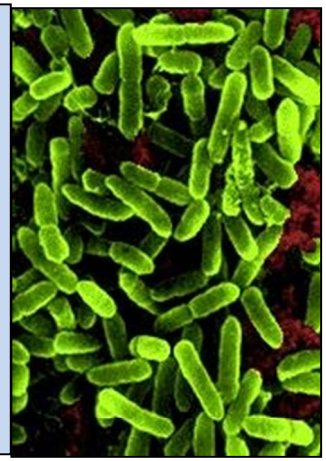
Applications of Nanotechnology to Improve Food and Food Supplies



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NanoUnion Worshop

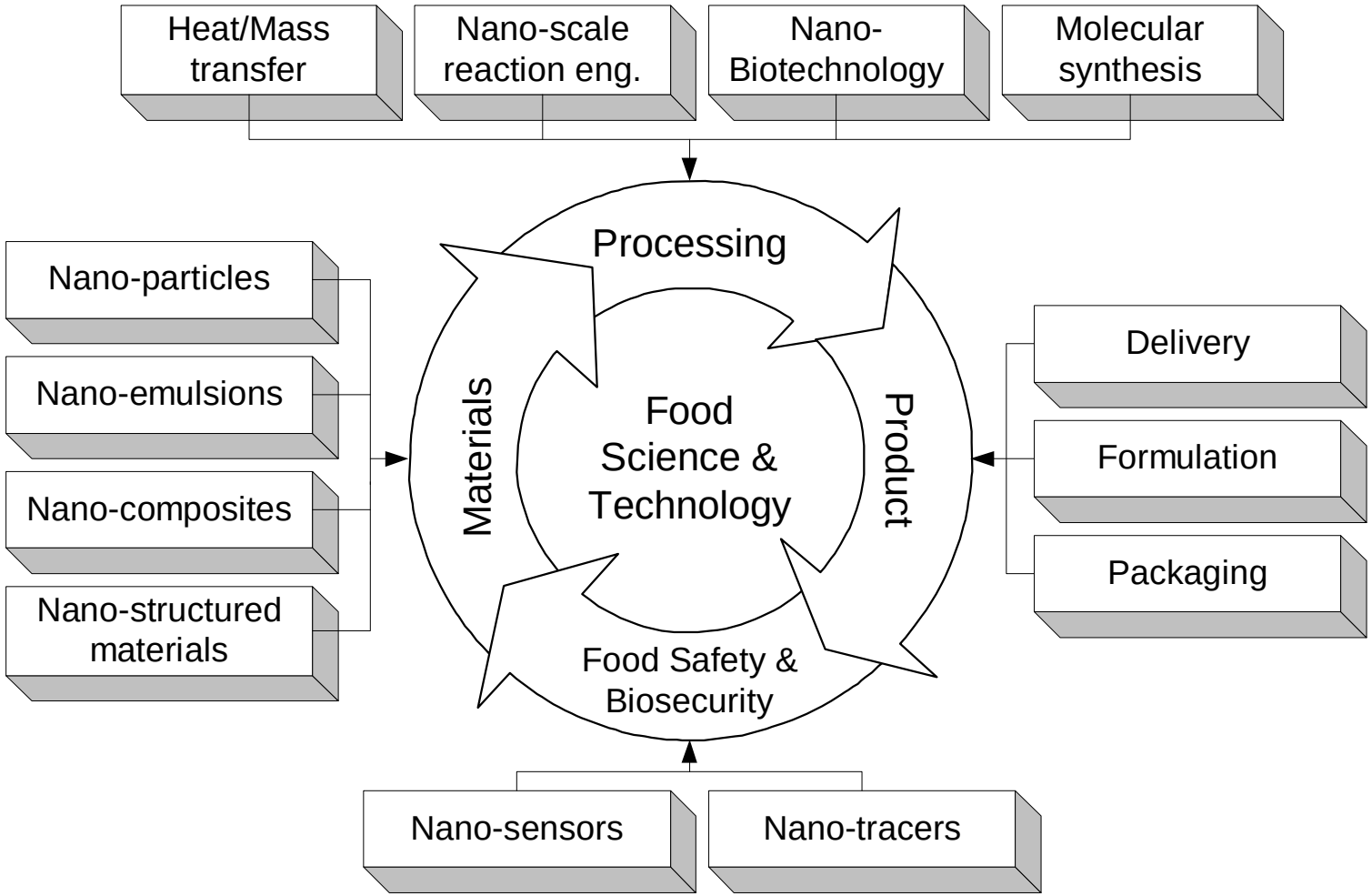
23rd-24th February 2012, Paris, France

Motivators for Use of Nanosciences in Food Applications

- **Diminishing Resources**:
  - **Energy Savings:** Nanofabrication processes may require less energy consumption than traditional processes → realize energy savings
  - **Waste Creation & Sustainability:** Raw materials may be more effectively used and previously not utilized materials (due to performance issues) may be functionalized to be of use (e.g. wider use of cellulose based renewable materials).
- **Consumer Demand:**
  - **Healthier Foods:** Nanoencapsulation will be a key tool to include bioactive ingredients in foods, new structures may also allow elimination of ñless healthyò ingredients (e.g. fat reduction, replacement)
