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Life Itself is 'Applied Nanotechnology'

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At first blush, nanotechnology (defined as working with things at the scale of a billionth of a meter - a nanometer) might seem little different from the work that semiconductor manufacturers routinely do today to make the chips that put incredible computing power on our desks and into our pockets. Indeed, today's semiconductor chips are incredibly complex and their internal components are already nanotech-tiny; some structures are just four to six nanometers -- *a fewatoms(!)* -- wide.

So, in one vein, we've been living with in-our-pockets nanotechnology for years.

A major difference between traditional computer chip manufacturing and the more generalized genre of "nanotechnology" is that nanotech focuses not just on elements within a computer chip, but in working with atoms and molecules in their own right, to create purpose-built structures and even machines that would be impossible using traditional manufacturing techniques.

Today, we almost exclusively 'tear things down' (such as from a tree trunk or a block of metal) rather than 'building things up' from their nano-sized atomic and molecular constituent parts. The thing is, our 'tear it down' manufacturing is highly wasteful of energy and of raw materials, and it dramatically limits what we can build. As we get better at working with things at the nano scale, especially considering that the structures that build "us" also fall in this size range(!), working in the nanosphere promises to turn just about everything around us, including "us," on our (figurative) ears.

That's rather a sweeping statement, so let's get some concrete ideas (many already being explored in the labs) of what nanotech may bring:

- **To Build, Or Not To Build.**

  One of the more intriguing potentials for nanotechnology is that of "nano-machines" that can autonomously build specific nano structures, as well as more complex nano-machines. Perhaps the ultimate expression of this would be "nano-assemblers" that could use basic elements, such as carbon atoms, to build just about anything -- *even copies of themselves(!),* from scratch.

  We're not quite ready yet for nano-assemblers, but as described in the Sept. 28, 2005 MSNBC, Joseph Jacobson and his team at MIT have developed special robots that float around at random on an air cushion, and then latch onto each other in explicit ways to form machines within the rules that govern the environment. It's similar to how DNA instructs "machines" within cells to form new DNA strands. Interestingly, Jacobson's robots have the ability to determine if the chain they've built has an error in it, and if so they detach from each other and try again. Can you say "no unintended mutation?"

  These are just the first fledgling steps towards nano-machines, but that's how science often begins -- baby steps that, in this case, will get smaller and smaller as our capabilities increase.

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- **Mr. Clean.**

  Consider a development that might change the nature of college dorms (and much more) -- clothes that clean themselves! Hong Kong Polytechnic University scientists have actually developed a fabric that keeps itself clean! The process coats a cotton thread with a structure of nano-sized titanium dioxide particles that react to sunlight by breaking down *"dirt and other organic material. The clothes then simply need to be exposed to natural or UV light... Once triggered, the fabric will be able to rid itself of dirt, pollutants, and micro-organisms."*

  It gets even more interesting when it comes to the huge amount of power consumed by washing and drying clothes -- it might no longer be washed down the drain. Of course if this happens, collateral damage could affect laundromat businesses, washer and dryer manufacturers, and more...

- **To Switch, Or Not To Switch.**

  How about "switches." Not the kind we use to flip on a light, but the transistor kind that forms computer memory ("ones" or "zeros" -- "on" or "off.") But nanotech switches will be so much smaller than today's memory cells that this new type of memory will change all the data storage rules. One form will likely be tiny "carbon nanotube" switches, such as those from Nantero, which mechanically bend or unbend to form non-volatile (permanent) memory. A 10-gigabit array has already been demonstrated, with production potentially as early as 2006. A short movie at makes it clear how these "switches" work.

  A sample of other interesting nano trends that may further make today's computers seem like the first Atari Pong games include:

Nanochip's 'Ovonics' - a tiny 600 degree C tip changes a tiny silicon spot from reflective to amorphous (a 'one' or 'zero'), similar to how a CD's laser writes to a CD. But CD lasers (commonly) use red light at a wavelength of 500 nanometers (nm), while these *"probes, potentially, could get down to 20 nm." - "I can see us doing 20 to 50 times the capacity per chip than [traditional flash memory manufacturers] do,"* according to Nanochip CEO Gordon Knight. Imagine a "Chiclet-sized chip" containing 50 gigabytes! Samples in 2005, production as early as 2006.

ZettaCore's "crafted molecule!" has the ability to contain or release up to eight electrons. Accepting or releasing these particular electrons allows each molecule of a non-volatile self-assembled memory array to retain not one bit, as in conventional memory; not two bits as in some Flash memory; *but four bits of data in each molecule* for extremely dense molecular memory. *""We have built workable chips at commercially interesting densities," according to ZettaCore's CEO Randy Levine. "All of the challenges at this point deal with manufacturability."*

"Manufactured molecules." Certainly something to think about...

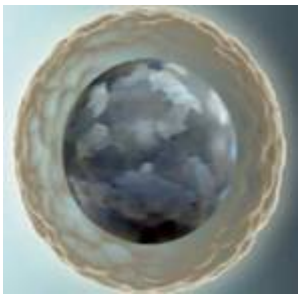
- **Living or Dead?**

  One fascinating element of nanotechnology that we touched upon earlier, is that at the nano scale the difference between things living and things dead becomes very tenuous.

In that light, consider another form of nano memory that is currently being explored by NanoMagnetics-- magnetized particles of "ferritin" encased in a 12 nanometer (outside diameter)

protein sphere. It can be used for ultra-dense data storage (e.g., a DVD's worth of storage on something the size of a floppy disk), as medical and diagnostic agents, and more:

*"We **grow** our DataInkTM magnetic particles inside identically-shaped hollow protein spheres that are just 8nm (inner diameter). This approach to synthesizing magnetic particles has two immediate benefits: (1) it ensures all particles to be uniformly sized and therefore exhibit uniform magnetic properties; and (2) it insulates each particle from each other in a carbon matrix."*



Note that word "grow." While in this case the memory isn't really alive as we define it, it is composed of proteins, and these spheres are FAR smaller than many of the things that we DO define as alive. For comparison, an AIDS virus is four-times larger than DataInk's spheres, having a diameter of 50 nm. If we can make things SMALLER than viruses, might we be making viruses, bacteria, or even cells be next?

Another example of why we may be scratching our heads (and our ethical considerations) in the future has to do with the computer "logic" that forms the basis of our computers. As we explored above, individual switches can be used to form memory (a switch, like a memory cell, is either "on" or "off"). But combining a number of switches forms basic logic circuits called AND, OR, NOR, etc. gates. It's these gates that form the basis for how our computers make the "decisions" that do out bidding (at least when we're not catering to them).

Well -- "logic gates," meet proteins!

Because UK physicists have now theorized how clusters of proteins -- those same proteins that transmit and process information within our cells -- can be taught to perform complex computer logic! Would such logic be "alive?"

This is still theoretical work, but again, that's often how new capabilities begin. You can find additional information on this further potential blurring between things living and dead in the Sept. 23, 2005 PhysicsWeb.

- **Regeneration?**

  If we lose a limb, damage an organ, or otherwise destroy some part of ourselves, we're stuck. Unlike some "lower" forms of life which can re-grow new limbs, tails, and more, we've lost that ability somewhere along the evolutionary road. But the fruits of nanotechnology, driven and aided by related advances in biology and medicine and

information technology, may just change this. According to the Sept. 29, 2005 Wired, Wistar Institute scientists are making progress towards enabling you and I to regrow a missing or failed part!

They've accidentally (I mean 'serendipitously' -- that has a bit more class) identified a strain of genetically engineered mice that will literally regenerate their limbs and organs and heal severed spinal cords and eyes! The offspring of the special mice can also regenerate. Perhaps even more significant is that placing cells from these special mice into normal mice give THEM the ability to regenerate!

The researchers believe that they're close to identifying the nanoscale molecule that causes this effect, and they're also working to isolate the genes that make this so.

