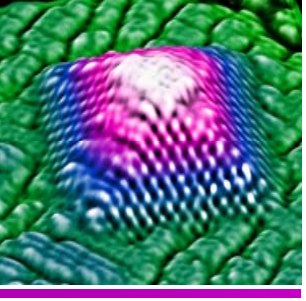
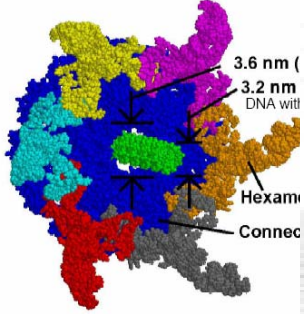
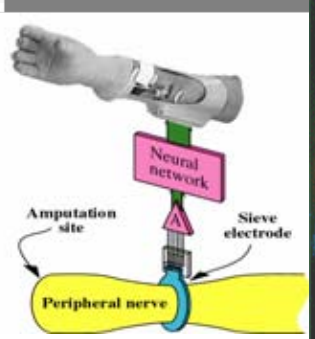
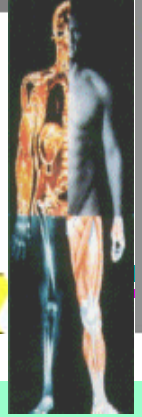
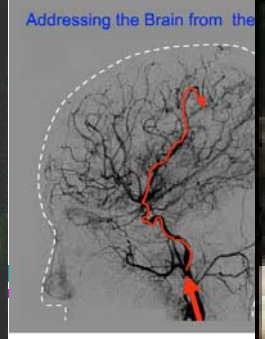





Governance of Converging New Technologies

M.C. Roco

National Science Foundation,
National Nanotechnology Initiative, and
International Risk Governance Council

ICMET

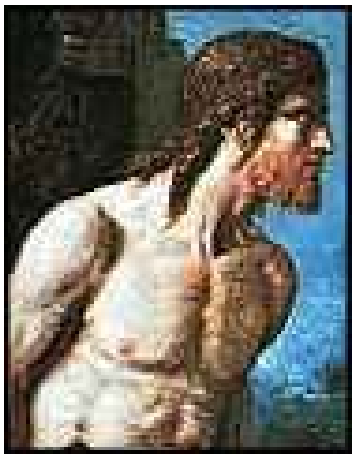
Portland, August 7, 2007

Topics

- Emergence and integration of nanotechnology – biotechnology – information technology – cognitive sciences
- Global governance of converging technologies
- Recommendations for the risk governance

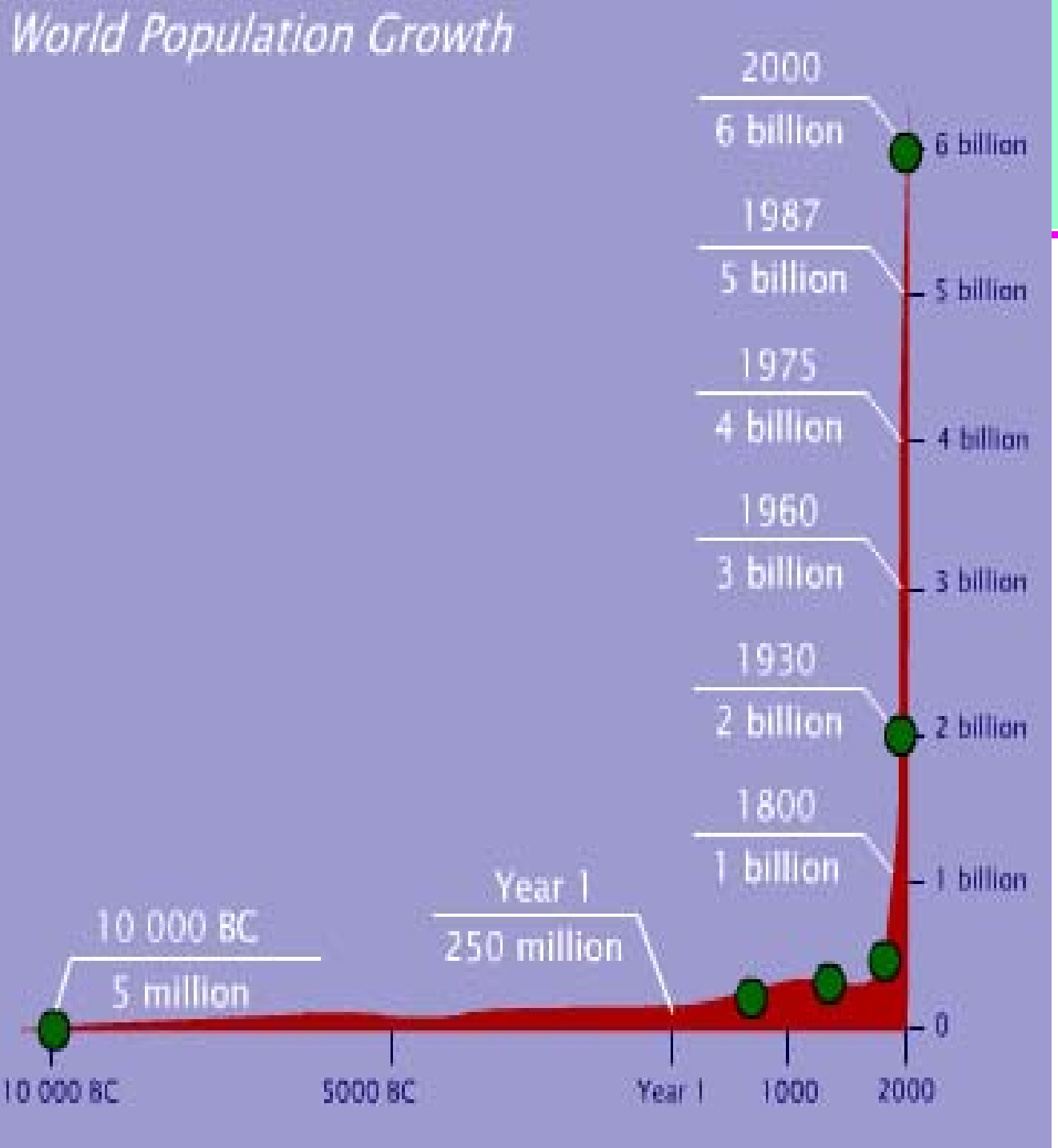
Benefits and risks of technology

- **<u>Human potential and technological development are coevolving</u>, and quality of life has increased tremendously with technological advancements**



S&T at the core of human endeavor; However, there is a perceived tension between the society and technology (maybe because significant changes, accelerated path, larger benefits & risks). Prometheus giving the fire: "An eternity of torture"

<u>Technology implications are global issues</u> (human development, EHS, E-W & N-S balance) that need to be addressed together through international collaboration

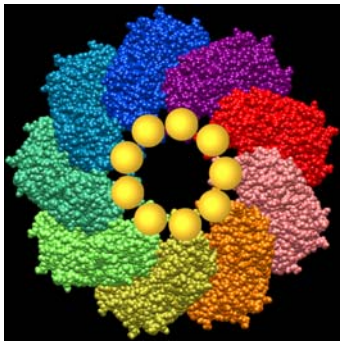


More people

9-10 billion by 2050

- Increased consumption of water, food, energy
- Changing environment
- Changing society
- Maintaining peace

NEED OF RADICALLY NEW TECHNOLOGIES



Converging Technologies Idea

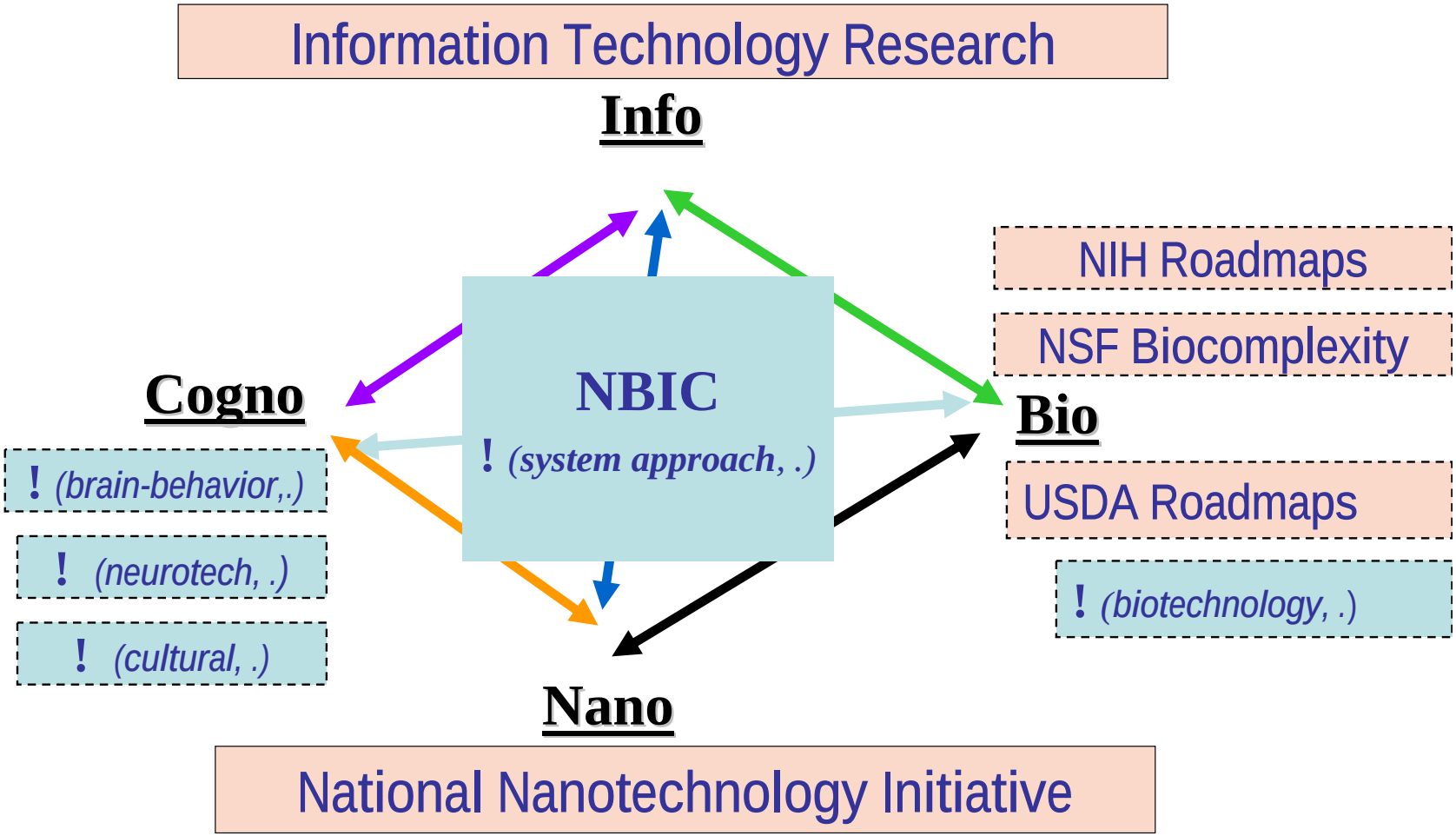
Advancing an integrative approach for converging and emerging S&E from the nanoscale, IT and system levels

- with re-focus on people
- new nanotechnology - biotechnology - IT - cognitive sciences (NBIC) platforms for science and technology
- co-evolution of new technologies and human potential

Converging New Technologies transforming tools
(overview in 2000)

The "Push"

The "Pull"



Timely, broad opportunity

2000 →

- Material unity at the nanoscale and technology integration from the nanoscale, beyond the "Renaissance ideal"

- Powerful transforming tools (nano-bio-info-cogno, NBIC) developing at the confluence of disciplines, integrated from the nanoscale

- Towards an "universal domain of exchange" for ideas, etc.

- Improvement of human performance becomes possible

- New social relations (adapting organizations and business)

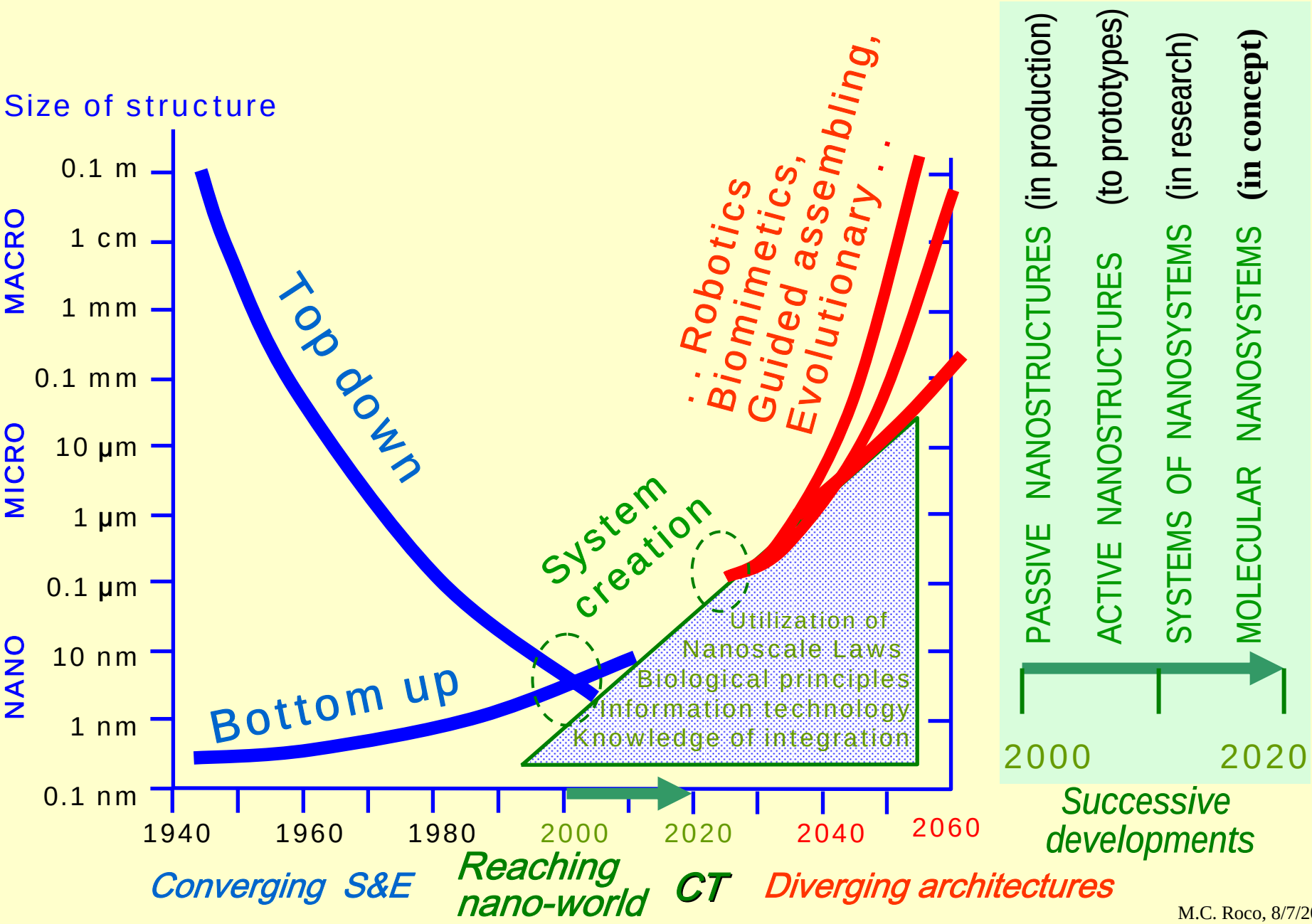
- Need for anticipatory and adaptive governance measures ('Learning before doing')

Expected NT, BT, IT and CT paradigm changes in the next decade (it favors a fresh look)

- NT: moving from scientific discovery to technological and medical innovation, and systematic methods of mass application
- BT: moving towards molecular medicine and pharmaceutical genome
- IT: the quest for smallness and speed will be enhanced by the needs for new architectures, 3-D integration, functionality and integration with application driven developments such as those in biosystems
- CognoT: - explanation of human behavior from understanding of physico-chemical-biological processes at the nanoscale, neuroscience, and large system approach

  - system-based technologies based on large, hierarchical, dynamic complex systems, towards new opportunities such as quantitative social sciences

Reaching nano-world and system creation using CT



M.C. Roco, 8/7/2007

Timeline of significant augmentations
to human potential

Generations	Key Advancements (human kind, transforming approach, tools and technology)
- m	Cell, body and brain development
- 100,000	Old Stone Age (Paleolithic), Homo Erectus, speech
- 10,000	Homo Sapiens, making tools: practical approach
- 500	Mesolithic, creating art
- 400	Neolithic, agriculture, writing, libraries
- 40	Universities
- 24	Printing
- 16	Renaissance S&T, accurate clocks: abstract approach
- 10	Industrial revolution
- 5	Telephone
- 4	Radio

Modified J. Spohrer et al.,
M.C. Roco, 8/7/2007

Timeline of significant augmentations (cont.)

(since the second WW)

-3 TV

-2 IT: Computers, microanalysis: analytical approach

-1 BIO: Microbiology; Internet

0 NANO: Control of matter at nanoscale: fundamental approach
Biotechnology products; Global connection via Internet

0.5 COGNITIVE sciences based on brain and social understanding
NBIC: Unifying knowledge from the nanoscale and using global networking; Nanotechnology/Bio/Info products.

1 Converging new technology products for increasing human potential (new products and services, brain connectivity, sensory abilities, innovation age, art understanding, etc.)
"New industrial revolution" based on molecular / nanoscale control; Reshaping organizations and business

n Evolution of human cell, body, and brain?

Benchmark with experts in over 20 countries

"Nanostructure Science and Technology"

Book Springer, 1999

Nanotechnology

*is the **control and restructuring of matter** at dimensions of roughly 1 to 100 nanometers (from about 1 atom to about 100 molecular diameters),*

where new phenomena

enable new applications

WHAT IS SPECIAL ABOUT NANOTECHNOLOGY?

