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Stress-based regulation of multicellular plant growth: a finite element modeling approach applied to planar leaf morphogenesis
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How do plant cells locally control their growth to coordinately produce macroscopic shapes?

➤ Mechanical tensions hypothetically provide cues governing local cell growth regulation [1,2].
What kind of emergent dynamical behavior can a stress-sensing tissue display?
➤ Finite element multicellular model coupling growth and stress feedback

MODEL / SIMULATION LOOP

Growth step
Mechanical equilibrium
Microfibril dilution/rotation
Microfibril stress-regulated synthesis
Update stiffness
Compute new equilibrium

Update element rest state (4):

$\frac{\partial P_e}{\partial t} = (E - \rho_0) - P_e$

Stress-dependent microfibril polym. [7]

$\rho = (\theta) \propto e^{i\phi}$

SOME RESULTS

• We simulate the local dynamics of various abstract shapes (ellipsoids) mimicking flat shape (~800-cell meshes).
• Epidermal feedback or inner feedback stabilize axial elongation of axisymmetric shapes.
• Flat expansion requires inner stress feedback: microtubules align in the axis of thickness to resist thickening.
• This mechanism allows amplification of organ asymmetry.
• Coupling inner and epidermal feedback leads to conflicting microtubule alignment (not shown) → possible mechanical instability?

TAKE-HOME MESSAGE

A single mechanism accounts for flat and axial expansion mode depending on initial shape.
Coupling inner and epidermal stress feedback reveals nontrivial behavior and possibly unstable regimes. → Need for additional regulation?

References: