

Health and Safety of Nanotechnology: Ensuring a Sustainable Development of Nanotechnologies

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- Nanotechnology is more an umbrella term than a well defined entity.
- The field is extremely varied.

- Nanotechnology is:

- Diverse

- Energy technology, information and communication technology or biotechnology.

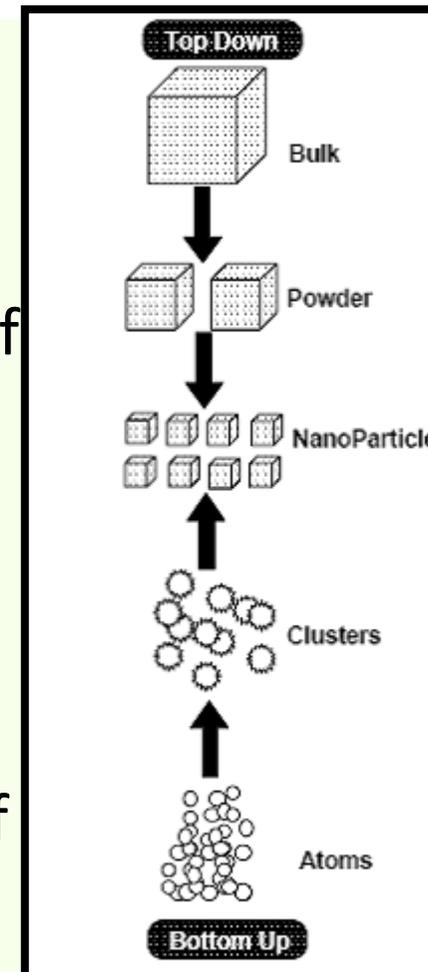
- Enabling:

- New discoveries in diverse fields of health, science and engineering.

- Cross-disciplinary

- Engineering and physics, chemistry, and health sciences.

- Two opposing directions of development:
 - top-down approach, originating in macro world > ever-greater levels of refinement > nano-level technologies; and
 - bottom-up approach, which begins at the atomic/ molecular level and involves self-organized formation of complex molecules/nanosystems.

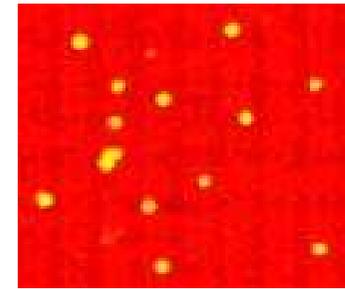
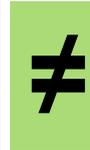
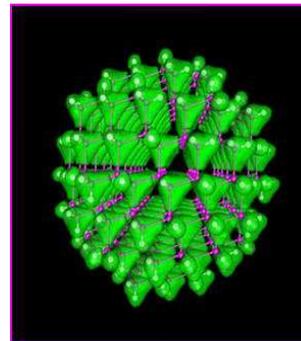
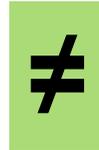
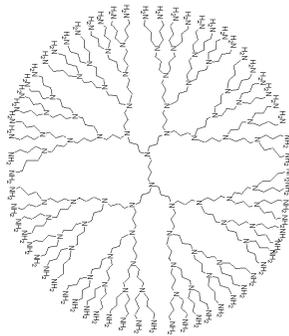
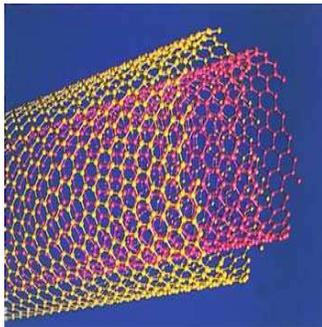


Therefore ...

- Nanotechnology is a collective definition referring to every technology and science which operates on a nanoscale bottom-up approach.
- At this scale new scientific principles and material properties can be found.

Nanoparticles: The building blocks of nanotechnologies

- Important premise:
 - Not all nanoparticles are alike except for **size**
 - Different chemical composition and shape



Carbon Nanotubes

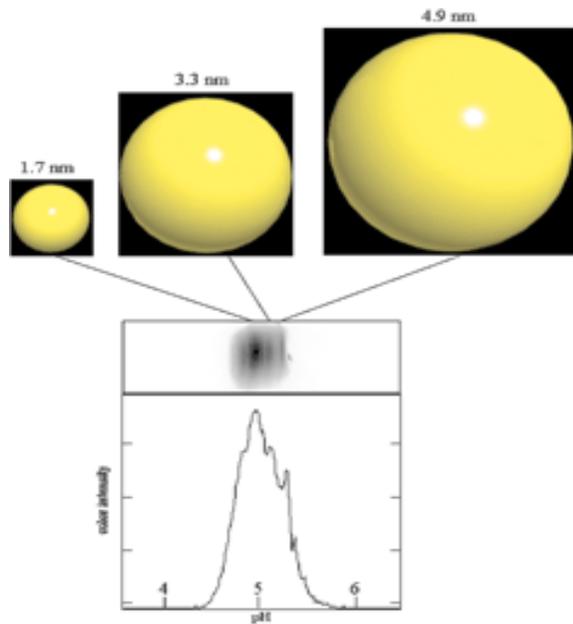
Dendrimer

Quantum dots

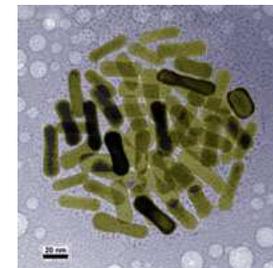
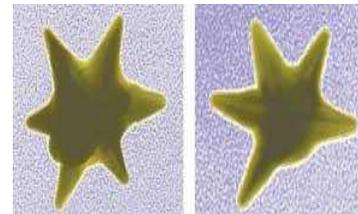
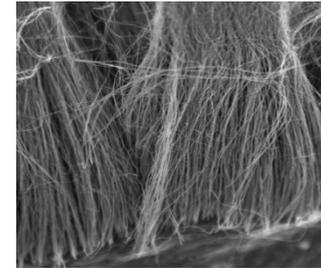
Gold nanoparticles

Nanoparticle properties

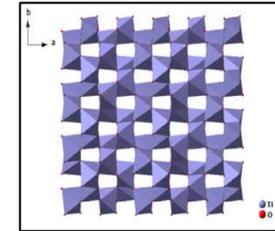
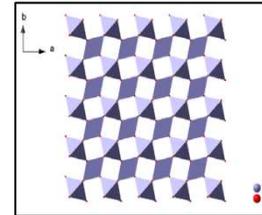
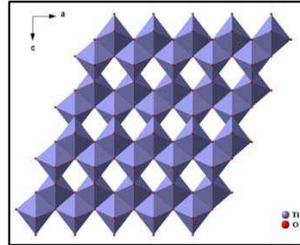
- Nanosize:



Shape



- Crystalline nature

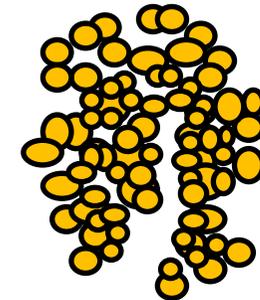
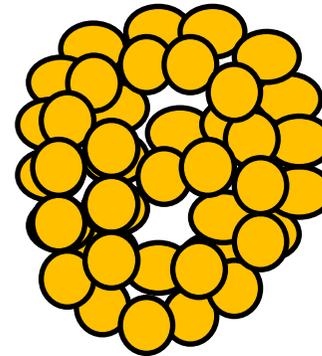
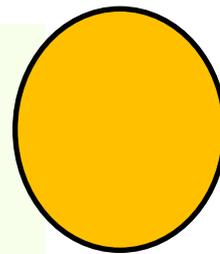


Anatase

Rutile

Brookite

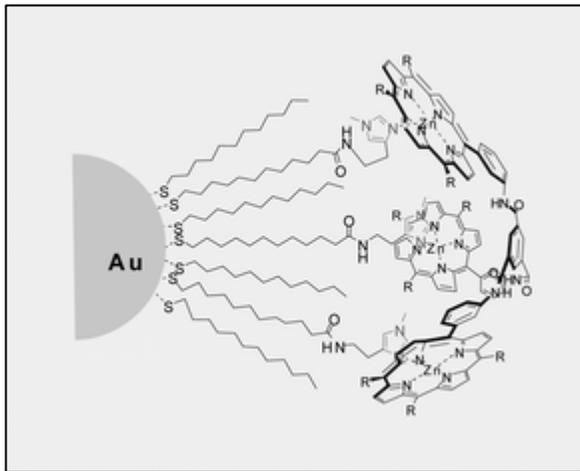
- Surface area
 - Larger surface, more active



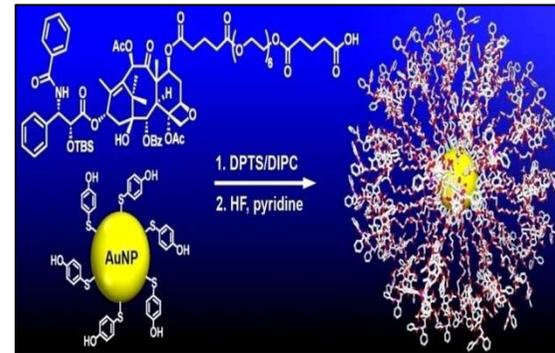
Size

Surface area

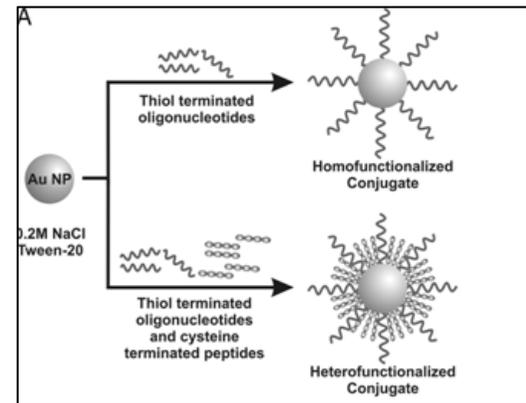
- Surface chemistry



N-Methylimidazole-functionalized gold nanoparticles

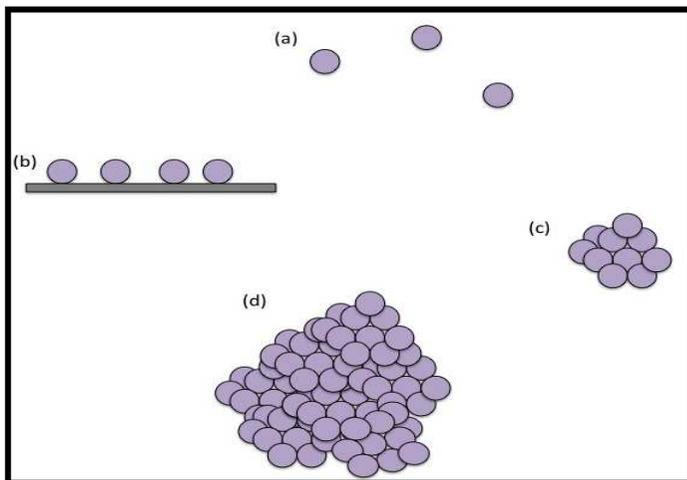


Paclitaxel-Functionalized Gold Nanoparticles

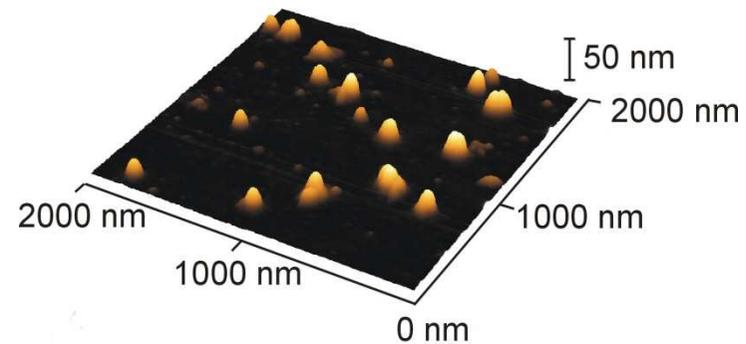


Oligonucleotide functionalized gold nanoparticles

- Tendency to agglomerate



- Dissolution
 - Metal ions (Silver ions)



- These new scientific principles and novel material properties that make nanotechnology so interesting **have also raised** many concerns related to the impacts nanotechnology may have on the society and the environment from the vantage point of **sustainability**.

Sustainable development of nanotechnologies

- Sustainability has become an umbrella term for many different things. While in most approaches environmental concerns are highlighted, economical and social aspects are also stressed.
- A responsible development of nanotechnology needs to address a wide range of environmental, health, social, ethical and regulatory concerns.

Sustainable nanotechnologies

- Sustainability, can also be specified into many other directions, such as 'higher efficiency' or 'reduced toxicity'.

Sustainable development

- Within the context of reduced toxicity, the following should be addressed:
 - Recent research: **free engineered nanoparticles** may produce a toxic response in cell cultures *in vitro* and also in experimental animals *in vivo*
 - **NO DISEASE AS YET OBSERVED IN HUMANS.**

Important premise

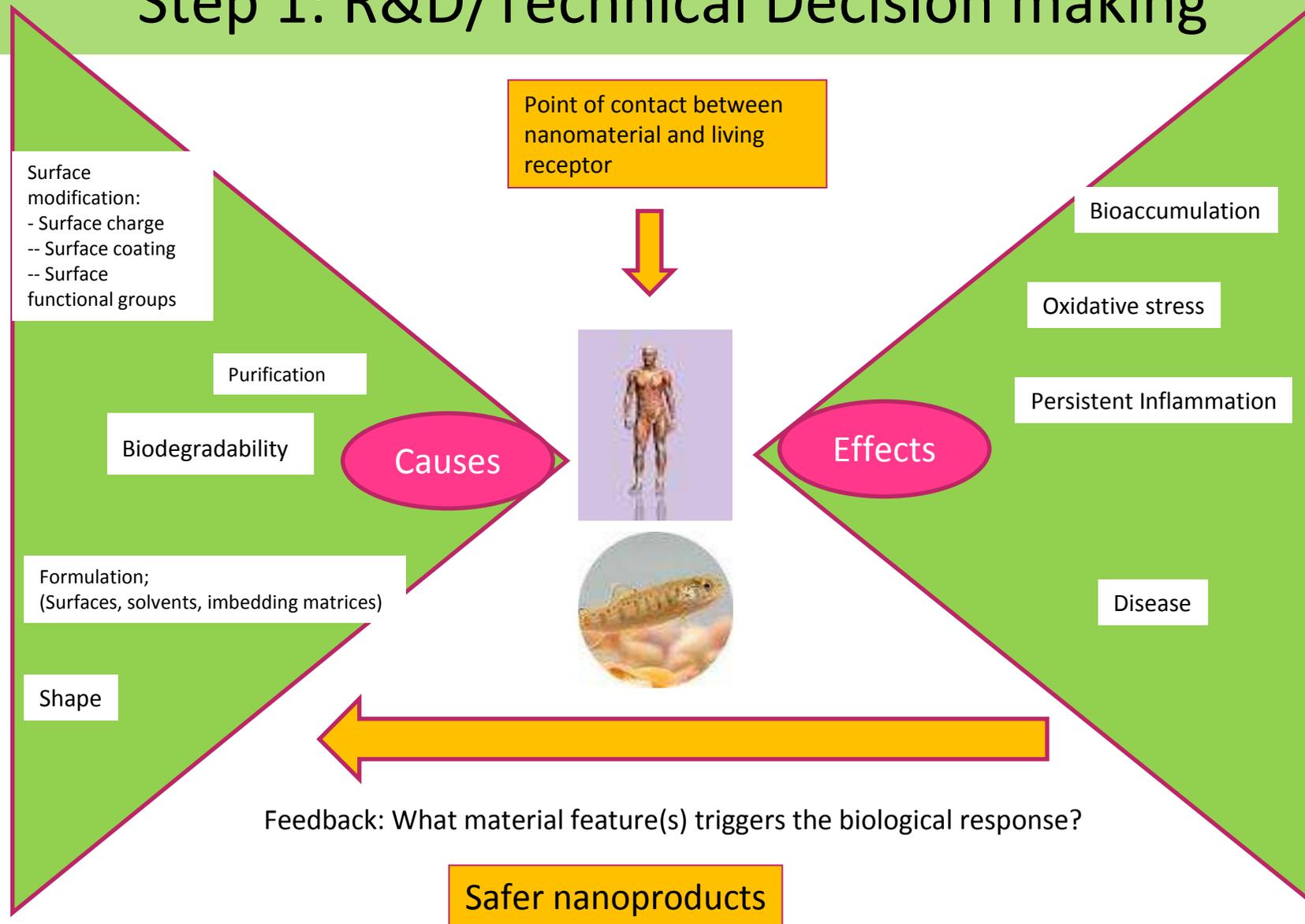
- With respect to the potential adverse health and environmental effects:
 - Nanostructures which occur as **free nanoparticles**, nanorods or nanofibres - toxicity.
 - Nanomaterials where the nanostructures are an **integral feature of a larger object** : to pose a lower or no risk as long as the nanoparticles remain fixed within the larger object and are not inherently dispersive.

