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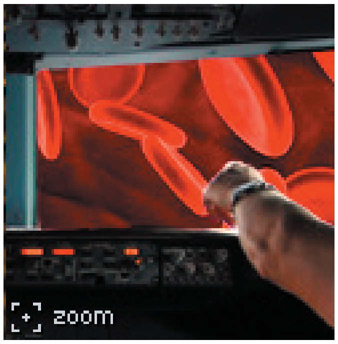
FANTASTIC VOYAGE—FROM FICTION TO REALITY

ÉCOLE POLYTECHNIQUE DE MONTRÉAL RESEARCHERS MAKE NEW INROADS FOR CANCER TREATMENT BY USING MRI TO TRACK AND PROPEL DEVICES THROUGH THE BLOODSTREAM.

By Véronique Barker



PROJECT

In the same vein as the 1960s classic movie, Fantastic Voyage, where a crew of scientists are miniaturized and injected into the bloodstream, **Sylvain Martel [1]**, director of the NanoRobotics Laboratory at École Polytechnique de Montréal, has successfully made travel through a living animal's bloodstream possible. "This is really what we are doing, except that we don't send tiny humans of course," he says with a laugh. Instead, Martel is developing tiny robots or nanorobots that can trek through blood vessels. Until recently, the study of **nanorobotics [2]** has been theoretical, but Martel has demonstrated its potential application with **magnetic resonance imaging (MRI) [3]**.

Martel is the first in the world to use MRI to show the feasibility of propelling and controlling nanorobots inside a living body. With his team, Martel developed software that allowed him to harness the magnetic power of an MRI to successfully move and control a magnetic bead through the artery of a living pig . "We are using the magnetic fields of nanoparticles to track them through the bloodstream." The success of his experiment opens the door to promising new cancer treatments, including non-invasive cures.

"This could lead to a revolution in interventional radiology," adds **Gilles Soulez [4]**, a member of the research team. Interventional radiology is a branch of medicine that diagnoses and treats disease using small needles, guide wires, and **catheters [5]**. The instruments are introduced through tiny incisions and then guided by x-ray, ultrasound, or other forms of radiological imaging.

Though more testing still needs to be done with MRI propulsion, Martel and his team can now work on applications for this new technology. "We have proven that it is possible to deliver anti-cancer drugs to precise areas of the body, and thus reduce side effects of treatments to the whole body," he explains.

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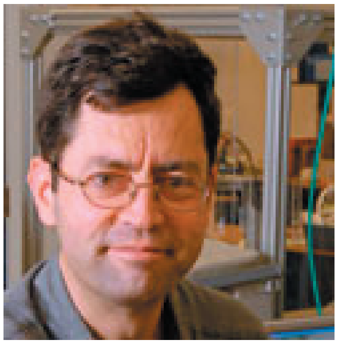
The widespread use and availability of MRI in every hospital also makes the development of nanorobot technology very attractive. MRI is not as invasive as x-rays, and it provides a 3-D image. Therefore, adapting existing MRI systems to perform the tasks that will be required by nanorobot technology would be very feasible without spending millions of dollars to develop a custom imaging platform. "You can put our program on a 35-cent CD, and implement it in each hospital," affirms Martel. He hopes for a nanorobot clinical trial in much smaller blood vessels within the next five years.

In the meantime, researchers focus on finding appropriate materials for the nanostructures. "There is a catalogue of particles that we can use depending on different types of applications. If we were to send the nanorobots to the brain, we would use a different material and design than for the liver," explains Martel. To achieve that goal, Martel has recruited **Jean-Christophe Leroux [6]**, a pharmaceutical scientist with expertise in biodegradable polymer materials. "We are at a preliminary stage, but we know we want a polymer that will be biodegradable in the body," explains Leroux. "At this point, we know it works. All we need is fine tuning."



