Nanotechnology in Food – Safe to eat?

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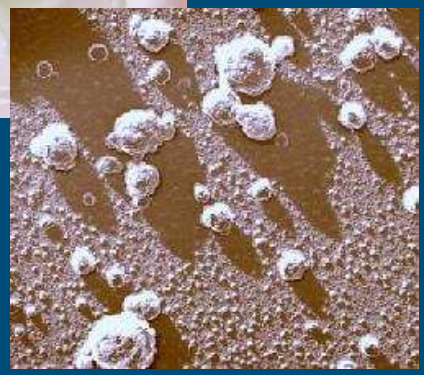
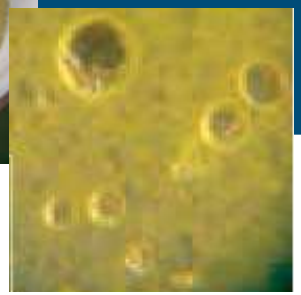
Euronanoforum 2009,
Prague/Czech Republic, 04-06-2009

Nano and food: a reality



- Naturally occuring nano-particles
  - milk: casein micelles (~ 100 nm), whey proteins (~ 3 nm)

- Conventionally produced food
  - Mayonnaise, Sauce Béarnaise: nano-sized droplets



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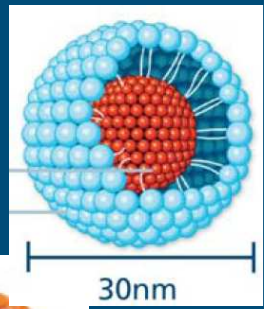
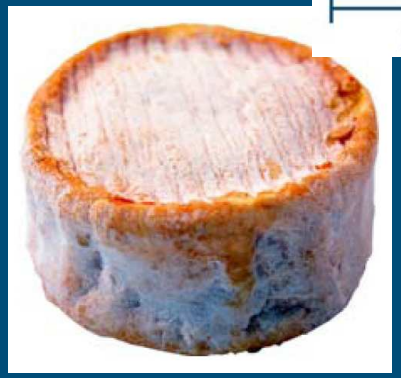
Nano and food: a reality

- Engineered nano-particles
  - nano-particles in PET bottles (e.g. titanium nitride, nano-clay)
  - nano-silver in food containers
  - nano-encapsulated ingredients/preservatives
  - and, and, and...





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Nanotechnology in food: Fiction

- Nano cures everything

Crystal Clear Nano
SILVER

protects against colds, flu,
and hundreds of diseases
(even anthrax)

