ADVANCED TECHNOLOGY RESEARCH IN UNIVERSITIES

Inaugural Address at the
Inauguration of Molecular & Nanomedicine Research Unit at
Sathyabama University

by

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Distinguished Scientist & Chief Controller R&D, DRDO
& CEO&MD, BrahMos Aerospace

17 March 2014

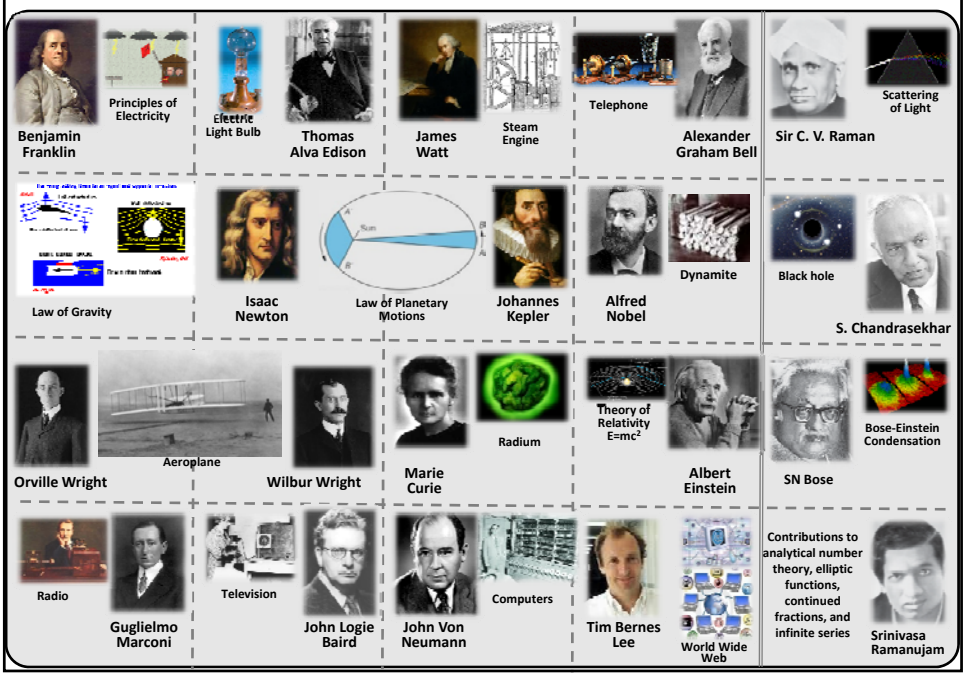
PURSUIT OF SCIENCE FOR HUMANITY

- **The growth of science and technology has been phenomenal in the recent past, improving the quality of life of the human being.**
- **Emergence of new technologies has opened up myriad of applications and now it is left to the ingenuity and imagination of the human mind to explore and exploit them further.**
- **With the established base of multiple technologies all over the world, scientific minds have to come together for new innovations.**

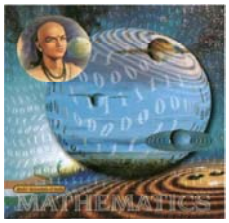
PURSUIT OF SCIENCE FOR HUMANITY

- In this endeavour to further innovations, **Sathyabama University** takes the lead by establishing "***Molecular & Nanomedicine Research Unit***"
- While every institution is waiting for Govt. funding to undertake research, **Dr Jeppiar** has taken pioneering leadership in promoting advanced technology research in a Private University to boost innovation in the country.
- Dr. Jeppiar's visionary thoughts in this direction is a remarkable step for others to follow.

GREAT INVENTIONS WHICH INFLUENCED HUMAN LIFE



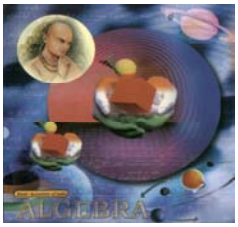
A GLIMPSE OF GREAT SCIENTISTS OF ANCIENT INDIA



ARYABHATT (476 AD)
ASTRONOMER & MATHEMATICIAN

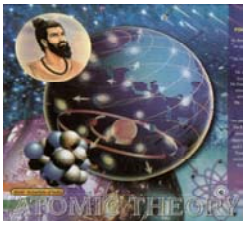
First to proclaim that the earth is round & rotates on its axis

Calculation of Π (Pi) to 3.1416 and sine table in trigonometry.



BHASKARACHARYA II
(1114-1183 AD)
GENIUS IN ALGEBRA

First to discover gravity, 500 years before Sir Isaac Newton.

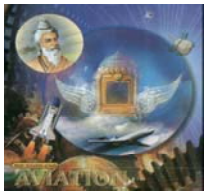


ACHARYA KANAD (600 BC)
FOUNDER OF ATOMIC THEORY

Said "Every object of creation is made of atoms which in turn connect with each other to form molecules".

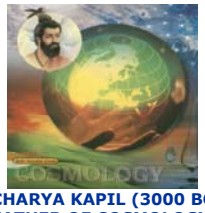
ACHARYA SUSHRUT (600 BC)
FATHER OF PLASTIC SURGERY

Performed Rhinoplasty (restoration of a damaged nose); prescribed treatment for 12 types of fractures & 6 types of dislocations.



ACHARYA BHARADWAJ (800 BC)
PIONEER OF AVIATION TECH.

Designed and described about the techniques in aviation technology

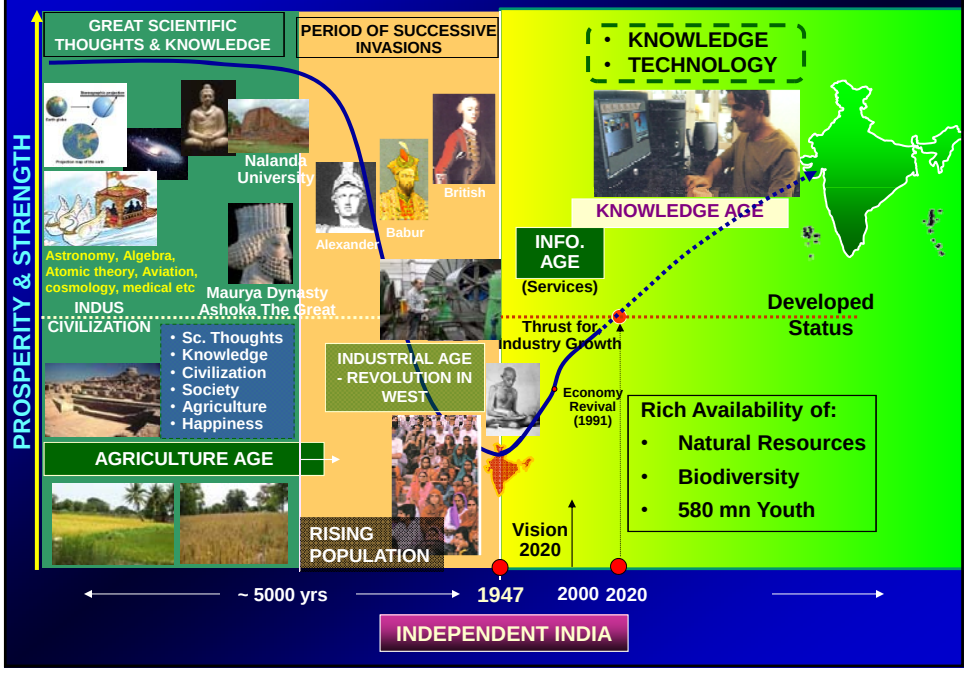


ACHARYA KAPIL (3000 BC)
FATHER OF COSMOLOGY

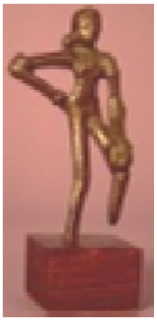
Given concept of transformation of energy

