

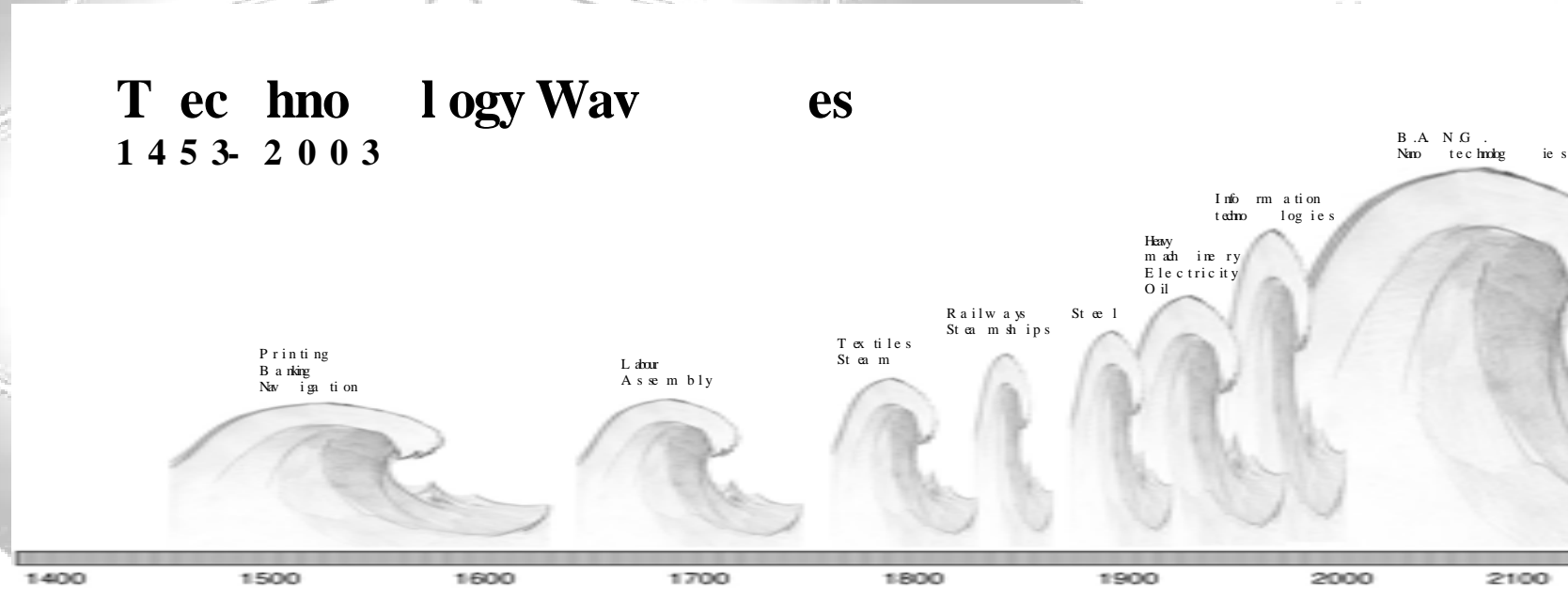


# Nanotechnology

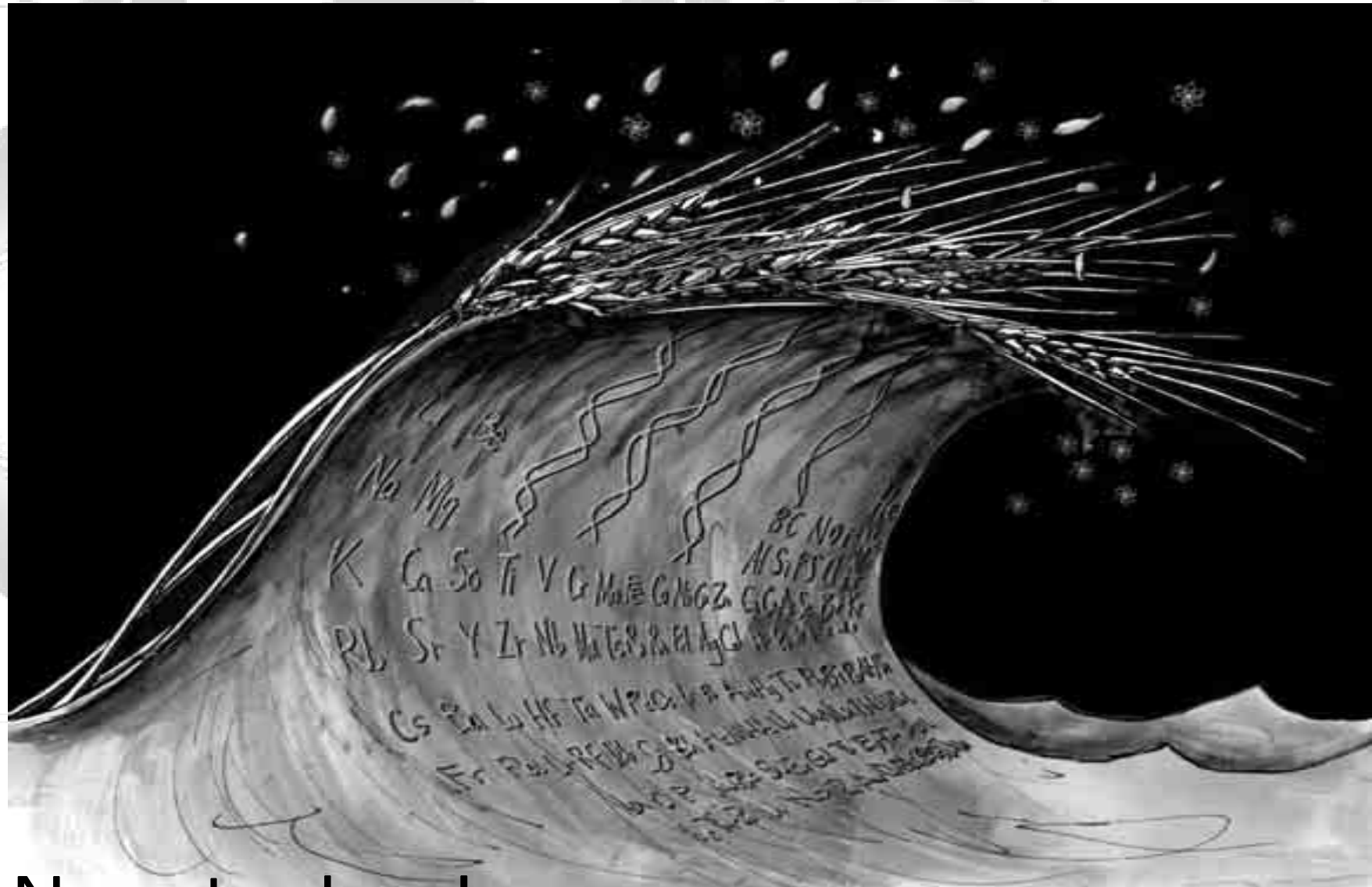
Implications for development, human rights, trade etc

Jim Thomas - ETC Group

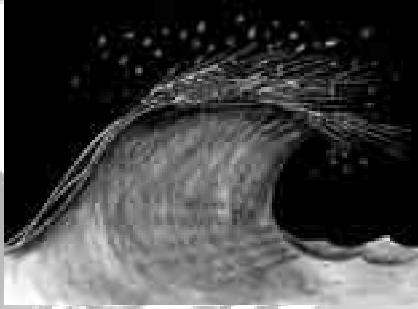
- Disruptive technologies: eg. Writing, irrigation, Steam, Electricity, computing, biotech and now Nanotechnology.



