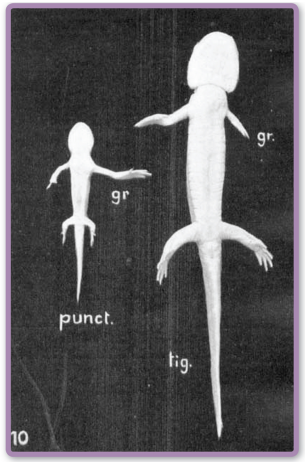

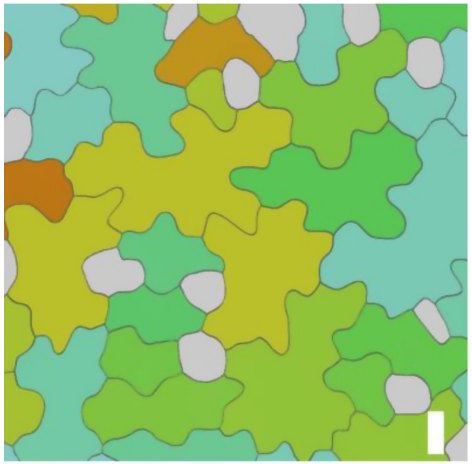

Growth and patterning in plant development

Dr. Aleksandra Sapala

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   - growth and development in general
   - growth of plants compared to animals
2. Plant biology – crash course
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4. Patterning in organ shape
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6. Tutorial: cell shape - case study

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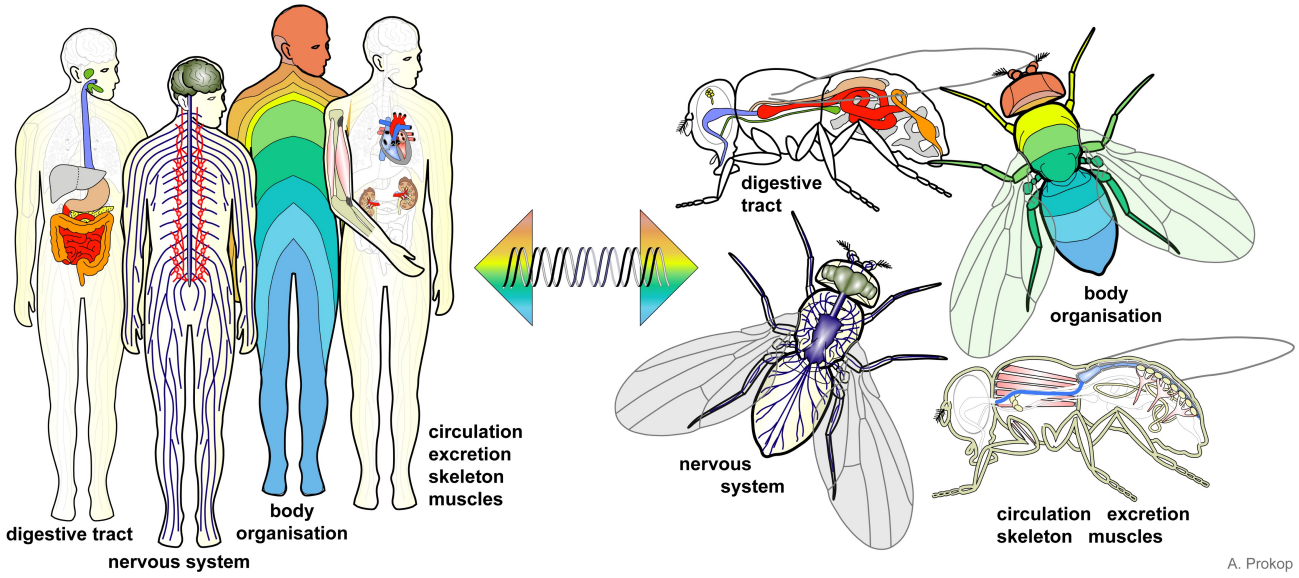
What is development?



- From egg fertilisation to a functional, multicellular organism
- Understanding the processes behind creating form and function
- Mostly basic science, but not only

What is developmental biology?

Basic questions:

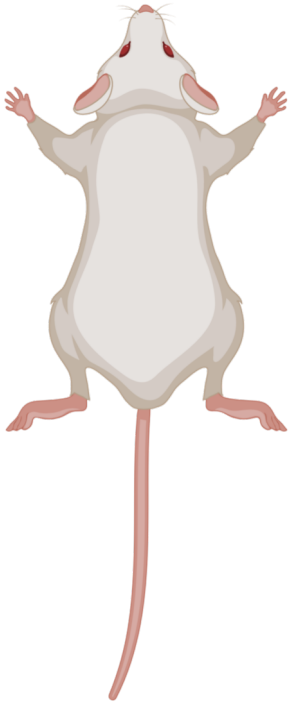
- How do organisms grow?
- How does an organ develop?
- When does an organ stop growing?
- How did a developmental mechanism evolve?

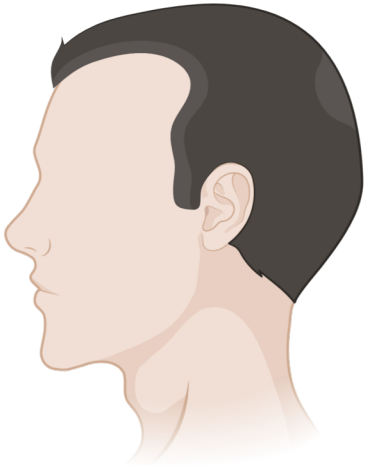
Practical applications:

- Human disease
- Human fertility
- Crop improvement
- Ecology

Types of growth

- Determinate growth – only until a certain size is reached
- Indeterminate growth – continues until an external factor stops it





Growth on different levels

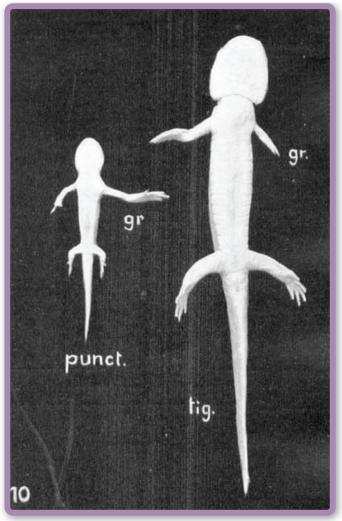
Animals

Organism level:

- Determinate growth

Organ level:

- Determinate growth



Vogel, 2013

Plants

Organism level:

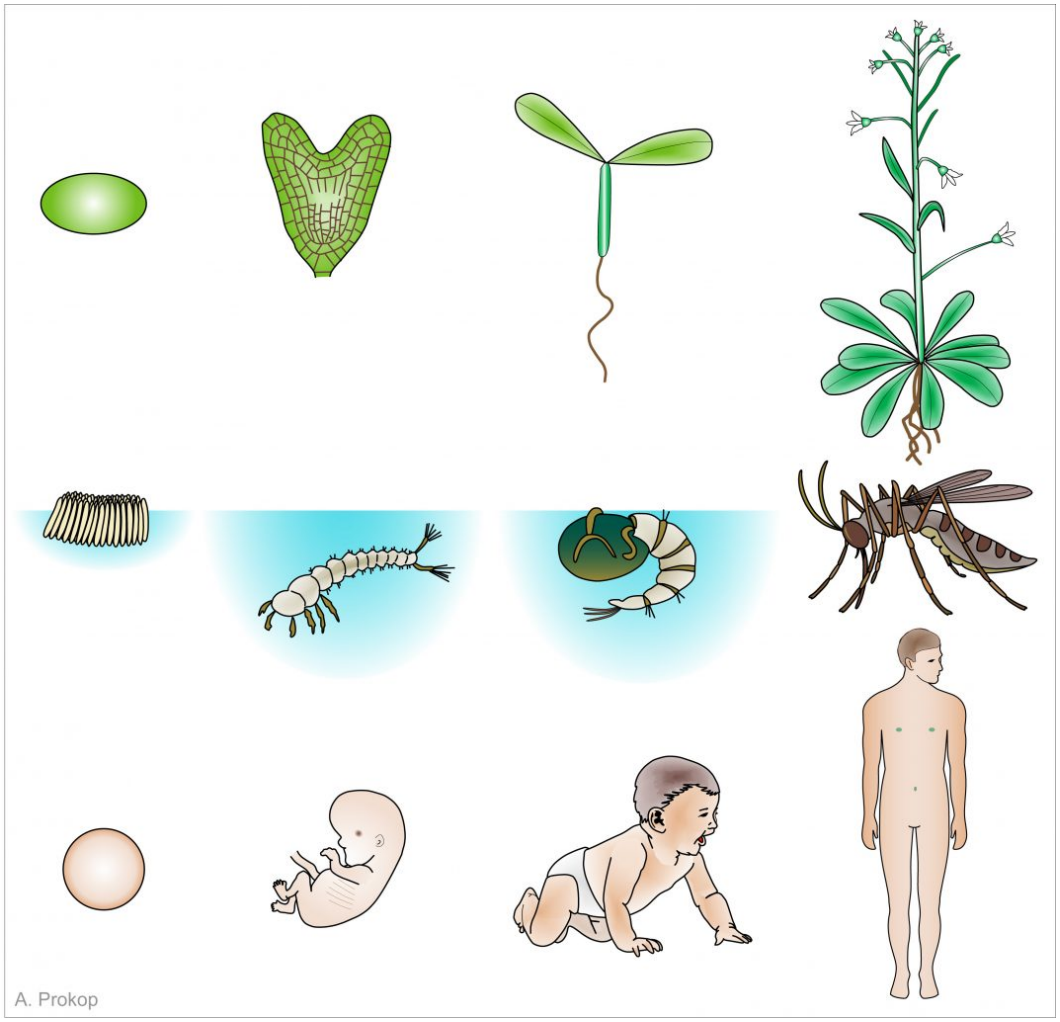
- Indeterminate growth

Organ level:

- Determinate growth

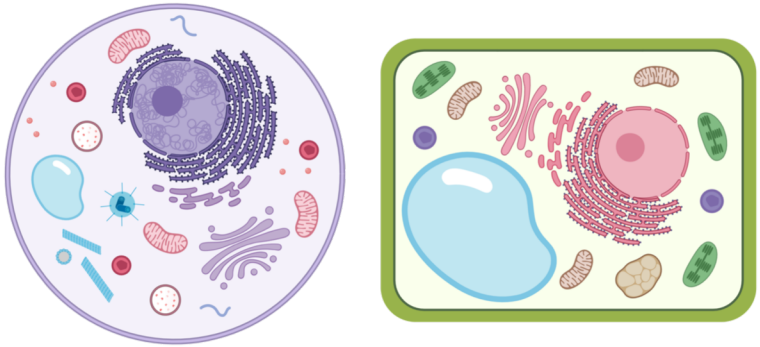
adapted from Hunter et al., 2016

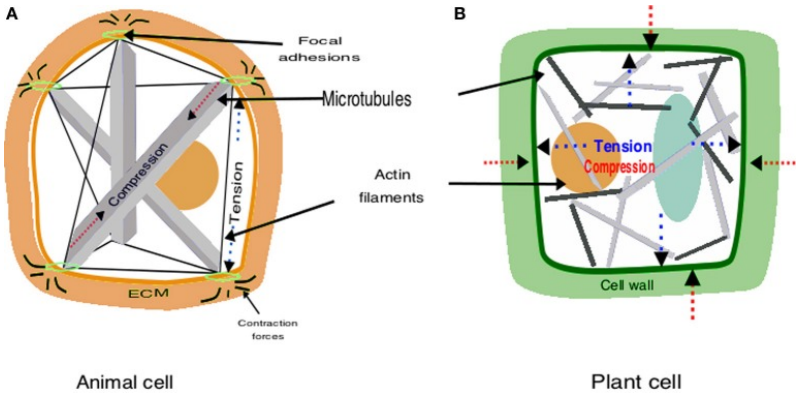
Animals vs. plants



- Plant and animal development evolved separately
- Nonetheless, they have similarities