Source: Indian Institute of Scientific Heritage, Trivandrum, www.iish.com

INDIA'S PROSPERITY DYNAMICS



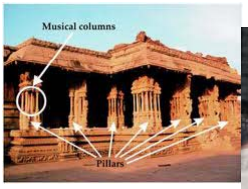
GLIMPSE OF TECHNOLOGY MARVELS OF ANCIENT INDIA



Bronze Statue
(2500 BC)

Rustless Iron Pillar
(Delhi) 912 BC

Panchloha Statue, 800 AD
(Chidambaram, TN)
(5 metals, Investment casting)



Musical Pillars at
Madurai & Hampi
"Sa Re Ga Ma "

Shaolin Temple
(5th Century)

Bodhi Dharma
3rd son of Pallava
King of Kanchi

... Many more

The Nalanda University – Knowledge Hub

- Once housed 9 million books
- Was the center of education for scholars from more than 32 countries
- Many Greek, Persian and Chinese students studied here

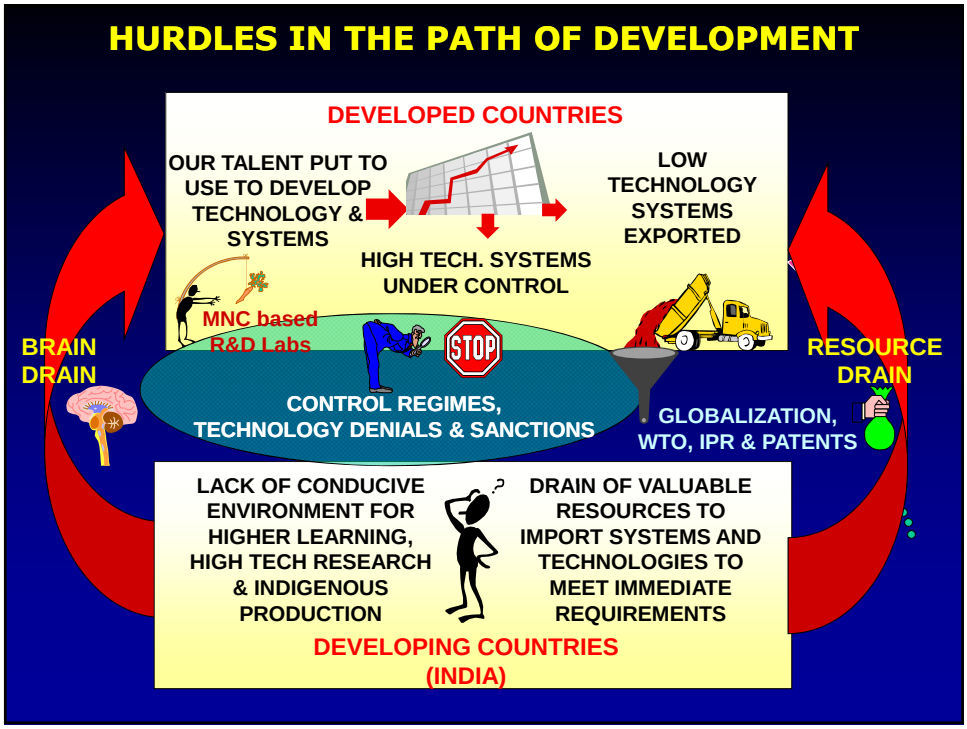
The wonder that was India

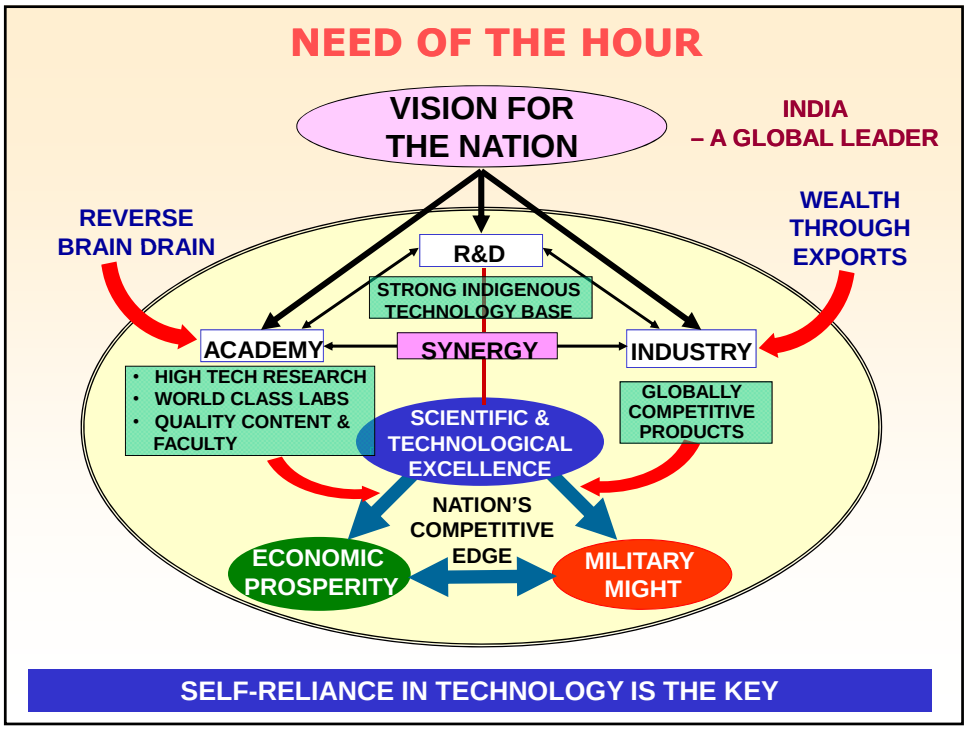
"India's glorious past is embedded with a
Rich Scientific and Technological Heritage from the Vedic age
and is an inspiration to create a scientifically advanced
and spiritually enlightened human society in which
peace, prosperity and happiness together
create a heaven on earth"

