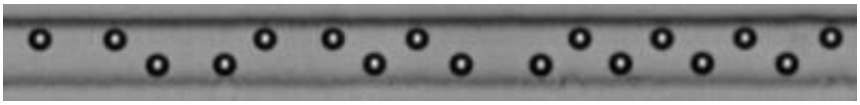
Bioengineers discover how particles self-assemble in flowing fluids

December 13 2010, By Matthew Chin and Wileen Wong Kromhout



A self-assembled lattice of 10-micrometer diameter particles flowing through a microfluidic channel.

(PhysOrg.com) -- From atomic crystals to spiral galaxies, self-assembly is ubiquitous in nature. In biological processes, self-assembly at the molecular level is particularly prevalent.

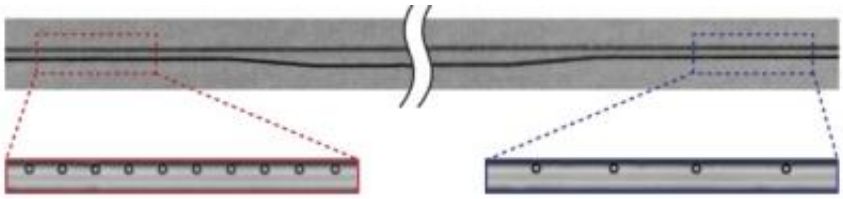
Phospholipids, for example, will self-assemble into a bilayer to form a cell membrane, and actin, a protein that supports and shapes a cell's structure, continuously self-assembles and disassembles during cell movement.

Bioengineers at the UCLA Henry Samueli School of Engineering and Applied Science have been exploring a unique phenomenon whereby randomly dispersed microparticles self-assemble into a highly organized structure as they flow through microscale channels.

This self-assembly behavior was unexpected, the researchers said, for such a simple system containing only particles, fluid and a conduit through which these elements flow. The particles formed lattice-like

structures due to a unique combination of hydrodynamic interactions.

The research, published online today in the journal Proceedings of the National Academy of Sciences, was led by UCLA postdoctoral scholar Wonhee Lee and UCLA assistant professor of bioengineering Dino Di Carlo.



A simple microfluidic "filter" structure converts microparticle streams with smaller interparticle spacings to trains of larger spacing. The channel width is about half the diameter of a human hair at the expansion.

The research team discovered the mechanism that leads to this self-assembly behavior through a series of careful experiments and numerical simulations. They found that continuous disturbance of the fluid induced by each flowing and rotating particle drives neighboring particles away, while migration of particles to localized streams due to the momentum of the fluid acts to stabilize the spacing between particles at a finite distance. In essence, the combination of repulsion and localization leads to an organized structure.

Once they understood the mechanism, the team developed microchannels that allowed for "tuning" of the spatial frequency of particles within an organized particle train. They found that by simply adding short regions of expanded channel width, the particles could be induced to self-assemble into different structures in a controllable and

potentially programmable way.

"Programmable control of flowing microscale particles may be important in opening up new capabilities in biomedicine, materials synthesis and computation, similar to how improved control of flowing electrons has enabled a revolution in computing and communication," Di Carlo said.

For example, controlling the positions of microscale bioparticles, such as cells in flowing channels, is important for the operation of blood analysis and counting diagnostic systems. In addition, improving the uniformity of cell concentrations entering the microscale volume of a print head can enable burgeoning fields such as "tissue printing," in which single cells in a polymer ink are sequentially positioned to form a functional tissue architecture, such as the cylindrical lumen of a blood vessel.

More complete control of lattices of particles may also allow tunable manufacturing of optical or acoustic metamaterials that interact uniquely with light and sound waves based on the arrangement of the embedded particles, the researchers said.

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