# Nanomaterials in the Environment: from implications to applications

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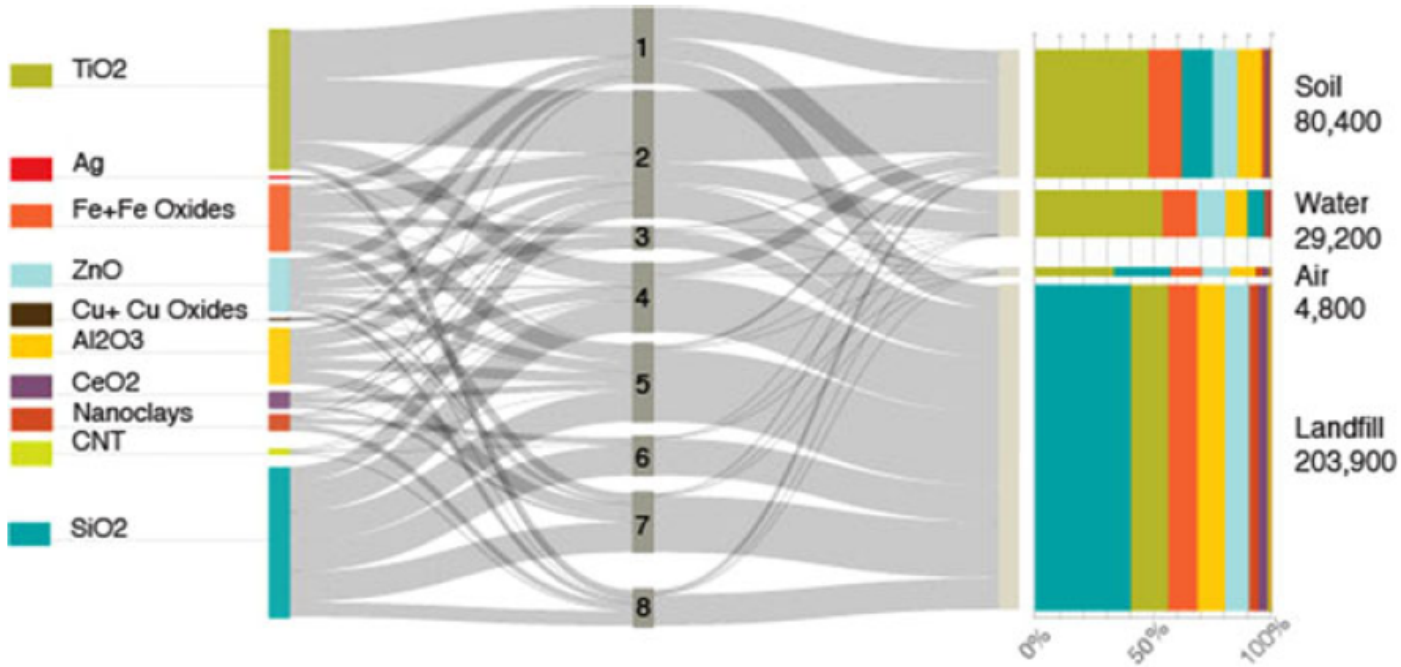
**IV Workshop NanoInnovation 2020 'Agri-nanotechniques: Nanomaterials for products and application in agriculture'.**

