Dry and Alive – the impact of hydration on the properties of bacterial cell membranes and its role in prokaryotic anhydrobiosis

Popular science summary

Water is essential for maintaining biological activity in living organisms however, some organisms developed a remarkable ability to withstand transient dehydration. Anhydrobiosis, which means "live without water", is the ability of living organisms to lose all or almost all water and suspend the whole metabolism until the moment when full hydration of the organism is restored. Nature is full of organisms capable of anhydrobiosis such as nematodes, yeasts, tardigrades, and bacteria. **Although much research has been done on unraveling the dehydration resistance in tardigrades, very little is known about how bacteria deal with the loss of water and why some bacteria are more resistant to temporary dehydration than others**.

Bacteria are categorized into two main groups: gram-positive and gram-negative. This classification is based on the structure of the membrane (the so-called cell envelope) that protects the interior of the bacterial cell from the surrounding environment but at the same time allows selective transport of ions, nutrients, and other macromolecules inside and outside the cell. Unlike cells of more complex organisms, bacteria are directly exposed to the unpredictable environment and constantly changing external conditions that can influence their bioactivity, and eventually define their survivability. To overcome these challenges, bacteria developed very sophisticated cell envelopes, whose **structure and composition define the outstanding ability to survive dehydration conditions.** Importantly, many bacteria exhibit a strong **correlation between resistance to dehydration and resistance to UV radiation**, which is routinely used as an antimicrobial treatment applied in hospitals, daycares, or rehabilitation centers. Thus, understanding the fundamentals of anhydrobiosis in bacterial cell membranes is crucial for revealing what truly defines **bacterial survivability under dehydration,** which is inevitably **connected to** bacterial **ability to maintain pathogenicity**. Consequently, recognizing the mechanisms that underlie the resistance of bacterial cell membranes to dehydration could help in the development of **more effective antimicrobial treatments.**

The main goal of the proposed here research is to determine the impact of hydration on the properties of model gram-positive and gram-negative bacterial membranes. Moreover, I intend to provide information about nanoscale changes in the structure and dynamics of lipid membranes under water scarcity conditions and to explain why some bacteria strains are more resistant to dehydration than others.

In the project, we will use a combination of different experimental techniques including fluorescence microscopy, atomic force microscopy, and fluorescence recovery after photobleaching to fully characterize model gram-positive and gram-negative bacterial cell membranes. Using the developed in our research group setup for controlling the hydration state of cellular membranes we will be able to simulate the exposure of model membranes to constantly changing hydration conditions that bacteria exhibit in nature. The structural rearrangement of lipids within the membrane and potential changes in lipid dynamics under decreased humidity will be monitored with the focus on providing answers to the following questions:

- Is there a minimum hydration level necessary for the bacterial membrane to maintain its integrity and structure?
- What structural changes occur in membranes under dehydration conditions?
- Which membrane structural features are responsible for better dehydration resistance in gram-positive bacteria?
- Which compounds of gram-positive and gram-negative bacterial membranes lead to increased dehydration resistance?
- How membrane dehydration affects local and long-range lipid dynamics in bacterial cell membranes?

The proposed here research merges knowledge from many different fields and it will contribute fundamental knowledge not only to biophysics but also to biochemistry, microbiology, and medicine.