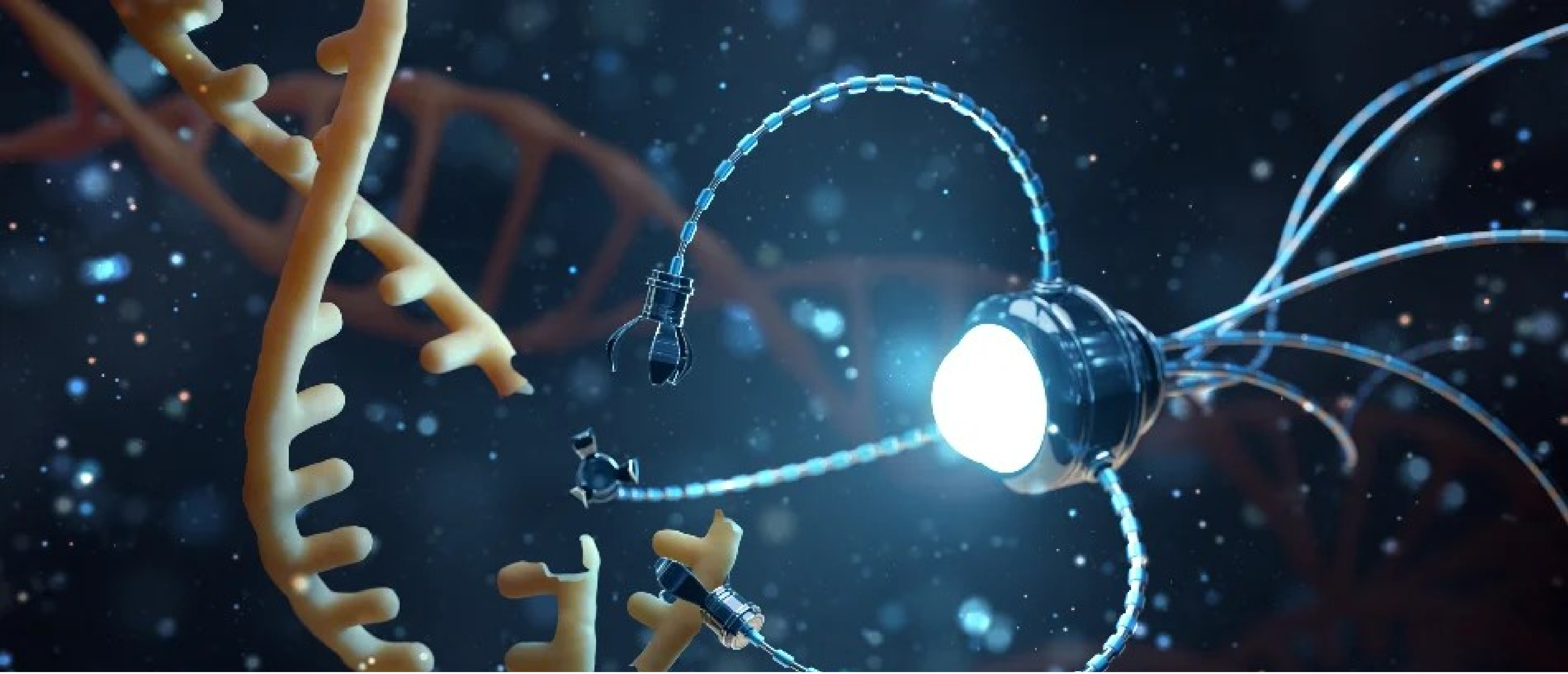


Nanomedicine and Enviromental nanotechnology

Nanotechnology

- Scale of 1-100 nm
- Application in nanomedicine,nanoelectronics...
- Toxicity and enviromental impact concerns
- nm:m = marble:earth

