

# 2018 CDB Part IB

## Plant Development

### Lecture 1

## Plant architecture and embryogenesis

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# Plant Development

**Lecture 1: Plant architecture and embryogenesis.**

**Lecture 2: Polarity and auxin flow.**

**Lecture 3: Regulation of gene expression by auxin.**

**Lecture 4: Patterning of indeterminate growth.**

**Lecture 5: Formation and specification of lateral organs.**

**Lecture 6: Morphogenesis.**

## Web resources:

An electronic version of the lecture slides, a colour version of these notes and additional teaching materials including review papers and essay topics can be found on the web site: <http://haseloff.plantsci.cam.ac.uk> (click the "education" menu choice and navigate to the CDB Part 1B resources section).

## Recommended Text books:

For an integrated overview of animal and plant development see:

***Principles of Development*, Lewis Wolpert and Cheryll Tickle, Oxford University Press, 2011.**

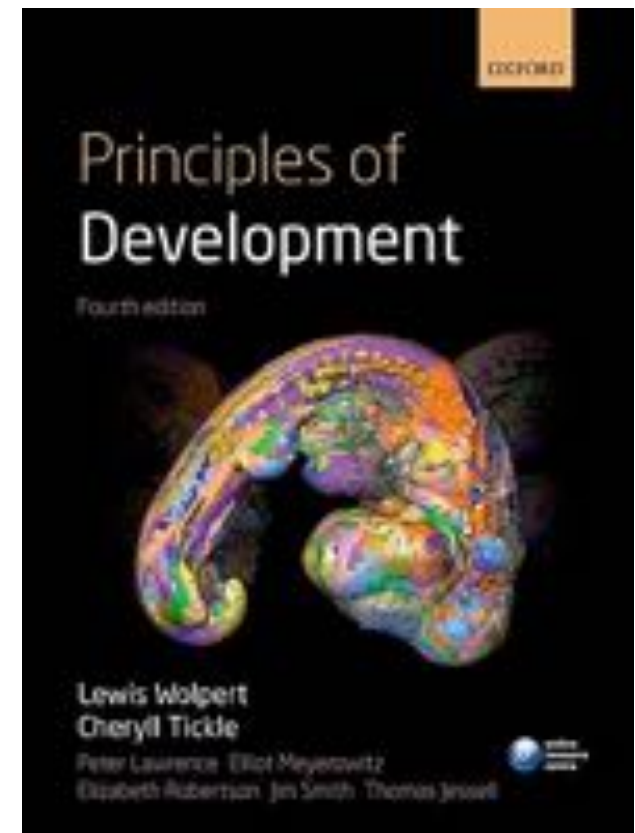
Chapter 7 provides a concise overview of the lecture content.

For coverage of plant development see:

***Mechanisms in Plant Development*, Ottoline Leyser & Stephen Day, Blackwell Science, UK, 2002.**

For a general discussion of self-organisation across physical and biological systems see:

***Nature's patterns: a tapestry in three parts, Shapes, Flow and Branches*, Phillip Ball, Oxford University Press, 2009.**

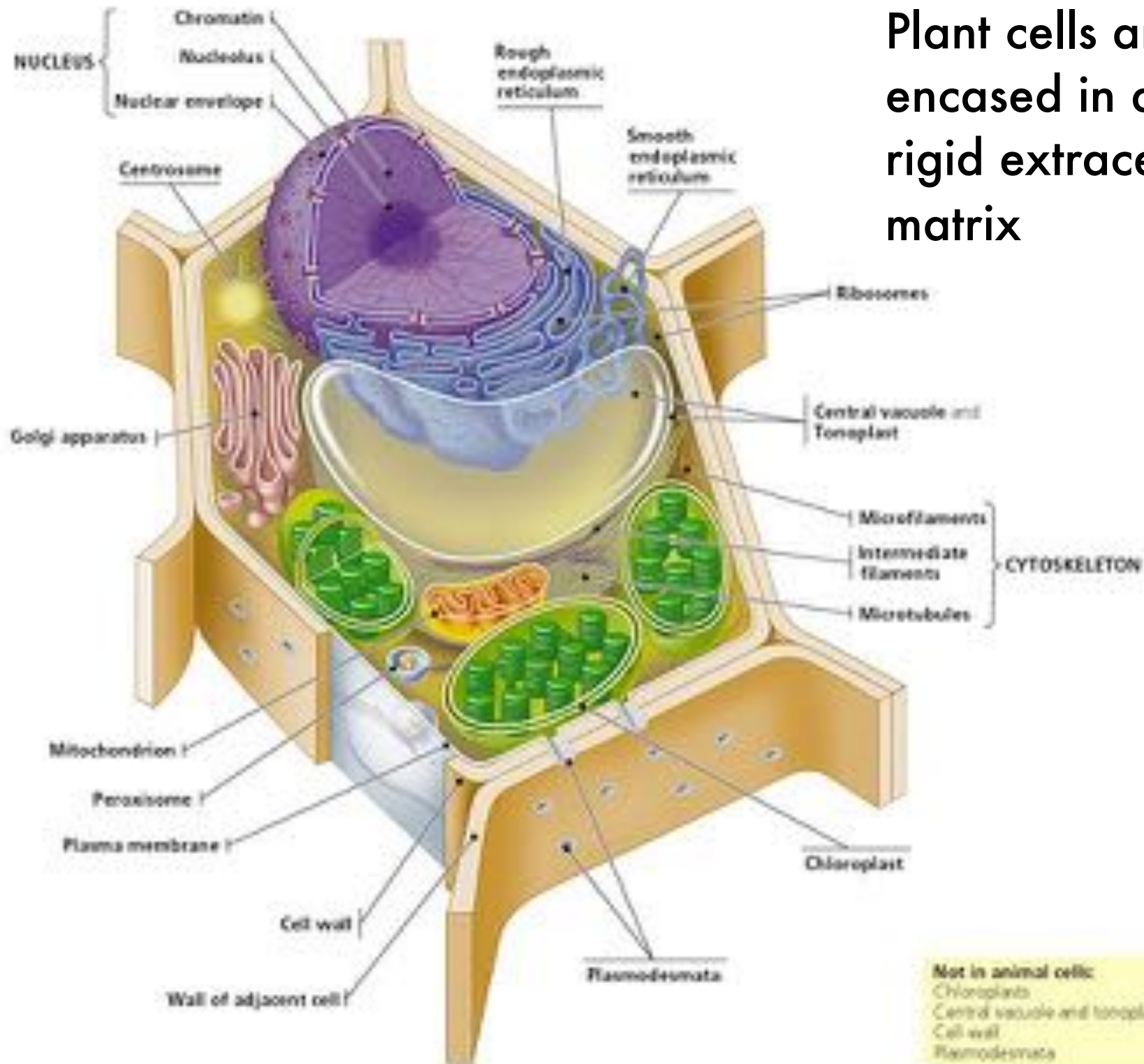


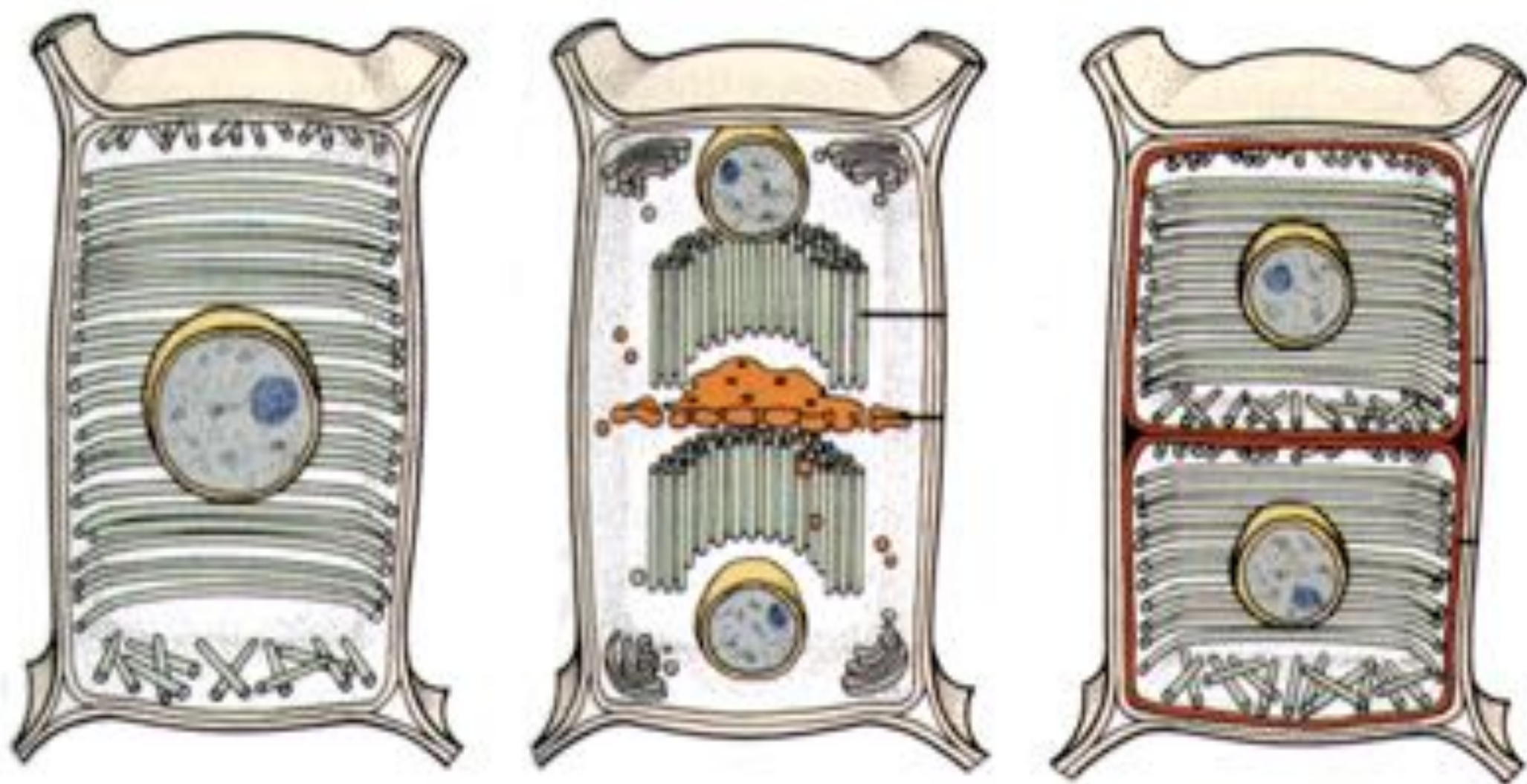


Immobile and Branched



Plant cells are encased in a semi-rigid extracellular matrix



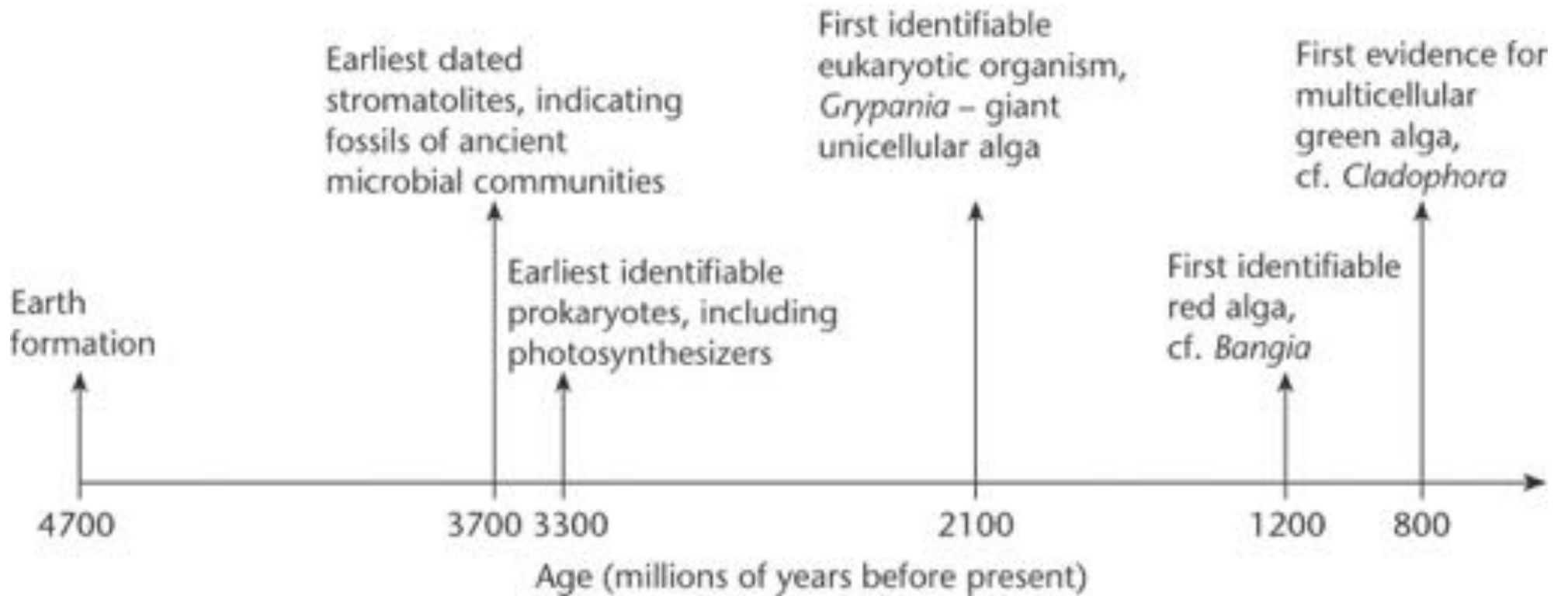


***Deposition of new cell walls during plant cell division.***

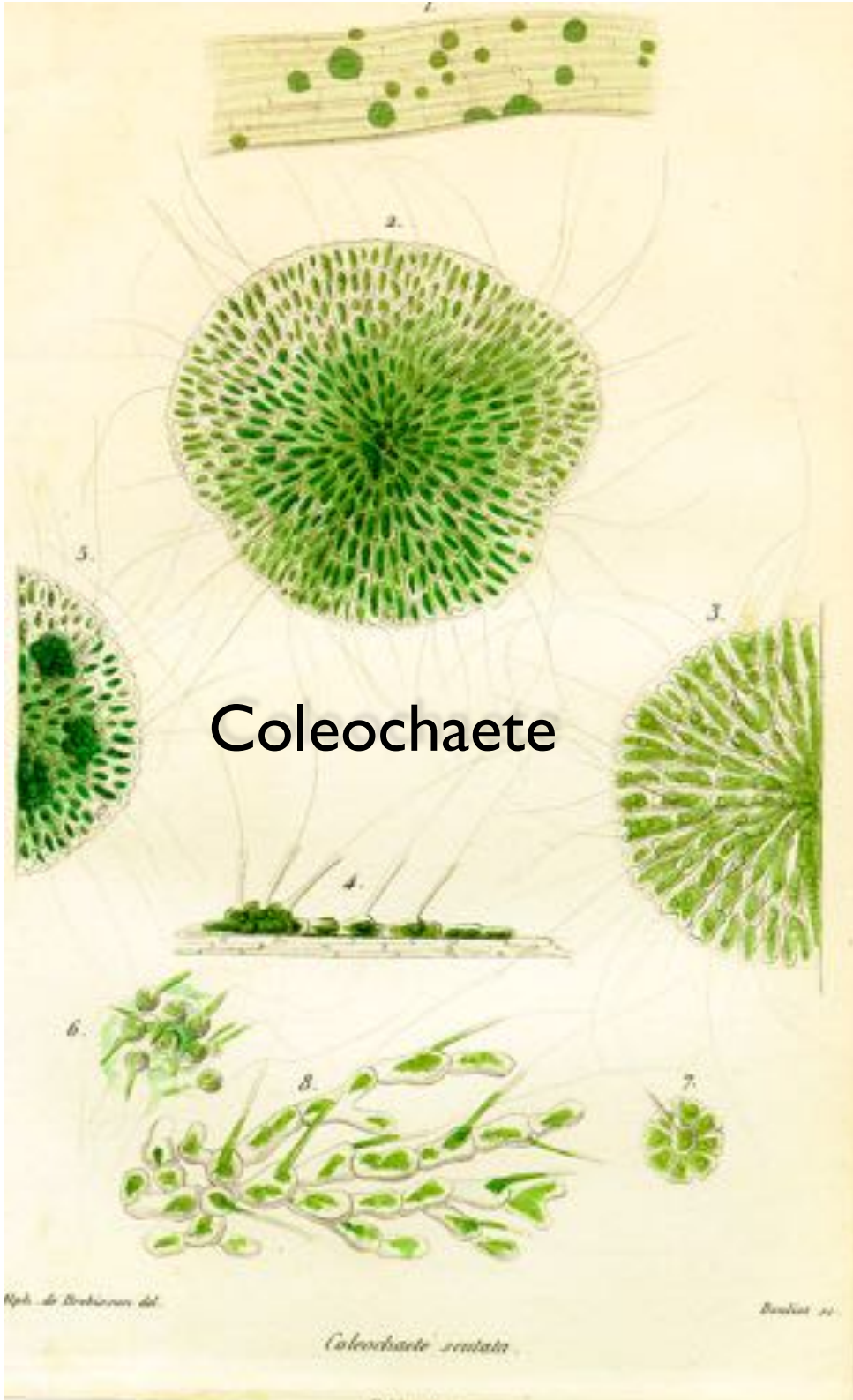
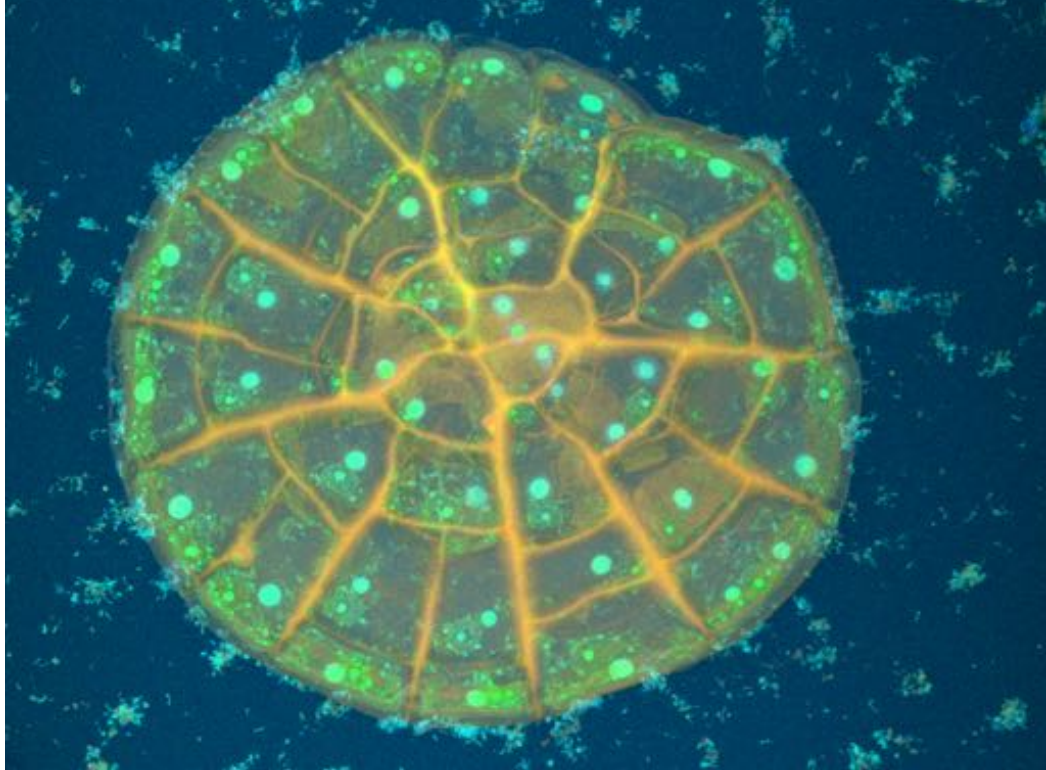
# Plant Morphogenesis







# Origin of terrestrial plants



Coleochaete





Colonisation of the land by plants

# Different conditions faced by algae and plants

Supportive medium (water)

