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Enlightening
Interdisciplinarity
in STEM
for Teaching

NanoScience-NanoTechnology module

Interdisciplinary Explorer Activity

Co-funded by the
Erasmus+ Programme
of the European Union

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Name some serious (science-related) **global problems/challenges** that the world is confronting in 2021

Image: pngtree.com

Contemporary problems/challenges:

- Environmental pollution & Climate change
- Energy crisis/global need for fuel
- Overpopulation/increased grobal need for food
- Healthcare, emerging diseases/need for targeted treatment
- Economical welfare & technological development

- **Environmental pollution & Climate change**
- **Energy crisis/global need for fuel**

Efficient & sustainable technologies

- Alternative energy sources: solar cells (only 0,04% or energy supply in 2007, ~2% in 2017)

(1st gen.) Conventional Si-based

- Not ecofriendly materials (Si)
- High manufacturing and energy costs
- 15-20% efficiency

(2nd gen.) Thin film amorphous Si, Cd compounds

- Cost-efficient
- Module stability problems
- 10-15% efficiency

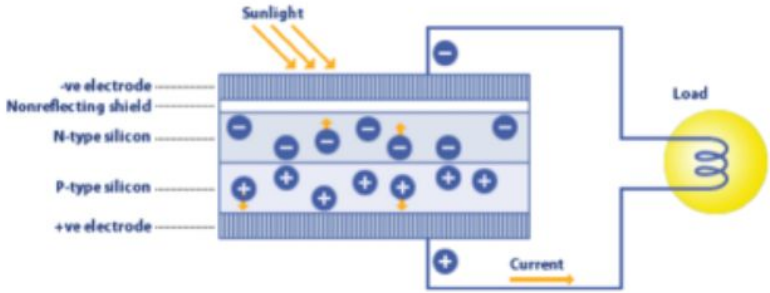


photo: https://www.elke.teicrete.gr/LinkClick.aspx?fileticket=M_PN6BSc9QY%3D&tabid=670

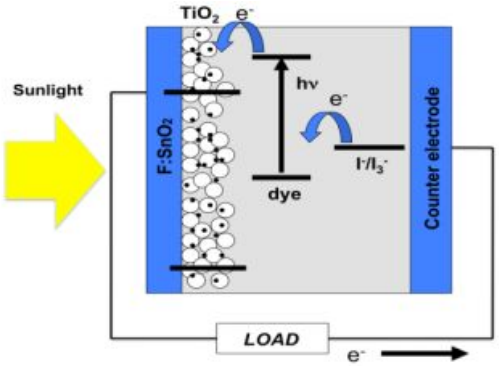
(Pathakoti et al. 2018)

- **Environmental pollution & Climate change**
- **Energy crisis/global need for fuel**

Efficient & sustainable technologies

(3rd gen.) Nanocrystals & Nanoporous materials

- Organic solar cells (conjugate polymer) (6% eff.)
- Dye-sensitised solar cells (dyes) (11% eff.)
- Quantum dot solar cells (semiconductor nanocrystal) (42%eff.)



Juice from Juice
NSF Center for Innovation in Solar Fuels
California Institute of Technology

(Pathakoti et al. 2018)

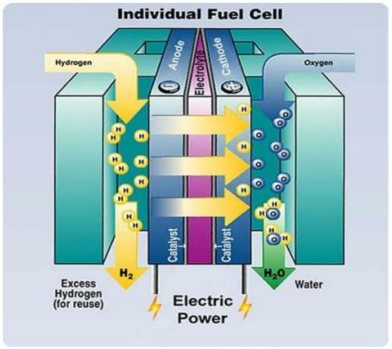
- **Environmental pollution & Climate change**
- **Energy crisis/global need for fuel**

Efficient & sustainable technologies

Fuel cells

$2H_2+O_2 \rightarrow 2H_2O$

- Zero-emissive, not polluting, efficiency 50-60%



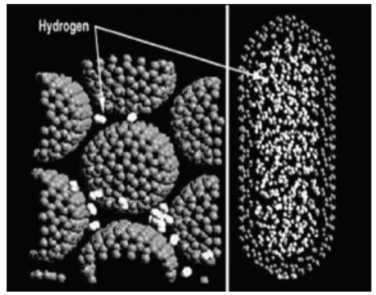


Fig. 4. Hydrogen Storage [18].