- Reaches at the basic level of organization of atoms & molecules, where the fundamental properties/functions of manmade and living systems are defined and can be changed

- Broad technology platform
  - for industry, biomedicine, food, energy & environment

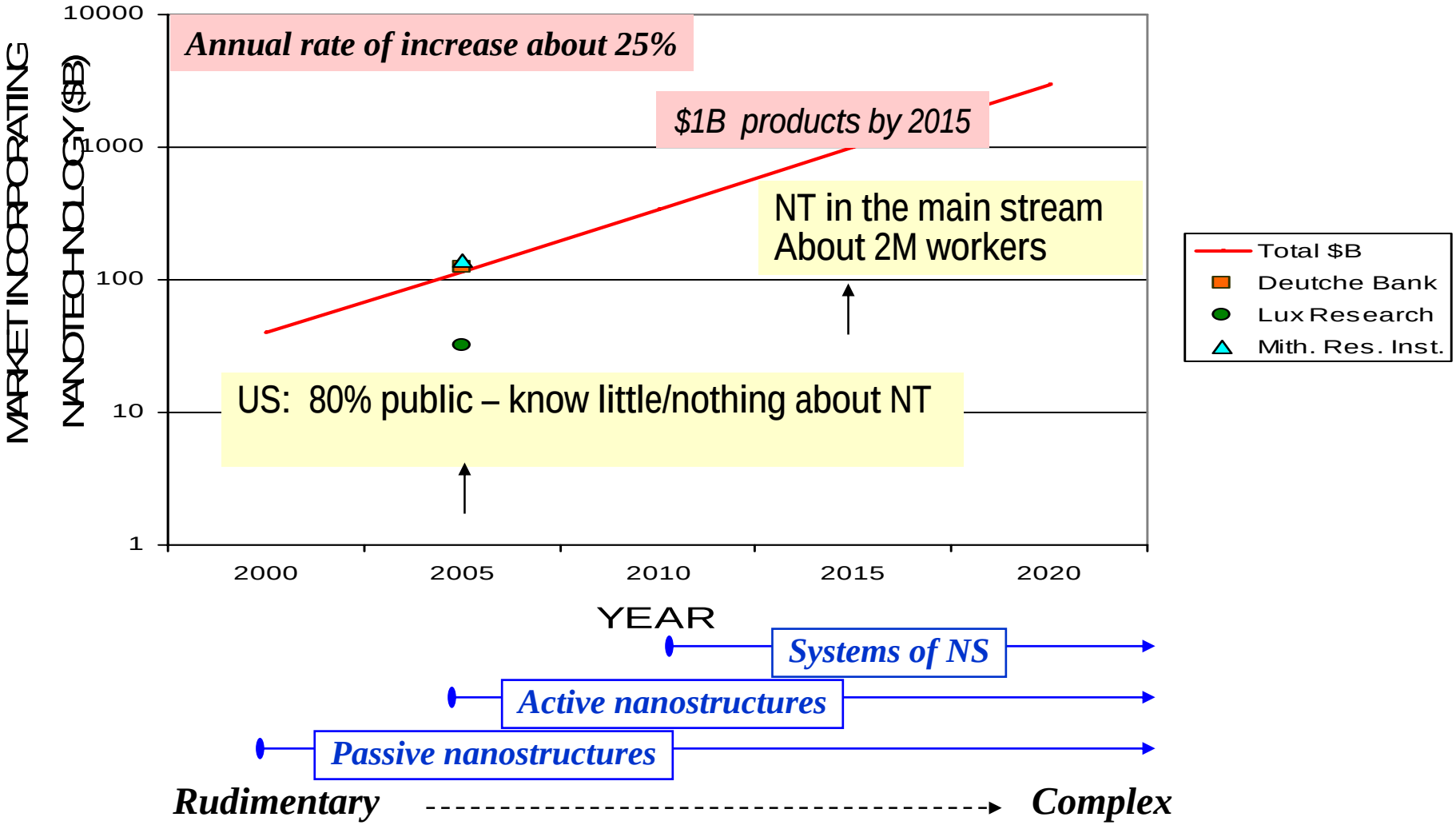
Consequences

- Has stimulated all developed countries and many countries in development to invest in nanotechnology R&D (over 60 countries)

- Has stimulated the speed and scope of R&D that exceeds for now the capacity of regulators to assess human/ environmental impact

WORLDWIDE MARKET INCORPORATING NANOTECNOLOGY

(Estimation made in 2000 after international study in > 20 countries)



M.C. Roco, 8/7/2007

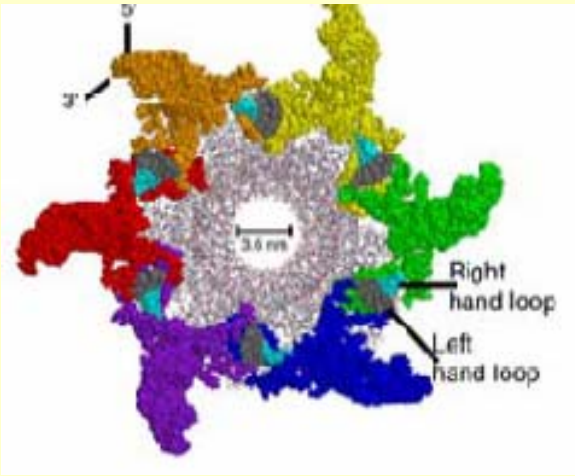
Converging New Technologies
Implications

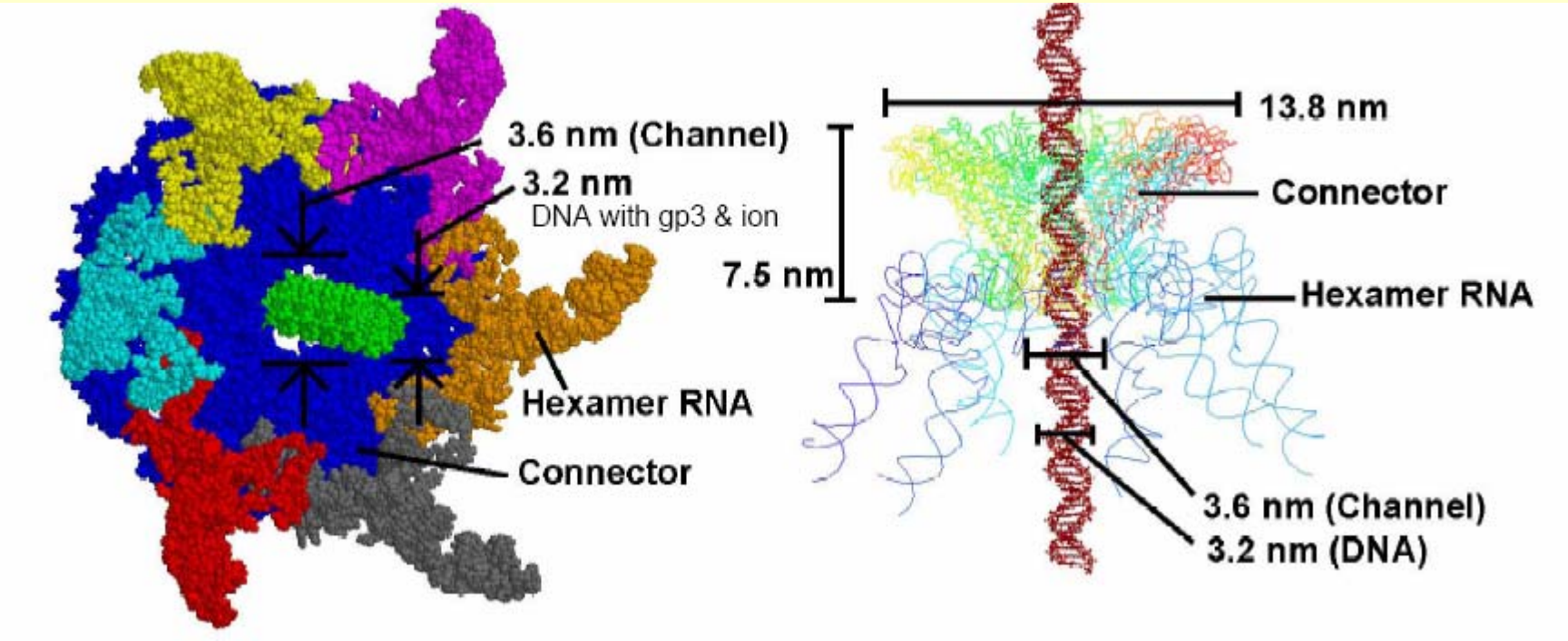
- Expanding human cognition and communication
- Improving human health and physical capabilities
- Enhancing societal (individual, group) outcomes, including new products and services
- Changing societal relationships, including reshaping
  - policies for R&D investments and infrastructure,
  - models for organizations and business
  - risk governance for innovative technologies
- Personal and national security
- Unifying science and education

Example - active nanostructure:

Construction of a Viral Nanomotor Driven by a Synthetic RNA

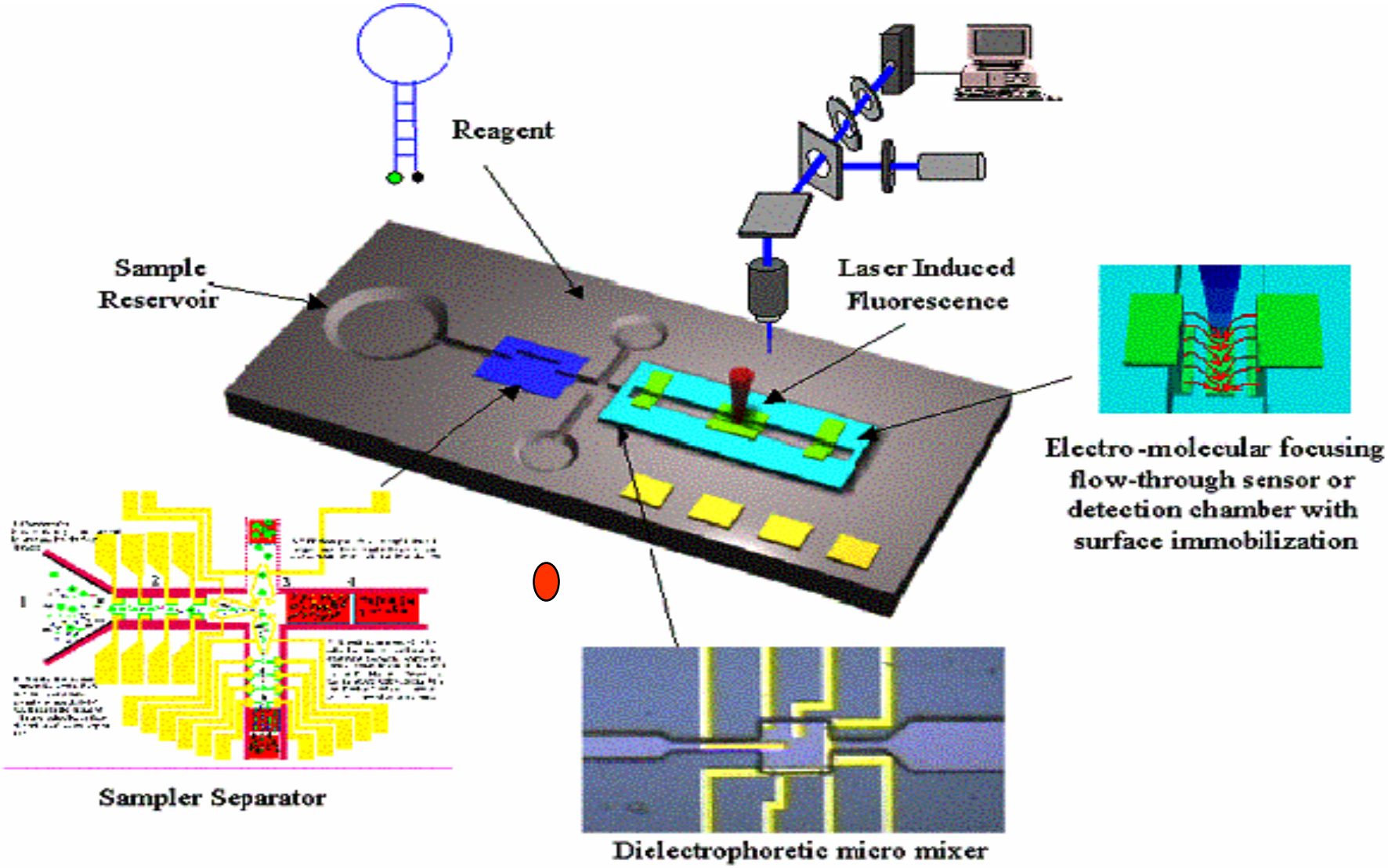
P. Guo, Molecular Virology, Purdue University, 2004





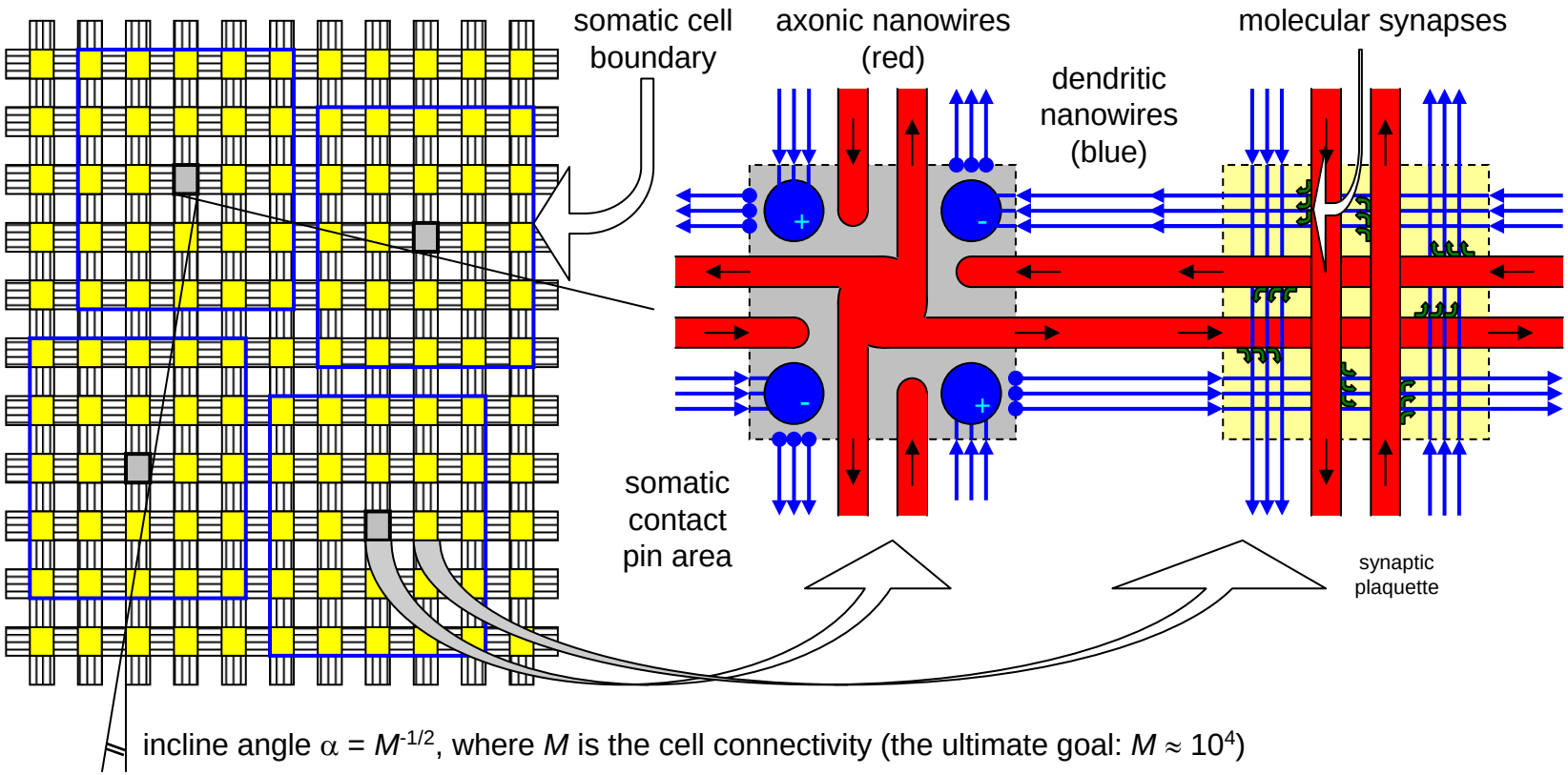
Ex: Biochips as integrated multifunctional systems

Detection of illnesses using saliva: the detection chamber that includes the different ligand for simultaneous optical detection of multiple analytes (**D. Wong, C.-M. Ho, UCLA)**



Ex: Nanoscale Single-Electron Switching Arrays for Self-Evolving Neuromorphic Networks

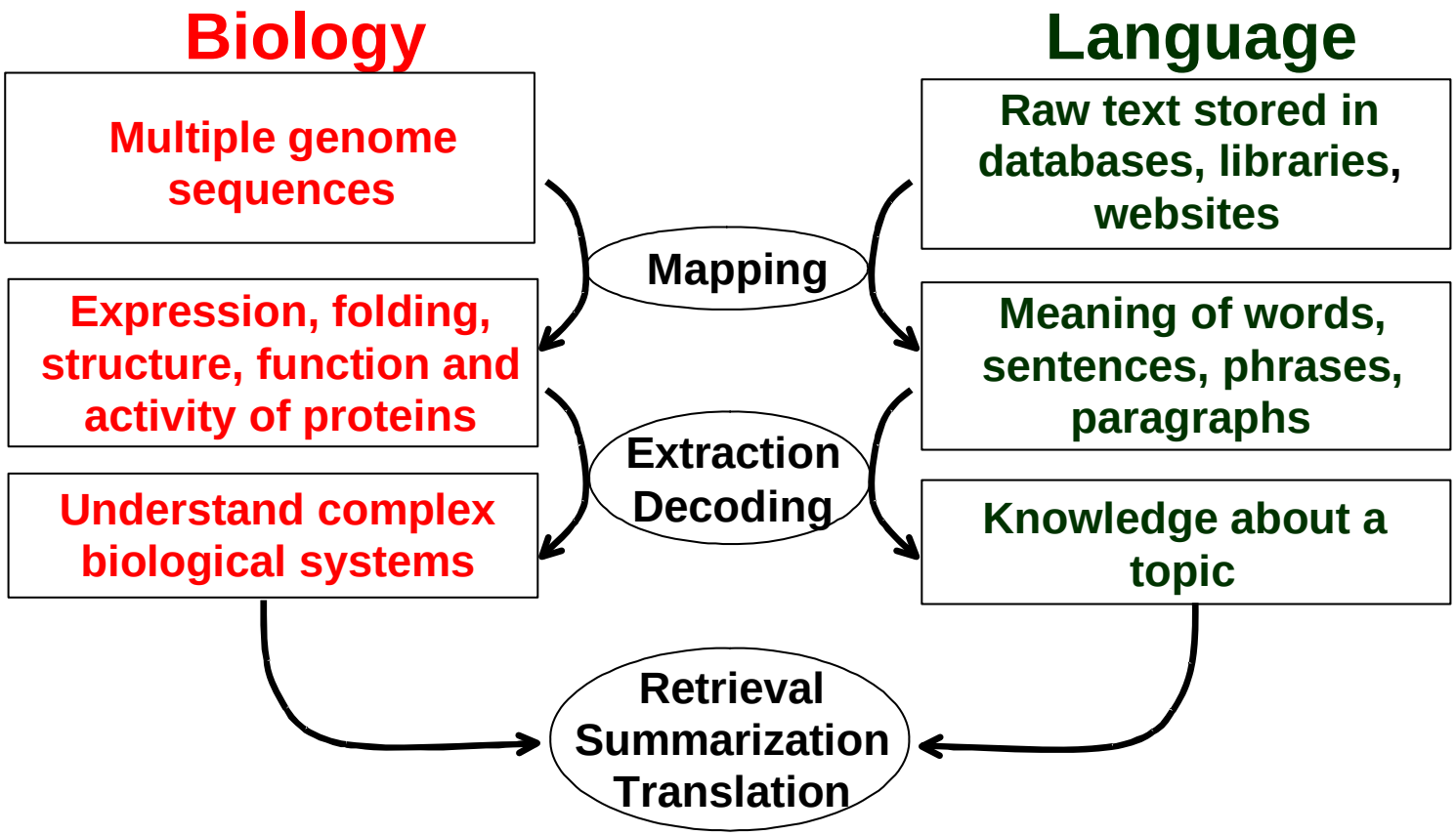
K. Likharev, SUNY Stony Brook, 2002



This architecture allows to combine high density CMOS-based somatic cells (up to 10^8 per cm^2) with extremely high density of single-electron latching switches working as synapses (up to 10^{12} per cm^2) necessary for our "final" goal: placing a hardware analog of a mammal cerebral cortex on a 10×10 cm^2 silicon area.

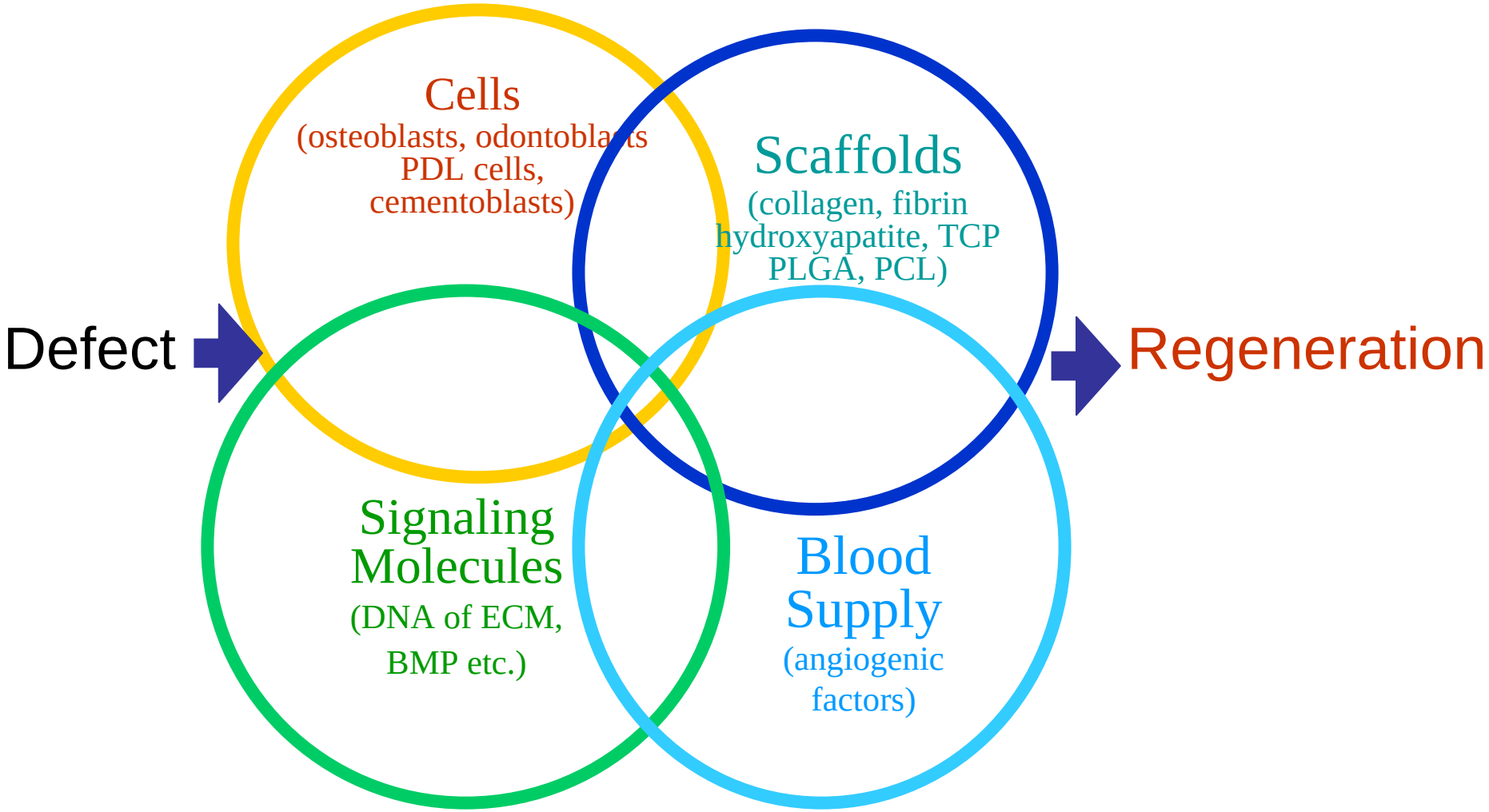
Analogy between biology and language

forms the basis for the convergence of computational linguistics and biological chemistry

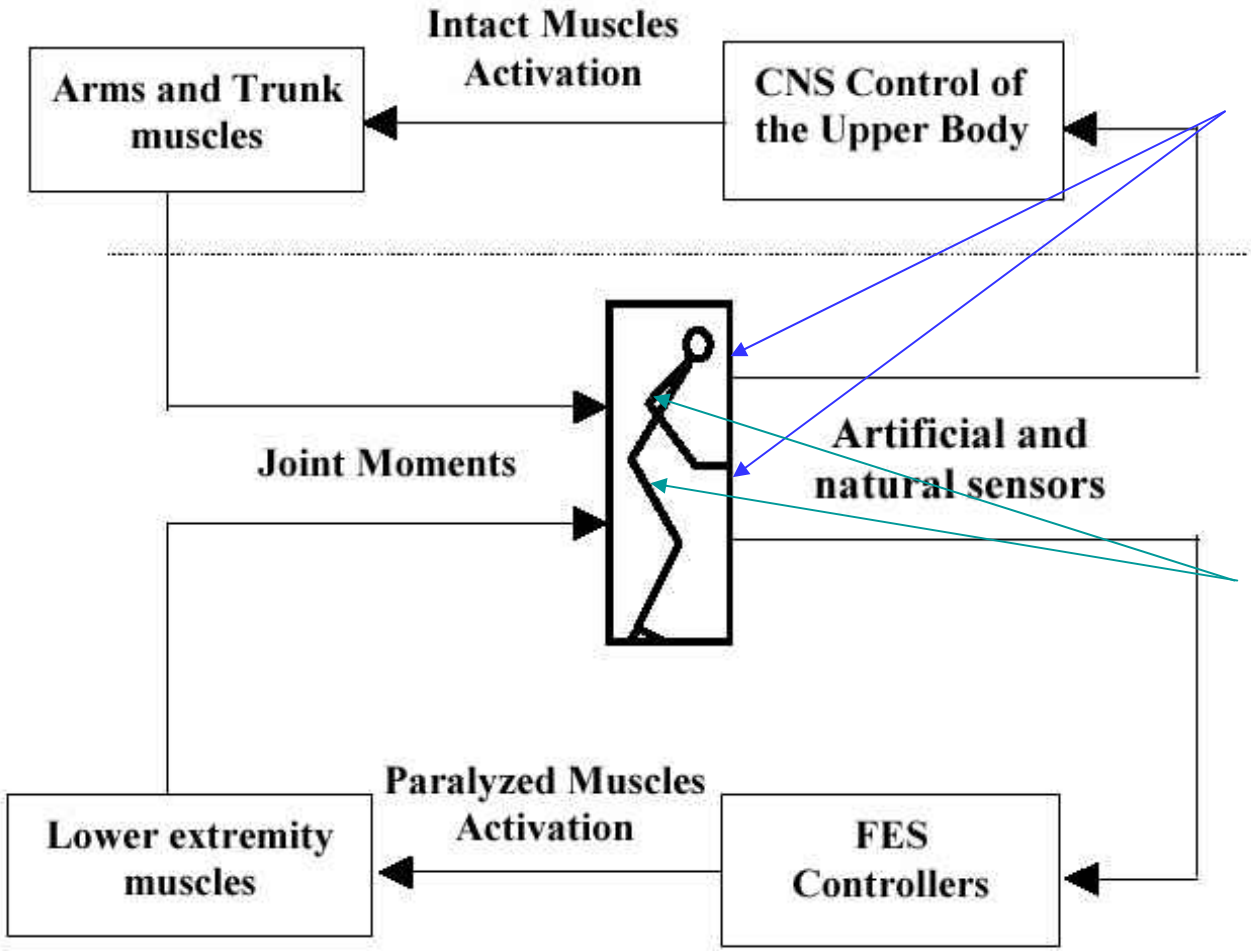


J. Klein-Seetharaman, 2002 in the NBIC Report

Regenerative biosystems from the nanoscale:
nanotools, bioprinciples, information control, and ethical aspects



Can we connect nanoelectronics to biology?
What is currently possible?

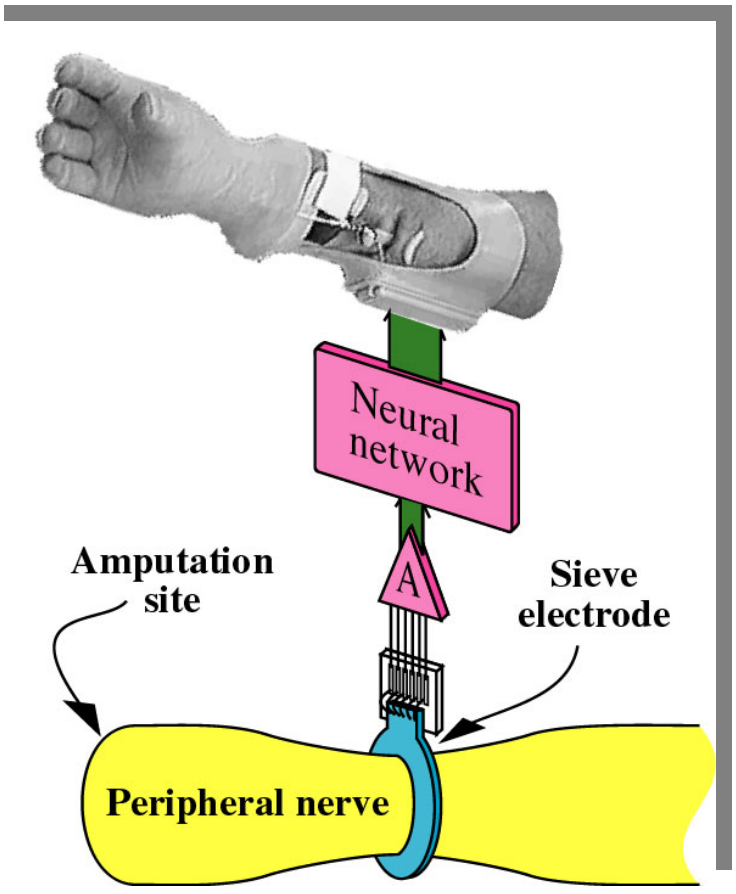


Sensors of neural activity are required for determining what is "desired."

Activation circuits are needed to "trigger" desired responses.

ARTHAND PROJECT: Mind controlled prosthesis

Lund University, 2003



Neurobiology
Neurophysiology
Biomaterials
Learning models
Rehabilitation and Sensory feedback

Example nanosystems: SELF-ASSEMBLED ARTIFICIAL BONE, CONNECTING NERVES, TISSUE SCAFFOLD

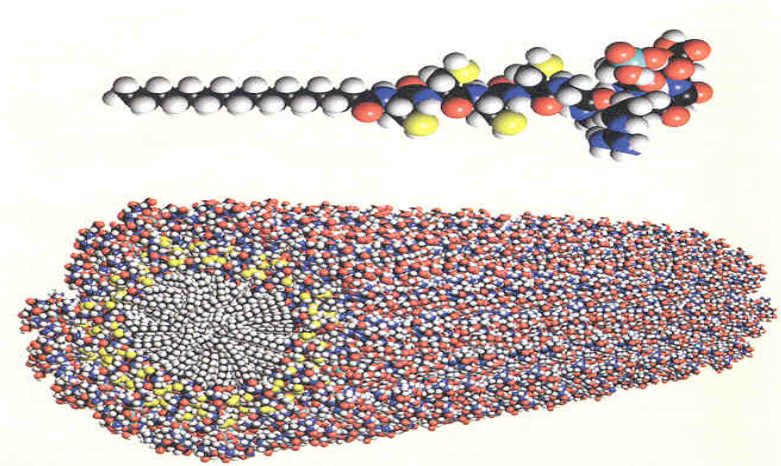
Sam Stupp (Northwestern U.)

SCIENCE & TECHNOLOGY

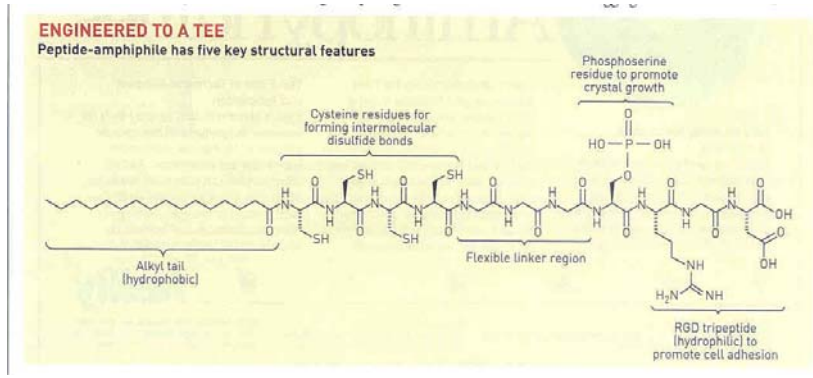
MIMICKING THE WAY NATURE GROWS BONE

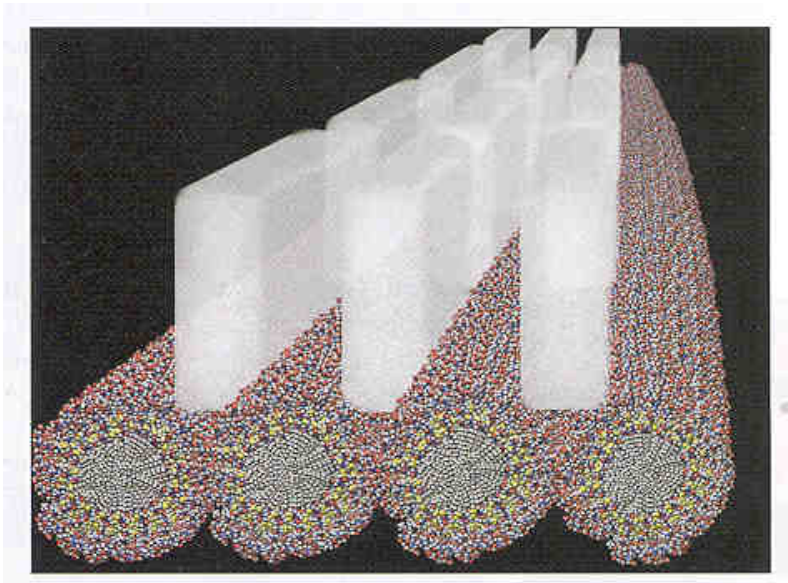
Exquisitely designed molecules assemble into nanofibers that promote the growth of mineral

R



PROGRAMMED ASSEMBLY Molecular model of the peptide-amphiphile (top) reveals its overall conical shape going from the narrow hydrophobic tail to the bulkier peptide region (carbon is black; hydrogen, white; oxygen, red; nitrogen, dark blue; phosphorus, pale blue; sulfur, yellow). Below pH 4, the amphiphile molecules assemble themselves into long cylindrical micelles, or nanofibers. The bulkier peptide region, which contains the RGD sequence and phosphoserine, lies close to the fiber surface.