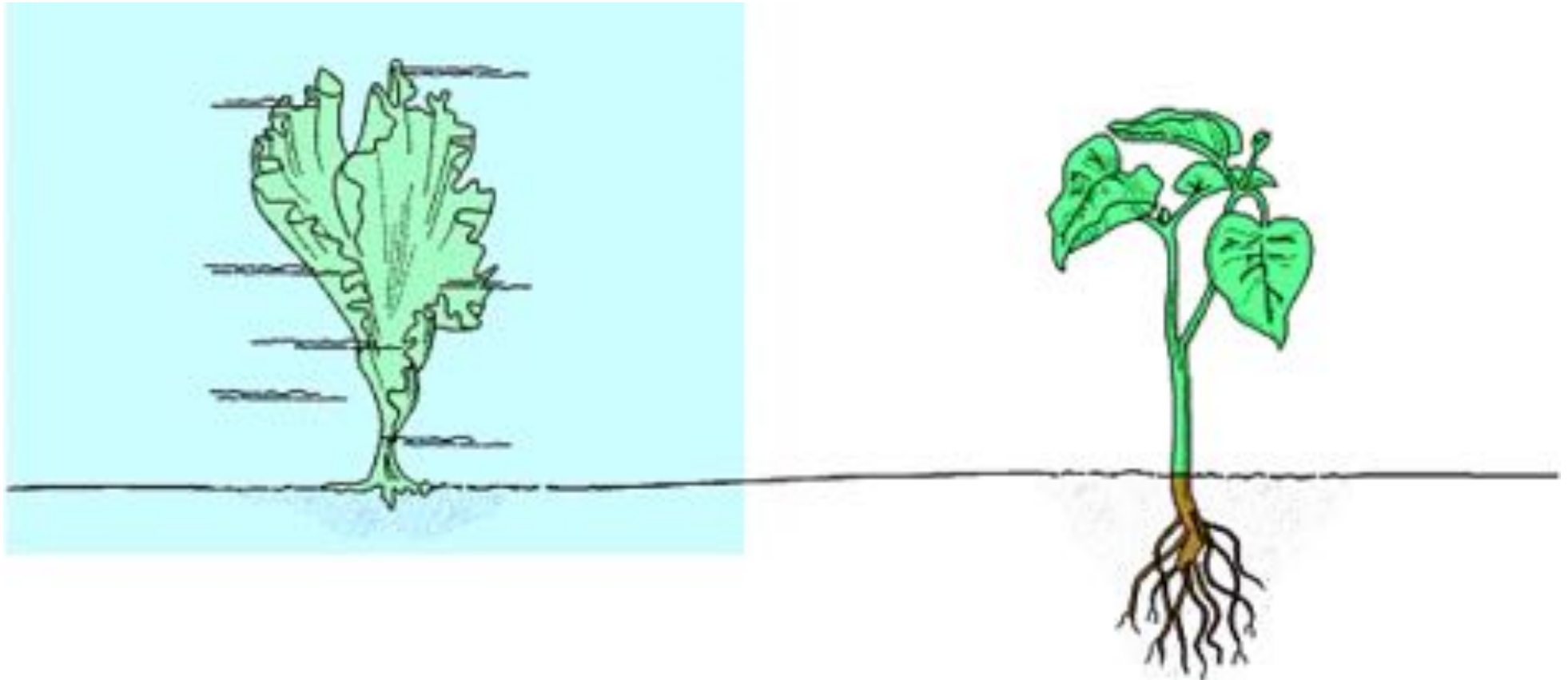
Photosynthesis in most cells

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

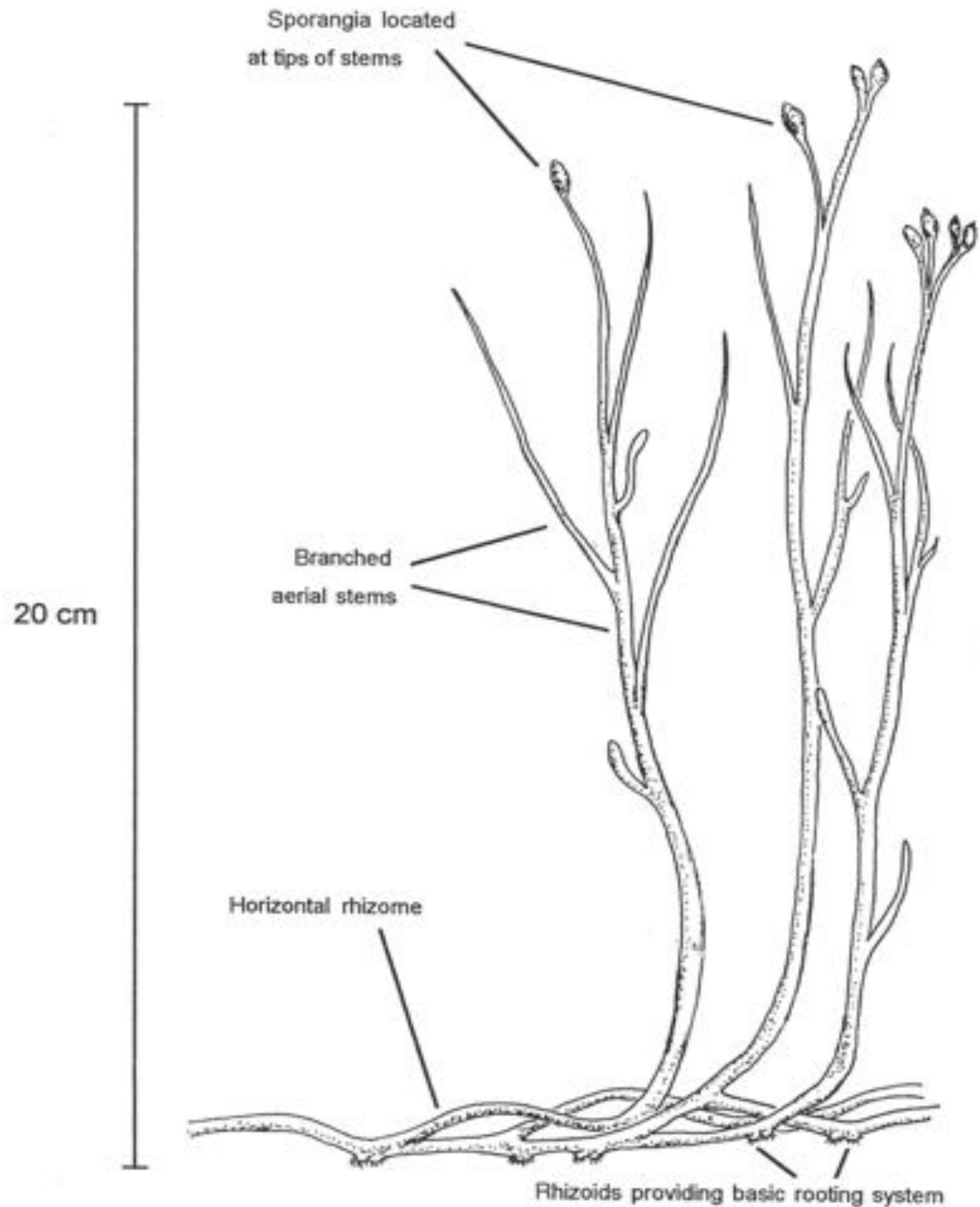






400 mya

# Early terrestrial plants

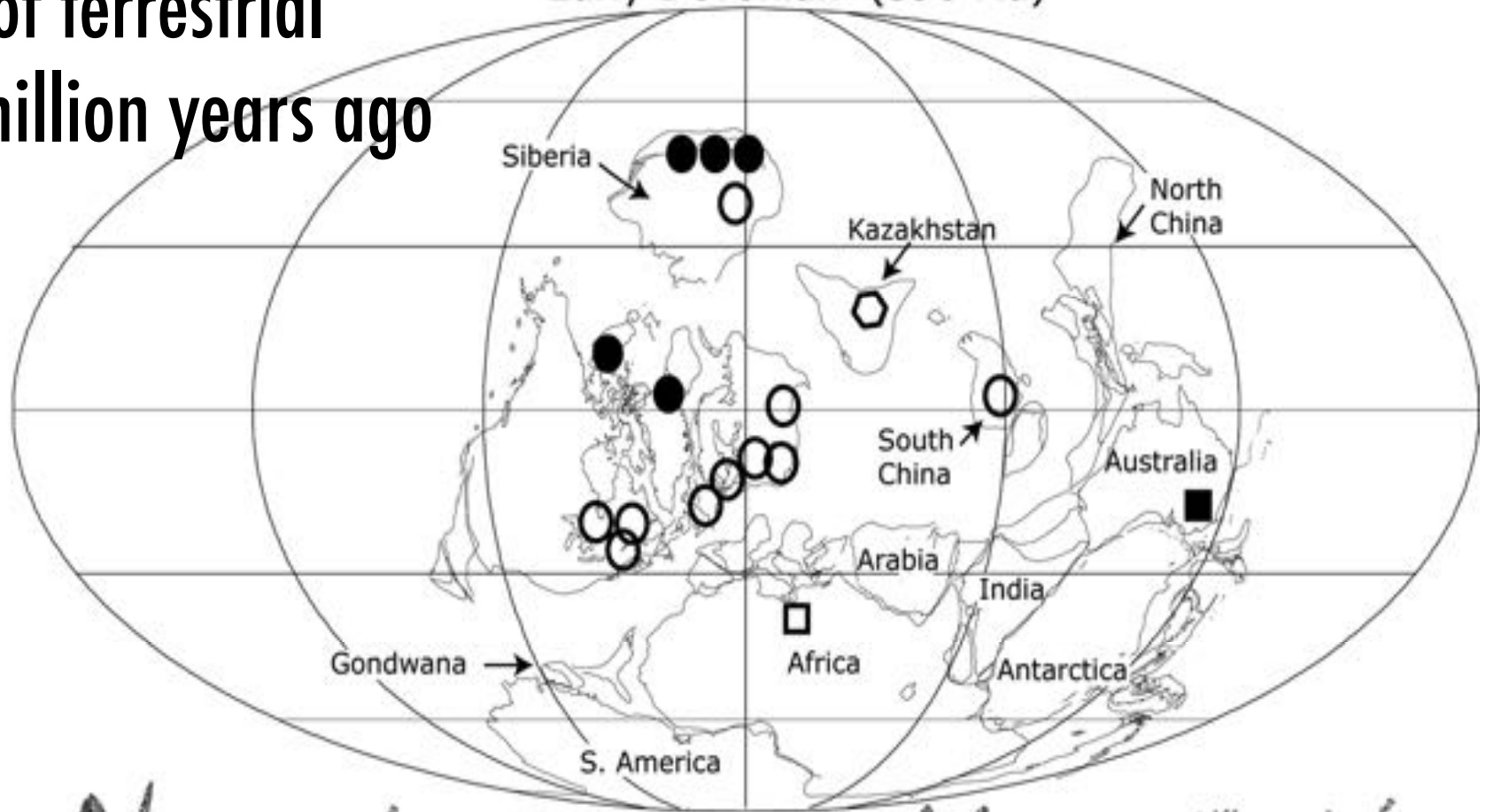


*Aglaophyton major*



# Distribution of terrestrial plants 390 million years ago

Early Devonian (390 Ma)



Siberia-North Laurassia ●



Rebuchia



Protobarinophyton  
Barinophyton



Zosterophyllum

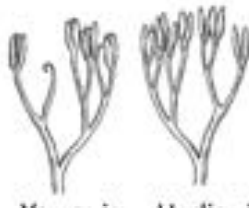


Psilophyton

Australia ■



Baragwanthia



Yarravia  
Hedia

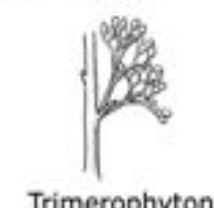


Zosterophyllum

South Laurassia ○



Pertica



Trimerophyton



Sawdonia



Psilophyton

Northern Gondwana □

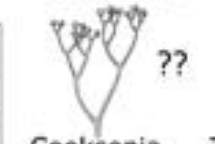


Cooksonia



Zosterophyllum

Kazakhstan ⬡

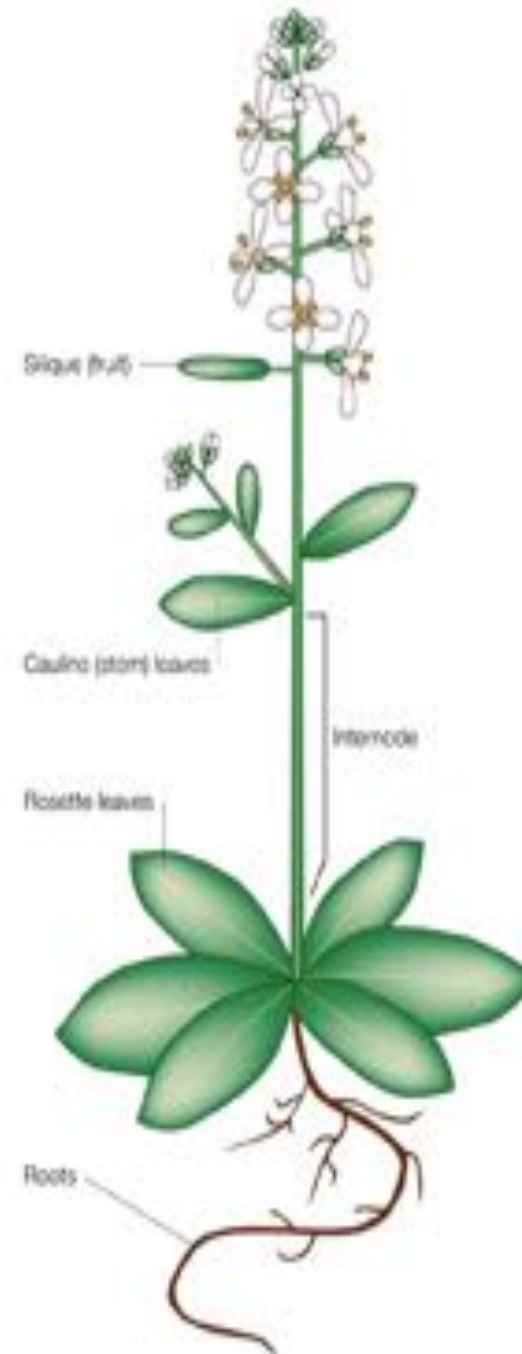


Cooksonia

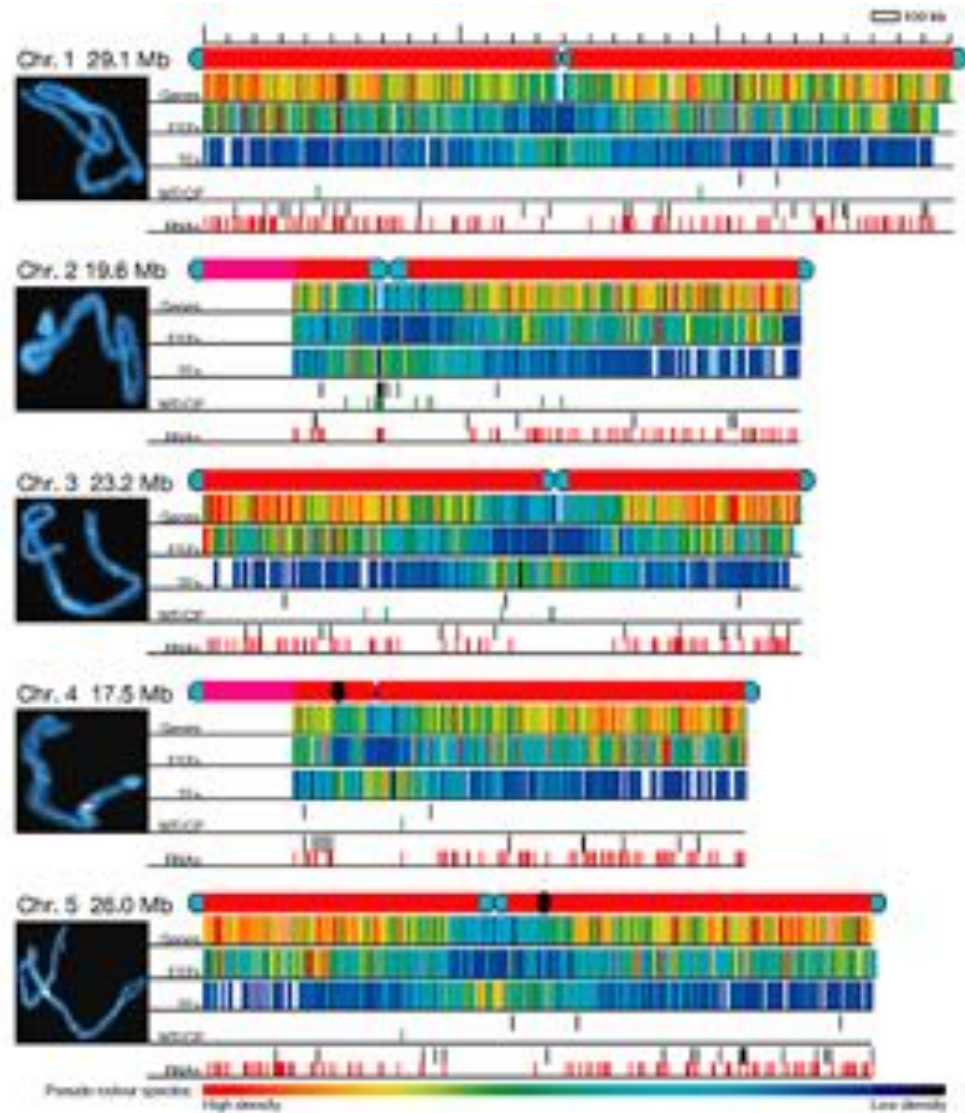


Zosterophyllum

# Arabidopsis thaliana as a model plant system



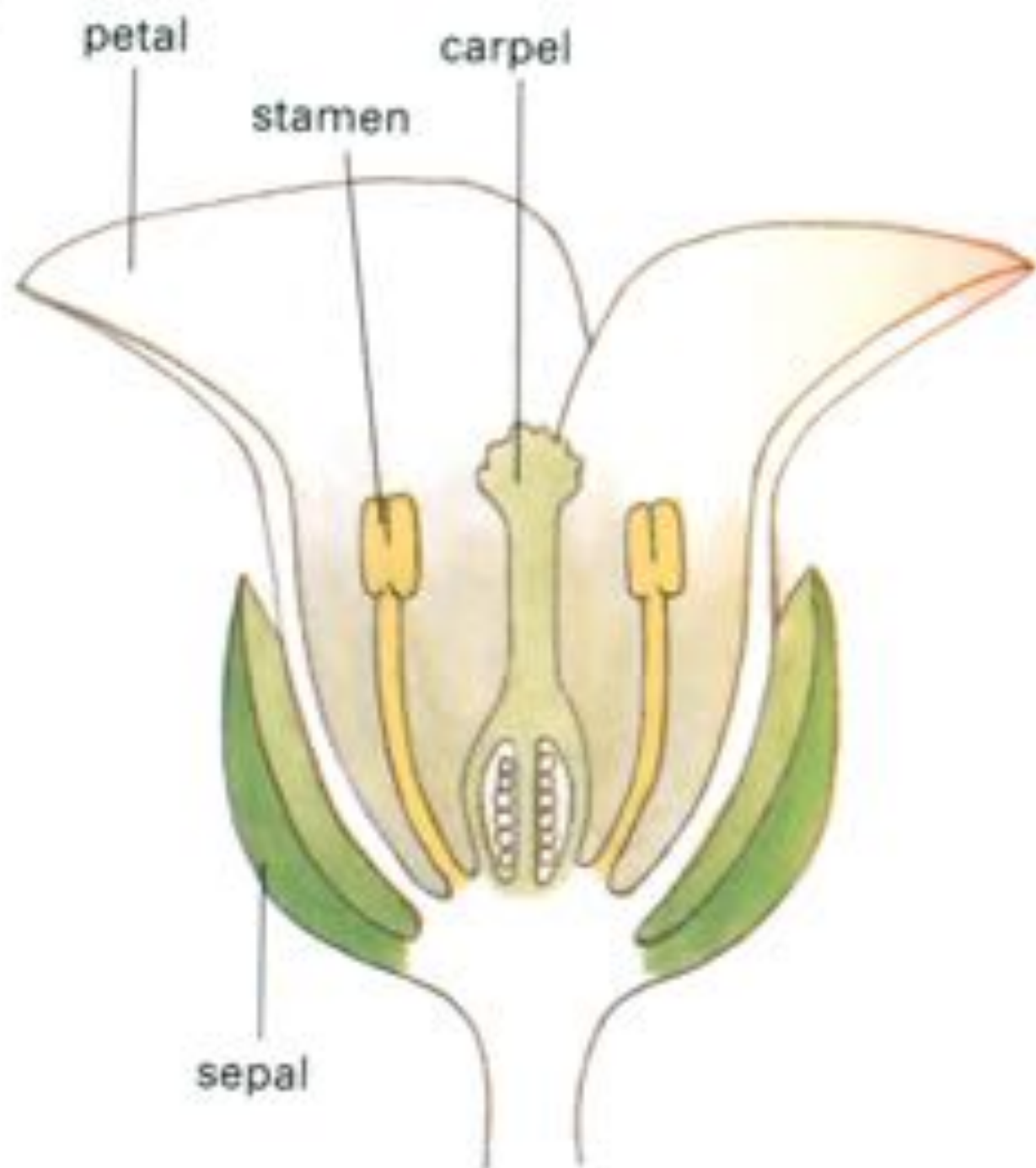
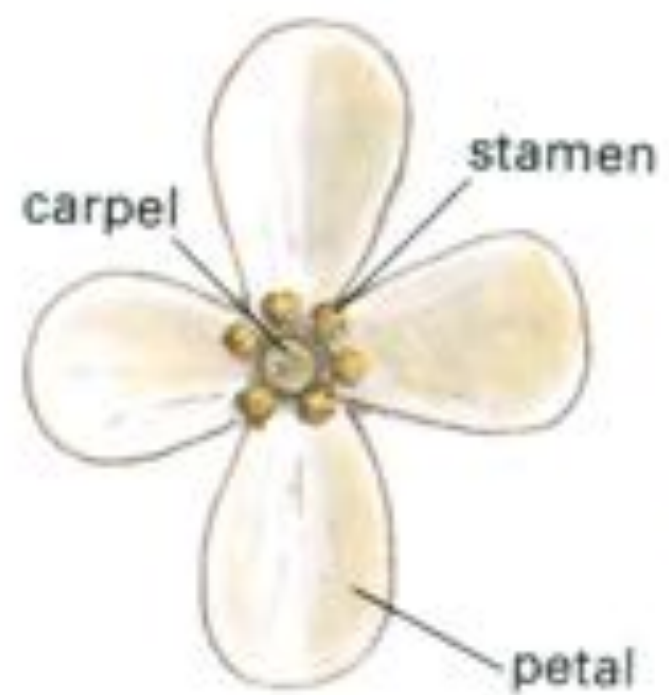


