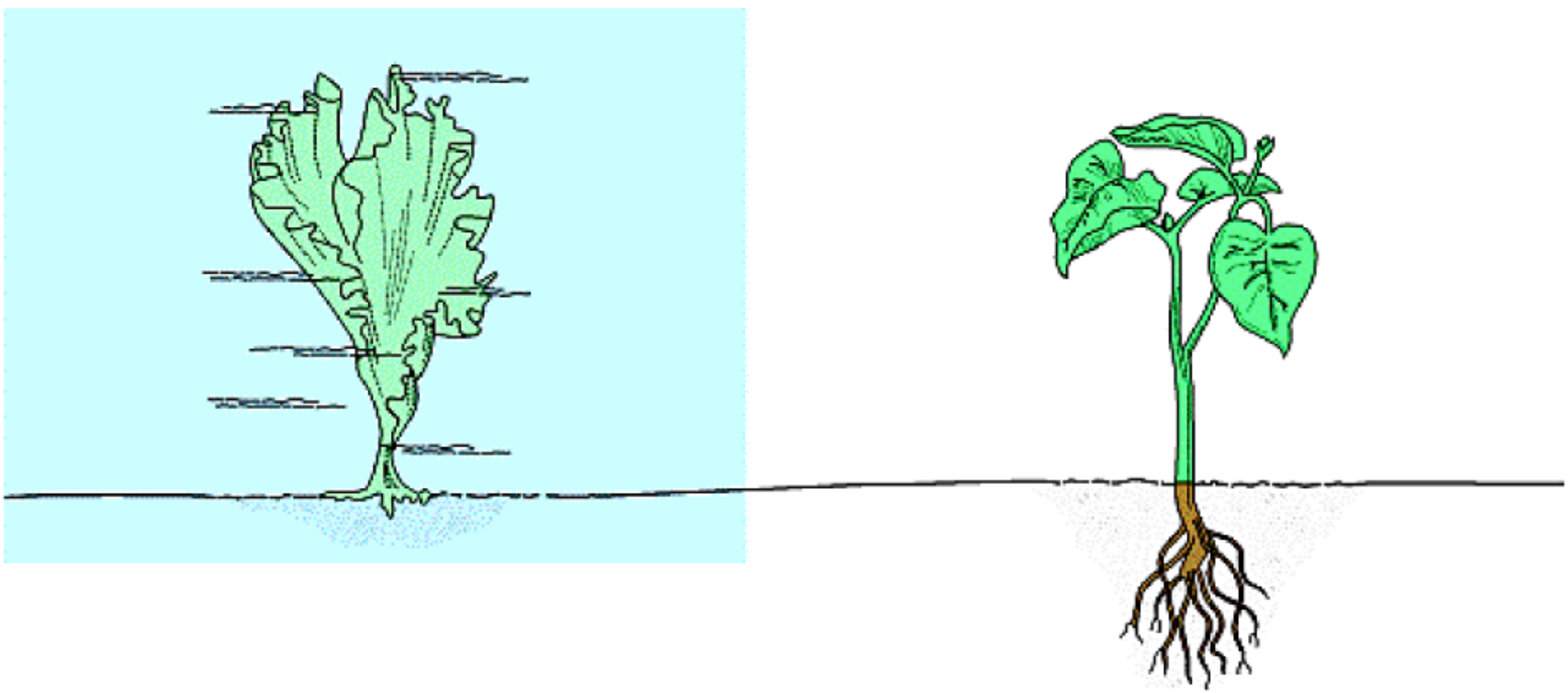
Photosynthesis in most cells

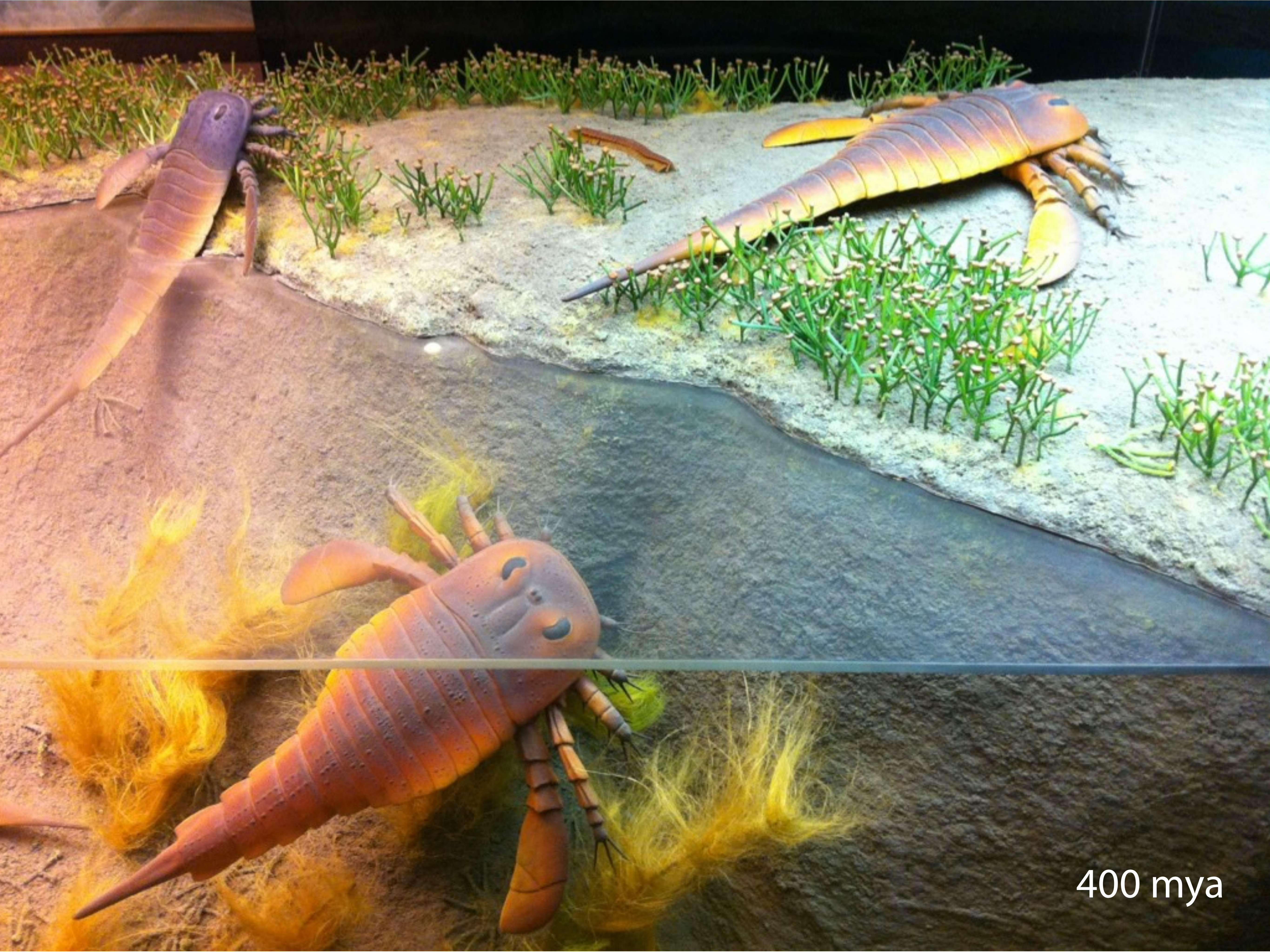
Direct access to minerals and water

Non supportive medium (air)

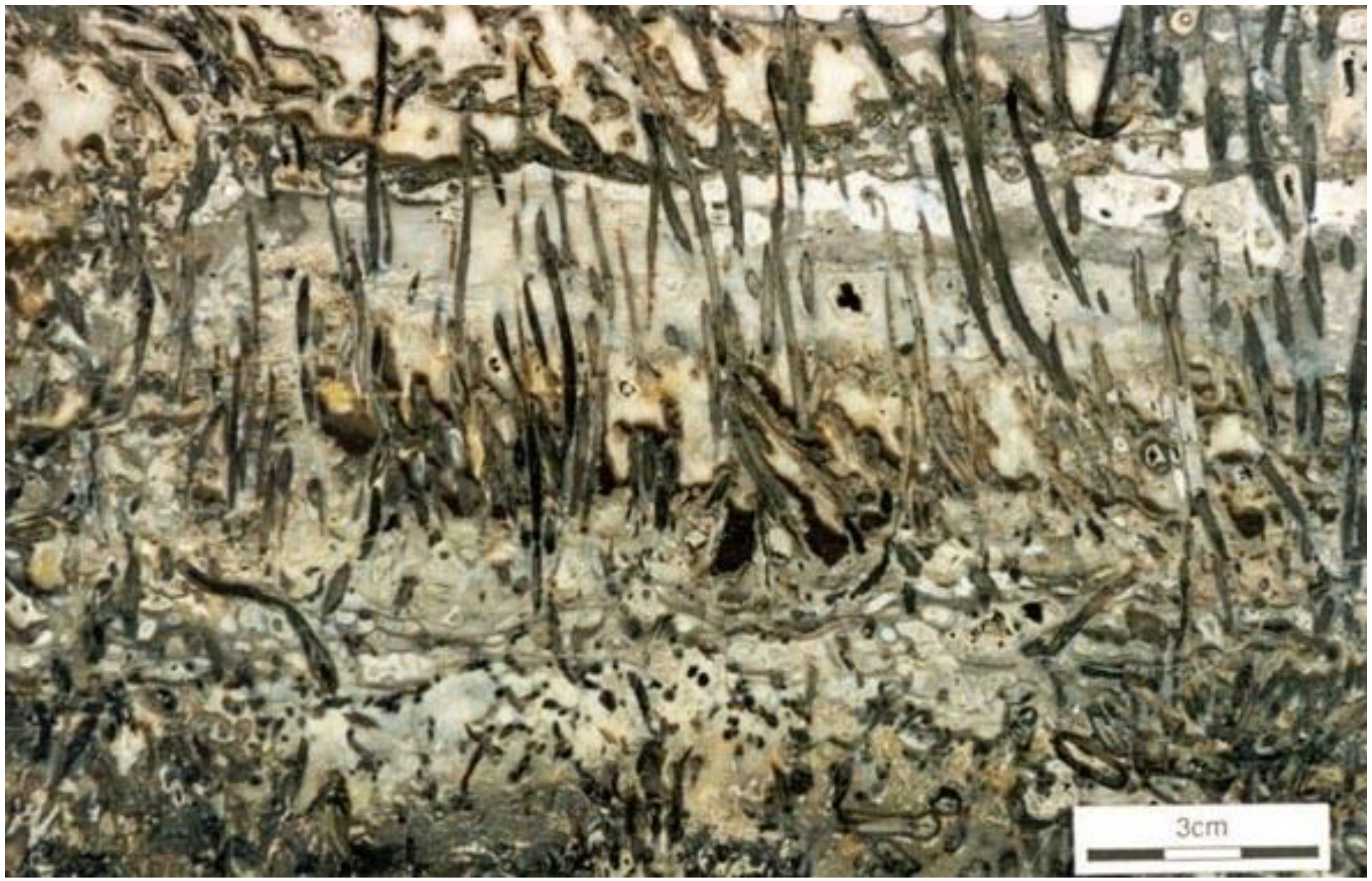
No photosynthesis in root cells

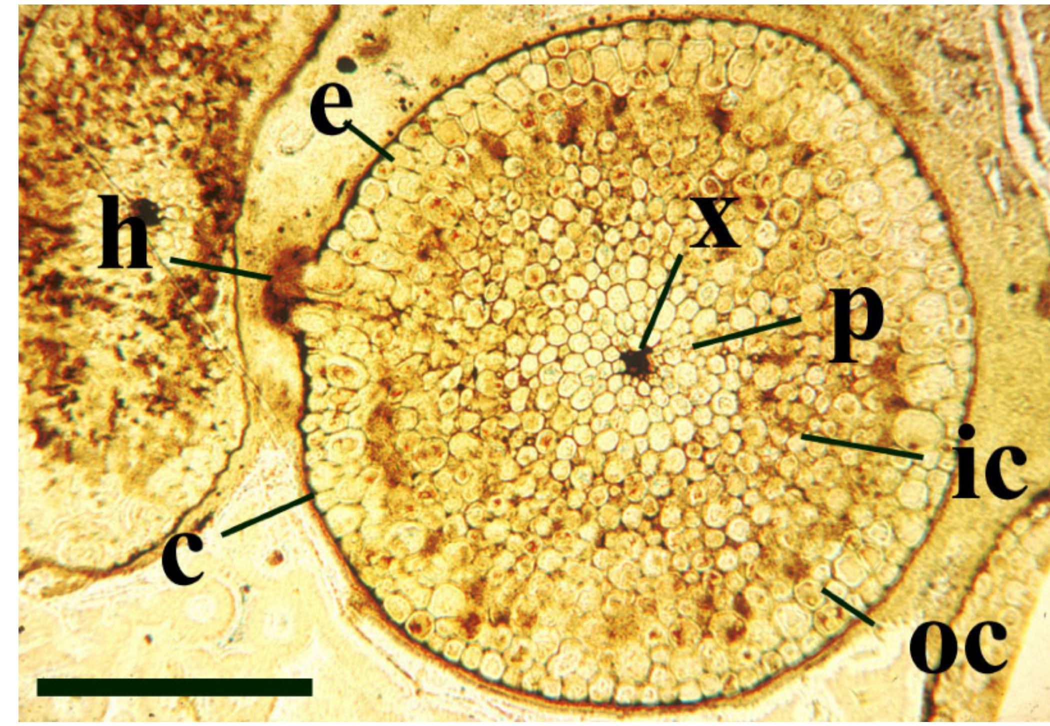
Aerial parts not in direct contact with minerals and water

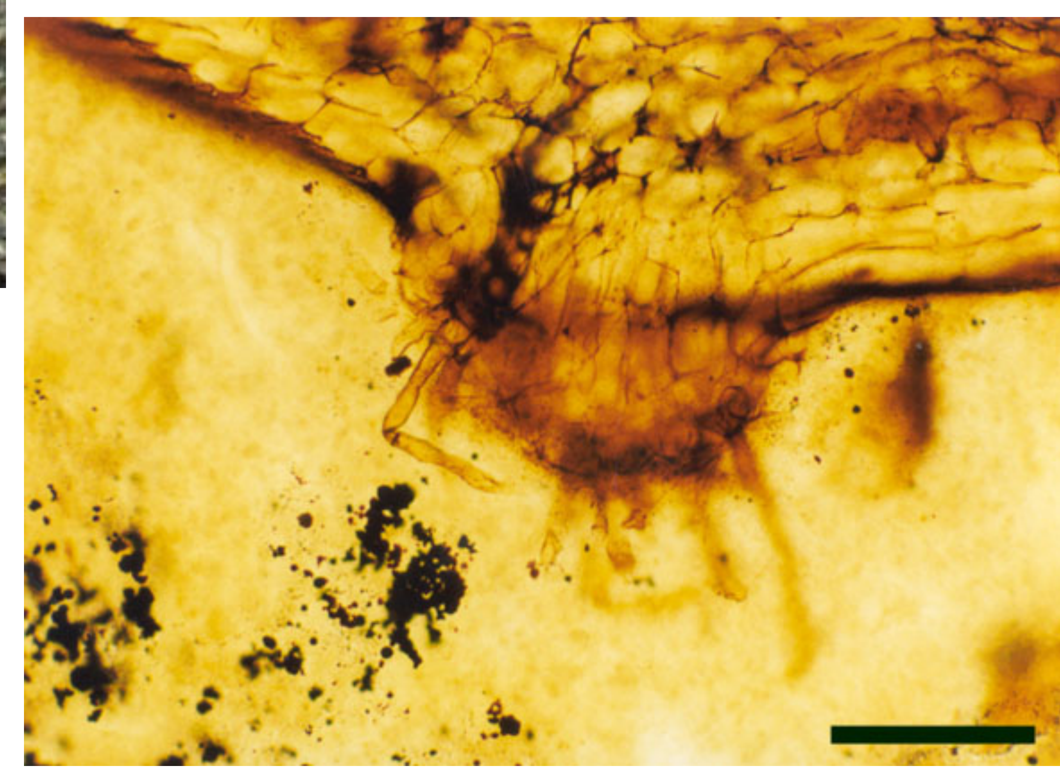



400 mya

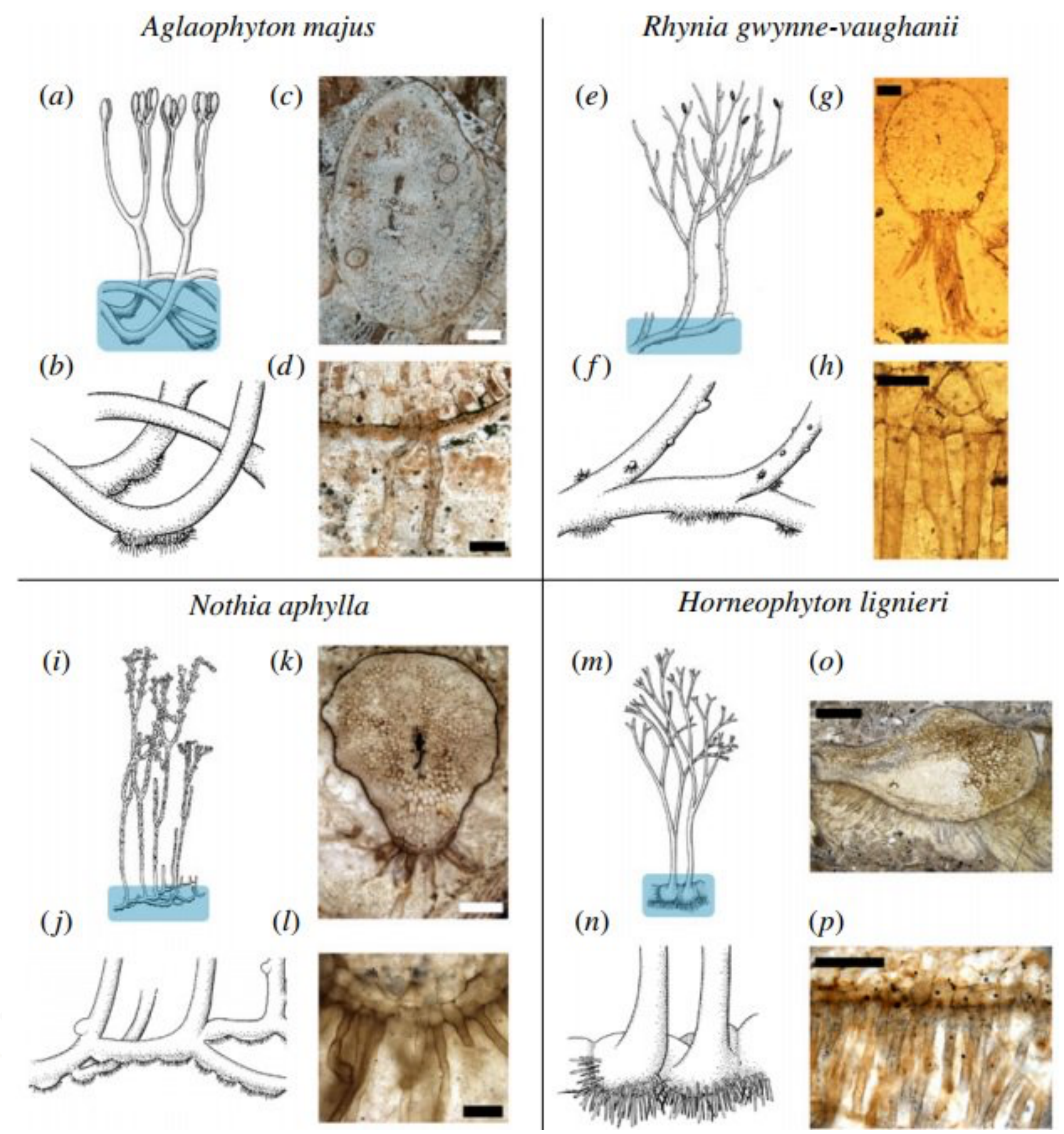
Early plant fossils, *Rhynie chert* (~400 Mya)





