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Mimicking the Interfacial Dynamics of Flowing White Blood Cells

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The rolling of particles on surfaces, facilitated by hydrodynamic forces combined with localized surface interactions of the appropriate strengths, spatial arrangements, and ranges, is a technologically useful means of transporting and manipulating particles. One's intuition for the rolling of a marble or a car tire cannot be extrapolated down to microparticle length scales because the microparticle interactions are dominated by electrostatic, van der Waals, and hydrogen bonding interactions rather than a friction that depends on an imposed normal force. Indeed, our microparticle rolling systems are inspired by the rolling of white blood cells on the inner walls of venules as part of the innate immune response: Selectin molecules engage with their counterparts on the opposing surfaces to slow cell motion relative to that for freely flowing cells. In the resulting rolling signature, ligand-receptor binding and crack closing on the front of the cell are balanced with molecular dis-bonding and crack opening at the rear. The contact region is relatively static, allowing other interactions (for instance signaling) to occur for a finite duration. Thus, achieving particle rolling in synthetic systems is important because it facilitates particle-surface interactions in a continuous nonfouling fashion where the contact surface is continually renewed. In developing a synthetic model for this system, we employ polymers to modify flowing particles and /or planar collectors, producing heterogeneous interfaces which can support rolling or produce other motion signatures such as skipping, arrest, or free flow. We identify, in the synthetic system, combinations of variables that produce rolling and demonstrate how the distinction between rolling and arrest is not a simple matter of the adhesion strength between the particles and the collector. Rolling is a cooperative process and the coordination of binding in one location with dis-bonding in another requires appropriate length scales in the design of the interface and in the processing parameters as well.