**Nanotechnology**

Chemists are very adept at thinking about matter at the atomic and molecular level. But to control the physical characteristics of everyday materials, we must first relate *molecular* properties to *bulk* properties. For example, an individual molecule’s shape and dipole moment influence the strength of interactions *between* molecules, which in turn determine the melting point of a solid made up of *many* of these molecules. A clear understanding of such microscopic/macroscopic chemical relationships is what allows scientists and engineers to create materials suitable for specific uses. But what if we could “engineer” directly at the molecular level? An emerging discipline known as *nanotechnology* concerns precisely that: designing molecule-sized devices to do the work of objects we’ve traditionally manipulated on a much larger scale.

Since a chemical bond is on the order of 1–5 Å in length (1 angstrom = 1 x 10–10 meter), molecules and small assemblages of molecules have sizes of up to a few hundred nanometers (1 nanometer = 1 x 10–9 meter). At this level, chemical particles have not yet reached the critical mass necessary for bulk behavior, and still behave like individual molecules in some ways. As a result, these “nanoparticles” often possess unusual or superior properties compared to larger structures.

One highly anticipated application of nanotechnology is molecular electronics, in which computer chip components (now reaching the lower size limits achievable with regular fabrication techniques) may be replaced with faster, more space-efficient devices made from individual molecules. For example, carbon nanotubes, tiny hollow structures composed entirely of carbon atoms, could potentially be used in this manner because their excellent thermal and electrical conductivity allows them to function as molecular “wires.” While regular wires drawn from conducting metals always contain some property-limiting defects, the single-molecule nature of carbon nanotubes renders them free of imperfections. Their flawless structures also generate other unique properties, such as strength per unit weight much greater than that of steel. Carbon nanotubes have already been used to toughen lightweight, high-end sports equipment such as golf clubs and bicycle frames.

Because many biological structures are nanoscale in size, the treatment of cancer and other diseases may derive immense benefits from nanotechnology. Particles smaller than approximately 50 nm in diameter can enter most cells, while those smaller than 20 nm can pass through the walls of blood vessels to surrounding tissues, allowing these materials to go easily where they are needed. Additionally, the molecular nature of nanomaterials means they can be precisely modified by chemical attachment of various substances required for diagnosis and therapy. A single anticancer nanoparticle, constructed from a large polymer or protein molecule, might simultaneously bear an antibody that selectively binds to cancerous cells (increasing the efficacy of treatment), a magnetic contrast agent for MRI imaging, and the actual drug molecules used for therapy. These tiny, multifunctional super-medications of the future are called “nanoclinics.”

Curing cancer and reinventing the computer chip seem sufficiently ambitious for any new technology. But nanotechnology has captured our imaginations to such an extent that a number of other, more wild-eyed proposals for its use have also appeared. These include artificial intestines made from nanoparticle-laden plastic films, “smart” bullets with tiny target-tracking computer chips, and a “space elevator” consisting of a 22,000-mile carbon nanotube-fiber rope connecting the Earth to a satellite, used to hoist materials into orbit without the use of rockets. Although these rather fantastic technologies may or may not ever come to pass, one thing appears certain given nanotechnology’s more pragmatic uses: many of the “big things” in our future may actually be very small.