**Waves are managed - Rich and powerful ride the crest, poor sink to the trough - vulnerable to turbulence.**



Nanotechnology =  
Technological Tsunami!!



# Manufactured Wave

***Nanotech is not a single technology - “nano-scale technologies”***

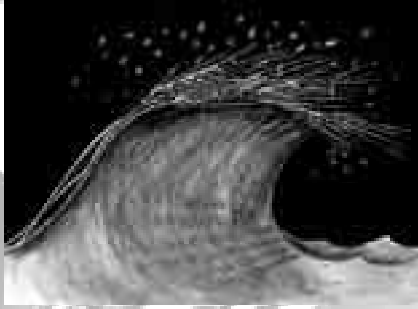
More correctly:

1) it's a **technology platform** (like genetics, electricity, digital)

... Common unit = atom.

2) its an **industrial strategy**

... to control manufacture from the atomic level



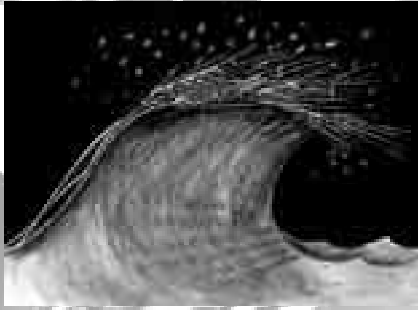
## Fundamental Wave

**“Nanotechnology has given us the tools... to play with the ultimate toy box of nature - atoms and molecules. Everything is made from it... The possibilities to create new things appear limitless”**

*- Horst Stormer. 1998 Physics Nobel prize winner*

***Biotech broke the species barrier.***

***Nanotech breaks the life/nonlife barrier***

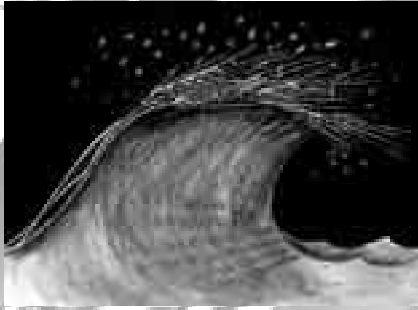


# Well Funded Wave

- **\$8.6 billion per annum investment.(2004)**

## **Government Nano race:**

- **USA - NNI - \$3.7 billion over next 4 years**
- **Japan - €1.16 billion (estimate) 2003**
- **EU - Framework 6 - €1.3 billion plus national research.**  
**Framework 7 - €4.8 billion over 6 years**
- **Plus China, Australia, Korea , Taiwan etc..**



# Wave of hype?

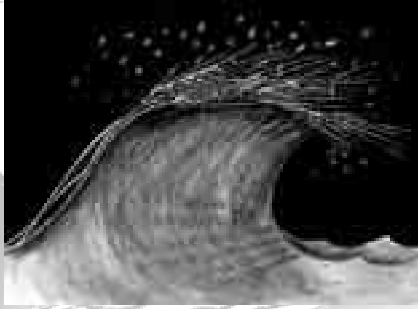
*“But when we launched the NNI, another equally important factor came into play to spur policymakers to make these substantial investments: **nanotechnology’s potential to achieve the nearly miraculous.** .*

*“On a human level, nano’s potential rises to near Biblical proportions. It is not inconceivable that these technologies could eventually achieve the truly miraculous: enabling the blind to see, the lame to walk, and the deaf to hear; **curing AIDS, cancer, diabetes and other afflictions; ending hunger;** and even supplementing the power of our minds, enabling us to think great thoughts, create new knowledge, and gain new insights.*

*“On a societal level, nanotechnology will deliver **higher standards of living and allow us to live longer, healthier, more productive lives.** Nano also holds extraordinary potential for the global environment through **waste-free, energy-efficient production processes that cause no harm to the environment or human health.** And nano is already showing great potential for repairing existing environmental damage as well.”*

**Philip J Bond**

**- US Undersecretary of State for Commerce and Tech (2003)**



# Industrial Wave

*Corporations expected to spend \$3.8bn*

**"If a company does not enter nanotechnology now - in five years it will be too late - it will be out of business."**

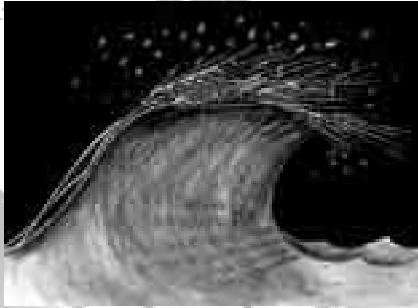
*-Mike Roco , Senior Advisor, US National Science Foundation and Head of the US Government's National Nanotechnology Initiative (2003)*

E.g..

**Food:** "every major food corporation has a program in nanotech or is looking to develop one." - Jozef Kokini, the Director of the Center for Advanced Food Technology at Rutgers University (New Jersey, USA),

**Drugs: 50% of pharmaceutical sales** will be based on nanotech by 2010 - according to NSF.

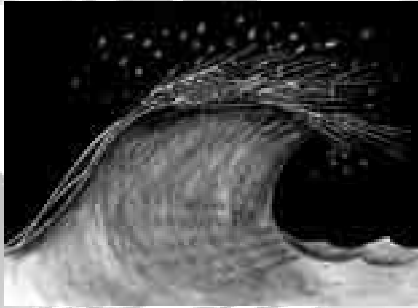




# Industrial Wave

Dupont, IBM, Kraft/Altria, Bayer, Syngenta, Unilever, Nestle, Fujitsu, Hitachi, L'Oreal, Philips, BP, Hewlett Packard, Samsung, Sandia/Lockheed Martin, Boeing, Motorola, Glaxo, Pharmacia, Monsanto, Burlington, 3M, Kodak, Xerox, Degussa, Lucent/Bell, NEC, Mitsubishi, Exxon, BMW, Renault, Pilkington, Smith and Nephew, BASF, Qinetiq, Renault, BMW, General Motors, Chevron/Texaco, Ford, Procter and Gamble, Dow, Delphi, Caterpillar, Merck, Alcoa, Sara Lee, Gap, Raytheon, AMR, General Electric, Henkel, Heinz, Shell, Haliburton, Texas Instruments, Microsoft, Nike ...