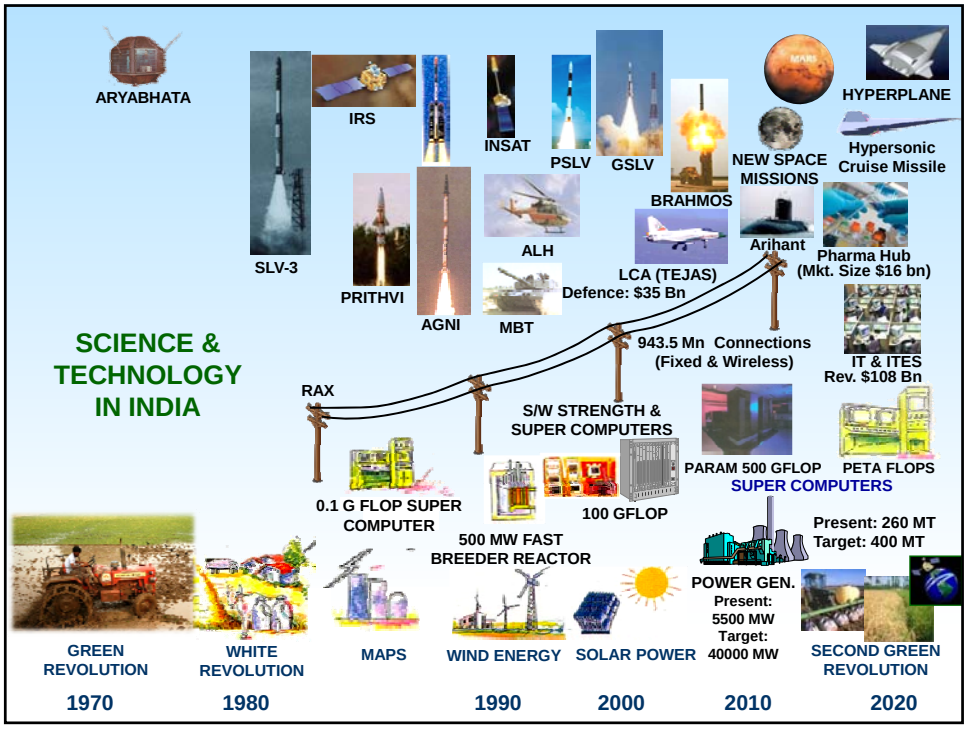
AL Basham
Reader in the History of India in the University of London
Published in 1954

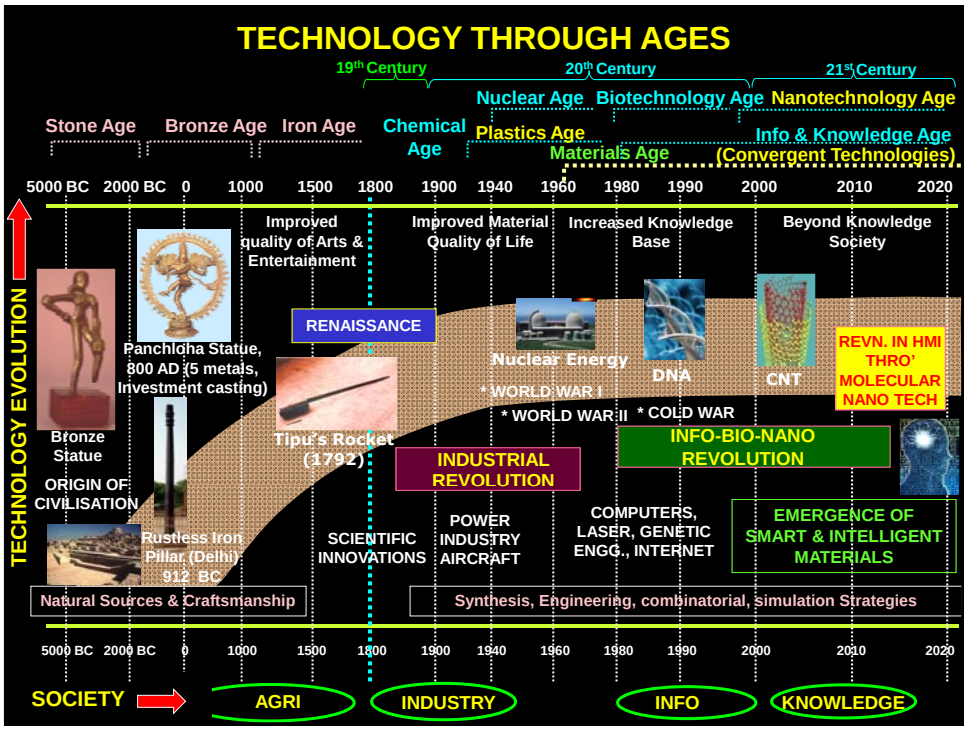
EVERYONE OF US BELONG TO THIS GREAT GENE

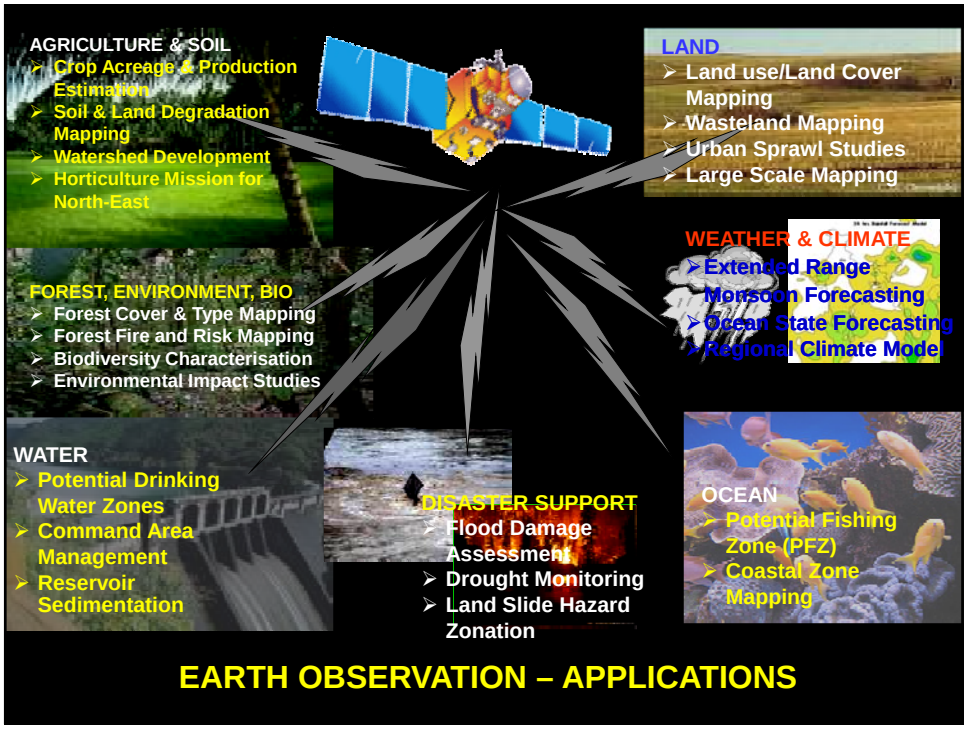
IF WE CAN ACTIVATE THAT GENE RESIDING IN US, WE WILL MAKE INDIA A GREAT NATION


HURDLES IN THE PATH OF DEVELOPMENT
DEVELOPED COUNTRIES
OUR TALENT PUT TO USE TO DEVELOP TECHNOLOGY & SYSTEMS
HIGH TECH. SYSTEMS UNDER CONTROL
LOW TECHNOLOGY SYSTEMS EXPORTED
MNC based R&D Labs
STOP
BRAIN DRAIN
RESOURCE DRAIN
CONTROL REGIMES, TECHNOLOGY DENIALS & SANCTIONS
GLOBALIZATION, WTO, IPR & PATENTS
LACK OF CONDUCIVE ENVIRONMENT FOR HIGHER LEARNING, HIGH TECH RESEARCH & INDIGENOUS PRODUCTION
DRAIN OF VALUABLE RESOURCES TO IMPORT SYSTEMS AND TECHNOLOGIES TO MEET IMMEDIATE REQUIREMENTS
DEVELOPING COUNTRIES (INDIA)


