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RNA could form building blocks for nanomachines

WEST LAFAYETTE, Ind. – Microscopic scaffolding to house the tiny components of nanotech devices could be built from RNA, the same substance that shuttles messages around a cell's nucleus, reports a Purdue University [profile] research group. By encouraging ribonucleic acid (RNA) molecules to self-assemble into 3-D shapes resembling spirals, triangles, rods and hairpins, the group has found what could be a method of constructing lattices on which to build complex microscopic machines.

From such RNA blocks, the group has already constructed arrays that are several micrometers in diameter – still microscopically small, but exciting because manipulating controllable structures of this size from nanoparticles is one of nanotechnology's main goals.

"Our work shows that we can control the construction of three-dimensional arrays made from RNA blocks of different shapes and sizes," said Peixuan Guo, who is a professor of molecular virology in Purdue's School of Veterinary Medicine. "With further research, RNA could form the superstructures for tomorrow's nanomachines."

The paper, which Guo co-authored with Dan Shu, Wulf-Dieter Moll, Zhaoxiang Deng and Chengde Mao, all of Purdue, appears in the August issue of the journal Nano Letters.

Nanotechnologists, like those in Guo's group, hope to build microscopic devices with sizes that are best measured in nanometers – or billionths of a meter. Because nature routinely creates nano-sized structures for living things, many researchers are turning to biology for their inspiration and construction tools.

"Biology builds beautiful nanoscale structures, and we'd like to borrow some of them for nanotechnology," Guo said. "The trouble is, when we're working with such tiny blocks, we are short of tiny steam shovels to push them around. So we need to design and construct materials that can assemble themselves."

Organisms are built in large part of three main types of building blocks: proteins, DNA and RNA. Of the three, perhaps least investigated and understood is RNA, a molecular cousin to the DNA that stores genetic blueprints within our cells' nuclei. RNA typically receives less attention than other substances from many nanotechnologists, but Guo said the molecule has distinct advantages.

"RNA combines the advantages of both DNA and proteins and puts them at the nanotechnologist's disposal," Guo said. "It forms versatile structures that are also easy to produce, manipulate and engineer."

Since his discovery of a novel RNA that plays a vital role in a microscopic "motor" used by the bacterial virus phi29 (see related

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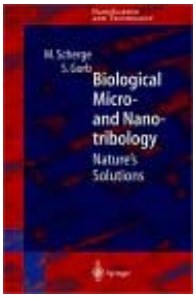

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story), Guo has continued to study the structure of this RNA molecule for years. It formed the "pistons" of a tiny motor his lab created several years ago, and members of the team collaborated previously to build dimers and trimers – molecules formed from two and three RNA strands, respectively. Guo said the methods the team used in the past made their recent, more comprehensive construction work possible.

"By designing sets of matching RNA molecules, we can program RNA building blocks to bind to each other in precisely defined ways," he said. "We can get them to form the nano-shapes we want."

From the small shapes that RNA can form – hoops, triangles and so forth – larger, more elaborate structures can in turn be constructed, such as rods gathered into spindly, many-pronged bundles. These structures could theoretically form the scaffolding on which other components, such as nano-sized transistors, wires or sensors, could be mounted.

"Because these RNA structures can be engineered to put themselves together, they could be useful to industrial and medical specialists, who will appreciate their ease of engineering and handling," said Dieter Moll, a postdoctoral researcher in Guo's lab. "Self-assembly means cost-effective."

Moll, while bullish on RNA's prospects, cautioned that there was more work to be done before nanoscale models could be built at will.

"One of our main concerns right now is that, over time, RNA tends to degrade biologically," he said. "We are already working on ways to make it more resistant to degradation so that it can form long-lasting structures."

Guo said that though applications might be many years away, it would be most productive to take the long-term approach.

"We have not built actual scaffolds yet, just 3-D arrays," he said. "But we have built them from engineered biological molecules, and that could help us bridge the gap between the living and the nonliving world. If nanotech devices can eventually be built from both organic and inorganic materials, it would ease their use in both medical and industrial settings, which could multiply their usefulness considerably."

This research was sponsored in part by the National Science Foundation, the National Institutes of Health and the Department of Defense. Moll's postdoctoral research is funded by the Austrian Science Fund's Erwin Schroedinger Fellowship.

Guo is affiliated with Purdue's Cancer Center and Birck Nanotechnology Center. The Cancer Center, one of just eight National Cancer Institute-designated basic research facilities in the United States, attempts to help cancer patients by identifying new molecular targets and designing future agents and drugs for effectively detecting and treating cancer.

The Birck Nanotechnology Center is located in Purdue's new Discovery Park, located on the southwestern edge of campus. Programs include undergraduate teaching, graduate research and technology transfer initiatives with industry partners. Scientists in biology, chemistry, physics and several engineering disciplines participate in the research.

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ABSTRACT

Bottom-up assembly of RNA Arrays and Superstructures as Potential Parts in Nanotechnology

Dan Shu, Wulf-Dieter Moll, Zhaoxiang Deng, Chengde Mao and Peixuan Guo (Department and Pathobiology and Department of Chemistry)

DNA has been extensively scrutinized for its feasibility as parts in nanotechnology, but another natural building block, RNA, has been largely ignored. RNA can be manipulated to form versatile shapes, thus providing an element of adaptability to DNA nanotechnology, which is predominantly based upon a double-helical structure. The DNA-packaging motor of bacterial virus phi29 contains six DNA-packaging pRNAs (pRNA), which together form a hexameric ring via loop/loop interaction. Here we report that this pRNA can be redesigned to form a variety of structures and shapes, including twins, tetramers, rods, triangles, and arrays several microns in size via interaction of programmed helical regions and loops. RNA array formation required a defined nucleotide number for twisting of the interactive helix and a palindromic sequence. Such arrays are unusually stable and resistant to a wide range of temperatures, salt concentrations, and pH.

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