NANOTECHNOLOGY

An illustrated public lecture given by Robert Anderson PhD

(28 pages and 48 slides)

Robert Anderson first presented this lecture in 2007.

N.B. Some facts and figures may have subsequently changed.

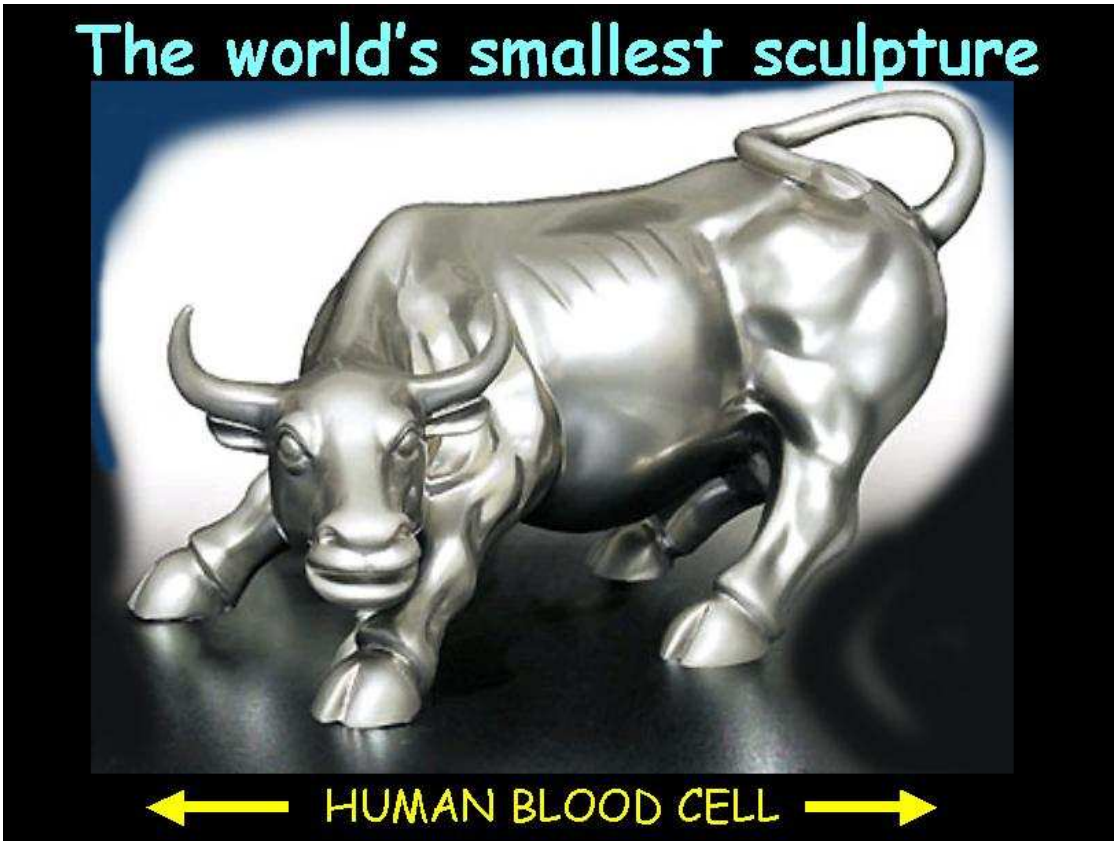
Sadly, Robert died in December 2008. Teaching was his passion and his profession. He held a combined honours degree in Physics and Chemistry, and a PhD in Science Education. He wrote for periodicals and authored 11 books.

Enquiries about his books should be addressed to connectedbooks@clear.net.nz.

Slide 1

In August 2006, scientists from Osaka University unveiled a beautiful sculpture.

Slide 2



This sculpture was made using lasers and it is the kind of work that is now common to the technology we going to talk about - Nanotechnology.

Nanotechnology is set to profoundly change our lives. The Internet became a self-supporting industry in 1995. A decade later, many people would have had difficulty understanding the concept.

Nanotechnology is at that same stage today, but in the very near future nanotechnology will be part of our everyday vocabulary and will affect almost everything in our lives.

Nanotechnology is the science and engineering of things so small they are measured in billionths of a metre and are even invisible to some powerful microscopes.

The scientific community generally attributes the concept of nanotechnology to the brilliant Nobel physicist Richard Feynman.

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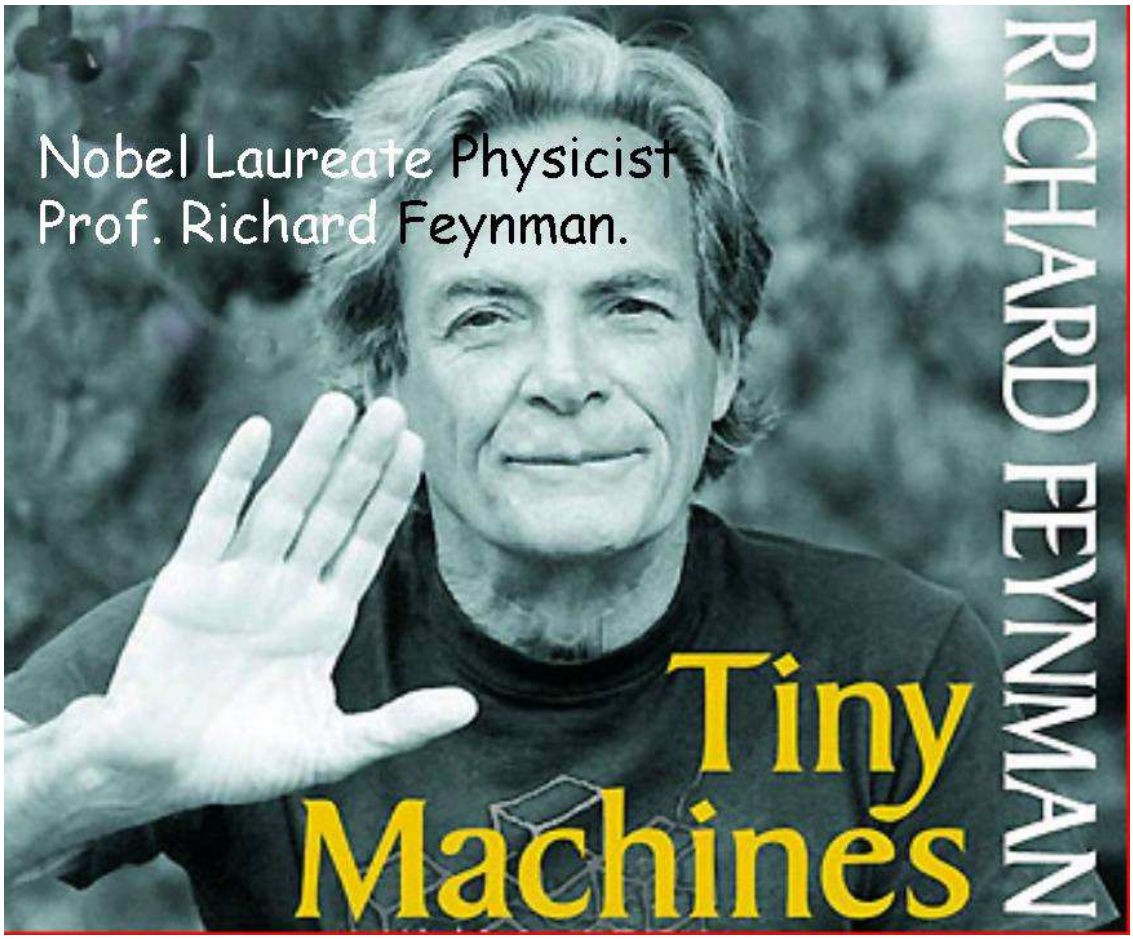

In his famous 1959 lecture - *"There's Plenty of Room at the Bottom"* - Feynman first proposed that the properties of materials and devices at the nanometer range would present vast future opportunities. He described how the entire Encyclopaedia Britannica could be written on the head of a pin, and how all the world's books could fit in a pamphlet and that machines could be built atom by atom.

What does industry think today?

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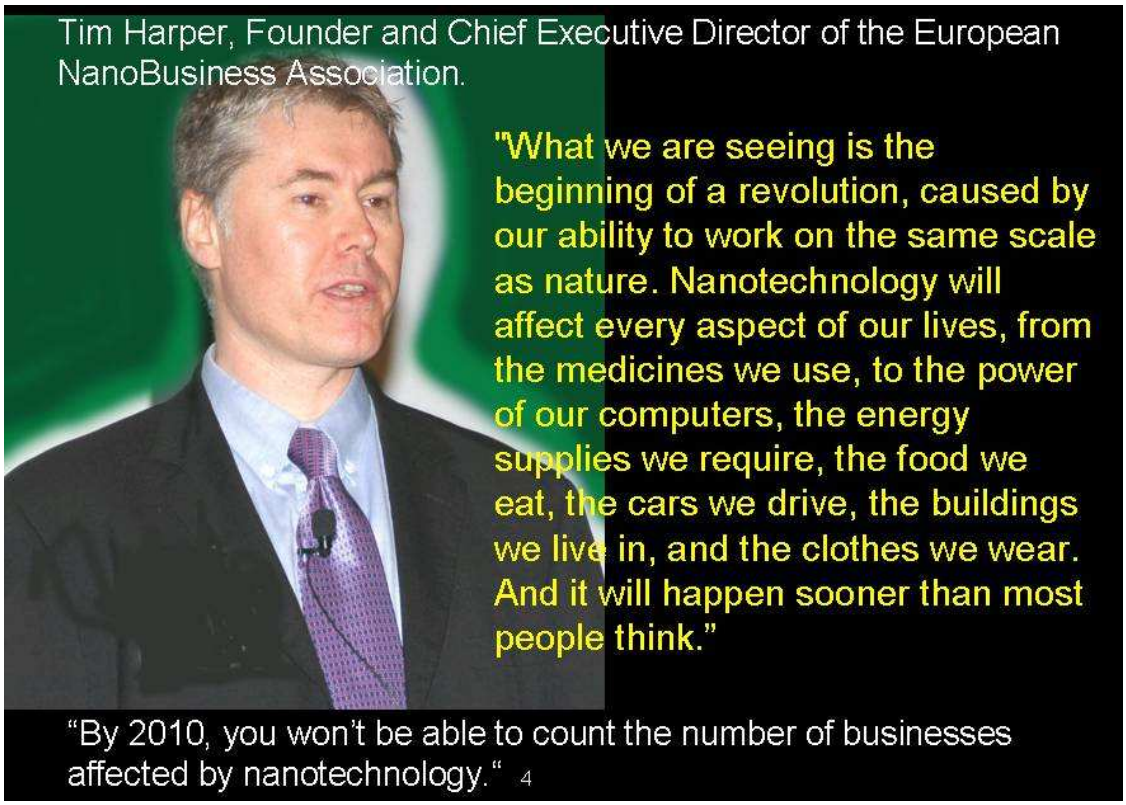
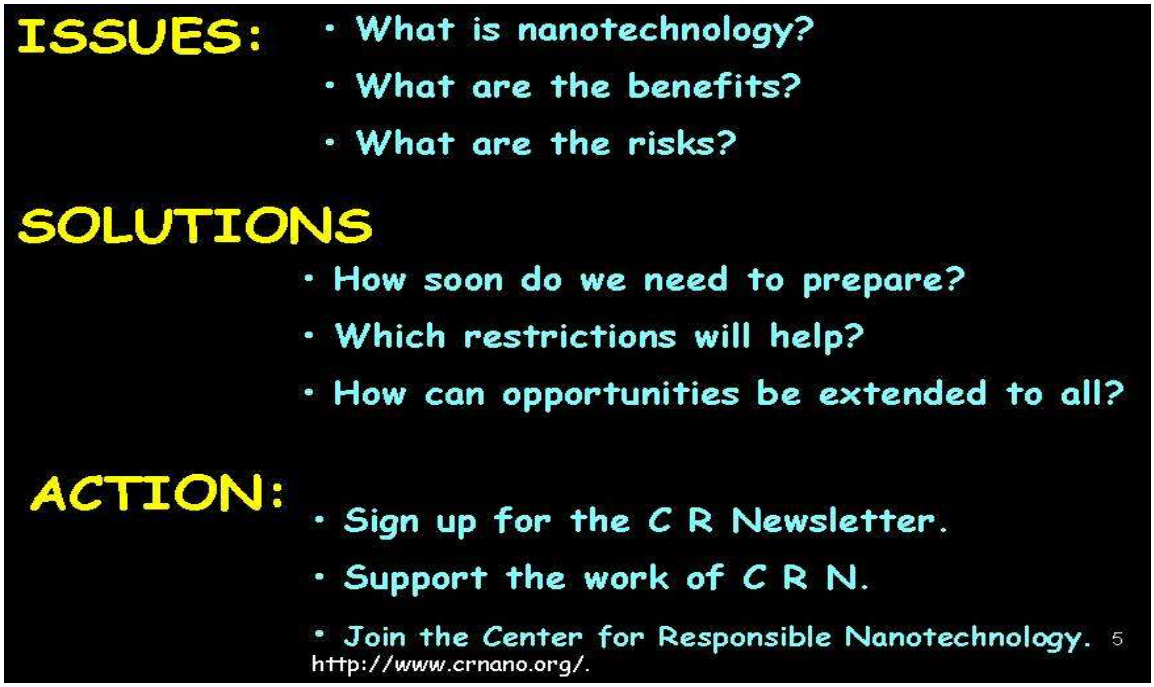


What is so special about nanotechnology? The nano world turns ordinary reality upside down, and this is very exciting to those working in this cutting-edge research. When substances are broken into nano-sized particles, their properties change dramatically, metals may become transparent, inert substances may suddenly become chemically active, and insulators may even begin to conduct electricity. For a given amount of material, as particle size *de*creases, surface area *in*creases enormously. Nickel and iridium nanoparticles have an extremely high surface area, and have found important uses as catalysts for a whole host of chemical reactions, and chemical cracking applications. So… what do we need to look at?

Slide 5 - Issues - solutions - action



Ok, so let us see what nanotechnology is.

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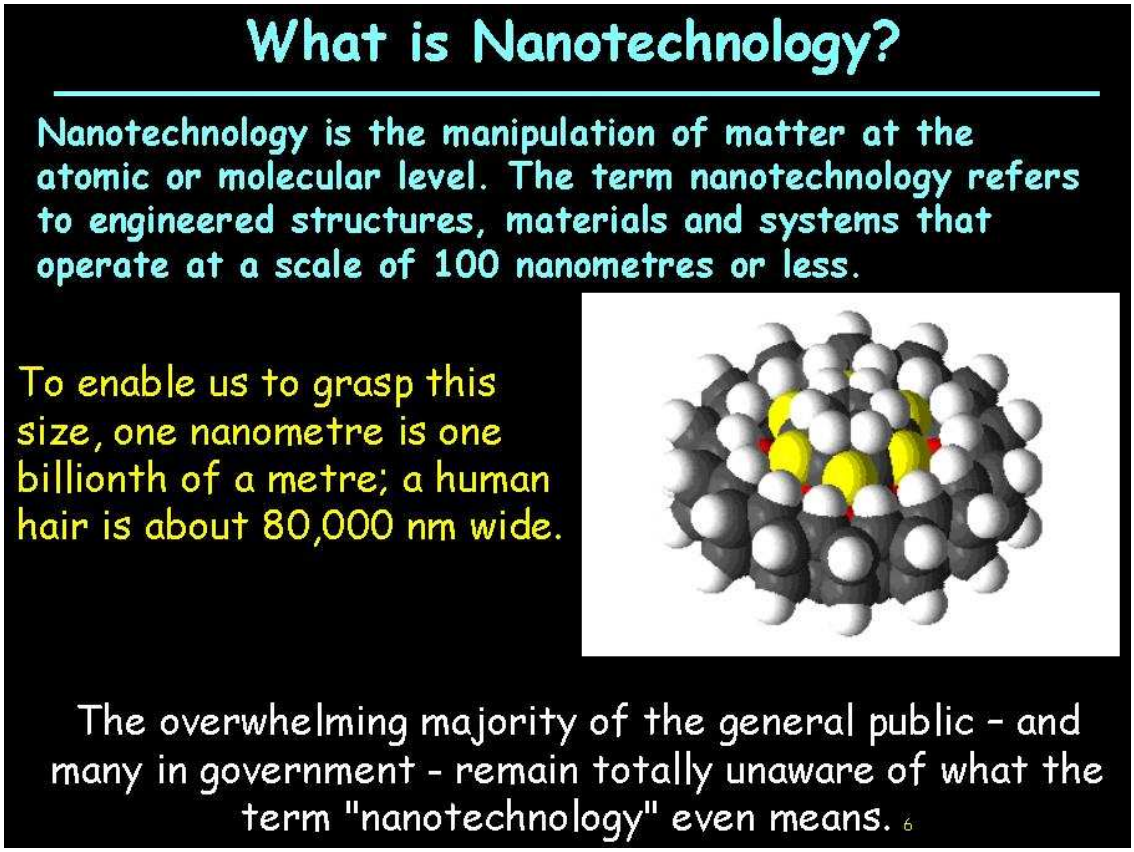

There are many wonderful applications on the horizon for the use of nanotechnology. Because of the tiny scale we can produce instruments that will be small enough to work in the confines of the human body. It will be much easier to understand if we look at a scale diagram of this ultra microscopic world.

