

M2 Internship Proposal

Physical transport and trapping of virus-sized particles in suspended biofilm aggregates

Host laboratories	ESPCI Paris - PSL, INRAE Jouy en Josas
Supervision	Maxime Ardre and collaborators
Duration	5-6 months
Fields	Biophysics, soft matter, microfluidics, quantitative microscopy

Scientific context

Biofilms are usually studied as microbial communities attached to surfaces. However, biofilms can also develop as free-floating aggregates in natural, industrial and engineered environments. These aggregates form highly heterogeneous porous materials composed of bacterial cells embedded within an extracellular polymeric matrix.

While the transport of molecules through biofilms has been extensively investigated, much less is known about the transport of objects with dimensions comparable to viruses. At these scales, transport can no longer be described solely by diffusion in a homogeneous medium. Particle size, surface properties, matrix architecture and physicochemical interactions may determine whether particles remain outside an aggregate, penetrate its matrix, become transiently trapped, or are irreversibly retained.

The FAViR project investigates whether suspended biofilm aggregates can therefore act as physical reservoirs for viral particles.

We have developed an acoustofluidic platform capable of trapping individual biofilm aggregates in suspension while continuously controlling the surrounding fluid. This provides a unique experimental system for directly observing particle transport into and out of a living biofilm without immobilizing the aggregate on a surface.

Objective

The objective of this internship is to establish the physical framework describing the transport and sequestration of virus-sized particles inside suspended biofilm aggregates.

Rather than initially working with biological viruses, the student will use fluorescent nanoparticles with controlled size and surface properties. These particles provide a quantitative physical benchmark for separating the effects of particle size, diffusion and particle-matrix interactions.

Central questions: How rapidly do virus-sized particles penetrate a biofilm aggregate? How deeply can they penetrate? What fraction becomes trapped by the matrix? And how rapidly are retained particles released when the external particle concentration is removed?

Experimental approach

Suspended bacterial aggregates, typically 10-500 micrometres in diameter, will be maintained within a microfluidic chamber using an acoustic standing wave. The surrounding medium will then be switched between

particle-containing and particle-free solutions while the aggregate is continuously imaged by confocal fluorescence microscopy.

A panel of fluorescent nanoparticles representative of viral length scales will be investigated, initially around 25, 80-100 and 200 nm. Surface chemistry will subsequently be varied using, for example, carboxylated, PEGylated or amine-functionalized particles.

Time-resolved 3D fluorescence imaging will provide concentration profiles within individual aggregates during both particle injection and washing. From these measurements, the student will quantify:

- particle penetration depth as a function of time;
- characteristic capture and release times;
- effective diffusion coefficients within the biofilm;
- spatial heterogeneity of particle transport;
- the fraction of particles retained after washing.

Physical modelling

The experimental data will be interpreted using minimal transport models. As a first approximation, particle penetration will be compared with diffusion into a porous medium, with characteristic penetration distances scaling as:

Expected outcomes

The internship will establish quantitative physical descriptors of particle transport in suspended biofilms and determine how they depend on particle size and surface chemistry.

The resulting parameter space will provide the physical reference for the subsequent FAViR experiments using bacteriophages. In particular, it will allow us to determine whether the behaviour of a given virus can be explained by its physical properties or requires additional virus-matrix interactions.

Ultimately, this work will contribute to understanding when a suspended biofilm behaves as a permeable porous material, a transient particle trap, or a long-term reservoir for viral particles.

Candidate profile

We seek an M2 student with a background in physics, biophysics, soft matter, microfluidics or quantitative biology. Experience in fluorescence/confocal microscopy, image analysis or Python/MATLAB would be advantageous. No previous microbiology experience is required, but an interest in working at the interface between physics and microbiology is essential.

Access requirements

The experiments will be carried out in a restricted-access laboratory, owing to the sensitive nature of some of the research activities conducted within the facility. Access is therefore strictly controlled and requires prior authorization and an administrative screening procedure.

Students **considering this internship should express their interest as early as possible**, so that the required clearance procedure can be initiated sufficiently in advance of the internship start date.