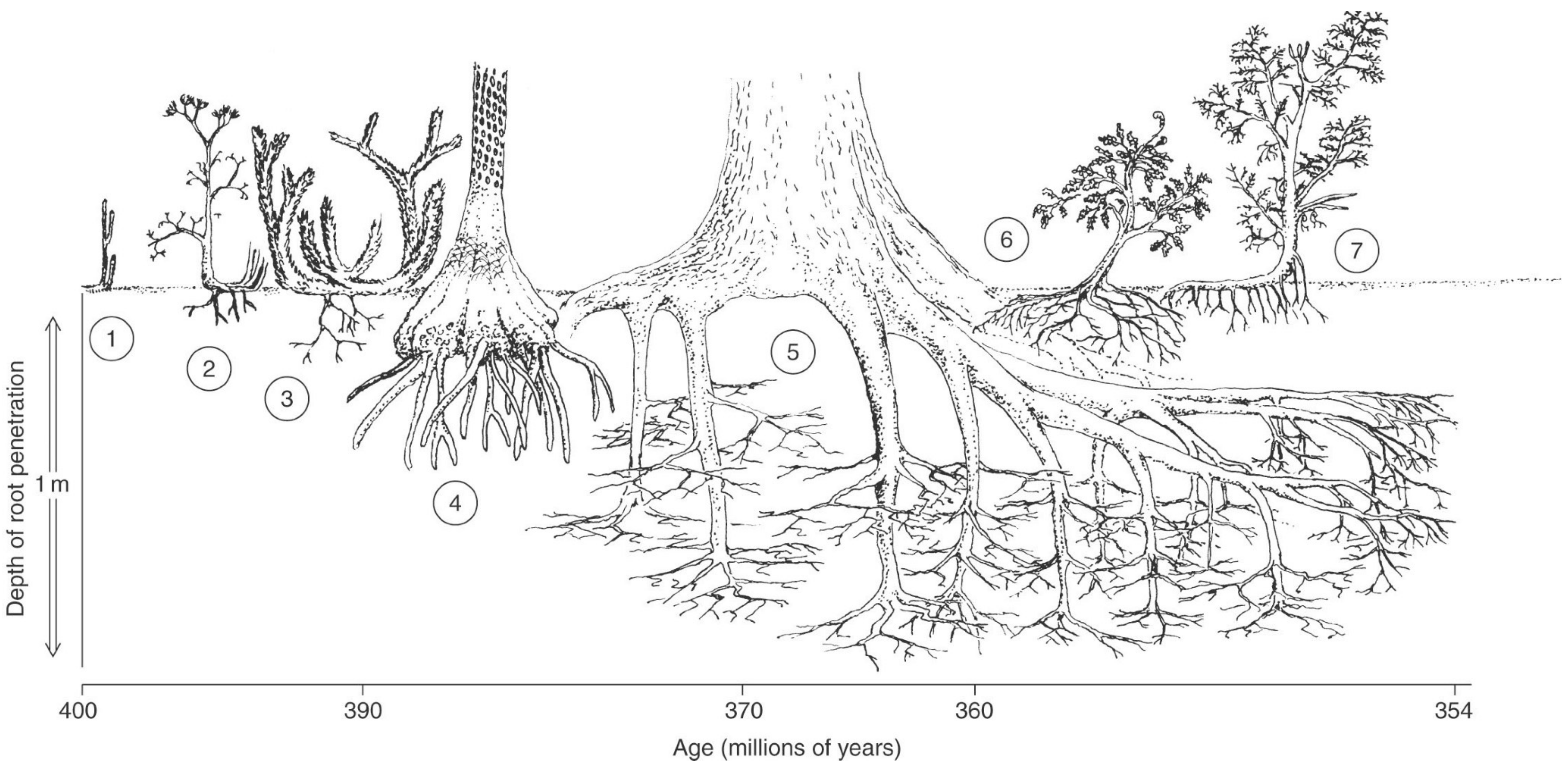


***Rhynia* sp.** (~400 Mya)

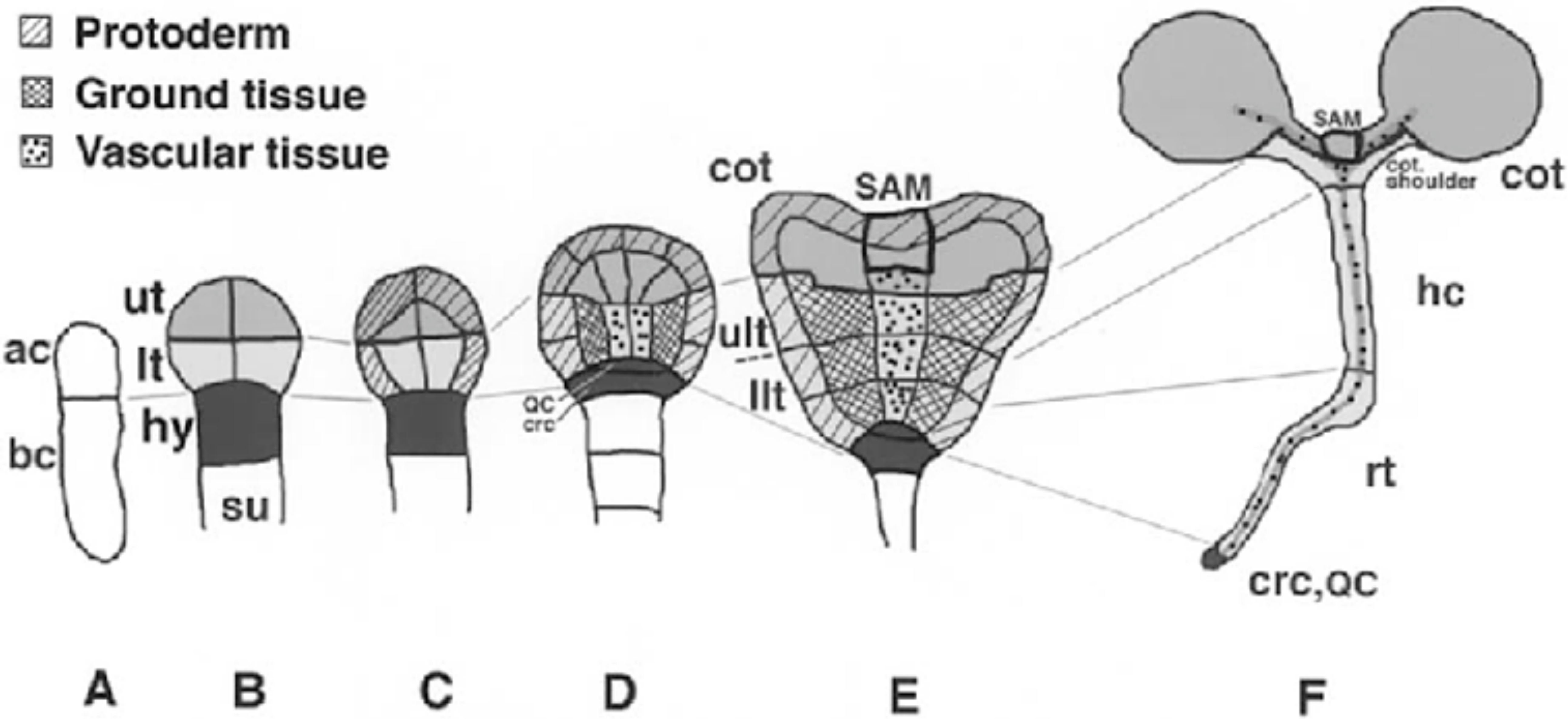


Niccolò Caranti, (MUSE) Trento

Evolution of root systems

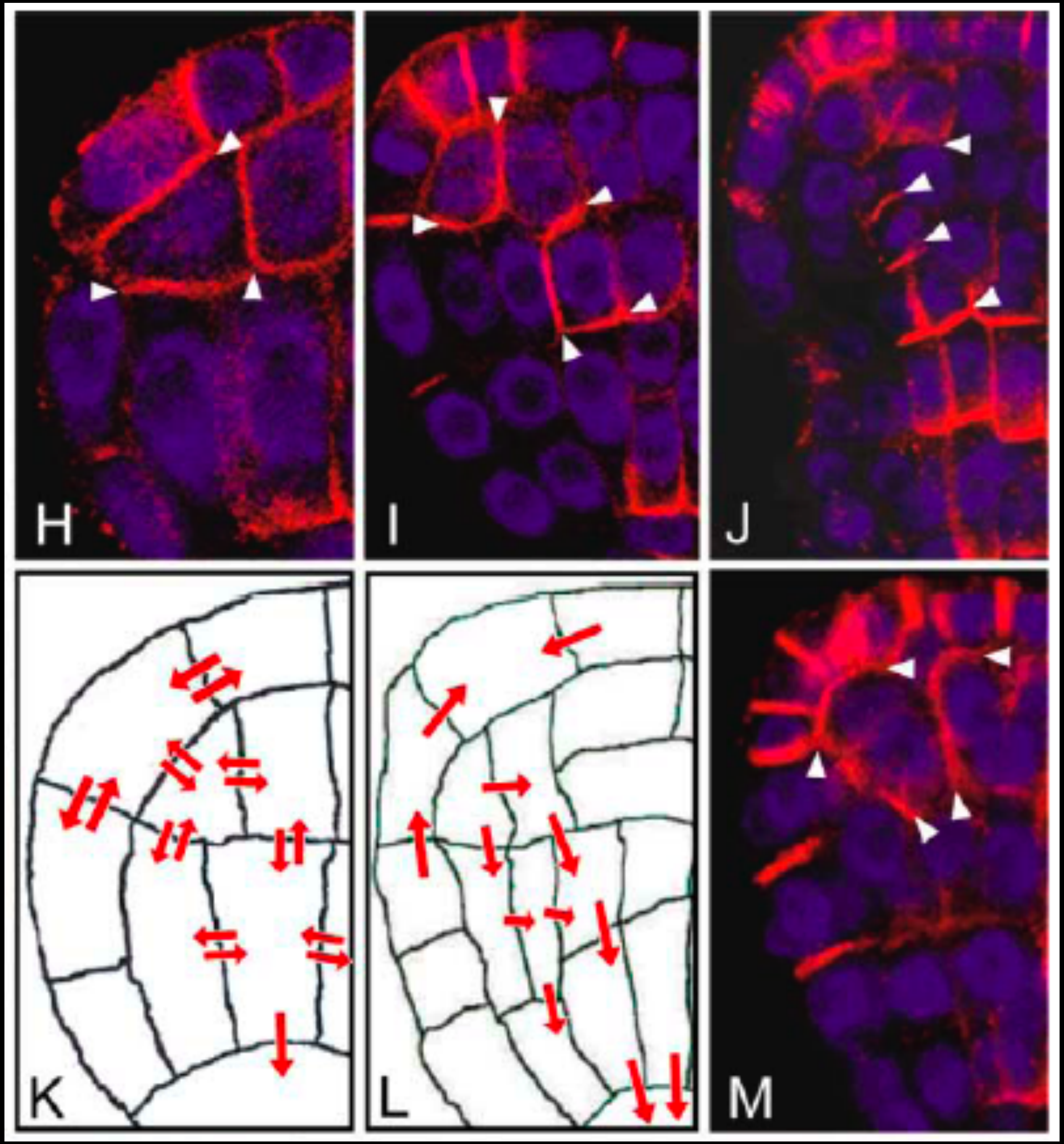


Origin of the root apical meristem during embryogenesis

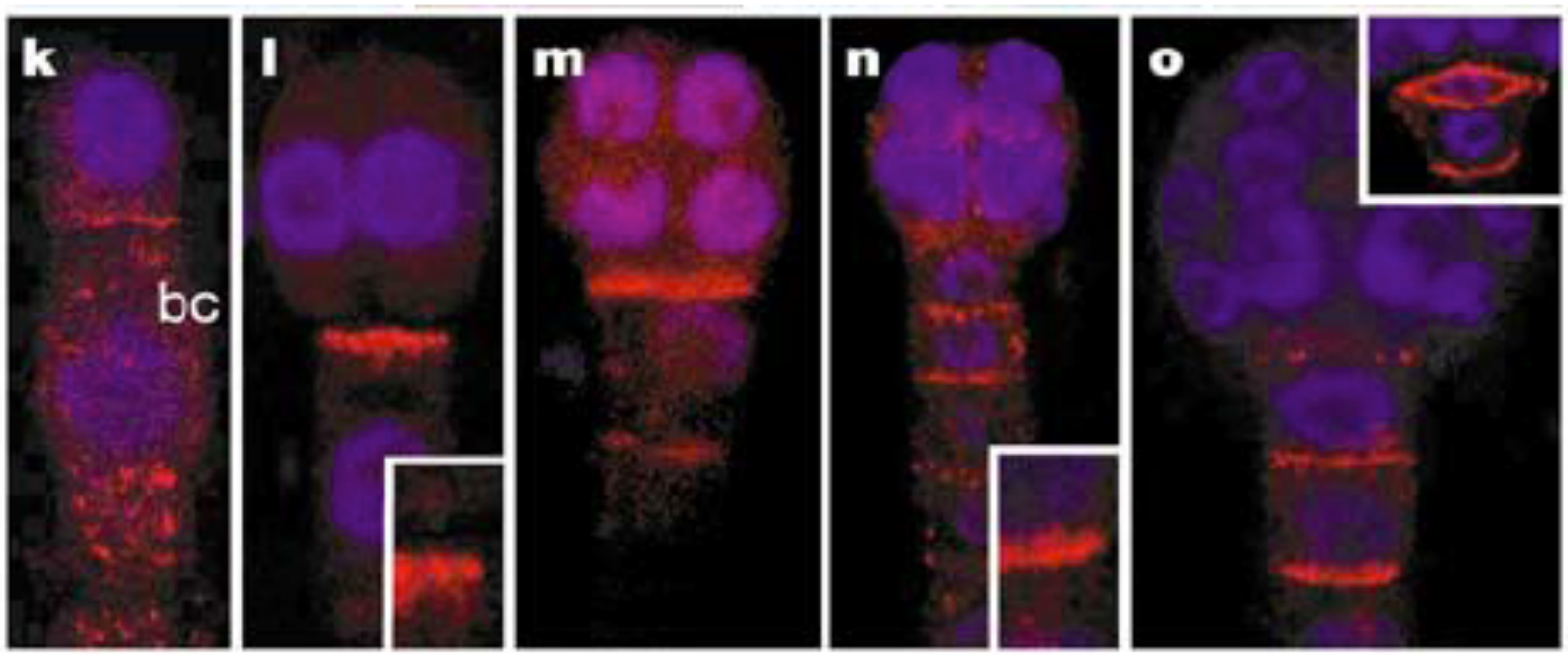


Auxin flow and accumulation regulates patterning in the embryo

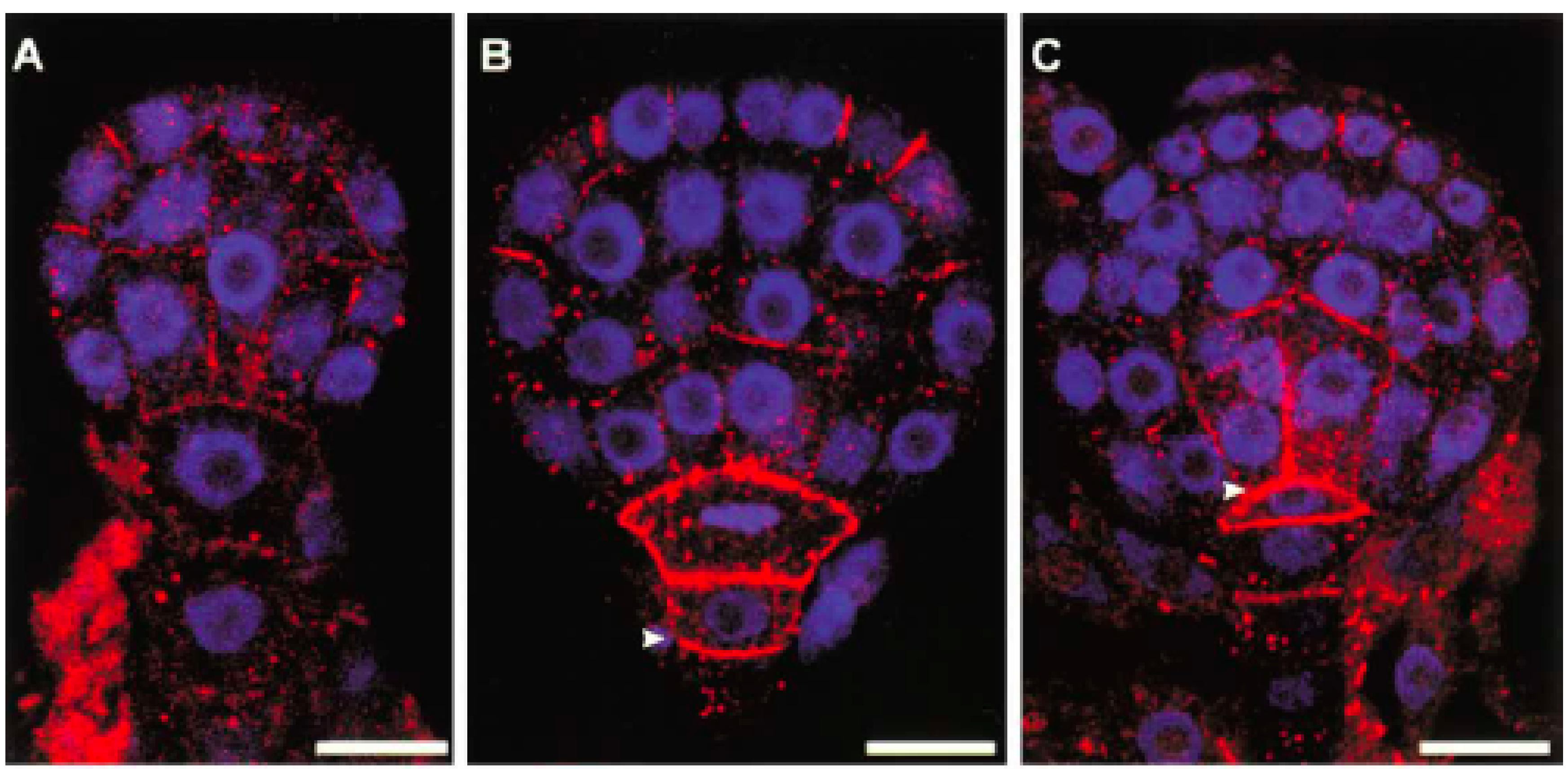
Changes in PIN1 in distribution during Arabidopsis embryogenesis