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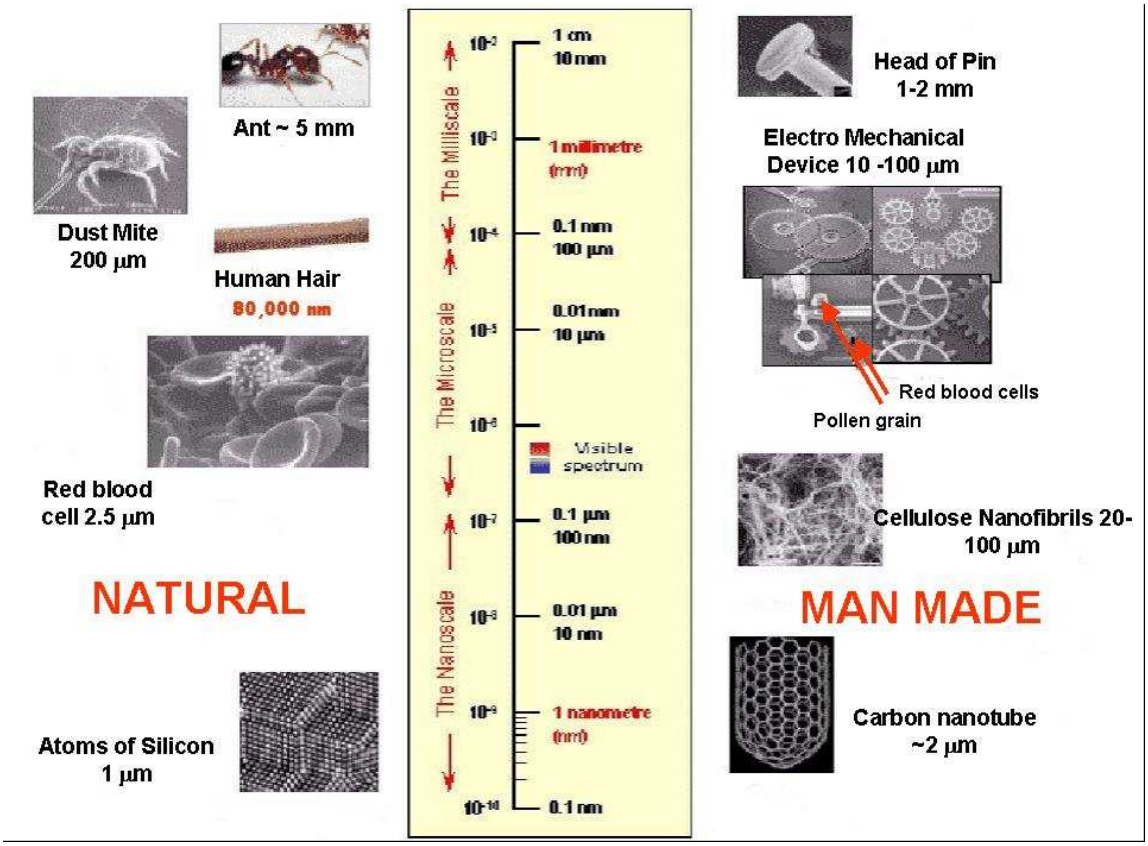

This is a whole new concept. It will revolutionise our world in a very profound way, much the same as the industrial revolution did. Because of this we need strict regulation and The Centre for Responsible Nanotech at least is a starting point for this. Let us look at what nano machines look like.

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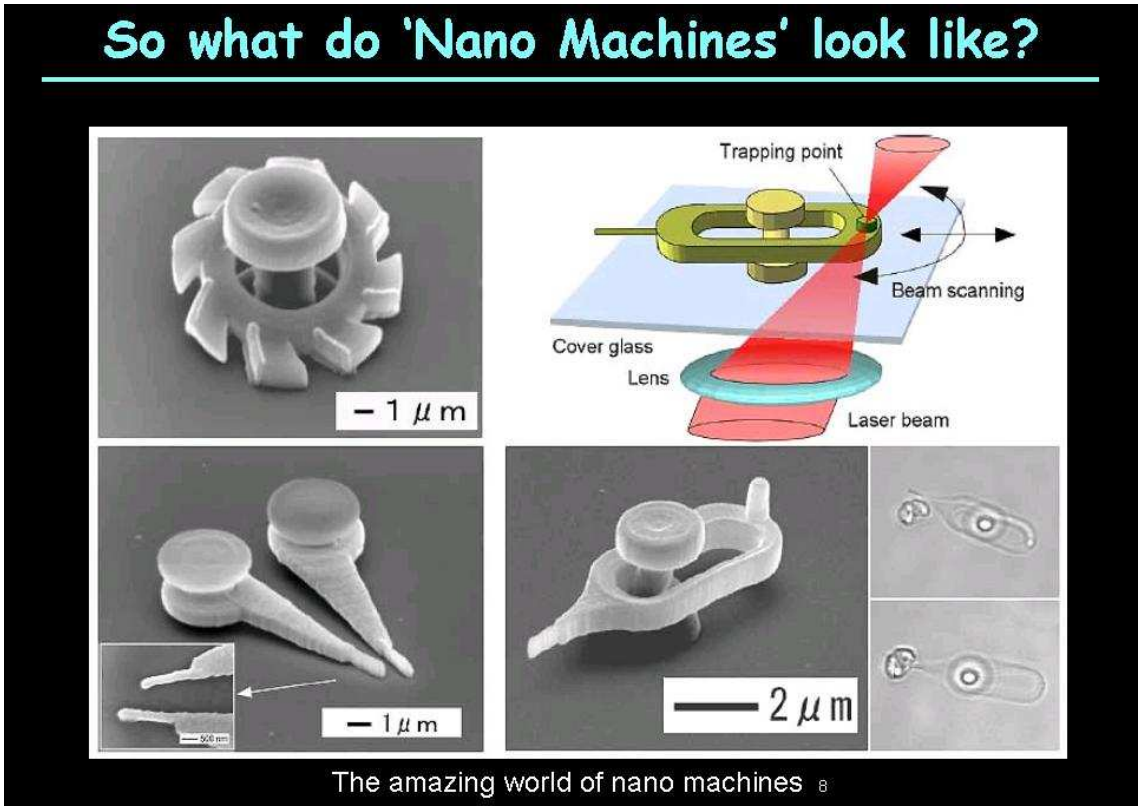

Using lasers and other technologies, these machines will be able to carry out enormously difficult tasks. They will be able to fit into areas where man has never been before: into blood capillaries, kidney cells and even our brain cells. We are talking here of the *very*, *very* small indeed.

I can illustrate this best with a cartoon.

Slide 9

Fourth generation nanotechnology - molecular manufacturing - will radically transform our world and the people of the early 21st century. Nanotech *really will* have a profound effect on our lives.

Slide 10

All this sounds laudable, but, like the promises of made of genetic engineering technology, profit and not consumer interests are more likely to be the driving forces. Moreover, as this technology progresses the industry is becoming aware that they are virtually free of regulation.

Nanotechnology is being applied to food and agriculture.

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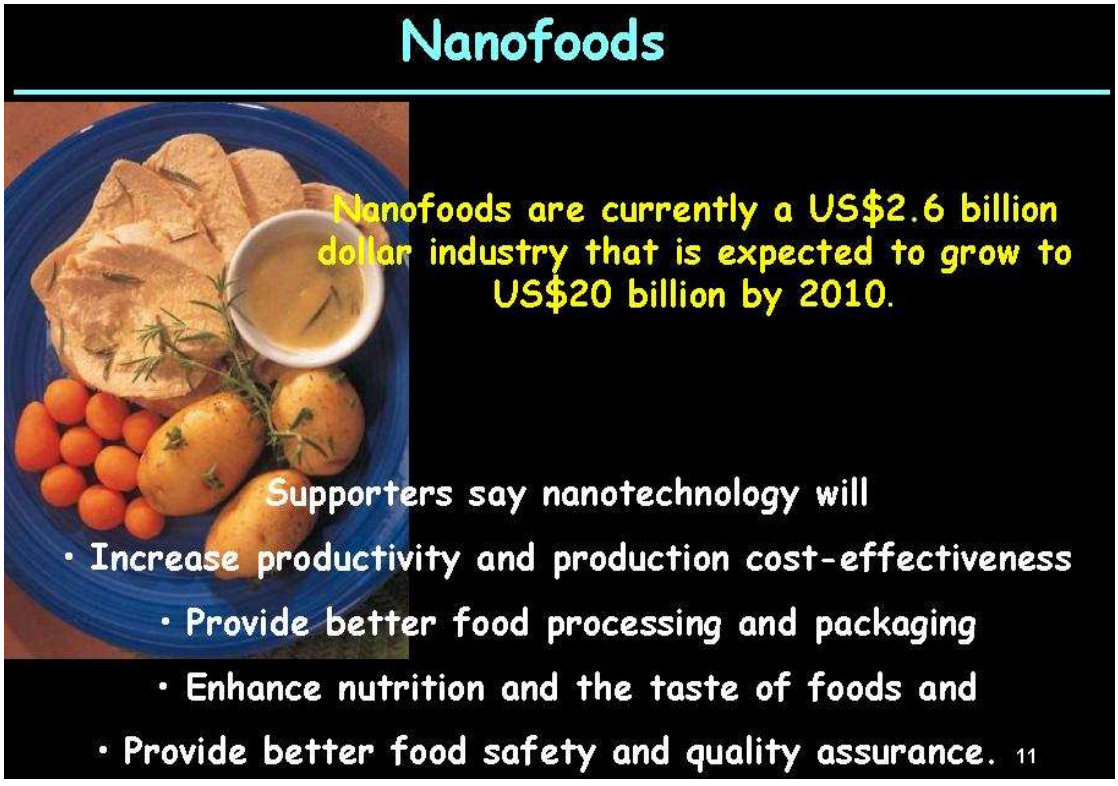

The same kind of claims were given by the biotech industry about genetic engineering technology and were not met, and we know that genetically engineered foods have still not been adequately tested by independent scientists to satisfy the *precautionary principle* in respect of safety.

Let me give you some examples of foods that use nanotechnology: ice cream containing nanoparticle emulsions to "improve" texture; "interactive" drinks which can change colour or flavour; nanocapsules concocted to smuggle flavours or nutrients into the body without any labelling. Kraft, Nestle and Unilever all use nanotechnology in their food products. This is another double-edged sword, but this time very much sharper and more dangerous than genetic engineering.

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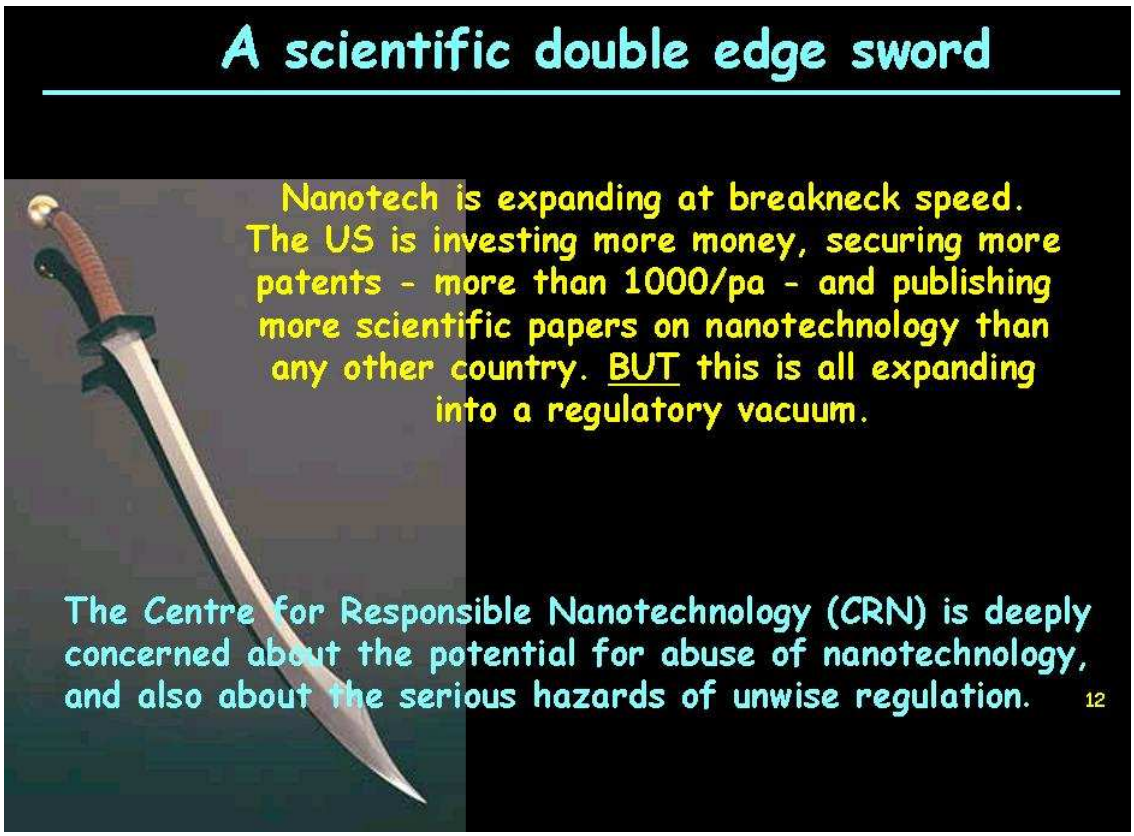

We have no form of regulation controlling this runaway express. We may end up with far greater dangers than asbestos or the nuclear industry produced. It is instructive to look at some of the dangers beginning to emerge. Recent studies highlight dangers; for example, nanoparticles from foods and cosmetics can enter the brain from the bloodstream and potentially cause health problems.

I would like to read you a paragraph from *The Tiniest Science*, an article that appeared in the New Zealand *Listener* (24 March 2007):

Speaking of Don Eigler,[1] described in the article as "a grandee of science, who spoke at a recent Wellington nanotechnology symposium": "He's convinced that nanotechnology will permeate almost every aspect of human life. 'The impact is likely to grow very dramatically. And much of the impact you'll never know about because it doesn't matter to you if you've got nanoparticles in your sunscreen. It matters to you that your sunscreen works."

The article speaks like technological evangelism at its snake-oil best. It is all so good and glossy and are we glad to have it! Eigler even says: "We need some aspects of nanotechnology to get to the point where grandmas identify it as nanotech and love it." Why then is nanotechnology not identified on packaging or in foods?

Will we get adequate regulatory research and control? How will we handle nano waste? Will the nano proponents' promises come to fruition, or are they designed to attract research funding? How safe is nanotechnology? Here are some initial findings:

[1] Don Eigler is a physicist at the IBM Almaden Research Centre in the US (http://en.wikipedia.org).