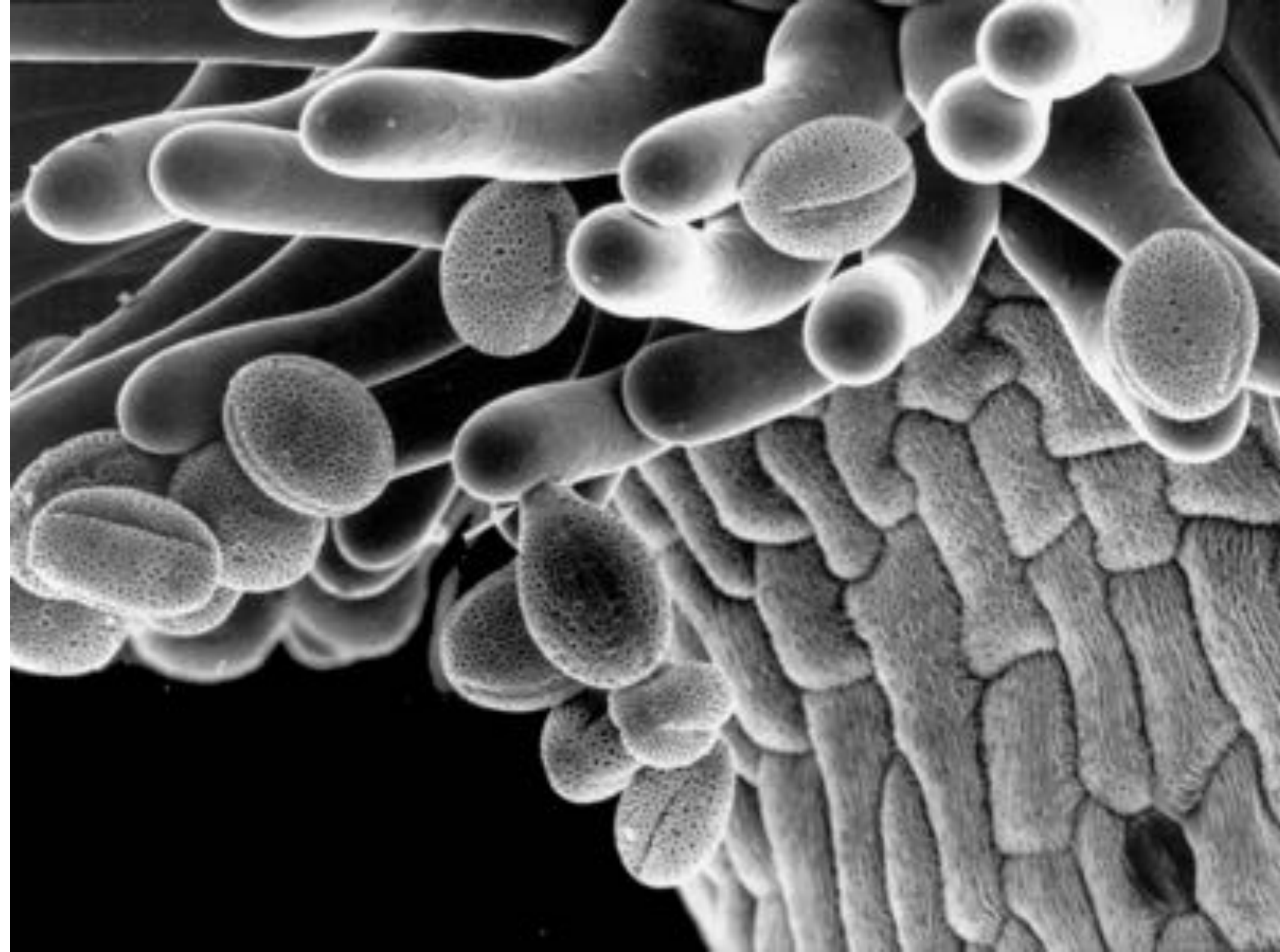


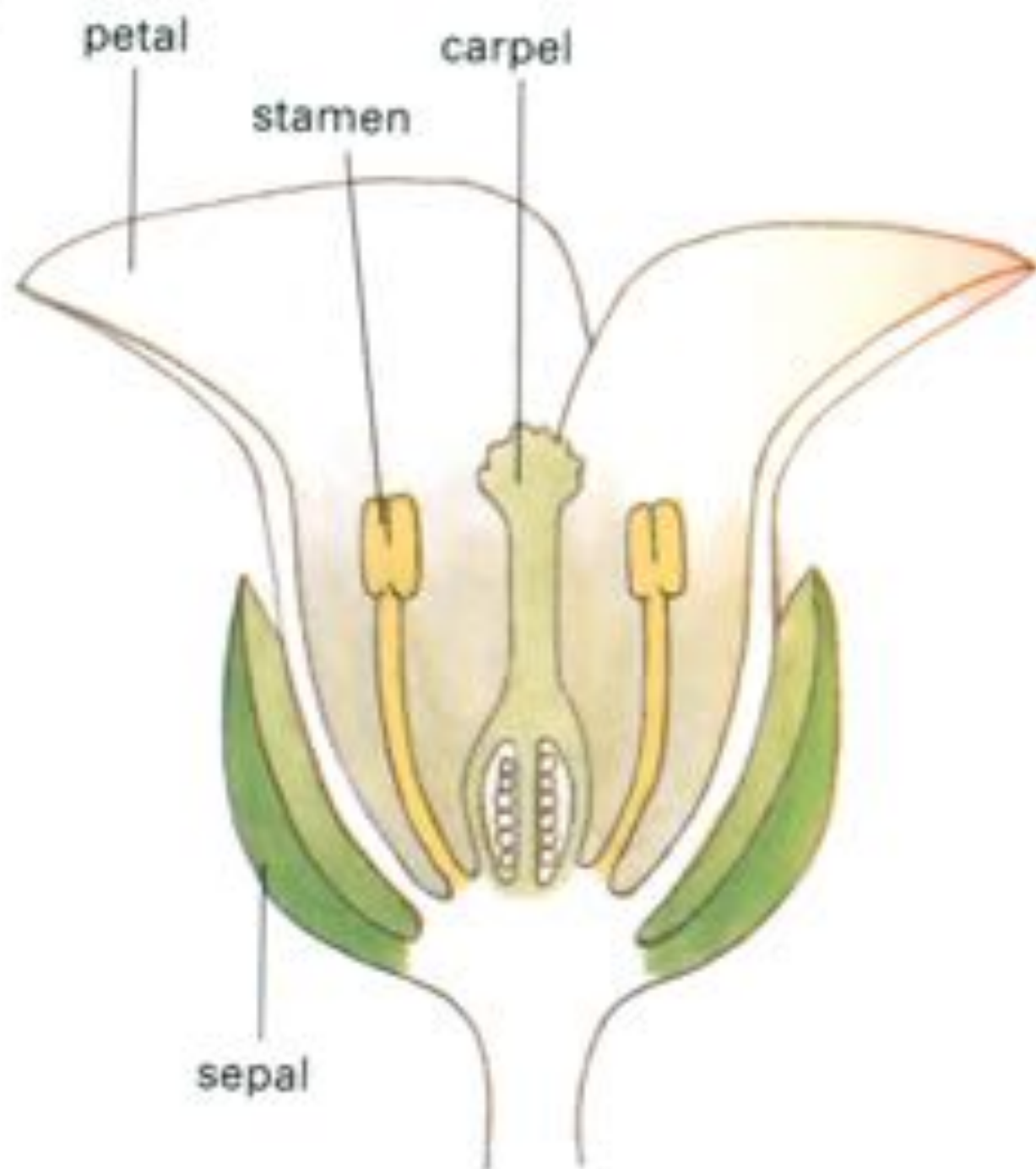
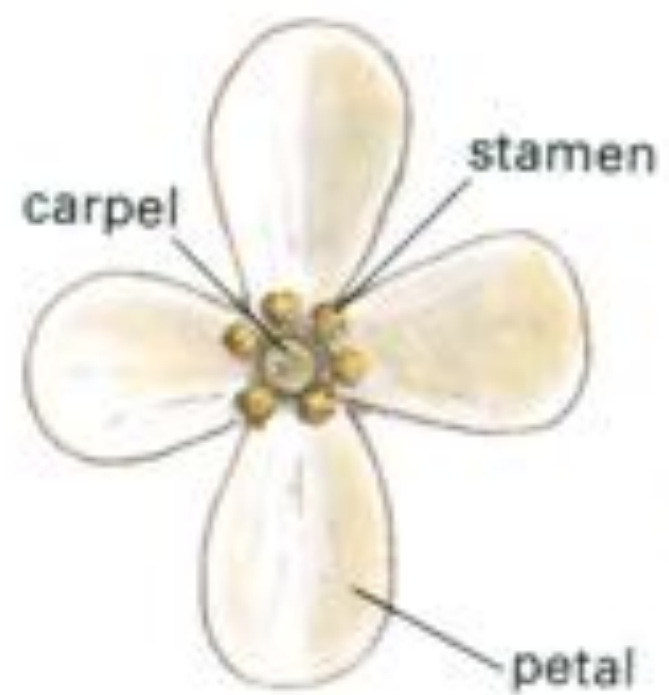
**Arabidopsis thaliana has the best characterised plant genome.**





