The potential impact of nanomaterials in the environment: limits and perspectives.

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Nanomaterials:
represent an opportunity of innovation for products and devices

NP properties differ from those of larger particles	
Properties	Examples
Chemical	High surface/volume ratio of NPs make them highly reactive increasing the effectiveness as **catalysts of chemical reactions .**
Electrical	NPs increase **electrical conductivity** in ceramics and magnetic compound. Moreover NPs increase **electrical resistance** in metals.
Mechanical	Increased **hardness and strength** of metals and alloys, **ductility and plasticity** of ceramics.
Optical	**Increase efficiency** of light **energy conversion** into electrical in photoelectric devices.
Steric	Spatial arrangement of atoms influences **chemical reactivity**.
Biological	**Increasing permeability** through biological membranes.

Nanotechnology : represent an opportunity to improve environmental sustainability

Examples

to store and convert efficiently solar energy into electricity
allowing to reduce dependence on non-renewable resources such as fossil fuels.

to get smaller electronic devices
make us save materials and energy.

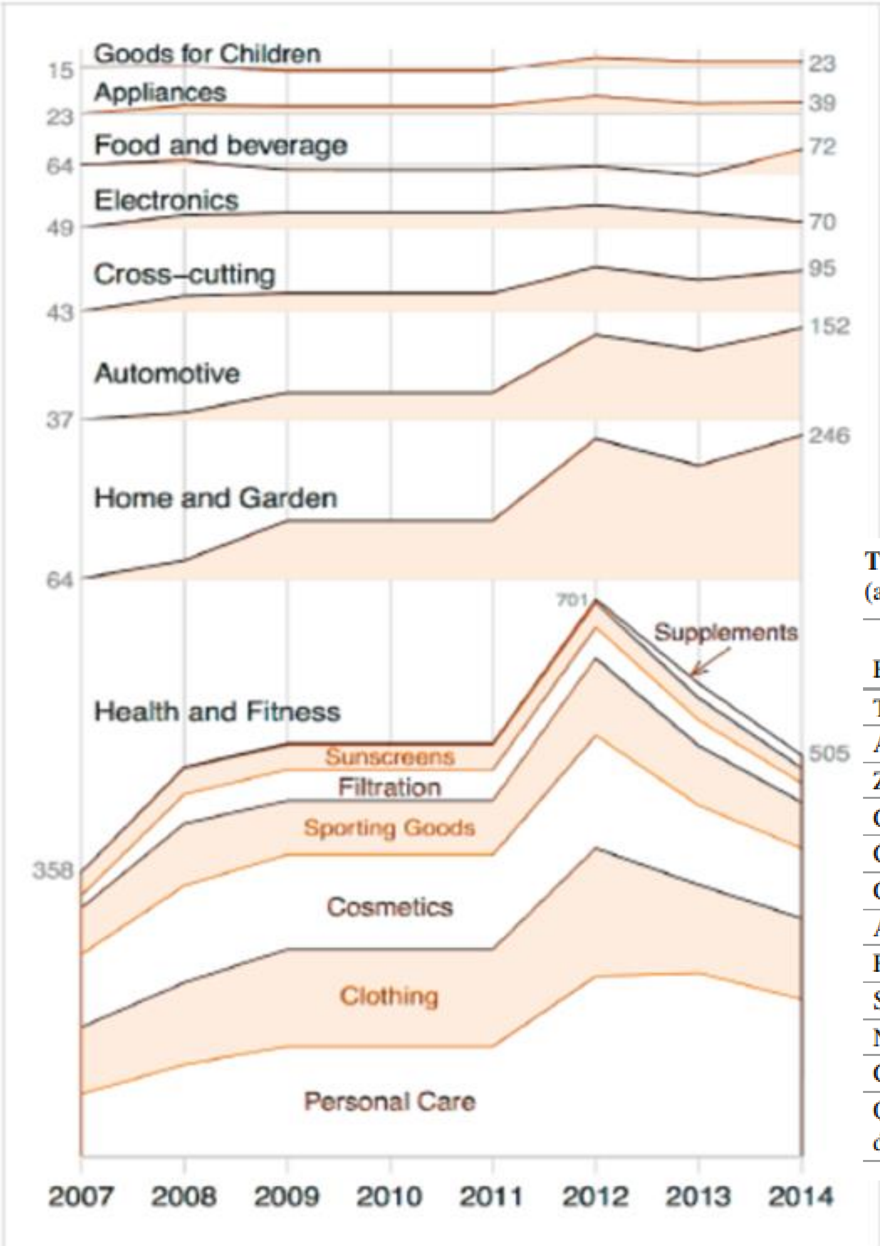
Emissions and effects on the environment

The loads of energy and materials that are emitted in the course of production, consumption and disposal is the dark side of most traditional technology.

Awareness about the need to analyze the entire product life cycle, until the end, when the product becomes waste.

Opportunity to make safe and sustainable nanomaterials since its conception

Nanomaterials: production amounts and application fields



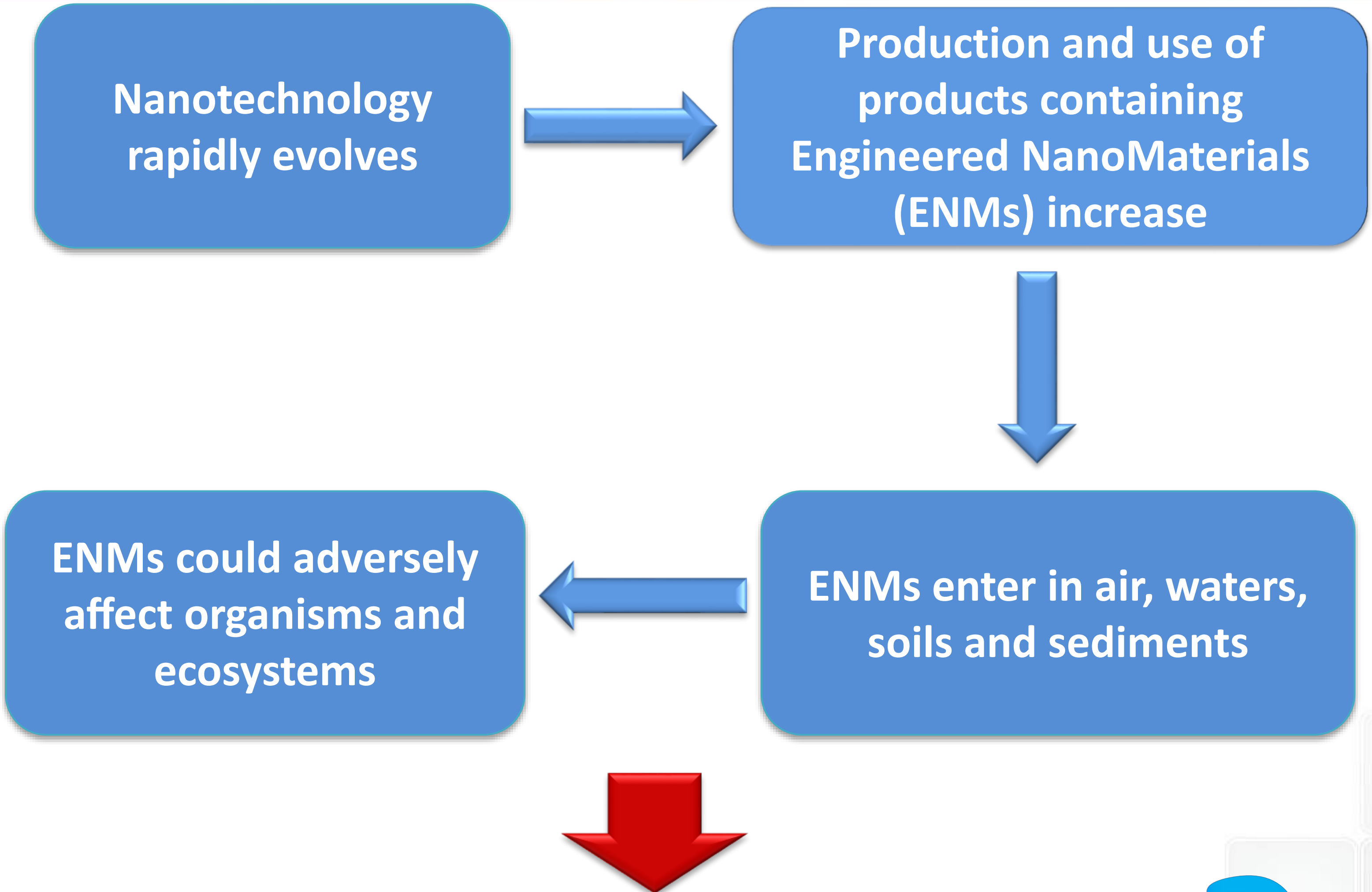
Number of available products over time in each major category. (Vance et al., 2015)

Table 1 Comparison of production amounts from six different sources scaled to the EU (according to the GDP) (in tons/year)

ENM	Schmid and Riediker [6]	Hendren et al. [7]	Piccinno et al. [8]	Keller et al. [9]	ANSES [11]	Sun et al. [12]
TiO_2	11,500	8,600–42,000	550	20,000	92,000	10,000
Ag	82	3–20	6	100	0.006	30
ZnO	1,900	–	55	7,900	1,900	1,600
CNT	26	60–1,200	550	740	–	380
C_{60}	–	2–90	0.6	–	<100	20
CeO_2	–	40–770	55	2,300	700	–
Al-ox	0.1	–	550	8,100	15,000	–
Fe-ox	9,700	–	550	9,700	6,100	–
SiO_2	2,000	–	5,500	22,000	990,000	–
Nanoclays	–	–	–	2,400	<100	–
Cu	–	–	–	46	<100	–
Quantum dots	–	–	0.6	–	–	–