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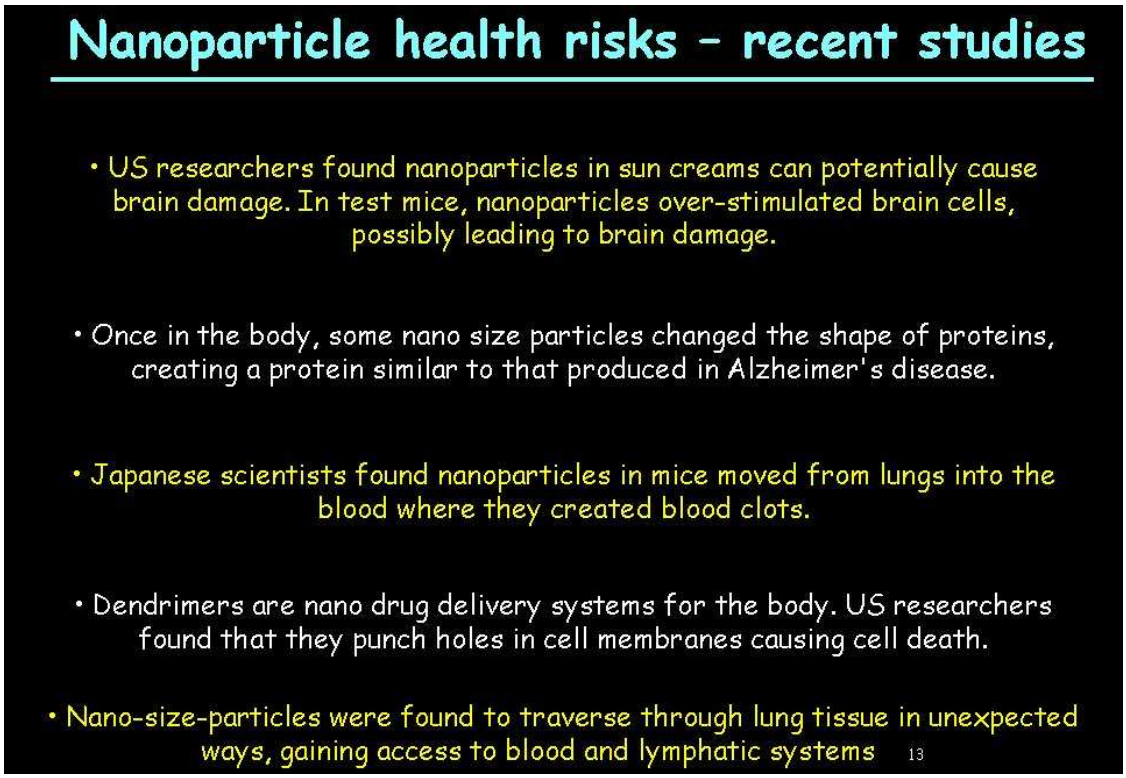

Nanotechnology is an industry crying out to be strictly regulated. As more and more problems arise, the likelihood of litigation and lawsuits from serious human health problems will arise. But let us look at the industry hype…

Slide 14

The prospect of what do we do with the waste nanomaterials is also significant? David Rejeski of the *Woodrow Wilson International Centre* thinks the waste question deserves an urgent answer. He said, and I quote to you:

"Who knows what happens when you grind this stuff up, incinerate it or it goes into a landfill? These products may be safe in the tennis racket, but all products become obsolete at some point - if nothing else because they go out of fashion."

It is a very important question. Sixty five years down the track, the nuclear industry still has no answer to their waste problems.

Slide 15

No one in the chorus mentioned that the US has never *effectively* regulated her nuclear OR petrochemical industries. The vast majority of chemicals in commercial use today have never been safety-tested and 1800 new chemicals enter the market place each year *almost entirely untested* for effects on human health or the environment. Is there any reason to believe that the nanotechnology industry will be any different? Basic questions like *can nanomaterials concentrate inside humans* or *how biodegradable are nanotube-based structures* urgently need answers.

A substantial sector of the environmental movement is committed to the "regulatory" approach. They have teams of attorneys and scientists spending millions of dollars trying to impose largely ineffective regulations on this industry. It is a kind of symbiotic dance between the industry and the environmentalists, each pretending to be scientific and effective.

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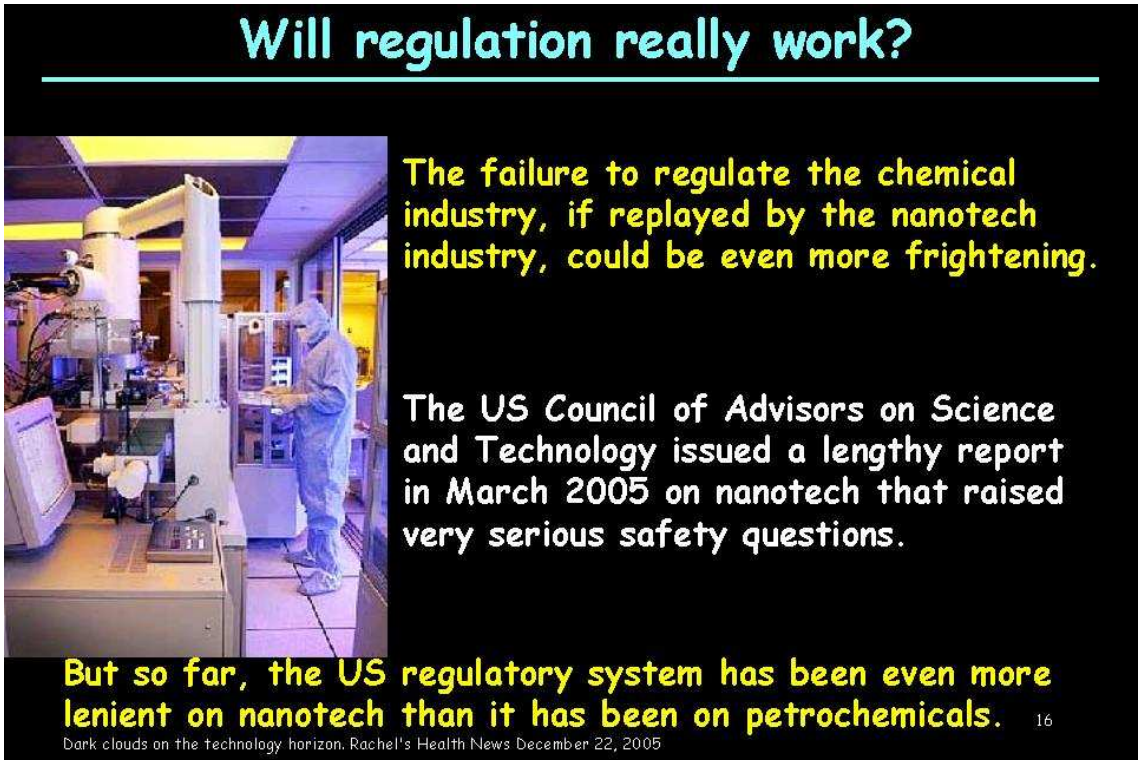

Let me illustrate for you just how 'regulators' can handle nanotechnology.

Regulators declared that nanoparticles of titanium or carbon are no different from a bulk quantity of titanium or carbon, and so no regulation is needed. Now… let us think about this for a moment. If there really were no difference between bulk quantities of a substance and the same substance in nano-sized particles, there would be no advantages to nano particles and *therefore no nanotech industry.*

Here is a simple example of what can occur when a particle becomes nano-sized. Gold is inert in bulk, but in the nanoparticle size it turns blue and binds to human DNA.

This is how regulators handled genetically engineered plants. They decided that transgenic crops are substantially equivalent to their conventional equivalent.

You can see that regulators are still clearly aiming at letting an industry develop as rapidly as it can, without regard to consequences. Government regulators are helping the nanotechnology industry get products to market, create jobs, and grow large before we, the public, notice.

Effective regulation will be impossible after the industry has grown because vested interests and jobs would be jeopardized, pitting such like against public health specialists (who would otherwise be natural allies). This "divide and conquer" strategy worked like magic with lead-in-gasoline, asbestos, and the nuclear industry, among many others, so there is no reason to think it will fail with nanotechnology. The money alone, now pouring into this field, is indicative of the enormous growth envisaged. Let me illustrate this for you..

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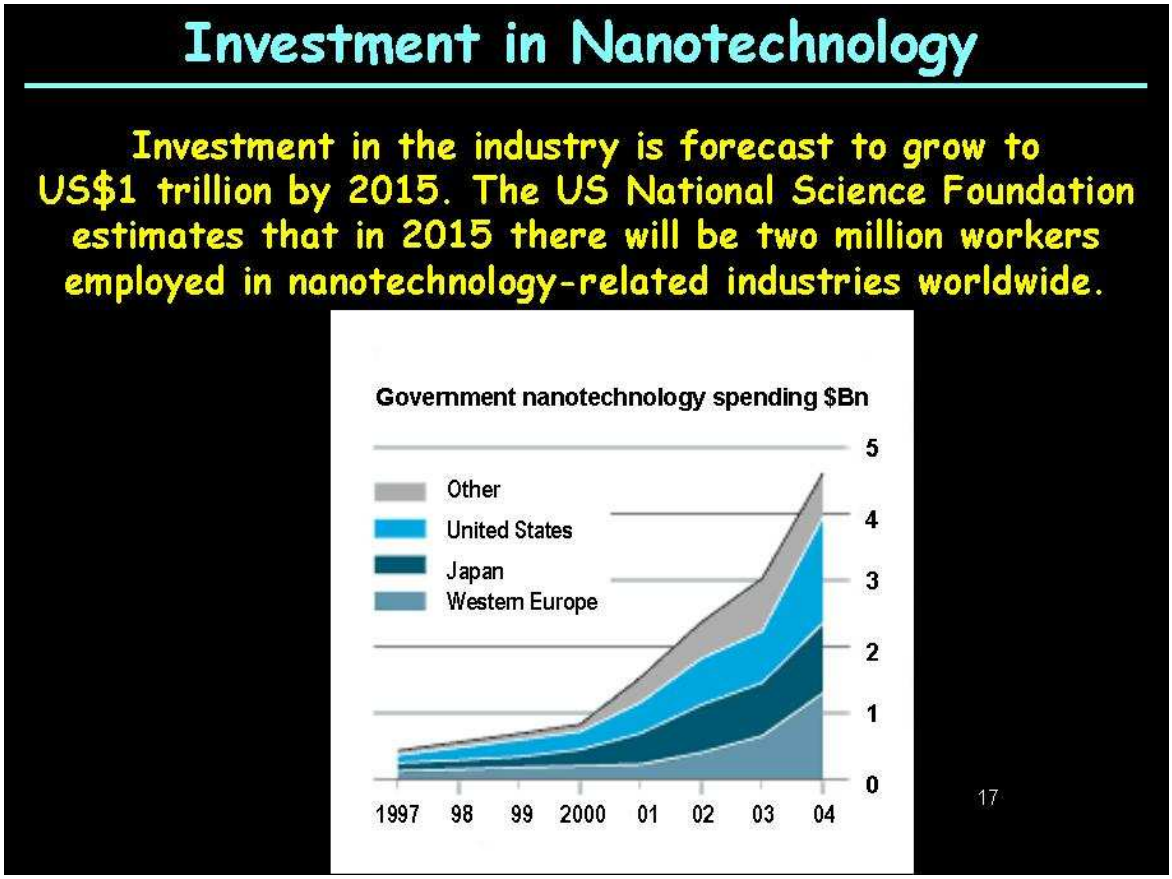

The US is investing more money and securing more patents - more than 1000 per year - and publishing more scientific papers on nanotechnology than any other country. We can see the focus of the industry from this pie chart…

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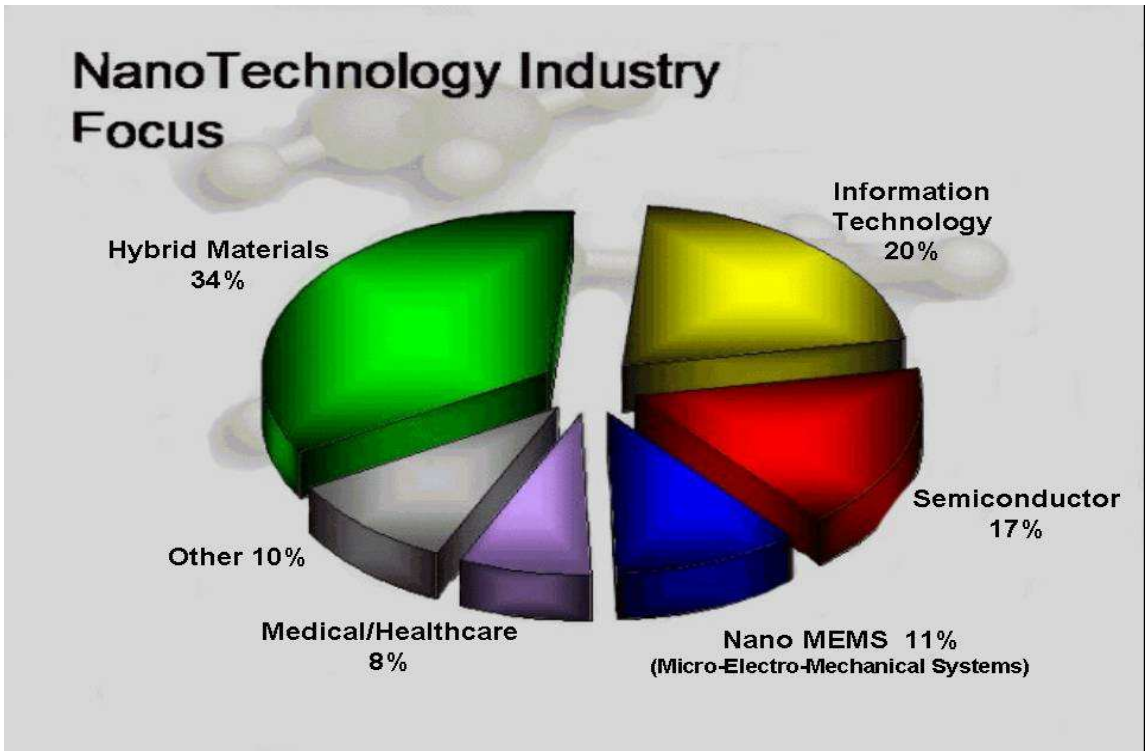

And this is just the beginning. Just the beginning...

Ok, let me give you some idea of the mind-boggling feats possible with this technology:

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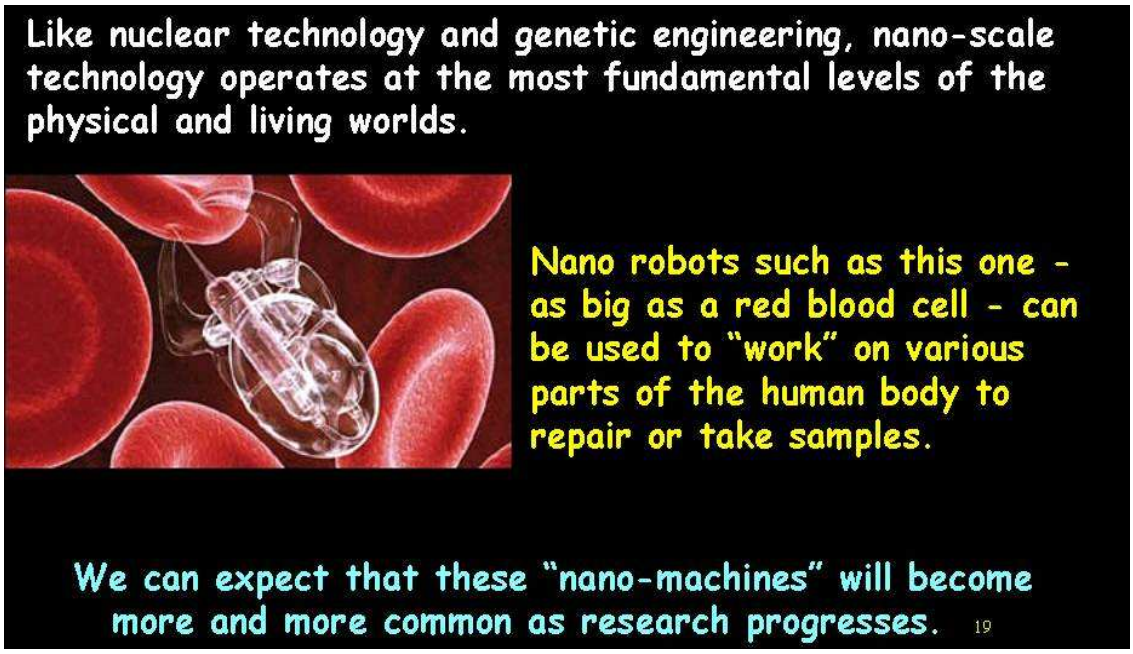

Nano-scientist, Dr Robert Freitas, designed a simple nano device, the respirocyte, that acts as an artificial red blood cell. It is made out of pure diamond. It works far more efficiently than a red blood cell, mostly thanks to the massive pressure that can be sustained within its rigid diamondoid shell. If your blood were saturated with respirocytes, it would become potentially possible for you to hold your breath underwater for hours, or sprint at top speed for hours.