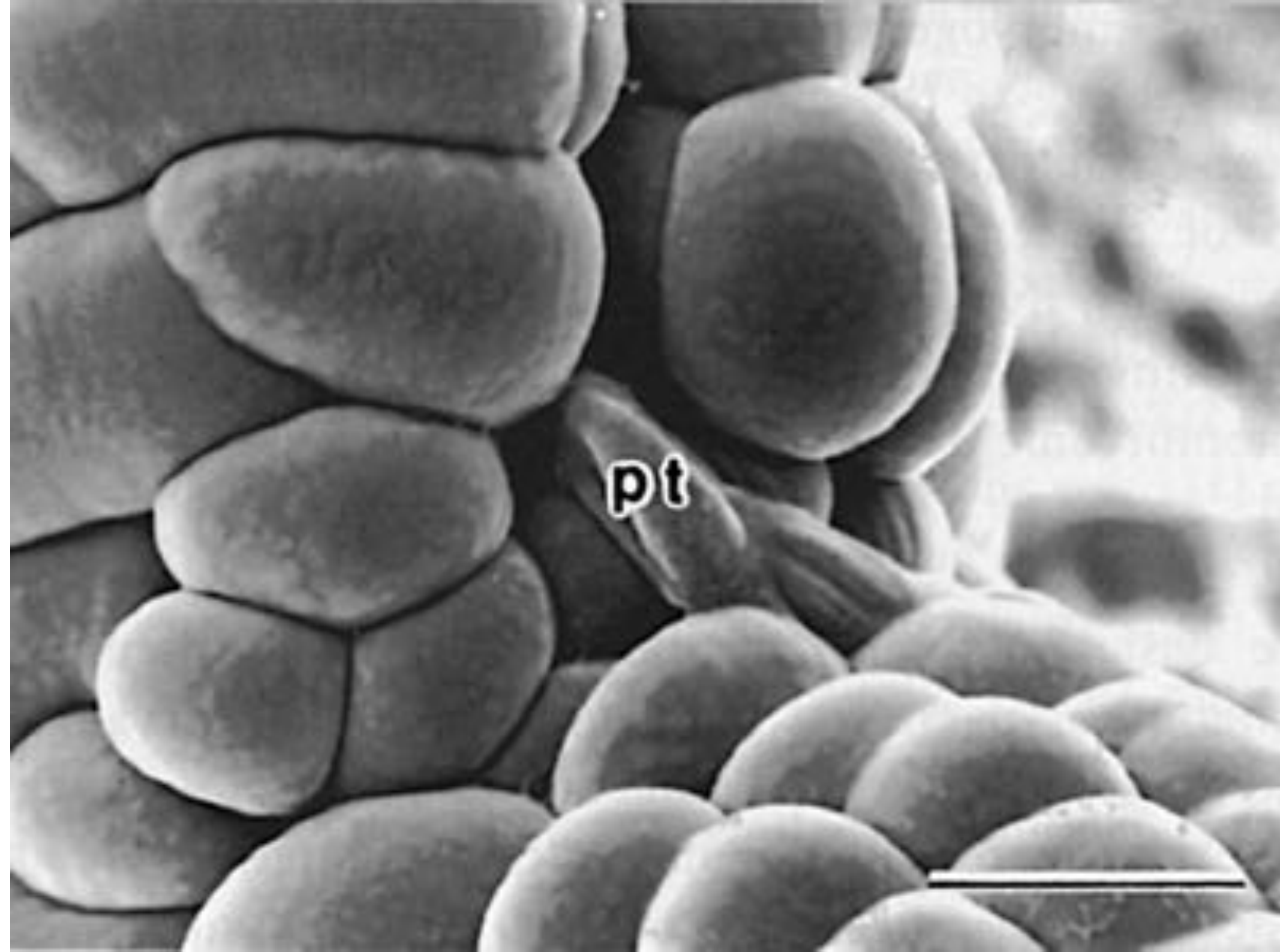


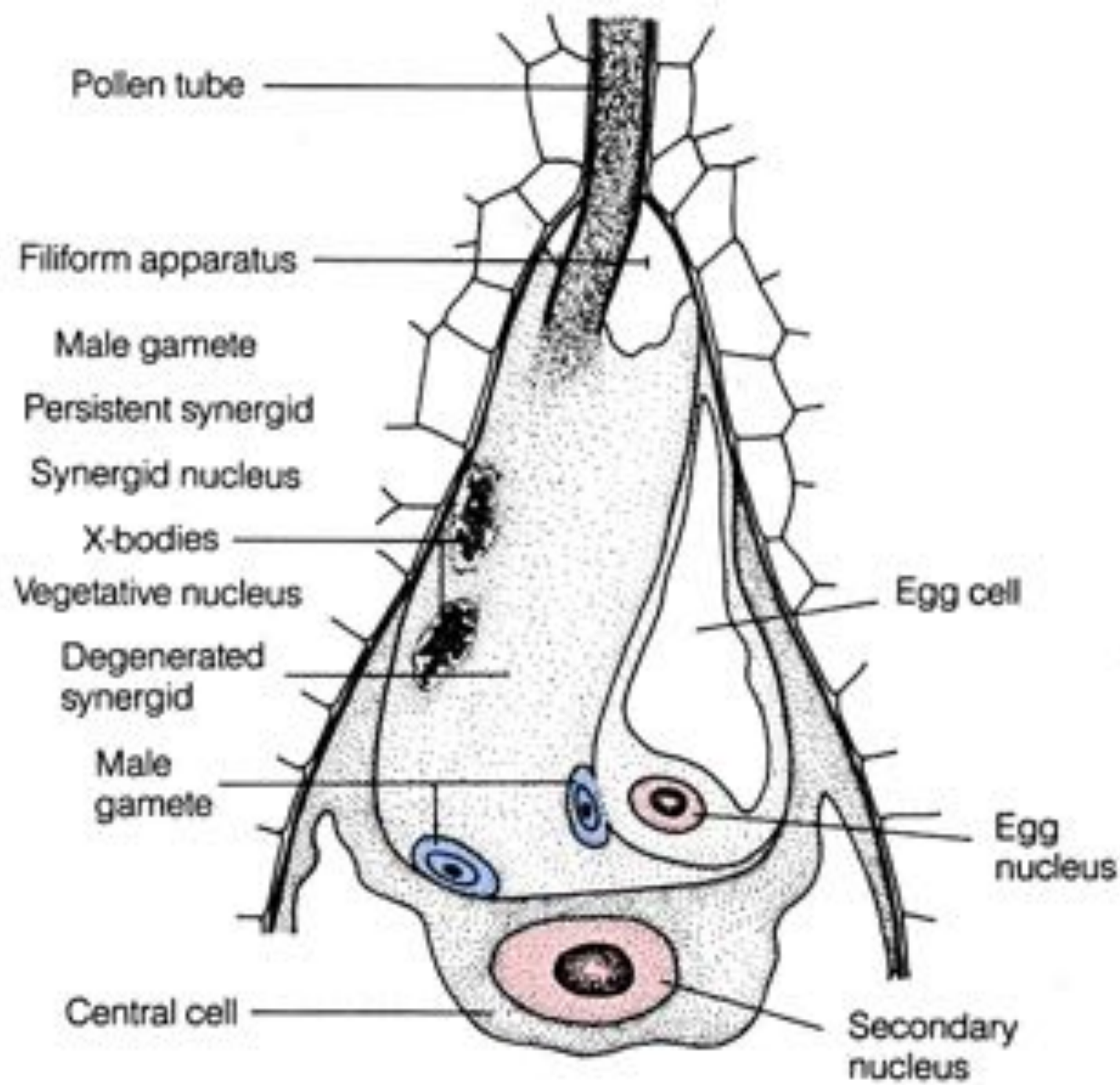




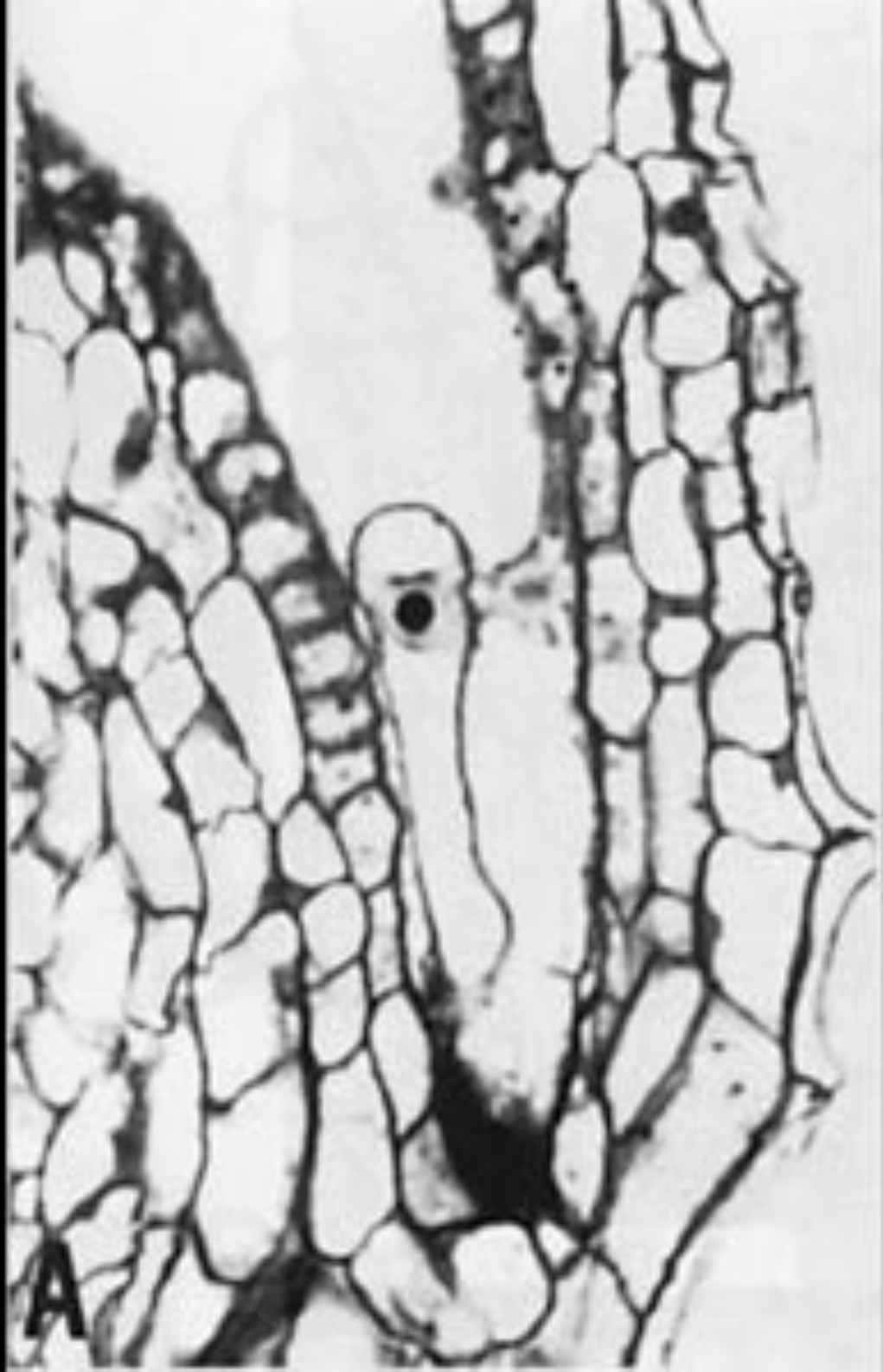


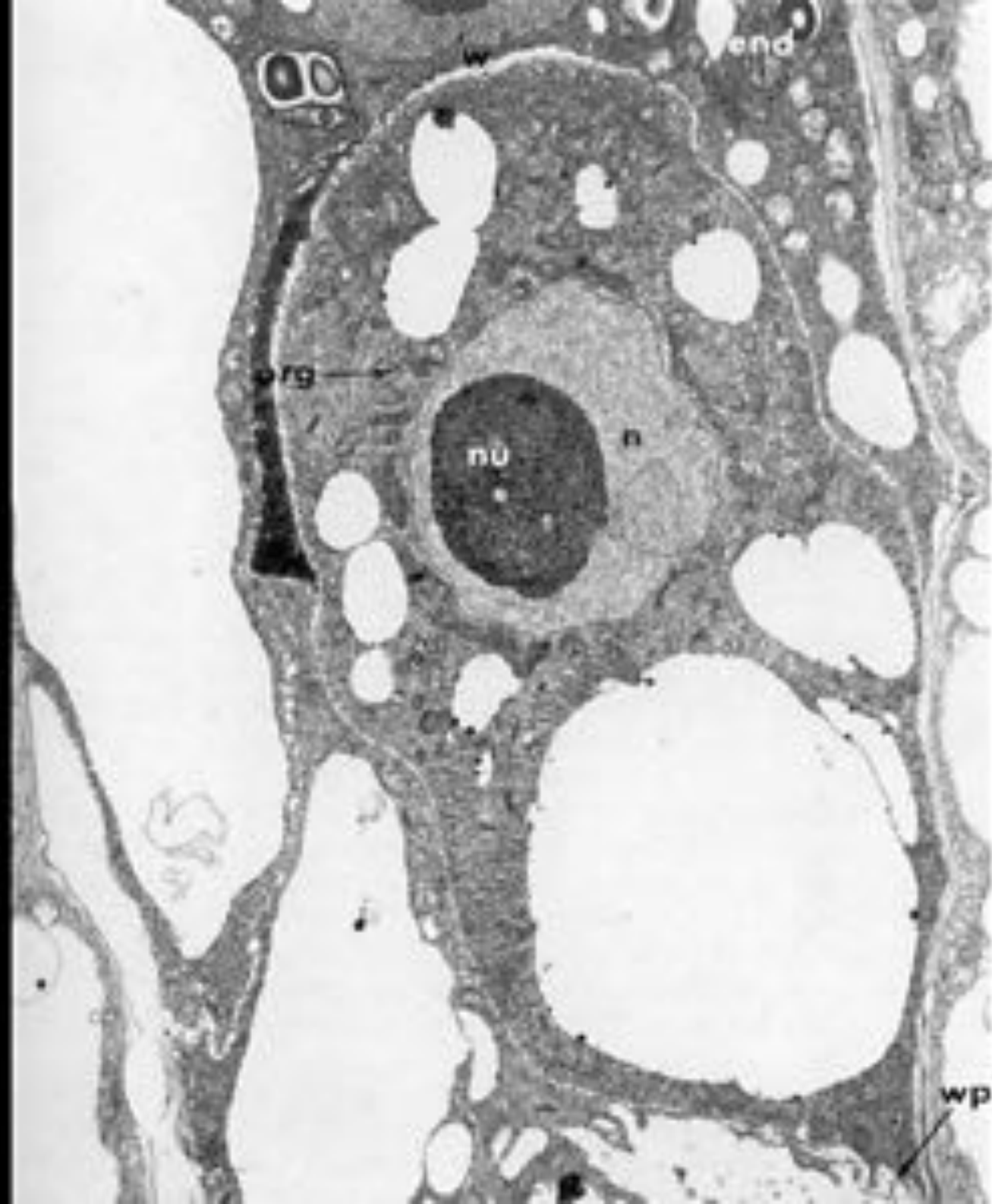




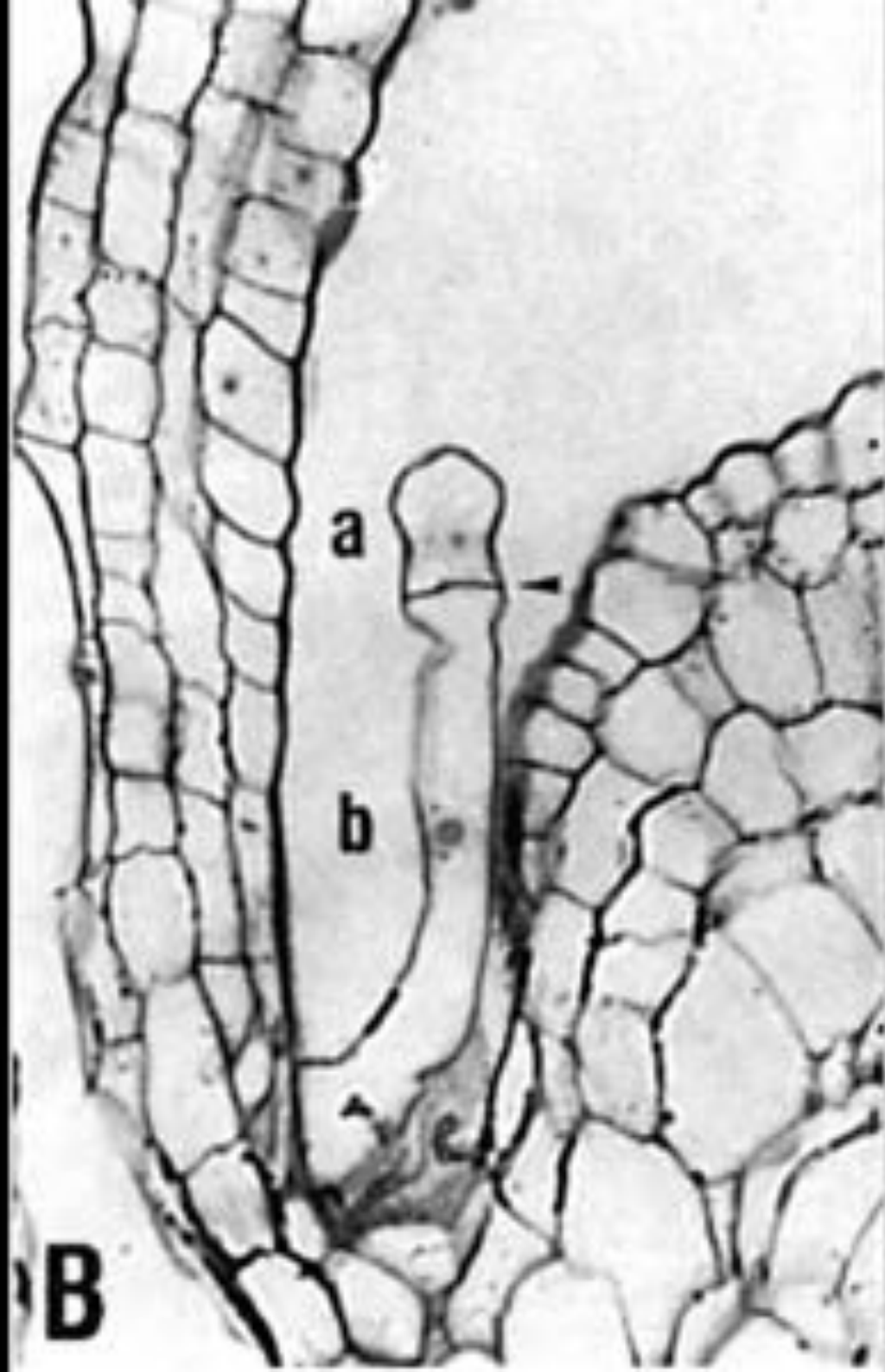






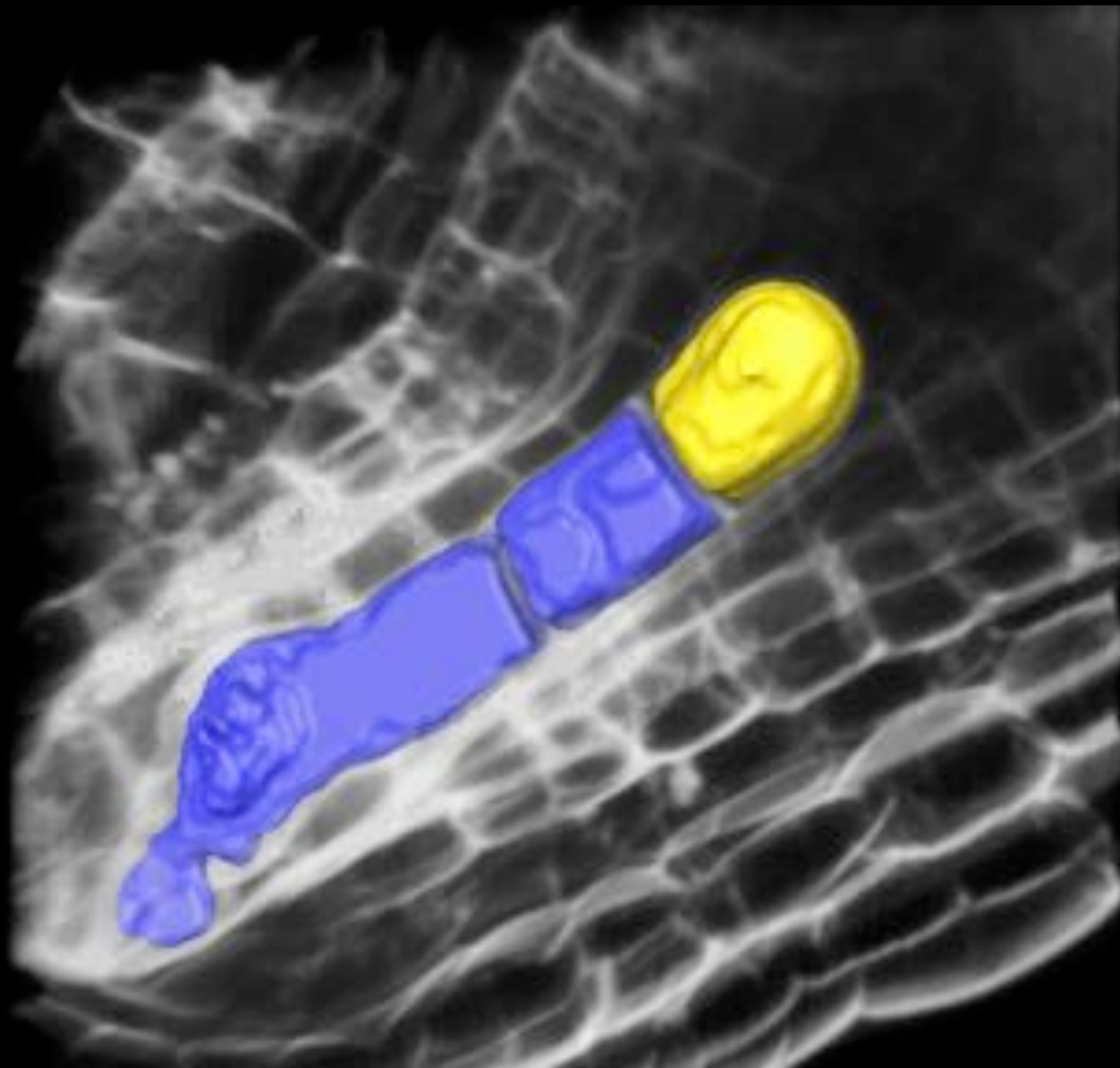






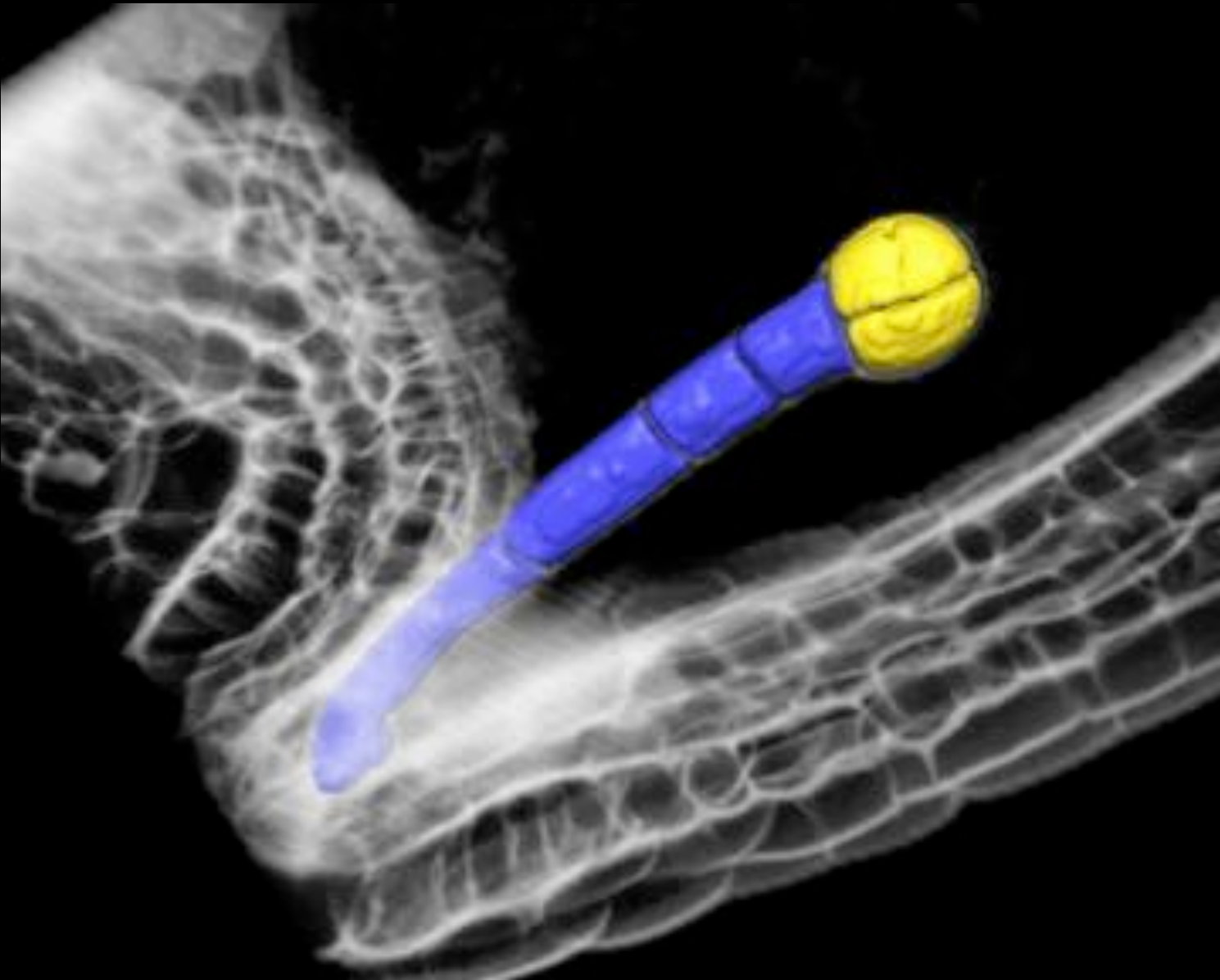
**B**

# 1 cell embryo





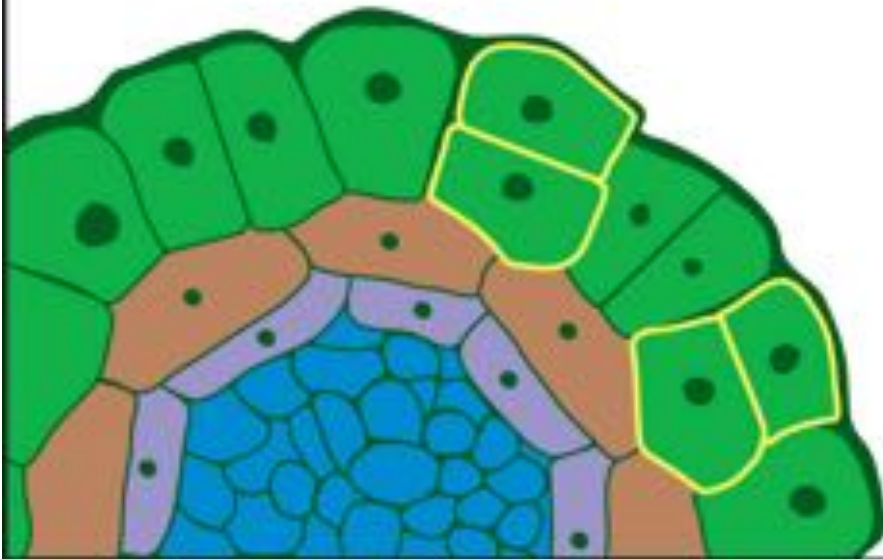
**4 cell embryo**



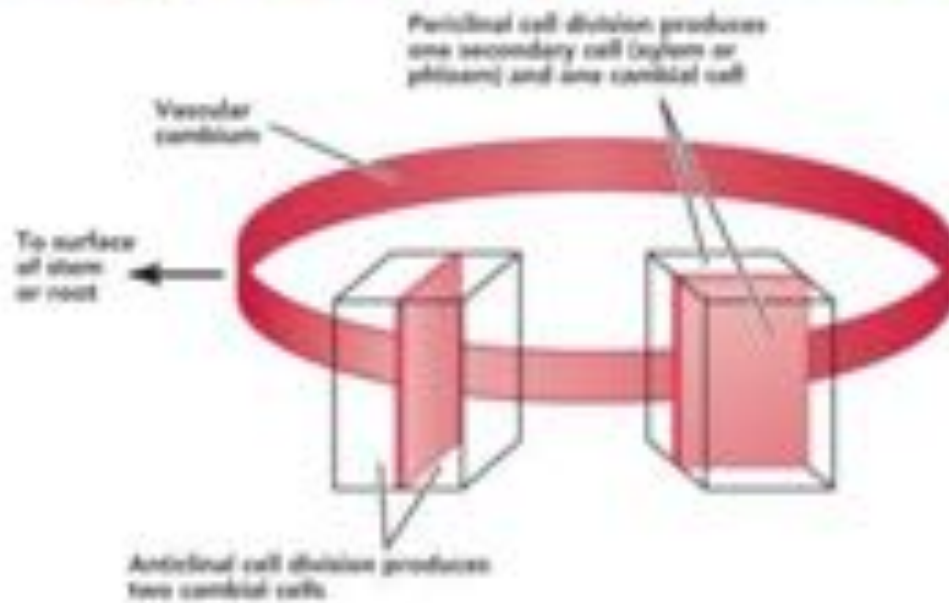
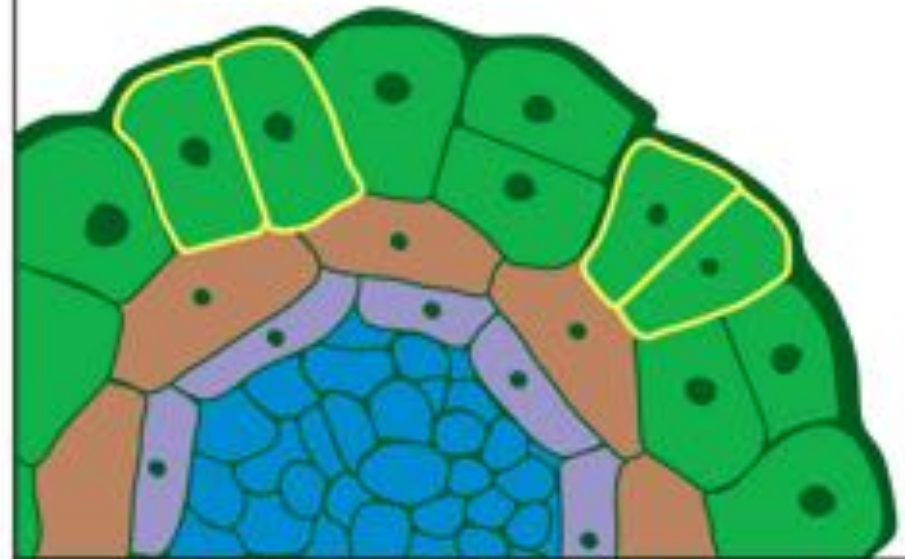
# Octant stage embryo



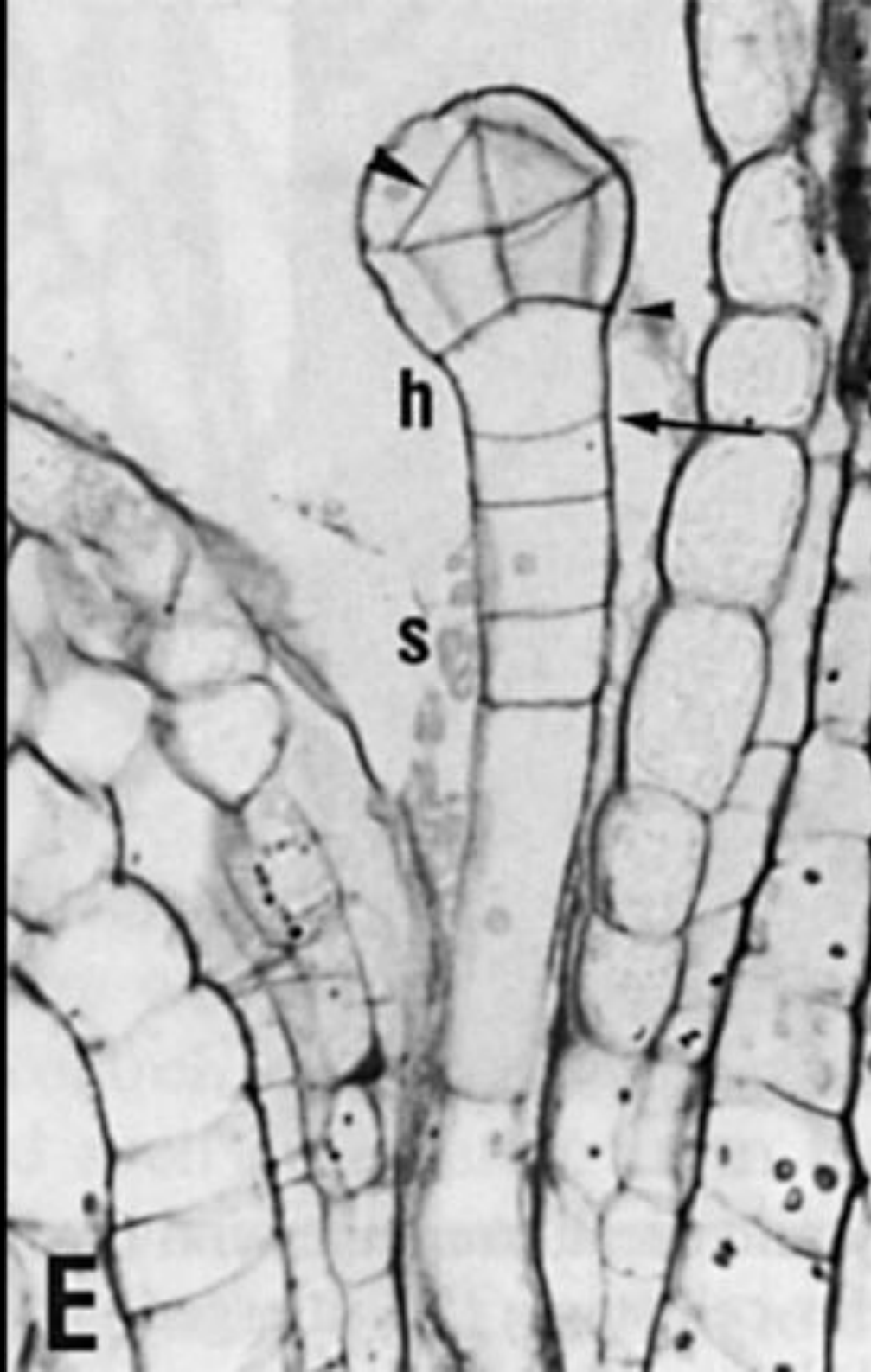
### Periclinal divisions



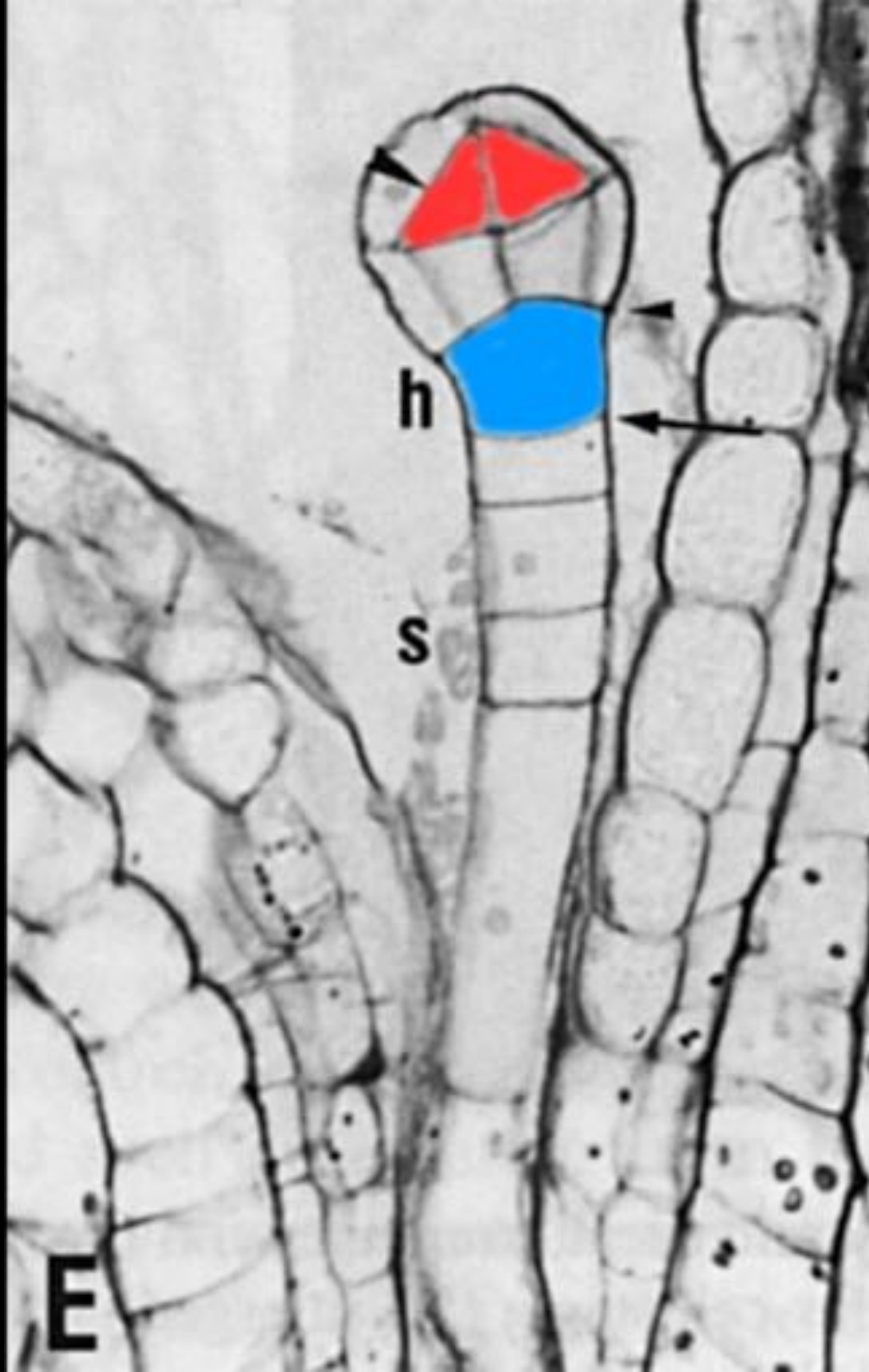
### Anticlinal divisions







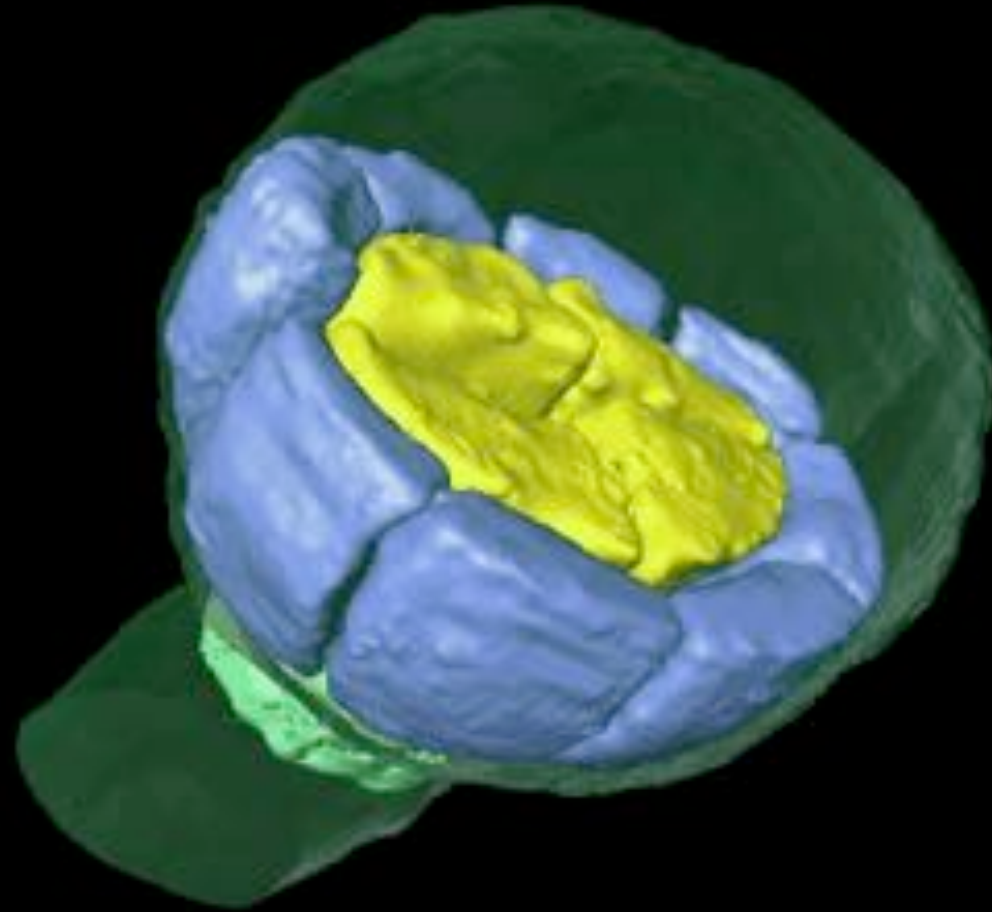
Radial asymmetry in  
the 16-cell embryo



Radial asymmetry in  
the 16-cell embryo

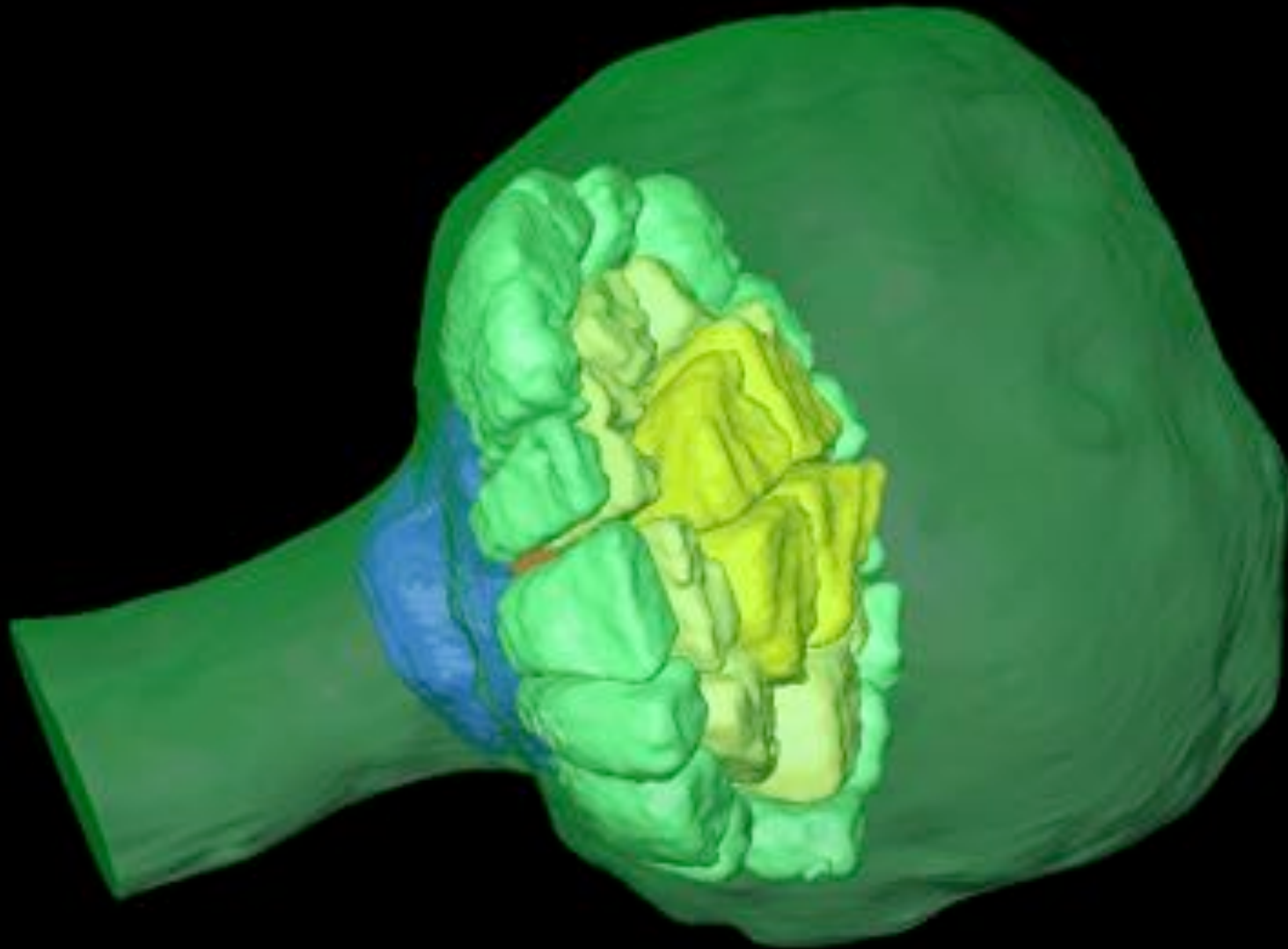
Specification of shoot  
and root meristems

