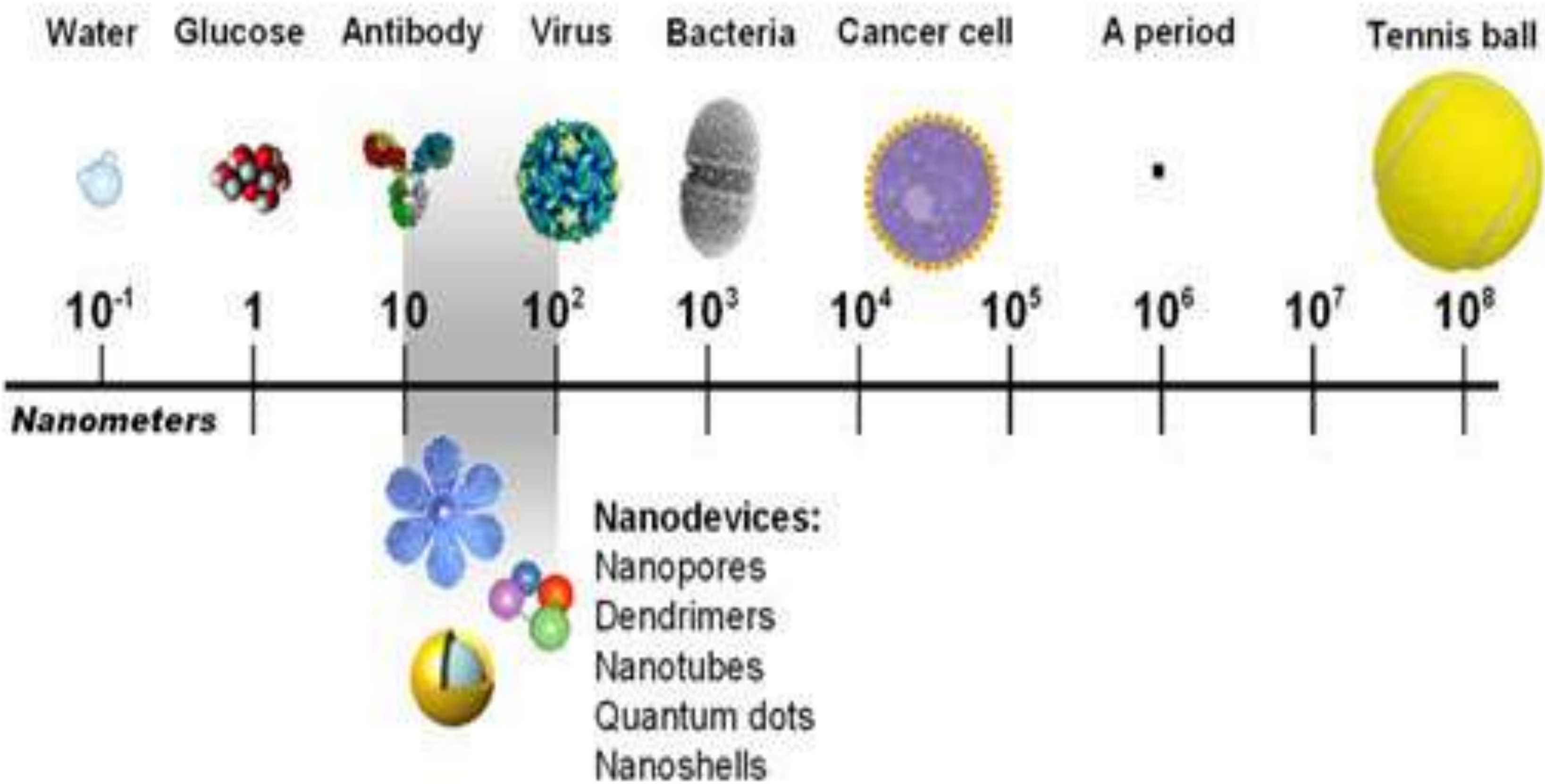
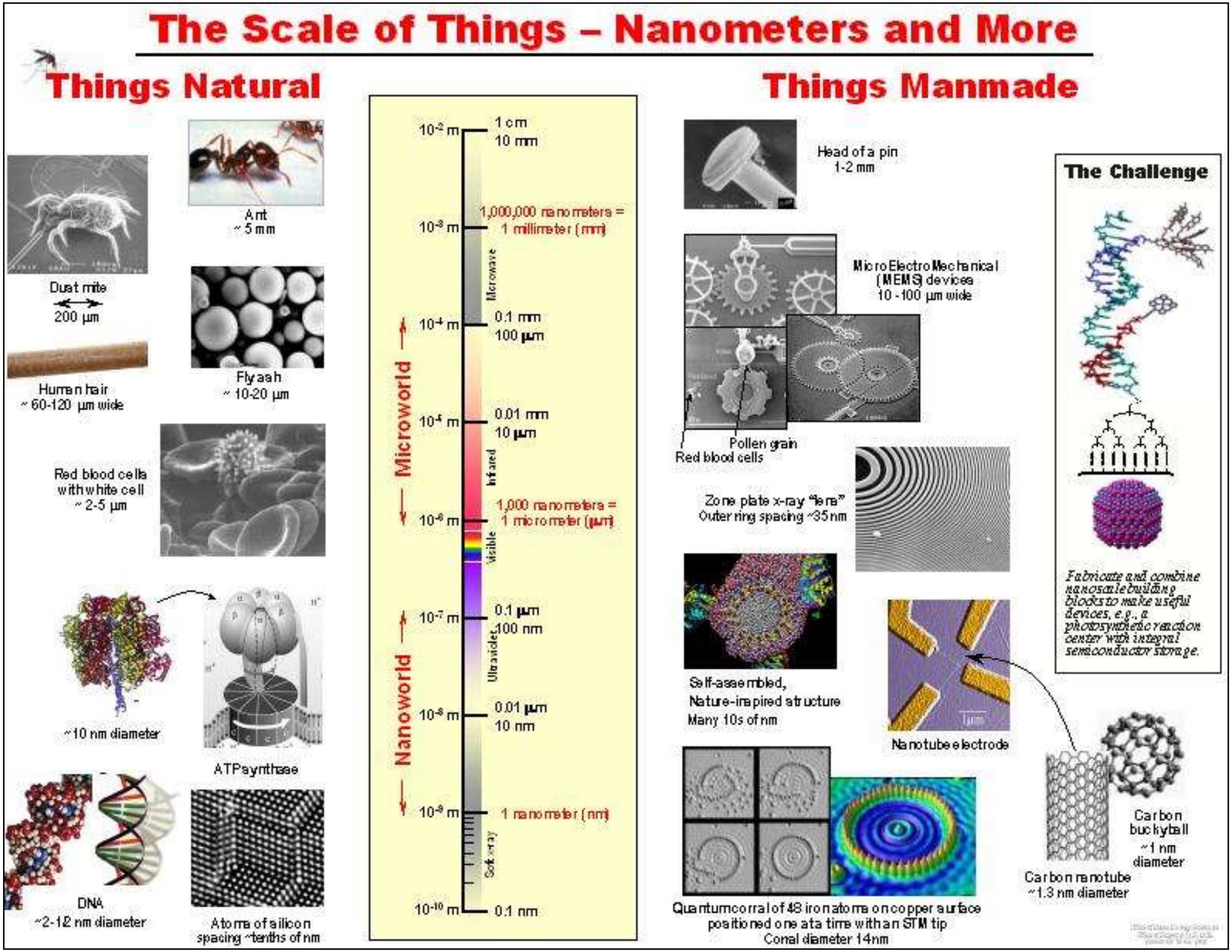
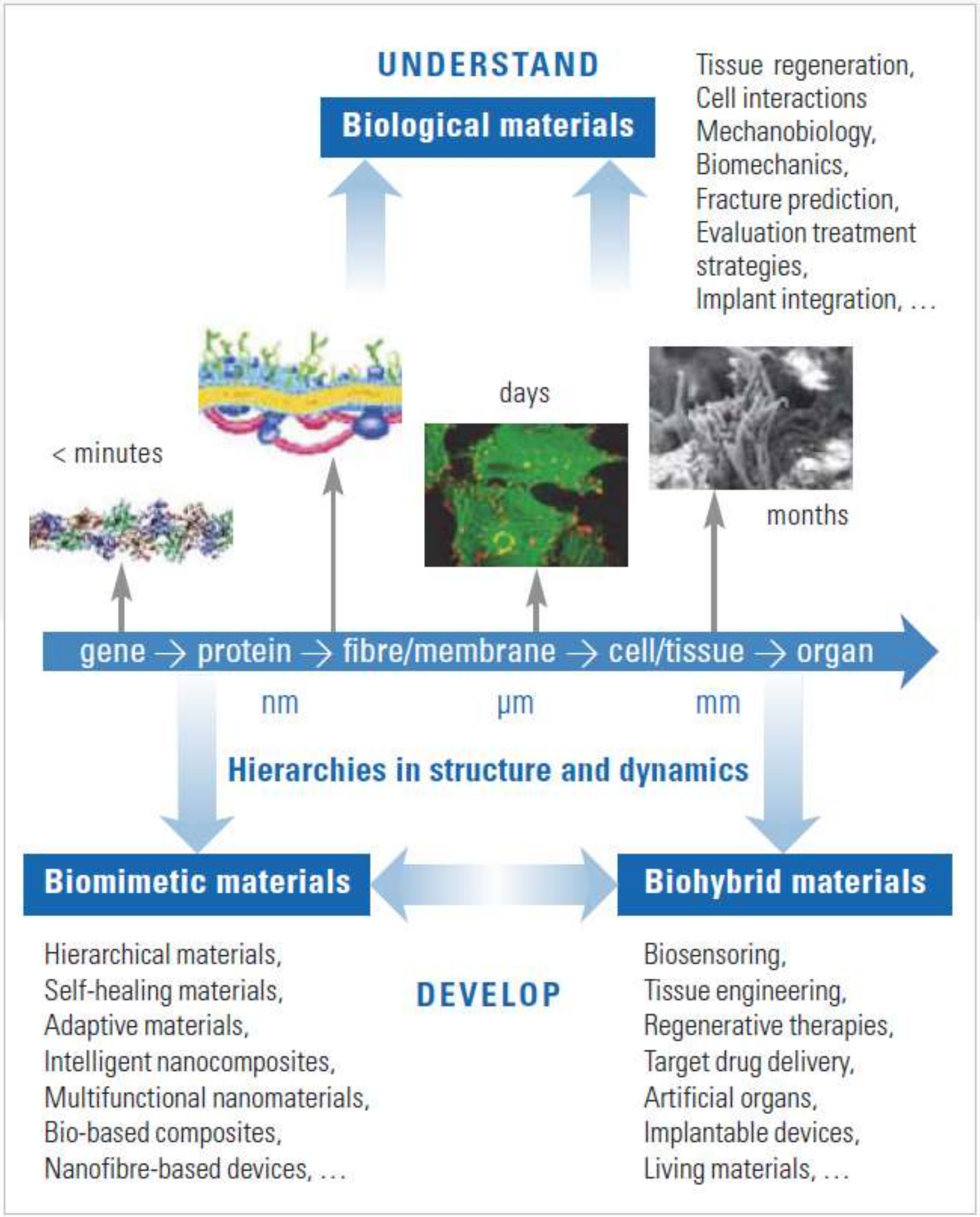
EDUCATION FOR FULL EMPLOYMENTWAAS RIO CONFERENCE
12 – 14 NOVEMBER 2018