Animal cell vs. plant cell





Animal cell

Plant cell

Hernandez-Hernandez et al. 2014

Plant cell has the **cell wall** which bears the load of **turgor pressure**

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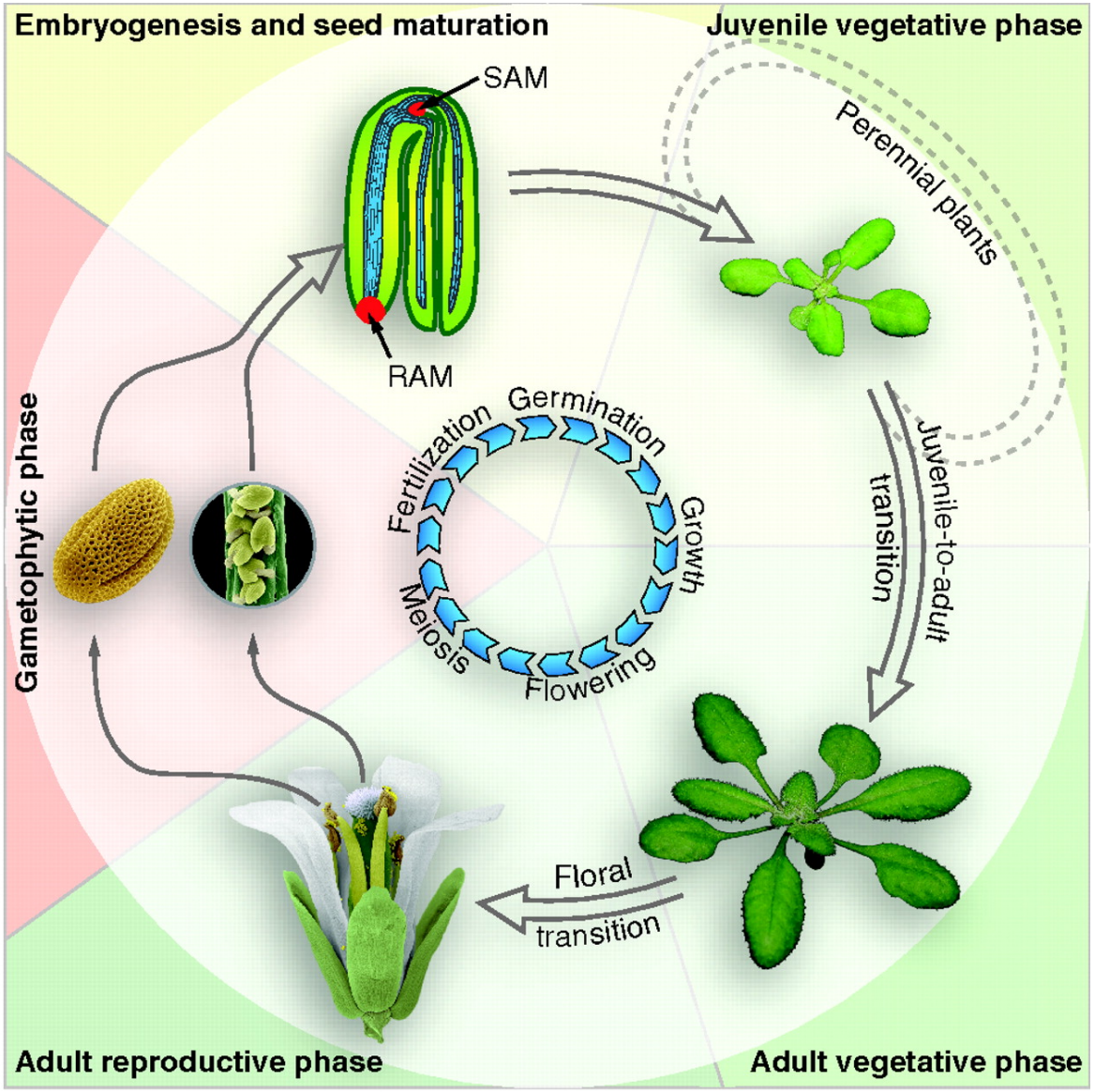
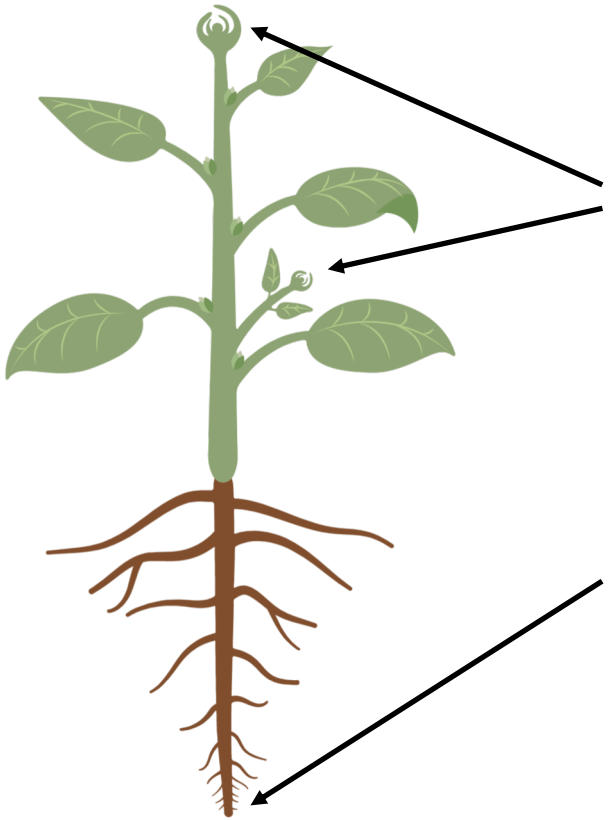


Image: Huijser & Schmid, Development, 2011

Meristems – stem cell niches

Meristems are centers of meristematic cells where the bulk of cell division and differentiation happens

1. Vegetative meristems:



Shoot Apical Meristem

Root Apical Meristem

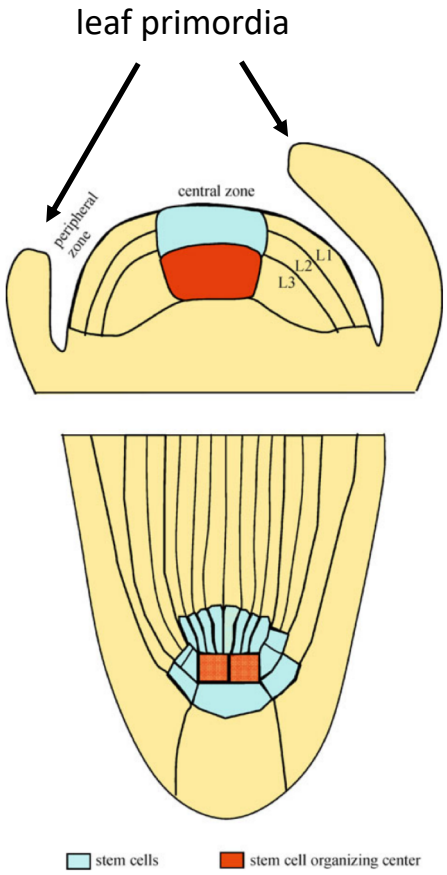
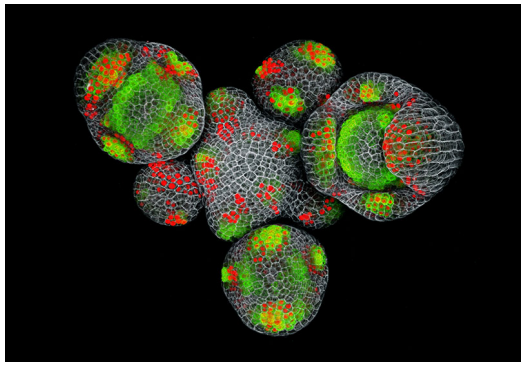