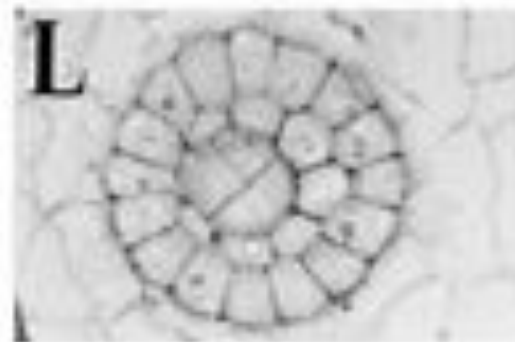
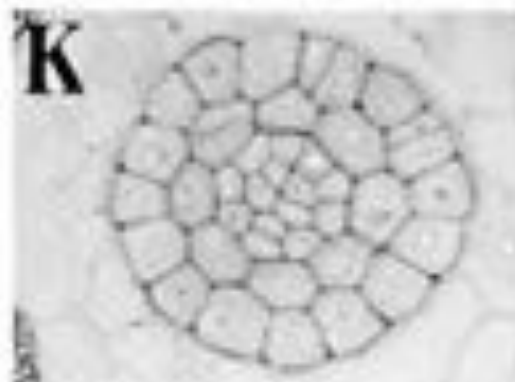
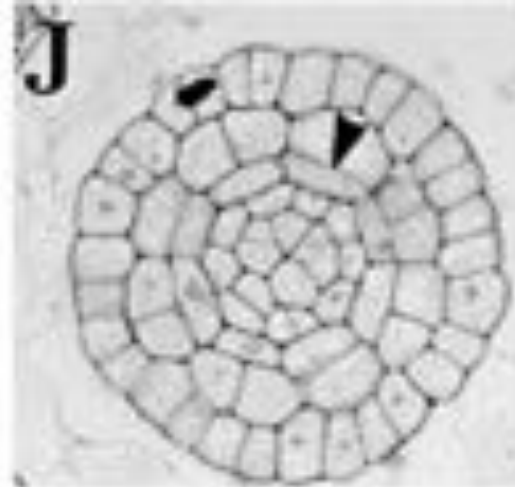
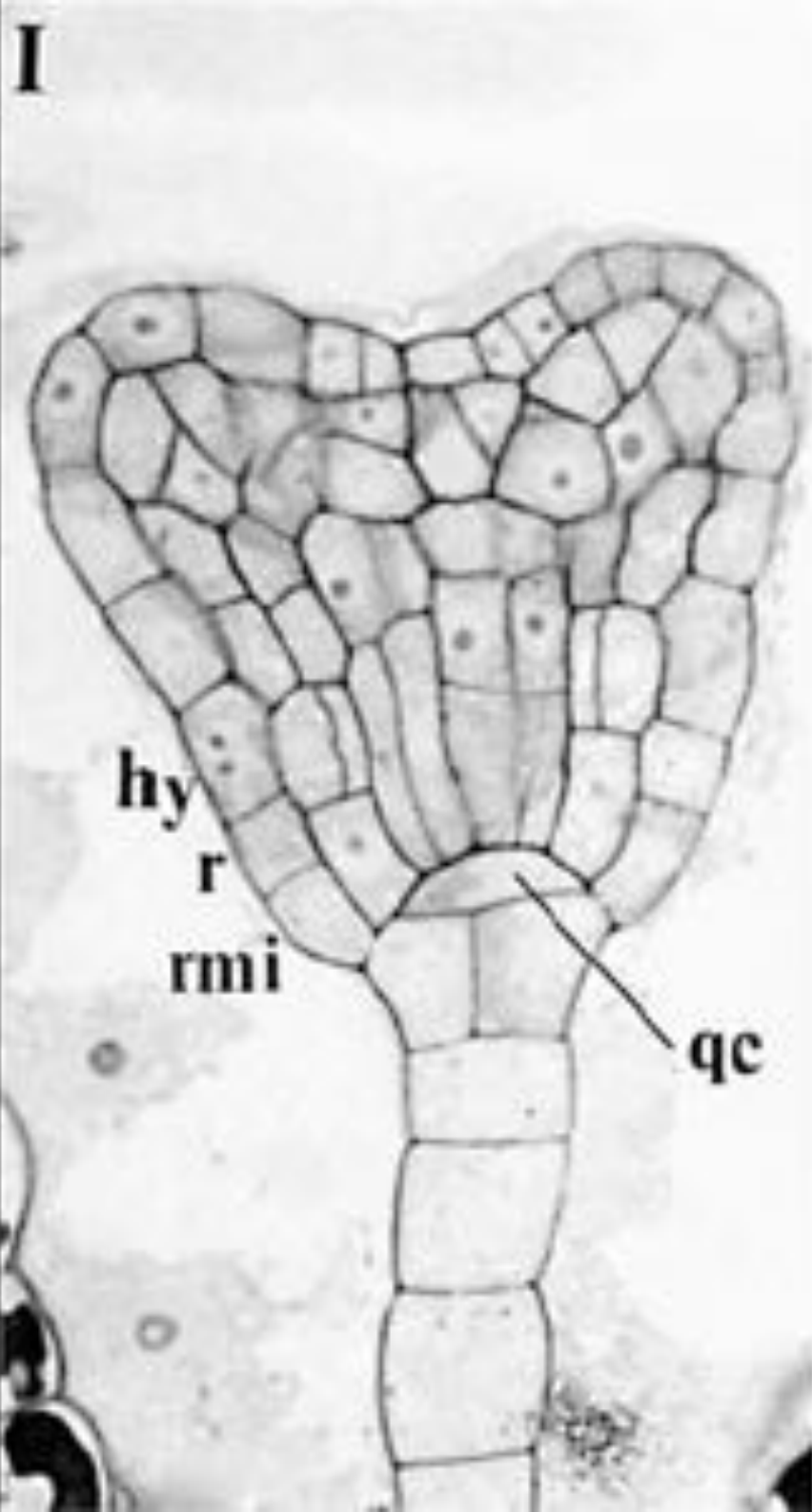
## Protoderm stage embryo

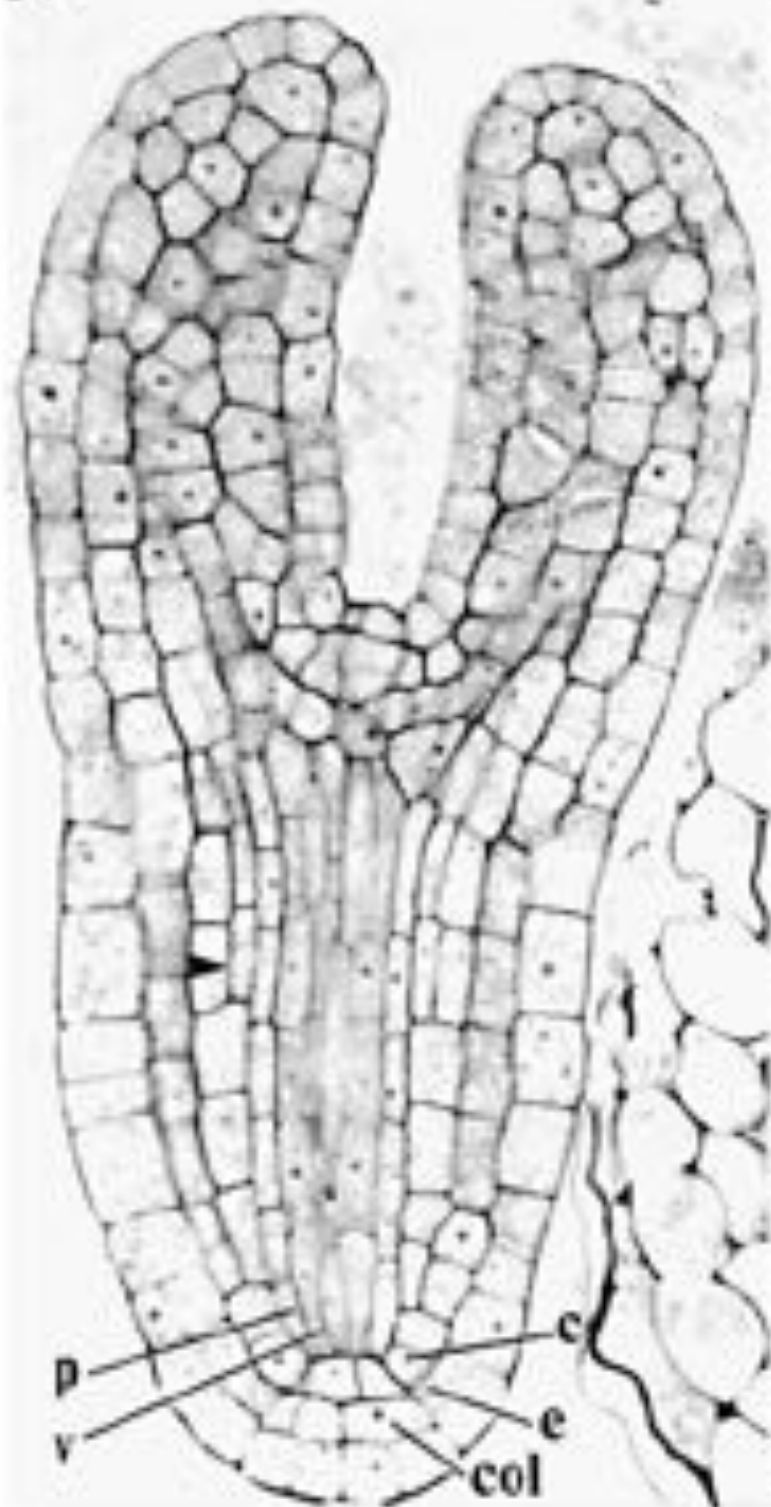
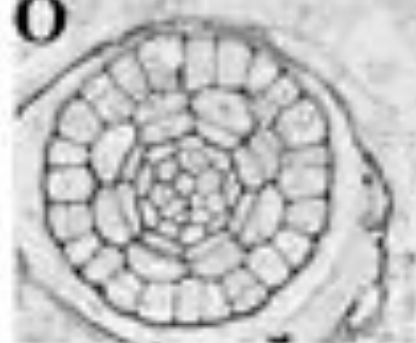
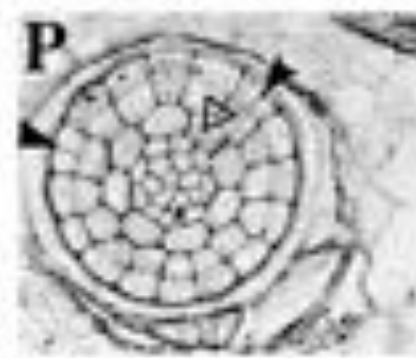




