Modeling blood flow and mass exchange in the human placenta

Internship project

Location:	Laboratoire de Physique de la Matière Condensée, École Polytechnique, Laboratoire d'Hydrodynamique, École Polytechnique
Internship level:	M1/M2 in Theoretical physics, Hydrodynamics, Applied Mathematics, Bioinformatics, Biosciences or similar
Internship duration:	4-6 months
Requested skills:	Basic knowledge of diffusion and hydrodynamics, some simulation/programming skills (e.g., in Matlab® or COMSOL Multiphysics®), as well as strong motivation for biological applications.
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Project description

The human placenta is the single link between the growing fetus and the mother during nine months of pregnancy. Since blood of the mother and blood of the fetus do not mix, the structure of the placenta is optimized for efficient exchange of oxygen, carbon dioxide, water, nutrients and waste products between the fetal and the maternal blood. Anatomical observations report the placental structure as a 16-generation branching tree of fetal vessels immersed in a basin of maternal blood. Understanding exchange in this sophisticated structure is necessary for understanding the function of the human placenta and can help diagnosing health risk for newborns.

The goal of this internship is to simulate maternal blood flow in a model structure of the human placenta and to compute oxygen uptake. The tree of fetal vessels will be modeled as an array of curved cylinders arranged in a structured or random fashion (Fig. 1) mimicking the experimentally-observed structure (Fig. 2). The Navier-Stokes equations in this model can be solved numerically with the help of COMSOL Multiphysics® and/or Matlab®. The influence of a driving arterial-venous hydrostatic pressure difference as well as the influence of non-slip boundary conditions at the wall of the vessels tree will be studied. Results of these numerical calculations will be compared to theoretical predictions [1,2].

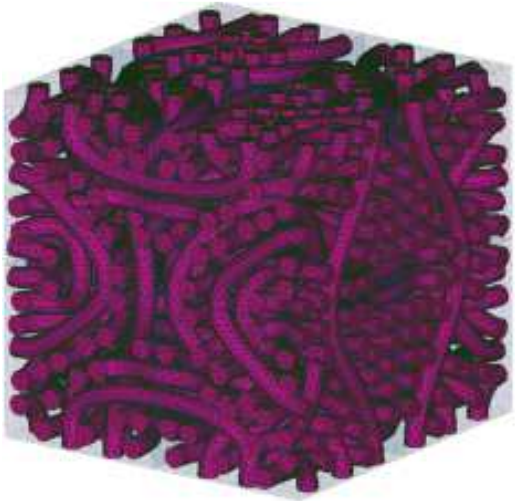

Figure 1. An example of a geometry imitating internal structure of the human placenta

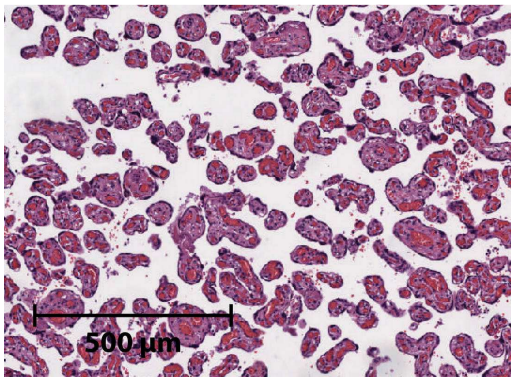

Figure 2. A typical histological placental section representing a 2D cut of the vessels tree of the human placenta (reproduced from Serov et al., 2014)

References

[1] A. S. Serov, C. Salafia, M. Filoche, and D. S. Grebenkov, *Analytical theory of oxygen transfer in the human placenta*, J. Theor. Biol. 368, 133-144 (2015).

[2] A. Serov, C. Salafia, P. Brownbill, D. S. Grebenkov, and M. Filoche, *Optimal villous density for maximal oxygen uptake in the human placenta*, J. Theor. Biol. 364, 383-396 (2015).