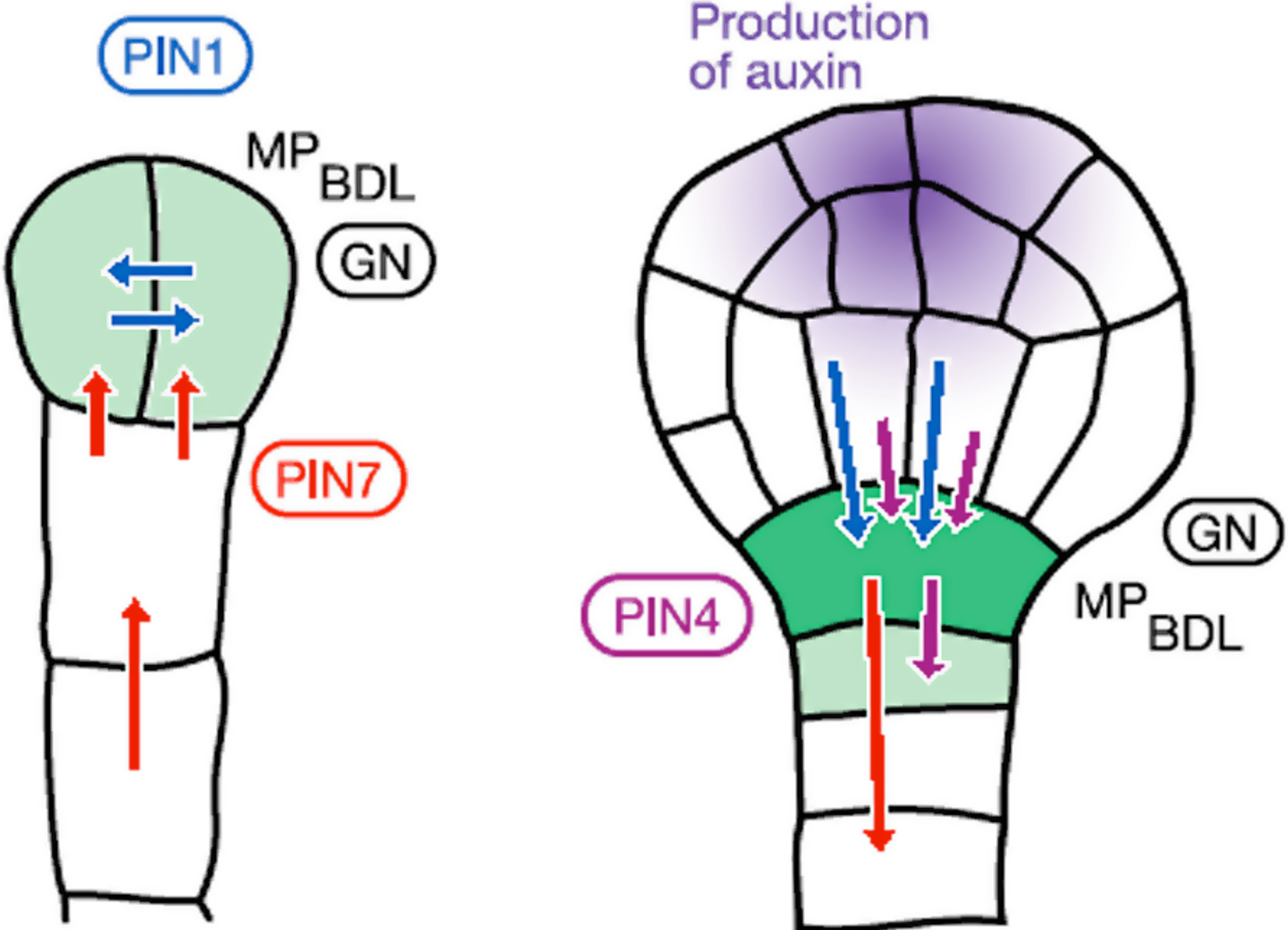


Immunolocalisation of PIN7 in Arabidopsis embryos

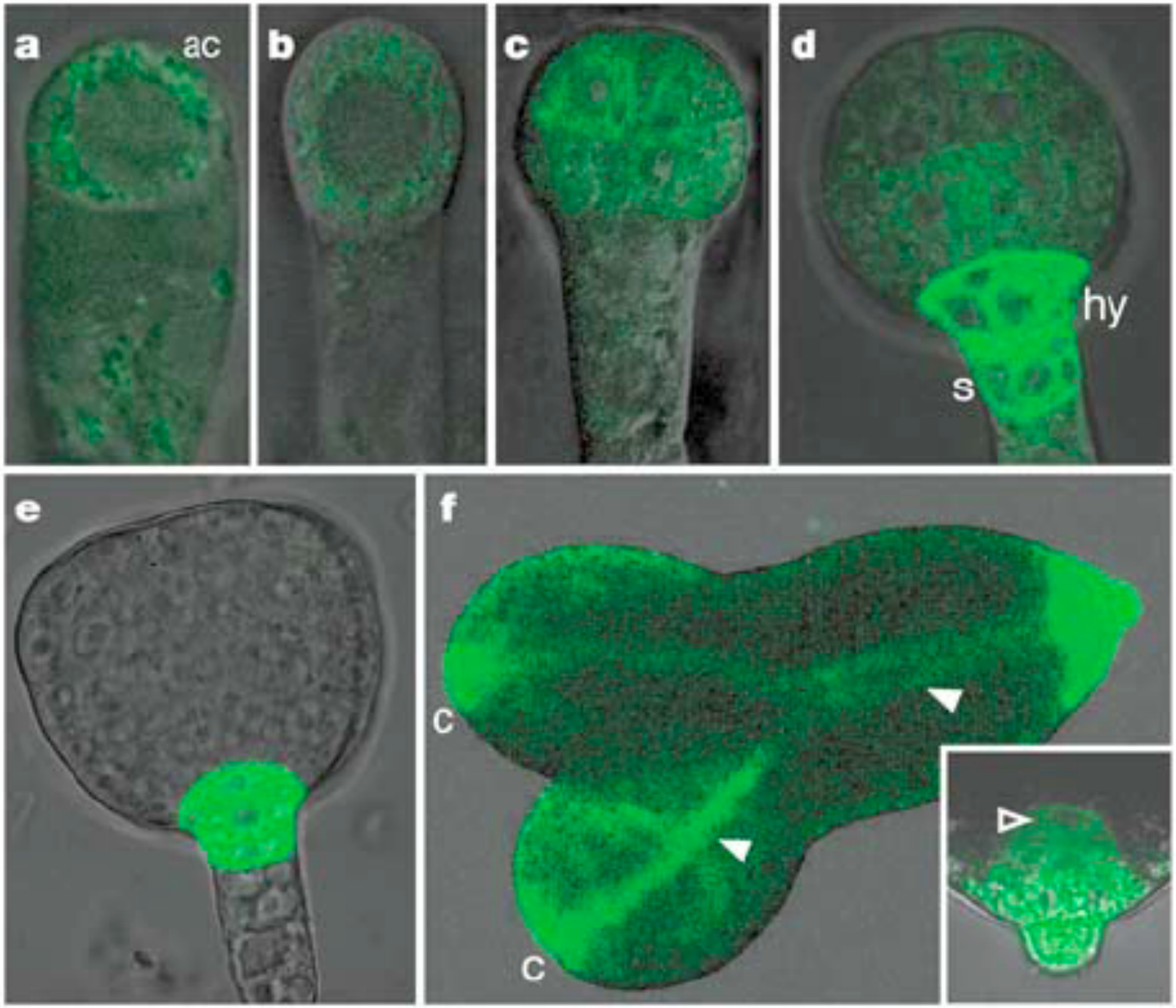


Immunolocalisation of PIN4 in Arabidopsis embryos



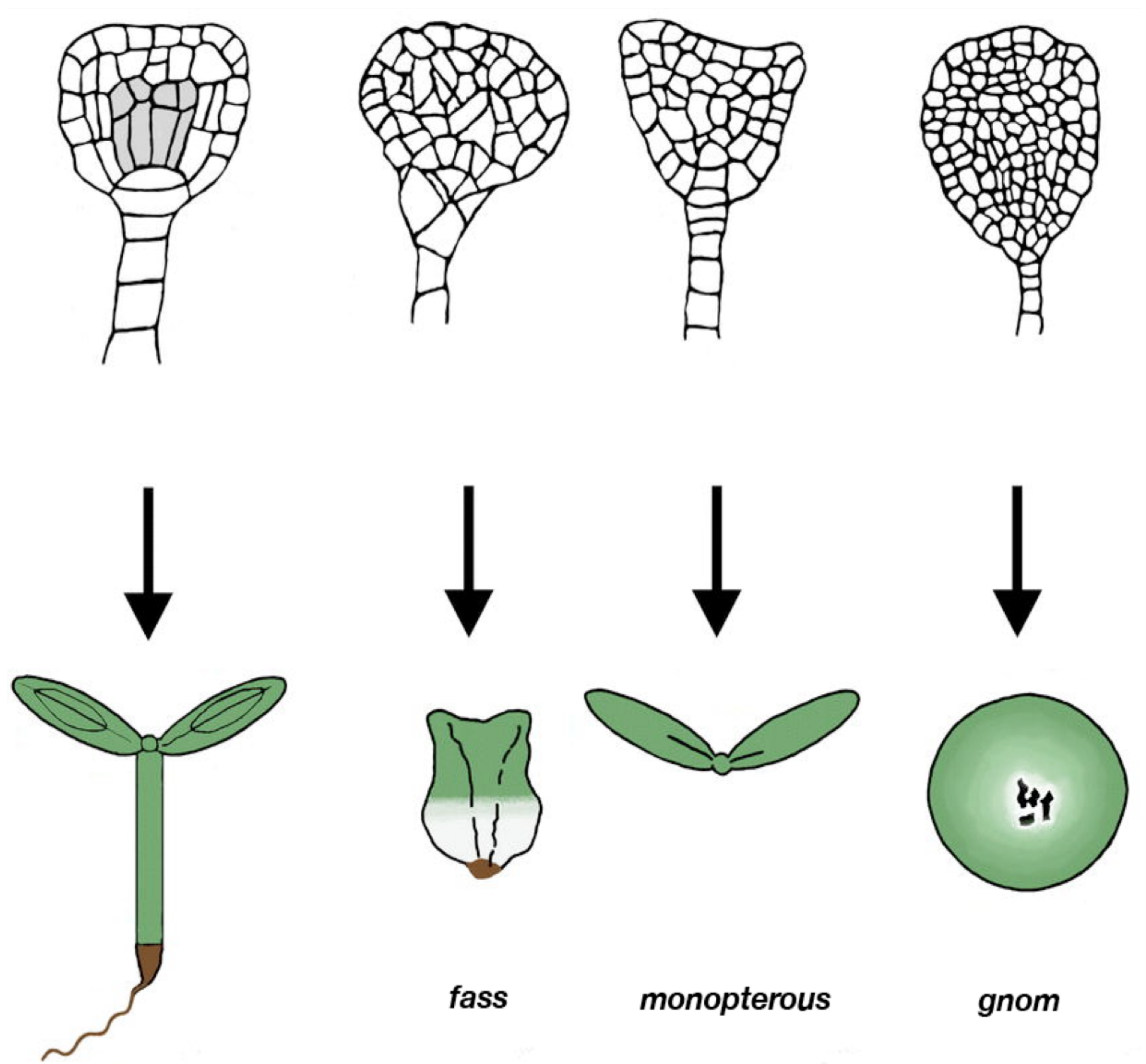

PIN1
MP_{BDL}
GN
PIN7
Production of auxin
GN
PIN4
MP_{BDL}

Auxin triggered gene expression during embryogenesis



DR5::GFP

Mutations that affect auxin traffic or perception give rise to plants with altered body plans.



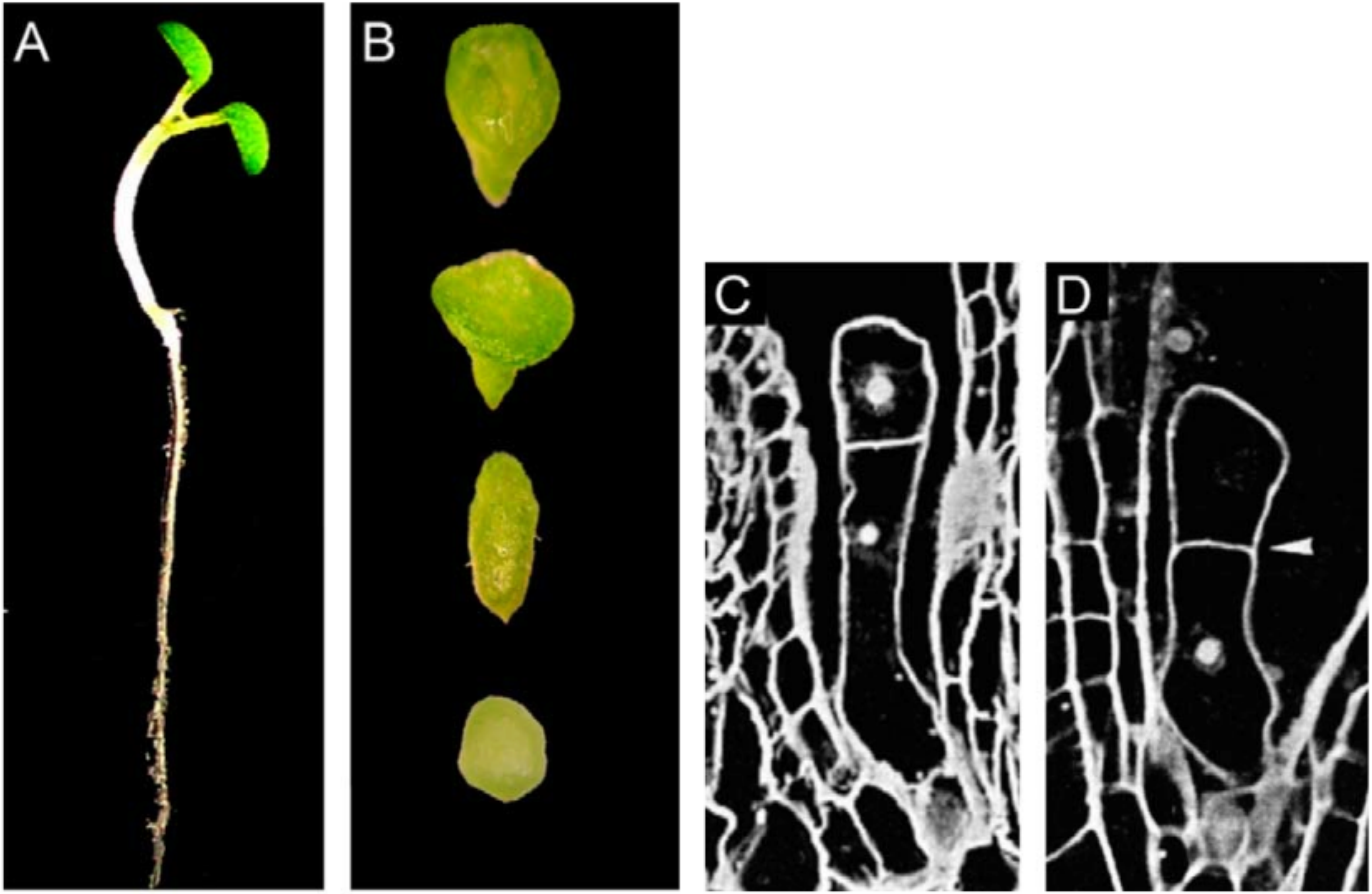
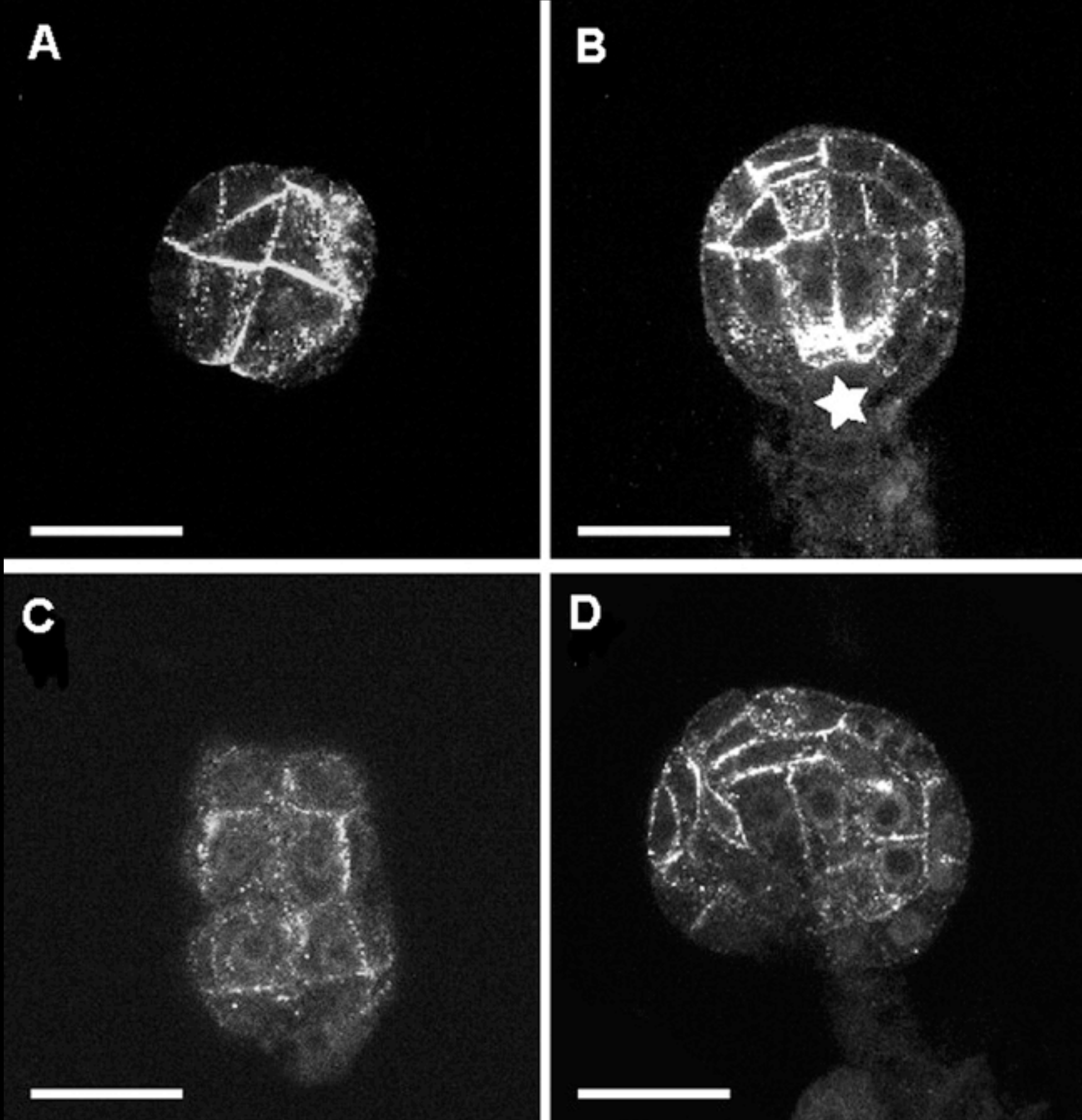


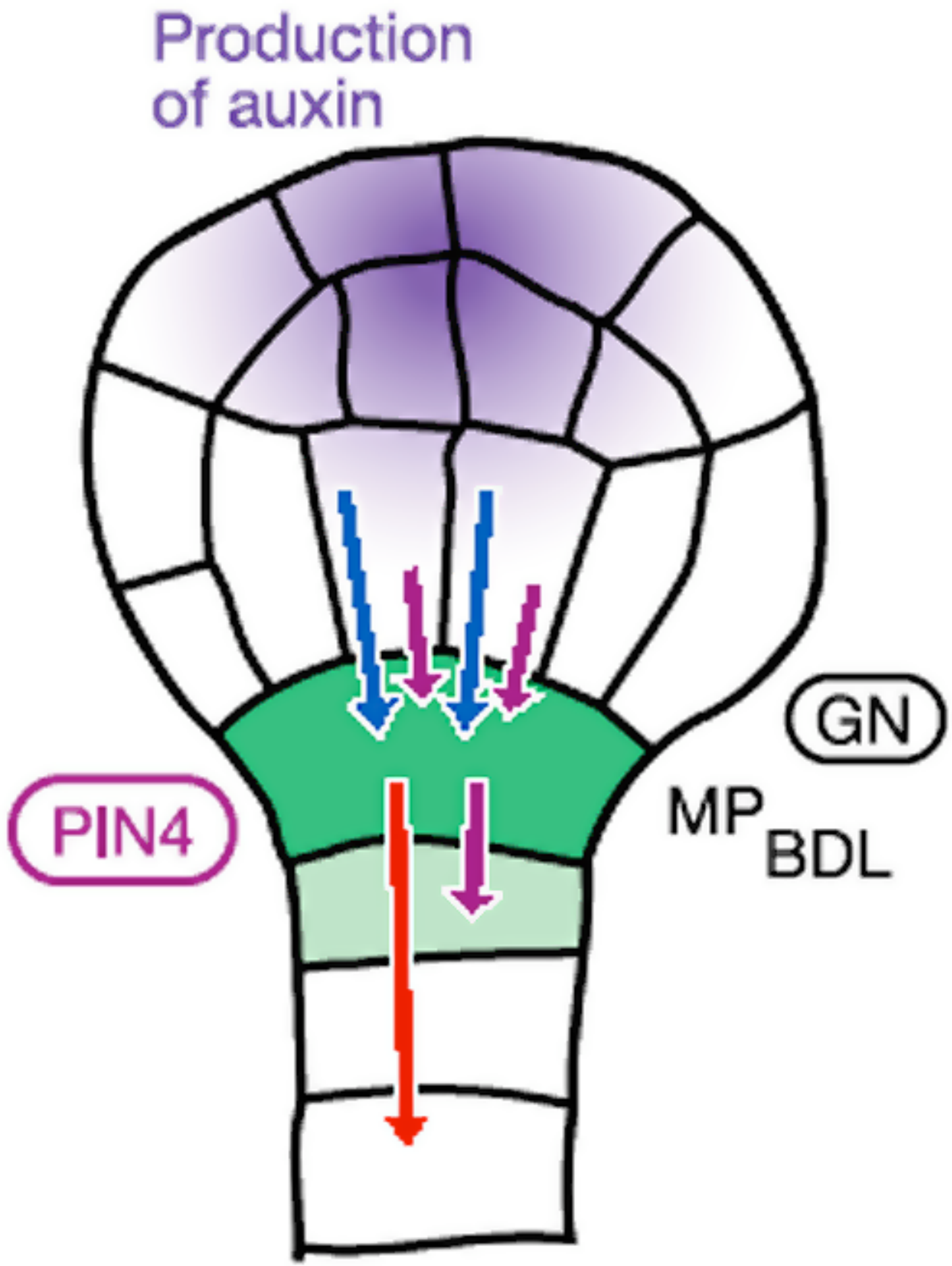
Fig. 1. *gnom* mutant phenotype. (A, C) Wild-type, (B, D) *gnom*. (A, B) Seedling, (C, D) One-cell stage of embryogenesis. Modified after (Mayer et al., 1993).



