Sap flow and sugar transport in plants

Green plants are Earth’s primary solar energy collectors. They harvest the energy of the Sun by converting light energy into chemical energy stored in the bonds of sugar molecules. A multitude of carefully orchestrated transport processes are needed to move water and minerals from the soil to sites of photosynthesis and to distribute energy-rich sugars throughout the plant body to support metabolism and growth. The long-distance transport happens in the plants’ vascular system, where water and solutes are moved along the entire length of the plant. In this review, the current understanding of the mechanism and the quantitative description of these flows are discussed, connecting theory and experiments as far as possible. The article begins with an overview of low-Reynolds-number transport processes, followed by an introduction to the anatomy and physiology of vascular transport in the phloem and xylem. Next, sugar transport in the phloem is explored with attention given to experimental results as well as the fluid mechanics of osmotically driven flows. Then water transport in the xylem is discussed with a focus on embolism dynamics, conduit optimization, and couplings between water and sugar transport. Finally, remarks are given on some of the open questions of this research field. Green plants harvest the energy of the Sun in the leaves by converting light energy into chemical energy in the bonds of sugar molecules, using water from the soil and carbon dioxide from the air. This review provides an overview of the vascular anatomy of plants and the physical models that describe the long-distance transport of water and minerals from root to leaf, and, in particular, of sugars from the leaves to the entire body of the plant sustaining growth and communication throughout even the tallest tree.

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