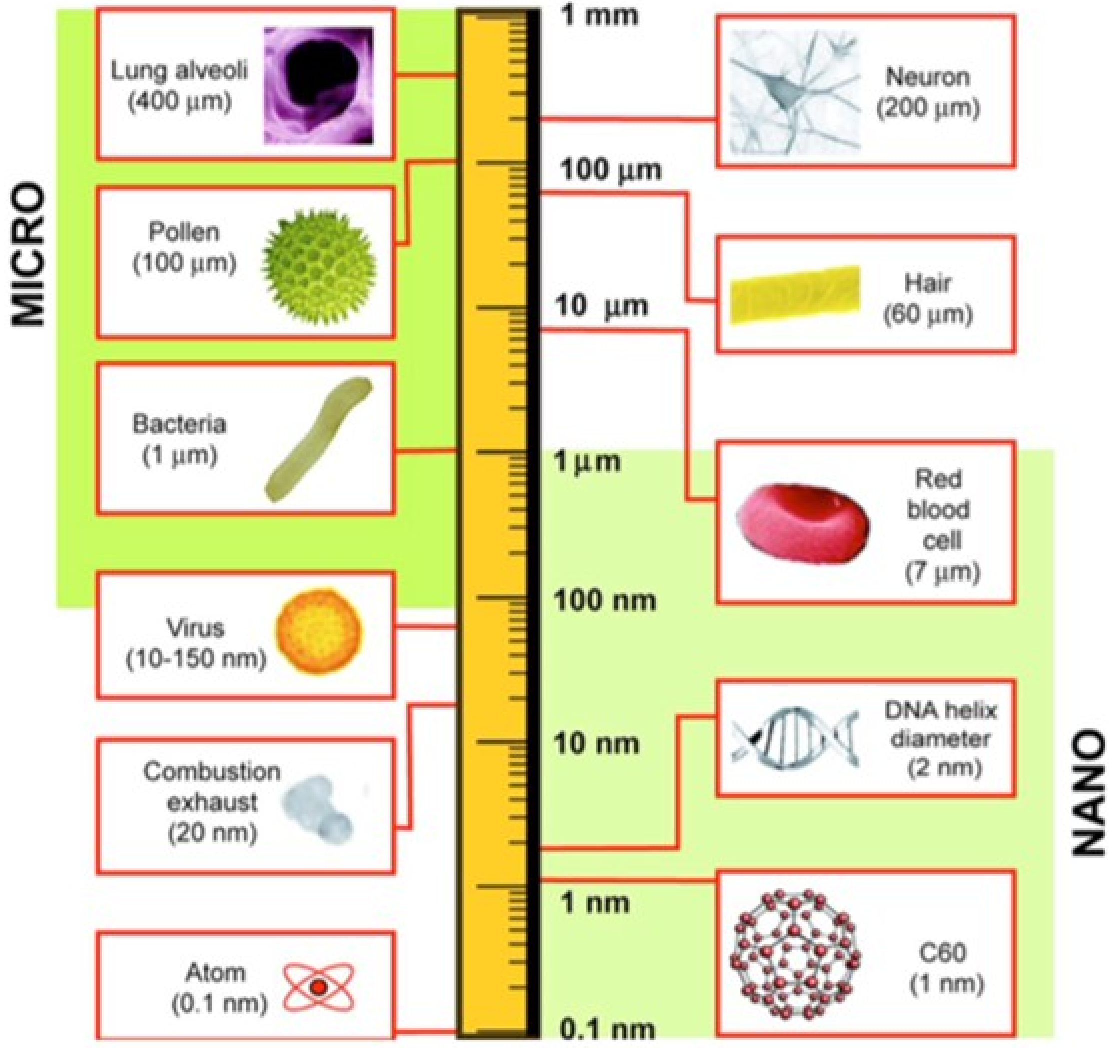


FIG. 2. Logarithmical length scale showing size of nanomaterials compared to biological components and definition of "nano" and "micro" sizes.

- Nanoparticles (NP) have a very large surface area [redacted] 1000 fold increase in reactivity
- Quantum effects [redacted] appearance of magnetic moments and changes in abilities related to electrical charge

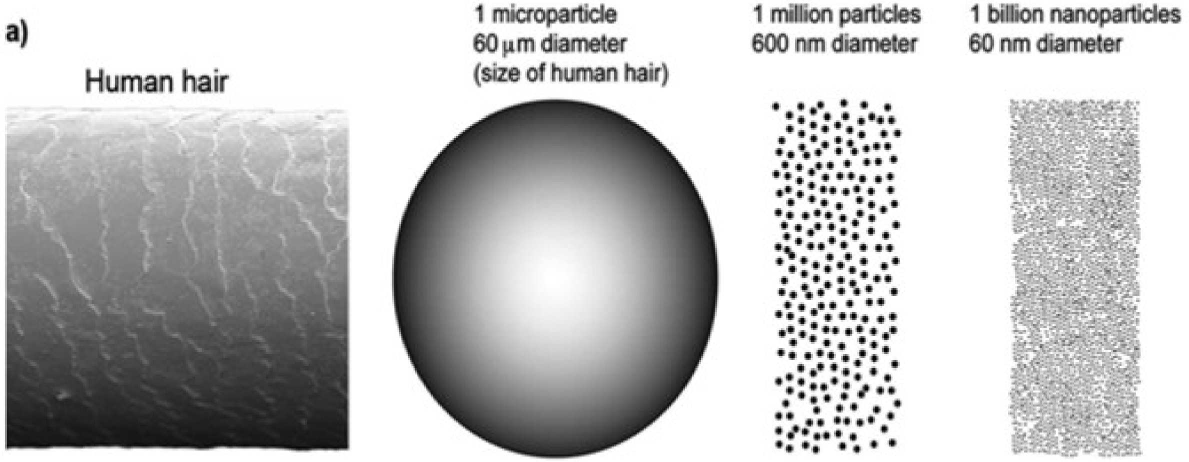
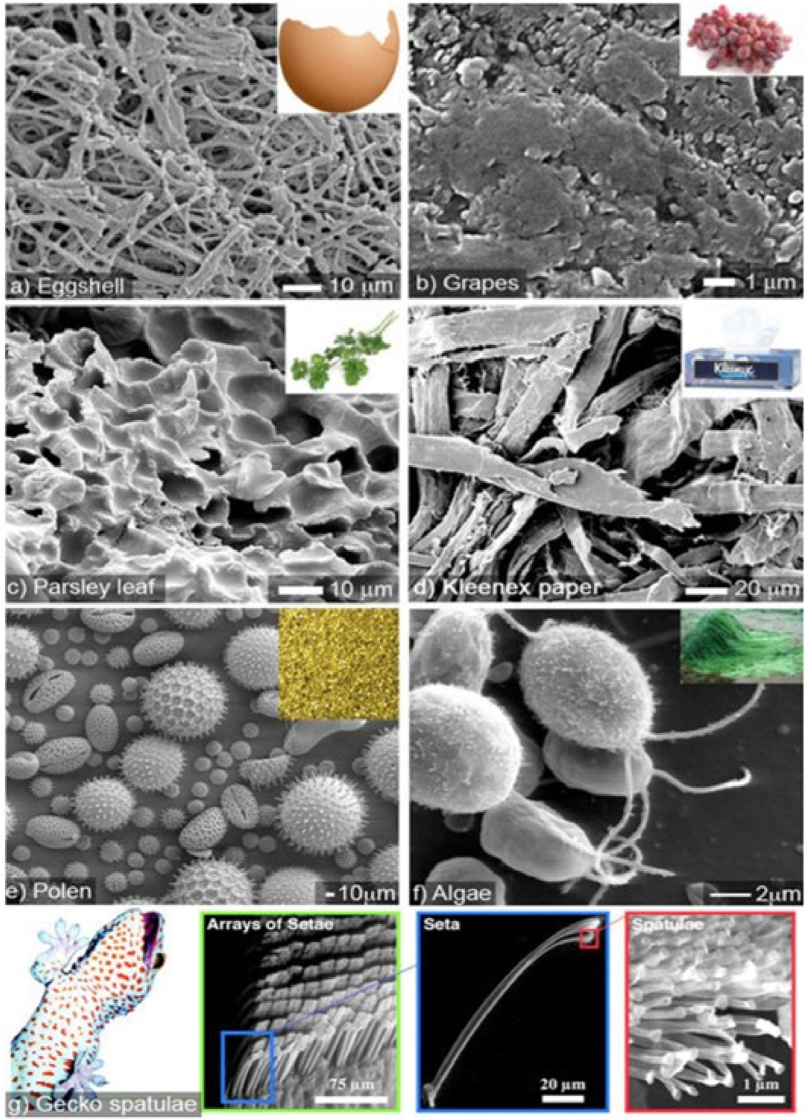