According to longevity expert Aubrey de Grey,

"When those genes (responsible for the mice regeneration) are found, we can start to think about manipulating them in humans with drugs or (later) with gene therapy, thereby enhancing our own regeneration."

It certainly sounds improbable. BUT - the reason that mice are used to test potential human drugs is specifically because their bodies work very similarly to the way that humans work. The potential here is extraordinary.

- **Energy Efficiency.**

  Nanotechnology will also likely improve energy efficiency in many ways, such as, according to the July 23, 2004 SmallTimes:

"Novel, lightweight materials to improve vehicle efficiency;

Selective catalysts for clean and energy-efficient processes;

Increased efficiency and reduced cost of solar energy;

Methodologies enabling water to be split via sunlight to generate hydrogen; and

Efficient and low-cost fuel cells, batteries, etc."

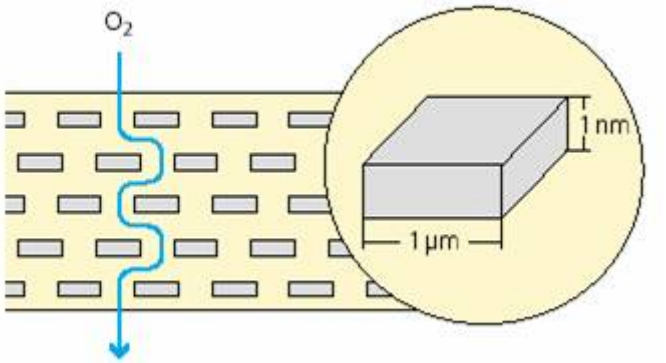
There are forthcoming tiny fuel cells, and far more efficient rolls of plastic film solar cells that may, eventually, result in a distributed and very "green" energy supply. (Not to mention "never-charge" notebooks and other portable electronic devices).

Other nano-inspired advances might include improved liquid filters to desalinate water using far less energy than current methods, and nano-air filters that could improve the environment.

- **Fresher Food.**

  This isn't about somehow shortening the supply chain from the farm to the table, but of wrapping all manner of foodstuffs in a new plastic film that is actually a "nano-wrap." Currently, there are only a few plastic films that can block oxygen (it is oxygen that causes

the fat in meat to turn rancid and makes the meat's color pale, and hastens the demise of other foods.) But according to "Securely Wrapped" in the fifteenth edition of Bayer's "Research" magazine, this new thin-film plastic wrap called "Durethan KU 2-2601" embeds a 3D matrix of nano-sized silicate platelets throughout the film, causing oxygen and other molecules to take a tortuous path from the outside to the inside. That's what keeps the contents fresher, longer.



- **And Far More**.

The potentials for paradigm-breaking "nano" products in every field are incredible, such as these noted in a July 28, 2004 BBC news article:

1 - Organic Light Emitting Diodes (OLEDs) for displays

2 - Photovoltaic film that converts light into electricity

3 - Scratch-proof coated windows that clean themselves with UV

4 - Fabrics coated to resist stains and control temperature

5 - Intelligent clothing measures pulse and respiration

6 - Bucky-tubeframe is light but very strong

7 - Hipjoint made from biocompatible materials

8 - Nano-particle paint to prevent corrosion

9 - Thermo-chromic glass to regulate light

10 - Magnetic layers for compact data memory

11 - Carbon nanotube fuel cells to power electronics and vehicles

12 - Nano-engineered cochlear implant

And that's only a partial list. The list that we'll actually populate with "nano-this-and-nano-that" will, conversely, be very long indeed.

(For more information, check out this BBC slideshow, and this blog by Walter Derzko. Also, see http://www.informit.com/articles/printerfriendly.asp?p=354352 for additional ideas of nanotech's potentials, and of some of the barriers that we'll have to hurdle as we get there).

It's Not Like We Have A Choice...

