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The Development and Application of a Computational Method for Modeling Cellular-Scale Blood Flow in Complex Geometry.

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In the human body, blood flows through highly complex geometries. It circulates throughout the body via networks of winding vessels that continually bifurcate into smaller vessels, and merge to form larger vessels. The smallest vessels have diameters on the order of the size of the individual blood cells, and interconnected networks of such vessels, known as microvascular networks, are critical to the healthy functioning of the circulatory system. In terms of the hydrodynamics of blood flow therein, both cellular-scale details as well as the complexity of the geometry are important to accurately capture what occurs in physiology. In the first part of this talk I will detail the development of a robust, high-fidelity direct numerical simulation method for modeling 3D cellular-scale blood through large-scale complex geometries. The approach utilizes immersed boundary methods (IBMs) in the context of a finite volume/spectral fluid flow solver. A continuous forcing front-tracking IBM is used to model the large deformation of individual cells, while a sharp-interface ghost node IBM is used to model complex stationary geometries as well as flowing rigid bodies of arbitrary shape. Validations will be presented establishing the accuracy of the method, followed by a brief demonstration of its capabilities. In the second part of this talk I will discuss the application of the method to study red blood cells (RBCs) flowing through physiologically realistic microvascular networks. Using data from the simulations, a number of topics related to microvascular blood flow have been studied, and an overview of novel findings unique to cellular-scale flows in complex vessel networks will be provided. This will include both general hydrodynamical observations, as well as more specific topics such as how RBCs distribute through multiple bifurcations in sequence, the three-dimensionality of the near-wall RBC-free region, and the influence of RBCs on 3D wall shear stress patterns.