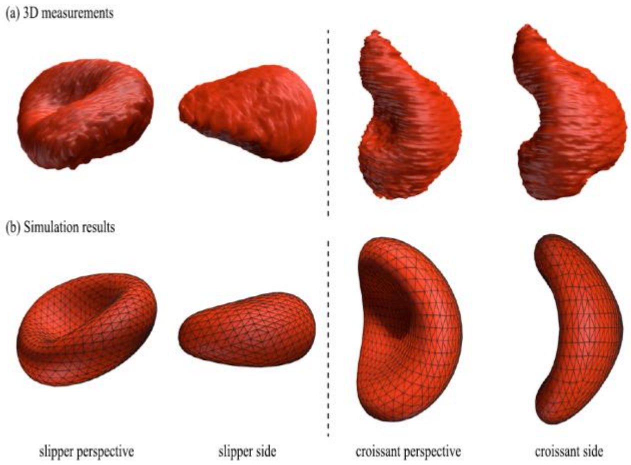
The physics of blood flow

Blood is a complex fluid composed of red and white cells suspended in a protein solution called plasma. At low shear rates, red blood cells form aggregates, which are broken up at high shear rates, resulting in pronounced shear thinning. Nevertheless, in most medical simulations, blood is treated as a Newtonian fluid comparable to water. However, thanks to recent advances in numerical simulation techniques and experimental methods, it is now possible to describe the flow of blood in terms of the physical properties of individual cells. Red blood cells can pass through capillaries smaller than their own diameter, thanks to their high deformability. This implies a strong interaction between fluid and structure that makes simulations costly and realistic simulations are limited to a few thousand cells. We will present in vitro, in vivo and in silico results of cells in different flow geometries. By directly comparing the observed shapes, we can estimate the mechanical constants of the cells. However, in many pathological situations, the cell properties are highly altered, and we have used our artificial intelligence-based recognition algorithm to develop a tool that can assess, for example, the quality of blood products.

Finally, we will show that a well-established nonspecific diagnostic test for inflammation, the erythrocyte sedimentation rate (ESR), can be physically described as a new class of fragile gel made of very soft, deformable objects. We find that sedimentation rate has a surprising functional relationship with interaction strength and propose new evaluation criteria for this test.



top: 3-D measurement of a flowing red blood cell at two different flow velocities.
bottom: numerical simulation.