by Drunvalo

Nanotechnology in food: Fiction

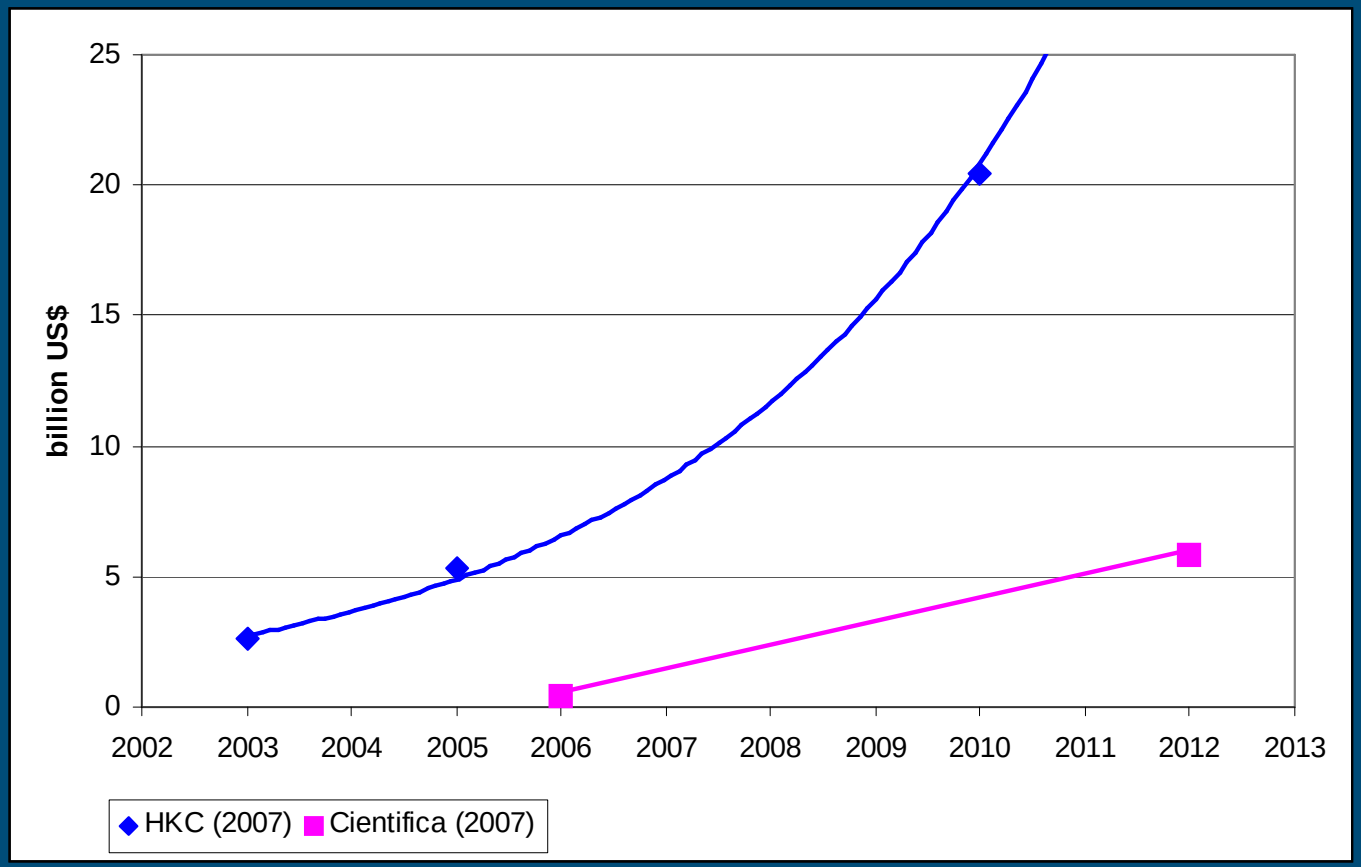
- Nano = Frankenfood

Nanotechnology in food: Facts

- Properties of nano-sized substances significantly different from their bulk and molecular analogues
- Variety of benefits described and expected
- Key technology in the development and production of value added foods

Nanotechnology in food: Facts

- Growing market

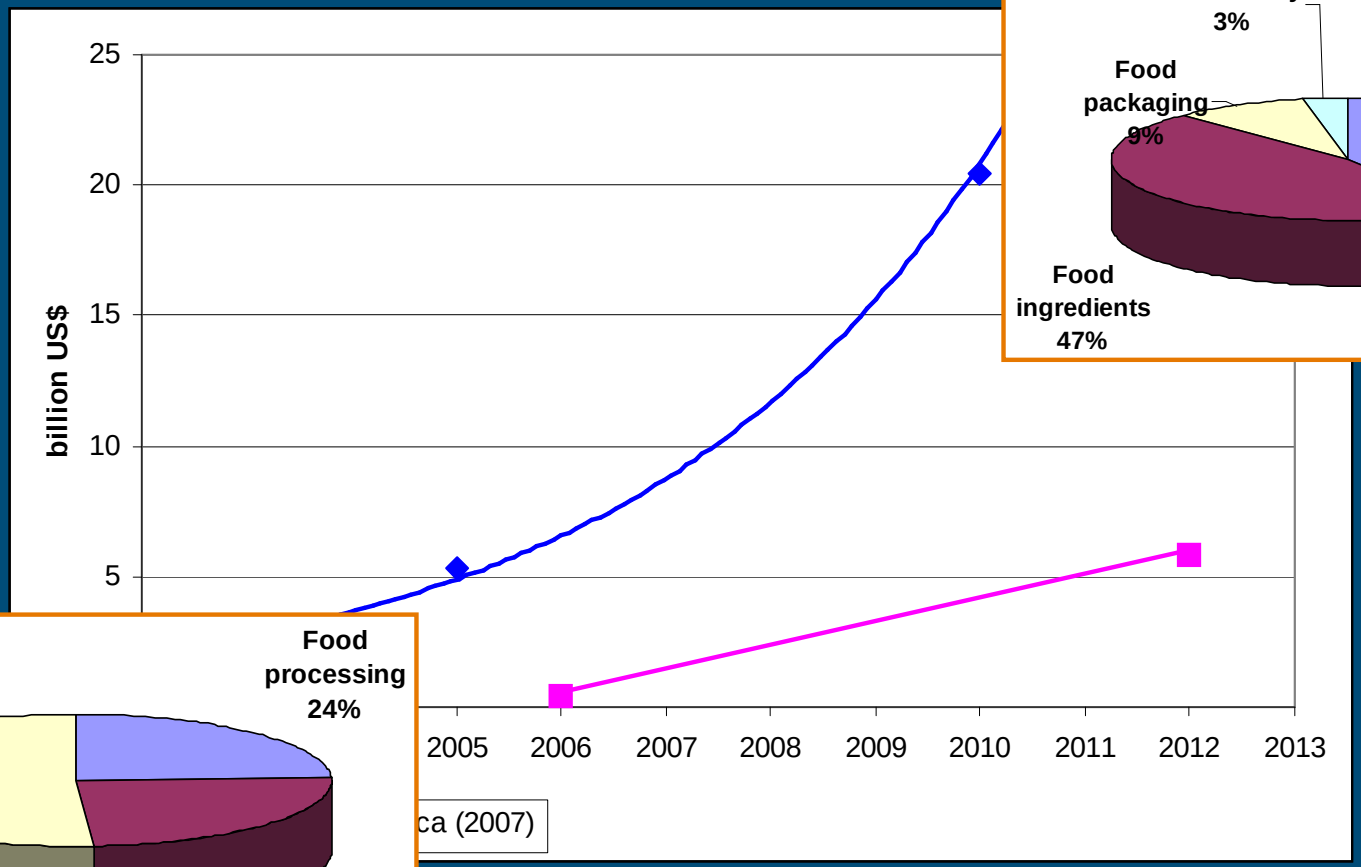


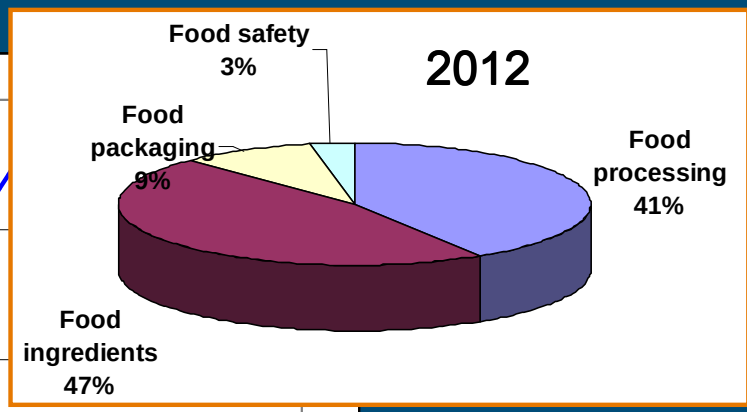
HKC: Helmut Kaiser Consultancy, Nano Food 2040 (2007)

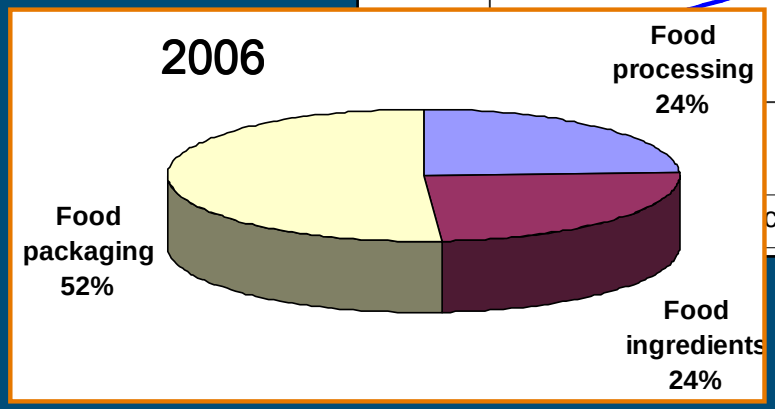
Cientifica: Cientifica Ltd., Half way to the trillion dollar market (2007)

Nanotechnology in food: Facts

- Growing market







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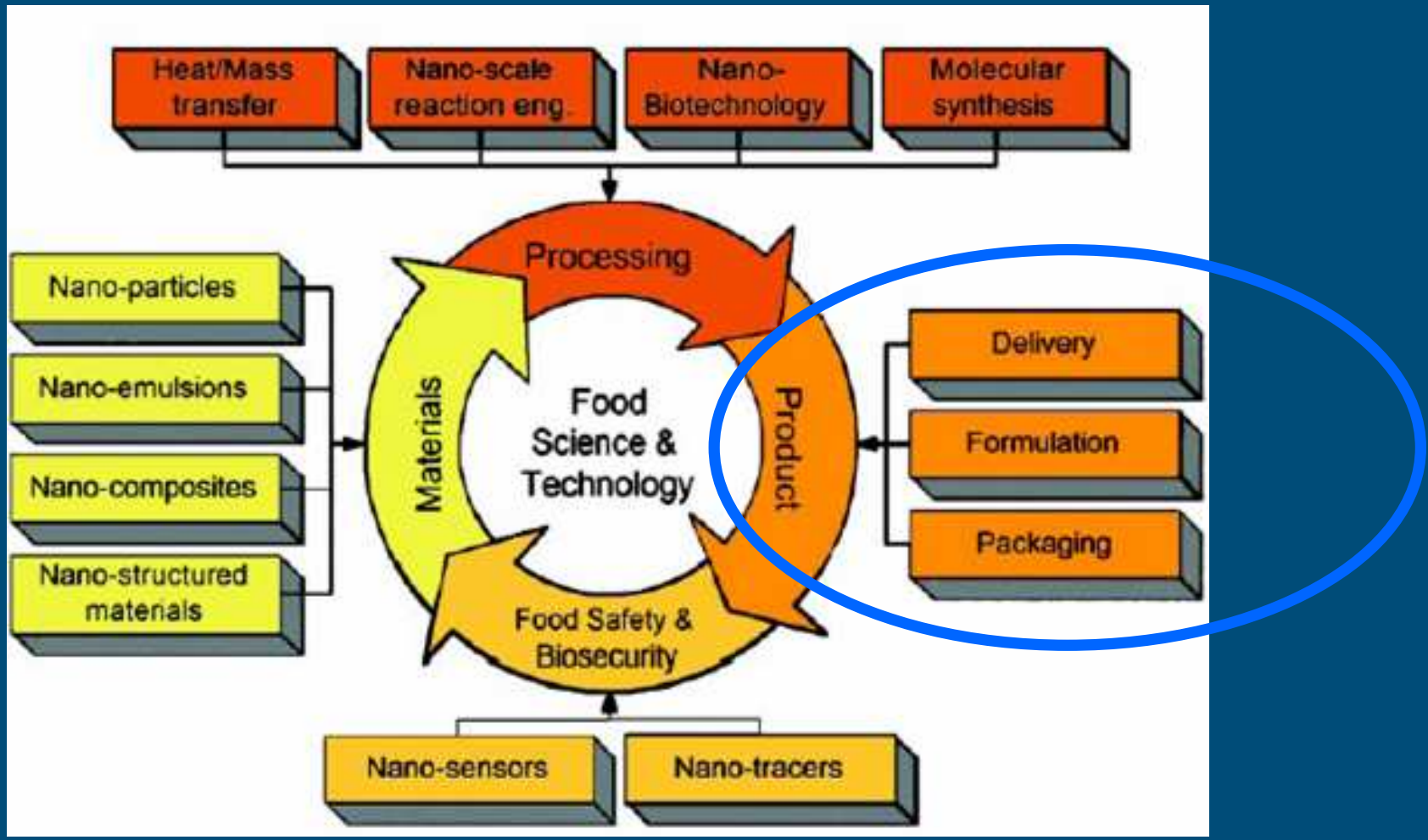
Nanotechnology in food: Facts

- Applications areas in the food chain



Carmen I. Moraru et al, FoodTechnology, 2003

Main application areas

Food packaging

- Sales packaging
  - nano-particles incorporated in polymer matrix: clay, TiN, nylon, TiO_2, ZnO, ...
  - improved mechanical and barrier properties, UV-protection
- Active packaging
  - nano-silver incorporated/coated: antimicrobial activity
  - absorbers, scavengers
- Preservation of quality, extension of shelf life

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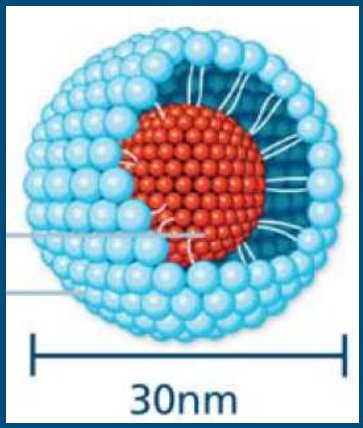
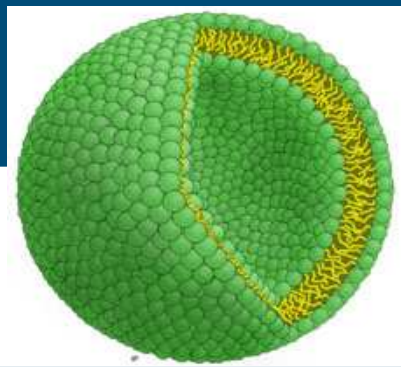
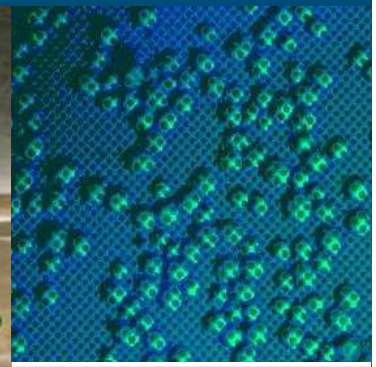
Main application areas

Food ingredients/supplements/auxiliaries

- Nano-SiO_2 as anti-caking agent
- Nano-encapsulates
  - preservatives, vitamins, lycopene, ...
  - increased solubility, oxidation protection
- Nano-formulated ingredients
  - e.g. protein micelles
  - improved texture, stabilty of emulsions, ...







Nanotechnologies in food: Safe to eat?