FIG. 3. (a) Schematics illustrating a microparticle of 60 μm diameter, about the size of a human hair—shown in the left at scale (courtesy Chelsea Elliott), and the number of nanoparticles with diameter of 600 and 60 nm having the same mass as one microparticle of 60 μm diameter.



Principles and properties of nanomedicine

- Application of nanotechnology for medical purposes = nanomedicine
- Nanodiagnosis, nanotherapy and regenerative medicine
- Perks of nanomedicine: Integration of effective but toxic molecules; maximizing efficacy and reducing dose/toxicity; controlled and site specific release of drugs
- Possibility to engineer nanomaterials to make them interact with specific biological targets

- A need for comprehensive knowledge about the patophysiological nature of diseases
- A need to better understand the interaction nanomaterial surface - biological enviroment

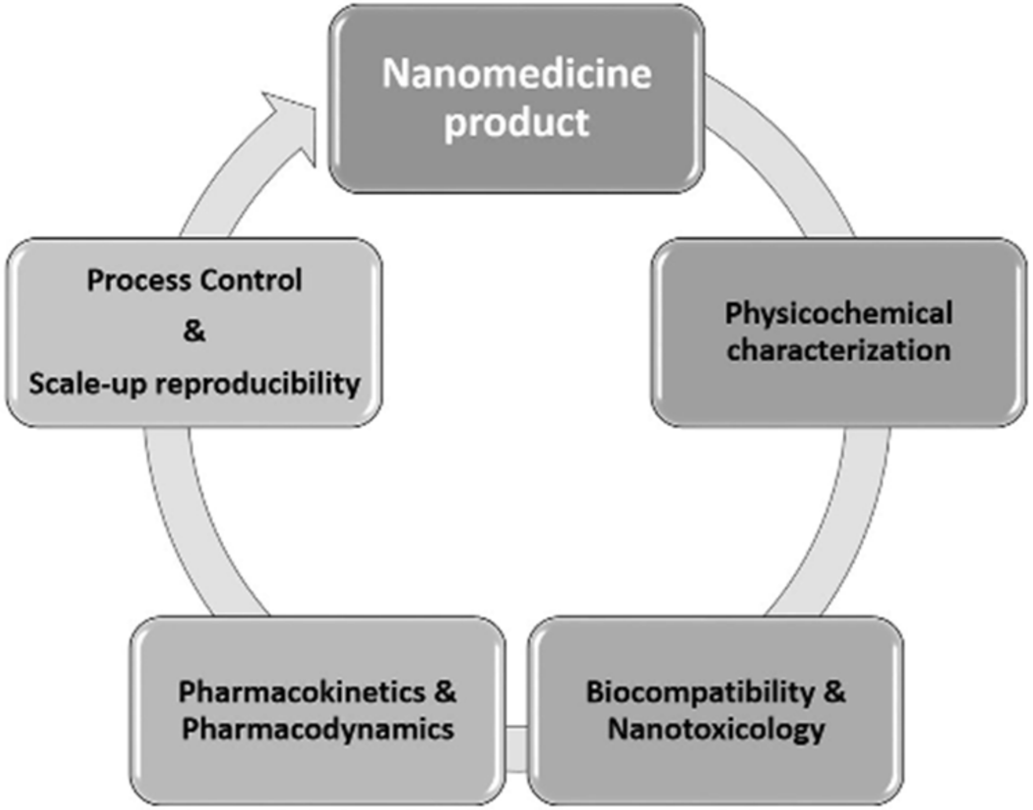


FIGURE 2 | Schematic representation of the several “barriers” found throughout the development of a nanomedicine product.