Existing knowledge

- The study of the hazardous effects of particles, **particulate toxicology**, has been underway for many decades.
- Past investigations on larger particles and fibres have identified properties that control hazardous nature of particles and also identified mechanisms involved in their toxicity.

Sustainable nanotechnology

Step 1: R&D/Technical Decision making



This means ...

- The key factors that determine toxicity may be identified that can be used to:
 - **Predict** toxicity.
 - Permit targeted screening.
 - Allow material scientists to generate new, safer nanoparticles with this structure-toxicity information in mind.

Sustainable development at the design stage

- This offers a framework:
 - On how sustainable development can be integrated into the research and development stages of nanotechnology.
 - With a goal to avoid the introduction of products into commercial use that present a negative impact to the natural environment and to human health.

For example:

- **Decrease in bioaccumulation** will contribute to the reduction of toxicity *via* the elimination and/or biodegradation of these nanoparticles.
- Examples:
 - Biodegradable silica nanoparticles.
 - Biodegradable carbon nanotubes

Sustainable nanotechnology

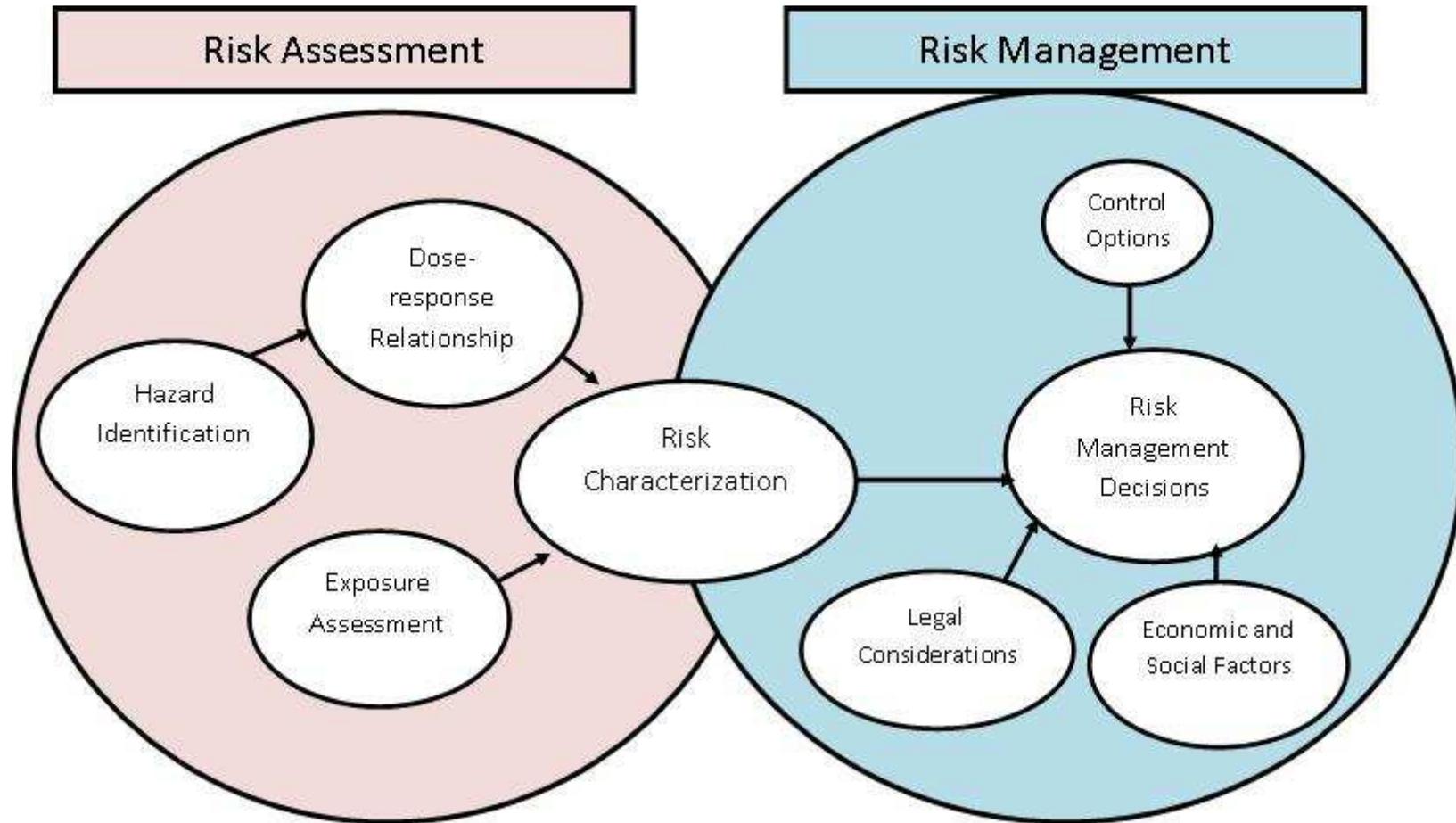
Step 2: Implementation of predictive tools

