Formation of wood grain: self-organization through alignment of elongated cells II

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In this project you will study the biological mechanisms that form the wonderful flame-like textures of wood (see Figure 1). These textures, called wood grain, form as new, elongated cells that are deposited on top of the existing wood in the vascular cambium, and align with the existing wood grain. In addition to the alignment of adjacent cells, it is thought that cells align with the flux of auxin, a plant hormone that is involved in practically all aspects of plant growth and development. Previous mathematical models of wood grain formation [1, 2] consider a fixed domain of oriented cells, and assume cells gradually align with their neighbors and with the flux of auxin. Although these models explain wood grain orientations around side branches and the orientations around topological defects, they incorrectly represent two key aspects of wood grain formation: a) once fixed within wood, cells cannot move or turn - cells align probably when or briefly after the vascular cambium deposits them; b) the models do not consider growth of wood, while growth-induces strains may contribute to alignment.

The aim of this project is to improve the biological realism of existing wood grain models, by including a) accretive wood growth and growth-induced strains, b) a wood maturation mechanism that will constrain the reorientation of cells. The mathematical techniques and project details are open to discussion. Possible directions include:

Figure 1: Wood grain
• Solve and analyze existing PDE-based models on a growing domains

• Construct and study a vertex-based mechanical, cell-based simulation model of the wood growth, using the modeling framework VirtualLeaf [3] - compare with mean-field approach

• Construct a lattice-based model of wood grain formation (e.g. Cellular Potts model[4])

• Focus on detailed, single-cell models of plant cell alignment

• Extend model with potential responses to auxin fluxes - e.g., local alignment or local growth

References


