European Phd Offer in Grenoble, France (Institute of Interdisciplinary Physics)

Simulation and Machine Learning of Blood Flow and Biochemical Signaling

Cardiovascular dysfunctions are the world's leading cause of mortality. Elucidating the biochemical and mechanical factors of blood flow regulation is a challenging issue due to the subtle mechanical and biochemical interplay between the red blood cells (RBC) and the endothelial cells (EC) that form the innermost layer of the blood vessel. EC translate shear stress and ATP (adenosine triphosphate) changes into plasma calcium (Ca) waves. Ca plays a pivotal role in the endothelial nitric oxide (NO) pathway involved in vasomotor control (blood flow regulation).
The motivation behind this project is based on the fact that, despite a huge number of biomedical experiments in the last few decades, the precise pathways of blood flow regulation have not yet been determined. The goal is to develop large scale simulations (using Lattice Boltzmann Methods) taking into account RBC-EC and biochemical signaling to identify and discriminate between various signaling pathways, and to combine them with deep learning and artificial intelligence strategies. This will open the door to future simulations of a predictive nature with potential consequences for diagnosis and therapeutic treatment.
Several fundamental challenges have to be overcome: (i) coping with the multi-level interactions in multicellular architectures and their effect on collective cell dynamic behavior and biochemical signaling, (ii) coupling biochemicals to RBC and EC is a complex, free-boundary, nonlocal and nonlinear problem, (iii) identifying the relevant degrees of freedom for an effective, reduced biochemical model is not an easy task. This work will benefit from close collaboration with experiments on a microvasculature-on-a-chip recently developed in our team. This project is an extension of that by a previous Phd (Hengdi Zhang). Below is a set of preliminary simulations obtained by him. This work may give rise to a Phd (see Fig.1 preliminary simulation).

We will address the following by Lattice Boltzmann simulation:

- Modelling and simulation of ATP generation and uptake by EC
- Analysis of how a RBC suspension will affect ATP generation by EC
- Analysis of the EC response in complex vascular networks, extracted from medical images (see preliminary simulation in Fig.1)
- Analysis of RBC adhesion effect (RBC clot formation, etc..)
- Analysis of ATP release and calcium waves under healthy conditions.
- Real blood flow simulations will be progressively substituted by deep machine learning, based on artificial intelligence for the benefit of a huge acceleration.

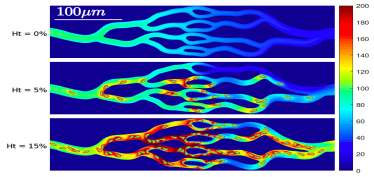

Figure 1: netwrok extracted from medical images. Closed red contours are red blood cells, and the color code refers to ATP; Ht is hematocrit

Skills/Qualifications

- Master in physics, engineering, mechanics or equivalent with excellent academic records.
- Experience with numerics
- Knowledge on hydrodynamics, low Reynolds number flows, soft matter, suspensions dynamics and complex fluids is a plus.

- Enthusiastic about performing research in a stimulating environment, looking forward to being an active member of our research group and eager to learn and gain new experiences. Being able to communicate in English.

Recruiting conditions

As the project is funded within the EU Marie Curie program, researchers can be of any nationality but need to demonstrate transnational mobility. To be eligible applicants must satisfy the requirements that apply to all Marie Skłodowska-Curie Early Stage Researchers, therefore on the date of appointment (their start date) applicants:

- must not have more than 4 years of research experience, must not hold a PhD and must not have resided or carried out their main activity (work or study) in the country where the post is based for more than 12 months in the previous 36 months.
- must be available to start the PhD in February-September 2020.
- must be in possession of their Master's degree or equivalent/postgraduate degree to enrol in the local graduate school.

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