- Technology assessment analyzes predicted or to-be-anticipated positive and negative effects of technologies, processes, and products using a well-established set of methods, including:
 - Cost-benefit analysis
 - Risk assessment and risk analysis
 - Life cycle assessment (LCA)

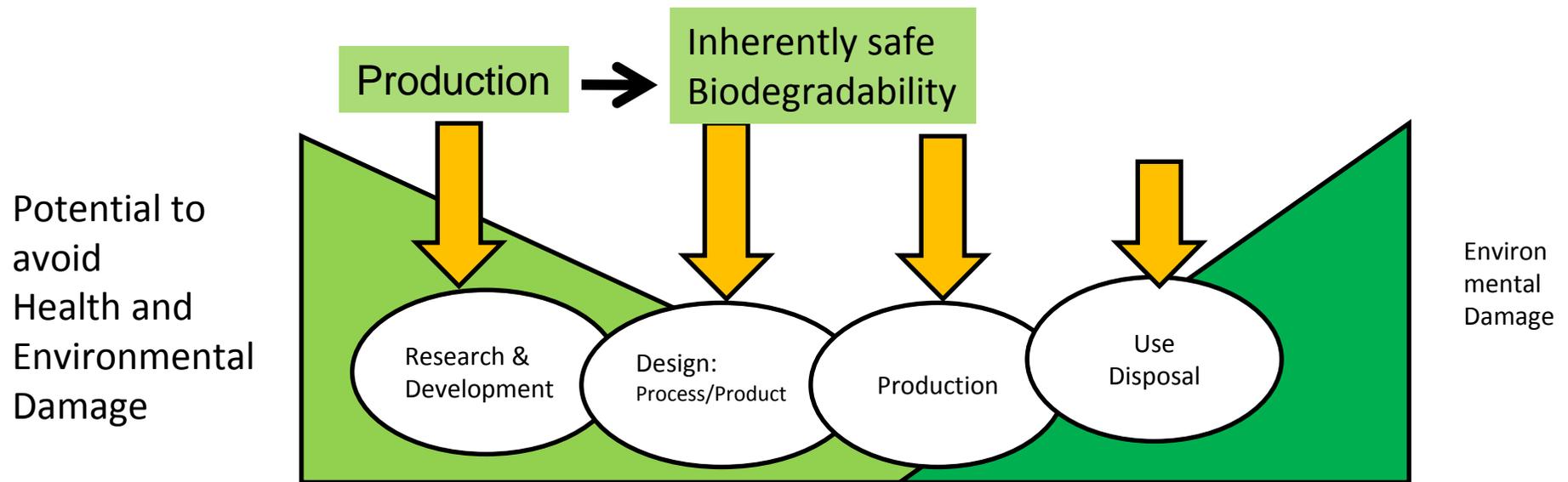
Risk Assessment

- **Risk = Hazard x Exposure**
- There will be no risk without exposure

Risk Assessment and Risk Management



Life cycle assessment



Therefore ...

- The technology is assessed by its full life cycle flow of material and energy in the systems of production, consumption and the disposal of technical products.

Prevention

- This implies a “forward looking” approach as they are “anticipatory and preventive” strategies.

Nanotechnology: getting it right the first time

- Instead of waiting for problems to emerge and then reacting, international attempts are in place to get ahead of the curve.

Conclusions

- Sustainable nanotechnology will lead to:
 - Societal Acceptance
 - Minimizing risk
 - Maximizing benefits