  - **Safer Foods:** Food safety may be enhanced through better detection methods (see later), improved packaging materials (PROBABLY THE KEY APPLICATION AREA)

Substantial interest in direct or indirect use of nanotechnologies, but considerable uncertainties (definition, regulations)

Applications of Nanotechnology In Food Science and Technology



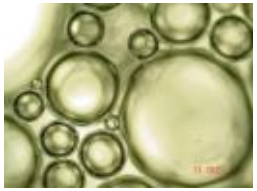
Fabrication Approaches to Nanoscalar Food Objects



Agricultural Raw Materials

Thermal Treatments
Shearing/Mixing
Homogenization
Extrusion

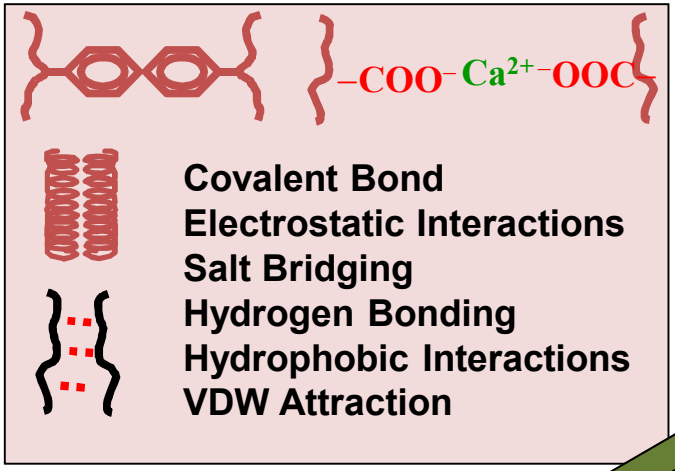
Bulk Processing



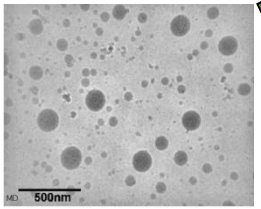
Microstructures

Nanostructures

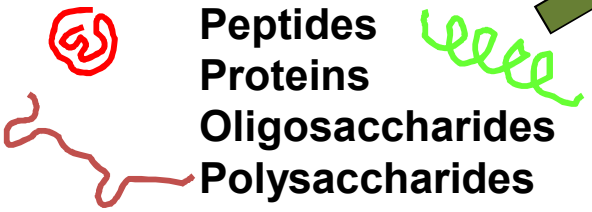
Food Product



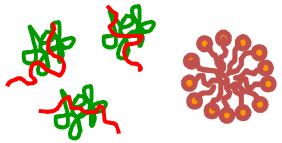
Covalent Bond
Electrostatic Interactions
Salt Bridging
Hydrogen Bonding
Hydrophobic Interactions
VDW Attraction

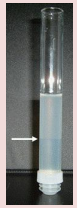


Self Assembly



Peptides
Proteins
Oligosaccharides
Polysaccharides

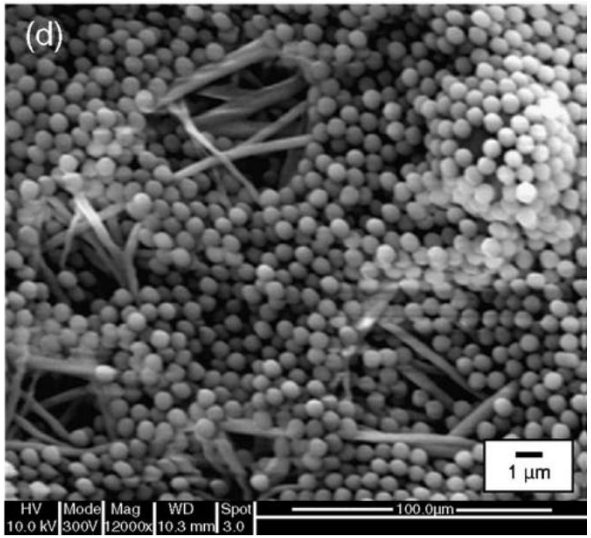


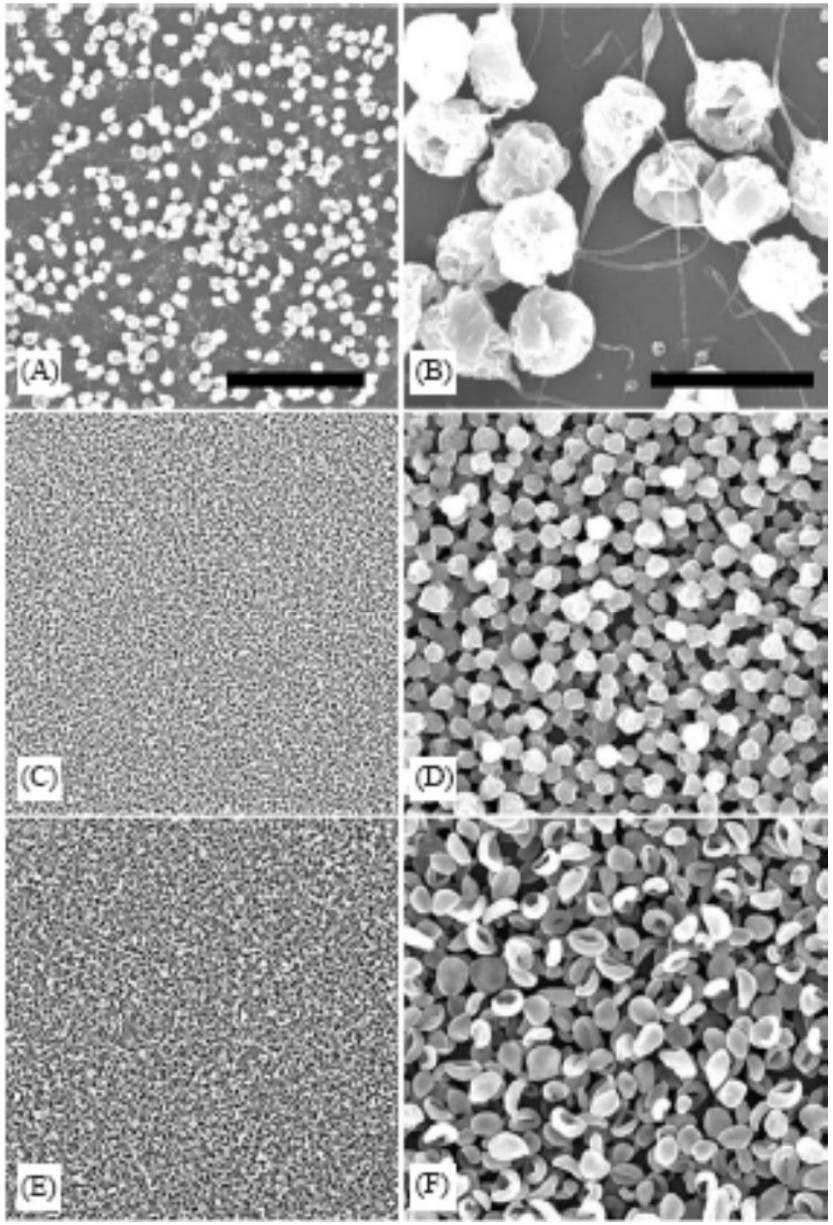
Phase Transitions
Network Formation
Phase Separation

I. Use of Nanotechnology in Processing: Filtration & Catalysis

- New separation techniques
  - E.g. removal of viruses and spores in food product (dairy products)
  - Separation of caseins leads to new generation of emulsifiers
- New catalysts:
  - Few chemical reactions in food science, but some , e.g. esterification, hydration of fats, Maillard reactions (aging and polymerization)