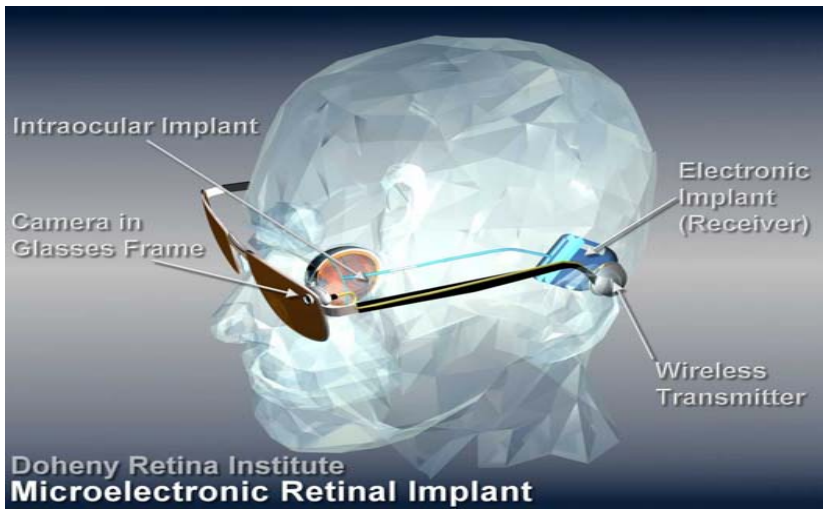




Interfaces with human cells and sensors

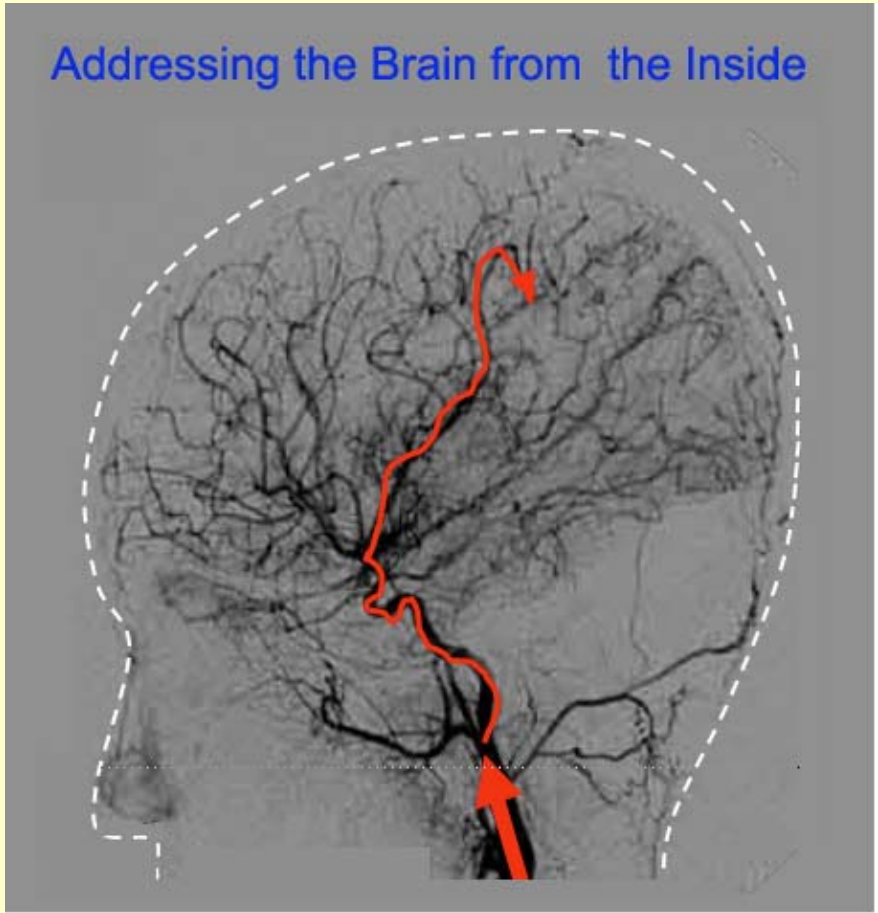
Ex:

- J. Heath (Caltech): Sensors for subcellular processes & computer of the size of a cell: **continuous monitoring and interaction**
- Robert Greenberg: **Interfacing to the sensory human nervous** system via chemical, electrical, mechanical, magnetic signals
- David Reinken (UC Irvine): **robotic devices for training** of movements after neurologic injuries
- James Gram (TAMU): **memory with spinal cord**
- **Various prosthesis**: may increase visual (infrared, X-ray, etc.), audio, smelling, tactile, nerves, or other capacities
- Chemical-mechanical **macromolecular machines**
- Doheny Retina Institute: **artificial retina**



Example: Neuro-vascular Central Nervous Recording/ Stimulating System: Using Nanotechnology Probes

R.R. Llinás, NYU School of Medicine
I. Hunter, MIT, Bioengineering



Nanostructured polymeric wires, biocompatible, biodegradable and with guidance

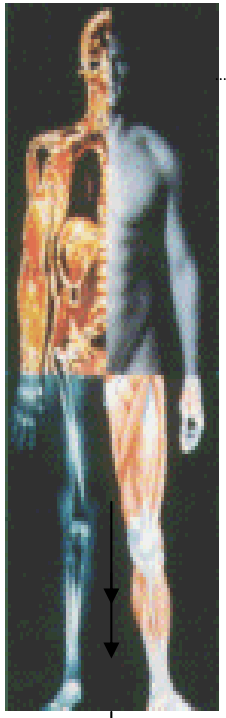
Several goals:

- neuro-to-neuron interaction
- simultaneous multiple probes for describing the system
- treatment Parkinson disease

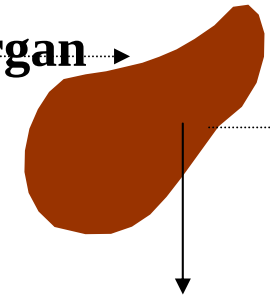
Examples of levels for intervention of nanobiotechnology

4 generations of products for human life extension

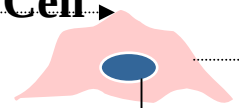
Human



Organ



Cell



Molecule

- **(1st)** Joint replacement
- Non-invasive and invasive diagnostics for rapid patient monitoring
- Cognitive-assist devices
- Targeted cancer therapies

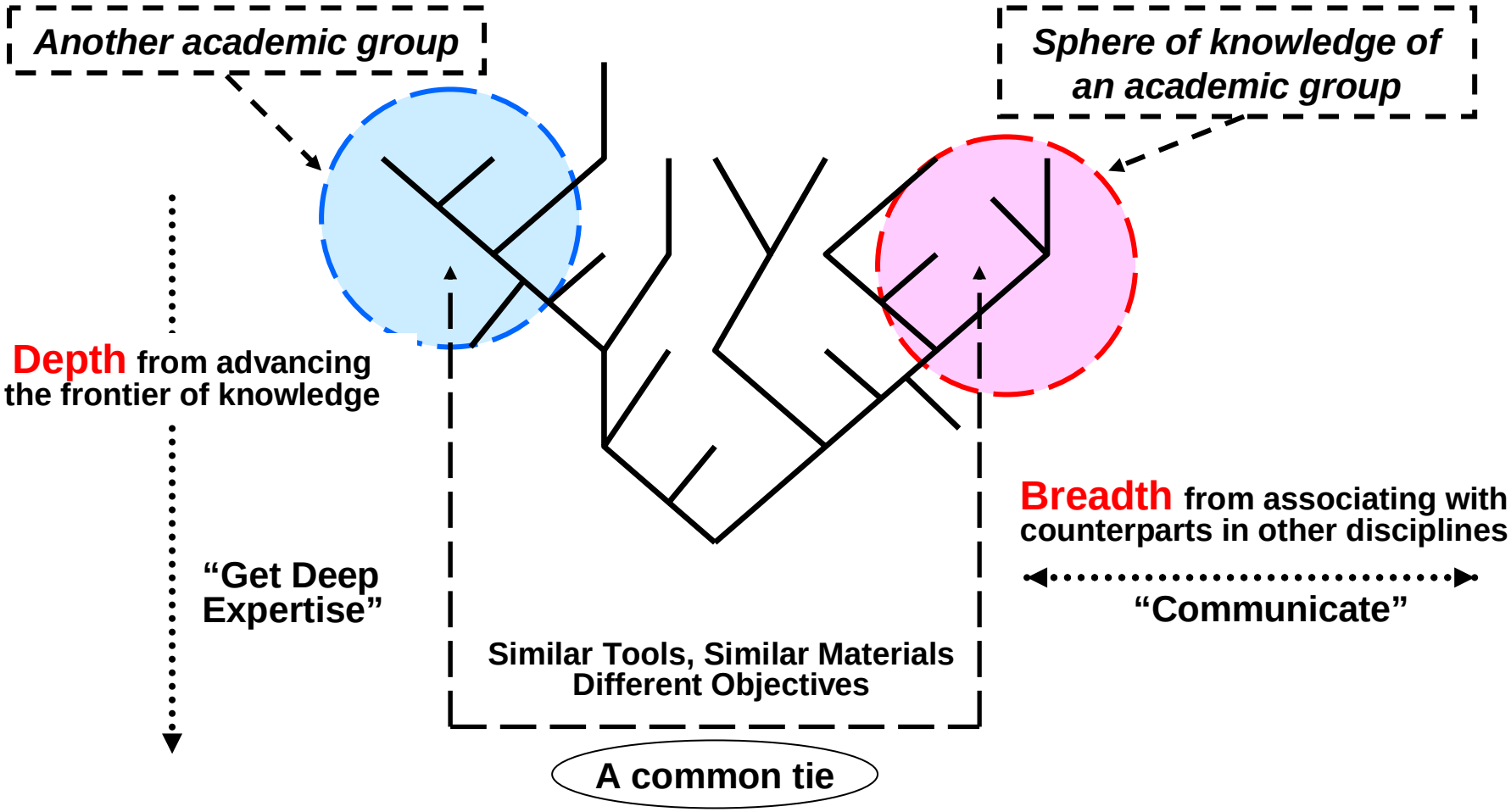
- **(2nd)** Sensors for in vivo monitoring
- Localized drug delivery
- Neural stimulation
- Cardiac therapies
- Artificial organs

- **(3rd)** Improved cell-material interactions
- Scaffolds for tissue eng.
- **(4th)** Genetic therapies
- Cell ageing
- Stem cell therapies

- Localized drug delivery
- Fast diagnostic techniques
- Gene therapy devices
- Self-assembly structures

(NBIC Report, 2002)

Combining "depth with breadth" in NBIC education and research



(NBIC Report, 2002)

NSF's Science of Learning Centers (using NBIC)

/Example R&D program: http://www.nsf.gov/home/crssprgm/slc/

Center for Excellence for Learning in Education, Science, and Technology (CELEST), Boston U. (http://cns.bu.edu/CELEST/)

Center for Learning in Informal and Formal Environments (LIFE), U. of Washington, Stanford U., SRI International, and other institutions across the country (http://life-slc.org/)

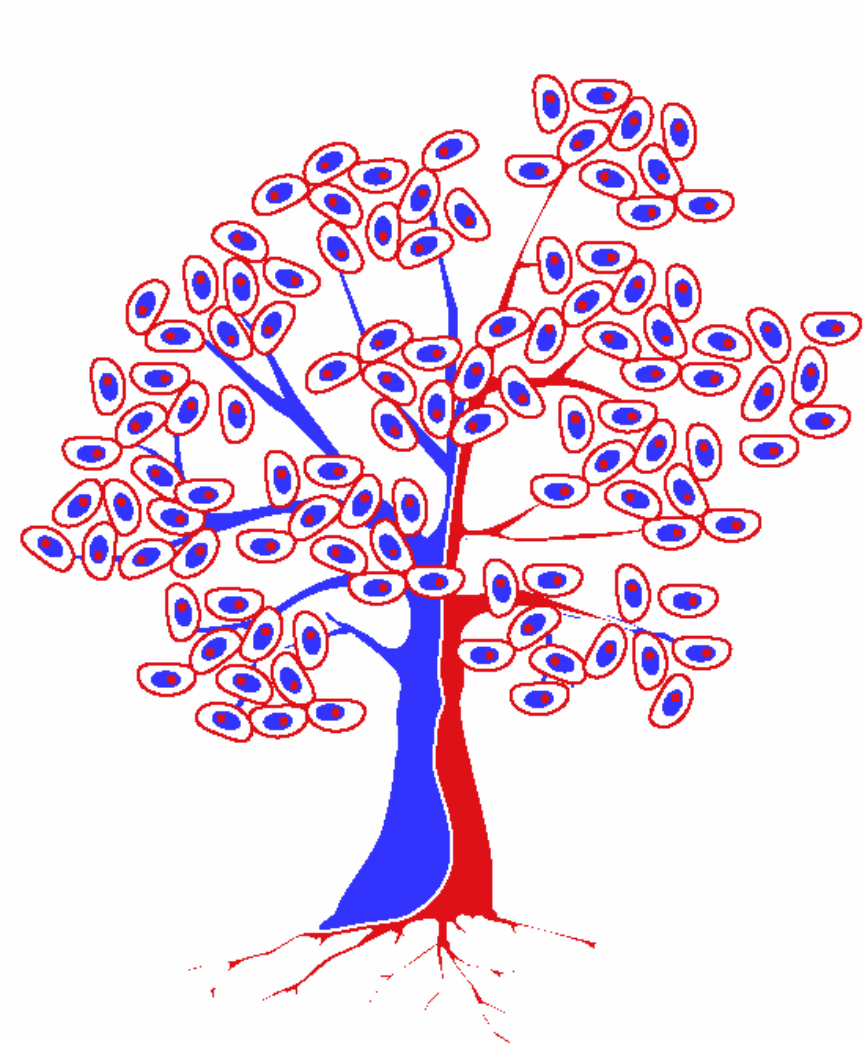
Pittsburgh Science of Learning Center for Robust Learning (PSLC), Carnegie Mellon U. and the U. of Pittsburgh (http://www.learnlab.org/)

Spatial Intelligence and Learning Center (SILC), Temple University, Northwestern University, the University of Chicago, the University of Pennsylvania, and the Chicago Public Schools (CPS)

The Temporal Dynamics of Learning Center (TLC) University of California, San Diego (UCSD)-based interdisciplinary team of scientists, with participation from scientists at Rutgers University, Newark, Vanderbilt University, UC Berkeley,

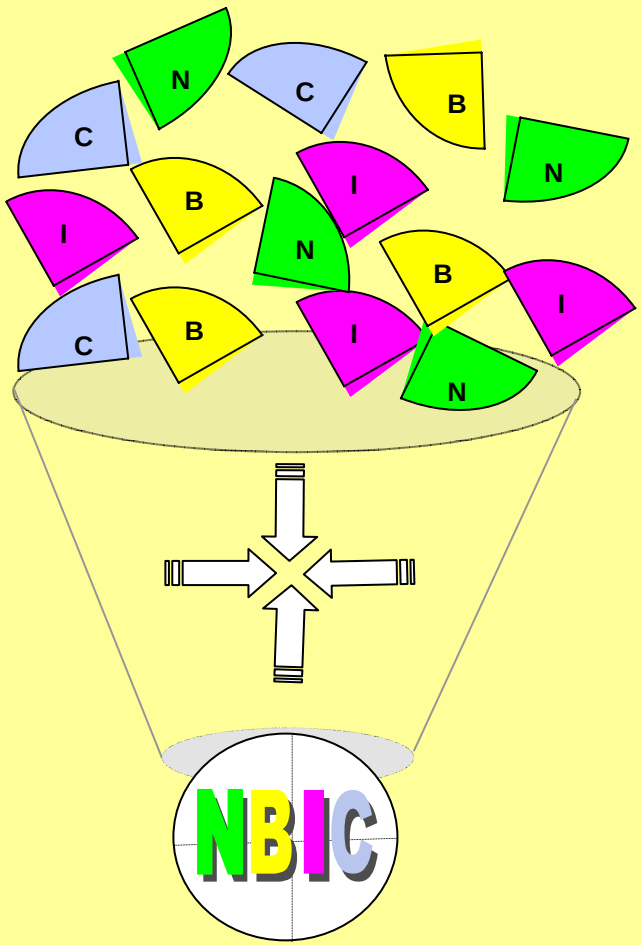
Visual Language and Visual Learning Center (VL2) Gallaudet University

Example R&D program:
Vision for 2020: Regenerative medicine (2004-)



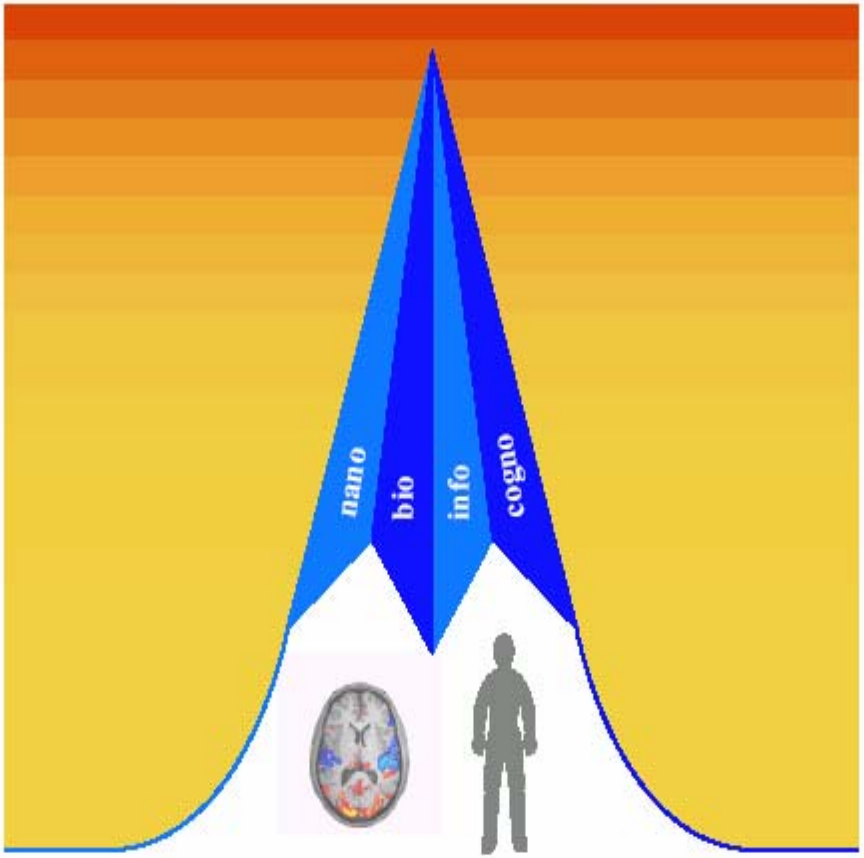
Combine precision assembly of matter (nanotechnology), building blocks of living systems biotechnology), spatio-temporal flow of information (IT), and cognitive sciences. Working group 6 Federal agencies (NIH, FDA, DOD, NASA, DOC, NSF; 1/2004)

Commercializing and Managing the Converging Technologies (2004)



NSF sponsored workshop (September 2003) and report (April 2004)

Northwestern University, Center for Technology & Innovation Management (CTIM)