**Plus 1500+ nanonichers:** Nanosys, Nanophase, Oxonica, Altair, Nanomix, Sequoia Pacific, Veeco, Flamel, Skyepharma, Nanogate, Powderject, Arrayx, Nanoproducts, Nanogen etc



# Profitable Wave?

***“ 1 trillion dollar industry by 2015” (now 2011)***  
***- US National Science Foundation***

- ✓ 2001 volume of nano sales was estimated at somewhat more than €50 billion (Nano Business Alliance 2001, DG Bank).
- ✓ Worldwide market for nanotechnology-related products at around £105 billion by 2005
- ✓ 50% of Pharma profits based on nano by 2010
- ✓ Nanobubble already underway: Nanogen Inc.: up 183 percent since the first of December and 503 percent since the beginning of 2003. Altair Nanotechnologies Inc.: up 502 percent since early 2003. Nanometrics Inc.: up 347 percent since early 2003.

# Nanoparticles: quantum effects

## Fixed Matter > Flexible Matter

Properties of element can be **tuned**  
by size and shape

**E.g. GOLD.**

**Macro** - yellow, inert, soft

**Nanoparticles** of gold - reactive

20nm brown

30nm red

40nm Purple

60nm Blue-green





## Zinc Oxide/TiO<sub>2</sub> Sunscreens

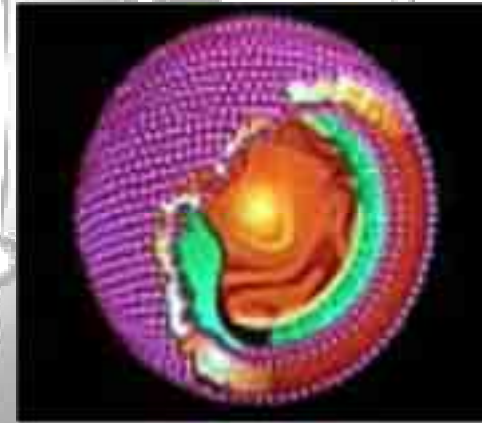
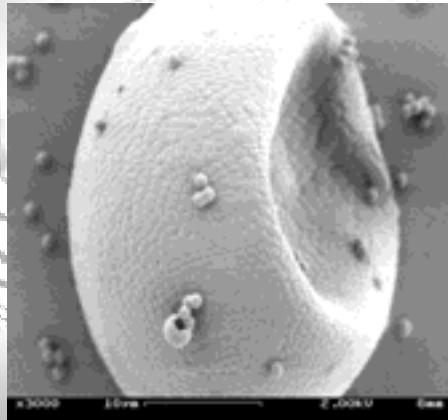
## Carbon nanotubes



## Silver nanoparticle wound dressings

# Nanocapsules - active nanostructures

(also nanoliposomes, colloidosomes, nanospheres, nanocochleates, microcapsules etc)



5-10  $\mu\text{m}$  diameter



3 nm thick walls



## Nanocapsule Pesticides:

- **Flamel/Monsanto - Roundup 'Agsome' (1997)**

- *“The aim of the Flamel-Monsanto agreement is to develop an improved, less-costly version of the Roundup herbicide that will allow Monsanto to secure a patent for another 17 to 20 years, said Flamel spokesman George Anania”*

- **Pharmacia Slow release nanocapsules (2002)**

- *“for biologically active agents such as drugs, insecticides, fungicides, pesticides, herbicides and fertilizers”*

- **Syngenta - Microcapsule insecticide**

- breaks down in stomach of lepidoptera (butterflies and moths)

- **Syngenta - “Quick Release” Microcapsules (on market)**

Eg. Karate with Zeon Technology - rice, peppers, tomatoes etc.





## Nanocapsule Vaccines

**1. Functionalized for targetted delivery.**

**2. DNA Vaccines.**

Eg. Clear Spring Foods/USDA - ultrasound mediated nanoparticle mass vaccination of fish (Idaho)

US produces 60 million tonnes of farmed trout - a third of this by Clear Spring Foods

Trials should have completed already.



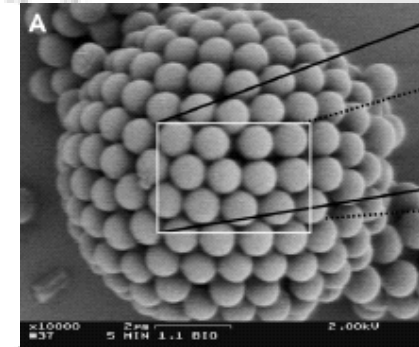
## **Nanocapsules/Microcapsules in food FUNCTIONAL FOODS:**

### **➤ Smart Drinks (Kraft) - Nano Colloidosomes**

"Imagine that you and I buy exactly the same beverage, but you want to have one today that is red and tastes like cherry and I decide that I want green and lemon," explained co-researcher Manuel Marquez, a physical organic chemist at the Nanotechnology Lab of Kraft Foods in Glenview, Ill. "If you have cherry flavor and a red color in a capsule that can be activated by a specific frequency, you can personalize your interactive beverage."

### **➤ Fishy Bread (George Weston) - Tip Top-up with Microcapsules of Tuna oil**

### **➤ Nestle and Unilever also interested - ice creams and spreads.**





## Regulatory Vacuum:

- No Nanotech control regulations anywhere in the world.
  - Strange properties of nanoparticles not considered by existing chemical safety regulations. Substantial Equivalence mk II!
  - Not even agreed protocols on safe laboratory handling of nanoparticles
  - Not even agreed testing protocols for assessing safety and full properties of nanoparticles
  - Not even on the radar of most CSO's/ IGO's or UN bodies.
- Yet probably hundreds of nanoparticle products in or close to marketplace.

## Major nanotoxicity concerns emerging:



TiO<sub>2</sub>/ZnO SUNSCREENS - studies since 1997 showing free radical production, DNA damage in skin cells.