- Hazards arising from the application of nano-technologies in food not yet well understood
- Many assumptions, little facts
- More information needed!

Nano-Food: Risk assessment

The European Food Safety Authority (EFSA):

- Specific uncertainties apply to the **difficulty to characterize, detect and measure ENMs in food/feed** and biological matrices
- Limited information available on **toxicokinetics and toxicology**.
- Limited knowledge of current **usage levels and exposure** from possible applications and products in the food and feed area.

(Scientific Opinion of the Scientific Committee on a request from the European Commission on the Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety. The EFSA Journal (2009) 958, 1-39)

Nano-Food: Societal aspects

- European Parliament calls for labelling

Home > International > European Parliament Urges the Labeling of Nanomaterials in Consumer Products

European Parliament Urges the Labeling of Nanomaterials in Consumer Products

Posted on April 24, 2009 by Lynn L. Bergeson

In an April 24, 2009, press release, the European Parliament (EP) calls for the provision of information to consumers on the use of nanomaterials in consumer products. According to the EP, all ingredients present in the form of nanomaterials in substances, mixtures, or articles should be clearly indicated in the product labeling. The press release also specifically calls for the European Commission (EC) to evaluate the need to review the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) concerning:

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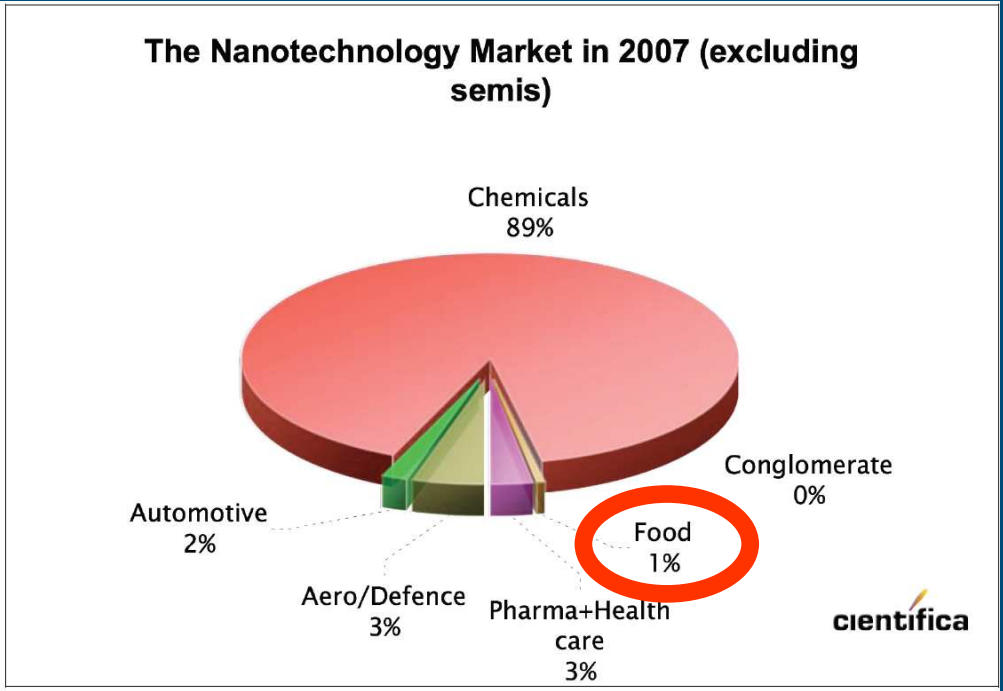
Nano-Food: Societal aspects

- Public opinion sensitive to manipulation of food (e.g. GMO, chemical contaminants)



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Nano-Food: Societal aspects

- Consideration of safety aspects is crucial for the acceptance of nanotechnologies in food!