wild type

gnom mutant

Immunolocalisation of PIN1 in Arabidopsis embryos


Production
of auxin
GN
PIN4
MP
BDL

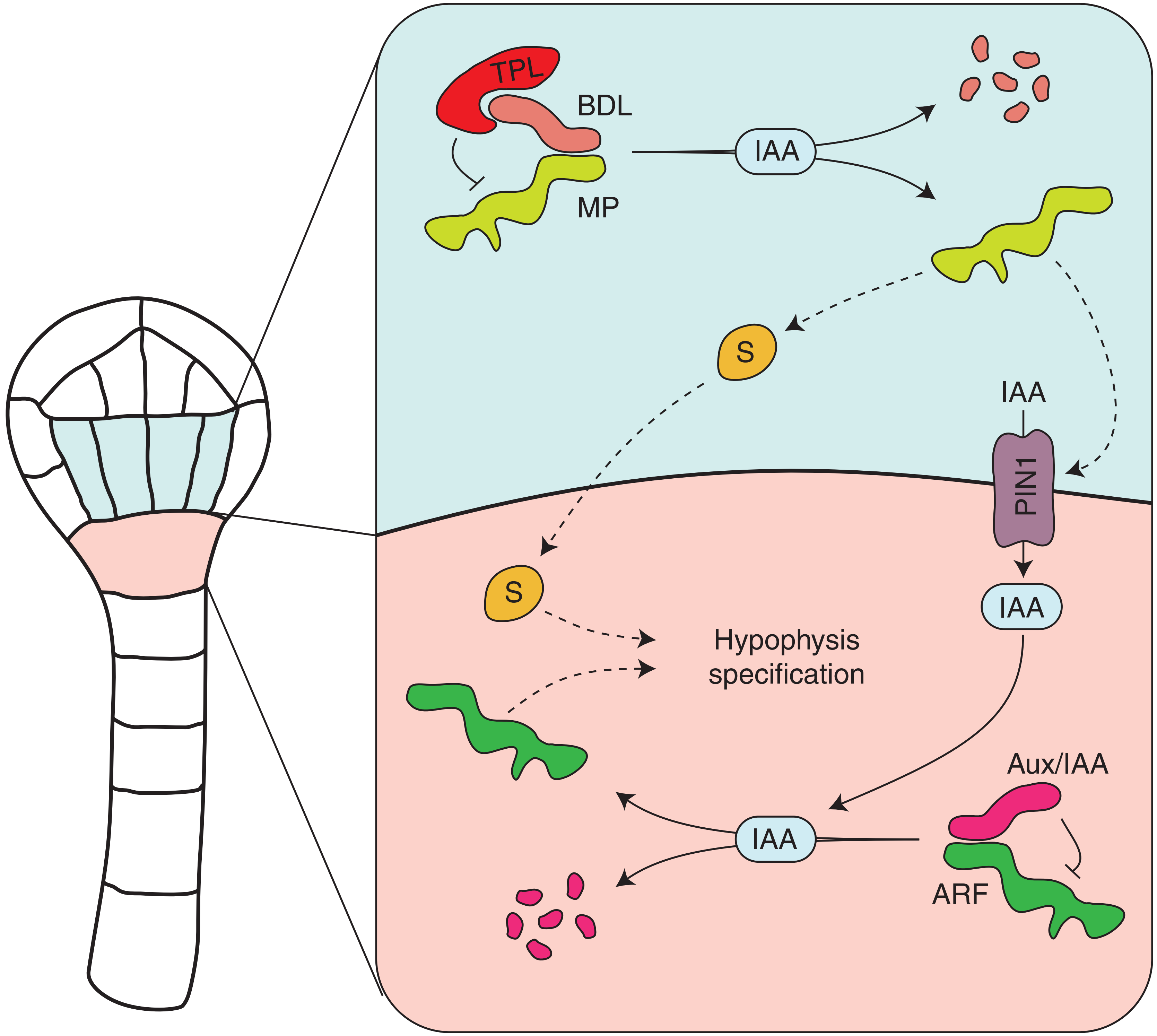
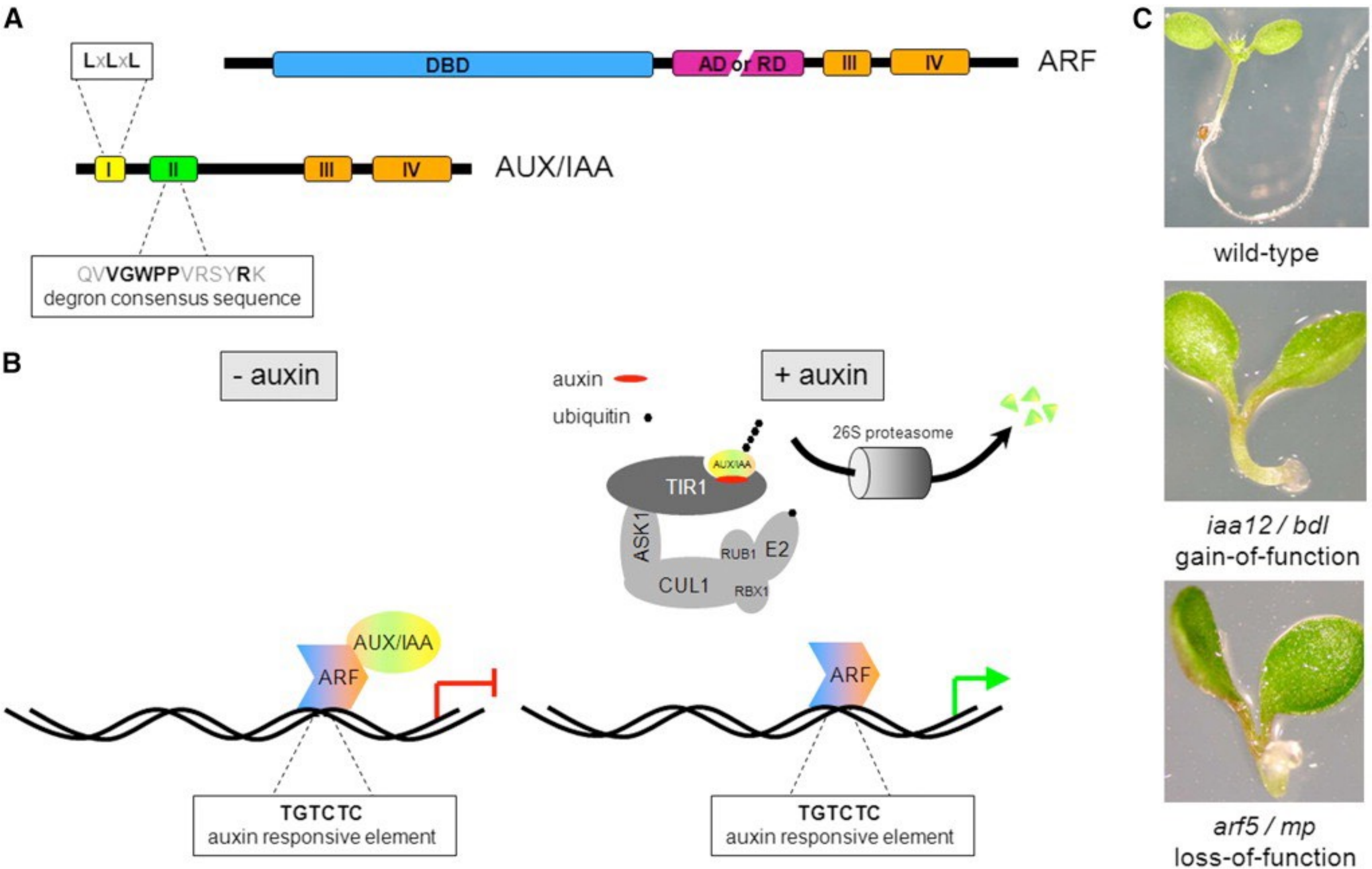
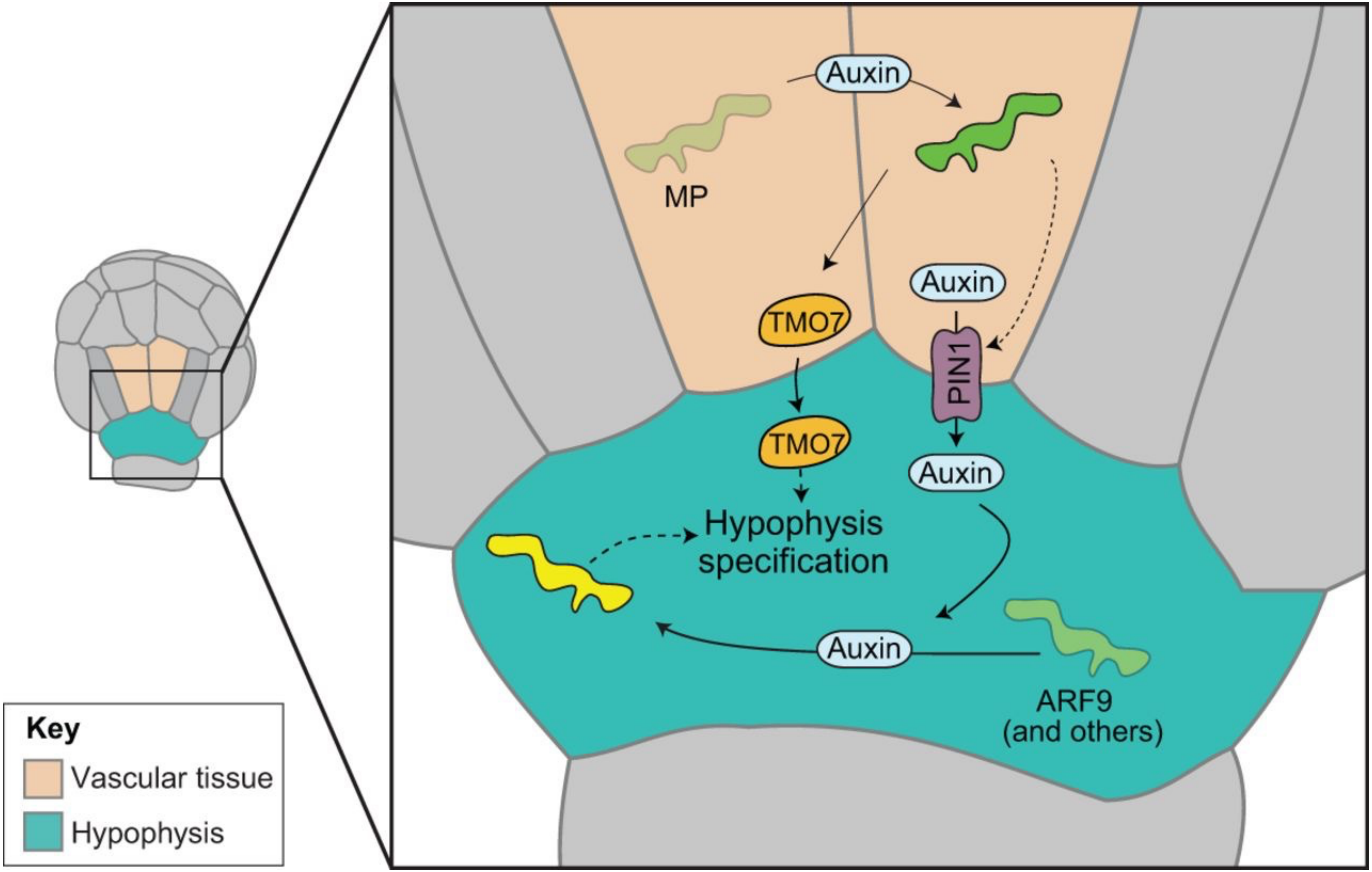


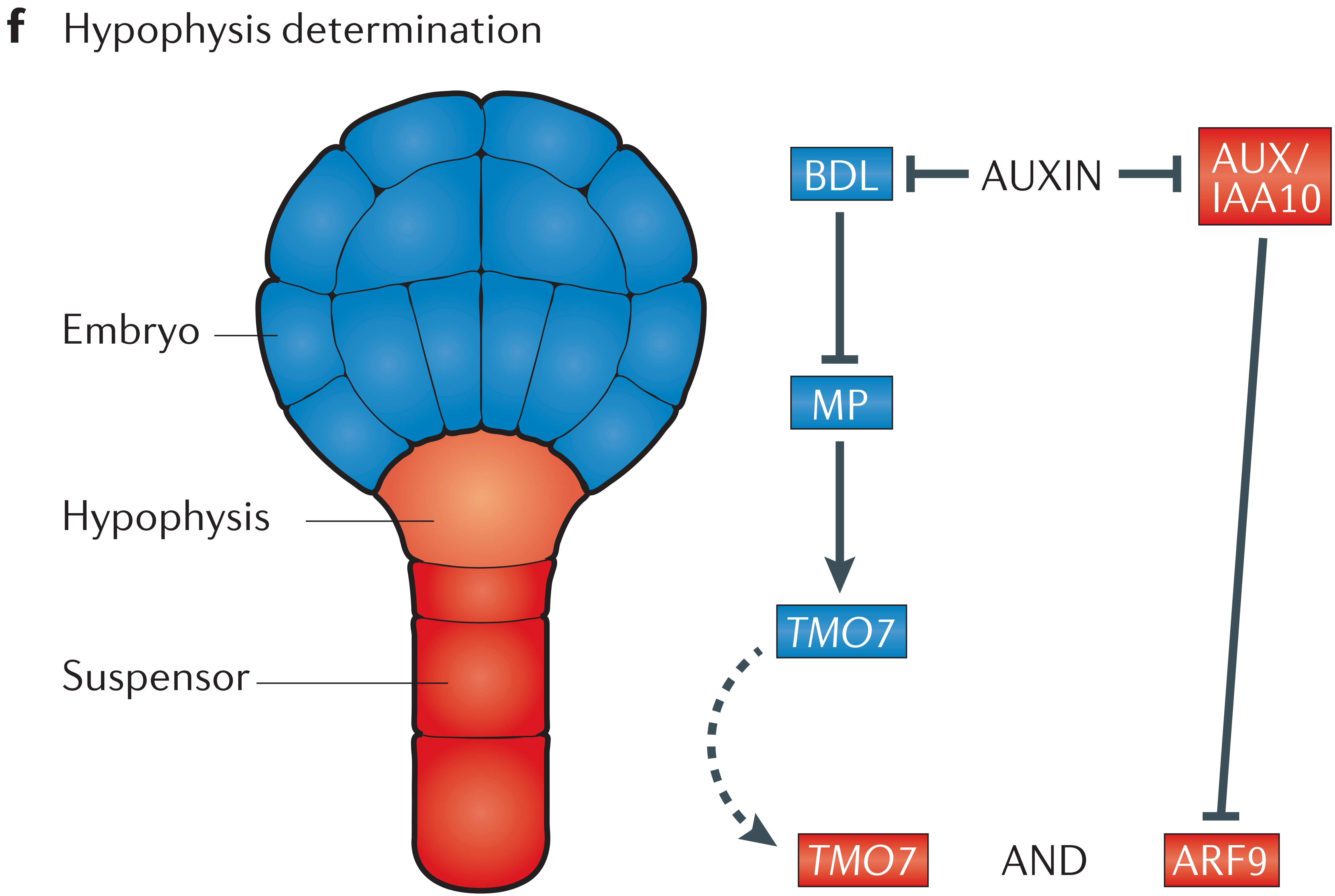
Figure 4. Hypophysis specification in the globular-stage embryo. MP activity is required non-cell-autonomously in the provascular cells (light blue) adjacent to the uppermost suspensor cell (pink) to specify this cell as hypophysis. In the provascular cells, high auxin levels release MP from its inhibitor, the Aux/IAA protein BDL, and the corepressor TPL. Subsequently, MP induces the expression of *PIN1* in the provascular cells, resulting in auxin transport to the uppermost suspensor cell. MP also promotes the transport of a hypothetical signal (S) to the future hypophysis. Here, auxin releases another yet unidentified ARF from a so far unknown Aux/IAA protein to elicit an auxin response that converges with S to specify hypophysis fate.

BODENLOS (IAA12) and MONOPTEROUS (ARF5) are required for the establishment of the root apical meristem during embryogenesis



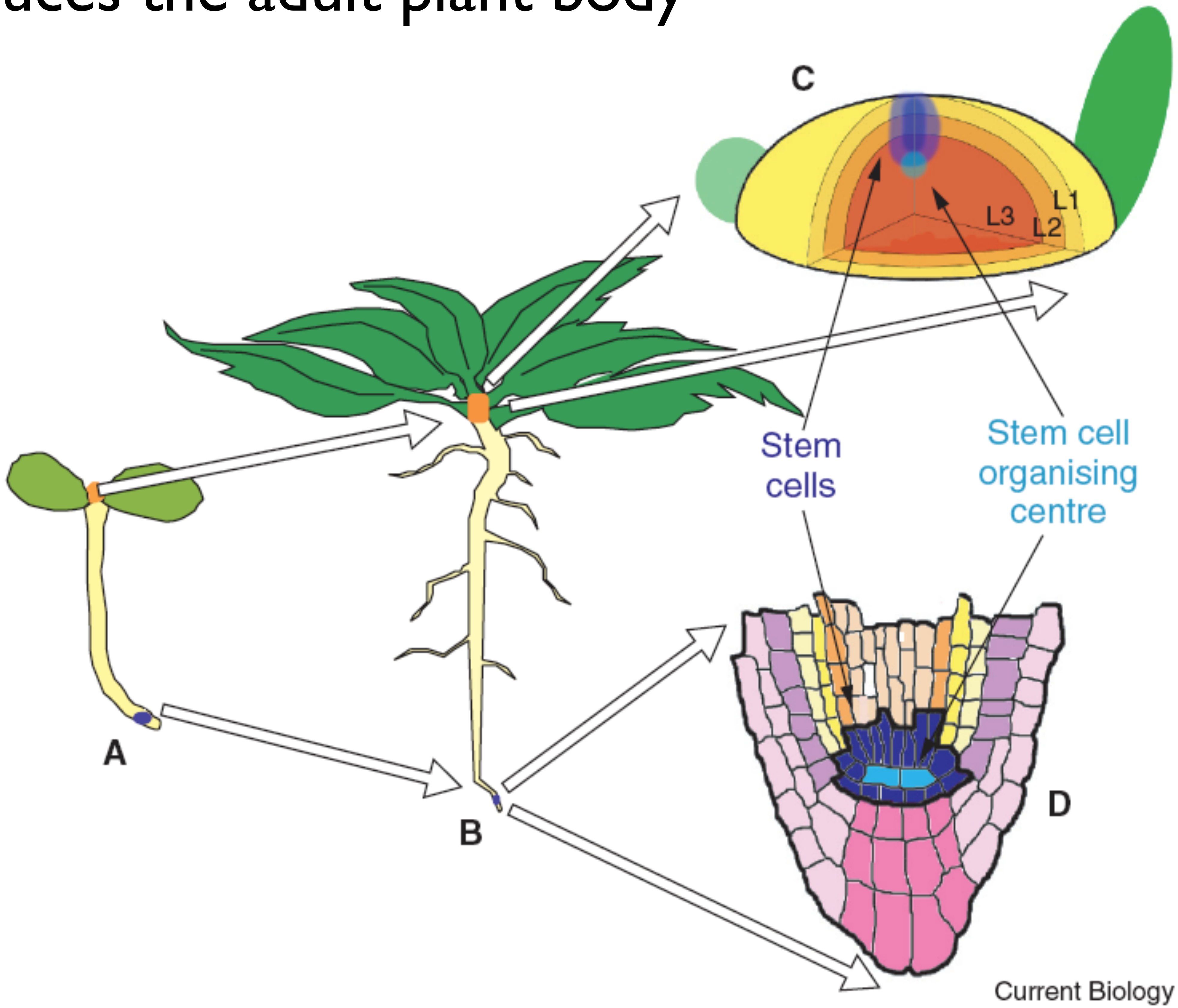


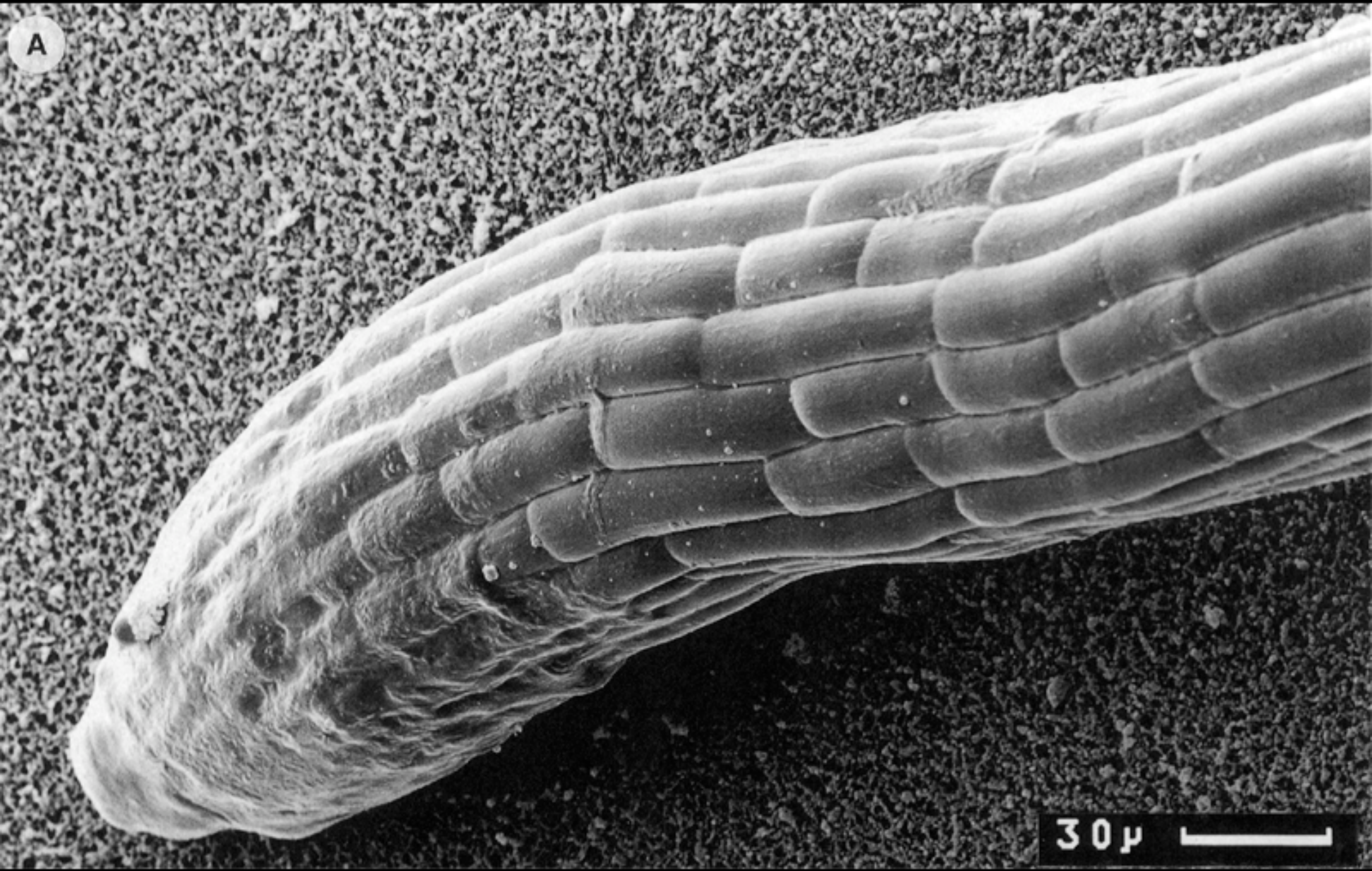
Cell-cell communication during specification of the root apical meristem