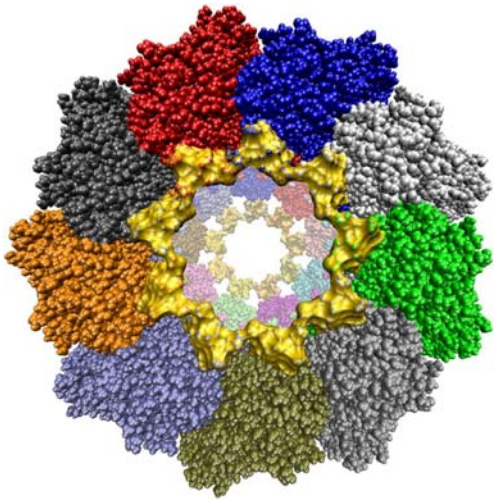


CONVERGING TECHNOLOGIES
FOR IMPROVING HUMAN PERFORMANCE

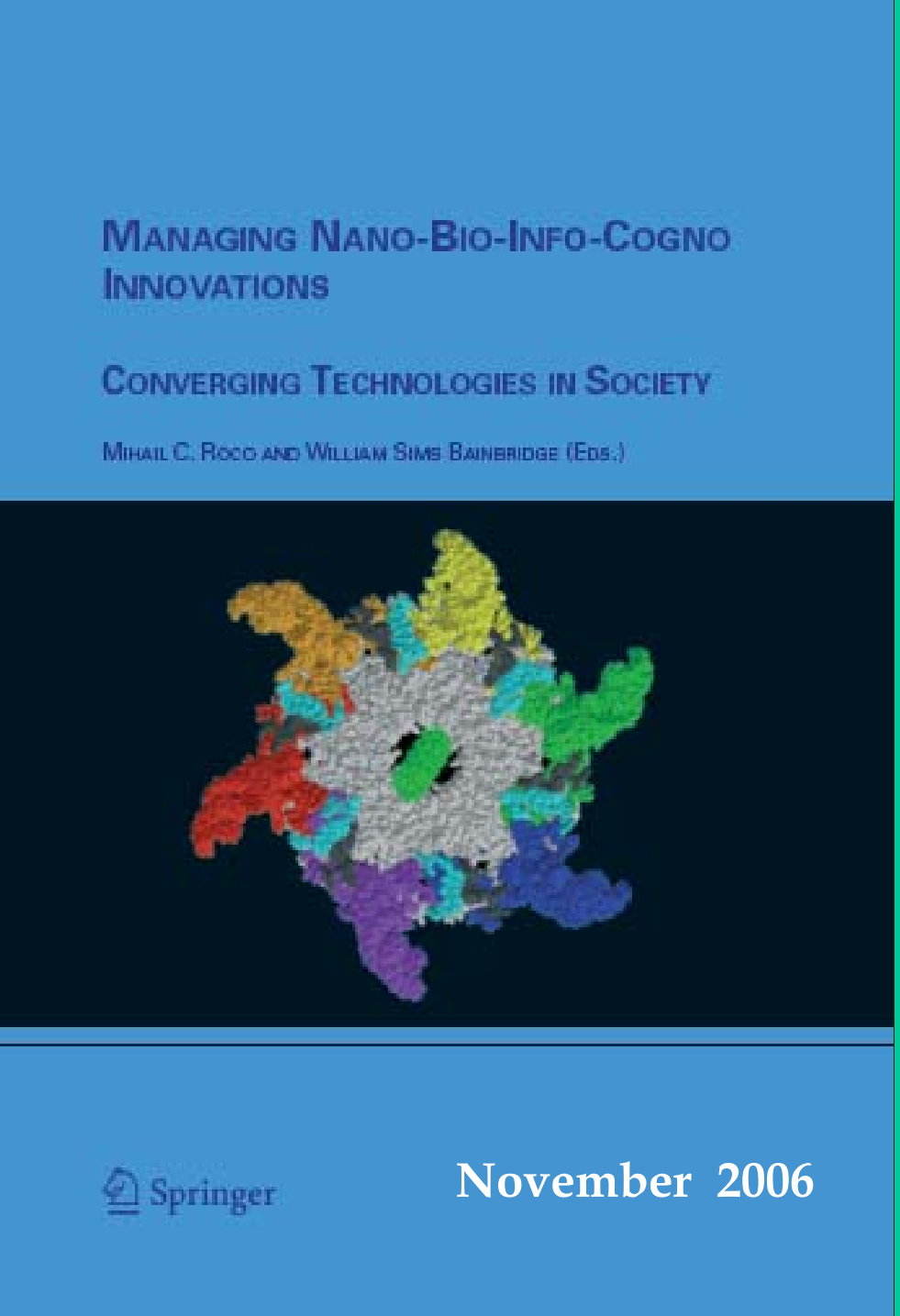
June 2002

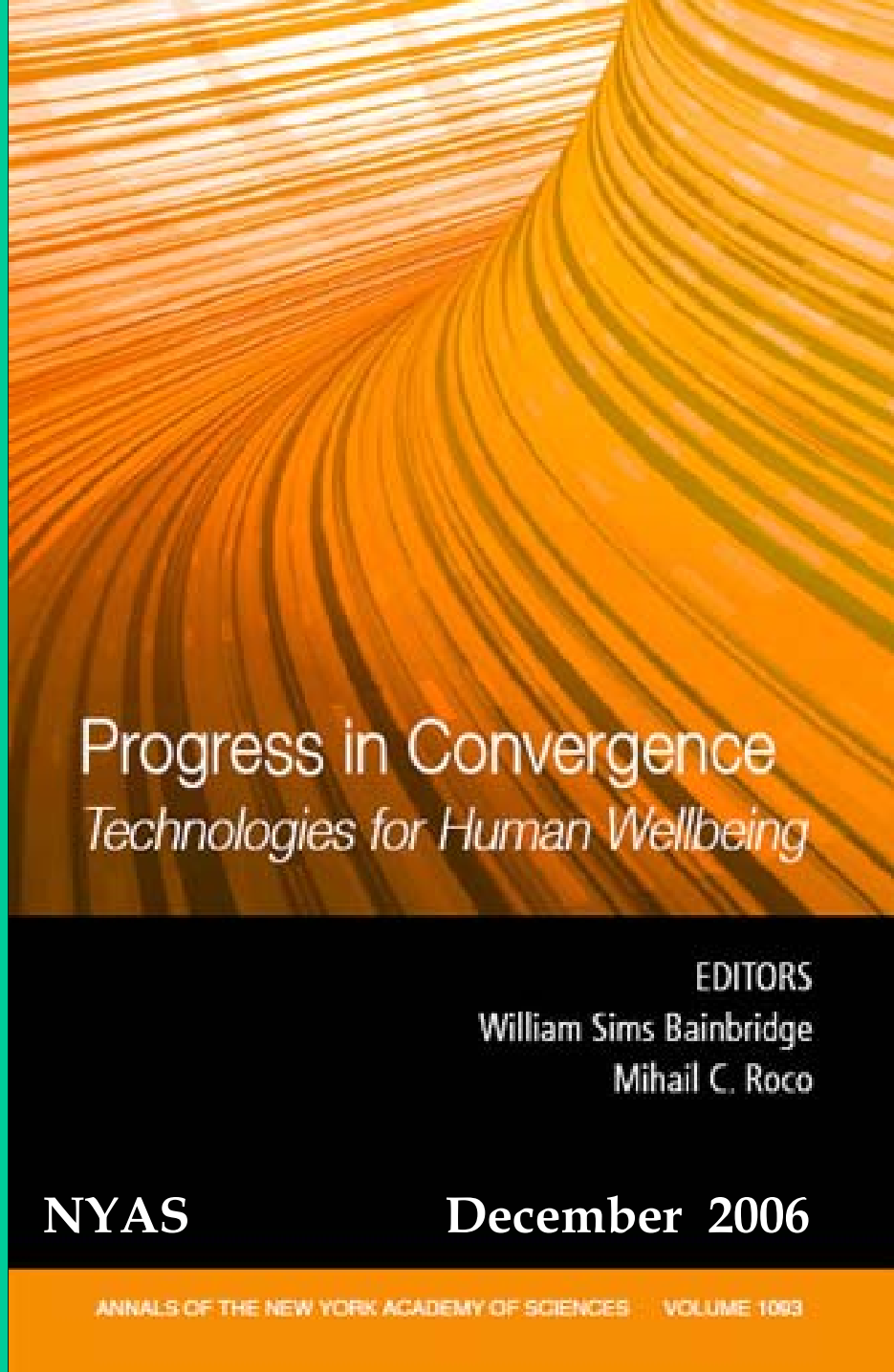
Workshop, Dec. 2001
www.nsf.gov/nano
Kluwer Acad. Publ, 2003

Coevolution of Human Potential and Converging New Technologies (Feb. 2003 and Feb. 2004 meetings)

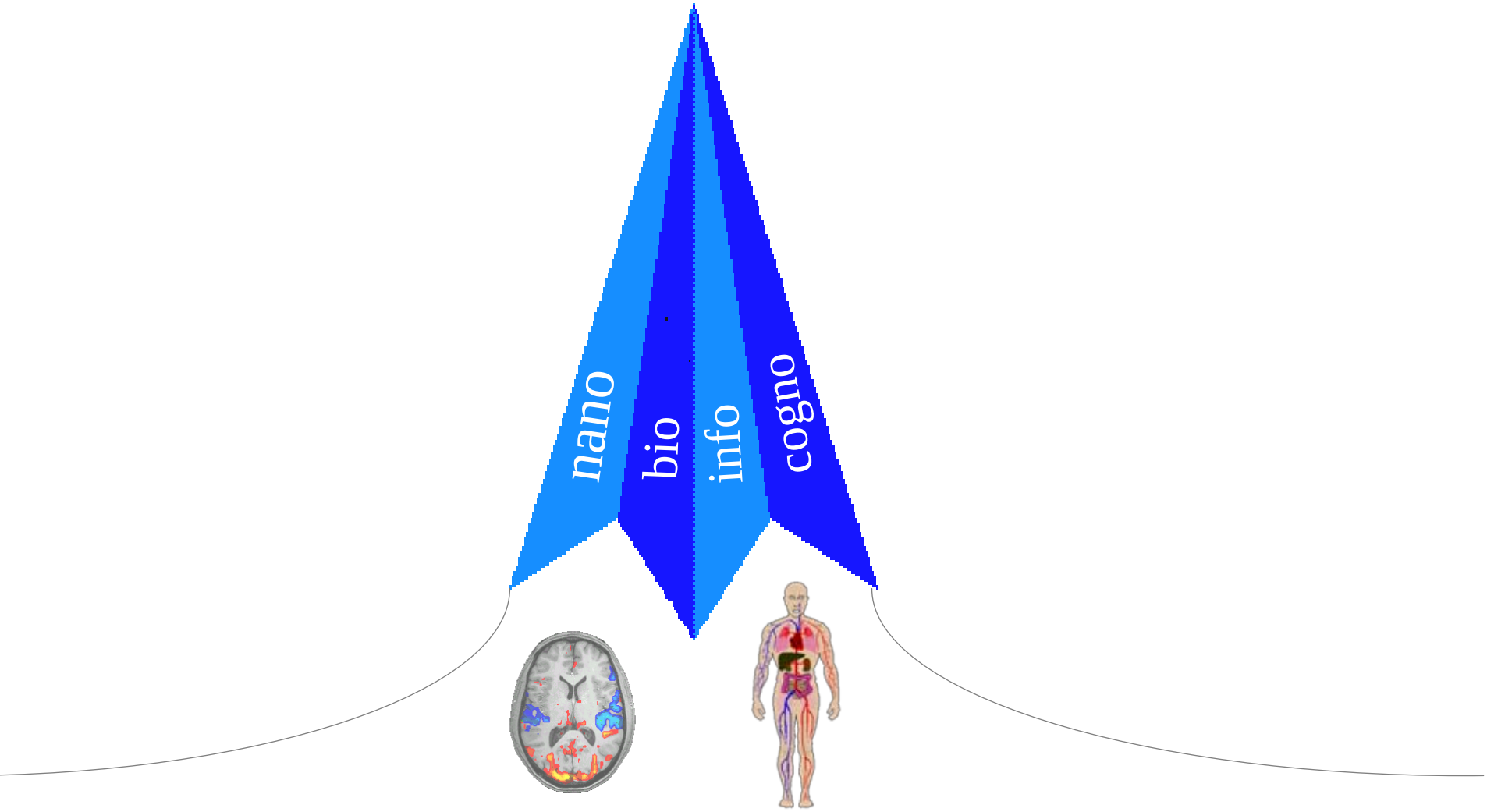


In: Annals of the New York, Academy of Sciences, Vol. 1013, 2004 (M.C. Roco and C. Montemagno)


Managing Nano-Bio-Info-Cogno Innovations
Converging Technologies in Society
Mihail C. Roco and William Sims Bainbridge (Eds.)
Springer
November 2006


Progress in Convergence
Technologies for Human Wellbeing
EDITORS
William Sims Bainbridge
Mihail C. Roco
NYAS
December 2006
ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
VOLUME 1093

Reaching and expanding human potential



ANTHRO . . MATH . . ENV . . ENERGY . . AGRIC . . FOOD . . TRANSP . . ECO . . URBO . . SOCIO .

OPPORTUNITIES AND UNCERTAINTIES OF CONVERGING NEW TECHNOLOGIES

M.C. Roco, 8/7/2007

What is Governance?

- "Governance" – a versalite term of widespread use
- Definition: Governance refers to processes, conventions and institutions that determine:
  - How power is exercised in the view of managing resources and interests;
  - How important decisions are made and conflicts resolved; and
  - How various stakeholders are accorded participation.
- General principles of "good governance" include e.g.:
  - Transparency;
  - Responsibility, accountability; and
  - Participation.
- Core principles + experience with NNI, ITR, BioCom + int.

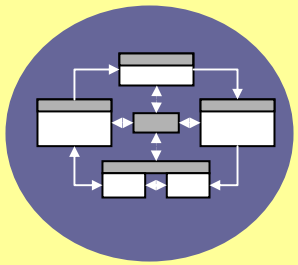
  ⟹ to be applied to global CT governance

CT Governance and Risk Governance

CT GOVERNANCE

- Investment policy
- Science policy
- Risk governance
- Others

Four key functions



EX: NANOTECHNOLOGY RISK GOVERNANCE (IRGC)

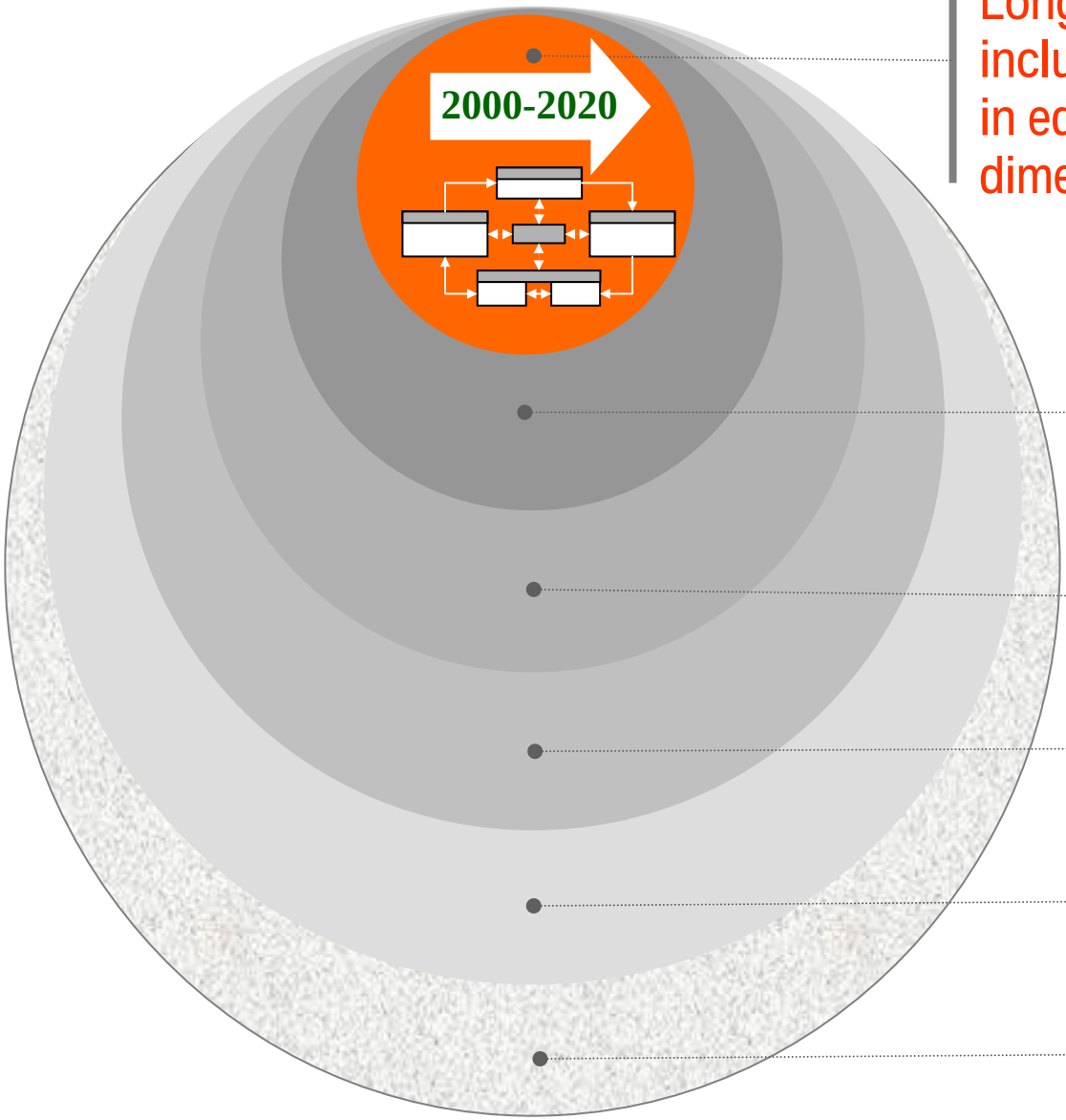
SCOPE
- Conceptual framework for integrated approach for decision-makers
- Neutral, constructive platform for all actors

GOALS
- Deficits & recommend.
- Cross stakeholders
- Multiple authorities
- Cross-boundary, global
- Short & Long-term view

WHAT IS DIFFERENT
- Structure NT development: 4 generations; 2 frames
- Include social context in assessment (ELSI +)
- Governance approach: corrective and adaptive

RISK GOVERNANCE APPROACH
- Begin with the IRGC framework
- Methodologies for 2 risk frames
- Focus: EHS, ELSI, EGI, PSI, HDI
- Stakeholder engagement
- Risk communication
- Risk governance methods

GOVERNANCE OVERVIEW



Core Governance Process

Long-term view, transforming, inclusive, horizontal/vertical, priority in education, addressing societal dimensions, CT risk governance

Main Actors

R&D Organizations
(Academe, industry, gov.)