With nanotechnology, it could become possible to "overclock" the biological processes of any life form.

So what other medical miracles can we expect from nanotechnology? In the microbiological field, for instance, antimicrobial dressings using silver nanoparticles are proving very effective..

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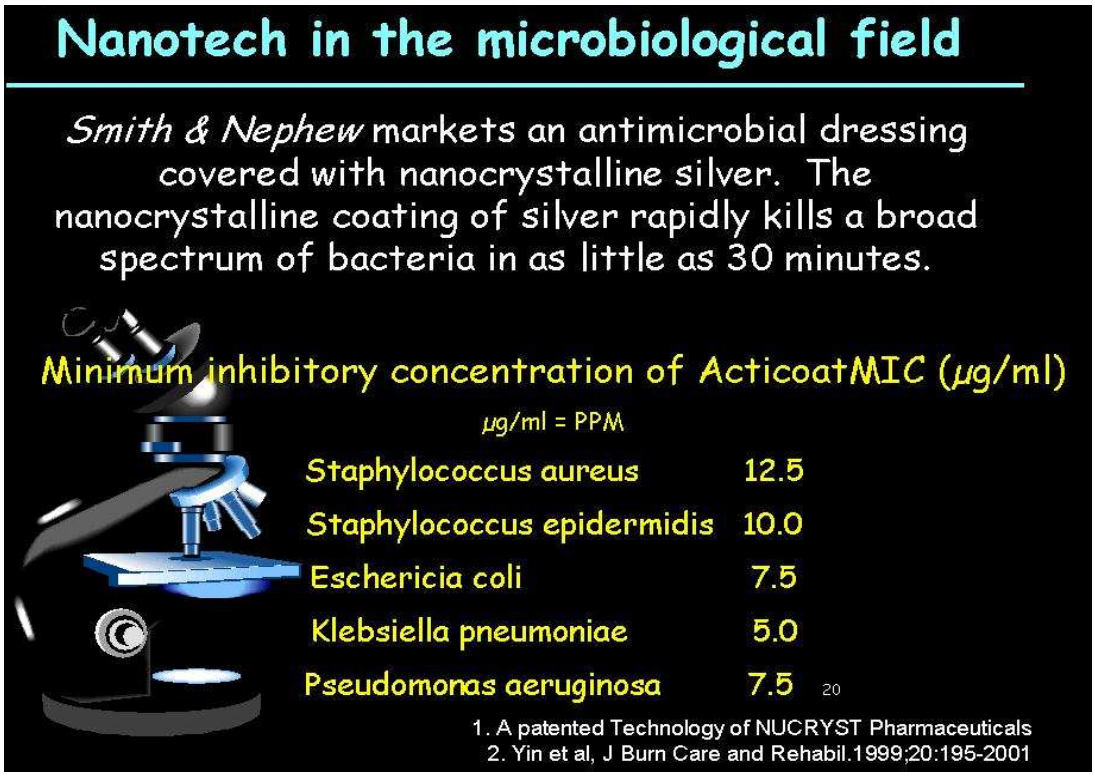

This is a powerful weapon against infection, especially with antibiotics failing. But what about handling waste?

How else can nanotechnology be used in the medical field?

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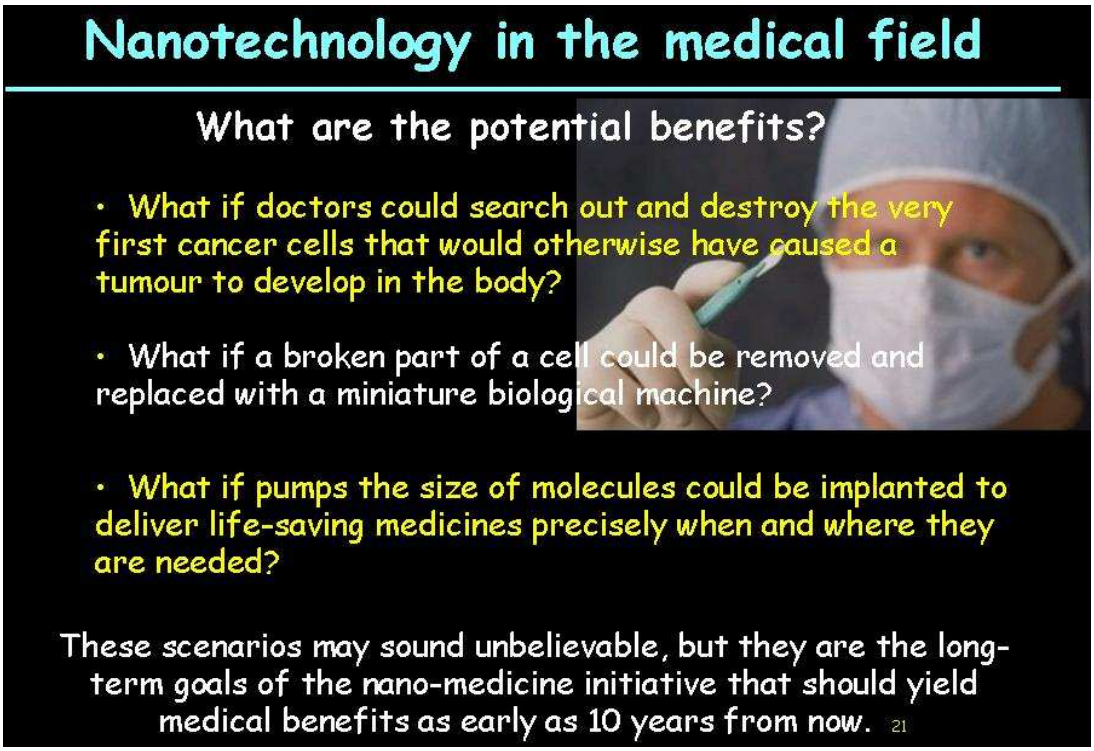

Such ideas could have wonderful possibilities. Researchers at Harvard University have achieved the ultimate in sensitivity: the detection of individual viral particles. The group's sensor uses nanowires and can electrically detect the presence of *a single virus*.

The most elementary nanomedical devices could be used to diagnose illness. Nanomachines could be employed to monitor the internal chemistry of the human body. So how could nanotechnology effect our medicine of the future? Some of the claims are worth looking at...

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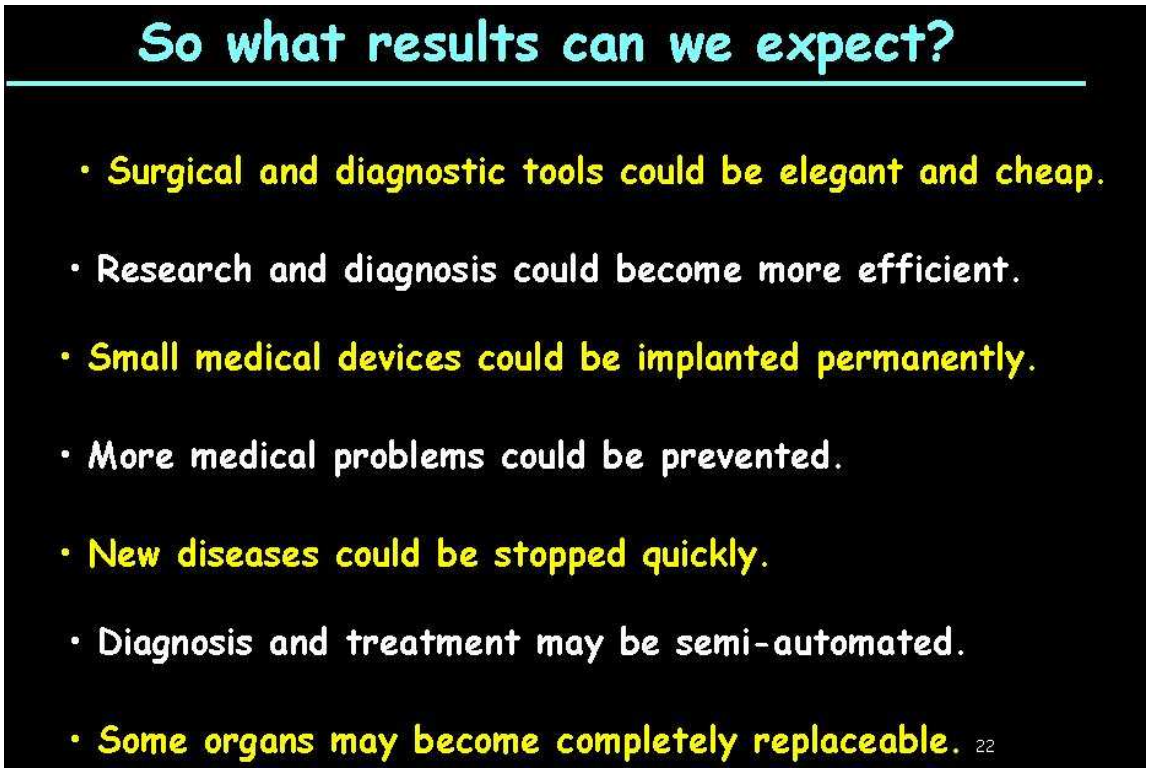

It is worth taking a moment to look in more detail at some of these devices. I mentioned earlier the artificial red blood cell designed by Dr Robert Freitas called a respirocyte. This is just one of these exciting devices to aid medicine.

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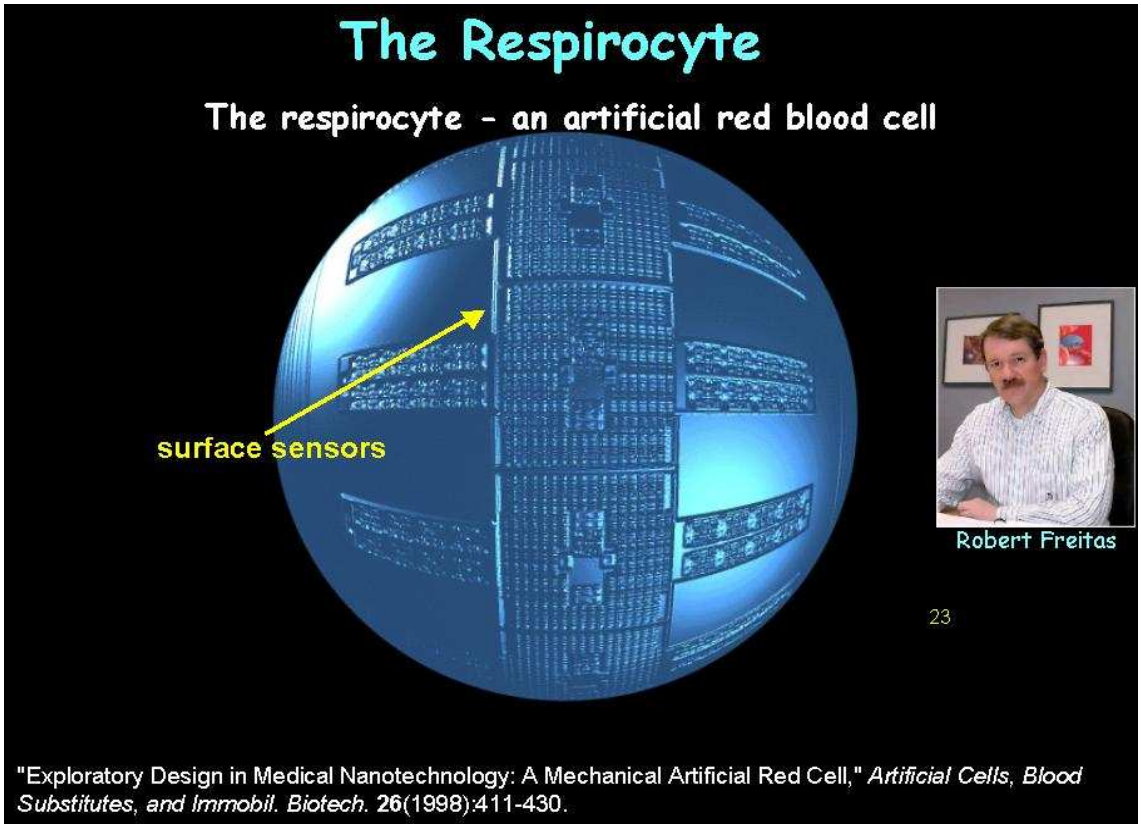

The original version of the refereed paper describing respirocytes was submitted for publication as far back as *April 1996*. Let me quote to you the operation and uses of this remarkable device:

“Medical Nanomachines will be among the earliest applications produced. The artificial red blood cell or ‘respirocyte’ proposed here is a bloodborne spherical 1-micron diamondoid 1000-atm pressure vessel with active pumping powered by serum glucose, able to deliver 236 times more oxygen to the tissues per unit volume than natural red cells and to manage CO_2 acidity. An onboard nanocomputer and numerous chemical and pressure sensors enable this complex device to be remotely controlled by the physician via externally applied acoustic signals.

“Primary applications will include transfusable blood substitution; partial treatment for anaemia, perinatal/neonatal and lung disorders; enhancement of cardiovascular/neurovascular procedures, tumour therapies and diagnostics; prevention of asphyxia; artificial breathing; and a variety of sports, veterinary, battlefield and other uses.”

I think you will agree this is really mind-boggling stuff.

