

NANOPARTICLES AND NANOTOXICITY

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Supervisor: Dr. Johannes Rheinlaender

25 June 2019

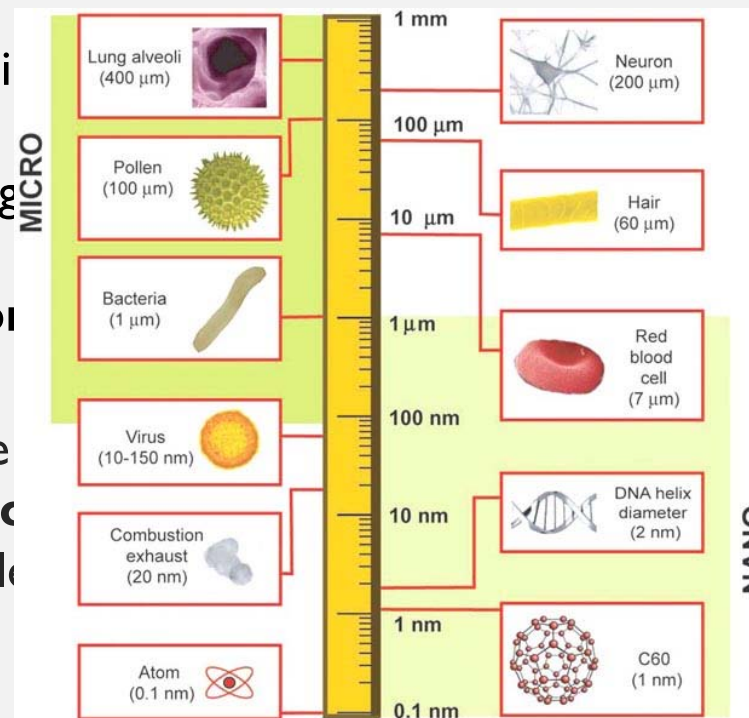
CONTENTS

- Nanoparticles
 - What are nanoparticles (NPs)?
 - Differences between NPs and bulk material
 - Applications of nanoparticles
- Nanotoxicity
 - Interaction of NPs with human body
 - Dependency of nanotoxicity

WHAT ARE NANOPARTICLES?

A **nanomaterial** is a material containing aggregate or as an aggregate of the particles in the external dimension of 100 nm or less [Commission of EU]

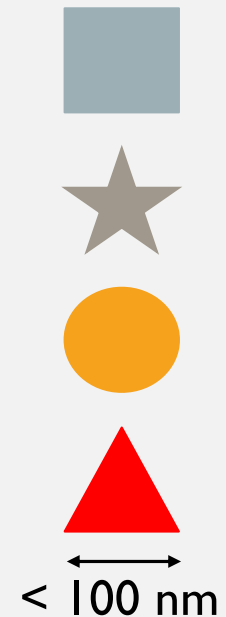
Nanoparticles are smaller than 1 micrometre, molecular length scale



Buzea et al. *Biointerphases* vol. 2, issue 4 14 (2007)

manufactured as an aggregate of more than 100 nm.

dimension of 100 nm or less



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HOW BIG IS A NP REALLY?