Implementation Network
(Regulators, business, NGOs, media, public)

Social Climate
(Perceived authority of science, civil involvement)

National Political Context

International Interactions

Possibilities for a Global Governance of CT

General approach

- Facilitate and provide reference models to the global self - regulating ecosystem:
  - open source models of CT development and its institutions, discovery, innovation, education, human resource, informatics
  - emerging and converging technology infrastructure;
  - use economical incentives for accelerating NT production;
  - foster suitable international organizations and agreements for nomenclature, standards, metrology, certification, labeling
- Focus on bottom-up and lateral interactions and less on top - down measures
  - using political leadership and democratic principles,
  - social consensus in knowledge based societies
- System of global communication and participation in all phases of governance, facilitated by international organizations

Foster suitable international organizations

Ex: International standards organizations working on nanotechnology

National Body International Standards Organizations

Treaty-Based International Standards Organizations

Standards Development Orgs. With Global Reach

ASME International

Foster suitable international organizations

Ex: OECD Working Party on Nanotechnology

Working Party on Nanotechnology (WPN) held its first meeting in Leuven, Belgium, on 8-9 May 2007, and decided to establish steering groups for 6 potential projects, that it would seek to implement in 2007 and 2008:

A. Statistics and Measurement.

B. Impacts and Business Environment.

C. International Research Collaboration.

D. Outreach and public engagement.

E. Dialogue on Policy Strategies.

F. Contribution of Nanotech to Global Challenges

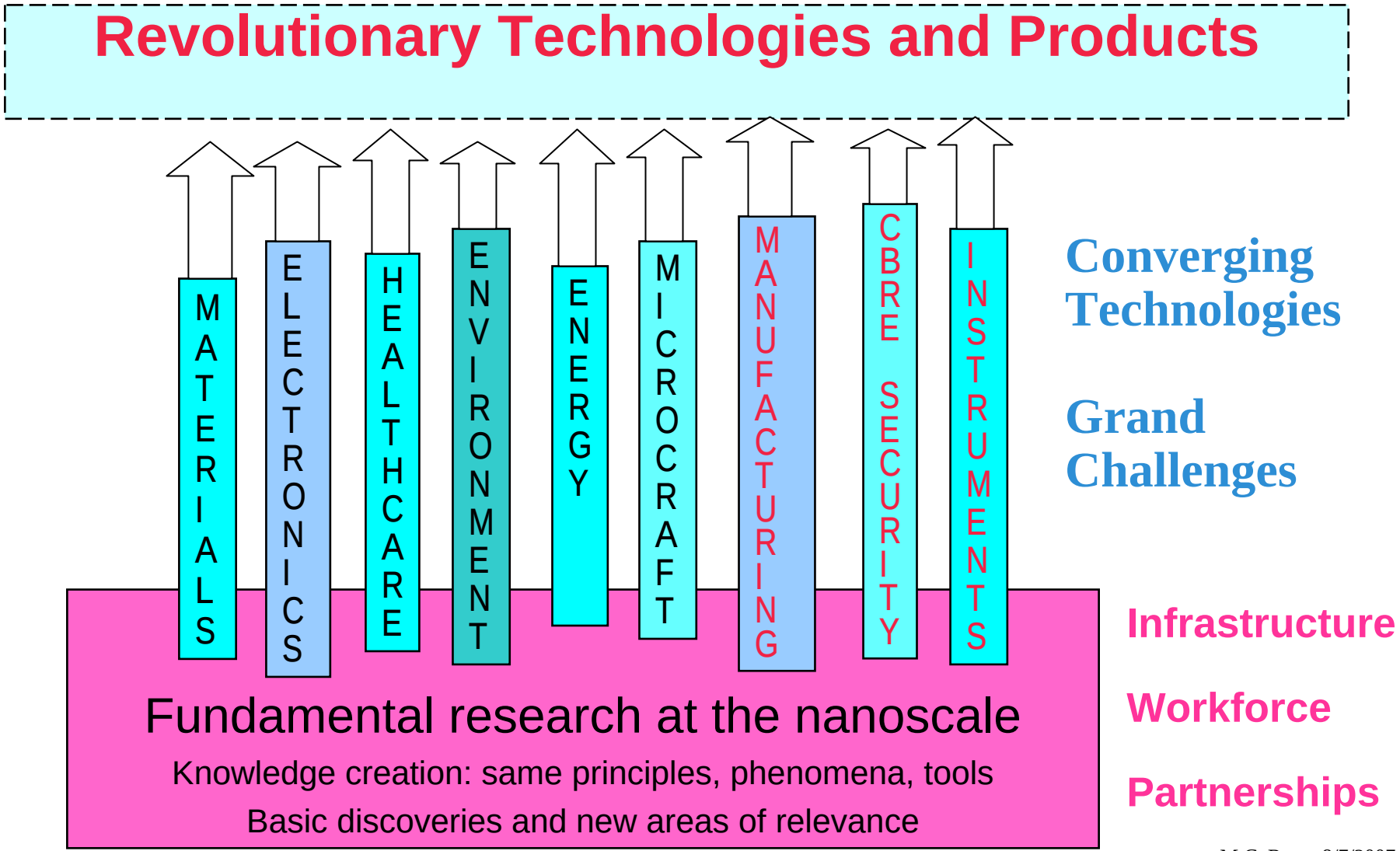
Governance of CT development: four main functions

- Transformative
  investment policy, S&T policy, support innovation & informatics, prepare pipeline in education, use NBIC integration tools
- Responsible development
  EHS, ELSI+, methods for risk governance, communication & participation, voluntary measures
- Inclusive, collaborative
  Building national capacity, multi-sector partnerships international capacity and leveraging
- Visionary
  Long-term and global view in planning & investment, human development/progress

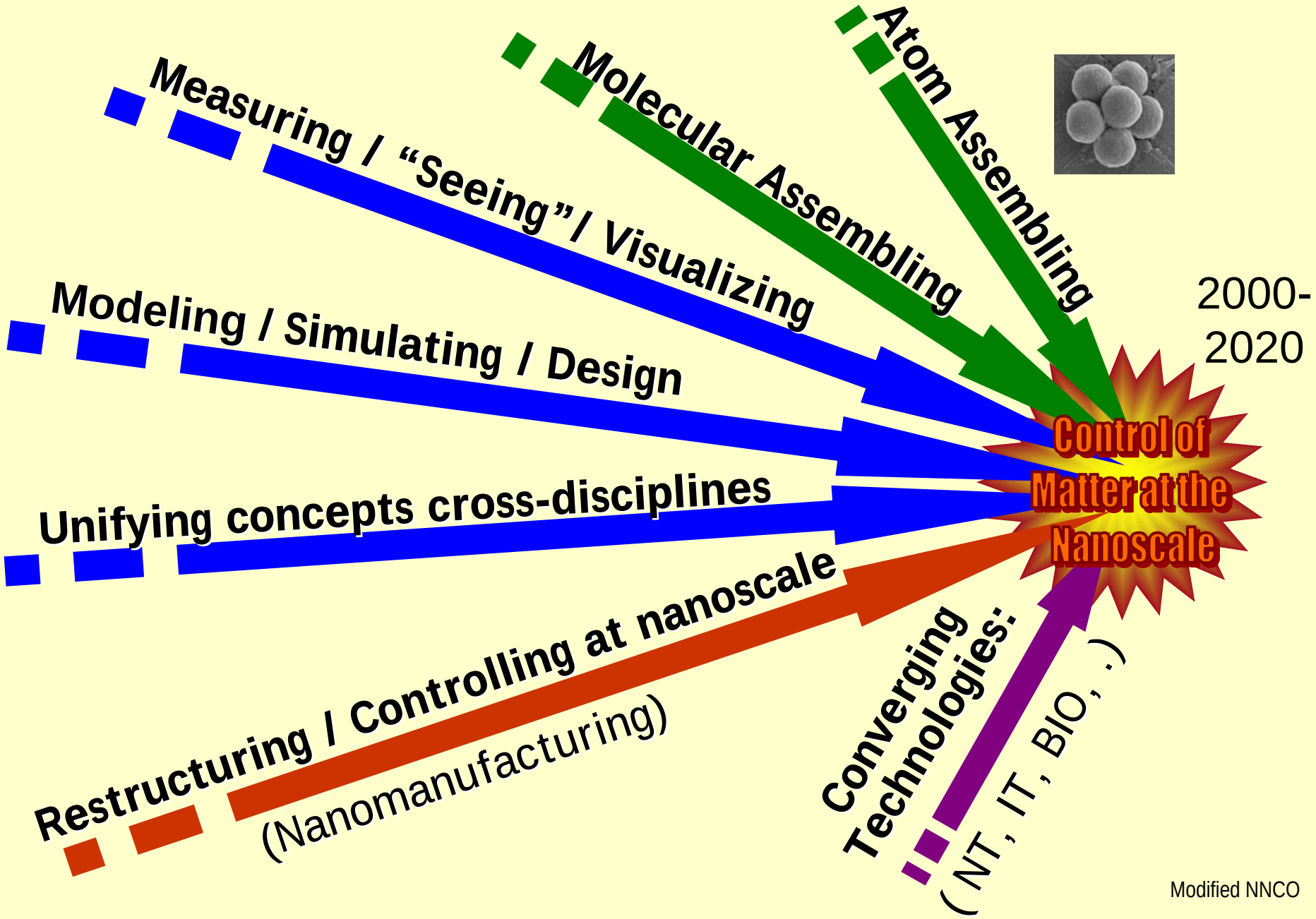
References: - "Governance of Converging Technologies Integrated from the Nanoscale", MC Roco, Annals New York Academy of Sciences, Vol. 1093 (2006), pp. 1-23
- "Possibilities for Global Governance of CT", J. Nanoparticle Research, 2007 web

Transformative: Ex.: Investment strategy in NNI

Interdisciplinary "horizontal" knowledge creation vs. "vertical" transition from basic concepts to applications

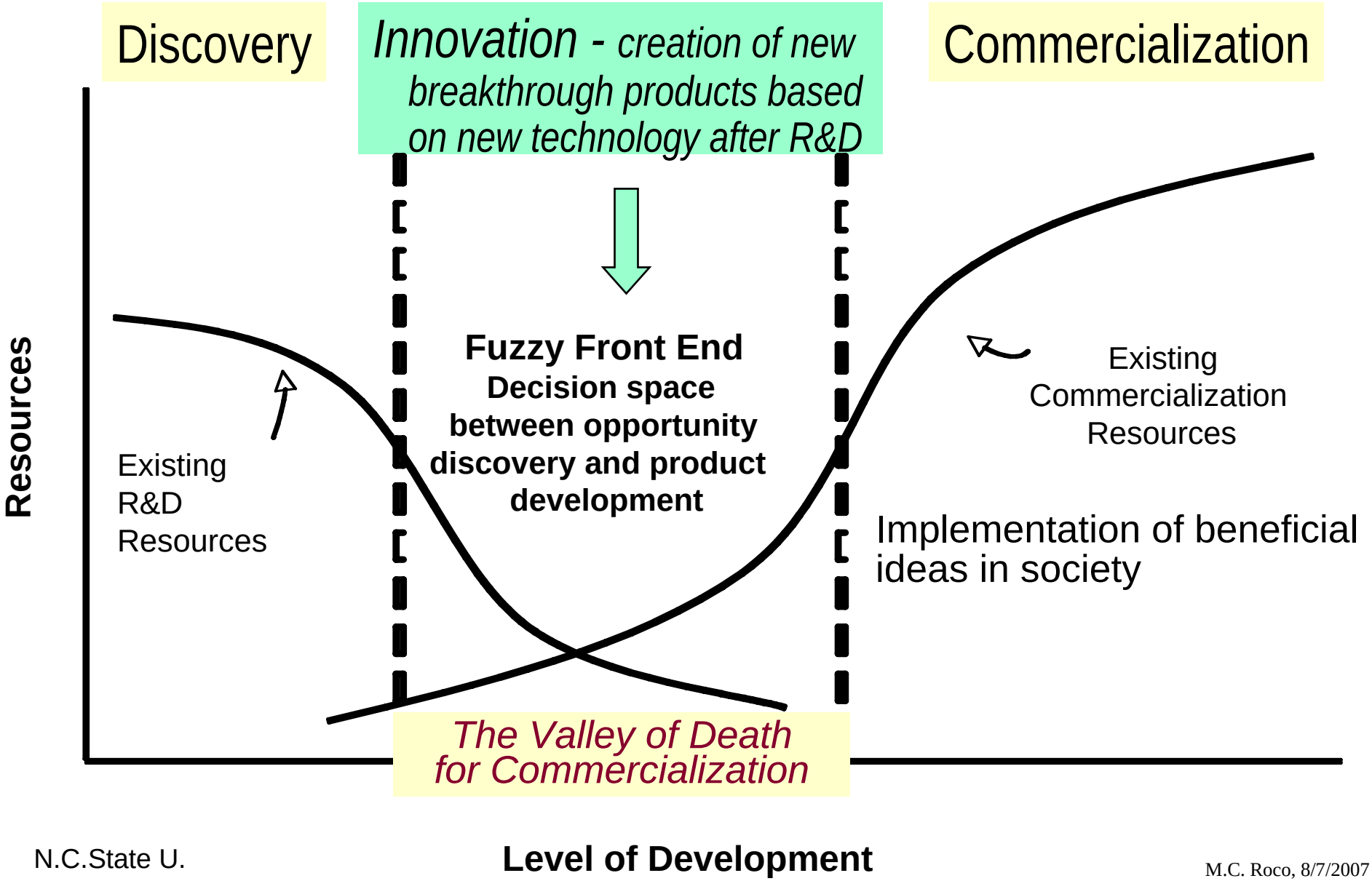


Nanotechnology innovation: *concurrence of capabilities*



M.C. Roco, 8/7/2007

Innovation: creation of wealth based on knowledge
- *The R&D perspective* -



How to strengthen the innovation culture?

In the societal framework

- **"Reduce the gap" between discovery and commercialization:** pre-competitive platforms, legislation, create non-traditional approaches in research and development that will speed the market deployment of NT
- **Support new "foundations":** knowledge, tools, education for appropriate skills, organizations, partnerships
- **Focus on "unifiers" or "integrators":** human dimension goals; complex system approach; information technology; nanotechnology; global-all-domains databases

How to strengthen the innovation culture?

Enhance the innovation process

- "Bridging" diverse ideas:
  converging technologies (convergence with biomedical, electronics and cognition), fostering R&D platforms

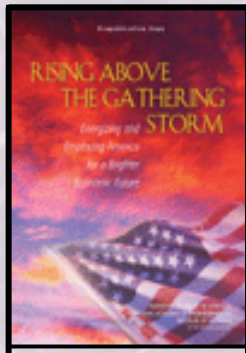
- Support both individual and group creativity; teams can overtake "individual creativity":
  ex: understanding and promoting the process of innovation
  'Science of Science and Innovation' at NSF

- Breakthrough innovations depend on creating communities. Breakthroughs are as much social and technical: prepare the users, new concepts in society, motivating education.

The call for innovation: United States (2004-2007)

- Three reports on innovation (2004-2005):
  - "Engineering Research and America's Future: Meeting the Challenges of a Global Economy" (National Academy of Engineering)
  - "Innovate American" (Council of Competitiveness)
  - "Rising Above the Gathering Storm" (National Research Council)
- Presidential Decree:
  "American Competitiveness Initiative" (2005)

  Congressional Act:
  "US National Competitiveness Act" (2006, 2007)



National Academies recommendations are realized in ACI.

The call for innovation in European Union (2006-)

EU *Communication,* September 2006

- ***The aim: "a broad based innovation strategy for Europe that translates investments in knowledge into innovative products and services".***

- **Innovation strategy with ten priority actions**
  - Establish innovation-friendly education systems
  - Establish a "European Institute of Technology"
  - Work towards a, single and attractive labor market for researchers
  - Strengthen research-industry links
  - Foster regional innovation through the new cohesion policies
  - Reform R&D and innovation state aid rules for R&D tax incentives
  - Enhance intellectual property rights protection (IPR)
  - Digital products and services – initiative on copyright levies
  - Develop a strategy for innovation friendly "lead markets"
  - Stimulate innovation through procurement

The call for innovation in other regions (2006-)

- ➔ Japan
- ➔ China
- ➔ Australia
- ➔ South Korea and other countries

Comments:

- Due to globalization and shifting research priorities - the relative technology/economical ranking of various countries changes
- Fast dissemination of similar policies, concepts and measures for stimulating innovation 2004-2006 (just in 2 years)
- A main difference between economies is in the implementation

Possibilities for a Global Governance of CT

Transformative function

- Support tool development, knowledge creation, infrastructure, innovation, and informatics for CT, in the international context;

- Creating better opportunities for development of CT in developing countries;

- Develop common capacity for application of CT: nomenclature, metrology, standards, patent evaluation, databases, and EHS methodologies including for a predictive approaches with international use;

- Use “incentives” and “empowering stakeholders” in the open and global ecosystem

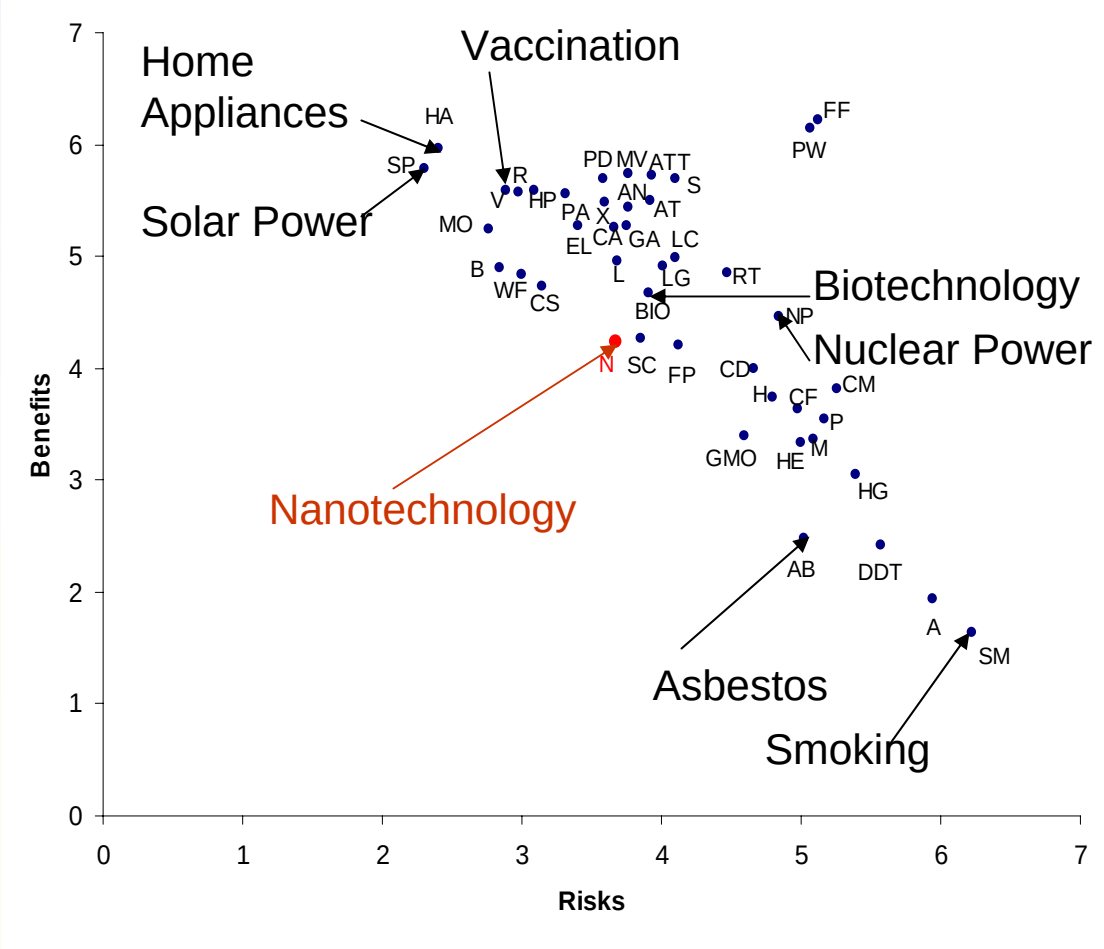
Responsible development context:
SPECIFIC RISKS INDUCED BY EMERGING TECHNOLOGIES

