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What's the Future of Chemistry?

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Chemistry is a mature field. A lot of chemistry is known, and a young person considering science might well ask what the future of chemistry is likely to be. Will there be exciting new developments? Or is most of the chemistry already done? Will chemistry and chemists have interesting, intellectually stimulating work to do? Or will becoming a chemist be tantamount to becoming a drudge?

The recent report that the initial sequencing of the human genome has been completed represents a triumph of chemistry, genetics, and several related disciplines. On Monday, June 26, 2000, U.S. President Bill Clinton and British Prime Minister Tony Blair (via video hookup) celebrated the achievements of the many scientists whose work led to this milestone in our progress in understanding genetics from a molecular perspective. Present at the ceremony were J. Craig Venter, president and chief scientific officer of Celera Genomics corporation, Francis S. Collins, Director of the National Human Genome Research Institute (sponsored by the U.S. National Institutes of Health), and James D. Watson, Nobel Laureate and co-discoverer of the structure of DNA.

More than 1000 scientists from five countries (China, France, Japan, the U.K., and the U.S.A.) participated in creating a genome map that accounts for 85% of the genetic code. There remain gaps to be filled, but the major work has been completed. When the two projects, one government-sponsored and the other private, jointly publish their results, the sequence of DNA base pairs that makes up the human genome will appear in the scientific literature and on the Internet.

A signal achievement such as mapping the human genome is often viewed as an end, leading one to consider whether there is anything more to do. Chemists have participated in many such successes throughout the 20th century, and we may well ask whether the heyday of chemistry is past and the future belongs to other sciences. Is the mother lode of chemical research and discovery played out? Should young people avoid chemistry and choose other careers?

I think not.

At the end of the 19th century, many physicists thought (some of them rather smugly) that they had discovered all of the basic laws of nature and all that remained was a mopping-up operation—tying up loose ends. Even before the turn of the century the discovery of radioactivity boded ill for such opinions, and in 1900 Planck's quantum theory started a revolution in thinking about the world of atoms and subatomic particles that even today provides challenging problems.

The chemists, geneticists, and others working on the human genome project have not assumed that they are at the end of their work—quite the contrary. Once DNA sequences have been deciphered, it becomes productive to ask about the structure and function of each of the proteins coded by the DNA. A next step, then, is to clone the DNA sequences, generate proteins, and set about the daunting task of crystallizing the proteins and determining their structures. This involves tens of thousands of protein structures every year. Doing this many structures using current methods is impossible, so the success of the human genome project is spurring efforts to develop new methods.

One such innovation involves robotic systems that quickly and precisely vary reagent concentrations, pH, and temperature in each of hundreds of samples, thereby increasing the chances that a crystal will grow in at least one sample (*Chemical and Engineering News*, July 3, 2000, p.27). In addition, extremely intense, highly focused x-rays make it possible to structure information from tiny crystals as small as 50 _ m long. To achieve the savings in quantity of protein that such small crystals make possible, a robotic system has to be able to handle volumes on the order of 100 nL, and an important parameter is controlling the size of droplets of solution over a range of different viscosities. Robots are envisioned that can run 138,000 crystallization conditions per day, and a robot has already succeeded in crystallizing 16 different proteins.

This opens tremendous opportunities not only for those interested in robotics and combinatorial chemistry, but also for those who will study and analyze the relations between protein structure and function based on the wealth of structural information that will soon become available. The blossoming of knowledge that a collection of protein structure/function data represents is truly mind-boggling. Studies of protein structures and functions are becoming the basis for design of many drugs and consequent alleviation of much human pain and suffering, and much more remains to be done in the future.

There are many other developments in which chemistry is important and new chemical innovators will be needed. For example, chemical analysis and chemical synthesis may be possible on microchips, and a number of companies are designing microscopic, lab-on-a-chip technologies. (See http://www.calipertech.com/tech/index.htm and http://www.hp.com/pressrel/sep99/15sep99b.htm .) Atomic-scale circuitry, millions of times smaller than today's computer microprocessors, may handle the computing tasks of tomorrow. Their tiny size would minimize power consumption, maximize speed, and permit nanoprocessors to be installed in a much broader range of everyday objects. (See http://www.almaden.ibm.com/almaden/media/image_mirage.html and http://www.hpl.hp.com/news/techforecast.html .) Carbon nanotubes, an outgrowth of the discovery of the carbon allotrope buckminsterfullerene, also show promise for incorporation into electronic devices on a Lilliputian scale. (See http://www.nytimes.com/library/cyber/week/021798molecule.html) In the field of nanotechnology, there are many more discoveries waiting for the right young scientist to make them. A worldwide report on this area is available on the Internet at http://www.whitehouse.gov/WH/EOP/OSTP/NSTC/html/iwgn/IWGN.Worldwide.Study/toc.html .

The potential for new discoveries and for young scientists in chemistry has never been greater. For more details on the current status of chemistry research and what is in store for the future, I recommend that you consult the *Journal of Chemical Education*'s Viewpoints series of articles. These appeared in the February, March, April, June, September, and October issues in

1998, and in the February, March and October issues in 1999. Each Viewpoints article was written by an expert, or a team of experts, in a particular field. These authors provide an overview of developments in the field during the past 50 years, and a projection of where the field will go in the next 25 years. In addition to Viewpoints, the *Journal of Chemical Education* publishes a broad range of other articles that delineate what modern chemistry is achieving, where it is going, and what opportunities it offers for young scientists who enter the field.

There is a great deal of truth in a remark attributed to George Bernard Shaw, “Science is always wrong. It never solves a problem without creating ten more.” That’s the beauty of a career in science. For anyone with creativity, intelligence, and persistence, science will never fail to provide new and exciting challenges—and lots of fun!