Scale-up and nanomedicine market

Nanomedicine class	Active substance/brand name	Pharmaceutical form	Therapeutic indications
Nanoparticles	*Nab-paclitaxel* Abraxane®	Powder for suspension for infusion	Breast neoplasms Carcinoma non-small-cell lung Pancreatic neoplasma
Liposomes	*Doxorubicin hydrochloride* Caelyx®	Concentrate for solution for infusion	Breast neoplasms Multiple myeloma Ovarian neoplasms Kaposi's sarcoma
Nanoemulsions	*Cyclosporine* Sandimmun Neoral®	Capsule, soft	Solid organ, bone marrow transplantation Endogenous uveitis Nephrotic syndrome Rheumatoid arthritis Psoriasis Atopic dermatitis
Nanocomplex	*Verteporfin* Visudyne®	Powder for solution for infusion	Degenerative myopia, age-related macular degeneration
Nanocrystals	*Paliperidone palmitate* Xeplion®	Prolonged release suspension for injection	Schizophrenia
Polymer-protein conjugates	*Perginterferon ahpha-2b* PegIntron®	Powder and solvent for solution for injection	Chronic hepatitis C

Toxicity of nanoparticles

- Toxic effects of nanomaterials are still examined
- Toxic effects will be specific to the type, size, shape and coating of NPs
- Big differences in toxicity
  - (↓spherical x ↑nanorods) (↑cationic x ↓anionic)
- Cytotoxicity vs. Cellular damage

Toxicity of nanoparticles

- Reactive oxygen species (ROS) generation
- Greater exposure leads to inflammation and cytotoxicity
- Some NPs may cause protein denaturation and DNA damage

Toxicity of nanoparticles

- Inhalation – possible circulatory acces
- Dermal exposure – immune system effects
- Ingestion – relatively safe?

Cancer nanomedicine: progress and opportunities

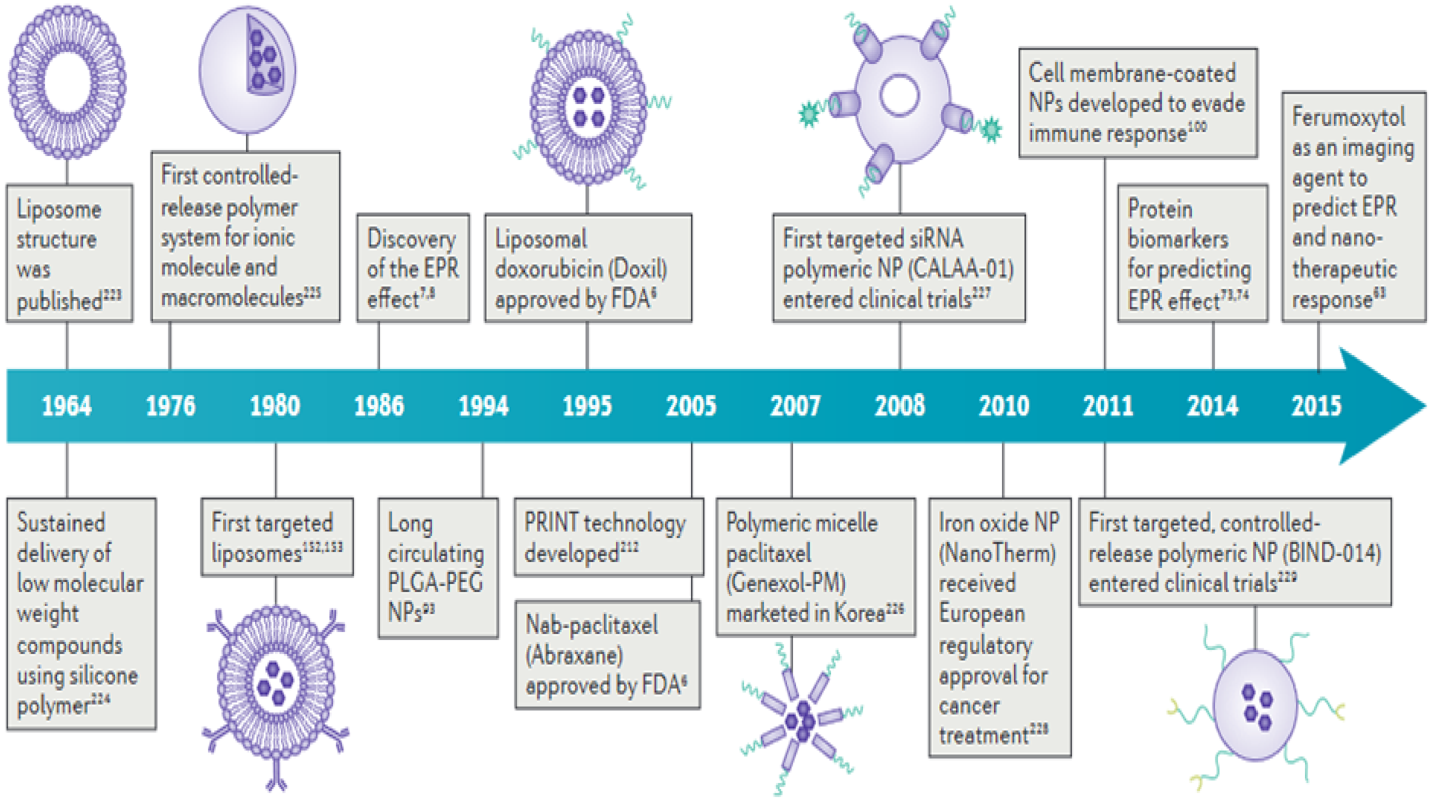


Figure 1 | **Historical timeline of major developments in the field of cancer nanomedicine.** EPR, enhanced permeability and retention; FDA, US Food and Drug Administration; nab, nanoparticle albumin-bound; NP, nanoparticle; PLGA-PEG, poly(D,L-lactic-co-glycolic acid)-*b*-poly(ethylene glycol); PRINT, particle replication in non-wetting template; siRNA, small interfering RNA.