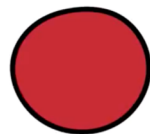
Diameter of a
soccer ball



Diameter of
the earth



Diameter of a
nanoparticle

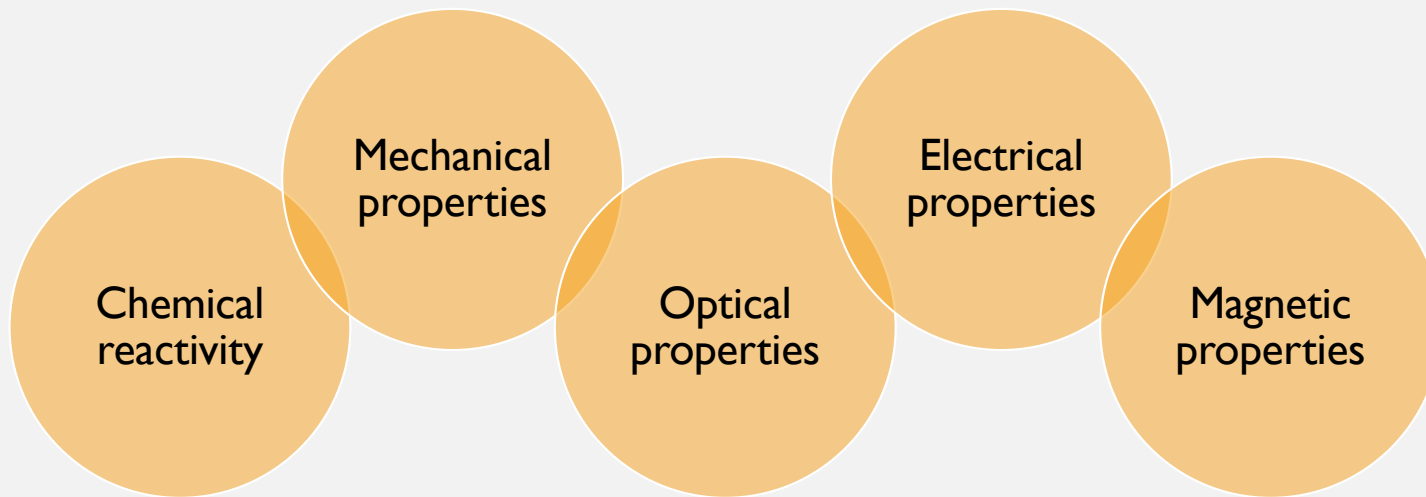


Diameter of a
soccer ball

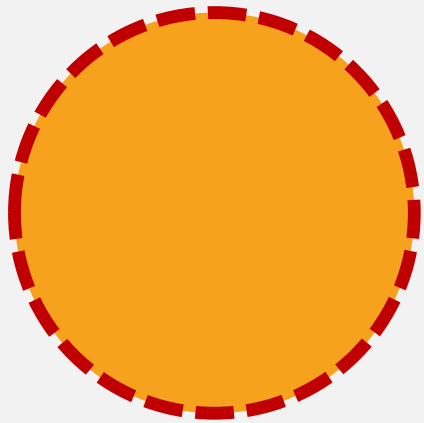


<https://www.youtube.com/watch?v=vvWx4KgOmGY>

DIFFERENCES BETWEEN NPS AND BULK MATERIALS



DIFFERENCES BETWEEN NPS AND BULK MATERIALS



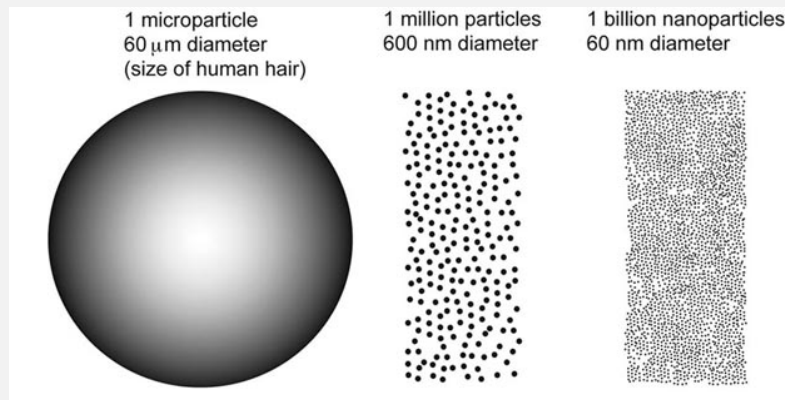
Surface effects



Quantum effects

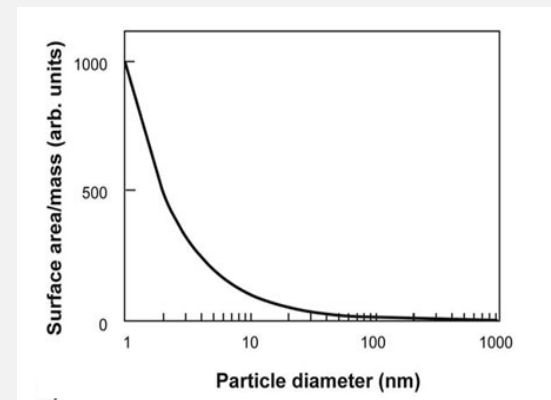
THE SURFACE AREA OF NPS

Compared to microparticles, nanoparticles have a very large surface area and high particle number per unit mass. [Buzea *et al.*]



$$SA = 4\pi r^2$$

$$V = \frac{4}{3}\pi r^3$$



Larger surface area $\rightarrow$ higher chemical reactivity

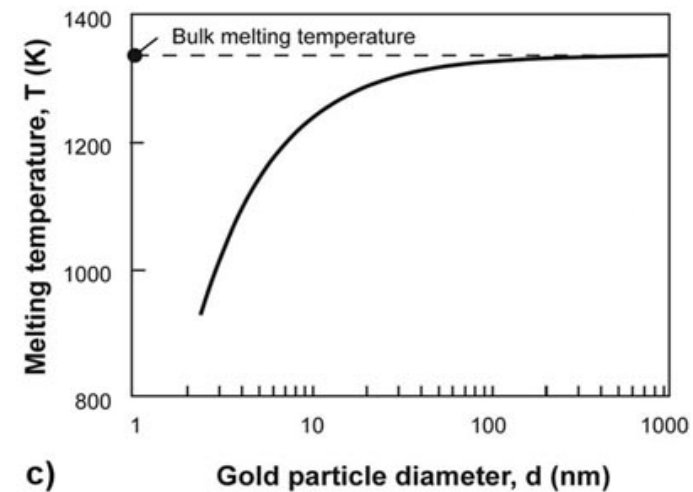
Buzea *et al.* *Biointerphases* vol. 2, issue 4 **16** (2007)

MELTING TEMPERATURE

- Atoms at surface have less neighbors than bulk atoms → lower binding energy per atom → melting point reduction

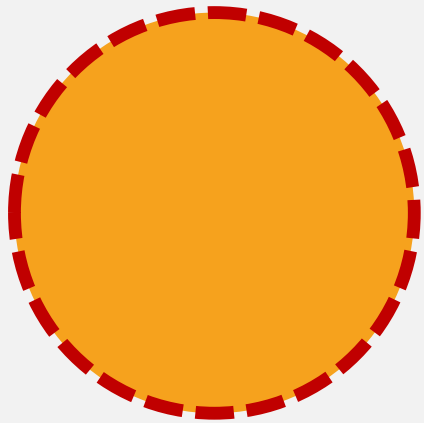
- Gibbs-Thomson equation:

$$T = T_{bulk} - \frac{C}{d}$$



Buzea et al. *Biointerphases* vol. 2, issue 4 16 (2007)

DIFFERENCES BETWEEN NPS AND BULK MATERIALS

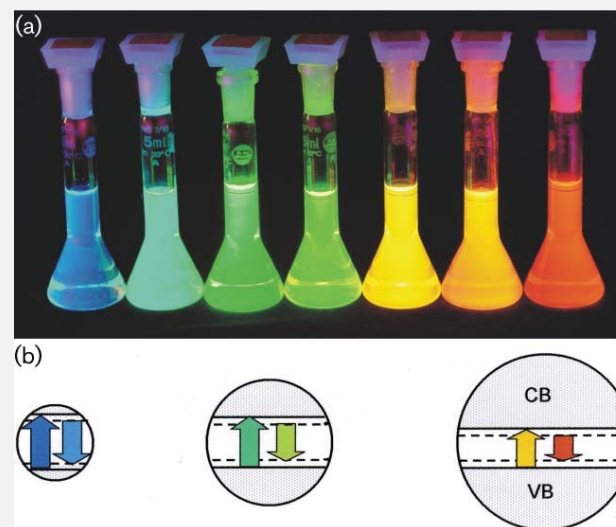
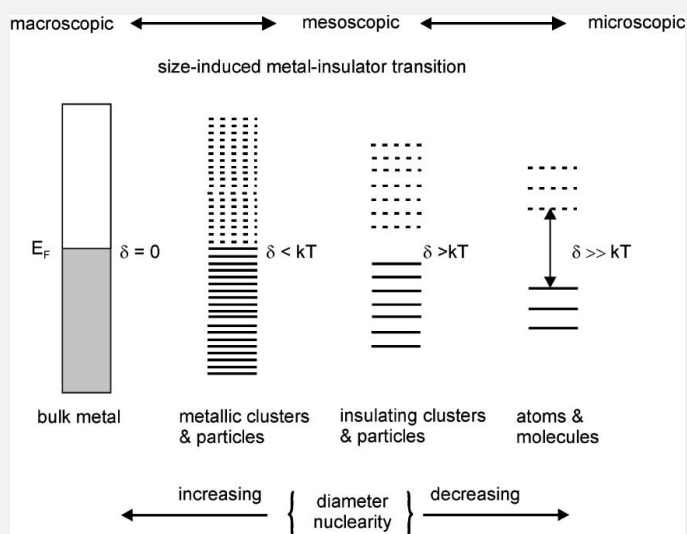


Surface effects



Quantum effects

QUANTUM EFFECTS



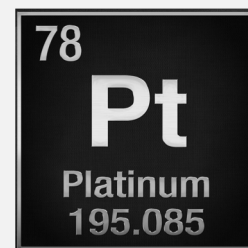
Roduner *et al.* The Royal Society of Chemistry **586-587** (2006)
DOI: 10.1039/b502142c

QUANTUM EFFECTS

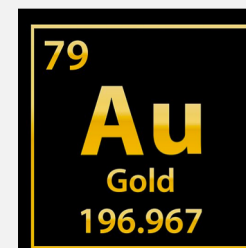
- Fluorescence behavior changes according to size
- Nonmagnetic materials can become magnetic
- Catalytic activity and selectivity are functions of size



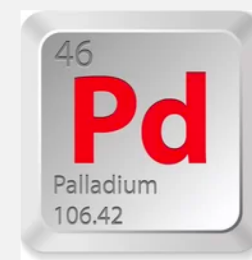
Roduner et al. The Royal Society of Chemistry **587** (2006)
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www.fineartamerica.com



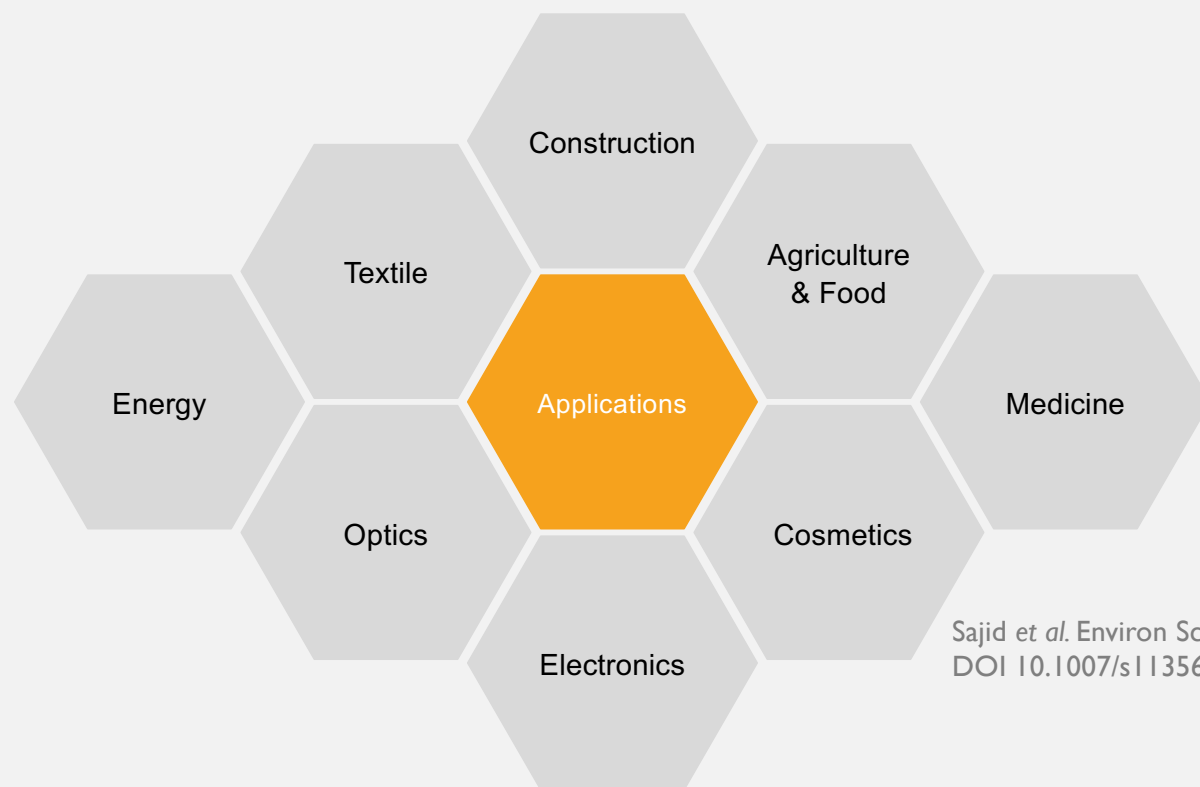
www.redbubble.com



www.livescience.com

HOW LONG HAVE NPS BEEN AROUND?