Nano 2020 Innovation
Rome, 15-18 September
Conference & Exhibition

# ENMs in the Environment

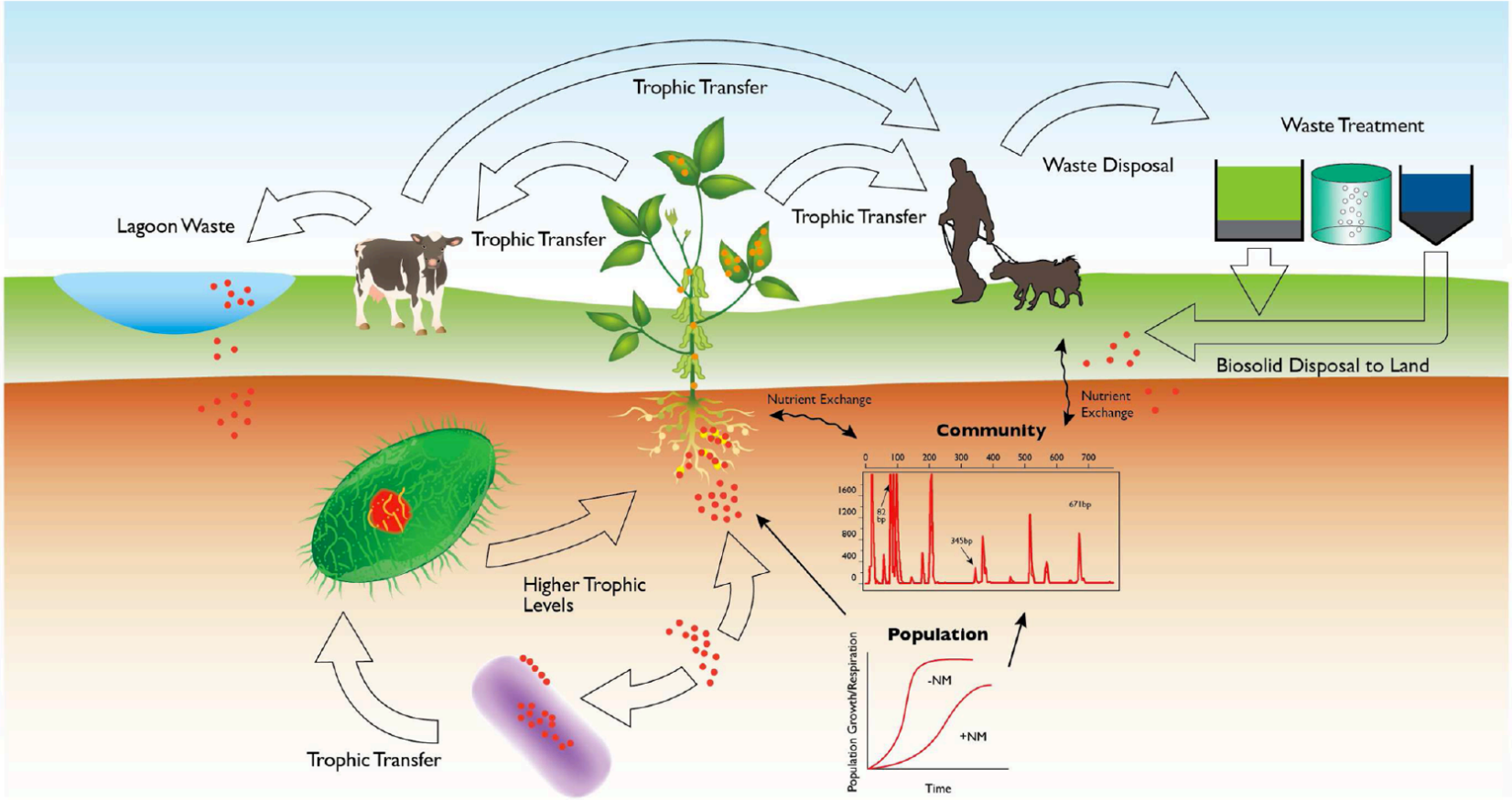



| | | | |
|---|---|---|---|
| 1. Cosmetics | 48,000 | 5. Electronics & Optics | 48,700 |
| 2. Coatings, Paints, & Pigments | 80,500 | 6. Automotive | 23,500 |
| 3. Medical | 13,400 | 7. Catalysts | 37,500 |
| 4. Energy & Environment | 43,700 | 8. Other | 22,900 |

***Keller et al.* 2013**

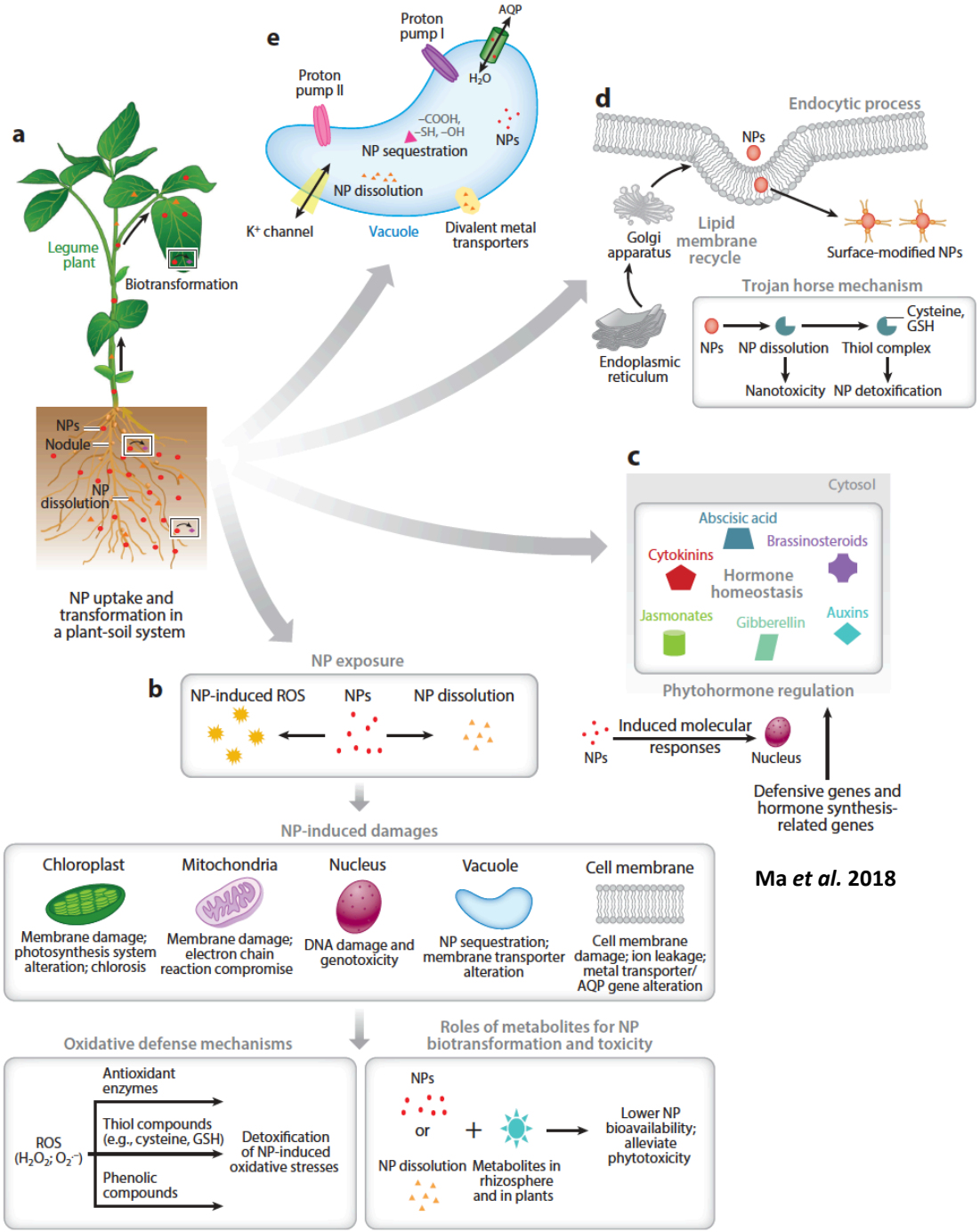
**What happens to ENMs after disposal?**

# ENMs in the Environment




*Holden et al.* 2013

# ENMs exposure induce oxidative stress response in plants



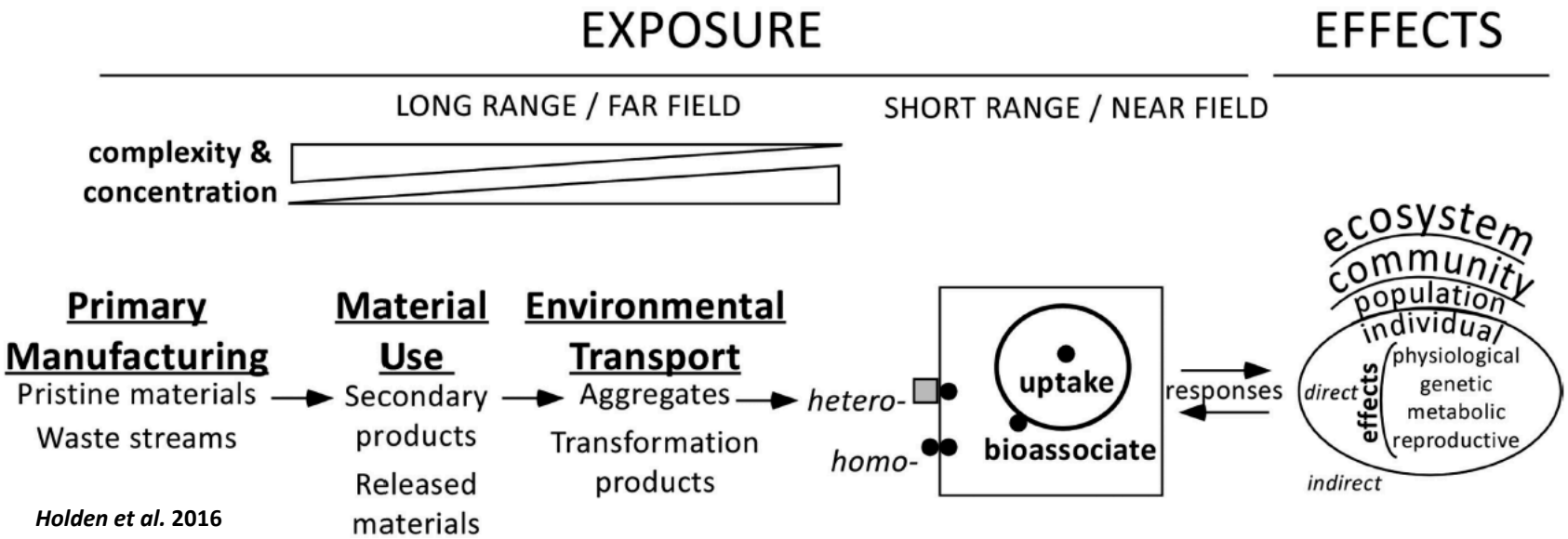

Ma *et al.* 2018

Effects on the various cellular compartments are able to trigger a series of responses to different stimuli (e.g. oxidative stress, abiotic and biotic stress)

Mitochondria and chloroplast in higher eukaryotes are not only the energy power plant of the cells but have an important regulatory and developmental role

Experimental data have shown that mitochondria and chloroplasts are between the primary targets of metal-based ENMs