- There is a growing interest in applying nanotechnology to cancer
- Most therapeutic NPs accumulate in the tumor throught the EPR effect
- NP properities (size, surface features, targeting ligands...) determine the therapeutic outcome
- NP behavior in humans is difficult to explore

Arsenal of nanomedicine platforms

- Potential of NPs to deliver various anticancer therapeutic agents- siRNA, DNA inhibitor oligonucleotides...
- Viral NPs- use of AAV, lentivirus, tobacco mosaic virus
- Inorganic NPs- nanodiamond and graphene
- Tolerogenic NPs carrying rapamycin didn´t induce the production of ADAs

Enhancing drug delivery to tumors

- NP-protein interaction **=>** formation of ´corona´
- Dysopsonin rich corona **=>** stealth effect
- Tumor penetration:
  higher affinity Abs < lower affinity Abs
- Cellular uptake improved with targeting ligands
- NP drug release: diffusion or intracellular trafficking pathway
- Neccessity to develop efficent NP platform for endosomal escape

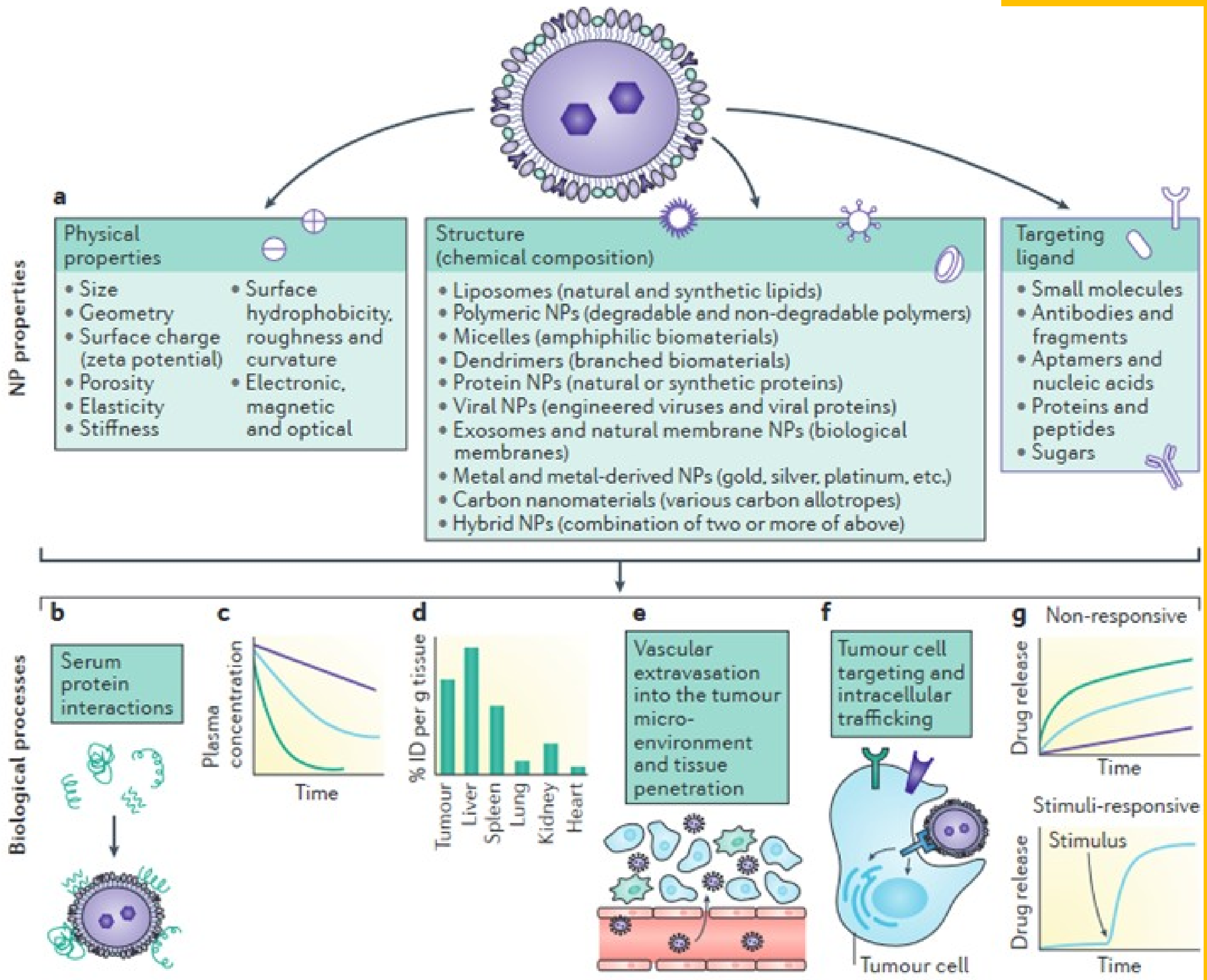
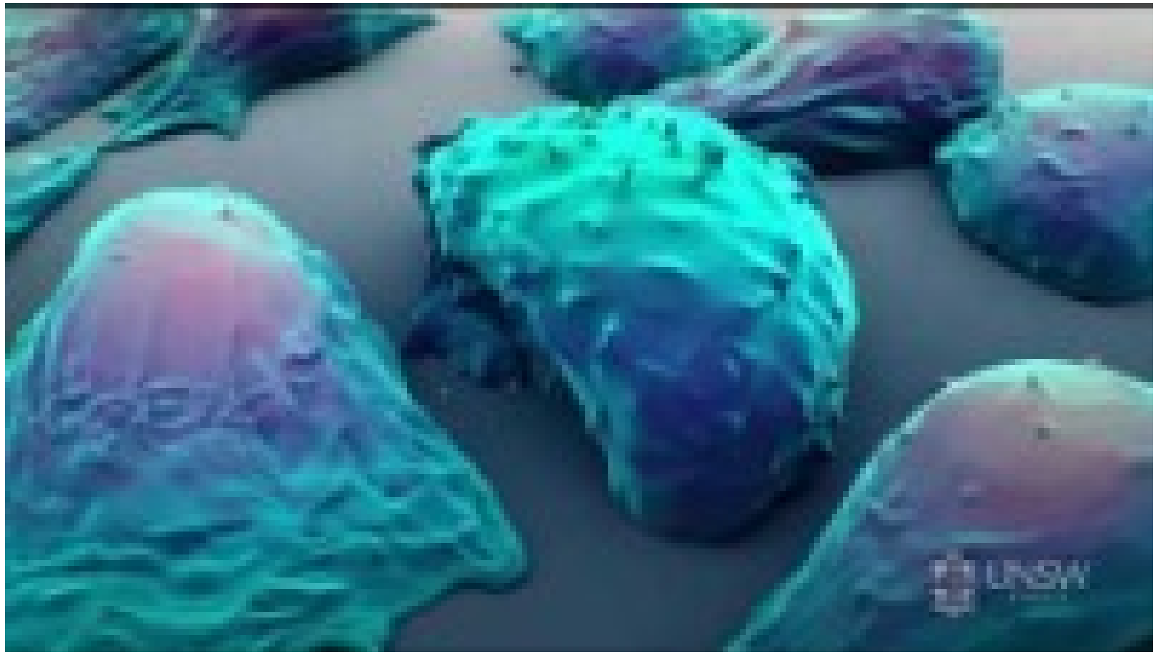