APPLICATIONS OF NPS



Sajid *et al.* Environ Sci Pollut Res 22:4122–4143 (2015)
DOI 10.1007/s11356-014-3994-1

BIOMEDICAL APPLICATION

Nanoscaffolds

Drug delivery

Medical imaging

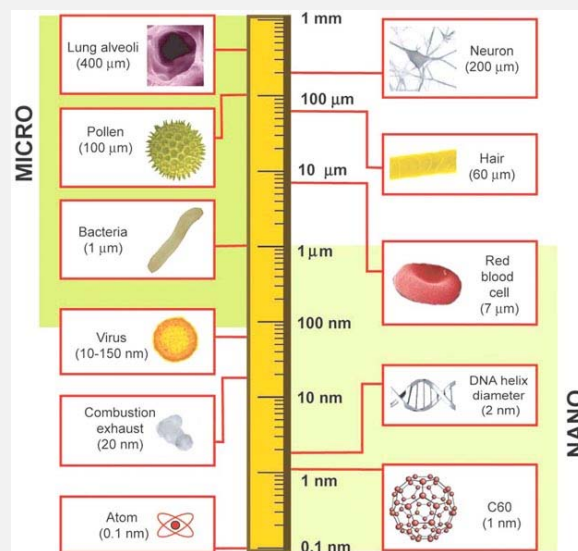
Nasal vaccination

Antimicrobial
nanopowders and
coatings

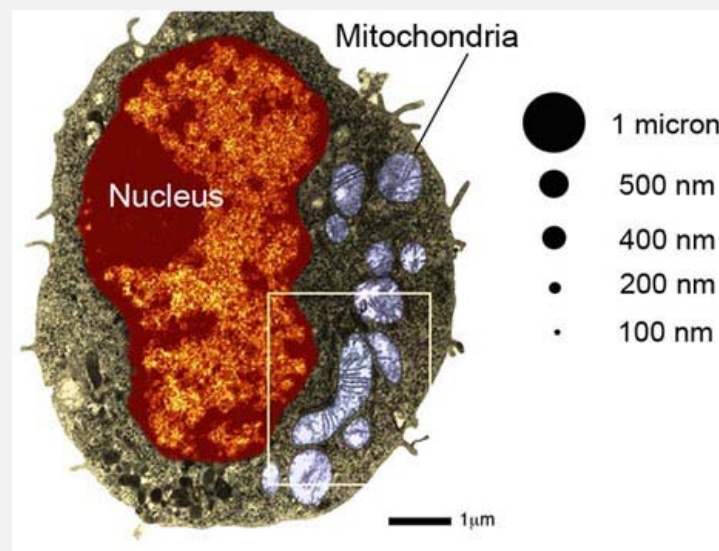
Buzea et al. *Biointerphases* vol. 2, issue 4 (2007)

NANOTOXICITY

NANOPARTICLES AND CELLS



Buzea et al. *Biointerphases* vol. 2, issue 4 **14** (2007)

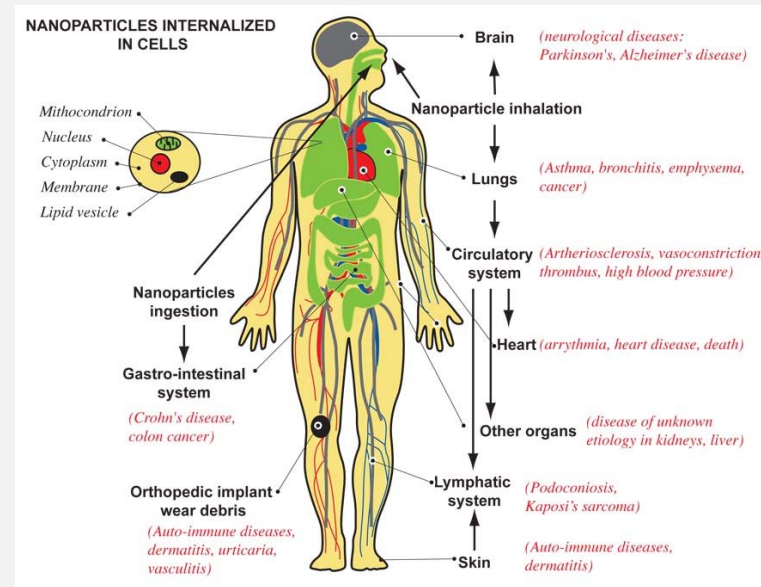


Buzea et al. *Biointerphases* vol. 2, issue 4 **18** (2007)

INTERACTION OF NPS WITH HUMAN BODY

- Following routes:
 1. Penetration through skin nodes
 2. Intake by the respiratory system via inhalation
 3. Intake by the digestive system via ingestion
 4. Direct exposure with implants

Sajid et al. Environ Sci Pollut Res 22:4122–4143 (2015)
DOI 10.1007/s11356-014-3994-1



Buzea et al. Biointerphases vol. 2, issue 4 19 (2007)

PENETRATION THROUGH SKIN



www.neutrogena.com



www.lamav.com

- Intentional exposure vs. non-intentional exposure
- Problem: penetration depth not given by manufacturers, health effects not known, must be investigated!



www.safetyandhealthmagazine.com



www.australianskinclinics.com.au



www.automotivenews.co.nz

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INHALATION

- Deep penetration into lung
- Can cause inflammation
- Transfer to lymph nodes and other organs



www.istockphoto.com

INGESTION

- NPs are either excreted or agglomerated → blockage of GI tract leading to death
- May result in
 - ulcers
 - weakening of the epithelium
 - malabsorption of nutrients
 - chronic bleeding



www.medicalnewstoday.com



www.themanufacturer.com

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TOXICITY DEPENDS ON...



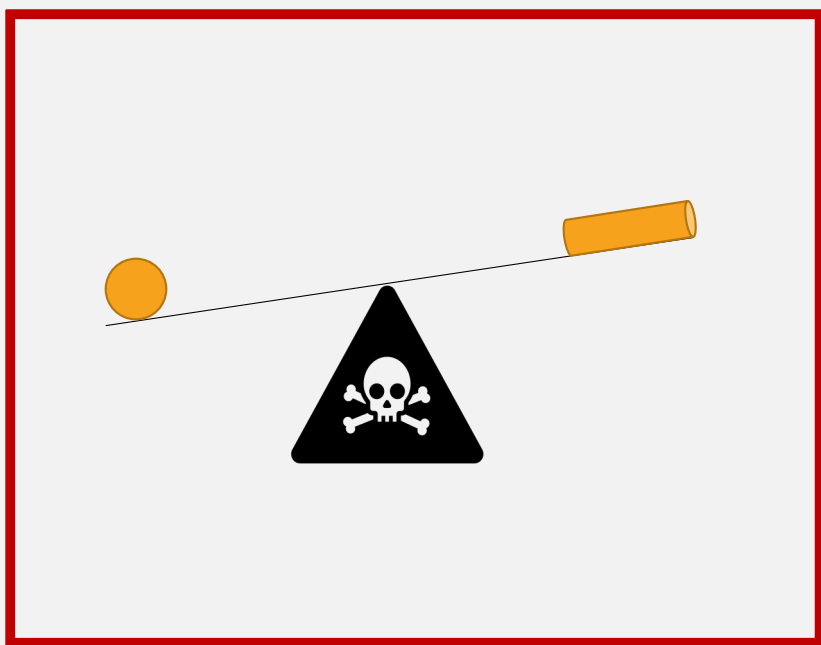
Size



Toxicity

Smaller NPs are more toxic:

- increased surface to volume ratio → more reactive and toxic
- increased penetration of plant and animal tissue

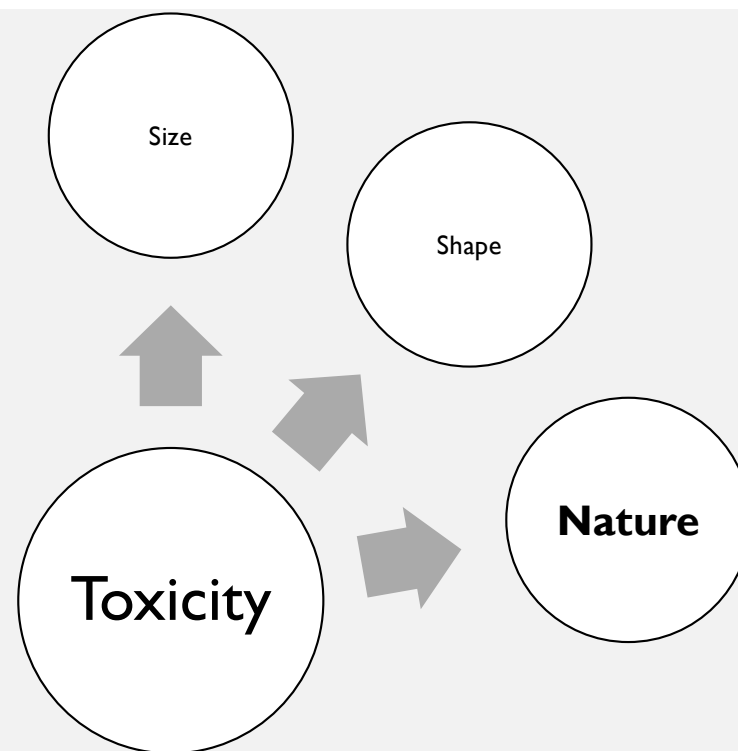


Size

Shape

Toxicity

Example: Spherical AuNPs more toxic than rod-type AuNPs

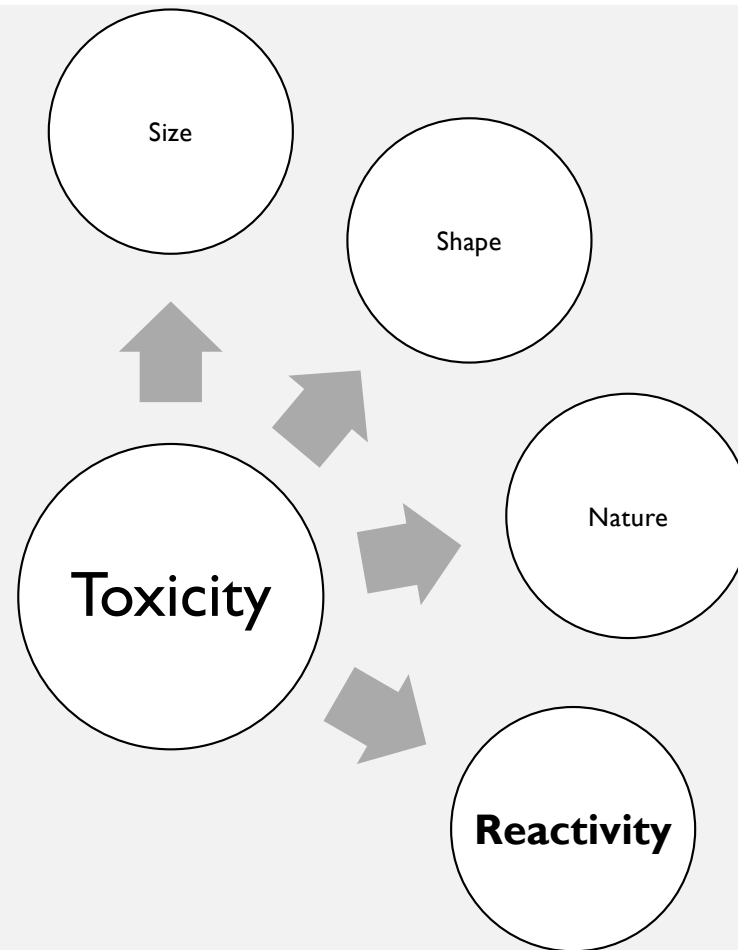


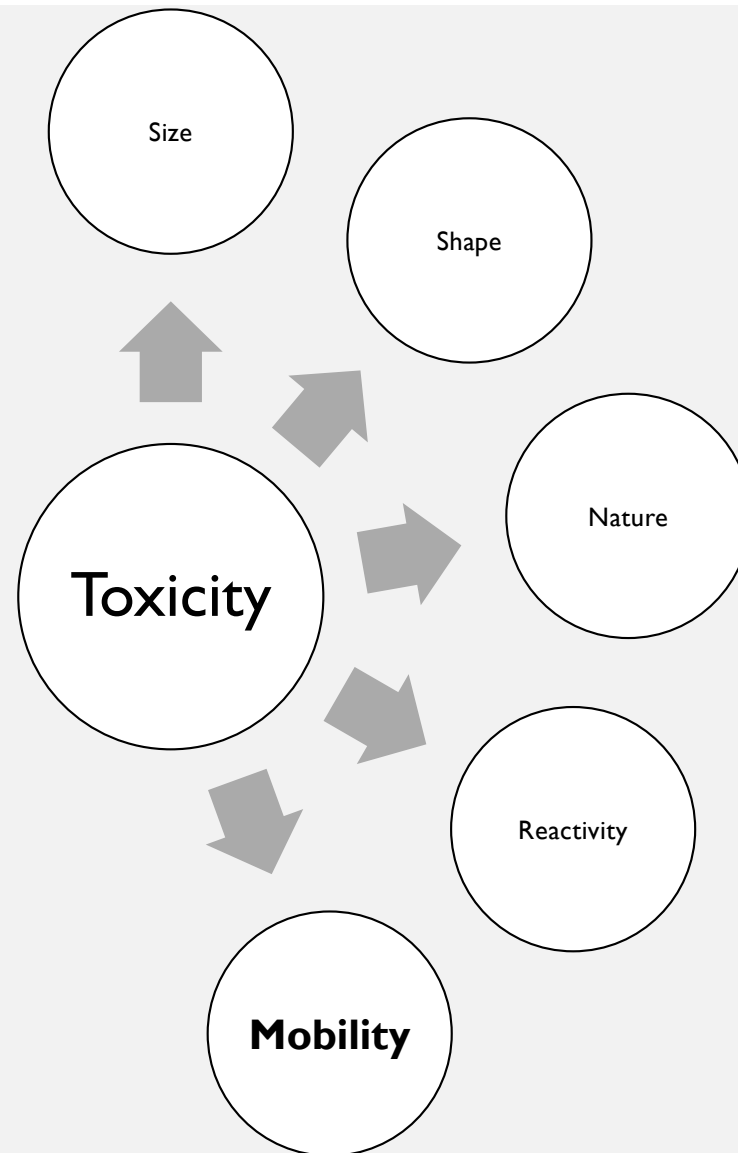