Mechanism for auxin-mediated specification of the root apical meristem

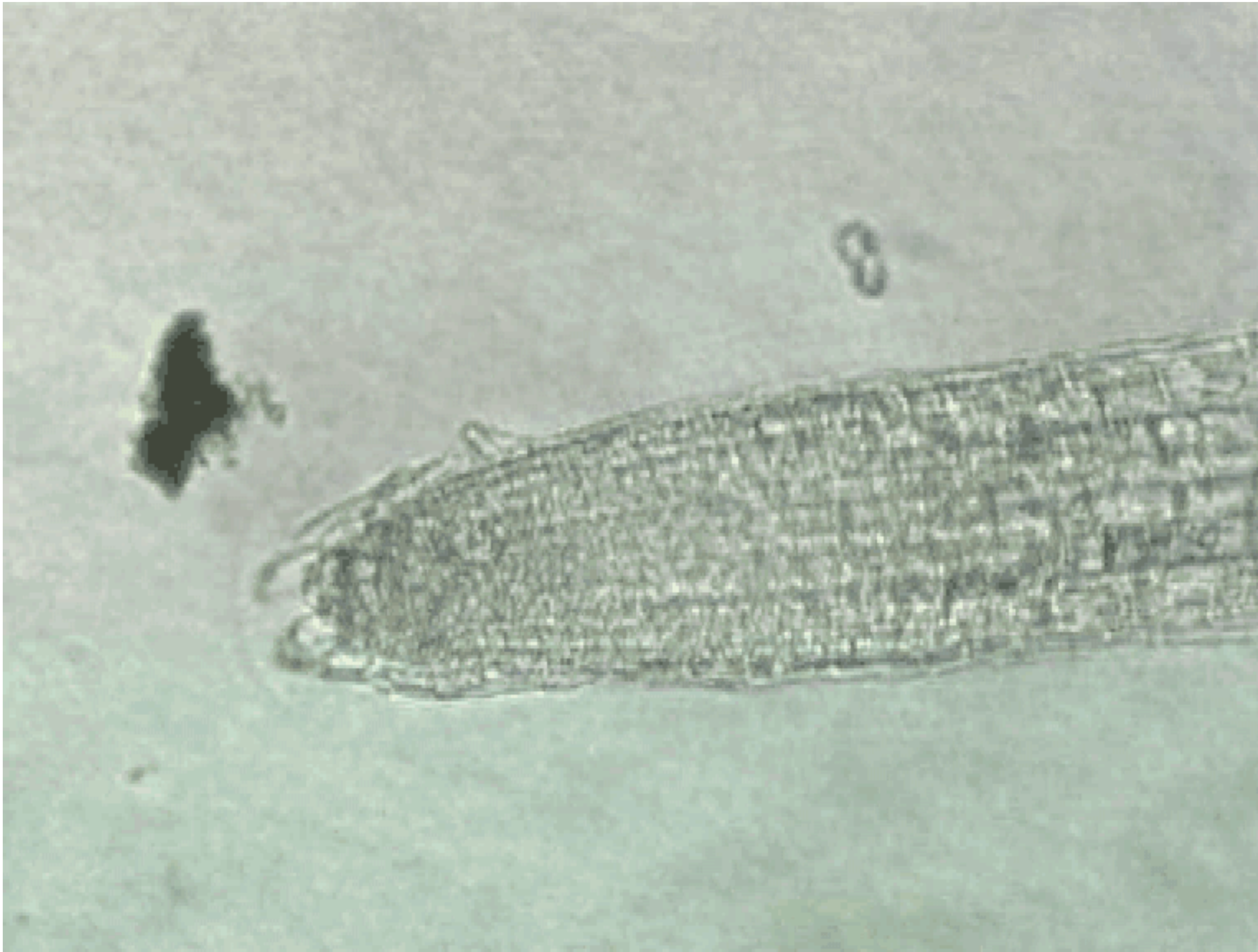
Continued growth of shoot and root meristems produces the adult plant body

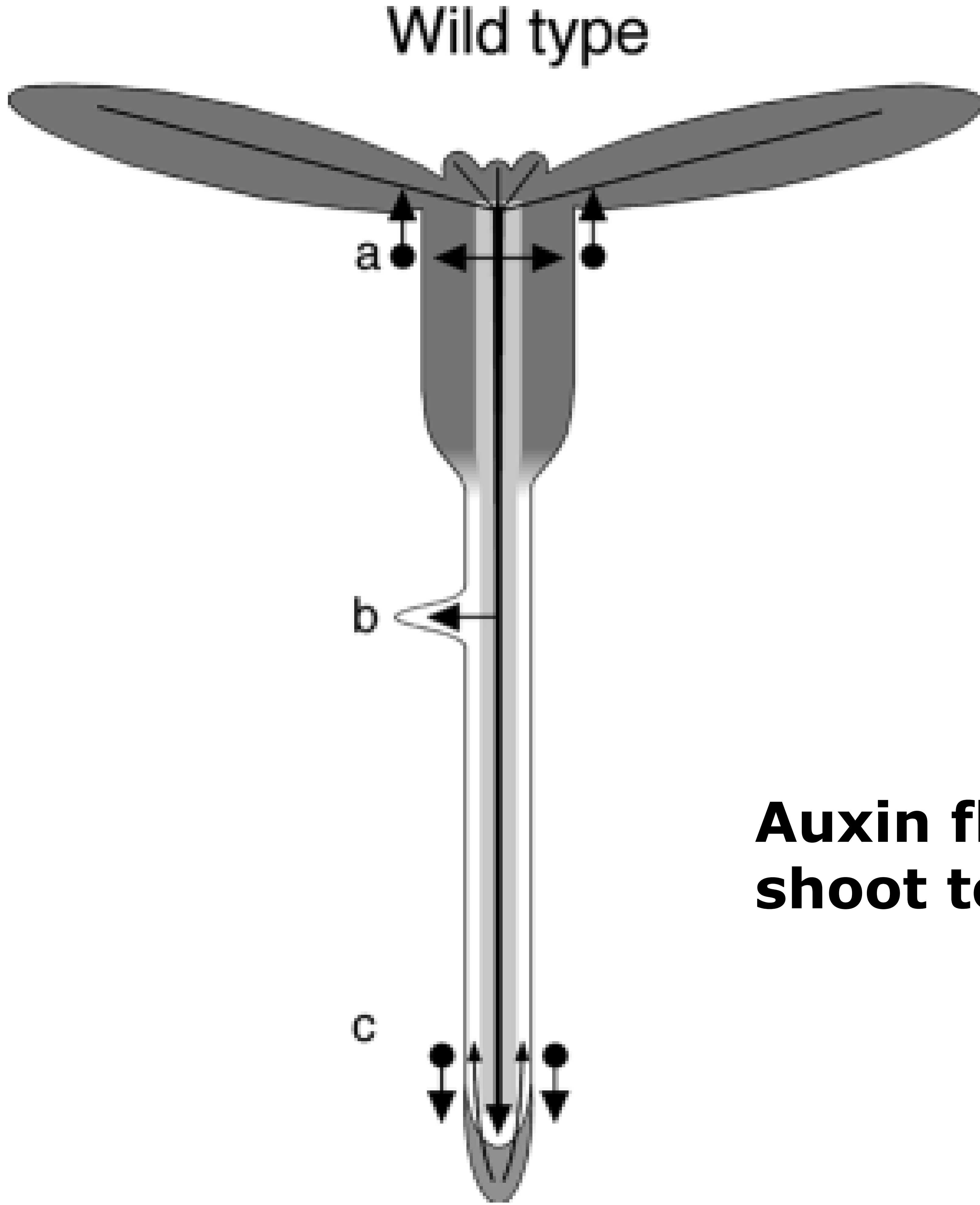




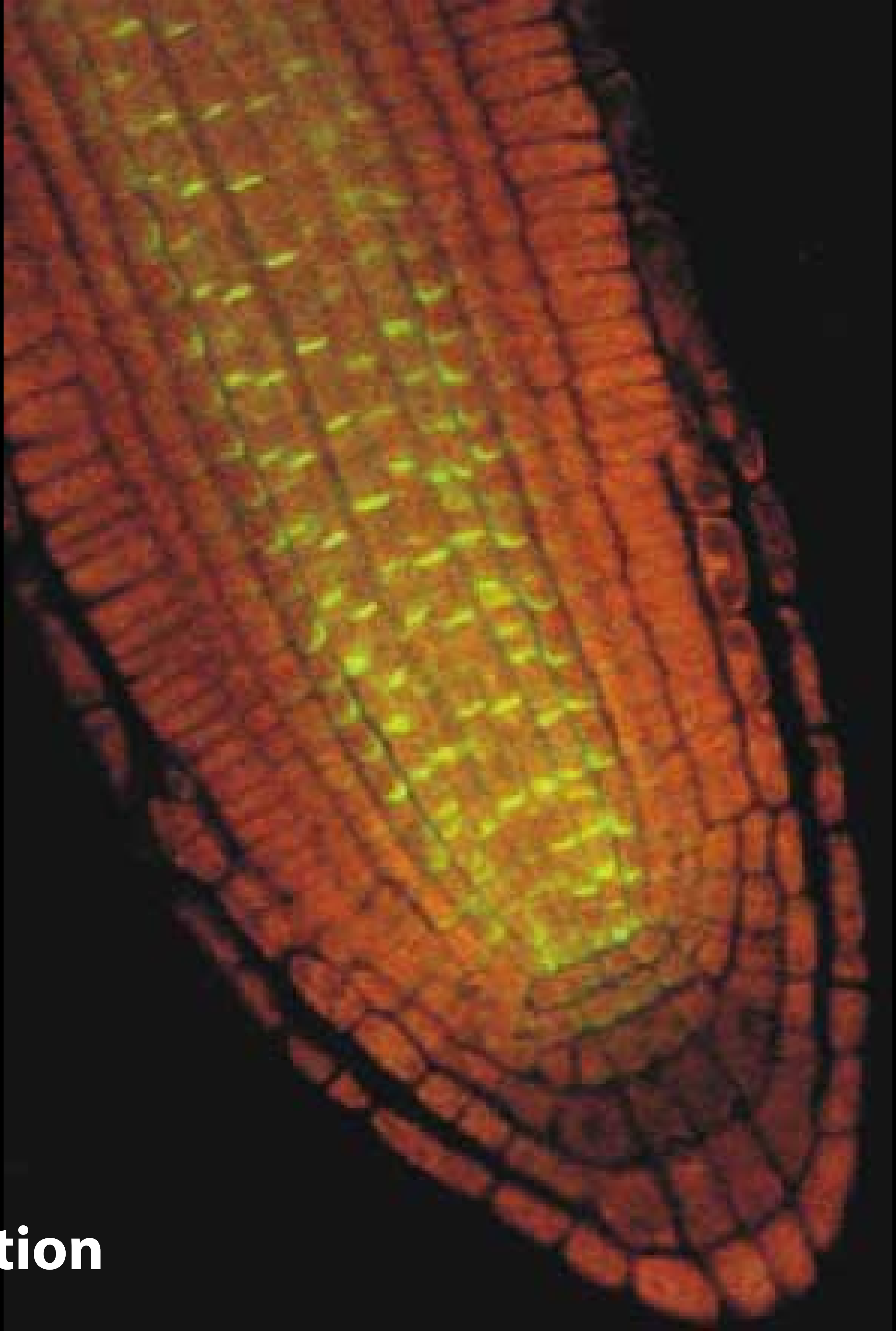
Arabidopsis root tip

Indeterminate growth of the Arabidopsis root meristem





Auxin flux from shoot to root



PIN1 localisation

Family of PIN genes in the Arabidopsis root

pin2 mutant seedlings show loss of gravitropism in the root

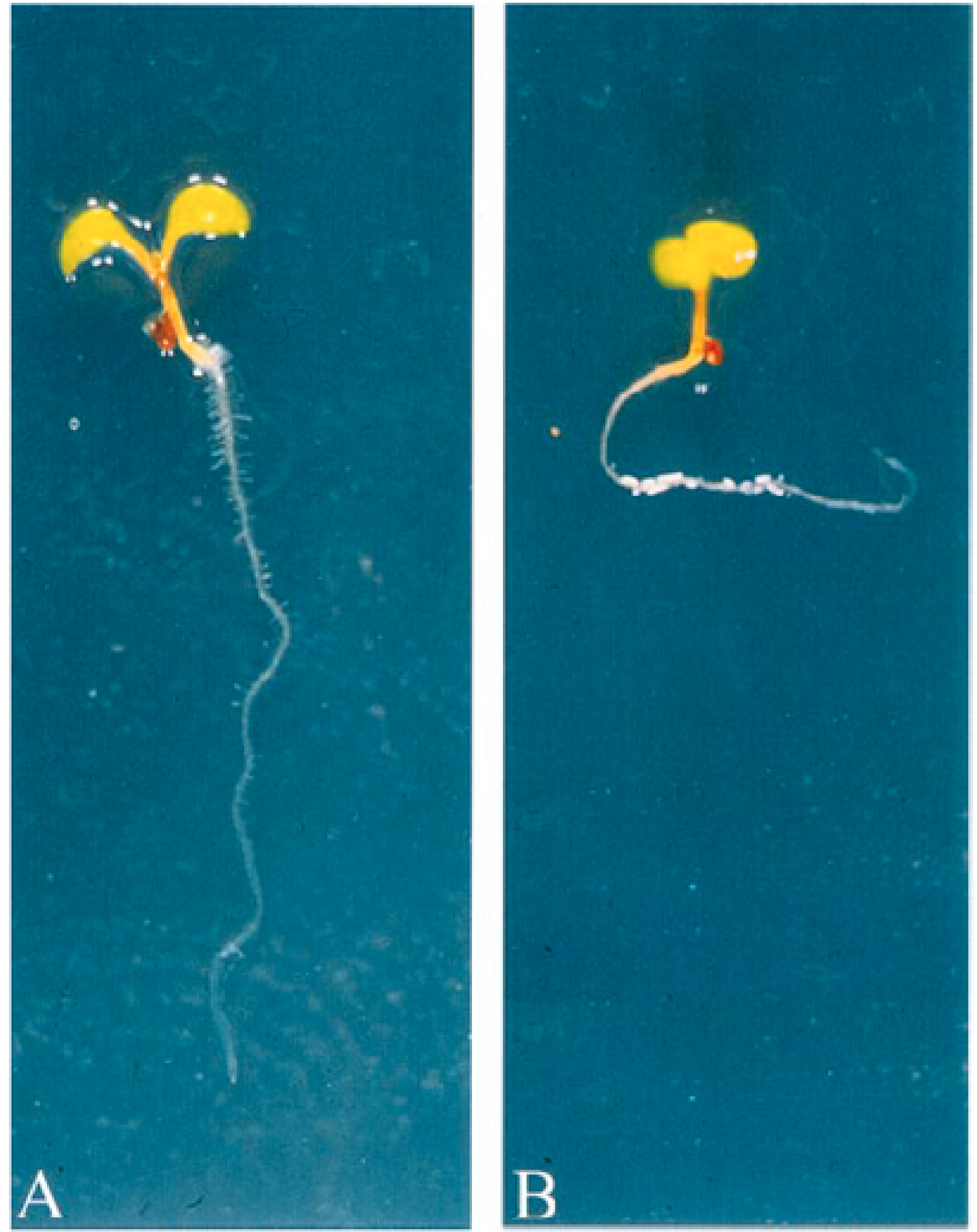
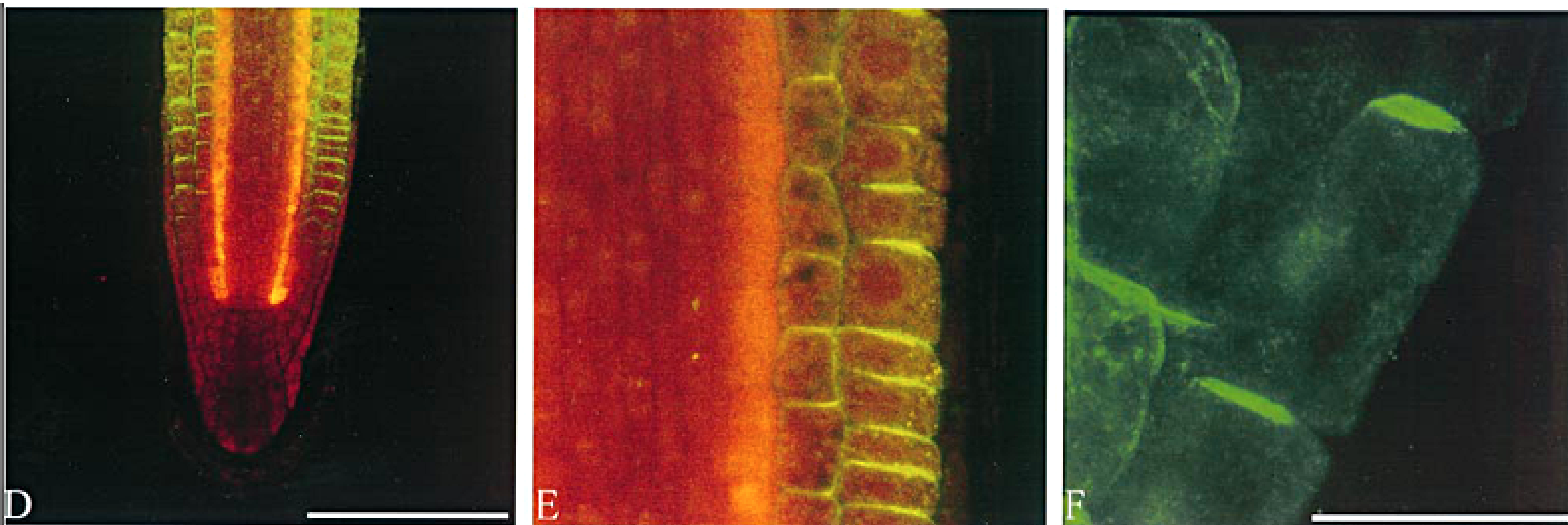
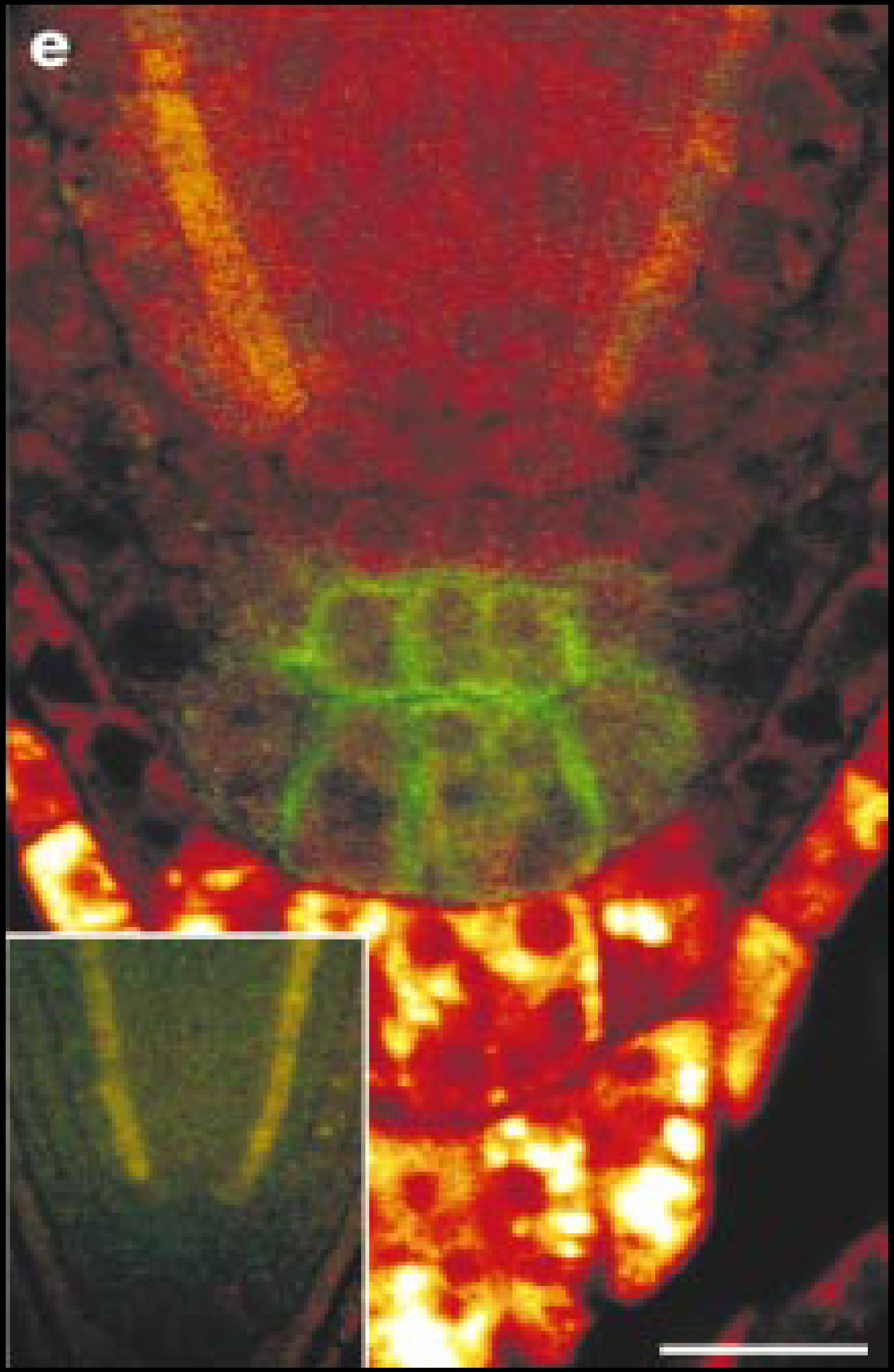


Fig. 3. Mutations in the *AtPIN2* gene alter root growth and gravitropism. Homozygous 5-day-old Columbia-0 wild-type seedlings (**A**) and *Atpin2::En701* mutant seedlings (**B**) were grown vertically on agar plates.