Figure 2 | **The impact of nanoparticle properties on systemic delivery to tumours.** Nanoparticles (NPs) can be made from different materials and have various physicochemical properties (for example, size, geometry, surface features, elasticity and stiffness, among others) and can be modified with a myriad of targeting ligands of different surface density (part **a**). NP properties affect the biological processes involved in the delivery to tumour tissues, including interactions with serum proteins (part **b**), blood circulation (part **c**), biodistribution (part **d**), extravasation to perivascular tumour microenvironment through the leaky tumour vessels and penetration within the tumour tissue (part **e**), and tumour cell targeting and intracellular trafficking (part **f**). NPs can also be designed to control the release profile of payloads (part **g**). ID, injected dose.

Nanobased drug delivery



Conclusion

Distinctive features of nanotechnology in oncological applications:

- Targeted drug delivery
- Enabling sustained or stimulus-triggered drug release
- Co-delivery of multiple drugs to improve efficacy and overcome drug resistance
- Facilitating delivery of drugs to intracellular sites of action
- Miniaturized medical devices for cancer diagnosis and drug screening

Environmental nanotechnology

Goals

- To reduce harm to environment
- To improve bioremediation
- Solutions to existing and future environmental problems
- To evaluate risks posed by the nanotechnology itself

Engineered types of nanoparticles

TiO_2

- Semiconducting, photocatalytic, energy converting properties
- Removal of organic pollutants from water
- Need for fixation
- Low recovery
- High operation cost