NEED OF THE HOUR
VISION FOR THE NATION
INDIA – A GLOBAL LEADER
REVERSE BRAIN DRAIN
WEALTH THROUGH EXPORTS
R&D
STRONG INDIGENOUS TECHNOLOGY BASE
ACADEMY
SYNERGY
INDUSTRY
• HIGH TECH RESEARCH
• WORLD CLASS LABS
• QUALITY CONTENT & FACULTY
GLOBALLY COMPETITIVE PRODUCTS
SCIENTIFIC & TECHNOLOGICAL EXCELLENCE
NATION'S COMPETITIVE EDGE
ECONOMIC PROSPERITY
MILITARY MIGHT
SELF-RELIANCE IN TECHNOLOGY IS THE KEY


SCIENCE & TECHNOLOGY IN INDIA
ARYABHATA
IRS
SLV-3
PRITHVI
AGNI
INSAT
PSLV
GSLV
BRAHMOS
NEW SPACE MISSIONS
HYPERPLANE
Hypersonic Cruise Missile
ALH
LCA (TEJAS)
Defence: $35 Bn
Arihant
Pharma Hub (Mkt. Size $16 bn)
MBT
IT & ITES Rev. $108 Bn
943.5 Mn Connections (Fixed & Wireless)
RAX
S/W STRENGTH & SUPER COMPUTERS
PARAM 500 GFLOP
PETA FLOPS
SUPER COMPUTERS
0.1 G FLOP SUPER COMPUTER
100 GFLOP
500 MW FAST BREEDER REACTOR
Present: 260 MT
Target: 400 MT
POWER GEN.
Present: 5500 MW
Target: 40000 MW
GREEN REVOLUTION
WHITE REVOLUTION
MAPS
WIND ENERGY
SOLAR POWER
SECOND GREEN REVOLUTION
1970
1980
1990
2000
2010
2020


TECHNOLOGY THROUGH AGES
19th Century
20th Century
21st Century
Stone Age
Bronze Age
Iron Age
Chemical Age
Nuclear Age
Plastics Age
Biotechnology Age
Nanotechnology Age
Materials Age
Info & Knowledge Age (Convergent Technologies)
5000 BC 2000 BC 0 1000 1500 1800 1900 1940 1960 1980 1990 2000 2010 2020
TECHNOLOGY EVOLUTION
Improved quality of Arts & Entertainment
Improved Material Quality of Life
Increased Knowledge Base
Beyond Knowledge Society
RENAISSANCE
Panchloha Statue, 800 AD (5 metals, Investment casting)
Bronze Statue
ORIGIN OF CIVILISATION
Rustless Iron Pillar (Delhi) 912 BC
Tipu's Rocket (1792)
Nuclear Energy
DNA
CNT
REVN. IN HMI THRO' MOLECULAR NANO TECH
* WORLD WAR I
* WORLD WAR II
* COLD WAR
INFO-BIO-NANO REVOLUTION
INDUSTRIAL REVOLUTION
SCIENTIFIC INNOVATIONS
POWER INDUSTRY AIRCRAFT
COMPUTERS, LASER, GENETIC ENGG., INTERNET
EMERGENCE OF SMART & INTELLIGENT MATERIALS
Natural Sources & Craftsmanship
Synthesis, Engineering, combinatorial, simulation Strategies
SOCIETY
AGRI
INDUSTRY
INFO
KNOWLEDGE


AGRICULTURE & SOIL
Crop Acreage & Production Estimation
Soil & Land Degradation Mapping
Watershed Development
Horticulture Mission for North-East
LAND
Land use/Land Cover Mapping
Wasteland Mapping
Urban Sprawl Studies
Large Scale Mapping
WEATHER & CLIMATE
Extended Range Monsoon Forecasting
Ocean State Forecasting
Regional Climate Model
FOREST, ENVIRONMENT, BIO
Forest Cover & Type Mapping
Forest Fire and Risk Mapping
Biodiversity Characterisation
Environmental Impact Studies
WATER
Potential Drinking Water Zones
Command Area Management
Reservoir Sedimentation
DISASTER SUPPORT
Flood Damage Assessment
Drought Monitoring
Land Slide Hazard Zonation
OCEAN
Potential Fishing Zone (PFZ)
Coastal Zone Mapping
EARTH OBSERVATION – APPLICATIONS


ROBOTICS
Unmanned Air Vehicle (UAV)
MICRO UAV
Legged and Wheeled Robot
Humanoid Soldier
Remotely Operated Vehicle
Battle Tank
UGV CONCEPT PROTOTYPE
Unmanned Ground Vehicle
Unmanned Sea Vehicle

NANOTECHNOLOGY APPLICATIONS

Information Technology

- Smaller, faster, more energy efficient and powerful computing and other IT-based systems

Energy

- More efficient and cost effective technologies for energy production
  - Solar cells
  - Fuel cells
  - Batteries
  - Bio fuels

Medicine

- Cancer treatment
- Bone treatment
- Drug delivery
- Appetite control
- Drug development
- Medical tools
- Diagnostic tests
- Imaging

Consumer Goods

- Foods and beverages
  - Advanced packaging materials, sensors, and lab-on-chips for food quality testing
- Appliances and textiles
  - Stain proof, water proof and wrinkle free textiles
- Household and cosmetics
  - Self-cleaning and scratch free products, paints, and better cosmetics

Defence & Security

- Nanofibres for Lighter Materials
- Active/reactive Ballistic Protection
- Environmental Protection
- Chem/Bio Detection and Protection
- Exoskeleton Components

Sources: Presentations of K. Varahramyan (IUPUI) & Dr. Gernot S. Pomrenke (AFOSR)