Image: Liu & Hu. Front. Biol. 2010

Meristems – stem cell niches

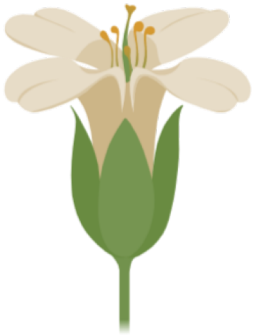
2. Reproductive meristems

Inflorescence meristem



Meyerowtiz Lab, CalTech

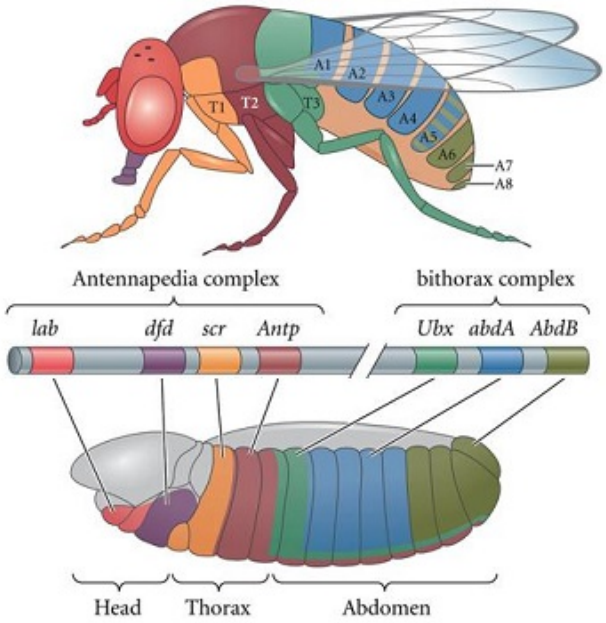
Flower



Fruit

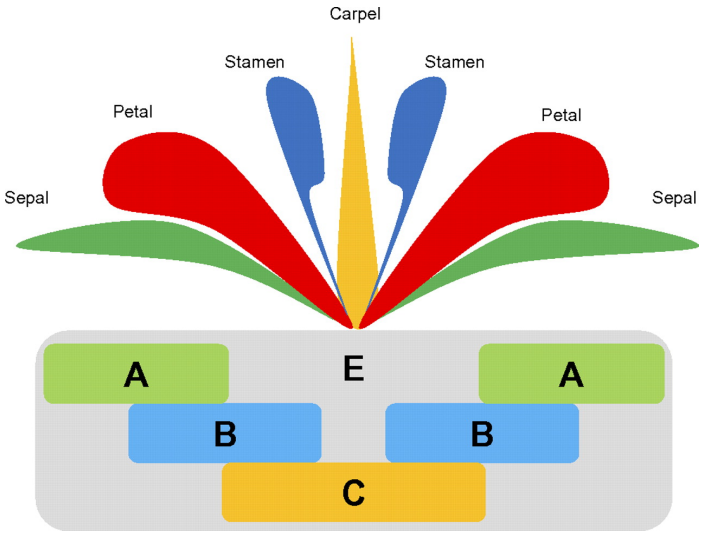
Pattern formation

Achieved by spatio-temporal distribution of gene expression in compartments (on different levels)



Drosophila melanogaster embryo segmentation

adapted from Gilbert et al. 'Developmental biology'



Arabidopsis thaliana flower development

adapted from Chanderbali et al. 2010

Certain genes are responsible for creating certain organs

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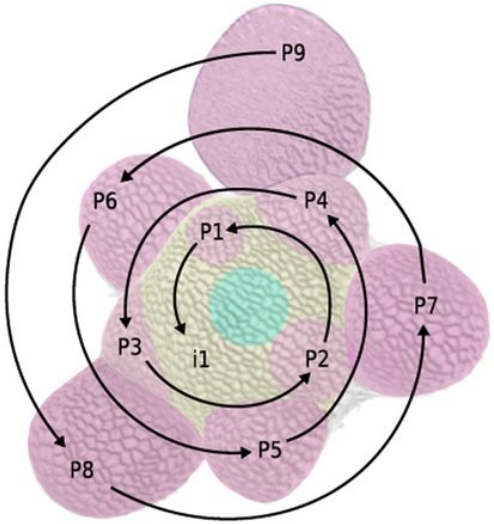
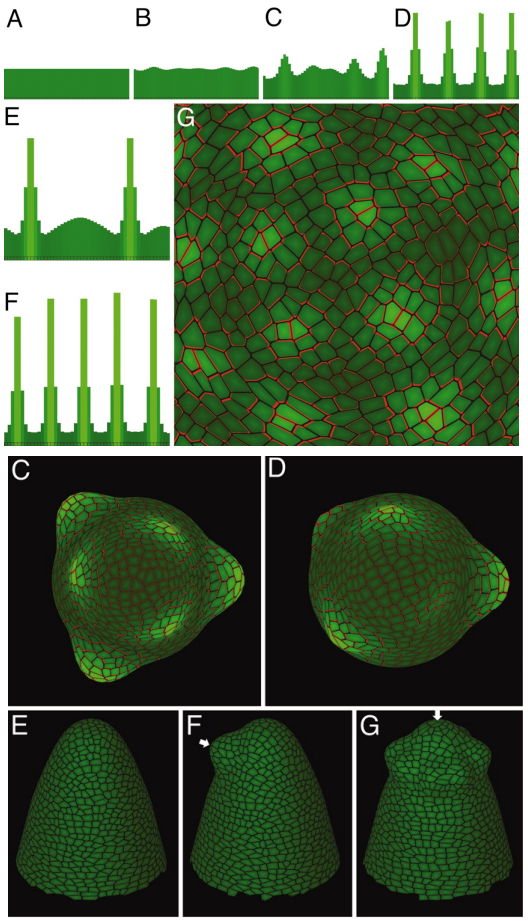
Patterning in organ creation

Phyllotaxis: organs (leaves or flowers) are created in a specific order always at the same angle