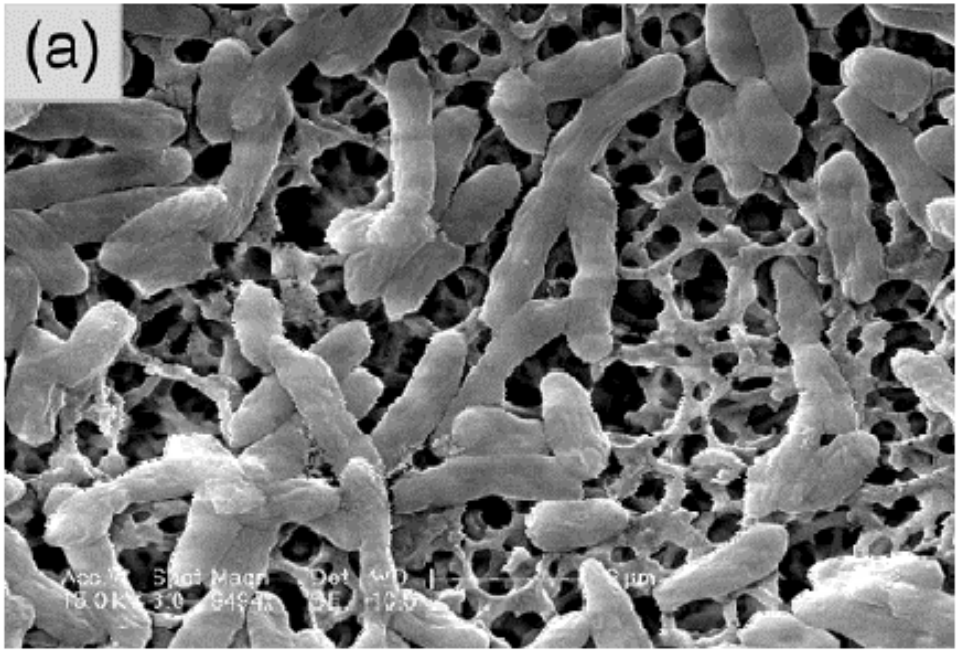
- Toxicological and toxicokinetic data is needed
- Analytical methods have to be developed for determination of ENP in food (and biological matrices)

Toxicology: Safety concerns

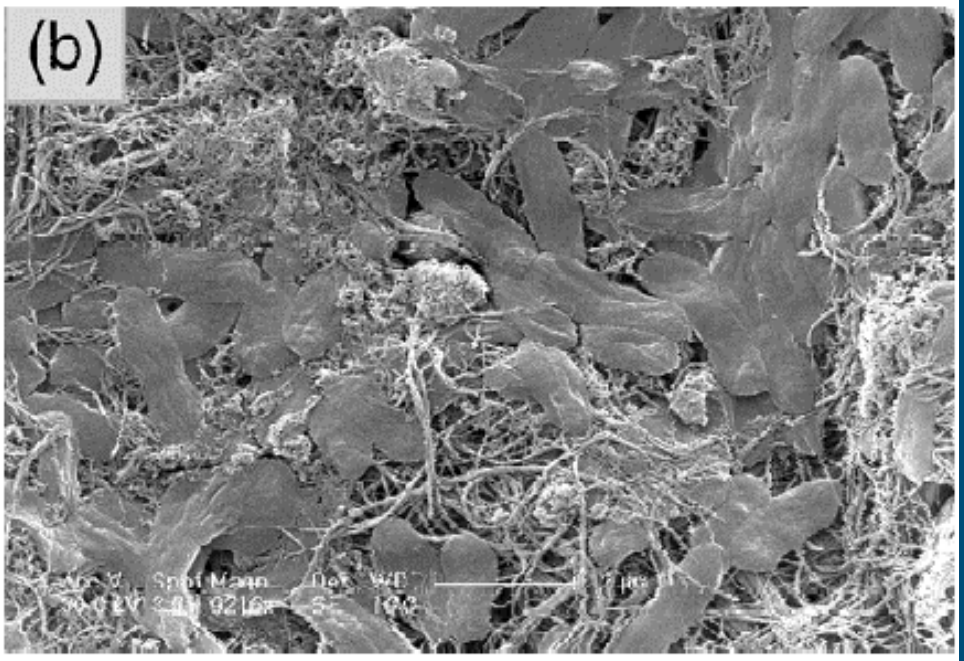
- **Specific toxicity** of NP as compared to their conventional analogues
- Due to size/surface properties NP may reach targets which are not accessible to conventional analogues (**Trojan horse**), e.g. passing membranes or the blood-brain barrier
- But: effects and kinetics very much dependent on type of particle, size, surface area, agglomeration, surface modification, etc. ...

Toxicology: Potential effects

- Pristine carbon nanotubes kill *Escherichia coli*



Cells incubated without SWNTs for 60 min. Cells were filtered and observed via SEM on the filter



Cells incubated with SWNTs for 60 min: 90% of the population killed, probably due to cell membrane damage

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Kang et al., *Langmuir* 23, 8670-8673 (2007)

Toxicology: Potential effects

Experimental NM effects	Possible pathophysiological outcomes
ROS generation*	Protein, DNA and membrane injury,* oxidative stress†
Oxidative stress*	Phase II enzyme induction, inflammation,† mitochondrial perturbation*
Mitochondrial perturbation*	Inner membrane damage,* permeability transition (PT) pore opening,* energy failure,* apoptosis,* apo-necrosis, cytotoxicity
Inflammation*	Tissue infiltration with inflammatory cells,† fibrosis,† granulomas,† atherogenesis,† acute phase protein expression (e.g., C-reactive protein)
Uptake by reticulo-endothelial system*	Asymptomatic sequestration and storage in liver,* spleen, lymph nodes,† possible organ enlargement and dysfunction
Protein denaturation, degradation*	Loss of enzyme activity,* auto-antigenicity
Nuclear uptake*	DNA damage, nucleoprotein clumping,* autoantigens
Uptake in neuronal tissue*	Brain and peripheral nervous system injury
Perturbation of phagocytic function,* "particle overload," mediator release*	Chronic inflammation,† fibrosis,† granulomas,† interference in clearance of infectious agents†
Endothelial dysfunction, effects on blood clotting*	Atherogenesis,* thrombosis,* stroke, myocardial infarction
Generation of neoantigens, breakdown in immune tolerance	Autoimmunity, adjuvant effects
Altered cell cycle regulation	Proliferation, cell cycle arrest, senescence
DNA damage	Mutagenesis, metaplasia, carcinogenesis

