Chemistry moves up science totem pole

The rise of molecular research and interaction among the sciences inject new life into the discipline
BY ANDY HOR

The end of the last millennium was best remembered as the birth of the triad "Bio, Nano and Info".

I suspect that the beginning of this millennium will be best revered as the evolution of the quartet "Bio, Nano, Info and Chemio".

We live in an age where the quality of life is determined largely by how well we understand the behaviour of molecules, and how clever we are in harnessing molecular forces in innovative technologies. This has infiltrated every field, from medicine to engineering and electronics.

Science and technology in Singapore has gone through several milestones.

The petrochemical refining industry helped lift Singapore out of the economic baseline, the IT revolution built the infrastructure for growth, the electronic and semiconductor sectors started the value-added industries and pharmaceutical manufacturing generated national wealth.

The more recent biomedical revolution will take us to the level of the big boys.

Singapore knows that we cannot promote life science research without supporting the chemical sciences. Neither can we push chemistry research without taking care of the environment and minding energy use.

New fields, new foci

In schools and universities, there are three classical hard-core sciences: chemistry, physics, and biology. Mathematics is a tool used by all scientists.

But chemistry is no longer a subject that focuses on compounds and their reactions. It is a molecular science that reveals how molecules are formed and disintegrated, as well as how they behave, interact and transform.

This knowledge makes chemistry the central science because molecules are molecules – whether they are in our bodies, in a manufacturing process, a physical system, or simply ingredient's in all types of domestic and industrial materials. Every material is made out of molecules or atoms. They are the matter which matters.

Modern biologists take a bottom-up approach to understanding how plants develop, how animals grow and how micro-organisms reproduce. A good dose of biology today is molecular biology. And physics today delves into complex solid-state materials, photonics, energy, devices and a myriad of engineering systems.

The world has changed and the science we do has changed with it. Among the most significant scientific evolutions of the 21st century has been the emergence of a range of new areas at the intersects of the classical sciences. Most familiar to people are the development of bioinformatics, the merging of biology and information science to understand the deluge of biological data; bioengineering, which combines biology and engineering to create devices and processes to treat disease; and interactive digital media, which is at the cross-roads of science, engineering, computing and art.

Many scientists believe that the most significant innovations will come from intersecting fields.

The most significant development of modern science is probably the marriage between chemistry and biology that has given birth to chemical biology.

This is a hotbed of biomedical research. It cross-fertilises chemistry with biology, medicine and engineering, further giving rise to siblings such as chemical genetics, chemical pharmacology and chemical enzymology. In this field, chemists try to develop artificial systems that mimic natural enzymes in the body.

Biologists use synthetic chemistry concepts to open up the field of synthetic biology, to illuminate the effects of unnatural molecules in natural systems. They make new biological parts and systems. The ultimate target is to tackle disease at its molecular root and, perhaps, create new forms of life. This would allow us to solve problems that cannot be solved today.

When all three giants - chemistry, physics, and biology - meet, expect fireworks.

In biomedical imaging, for example, by using biology to understand how diseases develop, chemical reactions to detect changes in the body and physics to create the best devices, the idea is to develop new techniques that can sniff out disease even before symptoms appear disease, symptoms and cures. Molecular medicine gives us new hope in tackling disease. For example, a protein folding in the wrong way may be the common denominator among seemingly unrelated diseases such as cancer and diabetes. The use of chemical genetic techniques to study the malfunction of molecules in our bodies is increasingly popular. Scientists around the world are working on this.

Biomolecular science underpins genomic and proteomic research: the study of the genes and proteins in the body and how they work. Looking at enzymes and genetic mutations in the world of biology is fundamentally the same as how chemistry studies chemical reactions and molecular transformation.

Chemistry’s reincarnation

Chemistry has transformed itself from the bottom of the totem pole to the centre¬-piece of modern science, technology and medicine.

The key lies in thinking small, really small. A nanometre (nm) is a billionth of a metre. A simple molecule, such as carbon dioxide or acetylene, is about half this size. As a rule of thumb, small molecules are sub-nano (smaller than 1nm); whereas the big molecules, such as DNA, are as big or bigger than 1nm.

The academic world has changed accordingly. Harvard's Chemistry Department is now called the "Department of Chemistry and Chemical Biology", for example. Dr Sydney Brenner (Nobel Prize for Medicine winner in 2002) founded a Molecular Sciences Institute in Berkeley in 1996. The Institute for Molecular Science in Okazaki, Japan, was created to investigate fundamental properties of molecules and molecular behaviour.

Many young assistant professors in the world's top chemistry schools are in the intersecting fields of chemistry with biology, physics and materials. Synthetic chemists in Cambridge and Oxford make molecules not just for fun, but also for functional purposes, such as medicine and nano-matertals. The National University of Singapore's Department of Chemistry hires professors in the chemical sciences, not just chemistry.

Even chemists, the original molecular scientists, are going back to the drawing board to learn how to harness molecular power to create wonders, not just in round-bottom flasks but also in complex biological and physical systems.

Chemists today are getting cleverer - making molecules store hydrogen and remove contaminants from water, for example. They also design catalysts to convert carbon dioxide into useful materials such as polymers. Many techniques are now applied to design molecular therapeutic agents.

In the past, our focus was to identify the problem and then look for a solution. In this molecular age, it is possible to develop therapies before symptoms appear. The nature of science makes it possible to create an invention without an obvious application in sight. When there is a solution waiting for a problem, you may have a much better chance of tackling big challenges such as cancer; global warming, nano-electronics and renewable energy.

In fact, great science is often driven by an idea or a concept, not a problem. Many applications are developed after an invention or molecule is discovered, not before. A molecule could well be discovered by accident, but after this happens, you begin to study how it is formed and how it behaves.

In a sense, the accidental discovery begins to chart the next course of research. Quite often, these subsequent experiments lead to applications.

Indeed, many ground-breaking inventions were developed by chance: the antibiotic penicillin, the laser and Teflon, the anti-stick material used to coat cookware, to name a few.

Chances are, if the science is great, technology will find a use for it.