Marcel H.Van de Voorde

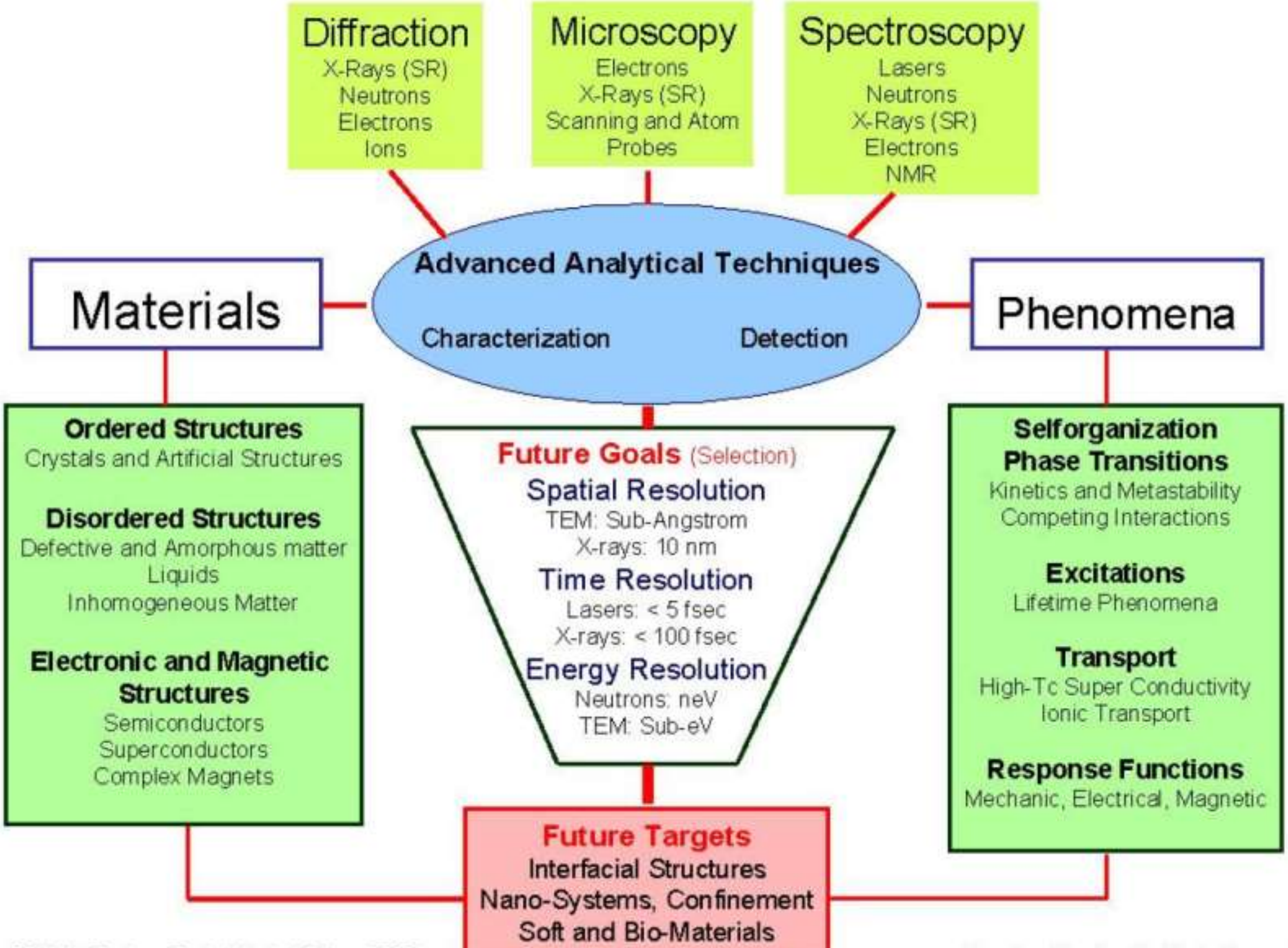
Rio de Janeiro, November 2018


Water
Glucose
Antibody
Virus
Bacteria
Cancer cell
A period
Tennis ball
10^{-1}
1
10
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
Nanometers
Nanodevices:
Nanopores
Dendrimers
Nanotubes
Quantum dots
Nanoshells


The Scale of Things – Nanometers and More
Things Natural
Things Manmade
Dust mite
200 µm
Ant
~ 5 mm
Fly ash
~ 10-20 µm
Human hair
~ 60-120 µm wide
Red blood cells
with white cell
~ 2-5 µm
~10 nm diameter
ATP synthase
DNA
~2-1/2 nm diameter
Atoms of silicon
spacing ~tenths of nm
10⁻² m
1 cm
10 mm
10⁻³ m
1,000,000 nanometers =
1 millimeter (mm)
Microwave
10⁻⁴ m
0.1 mm
100 µm
Microworld
10⁻⁵ m
0.01 mm
10 µm
Infrared
10⁻⁶ m
1,000 nanometers =
1 micrometer (µm)
Visible
10⁻⁷ m
0.1 µm
100 nm
Ultraviolet
Nanoworld
10⁻⁸ m
0.01 µm
10 nm
10⁻⁹ m
1 nanometer (nm)
Soft x-ray
10⁻¹⁰ m
0.1 nm
Head of a pin
1-2 mm
MicroElectroMechanical
(MEMS) devices
10 -100 µm wide
Pollen grain
Red blood cells
Zone plate x-ray "lens"
Outer ring spacing ~35 nm
Self-assembled,
Nature-inspired structure
Many 10s of nm
Nanotube electrode
Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm
The Challenge
Fabricate and combine nanoscale building blocks to make useful devices, e.g., a photosynthetic reaction center with integral semiconductor storage.
Carbon buckyball
~1 nm
diameter
Carbon nanotube
~1.3 nm diameter

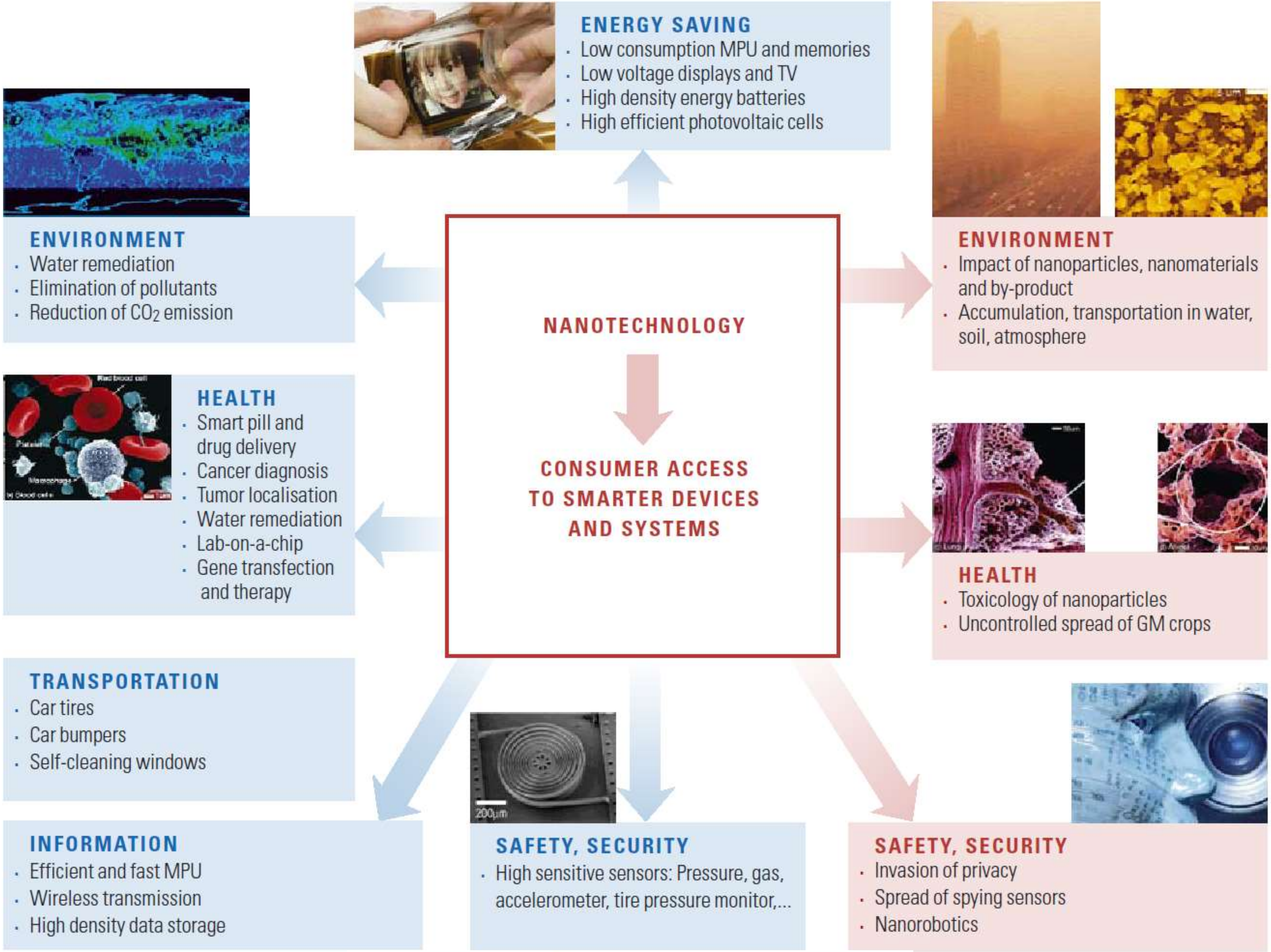


Overview of research directions in bio-nanomaterials



EC White Book on „Basic Materials Science" 2001

source: Max-Planck-Institute for Metals Research



Benefits and risks of nanotechnology; some examples.

SCHEMATIC DIAGRAMME FOR BIO-NANOSYSTEMS RESEARCH

NATURAL NANOSYSTEMS
- Precise design and control of architectural natural molecules (oligo- and polysaccharides)
- Natural block copolymer self-assembly
- Natural compartmented nanoparticles and intelligent surfaces
- Develop new and original strategies for elaborating functional polysaccharides-based nanoelectronic materials
- Flexible electrical displays using renewable raw materials
- Biomass valorisation and sustainable materials

BIOMATERIALS
- Library: engineered nanostructures for integration into complex shapes
- Hybrid bio-artificial structures with novel properties
- Integrated systems for sensing and repair in biological systems
- Antimicrobial / biocompatible surfaces
- Nanocoatings for surface wettability
- Nanocomposites for hard/soft tissue mechanical matching

MEDICINE
- Cancer diagnostics and higher resolution
- Tissue engineering and better organ support
- Artificial organisms as model system implants
- Bionanosensors for monitoring
- Nanobiotics for better treatment
- Therapeutics delivery
- Toxicology to understand dangers
- Gene therapy for disease management

FOOD
- Nanostructure-quality complexes
- Texture modifications for consumer value
- Nutrient delivery systems and drug release for extending benefits
- Process engineering for refined production
- Colloid technology
- Intelligent packaging – nano antibacterial coatings for better products
- Shelf life monitoring for safer storage

BIO-NANOSYSTEMS
- High performance reconstructed tissues and implants
- New delivery systems
- Optimised medical treatments
- Safer and higher quality nanobased products

DENTISTRY
- Tooth diseases diagnostics
- Dentine/enamel assembly
- Anti-caries, antimicrobial therapy
- Soft & hard tissue regeneration
- Oral nanoprobes
- Biomimetic dental implants and fillers – implant biocompatibility
- Cosmetic repair materials
- Bone repair

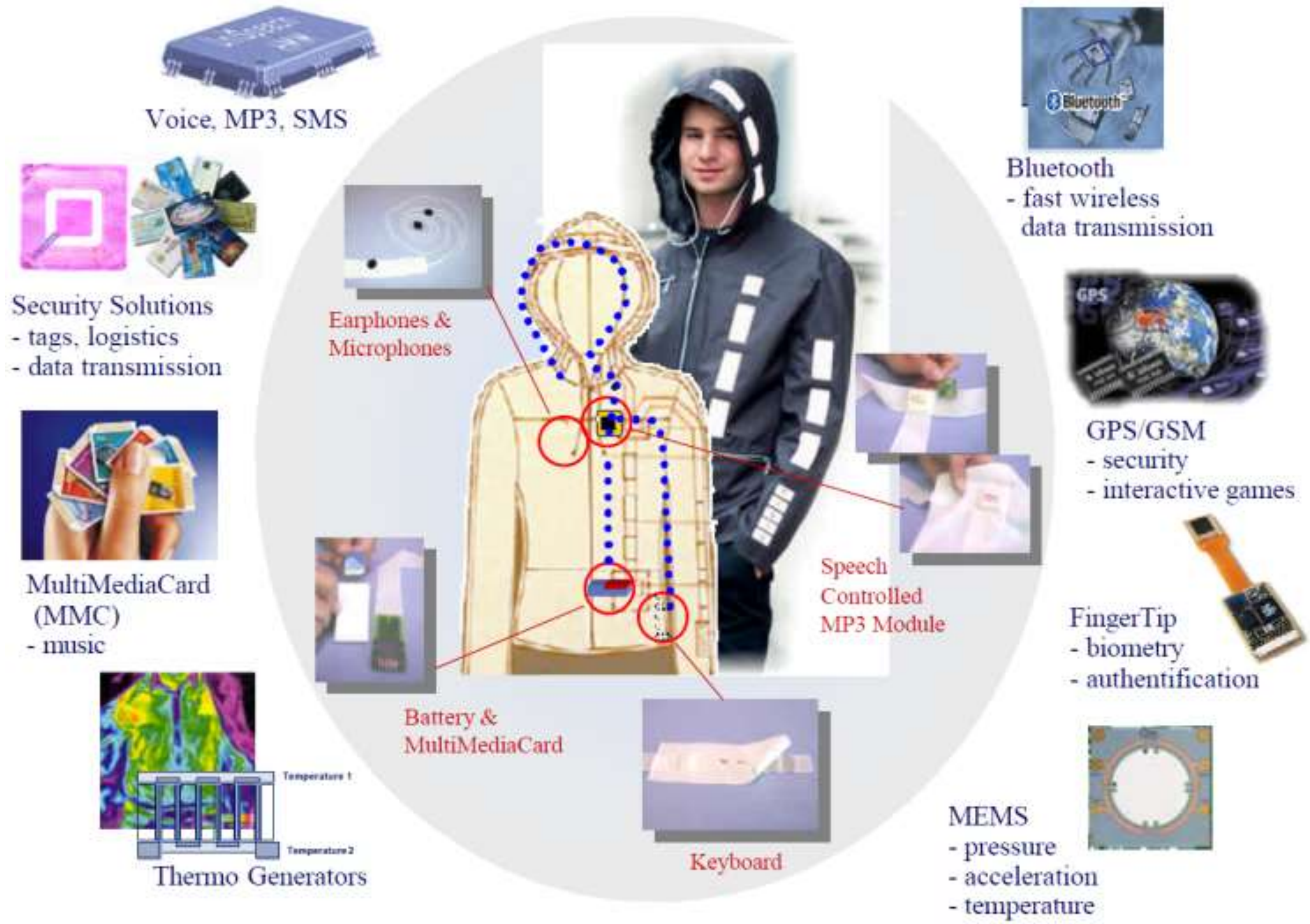
AGRICULTURE
- Health/resistance of plants and animals
- Lipid vesicles
- Precision farming: maximise crop yields/ minimise fertilisers & pesticides through monitoring
- New sources & implementation of bio-energies
- Agriculture based multifunctional nanoobjects
- Quality and safety of food

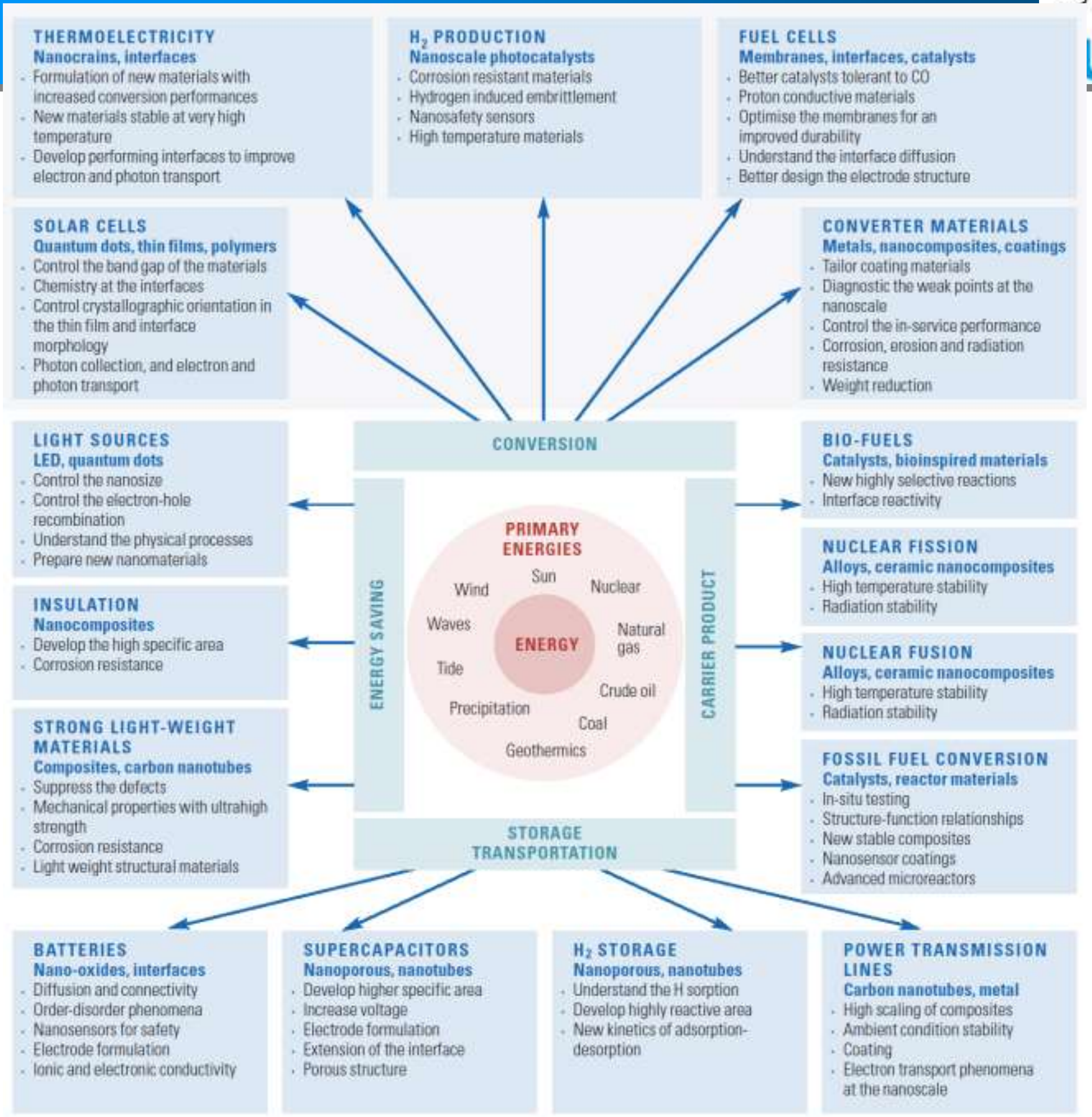
HEALTH CARE COSMETICS/OINTMENTS
- Nanosized soft formulation
- Controlled screens
- Reactive materials
- Local skin delivery
- Vaccines
- Stealth therapeutic agents
- Nanophotonics effects
- Safety aspects

PHARMACEUTICALS
- Drug delivery to specific tissue
- Drug targeting with low side effects
- Antimicrobial surfaces
- Nanobiotics for greater efficacy
- Lab-on-a-chip and bioreactors for screening, toxicology and drug targeting
- Biosensors and in vitro test systems for monitoring

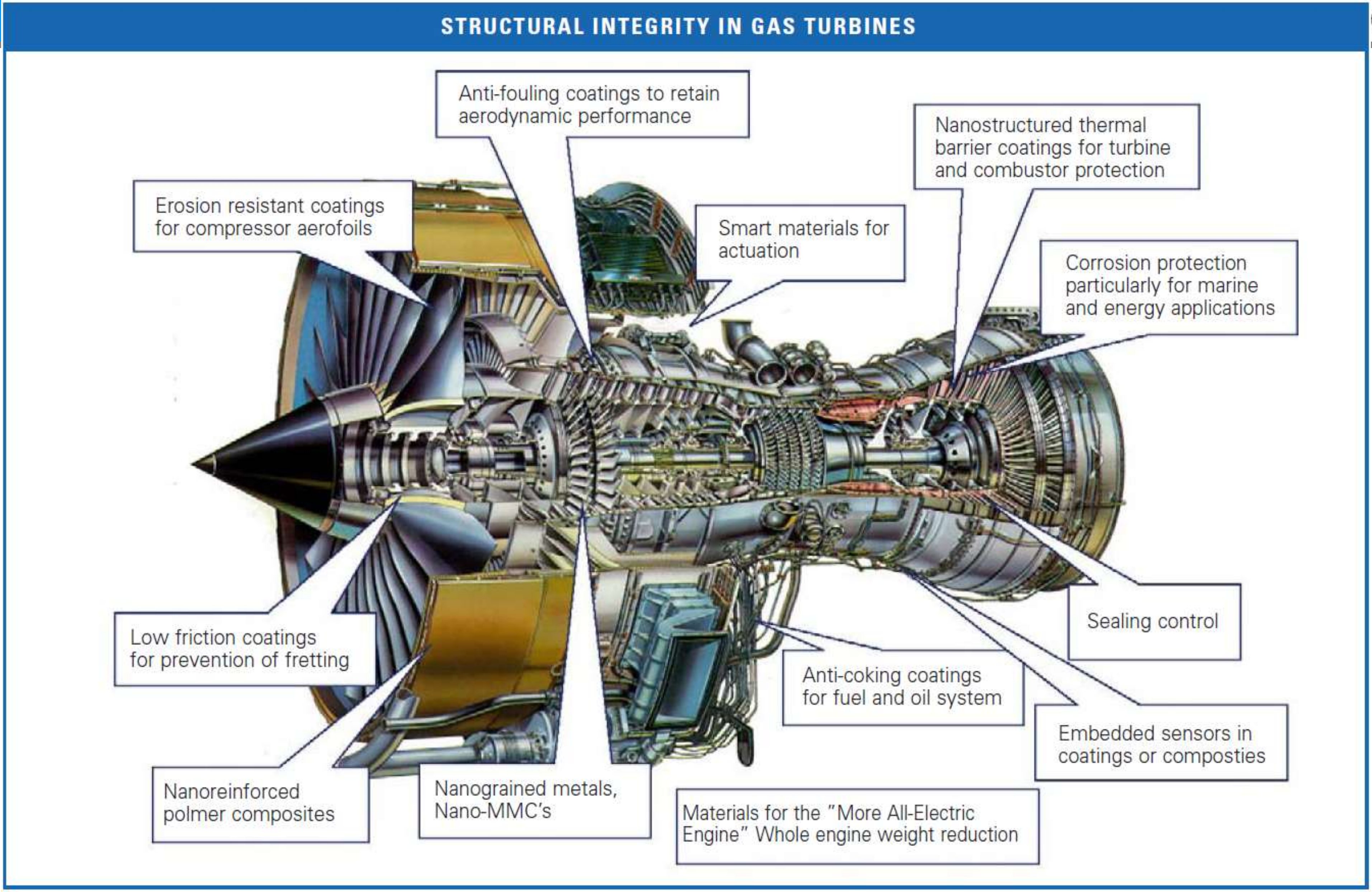
Overview of bio-nanosystem technologies.

Wearable Electronics: Nanoelectronics Integrated in Clothing





Energy targets and challenges for research and development.

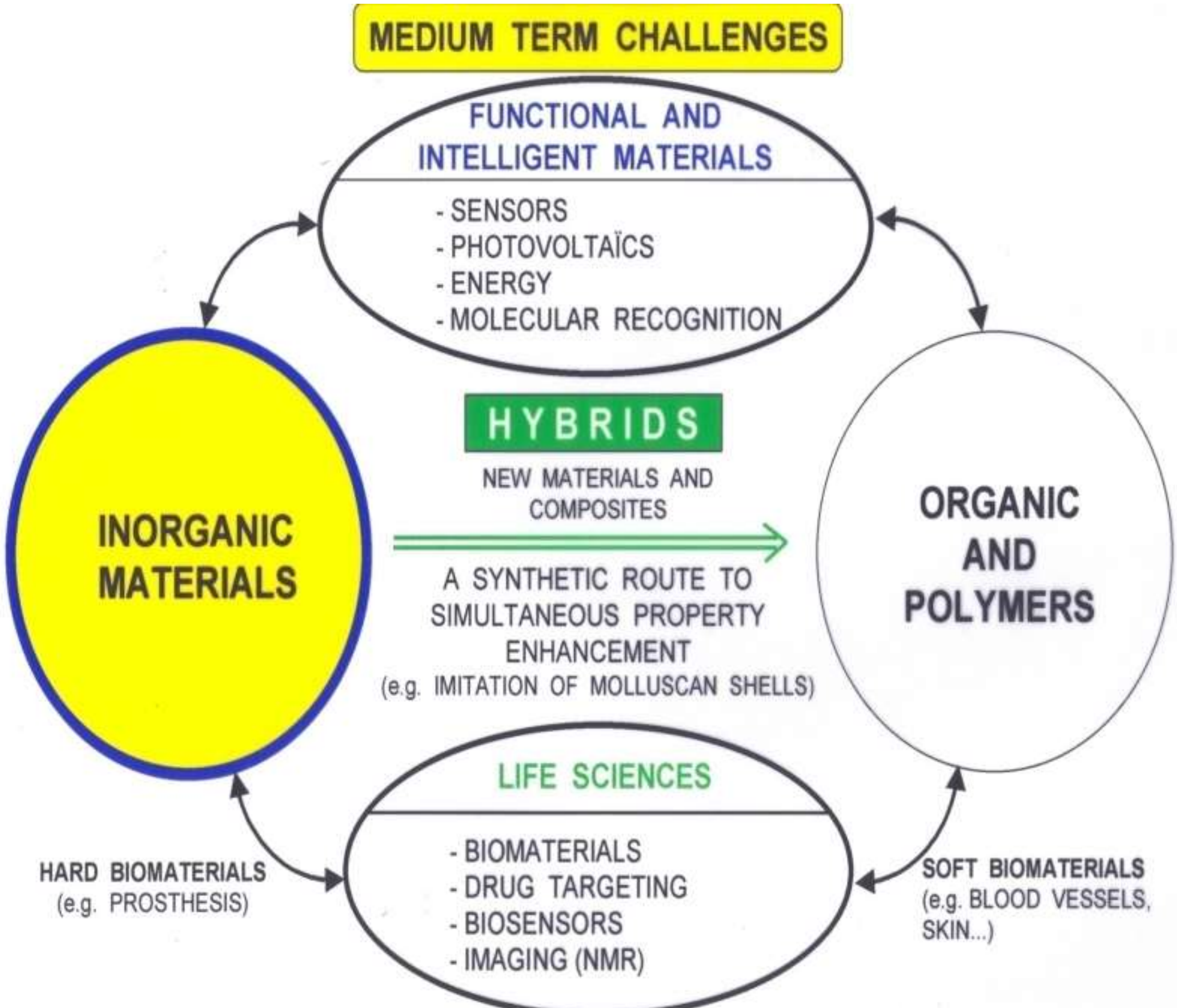


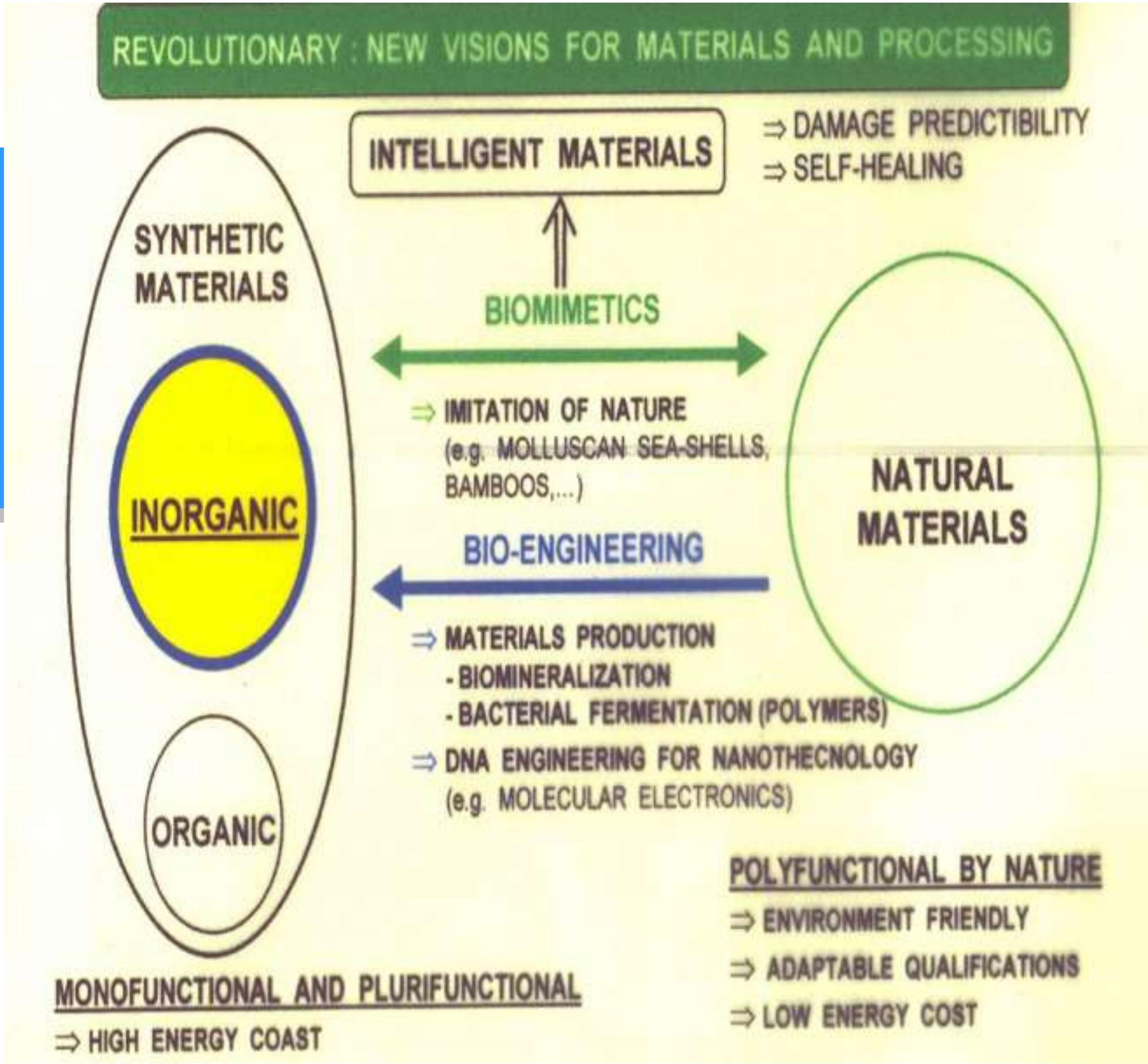
The role of nanomaterials in the aeronautics propulsion systems sector.

The elements for a high level education are

- Multi-disciplinary skills
- Top expertise in science & engineering
- Literacy in complementary fields
- Exposure to advanced research projects
- Literacy in key technological aspects: exposure to real technological problems
- Basic knowledge in: social sciences, management, ethics, foreign languages
- Literacy in neighbouring disciplines: international business, law, etc.
- Interlinkages between: education, research and industrial innovation: students will be ready for that research and development will provide
- Sharing of post-docs, Masters and PhD students to foster the mobility of permanent researchers and professors between different institutions are needed to create “team spirit”

Companies, universities, governments, research organisations and technical societies must all strive to define their roles in this partnership

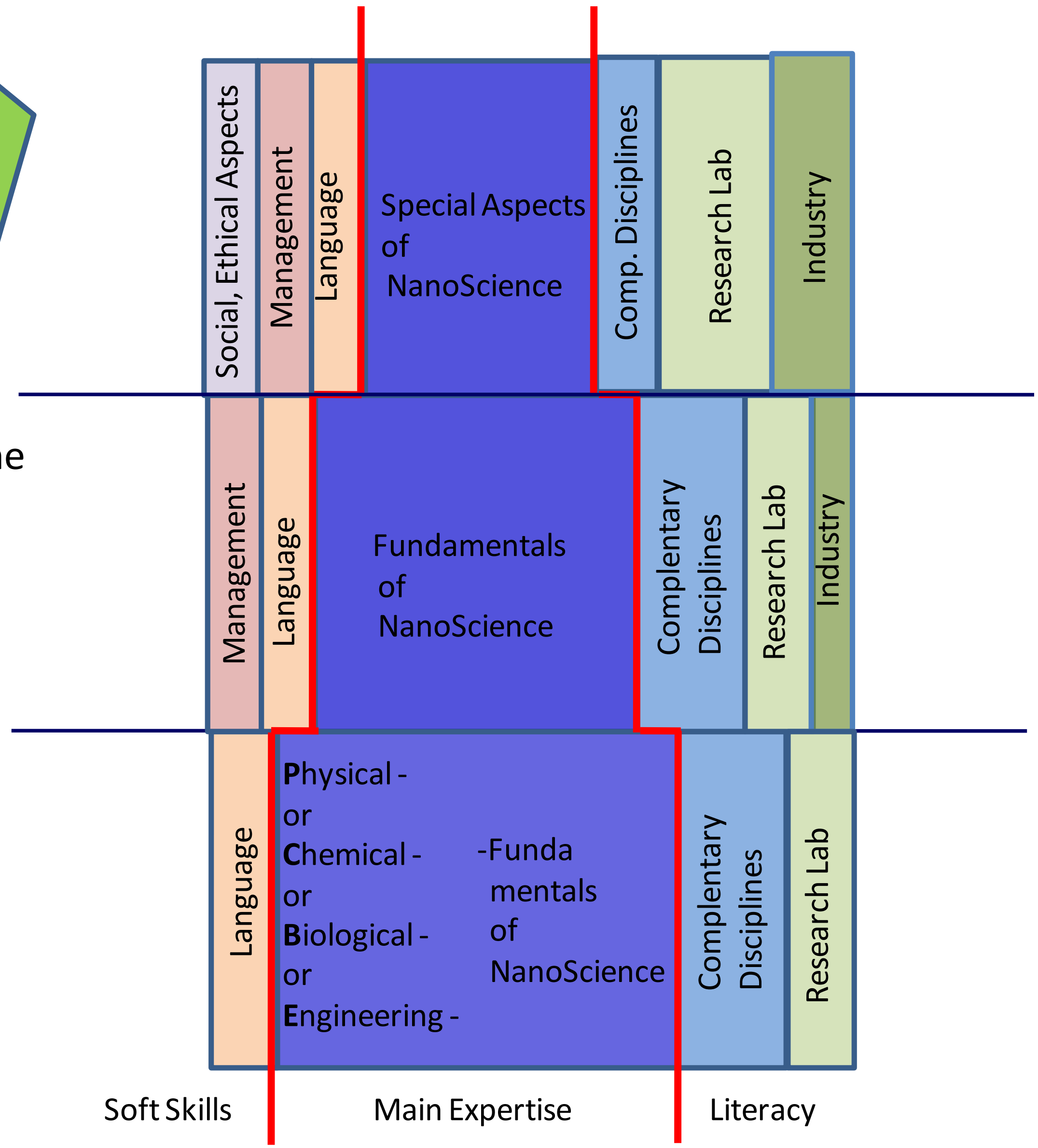

MEDIUM TERM CHALLENGES
FUNCTIONAL AND INTELLIGENT MATERIALS
- SENSORS
- PHOTOVOLTAÏCS
- ENERGY
- MOLECULAR RECOGNITION
INORGANIC MATERIALS
HYBRIDS
NEW MATERIALS AND COMPOSITES
A SYNTHETIC ROUTE TO SIMULTANEOUS PROPERTY ENHANCEMENT
(e.g. IMITATION OF MOLLUSCAN SHELLS)
ORGANIC AND POLYMERS
LIFE SCIENCES
- BIOMATERIALS
- DRUG TARGETING
- BIOSENSORS
- IMAGING (NMR)
HARD BIOMATERIALS
(e.g. PROSTHESIS)
SOFT BIOMATERIALS
(e.g. BLOOD VESSELS, SKIN...)


REVOLUTIONARY : NEW VISIONS FOR MATERIALS AND PROCESSING
INTELLIGENT MATERIALS
⇒ DAMAGE PREDICTIBILITY
⇒ SELF-HEALING
SYNTHETIC MATERIALS
INORGANIC
ORGANIC
BIOMIMETICS
⇒ IMITATION OF NATURE
(e.g. MOLLUSCAN SEA-SHELLS, BAMBOOS,...)
NATURAL MATERIALS
BIO-ENGINEERING
⇒ MATERIALS PRODUCTION
- BIOMINERALIZATION
- BACTERIAL FERMENTATION (POLYMERS)
⇒ DNA ENGINEERING FOR NANOTHECNOLOGY
(e.g. MOLECULAR ELECTRONICS)
POLYFUNCTIONAL BY NATURE
⇒ ENVIRONMENT FRIENDLY
⇒ ADAPTABLE QUALIFICATIONS
⇒ LOW ENERGY COST
MONOFUNCTIONAL AND PLURIFUNCTIONAL
⇒ HIGH ENERGY COAST

EUROPEAN NANOSCIENCE COLLEGE

for research-focused interdisciplinary intersectorial education

Syllabus
Master Programme



The benefits of a European Elite College

The students should:

- Receive an excellence degree recognised across Europe and appreciated worldwide;
- Become attractive top-experts with literacy and management skills;
- Get promotion to leading positions in universities, research institutes, industry and government in Europe;
- Get early contact with key industrial problems.

The universities in Europe will:

- Attract the best students;
- Be able to offer joint academic appointments across disciplines, between universities and industries;
- Be able to offer new professional degree programmes with research institutes, and industry;

The Research institutes will:

- Be directly involved in focussing the education to the current research fields;
- Be able to recruit the best suited students.

Industry will:

- Be able to directly influence the skills mix of the students;
- Get in touch with the best talents facilitating their recruitment processes;
- Get in direct contact with scientific discoveries;
- Be able to help in the creation of spin-off companies.

The Society will:

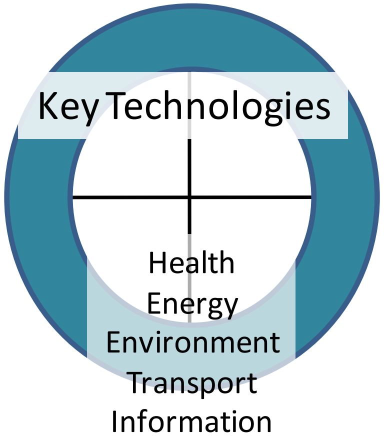
- Benefit from a targeted education of young talented people;
- See more efficient scientists and engineers who tackle the urgent problems in energy, environment, health, and climate change

International Partnership and Organisations for Promotion :

- Universal Degree System: BSc. MSc, PhD
- Develop Unified Study Programmes - Enable cross-disciplinary research
- Optimise the use of infrastructure and facilitie
- Develop integration mechanisms: to bridge the gaps between: education, research and industrial innovation; so that research discoveries spin-off into industrial applications
- UNESCO, UNIDO, UMU, IEA, OECD, G-20, DAVOS Conference, Intergovernmental Agencies and Bi-lateral Government Agencies.
- Set-up an International University Agency
- International Industrial Research Management Agency

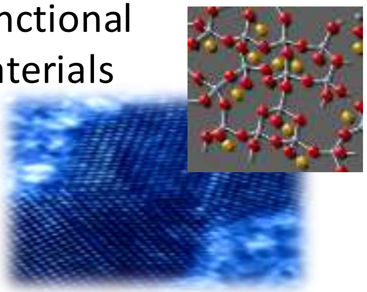
Research

Innovation



Development of
Advanced
Nanodevices
and Nanotechnologies

Design of
Novel
Multifunctional
nanomaterials



... Top expertise in nanomaterials engineering
Literacy in scientific aspects of nanomaterials,
Knowlede of urgent technological challenges,
Basic knowledge in:
International Business, law, ethics, languages

GENNESYS
Roadmap

.... Top expertise in nanomaterials science,
Literacy in complementary fields,
Literacy in technological aspects,
Basic knowledge in:
Management, ethics, foreign languages

Need for Scientist
with ....

Education

* The new millennium will see us enter an era of novelties in medicine, transport, society,…. With the new tools, new insights and understanding, and a developing convergence of the disciplines of physics, chemistry, materials science, biology, and engineering we may dare to dream of novel and superior products and systems that were, until the 21st century, the stuff of science fiction. “This will not be possible without collaborative links between disciplines”

- In future, post graduates have to operate in a multi-disciplinary environment unknown in the past
- The present generation of students must be convinced that they have good careers
- The real need is for young scientists to know how to move forward when faced with a real world-problem on a technical topic they never met before, on a real time scale, and a real world budget.

The University leaders should:

✓ recognize that teaching (a key-role) is largely for students who will not become future academics, and for careers that don’t exist yet

✓ recognize that research and teaching must be linked so that students will be ready for the new ideas of knowledge that research will provide

✓ recognize that research changes very rapidly. It is therefore wise to keep teaching close to recent developments and have institutes into which it is easy to bring people from various departments for the span of a project or suits of projects

1. Fifty years ago governments showed little interest in universities, unless they propagated anti-government views. Governments were content that universities should be seats of learning, and scholarship. Universities around the world had broadly similar structures, with essentially independent departments of history, physics, philosophy, etc. Governments accepted such structures, provided funding, and did not normally interfere.
2. In the last fifty years the world has fundamentally changed. Many governments now realise that new scientific knowledge holds the key to our future wealth and health. Many new medical drugs and industrial products are based upon discoveries made in universities. Hence, governments around the world are now intensely interested in their universities.
3. However, the structure of our universities has changed little in the past fifty years. We still tend to have departments of history, physics and philosophy, with inflexible high walls separating them. A key feature of the university-of -the-future must be FLEXIBILITY. Concerning teaching, we must make it easy for an engineer to learn i.e. Chinese or Japanese or an Indian language, history and culture. This will require a revolution in the way we teach our university students, and an emphasis at the undergraduate level on breadth as well as depth.
4. Concerning research, we must acknowledge that much of the most exciting and useful research is occurring at the boundaries between traditional disciplines. Many of our best structural biologists, who design new medical drugs to attach to specific protein molecules, have been trained as physicists. Next generation mobile phones, computers, cars and plans, are designed and developed by materials scientists working with chemists, physicists and engineers. However, current university departmental structures impede rather than facilitate multidisciplinary research. We need to create 'departments without walls' in our universities.
5. A major concern is the increased number of administrators, and the increased level of bureaucracy, in many European universities. We need better, well-paid administrators, but fewer of them. Their role should be to facilitate teaching and to provide the flexible structures required in the University-of-the-future.

Research and development partnerships should be encouraged in order to:

- Optimise the use of infrastructure and facilities
- Enable cross-disciplinary research
- Improve universities and research labs' appreciation of industry priorities and needs
- Develop integration mechanisms: to bridge the gaps between: education, research and industrial innovation; so that research discoveries spin-off into industrial applications
- Share the risks and returns of long term research
- Assemble teams that can recreate the fertile research environment of the former large industrial and governmental research labs
- Develop the commercial exploitation and patenting of new technologies

Issue of interdisciplinarity

- New fields of research and applications emerge that require interdisciplinary research teams.
- The present Universities insufficiently prepare students to work in interdisciplinary teams.
- The barriers for students to change from one faculty to another or from one university to another and learn a new field are too high
- The students are not trained to communicate interdisciplinary, nor to think interdisciplinary.

Inter, Multi, Trans-disciplinarity

- Also trandisciplinary thinking is strongly requested so that the interaction of disciplines between each other is enhanced and societal effects of research better assessed
- Also that scholars are aware of the broader social, historical, ecological and political impact of their activities
- The issue of reforms in the University are one very good example of a task that requires inter, Multi, Trans disciplinary approach

A problem for all of us

For companies the main task is simply to end up with more talented people than their competitors. Human-resource managers, once second-tier figures, now often rank among the highest-paid people at European firms.

Governments need to act and removing barriers:

- Europe still rations the number of highly skilled new member countries scientists and immigrants it lets in;
- Education inevitably matters most. <u>In Europe, it is easy to say that much talent is thrown away by “Europe’s dire universities”</u>. They suffer from too little competition and what George Bush called: “the soft bigotry of low expectations”.

Most societies will tolerate the ideas of well-rewarded winners, as long as there is equality of opportunity and the losers also clearly gain something from the system. If those conditions are not met, populist politicians from Ireland to Bulgaria will clamp down – and everyone will be poorer for it. A global meritocracy is in all our interests.

European visions and actions in nanomaterials education and research have urgently to be taken to assure a successful future and to keep Europe in a forefront position, worldwide.

The European education" is

- "old fashioned", very traditional and not prepared to safeguard the future welfare of the society and the industrial/economic challenges
- The walls between the university faculty/department buildings forbid multidisciplinary training and experience necessary for a good career
- Europe is confronted with the fact that there exist *too many "mediocre" schools/departments.*

It is severely fragmented and duplicated, since nanomaterials research is often performed in nationally isolated laboratories. *The number of materials research centres is exorbitant,* many with sub-critical means (personnel and budgets) to reach breakthroughs and cutting-edge results in their work

- In future business, it will become crucial to always be innovative

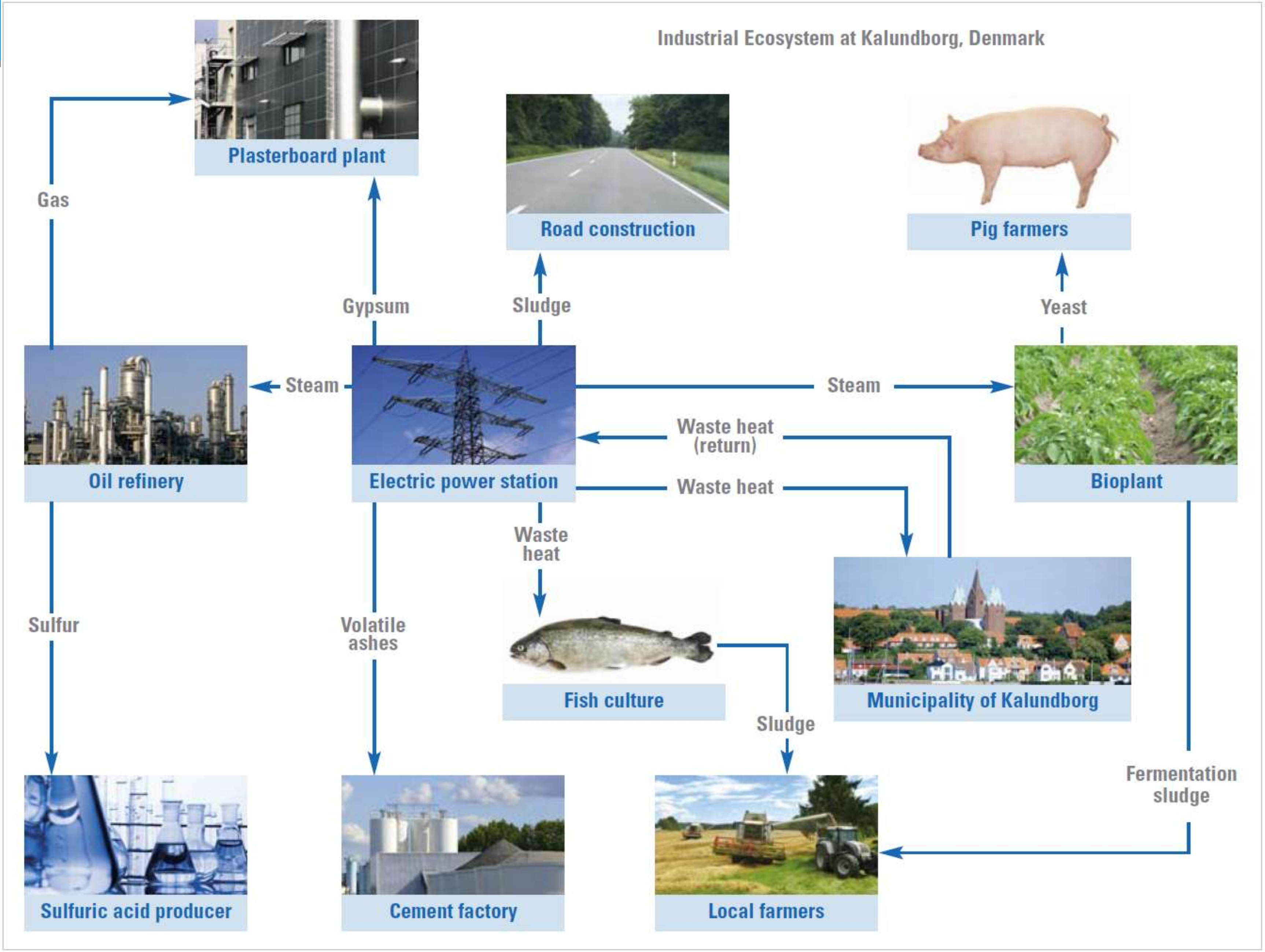
- The entrepreneur mindset certainly exists in European universities; it will certainly take years, may be decades before we catch up with the US

- To be excellent and competitive on an international scale the "European University" and the "European Industry" must work together in research to develop innovations and discoveries. Commercial companies, universities, governments, research organizations and technical societies must all seek to redefine their role in this expanding partnership

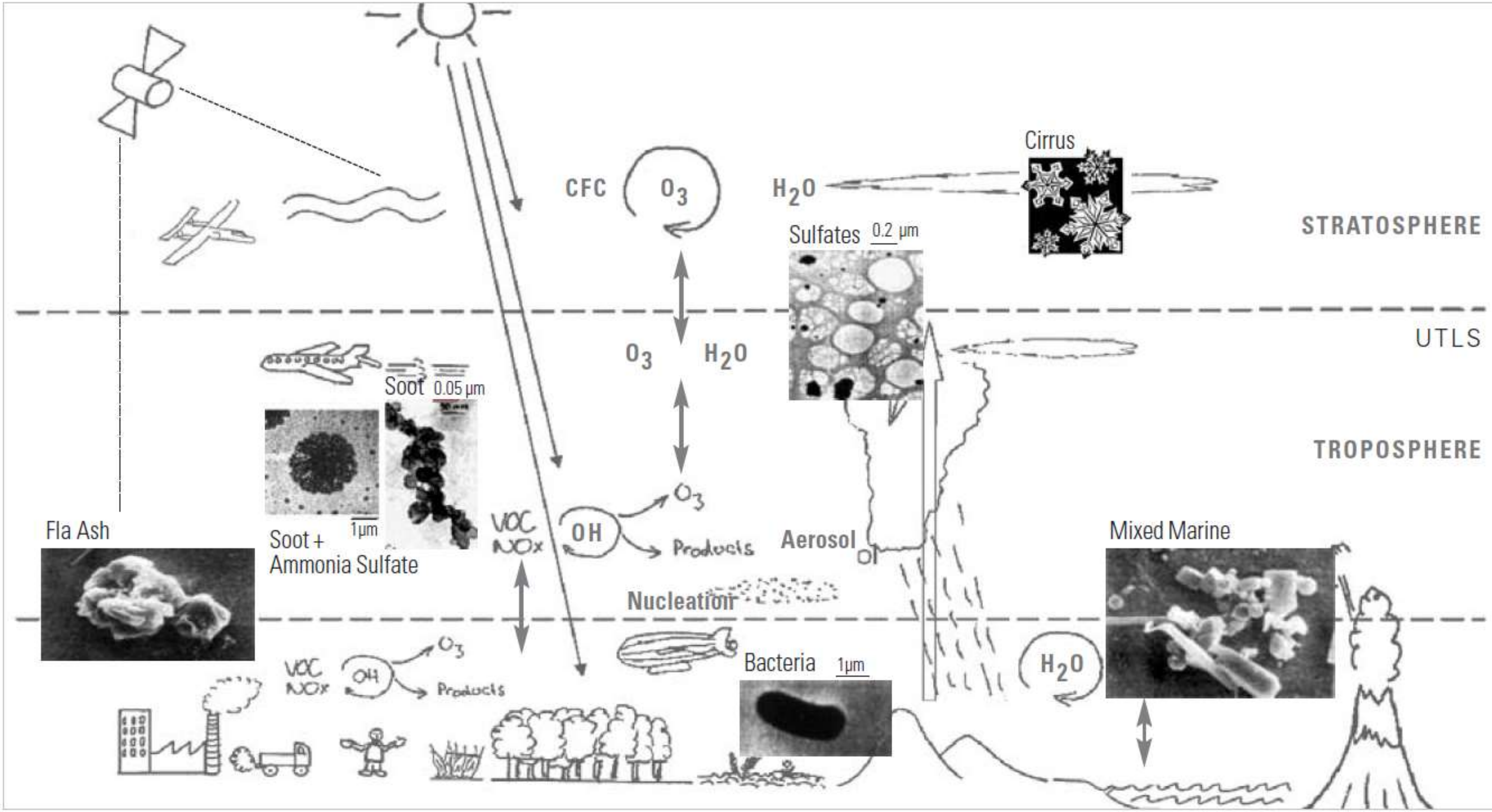
<u>The world's most valuable commodity is getting harder to find! </u>*- Explicitly applicable to materials science – physics – chemistry and engineering's*

Company management has a gnawing worry about the supply of talent. It used to mean innate ability, but in modern business it has become a synonym for brainpower (both natural and trained) and especially to think creatively. The modern economy places an enormous premium on brainpower, and there is not enough to go around. The best evidence of a "talent shortage" can be seen in high-tech firms - companies such as Yahoo! and Microsoft are battling for the world's best computer scientists.

