NANOPARTICLES IN MEDICINE

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An important characteristic of particles just a few nanometres across is that they are of the right scale to interact with biological molecules and living cells in a specific and guided manner. Metal nanoparticles, in particular, possess physical characteristics that make them ideal diagnostic probes or even therapeutic agents. A number research groups in the world are focusing on developing novel strategies involving gold, silver and magnetic nanoparticles to aid the treatment of disease. Gold and silver owe their colour and shininess to oscillations of free electrons on their surface called plasmons which control how light is reflected. The plasmon frequency is also affected by the size and shape of the metal surface. Consequently gold nanoparticles are deep red but change to blue when the particles cluster into larger objects; for silver particles the colour change is from yellow to orange.

A team at the University of Strathclyde led by Duncan Graham has developed a particularly sensitive biomedical sensor based on the fact that the plasmons of silver-nanoparticle aggregates enormously enhance the characteristic wavelengths of light scattered from an attached probe molecule – an effect called surface enhanced resonant Raman scattering. The silver particles are coated with a DNA sequence designed to bind to a specific target biomolecule or gene. When the particles recognise their target, they scatter the light illuminating them at a different wavelength which is then detected. Another type of multi-tasking DNA probe is being developed by Tracy Melvin and Tom Brown at the University of Southampton. It is based on gold nanoparticles and semiconductor quantum dots combined to create an optical 'nano switch'. Cadmium sulphide (or selenide) quantum dots fluoresce with a wavelength that depends on their size. However, on contact with gold nanoparticles, the fluorescence is switched off. The principle is to attach a strand of the target DNA to the quantum dot, and then link the DNA strand with the complementary base sequence to a gold nanoparticle. When mixed so that the strands bind, the light emission is turned off. If complementary DNA is then introduced from a clinical sample, it displaces the gold-linked DNA sequence and light emission is switched on again (see figure opposite left).

Gold nanoparticles could also be used to make cancer radiotherapy quicker, more effective and cheaper. David Hirst, Fred Currell from Queen's University Belfast are building a prototype X-ray system based on the principle that tumours have very porous blood vessels which preferentially accumulate injected metal particles. Gold atoms readily absorb X-rays of particular energies, releasing a shower of electrons. Unlike X-rays, they travel only a short distance before wreaking havoc on the surrounding tissue, in this case the tumour; in effect, each nanoparticle has a 'sphere of destruction' around it. Using gold nanoparticles in conjunction with tailored X-ray beams would reduce the number of treatments needed, as well as limiting damage to surrounding healthy tissue, and would be particularly effective on brain tumours, which are notoriously difficult to treat.

Magnetism is another property of metals that is being exploited in medicine. Magnetically responsive nanoparticles are already used as contrast agents in magnetic resonance imaging (MRI). Now, researchers are considering how to apply them to deliver drugs and even genes into cells. University has been attaching DNA sequences, which express a target protein, to nanoparticles with ironoxide cores, and then using an oscillating magnetic field to encourage cells to take up the DNA. In a further project, his research group is exploring how to deliver the corrected cystic fibrosis gene into the lungs of a sufferer using an external magnetic field to pull the nanoparticles through the thick mucus typically secreted by the lung tissue. The patient would lie on a table with an oscillating-magnet array underneath and inhale the particles from a nebuliser. Another application, which his team is investigating, is tissue engineering. By attaching molecules that recognize specific ion channels in cell membranes to magnetic nanoparticles, various cellular processes can be regulated to activate, for example, the formation of bone or cartilage. There is another using of magnetic nanoparticles. An exterior magnetic field can be manipulated such that it heats up the particles enough to kill targeted cancer cells. This burgeoning area of nanotechnology typifies how understanding the basic physics and properties of matter underpins applications that can improve the quality of life.