Textiles
Novel & Smart Fabrics

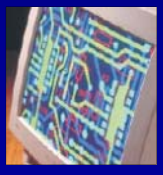
Medicine
Diagnostics & Drug Delivery

Commercial Impact of Nanotechnology

Environment
Filtration & Purification

Machinery
Materials & Coatings

Energy
Catalysts & Converters

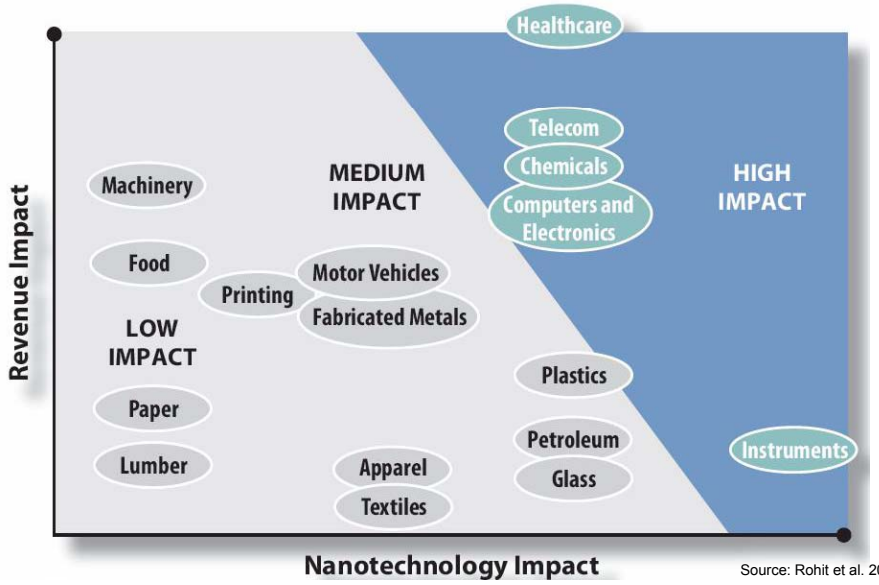


Electronics
Semiconductors & Switches

Source: National Nanotechnology Initiative; NanoBusiness Alliance

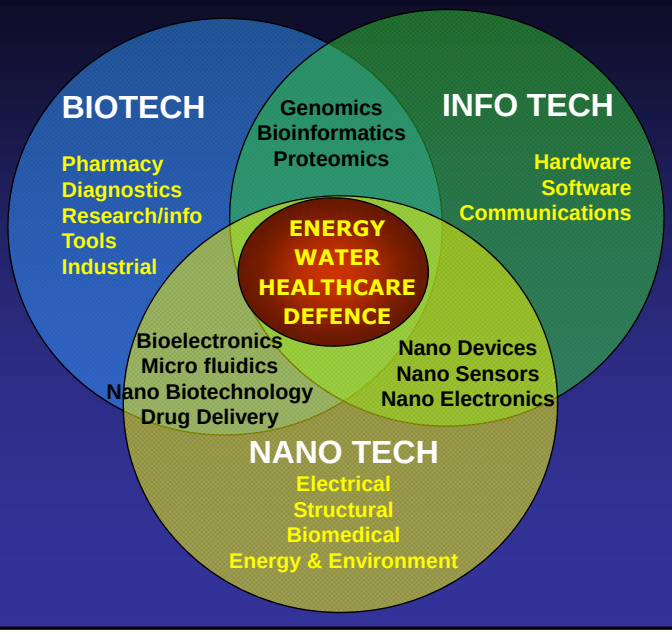
NANOTECHNOLOGY BUSINESS IMPACT

50% of new products in advanced industrial areas will use NS&E by 2015

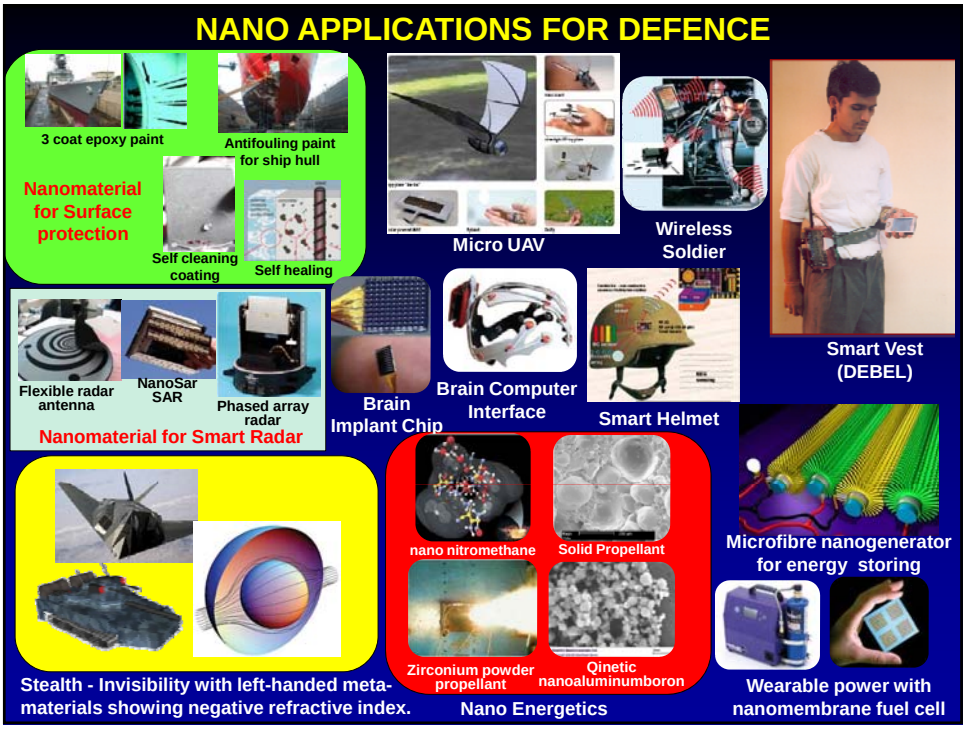


Source: Rohit et al. 2003

CONVERGENCE OF BIO-NANO-INFO TECHNOLOGIES



NANO APPLICATIONS FOR DEFENCE



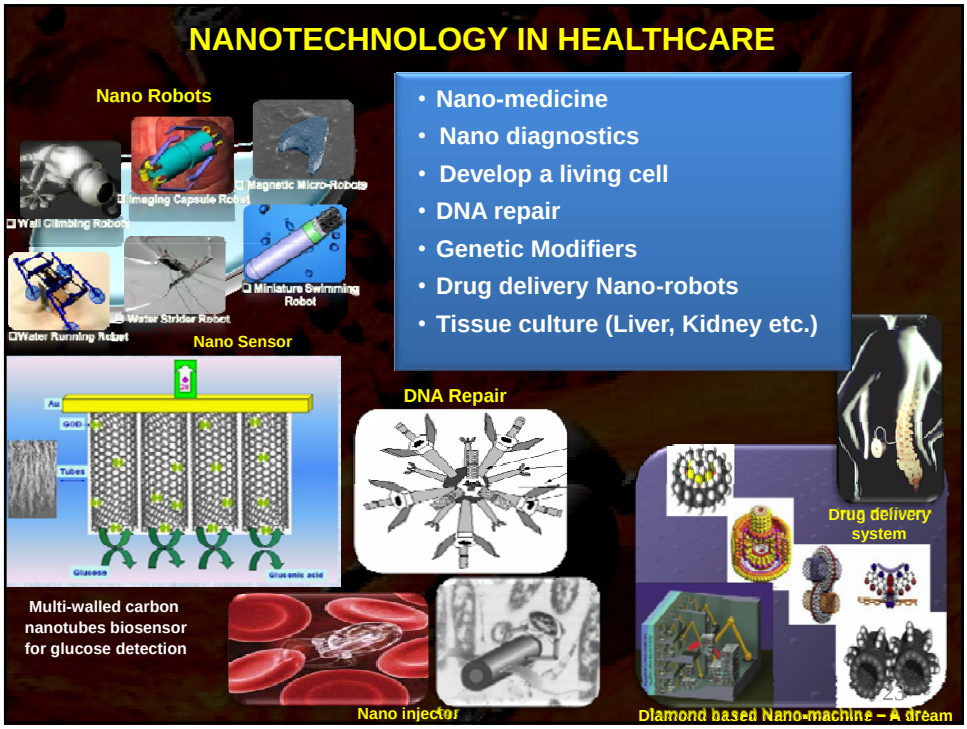
NANO SPY FOR RECONNAISANCE

Artificial hummingbird

- Wingspan : 16 cm;
- Weight: 19 gms (less than an AA battery)
- Speed: 17 km/h (Three axes)

- **Contains Nano batteries, motors, & communications systems; as well as the video camera payload**
- **Can climb and descend vertically; fly in all directions**
- **Manoeuvres using its flapping wings for propulsion and attitude control**
- **Could be deployed to perform reconnaissance and surveillance in urban environments or on battlefields**

Source: DARPA



NANOMEDICINE

- Premise:

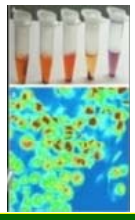
  Nanometer-sized particles have optical, magnetic, chemical and structural properties that set them apart from bulk solids, with potential applications in medicine.

- Potential applications

DRUG DELIVERY	IMAGING
DIAGNOSIS & SENSING	THERAPY

Nanomedicine allows doctors to approach the human body at the cellular and molecular levels

NANOPHARMACEUTICALS



Nanopharmaceutical

NanoEngineered Drugs

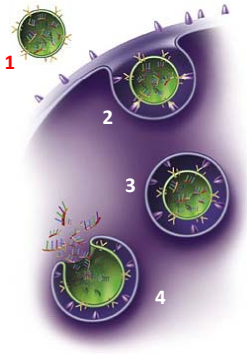
NanoCarriers

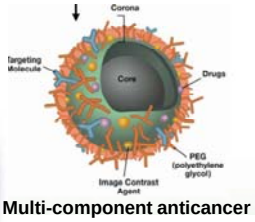
- Nanocrystaline material to increase oral bioavailability of drug molecules
- Different dosage forms (e.g. Nano-suspensions for parentals)
- Different routs of administrations (Ex. Nasal and ophthalmic delivery provides a patient-friendly alternative)

- Nanoparticles permeate in a typical tumor tissue and can be retained.
