Morphogenesis of looping transport networks in nature

While during evolution organisms enlarged, they had to find ways to overcome the small distance at which diffusion can take place to exchange gases and nutrients with the environment. Animals and plants have developed a great variety of strategies to achieve an active transport. Many of these strategies involve spatial network structures, like gastrovascular canal network in jellyfish, leaf venation or blood vessels (Fig. 1).

Such networks can take different shapes. They can form tree-like structures, composed of branches that grow and sometimes split. It can also happen that branches not only divide but also reconnect during growth, leading to looping structures. The latter, highly reticulated networks, appear to be ideally suited for actively transporting oxygen or nutrients to every cell in the body and carrying away metabolic products. An important advantage of looping networks is their robustness to damage – in networks without loops, the destruction of one branch can cut off all branches connected to it, while in networks with loops there is always another connection to the rest of the system.

While the physical processes involved in the formation of tree-like structures – such as branch expansion or bifurcation mechanisms – are relatively well understood, the key ingredient for obtaining loops in a network – the reconnection process – remains unclear. This project will specifically address the phenomenon of loop formation in transport networks during the process of network growth. What leads to reconnection between network branches? How do the loops created in such processes affect network properties such as robustness to damage or transportation efficiency? These are just some of the questions we will try to answer in this project.

A special case of a transport network that we want to study experimentally is the gastrovascular canal network of jellyfish. By studying such evolutionary primitive transport network, we can understand the basic principles behind its formation, which are useful for studying more complex systems such as blood vessel networks.

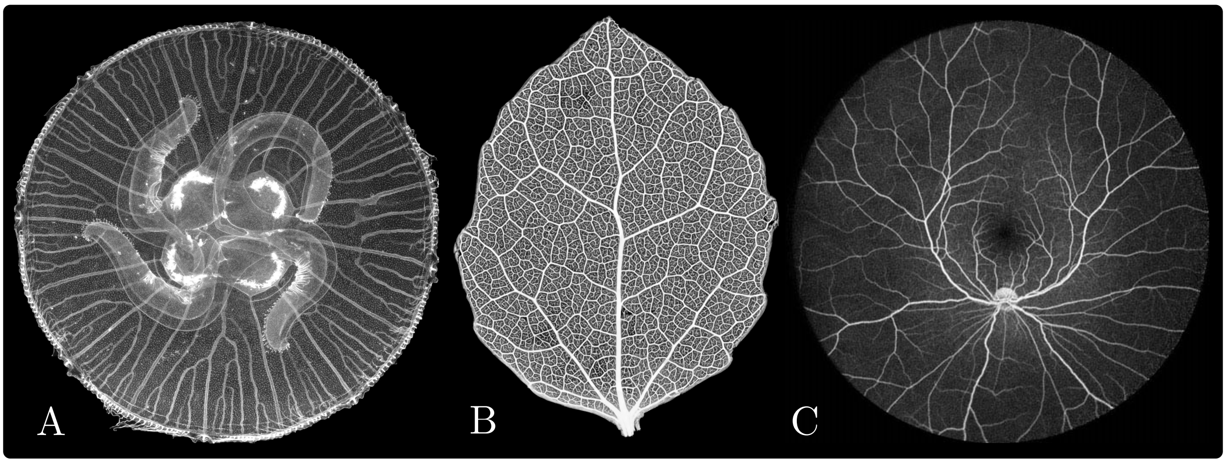

Figure 1: Examples of transport networks in nature: (A) Gastrovascular system of jellyfish *Aurelia aurita* (B) Venation network of leaf *Populus tremuloides* (photo: Blonder & Elliott) (C) Retinal arteries and veines (Kawali et al., Ocul. Immunol. Inflamm., 2017)