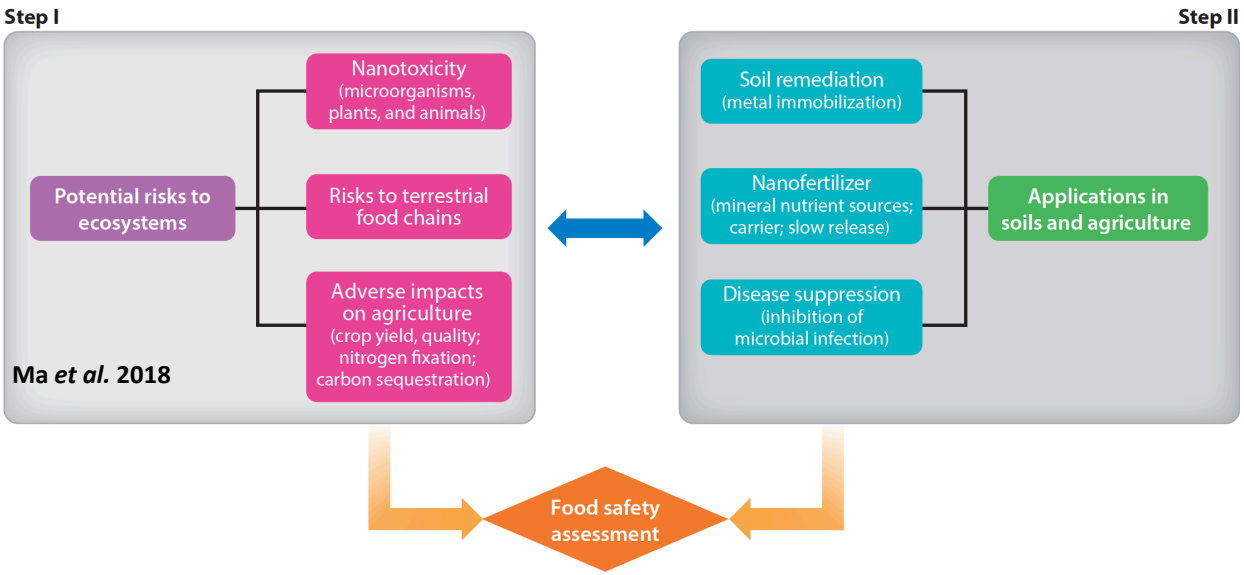
# ENMs Risk assessment




*Holden et al.* 2016

**How to assess exposure and effects in a ENMs risk assessment procedure?**

# From implication to application




**Effect of Metalloid and Metal Oxide Nanoparticles on Fusarium Wilt of Watermelon**

**Wade Elmer,**† Department of Plant Pathology and Ecology, The Connecticut Agricultural Experiment Station, New Haven; **Roberto De La Torre-Roche,** Department of Analytical Chemistry, The Connecticut Agricultural Experiment Station, New Haven; **Luca Pagano,** Department of Chemistry, Life Sciences and Environmental Sustainability, University of Parma, 43124 Parma, Italy; **Sanghamitra Majumdar** and **Nubia Zuverza-Mena,** Department of Analytical Chemistry, The Connecticut Agricultural Experiment Station; **Christian Dimkpa,** International Fertilizer Development Center, Muscle Shoals, AL, 35662; **Jorge Gardea-Torresdey,** Department of Chemistry and Biochemistry, The University of Texas at El Paso 79968; and **Jason C. White,** Department of Analytical Chemistry, The Connecticut Agricultural Experiment Station

Plant Disease

## Sensitive parameters to elucidate the ENMs response in the Environment

- ENM structure (physico-chemical properties, size, charge, stability, coating)
- Interactions of ENMs with environment (soil, microbial communities, living organisms)
- Interactions between differential ENMs or metals
- ENM behaviour within the living organisms tissues (biotransformation)
- Effects on tissues, organs of living organisms from physiological point of view to the molecular response at cellular and sub-cellular level.

NANOTOXICOLOGY, 2017
http://dx.doi.org/10.1080/17435390.2016.1277274

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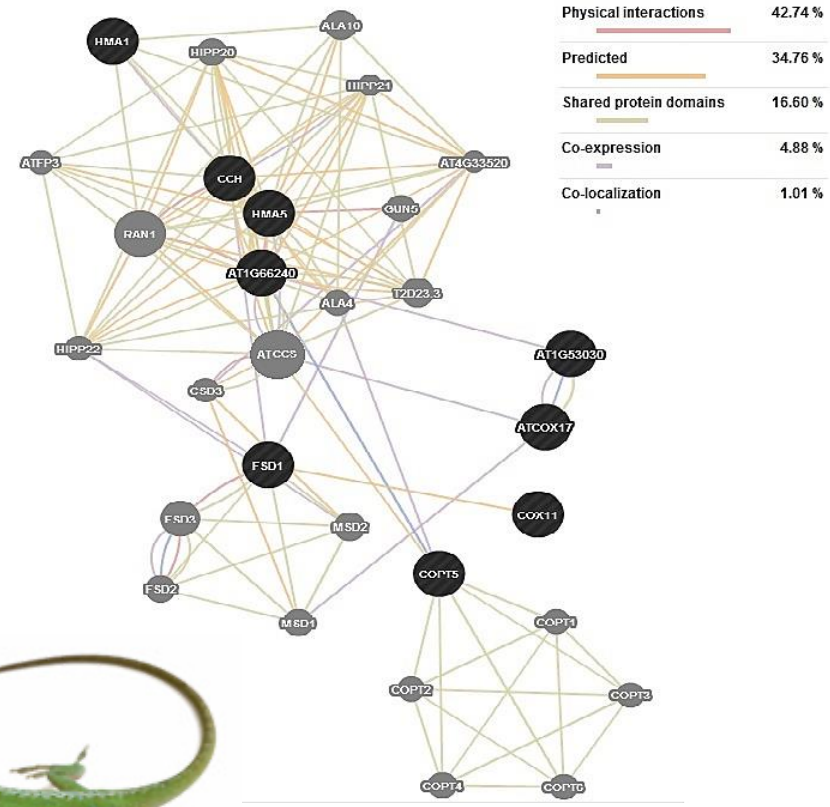
ORIGINAL ARTICLE

