Archaeacombisomes: Versatile Compartments for Synthetic Biology and Bioengineering

Project Overview

Biological membranes are highly organized structures that control the interactions between cells and their environment. **Archaeal lipids** are particularly interesting membrane-building blocks because of their exceptional chemical and physical stability. Unlike the ester-linked lipids commonly found in eukaryotic and bacterial membranes, archaeal lipids contain ether bonds that provide increased resistance to hydrolysis and chemical degradation. They can be found as **diether lipids**, which form bilayer-like membranes, and **tetraether lipids**, which can span the entire membrane and form highly stable monolayer structures. These unique molecular architectures give archaeal membranes remarkable stability and allow their properties to be tuned through lipid composition and molecular organization.

In parallel, **comb copolymers** are synthetic polymers consisting of a hydrophilic cationic backbone complex with dialkyl phosphates containing the hydrophobic moiety. Their molecular architecture allows the properties of polymer-based membranes to be tailored by modifying the chemical composition and structure of the polymer. These polymers can self-assemble into vesicular structures known as **combisomes**, providing synthetic compartments with properties that can be controlled at the molecular level. Combisomes therefore represent a promising platform for developing robust and tunable artificial membrane systems.

This project aims to combine these two types of membrane-forming molecules to create a new class of hybrid vesicles known as **archaeacombisomes**. By combining archaeal lipids with comb copolymers in different proportions, we aim to investigate how the molecular composition of the membrane determines the structure, dynamics, and physical properties of the resulting vesicles.

What will you do?

The project will focus on the **preparation and characterization of synthetic vesicles containing different ratios of archaeal lipids and comb copolymers**. By systematically varying the composition of the hybrid membrane, we will investigate how the interactions between the polymer and lipid components influence vesicle formation and membrane organization.

The characterization of the archaeacombisomes will involve **confocal fluorescence microscopy** and other advanced techniques for the characterization of vesicles and their membranes. Depending on the student's interests and the progress of the project, possible activities may include:

- Preparation of archaeacombisomes with different polymer-to-lipid compositions.
- Characterization of vesicle size, morphology, and membrane organization using fluorescence microscopy.

- Investigation of membrane properties such as fluidity, lateral diffusion, and membrane heterogeneity.
- Analysis of membrane domains and the spatial distribution of different molecular components.
- Characterization of vesicle properties using complementary advanced biophysical techniques.
- Quantitative analysis of microscopy images and experimental data to establish relationships between molecular composition and membrane properties.

The project will provide the opportunity to work with **modern microscopy and biophysical characterization techniques**, while exploring how molecular-level interactions can generate new properties in synthetic membrane systems.

Why is this interesting?

Archaeacombisomes combine the remarkable stability of archaeal membrane lipids with the chemical versatility and tunability of synthetic polymers. Understanding how the ratio and molecular organization of these components influence membrane properties could provide new strategies for designing **robust and functional artificial compartments**.

Such systems could ultimately be used as platforms for **synthetic biology, membrane protein engineering, artificial cells, drug delivery, and bio-inspired materials**. The project therefore sits at the interface of **membrane biophysics, polymer chemistry, microscopy, materials science, and synthetic biology**.

Who are we looking for?

We are looking for motivated **Bachelor's or Master's students** with an interest in interdisciplinary research. Students from backgrounds such as chemistry, biochemistry, biotechnology, biology, physics, materials science, or related fields are welcome.

Previous experience with membrane systems, fluorescence microscopy, polymers, or image analysis is advantageous but **not required**. Curiosity, motivation, and willingness to learn new experimental techniques are more important.

Depending on the scope and duration of the project, the results may contribute to ongoing research toward the development of **archaeacombisomes as versatile and tunable compartments for synthetic biology and bioengineering**.

Starting date: Immediately / September 2026

Working place: Max-Planck-Institute Magdeburg, Sandtorstr.1

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