Murray et al., 2012

study.com



Smith et al., PNAS, 2006

Can be explained by local maxima of growth hormone auxin

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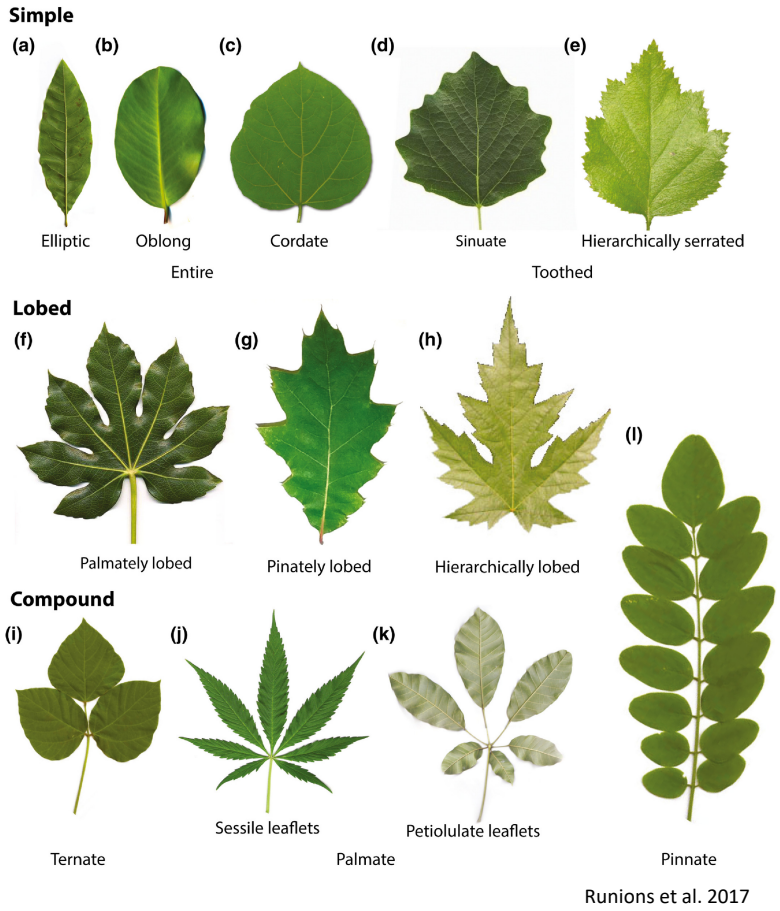
Patterning in leaf shape

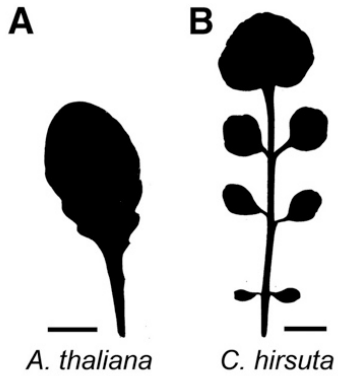


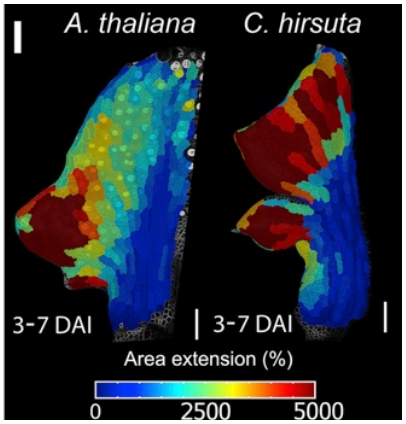
Runions et al. 2017

Where does the shape diversity come from?

Patterning in leaf shape

Comparative framework:
2 related species





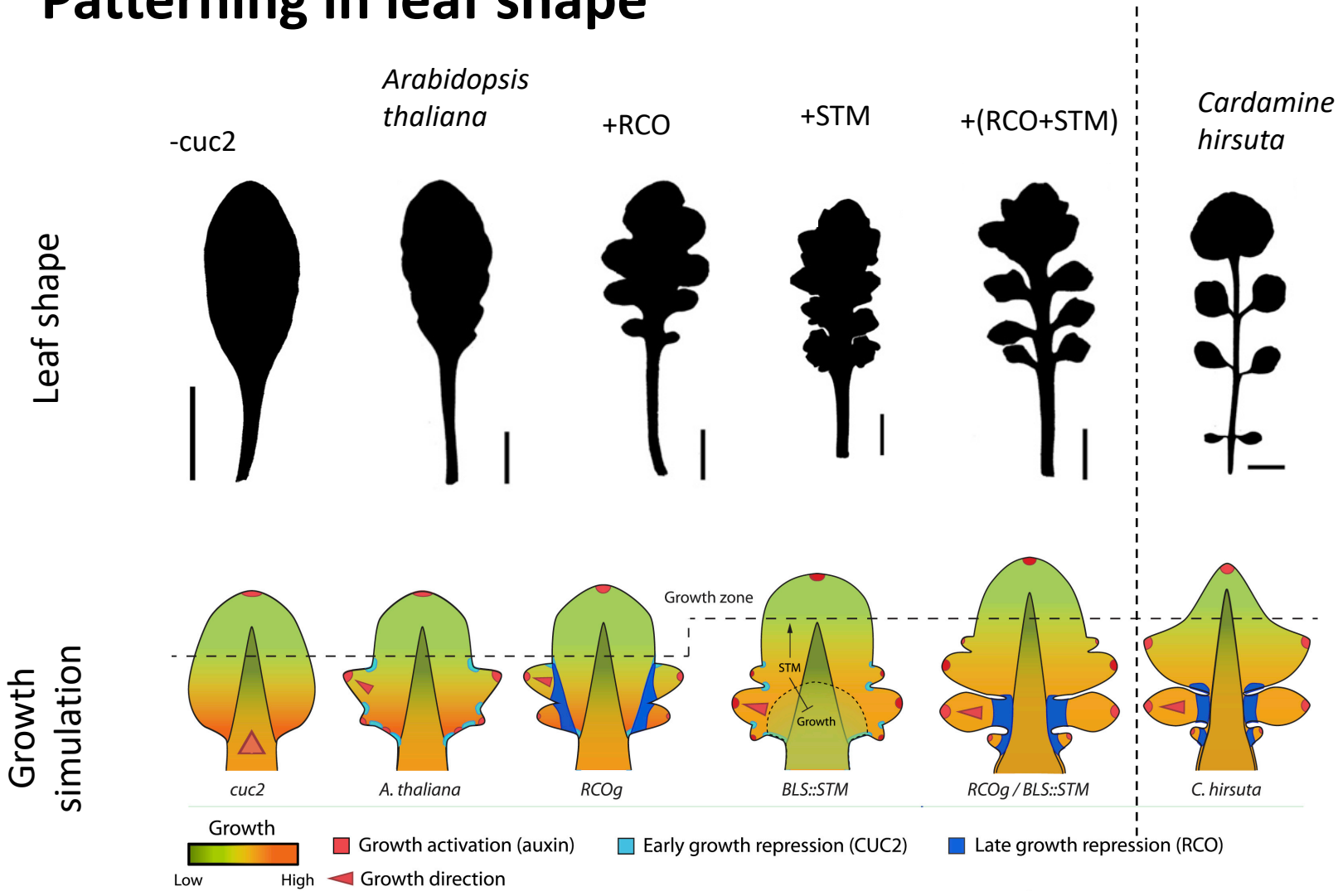
adapted from Kierzkowski et al. 2019

Genetics:
are there **unique genes** in one of the species?
(RCO and STM)

Microscopy:
How do leaves grow?