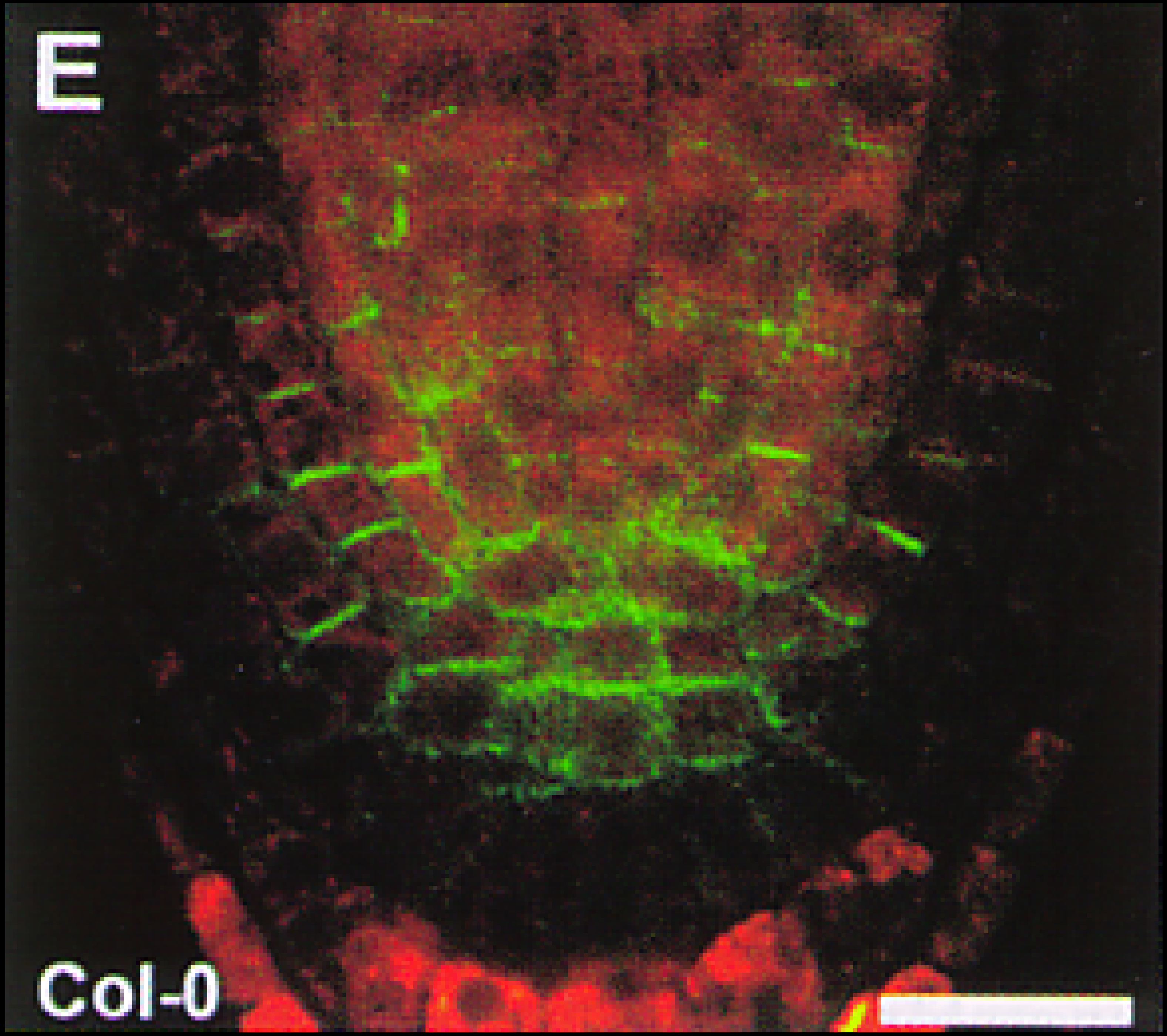


Localization of AtPIN2p in 4-day-old *Arabidopsis* seedling root tips.

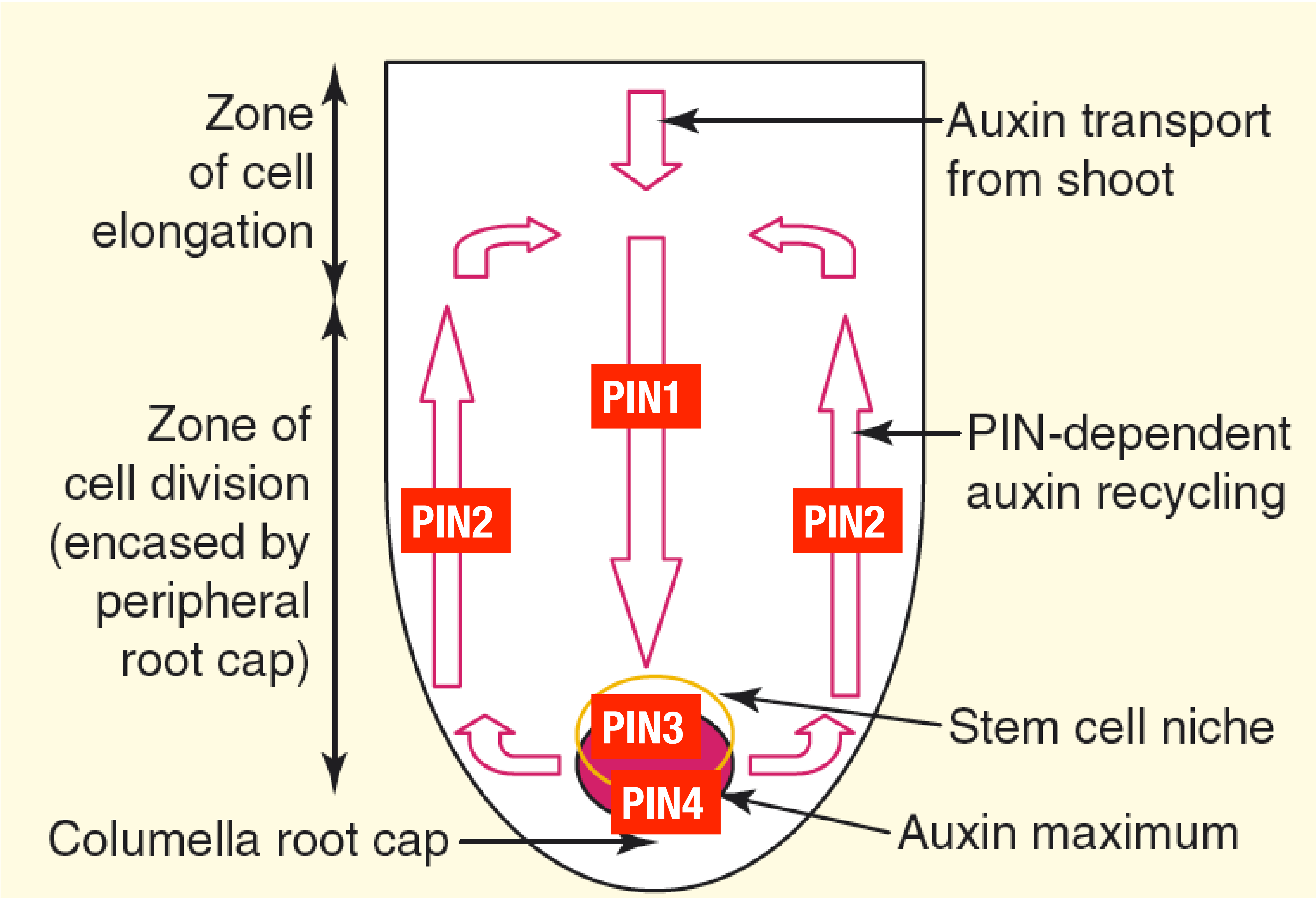
PIN2 localisation



PIN3 localisation



PIN4 localisation


Zone
of cell
elongation
Zone of
cell division
(encased by
peripheral
root cap)
Columella root cap
Auxin transport
from shoot
PIN1
PIN2
PIN2
PIN-dependent
auxin recycling
PIN3
PIN4
Stem cell niche
Auxin maximum

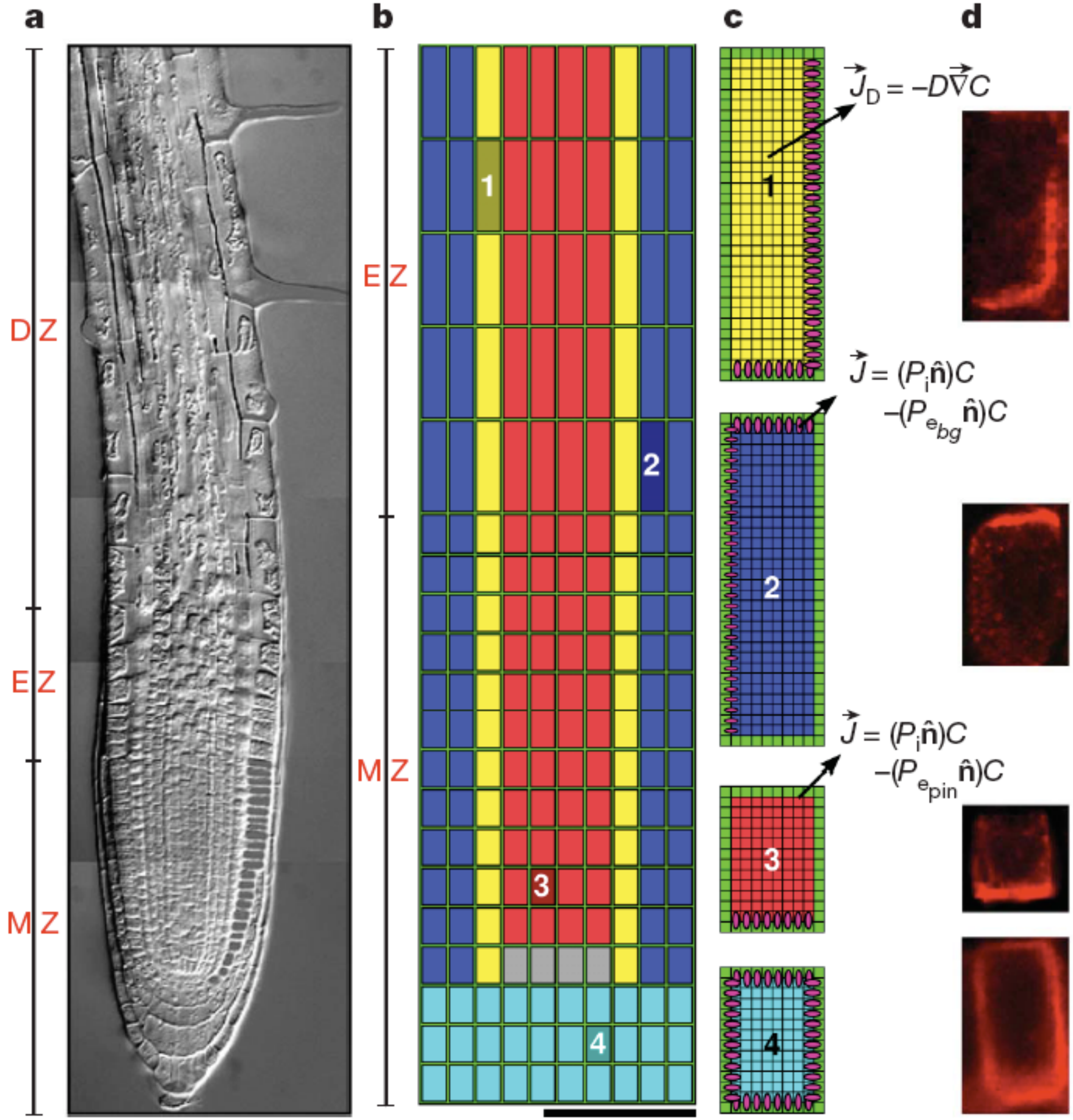


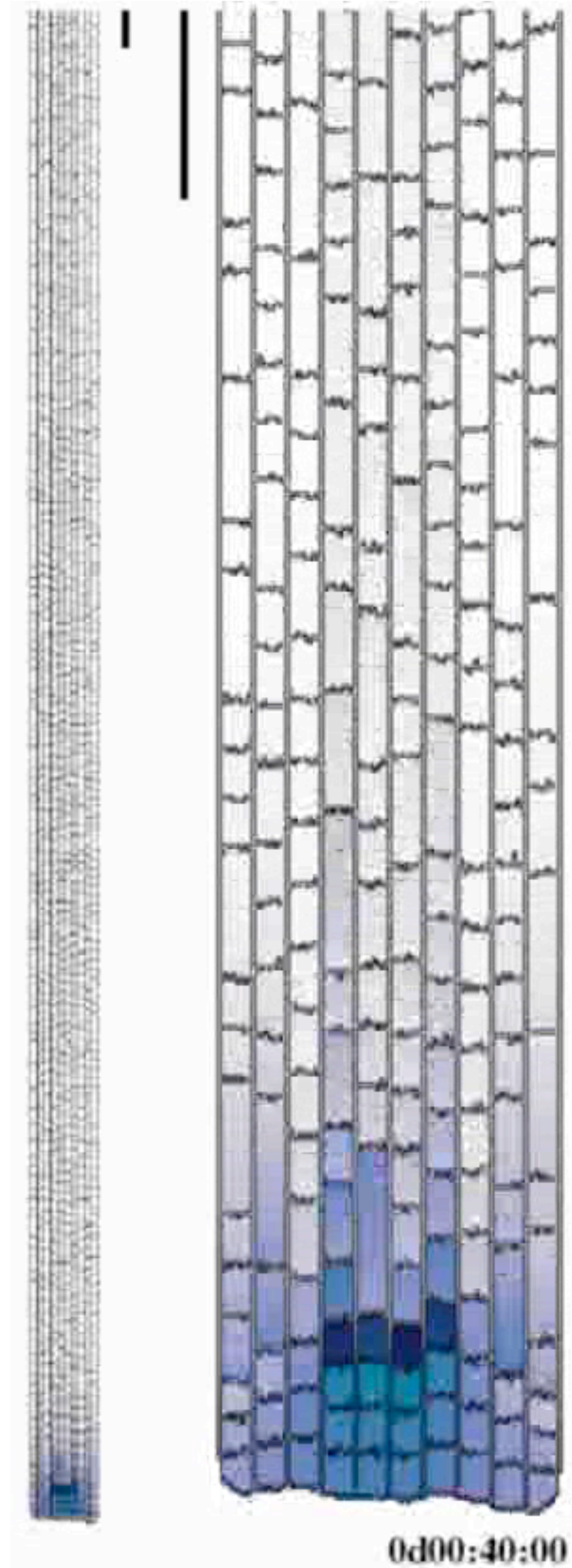
Figure 1 | Mesoscopic model for polar auxin transport. **a**, The *Arabidopsis* root. DZ, differentiation zone; EZ, elongation zone; MZ, meristematic zone.

Grieneisen *et al.*

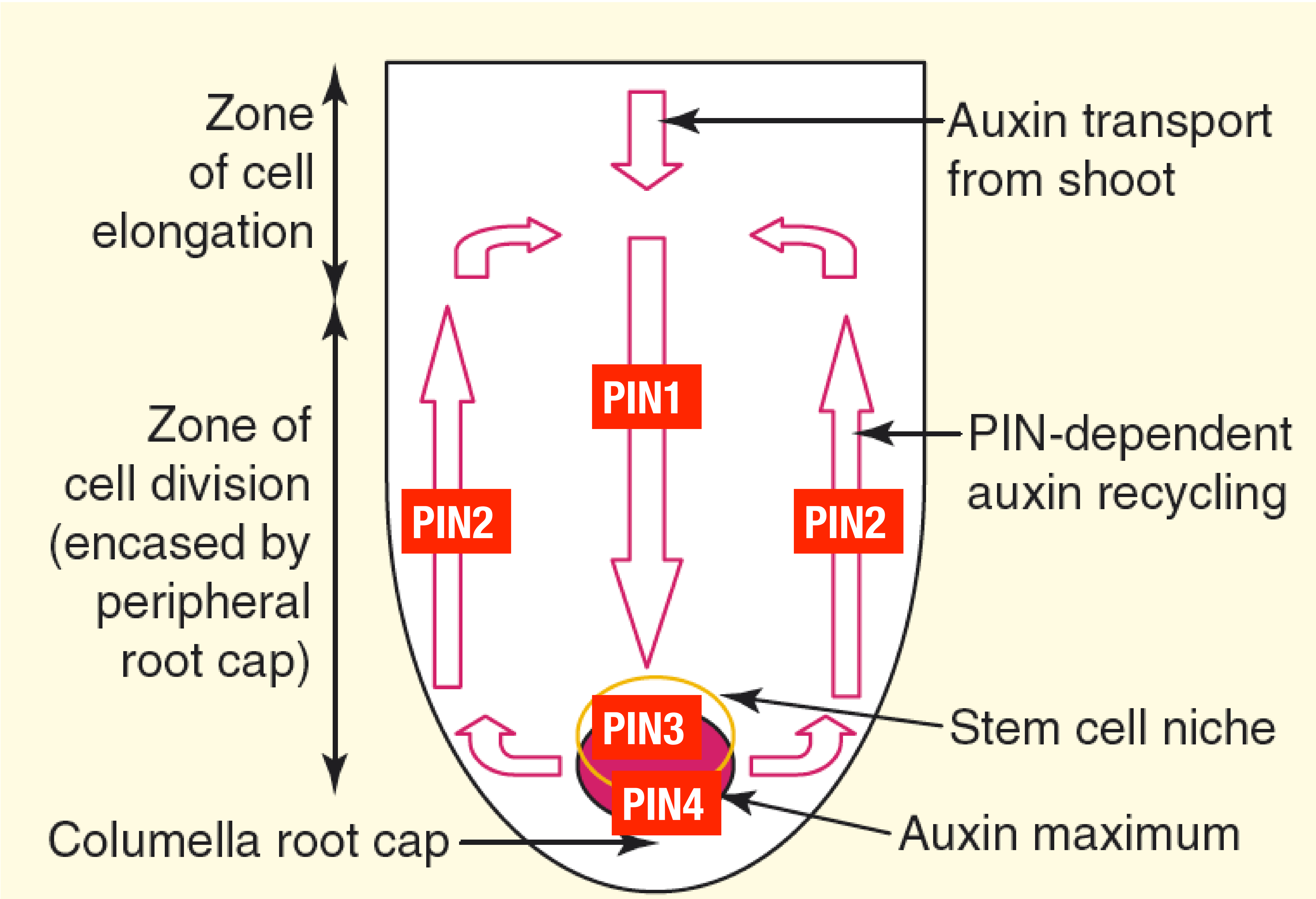
Supplementary Movie 1

Establishment of the auxin maximum in a root receiving shoot-derived auxin influx (simulation of Fig. 2b). Relative auxin concentrations according to the colour bar of Fig. 2d. Scale bar 100 μm.