# Weathering in soil increases nanoparticle CuO bioaccumulation within a terrestrial food chain

Alia D. Servin[a], Luca Pagano[a,b,c], Hiram Castillo-Michel[d], Roberto De la Torre-Roche[a], Joseph Hawthorne[a], Jose A. Hernandez-Viezcas[e], René Loredo-Portales[f,g], Sanghamitra Majumdar[a], Jorge Gardea-Torresday[e,h], Om Parkash Dhankher[b] and Jason C. White[a]

In order to assess the correlation between the CuO NPs, CuO bulk and $CuSO_4$, RT qPCR was performed on genes known as commonly involved in $Cu^{2+}$ response




- Untreated
- CuO NPs (400 mg/L) unweathered
- CuO bulk (400 mg/L) unweathered
- $CuSO_4$ (54 mg/L) unweathered
- CuO NPs (400 mg/L) weathered (60 days)
- CuO bulk (400 mg/L) weathered (60 days)
- $CuSO_4$ (54 mg/L) weathered (60 days)

***Lactuca sativa***

***Acheta domesticus***

***Anolis carolinensis***

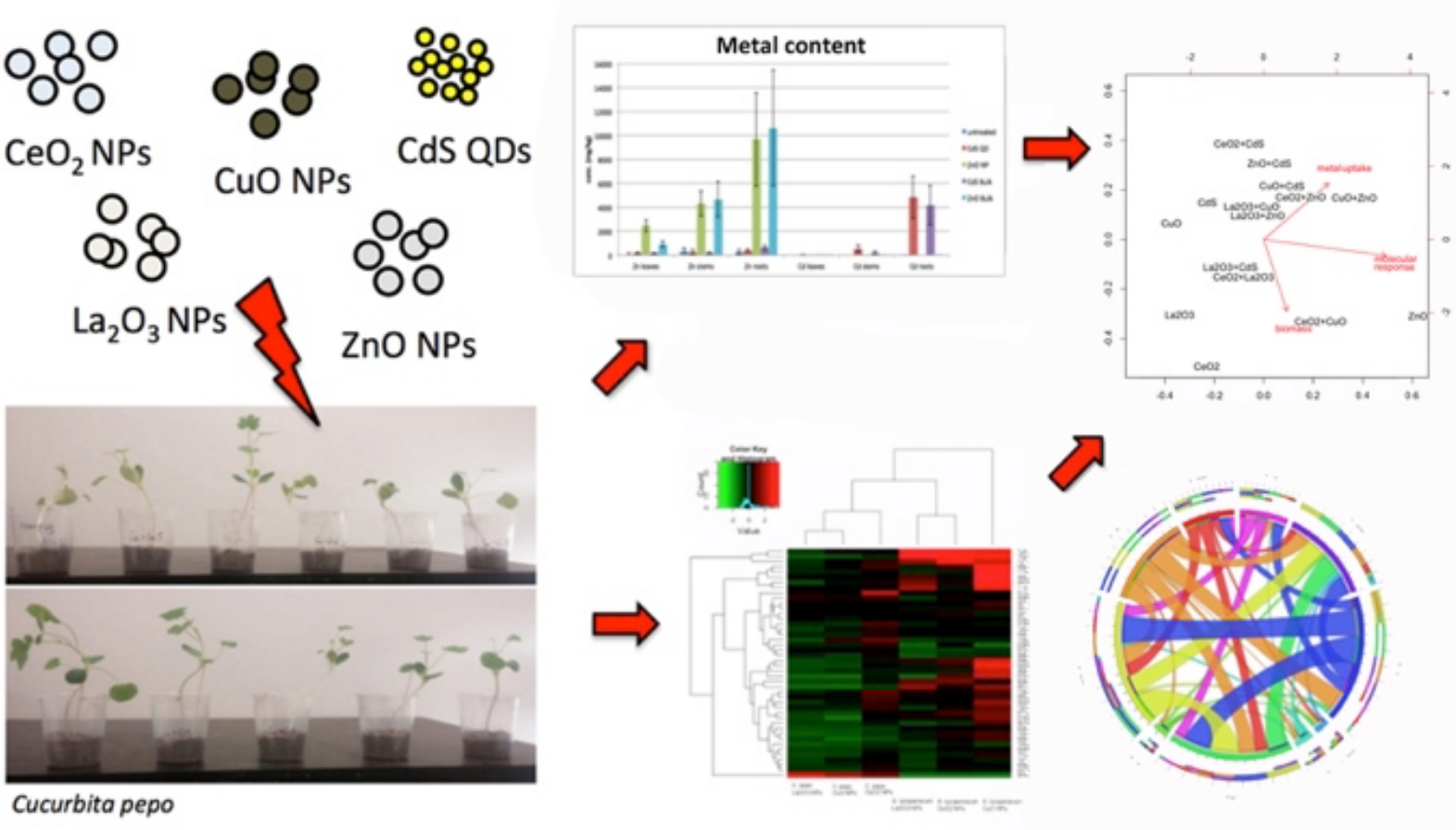
Environmental Science Nano

ROYAL SOCIETY OF CHEMISTRY

PAPER

# Exposure of *Cucurbita pepo* to binary combinations of engineered nanomaterials: physiological and molecular response†‡

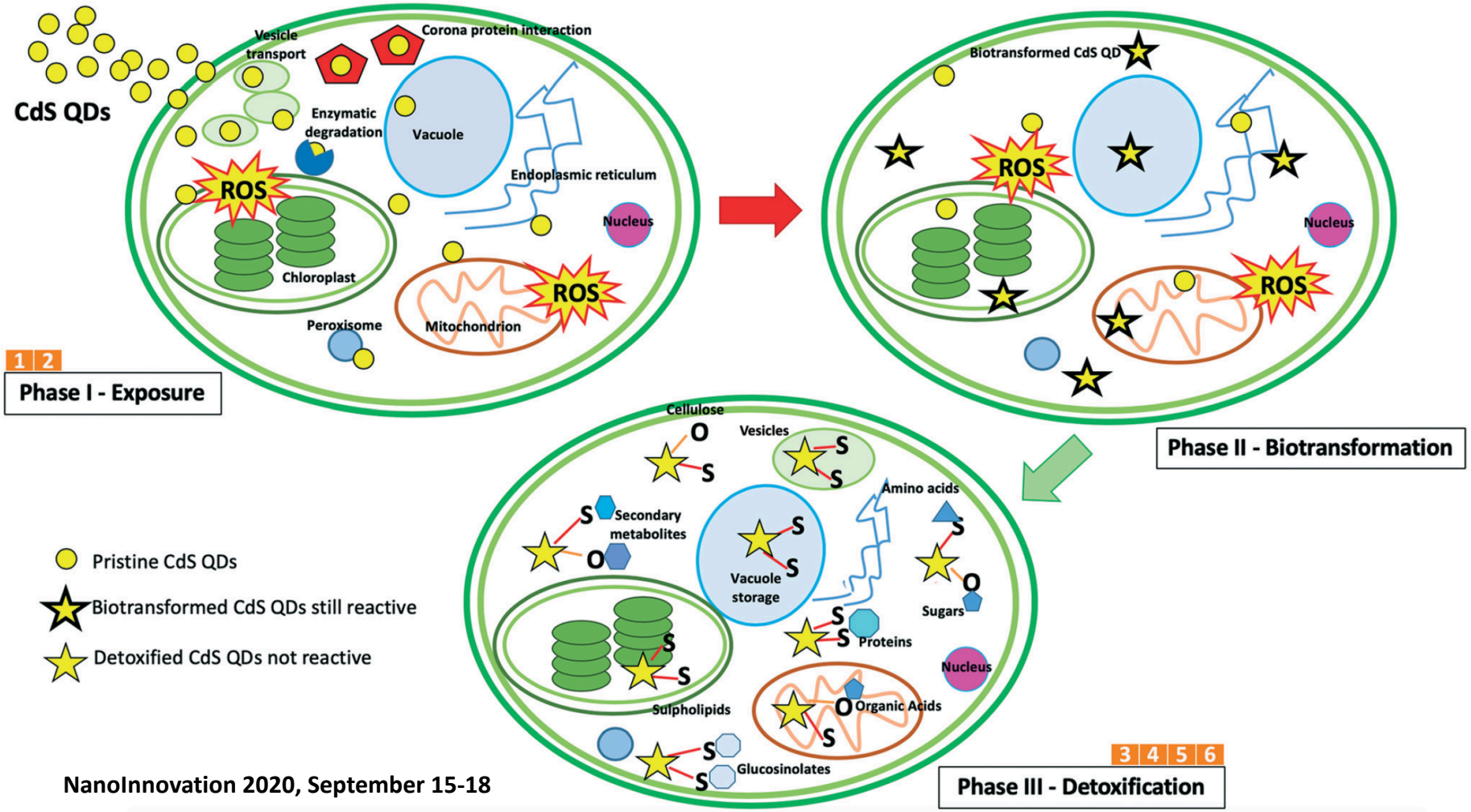
Luca Pagano,[abc] Francesco Pasquali,[a] Sanghamitra Majumdar,[c] Roberto De la Torre-Roche,[c] Nubia Zuverza-Mena,[c] Marco Villani,[d] Andrea Zappettini,[d] Robert E. Marra,[c] Susan M. Isch,[e] Marta Marmiroli,[a] Elena Maestri,[a] Om Parkash Dhankher,[b] Jason C. White *[c] and Nelson Marmiroli *[c]