Engineered types of nanoparticles

Fe based NPs

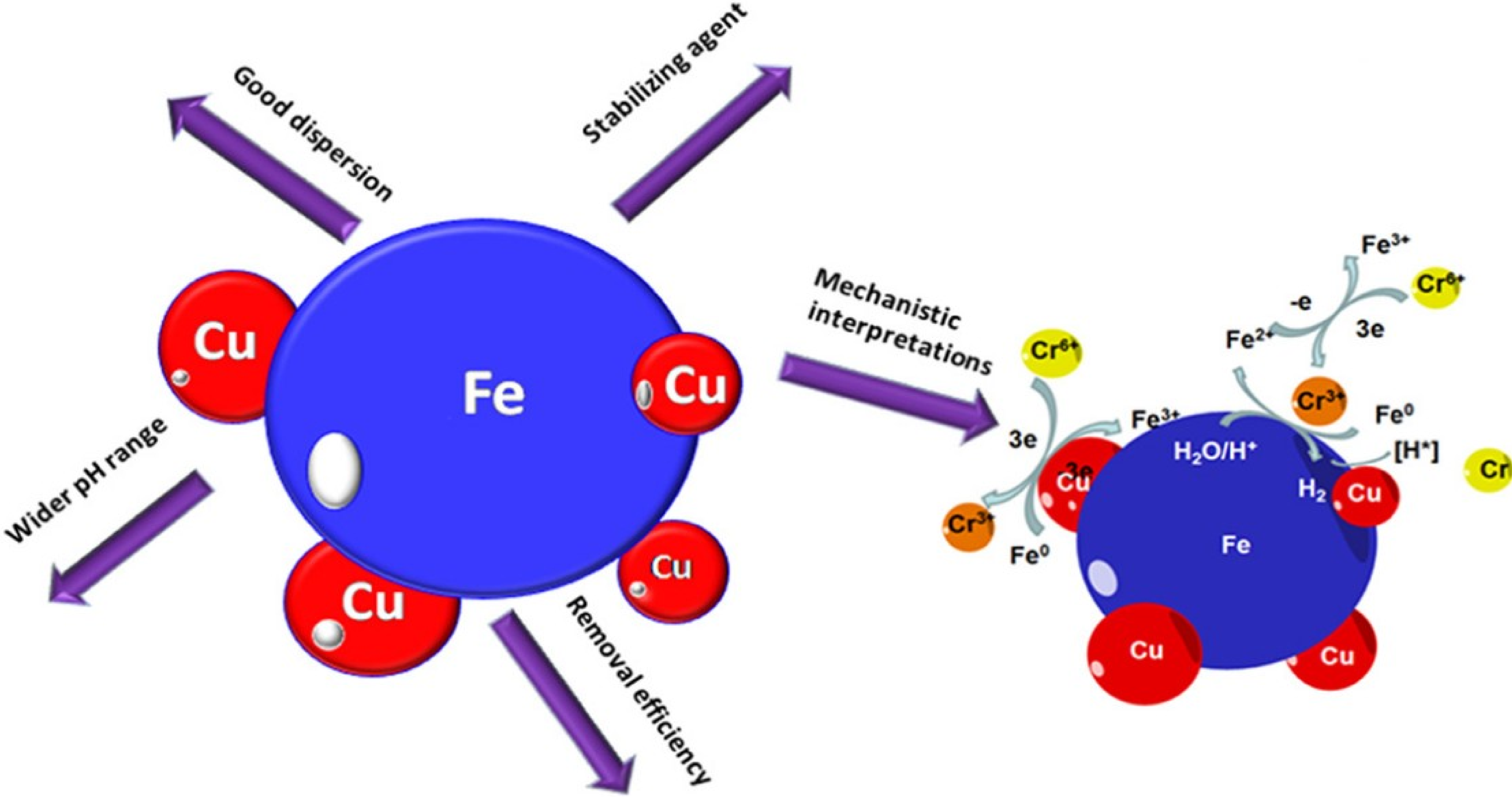
- Great flexibility
- Easy deployment in remediation of contaminated soil, sediments and solid wastes
- Treatment of water via fixation on carbon, zeolite or membrane
- Degradation of chlorinated organics
- Separation of aqueous metal ions by reduction (Cr, Pb)
- Partial dechlorination of PCB
- Advanced carriers

- Problem: Decrease in reactivity due to formation of passive surface layers

Engineered types of nanoparticles

Bimetallic NPs

- Combination of two metals
- Usually Iron NP with other metals deposited on surface
- Increased reactivity
- Reduction of less reactive lower-chlorinated products of dechlorination
- Generally better than plain Fe particles
- Palladized iron, Zinc NPs, Pd/Au NP, etc.