Flexed skin with berrilyium nanoparticles

CARBON NANOTUBES - 2003 studies (NASA and Dupont) - *"The message is Clear. People should take precautions. Nanotubes can be highly toxic"* - Robert Hunter University of Texas (Houston)





Nano-particles and Toxicity - Dr Vyvyan Howard -  
Toxicopathologist, University of Liverpool. - APRIL 2003

**Conclusions:**

- Size Matters - smaller is usually more reactive/more toxic.
- Shape also matters.
- Immune system has poor defense against nanoparticles, often not recognised (eg under 70nm not recog on lung, 50nm cells)
- Nanoparticles can get across skin, eyes, lung, around the body, intestine, blood/brain barrier and possibly placenta.
- Nanoparticles under 50nm can easily enter cells and can migrate to nucleus (eg nanotubes).

## Growing consensus on Nanotoxicity:

- Concern from Rice, Oxford, Leuven, Edinburgh etc

- Nanotox 2004 - January UK

- UK Study into Nanotech Royal Society/RSE

- Bundestag study.

- **Nanosafe Project (EU)** - *“We consider that producers of nanomaterials have a duty to provide relevant toxicity test results for any new material, according to prevailing international guidelines on risk assessment. Even some 'old' chemical agents may need to be reassessed if their physical state is substantially different from that which existed when they were assessed initially.”* - Nature Biotech

- **Report to European Parliament - published feb**

*-.“The release of nano-particles in the environment should be avoided. The state of research concerning [sic]...the behaviour of nano-particles is actually rather limited, preliminary as well as contradictory. Nevertheless, the advice to avoid the release of nano-particles to the environment might be appropriate and would be in accordance with the Precautionary Principle.”* Haum, Petschow, Steinfeldt, *Nanotechnology and Regulation within the framework of the Precautionary Principle. Final Report.* Institut für ökologische Wirstschaftforschung (IÖW) gGmbH. Berlin,



Toxic fish study - Buckyballs

## FIRST EVER WILDLIFE TOXICITY STUDY

March 2004 - Dr. Eva Oberdörster reports to American Chemical Society meeting that buckyballs cause brain damage within 48hrs in juvenile fish along with changes in gene function. They also are toxic to small crustaceans (water fleas) at the base of the food chain.

**"Given the rapid onset of brain damage, it is important to further test and assess the risks and benefits of this new technology before use becomes even more widespread."**

- Dr. Eva Oberdörster.

## Swiss ReInsurance:

*“Nanomaterials are already contained in numerous products worldwide and occur in various applications. There are indications that certain nanomaterials are potential health hazards. The danger is most probably not of an acute but chronic nature and it could be some time before it manifests itself. This is where the real risk for insurers lies, and the comparison with asbestos should be seen in this light.”*

*“In view of the dangers to society that could arise out of the establishment of nanotechnology, and given the uncertainty currently prevailing in scientific circles, the precautionary principle should be applied whatever the difficulties”*

*Nanotechnology, Small Matter, Many Unknowns (May 2004)*

## Royal Society (UK) Report:

*“There is virtually no information available about the effect of nanoparticles on species other than humans or about how they behave in the air, water or soil, or about their ability to accumulate in food chains. Until more is known about their environmental impact we are keen that the release of nanoparticles and nanotubes to the environment is avoided as far as possible. Specifically we **recommend as a precautionary measure that factories and research laboratories treat manufactured nanoparticles and nanotubes as if they were hazardous waste streams and that the use of free nanoparticles in environmental applications such as remediation of groundwater be prohibited.**”*

*– “Nanoscience and Nanotechnologies: Opportunities and uncertainties”  
Royal Society and Royal Academy of Engineering, July 2004*



**UK Government (in Response to RS/RAE report):**

"The government.. accepts that safety testing on the basis of a larger form of the chemical cannot be used to infer the safety of the nanoparticulate form of the same chemical and therefore individual regulations within the existing framework will need to be reviewed to reflect the possibility that nanoparticulate material may have greater toxicity than material in the larger size range" - para 22

"Their properties will be dependent upon both their size and shape and of the material of which they are made" - para 14

"There is some evidence that some materials are more toxic in a nanoparticulate form, possibly because of their greater surface area"  
- para 14



## UK Government (cont) :

"The government accepts that a precautionary approach should be taken [to deliberate release for environmental remediation] - para 46

"Exposure in the workplace and releases to the environment should be minimised until the possible risks posed by nanoparticles and nanotubes are better understood" - para 17

"The government agrees that ingredients in the form of manufactured free nanoparticles should undergo a thorough safety assessment by the relevant scientific advisory body before they are used in consumer products" - para 24 and 62

"The government recognises.. that there is much baseline fundamental science to be done" - para 33

"The government agrees that there is a need for further work on environmental fate and potential bioaccumulation of nanoparticles and nanotubes, " - para 40

The background of the slide is a grayscale illustration. It features a central globe showing the continents of North and South America. Overlaid on the globe are several interlocking gears of different sizes. A network of white lines connects various points, resembling a molecular structure or a complex network diagram. The overall aesthetic is technical and scientific.

## Unexamined safety questions:

- Could nanoparticles interfere with Protein Folding?
- Other biological interactions at the nanoscale - eg what happens to nanotubes/particles inside cells, in the nucleus etc.
- transport and fate of particles in soils? Initial concerns.
- Nanoparticles in the brain.



Other Nanoparticle Concerns:

- **Nanocapsules as Bioweapons.**
- **Nanoparticles as explosives - e.g. aluminium oxide**
- **Nanocapsule/Microcapsules for exercising control enforcing IP - like Terminator/ Microsoft.**

## **Patents on Nature: *Nanopiracy and Matter Monopolies***

o **Around 80,000 nanopatents exist so far - on nanostructures, molecules, processes and elements:**

*Glen Seaborg - patented Americium and Curium*

*Yang Mengjun - 466 nanopatents on chinese herbs*

*“It is true that one cannot patent an element found in its natural form; however, if you create a purified form of it that has industrial uses – say neon- you can certainly secure a patent.”* – Lila Freisee, Director for Government relations and intellectual property, Biotechnology Industry Organisation. April 11 2001.

**BROAD PATENTS > MATTER MONOPOLIES** - across sectors. E.g. IBM/NEC fighting over Carbon Nanotubes. NEC licenses nanotubes to pharma, materials, electronics

# IMPACT ON TRADE/LIVELIHOODS:

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

**Gap, Lee, Old Navy, Eddie Bauer, Kathmandu**

“I was sitting in my office thinking one (synthetics) is strong and cheap while the other (cotton) looks good but isn’t robust,” [Nano-Tex founder] Soane said. He began to imagine a hybrid, a synthetic core such as nylon with cotton-like nanomaterials that molecularly cross-link onto and around the core. The cotton-like outer layer is what the wearer will feel, he said. “This will be our blockbuster.”

