Researchers create self-assembling nanodevices that move and change shape on demand

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By emulating nature's design principles, a team at Harvard's Wyss Institute for Biologically Inspired Engineering, Harvard Medical School and Dana-Farber Cancer Institute has created nanodevices made of DNA that self-assemble and can be programmed to move and change shape on demand. In contrast to existing nanotechnologies, these programmable nanodevices are highly suitable for medical applications because DNA is both biocompatible and biodegradable.

The work appears in the June 20 advance online *Nature Nanotechnology*.

Built at the scale of one billionth of a meter, each device is made of a circular, single-stranded DNA molecule that, once it has been mixed together with many short pieces of complementary DNA, self-assembles into a predetermined 3D structure. Double helices fold up into larger, rigid linear struts that connect by intervening single-stranded DNA. These single strands of DNA pull the struts up into a 3D form -- much like tethers pull tent poles up to form a tent. The structure's strength and stability result from the way it distributes and balances the counteracting forces of tension and compression.

This architectural principle—known as tensegrity—has been the focus of artists and architects for many years, but it also exists throughout nature. In the human body, for example, bones serve as compression struts, with muscles, tendons and ligaments acting as tension bearers that enable us to stand up against gravity. The same principle governs how cells control their shape at the microscale.

"This new self-assembly based nanofabrication technology could lead to nanoscale medical devices and drug delivery systems, such as virus mimics that introduce drugs directly into diseased cells," said co-investigator and Wyss Institute director Don Ingber. A nanodevice that can spring open in response to a chemical or mechanical signal could ensure that drugs not only arrive at the intended target but are also released when and where desired.

Further, nanoscopic tensegrity devices could one day reprogram human stem cells to regenerate injured organs. Stem cells respond differently depending on the forces around them. For instance, a stiff extracellular matrix—the biological glue surrounding cells—fabricated to mimic the consistency of bone signals stem cells to become bone, while a soupy matrix closer to the consistency of brain tissue signals the growth of neurons. Tensegrity nanodevices "might help us to tune and change the stiffness of extracellular matrices in tissue engineering someday," said first author Tim Liedl, who is now a professor at Ludwig-Maximilians-Universität in Munich.

"These little Swiss Army knives can help us make all kinds of things that could be useful for advanced drug delivery and regenerative medicine," said lead investigator William Shih, Wyss core faculty member and associate professor of biological chemistry and molecular pharmacology at HMS and Dana-Farber Cancer Institute. "We also have a handy biological DNA Xerox machine that nature evolved for us," making these devices easy to manufacture.

This new capability "is a welcome element in the structural DNA nanotechnology toolbox," said Ned Seeman, professor of chemistry at New York University.

More information: Nature Nanotechnology, online publication, June 20, 2010 "Self-assembly of 3D prestressed tensegrity structures from DNA" Tim Liedl, Bjorn Hogberg, Jessica Tytell, Donald E. Ingber, William M. Shih

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