Environmental Science Nano

# The fate of CdS quantum dots in plants as revealed by extended X-ray absorption fine structure (EXAFS) analysis†

Marta Marmiroli, ‡*[a] Giovanni Orazio Lepore, ‡*[b] Luca Pagano, [a] Francesco d'Acapito, [b] Alessandra Gianoncelli, [c] Marco Villani, [d] Laura Lazzarini,[d] Jason C. White [e] and Nelson Marmiroli [af]



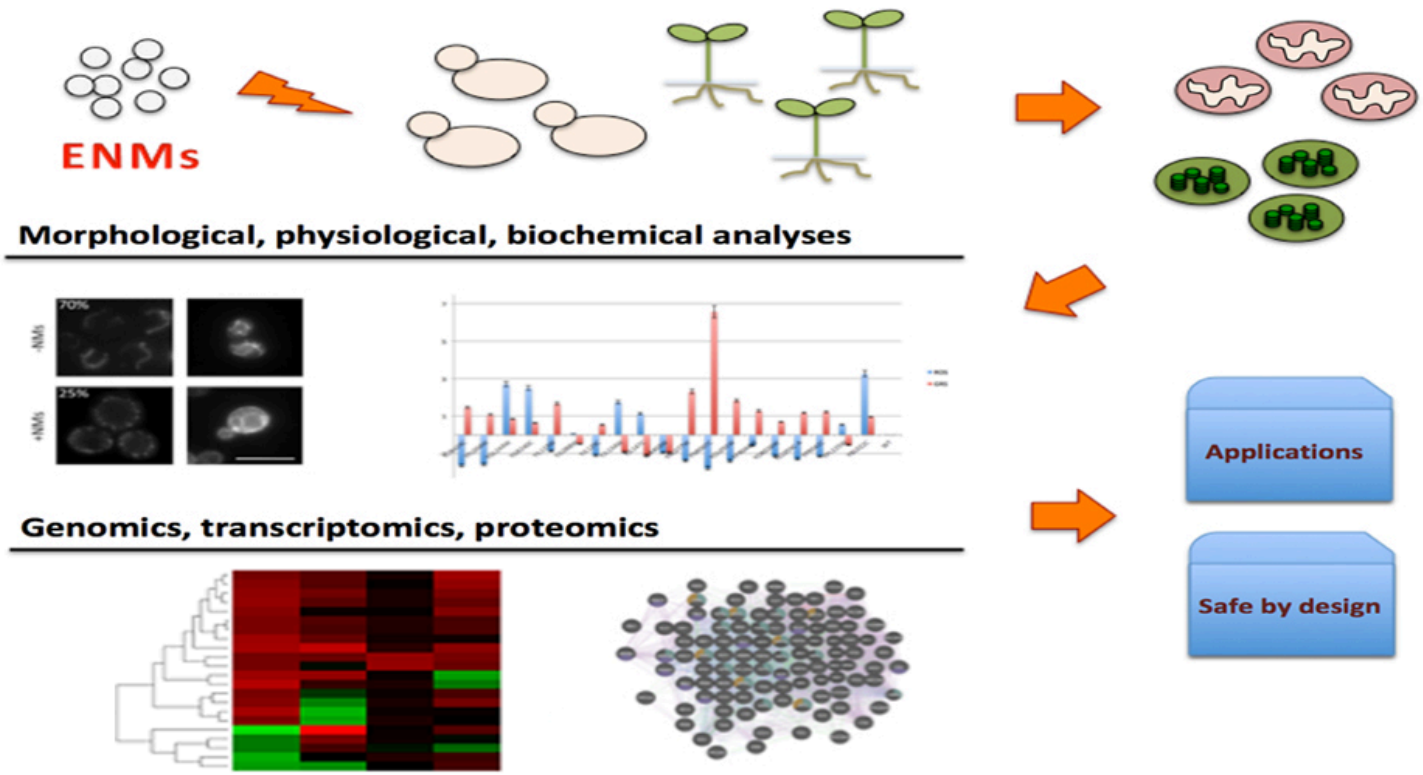
ACS Sustainable Chemistry & Engineering

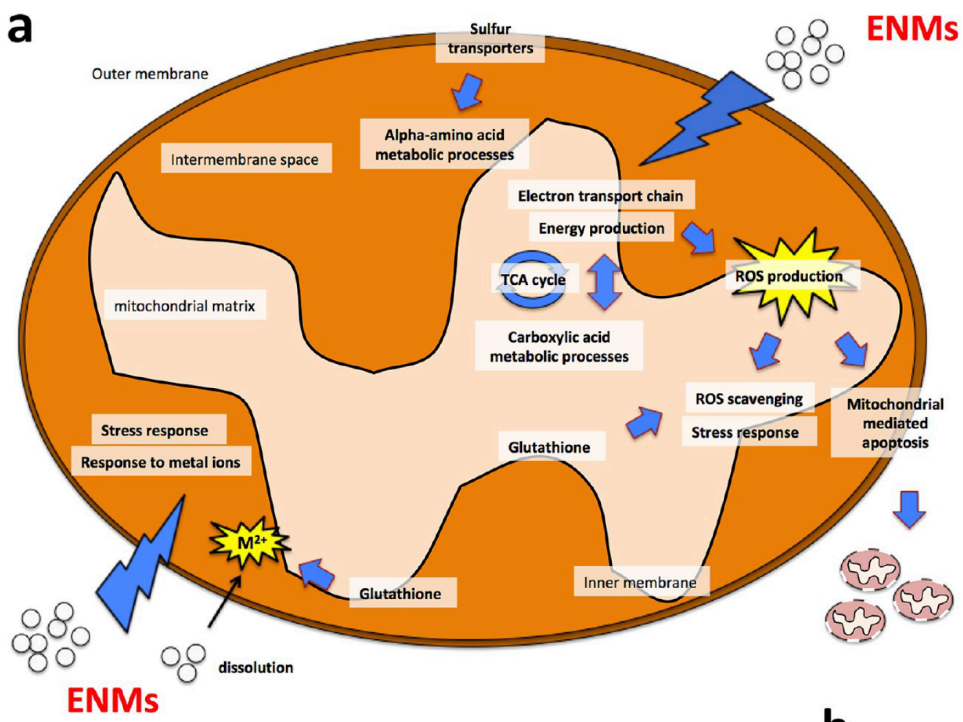
Perspective

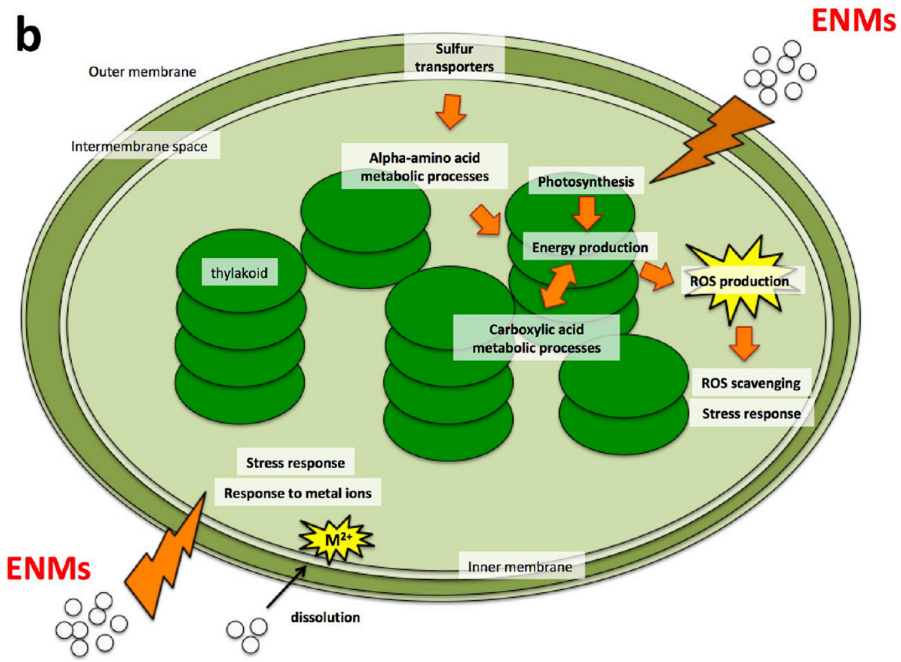
pubs.acs.org/journal/ascecg

# Engineered Nanomaterial Activity at the Organelle Level: Impacts on the Chloroplasts and Mitochondria

Luca Pagano,[†] Elena Maestri,[†] Marina Caldara,[†] Jason C. White,[‡] Nelson Marmiroli,[*,†] and Marta Marmiroli[†]




a
ENMs
Sulfur transporters
Outer membrane
Alpha-amino acid metabolic processes
Intermembrane space
Electron transport chain
Energy production
TCA cycle
ROS production
mitochondrial matrix
Carboxylic acid metabolic processes
ROS scavenging
Mitochondrial mediated apoptosis
Stress response
Stress response
Glutathione
Response to metal ions
M2+
Glutathione
Inner membrane
dissolution
ENMs


b
ENMs
Sulfur transporters
Outer membrane
Intermembrane space
Alpha-amino acid metabolic processes
Photosynthesis
Energy production
thylakoid
ROS production
Carboxylic acid metabolic processes
ROS scavenging
Stress response
Stress response
Response to metal ions
M2+
Inner membrane
ENMs
dissolution

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