

Organellogenesis: How cells build membrane-bound organelles

Almost all living cells contain a spectrum of membrane-bound biophysical machines called *Organelles*. These are responsible for most metabolic, molecular synthesis and regulatory processes within the cell. A selection of these organelles include Mitochondria, responsible for the distribution of chemical energy, the Golgi apparatus and Endoplasmic Reticulum, associated with lipid and protein synthesis and transport, and the Contractile Vacuole, found in plants, responsible for osmotic regulation. How these organelles spontaneously self-assemble within the cell, a process that we term *Organellogenesis* is a subject of great interest to cell biologists but is a process about which remarkably little is known. In this project we propose to focus on what is arguably the most simple form of cellular organelle, the Contractile Vacuole and seek to understand its function and spontaneous emergence.

Fresh water dwelling single celled organisms (e.g. algae and protists) require a method of osmoregulation. This is due to the high ionic concentration within cells. One possible outcome would be a slow influx of water until the (extremely high) osmotic pressure is balanced by the stress in the cell wall or cell membrane. Instead many cells actively pump volume out by using the highly conserved Contractile Vacuole Complex[2]. This is made up of several quasi-spherical lipid membrane “sacks” connected to the cell membrane by a pore which acts as a “Tension Gate”[1, 3]. These are observed to rhythmically fill, becoming tense and then suddenly empty, expelling fluid out through the pore. They are also connected to a network of narrow membrane tubes, which can also be observed to undergo some rhythmic volume changes and seem to be connected to the primary sacks.

This project will aim to study the physics of a tubular membrane in which water fluxes follow an actively generated osmotic gradient. The membrane will be treated as a continuous surface [4, 5]. The fluid dynamics of transport within the tube-sack complex will be studied analytically by employing a standard equation for the membrane mechanics coupled to high symmetry, Low Reynolds number hydrodynamic equations for the flows of the membrane, fluid and ions. The tube is initially a cylindrical, semi-infinite fluid membrane surface that is permeable to water. Crucially this has energy-consuming ion pumps embedded in its surface that set up an osmotic gradient, driving a passive influx of water. We will examine the stability of analytical solutions for any signatures of the spontaneous formation of large sack-like structures at the end closest to the pore. Such solutions would be an extremely promising signature of spontaneous genesis of the main sack-like compartment from the ubiquitous tubular network known to be present within cells. Numerical simulations remain an option in this high-symmetry setting if full analytic results prove challenging. There is clear scope for extension to a full PhD project.

As well as a clear motivation from Cell Biology a good physical understanding of such tubular membrane pumps could lead to new designs of bio-machines and synthetic micro-swimmers. This work will be done in collaboration with Prof. Pierre Sens of Institut Curie, Paris with funds for multiple trips by the student already agreed by Prof Keeling.

This project was developed together with Sami Al Izzi and is reserved for him.

References

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