Carrying oxygen to muscles and tissues, this device would allow us to stay under water for half an hour or more. Here is an artists impression showing them flowing through an artery

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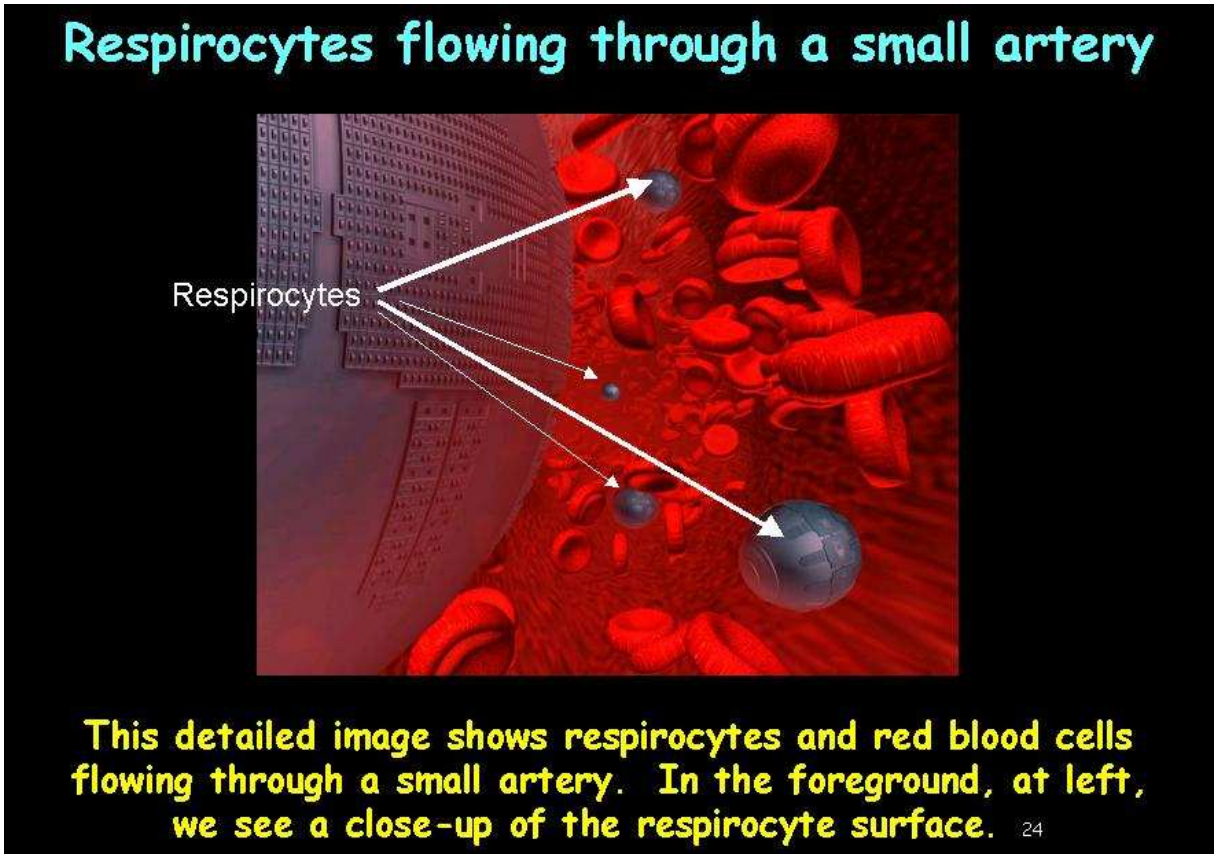

Another nanomachine on the drawing board is a device to repair damaged nerves. This would have application accident victims with spinal cord or brain damage.

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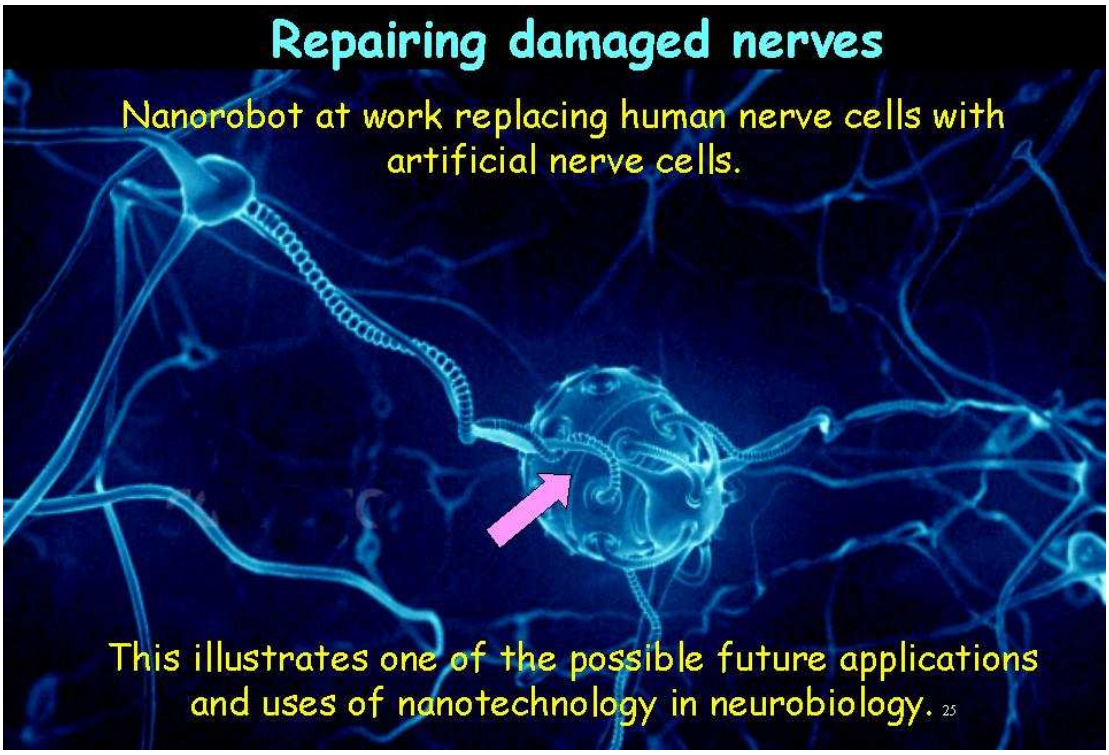

These are the type of projects that nanotechnologists and scientists are engaged in at places like Princeton University and M.I.T. These people are already redefining the meaning of the word miniature. Already, nanotechnologists have built gears far thinner than a human hair and tiny molecular "motors" *only 50 atoms long*. But that is just the beginning. Within a few decades, scientists predict, they will be creating machines that can do just about anything, as long as it is small. I am not joking when I say to you that if the nanotech guys are right, when you call your doctor in the future he may just reply: "Take two teaspoons of diagnostic sensors, and call me in the morning."

A further use of nanorobots would be the removal of viruses. Just in case you do not know what a virus looks like, here is an example.

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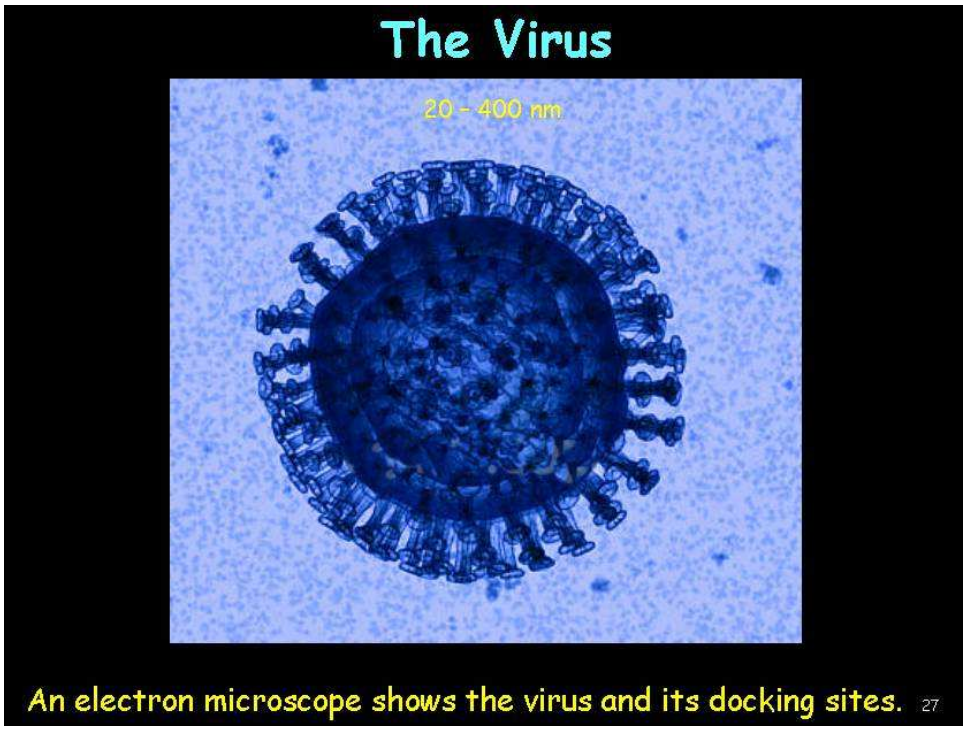

Our arsenal of antibiotics have shown a decline in dealing with such menaces. With nanorobots, however, we may have a much more efficient weapon.

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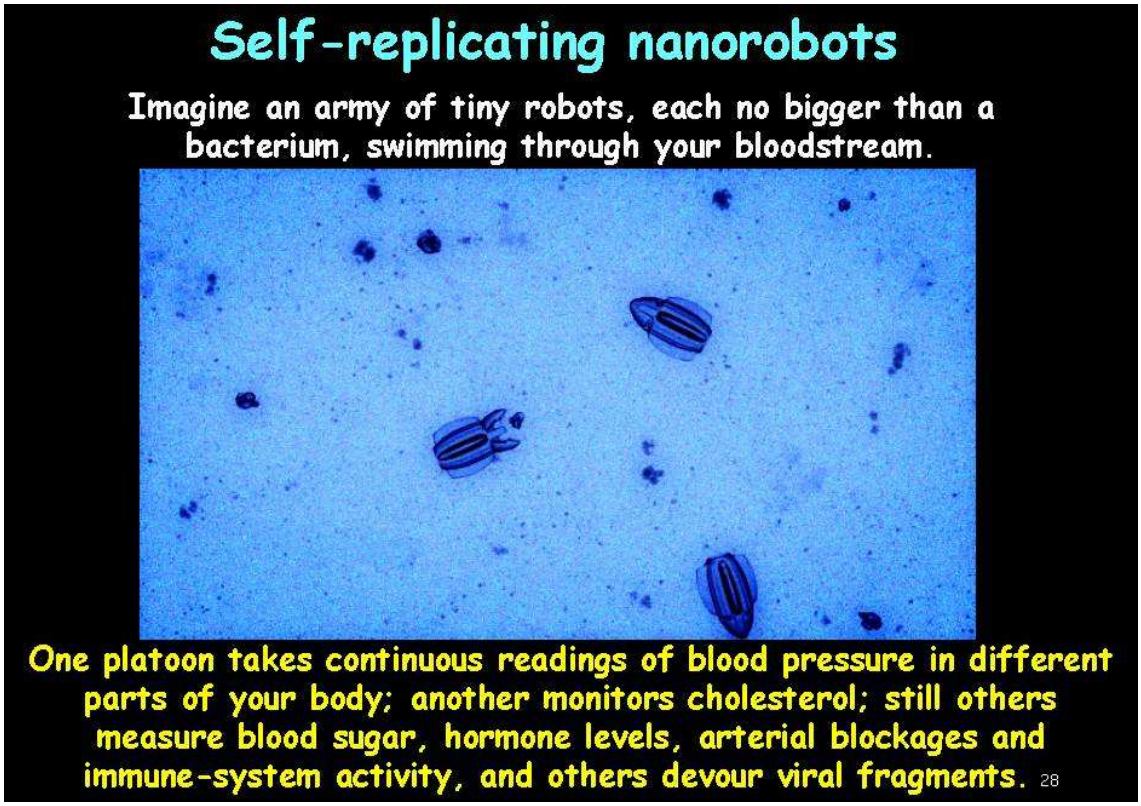

All this is exciting provided we also know how to stop them replicating when the job is done. The biomedical fields have found near limitless uses for nanoparticles. Another example is artificial bone composites now being manufactured from calcium phosphate nanocrystals. These composites are made of the same mineral as natural bone, yet have strength in compression equal to stainless steel. Already nanomaterials are finding a place in dentistry as confirmed by my dentist.

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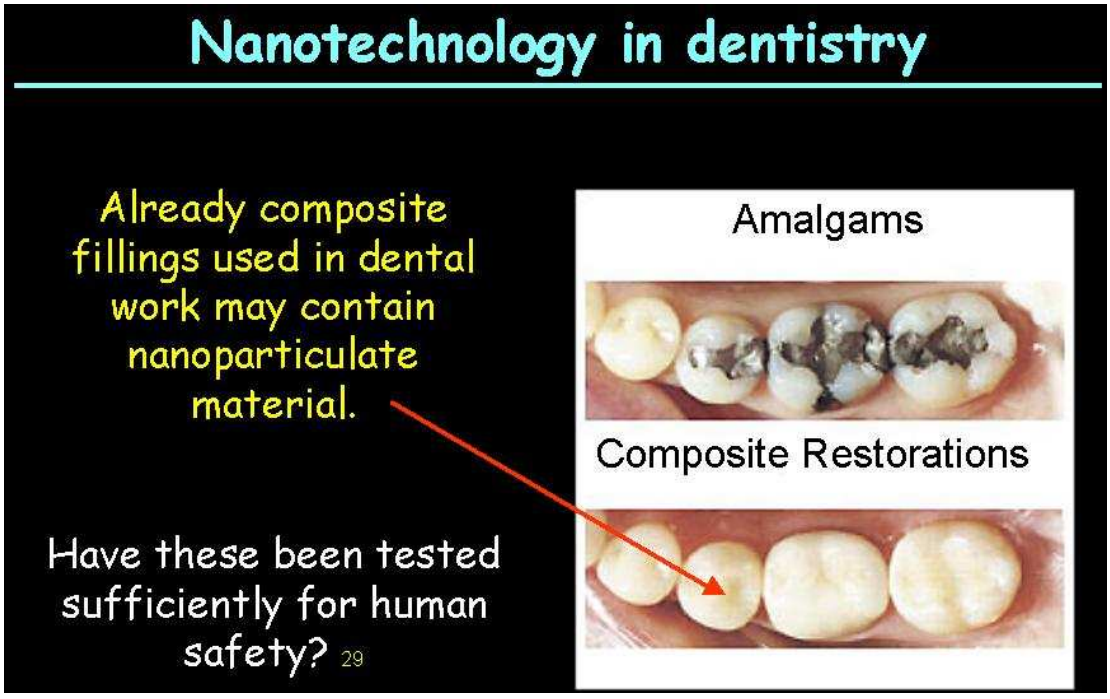

Potentially, this composite material could be ground off and swallowed by the patient. The chances are it would pass harmlessly through the body, but these materials do need to be scrutinised for health hazards.

Another remarkable application is filtration techniques. US firm *Argonide Nanomaterials*, have manufactured a super filter nanofiltration product capable of filtering the smallest particles - even viruses. The performance is due to its nano size alumina fibber, which attracts and retains even nanosize particles. It is worth looking at the specifications…

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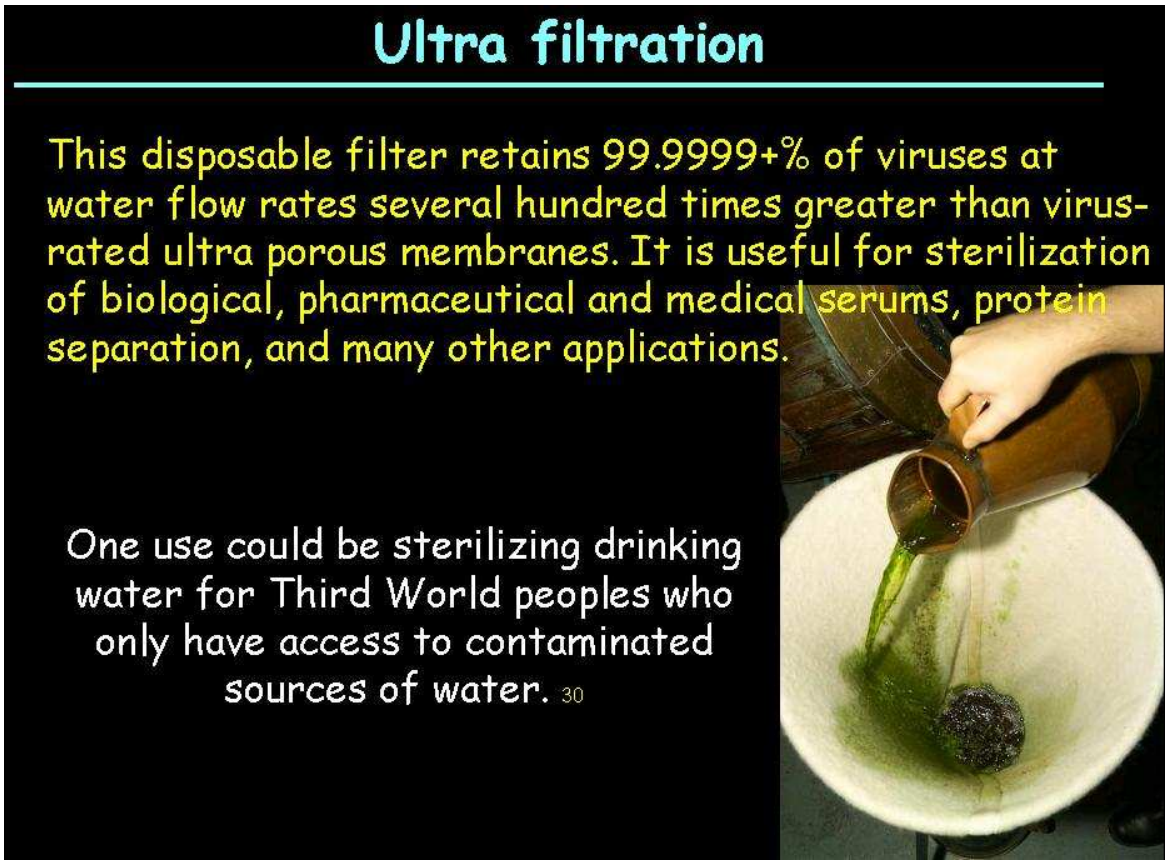

I've used various filters in my laboratory and it takes some imagination to conceive of this level of filtration. To be able to filter to this level is staggering and demonstrates the power of applied nanotechnology.

