Unleashing The Bionanotechnology Talent

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The tissue re-engineering business is big business. According to Dr. Seeram Ramakrishna, director of NUS Enterprise (Singapore), some US$350 billion is spent on tissue/organ replacement each year, worldwide.

Synthetic tissues are a wonder science that helps stimulate living tissues to repair themselves in various parts of the human body, such as cartilage, blood vessels, bones and so forth, due to diseases or wear and tear.

Victims whose skin are burned or scalded by fire or boiling water may also find an answer in synthetic tissues. According to Reuters Health, the newest generation of synthetic implant materials, also called biomaterials, may even treat diseases such as Parkinson's, arthritis and osteoporosis.

The uses of synthetic tissues are numerous. And there are several methods available to create them. One method is to make use of scaffold fabrication technology. Under this technology, synthetic tissues are cultured and placed in the scaffold that is shaped accordingly to, say a tendon or ligament, and then "grafted onto the damaged part of the body," said Dr. Vincent Tan, assistant professor, faculty of engineering, NUS.

"Scaffolds can also be made of biocompatible and biodegradable materials", he added. "That is, once the new tissues grow over the damaged part of the organ or achieved sufficient structural integrity, the scaffolds would have done their job and will eventually degrade until only the tissues remain. It is also possible to use biocompatible materials that do not degrade, in which case, the scaffolds remain harmlessly in the body."

Although considered a breakthrough, the team believes that existing technologies used to generate synthetic tissues are costly and have their limitations. This is where "we aim to make a mark in the medical field by coming up with better but cheaper techniques to regenerate synthetic tissues for use in the human body," Dr. Ramakrishna explained.

And this daring inspiration has resulted in the setting up of a Bionanotechnology Lab; Nano/Micro Mechanics Lab in NUS in January 2002 for the specific purpose of focusing on the next generation of tissue engineering applications.

Dr. Ramakrishna will be heading the project. Joining him are Dr. Lim Chwee Teck, program manager, division of bioengineering, also the assistant professor, assistant dean, faculty of engineering at NUS whose main responsibilities include sourcing for equipment and resources; and Dr. Tan whose main responsibilities include bringing all the researchers in the science and engineering faculties together.

Small Is Beautiful

So what is unusual about the team's R&D work in the tissue re-engineering field?

Dr. Tan has the answer: "It is generally accepted that nanotechnology encompasses structures/devices that are less than 100 nanometers which is the average diameter of the nanofibers that we are producing now."

Picture this: a nanofiber is about 10,000 times smaller than the width of a human hair. Existing synthetic fibers are in micro-size, where one micrometer is 1,000 times thicker than one nanometer, explained Dr. Tan, and microfibers are generally bigger than a typical cell, which is of the order of one micrometer (depending on the type of cell).

Nanofibers have a large surface area in comparison to their size. The smaller than usual fibers will allow cells to adhere to them better, speeding up the healing process.

"Another advantage of using nanofibers to grow tissues stems from the fact that natural scaffolds themselves are of fibers in the nanometer size range. In another words, nanofibers are closer replicas of the natural environment of the cells than micron range fibers," he added.

According to Dr. Lim, the nanofibers, made of polymers such as Poly (ethylene dioxide) PEO, PLA, PLGA, PCL and Collagen are developed using the electrospinning process. There is also the possibility of selectively doping or introducing certain biological molecules into the nanofibers which promote cell viability and proliferation.

Based on a report by Small Times, electrospinning was first patented in 1897 and used in the textile industry in the 1930s.

The Korean Times has also stated that the electrospinning process uses electrostatic and mechanical forces to drive the fiber spinning process, thus "producing electrospun materials that may exhibit unusually high porosity and surface area and very small pore size."

Plans In The Pipeline

The team has only just begun working on producing the nanofibers to build the scaffolds and are giving themselves three to fives years to come up with a success story, said Dr. Ramakrishna.

For a start, they will be looking at applying synthetic tissues in the blood vessels before it moves on to other areas. And they will not stop at just growing synthetic tissues for use in the human body.

"We will also be analyzing how the cell will interact with and adhere to the substrate of nanofiber using atomic force microscope and laser tweezers as analytical tools," said Dr. Lim.

"Previously, people tried analyzing how well cells adhered to substrates but were not able to put a figure to it. We are working towards this and hope to be able to come up with a figure as to how much force there is between the cell and the substrate," Dr. Lim further explained. And this has stirred the curiosity of many a biologists who are keen to work with the team.

To sum it up, the team will not be satisfied with merely 'making medical history' by coming up with smaller nanofibers, but it aims to "assemble and apply our collective knowledge, in engineering, biology, chemistry and physics, to develop functional and clinically relevant tissue substitutes for use in the medical field," said Dr. Ramakrishna.

The bionanotechnology lab forms one of the four nanotechnology corridors, or nanoscience and nanotechnology initiatives (NUSNNI), set up by the Science and Engineering Faculties of NUS. The other three nanotechnology labs are: Silicon Nano Devices Lab Information Storage Materials Lab; Center for Optoelectronics; Nano Wafer Level Packaging Lab; and NEMS/MEMS Lab. All four labs will be operational at the end of 2002.

The aim of the NUSNNI was to put the prime research groups in the science and engineering faculties together to identify the key nanotechnology areas to focus in.