Nanotechnology

A Better Understanding of the Small World
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Contents

1. Nanotechnology
   Introduction 1

2. Basics
   The Building Blocks 3
   NANOASSEMBLERS
   NANOFACATORIES
   NANO-ROBOTS
   NANOSPHERES
   CARBON NANOTUBES
   ORGANIC DENDRIMERS
   FULLERENES/BUCKYBALLS
   DIODES
   TRANSISTORS
   CAPACITORS
   RESISTORS
   NANOWIRES
   CONCLUSION

3. The Interesting
   Applications 9
   INTRODUCTION
   Bionanotechnology Applications 9
   BASIC POSSIBILITIES AND OUTCOMES
   Environmental Applications 14
   INTRODUCTION
   ENERGY AND FUEL APPLICATIONS
   WATER AND SOIL APPLICATIONS
   Computer Engineering Applications 20
   HARDWARE: INTEGRATED CIRCUITS
   FUTURE OF NANOCOMPUTING
   Computer Science Applications 24
   GETTING TO KNOW YOUR SWARMS
   ANT COLONY OPTIMIZATION
   PARTICLE SWARM OPTIMIZATION
   CONCLUSION
4. Issues

Looking Before We Leap 30
INTRODUCTION

Regulation, Subjugation, and Degradation 31
ETHICAL ISSUES

Nanotechnology, Prepare to be Subpoenaed! 33
LEGAL ISSUES

“Danger, Will Robinson, Danger!” 35
VIOLENCE ISSUES OF NANOTECHNOLOGY
9/11-WAS IT PREVENTABLE

Just A Spoonful of Nanotech 37
ENVIRONMENTAL AND HUMAN HEALTH

Nanotechnology’s Beginning 39
CONCLUSION

5. Bibliography  B-1

6. Glossary  G-1

7. Credits  C-1
**Nanotechnology**

INTRODUCTION

In the dawn of this new era, science and modern technology have advanced beyond our wildest dreams. Dreams, ideas and theories have been fostered, created before our eyes, and even come to life. Our wildest imaginations are slowly becoming reality, and the reality we once knew is now becoming fiction. These new concepts and inventions never cease to amaze us, broadening the very scope of scientific possibility. The world around us is constantly changing and new devices are becoming smaller, more compact, and more complex than ever before. One new branch in science has sparked a revolution, seizing the interests of scientists, engineers, politicians and general citizens all over the United States. That new sector of interest has been termed nanotechnology.

What we consider to be nanotechnology today was not just developed overnight. It took brilliant minds to discover this type of science and years of research. Three of the most prominent scientists that developed this discipline include Richard P. Feynman, Norio Taniguchi, and K. Eric Drexler. These men used incredible mathematics to better understand the immensely small scale of nanotechnology.

Doctor Richard Feynman is considered one of the most brilliant physicists to live since post-World War II. In 1965, Feynman was awarded the Noble Prize in physics for *Quantum Electrodynamics*, the theory of the reaction between light and matter. Before nanotechnology had an actual name and scientific field, Feynman began mentioning many of the basic and distinguishing topics. He described to his colleagues in 1959 different processes one might use to manipulate single atoms and molecules. The science of nanotechnology was born from this process and idea. He soon began to describe the basics of nanotechnology in theoretical and mathematical terms, and also how the laws of physics would change at such a small molecular/atomic level.

Nanotechnology did not get its name until much later when in 1974 a Japanese scientist by the name of Doctor Norio Taniguchi detailed that “Nano-technology mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or one molecule” (Kazlev, 1998). He was later given the Euspen’s Lifetime Achievement Award in 1999 for his dedication to the subject and its early developments.

Doctor K. Eric Drexler was another pioneer in the field of nanotechnology. Drexler developed the basic idea of molecular nanotechnology. By 1975 Drexler had been able to create metal films that were only a few nanometers thick. The only barrier that he reached was the ability to create these machines on the molecular scale. Since this is a strange and sometimes scary subject matter brought up in making nano-bots (the idea of having robots running the world is a frightening idea), Drexler created an institute to prepare society for the anticipated advent of the new and advanced technologies. He called it the Foresight Institute.

**Nanotechnology** is a term used to encompass the manipulation and creation...
of materials the size of atoms or molecules to fabricate devices. As more and more scientists and engineers discover the potential uses of atypical properties and advantages in the nanoscale, more and more possible applications are sought and invented. As aspiring biologists, computer engineers, computer scientists, electrical engineers, environmentalists, and physicists, we have vested interests in how nanotechnology will sculpt our future careers and our nation in the near future. We have joined forces in researching the progression of nanotechnology in current processes and methods to soon alter the future and shape of society. We as a team have undertaken the daunting task of writing a book of our research in the world of nanotechnology in a more per-se “user-friendly” format.

Society has the opportunity of applying the knowledge we derive from experimentation through the action of rearranging these elemental pieces for specific devices; the regular human way of life will be turned around. Just biologically, nanotechnology has the possibility of being used to completely change a person’s physical appearance through the rearrangement of atoms. DNA could be woven to all forms of shapes and there are even experiments to prove that DNA “origami” can exist. Organs can possibly be regenerated or regrown using nanotechnology. Cancer may even be cured through a series of treatments. Methods include organic dendrimers and catheters advancing the transfer of drugs and liquids throughout the human body. Environmentally, nanoparticles can be used to provide clean soil no longer exposed to toxic chemicals or provide sanitized, filtered water available to the public all over third world countries to consume. Nanotechnology can even help advance the consumption and generation of alternate clean sources of energy, such as the replenishing source of sunlight to power our homes or charge our smaller transportable devices. And from the technology we will see many new devices such as smaller computers, more reliable cars that burn gas cleaner, and easier ways to keep track of our belongings. However, with these advantages that will benefit society and extend years of life, nanotechnology may also create some unforeseen problematic issues and risks.

While there are so many great ideas and technologies that can be developed with nanotechnology, there are also many concerns that people continue to discuss. Some of these concerns deal with safety, the environment, and religion. Many people wonder that when nano-bots are eventually developed, what will happen when replication continues uncontrolled? Will nano-bots eat away at the fabrication of life, or will we eventually be consumed by these nano-bots, and in turn become robots ourselves? These two thoughts are very farfetched but should be considered. Other risks include the health safety during fabrication of nano-materials. These risks have been studied and it has been found that exposure to these nano-particles during manufacturing via inhalation or dermal contact are much more severe than when a worker comes in contact with, say, a much larger particle. Also since the design of the materials used are much different than many naturally occurring materials, health safety is of much more concern. Nanotechnology also has the ability to be crippling to the environment. Since this technology brings on much smaller devices which may be more powerful than today’s, its widespread use could theoretically cause environmental and human health damages not foreseen. Trying to control this use by creating laws would create an illegal demand for these devices and allow the trade of nano-devices over a black-market, keeping the government out of control. In the religious realm there are many concerns that people have
brought up. One interesting view is that of Laurie Zoloth, a professor of medical ethics, humanities and religion at Northwestern University's Feinberg School of Medicine “[Nanotechnology] challenges naturally observable limits. Is it hubris to go beyond them” (Connolly, 2004, para. 4). This is an idea that comes up many times when theology is discussed in tandem with nanotechnology. Since we cannot see what we are doing, why must we try this type of science or manipulate this natural habitat? Many people believe that it is important that seeing is believing, so to them nanotechnology is flawed and should not be used. Other religious figures believe that by diving into such a small “universe” we could get confused “to where life exists and where it doesn’t”. Overall there are many concerns dealing with nanotechnology and it is very hard to cover each, but by understanding a few it is easier to understand where many people in society are taking their stances on nanotechnology.

Nanotechnology is a basis for dramatic social and international change. In order to understand this comprehensive field of discovery and potential, we must examine it from an interdisciplinary approach. That is the goal of this composition, to present the reader with a holistic view of nanotechnology and its implications to all of mankind.

Basics

♦ The Building Blocks ♦

The nanoassembler has been hailed as the “...chief vehicle of [the nanotechnology] revolution...” It would essentially fuel the engine to what we call the nanotechnology revolution. The nanoassembler is a nanomachine capable of “...repositioning reactive molecules in any desired molecular arrangement with atomic precision.”

Nanoassemblers by design will be able to do a few standard operations, the most important of which will be to self-reproduce (we will explain why in about thirty-seven or so words). Other operations for the nanoassembler are also quite simple—it must be able to rearrange a molecule with atomic precision in two or three dimensions, unlike our current abilities to only create items in linear chains.

A single nanoassembler is pointless—why? Because the time required producing any one object would take many years (think millions). That’s why although a nanoassembler by definition does not need to include the ability to reproduce itself to be considered a nanoassembler, all signs point to nanoassemblers simply being self-reproducing in order to lower the costs of creating nanoassemblers as a whole. The only “supplies” needed for the nanoassembler to reproduce are the molecules it was created with in the first place—brings a whole new meaning to the chicken or the egg conundrum, does it not? This will allow us to multiply these little machines into quantities we quite honestly can not fathom properly (think billions and trillions). These little fellows could probably crank out a freshly painted BMW in a few minutes. Well, they could do it hypothetically, much of this technology is still under development, and still far from being actually developed, but obviously, most would not mind a new BMW.
Not to shatter all dreams, but the BMW will not be the first thing these groups of nanoassemblers, or nanofactories, are going to produce. The first thing they are going to produce is more nanoassemblers—but with materials that are more durable than the materials in which the original machines were created. Why you ask? In short, this is explained by the fact that solution chemistry “…lacks the key ability of precise positional molecular bonding” (Hughes, 2005, para. 26).

To understand how these machines work, we will throw in an example or two free of charge. For the computer savvy—these little machines would work much like server-farms work with the parallel processing concept in order to generate such movies as Toy Story or Cars, but in a realistic amount of time.

If you are not computer savvy, picture this. These machines are going to work together like Ford’s production line, each doing a little piece (although not necessarily in a linear, or direct line) in order to pump out more cars (in this case objects) faster than if each person worked on one car at a time.

NANOFACTORIES

If nanoassemblers are to be compared to a single person in a production line, or a single computer in a server-farm, then the nano-factory is the production line or server farm itself.

Nanofactories are simply lots and lots (and lots) of nano-assemblers working together in order to accomplish a single task. Just like in a production line, each nano-assembler can perform a different piece of the larger puzzle. Nanofactories are still theoretical, although according to many, within a few weeks of a general nanoassembler being created, the first nanofactory will also be created (Hughes, 2005, para. 8). According to an article written by David Hughes, there are two approaches to manufacturing molecular nanomachines. First, consider a “bottom-up” approach in which we mimic the way our body uses “…DNA, RNA, enzymes and proteins to synthesis to duplicate useful devices” (para. 8).

NANO-ROBOTS

Richard Feynman sought to discover the limits of miniaturization. He wanted to see what was possible by physical laws. Feynman argued that building an object one atom at a time could be a possibility in the future.

Where the medical nanobots will be a scientific breakthrough. It is thought that such robots could be ingested and scout and destroy viruses and cancerous cells. Medical nanobots could be essentially considered, once they are actually made, to be one of the most important and life saving inventions of our entire life-time, because the possibilities of what you can do with the medical nanobots is infinite. Another application would be to revive those that are legally deceased, but the bots would be used in the most beneficial way.

Nanotechnology use in robots will probably be most beneficial when they are able to do what automated factories do today. One example is robotic automakers. The machines are programmed to assemble automobiles and do the task with relatively good precision. Once programmed, the machines can do the work assembling several vehicles every hour effortlessly while a single operator controls it. Imagine that at the nano-scale level—a robot that can assemble parts at the atomic or molecular level.
Nanorobot

Image courtesy of Institute of Electrical and Electronics Engineers

NANOSPHERES
Nano-spheres can be helpful in controlling organic and inorganic nanoscale self-assemblies. One type of nano-sphere, the durable silica spheres, can be used to release drugs into the body. These tiny spheres can be created by using liquid droplets. They then are passed through a reactor and when the liquid evaporates, what is left is an ordered particle. When this particle is heated, it will keep its shape. The particles range from 2 to 50 nanometers in diameter which makes it very practical for ingestion.

Microspheres and Nanospheres

Image courtesy of Microspheres-Nanospheres

CARBON NANOTUBES
Nanotechnology is basically based on the science of carbon nanotubes, and
without them there would be no idea of nanotechnology in existence. Nanotechnology can be based on other atoms, but it is the carbon that is key to its dynamic properties. Carbon nanotubes are long, thin cylinders of pure carbon and with their interesting characteristics with other atoms they make a very useful tool in applications of nanotechnology (Adams, 2000, para. 2). They are essentially large macromolecules that are unique in their size, shape, and remarkable physical properties. They are about 1-3 nanometers (1nm = 1 billionth of a meter) in diameter and hundreds to thousands of nanometers long. “Carbon nanotubes also have great strength; usually they are compared to graphite steel which is the strongest material out there in production” (Adams, 2000, para. 2).

ORGANIC DENDRIMERS

Dendrimer, from the Greek word (dendron) for tree, refers to a synthetic, three-dimensional molecule with branching parts. Dendrimers are formed using a nano-scale, multi-step fabrication process. Each step results in a new “generation” that has twice the complexity of the previous generation—a first generation dendrimer is the simplest; a tenth generation Dendrimer is the most complex and can take months to engineer. Donald Tomalia, a researcher working for chemical giant Dow, first synthesized and named dendrimers in 1979. Dendrimers have many potential applications including diagnostic and therapeutic applications. They can be used for drug delivery, diagnostic imaging and as carriers of genetic material. They can store a wide range of materials including metals, organic and inorganic molecules amongst their branches. Dendrimers are called “Stealth Molecules” because they can move across biological membranes without letting the body’s immune system know about it (Nanotech’s “Second Nature” Patents, 2005b).

FULLERENES/BUCKYBALLS

Fullerenes are a class of molecules that possesses the characteristic of being a pure carbon cage, where each carbon atom is bonded to three other carbon atoms. Every fullerene has 12 pentagonal faces with a varying number of hexagonal faces. The buckyball is one of the more common examples of a fullerene. It is soccerball-shaped and made out of sixty carbon atoms. Harold Kroto, James Heath, Sean O’Brien, Robert Curl, and Richard Smalley together invented Fullerenes in 1985 during an unplanned and unexpected experiment of a microscope. Fullerenes are named after the American architect Buckminster Fuller (Fuller, 1983). Fullerenes could potentially be used as chemical sponges to clean up dangerous chemicals during surgeries or in labs, as lubricants, catalysts and superconductors, in microscopes and miniature circuits to increase conductivity, and as drug delivery vehicles (Buckyballs–a new sphere of science, 2003).

DIODES

Diodes are easy to overlook, much as are many other electronic wonders. Diodes conduct a flow from one of their ends to the other, or, more precisely, from the anode to the cathode. This flow is one way. Older diodes were primitive vacuum tubes, where the current passed through the diode as if it were a light bulb—that is, via a filament suspended within the vacuum. Modern diodes are called semiconductor diodes, which are literally large chunks of semi-conductive material, like silicon or germanium. As the material is a semiconductor, the flow of electricity is encouraged by certain impurities added to either end. This process, called “doping,” is how diodes maintain their one-way current (Brain,
Diodes are used to pick up AM radio frequencies, convert AC power to DC power, offer over-voltage protection, and of course, produce light. LED, or light emitting diodes (diodes that emit photons), are used widely in anything from computers to cell-phones to wristwatches. From the humble backlight of a cell phone’s keypad (typically a color known as “Chernobyl Blue”) to the latest, greatest high-definition television sets, LEDs are everywhere thanks not only to their diverse uses, but also due to their outstanding light to heat ratio. That is, given a power supply, they produce more light and less heat in comparison to other traditional light sources (Harris, 2000). Nano-scale applications for diodes might include anything from protecting from static (a problem even to full-sized electronics) to simple lighting for microscopic tasks via the now ubiquitous LEDs.

**TRANSISTORS**

In speculating about the most influential invention of the 20th century, some might speak of airplanes, nuclear weapons, or something in that ilk-something big; something flashy. How surprising it must be, then, to find that something so small and innocuous as a tiny voltage-controlled switch has changed the way we live.

The transistor was created by a team at Bell Labs in the late 1940’s. They were looking into creating a “triode” for amplifying the signal strength of long distance telecommunications, as reflected in some of the names tossed around before “transistor” was finally settled upon (like “Semiconductor triode,” “Solid Triode,” “Surface States Triode,” “Crystal Triode,” or, on a completely different note, “lotatron”) (Augenbraun, Hammer, 1999a). From there the tiny device which registers either a current or a lack thereof (hence computer’s reliance on binary logic) came to be integrated into just about everything.

At first, transistors, while still exhibiting the same properties they do in any form, were extremely bulky, and thanks to all the connections to other parts that were functionally necessary, a large part of that bulk was in wire. The key to creating a smaller transistor was removing the need to connect it to other devices and power supplies via bulky wires—hence the integrated circuit was born. This circuit took all the necessary parts and placed them on a single circuit board, and connections were traced from place to place in much thinner wiring (Augenbraun, Hammer, 1999b). Integrated circuits were the key to getting complex hardware into an easy to manage package, and IC technology is now included in nearly every electronic device, even down to shoes that light when stepped on.

From there, these circuits have been getting smaller and smaller every year in accordance to Moore’s Law, the highly accurate prediction formulated by its namesake and Intel co-founder Gordon E. Moore, stating that IC technology will double in complexity roughly every eighteen months (Hiremane, 2005). Although he uses the term complexity, his usage is tantamount to saying that the number of transistors will double. Simply saying that complexity will double is not very impressive, but one must think about the cumulative effects of such a statement. For example, a leading-edge chip from 1981 had around 10,000 transistors on it, while a leading-edge chip from 2002 had around 150,000,000 (Vahid, Givargis, 2002). That is, on a leading-edge chip in 2002, there was the equivalent of 15,000 processors from 1981. Taking this into consideration, Moore’s Law is a very powerful prediction. Having kept to this “law” since

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**Binary Logic:** Much like how we count using the decimal system because we have ten fingers, computers use binary logic as they can only recognize two states: on and off. Using this system, one is marked as “1,” two is marked as “10,” three is marked as “11,” four is marked as “100” and so on. In addition to counting, this system can also carry out Boolean operations.

**Boolean Operations:** Logical operations such as AND, OR, or NOT. Using these operations which return true or false based on certain inputs, logical operations can be strung together into much more complex devices, like calculators or alarm clocks.
Moore made it, current IC technology is produced at sizes around 90 nm, with 65nm and even 29.9nm production processes in the foreseeable future.

With transistors and integrated circuits being at the heart of modern computing, they stand to assume the same role in nano-scale computing. It is no overstatement to say that transistors touch nearly everything we do—the same will go for the field of nanotech. With Moore’s Law still accurately predicting the development of smaller and smaller transistors, IC technology small enough for viable use in nanotech is only a few more cycles away.

**CAPACITORS**

Capacitors are simple devices—basically, they are storage for electrons. When connected to a power source, the capacitor draws in power until it is full. The difference between something like a battery and a capacitor is that capacitors have to collect all of their electrons from outside the capacitor proper, whereas batteries already have their electrons to draw from within themselves (Brain, 2000b). Capacitors can carry a large charge, and in something comparable to the scale of monitors and televisions, large enough to be lethal. Capacitors can be found in many devices due to their ability to discharge completely in a very short amount of time, making them suitable for things like the flash in a camera. Potential uses in nano-tech are likely to be something related to power sources.

**RESISTORS**

As one might gather from the name, resistors limit the flow of electricity. Resistors are commonly used to keep voltage within safe levels, particularly with sensitive items like LED (Zandman, et al., 2002). Due to regulating voltage, resistors are also used for their heat dissipation, and are the basis for electric heaters. It stands to reason that resistors would be put to use regulating voltage in small and delicate nano-machines.

**NANOWIRES**

Nanotechnology is making a breakthrough in the technological world because of its minute size and ability to manufacture materials from the atomic level up. However the actual application of this science could not be carried out efficiently because of the lack of connection between nanoparticles. The wires that connect these particles together are essential to create a solid unit. This is where nanowires come into play. Nanowires are the connectors that are equivalent in size to nanoparticles; making a way in which the particles can finally be connected together. (When thinking of nanowires envision medium sized strings of spaghetti all laid out side by side.) Currently nanowires are being used as detectors of certain diseases, such as cancer (Andrew, 2005).

The human body is such a complex unit and there are many entities that help it run more efficiently. Nanowires may potentially play a role in body function efficiency in the near future. The direction nanowires are gearing toward in the future are going to be helpful, the most important reason being that “further progress is to find methods of organizing the assembly of nanoparticles into wires that are compatible with standard microelectronics processes, and that result in precisely positioned, electrically contacted wires on non-conducting substrates” (Andrew, 2005). Nanowires are considered very useful in the semiconductor manufacturing. “They can be fashioned to act as sensors for electromagnetic radiation, magnetic fields, chemical and biological species, and could be used as laser sensors, magnetic read heads, hydrogen sensors and...”

THERE CAME FROM INNER SPACE—Sandia researcher Jeff Brinker observes the structures of a variety of submicroscopic spheres created by his team at the nanometer scale. The regular pore structure can be hexagonal, spherical, or square; one type of sphere resembles a soccer ball in its internal whorling.

Photograph courtesy of Sandia National Laboratories
sensors for normal biological molecules (i.e., glucose) or abnormal molecules (bacteria, viruses or chemical weapons)” (Andrew, 2005). Nanowire’s ability to screen is the reason why they are so useful. From chemical weapons to viruses in the body, nanowires are very sensitive and can detect almost anything.

**CONCLUSION**

Everyday there are further advances in nanotech, whether or not such advances are on purpose or not. Many technologies that already exist are being looked at for their promise in the field of nanotechnology, and now it’s merely a matter of applying them. It is therefore becoming more and more important to know what we have already, as any concept, nano-centric or not can be applied to this growing field. And while hurdles have to be jumped in order to get to a point where nanotech becomes a feasible reality, it’s a testament to how far humanity has come technologically to realize how much we’ve already done can be applied to something we can’t even see. Atomic laws may have more sway over the properties of nanotech, but we already know where to start, and that counts for more than we know.

## The Interesting

### Applications

**INTRODUCTION**

Nanotechnology’s applications can and will possibly help the world be more efficient, and help out humans in the world. The idea of capabilities to make skin or also destroy some of the viruses in the human system is deemed possible through the application of nanotechnology. In other fields, such as the environment, nanotechnology will aid great advancements in water and soil remediation. The future engineers of the world will make the new fuels of the world that will be renewable and lead to less dependence on fossil fuels. While the environmental advancements will lead to better world conditions for humans, computer related advancements will pull the world to a more electronic and computer dependent world. The robots and storage devices in computing areas that will lead to clearer graphics displays and a more real looking picture instead of one that is all pixilated. It is apparent that nanotechnology’s scope and range of applications is fundamentally interdisciplinary. The purpose of this chapter is to introduce and expand on the leading applications from the respective areas of bionanotechnology, the environment, and the technical hardware and software areas.

### Bionanotechnology Applications

The possible impact of nanotechnology is so huge that in 2001, the nation’s total investment in nanotech related research was estimated to be around $497 million (Bonser, 2006, para. 2). Research agendas included the fields such as medical and biotechnology as well as the computer sciences, environmental, and many other types of sciences. Accordingly, once these nanotechnological products get developed, there is going to be a huge change in how the world works. Surprisingly why is this surprising?, nanotechnology may have its biggest impact on the medical industry, because of its funding and the possibilities of applying it to cure many diseases. In the years to come, bionanotechnology will make functioning as a human much easier. Some speculations and applications might include, that one day patients will drink fluids containing **nanorobots**
programmed to attack and reconstruct the molecular structure of cancer cells and viruses to make them harmless, thus eliminating diseases. There is even speculation that nanorobots could slow or reverse the aging process, and in accordance life expectancy could also increase significantly. Nanorobots could also be programmed to perform delicate surgeries—such nanosurgeons could work at a level a thousand times more precise than the sharpest scalpel (Bonser, 2006, para. 3). By working on such a small scale, a nanorobot could operate without leaving the scars that conventional surgery does. Additionally, nanorobots could change one’s physical appearance. They could be programmed to perform cosmetic surgery, rearranging atoms to change the ears, nose, eye color or any other physical feature one wishes to alter (Bonser, 2006, para. 3). Is this entire paragraph from Bonser? You have a lot of facts in here, and it might help clear things up if citations were provided along the way, instead of just at the very end.

These possibilities are what define bionanotechnology as a limitless and infinite area. As mentioned above, the bionanotechnology will be used to not only cure diseases but also prevent them as well. Moreover, with this bionanotechnology in hand, we can create new organs to replace old and nonfunctioning organs, and even find ways to cure cancer, or improve the use of old tools to new improved tools to make the human body function at its optimal level. If all these current and future research efforts are accomplished, life on earth, or possibly on other planets, will be much easier. Also, with genetically modified foods and the new technology being developed to engineer foods with more nutrients and package food with greater efficiency, there will be a decrease in the number of people who die from malnutrition and starvation. In the following pages, we will take a glimpse into the complex world of bionanotechnology and how it will further our existence on this planet as only a way of showing what the human mind is capable of finding out and researching applications that will be used. The whole idea of nanotechnology is controversial in many ways, but in these pages, we will not be addressing the issue of “God” but instead show ways of showing improvement in life, and not immortality of life on this planet.

Nanotechnology is basically based on the science of carbon nanotubes, and without them there would be no idea of nanotechnology in existence. Sure nanotechnology can be based on other atoms, but it’s the carbon that is the key to the dynamic properties of nanotechnology. Carbon nanotubes are long, thin cylinders of carbon and with there interesting characteristics with other atoms they make a very useful tool in applications of nanotechnology (Adams, 2000, para. 2). Carbon Nanotubes can essentially be considered the “Legos” of the nanotechnology world. One interesting discovery on the applications of carbon nanotubes in biology originates from the University of California, Riverside, where researchers published findings that show, for the first time, that bone cells can actually grow and reproduce on a scaffold of carbon nanotubes. Laura Zanello an assistant professor of biochemistry at UCR joined by graduate students Bin Zhao and Hui Hu, and Robert C. Haddon, have published their findings in the March 8th edition of Nano Letters, a journal of the American Chemical Society. Zanellos’s paper builds on a previous research conducted by Robert C. Haddon which shows that carbon nanotubes can in fact be chemically compatible with bone cells (UCR, 2006, para. 2). "In the past scientists have been plagued by toxicity issues when combining carbon nanotubes with living cells, Zanello claims. So we have been looking for the most pure nanotubes we could get to reduce the presence of heavy metals that are frequently introduced
in the manufacturing process” (UCR, 2006, para. 2). Also “because carbon nanotubes are not biodegradable, they behave like an inert matrix on which cells can proliferate and deposit new living material, which becomes functional, normal bone, according to the paper” (UCR, 2006, para. 3). They therefore hold promise in the treatment of bone defects in humans associated with the removal of tumors, trauma, and abnormal bone development and in dental implants, Zanello adds in her interview (UCR, 2006, para. 3).

Until very recently, nanotechnologists concentrated almost entirely on electronics, like computers, telecommunications and the use of fiber optics. However, Nanotechnology in the world of biology is also slowly increasing to include research for nanoparticles which are similar to biomolecules such as proteins and DNA. Some examples include the work of Dr. Shuming Nie, professor in the Coulter Department of Biomedical Engineering at Emory University and the Georgia Institute of Technology and director of cancer nanotechnology. Nie is developing molecular nanoprobes to rapidly analyze biopsy tissue from cancer patients, and to basically administer controlled amounts of drugs into the genetically scarred tumor cells.

An interesting forefront of research that is making its way to bionanotechnology is the idea of making “origami” with DNA. Nanotechnology researchers at the California Institute of Technology have invented a method for quickly and easily folding and weaving strands of DNA to any shape they want (Tindol, 2006, para. 1). Paul Rothemund, a senior researcher explains. "A physicist, for example, might attach nano-sized semiconductor 'quantum dots' in a pattern that creates a quantum computer. A biologist might use DNA origami to take proteins which normally occur separately in nature, and organize them into a multi-enzyme factory that hands a chemical product from one enzyme machine to the next in the manner of an assembly line" (Tindol, 2006, para. 1). Basically, each new DNA strand that is created can imitate a pixel in a computer image, which can be in turn used to make complex patterns, such as words or images. “These resulting shapes and patterns are going to be each about 100 nanometers in diameter and about a thousand times smaller than a human hair. The dots themselves are six nanometers in diameter. While the folding of DNA into shapes that have nothing to do with the molecule’s genetic information is not a new idea, Rothemund’s efforts provide a general way to quickly and easily create any shape” (Tindol, 2006, para. 2). Last year alone, Rothemund has created half a dozen shapes, including triangles, squares, five-pointed stars, and even a smiley faces. "At this point, high-school students could use the design program to create whatever shape they desired," he says (Tindol, 2006, para. 6).

Another interesting example of nanobiotechnology is the work of Dr. Tejal Desai and his work on an artificial pancreas. Dr. Desai, who works at the Boston University, is aiming to produce something that can be implanted to help diabetic patients who are using insulin. Basically she is developing an islet cell which would react with the nanopores which she has studded around the membrane of the pancreatic cells, and when the glucose from the blood washes in through the nanopores the islet cells would release insulin, thus, eliminating the constant struggle of needles and pills to obtain the correct level of sugar in the blood stream (The good of small things, 2001, para. 5). You can picture the above description as a dark tunnel, that whenever a car passes through, its automatic tunnel lights turn on to illuminate the cars path so that the car can see. Consequently, This is well on its way to being a successful nanoscale

**Biodegradable:** An organism of an organic nature that can be broken down (e.g. a banana peel, will go back into the soil without any problems (Grow, P.).

**Nanoprobes:** A nanoprobe is a device used usually on an AFM (atomic force microscope) to see extremely small things.

**Quantum Dots:** tiny crystals that light up when stimulated by UV light; remains a significant part of chemical interaction because removal of an electron from a quantum particle causes its molecular properties to change immensely.

**Quantum Computer:** a computer that is advanced and fast enough to compute quantum levels of science and mathematics. Usually, a quantum computer can calculate quantum mechanical levels of electrons, protons and atomic nuclei (Vittorio, S.).

**Islet Cell:** cells that are produced by the pancreas that produce insulin (Geron Glossary).

**Nanopores:** essentially the ultimate storage housing centers. They have high strength and durability which makes them a vital key to the world of nanotechnology (Nuke, A.).
Accordingly in theory, the regeneration of organs is a process that has not yet been mastered by contemporary science. Though the technology that is being researched today is being worked on to make the regeneration of organs more efficient, the process is still under construction. So, the question remains—if technology is underdeveloped in the regeneration of organs, what can help make the process more effective? The best answer seems to be to start specifically focusing on biological factors regarding organ DNA analysis of an organ structure to further our understanding in the regeneration of organs.

Consequently, there are many reasons why someone might lose an organ or have a organ failed. This may include the dysfunction of organs due to “old age” and or illness (Switzerland, 2006, para. 5). Although modern technology has produced prosthetic parts in an attempt to replace lost organs, their size has made the use of these prosthetics only temporary. “Clearly, conventional materials, or those materials with constituent dimensions greater than 1 micron have not invoked proper cellular responses to regenerate tissue that allows for these devices to be successful for long periods of times therefore proving their short shelf life ” (Switzerland, 2006, para. 1). Therefore as a result, we can instead turn to bionanotechnology which will help grow particular organs backs using a more natural process where the body is more ready to accept the replacement. The regeneration process is made more advanced because “nanotechnology makes it possible to impregnate substances into regenerating tissues to stimulate healing and counteract infection. Tissue engineering at the nanoscale level is leading to the development of viable substitutes which can restore, maintain or improve the function of human tissues” (Switzerland, 2006, para. 5). Clearly, the minute size of nanotechnological procedures gives the science its effectiveness, allowing for the nanoparticles to do more than the human hand ever could.

Another interesting advancement in the world of biology can be the current research that is going on for cancer, and how it affects the human body. “Cancer is one of the most feared diseases in America. One in two men and one in three women will hear the words ‘you have cancer,’and one of every four deaths is from cancer. Cancer takes approximately 8.6 million Americans each year, and in 2005 will cost the nation an estimated $210 billion in medical expenditures and lost productivity (Runowicz, 2006, para. 2).” Though there can be a stop to this widespread epidemic that is sweeping across our nation, the answer lies in the application of medical research that is going on for bionanotechnology in cancer research.

The treatment of cancer in nanotechnology has been a subject of great interest by researchers for a while now. They are researching methods of treating cancer by including techniques on flushing the body with drugs, which sadly enough more often produces harmful side effects; thus limiting the drug’s effectiveness, but it should be applauded that is it an attempt to do the impossible. Also some more advance cancer research applications are being conducted by scientists in the field of bionanotechnology that include: methods for tumor targeting in the field using viral particles, organic **dendrimers, polymer capsules** and, photodynamic cancer therapy.
One of the more developed methods for tumor targeting that has received special focus is the use of viral particles. Viruses are basically infectious agents that range from 20 nanometers to 400 nanometers in size. Viruses attack a cell by attaching their surface particles to the receptors of the victim cells and thus enter into the host cell. Because of their small size, viruses have been explored as nano-containers for specific targeting applications. But, since viruses are infectious agents, their surface molecules need to be modified using chemical and genetic means (so that they cannot attack a specific cell) before it can be used as a nanocontainer for drug delivery. After the surface proteins have been modified, these viruses can be manipulated in various ways for acting as a nanocontainer and treating cancer (Singh, 2006, para. 1).

Besides the use of viral particles, organic dendrimers are also used in tumor targeting. Organic dendrimers are essentially molecules that can carry drugs or biological markers on their different arms (Schirber, 2005, para. 1). Dendrimers can also be designed in such a way that they release the content on their arms only when certain kinds of molecules or certain kind of environment is present around it (Deaconu, 2001, para. 5). Cancer molecules have certain complex cells that are not present in any other normal cells; so the dendrimer would carry the drug with it and release it only when it feels the presence of these certain complex cells around it. Thus, organic dendrimers can be used to carry drugs to a specific target like a tumor cell, and actually in the future put a end to all sort of tumor related diseases.

Photodynamic cancer therapy is another complex but nonetheless intriguing method that is used to treat cancer. Photodynamic cancer therapy is based on destruction of cancer cells by laser generated atomic oxygen, which is cytotoxic. The negative point of this method is that the dye used in making the cytotoxic oxygen spreads to the skin and eyes when the cancer cells do not absorb it and thus creates side effects. To avoid this side effect, the water repellant version of the dye molecule is trapped inside a porous nanoparticle or a nano-container. By enclosing the dye inside the porous nanoparticle, the dye stays trapped inside and does not spread to the other parts of the body because of its unique characteristics of being water repellant. Also, the oxygen generating ability is not affected and the pore size of about 1 nm freely allows the required amount of oxygen to diffuse out to the cancer cells and destroy them (Salata, 2004, para. 16).

Though the idea of actually developing a way to actually target only cancer cells is far off and near impossible at this time, researcher Dr. James Barker at the University of Michigan School of Medicine, is trying just that. Dr. Barker and his colleagues are developing a method of treating cancer cells by inventing nanoparticles that would take drugs directly into the cell without affecting other normal cells. The main idea behind doing this is to trick the cancer cells to make them ingest the nanoparticles carrying a payload of anti-cancer drugs, and thus kill them. Baker’s method of doing it is to inject the unremarkable-looking clear fluid into the body. This unremarkable-looking clear fluid has particles that are precisely engineered to slip past the blood vessel walls, latch onto cancer cells and trick the cells into engulfing them as if they were food molecules. These particles then flag the cells with a fluorescent dye and at the same time destroy them with the drug (Bullis, 2006, para. 2).

Bionanotechnology can even reinvent old ideas or old concepts that have been...
designed years ago as a means of aiding people in how they live. More and more often old ways are being research, thus the abundance in catheters. In order for these catheters to work well they need to be more advanced in their machining. In order for a catheter to enter a blood vessel the operator needs to control the motion of the tip from the outer body. Though these devices are really useful nowadays, the goal is that multifunctional catheters will be developed to improve their efficiency and performance (New industry creation hatchery center, n.d., para. 5).

With advanced catheters, one will not only reach blood vessels and expand passageways, but one will also be able to enter the brain. These catheters will be disposable, therefore they must be inexpensive. Using micromachining for the development of advanced minimally invasive systems that consist of an active catheter, active guide wire, forward-looking ultrasound imager, catheter tip position/direction sensor, and fiberoptic pressure sensors would be an advance in the medical field. Minimally invasive medical tools based on such micro-nanotechnology facilitate diagnosis and therapy in vascular disease (New industry creation hatchery center, (n.d), para.5). Such technology could replace conventional invasive medical technology and lead to the furthering of newer instruments.

The world of nanotechnology is complex, and currently it is applauded that we are trying to use all new technology to preserve human existence. Yet the attainment of nanotechnology itself is still far from reality. Sure, we are slowly researching nanotechnology and experimenting with its uses, but the idea of nanotechnology of actually helping human existence is a very long time from now. We will still continue to live the same way we do for at least the next 100 years, because there is no way of actually finding the holy grail of nanotechnology. Even with all these advancements in using organic dendrimers and using DNA receptors to transport the good drugs to the tumor parts of the cell is all speculation and theory. But given time, nanotechnology will offer more to biology than what it will contribute to the stuff of science fiction, because the knowledge and the power of nanotechnology is infinite, and only time will tell us when it is truly a part of our everyday lives. Furthermore, nanotechnology is not necessarily a means for immortality of human existence, but it is a way of improving everyday human interactions, with body and soul.

♦ Environmental Applications ♦

INTRODUCTION

In the world today, companies and governments are trying to minimize the pollution of the world, since it is starting to have an effect on future generations, and are trying to increase awareness of alternative fuel sources to have less of a dependence on fossil fuels. These alternative fuels are to be a reliable fuel source that can be made from products that already exist, like, for instance, the sun or hydrogen. Other than alternative fuels the focus is also on cleaning the already polluted environment and making it cleaner for generations to come.

ENERGY AND FUEL APPLICATIONS

The idea of having a new source of energy that will be renewable will lead to less of a dependence on fossil fuels. Renewable energy includes “hydroelectricity, wind, tides, geothermal, and biomass” (Buchanan, Crabtree, and Dresselhaus, 2005). The need to use these renewable sources of energy has become more and more vital as the supply of fossil fuels around the world is depleted. The only
truly reliable, continuous source of renewable energy is the sun. The initiative to find the best approach to address the challenge of the most efficient and inexpensive source of energy has led the United States to research in fuel cells and solar energy.

There are many improvements to be made in solar power energy. Solar panels are usually used to absorb the light from the sun by using silicon material that contains photovoltaic cells. **Photovoltaic cells** are used to generate electricity by allowing sunlight to excite the electrons from the negative pole to the holes in the positive pole. The use of the nanoscale thickness of the surface of photovoltaic cells has become more efficient than the thicker size because only the surface area is needed. This nanomaterial has allowed for the silicon to be utilized more efficiently, is also stronger, more flexible, and can attain a larger variety of shapes. However, more research has to go into the restoring the loss of sunlight protons, such as the band gaps used to receive the electrons reforming together, or forming electricity from a larger spectrum of wavelengths given off by the sun. The prospect of possibly making solar panel production inexpensive and harnessing more energy per surface area on the roofs of every resident from a replenishing source such as the sun is hopefully not too much to aspire to.

Lighting is something that has led people across the nation in being able to accomplish tasks once the sun sets. However, less than twenty-five percent of electrical energy is being converted to visible light (National Nanotechnology Coordination Office [NNCO], 2004). The light emitted diode (LED) is a **semiconductor** that produces light by the electric power generated from excited electrons. LED semiconductors have been found more useful because they generate more electricity than the common light bulb, or even halogen incandescent lamps. The distance of the semiconductor gap helps create different visible light colors. At first red was found, green and blue, and finally white light emitting **diodes** can also be used. By adding quantum dots, or segments of energy in the structure, or using photovoltaic crystal structures to direct the flow of electrons, the efficiency of LEDs can be increased even further. The use of LEDs of different colors has already been found to save $1000 per intersection per year (NNCO, 2004, p. 7).

With this type of money saving ideas the united states is looking into cutting thier cost of energy usage. The United States energy usage can be divided into four quarters. One quarter of the US energy usage is in transportation, the second residential, the third industrial, and the fourth is lost in conversion of energy from one form into another (Buchanan, et al., 2005, p. 521). The possibility of generating energy when using our vehicles with an environmentally friendly and inexpensive source of energy that is very attractive, especially with more money coming out of our pockets to pay for the expensive, diminishing, imported oil.

Fuel cells have also become another alternative of generating energy. Fuel cells use a chemical reaction, with a small amount of heat lost and thus the potential to generate energy fully. Fuel cells are composed of a cathode and anode to complete a circuit through the transfer of an ion through an oxidation or reduction reaction.

On January 28, 2003, in the State of the Union Address, President George W. Bush announced the 1.2 billion dollar Hydrogen Fuel Cell Initiative to stifle our
dependency on imported sources of energy. With the growing dependency of energy resources that are drying up in foreign soil, the cry for a cheaper source of energy to fuel our lives has been sought. One of these answers has been hydrogen. There are many reasons why hydrogen is picked out of other molecules to generate electricity. Hydrogen is particularly small in atomic weight, yet it generates a sufficient amount of energy in comparison to other atoms. There are three aspects to acknowledge in the use of hydrogen, primarily for transportation usage such as production, storage, and utilization of hydrogen fuel cells. Also there are many different methods of producing hydrogen through nuclear and solar thermo chemical cycles, solar wind hydrolysis, biology, and fossil fuel reforming and carbon capture (Buchanan, 2005, p. 521).

One way of producing hydrogen is by splitting apart water into hydrogen and oxygen. Through the use of a catalyst titanium dioxide, TiO₂, water can split into hydrogen and oxygen through the electron transfer in oxidation-reduction reaction that is triggered with ultraviolet light contained in sunlight (Office of Science Laboratory [OSL], 2004). However, the proposed goal by the Department of Energy to raise our hydrogen production from 9 million tons per year to 150 million tons per year (Buchanan, 2005, p. 521) in order to make it more accessible by the entire nation is difficult to achieve.

Hydrogen storage has become a key issue as an energy source that has to be kept at high pressure and released at high temperatures. With hydrogen’s high density and low compressibility, practical storage of hydrogen is an issue for the future of hydrogen economy's since it is physically possible to store hydrogen for automotive use (Buchanan, 2005, p. 521). Nanomaterials that have the ability to be very stable and do not rapidly change in temperature have become a good solution. However, it is difficult to find a material that will not “stick” to hydrogen too strongly or too loosely. If the material to stick the hydrogen were to be too “sticky” then it would be too difficult to release the hydrogen to use, if it is not “sticky” enough, then there would be less hydrogen in the tank, and require a higher temperature to release it (NNCO, 2004, p. 21). The use of nanostructures such as carbon nanotubes (OSC, 2004, p. 44) to store the hydrogen within and around stacks of nanotubes has been found to effectively store hydrogen. However, more information on the subject is necessary and more research needs to be done to apply this on a grander scale.

If advancements in energy continue, there will be visible differences. If solar panels were to become cheaper to fabricate, they could be used on almost everything. Imagine charging any electronic device, or lighting every street corner just by detecting and consuming everyday sunlight. With light emitting diodes, not only will lights brighten up dark volumes of space, but also last longer, shine brighter, and cost less. Imagine using the one replenishing renewable energy and no longer having to rely on just two types of energy sources but actually have a choice on which type to use depending on one's discretion. The sun could be accessed almost anywhere. Houses could be powered by solar panels on roofs, across miles and miles of rooftops, all generating their own source of power. The cost of electricity would be cheaper, and more readily available to power almost everything.

Now days even the big cities around the nation are being seen as energy efficient and cleaner then previous years. It is rare to see the Los Angeles sky without seeing the coat of gray-brown filthy smog hovering over the surrounding hills. It

**Thermo chemical cycles:** A cycle that is associated with chemical heat.
is also extremely rare to see a large truck drive by without a huge puff of brown toxic gasses released and camouflaging into the already polluted air. Hydrogen fuel cells have the possibility of powering our automobiles and other forms of transportation so as to emit no toxic gasses and even keep some change in our pockets for the price of “fuel.” Imagine walking outside in Los Angeles and smelling the clean, fresh, crisp air we have summer mornings rather than the tainted air which we have today. Imagine standing on the sidewalk without a bus discharging foul smelling pollution into your face. Imagine spending money for gasoline that is not dependent on another country’s supply. Imagine jogging around the block and being able to take longer, cleaner, more effective deep breaths. Not only will the Earth be treated better, with cleaner automobile emissions, but the human lifespan will prolong, less money will be spent on the cost of traveling, and the human race will thrive with the happiness of fewer worries concerning what greenhouse gasses they are inhaling or how much money from their pockets is going into gasoline.

WATER AND SOIL APPLICATIONS
The transportation of chemicals in water is pretty much the only way chemicals spread in the soil from the point they are spilled. Since normally the spills that occur are accidental they are not cleaned 100 percent when they occur due to the soil absorption that occurs in the ground when a liquid is spilled. Due to this (somewhat) instant absorption the ground cannot be cleaned fully at that instant unless the ground of the spill is dug up and put into sealed containers and sent to treatment plants for cleaning. This ground or soil can vary with absorption, depending on the soil type. The soil can be very absorbent and is able to intake or absorb lots amounts of chemicals and fluids before showing any signs of wetness as in sand, while with other soils, such as clay, just a slight amount of liquid will leave a slick surface that has a small absorption (Chiou, 1986, p.8). The pollutants that are in ground water are very difficult to remove. Organic solvents are a continuous source of water pollution due to their inability to be removed as no by-product is able to completely remove the toxins. A macro molecular iron molecule was made to have two sides to destroy the toxins in the water and water table. One half of the molecule was made to be a water lover, meaning the first part would want to follow the water and become set into the aquifers of the earth. The other half would become activated once the outer shell was used up, or reached the water table. Then this iron molecule would stick to anything that is not water, like toxins or certain specific metals. Once the ion or molecule stuck to these metals it would start to degrade the metal and for some type of residual product that would not be harmful to the environment. This nano-particle would treat underground pockets of chlorinated organic molecules and also can move through the soil very easy due to its small size. This nano-particle could also be used in the near future for any toxic spills on the ground and also in any industrial situation for immediate cleanup. Thus far this two-shelled molecule is in field testing to see how efficient it is in actually cleaning up the spilled material. The different soil type is only one way of fast transport through a soil. The chemical that has been spilled also effects the absorption into the ground and also how long it will take before it reaches the ground water. Certain chemicals can react with the minerals in the ground and also with certain metals that can increase the movement of the chemical in soil. Research has shown that the chemical ethylene glycol can move through the ground and also in water faster then water itself. Since this metal can be found in deep layers of the soil, water and chemical migration can not always be correct due to the uncertainty of what soil is under the layers that have been dug

**Chemical ethylene glycol:**
An alcohol molecule that has two hydroxyl groups. What are hydroxyl groups? Why is this important?
up. The soil that is in the earth also contains some type of organic material that has been dissolved. Since organic material is in the ground the chemicals that are spilled and that are absorbed into the ground can turn hazardous (Malcom, 1986, p. 8). There can be certain types of chemical reactions in the soil and also in the ground water turn some chemicals and or metals into highly hazardous materials. This is a reason why chemicals and solvent spills are very hazardous to people and also to the ground table water. Thus, due to these chemical interactions, monitoring wells are drilled.

Monitoring wells are drilled around the plum and or contaminated area. These wells are drilled and samples are regularly taken from them in order to make sure no drastic changes are made in the chemical spill. The drilling has to be precise and made sure to disrupt the area as little as possible since some of the drilling fluids, as in mud, air and also liquids, can wreak havoc on the plume and or effected water/soil. Drilling can cause the plume to spread into two that used to be one, and also can disrupt the chemical balance that is in effect where the groundwater is. These foreign materials can be removed from the well with a process called well development. It is a process in which a swab (squeegee) is pushed down the well casing or pipe to make sure no debris is in there. Once the well is bailed in which sand and or other materials/debris are taken out of the well and then placed into tanks and containers to be cleaned, and or disposed of (Brinton. 1986 p. 9). Once wells are drilled and cleaned the water from these wells are regularly sampled. Since the material in the ground can change with time, water samples are taken to make sure no other types of chemicals are found to be perturbing into the ground water and causing havoc downstream, and also to later generations. These samples help scientists and engineers predict the materials that will react in the future and also predict where the chemicals are bound to go since the water is always moving and could be making a greater plume which in turn could cause greater problems for future generation since the ground water that everyone drinks will be polluted.

In nanotechnology the transportations of water will pretty much be the same since water can only move at a constant rate through any type of soil. It might, however, be made to move faster through certain types of materials with the addition of certain metals to the water or chemicals that are found in the soil. If the nanotechnology is made to be able to react with water to in turn make it move faster through non-porous or less permeable soils. This technology of making water migrate faster would in turn help our water supply and also help the world replenish the water table in order to have a good clean and reliable source of water.

Researchers at Rice University have discovered that gold and palladium nanoparticles are being used to clean a known chemical that is in ground water around the world. TCE or also know as trichloroethylene is one of the nation’s most troublesome ground water pollutants (Boyd, 2005, para. 1). This new nanotechnology is making the ability to clean up the water pollutant more effective. It is letting the palladium contact the chemical more often and is making a stronger effort in reducing the chemical from the ground water and thus in return is making it a more effective catalyst than the one being used currently.

TCE, which is commonly used as a solvent to degrease metals and electronic parts, is one of the most common and poisonous organic pollutants in U.S. Plume: Area that the contaminate is currently in and is moving downstream with water movements.

Palladium: A soft, ductile, steel-white, tarnish-resistant, metallic element occurring naturally with platinum, especially in gold, nickel, and copper ores. Because it can absorb large amounts of hydrogen, it is used as a purification filter for hydrogen and a catalyst in hydrogenation. Atomic number 46; atomic weight 106.4; melting point 1,552°C; boiling point 3,140°C; specific gravity 12.02 (20°C); valence 2, 3, 4.

Trichloroethylene: A heavy, colorless, toxic liquid, C2HCl3, used to degrease metals, as an extraction solvent for oils and waxes, as a refrigerant, in dry cleaning, and as a fumigant. Prolonged exposure to high concentrations of the vapor can lead to cardio toxicity and neurological impairment.
groundwater. It is found at 60 percent of the contaminated waste sites on the Superfund National Priorities List, and it is considered one of the most hazardous chemicals at these sites because of its prevalence and its toxicity. Human exposure to TCE has been linked to liver damage, impaired pregnancies and cancer (Boyd, 2005, para. 6).

This approach is very expensive due to a couple of reasons. First, a well must be drilled in the effected area or the monitoring well can be used in order to clean the water. Second, there must be a pump to pump out the water in order for the organisms to eat and start to dissolve the TCE. On the other hand, if environmental technology was used it would make the clean-up process very inexpensive. The palladium would be in a powder form that could be dropped into the well and then this powder would go towards the TCE (Boyd, 2005, para. 6). The TCE would then convert the toxic chemical into a non-toxic form of ethane. The powder would be placed at the bottom of the well in the water, while the pump would pump out the clean water into holding tanks. In the tanks it could then be transferred into any type of water needed in the area, from irrigation water to drinking water. This powder process is a very cheap and effective way of cleaning the water. The process could take in large volumes of toxic substances and then treat the TCE and produce clean water with only a small price to the user. The biggest cost to the consumer would be the price of lifting the clean water from the bottom of the well to the holding tank, since electricity would be an adverse cost other than the powder from palladium. Along with this method of cleaning water effectively, there is another new method that might be used.

The recent developments in zero-valent iron particles (ZVI) have made a big jump in the way future problems will be tackled. This new development is one that took a new approach on cleaning toxic chemicals. The ZVI is a relatively new and proper way of attacking the ethylene chemicals that are harmful to the environment. To attack these ethylene chemicals, ZVI is injected into the ground by certain methods such as air purging. Then, once the ZVI is in the affected region, it breaks the ethylene down into a simple form of ethane which is not toxic to the environment (Simon, 2006, p. 1). This process can also change the chemical nature of the substance and make an insoluble object soluble and vice versa. This is very helpful in causing certain metals to stay in the soil and have others dissolve, creating an even cleaner environment. The Nanoscale ZVI (NZVI) has approximately 35 times greater the surface area than the normal ZVI (Simon, 2006, p. 2). This in turn makes the chemical and also the particle more receptive to the chemicals, and allows this particle to remain active during a longer time than the original (Simon, 2006, para. 2). These particles are extremely small in size and can purify the groundwater and plumes that may spread over a certain distance. The particles can be controlled once they reach the water. In the water they are able to spread over a larger distance and transport the plume to a certain region, affecting the specific area. A test was also made to see which size particle was more affected in the certain concentrations and also in the diverse chemicals. It was shown that the smaller particles with the larger surface area are more capable of cleaning the water and thus in turn making a significant difference in readings for monitoring wells and reducing the levels of toxicity (Simon, 2006, p. 2). The decrease in toxicity will be a positive impact to the nation's chemical spill and disposal issues of the past decades.

Zero-valent iron particles: A small piece of the element iron that is in a microscopic sense that has no valent electrons and is used to attach to other molecules and or chemicals thus forming other non toxic forms of iron.

Air purging: the direct injection of air and some type of liquid or powder into the ground by high pressure pumps.

Monitoring wells: A deep hole or shaft sunk into the earth to obtain water, oil, gas, or brine. This hole or shaft is then used to collect water samples from various depths in the earth to see if any chemicals are spreading beyond the estimated place and also to see if levels of toxicity are decreasing.
The clean up problems that we are facing today are the ones that we believe we solved many years ago. By just digging pits and dumping millions of gallons of waste and chemicals onto soil and bedrock, most people believed that nothing would happen other than it just be closed off to the people and just being deemed a hazardous site. Since the common price for contaminated soil or water is $100/ton or $100/m³ financial burden for site cleanup is truly colossal (Zhang, 2003, p.323). Since this is a big burden on most sites and governments, methods of cost effective cleanup is truly needed.

The Iron Particle clean up method that is being researched is one of great importance to companies and superfund sites around the nation. Since the application of this particle is very easy due to the gravity feed approach, which takes slightly longer than the under pressure approach, the particles are pushed into the ground through wells which just feed a steady flow of particles to the affected site (Simon, 2006, para.4). The tests that were made in Lehigh University, in Pennsylvania and around the university, showed that the iron particles acted more quickly in water than in the soil. The reactions that occurred in the soil that were not rich with water, still produced results in treating the chemicals and particles but it was a longer period of treatment. Since there was no ground water, the iron moves throughout the sample slower, since there was nothing to help along the transportation of the iron particles. Thus, injecting the particle into the soil within a water base or being able to inject it into the water table would be most effective. Because of this, there was a tank made to have a mixed batch that was being pumped into the well, in which there was also another pump towards the bottom of the well. This well that leads to the top of the ground water to create a constant circulation of water, and thus the iron particles were more apt to start treating the polluted water by means of mixing. Since the wells were upstream and or above the plume, the particles are able to do the most work. And as it is able to use gravity and also use the plume as a second source of transportation, the particles will thus be able to help clean up the plume and follow it until the monitoring wells read a dramatic reduction in chemicals and toxins in the water. Since the simple method of drilling a hole in the ground will be applied in advanced technologies as well as older technologies, cutting edge ideas can now tie them together.

**Computer Engineering Applications**

Calculating the natural log of four would be difficult for a person to handle, but with the help of a simple device known as a calculator, such a problem is simple. The calculator is no more than a simple computer. A person just inputs the problem into the calculator and within seconds the calculator gives an answer. Within this machinery, there are components that make up this particular device and many other electrical devices, from computers to cars, known as hardware. Webster's New Collegiate Dictionary defines hardware as “the physical components of vehicle or an apparatus used as instructional equipment.” As the years go by, scientists and engineers today are creatively augmenting these computer components, making them smaller, better, faster, smarter. In other words, today’s scientists are in the process of developing these devices with the ideal of nanotechnology in mind.

One device that has been frequently studied and modified for better reliability is the integrated circuit. This apparatus can be found in almost every modern electrical device such as the computer. A specific type of integrated circuit called
the microprocessor helps computers run programs, count numbers, keep track of what keys have been pressed, and operate the system as a whole (The history of the integrated circuit, 2006, para. 1). Compared to the earliest form of the integrated circuit microprocessor, which is capable of processing 5000 binary-codes per second, today's microprocessors are more efficient. The present microprocessor can process binary codes 600 times faster. Scientists predict by the year 2012 the advances to the microprocessor will make it more energy efficient, more reliable, and cheaper. Yet, to some scientists this prediction is unreasonable, because the energy needed to run this integrated circuit is difficult to obtain (Heath, 1998, para. 1). In Japan, efforts to enhance the capability of the integrated circuit are currently in process. A company called Asuka II is spending more than $150 million to develop more top-class circuits. Company officials are planning on creating circuits that will be able to process binary codes at speeds of 32, 45, and 65 nanometers by the year 2011 (Hara, 2006, para. 1). IBM has developed machinery that will be “embedded” into the microprocessor and will enhance the security of laptops today. The new tool that will be embedded into the microprocessor will safeguard one’s personal information such as medical or financial data from being lost or stolen (Catrell, 2006, para. 1). As stated by the Vice President of IBM, Tim Ravey, “The technology is stored in circuits that are added to the microprocessor. The circuits contain sensors than can detect a physical attack on a device in the event that a thief tries to retrieve the chip from a laptop...” (para. 7). However, with the advancements of the integrated circuit, complications will arise. With the upgrades being done to the circuit, the current methods of manufacturing this circuit are unable to fabricate these up-to-date developments. New methods in manufacturing are considered necessary and must be developed soon. New methods of manufacturing foretell mass production of the integrated circuit.

An integrated circuit is no more than four devices put together. The circuit is made up of resistors, capacitors, diodes, and transistors. These four components can be by definition considered as hardware as well. These four components are attached to one another in discrete ways that operate to give the integrated circuit its specific function. An integrated circuit is so small that an area of the circuit is no bigger than a fingernail, but consists of hundreds, even millions of these components. The estimated size of a transistor is 90 nanometers small (The history of the integrated circuit, 2006, para. 8).

How small will the integrated circuits get in the future? As the phrase goes, “size does not matter.” The integrated circuit is a tiny device, with a dimension of 0.1 um, that is capable of running certain functions for something larger, like a computer. Without the development of the integrated circuit, much of today’s technology will not run or even exist. The integrated circuit can be found in many electrical devices such as cars, televisions, computers, and cell phones. Engineers and scientists are continually developing new types of integrated circuits that are better-quality than today’s integrated circuits; they will be faster, smarter, and more reliable. Currently, with nanotechnology in mind, researchers at the University of California Berkeley have created the first integrated silicon circuit which features nanotube transistors. With the development of this circuit, “ultra-sensitive” bomb detectors and “super-fast” computer memory chips are possible (Xuan, 2004, para. 2). Studies have found that the development of the integrated silicon circuit “brings us a significant step closer to using carbon nanotubes for memory chips that can hold orders of magnitude more data than current silicon chips-10,000 times greater, according
to some estimates—or for sensors sensitive enough to detect traces of explosives or biochemical agents at the molecular level” (para. 5). Today, circuit carbon nanotubes are now tens of thousands of times thinner and more durable than a human hair improving the creation of high performance transistors (para. 8).

More and more advances in today’s integrated circuit are being made that will make the present technology obsolete. Scientists from Philips Research and the University of Groningen have taken another step into the field of integrated circuits involving molecular diodes. These newly constructed forms of molecular diodes are as thin as a molecule and are “suitable for integration into standard plastic electronic circuits” (Philips and University of Groningen demonstrate breakthrough in fabricating molecular electronics, 2006, para. 1). Molecular electronics is a promising new idea in the field of molecular electronic circuits (para. 1). This new process now holds the potential to create single-layered-molecule electronics that incorporate an entirely different method of forming the circuits. In opposition to the use of photolithography to create the nanoscale designs, “molecular electronics can be engineered to use organic molecules that spontaneously form the correct structures via self-organization” (para. 2). These self-organized chips are inspired by nature’s own self constructed circuits including, “photosynthesis in plants and nerve systems in mammals” (para. 2). Like most other designs employed in nature, these circuits are far more efficient than any man-made product. However, these new types of electronics will not compete with silicon-based circuits (para. 3). They will be more applicable for particular jobs concerning plastic electronics where low temperatures or low costs are a factor (para. 3). This new process of self organization is a factor that has been missing in the development of molecular electronics for the past 20 years (para. 4). A common problem prior to this type of assembly was the shorting of circuits during operation due to the inability to control the probability of error factor at the nanoscale, resulting in metal parts coming into contact with each other (para. 4). The research performed by Phillips Research has reduced this factor of error by creating predetermined areas for the electrodes, or metal parts, to come into contact with the monolayers, eliminating contacting electrodes (para. 4). Utilizing self-organization, this error factor has been largely reduced and the depth into molecular electronics has been further improved.

FUTURE OF NANOCOMPUTING
The future of nanocomputing presents a potentially dramatic jump in the technological capabilities of the PC known today. Size has been a persistent problem in the area of computer construction, either with imperfections in design or inefficient power flow, and has been a road block in the path of technological pioneers. However, with the use of nanotechnology, entirely new paths have been unveiled through the design of microscopic precision.