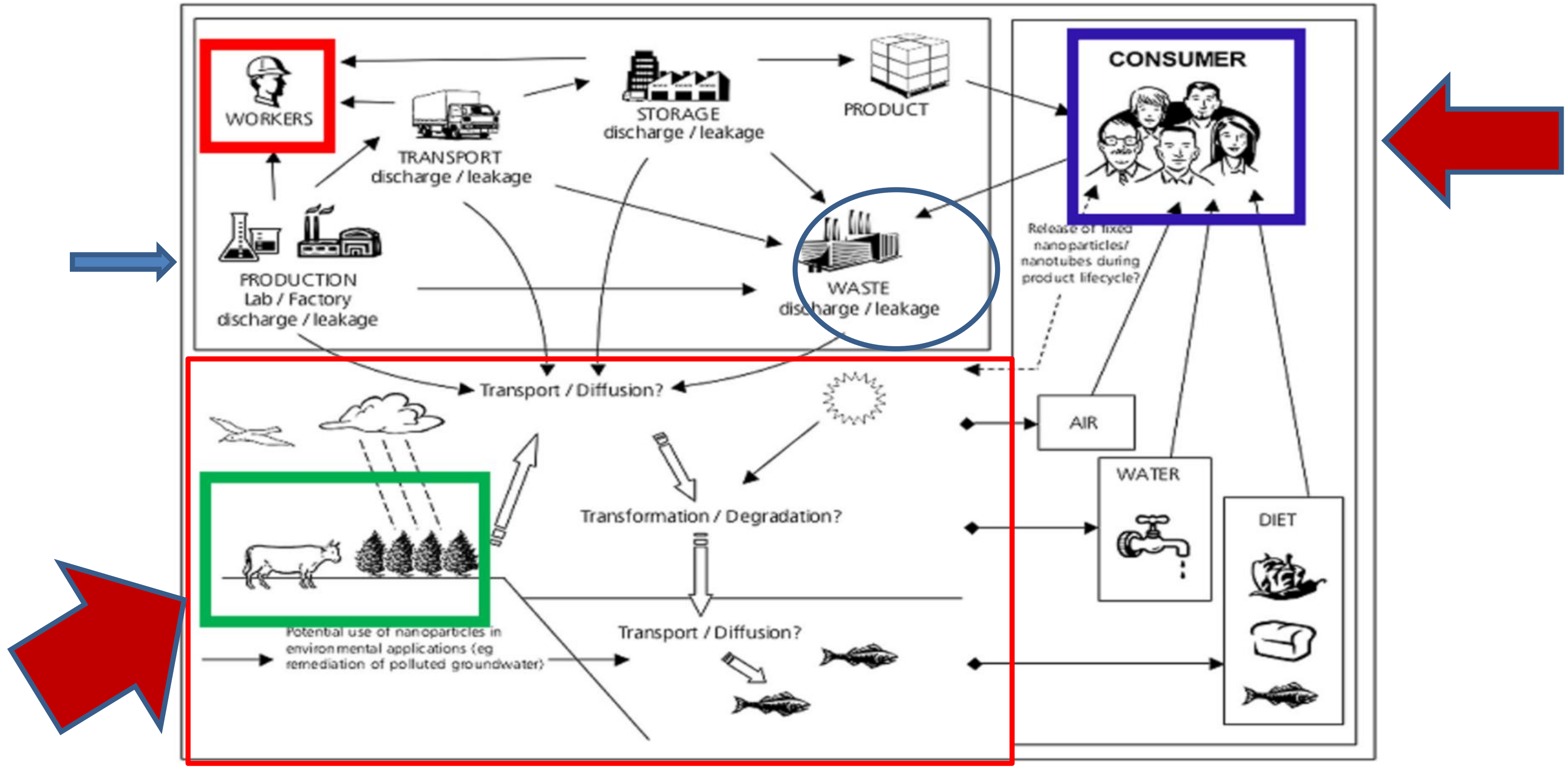
Novack et al., 2015

High Variability!!



ENMs represent a real environmental / human hazard ?

ENMs release in the environment

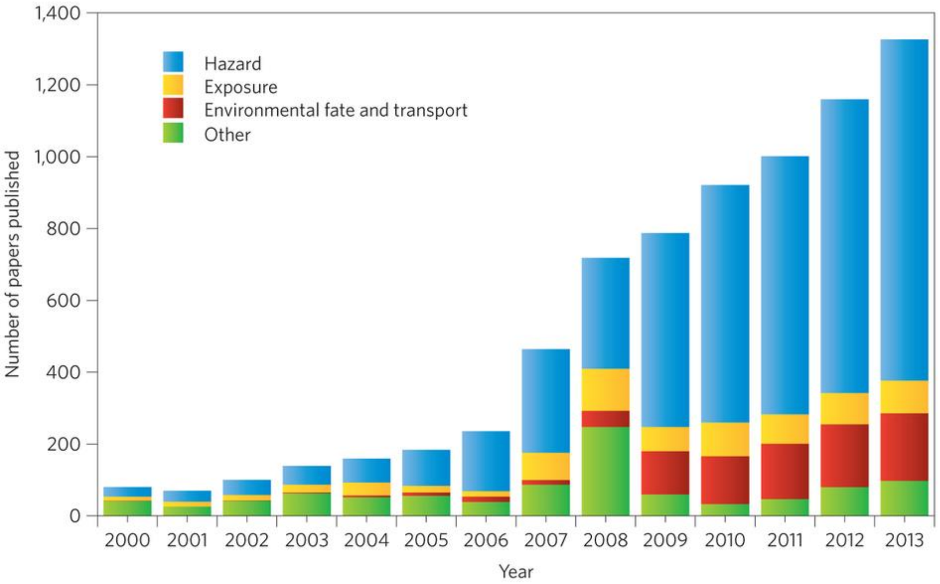


ENMs could reach the environmental compartements in different ways, also as consumer waste.

ENMs could be again available to consumers via air, food and water.....

ENMs represent a real environmental hazard?

Many research works have been done in these last



Many Uncertainties are still present about
<u>ENM actual environmental impacts</u>
and
<u>how to evaluate them</u>

To help in overcome this impasse…….

it needs
to perform studies with
more ecological relevance and environmental realism

Safer innovation!

Critical points:

Actual environmental impacts

Evaluation

More ecological relevance
and environmental realism

Some questions to be addressed:

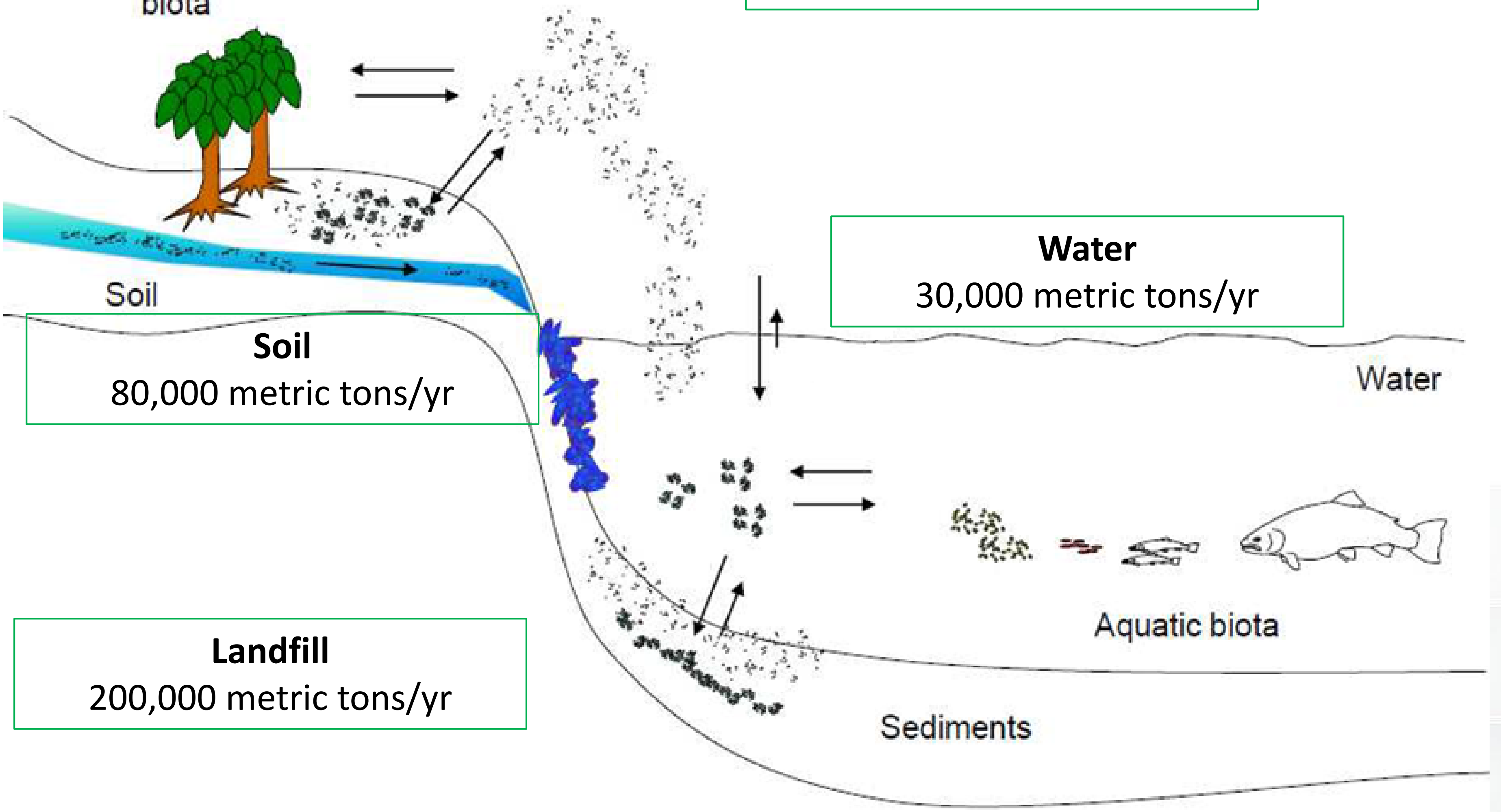
What ENM quantities are involved?
What are their transformation in the environmental matrices?
What are their bioavailability?

In ENM evaluation of effects,
Is experimental design

- Organisms
- Exposure condition (dose/ bioavailability)
- Endpoints at different levels of biological complexity
- Battery of toxicity test with different organisms

properly built to have a result ecologically relevant ?

What ENM quantities are involved?



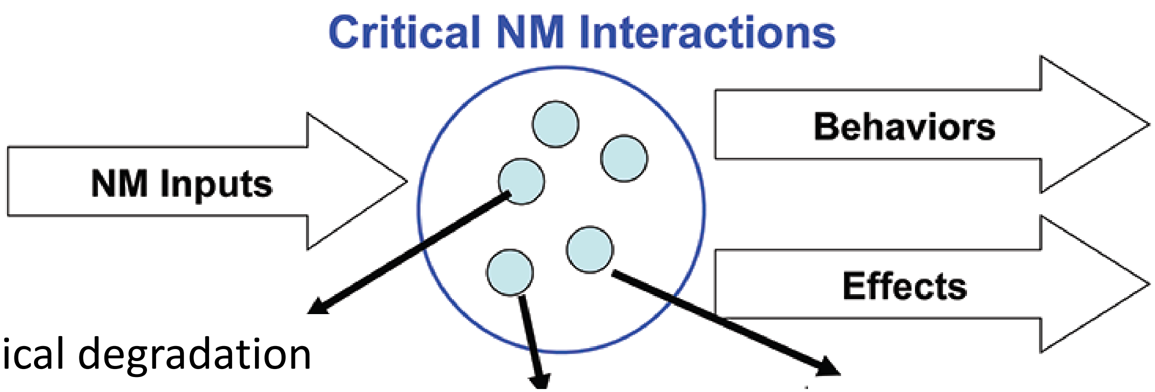
Air
10,000 metric tons/yr

Water
30,000 metric tons/yr

Soil
80,000 metric tons/yr

Landfill
200,000 metric tons/yr

What are ENM transformations?