So who is paying for the R & D?

Money for nanotech is rolling in. The National Institute of Health recently awarded US$10 million to Emory University to establish a cancer nanotechnology research programme. The goal is to develop a new class of nanoparticles for molecular and cellular imaging. The primary focus being on improving the detection and treatment of prostate cancer.

So great strides are being made in the medical fields. BUT - and this is a big but - problems are looming.

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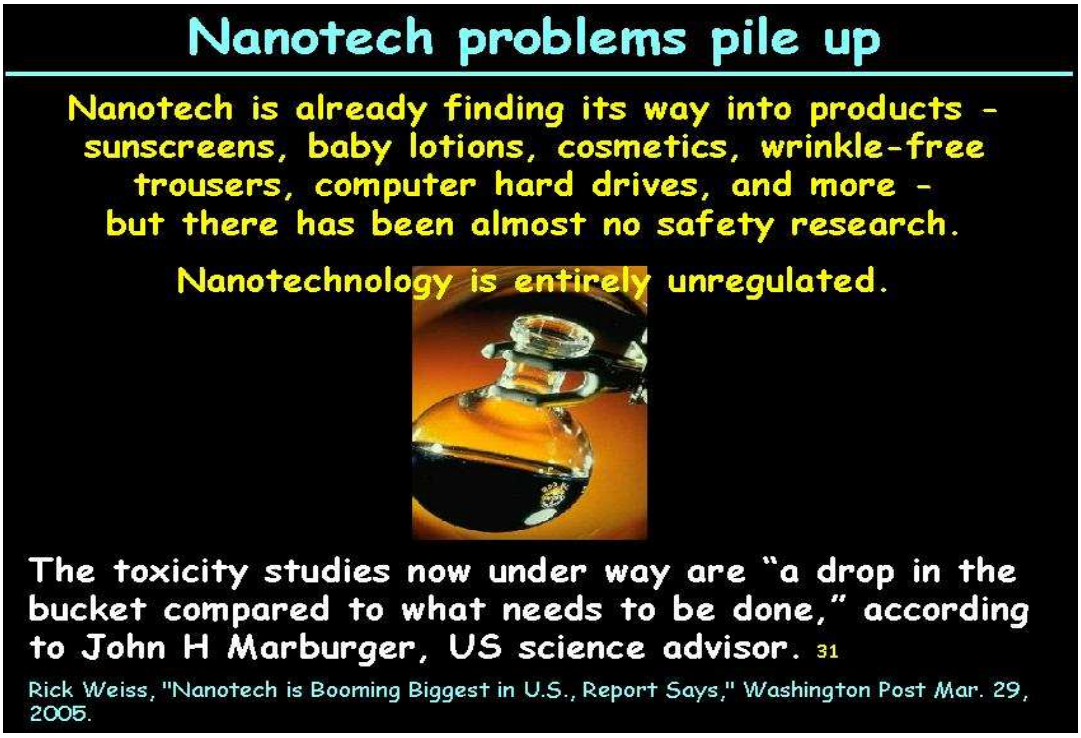

We need to understand the potentially catastrophic consequences of freely unleashing industrial nanotech. For example, scientists and policy-makers have warned that women are acting as unwitting 'guinea pigs' for the cosmetics industry. Some of our most popular health and beauty products now contain ingredients manufactured using nanotechnology. So how soon do we need to prepare?

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For several years, BASF have been among the leading suppliers of UV sunscreens based on nanoparticles of zinc oxide. Incorporated in sun creams, the small particles filter the UV radiation out of sunlight. Because of their tiny size, they remain invisible to the naked eye and so the cream is transparent on the skin. These sunscreens were so successful that by 2001 they had *captured 60% of the Australian sunscreen market*.

As I have said, the commercial applications of the technology are so new it is not subject to any special licensing or labelling regulations. And there are still concerns over its safety for human use in cosmetics. Time will tell, but what will be the consequences?

What about other industries? It seems the sky is the limit for nanotechnology. Toyota recently began using nanocomposites in bumpers that makes them 60% lighter and twice as resistant to denting and scratching. This industry has not been slow to see the advantages of nanotechnology.

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The US based company *Argonide* have created copper nanoparticles that are incorporated into engine oils to reduce engine wear. Superb sponges for adsorbing pollutants are in production.

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The textile industry has also welcomed nanotechnology with open arms. It offers a new way of processing fabric that will revolutionize the clothing industry. *Nano-Tex*, a leading US company in the field, developed a process that makes traditional fabrics resistant to spills that would normally ruin clothing.

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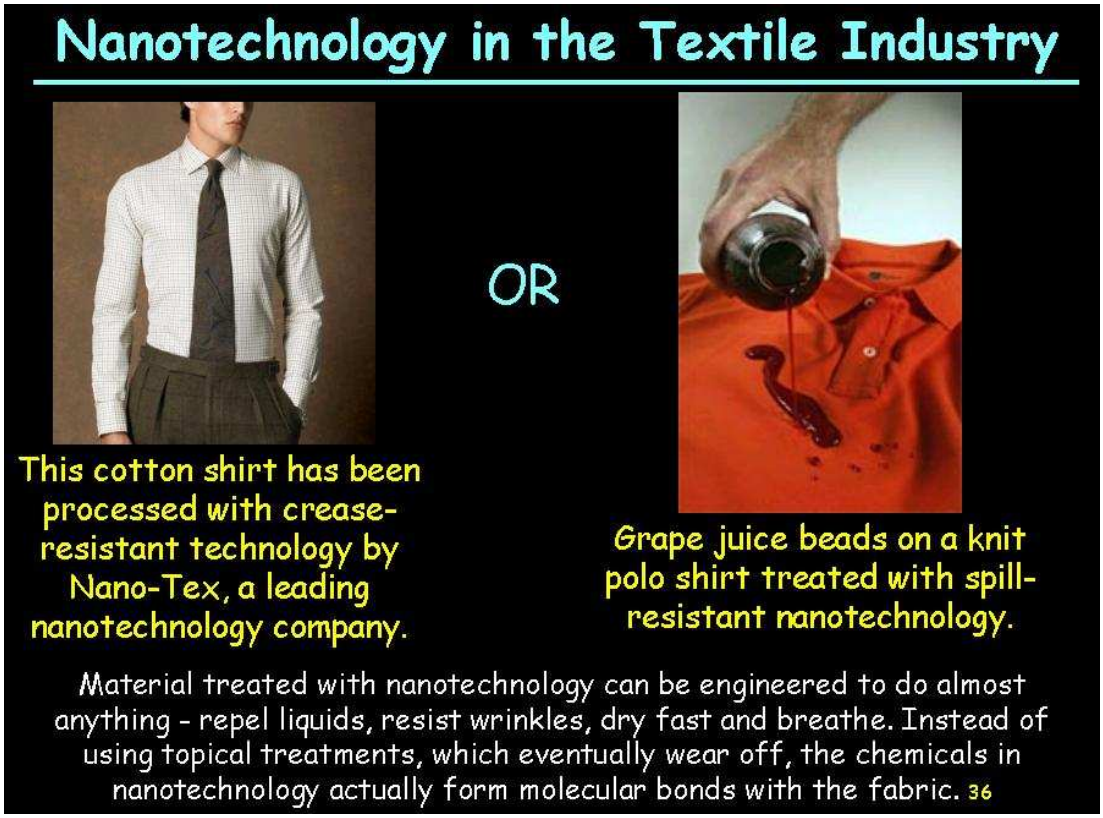

There is now a move to produce an artificial material that will replace cotton. What will happen to cotton growers, especially in the third world? It could devastate their economies. Cotton growers have already tasted the failure of GE-cotton, driving many thousands in the Third World to commit suicide because of the indebtedness in growing it and other transgenic crops.[1]

Talking of cloths you may even have already bought cleaning cloths made of "micro-fibres". These may not be labelled as nanotech products, but may well be. I have personally purchased one from a New Zealand super-sized store.

Let us have a look at what other innovative developments are on track for commercialisation.

[1] www.organicconsumers.org; www.independent.co.uk. .

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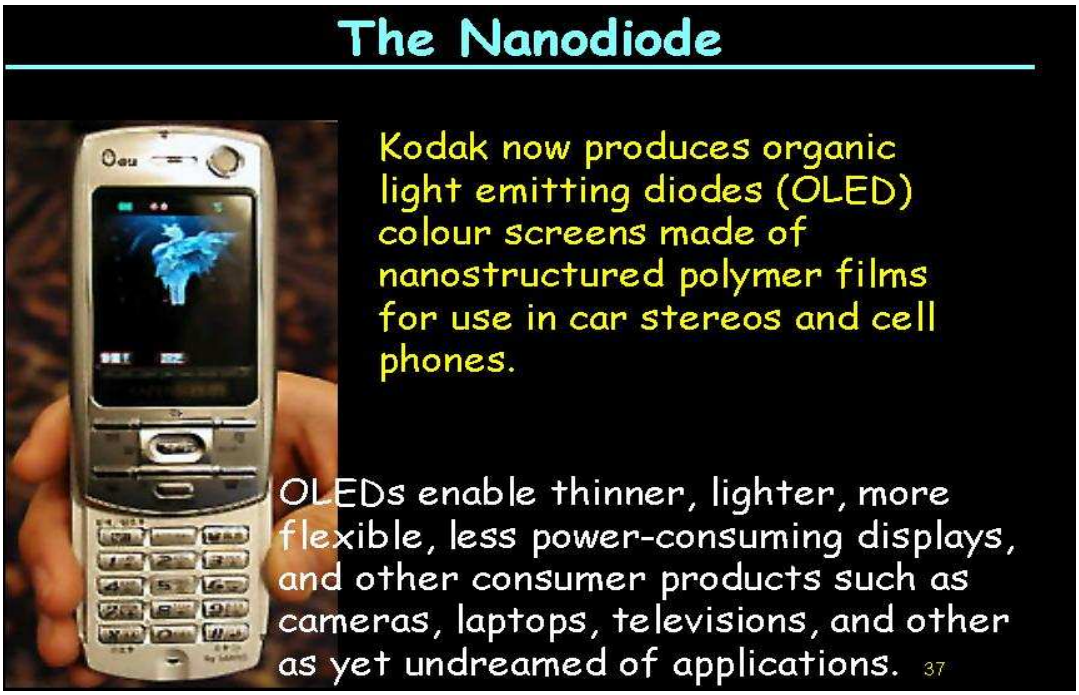

While LCDs require a light source, OLEDs emit their own light. They use less power, take up less space and are lighter - all effective advantages over LCDs. Barry Young, vice president of *DisplaySearch*, a US research company, forecast that OLED screen sales would reach $2.5 billion US by 2006. They did.

What about the engineering industry? This sector has also been keen to adopted nanotechnology.

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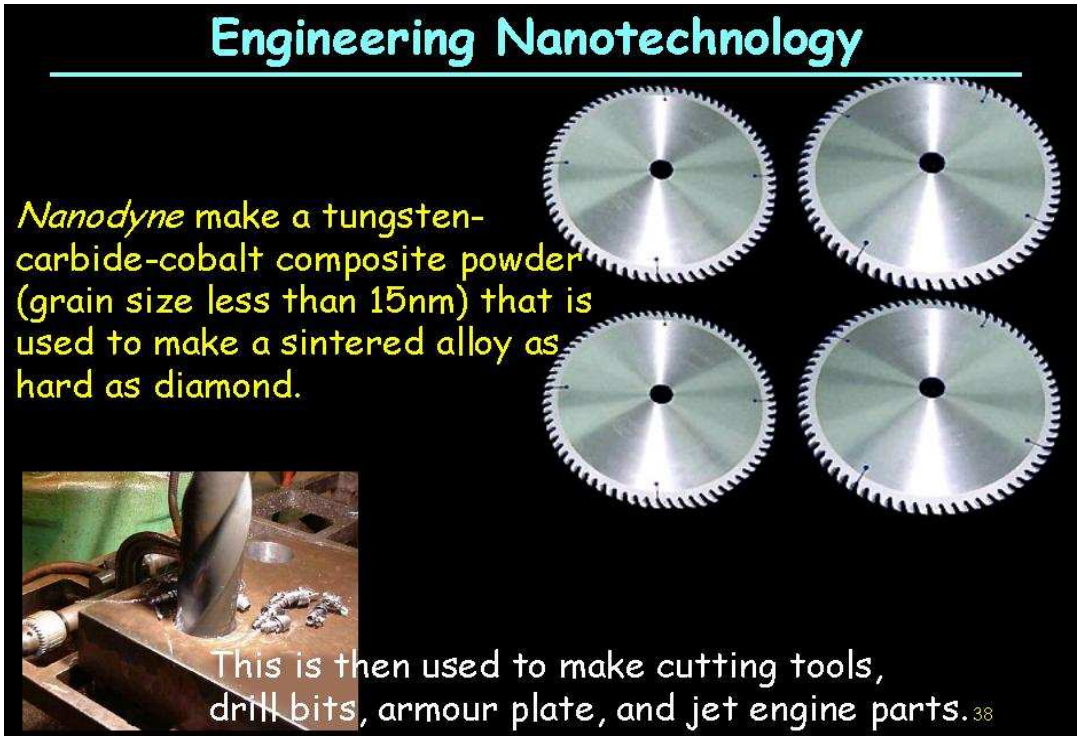

The cutting edge of such tools as these would remain sharp for very long periods of time.

Now let me show you a few other remarkable engineering projects. This next slide is of a parallel-shaft speed reducer gear.