- Increased technology complexity and uncertainty in comparison with traditional technologies

- Interdependency with wide ranging effects throughout our industrial and social systems, including convergence and integration trends

- Increased importance of societal implications which may not be known at the release of the technology. Importance of reducing the time delay between development of scientific knowledge and evaluation of societal implications

Steven Currall et al. Survey on Public's Risk-Benefit Perceptions



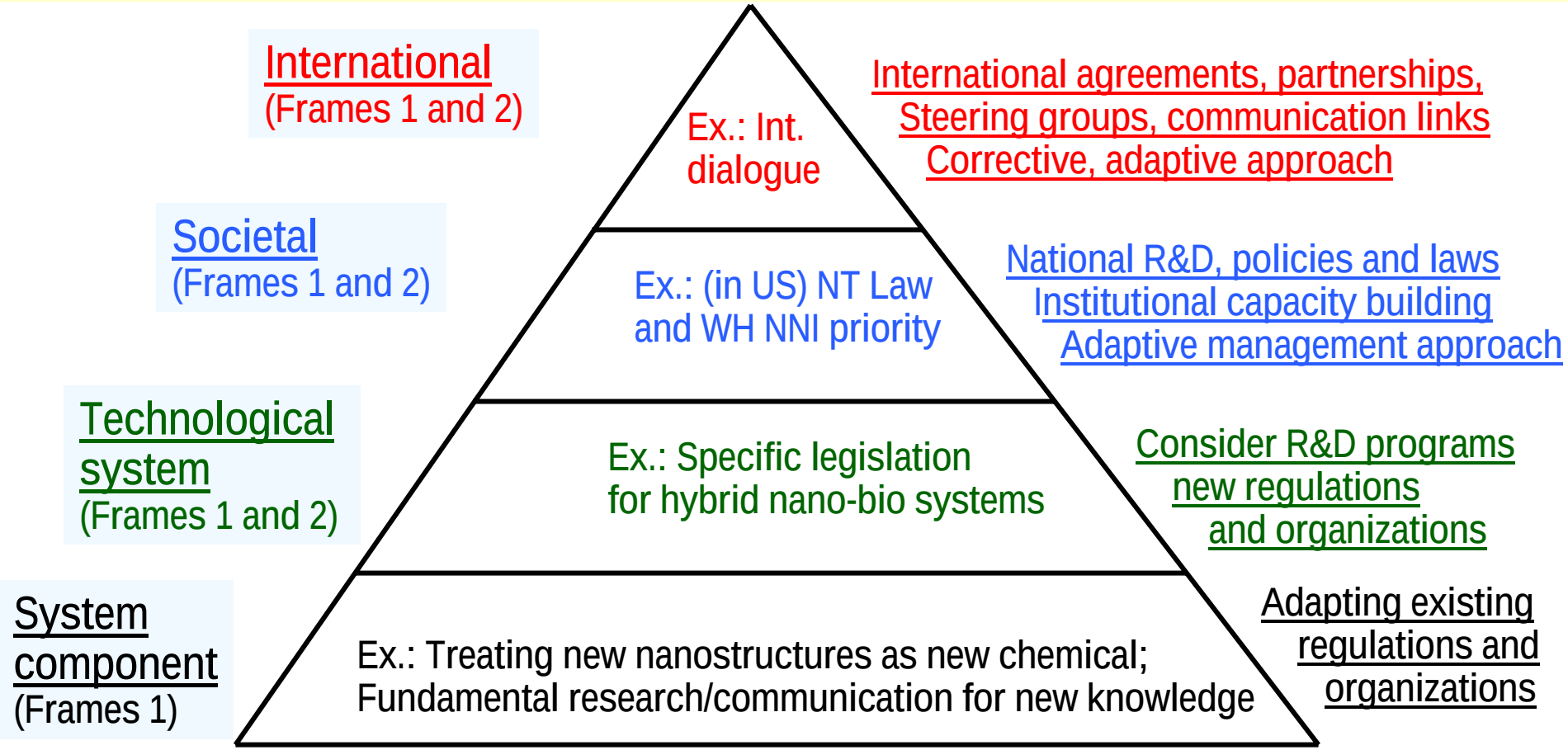
Air travel	AT
Alcoholic beverages	AB
Anesthetics	AN
Asbestos	A
Automobile travel	ATT
Bicycles	B
Biotechnology	BIO
Chemical disinfectants	CD
Chemical fertilizers	CF
Chemical manufacturing plants	CM
Commercial aviation	CA
Computer display screens	CS
DDT	DDT
Electric power	EL
Fire fighting	FF
Food preservatives	FP
General aviation	GA
Genetically modified organisms	GMO
Handguns	HG
Herbicides	H
Home appliances	HA
Human genetic engineering	HE
Hydroelectric power	HP
Large construction	LC
Lasers	L
Liquid natural gas	LG
Microwave ovens	MO
Motor vehicles	MV
Motorcycles	M
Nanotechnology	N
Nuclear power	NP
Pesticides	P
Police work	PW
Prescription antibiotics	PA
Prescription drugs	PD
Radiation therapy	RT
Railroad	R
Smoking	SM
Solar power	SP
Stem-cell research	SC
Surgery	S
Vaccinations	V
Water fluoridation	WF
X-rays	X

Source: *Nature Nanotechnology*, Dec. 2006, 1:153-155.

Responsible development

Multi-level structure of risk governance

Implication Domain / Examples of RG activities / Implementation approach



Reference: International Risk Governance Council, http://www.irgc.org/irgc/projects/nanotechnology/

The communication gap between emerging CT development and governance decisions

The Valley of Death
For Governance

EMERGING CT

RESEARCH
Creation of new information

COLLECT
VALIDATE
PRESENT
CRITIQUE

INFORM

FILTER
ORGANIZE
EXPLAIN
SUMMARIZE

EDUCATE

SYNTHESIZE
DEBATE
COMPARE

FRAME

GOVERNANCE

DECIDE
Recommend Actions

Modified M. Roco, ICON

Possibilities for a Global Governance of CT

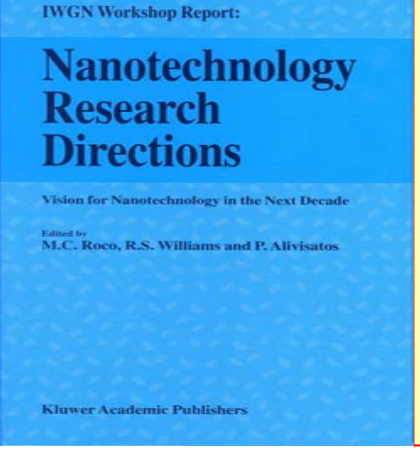
Responsible development function

- Development with priority of general benefit applications such as increasing productivity and sustainable manufacturing; Applying CT for improving availability of common Earth resources such as water, food, energy, and sustainable clean environment;

- Voluntary measures and science-based decision for risk management: EHS in industry; Code of Ethics in science and government agencies;.

- Public inclusion and participation in international activities; and

- Develop organizational capacity



Ex.: *Inclusive:* industry, academe, government, non-government and international organizations, communication institutions, public at large.

S&T agencies participants in the National Nanotechnology Initiative

2001: Six Agencies

- NIH
- NIST
- NASA
- DOD
- DOE
- NSF

2002: Seven New Agencies

- DOTr
- DOT
- EPA
- DOS
- IC
- USDA
- DOJ

2003-4: Four New Agencies

- FDA
- NRC
- DHS
- DOC TA

2005: Six New Agencies

- USDA FS
- DOC BIS
- USPTO
- ITC
- CPSC
- NIOSH

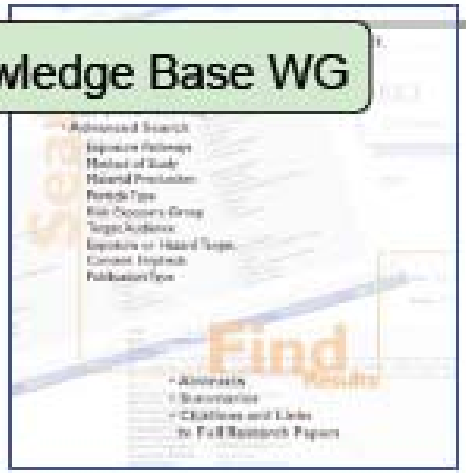
2006: Three New Agencies

- USGS
- DOL
- DOEd

Foster communication and public partnerships

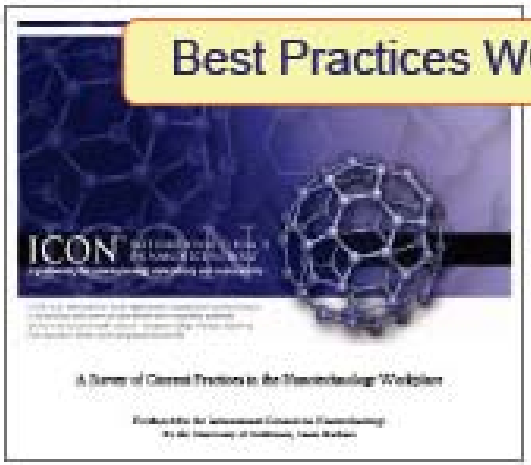
Ex.: International Council on Nanotechnology (ICON) activities

Knowledge Base WG



Database of EHS technical papers

Best Practices WG



Survey of current workplace practices

International nanoEHS research needs assessment

Communications WG

ICONsultations with diverse stakeholders

RICE

ICON Working Groups

ICON

Raise citizens' inclusion and participation

- Support both formal and informal science education for converging technologies
- Empower citizen input in research investments
- Funding: combining major strategic programs with bottom up investigator-initiated funding opportunities
- Facilitate citizen participation in international debates and decisions

Emerging model of practice:
Empowering the Public through the Science Shops

Provide independent, participatory research support in response to concerns experienced by civil society on a demand driven and affordable basis.

- Analogue of legal advice office;
  Originated in Dutch student movement in early ’70
- USA: Community-based Research (CBR)
- Today: 70 science shops exist in Europe alone.
  Most of them are located in the Netherlands, Austria, Denmark, France, Germany, Romania, and the UK;
- EC promotes the Science Shops:
  Science & Society Action Plan 2002

Ex.: International Dialogue on Responsible Nanotechnology R&D

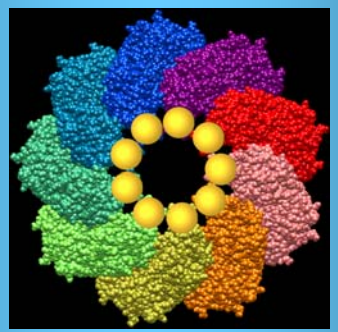
First: June 2004, Virginia, USA
Second: June 2006, Japan
Third: Brussels, EC

Survey Investments

Current Norms

Recommended measures

International Dialogue



26 countries

Joint Statement

Immediate Actions

June 2004, Virginia

http://www.nsf.gov/home/crssprgm/nano/dialog.htm

M.C. Roco, 8/7/2007

Possibilities for a Global Governance of CT

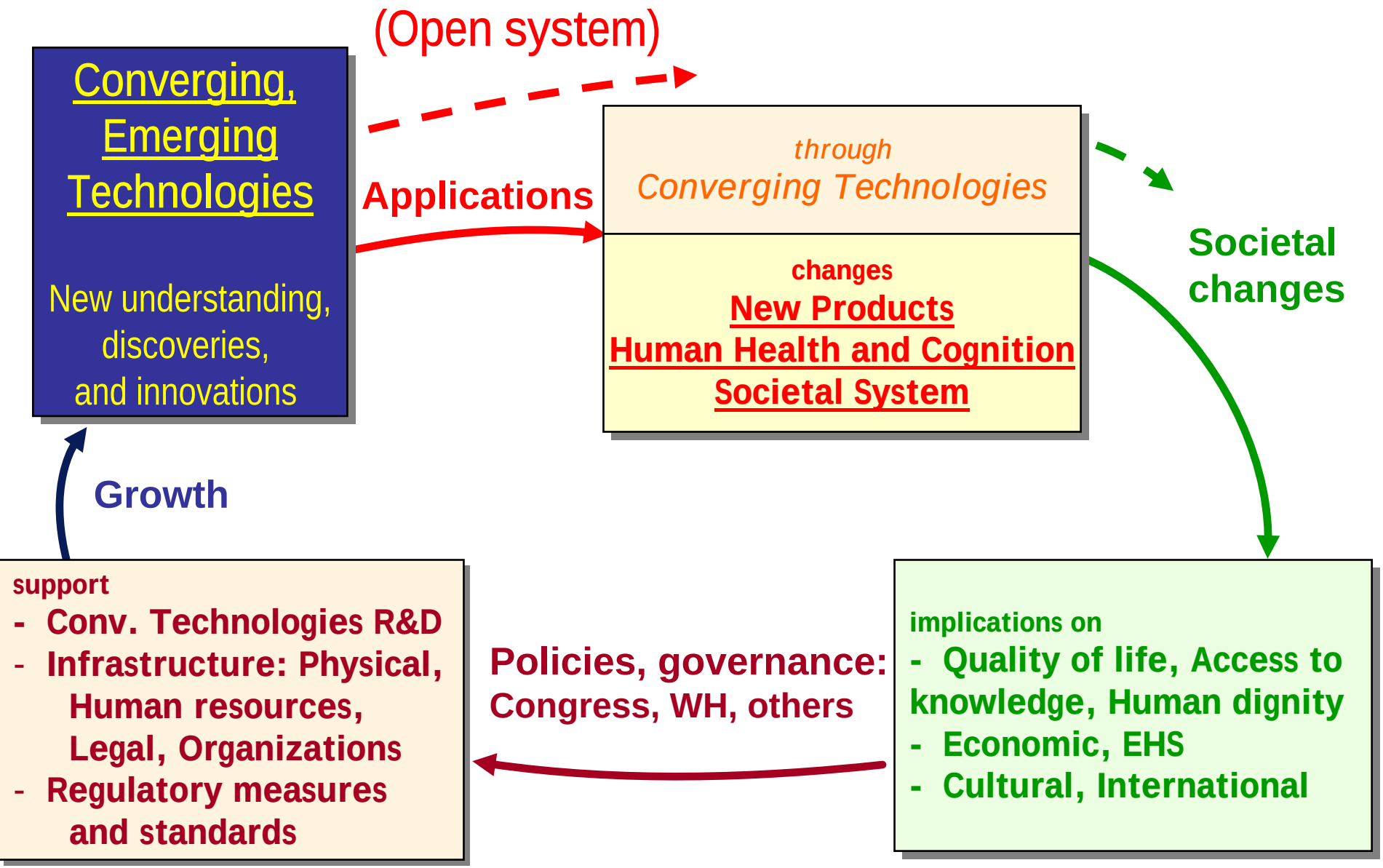
Inclusiveness and partnership function

- Supporting partnerships between various stakeholders active in converging new technologies applications

- Global communication and information;

- Involving international organizations to advance multi stakeholder global challenges;

- Encourage international and cross-sector interactions



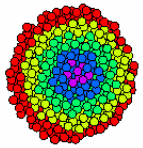
Converging Technologies in Society: an open system

J. Nanoparticle Research, Vol. 7, 2005 (Roco); Vol. 8, 2006 (Renn and Roco); IRGC (2006)

M.C. Roco, 8/7/2007

Ex.: Visionary

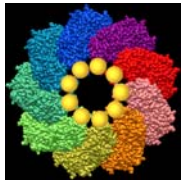
Timeline for beginning of industrial prototyping and nanotechnology commercialization: Four Generations



1st: Passive nanostructures (1st generation products)

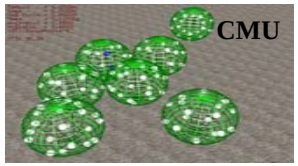
Ex: coatings, nanoparticles, nanostructured metals, polymers, ceramics

~ 2000



2nd: Active nanostructures Ex: 3D transistors, amplifiers, targeted drugs, actuators, adaptive structures

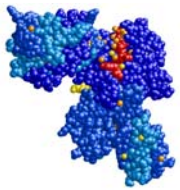
~ 2005



3rd: Systems of nanosystems

Ex: guided assembling; 3D networking and new hierarchical architectures, robotics, evolutionary