According to Moore’s Law, forecasts have been predicted that envision speeds and storage capabilities that surpass the greatest limits of today’s computers. In a paper written by Paul Beckett and Andrew Jennings at RMIT University, a vision of nanotechnology has been scripted through various tiers including computation speed, storage space, and applications. Nano-computing will drastically increase the capabilities of each of these areas, by allowing for the increase in performance to take place without having to compromise the size of the chip, a common problem in computer architecture (Beckett, 2002, para. 2). Hardware like microprocessors and hard drives will be improved

Photolithography: Referring to the use of imaging plates to create a photo.
dramatically by adding transistors at the nano-level.

Several other problems that have been encountered in computer design include power management, bottlenecks at inter-connectors, and transistors. Each of these have been dealt with by infusing nanotechnology into the chip designs by ordering molecules to sit and rest in structural areas, and guiding specific charges through the transistors to other areas (Beckett, 2002, para. 4). This ability to control the entire process down to the molecule will allow for the future of computers to be controlled through nano-sized spaces between the transistors. These spaces will also allow for the creation of new types of RAM, or random access memory modules, that act as the main type of memory inside a computer that stores the functions and data, that are non-volatile and perform drastically better than today's RAM (para. 21). This new RAM will theoretically hold vast more amounts of memory and increase the speed and processing ability of the computer.

Also other areas that will be taken into consideration are synthetic neural systems. These electronic systems are modeled after human brain patterns and have the potential to tolerate faults in the system and self-organize (Beckett, 2002, para. 30). The ability to tolerate faults and self-organize means in the event a transistor fails (which is expected to happen) the chip will be able to correct itself and guide the electrons along a different path, and keep the computer functioning. The possibilities of computing steadily increase with the maximization of the potential of computers through nanotechnology.

A new development in nano-computing is on the way. K. Eric Drexler, a researcher from Stanford University, envisions that nano-computers will consist of components known as universal assemblers. These universal assemblers will be capable of measuring one-tenth of a micron, which compared to an average human hair which is about 100 microns thick, (Woods, 1989, para. 7). Furthermore, these assemblers will be able to rotate and move molecules. With this ability, they will initiate microscopic operations by relocating reactive molecules side by side, therefore creating a chemical reaction. A scientist can control where and when a reaction occurs. Drexler states "...they will be able to build complex molecular structures" (para. 8). With the use of universal assemblers, engineers will be able to build smaller and faster three-dimensional computers with atomic precision (para. 8). Computers will have a vast increase in their general computing power compared to today's computers. A present computer has the capabilities of a small fraction of the overall activity of a human brain. Drexler estimates this to be one one-thousandth and one one-millionth of the brain's capacity (para. 19). With the vast increase in power, artificial intelligence may even become a reality. In theory, with this on-going development of nanotechnology, nanocomputing will allow scientists to explore unknown territory of the human body. Nanocomputers will also revolutionize 3-D modeling and computer aided design. These new enhancements to computers created by the utilization of nanotechnology present a plausible path for the future, but is still limited in many areas because of the inadequacy of the technology at hand today. Merkle, a Xerox researcher states, "with this kind of computational power, you could create a three-dimensional model of an environment so realistic that you could photograph it and use it as a movie set" (para. 20).

However, with the pros there come cons. Nano-computers will not be electronic.

**Hard drive:** An item that reads and or stores information on a disk.

**Microprocessor:** A circuit that contains the entire processing unit of a computer chip.

**Random-access-memory (RAM):** Main memory inside a computer used to store data and programs performed during operation.

**Universal assemblers:** A program that takes multiple computer code and translates it into a single code.
Contradictory to electronic computers, which are faster solely because electronic signals can pass through circuit boards faster. Nano-computer signals will only have to travel one-millionth as far and this process is difficult to attain (Woods, 1989, para. 12). Additionally, if we were to start the development of the universal assembler, we will be not able to do so. Engineers have not yet created micro-machinery capable of “stacking” atoms into molecular devices (para. 17).

Nanotechnology has opened an entirely new set of possibilities with the overall enhancement of computing power in today’s PC’s. In an exponentially growing cycle, with each advancement of computer technology, an equally large advancement of nanotechnology will be produced due to their link and vice versa. Thus, an overall rapid growth of both computer technology and nanotechnology will eventually occur.

Computer Science Applications

Swarm Intelligence is the fundamental idea behind Autonomous Nanotechnology Swarms (ANTS) and, as the name suggests, systems based on swarm intelligence deal with large numbers of agents (in this case, the robots performing tasks). In nanotechnology, swarms are said to be able to empower us to solve very complex or intricate problems by mimicking the way nature’s creatures overcome obstacles in their own environment. Nature, birds, bees, ants, and fish all use swarm intelligence to quickly and efficiently do their jobs.

Although no physical swarm technology has been implemented with nanotechnology to date, there are many swarm algorithms, and some have even been implemented in related disciplines such as computer science. Two of the most popular swarm intelligence algorithms mentioned when discussing nanotechnology are the Ant Colony Optimization and the Particle Swarm Optimization (Xiaohui, 2006; Story, 2003). Both optimizations are capable of solving very complex, multi-dimensional problems, but they do so in two distinct, yet similar ways. Both optimizations analyze the way a natural organization unit works, be it an ant colony or a flock of birds, to complete a given task.

**ANT COLONY OPTIMIZATION**

Ant Colony Optimization (ACO) is a swarm type that uses a trail tracking system. Have you ever noticed the way a foraging ant wanders? Ants move in what appears to be random scouring. But in reality, the ant is actually dropping a pheromone trail while it walks, and once a food source is found, its steps are retraced. The wandering ant returns to the colony using its previous scented trail and leaves a second pheromone trail making the scent stronger. Provided the ant is the first one back with the location of the food, other ants assume that this ant found the shortest route back and begin to follow this newly created route. In the event that a route becomes blocked, another route is found using this same technique, and the process starts over—the ants will begin to follow the newly lain pheromone trail (Story, 2003).

The ACO swarm type found in nature has been used in business networks. As briefly covered in an interview with Eric Bonabeau (Story, 2003), Dr. Bonabeau details his routing solutions based on swarm intelligence. Simply put, when a message is sent, it must make the correct connections to get to the recipient. Typically, large businesses will only have a few connections to the Internet, so in...
order to help a message get around the complex workings of the business's local area network, Bonabeau implemented a system in which a small program goes through the network, plotting a course for the message to take, marking its trail along the way. He makes the comparison to ants and how they leave pheromones along their path in order for others to follow. The potential of this type of application could reduce the delay in network traffic, allowing for faster transfers over networks—a mighty feat, indeed.

**PARTICLE SWARM OPTIMIZATION**

Similar to ACO, Particle Swarm Optimization (PSO) (Hu, 2006) is another type of swarm. PSO is a swarm type that moves from area to area as a collective group. A flock of birds and a school of fish both use PSO. If an individual in the group sees the objective point or a means of accomplishing its task (such as reaching a waypoint, or building a windmill), the rest of the group will act accordingly even though the means to accomplish the task are being transmitted from one end of the group to the other. The members of the swarm move according to the best position they have seen. Then comparing that position with their current position, they can optimize their velocity and travel speed. Members communicate these positions and viewpoints to each other and the swarm moves and acts according to the best solution accordingly, striving to reach its group objective using the means initiated by its individuals.

The Particle Swarm Optimization is imbued with such computational techniques as Genetic Algorithms. These algorithms allow for a sort of evolutionary chain in which each generation has a system optimized by random searches and solutions based off current and previous functions. By storing the best possible route to take and the current position, the velocity is determined at each step creating quick and efficient movement. The algorithm of constant updates and revised paths has used the PSO system successfully many times through research. The beauty of the system is that each particle updates off each other one, giving every particle the ability to determine its best possible route. Kennedy (1997), one of the founders of PSO, says:

> Particle swarm optimization is an extremely simple algorithm that seems to be effective for optimizing a wide range of functions. We view it as a mid-level form of A-life or biologically derived algorithm, occupying the space in nature between evolutionary search, which requires eons, and neural processing, which occurs on the order of milliseconds. (“Conclusions”, para. 1)

In Michael Crichton’s *Prey*, swarm intelligence is used to capture an image as a camera would. The image is made up of millions of minuscule camera obscura that each capture a small piece of the scene. All the pieces from the nano-cameras are reassembled into a cohesive whole and thus a complete image is rendered. The swarm is able to conduct simple communication among itself in order to get into position, and seeing as how it’s a swarm, even if the collective gets hit or disrupted, it can simply reform using similar communication. In this sense, swarm intelligence is used for something conventional, like a camera, but is much more efficient and has attributes normally impossible.

**CONCLUSION**

Why is this important? Nature has been successful in using ACO and PSO swarm methods for ages. Ants use these techniques in seeking food, bees in
making honey, and fish in avoiding capture. Nature’s ways have been adapted to be used in computers. And through a sort of natural evolution, the techniques and programs computer scientists make in relation to Nanotechnology are completely astounding. This method for solving problems has been applied to network routing. In Ant Colony Routing, this technique is used to determine the best path for a network packet from a source node to its destination node. It does this by reinforcing fluid and short delayed network paths more, like the ant does with its pheromone trail, leaving slower paths with a weaker trail, to be used more as a contingency route such as in the case of network hardware failure (Bonabeau et al, 2000). Where as

Particle swarm optimization is very effective for optimization of communication. The benefits of being able to use simple instructions to achieve complex results stands to change the way people program. Since video games need to host complex intelligence schemes capable of processing multiple paths and multiple actions (or reactions) at any given moment (and not to mention their digital and therefore safe testing environment), it is easy to presume that they might host some of the first ventures into more complex swarm intelligence.

The uses for nano-scale machines are nearly endless. Given the small scale, there isn't enough memory or computing power for a program that is too heavy on either. Because of that, the natural solution is to turn to swarm intelligence. It makes up for the lack of computing resources, the scale, and the assuredly high rate of loss of the nanobots.

More than anything, swarm intelligence opens a lot of doors for the advancement and refinement of many technologies, especially in nanotechnology. It allows computer scientists to input relatively little, features emergent solutions to various problems, and, properly executed, is ridiculously robust.

So next time you have a picnic and are bombarded by ants and bees, be a little nicer to them, as these little creatures have taught us a thing or two about efficiency and communication and may eventually be the answer to our problems in the future.

INTRODUCTION TO ADVANCED FOUNDATIONS FOR DISCUSSING EVOLUTIONARY ALGORITHMS

Popular notions of “nano-robots” suggest that they can apply evolutionary algorithms to solve problems in the physical world (Crichton, 2002). Even if physical solutions are not explored with physical objects, they can alternatively be approximated through computation (Higuchi, T. et. al. 1996). Each evolutionary problem-solving method entails characteristic risks and assumptions. Due to the innate nature of an evolutionary approach, these characteristics are often shared. A helpful analysis of the application of evolutionary problem-solving methods requires a working knowledge of these characteristics. This section strives to review evolutionary problem-solving methods from a more in depth and critical perspective.

Evolutionary problem-solving methods are generally perceived as algorithms, i.e. a series of clear instructions that can be given to an autonomous computer. We will review example evolutionary algorithms and summarize their shared characteristics including their risks, costs, and required assumptions. The main risk takes the form of local optima, which we will define in greater depth.
Additionally, the computing costs of these algorithms are often unpredictable if the domain has not been explored before, and may require expensive trial and error. Finally, the assumptions of these algorithms restrict the range of applications for evolutionary algorithms, and they are often difficult for nano-robot environments to satisfy.

**EVOLUTIONARY ALGORITHMS IN GENERAL**

We begin by considering the most general evolutionary algorithm (Pham, Karaboga, 2000):

1. **Initialization:** Create a set of random, presumably bad, solutions to the given problem.

2. **Fitness Step:** Evaluate each solution for how well it solves the problem.

3. **Selection Step:** From the set of solutions, choose the ones that passed the fitness evaluation best. Discard the rest.

4. **Potential Finishing Step:** If a satisfactory solution is present, stop this algorithm. This solution is your final solution to the problem.

5. **Evolution Step:** From the chosen solutions, derive new "children" solutions (using some method) with similar characteristics to their "parents", but enough differences to produce a different performance on the fitness test.

6. **Go to step 2 and repeat this process indefinitely.**

The other algorithms we will review all bear a resemblance to this general algorithm. After performing step 3 through many iterations, the child generations will inevitably stop outperforming their parents. If so, the algorithm has probably reached an optimum and should be stopped. The best solution from the current set can be chosen as the final solution.

**GENETIC ALGORITHMS IN DEPTH**

The first algorithm we consider is actually a general class of algorithms, the genetic algorithms (GAs). These algorithms are almost identical to the general algorithm above, and thus provide a strong foundation from which to discuss the other algorithms (Fitzpatrick, Grefenstette, 1988). The evolution step (step 5) in a GA is very specific. GAs produce child solutions from parent solutions either by mutation or by cross-over. Mutation is defined as changing an existing solution to produce a child solution. Cross-over is defined as composing a child solution from the parts of two existing solutions. These two mechanisms are analogous to asexual and sexual reproduction.

As an example, suppose we are trying to find the shortest path from Los Angeles to New York. We want to optimize the cost of travel to be as low as possible. Suppose we have a path that goes through San Antonio, Texas, and a path that goes through Las Vegas, Nevada. To produce a child solution, we could mutate the path through San Antonio, and have it go through Houston instead of San Antonio. Alternatively, we could cross-over the two solutions, and derive a child path that goes through both Las Vegas and San Antonio. Of the paths we’ve mentioned in this example, it isn’t clear which is the best, but we could apply a fitness test to see which costs the least mileage, and then discard the rest. The

**Optima:** The most favorable condition for something to work.
algorithm could continue until all derived children stopped out-performing their parents.

Recall that eventually, parent solutions stop yielding better child solutions altogether. In fact, in the early iterations, child solutions tend to rapidly outperform and replace parents. As time goes on, however, the room for improvement diminishes, and eventually an optimal solution, or optimum, is reached. The critical question is whether the optimum is a global or local optimum. In general, there is no way to know. The most common method to avoid finding a local optimum is to randomly restart the entire algorithm with different starting solutions. We will revisit this problem shortly.

SIMULATED ANNEALING IN DEPTH

The next type of evolutionary algorithm we consider is Simulated Annealing (SA). SA was introduced by Kirkpatrick, et. al. in 1983 in a beautiful example of cross-disciplinary influence (Kirkpatrick, Gelatt, Vecchi, 1983). It draws its name from the process by which crystals must cool to retain their low-energy perfection and avoid becoming glass: annealing. SA algorithms can be described in terms of the general algorithm above, with a couple changes.

The first key difference is that SA generally maintains only one solution at a time. Furthermore, it exclusively uses massive random mutations, not crossover. Finally, step 3 of the algorithm is very different. Instead of rejecting less fit children immediately, SA may accept them over their better parents with a certain probability. The probability with which this occurs is proportional to a “temperature”, which the algorithm also keeps track of. The temperature is merely a numeric value. Over large time intervals, the temperature gradually cools down, or approaches zero, and the probability of accepting less fit children diminishes. SA should not cool down, however, until the quality of solutions at the current “temperature” reaches a certain level of stability. A good definition of what indicates stability is nonexistent—the schedule of lowering the temperature must be determined and given as parameters to the algorithm in advance (Kirkpatrick, Gelatt, Vecchi, 1983).

To see why accepting less fit children might be useful, recall the problem of local optimum. In all of the papers on evolutionary algorithms, it is virtually impossible not to find mention of how well a given algorithm handles this problem (Kirkpatrick, Gelatt, Vecchi, 1983; Pham, Karaboga, 2000; Grefenstette, 1987; Dorigo, Di Caro, Gambardella, 1999). If an evolutionary algorithm finds a local optimum, it may very well be that the global optimum is far better, but due to the nature of the fitness test and selection, the evolutionary algorithm may never find it (see Figure 1).
This is why mutation is critical in the GA—it introduces random variability, and this is the only way to introduce new information into the set of solutions, and thus escape from a local optimum. For the same reason, an SA algorithm may accept a less fit child, so that the child can take the algorithm toward a different direction of solutions, and thus hopefully find an optimum better than the former one. Neither of these methods always works. Parameters need to be set for both types of algorithms, and often it is impossible to know how to set those parameters before the algorithm has already been run. This uncertainty is the risky part of evolutionary algorithms, and we note it here so that we may be cognizant of it.

ANT COLONY OPTIMIZATION IN DEPTH

Ant Colony Optimization (ACO), which has already been discussed, is relatively different compared to the other algorithms we have discussed so far. Our discussion is drawn primarily from works by its creator, Marco Dorigo (Dorigo, Maniezzo, Colomi, 1996; Dorigo, Di Caro, Gambardella, 1999). ACO is specific to optimizing paths in a graph. A “graph” here does not refer to a function on a Cartesian coordinate system, but the concept in computer science of a collective set of points, or nodes, and the set of connections between the points. It requires that whatever problem it will solve be expressed in terms of a graph. Without the graph, the concept of a pheromone trail indicating the “shortest path” makes no sense, and the algorithm loses its meaning.

Thus, implementing ACO on autonomous computers equates to abstracting a shortest path problem into the discrete world of graphs. One creates “virtual” ants, a virtual problem space, and then runs a simulation allowing the virtual ants to search and create pheromone intensities. In addition to simulating the ants, the graph itself must be simulated to store virtual pheromones and exhibit a gradual decay of the pheromone intensity. This requires that certain parameters be adjusted to prevent the algorithm from converging on poor solutions too early, either by being too social or too independent. These parameters must be experimentally determined for each problem.

Compared to the other algorithms, ACO is the most unique, and is sometimes
not even classified as an evolutionary algorithm. Like the others, however, it
solves optimization problems. Like an evolutionary approach, it uses the history
of the search to influence its directions, only instead of the solution population
holding this information, the graph itself holds it implicitly with a pheromone
trail. Its applicability is more restricted than any of the algorithms we have
discussed so far. It can only be applied to problems that can be expressed in
terms of a discrete graph, as oppose to an infinitely fine-grained, continuous
solution space like the real world. There is no “fitness function” explicitly
applied to each ant or path. Instead, the “fitness” of a path is implicitly revealed
over time by the strength of its pheromone trail and the decisions of the ants.

CONCLUSION

With this foundation, we can finally make general conclusions in the context of
nano-robot applications. First, it’s worth noting that these algorithms are clearly
not much more complicated than a blind “trial and error” approach – this is
innate to the nature of evolution. Using such a simple approach is elegant in the
sense that it is trivial to implement and understand, but it is expensive in the
sense that trial and error can take a very long time. Most of us are used to the
computer returning results instantly. Evolutionary algorithms, on the other
hand, often run on computers for hours or even days before returning an
answer. They are expensive in time.

Secondly, while it is certain that these algorithms improve solutions over time,
the final quality of the solution may be a local optimum. This is a risk that is
always being taken each time an evolutionary algorithm is used. The algorithms
all have ways of reducing this risk by experimentally determining ideal
parameters specific to the problem at hand (Grefenstette, 1987), but this
requires experimentation.

Finally, we can see that each of the evolutionary algorithms we have examined
requires that the problem be an optimization problem. Thus, if nano-robots will
ever apply evolutionary algorithms to construct solutions for problems, the
problems must be expressible as optimization problems. Furthermore, it must
be easy to apply a fitness test to each solution. When the algorithms are applied
on a computer, the fitness test is applied instantly. In contrast, applying this test
in the physical world will be both challenging and relatively slow if the solutions
are microscopic in size.

To conclude, we examined three general categories of evolutionary algorithms:
genetic algorithms, simulated annealing, and ant colony optimization. After
discovering that these algorithms are similar, we discussed the characteristics
and challenges that they share, especially in the context that they are often put
in: as programs for nano-robots. Equipped with both examples of evolutionary
algorithms, and knowledge of their characteristics and risks, we can intelligently
begin to discuss their future applications as nanotechnology approaches reality.

Issues

♦ Looking Before We Leap ♦

INTRODUCTION

Whenever we create something huge, something mind blowing, something
devastating, or something revolutionary, there will always be issues or
problems. When any idea comes out, people must study and realize the effects that it would hold against us. Nanotechnology will be an issue that will require this kind of scrutiny. Nanotechnology will be huge, mind blowing, devastating, and revolutionary. We could change our lives with the creation of these devices.

So what kinds of issues are there, you ask? There are hundreds. For instance, we could talk about how nanotechnology will affect the population of cows in 2092, or how nanotechnology can replace modern medicine. In this chapter, we will discuss some of the issues surrounding nanotechnology from a variety of perspectives including: ethics, legal, violence from these machines, and the environment. What we present here may change one’s opinions about nanotechnology. These issues are complex; there are no easy answers. If you are going to dwell on these problems, thinking caps will be required.

Oh and the cows will be safe, don’t worry.

♦ Regulation, Subjugation, and Degradation ♦

**ETHICAL ISSUES**

The government, being the final deciding factor on most issues and research, is involved in everything from the latest safety devices, to the newest and most recent finds in new power. Sherwood Boehlert (R-NY) from the House Science Committee Chairman said:

Nanotechnology is a subject on which there is already broad agreement-on this dais, at the witness table, and indeed in the Congress and country at large. We all understand that nanotechnology can be a key to future economic prosperity and might improve our lives and that the federal government needs to play a role in making that so. (SpaceRef News, 1999-2006, para. 6)

He and Mike Honda (D-CA) introduced H.R. 766, the Nanotechnology Research and Development Act of 2003. It is clear that the government is already putting forth bills and ideas as to what it believes to be the best implementation for nanotechnology in society. However, should the government really have a claim in this topic?

It seems that many believe the government makes the best decisions for its people, yet on the other hand, many believe the government is ill-informed. The government surely funds research on nanotechnology, and will continue as long as it sees benefits. For it is in the government's interests for private businesses to invest wisely and shrewdly in this new technology in order to maintain a strong and large economy. Now how can a government that is largely driven by economics be really interested in the needs of its people? The government might not directly profit monetarily, however it profits when the business owners and employees vote in upcoming elections. “The nanotechnology industry could become one of the new engines of our economy,” said Honda, lead Democratic cosponsor of H.R. 766 (SpaceRef News, 1999-2006, para. 7). Yet, economics is not the only area that will be affected:

It is important that the United States lead the world in the development of the nanotechnology industry, and it will take many years of sustained federal investment in research and development to achieve this goal. It is clear that nanotechnology applications will have a dramatic impact on society, and we set
up structures to assess and understand the technical, social, ethical, philosophical, and legal issues that will arise. (SpaceRef News, 1999-2006, para. 7)

These are things that people might want to think about and take into consideration when voting in elections for potential leaders in their country. The government also has a huge burden on its shoulders when considering the needs of the people. "The science is barreling forward, but the ethics aren't, and there's very little public engagement," says Peter Singer from the Joint Centre for Bioethics (JCB) at the University of Toronto, Canada (Nanotech may spark fierce ethical row, 2003, para. 21). Therefore, the government needs to fully inform the public before making any decisions in order to perceive risks as well as benefits of nanotechnology.

So if the government is being largely driven by economic motives, what are the chances of there being privacy within the government itself? According to many, privacy will not exist and to some it never really has. It seems as though the more advanced technology gets, the less privacy we have. Already there are tiny cameras being installed in many department store’s fitting rooms; many are installed in family homes. What makes us think that privacy will be held once this new and improved technology comes? Undoubtedly, there will be no privacy; there will be no assurance that one’s personal information and the country’s itself will be held secret. The privacy of an individual can be hindered; therefore, there needs to be rules and regulations for this made through commissions. Working mutually with the public to enforce one’s privacy is already a big step.

Privacy and governmental issues is not the only ethical issue, however. Reverend David Cadriel, pastor of a Pentecostal denominational church was asked what he felt on the advances of nanotechnology, and he replied, “I think technology is great; its advances have provided tremendous help for humans. Advances in technology will help us expand the lives of many and even end poverty.” This belief subsists in many Protestant groups—that nanotechnology is good as long as it helps human beings and is not used to cause harm to others.

“The danger enters when mankind starts to ‘play God’ and people solely rely on the advances of this technology,” states Reverend Cadriel. He believes “According to the Bible” God gave doctors and scientists the ability and wisdom to be able to create and come up with new material to help humans. He further states, “…all technology is creation of God. He created it. It’s just that humans are barely discovering it and applying it.” It is a great thing to help postpone mankind’s greatest fear—death and suffering. Yet, there can be raised concerns of possible consequences that come from increasing the average life span. Cadriel also believes that the family structure will certainly be affected, once all eyes are set on the materialistic side of technology. People, he fears, will start to turn away from their creator.

Religion will always be an important matter; there will always be the predicament that religions do not coincide with one another. And therefore, their views on nanotechnology will differ. However, people need to understand that not everyone has their same beliefs, and a world full of ill people that necessitate medical care may be reason to put aside religious reproach.

Though nanotechnology is still in infancy it is important to take into
consideration the implications and benefits of it. The breadth of its social impact must be considered as newer and newer material is being introduced. It is helpful to all when the government works in partnership with the people. No matter what political party one may be, it is clear that all want to be prosperous and therefore, all will act in this interest. It is impossible for the government to meet all the requests of its citizens—with the plethora of political and religious views. Moreover, ethics are important here because they drive these social consequences. Ethics can be shaped by one's religion and therefore show up in politics. How one group in society views nanotechnology advancements will affect other groups' views and most importantly, their actions. Issues arise because ethics encompass a diversity of subjective ideals, philosophies, and values. Each view is publicized and adhered to by many, yet it is one's life to do as one shall please. It is the greatest gift of America—free will. Yet, despite the many ethical issues that seem to warrant a halt to nanotechnology developments, a progressive stance will remain. As Singer states, "I don't want the science to slow down. I want the ethics to catch up" (Nanotech may spark fierce ethical row, 2003, para. 25).

♦ Nanotechnology, Prepare to be Subpoenaed! ♦

Legal issues concerning nanotechnology are just some of many that should be noted, as they affect both our society and government. Every day, we become aware of issues and laws that our government imposes on us that change our lives, our societies, our businesses, and basically everything around us. Nanotechnology will certainly be one of these things. In a related article, a lawyer, John C. Monica Jr., states:

No industry—including the nanotechnology industry—is beyond the reach of American trial lawyers. Concerns about possible health and safety hazards posed by nanomaterials are being raised among labor unions and environmentalists; trial lawyers cannot be far behind. Some have even begun to compare nanotechnology to asbestos, a material plagued by $70 billion in litigation over the past three decades. (Davidson, 2005, para. 6)

As this new technology has begun to emerge, there has been more and more research into the field and what effects it has on the populous and the environment. This has been reinforced by research in labs that recently reported that certain nanomaterials have toxic effects on the environment, although they say the results are preliminary and that further research must be done (Davidson, 2005, para. 7). So, what does this mean to the average everyday consumer you might ask? Well, the reliability and safety of future nanoproducts and nanomaterials is still unclear. However, some products today, unknown to the average consumer, already have nanotech in them and are perfectly safe. It has been observed:

Some of the products—such as cell phone battery boosters, tennis racquets, indoor air purifiers and stain resistant pants—are already available in the market, but more efforts to improve it are underway. The technology is so revolutionary that its impact on human life will exceed the inventions of fire, writing, the printing press, modern medicine and electricity all rolled into one. (Al'Afghani, 2006, para. 2)

This brings up an interesting point. Just as with any emerging product there are
always going to be bugs, or errors; accidents are bound to happen. Yet, with these new emerging technologies also comes great improvement. With each iteration (if it may be called so), certain products are always improving. The technology is extremely revolutionary and is pretty much what will carry us as a population into the future, but without rigorous safety and legal nets put in place, it could also lead to our demise.

A ton of money is being poured into this growing industry as stated, “The U.S. National Science Foundation suggested that the nanotechnology market may be worth as much as $15 trillion by 2015 and the U.S. government approved nearly $3.7 billion to fund research through its Nanotechnology Research and Development Act of 2003” (Al’ Afghani, 2006, para. 1). This is just an incredibly mind boggling number, but it shows how committed the country is to further developing this technology. With all that money being spent however, there obviously is a need to spend some of it on legal and safety issues. Davidson spoke of this need referencing another authority’s opinion:

Former Sierra Club president Adam Werbach, in a speech Oct. 24 at a different nanotech conference in Burlingame, called for a ‘tenfold increase’ in federal funding of research on the potential environmental effects of nanotech. He advised nanotech buffs not to repeat the mistakes of past techno-utopians who assumed technological wonders could be developed without risk: ‘Don’t blow it.... (There is) incredible opportunity to reduce human suffering.... Forget Buck Rogers.... Offer solutions, not technologies.’ (Davidson, 2005, para. 13).

Most people today have heard nanotech will be used a lot in the medical field, helping to fight cancer and other bodily ailments using nanotubes and bots to work on the body at a molecular level. Nanotech is being used in the military department of countries as well. While both of these advances are in the foreseeable future, they both raise the same legal questions. First, with the medical, what will happen when say, hypothetically, someone who is being treated for cancer is given nanomaterials to ingest and ends up dying from it? Obviously there will be intense research and study on nanotech to bring it to this point, but most definitely, complications are not impossible. Or secondly, a country is developing nanotech weaponry and it is stolen somehow by a terrorist group and used against a populous. Or if a nanotech research location is somehow compromised and ends up harming the environment, who will be to blame?

There are several different things that could vary the blame one way or the other. Liability would be the big question and depending on the situation would be handled differently case by case. For example, in the medical scenario there would have to be an investigation that would need to determine if it was the user’s fault for improperly using and distributing the nanobots and nanomaterial, the hospital/company’s fault, or the nanotech producer. The same can be said at the weaponry level; would governments be held strictly liable when something as the described scenario happens? (Al’ Afghani, 2006, para. 12). These are the grey questions that will drive legal battles in court and have jurors debate over who is to blame for oversight of nanotechnology’s fallbacks. Overall, this legal discussion will no doubt idly continue, but let us hope that most of these legal and safety issues are addressed before something horrific happens.
Ever have a machine not work when you want it to? Think about your abusive VCR player and its psychological mind games it plays with you as the timer flashes twelve a.m. over and over again. Annoying right? How about your computer, when it acts up and deletes a file you were working on? Horrible I'm sure. If you think your problems are bad now, think about the future when we have machines so advanced we will not have the slightest clue what they do; we are just sure they do something. Now imagine those machines malfunctioning.

We have already discussed the applications that nanotechnology will eventually hold, and we even introduced the types of technology that has the capability of enforcing itself autonomously. Nanorobots may use algorithms such as swarm intelligence or ideas about self-replication. These two combined however can be a deadly thing. First let us look at self-replication. The idea behind self-replication is programming a robot to be able to create an identical version of itself.

