Girton150 Anniversary Lectures

The Founders' Science Lecture by Professor Dame Pratibha Gai, FREng, FRS

On Tuesday 12 March 2019 Girton College was honoured to welcome Professor Dame Pratibha Gai to give the inaugural Founders' Science Lecture, the second of a special series of five public lectures in Girton's 150th Anniversary Year. The packed audience included distinguished guests from the University, and Fellows and Scholars of the College and their guests.

Dame Pratibha said she was honoured to have been asked to give this lecture and was pleased to be back in the College where she had been as a graduate student, while completing her PhD at the Cavendish Laboratory over 40 years ago under the supervision of Archie Howie. Reflecting on the long process by which she had come to study in Cambridge, she noted that although a few thousand years ago in ancient India, women had been scholars, the situation had subsequently changed for the worse until, in the late nineteenth century, Dame Edith Brown - one of a number of Girtonians who had come to India as educators - started the first medical college in the 1890s. It was through such examples that Girton became known in India, prompting Dame Pratibha to choose Girton as her college. After Cambridge she moved to Oxford and then to the USA for nearly twenty years, and finally back to the UK, to co-found the Nanoscience Centre at the University of York, cementing the truth of her conviction that "Science needs women"!

Her lecture was entitled:

Catch me if you can! Atoms in Action for energy, environment and healthcare

Atoms matter – they are the building blocks of everything. It is essential therefore to be able to view and analyse chemical reactions between them at the atomic scale. This, however, poses problems. Imagine trying to see a golf ball on the Moon—that's how hard it is to see atoms! As Professor Gai observed, the size of an atom (0.1 nanometres, 10^{-10} m) is as small compared to a football as the size of a football is to that of the Sun.

Professor Gai compared performing chemical reactions, key to technology and healthcare, to making a cake—both are carried out with a specific final product in mind. Chemical reactions are 'alive'—they are dynamic processes and take place at the atomic level. To create them one often needs a catalyst, usually a surface that helps to bring atoms together so they can react. Globally the chemical economy is worth $10 trillion a year, so catalysis is of great importance. To work out how best to combine any of the 91 different chemical types of atom - which is theoretically possible in many different ways - it is very useful to be able to view the atoms at the intermediate stages of a reaction. This is the challenge Professor Gai set out to embrace.

Electron microscopes (EMs) that are capable of imaging atoms have been around for a long time. They fire a beam of electrons at a sample (object) and image those that are transmitted through the sample. However, such machines generally require a high vacuum inside, so as not to damage the electron source or scatter the electrons on their way to the sample. So how can one watch a chemical reaction, in which gases (or liquids) of the reagents meet and react at high temperature, in such a machine? Dame Pratibha had earlier worked on a modified high-voltage transmission EM in Oxford, which used electrons at 1 million volts and had a reactor device inserted into it, achieving nanometre resolution. For atomic resolution, what she and colleagues decided to do was to feed gases directly into the small space containing the sample in the middle of a commercial microscope, pumping them away before they could reach the rest of the machine. This required a radical (and rather risky) modification to the microscope: drilling small radial holes right through the surrounding metalwork, missing the coils of wire they contain, which act as lenses to focus the electrons on to

the sample. With this they were the first people to look at atoms and their clusters reacting on a surface. The atomic-resolution Environmental Transmission EM (ETEM) was born.

Professor Gai went on to describe a variety of representative applications of her technology. Firstly, she showed pictures of titania (TiO_2), which is used as a white pigment. Paper and coatings are produced with coated nanoparticles of titania using an environmentally sustainable process. By observing the growth of such minute particles atom by atom, one can invent new types of coating. A solid coating can even be made around a liquid, to encapsulate fish oil and other healthcare products.

Dame Pratibha moved back from DuPont in the US to the University of York to found the Nanoscience Centre there. She and her team rebuilt a state-of-the-art environmental (scanning) TEM (E(S)TEM), in which the sources of beam distortion (aberration) were corrected to have the same capability to observe reactions as in the earlier ETEM microscope, but with far higher resolution, below 0.1 nanometres, so that individual atoms could be easily resolved, for example in gold nanoparticles. Surfaces that catalyse chemical reactions may sometimes stop working, and it is important to understand why, by observing the process happening. When sintering nanoparticles, they coalesce, and this is fascinating to watch in real time using this new E(S)TEM, as is the movement of single atoms between clusters in a fuel cell. One can see how the growth of clusters changes as gases and temperature are changed. This allows one to make more efficient catalysts and to use less material. In healthcare, heterogeneous processes with atoms and clusters can lead to pain medicines and potent antimicrobials. To reduce carbon emissions, there is a need for renewable fuels made from plants, and the E(S)TEM is helping Dame Pratibha to find efficient catalysts for converting plants such as rapeseed and grass to such biofuels. One can also learn about the atomic-scale reactions in diesel and petrol engines in an attempt to make them produce less pollution.

Dame Pratibha summarised her fascinating talk by saying that she had given a variety of examples of how science can benefit society, and that this had come from the development of the capability to watch chemical reactions. Her work thus exemplifies Nobel laureate Rosalyn Yalow's claim that "New instrumentation leads to new science".

Chris Ford, Professorial Fellow