Life above a certain size relies on a circulatory system for oxygen and nutrient delivery. Without it, no complex animal would exceed a few millimeters: by diffusion alone, oxygen would not be able to travel more than $100\,\mu m$ in the tissue. Plants, animals and fungi have developed circulatory systems of striking complexity to solve the formidable problem of nutrient delivery and waste removal. Typically, biological transport networks have to satisfy competing demands to operate efficiently and robustly while confronted with an ever-changing environment. The architecture of these networks, as defined by the topology and edge weights, determines how efficiently the networks perform their function. In this talk we present some general models regarding the emergence and function of biological transport networks, from the reticulate vascular architecture of the leaf, to the hierarchies of the veins and arteries in our brain. We demonstrate that the network topologies generated by adaptation represent a trade-off between optimizing power dissipation, construction cost, and damage robustness. We identify the Pareto-efficient front and eventually the spectrum of venation phenotypes that evolution is expected to favor and select. Next, inspired by hemodynamic fluctuations in the brain, we examine how a network can dynamically adapt to reroute flow to prescribed network locations. In particular, we investigate how many simultaneous functions a given network can be programmed to fulfill and we uncover a phase transition that is related to other constraint-satisfaction transitions.

“The Spectrum of Efficient Venation Phenotypes”