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Innovations

Tools for Nanoscience at McGill University:
Sometimes Smaller Is Better

"At the nanometer level, the traditional boundaries between physics, chemistry, engineering, and the life sciences vanish," explains Dr. Peter Grütter, a McGill University Physics professor and one of ten researchers behind the new Tools for Nanoscience Facility at McGill. This facility, which opened November 2003, is based at the Rutherford Physics and Wong Engineering Buildings on the McGill campus and catapults the university into top tier status in the nano world.

"Nano" has become the new catchphrase in science. The word itself has been thrown around wantonly, almost like "organic" was several years ago. And, though the word has found new popularity, physicists and engineers have been in their nano worlds for decades. "The hardcore definition of nanoscience," says Dr. Grütter, "is that at least one critical dimension has to be nanometers in size—that is necessary, but not sufficient. The second part it is that some property has to be fundamentally different." It is this difference or change in property that distinguishes nanoscience from macromolecule biology, organic chemistry, and solid-state physics. For example, a transistor that has been reduced in size from 1 micron to 160 nanometers is not "nano" because of its reduced size. The fundamental operation principles are still the same in the 1 micron and 160 nm transistor. However, a molecule used as a semiconductor on a computer chip is "nano." Nanotechnology is the construction of tools that can manipulate atoms and molecules at nature's basic level. It's a structure, a chemical, a compound, or an ingredient of life at the smallest (atomic) level.

The Tools for Nanoscience Facility at McGill is composed of three closely linked components. The first is a clean room with a micromachining facility where all the custom nano needs are fabricated. A second component is an atomic manipulation facility allowing researchers to construct new devices atom by atom, thus taking the electronic and biochemical systems into the next stage of development. The third component is a Beowulf supercomputer dedicated to the modeling of nanomaterials. The Beowulf consists of 700 processors, runs at 1.3 Tflops (one trillion floating point operations per second), and fills an entire room. "There are a lot of good facilities around the world that do nano," says Grütter. "And, if you have this facility (the atomic manipulation facility) combined with the supercomputer and the micromachining facility, it makes it easier to attract really good research associates and faculty."

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As mentioned, nanotechnology is not new, but new advancements in technological capabilities have enabled researchers to more easily manipulate and construct at the atomic level. This ability has brought all sciences—the physical and chemical hard sciences as well the life sciences—to a crossroads. Each of these disciplines have been steadily progressing down their respective research paths. With so many questions to ask in science, it has been easier to separate the disciplines and proceed with the experiments. However, once the macro aspects have been addressed, the next level is what are the molecules and atoms doing in a plant, in a cell, in a piece of metal, in a specific chemical liquid? These questions can all be addressed in a similar manner.

Molecular electronics is one of the many nano fields at McGill. According to Grütter, a researcher in molecular electronics, one of the major issues is the role of the contact lead measuring the electrical characteristics of a molecule (nano structure). These electrical properties of particular molecules might allow for usage in information storage or processing applications, for example, a molecule to be used in computer chips. "In order to have a fundamental understanding of molecular electronics, one must first understand…how the structure of a molecule affects its electronic functionality," explains Grütter. "Conceptually, it is not possible to separate the contribution of the contact wire and the molecule." Up until recently, without the ability to control the atomic structure of the contact wire, those in the field of molecular electronics would for the most part disregard the contact wire, take a thousand or so measurements, semi-interpret those that looked interesting, and publish. However, if a contact wire has three atoms attached to the molecule instead of one atom, it is essentially like having a different type of molecule. Unequivocally, it is desired to replace gross approximations with more precise calculations of a molecule's electronic properties.

Of the most interest and utility will be the electronic characteristics of three-terminal devices. That is, measuring the IV (current/voltage) characteristics of a molecule using an input wire and an output wire, as well a control wire, which can apply a magnetic field or amplification, since background noise is substantial. From such experiments, it will be possible to learn how to move metal atoms on surfaces and how to move molecules on surfaces. "Atomically, we will be able to characterize and build a three-terminal device in which we know where each atom is at the contact region, and we can then measure its electronic characteristics," says Grütter. This research of atomic scale conductance is essential as the silicon integrated circuits continue to decrease in size. Some of the tools needed to build these three-terminal devices are constructed in the micromachining facility. The data from these three-terminal experiments are then collected using an atomic microscope in the manipulation facility. The data from the atomic microscope can then be taken to the local collaborators at the Beowulf supercomputer where the transfer properties of these molecular structures can be calculated, and the theory/experimental loop is thus closed.

Another strong nano field at McGill is in the area of photonics, the study of information processing and transmission by photons of light. A new area of research in photonics uses molecular self-assembly technology to pattern surfaces in materials that have useful optical applications. Self-assembly technology itself is an upcoming field involving the natural tendency of certain polymer molecules to cluster themselves into precise and organized patterns. Once patterns on material surfaces are determined and understood, they can be integrated into larger systems. These self-assembly experiments can be applied to the development of smaller and more efficient semiconductors as well as the generation of improved genomic tools. Just as fiber optic technology can measure and transfer vast amounts of data optically for internet purposes, fiber optics (photonics) can also be used to build much more powerful DNA microarray chips.

McGill's Nanoscience Facility is also working in the fields of nanomedicine and anti-infective nanomaterials. Nanomedicine is a field in its infancy. The details of its potential sound like science fiction, e.g., the use of nanorobots as miniature surgeons that could replace or repair damaged cells and intracellular structures. However, more elementary nanomedicine will include nanodevices for diagnosing illnesses. The next advancement from there is expected to be the implantation of nano devices for hormone or drug release. The current research is simply to understand how to control individual cellular atoms and molecules so these futuristic nanodevices and nanosurgeries can be fathomable, or at least more so. The area of anti-infective nanomaterials also relies on similar principles: controlling atoms on a material's surface that will not accept dust or the growth of bacteria or fungi.

Thus, as the roads of science have converged, so have the scientists. Interestingly, the evolution of nano centers like the facility at McGill came about out of circumstance. As all science fields have progressed to the atomic level, physicists and biologists both found themselves in microfabrication labs asking for (biologists) or building (physicists) their needed nanotools. From these gatherings, fruitful collaborations have come about, leading to collaborations of not only facilities but also of grants and monies. "If we get together, we can actually make an impact," says Grütter.

These different science disciplines have many man years and research behind them and many different ways at looking at the same problem. "If you can somehow bring them together, you can make progress and gain understanding in a faster manner. I see a great push for life scientists and hard scientists to come together in collaboration. The life sciences are moving away from the descriptive stamp collecting sort of approach to really trying to get a model system and make a theory and establish a theory and experimental feedback loop." Grütter continues, "It takes a generation to change anything on a big scale." The joining of forces and minds is one way to accomplish this transition into the powerful world of nano.

Chemistry & Biology **invites your comments on this topic. Please write to the editors at chembiol@cell.com.**

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