Chemistry says it can't happen
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The word "nanotechnology" means very different things to different people. While most would agree that nanotechnology is technology performed on the scale of nanometers — one nanometer being about the size of four zinc atoms laid side-by-side — that is where the agreement often ends.

To Howard Craighead, director of the National Nanofabrication Facility at Cornell University, nanotechnology is a science that uses the chipmaking techniques of the microelectronics revolution to produce devices of increasingly smaller dimensions.

To Rick L. Danheiser, a professor of chemistry at the Massachusetts Institute of Technology, nanotechnology is a word that describes synthetic organic chemistry — a science which seeks to place atoms in precise and complex arrangements in order to accomplish exacting goals.

To K. Eric Drexler, an author and visiting scholar in the Computer Science department at Stanford University, nanotechnology describes a technology of the future -a technology based upon self-replicating microscopic robots controlled by tiny mechanical computers, capable of manipulating matter atom by atom.

Who is right? Everybody and nobody, really, because "nanotechnology" isn't a scientific term. Nanotechnology is a mind set, an ideology, a way of solving big problems by thinking small, thinking very small.

The basic tool of the nanotechnologist is the "assembler", according to Engines of Creation, the book by K. Eric Drexler that reads like the Nanotechnologist Manifesto. No larger than a few hundred atoms across, assemblers would be constructed from gears that use single atoms for teeth and turn on frictionless pivots made from single chemical bonds. These nanomachines would come equipped with a computer and a robotic arm, and have the remarkable ability to construct ("assemble") materials or molecule-sized devices a single atom at a time. Assemblers would reproduce by building exact copies of themselves — thus it would only be necessary to build a single assembler, and this first assembler would build the rest.

Although it would be slow for a single assembler to construct anything larger than a fly speck, billions of assemblers working together could do almost anything. You could set a fleet of them about the task of covering your car's paint job with a micron-thin coating of diamond, constructed an atom at a time by assemblers using carbon from carbon dioxide plucked from the surrounding air: forget about rust and car washes. Assemblers could restore the ecological balance of the planet by making more ozone in the upper atmosphere. They could clean up oil spills by eating up the oil, or alternatively they could make oil from air and sea water. In war time, assemblers would be the ultimate weapon, programmed to be "omnivores" and rip apart attacking armies atom by atom.

There is certainly evidence that such manipulations at the atomic level are possible. Every cell of every living thing is constantly manufacturing, using and destroying tremendous numbers of relatively simple nanomachines called proteins. Some of them are structural, some of them perform chemical reactions, and some of them transmit messages. But proteins are almost always single-purpose devices which require nearly all of the machinery of the cell to produce and regulate them. No protein does all of the things that an assembler would supposedly be able to do.

One of the most intriguing of the proposed nanomachines is the nanosub, a device a little smaller than a red blood cell which could swim through a person's circulatory system in search of plaque or fatty deposits. Whenever the sub bumped into something that doesn't belong, it would switch on a powerful set of drills and shred the offending blockage. With a few robot arms, the sub could even repair damage. Sort of a nano-Fantastic Voyage, the concept of this sub has appeared in prestigious newspapers like The New York Times and The Wall Street journal, as well as magazines such as Scientific American. The sub represents the best of what nanotechnology has to offer: the ability to make our lives better.

The Cult of Nanotechnology paints a future in which technology has grown unimaginably more powerful than it is today. As a much bigger lever than any technology before it, they argue, it would do us well to think about the potential of the technology before the revolution happens: this is what they are doing. The problem with these people's ideas is that they envision working with atoms the same way a model-maker might work with wooden sticks and styrofoam balls breaking a bond here, moving an atom to the other side, and forming a new bond. It is that conceptual model which is at the heart of all the nanotechnologists' drawings of gears, motors and nanocomputer parts, as well as the very idea of the assembler's robot arm and the nanosub's drill. But atoms don't work that way.

"(Drexler) discusses these molecular systems as mechanical systems", says Robert J. Silby, a professor of chemistry at MIT. "He bangs them and they go." The problem is, Dr. Silby explains, "molecules are not rigid — they vibrate, they have bending motions."

Even cross-linked or interlocked networks of carbon atoms exhibit these characteristics, Silby explains. "Therefore these will not act, mechanically, in the way he has written down. There is more to it than he has said."

Take the example of the assembler's "robot arm." Such an arm could probably pick up a single atom, since lone atoms are very reactive and likely to stick to anything that they come into contact with. Getting the atom off the arm, on the other hand, would require a lot of energy — quite possible more energy than the nanomachine would have available.

The robot arm might have a little more luck working with groups of atoms, called molecular fragments. The energy required to work with molecular fragments is much lower than the energy needed to work with single atoms -this is the reason that proteins almost always work with molecular fragments. The only ways that a robot arm could hold a molecular fragment in place would be by making a chemical bond to it or by clamping the fragment in place with some sort of molecular cage.

Molecular cages do occur in nature, but they tend to be bulky and unwieldy. While there are some proteins which hold molecules in their active sites with flaps constructed from chains of amino acids, such active sites are always at the heart of the protein — not on flexible arms which can easily be maneuvered around. And, as with molecular bonds, the cages and the molecular fragments they hold always come in matched sets.

Presuming an "arm" could be constructed, it would need some sort of "eye" to locate molecular fragments that it would reach out and grab. What sort of sensors would the nanocomputer at the heart of the assembler use to locate the fragments in the first place? What would such a sensor be based on? Visible light has a wavelength fifty to a hundred times the size of a molecule. Light does not "bounce off" a molecule but more often goes straight through, only causing slight disturbances in the very outermost electrons of the molecule's atoms.

Light that has atomic-sized wavelengths is known as X-rays. However, even if the nanomachines could not generate enough energy to emit an X-ray without breaking apart, there is no way that they could detect the reflected rays or collimate them into recognizable images.

The idea of a universal assembler is somehow a very comforting one: a programmable machine, capable of manipulating atoms and carrying out reactions the way that a blacksmith might repair a horseshoe with anvil and fire, is an easier image than proteins or inorganic catalysts carrying out complicated chemical reactions by transferring electrons from atom to atom. And indeed, in the beginning of his book, Drexler describes an assembler grasping "a large molecule (the work piece) while bringing a small molecule up against it in just the right place. Like an enzyme, it will then bond the molecules together."

The idea of using a few well-crafted machines to make billions, and then using a billion machines to solve the world's problems is really an appealing one. It is especially appealing to a generation of computer scientists that has been raised on ideas such as recursion (a way of solving a problem with a function that refers to itself) and massive parallelism (an approach that uses thousands or millions of simple computers, all working together in unison to solve different chunks of complicated problems in seconds, instead of the days that a conventional computer might take.) Nanotechnology is the physical embodiment of these mathematical ideas.