1) Transport of fluids and entropy generation in plant leaves

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Plant leaves are open thermodynamic systems that exchange water, nutrition, O_2 and CO_2 with environment and other parts of the plant (roots, shoots, branches, flowers and fruits). The mechanisms of the heat and mass exchange in plants are still unclear. It is known, water and nutritions come into a leaf through a bunch of porous vessels in its petiole due to active water suction by roots. The leaves have high evaporating area that creates very low (and even negative) hydrostatic pressure (additional top pump). The conducting system of leaf is composed by a network of veins while the short-range cell-to-cell transport is provided by microflows through the porous cell walls and diffusion. Since the leaf shapes and vein systems are proposed for different engineered systems (solar panels, absorbers of CO_2 and pollutants, etc.) understanding of the nonequilibrium thermodynamics of the transport and its optimization is essential.
Based on the balance equations for liquid and solid components with biochemical reactions in the leaf due to sun radiation (photosynthesis), the expressions for driving forces for the xylem and phloem transport can be derived and analyzed at different ambient conditions (soil, air, sun radiation) with non-equilibrium thermodynamics approach.

In this project, the student will familiarize with irreversible thermodynamics in the fluid dynamics problems at the microscale, balance equations and the linear force-flux relations, and learn how the short-range water delivery problem is solved in plants based on the thermodynamics laws. The project will be carried out according to the following steps:

1. Analysis of the balance equations for the plant sap flow in the leaves of different types.
2. Derivation and analysis of the entropy generation expression accounting for osmotic factors and chemical reactions.
3. Numerical computations of water transport in a model system at different ambient conditions (atmospheric pressure, temperature, humidity).
4. Elaboration of nature-inspired engineered units based on the principles studied.