## Lecture-1. Getting Small with Nanotechnology.

Nano, Greek for “dwarf,” means one billionth. Measurement at this level is in nanometers (abbreviated “nm”) — billionths of a meter. To put this into perspective, a strand of human hair is roughly 75,000 nm across. On the flipside of the concept, you’d need ten hydrogen atoms lined up end-to-end to make up 1 nm. Figure 1-1 illustrates the differences in scale that range from you all the way down to one hydrogen atom.

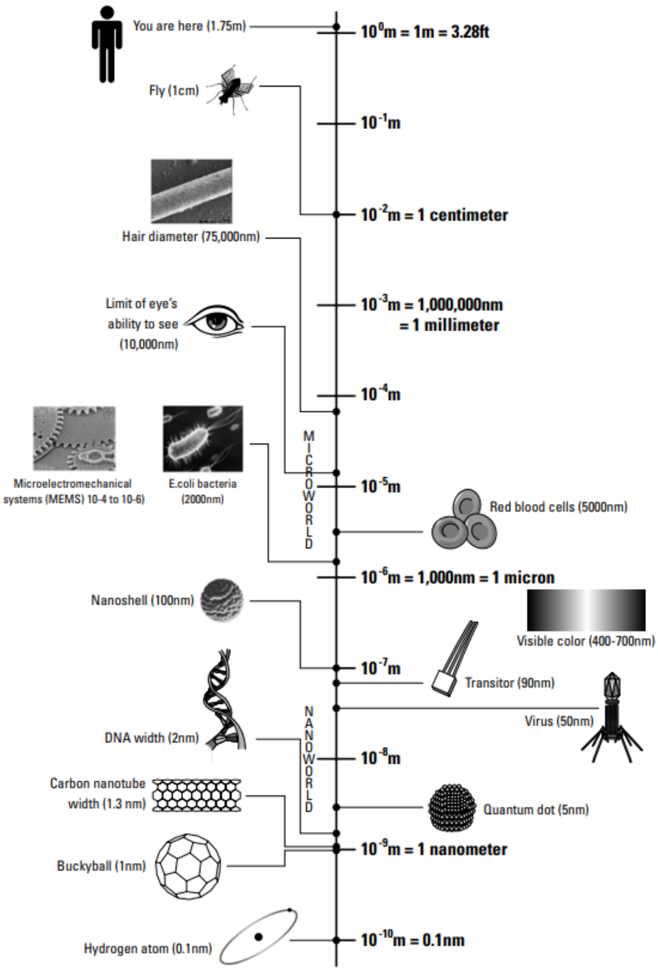


**Figure 1-1:** Size comparisons, from you (1.75 meters, or approximately 5 ft. 7 in.) all the way down to the hydrogen atom (0.1 nm).

Nanotechnology can be difficult to determine and define. For example, the realm of nanoscience is not new; chemists will tell you they’ve been doing nanoscience for hundreds of years. Stained-glass windows found in medieval churches contain different-size gold nanoparticles incorporated into the glass — the specific size of the particles creating orange, purple, red, or greenish colors. Einstein, as part of his doctoral dissertation, calculated the size of a sugar molecule as one nanometer. Loosely considered, both the medieval glass workers and Einstein were nanoscientists. What's new about current nanoscience is its aggressive focus on developing applied technology — and the emergence of the right tools for the job. When faced with a squishy term that can mean different things to different people, the best thing to do is to form a committee and charge it with drawing up a working definition. In fact, a committee was formed (the National Nanotechnology Initiative) and the following defining features of nanotechnology were hammered out: 1. Nanotechnology involves research and technology development at the 1nm-to-100nm range. 2. Nanotechnology creates and uses structures that have novel properties because of their small size. 3. Nanotechnology builds on the ability to control or manipulate at the atomic scale.

Nanotechnology is, at heart, interdisciplinary. You'll get only part of the story if you just use chemistry to get at the properties of atoms on the nano level — adding physics and quantum mechanics to the mix gives you a truer picture. Chemists, physicists, and medical doctors are working alongside engineers, biologists, and computer scientists to determine the applications, direction, and development of nanotechnology — in essence, nanotechnology is many disciplines building upon one another. Industries such as materials manufacturing, computer manufacturing, and healthcare will all contribute, meaning that all will benefit — both directly from nanotechnological advances, and indirectly from advances made by fellow players in the nano field. (Imagine, for example, quantum computers simulating the effectiveness of new nanobased medicines.) There are two approaches to fabricating at the nano scale: top-down and bottom-up. A top-down approach is similar to a sculptor cutting away at a block of marble — we first work at a large scale and then cut away until we have our nano-scale product. (The computer industry uses this approach when creating their microprocessors.) The other approach is bottom-up manufacturing, which entails building our product one atom at a time. This can be time-consuming, so a so-called self-assembly process is employed — under specific conditions, the atoms and molecules spontaneously arrange themselves into the final product. (Self-assembly is described further in Chapter 8.) Some science-fiction plots — they know who they are — revolve around this self-assembly concept, conjuring up plot lines infested with tiny self-replicating machines running amok. (For a closer look at this far-fetched notion, see the "Welcome to Nano Park" sidebar in this chapter.) For the near-term, it looks like the top-down approach will be favored because it tends to provide us with greater control (and, more importantly, it uses some time-tested techniques of the computer industry). If we were betting men — which we are not, because as men of science we know that the House always wins — we would venture that the top-down approach will be the fabrication method of choice for quite awhile.

Futuristic excitement aside, our expectations for nanotechnology need to be realistic and we need to be patient, for not all the advances that nanotechnology is set to bring will happen overnight. Nanotechnology will not be a miracle cure. Although there will be some fantastic advances, not everything that we imagine will come to fruition. However, nanotechnology is also sure to usher in things that we never envisioned coming — products that could end up changing the world. Nano-scale science isn't a free-for-all — there are rules. We won't be able to manufacture something that, at the molecular level, is chemically unstable. Scientists know how most things work chemically and physically, but there have been a few surprises — and we learn the rules along the way. Time to take a look at some examples of the nanotechnology we now have, what we can improve upon, what will be new, and what (we can confidently say) will never happen.