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

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## COMMODITY DISRUPTION:

Cotton vs Nanofibres

Rubber vs Nanoparticles/ Nanogels

Copper vs Nanotubes

Dyes/Inks vs Quantum Dots

Tropical flavourings vs Nanoflavourings

++

Impact of nanopackages on storage/price

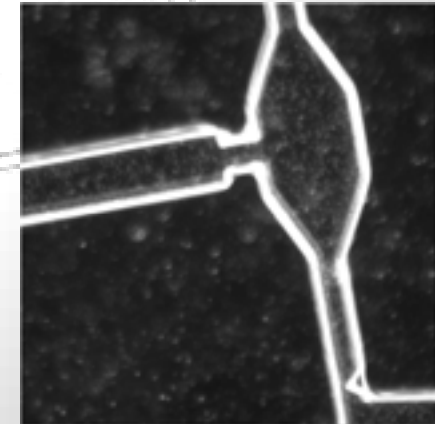
Smart materials replace human labour - eg  
cleaning services,

# Nanofabrication

Assembling more complicated, functional nanostructures eg nanodevices or nanostructured materials .

One of the most significant areas is **NANOSENSORS**

- Nano-cantilever arrays
- Microfluidics - thin channels in silicon
- Handheld Diagnostics (lab on a chip)
- Wireless remote sensor networks.



## Wireless remote sensor networks..

*"The impact of sensors will be as surprising in the decade ahead as microprocessors were in the 1980s and lasers in the 1990s...Now, in this decade, we are hanging eyes, ears and sensory organs on our computers and our networks. We're asking them to observe the physical world on our behalf and to manipulate it. This decade will be marked by a sensor revolution – a big leap in automation that will have a far-reaching influence on business and society."*

– Paul Saffo, Director of Silicon Valley's Institute for the Future.

**Ambient Intelligence....**



Wireless remote sensor networks..

***From battle fields to farm fields... and everywhere!***

- **SMART DUST (DARPA)**- sense movement, contaminants. Replace soldier reconnaissance as part of Precision Warfare.



- **LITTLE BROTHER PROJECT (USDA)** - sense nitrogen, water, pests (“Smart Fields”) disease, animal health, movement (“Smart Herds”). Replace farmer scouting as part of Precision Agriculture.

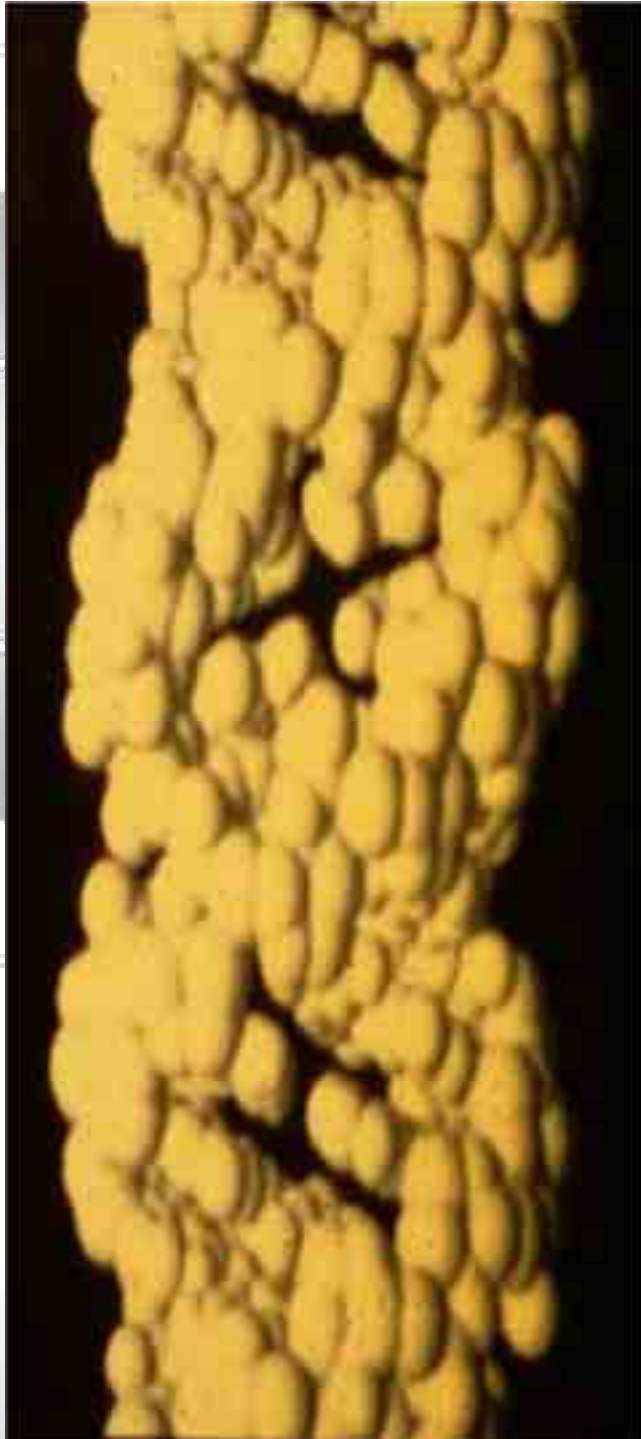
- **FUEL INJECTION PRINCIPLE** - in Drugs, Animal Health and Crops. Ultimately replace farmer/doctor altogether?