# Globular stage embryo

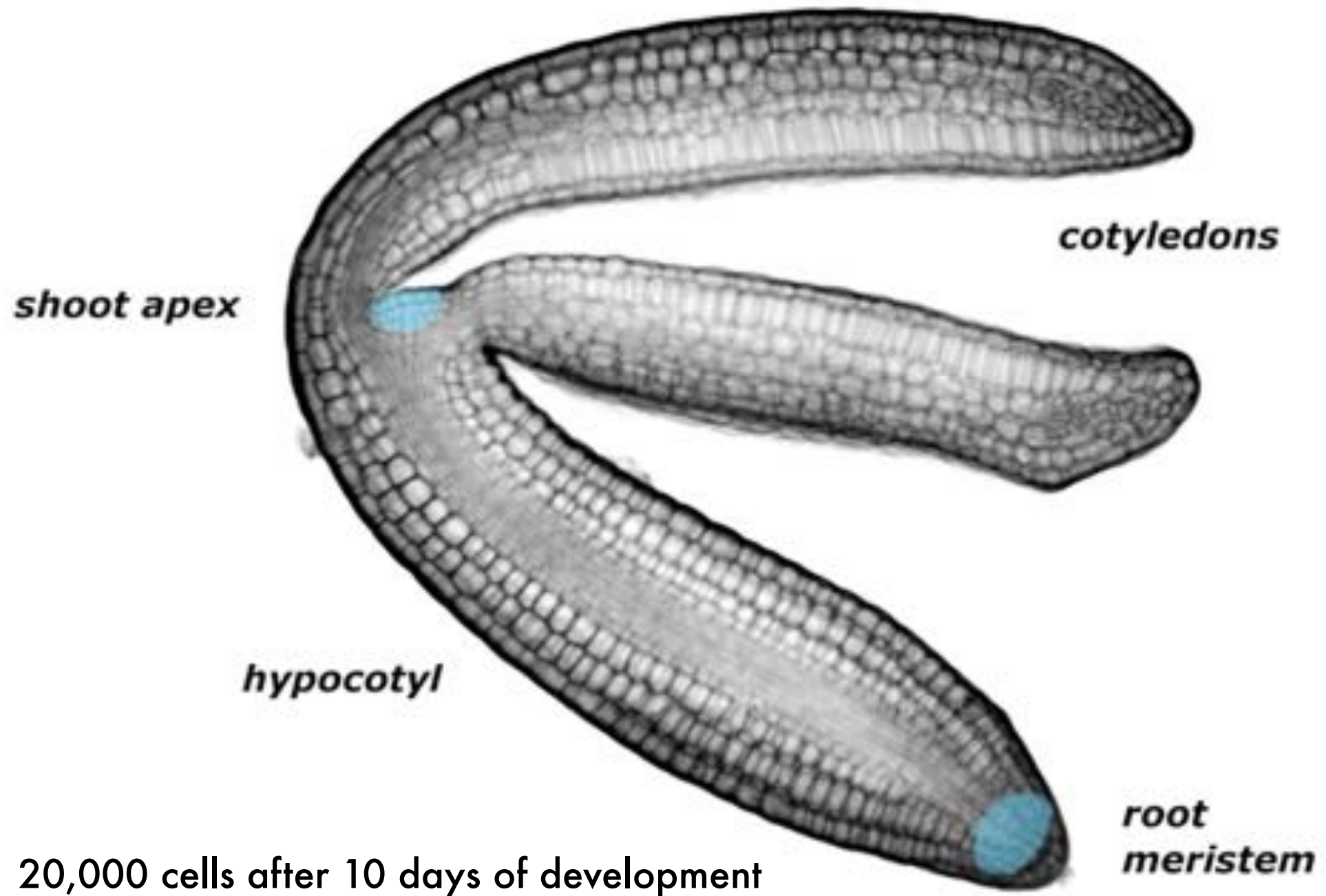




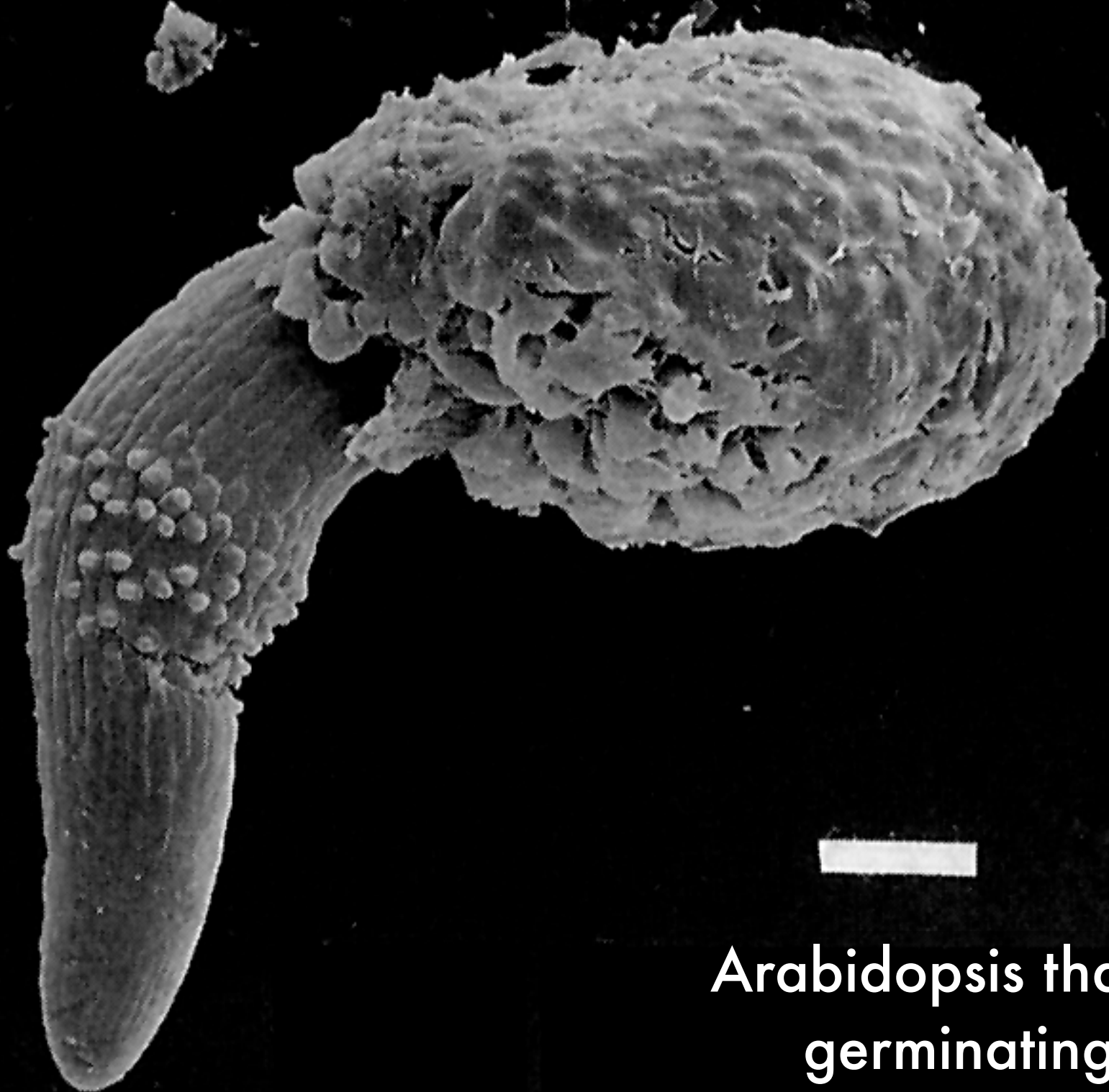
**Z****O****P****O****R**



# *mature embryo*





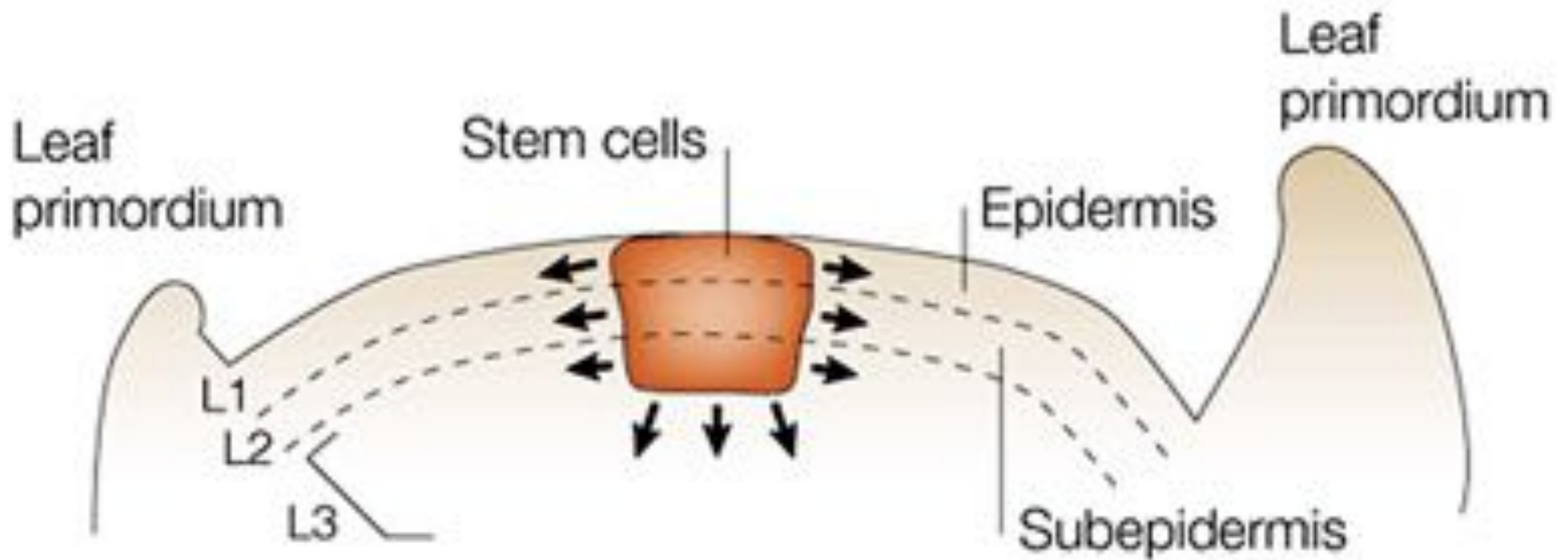


*Arabidopsis thaliana*  
germinating seed



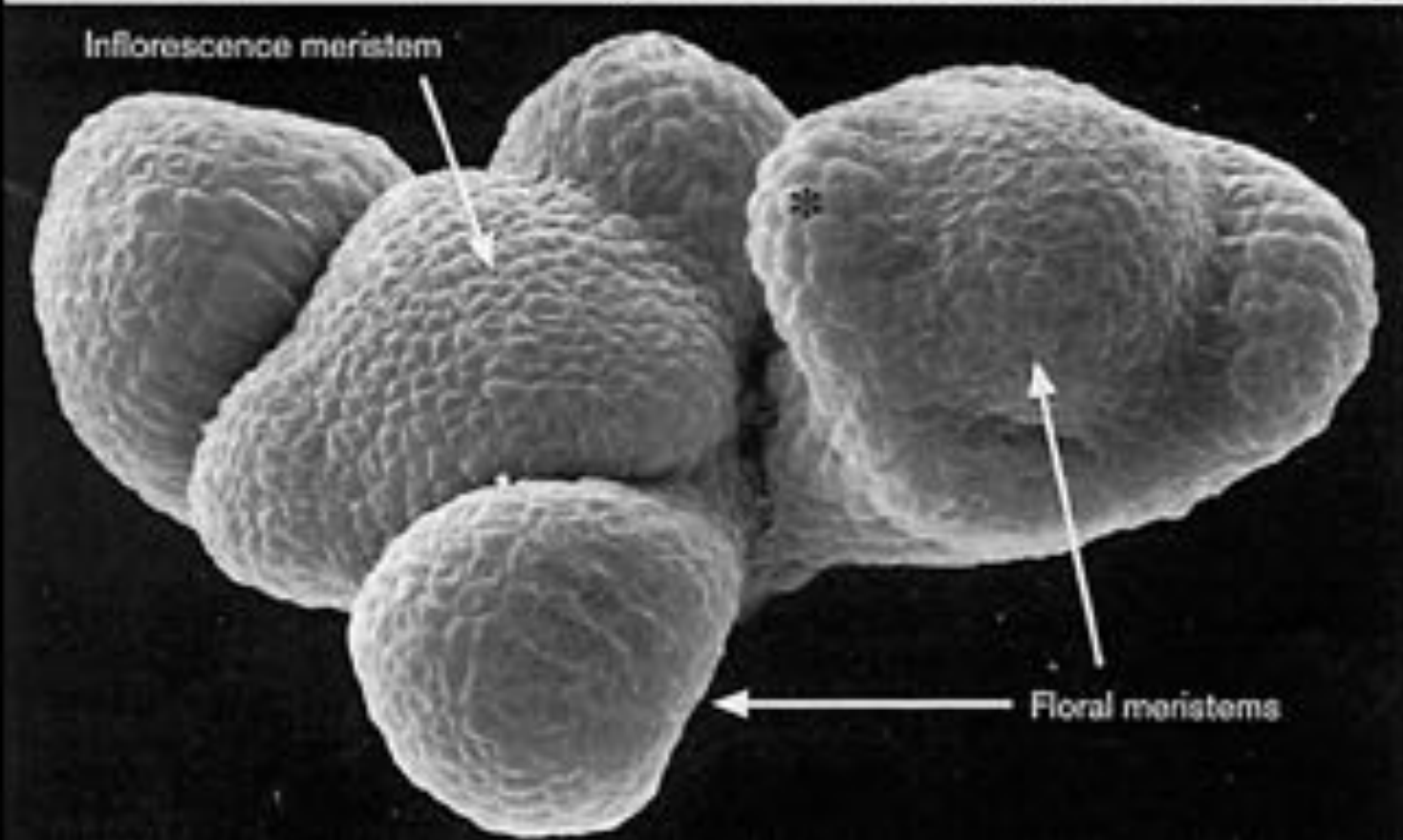
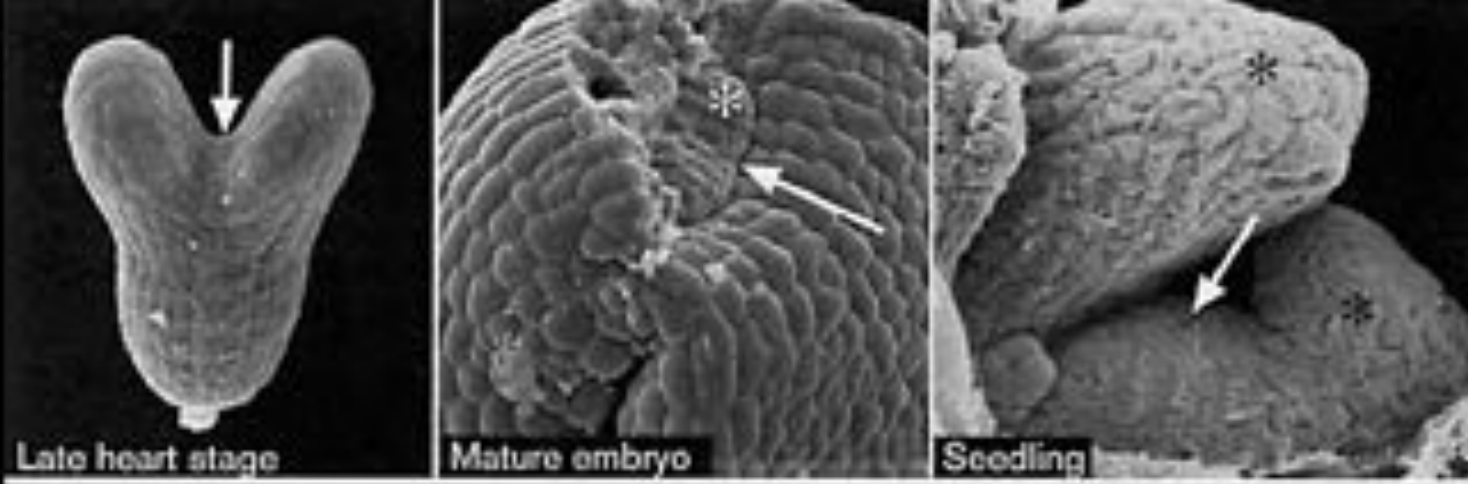


**Arabidopsis thaliana seedling  
4 days after germination**



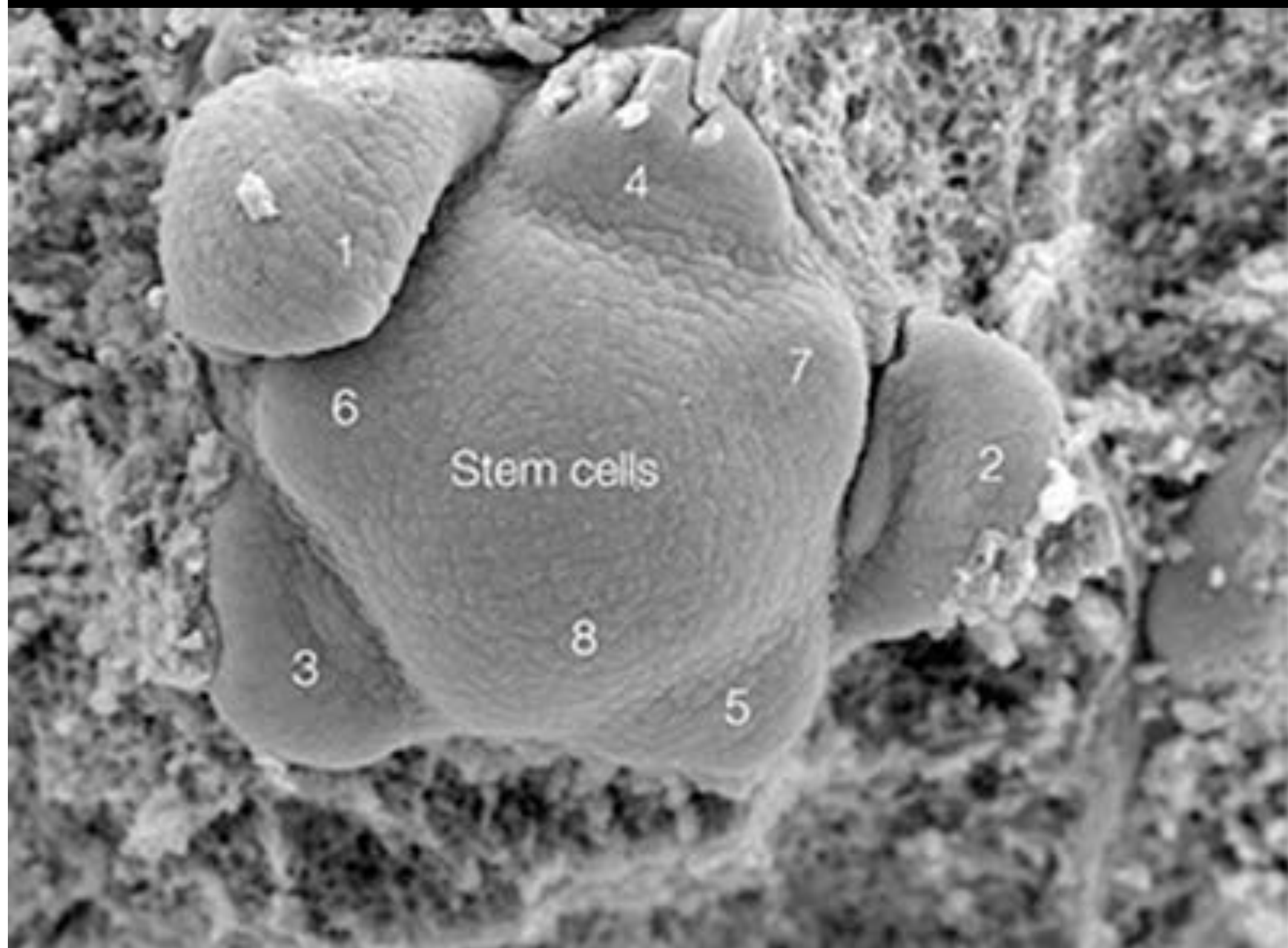
**A meristem is self-organising  
and renews itself.**

*Arabidopsis*  
apical  
meristems

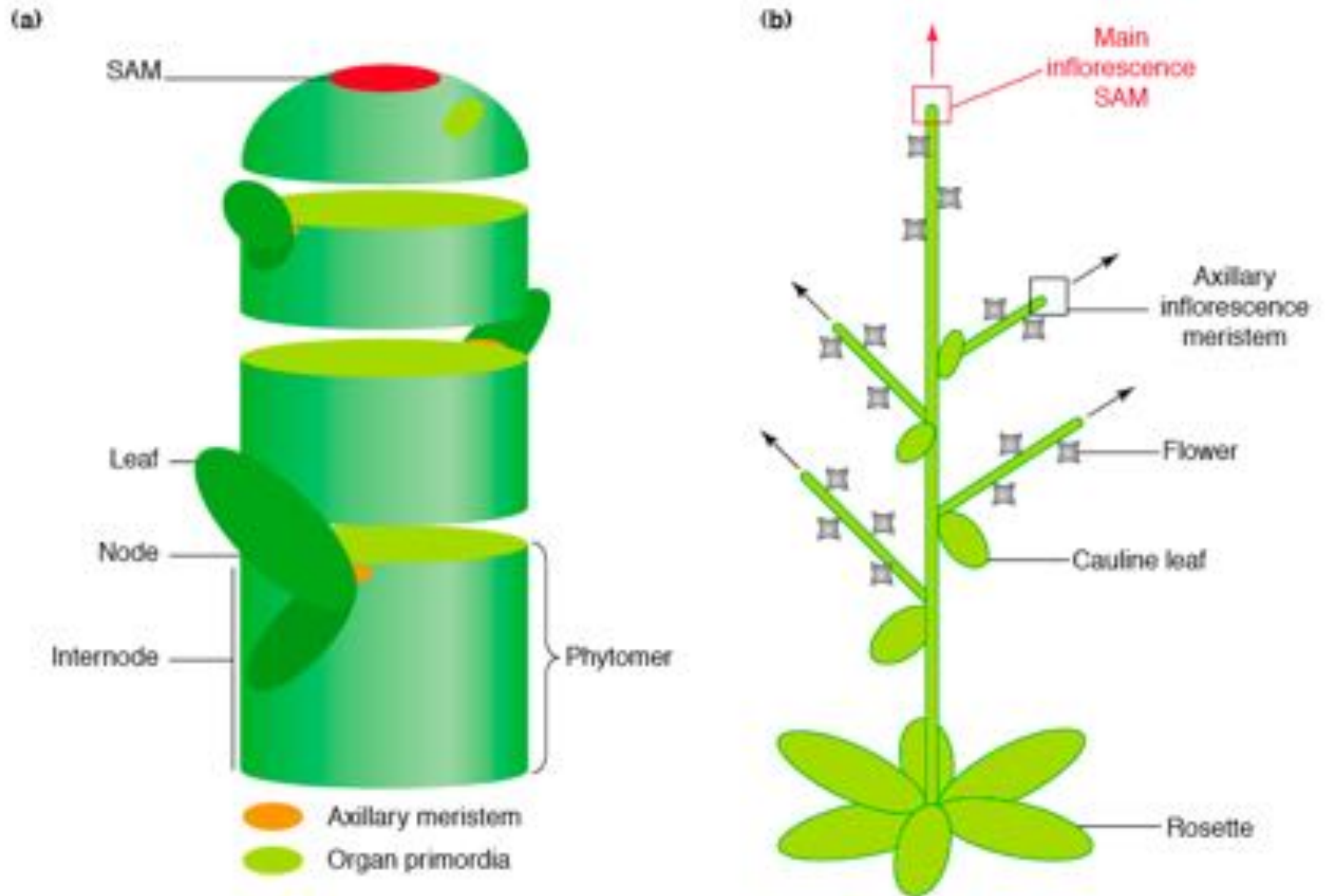


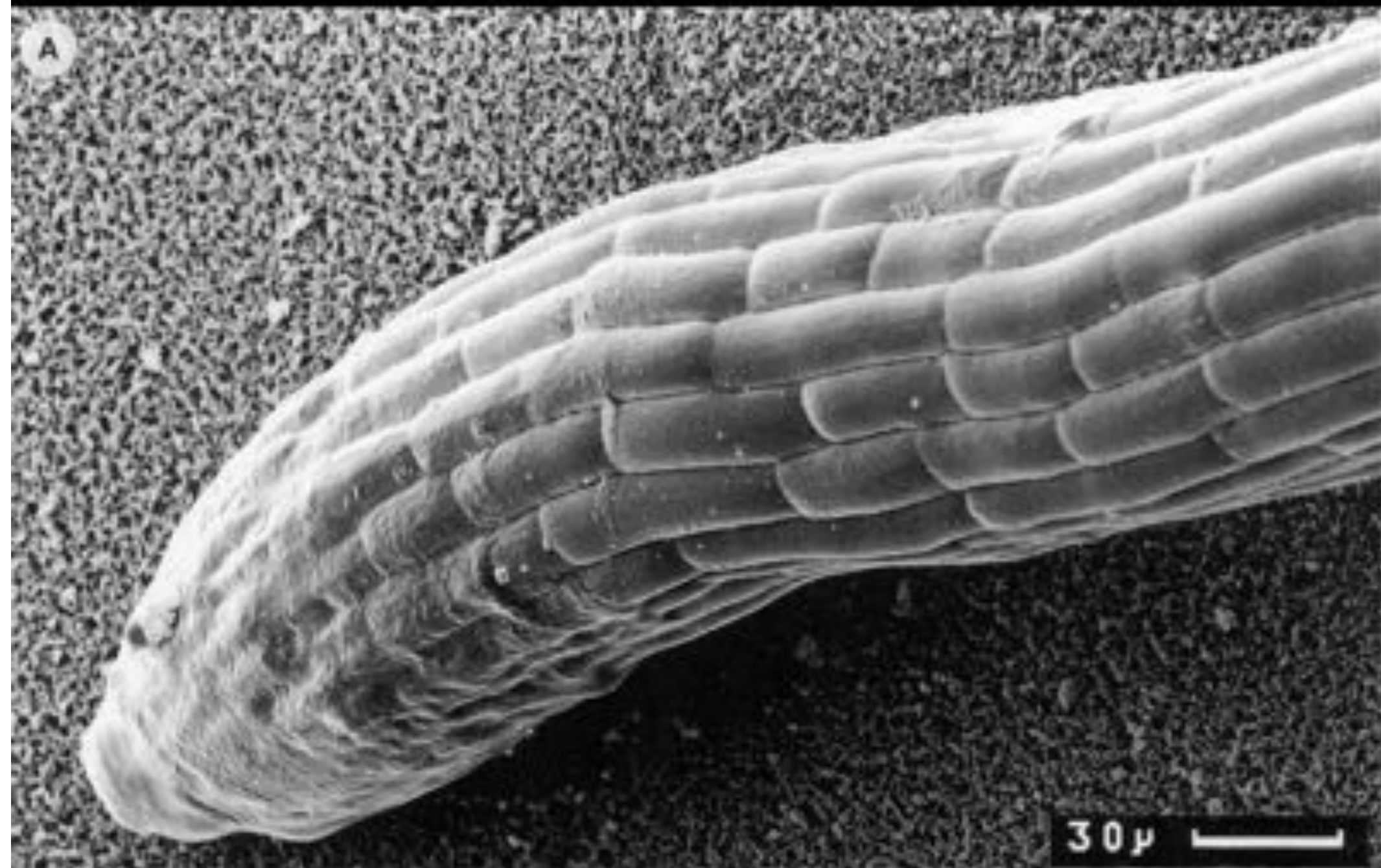
**The shoot meristem is branched and indeterminate, capable of producing lateral primordia at the flanks of the meristem.**