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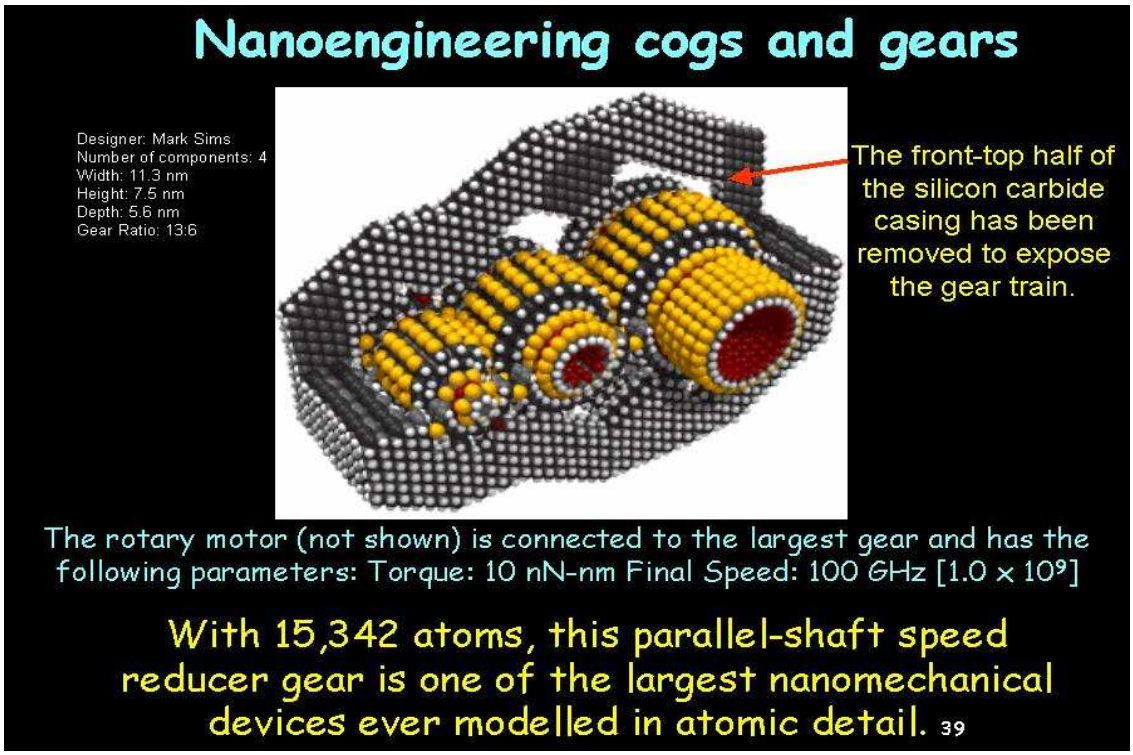
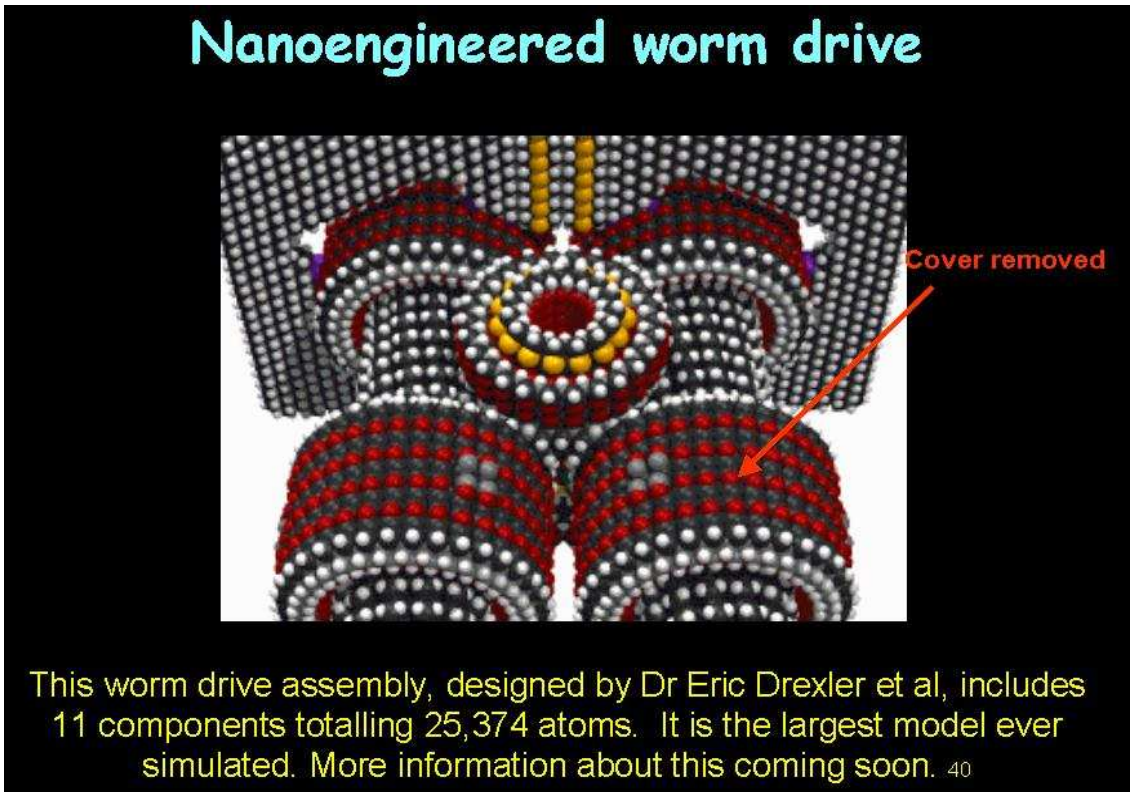


In comparison, how about a complex worm drive assembly? To give some idea of size recall a blood cell is about 5000 nm!

Slide 38



If we want to get really complex, we could even consider a molecular differential gear.

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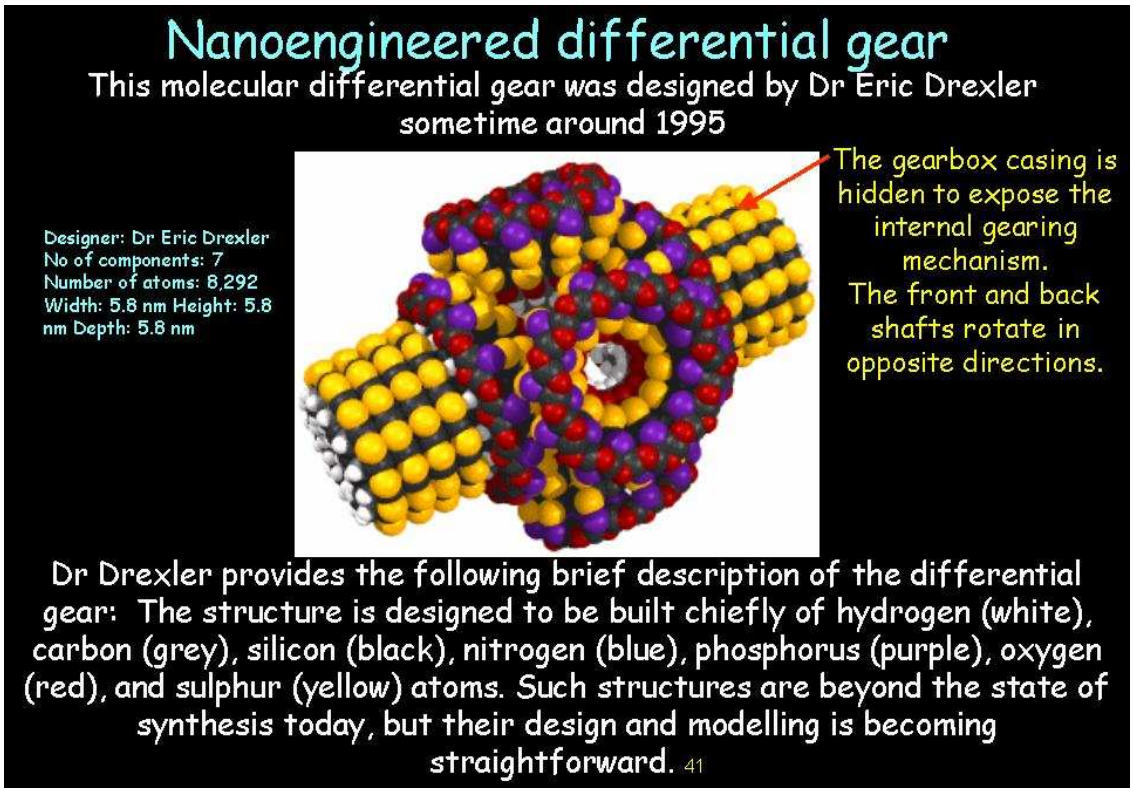


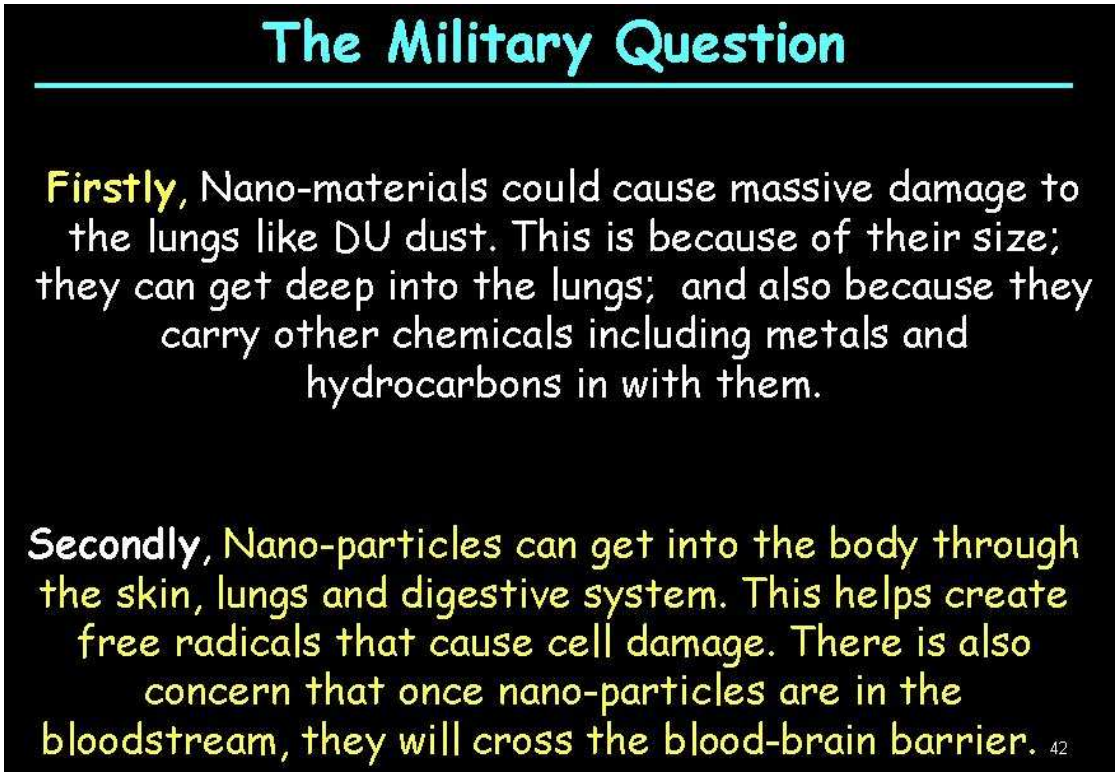
These last few examples illustrate the enormous potential power of nanotechnology - in medicine, sports goods, the car industry, engineering and many other fields.

But the most frightening aspect of the technology will come from the research organizations looking to defence. They are working to understand the impacts of nanotechnology for military applications.

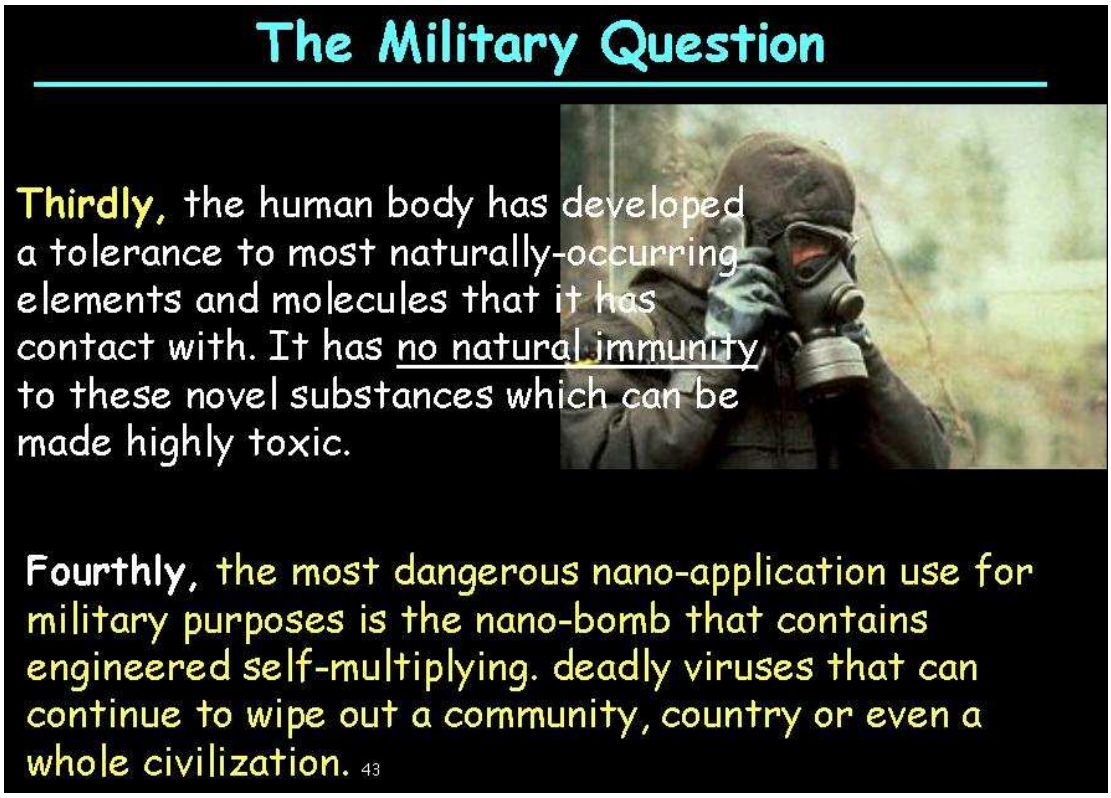
As I have shown, nanotechnology could provide enormous benefits; however, it could also be used by the military to create weapons of mass destruction that we cannot even begin to imagine with a conventional mindset. And this would benefit richer, more scientifically advanced countries.

The immediate use can be classified in four main ways.