-00:00

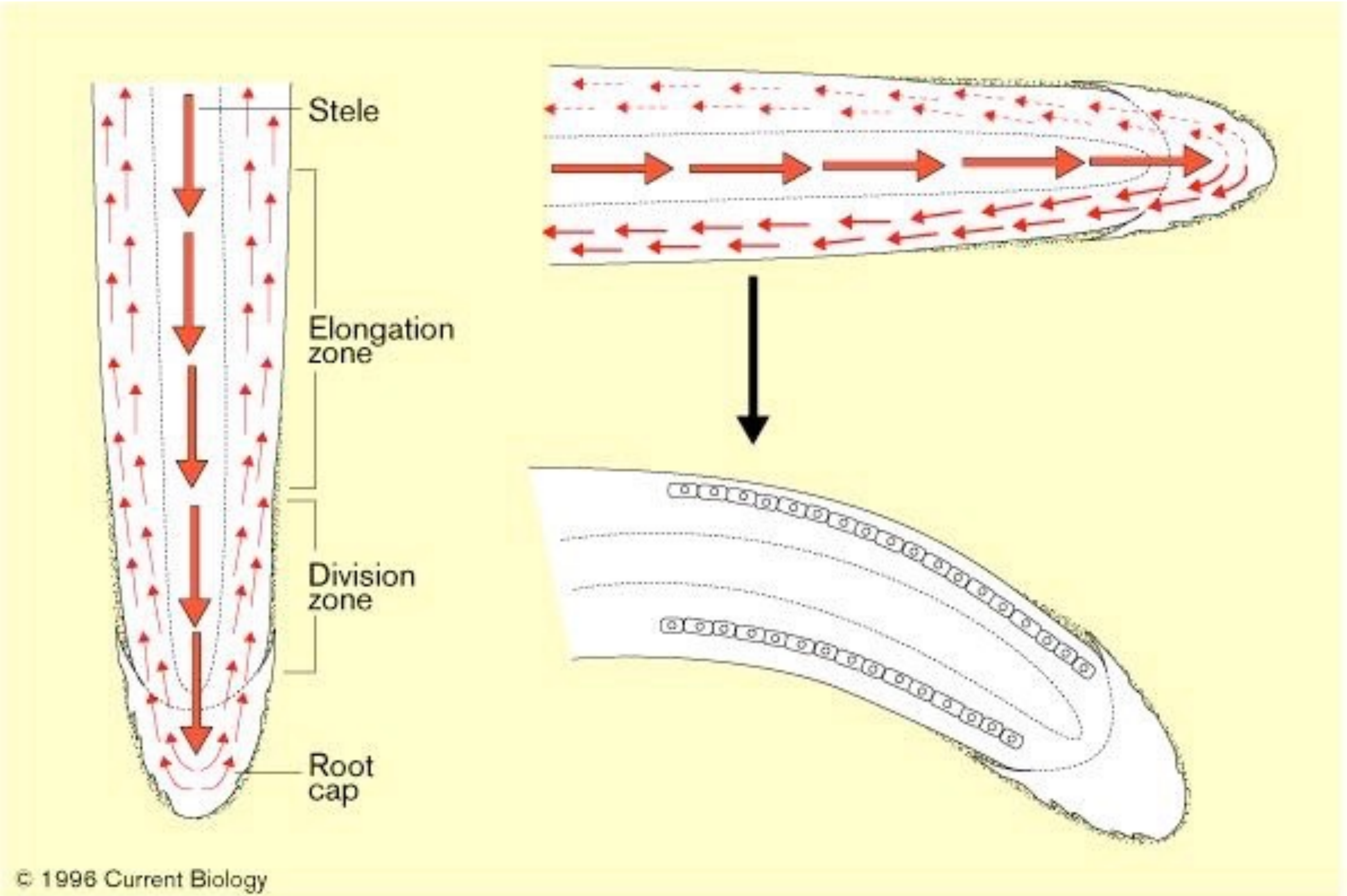


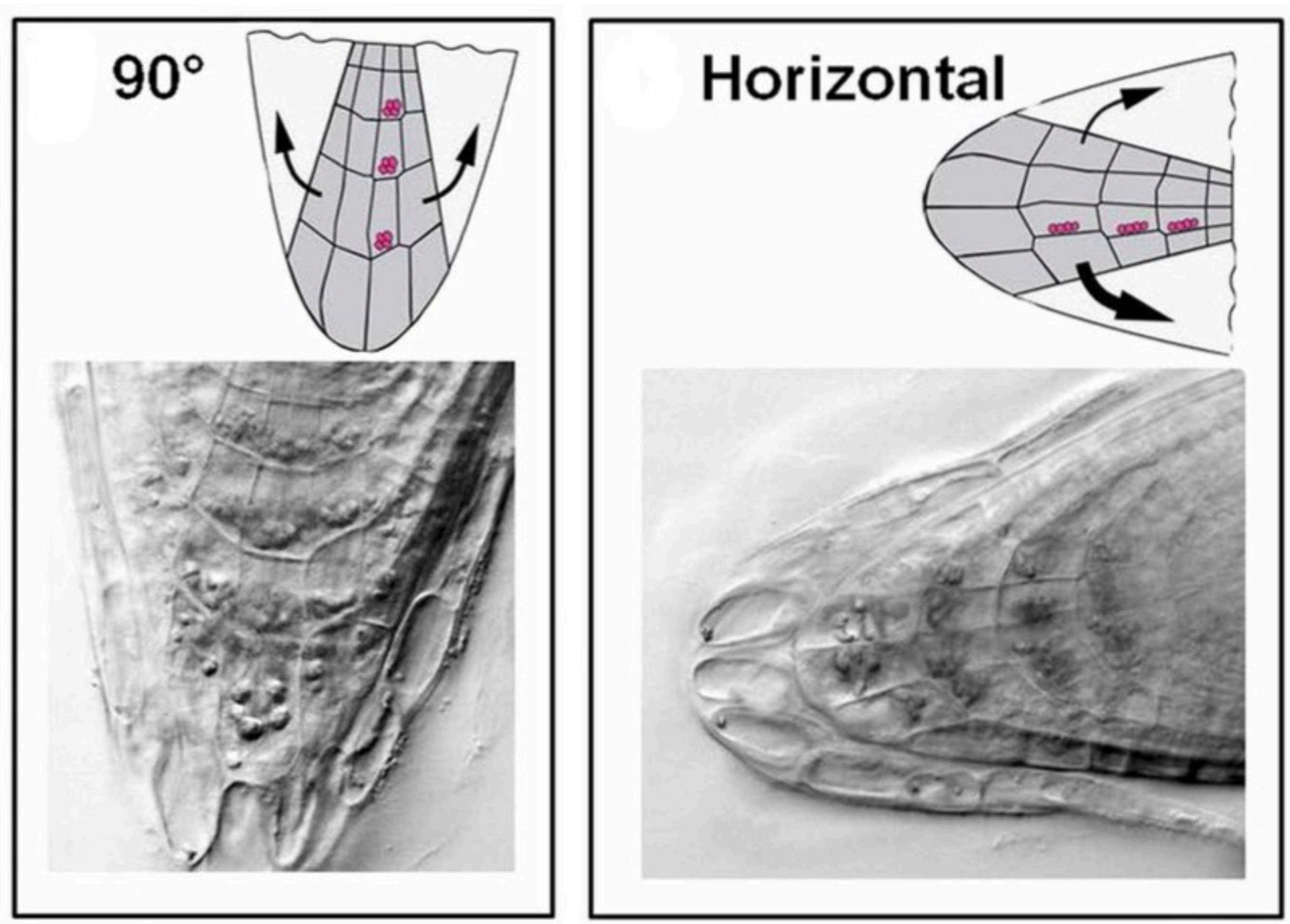
Modelling of auxin dynamics in the root

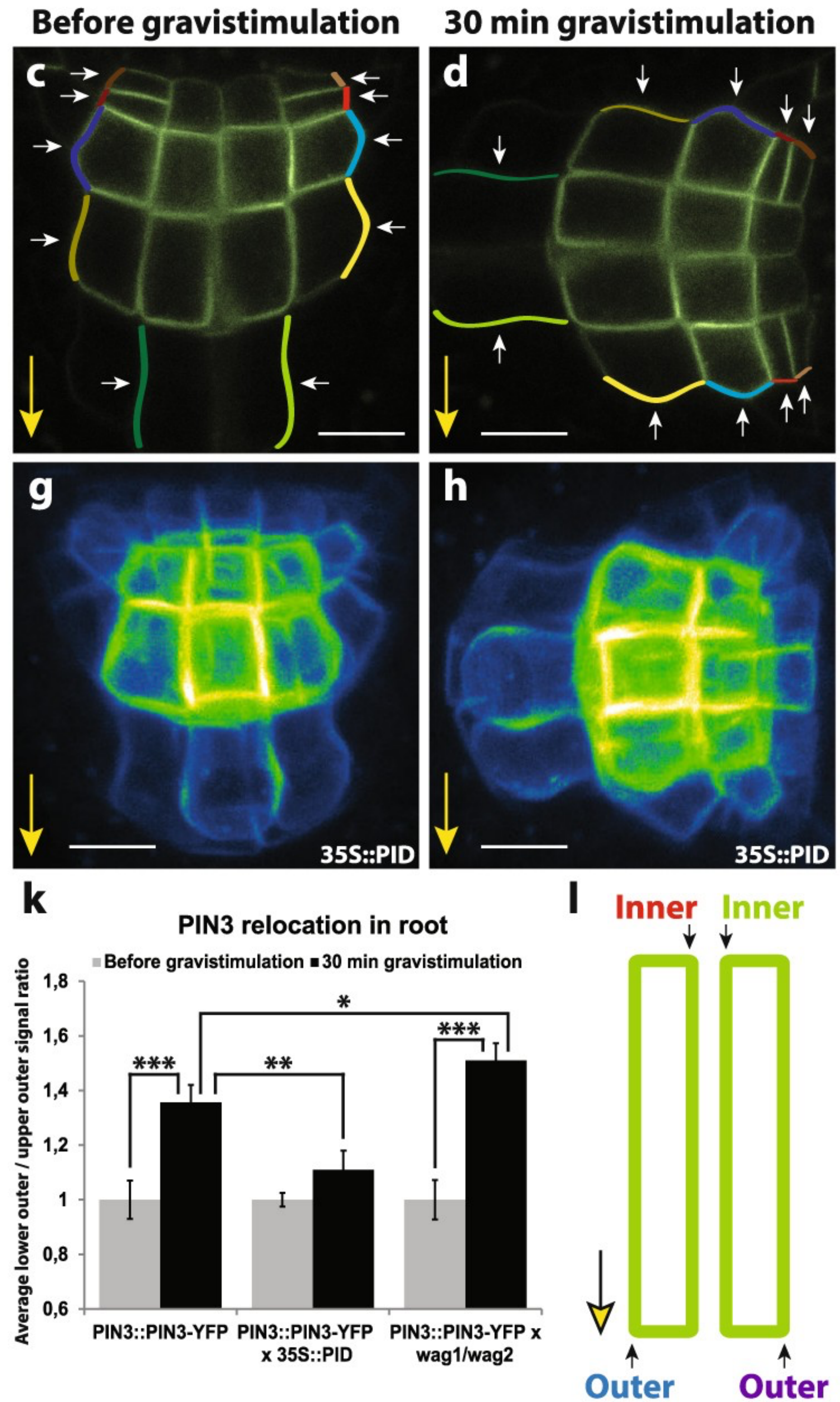


Zone
of cell
elongation
Zone of
cell division
(encased by
peripheral
root cap)
Columella root cap
Auxin transport
from shoot
PIN1
PIN2
PIN2
PIN-dependent
auxin recycling
PIN3
PIN4
Stem cell niche
Auxin maximum

Gravity and PIN3 mediated redirection of auxin flow at the root tip regulates the direction of root growth

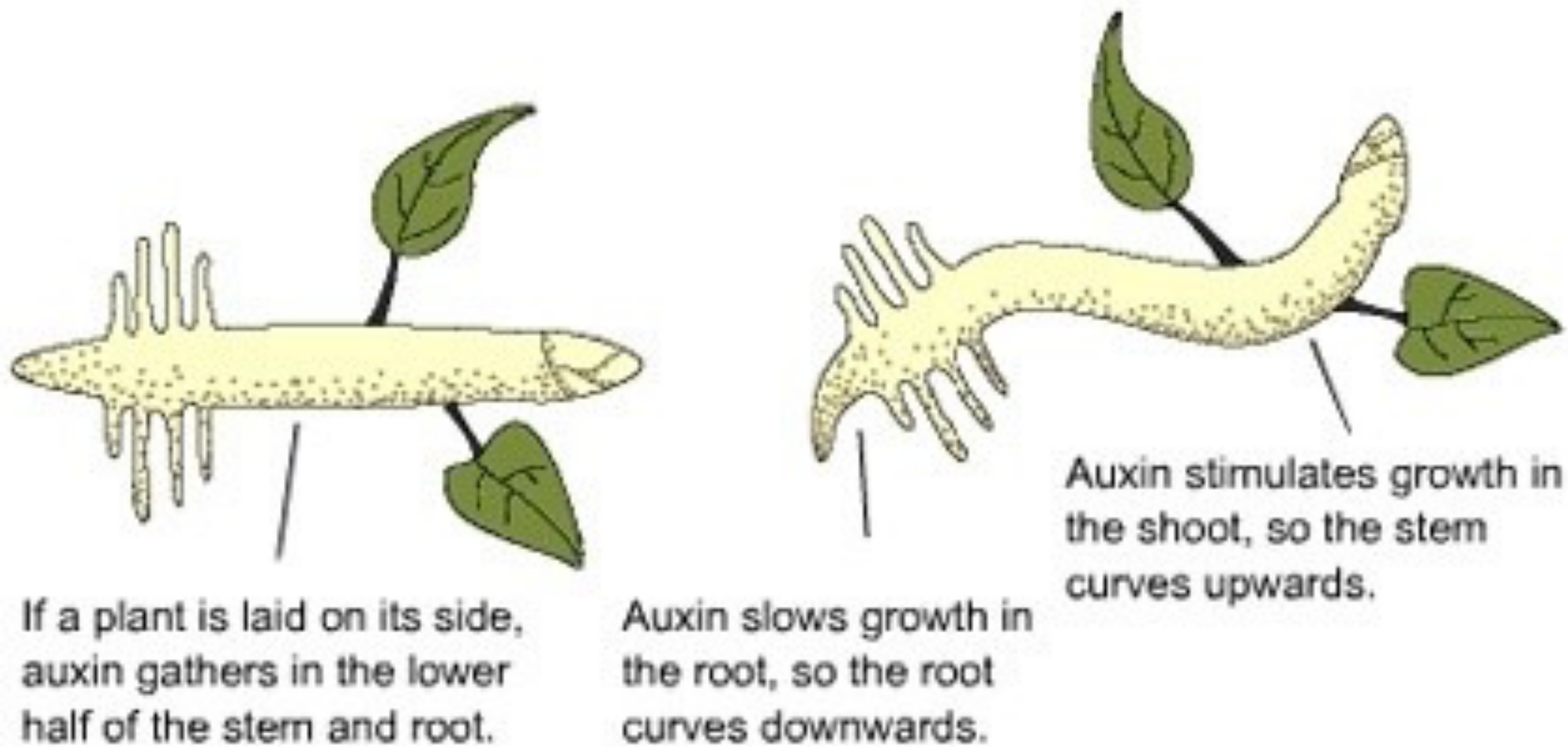




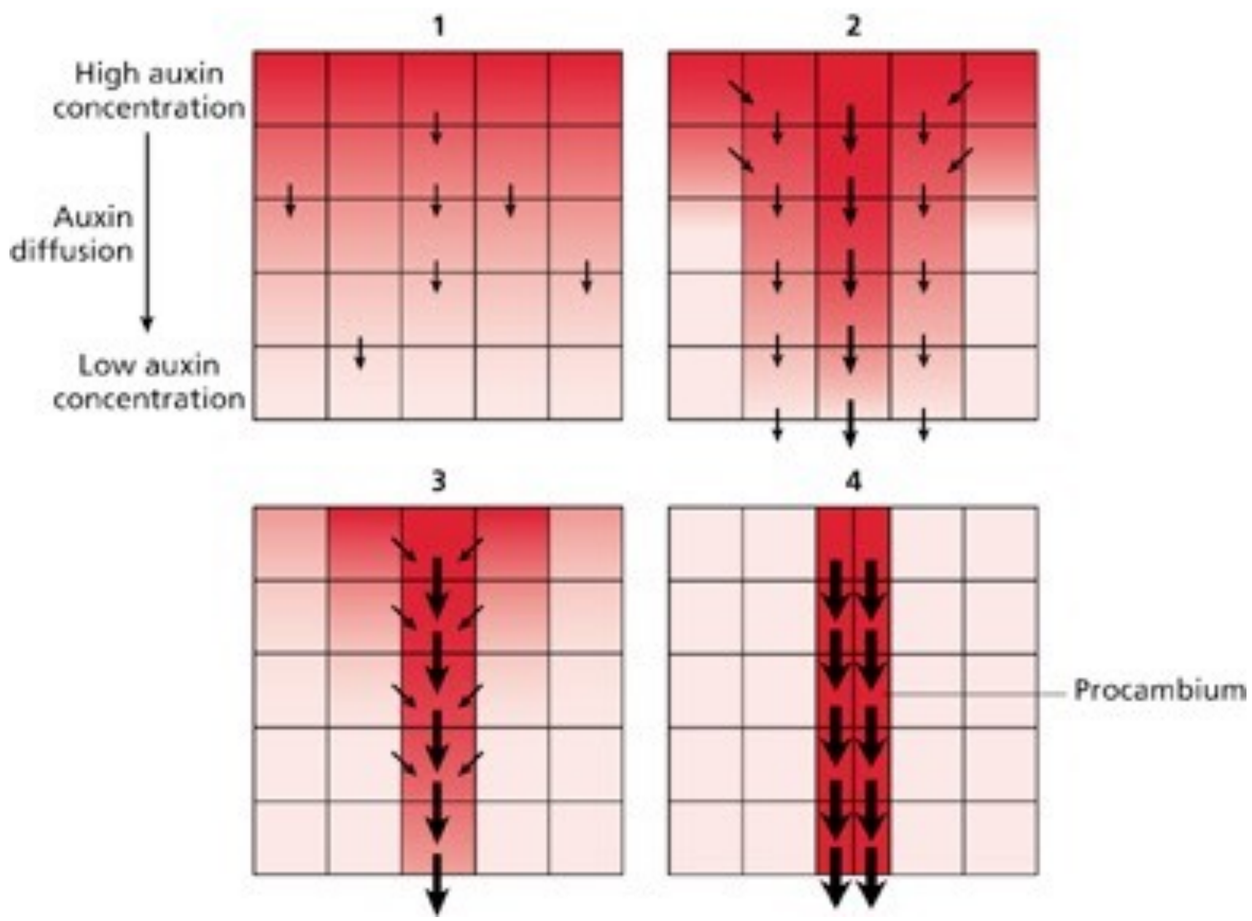


Gravitropic relocalisation of PIN3 protein in the Arabidopsis root columnella

PID/WAG-mediated phosphorylation of the Arabidopsis PIN3 auxin transporter mediates polarity switches during gravitropism. Peter Grones, Melinda Abas, Jakub Hajný, Angharad Jones, Sascha Waidmann, Jürgen Kleine-Vehn & Jiří Friml. Scientific Reports 8: 10279 (2018)


If a plant is laid on its side, auxin gathers in the lower half of the stem and root.
Auxin slows growth in the root, so the root curves downwards.
Auxin stimulates growth in the shoot, so the stem curves upwards.