- Called as "Stealth" liposomes with size <200nm
- Can be attached with ligands for active targeting

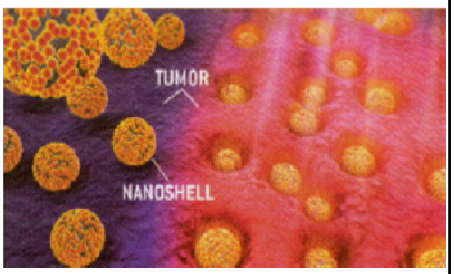
DRUG DELIVERY

Because of their small sizes, nanoparticles are taken by cells where large particles would be excluded or cleared from the body





Multi-component anticancer vaccines with nano-scale vehicles for delivery

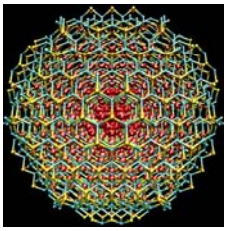


1) Nanoparticle carries the pharmaceutical agent inside its core
2) 'Targeted' nanoparticle recognizes the target cell.
3) The nanoparticle is ingested inside the cell, and interacts with the biomolecules
4) The nanoparticle particles break, and the pharmaceutical agent is released

Source: Comprehensive Cancer Center Ohio University

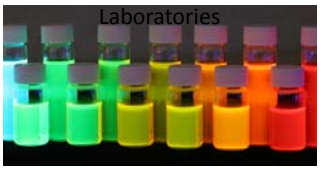
MEDICAL IMAGING

Optical properties of nanoparticles depend greatly on its structure. Particularly, the color (wavelength) emitted by a quantum dot (a semiconductor nanoparticle) depends on its diameter.



CdSe nanoparticle (QD) structure

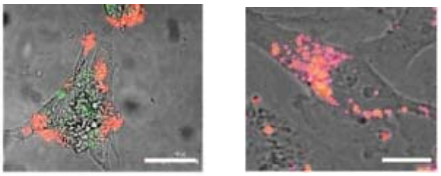
Source: Laurence Livermore Laboratories



Solutions of CdSe QD's of different diameter

Source: Department of immunology, University of Toronto

Quantum Dots (QD) can be injected to a subject, and then be detected by exciting them to emit light



Imaging of QD's targeted on cellular structures

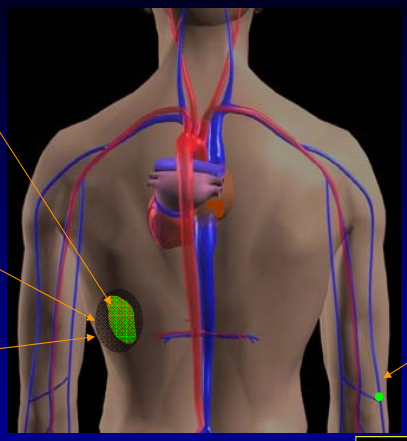
Nano Letters 2008., Vol. 8, pp3887-3892

THERAPEUTIC APPLICATIONS OF MAGNETIC NANOPARTICLES

Solid tumor

Apply magnetic field to concentrate particles

Modulate field to release drug from particles



Other option for targeting:
Direct injection into tumor site

Inject MNPs, and the MNPs will circulate through the blood stream

Magnetic nanoparticles have found many therapeutic applications, such as

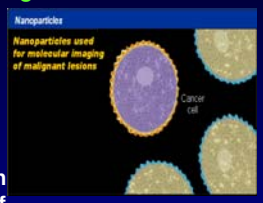
- Magnetic delivery of drugs and genes; Hypothermia treatment & Eye surgery

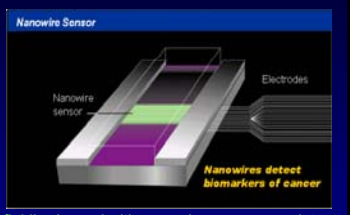
EARLY DETECTION OF CANCER & CURING OF CANCER CELLS THROUGH NANOPARTICLES

Nanotechnology offers tools and techniques for more effective detection, diagnosis and treatment of diseases