Biological degradation

Interactions with macromolecules

Physical and Chemical transformations

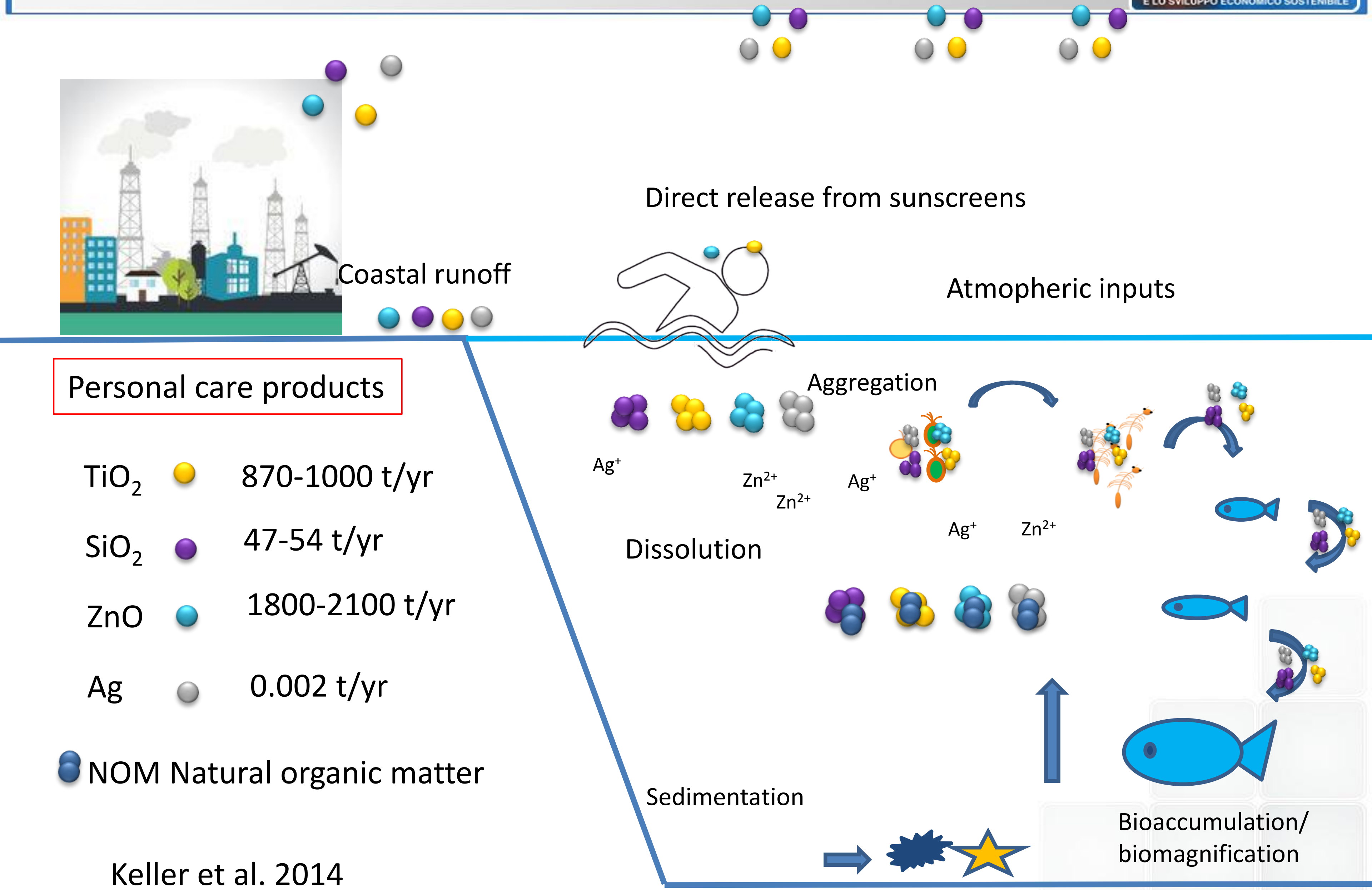
Biological degradation of polymer coatings on ENMs
- **can affect their surface properties and lead to aggregation**

Adsorption of biomacromolecules
- **affects aggregation, uptake, biodistribution and dissolution of ENMs**

Aggregation process increases NMs size reducing the surface area and reactivity, while dissolution process causes the release of ions by ENMs

Environmental Transformations

An example…



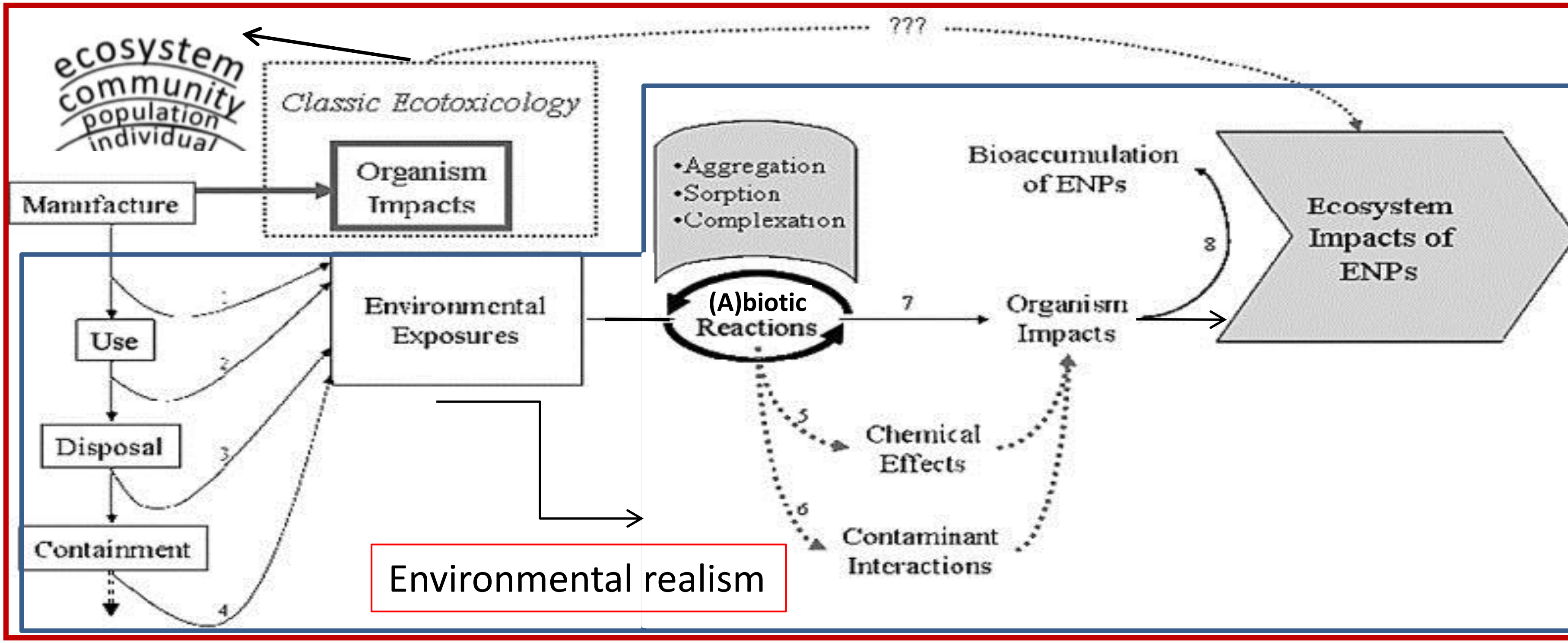
Keller et al. 2014

How evaluate the ENM effects in the environment??

