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Fluid mechanics of osmotic pipe flows and limitations on the lengths of conifer needles. TOMAS BOHR, HANNA RADEMAKER, KAARE JENSEN, Physics Department, Technical University of Denmark, MACIEJ ZWIENIECKI, Department of Plant Sciences, University of California, Davis — Plant leaves produce sugars, which are exported osmotically through the sieve tubes of the leaf. Leaf sizes vary by more than 3 orders of magnitude, from a few millimeters to over one meter. Conifer leaves (needles), however, are relatively short and the majority of needles are no longer than 6 cm. The reason for this limitation is unknown, but we argue that it can be explained by the linear venation pattern and the narrow sieve tubes, combined with the osmotic flow mechanism. Thus sugars produced near the tip of long needles cannot be exported efficiently, because the pressure required to drive vascular flow would exceed the greatest available pressure (the osmotic pressure). This basic constraint leads to the formation of an inactive region of stagnant fluid near the needle tip, which does not contribute to sugar flow. The active region, emerging from the base of the needle, has the length $L_{eff} = r^{3/2}\,(16\eta L_p)^{1/2}$, where r is the conduit radius, η is the sap viscosity, and L_p is the cell membrane permeability. It is independent of the needle length and corresponds well with maximal needle lengths observed in nature.

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