With nanotechnology, this goal could be quite easy. If robots eventually take over certain jobs and begin to create more robots (think of an assembly line), then eventually with nanotechnology, small robots should be able to create small robots. If we look at self replication as a factory, then self replication is pretty easy, states Drexler (1986) who says “If the factory can also take machines apart, repairs are easy: simply disassemble the faulty machines, test all their parts, replace any worn or broken parts, and reassemble them. A more efficient system would diagnose problems without testing every part, but this isn't strictly necessary” (“Clanking replicators” section, para. 6).

So what happens when a faulty robot begins its own self-replication? We have a problem then. Drexler defines these self-replicating machines as "replicators" and there is no way that the human eye (currently) could see molecules replicating by themselves. And what happens when a nanorobot begins to self-replicate? We could never tell, especially if this robot is faulty. If instead this new swarm of robots goes from destroying a disease to destroying the human world—what would happen? Drexler (1986) chronicles this danger and calls it the “Gray Goo" scenario.

Already we can see the dangers of a “Gray Goo” scenario by taking a short look at bacteria. Bacteria, in the most dangerous sense, could replicate fast and create dangerous diseases in short time periods, much like the Bubonic Plague, etc. That is how dangerous the “Gray Goo” scenario is. Drexler (1986) says:

Dangerous replicators could easily be too tough, small, and rapidly spreading to stop ... Though masses of uncontrolled replicators need not be gray or gooey, the term “gray goo” emphasizes that replicators able to obliterate life might be less inspiring than a single species of crabgrass. They might be "superior" in an evolutionary sense, but this need not make them valuable. We have evolved to love a world rich in living things, ideas, and diversity, so there is no reason to value gray goo merely because it could spread. Indeed, if we prevent it we will thereby prove our evolutionary superiority. (“The threat from the machines” section, para. 4-5)
If machines go through this replication process then eventually they could overcome humankind. These machines, being self-replicated, would have to be destroyed in a very small and large scale. If we were to leave just one failed machine, it could reproduce millions and start to attack people with no way to stop it.

How do we stop this eventual destruction of human kind? Fail-safe mechanisms. These mechanisms would involve simple solutions to stop the threat of machines from overtaking us. The simplest fail-safe would be redundancy, which would be using the same guard over and over to make a simple task fool proof, in which if an answer was not given correctly the machine would shut down or would keep repeating the instructions until an answer was given. Drexler (1986) envisions a bridge saying, “If [a] bridge falls when a cable breaks, it will be too dangerous to use. Imagine, though, that a broken cable takes a day to fix (because skilled repair crews with spare cables are on call), and that, though it takes five cables to support the bridge, there are actually six. Now if one cable breaks, the bridge will still stand” (“Trustworthy systems”, para. 5).

Okay, but we can stop this from happening. We can design systems that have such a low chance of failing that we do not need to worry about it, or ways to destroy/repair any malfunctioning system. But what about working machines designed to attack or hurt others? With just one more step in the nanotechnology direction we see that weapons will move from biological to nanotechnological. Meaning that instead of chemicals we inhale, there would be robots attacking us, from inside or outside our bodies.

Moreover, criminals and terrorists could use nanotechnology to produce nano scale weapons to damage a society. It is possible for criminals and terrorists to come up with these weapons, whether it is biological weapon or physical military hardware, that are much stronger than the defensive weapons or detectors. What kind of defenses would we be able to make? Drexler also termed the phrase active shields. Basically, we’ll be using machines to defend ourselves against other machines, which basically are the same machines, just sort of broken down.

Once again you have to look at the systems that we create. With careful planning we should be able to avoid any of these types of problems and dangers. Drexler (1986) once again says it best:

Personal restraint, local action, selective delay, international agreement, unilateral strength, and international cooperation—all these strategies can help us in an effort to develop active shields. Consider our situation today. The democracies have for decades led the world in most areas of science and technology; we lead today in computer software and biotechnology. Together, we are the leading force. There seems no reason why we cannot maintain that lead and use it. (“A synthesis of strategies” pars. 1-2)

Thus, with the implementation of nanotechnology will come a burden of responsibility to be brunt on the shoulders of those who aid in its development. Only denial of this imminent obligation can result in negative effects.

Active shields: Using nanorobots with the sole purpose of defense against other nanorobots.

9/11-WAS IT PREVENTABLE?

Most people still remember what happened on September 11, 2001. On that day,
terrorists killed nearly 3000 innocent people along with themselves. Take a moment to imagine what the world would be like if terrorists had nanotechnology in their hands. Then, not only would these potential attacks be dangerous, since it would be on the molecular scale, but it would be hard to detect, if not undetectable. The Center for Responsible Nanotechnology (2004) states:

If such devices were available from a black market or a home factory, it would be quite difficult to detect them before they were used; a random search capable of spotting them would be a clear violation of current human rights standards in most civilized countries. Detecting a criminal user after the fact might also be difficult; since many devices can be computer-controlled and networked, the criminal does not have to be at the scene. (Center for Responsible Nanotechnology, 2004, para. 14)

No matter how much we improve our surveillance systems, there will always be challenges from terrorists, and there is no guarantee that the terrorists’ attacks will be stopped. Two days after the attacks on the World Trade Centers, W. Knight (2001) wrote an article entitled, “Intelligence technology may not stop terrorists.” Knight wrote that “the US operates the most technologically sophisticated international surveillance network in the world […] But none of this gave any hint of the audacious and tragic events, which destroyed the World Trade Center and killed many thousands of people” (Knight, 2001, para. 8). There is always a loophole in the surveillance systems that terrorists can take advantage of. This is because as technology develops, terrorists are able to obtain new weapons based off this technology at the same rate.

Even everyday technology can be used by terrorists, as for example, terrorists used airplanes to attack the World Trade Center and the Pentagon. Also, according to the Department of Homeland Security, terrorists can even use Wi-Fi networks in attacks (Boutin, 2002, para. 1). If this is true, and terrorists really take advantage of these Wi-Fi connections, it will be hard to trace terrorists because they will be using Wi-Fi to control their attacks remotely. Considering what terrorists can do with everyday technologies, take a moment to imagine what they could do with nanotechnology. As Peterson said, “In the coming decades, nanotechnology will give us greater powers for both good and ill than we have ever had before” (Peterson, n.d., para. 3).

So, we know that terrorist can get their hands on nanotechnology and use it for their advantage. What can we do to prevent such attacks? We need to think of ways in which terrorists might strike. We need to look through their eyes and think of the possible ways they might use new advanced technologies against us—“Even though many people knew intellectually that a modern airliner carried enough fuel to release a kiloton of energy, this fact and its theoretical consequences were not taken seriously—not until after the event did we start to implement effective policies to prevent such a catastrophe” (Peterson, n.d., para. 4). We need to do our best to stay one step ahead of the terrorists at all times; the Department of Homeland Security stated that they require “practical applications of evolving technologies in order to stay ahead of terrorists in order to protect the United States from terrorist incursion” (Lum, n.d., p. 5).
When discussing nanotechnology and its role in the environment, we need to keep in mind that "Nature is already working at the nanoscale. One needs to understand what is different when nanostructured contaminants produced by manufacturing or combustion enter the environment" (Roco, 2003, p. 185). Most researchers in nanotechnology toxicology and environmental health share this concern. Many comfortable with the current development and focus of nanotechnology find comfort in believing that hardware and nanotech integrated applications would not result in direct exposure to nanomaterials (in the sense that we usually are not keen on taking apart our computers and sniffing the circuit boards for entertainment).

Yet, from a big picture perspective, everything has a life cycle. What happens to the old, slow, heavy computers that we want to get rid of? It all goes back into the environment. Furthermore, how many people responsibly recycle their wastes? This "life cycle view," as coined by senior scientist Richard A. Denison of Environmental Defense during Congressional testimony (Environmental and Safety Impacts, 2005) is imperative. He explains it best:

> While exposure to individual nanoparticles during such a product's intended use seems unlikely, a lifecycle view is critical to understanding the potential risks. A product's lifecycle includes not just the product's use phase, but also its manufacture (and the manufacture of its components) and its disposal or recycling/reclamation. Human or environmental exposures during these other stages may be substantial. (para. 31)

Point being, the environment always takes all residuals, runoffs, and wastes from human consumption and activity. Nanoparticles and their residuals will all end up in the environment somehow, may be absorbed, and then brought into human consumption again. This cycle of passing nanomaterials through the environment is by no means circular and always complete. For example, Sharon Walker, assistant professor of the University of California, Riverside studies water quality, and she explains that one of the biggest problems in water treatment is filtering out pharmaceuticals—tiny residuals from our intake of drugs and multi-vitamins that pass through the primary processes of treatment. These residuals build up, like a plume of concentrated contaminants that gets released to the ocean and results in mutations and deformities of the wildlife. One can imagine if the same were to happen with nanomaterials, and even smaller substances that would change and contaminate water sources and the environment. Oberdörster's study (2004) shows that the brain, liver, and gills of juvenile largemouth bass were negatively affected by exposure to fullerenes, the soccer-ball-shaped carbon buckyballs.

E. Clayton Teague, director of the National Nanotechnology Coordination office, nicely nut-shelled the environmental issues concerning nanotechnology:

> Concern is focused on possible risk due to exposure to the relatively small number of end-use products that contain 'free' (i.e., unbound) engineered nanomaterials, which may be inhaled, ingested, or absorbed through the skin or that may find their way into the air, soil, or aqueous environment. (Environmental and Safety Impacts 2005)

According to Teague, the chronic toxicity of nanomaterials causing cancer or having long-term adverse effects is relatively understudied. Yet, of few studies
done, there are cases of single and multi walled Carbon Nano Tube (CNT) exposure that resulted in unexpected results. For example, CNTs that were inhaled caused granuloma formation where the particles were initially deposited, but later lesions elsewhere on the lungs formed (Lam, et. al, 2004). Not to mention that CNTs in the respiratory tract can actually be directly absorbed into the systemic system and then get to the brain cells. While C60 fullerenes, or carbon “buckyballs” have not been shown to be highly soluble in water, they can be taken in through the gills of fish and then to their brains, which could lead to the mutation and possible destruction of certain ecosystems (Oberdörster, 2005). This would have obvious ecological impacts.

The investment in this rapidly growing technology requires an investment in its possible limitations, drawbacks, and opportunity costs. At this point, if we are hyped up about nanotechnology and want to start mass-producing carbon nanotubes, we need to establish a solid foundation of knowledge about its human health effects to minimize possible harmful exposure. Unfortunately, many of the studies for nanotoxicology are not complete, especially in regards to direct human health. Essentially, we have no real idea of what “dosage” of nanotech can be harmful. The funding that was finally put aside for nanotechnology research in environmental health impacts is so recent that the grants for such research projects are still ongoing. Published papers and presentation of experimental results are anticipated, but the pace of nanotechnology research and development in other areas is still on the rise. While researchers and the scientific community wait for such results, we may be sitting on the edge of our seats anticipating the “nay” or “yay” on nanotechnology. Yet, is anything ever that simple?

Granuloma: Raising of the skin with mucous membranes that appears like a tumor; generally considered a benign tumor, but may cause health complications depending on location

Nanotoxicology: The study of nature effects, and detection of poisons on a nanoscale

Every action has an equal and opposite reaction. It is one of Newton’s three laws at the heart of physics. And it is no different in nanotechnology. Even in its theoretical and practical construction, it still has hypothetical situations that we must think about before it is too late. If we don’t plan for the future, then when dangers come, we will not know how to handle them. Chaos will occur, and no one likes chaos. So, by looking right now at possible reactions that nanotechnology will bring, we may be able to control it, to bind it, to grasp it before it is too late.

It is a good thing to look through ethical, legal, violence, and environmental and human health issues because now we understand how much these will all affect human kind. Our lives are in danger unless we can come up with ways to solve problems that are not even there yet. If we can create safeguards for humanity, start our defenses before danger even comes, then we can be safe from ourselves. So, start thinking now, because when it is too late, then well, it is too late. We will confront problems unless we can build a time machine to take us back before the release of nanotechnological problems. Yet what about problems with time machines? With any new technology, we must review all possible options of defense and then the repercussions of those defenses. Dwight Eisenhower (2006) said it best, “The problem in defense is how far you can go without destroying from within what you are trying to defend from without.”

Nanotechnology’s Beginning

CONCLUSION

Every action has an equal and opposite reaction. It is one of Newton’s three laws at the heart of physics. And it is no different in nanotechnology. Even in its theoretical and practical construction, it still has hypothetical situations that we must think about before it is too late. If we don’t plan for the future, then when dangers come, we will not know how to handle them. Chaos will occur, and no one likes chaos. So, by looking right now at possible reactions that nanotechnology will bring, we may be able to control it, to bind it, to grasp it before it is too late.

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The article described the process of cleaning the TCE from the water using a simple process. The palladium in a powder form was mixed with the TCE water and then the palladium bonded and broke down the toxic TCE into a non-toxic ethane. It involved the process of a well which pumped the water and then powder was added into which it was mixed and then the toxic was taken out of the water.
consumption through application of nanoscience and advanced materials will have an effect on everyday lives. As 80% of the world’s energy comes from fossil fuels, alternative renewable energy sources have fallen short except from the sun. Environmental impacts from human usage of the earth’s natural resources have caused climatic alterations due to carbon dioxide gasses and emissions. Nanoscience may assist in finding better applications or alternative solutions. Nanoparticles have helped improved catalysts. Nanostructures that improve the storage capacity of particles, nanoscale particles that have been found to hold different characteristics such as thermoelectric, semiconductor properties create an electric current we can harvest, and light-emitting diodes that fabricate more efficient light bulbs are just some of nanotechnologies hand in renewable, efficient, and more affordable energy. The Hydrogen Fuel Initiative has also been moving forward through nanomaterials and has driven the hydrogen economy with the hopes to alleviate the use of fossil fuel and produce a cheaper, more efficient and cleaner source of energy to drive our future economy.


This article helped me understand the way some particles and or materials are able to break up into other more toxic molecules in the ground water. Also helped show which chemicals will break up in ground water and which ones are unable to due to the chemical reaction tools. Gave a good description on wells and why they are use in helping find where chemicals are traveling and also where future problems might occur.


Coleman presents us in this article with an examination of “… an emerging technology that has the promise to become core to homeland
security. We will look at the role Nanotechnology will have in the fight against terrorism. ‘Coleman does a good job in presenting forth topics or concerns that other people might have. Topics on homeland security, the history of nanotechnology, current state, trends, future advances and even feedback. He uniformly addresses these questions with reasonable feedback and very informative images of graphs.


This article not only talks about legal issues but ethical issues as well. Also stating about how governments around the world will need to spend significant amounts of money to research safety hazards, not only to the human population but the environment as well.


Drexler describes nanotechnology as both a savior and a destructor of mankind. We can use nanotechnology in mechanosynthesis to be able to create new types of machines and materials. However these machines may surpass humans by the fact of its own self-replication and synthesis. This problem may lead to a ‘Gray Goo’ scenario in which will basically be the end of the world for humans.


A paper dealing with particle swarm optimization, talking about its
origins and how the algorithm is both simple and complex. Deals with
the complexity issues and talks about the mathematical factors of PSO.

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In this article BBC News does its job in presenting an article which focuses on the issues of science and ethics. It talks about equity as to who will benefit the most from such technological advances, the rich or the poor? It mentions privacy and security and in how invisible microphones and cameras and tracking devices could help and improve security to catch terrorists yet there could be backfiring. Also, issues within the environment about what will happen when these new nanomaterials do when they are released. This article presents all these concerns and even more as unto how much it has been spent as expected to be.