Slide 40

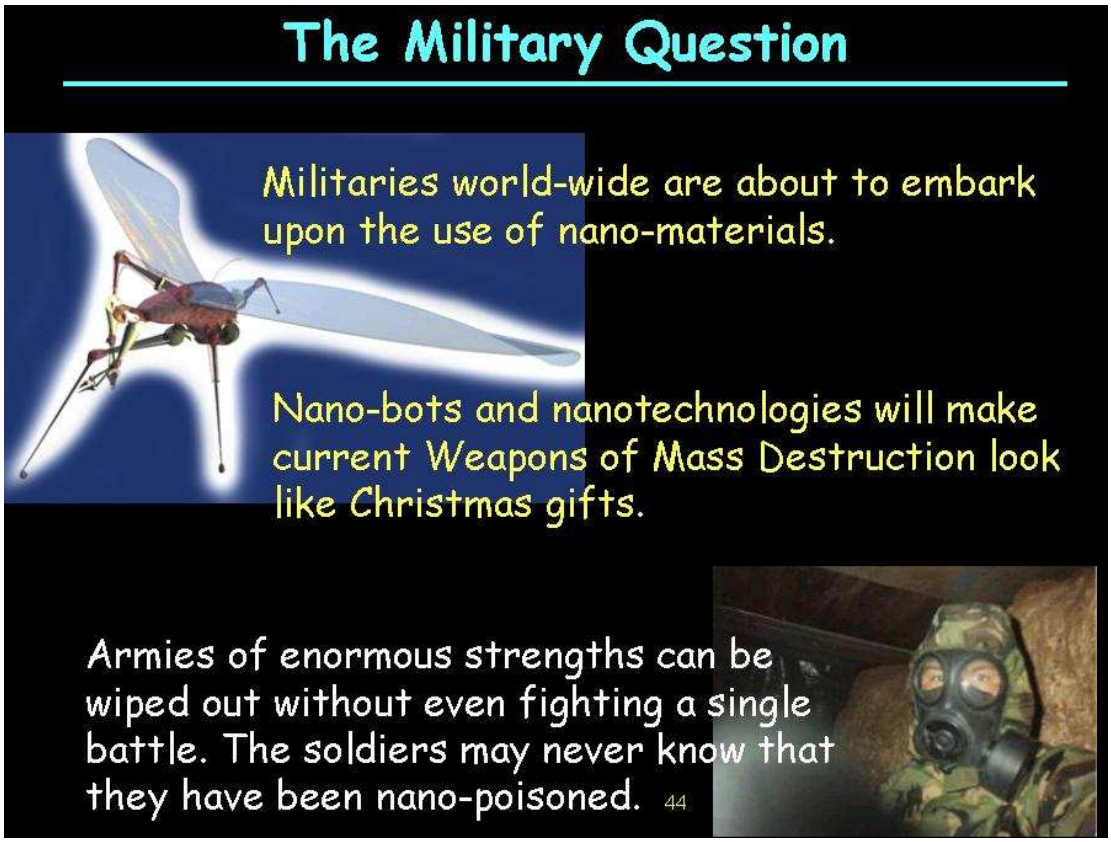


Slide 41



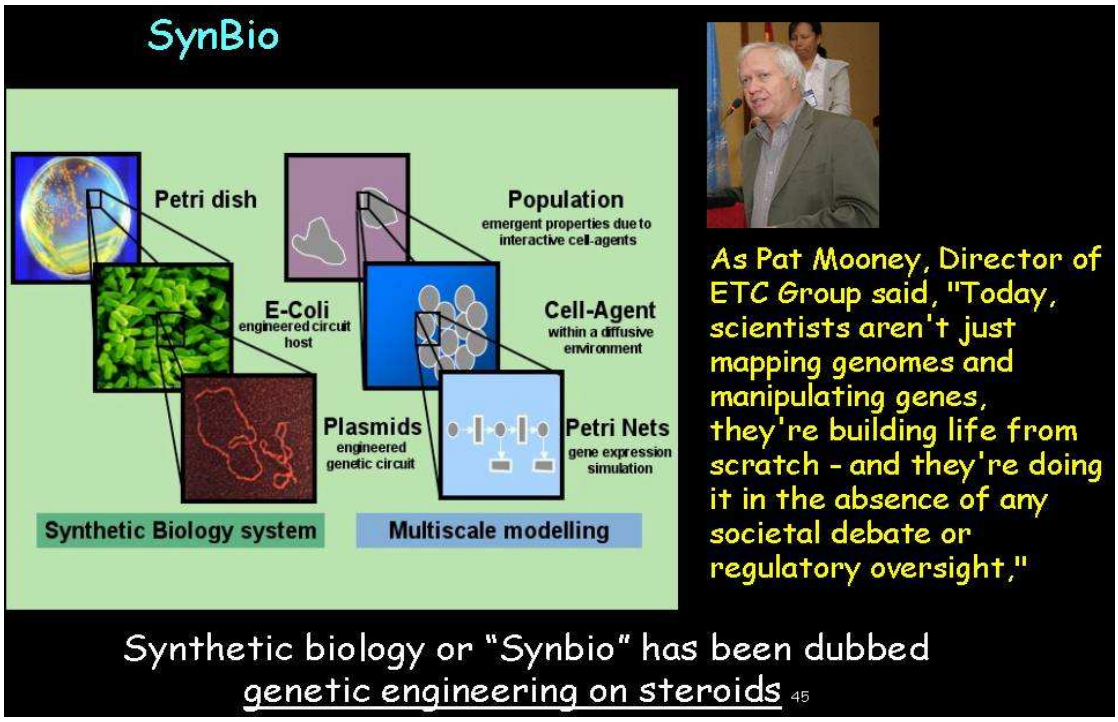
We can see from this that a war involving nanotechnology would be unconscionable.

Slide 42



Before we leave the military question I want to briefly mention a technology closely related to nanotechnology; synthetic biology (public talk also available on this website). Synthetic biology has been inspired by the convergence of nano-scale biology, computing, engineering, and genetic engineering at the micro level.

Slide43

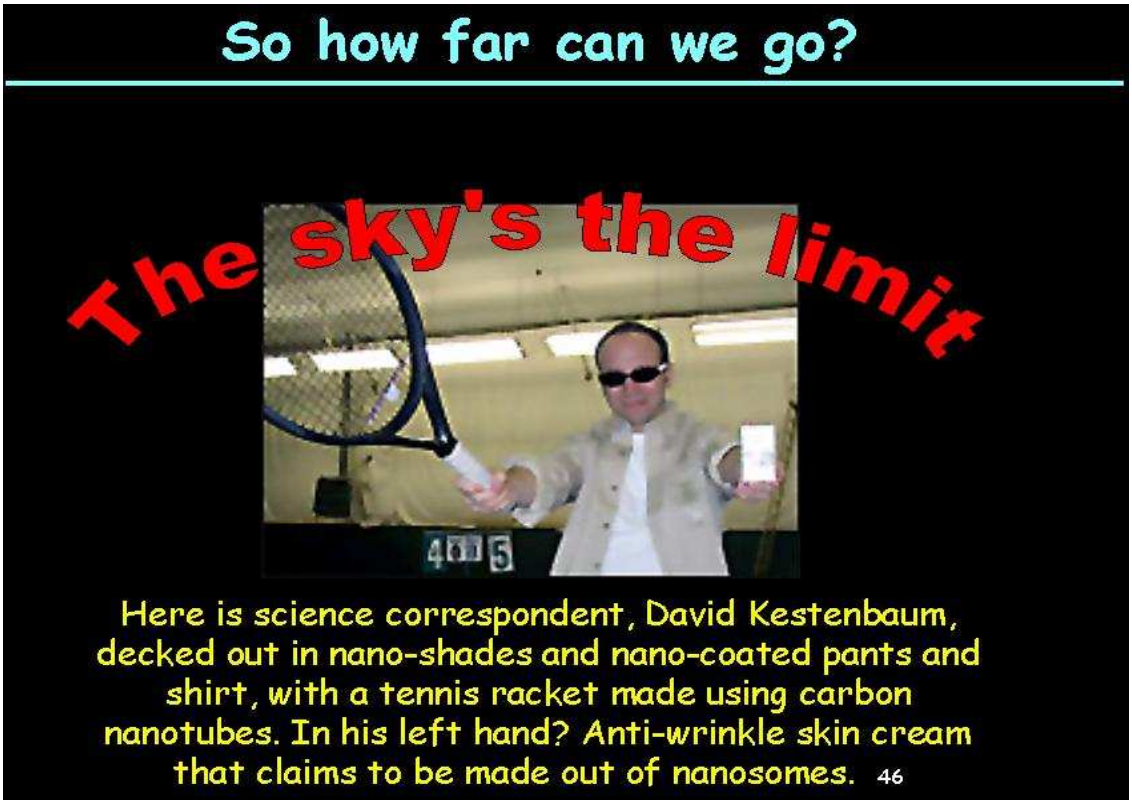


Scientists predict that within two to five years it will be possible to synthesise *any* virus. For example:

- In October 2005, scientists at the US Centres for Disease Control recreated the 1918 Spanish flu virus (Posfair, G et al 2006), caused by the H1N1 virus.[1]
- In May 2006, researchers at the University of Wisconsin-Madison created a version of *E. coli* bacteria using this new science of synthetic biology.

So just how far can we go with this? It seems as far as our imaginations will stretch.

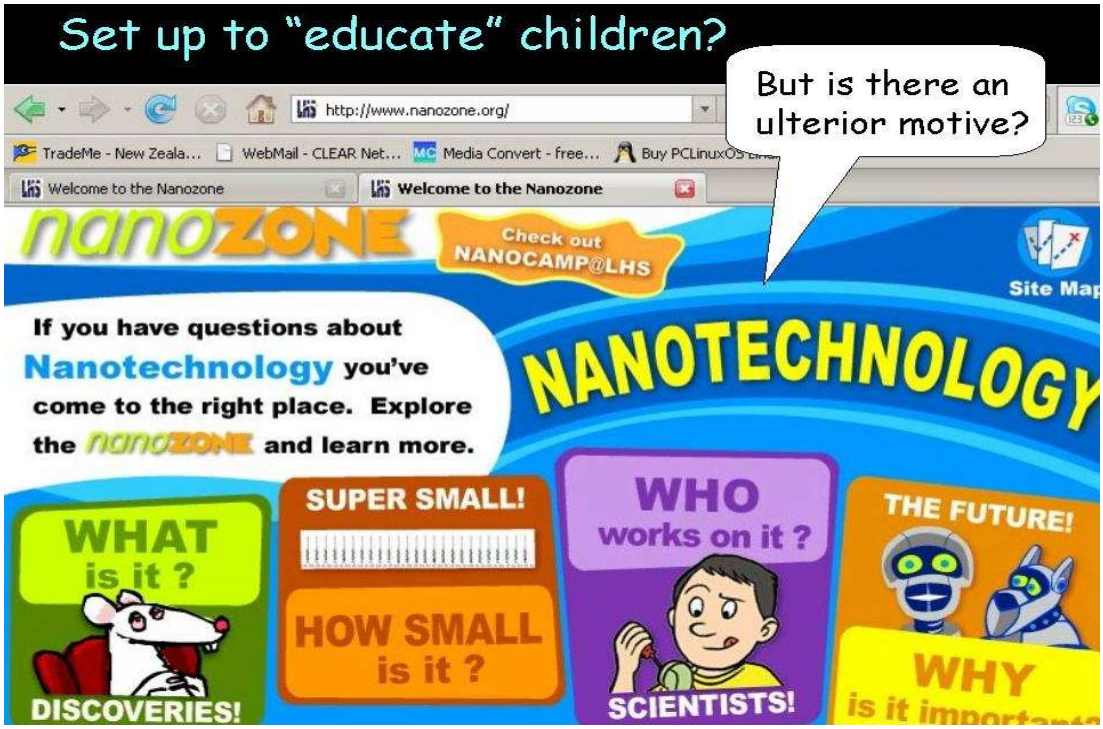
Slide 44



[1] It claimed purpose of the recreation was to advance the ability to prepare effective vaccines and drugs in case of a flu pandemic, urged on perhaps because the H1N1 virus is related to H5N1, the "bird flu" virus, which became of concern in 2004. In June 2009, the World Health Organization declared a new strain of H1N1 was responsible for the 2009 flu pandemic referred to as "Swine flu": that A/H1N1 influenza virus being a subtype of influenzavirusA and the most common cause of flu in humans.

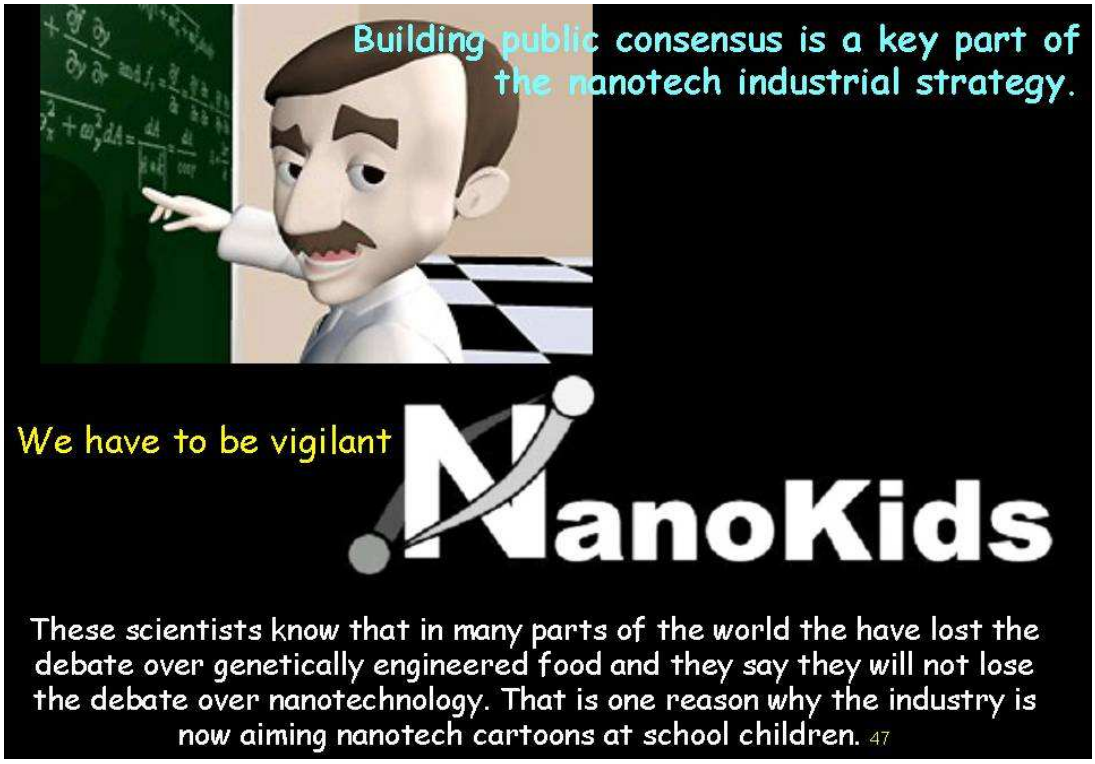
It is important to keep informed of these new technologies. Political systems can be driven by public pressure which should prompt more stringent oversight. Regrettably, corporate compliant media must not be allowed to use vested interest as an excuse to hide dubious applications of nanotechnology - or synthetic biology or any other new technology. Already signs are coming from spin-doctors intent on catching the crowd and gaining public consensus. There are video introductions aimed at children. This directs them to the nanozone children's website.

Slide 45



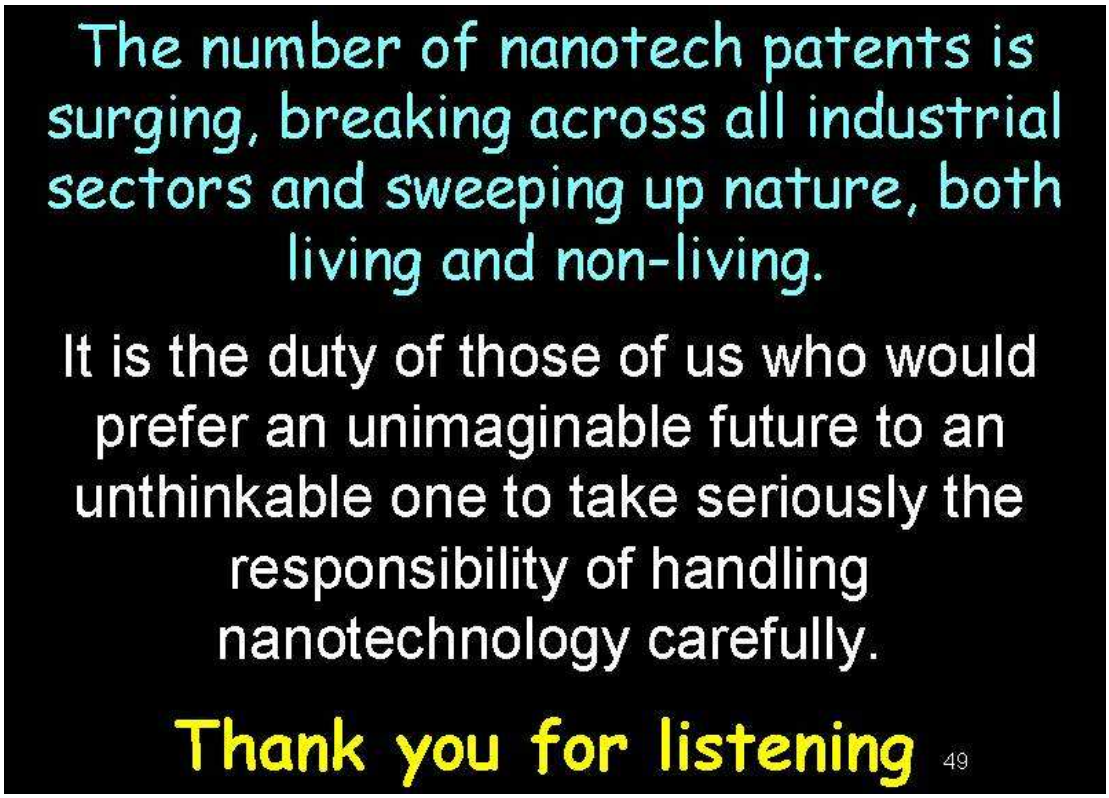
This is the Nanozone Website and, needless to say, it says nothing of the dangers arising from the technology.

Slide 46 *NanoKids*



You can see, it is essential that we all stay informed if we are to make rational decisions about this new technology which will come to effect us all.

Slide 47



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Enquiries about *Exploding the Myth of Nanotechnology* by Robert Anderson should be addressed to connectedbooks@clear.net.nz.