- **Factories, production, energy network etc**



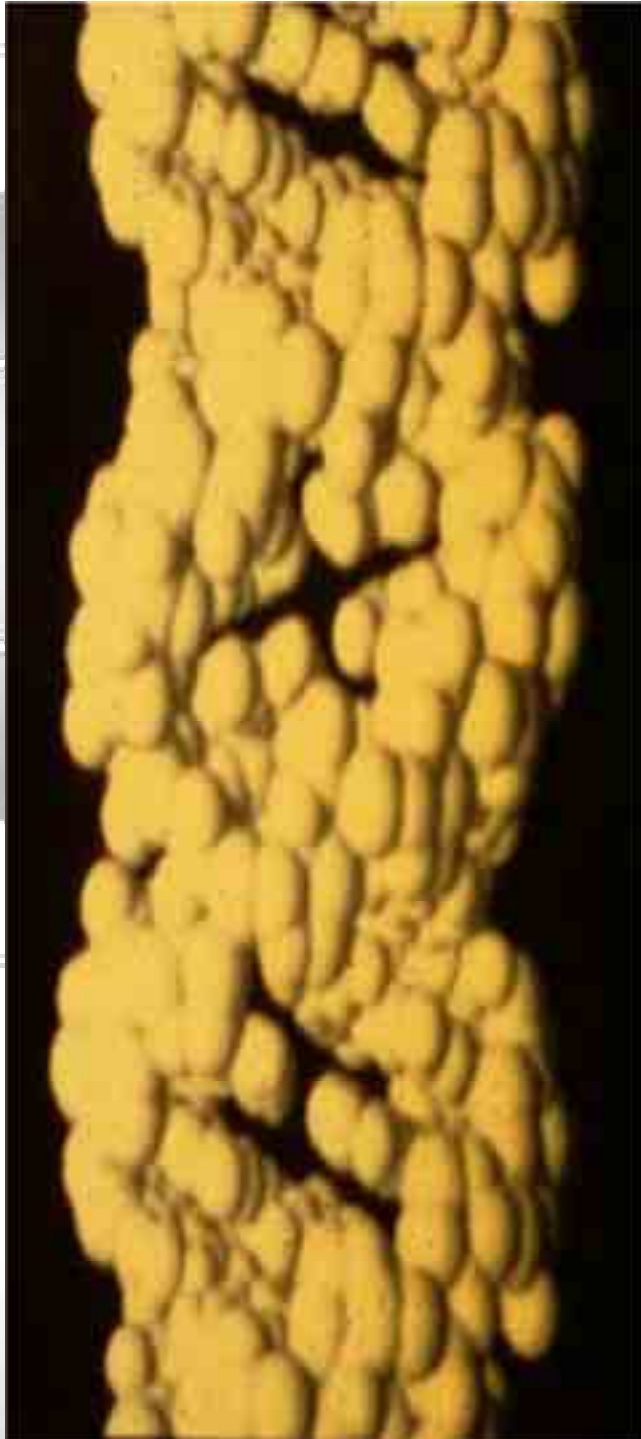
## Nanosensor concerns..

- ❖ **Loss of control/knowledge/skill - e.g. plantations.**
- ❖ **Civil liberty/Surveillance - esp SensorNet (US)**
- ❖ **Consumer surveillance/ Worker surveillance**
- ❖ **Ability to spy (e.g.. on competitor agriculture.)**
- ❖ **Not a pro-poor / appropriate technology for South.**
- ❖ **Ethical concerns - “2nd nature”**



# NANOBIOTECH

- Interface of nanotech and biology.
- Altering and manipulating living structures from the atoms up.
- Harnessing nanoscale biological mechanisms/ processes - especially self assembly.
- Reconfiguring life to serve the needs of industry



# NANOBIOTECH

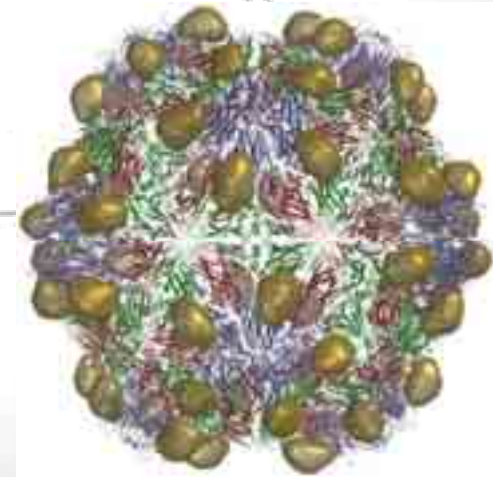
“Our thirty-year goal is to have such exquisite control over the genetics of living systems that instead of a growing a tree, cutting it down, and building a table out of it, we will ultimately be able to grow the table. “

**Rodney Brooks**, *director of Artificial Intelligence Laboratory at the Massachusetts Institute of Technology*



**Growing nanoparticles in geranium cells and bacteria then controlling shape by genetic engineering, (Pune, India)**

**Genetically engineering cowpea mosaic virus in order to grow nanowires for molecular computer circuits - Scripps (La Jolla - USA)**





## Nanobiotech Rice - Thailand

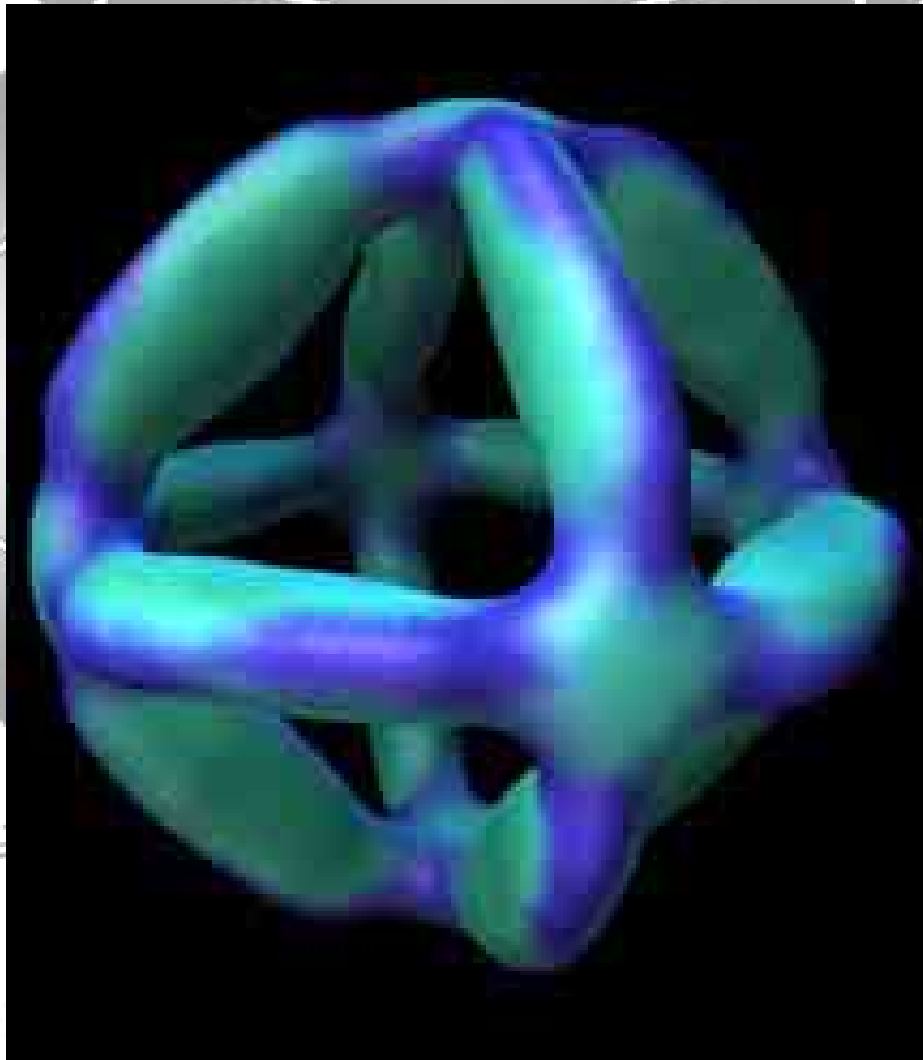
"In the nanotechnology-based study, physicists need to make a hole through a rice cell with a width as tiny as a nanometre scale. A nitrogen atom will then be gunned through the hole to stimulate the rearranging of base substances in a rice DNA, which controls its genetic characteristics..."