# Modular growth and production of lateral organs

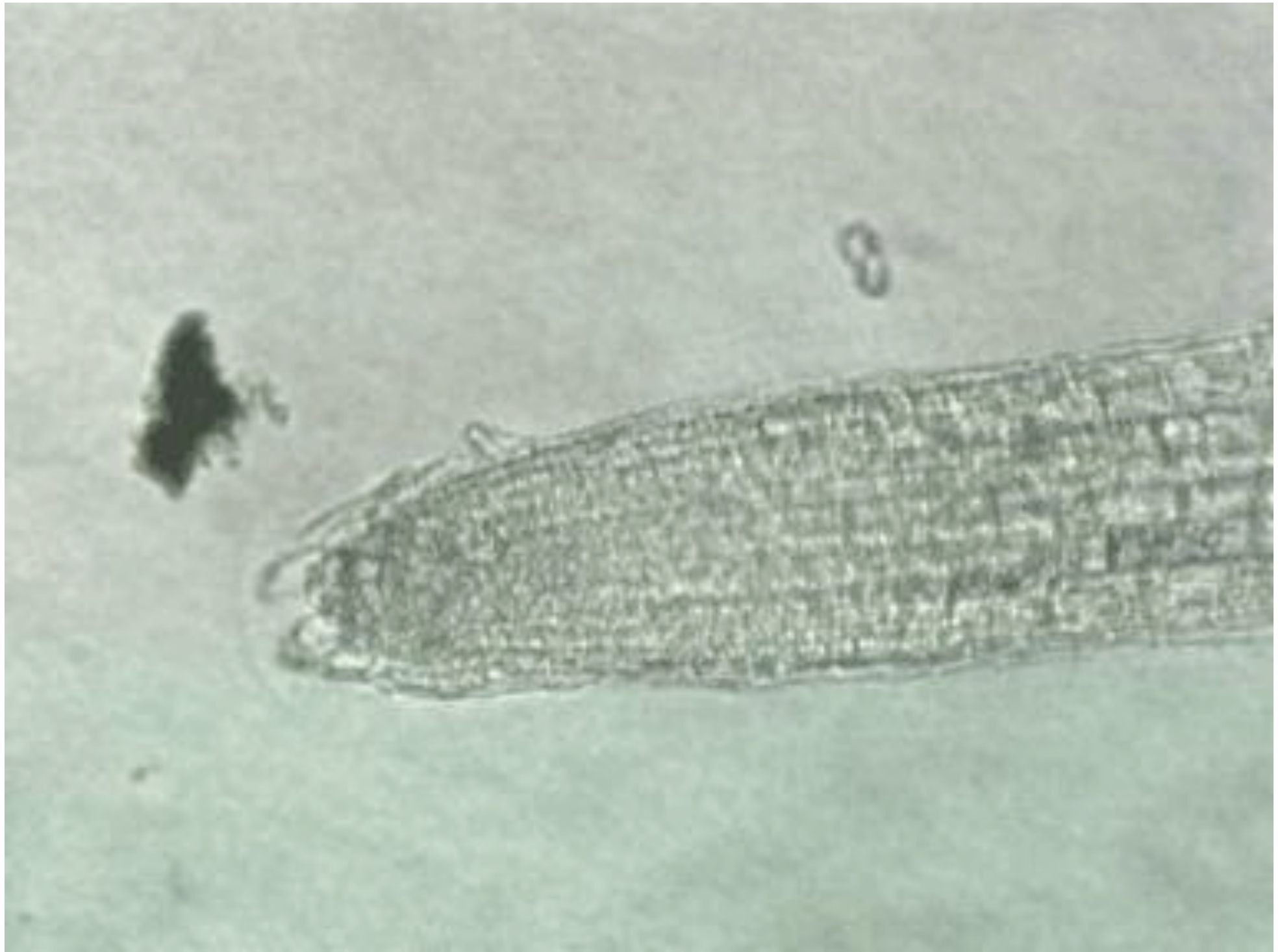


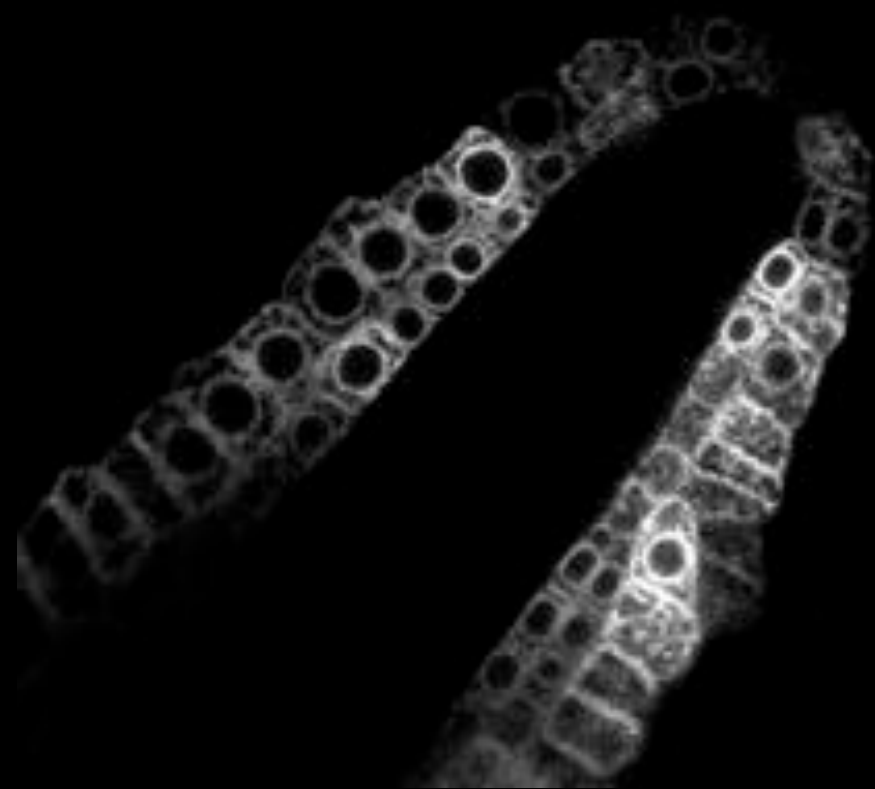


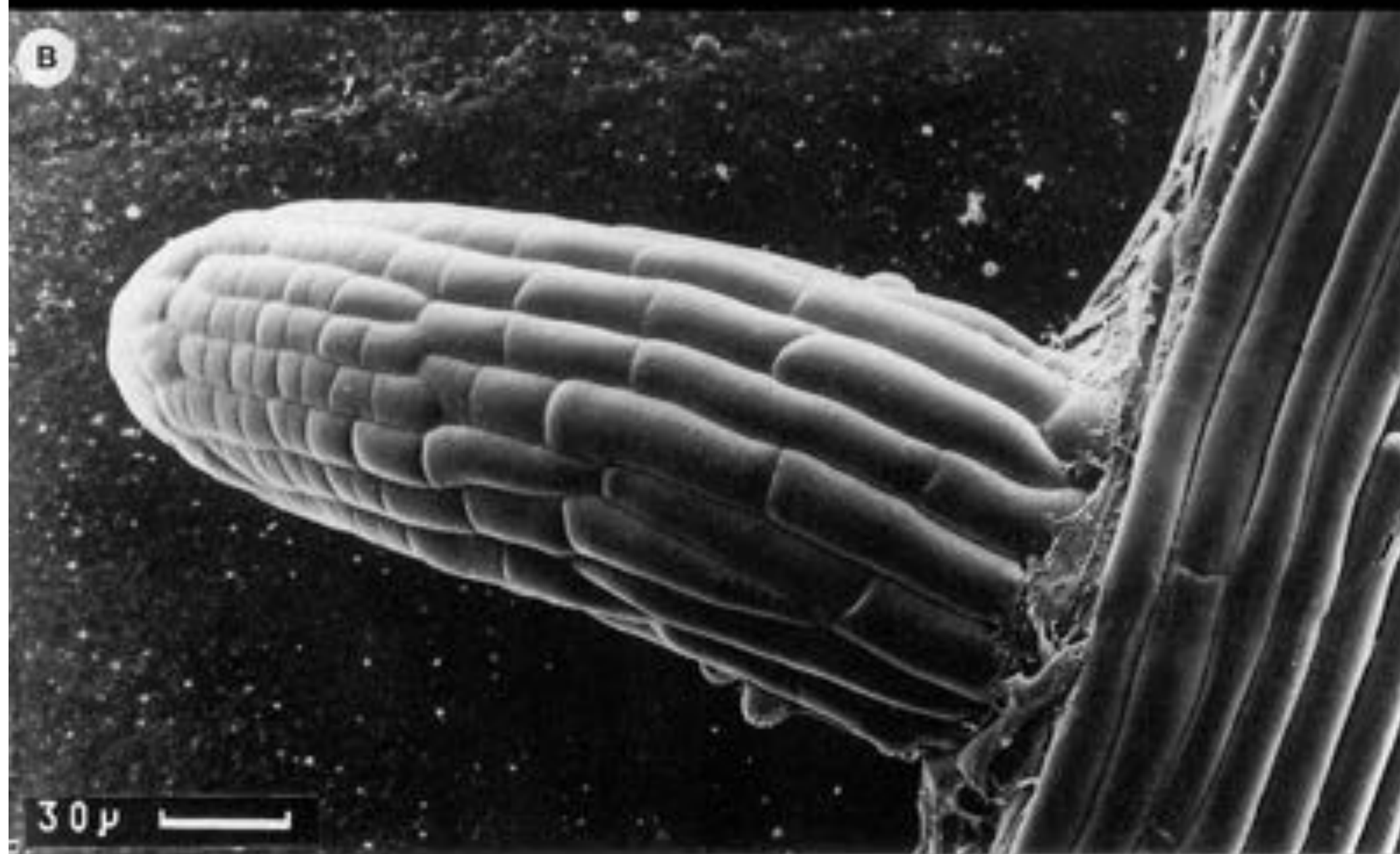
*Arabidopsis* root tip



# Indeterminate growth of the *Arabidopsis* root meristem



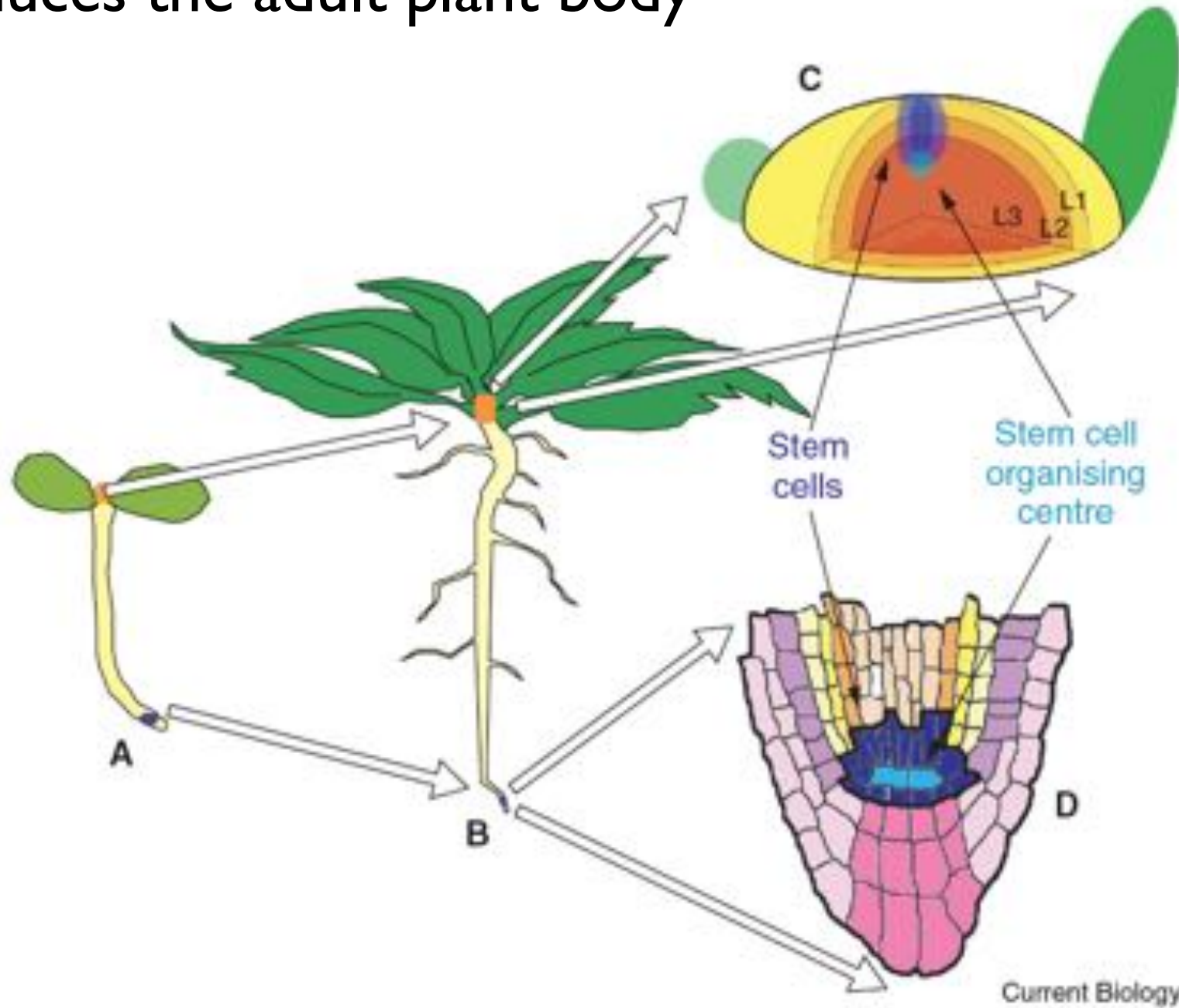




*Arabidopsis lateral root*



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






# **How is an adult body plan built?**

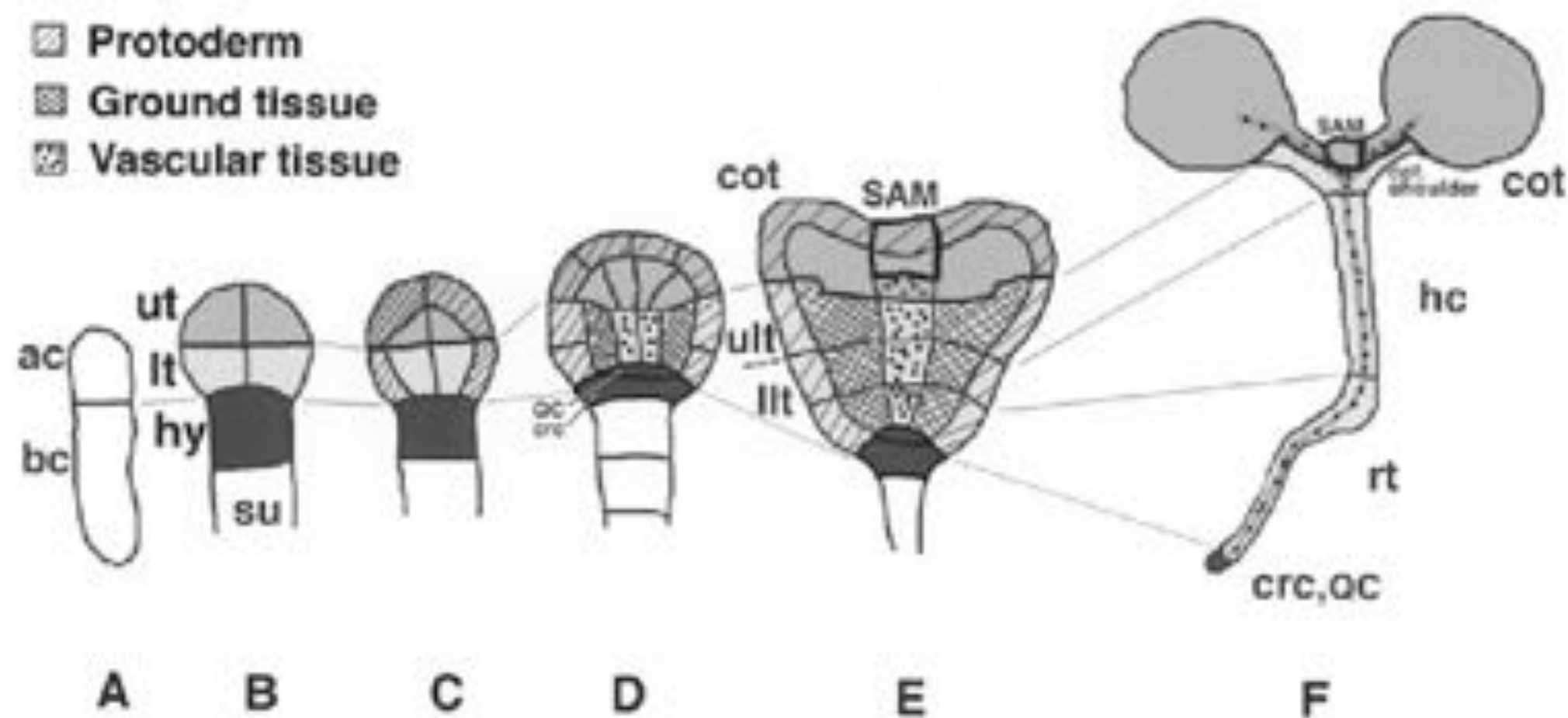
**Precise sequence of divisions during early embryogenesis.**

**Are plant cell fates controlled by**

**(1) segregation of determinants?**

**(2) positional information?**

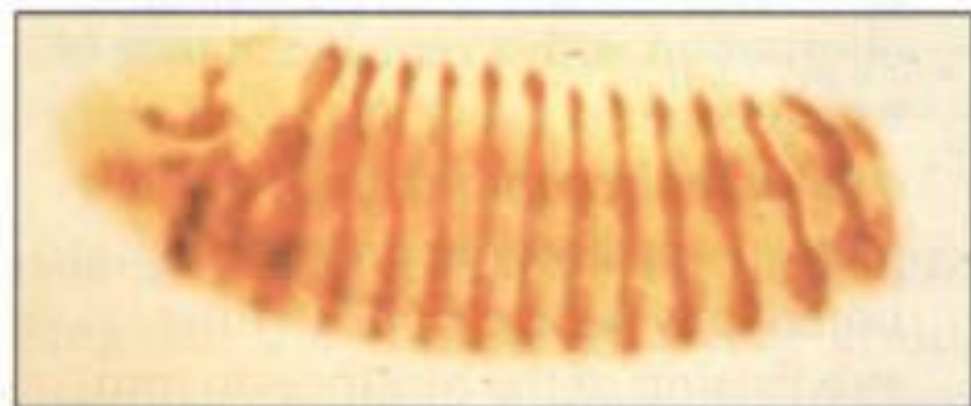
-  Protoderm
-  Ground tissue
-  Vascular tissue





5-hour embryo

100  $\mu\text{m}$



10-hour embryo

100  $\mu\text{m}$

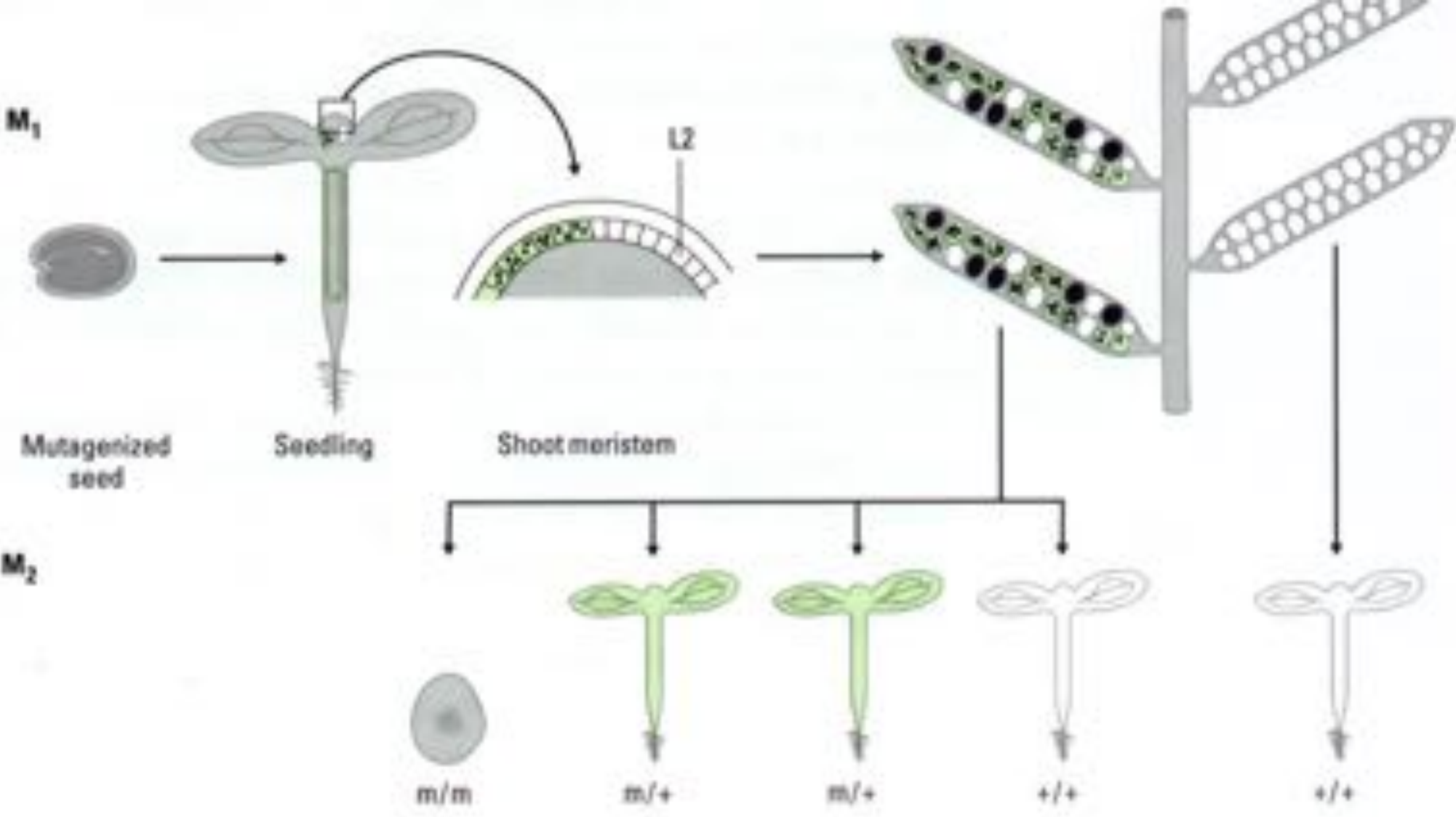


adult

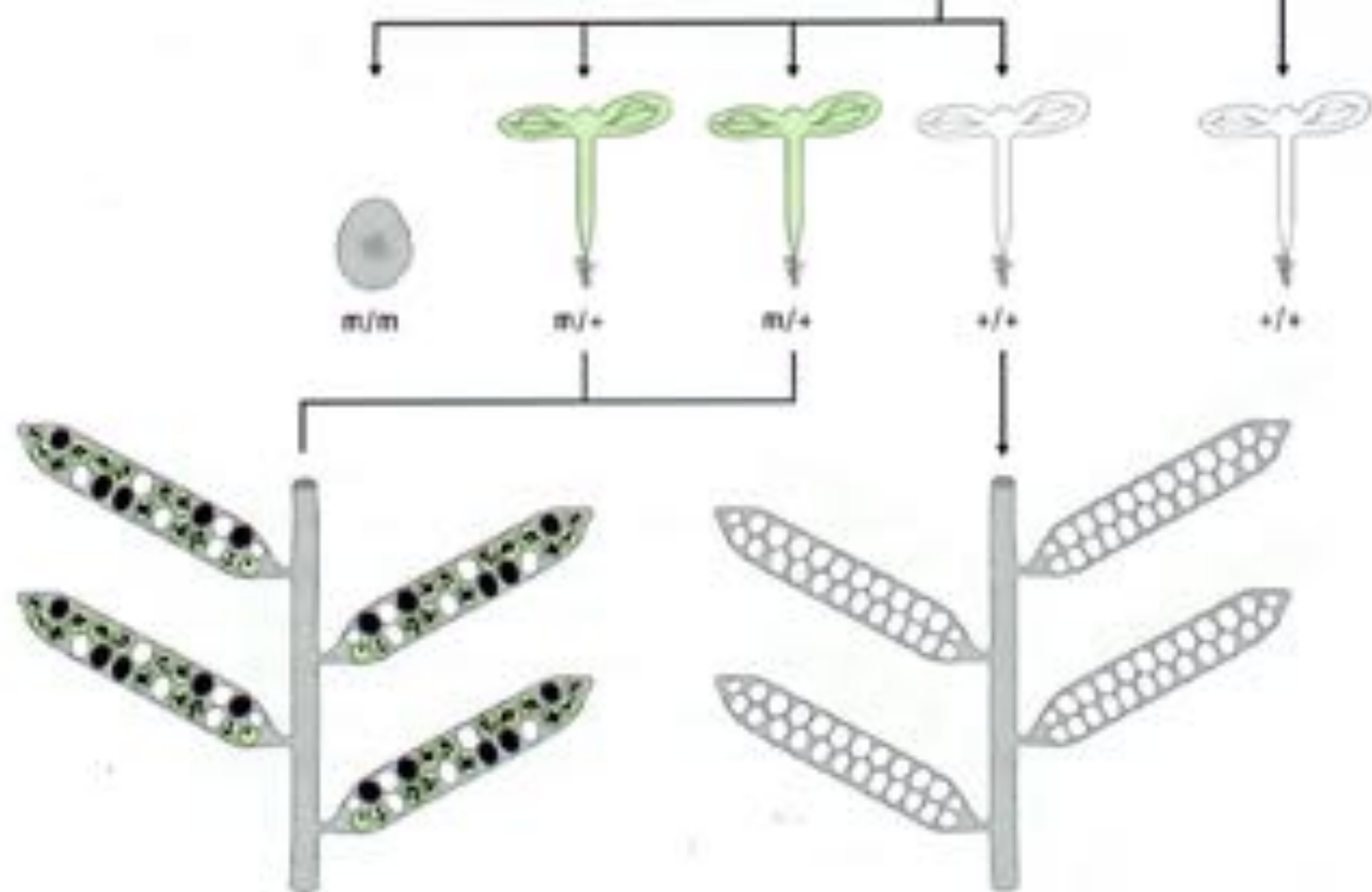
500  $\mu\text{m}$



# Genetic screening for mutants in Arabidopsis development

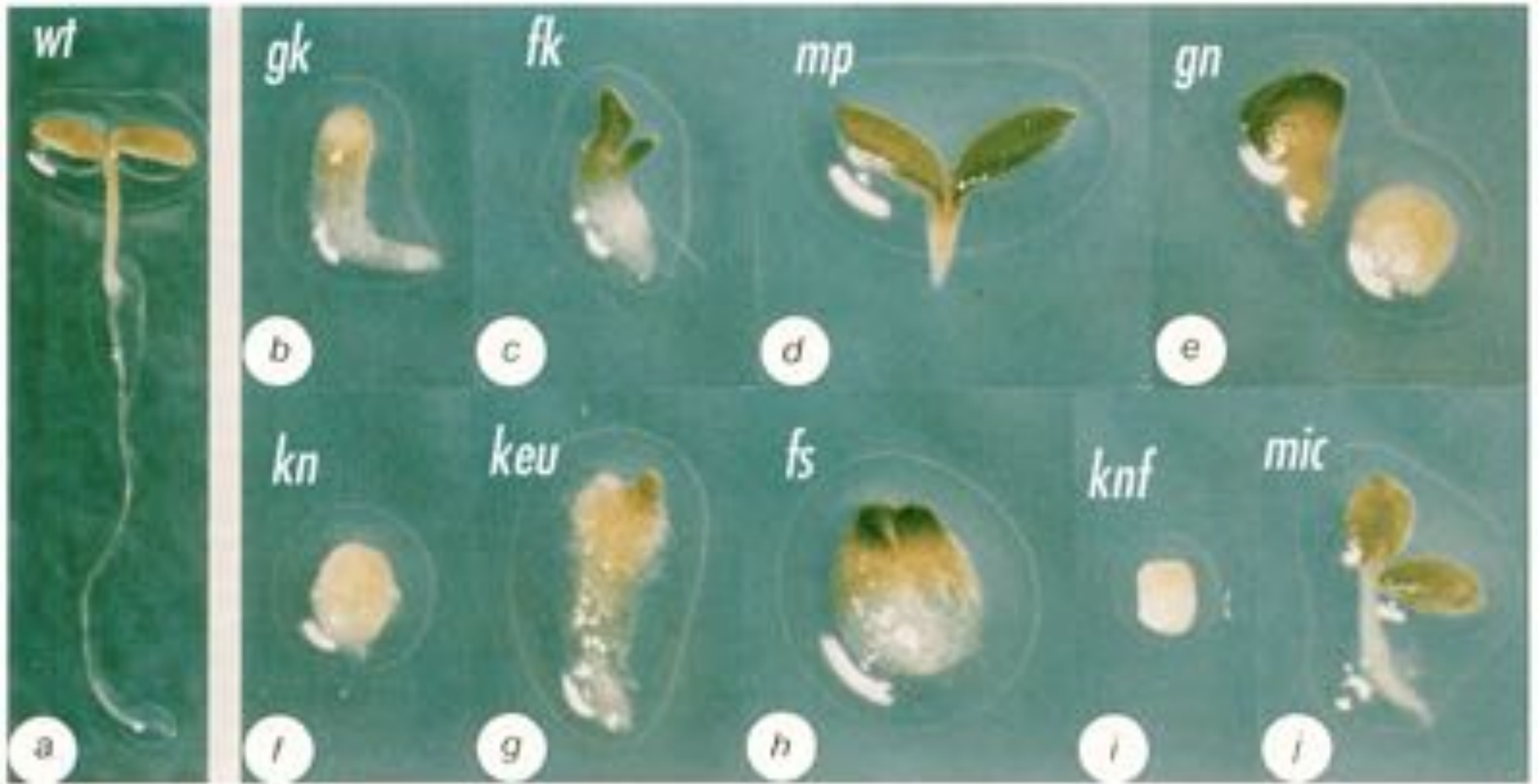


$M_2$



$M_3$





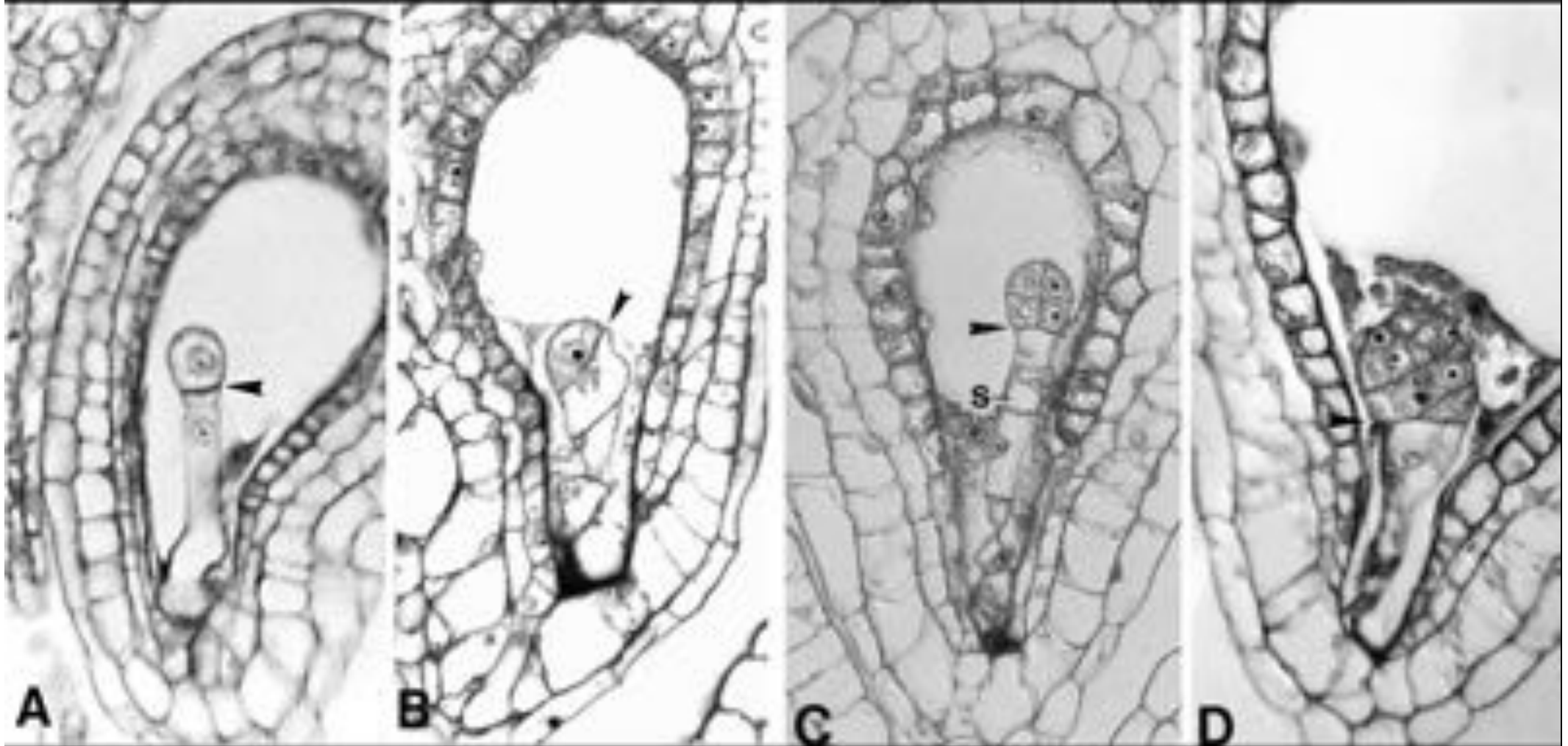
**fass mutants have cytoskeletal defects, with altered patterns of cell division**

