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Morphogenesis of walled cells

OTGER CAMPAS, Harvard University

Walled cells have the ability to remodel their shape while sustaining an internal turgor pressure that can reach values up to 10 atmospheres. This requires a tight and simultaneous regulation of cell wall assembly and mechanochemistry, but the underlying mechanisms by which this is achieved remain unclear. In this talk I will discuss the interplay between growth and mechanics in shaping a walled cell, in the particularly simple geometry of tip-growing cells, which elongate via the assembly and expansion of cell wall in the apical region of the cell. Using only conservation laws and describing the observed irreversible expansion of the cell wall during growth as the extension of an inhomogeneous viscous fluid shell under the action of turgor pressure, we determine theoretically the radius of the cell and its growth velocity in terms of the turgor pressure and the secretion rate and rheology of the cell wall material. Moreover, we derive simple scaling laws for the geometry of the cell and find that a single dimensionless parameter, which characterizes the relative roles of cell wall assembly and expansion, is sufficient to explain the observed variation in shapes of tip-growing cells. Our work shows that the physics of cell wall expansion tightly constrains cell shape, providing a unified explanation of the characteristic morphologies of tip-growing cells across species that span several kingdoms, even though their underlying molecular mechanisms of cell morphogenesis are very different. More generally, our description provides a general framework to understand cell growth and remodeling in plants (pollen tubes, root hairs, etc.), fungi (hyphal growth and fission and budding yeast) and some bacteria.