Computer model:
Spatio-temporal patterns of growth factors

Patterning in leaf shape



adapted from Kierzkowski et al. 2019

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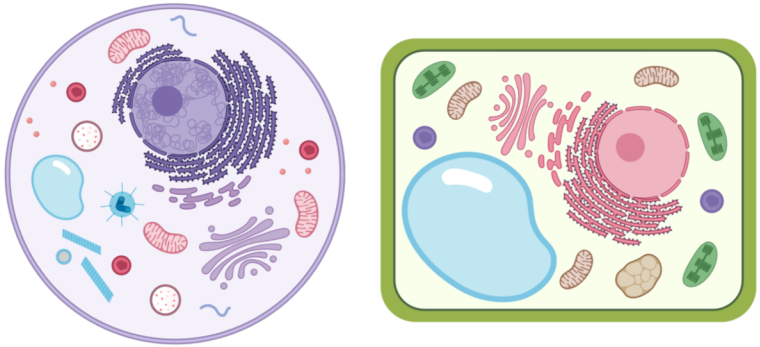
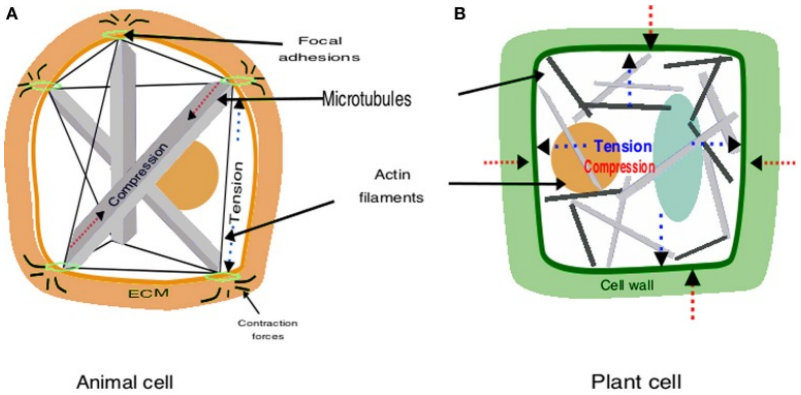
Animal cell vs. plant cell





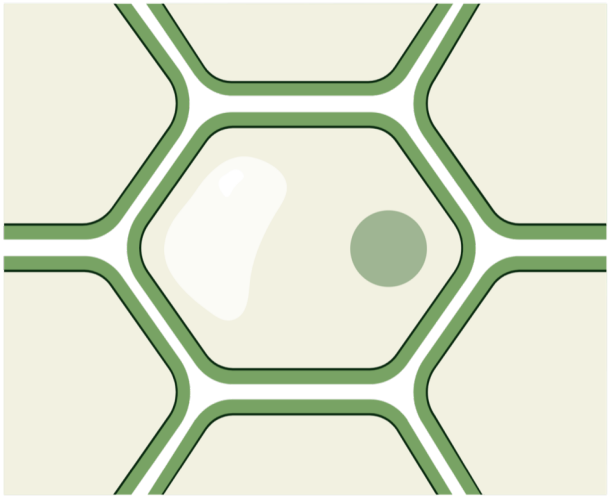
Animal cell

Plant cell

Hernandez-Hernandez et al. 2014

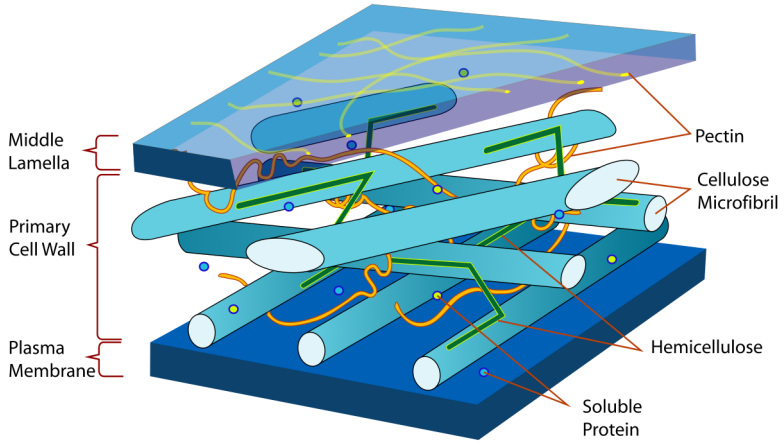
Plant cell has the **cell wall** which bears the load of **turgor pressure**

Cell wall



The cell wall acts as a **scaffold** and **contains the very high turgor pressure** inside cells

Cellulose is composed of very rigid **microfibrils**



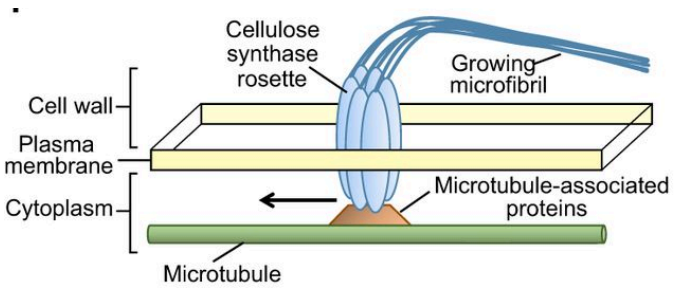
Cellulose deposition guides growth direction

Cortical microtubules guide the direction of cellulose deposition

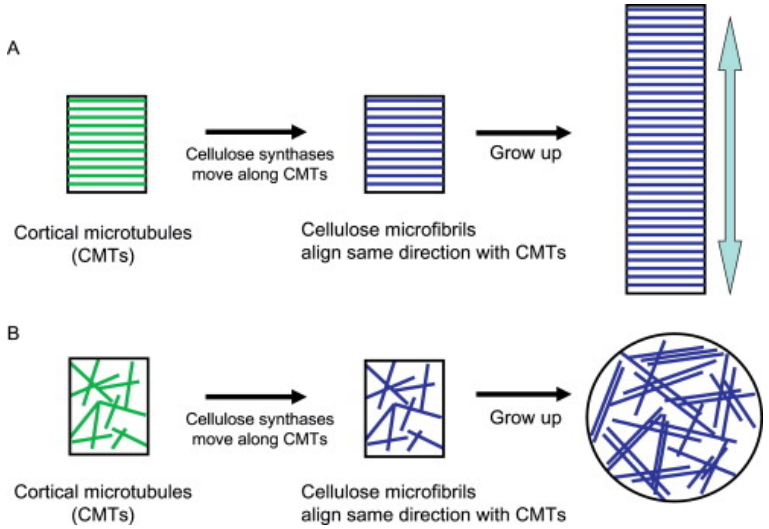
↓

Cellulose microfibrils guide growth in perpendicular direction

What guides microtubules?



adapted from Smyth, 2010

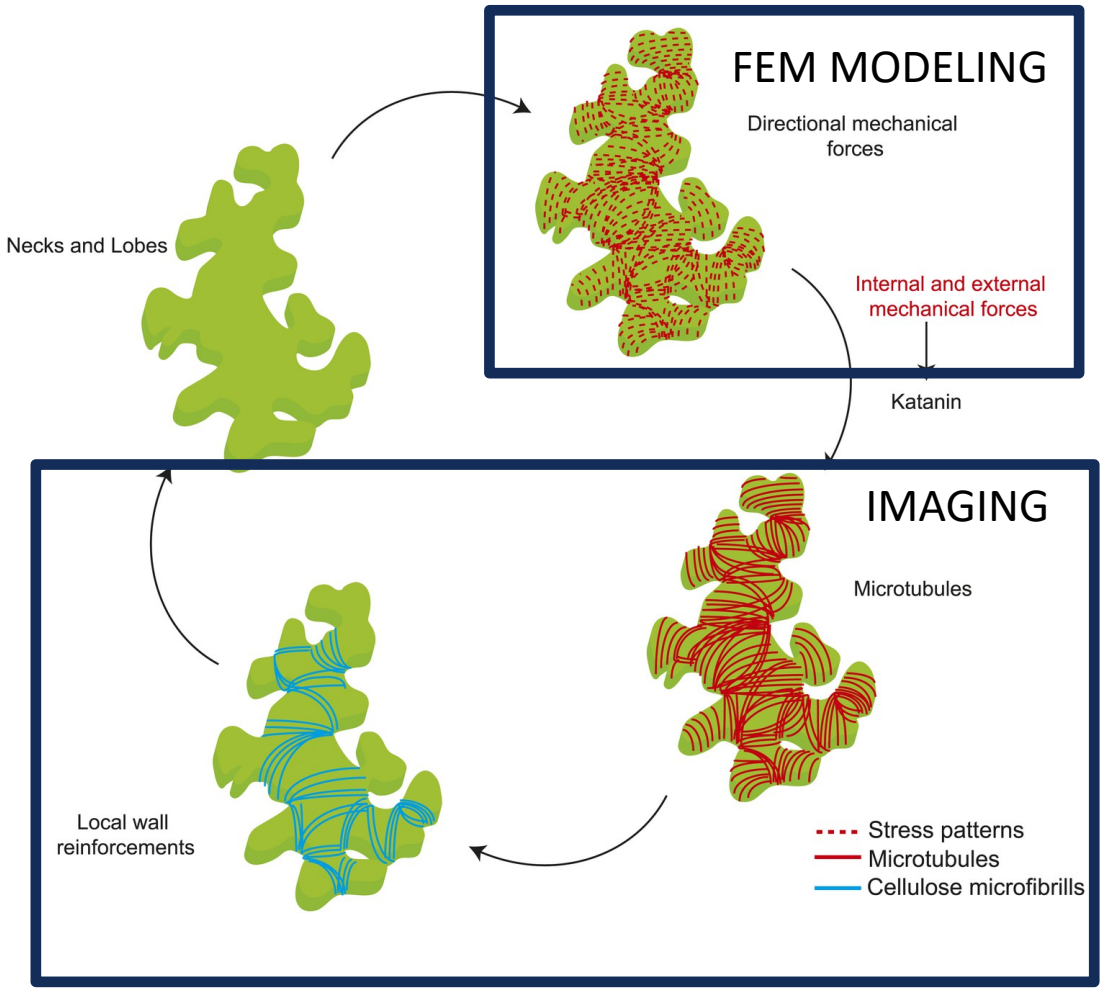


adapted from Hamada, 2014

Mechanical feedback on cell shape

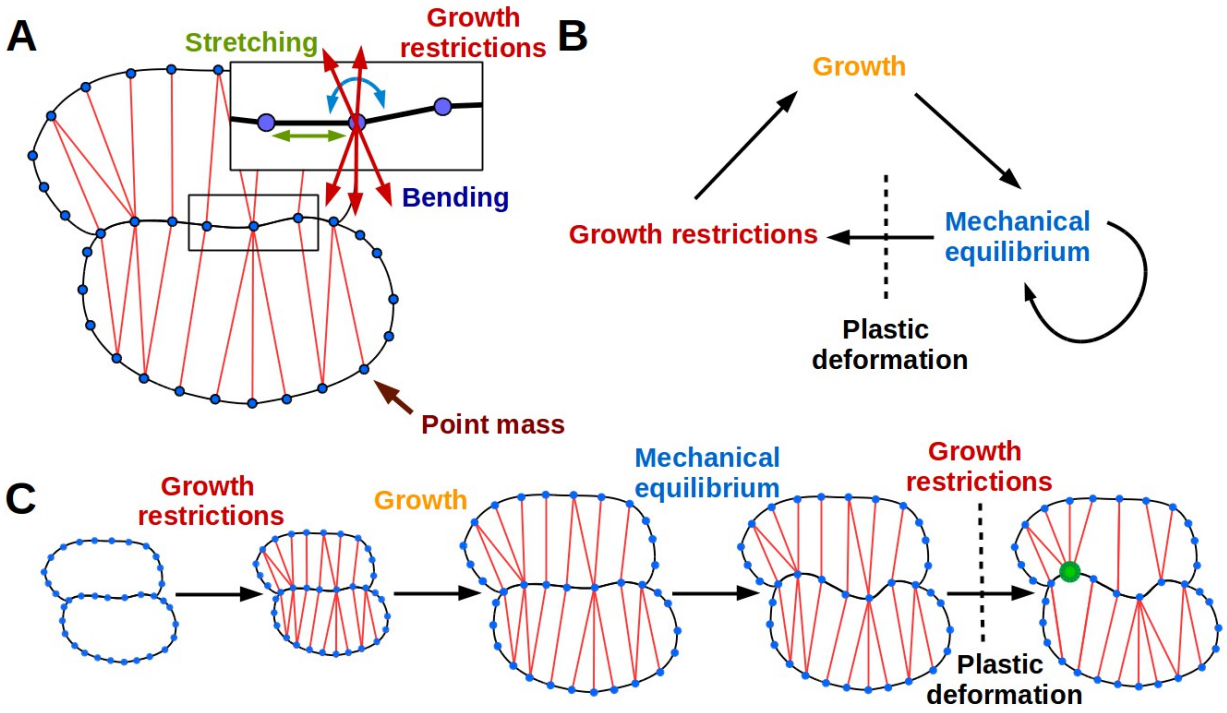
Microtubules sense direction of mechanical stress

Question:
Can microtubules (guiding cellulose) create this shape from scratch?