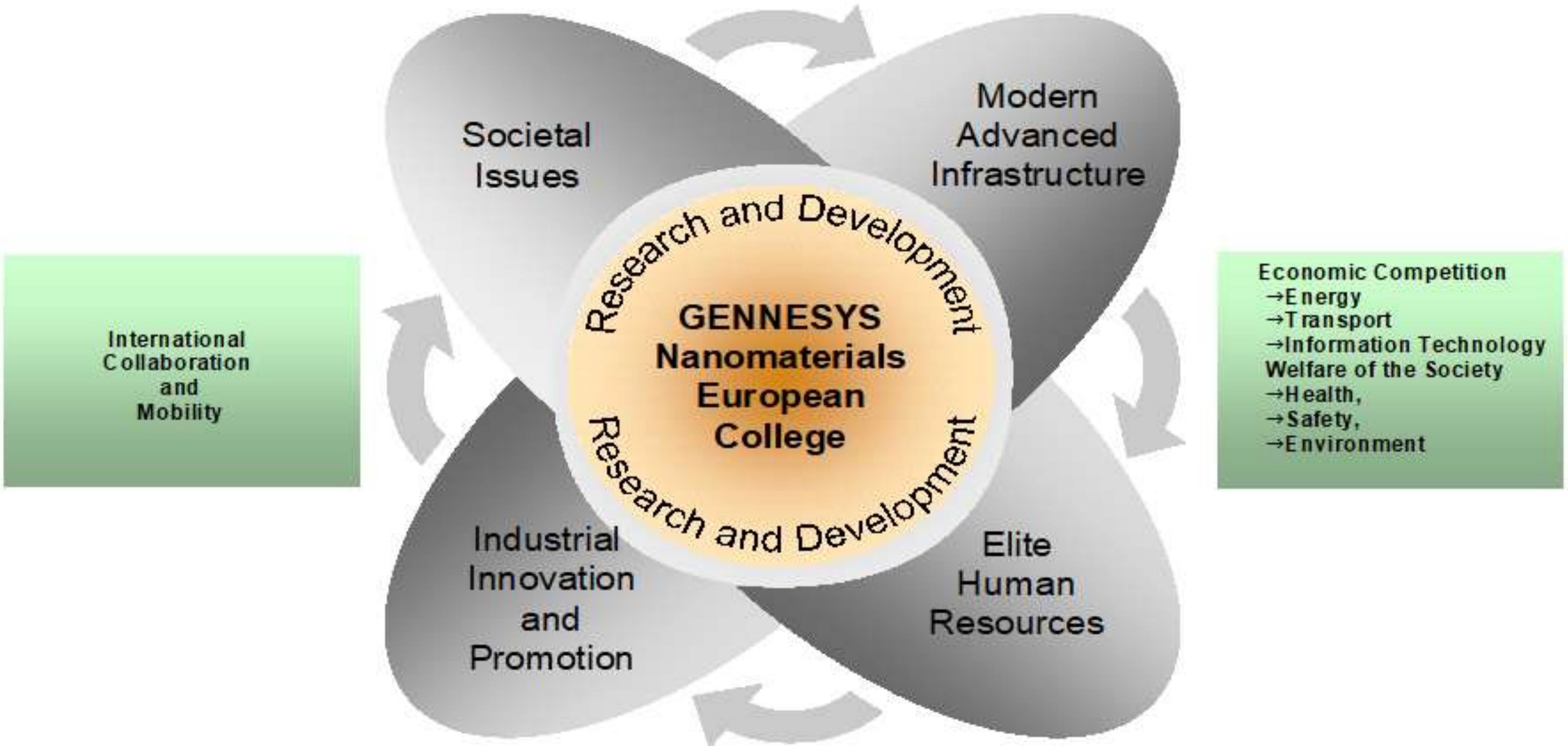
Companies in Europe of all sorts are taking longer to fill jobs – and say they have to make do with sub-standard employees. Even more money is being thrown at the problem - last year hundredths of firms adopted some form of talent-management technology. These days Goldman Sachs has a "university", Mc Kinsey has a "people committee" and Singapore's Ministry of Manpower has an international talent division.



Industrial ecosystem at Kalundborg, Denmark



Overview of atmospheric nanoparticles.

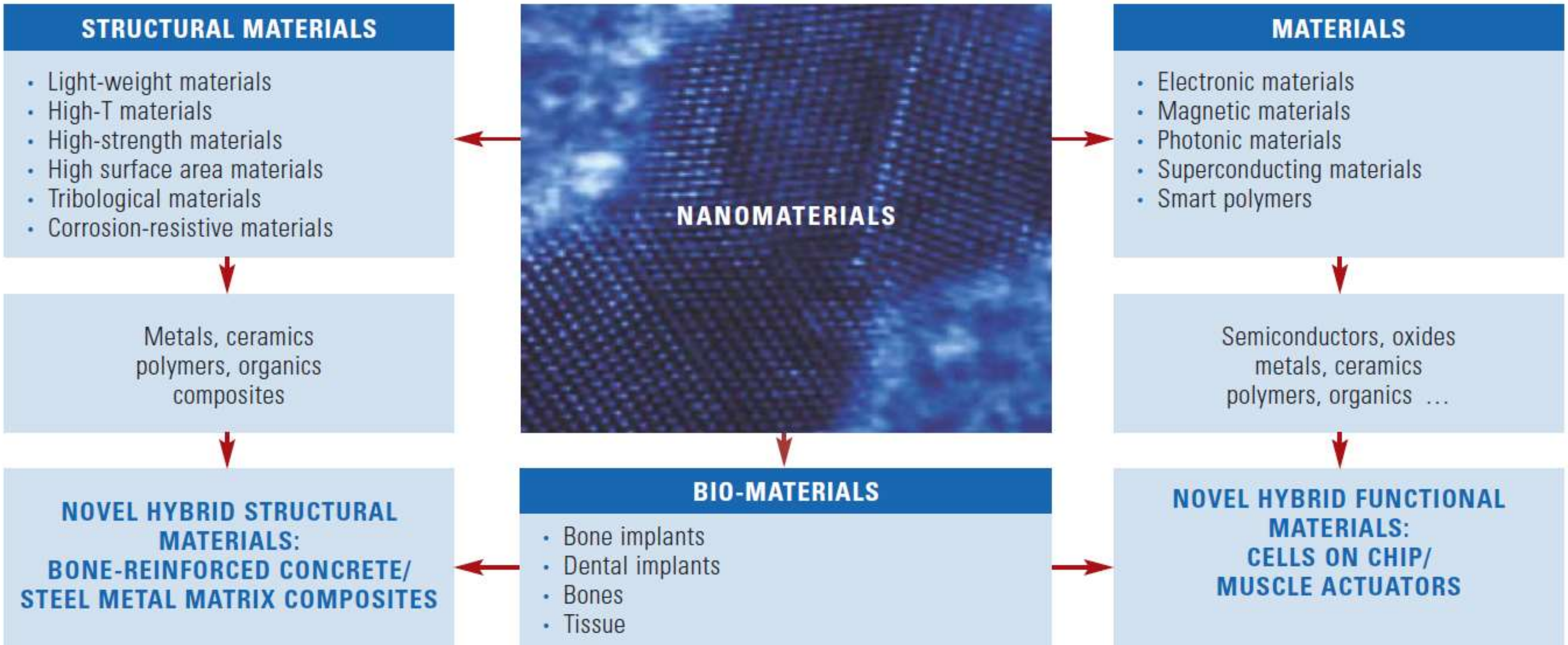


GENNESYS COLLEGE: „Nanomaterials Development Scheme“

- Conclusions
- Inter-disciplinary education is vital for a successful future
- It is to encourage to study at various universities for a university degree e.g. two Masters is better than one PhD
- Study at colleges which offer inter-disciplinary education
- Research projects with industry in advanced technologies e.g. nanoscience

Inter/Multi disciplinarity – a factor for dynamism of universities

- Inter/Multi and Trans disciplinarily may foster higher efficiency of University teaching and research.
- But...
- There is a danger of superficial teaching of various fields instead of deep knowledge of the given field.
- Do interdisciplinary teams need members with specialised knowledge but able to communicate and work in multidisciplinary teams, or members with superficial knowledge of various fields able to learn what is needed? The success of interdisciplinary teaching will depend on successful answer to this dilemma.
- During the meeting the opinion prevailed for well trained experts able to work well in multidisciplinary teams, but leaving also the option for changing of fields. The later option might appear to be attractive for students.



Overview: nanomaterials.

- Nanomaterials and Nanomaterials related community: physics, chemistry, engineering… throughout the whole of Europe is strongly divided, fragmented and much discipline oriented and often operates in sub-critical ways

- Many industries throughout Europe report problems in recruiting the types of graduates they require. Frequently industrial problems need multidisciplinary teams of scientists/engineers for their solution, yet most universities are not producing the multidisciplinary graduates to solve these problems, nor are they producing specialists with sufficient multidisciplinary training to be able to communicate easily with other specialists

- It is not only industry that requires multidisciplinary science and engineering graduates: many other areas of society have this need. For example, in today's world it is important that a significant number of our politicians, journalists, venture capitalists, etc have had a multidisciplinary science education

It is well known that universities are slow to change. In order rapidly to produce the scientists and engineers that Europe needs a new university is therefore required: one that will be a beacon for other universities in Europe to follow

Trespassers will be recruited

People often talk about shortages when they should really be discussing price. Eventually, supply will rise to meet demand and the market will adjust. But, while you wait, your firm might go bust. Also, while we wait, the US and China get further ahead. Talent shortage is likely to get worse:

- the proportion of European workers doing jobs that call for complex skills has grown three times as fast as employment in general;
- by 2025 the number of people aged between 15 – 65 is projected to fall by 10 % in Western Europe. Many companies will lose large numbers of experienced workers in a short space of time (half of the top people at Europe's 300 leading companies will go in the next five years).

Two things are making it much harder for companies to adjust:

- the collapse in loyalty: people leave easy companies and are moving to the highest bidder;
- **the mismatch to what schools are producing and what companies need**

<u>In Western countries schools are churning out too few scientists and engineers – and far too many people who lack the skills to work in a modern economy</u> (that's why there are talent shortages at the top alongside structural unemployment for the low-skilled).