Ecotoxicology
evaluates the effect of the chemicals in the environment

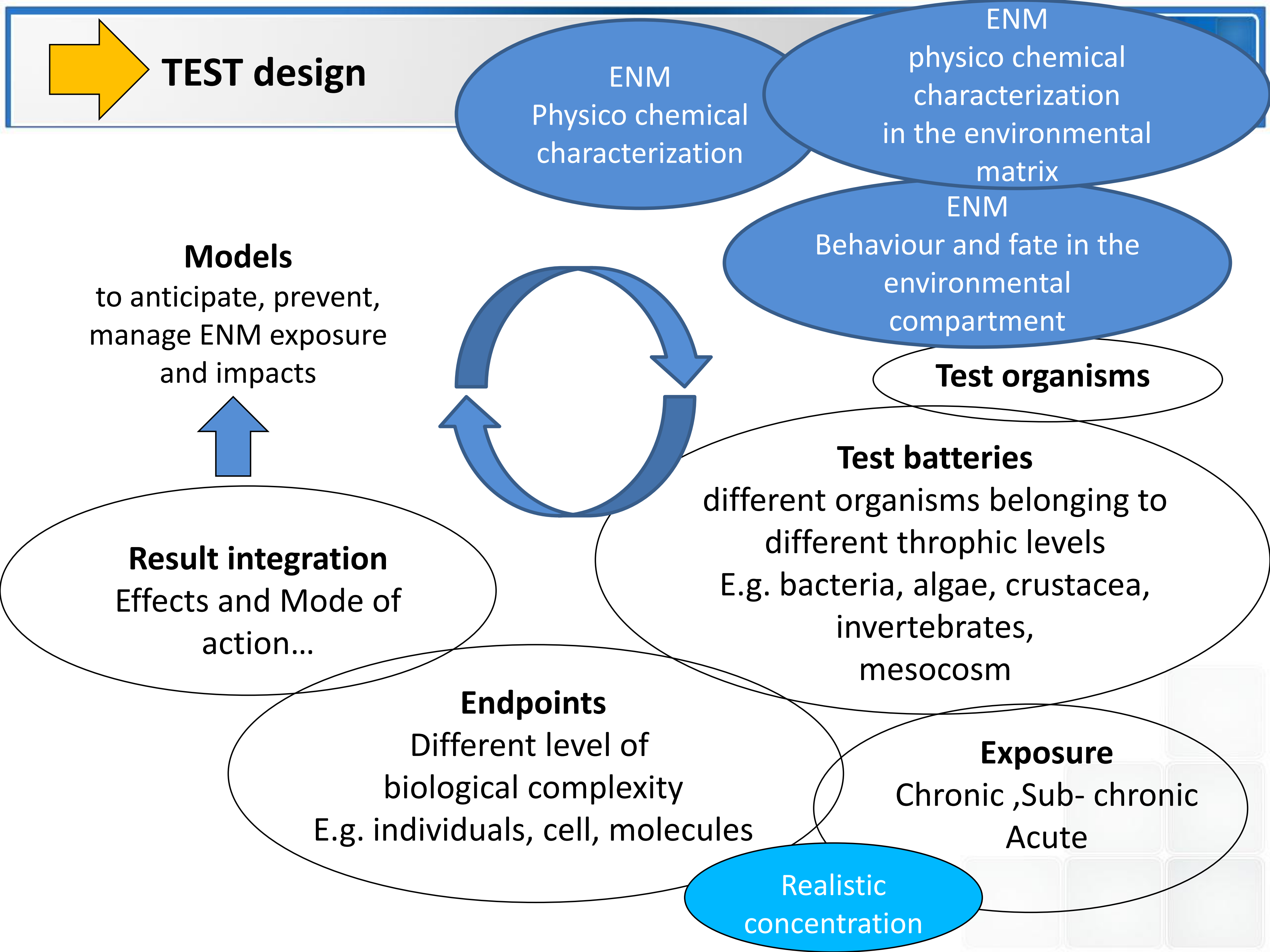
Nanoecotoxicology
derives the main principals from the first discipline but introduces new rules and procedures