adapted from Sampathkumar et al. 2014

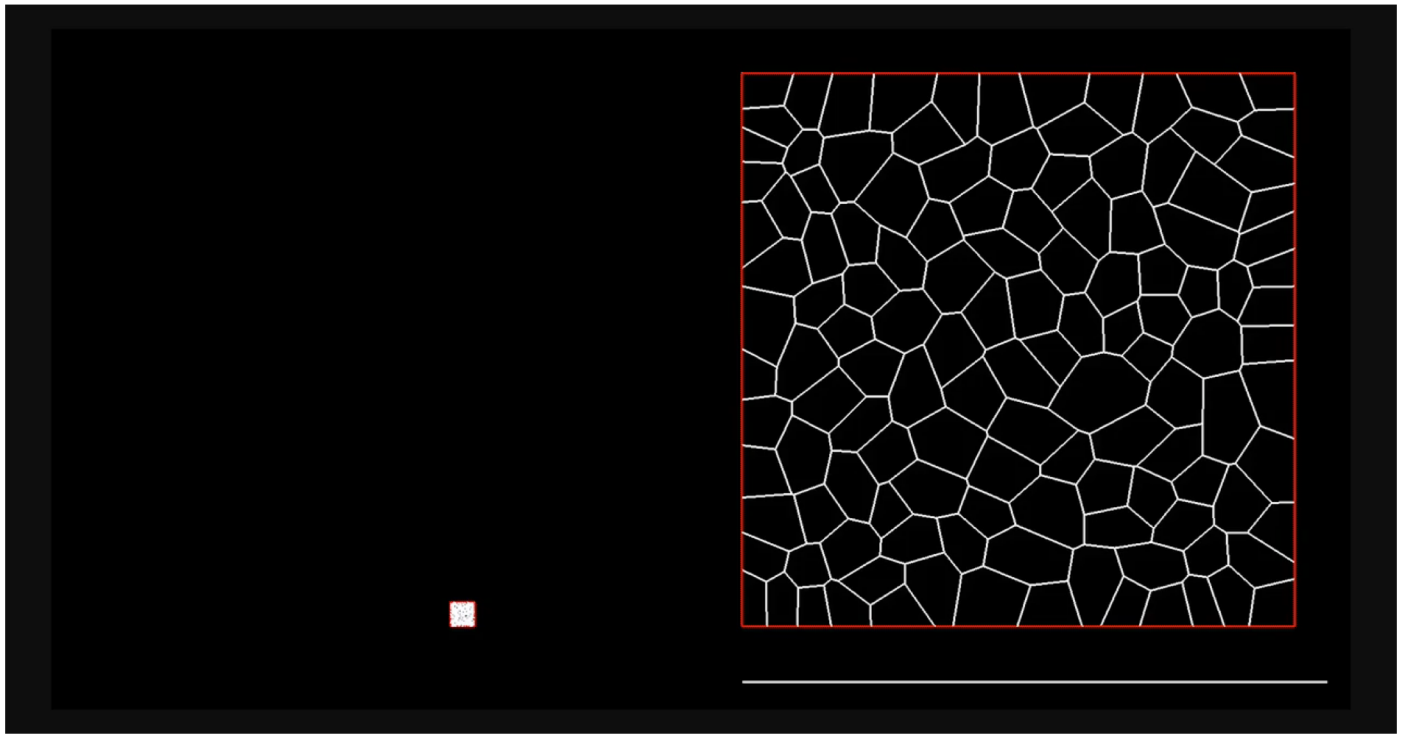
Patterning in cell shape



Each simulation step:

- Growth is restricted by connections across the cells (symbolising microtubules and cellulose)
- Forces within cells are minimised
- Cell shape is adjusted accordingly

Patterning in cell shape



Conclusion: a mechanical model confirms that the cortical microtubule-driven growth restriction mechanism recapitulates real-life cell shapes

Summary

Cell geometry

Mechanical stress

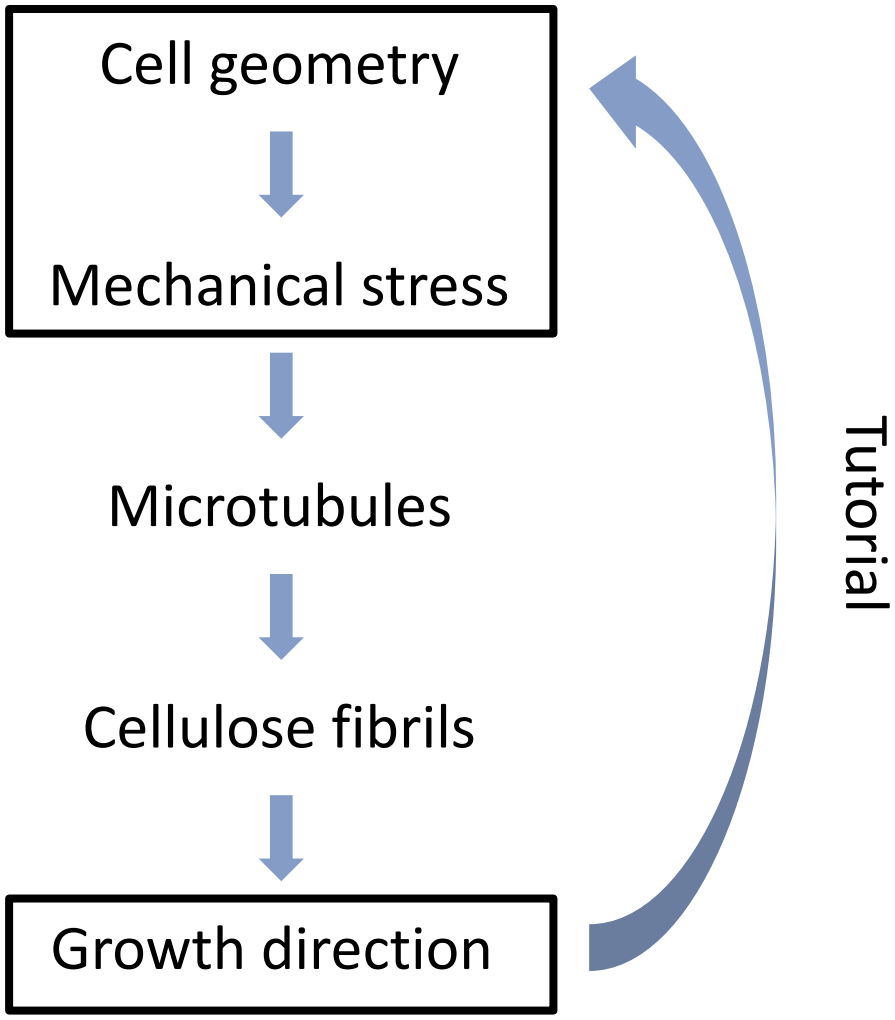
Microtubules

Cellulose fibrils

Growth direction

Summary

Adjusting cell shape to minimize mechanical stress on cell wall upon defined growth direction



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Q&A