Nanoparticle Filtration

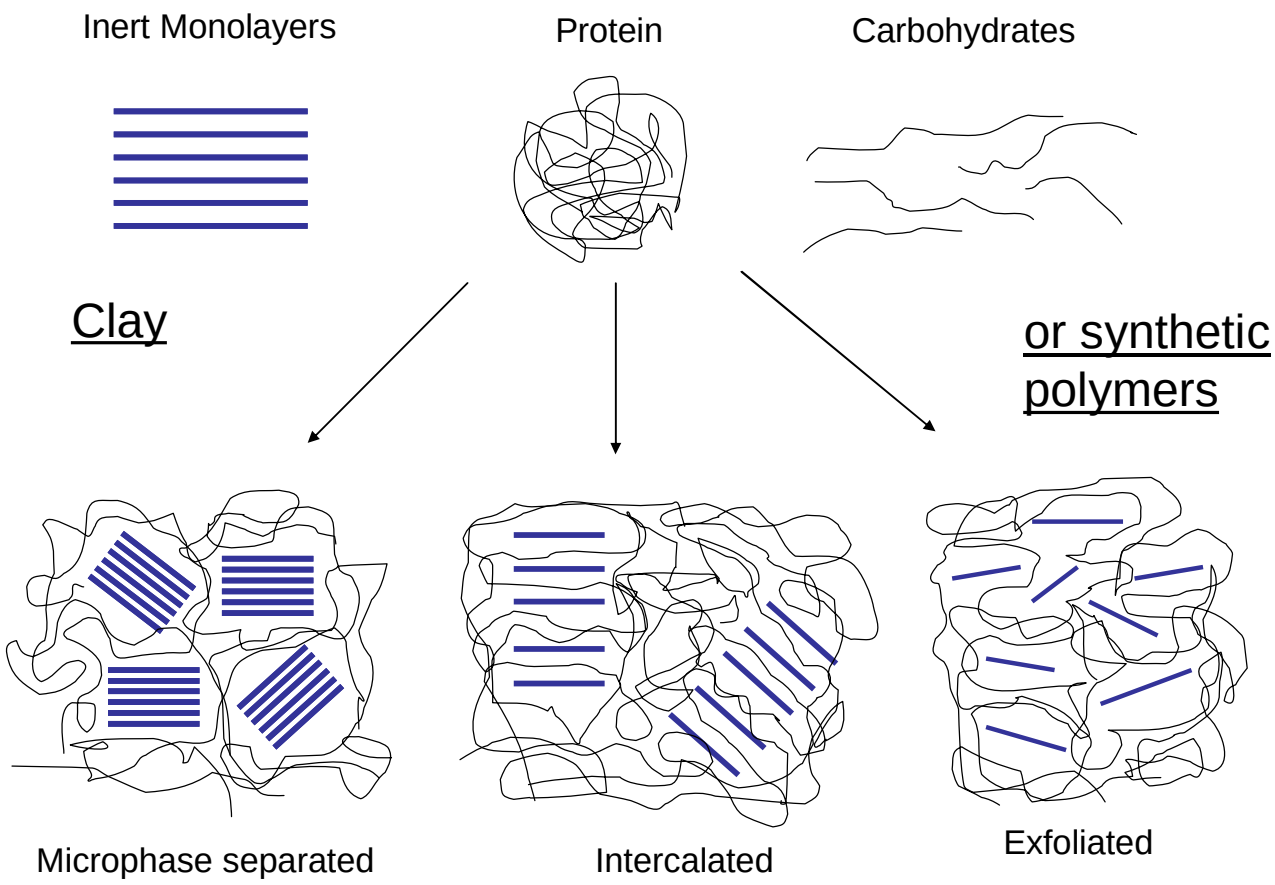


Electrohydrodynamically Sprayed Nanoparticles

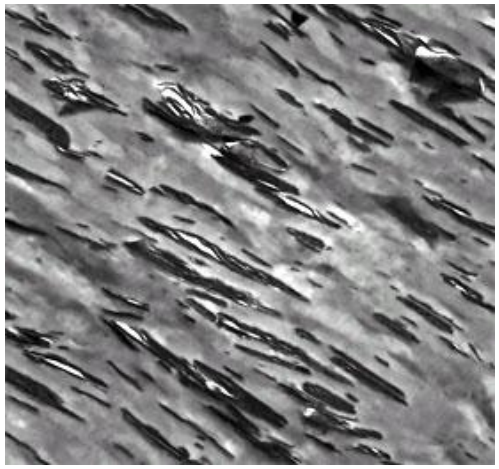
- Uniform particles produced under various conditions
- A & B: Uniform particles ~2.5 um by spraying 5 wt% PLG in acetone (8 kV)
- C & D, PLG in methylene chloride, 15kV
- E & F, PLG in acetonitrile, 10 kV,
- C,D,E,G approx. 80 ï 200 nm in size