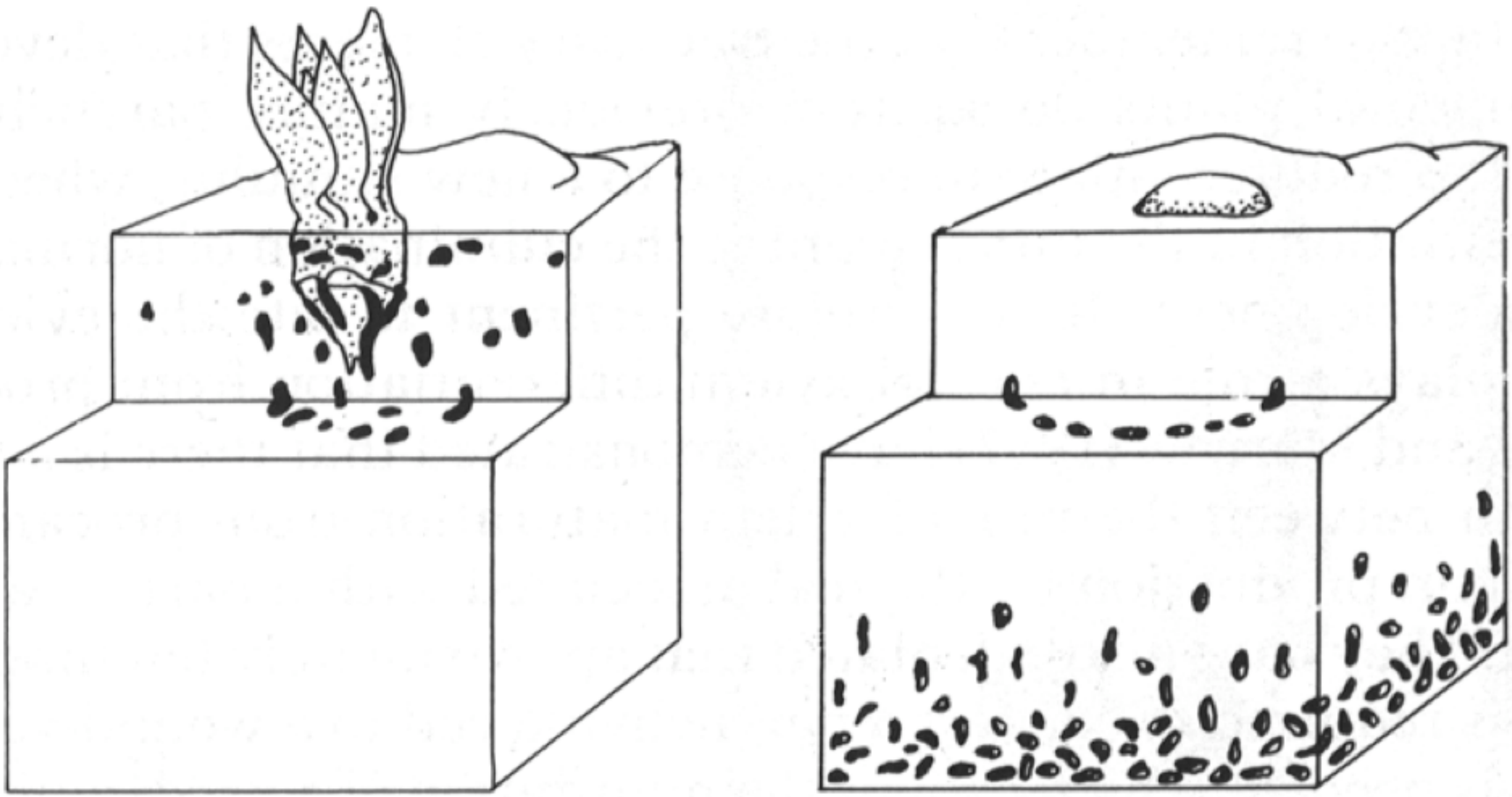
Feedback-regulated traffic of auxin coordinates polar coordination of plant cell growth



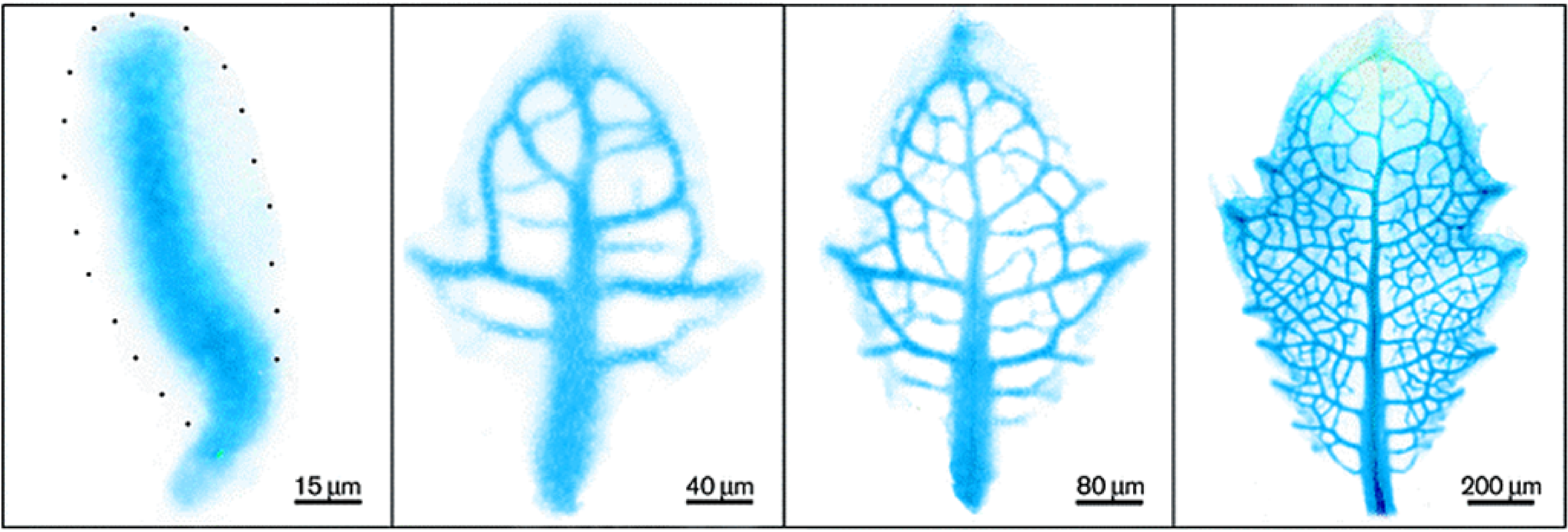
"Canalisation" of auxin flow

It provides both long-range coordination of plant architecture, and a short-range mechanism for controlling individual cell fates.

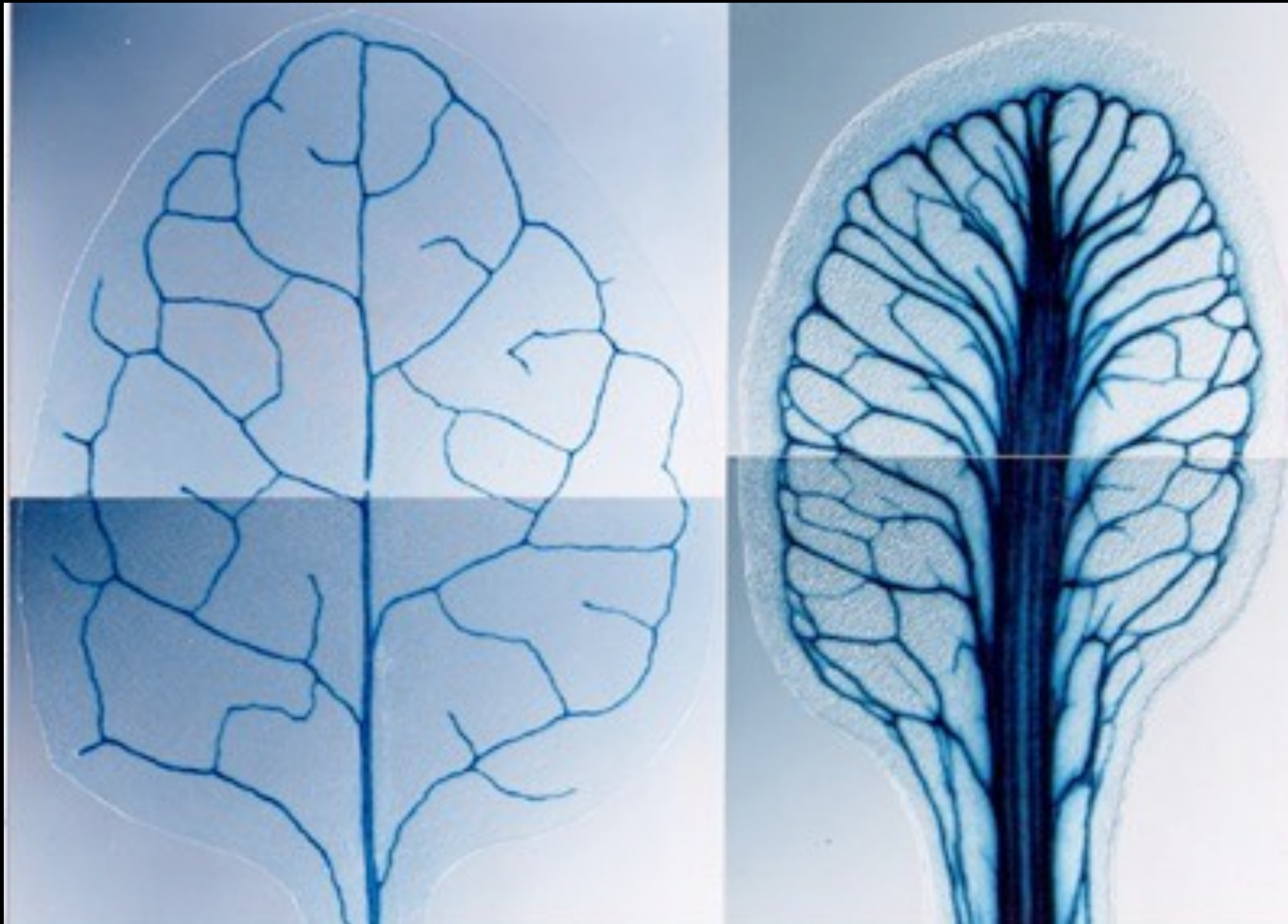
- Embryo patterning
- Meristematic growth
- Vascular development



Elaboration of vascular cell fates in developing Arabidopsis leaves

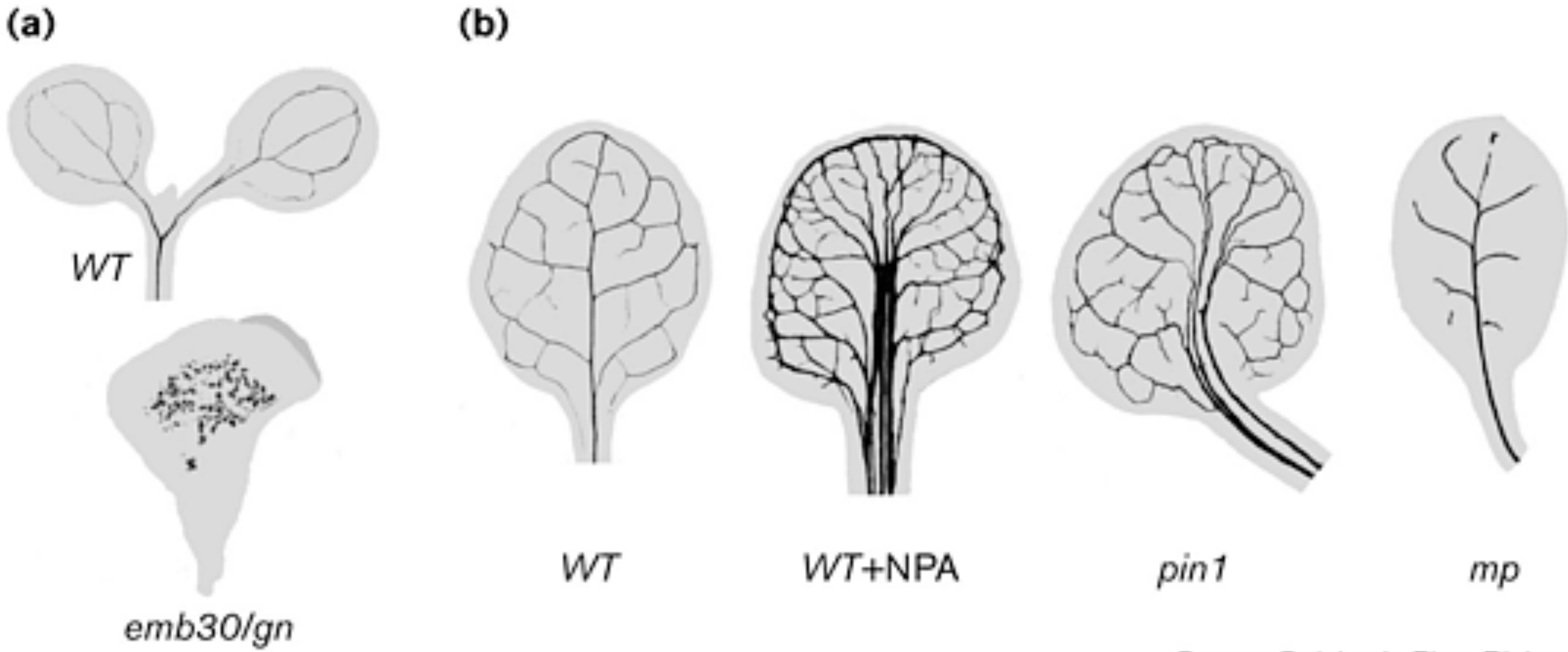


ATHB8:GUS expression



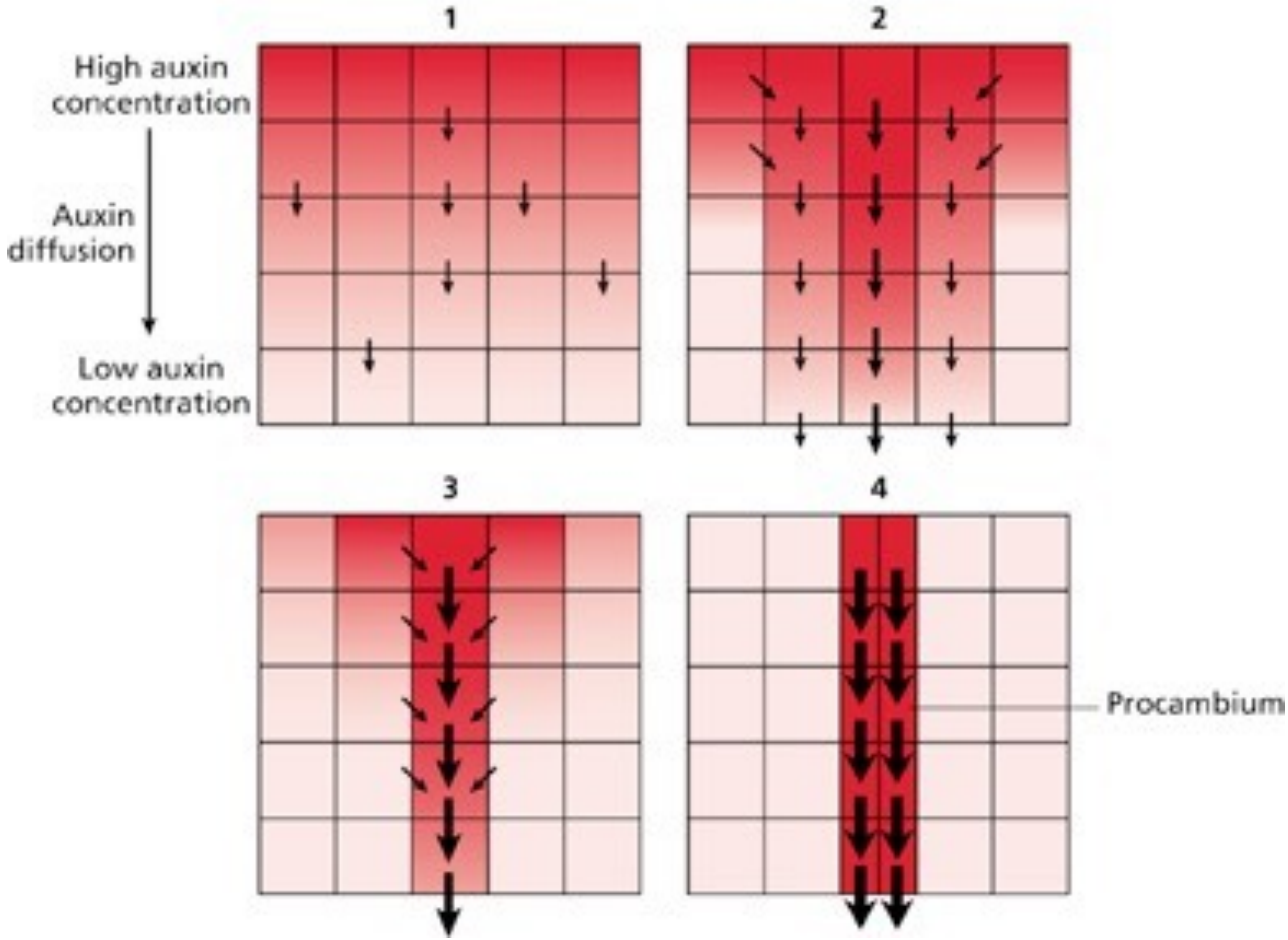
Inhibition of auxin transport by application of NPA

Defects in auxin transport or response affect patterning of the plant vascular system



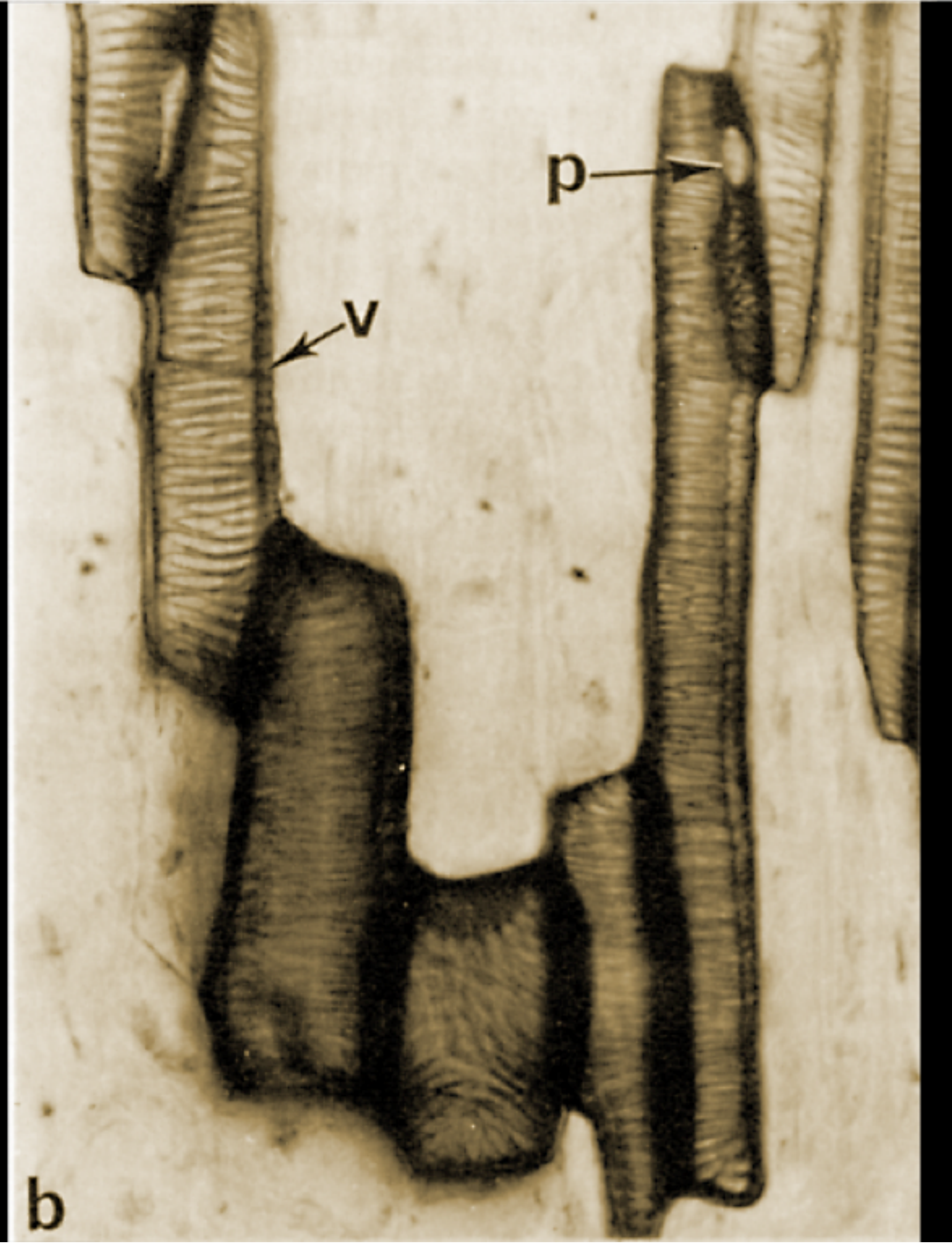
Current Opinion in Plant Biology

“Canalisation” of auxin flow



Coleus stem:
needle puncture of vascular trace

Coleus stem:
differentiation of new xylem vessels in response to local wounding



Traffic of auxin plays a key role in coordination of whole plant growth