From ecotoxicology to nanoecotoxicology

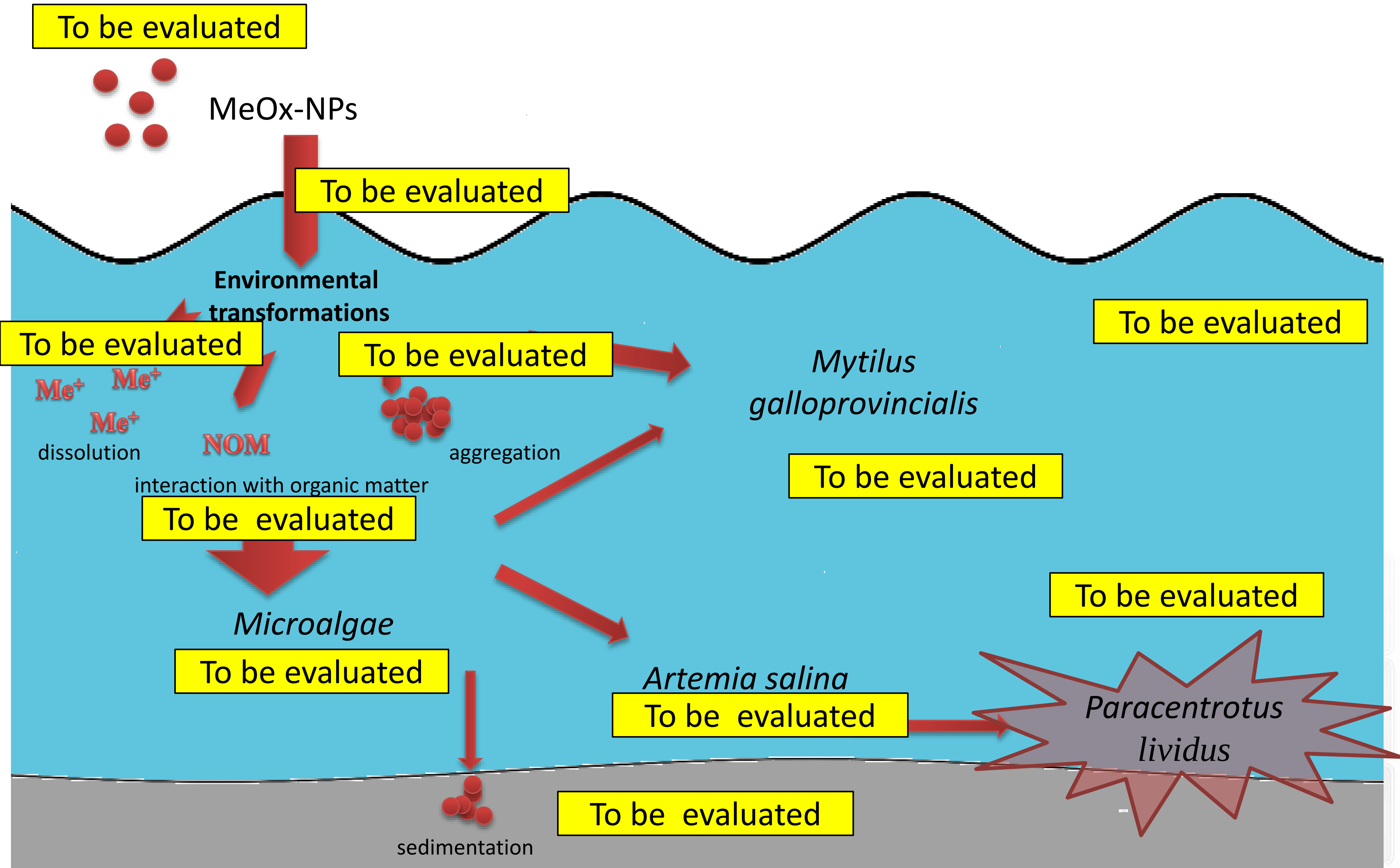


ENMs ecotoxicology overlaps with conventional ecotoxicology, but since ENMs are particulate and diverse, with varying cores, native or acquired surface chemistries, etc….. affecting their environmental reactivity and biological interactions,

additional processes and parameters should be considered to reach the objective of a realistic exposure with ecological relevance.


TEST design
ENM
Physico chemical
characterization
ENM
physico chemical
characterization
in the environmental
matrix
ENM
Behaviour and fate in the
environmental
compartment
Test organisms
Models
to anticipate, prevent,
manage ENM exposure
and impacts
Test batteries
different organisms belonging to
different throphic levels
E.g. bacteria, algae, crustacea,
invertebrates,
mesocosm
Result integration
Effects and Mode of
action…
Endpoints
Different level of
biological complexity
E.g. individuals, cell, molecules
Exposure
Chronic ,Sub- chronic
Acute
Realistic
concentration

Methods and experimental design: an example



Methods and experimental design

The test will be performed with:

✓Metal oxide particles of different sizes such as

MeOx-NPs < 100 nm

MeOx Bulk >100 nm

→ To evaluate the toxicity related to the size.

✓Ionic form (Me^{+})

→ To evaluate the toxicity related to ions released by MeOx.

Physico-chemical-characterization of nanoparticles in seawater.

NPs in marine environment are subject to different transformations that affect their potential toxicity:

Dissolution

MeOx-NPs release potentially toxic ions

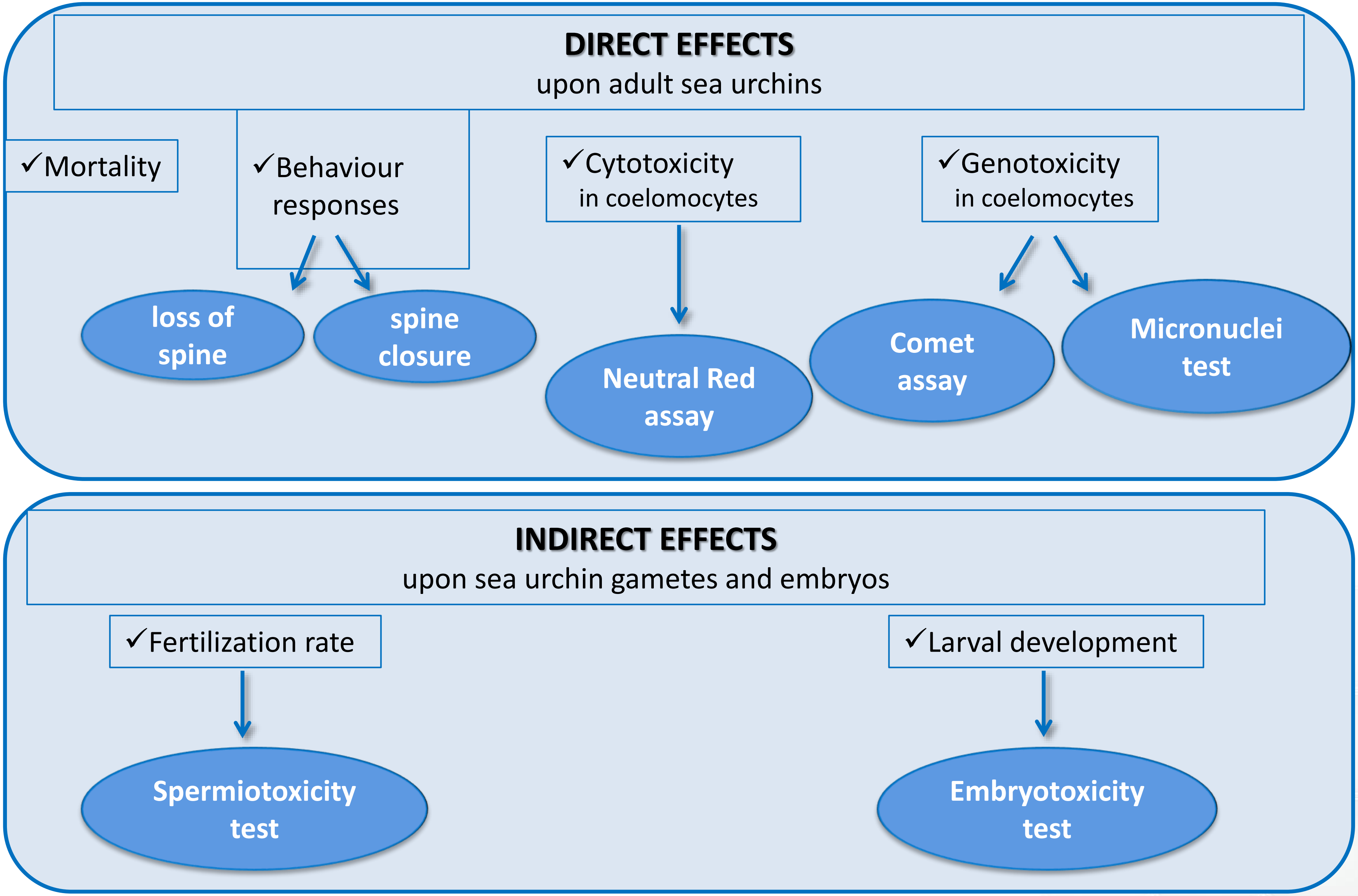
Interaction with macromolecules

Adsorption of biomacromolecules affects the behaviour of NPs in environment

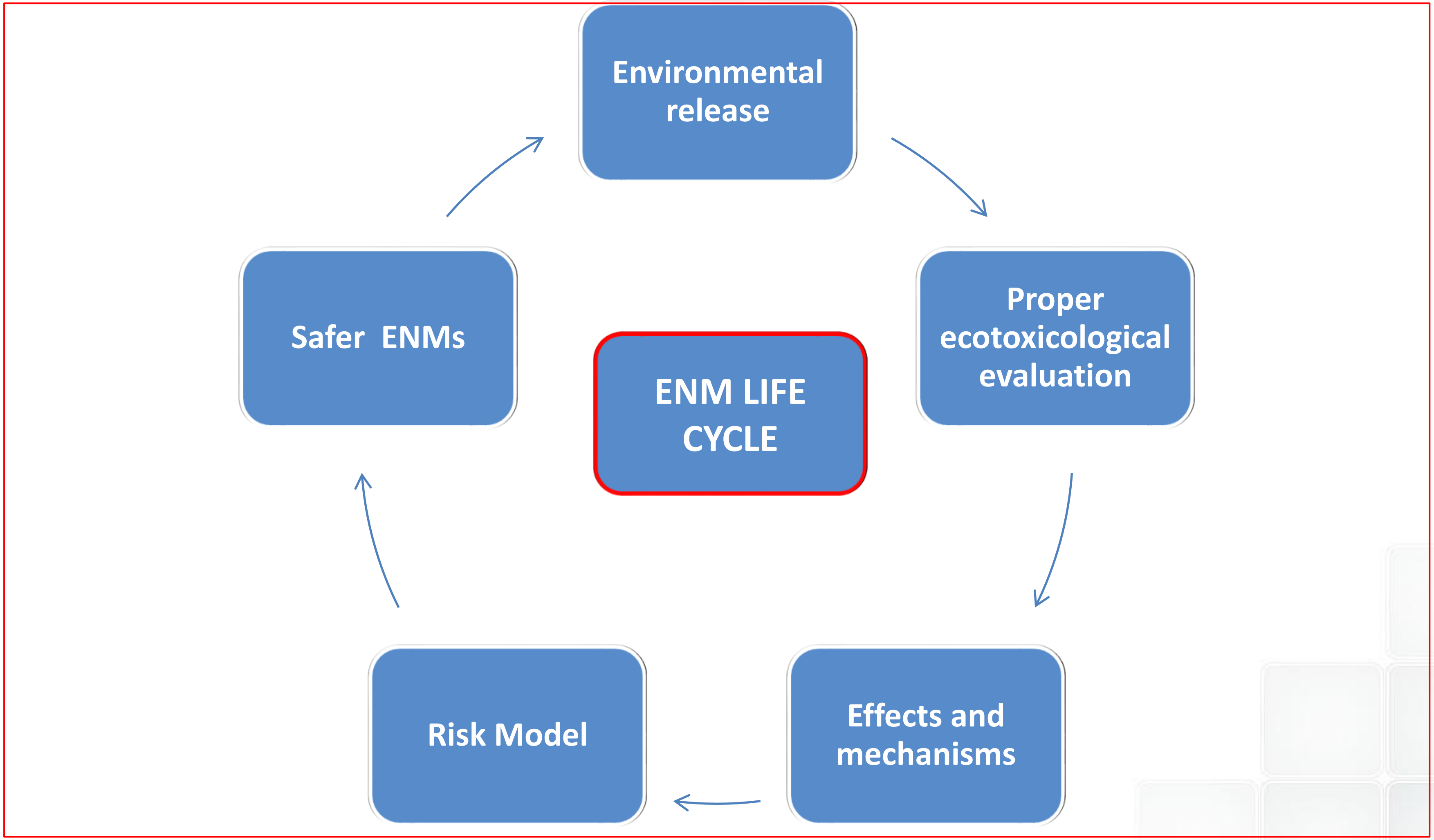
Aggregation

NPs form aggregates with the size more large than single nanoparticles

Methods and experimental design: examples of endpoints



Innovation in nanotechnology hinges on having the science to evaluate ENM safety.



Conclusions

First, researchers should improve ecotoxicology of ENMs by choosing test end points, duration, and study conditions including ENM test concentrations that align with realistic exposure scenarios.

Second, testing should proceed via tiers with iterative feedback that informs experiments at other levels of biological organization.

Finally, environmental realism in ENM hazard assessments should involve greater coordination among ENM quantitative analysts, exposure modelers, and ecotoxicologists, across government, industry, and academia.

Thank you