Berkland et al, 2004

II. Use of Nanostructures in Packaging: Nanoclay Composites



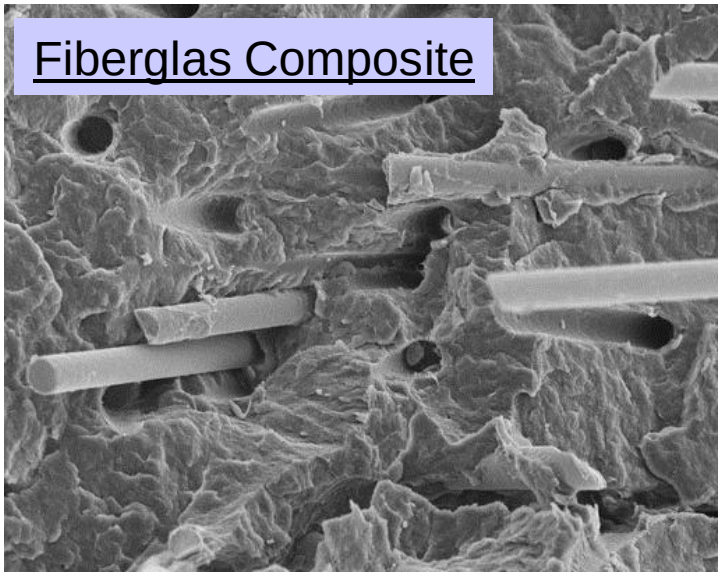
- Torturous Path
- Reduced O_2 and H_2O transmission
- Microwavable
- Increased mechanical strength



Use in Packaging Materials

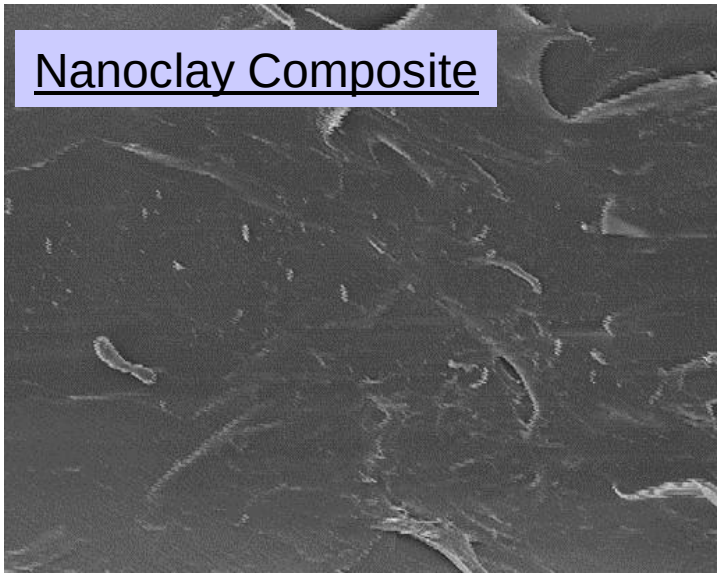
- About 50% of ALL packaging material is food packaging material
- Increased mechanical performance ï thinner packaging materials
- Decreased transmission of gases and water →increased shelf life of products
- Functionalization: e.g. antimicrobial, antioxidant
- Nanopaints, Labels, Indicators