~ 2010



4th: Molecular nanosystems

Ex: molecular devices 'by design', atomic design, emerging functions

~ 2015-2020

New R&D challenges

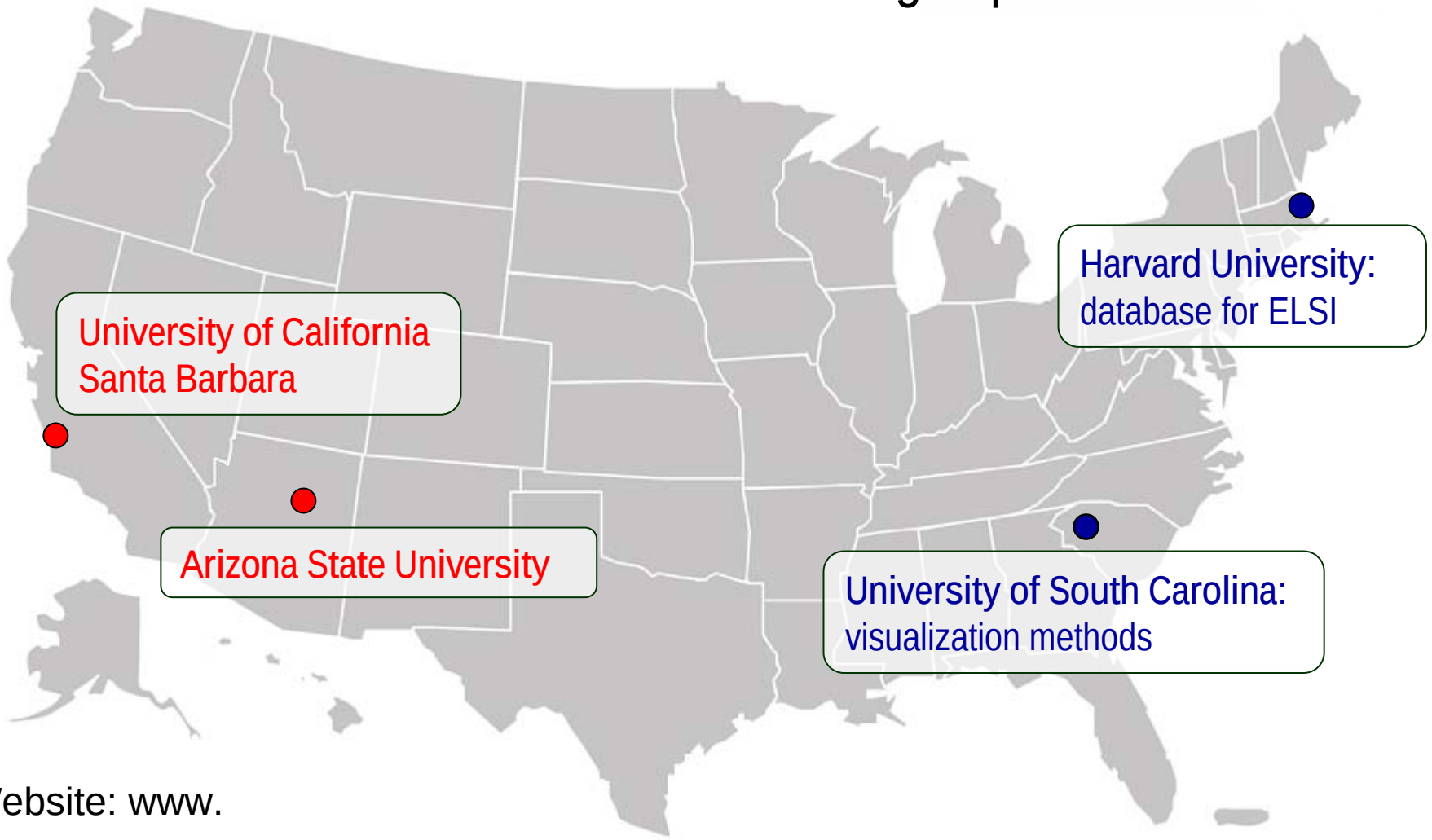
	R&D	→	Broad Use	
IT	1960	-	2000	(40 years)
BIO	1980	-	2010	(30 years)
NANO	2000	-	2020	(20 years)

AIChE Journal, 2004, Vol. 50 (5), MC Roco

NSEC: Nanotechnology in Society

Four nodes established in September 2005:

● 2 centers and ● 2 small-groups

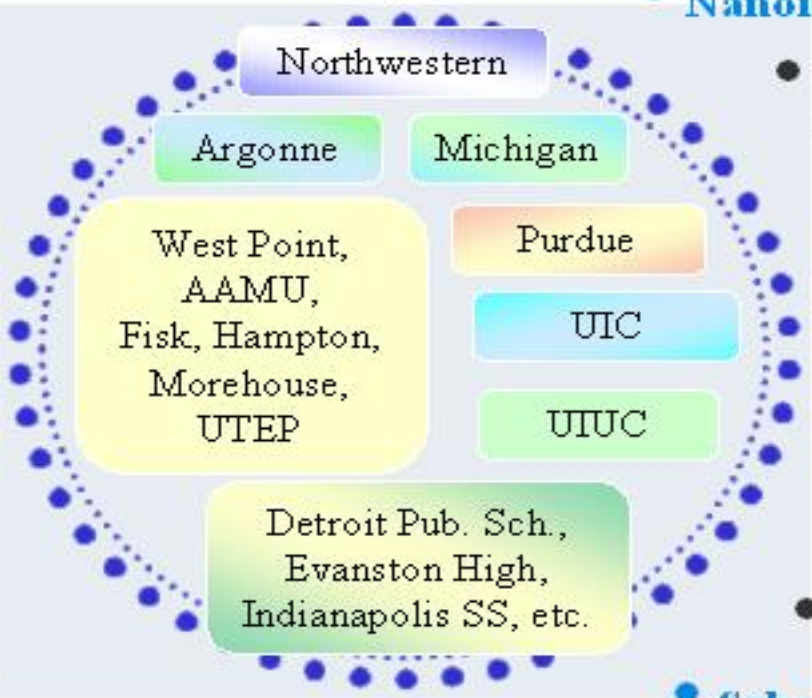


Website: www.

To address Ethical, Legal and other Social Issues related to Nanotechnology

Nanotechnology Center Learning and Teaching (2004 -)

The NCLT Community



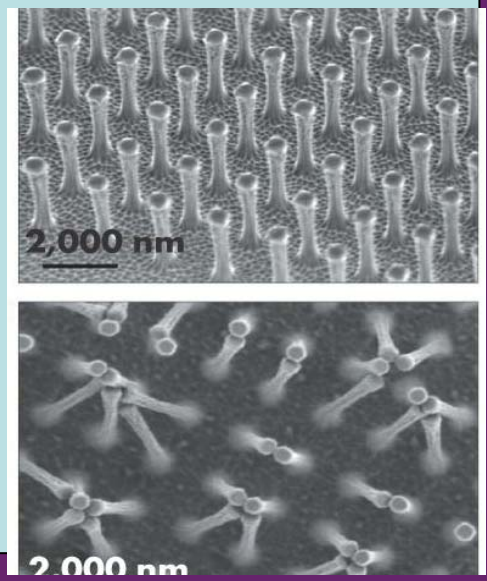
- Nanomaterials Research: MRSEC, NSEC, DOE, NASA
- Curriculum Development: NSF-funded CCMS and MWM
- Education Research: NU-Searle Center, CCMS (led by AAAS)
- Professional Development: Summer programs on partner campuses, US-Minority Institutions
- Visualization & Learning Tools: EVL
- Simulation & Modeling: NCN
- School District Partnerships nationwide

To reach 1,000,000 High School children in all 50 states in 5 years (by 2009)

Website http://www.nclt.us/

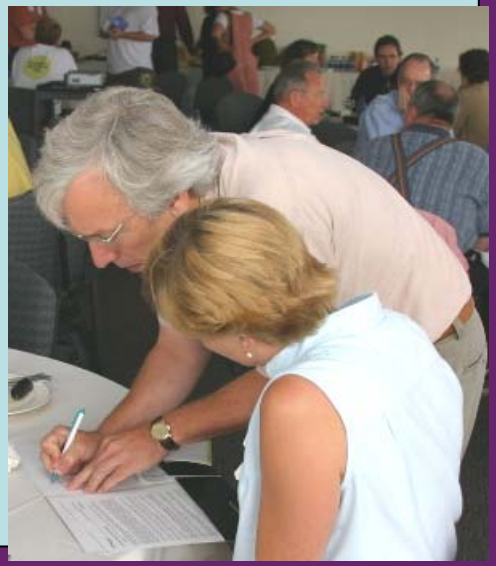
Nanotechnology Informal Science Education Network

Center for
NISE Research
Exploratorium
San Francisco



- **Visualization Lab**
- **Resource Center**
- **Research and Evaluation**
- **Professional Development**
- **Public Website**

Center for Public
Engagement
Museum of Science
Boston



- **Network Media**
- **Forums**
- **Network Administration**

Center for
Exhibits & Programs
Science Museum of
Minnesota

- **Exhibit and Program Packages**

To create 100 science museum sites in U.S. by 2010

Website: www.nisenet.org

Possibilities for a Global Governance of CT

Commitment to long-term view

- Detecting earlier signs of change using international expert groups; adopt real time technology assessment
- Commitment to long-term planning using global scenarios and anticipatory measures on nanotechnology development
- Integrate development of emerging and converging technologies; Conduct research specific for future generations of technology products (Frame 2, IRGC)
- Evaluate the trends for exponential growth of NBIC knowledge and technology capabilities

Nanotechnology risk governance issues

EHS, ELSI, Education Gap, Human Development, Political and Security

- Investment policies (R&D, infrastructure) for best and equitable outcomes in society
- Occupational safety
- Consumer safety
- Environmental safety
- Legal framework (science testimony, new cases; at national and international levels) and its impact on international trade
- Individual rights to tion and knowledge
- Social implications: human integrity and dignity; new opportunities and losses; societal structure; etc.)
- International relationships: IP, North-South divide, equity between haves and have-nots
- Long-term human development – need for anticipatory measures
- Need for principles to be converted to defined and planned actions

SURVEY ON NANOTECHNOLOGY GOVERNANCE

www.irgc.org/nanotechnology (M.C. Roco and E. Litten)

- **Part A: The Role of Government**

  Responders: 11 countries on nanotechnology governance; and 26 countries and EU on their nanotechnology R&D programs; December 2005 (146 pages, on the web)

- **Part B. The Role of Industry**

  Responders: Industrial Technology Research Institute (Chinese Taipei), Allianz and NanoBioNet (Germany), Ayanda Biosystems and Swiss Re (Switzerland), Chair of the International Organization for Standardization Technical Committee 229 on Nanotechnologies (UK), Canon, Environ, Intel, NanoDynamics Inc. and Pfizer (US)

- **Part C. The Role of Risk Research Organizations**

  Responders: Ochanomizu University (Japan), Institute for Occupational Health Sciences (IST) (Switzerland), Centre for Nanotechnology in Society (University of California, US); Center for Science Technology and Public Policy (University of Minnesota, US); Woodrow Wilson International Center for Scholars (US)

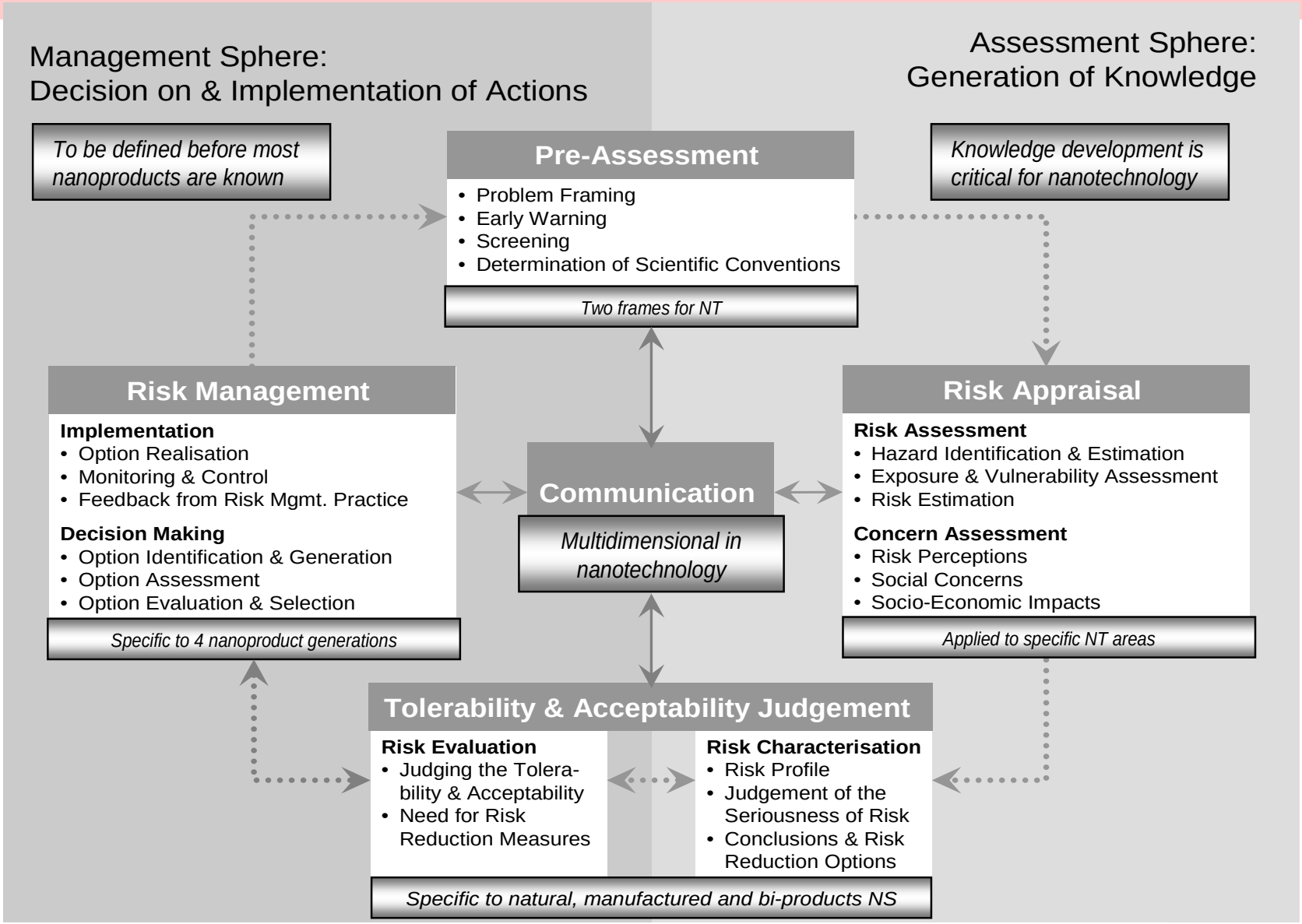
- **Part D. The Role of NGOs**

  Responders: ETC Group (Canada), Demos, The Forum for the Future, Greenpeace (UK), the Center for Responsible Nanotechnology, Environmental Defence, Foresight Nanotech Institute, the National Resources Defence Council and Sciencecorps (US).

IRGC Survey on Nanotechnology Governance
Areas of relevance in governance (December 2005)

Table 2	EHS	ELSI	Education Gap	Political and Security	Human Develop.
A. Government	2	1			
B. Industry	2	-	1		-
C. R&D risk organizations	2	1			
D. NGOs	2	1+			
Summary:	**8**	**3**	**1**	**0**	**0**

IRGC RISK GOVERNANCE FRAMEWORK FOR NANOTECHNOLOGY



Strategies as a function of the NT generation: Application to Frame 1 and Frame 2

IRGC model for analysing nanotechnology risks and implementing a risk governance system

(IRGC White Paper No3, “Nanotechnology Risk Governance”, www.irgc.org)

Particularities:

- Distinguishes between risk problems that are simple, complex, uncertain, and ambiguous (Frames One and Two)
- Ensures the early and meaningful participation of all stakeholders, including civil society, by assessing and actively integrating their views, values, and potential roles (pre-assessing, communication, ..)
- Incorporates the principles of good governance, including transparency, effectiveness and efficiency, accountability, sustainability, feasibility, equity and fairness, and respect for the rule of law

Characteristics of a risk governance framework

(IRGC Nanotechnology Policy Paper, 2007)

- *Adaptive*, valuing flexibility in the application of risk management strategies as knowledge and understanding of the field develops
- *Collaborative*, sharing information, skills and expertise internationally among different agencies and stakeholders
- *Global*: proposing international minimal "level playing field" guidelines and reference models to generate confidence in safety management in a globalized economy
- *Realistic and Fast*, recognizing that such a dynamic field calls for active and ongoing learning, rather than an "after the fact" approach, including building on emerging experience of those new technologies.
- *Responsive to essential human values*, such as equity, respect of ethics, safety, equal opportunities and right to privacy.

Regulation

- A “Nano-law”: not appropriate to govern risk
- Adaption of ordinance level of law required: licensing conditions and standardised test procedures
- Application of “precautionary approach” in order to avoid possible inherent system errors
- Some misunderstandings about “precautionary approach”:

it means:

– safety first

– responsible care

– tolerability of risk if offset by benefit

it does **not** mean:

– safety only

– liability to serve as gate keeper

– “zero” risk tolerability

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The Risk Management Escalator and Stakeholder Involvement

(from Simple via Complex and Uncertain to Ambiguous Phenomena) with reference to nanotechnology

Naturally nanostructured materials	Engineered nanostructured materials	Active nanostructures and systems	Large and molecular nanosystems
		Risk Balancing Necessary + Probabilistic Risk Modelling	Risk Trade -off Analysis & Deliberation necessary + Risk Balancing + Probabilistic Risk Modelling
		Remedy	**Remedy**
	Probabilistic Risk Modelling	• Cognitive • Evaluative	• Cognitive • Evaluative • Normative
	Remedy	**Type of Conflict**	**Type of Conflict**
Statistical Risk Analysis	Cognitive	• Agency Staff • External Experts • Stakeholders - Industry - Directly affected groups	• Agency Staff • External Experts • Stakeholders - Industry - Directly affected groups - General public
Remedy	**Type of Conflict**		
• Agency Staff • External Experts	• Agency Staff • External Experts • Stakeholders		
Actors	**Actors**	**Actors**	**Actors**
Instrumental	Epistemological	Reflective	Participative
Type of Discourse	**Type of Discourse**	**Type of Discourse**	**Type of Discourse**
Simple	Component Complexity induced	System uncertainty induced	Ambiguity induced
Risk Problem	**Risk Problem**	**Risk Problem**	**Risk Problem**
Frame 1		**Frame 2**	

Five possibilities for global CT governance

1. *Establish models for the global self-regulating ecosystem* to enhance discovery, education, innovation, nanoinformatics and commercialization

2. *Create and leverage S&T NBIC platforms* for new products in areas of highest societal interest

3. Develop NT for *common resources and EHS requirements*

4. Support *global communication and international partnerships*

5. Commitment to *long-term, global view* using scenarios and anticipatory measures

Closing remarks

- Seeds for global CT / NBIC governance have been created, and there are opportunities for a systemic approach in several areas
  - such as for innovation, nanoinformatics, standards, EHS and ELSI (and less on policies and investments where cultural and ideological differences and economical competition are important)

- Increased interactions are needed for addressing the common and longer-term human goals
  - such as using NBIC for basic discoveries, education, common resources (water, energy, food, environment), and health