NPs have higher reactivity → used for catalysis → reactive oxygen species

When ROS levels increase → damage to cell structure

Charged and smaller NPs are more reactive

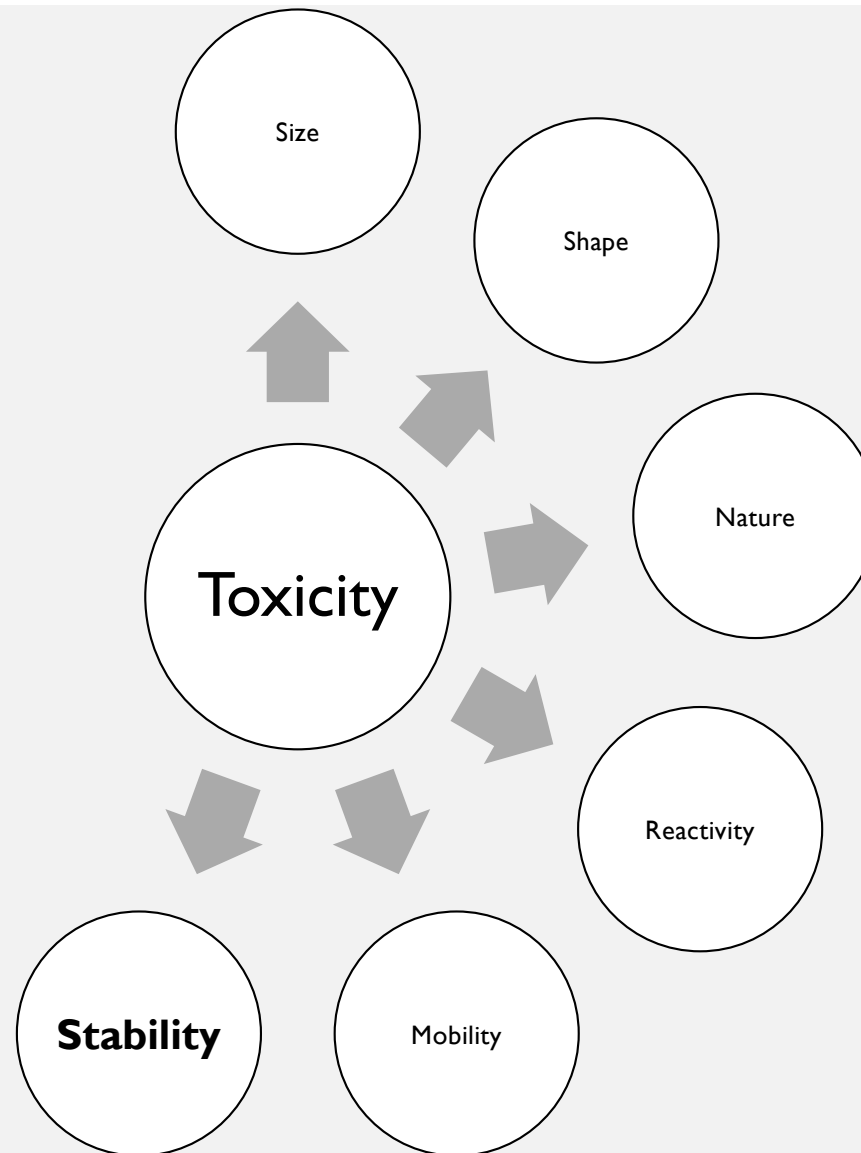
↑ ROS levels =



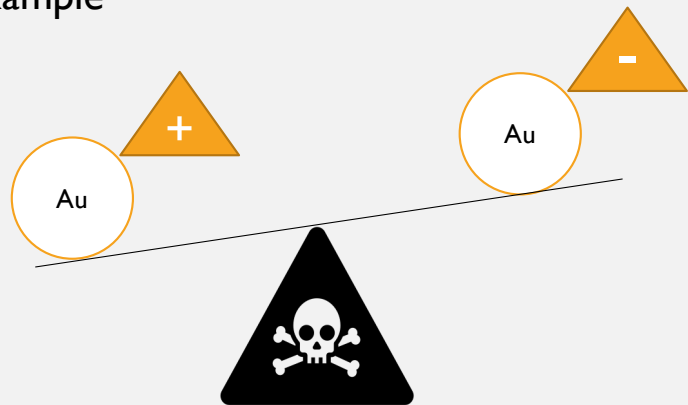


Depends on:

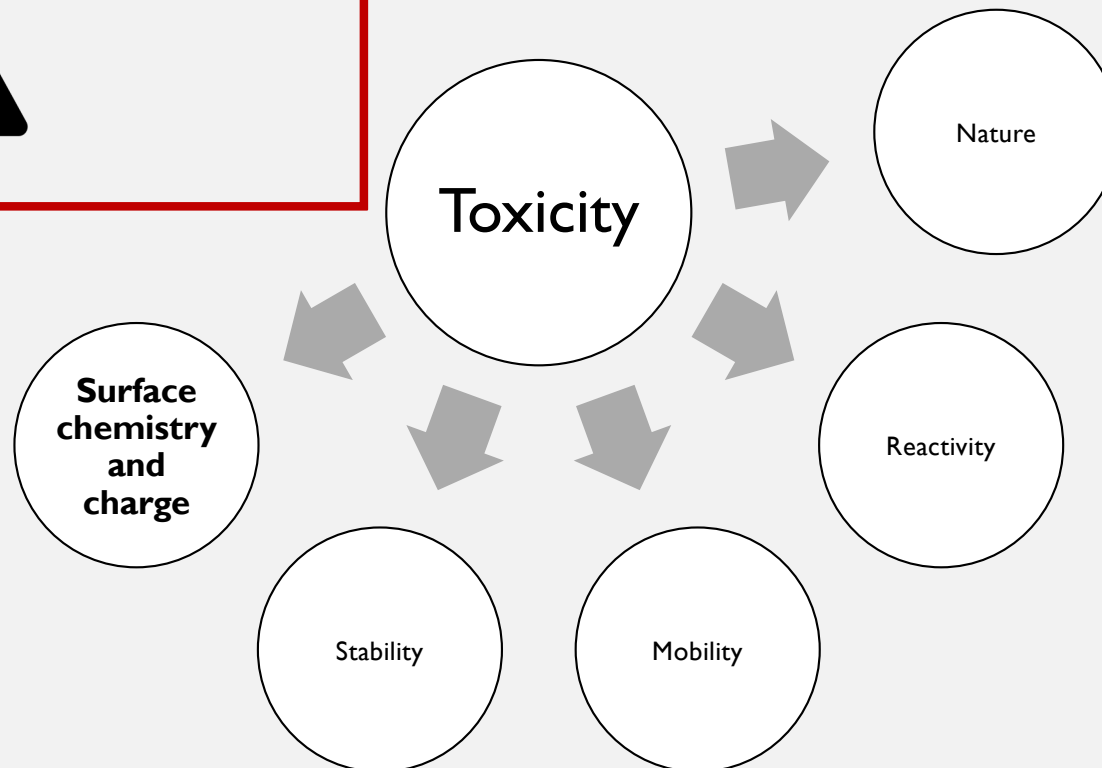
- Size
- Nature
- Concentration
- pH



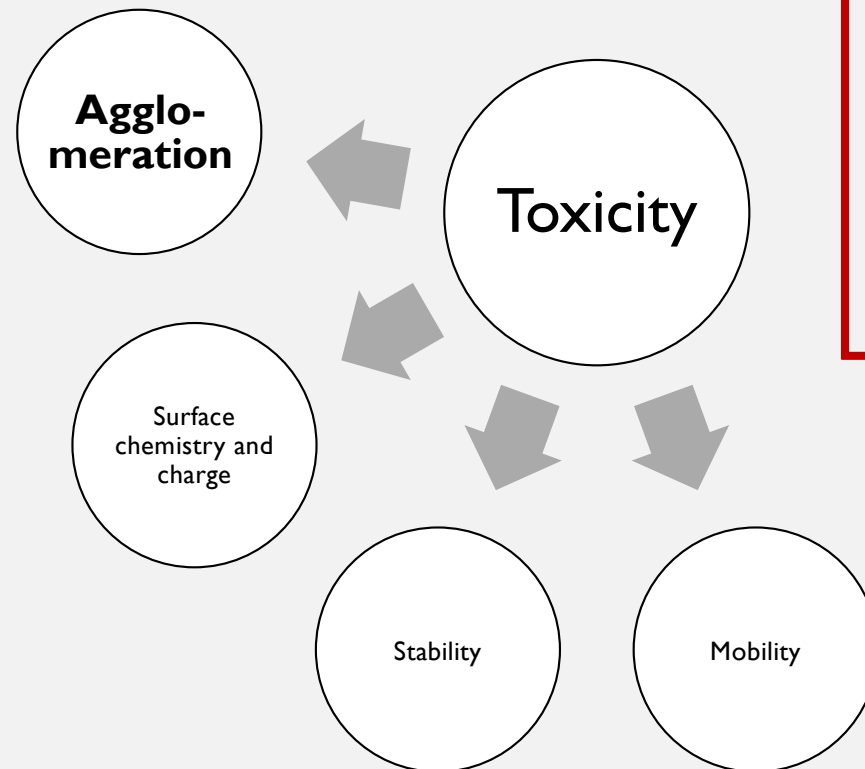
Example

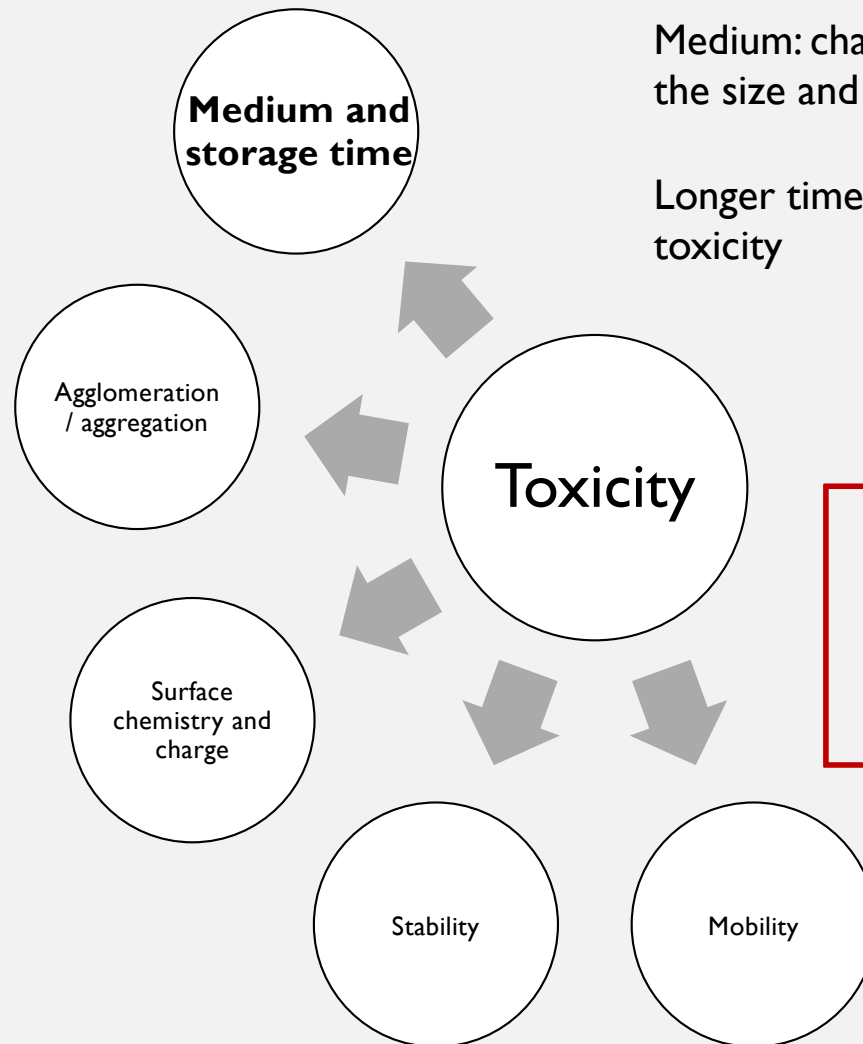


charge and type of functionalized group affect toxicity



Agglomerated NPs behave differently because of different surface properties → interaction with cells highly affected





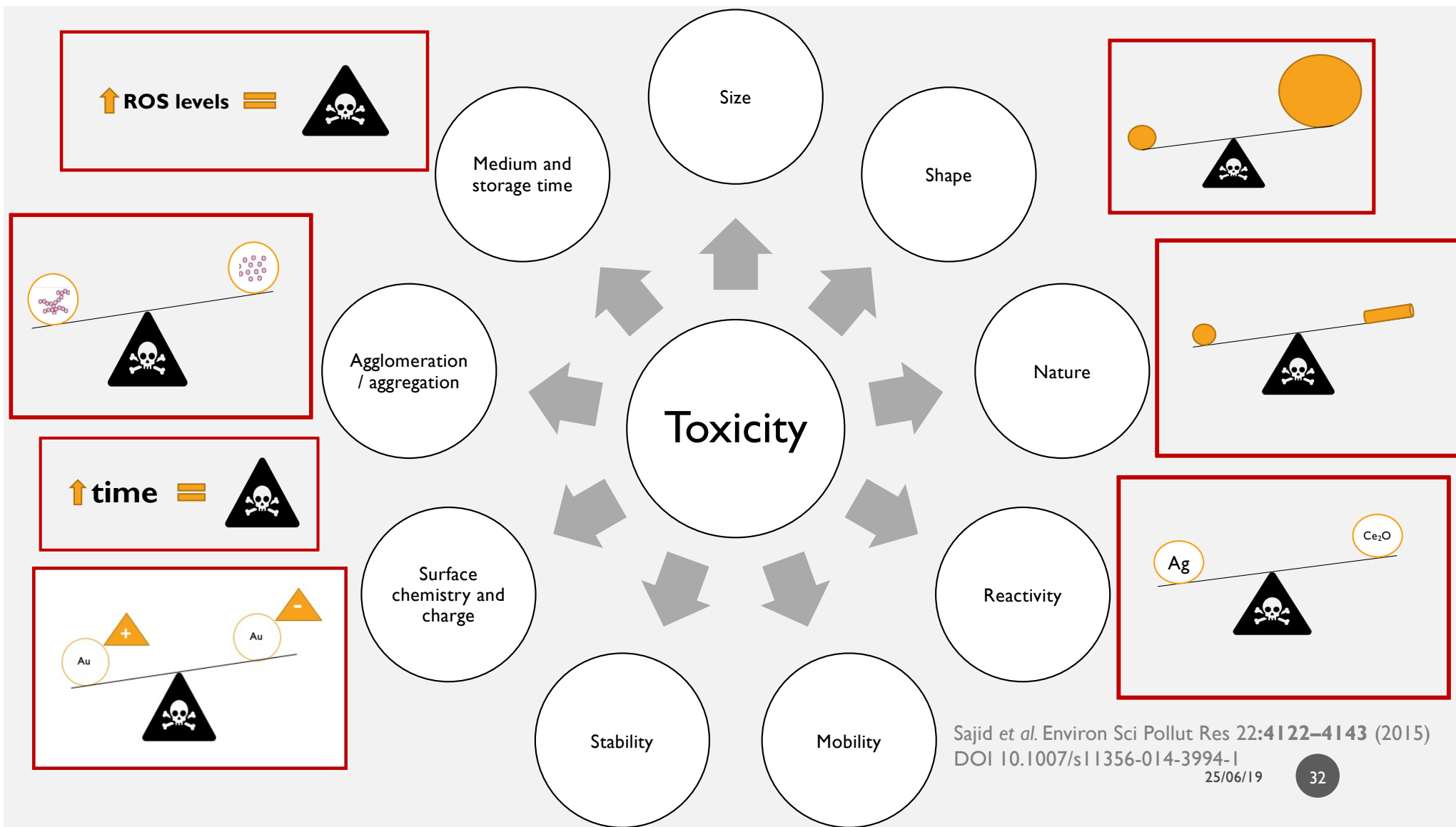
Medium: change in ionic strength → may change the size and the toxicity of NPs

Longer time: NPs will dissolve better → higher toxicity

↑time

=





SUMMARY

- NP have been around long before humans existed
- NPs have different physical and chemical properties than bulk materials
- → are used in new technologies
- Nanotoxicity highly depends on a lot of factors, most importantly size
- Nanotoxicology is a field which requires more attention

THANK YOU FOR YOUR ATTENTION