Fiberglas Composite



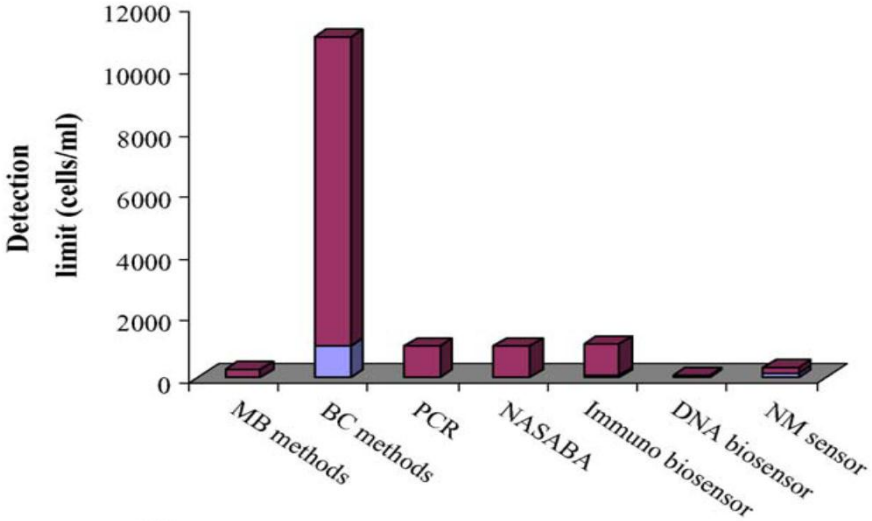
Surface after extensive stress testing

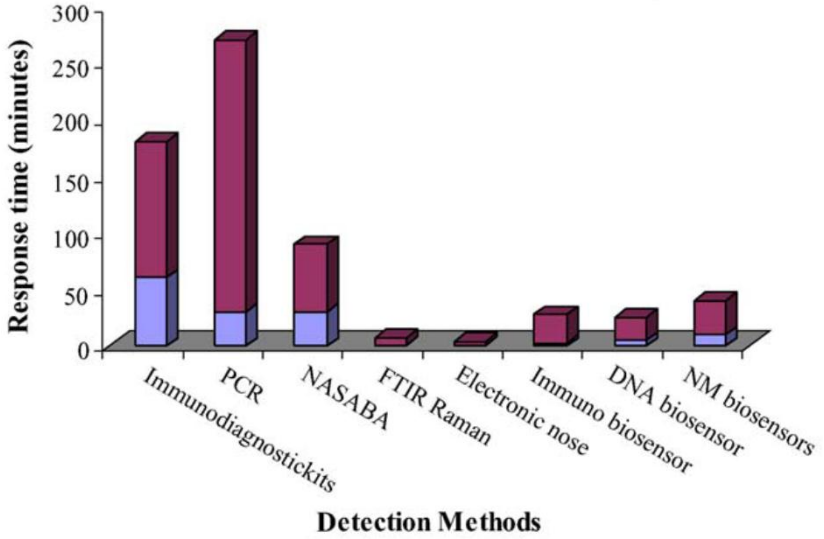
Nanoclay Composite



III. Use of Nanotech in Food Safety: Biomolecular Sensors for Food Pathogens

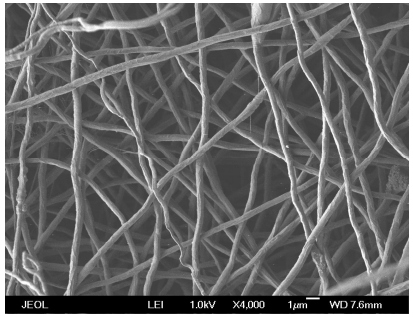
- Application of new materials:
  - Carbon, Au, Zn
  - Quantum Dots
  - Nanocomposites
  - Condcting polymers
  - Langmuir-Blodget films
  - Self-assembled monolayers
  - Microfluidics
  - Molecular switches and gates
- Advantages:
  - Smaller size
  - Quicker response time (seconds to minutes)
  - Reusability
  - Portability
  - Multi-analyte detection
  - High sensitivity → 10 cells/0.1ml, 10^{-2} cfu/ml, 10^{-14}M oligos

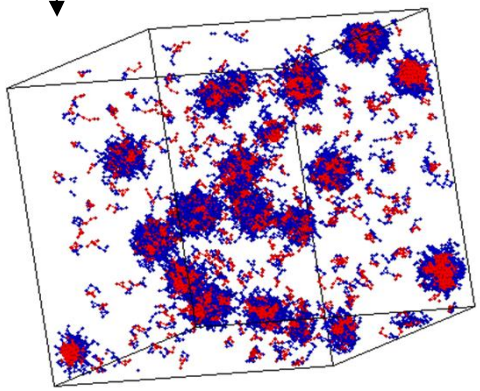


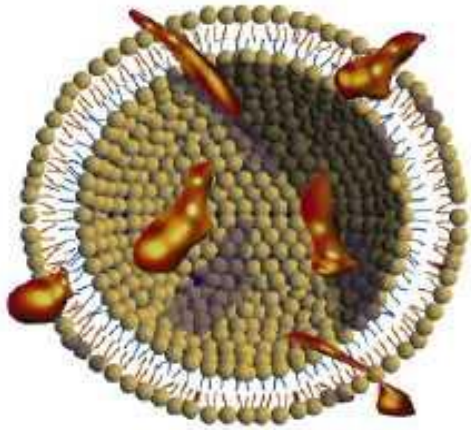


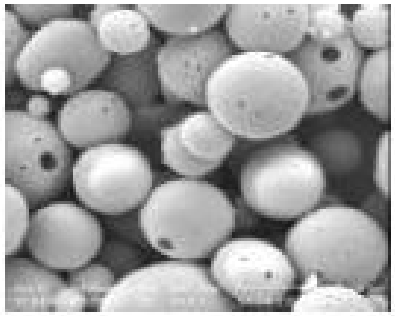
IV. Functional Ingredients From Nanostructures

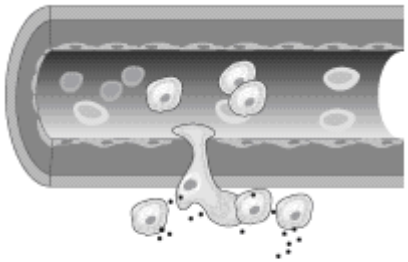
- Microemulsions
- Liposomes
- Nanoemulsions
- Particles
- Fibers