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Nel et al. *Science* 311, 622 (2006)

NP oral exposure: Acute toxicity

- Oral exposure studies in rodents for several inorganic NP
- Acute toxicity observed for some NP at high doses

NP oral exposure: Long term toxicity

- No information on toxicity after chronic or acute low dose oral exposure available
- Chronic exposure via other routes indicated effects on:
  - immune system
  - inflammatory system
  - cardiovascular system

NP oral exposure: Toxicokinetics

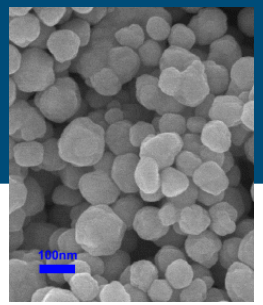
- Gastrointestinal absorption
  - dependent on particle size, surface charge/chemistry
- Distribution
  - widespread distribution has been shown in animals, e.g. to brain, bone marrow, spleen, liver
  - membrane translocation
- Further data on absorption, distribution, meta-bolisation, excretion after oral uptake is needed

Toxicology: perspectives, challenges

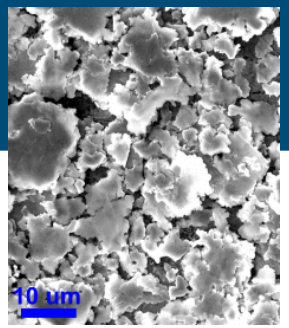
- Are current test guidelines (OECD) adequate for nanomaterials?
- Analytical methods for determination/charaterisa-tion of NP in food matrix and biological matrices
- Characterised, standardised NP for comparison of data
- Development of short term in-vitro tests

Analytical methods: Challenges

- Methods available for pure NP, only few for complex matrices
- Availability of standard materials
- Interaction of ENP with matrix, behaviour largely unknown
- Agglomeration, affinity for surfaces
- Detection levels: ppm to ppb levels
- Interference of matrix with detection methods
- Natural NP present in food
- Diversity of ENP



Ag

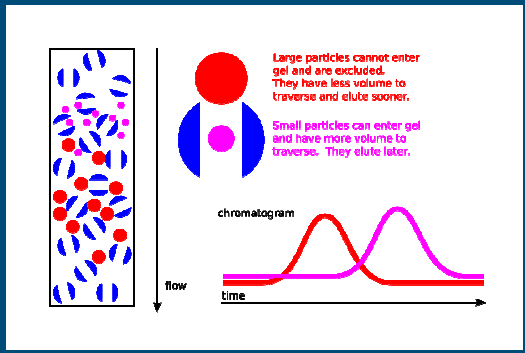


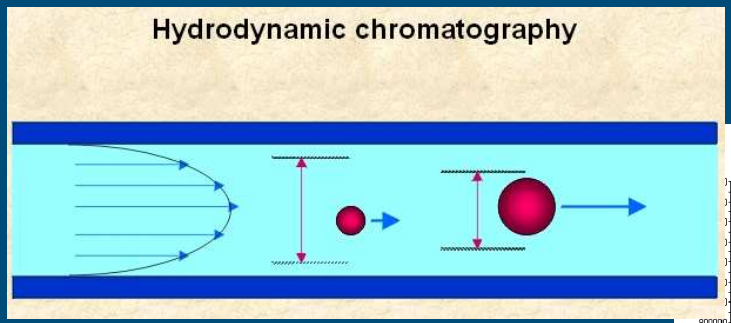
Analytical methods: Sample preparation

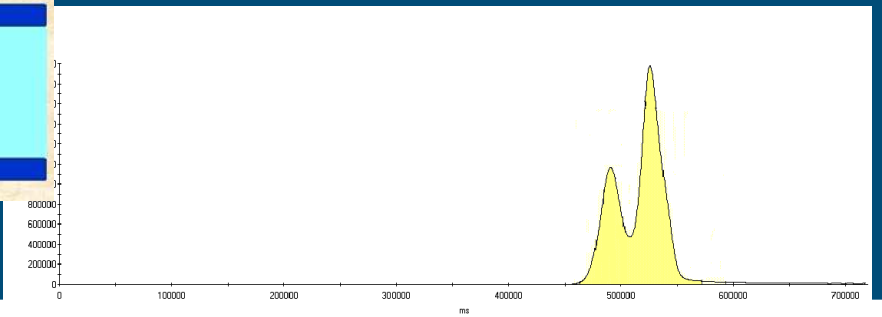
- No published methods
- Filtration, centrifugation
- Liquid/liquid extraction
- Digestion (chemical, thermal, enzymatic)
- But: how will sample treatment affect the particles?