This article was written two days after the 911. It talks about how the U.S. had one of the greatest technologically sophisticated international surveillance network in the world, but still failed to prevent the attack.


This paper provides some very interesting evidence that nanoparticles could have very detrimental health effects when inhaled. The study was done on mice in which nanotube materials of varying composition were injected into the mice by intratracheal instillation. Results showed that although iron containing nanotubes were less harmful than the zinc...
containing nanotubes, purified (less than 2% iron) nanotubes still had harmful effects. This suggests that size and the structure of the nanotube is the cause for the lung irritation—not necessarily composition. The researchers’ findings spawn the need to fund and perform more research in nanotube toxicology at least to prevent and predict any negative human health effects while we enter the nanotechnology age.


Maynard’s paper provides the most up to date holistic discussion of the current issues regarding nanostructured particles and human health. With over a hundred recent references listed, the paper is actually like a research paper pulling together the bank of toxicology studies and theories that other papers are devoted to in detail. Maynard examines nanostructured particles through discussing factors of size, surface area, chemical reactivity, solubility, and shape by citing the results of major studies to formulate a general impression of these factors’ effects. Surface area turns out to be a major contributor, in which the larger aggregate surface area of all the small particles have a greater damaging effect than the same mass of particles of larger size and same composition. Overall, Maynard contends that in the onset of the nanotechnology age, a preset precautionary system needs to be put in place so workers that become involved in the manufacturing of the particles, are taking proper safety measures.


This is a government publication by the Office of Science of the U.S. Department of Energy concerning research initiatives for energy using nanotechnology. This includes the future of creating hydrogen for hydrogen fuel cells by splitting water molecules using nanoscale catalysts, creating more energy efficient solar powered surfaces through the use of nanomaterials to absorb more photons of different sunlight wavelengths, increasing the amount of electricity efficiency for incandescent lighting using quantum dots, creating lighter weighing planes and cars, and using cheaper conductors of nanomaterials to generate electricity. These future applications may be made possible through the use of catalysts, energy transportation, and understanding the modeling, structure, characteristics and processes at the nanoscale.


Solar hydrogen, made by splitting water using sunlight, has a great potential of being used to attain energy. There are different ways nanotechnology is being applied to produce hydrogen. One way is the use of dye-sensitive photo electrochemical cells called the Gratzel cell contain the dye-sensitive titanium oxide layer on the surface, to complete the oxidation reduction chemical reaction to produce an electrical current to generate electricity. Titanium oxide's ability to absorb photons and its great nanocrystal surface area. It is found to be cheap, more effective, and durable over years.


This article shows the concerns about the future of the nanotech, and how it might bring new kinds of weapon available to the terrorists. It shows the ways to prevent the attacks, which is to think of possible ways of attacks, and making effective policies.


This 134 page white paper was produced by a workgroup of scientists that were organized to research and present all findings of the potential for nanotechnology in the environmental discipline. The introduction offers some good insight into the organization of federal funding and research for nanotechnology in the U.S., and it presents the EPA as one of the few federal bodies investing in nanotechnology research and development for the environment (rather than marketable technologies). The paper just about touches upon all nanotechnology applications for the environment—from the fate of nanoparticles and nanomaterials in the environment, to the preliminary social impacts, and to the technological applications in environmental monitoring. In the end, the council made several research recommendations to direct attention to the continuing need to sustain more knowledge of the health and environmental effects of nanoparticles. This includes more in depth analysis of the nanoparticle emissions, monitoring its use as a water remediation technology, and formulating procedures for workplace handling and exposure.


This article gave a better understanding on how the Lehigh University was using nanotechnology to clean water that was polluted by certain iron particles. It gave the types of experiments they preformed and also the gave an overview how the product would actually be injected in to the earth. The article also gave other types of particles that they were experimenting with that were not as effecting in trying to treat and also
contain the plume.


This article presents information on a bill endorsed called H.R. 766, the Nanotechnology Research and Development Act of 2003, an important step in meeting the problem faced in this rising industry of nanotechnology. H.R. 766 was introduced by House Science Committee Chairman Sherwood Boehlert (R-NY) and Rep. Mike Honda (D-CA). H.R. 766 authorizes $2.1 billion over three years for nanotechnology research and development programs at the National Science Foundation, the Department of Energy, the Department of Commerce, NASA, and the Environmental Protection Agency. In addition to establishing a research program to address societal and ethical concerns, the bill responds to a recent National Academy of Sciences report by establishing a Presidential-appointed advisory committee and a committee headed by the Office of Science and Technology Policy to promote interagency coordination.


Researchers and engineers in the field of Nanocomputing are planning on building computers circuits that are as small as a nanometers, or billionths of a meter. Chemical synthesis, protein engineering, and atomic microscopy has resulted in allowing researchers to rearrange matter on an atomic level. Nanocomputing engineers, and researchers predict that nano-computers will consist of components known as universal assemblers. These universal assemblers will hopefully rotate and move molecules in a robotic manner, and create chemical reactions. Nanocomputer will be able to enter cells to perform surgery on a molecular level to cure diseases, and possibly reverse the aging process.


As basic structures include nanoparticles, nanolayers, and nanotubes, can serve as rearranging forces, catalysts, or conductors. Nanostructured catalysts used in manufacturing, for example, zeolites which help oxidize hydrocarbons, are benign in the environment, reduce energy consumption, and increase yield of production through its oxidation process initiated by visible light. Using nanoscale bio-inspired materials and nanotechnology to replace toxic materials into electronics are also benign to the environment. Nanoparticles can also help purify pollutants in the environment due to their reactivity size, and larger surface area. Some nanoparticles are offset by light operate as removing contaminants or are more flexible in the treatment of water or soil. Also, the shape of nanotubes is found to be very absorbent of toxins. As nanotechnology holds a lot of possibilities of sensing and detecting pollution as well, there are also many unknown resultant implications and repercussions.
Glossary

**Active shields:** Using nanorobots with the sole purpose of defense against other nanorobots.

**Air purging:** The injection of air into the soil and or water under high pressure.

**Ant colony optimization (ACO):** Using lots of people and/or processes in order to make the whole unit act as an efficient team.

**Any colony routing:** A form of communications routing that uses the ant colony optimization to use the best available paths, and when the best path is not available, other less ideal paths are used until the fastest path is available again.

**Autonomous nanotechnology swarms:** See Particle Swarm Optimization

**Binary logic:** Much like how we count using the decimal system because we have ten fingers, computers use binary logic as they can only recognize two states: on and off. Using this system, one is marked as “1,” two is marked as “10,” three is marked as “11,” four is marked as “100” and so on. In addition to counting, this system can also carry out Boolean operations.

**Biodegradable:** Something of an organic nature that can be broken down. For example, a banana peel is called biodegradable because it is something that is organic and that it will turn back into organic molecules when degraded by microorganisms.

**Biomolecules:** An organic molecule that is a part of a living organism.

**Bionanotechnology:** The technology of building organic molecules and biological items from molecules.

**Biopsy tissue:** A piece of tissue that is cut from the person in order to diagnose it. There are different types of biopsies done, e.g. Open Biopsy and Needle Biopsy.

**Bioremediation:** The use of biological components to clean up toxic chemicals.

**Boolean operations:** Logical operations such as AND, OR, or NOT. Using these operations which return true or false based on certain inputs, logical operations can be strung together into much more complex devices, like calculators or alarm clocks.

**Camera obscura:** The ancestry device which gave inspiration to a camera. It worked by allowing light in through a small hole in a large surface, after which the light could be copied by an artist.

**Capacitors:** An item in an electric circuit used to temporarily hold charge.

**Carbon nanotube:** A long, but thin tube made of pure carbon that is used for drug transport, as building blocks, etc. They can be hundreds of
Catheters: A tube-like object that is usually used in vascular portions of the body to gain access to a specific part of the body. They are usually injected in a vessel to gain access to other vessels in which work needs to be done.

Chemical catalysts: A substance used in small quantity during a chemical reaction to increase the rate of reaction. It is not consumed during the reaction and thus so does not affect the result of the reaction in any way.

Computer memory/storage: The parts of a computer which store data, even while the electrical power to the machine is on or off. Faster forms of storage (such as RAM) are referred to as memory—while slower forms (such as HDD) are referred to as Storage.

Cross-over: Composing a child solution from the parts of two existing solutions.

Cytotoxic: Something that is toxic to cells, molecules, or tissues.

Dendrimes: A dendrimer (from Greek “dendra” for tree) is an artificially manufactured or synthesized molecule built up from branched units called monomers.

Diode: An electronic device that allows electronic flow in only one direction.

Emergent behavior: Behavior of an entity that is an indirect consequence of other explicit rules. For example, an organism that is explicitly told to seek food but avoid precarious situations will, as a consequence, find particularly safe routes that lead to food even though it has not been explicitly told to do so. The term is usually used to define particularly surprising, but useful, behaviors.

Ethylene glycol: It is a colorless, odorless, sweet-tasting chemical found in many household products, including: antifreeze, de-icing products, detergents, paints, and even cosmetics. Ingestion causes poisoning, and it can also cause severe eye irritation on contact.

Fiber optic pressure sensor: A pressure sensor designed with lightweight and thin materials that is based off a design for minimally invasive medical technology.

Genetic algorithms: A class of evolutionary algorithms defined by their ability to reproduce new solutions to a problem by mutating and combining existing solutions. It is also known as the natural mixing of chromosomes in order to construct certain crossovers in which persons genes are formed.

Granuloma: Raising of the skin with mucous membranes that appears like a tumor; generally considered a benign tumor, but may cause health complications depending on location.

“Gray Goo” scenario: A scenario in which machines reproduce themselves at a fast and uncontrollable rate. One of the fears of self-replicating nanorobots is that they will replicate at an uncontrollable rate and will
wipe out all life on earth.

**Hard drive:** An item that reads and or stores information on a disk.

**Insulin:** Insulin is a hormone made by the Islet Cell that helps balance the blood glucose level.

**Internet:** Global network of computers.

**Islet cells:** Islet cells are cells that are produced by the pancreas that produce insulin.

**Macromolecules:** A large molecule that is normally composed of small molecules that bonded together. Normally are proteins or polymers.

**Microorganisms:** A microscopic organism or organic material that is seen under a microscope.

**Microprocessor:** A circuit that contains the entire processing unit of a computer chip.

**Molecular nanotechnology:** The idea of making nano-machines to do work at extremely small sizes.

**Monitoring wells:** A steel tube or casing that is in the ground in order to take water samples and or soil samples of toxic substances.

**Mutation:** Changing an existing solution to produce a child solution.

**Nano-container:** A theoretical containment that contains small amounts of drugs, thereby reducing the risk of allergic reactions. With this idea, small viruses may be used as containers to administer a drug.

**Nanomachines:** A small machine in the “nano” size that is toward medical use.

**Nanometers:** A unit of length that is one billionth of a meter.

**Nanoparticles:** A particle that is measured in the nano size.

**Nanopores:** Nanopores are essentially the ultimate storage housing centers. They have high strength and durability which makes them a vital key to the world of nanotechnology; a nano sized opening that is in the skin of humans used to absorbed or secrete fluids.

**Nanoprobe:** A nanoprobe is a device used usually on an AFM (atomic force microscope) to see extremely small things.

**Nanorobots:** Nano-sized robots designed to perform tasks to extreme accurate precisions in the nano-sized universe. Nanorobots can be regarding as one of the most important additions to nanobiotechnology. It has been suggested that Nanorobots can enter a body and serve as anti-bodies and even antiviral agents.

**Nanoscale machines:** A complete autonomous computer built on the nanoscale. These machines are predicted to suffer from an extreme shortage of conventional resources, most notably memory and power.

**Nanosurgeons:** Small particles and/or machines that will be used only for
surgery.

**Nanotechnology:** Science and technology of building electronic circuits and devices from individual atoms and molecules.

**Nanotoxicology:** The study of nature, effects and detection of poisons and toxins on a nanoscopic scale.

**Network:** Group of two or more computer systems linked together.

**Network traffic:** The load on a communications device or system.

**Optima:** The most favorable condition for something to work.

**Optimum:** The most favorable condition.

**Organic dendrimers:** Dendrimers made out Carbon, Hydrogen and Oxygen (organic molecules).

**Palladium:** A metallic element occurring naturally with platinum in gold, nickel, and copper ores. It is soft, ductile, steel-white, tarnish-resistant and has all the metallic properties. It is alloyed for use in electric contacts, jewelry, nonmagnetic watch parts, and surgical instruments.

**Particle Swarm Optimization (PSO):** A group of particles used to make a certain task extremely efficient using the entire group of workers.

**Pentecostal:** Religious term, referring to members of Christian congregations who worship the “Holy Spirit.”, and speak in tongues.

**Pheromone trail:** In ant colony optimization, this is a term referring to how ants use scent trails to make other ants follow the trail to an objective. Other ants then use their own scent trail strengthening it each time it is followed.

**Pheromones:** Chemicals secreted by humans and or insects normally to attract the other sex and or to influence behavior.

**Photodynamic cancer therapy:** Method of using light rays and drugs to kill tumor cells and thus treat cancer.

**Photolithography:** Referring to the use of imaging plates to create a photo.

**Photovoltaic cells:** A device that converts sunlight to energy.

**Plume:** The spread or effected area of a spill.

**Polymer Capsules:** Polymer capsules are essentially boxes within boxes. It is usually described as surrounding one substance with another substance around it; a synthetic container that is used to transport medicine in humans.

**Program:** In computer science, a program is a set of instructions that scientists give to a machine, which the machine interprets and uses. Programs range from the basic calculator to your car's alarm system.

**Quantum computer:** A computer that is advance and fast enough to compute quantum levels of science and mathematics. Usually, a quantum computer can calculate quantum mechanical levels of electrons, protons
and atomic nuclei.

**Quantum dots:** Tiny crystals that light up when simulated by UV light. It remains a significant part of the chemical interaction because if you remove an electron from a quantum particle its molecular property changes immensely in a very useful way.

**Quantum electrodynamics:** The theory of the reaction between light and matter

**Random-access-memory (RAM):** Main memory inside a computer used to store data and programs performed during operation.

**Receptor:** Essentially something that bonds cell membrane together; it is the bridge that connects two microorganisms together.

**Replicators:** Machines capable of self-replication.

**Resistor:** It is a part of equipment that regulates the flow of electricity and controls the amount of current that passes.

**Semiconductors:** A crystalline structure that has electrical conductivity and is used for circuits and computer chips.

**Simulated Annealing (SA):** An increased activity of heating and cooling an object to make it stronger.

**Swarm intelligence:** The concept of having lots of little ‘units’, all working towards a common goal independently of each other, but dependant of the system to which they are a part of as a whole.

**Swarms:** A group of similar objects that move as a group.

**Thermo chemical cycles:** A cycle that is associated with chemical heat.

**Transistors:** An item that is capable of turning the electricity on or off, or increasing the current flow.

**Trichloroethylene:** A colorless, toxic liquid that is used to degrease metals.

**Universal assemblers:** A program that takes multiple computer code and translates it into a single code. It is capable of measuring one-tenth of a micron. Compared to an average human hair which is about 100 microns thick, one-tenth is remarkably small (Woods 1989 para. 7). Furthermore, these assemblers will be able to rotate and move molecules. With this ability, it will initiate microscopic operations by relocating reactive molecules side by side, therefore creating a chemical reaction.

**Wi-Fi:** Wireless Ethernet.
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