[1] Sylvain Martel

Dr. Sylvain Martel
Canada Research Chair in Micro/Nanosystem Development Construction and Validation
Associate Professor, Department of Computer Engineering and the Institute of Biomedical Engineering, École Polytechnique de Montréal (EPM)
Director, NanoRobotics Laboratory, EPM

Dr. Sylvain Martel received his Ph.D. in Electrical Engineering from McGill University, Institute of Biomedical Engineering, in 1997. Following postdoctoral studies at the Massachusetts Institute of Technology (MIT), he was appointed Research Scientist at the BioInstrumentation Laboratory, Department of Mechanical Engineering at MIT. From February 2001 to September 2004, he had dual appointments; at MIT as Assistant Professor in the Department of Electrical and Computer Engineering, and the Institute of Biomedical Engineering at École Polytechnique de Montréal (EPM), Campus of the University of Montréal. He founded the NanoRobotics Laboratory at EPM in 2002, and is currently its director. He has over 140 refereed publications, several patents, and is an active member of several international committees and organizations worldwide. Martel's main expertise is in the field of nanorobotics and the development of novel instrumented platforms and support technologies targeted mainly for biomedical and bioengineering applications, and nanotechnology. He also has vast experience in electronics, computer engineering, and has worked extensively in biomedical and mechanical engineering.

Aside from his academic and industrial experience, Martel also held several positions in the Canadian Naval Reserve from 1976 to 2004, and participated in several NATO coastal defence exercises. From 1994 to 2004, he acted as warship commanding officer, which involved oastal defence operations along the Atlantic and Pacific coasts.

[2] Nanorobotics

Nanorobotics is the technology of creating machines or robots at a very small scale. More specifically, nanorobotics refers to the still largely theoretical nanotechnology engineering discipline of designing and building nanorobots. Nanorobots (nanobots or nanoids) are typically devices ranging in size from 0.1-10 micrometres and constructed of molecular components (or at nanoscale). As no artificial non-biological nanorobots have so far been created, they remain a hypothetical concept. Another definition of nanotechnology is a robot which allows precision interactions with nanoscale objects, or that can manipulate with nanoscale resolution. Following this definition, even a large apparatus can be considered a nanorobotic instrument when configured to perform nanomanipulation.

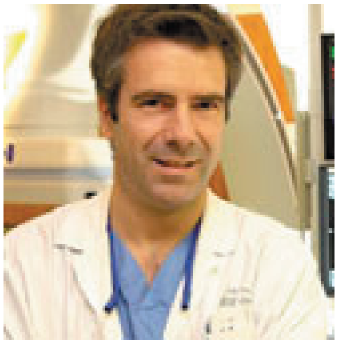
Referenced in part from Wikipedia
http://en.wikipedia.org/wiki/Nanorobotics

[3] Magnetic resonance imaging (MRI)

MRI is a non-invasive method used to render images of the inside of an object. It is primarily used in medical imaging to demonstrate pathological or other physiological alterations of living tissues. MRI also has uses outside of medicine.

Referenced in part from Wikipedia
http://en.wikipedia.org/wiki/MRI

[4] Gilles Soulez



Dr. Gilles Soulez
Professor, Department of Radiology, Université de Montréal
Director of Research, Université de Montréal's Radiology Department
Director, Imaging Research Platform, Centre hospitalier de l'Université de Montréal (CHUM)

Dr. Gilles Soulez is a clinical scientist in interventional vascular radiology and imaging. He has vast experience in endovascular treatment of peripheral occlusive and aneurismal diseases, and in vascular imaging. He has received numerous national and international recognitions for his work and published over 75 refereed articles in his career. He has active collaborations with several companies producing endovascular devices and imaging platforms and holds four patents. He was involved in Martel's research in the conception of animal experimentation, catheter manipulation, and interpretation of MR images.

[5] Catheter

A catheter is a tube that can be inserted into a body cavity, duct, or vessel. Catheters allow drainage or injection of fluids or access by surgical instruments.

[6] Jean-Christophe Leroux

Dr. Jean-Christophe Leroux
Canada Research Chair in Controlled Drug Delivery
Associate Professor, Faculty of Pharmacy, Université de Montréal

Dr. Jean-Christophe Leroux received his B.Pharm from the Université de Montréal, followed by a Ph.D. in Pharmaceutical Sciences (1995) from the University of Geneva (Switzerland). From 1996 to 1997, he completed postdoctoral training at the University of California and then joined the Université de Montréal as an assistant professor. His research interests include the design of novel biopolymers, stimuli-responsive drug delivery systems, and the targeting of anticancer drugs. He is the author or coauthor of more than 80 refereed articles, eight book chapters, and 13 patents/patent applications. He is the associate editor of the *European Journal of Pharmaceutics* and Biopharmaceutics, and serves on the editorial board of five journals, including the *Journal of Controlled Release of the Controlled Release Society* (CRS), and the Journal of *Pharmaceutical Sciences*. A few of the awards he has received include the CRS–Capsugel (1997 and 2003); AFPC–AstraZeneca (2003); and the CRS Young Investigator Award (2004) for innovative research in pharmaceutical technology.