Analytical methods: Separation

- Flow field fractionation
- Size-exclusion chromatography
- Hydrodymamic chromatography





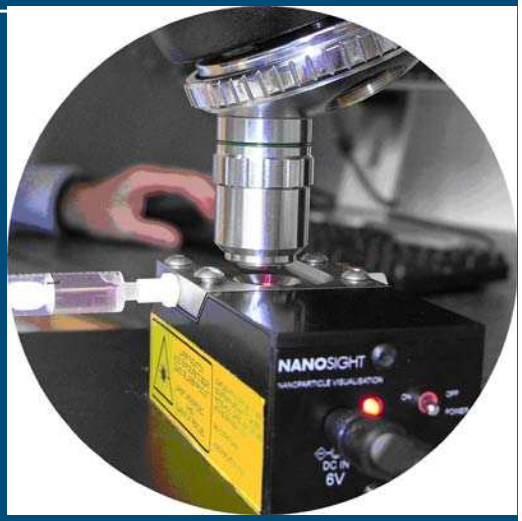


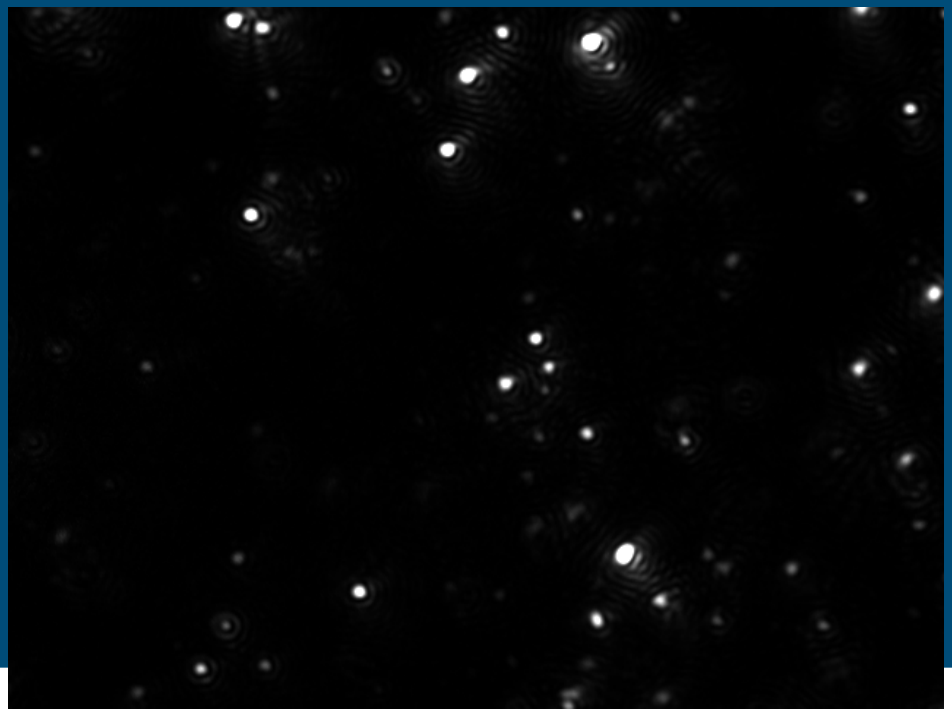
Analytical methods: Detection

- ICP-MS: inorganic NP
  - covers multiple elements: Ag, Au, Ti, Zn, Si, ...
- Sensor technologies: established for air monitoring (CPC), not applicable for food
- Imaging techniques
  - electron microscopy (SEM, TEM)

Analytical methods: Detection

- Light scattering
  - SLS, DLS, MALS
  - particle size, size distribution





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source: R. Peters, RIKILT

Analytical methods: perspectives

- Standard and reference materials needed, well characterised and stable
- Knowledge on behaviour of NP in food
- Sample preparation
- Coupled separation and detection methods for determination of size and (chemical) identity
- Automated screening methods

Conclusions

- Nano-food safe? Decision case by case, answers needed for consumer acceptance
- Toxicological assessment of NP in food has just started
- Development of analytical methods for NP in food crucial for risk assessment,
  adressed by new FP7 project: NanoLyse
  (under negotiation)

Thanks for your attention

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