"The technique is not GMO [genetically modified organism]. At least we can avoid it," said Prof Thiraphat Vilaithong, director of the Fast Neutron Research Facility of Chiang Mai University, as he compared it with the controversial GM know-how, that adds alien genes to plant species to gain desired qualities."

*- Thailand embarks on new technology development path Bangkok Post  
- Thailand; Jan 21, 2004*

**+ working on nanobio Silk also.**

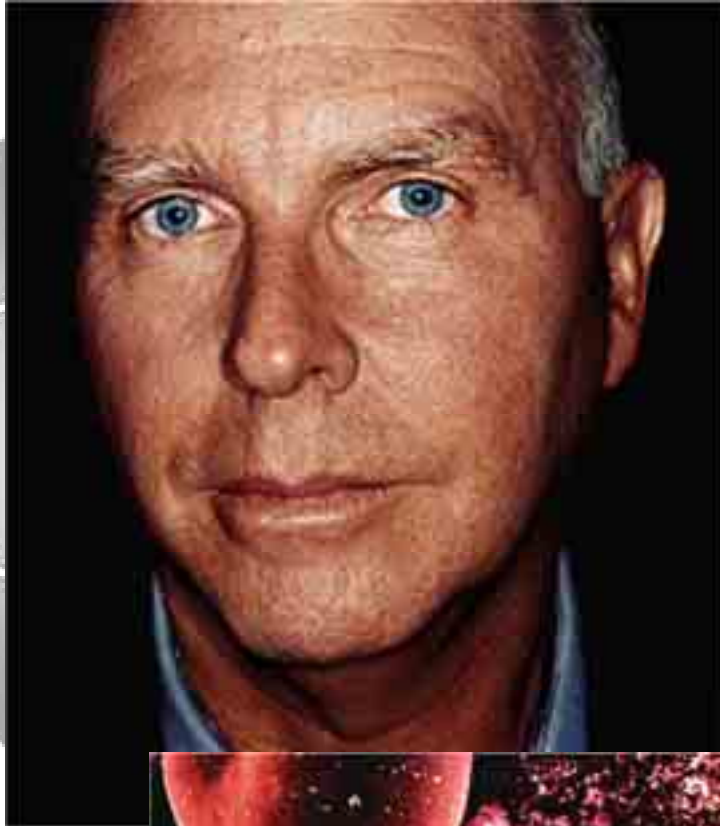




Synthetic single, clonable strand of DNA (1669-nucleotide) that self assembles into an octahedron.

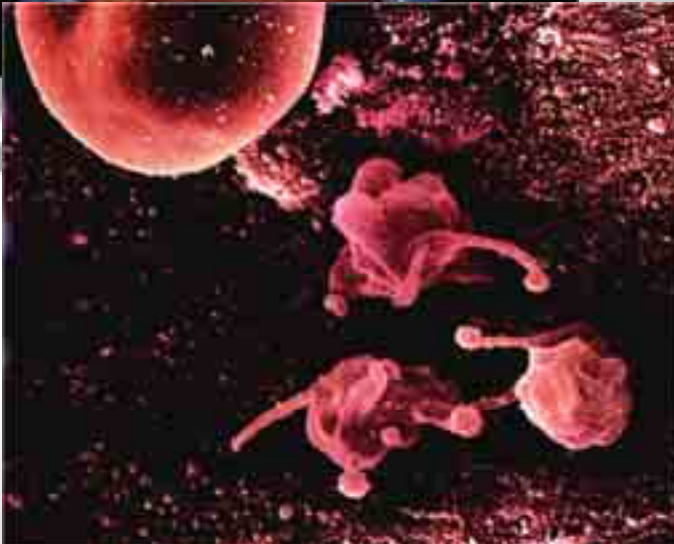
Designed to have a number of self-complementary regions, which induce the strand to fold back on itself to form a sturdy octahedron.

(Scripps, USA)



## J Craig Venter - IBEA

- \$3 million - Dept of Energy
  - Synthesised virus in 14 days
  - Now working on Mycoplasma Genitalium to create new life form.
- Reducing 600,000 nucleotides



*"Synthetic genomics will become commonplace and will provide the potential for a vast array of new and complex chemistries altering our approaches to production of energy, pharmaceuticals, and textiles."*





## Price of DNA Synthesis:

**2000** - \$10 - \$12 per base pair

**2004** - \$2 per base pair

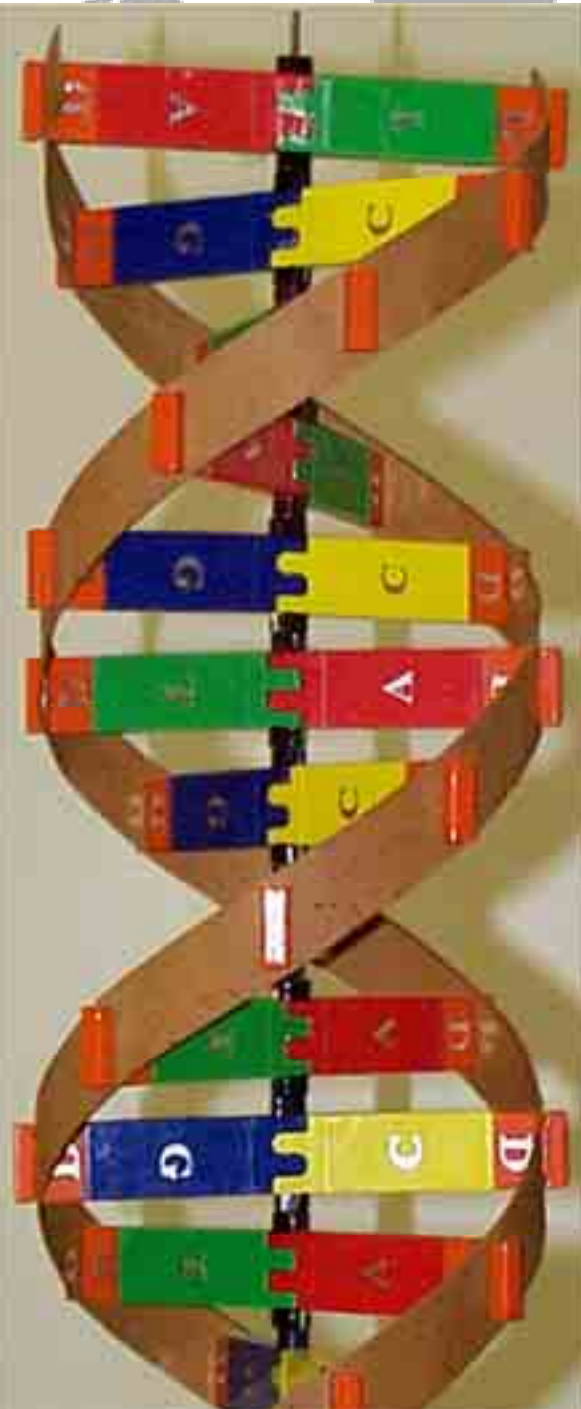
By **2007** - 1 cent per base pair

ie. \$10 per gene, only thousands of dollars per genome.