Nanotechnology is about to dramatically change virtually every aspect of how we work, live, and play; in fact the process has already begun. If you've used a UV-blocking sunscreen it may well be "powered" by nanospheres of titanium dioxide - the opaque stuff of lifeguards' noses - which, in its nano form, happens to be transparent to visible light, but not to UV. Similarly, nanospheres in your toothpaste are (or will soon be) giving you that ultra-bright smile. And Berkeley Lab's 'Materials Sciences Division' has recently demonstrated how to use a new electro-thermal technique on carbon nanotubes to turn them into "conveyor belts" that move individual atoms to precise targets, potentially forming the basis for far more efficient nanoscale manufacturing.

Yet as with the "Regeneration" potential that we discussed above, I suspect that nanotech's *premier* value will lie within - us!

According to Bayer Research,

"All spheres of life will be affected by [nanotechnology], but particularly the field of medicine. That's because life itself is applied nanotechnology.

In the course of billions of years, evolution has learned to optimally exploit its materials on the atomic level. Modeled after this principle, for example, are DNA chips for diagnosing diseases, and biocompatible implants. I would venture to predict that no branch of science will remain unaffected by the impact of nanotechnology in the next 50 to 70 years. And that in turn will be good for the man in the street; not only because he can buy more effective products, but also because this technology creates secure jobs for the future.

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"The nature of nanotechnology is to achieve effects with tiny amounts of material. That minimizes our dependence on raw materials and offers advantages in terms of recycling and disposal. The decisive question, however, will be whether we can succeed in replicating the production principles of nature and transferring them to the technical world. Living beings have innumerable nanomotors and nanogrippers. In nature, they aren't produced by machines, but by the principle of multiple, parallel self-assembly, controlled by proteins and genes."

Risk vs. Reward -- Be Vigilant!

The potential of a nano-future certainly seems bright. By you might also be (rightfully) thinking: *"As valuable as nanotech may be, how can we possibly deal with the similarly high risks that we can't, currently, even define?"*

Indeed, some risks are very real. Yet "risk" has been the case with virtually every technological (and social) development throughout history. Remember the origin of the Nobel peace prize? Or communism? From the Bayer report:

"Any new technology is associated with risks. Stone age man discovered the hand axe to cut materials, but the tool was also a powerful weapon. But nanotechnology doesn't pose any greater threat than other established technologies.

In any case, there's no sense in elaborating frightening scenarios that are just as misleading as naive promises that "the whole thing's harmless." It would be more effective for the development of this new technology to be accompanied by information, education and critical examination."

Besides, it's not really a matter of IF we're ready for nanotechnology. Working at the same scale that Nature does is already here, and moving forward ever-faster.

A Vitally Important Race!

Even if some governments were to ban or restrict nanotech research, others would encourage it through enhanced education and funding to help them gain a nano-edge. "Nano-crippled" or "nano-banned" countries will fall far behind on this new, vastly more important technology curve. An Emailed teaser of findings from a recent Lux Research study, *" How Leading Countries Compare in Nanotech,"* offers a few brief insights into the current state of global nanotech leaders:

"Attention tends to focus on widely-publicized efforts like the U.S.'s $3.7 billion, four-year National Nanotechnology Initiative. But competitive nanotech efforts also appear in unexpected countries. Consider that:

- *China has moved from also-ran to power player when it comes to nanoscience. China's share of academic publications on nanoscale science and engineering topics rose from 7.5% in 1995 to 18.3% in 2004, taking the country from fifth to second in the world.*
- *Iran's NanoTechnology Initiative was ordered by none other than former President Mohammed Khatami. Applications focus on fields ranging from textiles to agriculture; the country's Agriculture-Jihad ministry recently launched a nanotech web site.*
- *Thailand's Ministry of Science and Technology devised a nanotechnology plan that went before the country's cabinet in June, recognizing that the nation has missed past tech*

waves but can get in early on this one. It calls for training 2,500 researchers, registering 300 patents, and spending $294 million over ten years."

The results of this race -- it is a critical race -- could easily change the global balance of power.

So it's up to us -- to all of us -- to assure that nanotechnologies are developed quickly, and deployed in a safe and sane and positive manner. Because it will happen. With or without us.

It's up to us, today, to chart our competitive nano futures, and to be sure that the resulting nano-world is a place in which we'd like our kids to live.

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