BENEFITS

Sylvain Martel's successful MRI navigation of a magnetic bead through a live bloodstream holds great promise for medicine and bioengineering. Because the human bloodstream is made up of close to 100,000 kilometres of pathways, it offers access to every part of the body. Such localized access could make it possible for novel cancer treatments, such as confined hyperthermia, which involves increasing the temperature at a specific area to potentially kill cancerous tumours. It could also lead to the development of new, minimally invasive surgical techniques.

For bioengineering in particular, Martel's discovery has led to efficient work at the nanoscale. Researchers can control devices and have direct access to the human body at a scale invisible to the naked eye. The computer platform required to perform such activities is extremely complex and unique, and was made possible through the highly interdisciplinary environment in which Martel and his team operate.

Martel's studies involve teams of researchers and graduate students from various backgrounds, including medicine, microbiology, physics, chemistry, fluid dynamics, material sciences, nanotechnology, micromechanics, microelectronics, software, and computer engineering. This research setting has delivered results at the academic level as well. For instance, six MA students working with Martel now plan to pursue doctorate degrees with hopes of advancing their own research in the field of nanomedicine.

PARTNERS

Sylvain Martel had 11 team members for his nanorobotic research using MRI—all from the NanoRobotics Laboratory at École Polytechnique de Montréal (EPM). They helped develop the computer software to track objects in the bloodstream, which requires eliminating distortion when the object is moving, and increasing resolution using many algorithms. The computer program makes 24 decisions every second to constantly adjust the movement of the object. "No human being is capable of making decisions this quick, and in this sense, our computer program is infallible," says Martel. In the next phase of the project, the team aims to find the right material to eliminate all risks of toxicity, and to ensure biodegradability once the nanovehicle has accomplished its task. He also collaborates with other researchers at McGill University, l'Université de Montréal and the Centre hospitalier de l'Université de Montréal.

LEARN MORE

Find out more about Sylvain Martel's NanoRobotics Laboratory.
http://www.nano.polymtl.ca/

See a still **photo [7]** of the bead being tracked through a blood vessel.

Watch a 3D virtual animation of targeted drug delivery using an MRI based platform.

Read the full report of Martel's research results from Applied Physics Letter, a weekly journal featuring new findings in applied physics.
http://www.innovationcanada.ca/29/en/pdf/martel_applied_physics_letter.pdf

Learn more about nanotechnology in a past issue of InnovationCanada.
http://www.innovationcanada.ca/25/en/

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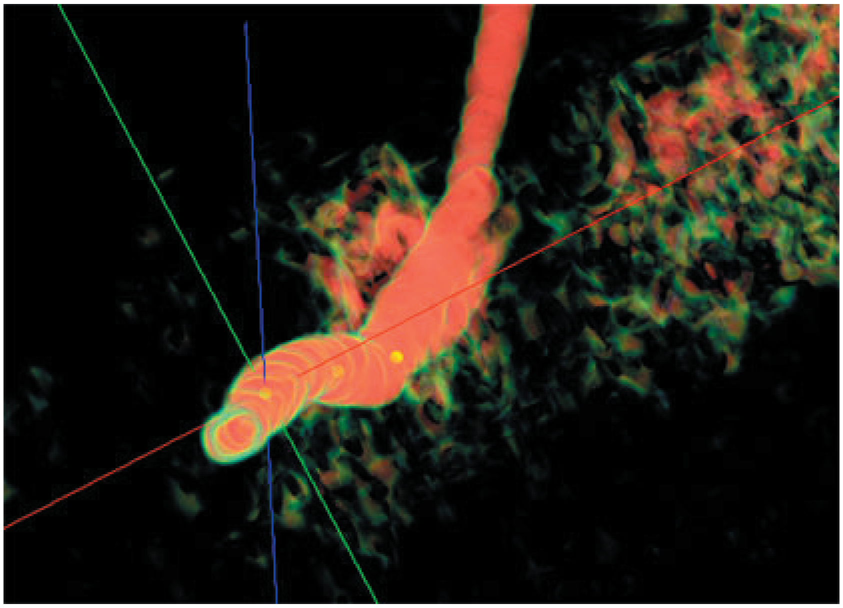
[7] Photo

Track: blood vessel



Blood vessel

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