Using biology: how softness and shape anisotropy determine the percolation threshold of Red Blood Cell networks

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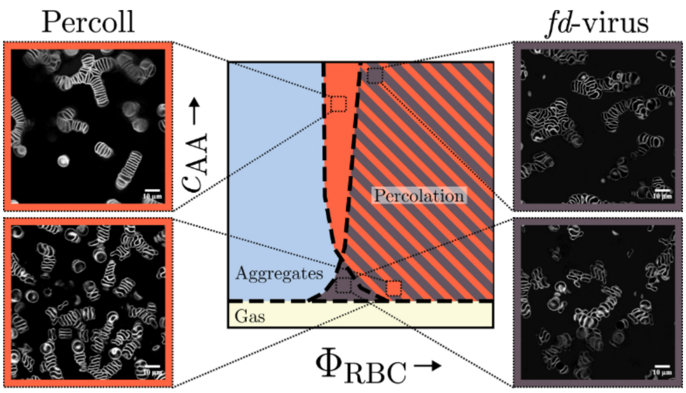
The phase behavior of hard spheres in depletant-containing solutions, including non-equilibrium gel states, has been the subject of research for decades [1]. More complex colloidal mixtures, including soft and anisotropic particles with directional interactions, have received less attention [2]. However, many real-life systems, like cosmetics, foodstuff or biological systems, are constituted of such complex colloidal particles. Red blood cells (RBCs) are inherently monodispersed, soft, and anisotropic particles (diameter 8 μm, thickness 3 μm). In the absence of flow, RBCs self-assemble into complex space-spanning networks in blood plasma, driven by depletion interactions induced by plasma proteins [3]. RBCs thus serve as an ideal model system for studying the phase behavior of soft, anisotropic colloids. In this work, we use confocal imaging to map the state diagram of RBC-depletant mixtures, varying the length scale of the interaction by the addition of either Percoll (silica nanoparticles; 13 nm) or *fd* -virus (880 nm). We extract the resulting 3D structures using deep neural network segmentation. While Percoll induces rouleaux formation, *fd* -virus gives rise to disordered house-of-cards structures, causing a lower percolation threshold for *fd* -virus than for Percoll at low concentrations. However, at elevated concentrations, Percoll becomes more effective in percolating the network, while induced-shape changes in the RBC aggregates cause an increase in the threshold for *fd* -virus. Our results not only show how depletion range, strength, and RBC deformability together give rise to intricate 3D network structures but also emphasize the added richness in the phase behavior of more complex colloids.

Keywords:
percolation, network structure, red blood cells



Shift in percolation threshold with increasing fd-virus (gray) and Percoll (orange) concentration and representative RBC network structures.

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