If current acceleration continue:

*“by **2010** a single lab worker would be able to synthesise a couple of human genomes from scratch every day”*

- Wired (Jan 05)



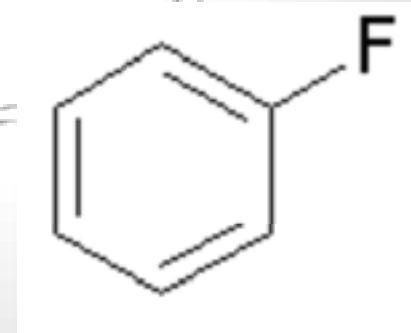
DNA's fifth letter.. F

Fluorobenzene (or Floyd?)  
*Scripps (La Jolla, USA)*

Increases possible arrangements  
from 256 combinations to 3125  
combinations

-greater diversity? Novel proteins.  
Novel life forms.

-And sixth letter?



-++ **“Big Genes” - XDNA** larger  
molecules > new genetic system.



*“I suspect that in five years or so, the artificial genetic systems that we have developed will be supporting an artificial life form that can reproduce, evolve, learn and respond to environmental change”*

**- Professor Steve Benner University of Florida**

*“If Biologists are indeed on the threshold of synthesizing new life forms, the scope for abuse or inadvertent disaster could be huge”*

**Philip Ball, Deputy Editor of Nature.**

**Will we see digital storage of diversity?**

**Nano cloning?,**

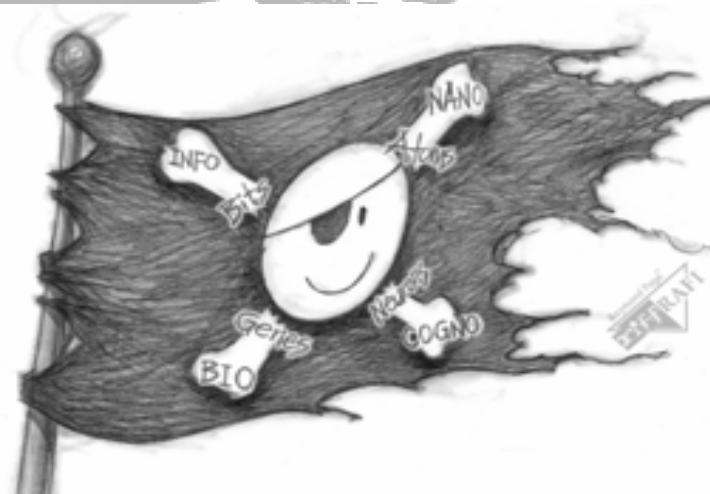
**New Biosafety threats?**

NANO BIO just part of

TECHNOLOGICAL CONVERGENCE: (GRN,  
**GRAIN, Singularity, NBIC, BANG**)

- NBIC: Nano - Bio - Info - Cogno
- CTEKS - Converging Technologies for European Knowledge Society
- BANG: Bits Atoms Neurons Genes

“material unity at Nanoscale” - all just atoms





## Examples of BANG technologies:

- **Human Enhancement** - artificial eyes, ears, legs, muscle - transhumanist
  - brain/machine interface - Braingate (Cyberkinetics)
  - Fuel injected people/workers (sensors/devices)
  - **Super Soldiers** (MIT inst of Soldier Nanotech)

“Nanotechnology is a ‘force multiplier.’ It will make us faster and stronger on the battlefield.” **Clifford Lau**, senior

### **Major Implications for Disability Rights:**

‘Fix the disabled’ rather than build inclusive society.

Existing struggles by Disabled Rights activists: Cochlear implants, Genetech

Change definition of ‘normal’ we all become subnormal/disabled



So what are the Concerns.

- **Patents on nature and wide matter monopolies.**
- **Massive shifts in trade/commodities and livelihoods.**
- **Impacts on labour - inc farmers. Esp self-assembly/sensors/ enhancement.**
- **Potential for new nanobioweapons/ surveillance overwhelming military superiority, crushing dissent.**
- **Cultural, Ethical considerations - especially for indigenous and non-western worldviews.**
- **Human rights impacts - eg Disability Rights, surveillance**
- **Impact on indigenous technology systems - water, energy, farming, medicine etc.**



# New Paradigm for Technopolitics

**POLITICS** - Technologies are inherently political and involve exercising power. - The neutrality of technology is a myth.

**JUSTICE** - Technology introduction can exacerbate Injustice/ widen the gaps between the powerful and the marginalized - inc access issues.

**RISKS** - Some technology risks are unacceptable and not to be simply 'managed'. New attitudes to risk - precautionary principle. intergenerational equity.

**KNOWLEDGE** - Scientific experts are no longer sovereign.. R-emphasis on lay knowledge, democratic technologies and open innovation (eg open source)

**MONOPOLY** - Corporate technology agendas are not welcome. Rejection of commercial/monopolistic science and technology - inc patenting, university capture, corporate agenda setting.

**SOLUTIONS** - We need Social change not technofixes. Liberation theology before liberation technology. New technologies do not solve old injustices.

**INDIGINOUS TECHNOLOGY** - Appropriate technology comes from those who are going to use it. Valuable indiginous technology systems often get sidelined and replaced by new tech.

**REALISM** - Technologies should be viewed sceptically - pragmatic use of new tech - eg ICT, cars shouldn't be confused with endorsent

**BIG PICTURE** - stop chasing individual technologies (GM crops, nanoparticles) - technologies are embedded in technosystems and platforms- can't just pick and choose within a platform.

## Some positive principles:

**Open innovation** - user led, unpatented, driven by needs (not profit)

**Precautionary Principle** - taking action on early warnings

**Technology Democracy** - 'upstream' public participation/governance in innovation.

**TechnoDiversity** - maintain existing technological systems - as backup/ alternatives