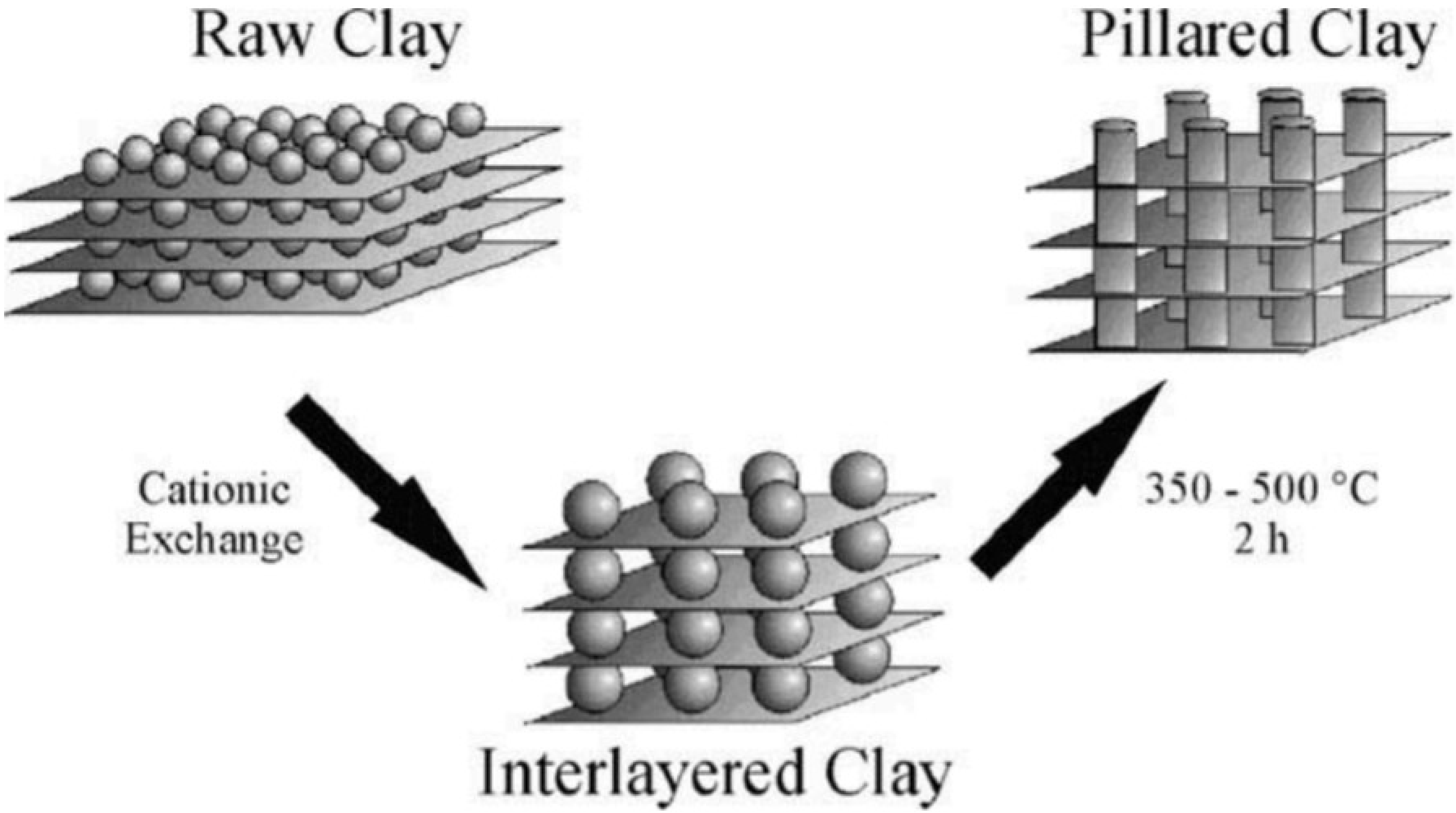


Jiang, Danni, Danlian Huang, Cui Lai, Piao Xu, Guangming Zeng, Jia Wan, Lin Tang, Haoran Dong, Binbin Huang, a Tianjue Hu. „Difunctional Chitosan-Stabilized Fe/Cu Bimetallic Nanoparticles for Removal of Hexavalent Chromium Wastewater". *Science of The Total Environment* 644

Engineered types of nanoparticles

Nanoclays

- Layered mineral silicates
- Nanocomposites with NP → pillared clays
- Preserved porosity and increased efficiency
- Water treatment
- Removal of organic polutants and heavy metals
- Low cost
- High sorption capacity
- Easy recovery



Galeano, Vicente, a Gil, „Catalytic Degradation of Organic Pollutants in Aqueous Streams by Mixed Al/M-Pillared Clays (M = Fe, Cu, Mn)"

Engineered types of nanoparticles

Nanotubes and fullerenes

- High thermal and electrical conductivity, high strength
- Low adsorption capacity, but great specifity
- Treatment of pollution from air and water
- Hard recovery
- High capital cost
- Health risks

Engineered types of nanoparticles

Magnetite NPs

- Magnetic properties
- Simple separation
- Good reusability
- No waste generation
- Costly for large operations
- Need for external magnetic field

Use of NPs in agriculture

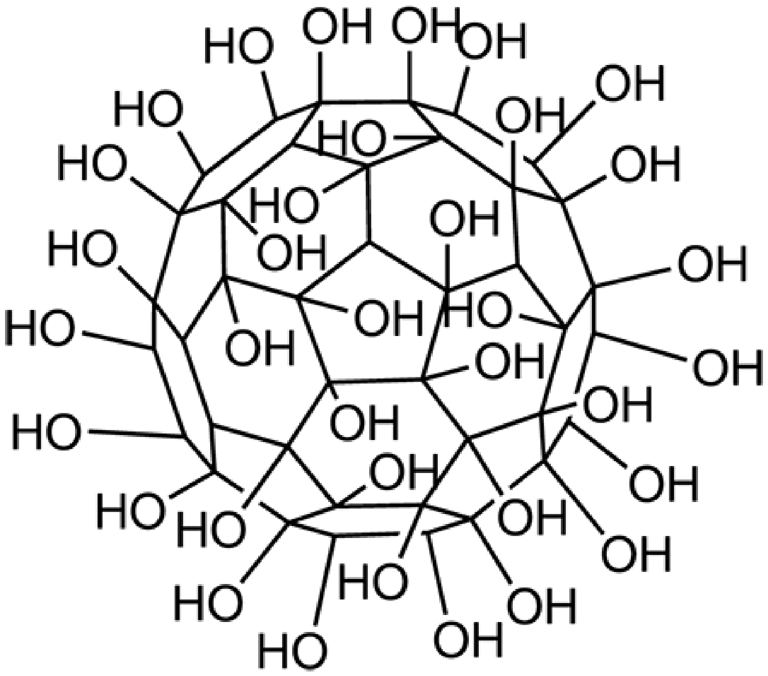
Nanotechnology in agriculture

- Nanotechnology applications in agriculture are being increasingly explored
- Promotion of plant growth and increase in crop yield

Nanoregulators

- **Improvement of plant growth and resistance under abiotic stress**

- Heat, drought, salinity, cold, nutrient deficit → primary cause of crop loss worldwide
- NPs with antioxidant-enzyme-mimicking abilities (nanoenzymes)
- CeO_2, fullerene C60, Au and Pt NPs



Nanoregulators

ullerol NPs alleviate oxidative stress by serving as an aditional intercellular water supply during drought

Nanofertilizers

- Lessening the amount of fertilizers used
- Improve nutrients uptake
- Fe,Zn, Cu, Mg, Mn, Mo based NPs all positively effect plant growth by adding essential micronutrients
- Polymer-coated NPs used to controlled-release ability

- Ammonium charged zeolites – enhancement of solubility of phosphate minerals
- Graphene oxide films – prolongation of nutrient release

Environmental impacts of Nanotechnology

Positive

- More efficient industrial processes
- Improved ability to detect and eliminate pollution
- Reducing amount of waste by high precision manufacturing
- Decreased need for large industrial plants
- Remediating environmental damages

Negative

- Environmental risks and effects of nanotechnology are poorly understood
- High energy requirements for synthesizing NPs
- Spread of toxic, nondegradable NPs
- Mostly low recovery and recycling rates

Thank you for your attention