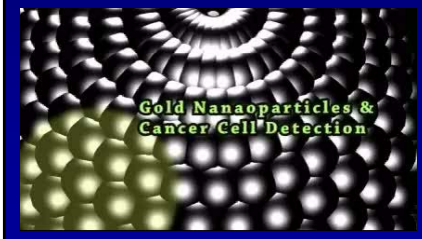
Detection and Diagnosis

- **Lab on chips help detection & diagnosis of diseases more efficiently**
- **Nanowire and cantilever lab on chips help in early detection of cancer biomarkers**





The microfluidic channel with nanowire sensor can detect the presence of altered genes associated with cancer



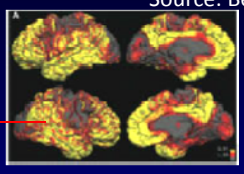
Curing of Cancer using Gold Nanoparticle

The nanoscale cantilever detects the presence & concentra-tion of various molecular expressions of a cancer cell

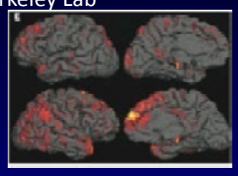
GOLD NANOPARTICLES VS. ALZHEIMER

Alzheimer and other degenerative diseases are caused my the clustering of amyloidal beta (*Aβ*) protein.

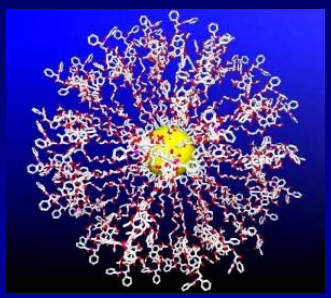
Source: Berkeley Lab



Alzheimer's brain

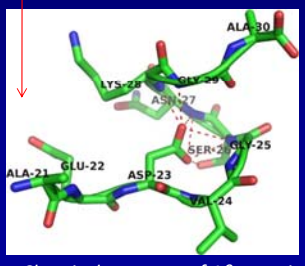


Healthy brain



Functionalized nanoparticle

Source: www.internetchemistry.com



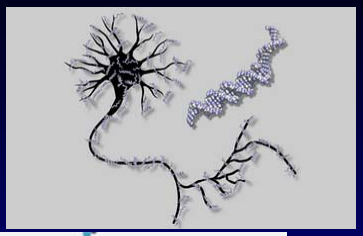
Chemical structure of Aβ-protein

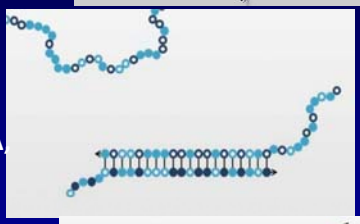
Source: wwwthefutureofthings.com

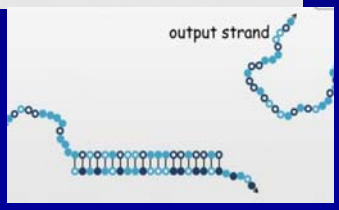
Gold nanoparticles can be functionalized to specifically attach to aggregates of this protein (amyloidosis)

FIRST ARTIFICIAL NEURAL NETWORK OUT OF DNA

- Major step toward creating artificial intelligence in a test tube
- DNA based neural network consists of 4 neurons made from 112 distinct DNA stands
- This network proved to figure out the incomplete pattern as to what it might represent
- Artificial neural network made out of DNA, creating a circuit of interacting molecules can recall memories based on incomplete patterns, just as a brain can







DUPLICATING HUMAN BRAIN IS NOT FAR

THIS IS NANO REVOLUTION

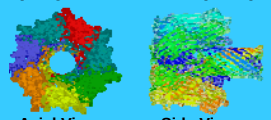
Source: Caltec University

DNA SEQUENCING WITH NANOPORE

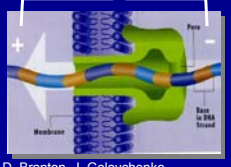
CONCEPT

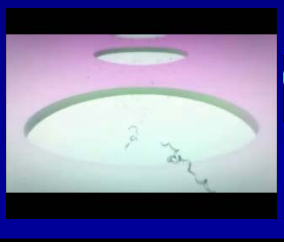
- Nanopore in membrane
- DNA in buffer
- Voltage clamp
- Measure Current

a-hemolysin pore (very first, natural pore)

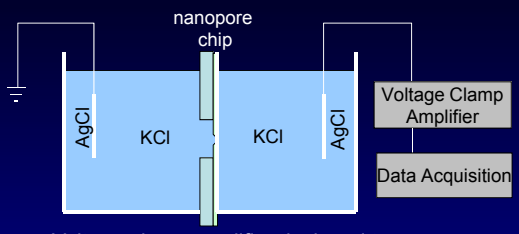


(~2nm diameter)



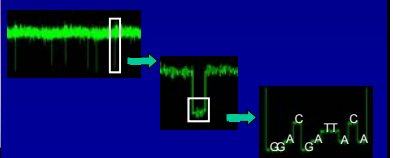


DNA Sequencing Experiments



- Voltage-clamp amplifier designed to measure pA level currents
- Fast (up to 1GHz) data acquisition
- Software for automatic blocking event detection and recording

DNA Sequencing Experiments



G. Church, D. Branton, J. Golovchenko , Harvard, D. Deamer, UC Santa Cruz

Nanotechnology in Biomedical Applications, M Meyyappan

NANOROBOTS FOR NANOWORK

- Teeth cleaning robots
- Lung cleaning: remove toxic effects due to smoking, foreign particles and fibers
- Removal of extra fats from arteries and cleaning the clots
- Elimination of H1N1 Virus

NANOBOTS & NANOLASERS

MAY HOLD THE KEY TO THE FUTURE SURGERY INSIDE THE HUMAN BODY

- Can swim through the bloodstream
  - Dominate the viscous forces
  - Determined by the total surface area
- Intracellular nanodevices
  - Intended to perform inside human tissues

NANOMEDICINE IS THE FUTURE

1. Nanoparticles have very special properties that make them attractive for nanomedicine
2. Nanoparticles can be functionalized with antibodies to target their binding toward specific cells
3. Nanoparticles can be used in diagnosis through the detection of biomarkers
4. Nanoparticles can respond to external radiation and release heat, killing cells around them

Contd. .....