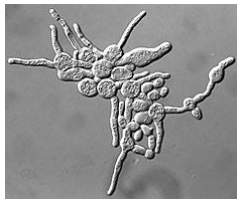


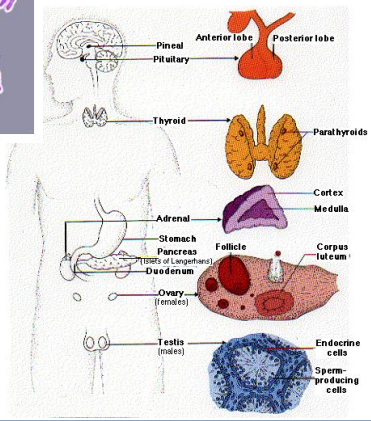






migration of white blood cells out of blood vessel and release of white blood cell chemicals





Inflammation

Cell Division And Growth

Apoptosis

DNA Repair

Hormon-Regulation

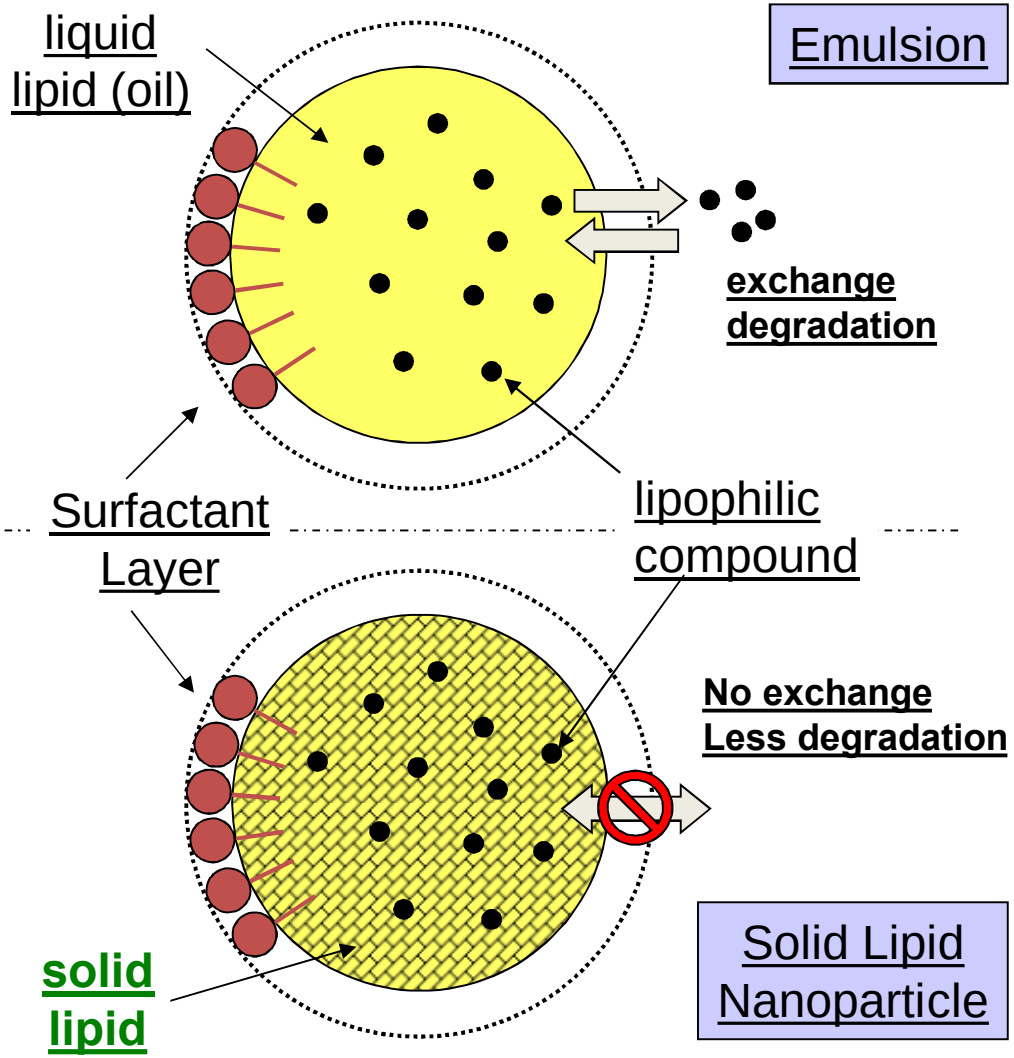
Cancer Metabolism

Energy Balances

Bioactive Food Components

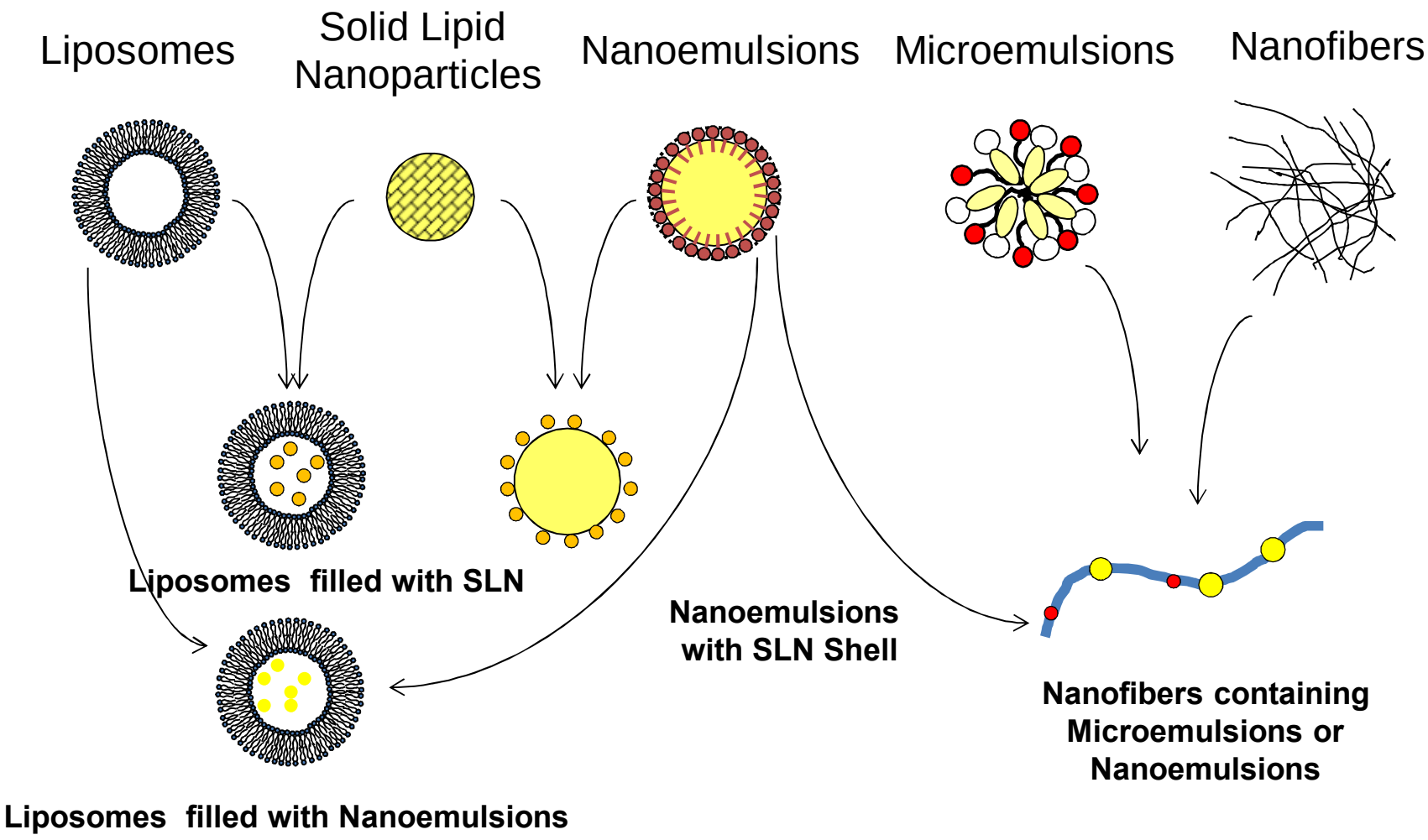
- Isoprenoides
  - Carotenoides, Saponines, Tocotrienoles, Tocopheroles
- Fatty Acids
  - MUFA, PUFA, ω-3, CLA
- Phenolic Compounds
  - Flavonoles, Flavonones, Anthrocyanines, Lignins, Tannins
- Proteines / Amino Acids
  - Isothiocynate, Allyl-S Components, Capsaicinoides
- Polysaccharides
  - Ascorbic Acid, Oligosaccharides
- Minerals
- .....

ñSolid Lipid Nanoparticlesò(SLN)



- Liquid lipid in emulsion is replaced by high melting point lipid
- Glycerides or waxes suitable
- Typical medium size ranges from 50 - 1000 nm
- At small sizes, crystal structures become dependent on surfactant and size
- Crystal structure can be ñdialedòin

Currently Under Investigation: Composite Nanostructures



Conclusions

- Large number of potential applications
- Developing regulations currently the largest problem (at least in Europe)
- Currently attempt at definition of nanomaterials extremely problematic for the development of the technology
  - Example: ñnaturalò structures ï would encompass EVERY SINGLE FOOD!
- One should define what needs to be regulated not what needs not to be regulated
- There is ZERO evidence that nanostructures build from food components are not digested or are digested in a different way.