Research projects 2020-2021

Master M1&M2 – PhD – Post-Doc

Microrheology of lung fluids

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Describe the team that the student will join for the project.

Our research group develops novel functional structures, devices and systems with stimuli-responsive features at the nano and microscales. Our objectives also deal with applications in medicine, biology and in the environment. It includes the development of tools for imaging and therapy in vivo, microfluidics and microrheology as well as the study of living system-machine interfaces.

Project description

Lungs are large, spongy, air- filled organs that provide a large surface area for efficient gas exchange, transporting oxygen into the blood and removing CO2. Lungs have two main airway regions, the conducting zones and the respiratory zones. The conducting zones (upper airways and bronchi) form a passageway for air, whereas the respiratory zones contain the alveoli where gas exchange takes place. Lungs play also the role of a filter for the air we breathe, eliminating particulate matter present in suspension through complex processes. Thanks to their high surface area, the respiratory track is also a target for drug delivery of aerosols and nebulized suspensions.

In our group at Matière et Systèmes Complexes (University Paris-Diderot), a long-term project aims at understanding the behavior of inhaled particulate matter at the level of the bronchi and of the alveoli, either for nanomedicine applications or environment related studies.

Mucus is a thick substance that lines the surface of the respiratory tract in the bronchi zone. Mucus acts as the outermost line of protection against foreign pathogens and environmental particles. It protects by trapping particulate matter and by slowing down the aerosol diffusion. At the chemical level, mucus has the properties of a biopolymer gel. Its solid content is

approximately 5% – 10% by weight, and it mainly contains entangled mucin fibers that impart its viscoelastic gel-like properties.

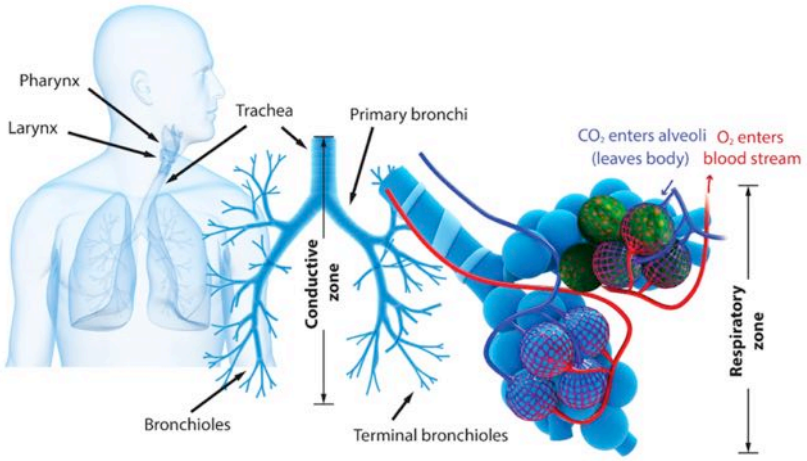

***Figure 1**: Dichotomy of the human lung. Human lung consists of a fractal structure of bronchioles and grapes like alveolar sacs [1].*

Alveoli are 200 µm large sacs connected with each other and to air ducts. Their interior is lined up with a fluid called the *pulmonary surfactant*, which functions are to lower the surface tension with the air and facilitate breathing. The lung surfactant is composed phospholipids and proteins organized into vesicles. In vitro experiments have shown that particulate matter brought in contact with lung surfactant modifies its physical properties, via interaction with the vesicles [2,3].

In this project we will study the modification of the lung fluid physical properties by the addition of nano-objects (simulating inhaled particulate matter) known to induce critical phenomena, including vesicular aggregation and respiratory misfunction. Beyond structural studies (done with electron microscopy), emphasis will be put on the measure of mucus and surfactant phase viscosity using an original microrheology set-up. The technique, recently published in Nature Communications is based on the monitoring of magnetic nanowires under rotating field [4].

[1] **P. Bajaj, J.F. Harris, J. Huang, P. Nath and R. Iyer**, ACS Biomater. Sci. Eng. (2016)
[2] **F. Mousseau, C. Puisney, S. Mornet, R. Le Borgne, A. Vacher, M. Airiau, A. Baeza-Squiban, J.F. Berret**, *Nanoscale*, **9** (2017) 14967-14978.
[3] **F. Mousseau, J.F. Berret,** *Soft Matter*, **14** (2018) 5764-5774.
[4] **J.-F. Berret**, Nature Communications 7, 10134 (2016)