NANOMEDICINE IS THE FUTURE

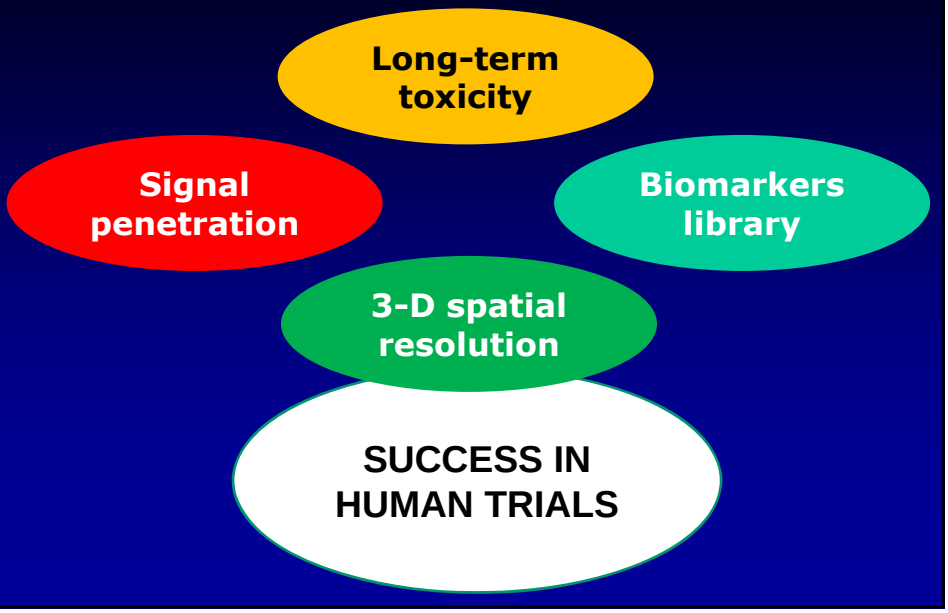
5. Nanoparticles can be made of lipids or polymers than decompose once a target is reached and deliver a pharmaceutical agent

6. Quantum dots are special nanoparticles that emit light of different colors according to its diameter, and can be used for complex diagnosis

7. Poly Ethylene Glygol (PEG) is the most used polymer to coat nanoparticles due to the biocompatibility and biomobility that confers to the nanoparticle

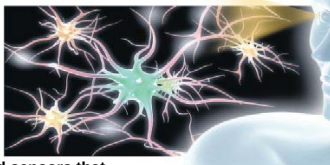
8. Targeted nanoparticles offer a light of hope for the fight against cancer / HIV

CHALLENGES



THE FUTURE

Nanotechnology is creating smart materials that will replace & improve every part of body.
Powerful new senses & abilities will create a super human



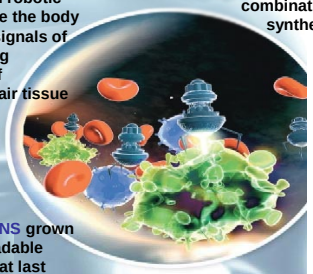
BRAIN – Implanted sensors that convey where you are, where you're moving and hove to find your friends in a crowd

ARTIFICIAL VISION that allows us to see in infrared, ultraviolet and x-ray

EARS that hear across a wider range of frequencies.
TRANSLATION Tiny molecule-sized computers able to translate conversations

NANONURSES small robotic devices moves above the body detecting chemical signals of damage & dispensing appropriate doses of drugs or cells to repair tissue

FLAWLESS SKIN from combination of cells & synthetic polymers



MUSCLES fatigue-resistant stronger muscles with smart materials

DNA HAND SHAKE – sensor to check a person's identity from their DNA

NEW ORGANS grown on biodegradable scaffolds that last longer and perform better than the original

BODY WASTE Automatically analysed for signs of illness

UNBREAKABLE BONES – strengthened with CNT or artificial mother-of pearl

Source: http://www.smh.com.au
Illustration: Jojin Kang

RESEARCH AREAS

* **Carbon Nanotubes**
  - Growth (CVD, PECVD)
  - Characterization
  - AFM tips
    - Metrology
    - Imaging of Mars Analog
    - Imaging Bio samples
  - Electrode development
  - Biosensor (cancer diagnostics)
  - Chemical sensor
  - Logic Circuits
  - Chemical functionalization
  - Gas Absorption
  - Device Fabrication

* **Molecular Electronics**
  - Synthesis of organic molecules
  - Characterization
  - Device fabrication

* **Inorganic Nanowires**

* **Protein Nanotubes**
  - Synthesis
  - Purification
  - Application Development

* **Genomics**
  - Nanopores in gene sequencing
  - Genechips development

* **Computational Nanotechnology**
  - CNT - Mechanical, thermal properties
  - CNT - Electronic properties
  - CNT based devices: physics, design
  - CNT based composites, BN nanotubes
  - CNT based sensors
  - DNA transport
  - Transport in nanopores
  - Nanowires: transport, thermoelectric effect
  - Transport: molecular electronics
  - Protein nanotube chemistry

* **Quantum Computing**

* **Computational Quantum Electronics**
  - Noneq. Green's Function based Device Simulator

* **Computational Optoelectronics**

* **Computational Process Modeling**

TBI for Nano-Enabled Products (Research + Industry)

WATER

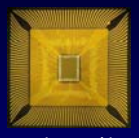
Silver Nanotechnology based water Purifier

SENSORS

Glucose Monitoring Device

Infectous disease biosensor

HEALTHCARE



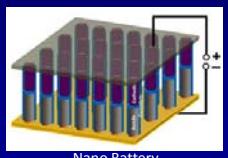
Brain on a chip

DNA Repair Nanorobot

COMMERCIAL APPLICATIONS

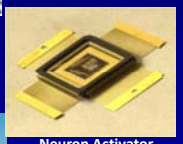
Lab on a chip
diagnostic device promises confirmation of HIV, TB and other conditions in 10 min.

ENERGY



Nano Battery

Light-weight, stronger bicycle frames



Neuron Activator chip

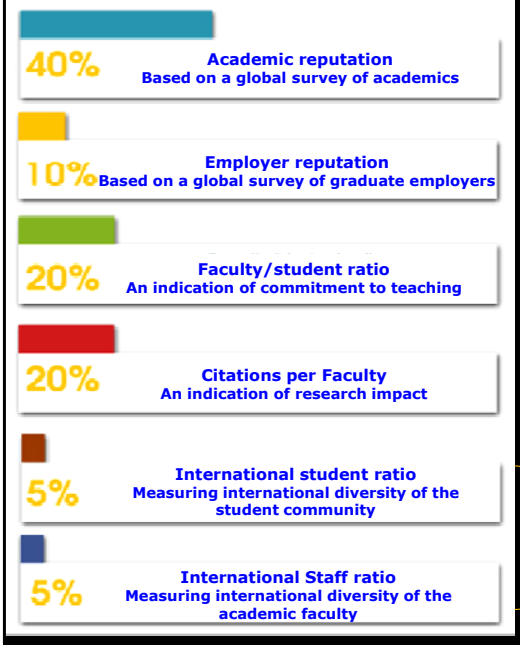
Nano based Solar panel

Low-power chips for nano computer

Nano coatings to protect against scratches and radiation

Burn and wound dressings

Criteria – World University Rankings



- **Academics to tell us where the best work is currently taking place within their field of expertise**
- **To identify the universities that in their view produce the best graduates. It is unique among Intl. university rankings.**
- **Simple measure of the number of academic staff employed for every student enrolled**
- **Aims to assess universities' research output. More highly cited research papers a Univ. publishes, stronger its research output is considered**
- **Measuring the proportion of international students and faculty members in relation to overall numbers.**


SATHYABAMA UNIVERSITY IS POISED TO BECOME
INDIA'S NUMBER ONE UNIVERSITY OVERTAKING IITs
AS IT HAS A THRUST FOR ADVANCED RESEARCH
SATHYABAMA UNIVERSITY


Thank you
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