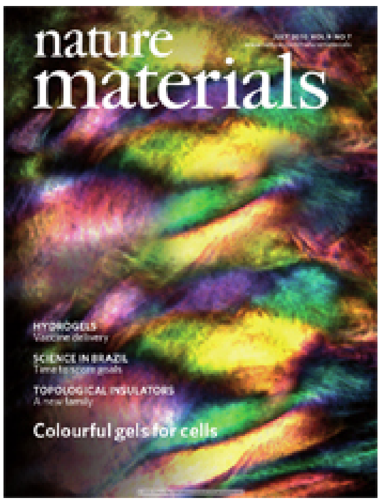
Spaghetti highway for cells: Noodle-shaped string of aligned nanofibers promises better tissue regeneration

June 25 2010, By Megan Fellman



Courtesy of Nature Materials

(PhysOrg.com) -- A big question in regenerative medicine is how to most effectively deliver stem cells -- as well as other beneficial cells, proteins and large molecules -- to damaged tissues such as the spinal cord, heart and brain.

A Northwestern University team is the first to demonstrate a method that delivers cells in the same alignment as the cells found in these tissues, which could jumpstart new growth and healing. The findings are published as the cover story in the July issue of the journal Nature

Materials.

In the study, the researchers produced centimeter-long gel "strings" of aligned nanofibers containing living cells aligned in linear fashion. These strings of cells, which are flexible, biodegradable and can be made into different lengths and widths, could be surgically placed on damaged tissue, where they would adhere naturally.

"We have discovered how to align nanoscale filaments with the human hand over long distances, producing a scaffold which we can populate with cells, proteins or other large molecules," said Samuel I. Stupp, the paper's senior author, Board of Trustees Professor of Chemistry, Materials Science and Engineering, and Medicine, and director of the Institute for BioNanotechnology in Medicine (IBNAM).

The cells, proteins or other molecules move through the noodle-shaped string, parallel to the string's walls and much like vehicles on a highway, and diffuse out the ends to the tissue. "It is a highly directional delivery, which increases the chances of successful regeneration," Stupp said. "We are matching the morphology of natural tissues."

The method already has shown promise in accelerating tissue regeneration. A recent study, led by Carol Podlasek, assistant professor of urology at Northwestern's Feinberg School of Medicine, showed a critical nerve often damaged during prostate surgery to remove a cancerous gland regenerates more quickly when a special protein is delivered to the nerve via Stupp's noodle gel.

Stupp is collaborating with other researchers on studies using the noodle gel for stem cell delivery. One project with H. Georg Kuhn from the Center for Brain Repair in Gothenburg, Sweden, will focus on the use of the aligned structures as highways to divert stem cells from one part of the brain where they are abundant to others where they might be needed to cure diseases, such as Parkinson's disease. Stupp and John A. Kessler, the Ken and Ruth Davee Professor of Stem Cell Biology at Feinberg, are exploring using bioactive forms of the noodle gel as a strategy to reverse paralysis in chronic spinal cord injuries.

To create the noodle gel, Stupp and his team start with aggregates of specially designed peptide amphiphile molecules in water. Heating the solution causes them to emerge into two-dimensional flat sheets suspended in water. When cooled, the sheets break spontaneously into bundles of fibers, forming irreversibly an unusual liquid crystal. The researchers then mix cells into the liquid crystal and, using a pipette, draw the liquid by hand across a salt solution. The liquid gels immediately; the result is a string shaped like a piece of cooked spaghetti and composed of aligned nanofibers with huge populations of encapsulated cells.

As part of the study, the researchers encapsulated cardiac cells in the noodle-like string and measured the electrical signals. The signals flowed from one end of the string to the other in milliseconds -- like a wire, but of cells, not metal. This demonstrates the potential for the aligned nanofiber gel to be used for long-range signal transmission in major organs in the body.

This new method is less harmful to living cells than existing methods to create aligned fibers over long distances, which typically rely on electrical or mechanical forces.

The gentle force of a human hand dragging the liquid crystal across a surface aligns the fibers in one direction; a salt solution can instantly freeze the alignment before disorder sets in. Stupp and co-author Monica Olvera de la Cruz, a Lawyer Taylor Professor and professor of materials science and engineering at Northwestern's McCormick School of Engineering and Applied Science, believe the unusual liquid crystal forms as a result of a phenomenon they describe as "two-dimensional Rayleigh instability." The facile alignment of nanoscale filaments also can be used to align the carbon nanotubes, as demonstrated in the study, or other conductive structures of interest in non-biological electronic applications.

More information: The title of the paper is "A Self-assembly Pathway to Aligned Monodomain Gels." (www.nature.com/nmat/index.html)

Provided by Northwestern University