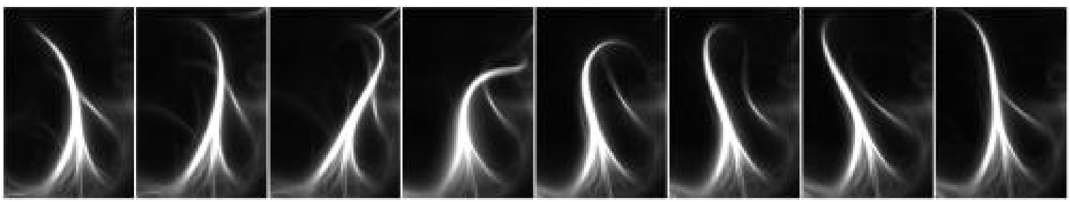
Artificial cilia spur new thinking in nanotechnology

July 27 2011



Artificial cilia exhibit spontaneous beating

(PhysOrg.com) -- Cilia, tiny hair-like structures that perform feats such as clearing microscopic debris from the lungs and determining the correct location of organs during development, move in mysterious ways. Their beating motions are synchronized to produce metachronal waves, similar in appearance to "the wave" created in large arenas when audience members use their hands to produce a pattern of movement around the entire stadium.

Due to the importance of ciliary functions for health, there is great interest in understanding the mechanism that controls the cilias' beating patterns. But learning exactly how cilia movement is coordinated has been challenging.

That may be beginning to change as a result of the creation, by a team of Brandeis researchers, of artificial cilia-like structures that dramatically offers a new approach for cilia study.

In a recent paper published in the journal *Science*, Associate Professor of Physics Zvonimir Dogic and colleagues present the first example of a simple microscopic system that self-organizes to produce cilia-like beating patterns.

“We’ve shown that there is a new approach toward studying the beating,” says Dogic. “Instead of deconstructing the fully functioning structure, we can start building complexity from the ground up.”

The complexity of these structures presents a major challenge as each cilium contains more than 600 different proteins. For this reason, most previous studies of cilia have employed a top-down approach, attempting to study the beating mechanism by deconstructing the fully functioning structures through the systematic elimination of individual components.

The interdisciplinary team consisted of physics graduate student Timothy Sanchez and biochemistry graduate student David Welch who worked with biologist Daniela Nicastro and Dogic. Their experimental system was comprised of three main components: microtubule filaments — tiny hollow cylinders found in both animal and plant cells, motor proteins called kinesin, which consume chemical fuel to move along microtubules and a bundling agent that induces assembly of filaments into bundles.

Sanchez and colleagues found that under a particular set of conditions these very simple components spontaneously organize into active bundles that beat in a periodic manner.

In addition to observing the beating of isolated bundles, the researchers were also able to assemble a dense field of bundles that spontaneously synchronized their beating patterns into traveling waves.

Self-organizing processes of many kinds have recently become a focus of the physics community. These processes range in scale from microscopic cellular functions and swarms of bacteria to macroscopic phenomena such as flocking of birds and traffic jams. Since controllable experiments with birds, crowds at football stadiums and traffic are virtually impossible to conduct, the experiments described by Sanchez and colleagues could serve as a model for testing a broad range of theoretical predictions.

In addition, the reproduction of such an essential biological functionality in a simple system will be of great interest to the fields of cellular and evolutionary biology, Dogic says. The findings also open a door for the development of one of the major goals of nanotechnology — to design an object that's capable of swimming independently.

More information: Paper: www.sciencemag.org/content/333/6041/456.abs

Provided by Brandeis University

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