*WT*

*fass*

*WT*

*fass*



*2-cell stage*

*octant stage*

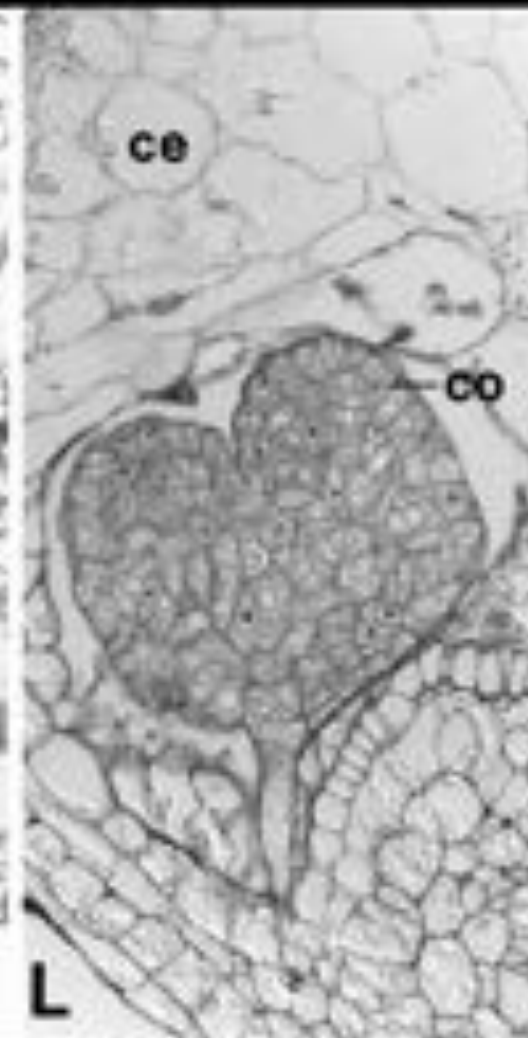


*WT*

*fass*

*WT*

*fass*

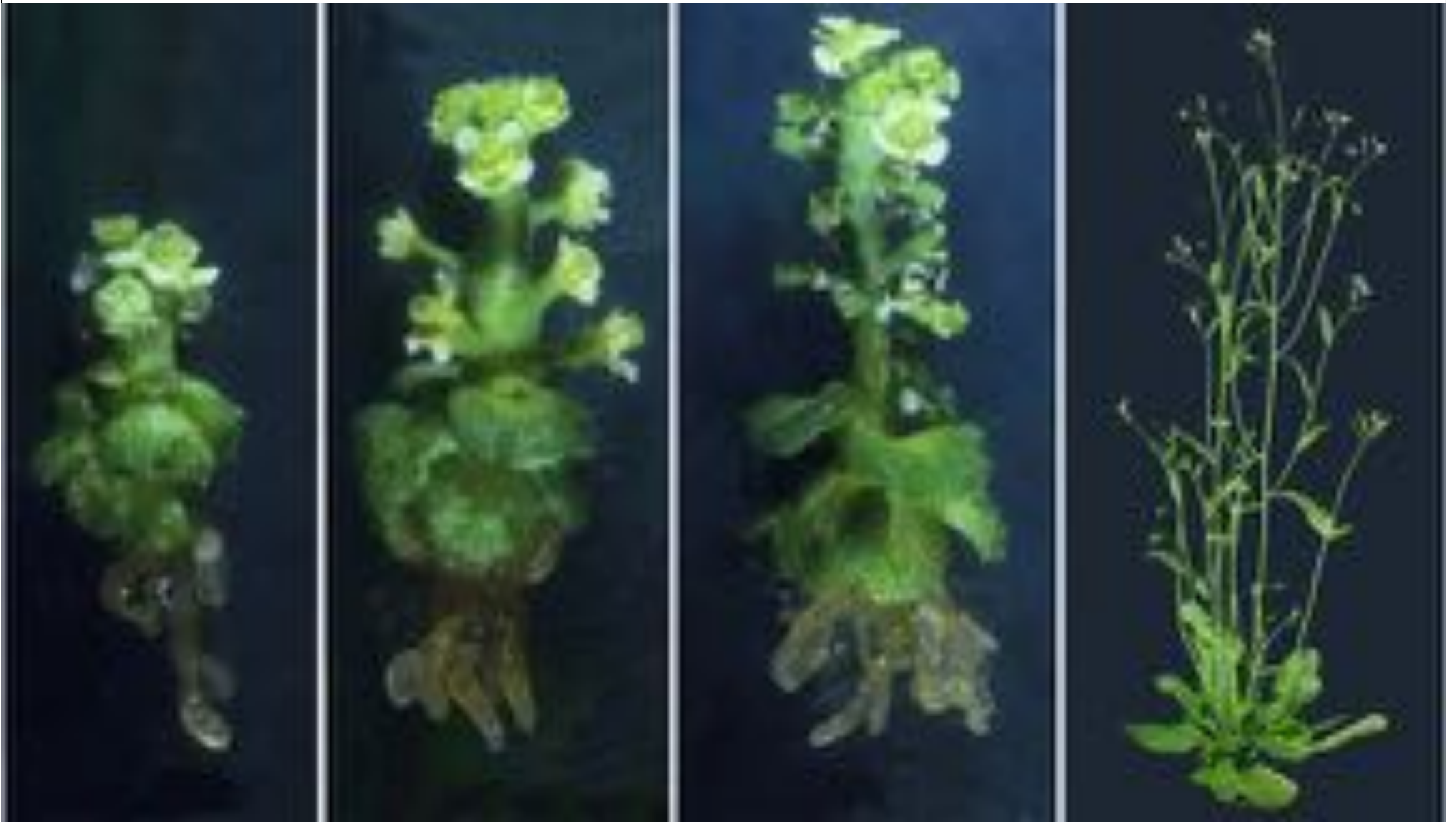


*heart stage*

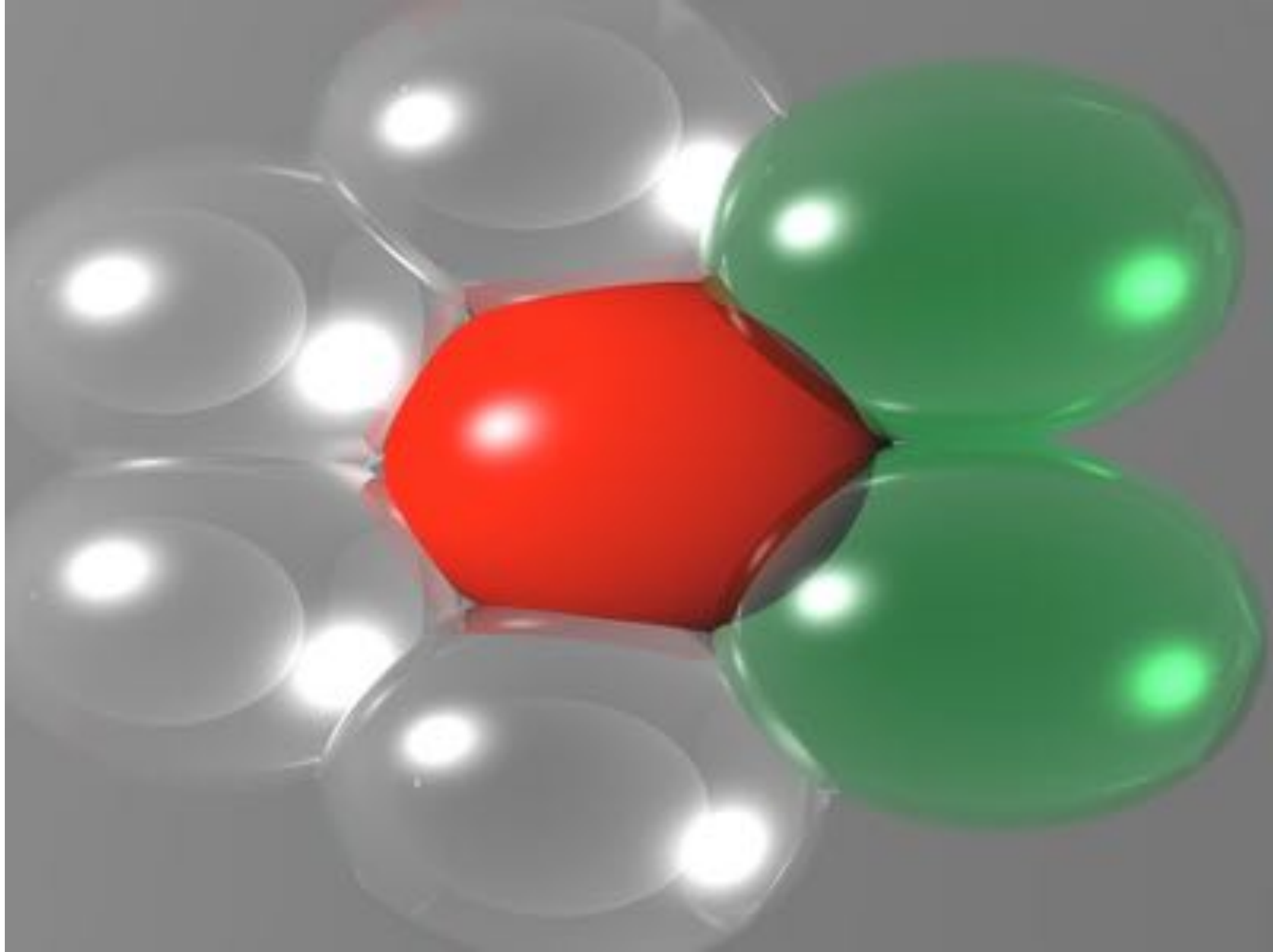
*torpedo stage*

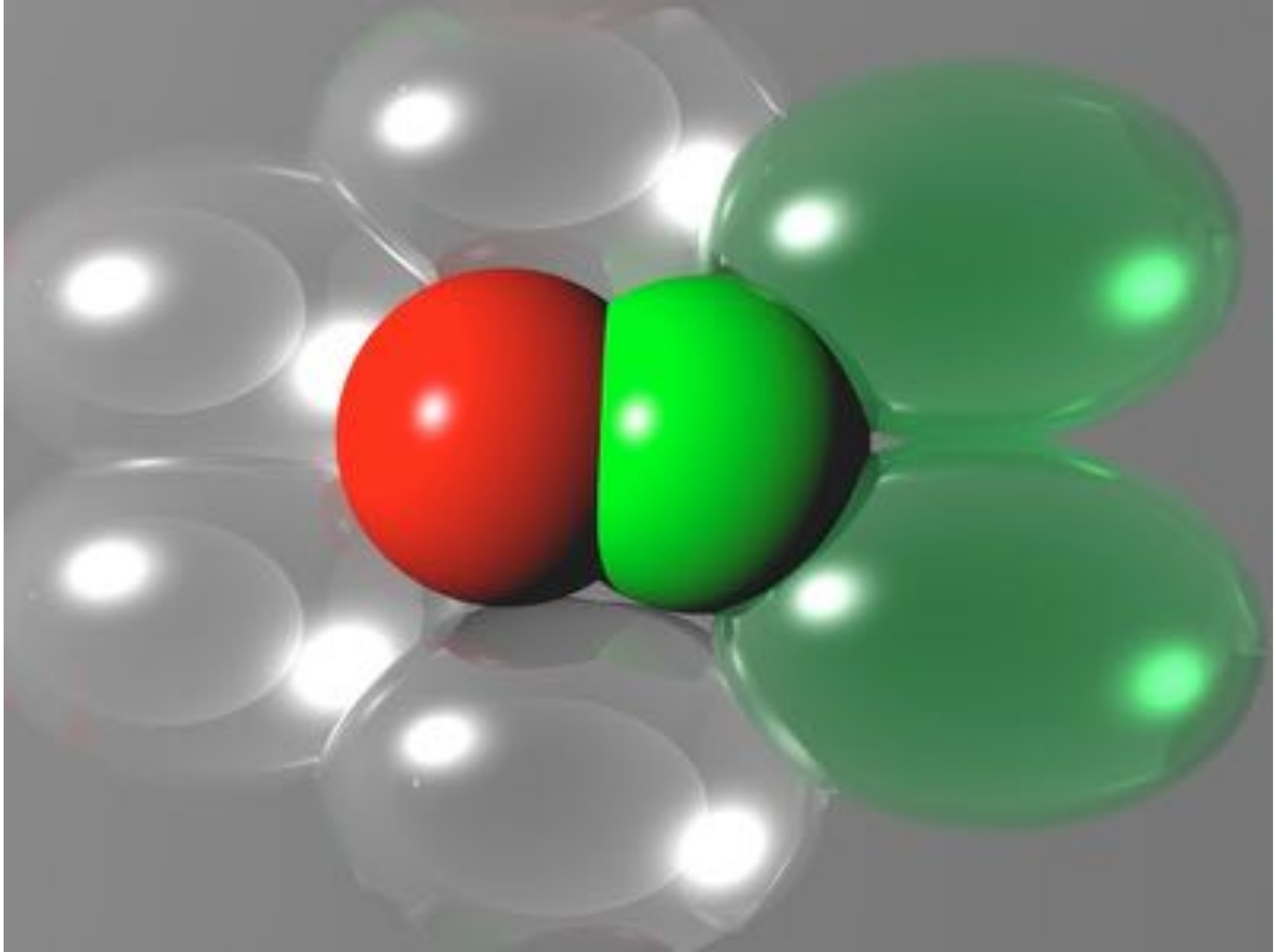
**fass alleles**

**Wild type**

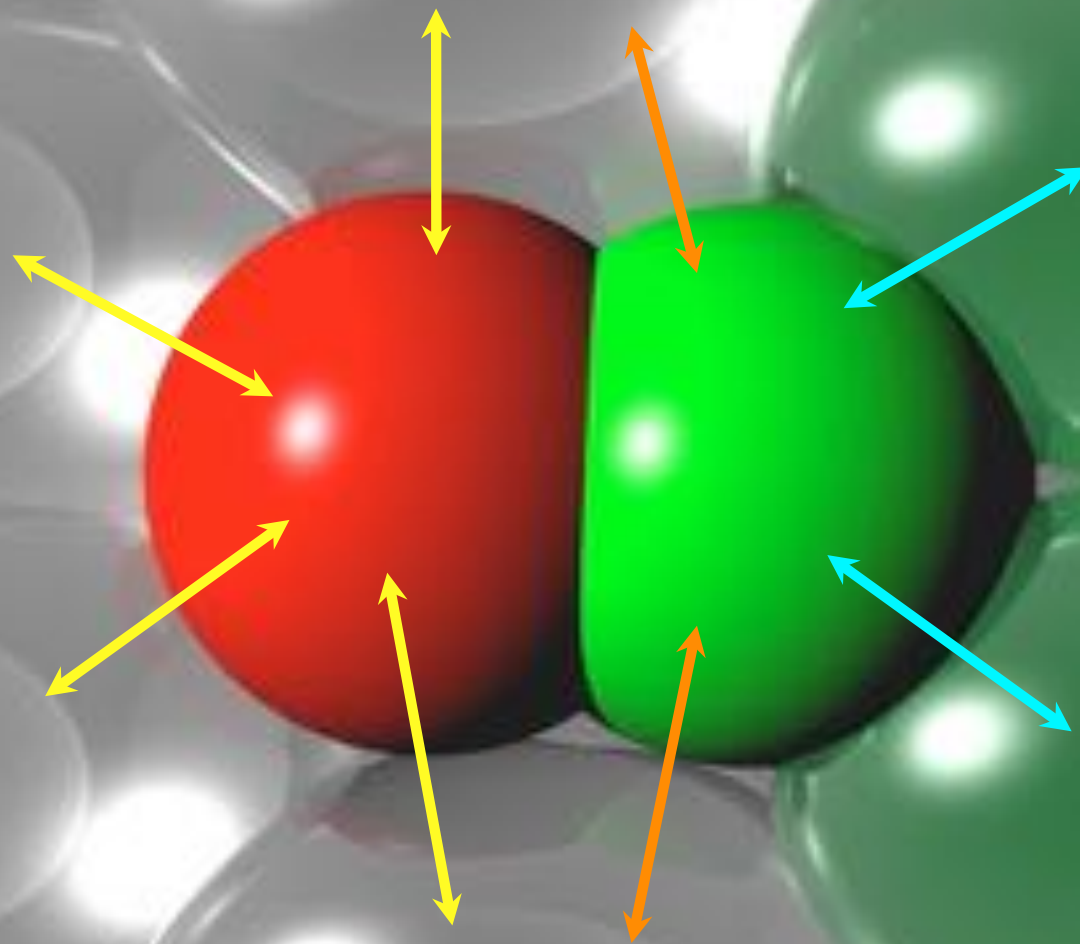


**fass plants form organised tissues despite deranged cell divisions**







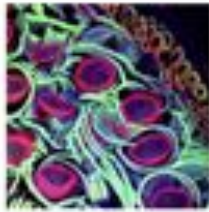


**Exchange of positional information**

Root- to Shoot Signaling: Environmental Strategy

For a complete list of references, click on the 'References' link in the right-hand margin.

**Abstract**  
There is a bidirectional communication pathway between the shoot and root. The shoot sends signals to the root via hormones and other molecules, and the root sends signals to the shoot via hormones and other molecules. This communication is essential for the plant to respond to environmental changes.



**References**

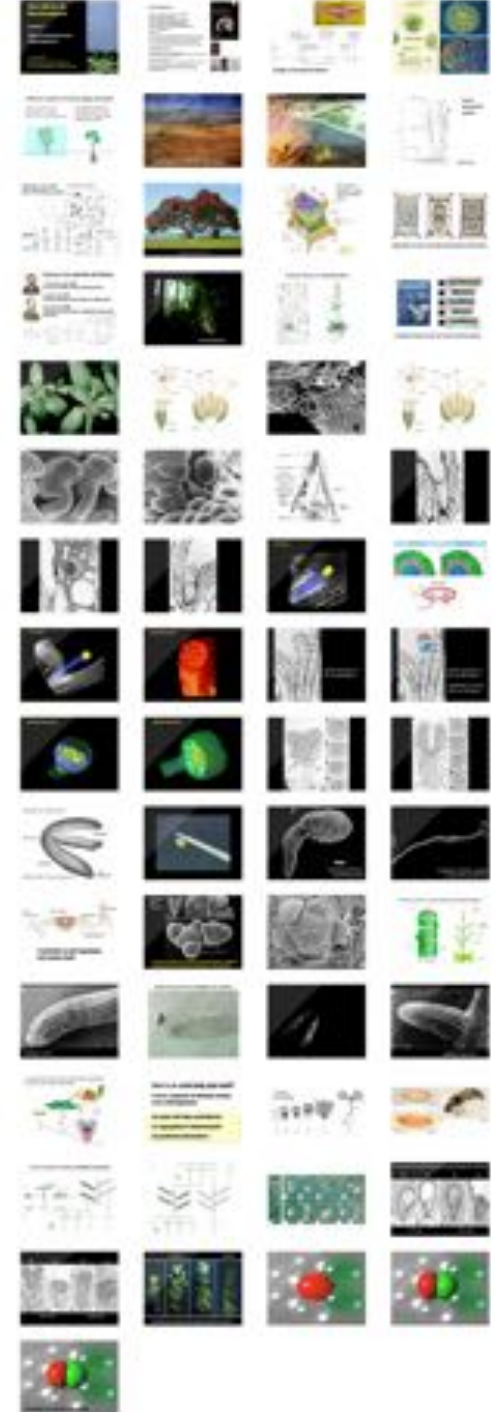
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**Recommended reading**

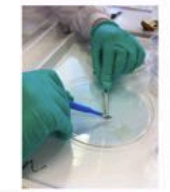
Book covers and titles for 'PLANT' and other recommended reading materials.

**Lectures**

- Lecture 1: Plant development and evolution
- Lecture 2: Plant development and evolution
- Lecture 3: Plant development and evolution
- Lecture 4: Plant development and evolution
- Lecture 5: Plant development and evolution
- Lecture 6: Plant development and evolution
- Lecture 7: Plant development and evolution
- Lecture 8: Plant development and evolution
- Lecture 9: Plant development and evolution
- Lecture 10: Plant development and evolution
- Lecture 11: Plant development and evolution
- Lecture 12: Plant development and evolution
- Lecture 13: Plant development and evolution
- Lecture 14: Plant development and evolution
- Lecture 15: Plant development and evolution
- Lecture 16: Plant development and evolution
- Lecture 17: Plant development and evolution
- Lecture 18: Plant development and evolution
- Lecture 19: Plant development and evolution
- Lecture 20: Plant development and evolution



The differentiation of cambial cells into vessels or tracheids with lignified walls is triggered by auxins. Auxins will induce xylogenesis in a number of plant tissues and, as in all other hormone-mediated processes, there may also be a requirement for gibberellins and/or cytokinins (Sugiyama and Konomi, Cell Differentiation Dev. 31, 77, 1990).



Overview: Click here to see an illustrated overview of the experiment.

Explants of *Juniperus communis* (red-leaved Juniper) have been shown to develop wound vessel members (WVM) on a nutrient agar containing an auxin. The addition of cytokinins and gibberellins alters the arrangement of the tracheids (Zelazny and Roberts, Am J Bot. 88, 376, 1971; Zelazny, F Cell Physiol. 14, 135D, 1970).

- Review: The control of vascular development**  
Shimizu, Andrew. Plant Physiol. 1979. 52:313-27. (PDF, 140 KB)
- Review: Xylogenesis - initiation, progression and cell death**  
Fubny, Arno. New Phytol. 1996. 136: 47-59-325 (PDF, 1.8 MB)
- Practical notes**  
Experimental instructions  
Yellow sheet
- The contribution of auxin and cytokinin to symmetry breaking in plant morphogenesis.**  
D.E. Hanks & S.J. Green. Shape and Form in Plants and Fungi (1994) (PDF 1.1 MB)

Revision

Essay questions

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Practical exam question

Question about the practical experiment, including a PDF file.