Images: Pandiyan & Prabaharan (2020)

Production of H with the use of nanoparticles and water (s/v ratio)

Designer molecules for production of H (emulating natural processes e.g. chlorophyl)

Storing H (carbon nanotubes) vs conventional compressed gas/liquid (space needed)

Miniature fuel cells for portable devices

Application: aircrafts, spacecrafts

(Pandiyan & Prabaharan 2020, Pathakoti et al. 2018)

- **Environmental pollution & Climate change, Healthcare**

Nanomaterials for sustainable water treatment systems

- 2millions deaths per year (mostly children) from biologically unsafe water & preventable waterborne diarrheal diseases

- Conventional solutions: chemical disinfectants (eg chlorine, chloramine, ozone) or germicidal UV radiation
- Extensive infrastructure,
- Energy-, chemical-intensive
- Chemical by-products

(Mauter et al. 2018)

- **Environmental pollution & Climate change, Healthcare**

Nanomaterials for sustainable water treatment systems

Engineerered nanomaterials (e.g. NP of Ag, ZnO, TiO_2, fullerenes, C nanotubes, graphene)

Pathogen inactivation & decontamination

- cell-wall disruption by nanoscale structures,
- surface-active processes (electrostatic interactions)
- photochemical generation of reactive oxygen species
- targeted delivery of disinfected agents

Affordances:

- Large surface area
- Specific reactivity

(Mauter et al. 2018)

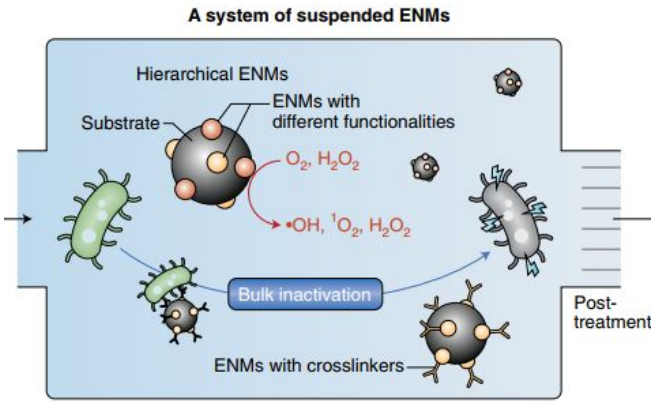


Image: Mauter et al. (2018)

- **Environmental pollution & Climate change, Healthcare**

Photocatalytic dyes for improved air quality

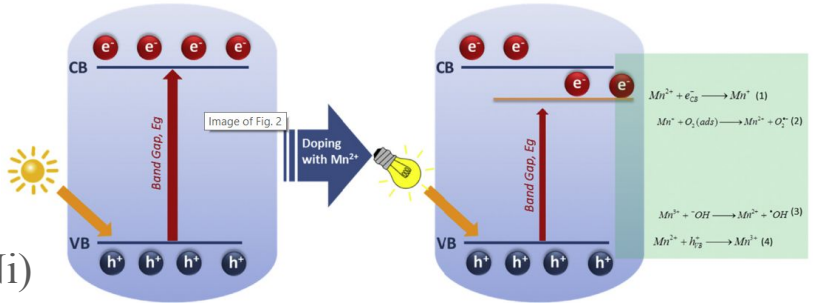
- Air pollution possesses the sixth place among the leading causes of death globally (W.H.O.)

Light and nanoparticles of TiO_2 for creating hydroxyl radicals OH^- and hyperoxide radicals O_2^-
Degradation/mineralisation of pollutants, oxidative microrganisms causing their inactivation

Activation in the UV spectrum.
Activated in the visible spectrum through:

Semiconductors in the nanoscale –increase on surface area

Doping with non-metal (C, N, S, I) and metal (Cr, Mn, Fe, Ni) ions



(Binas et al. 2017)

Image: Binas et al. (2017)

- **Overpopulation/increased grobal need for food**

  - Extensive usage of fertilizers irreversibly alter the chemical ecology of soil, further reducing the available area for crop production
  - Reduced crop yield due to biotic and abiotic stresses, including nutrient deficiency and environmental pollution

(Swang et al. 2019)

- **Overpopulation/increased grobal need for food**

- Increased surface area to nanofertilisers and nanopesticides
- Site-targeted controlled delivery of nutrients eg Ag
- Nano-biosensors for precision farming

(Swang et al. 2019)

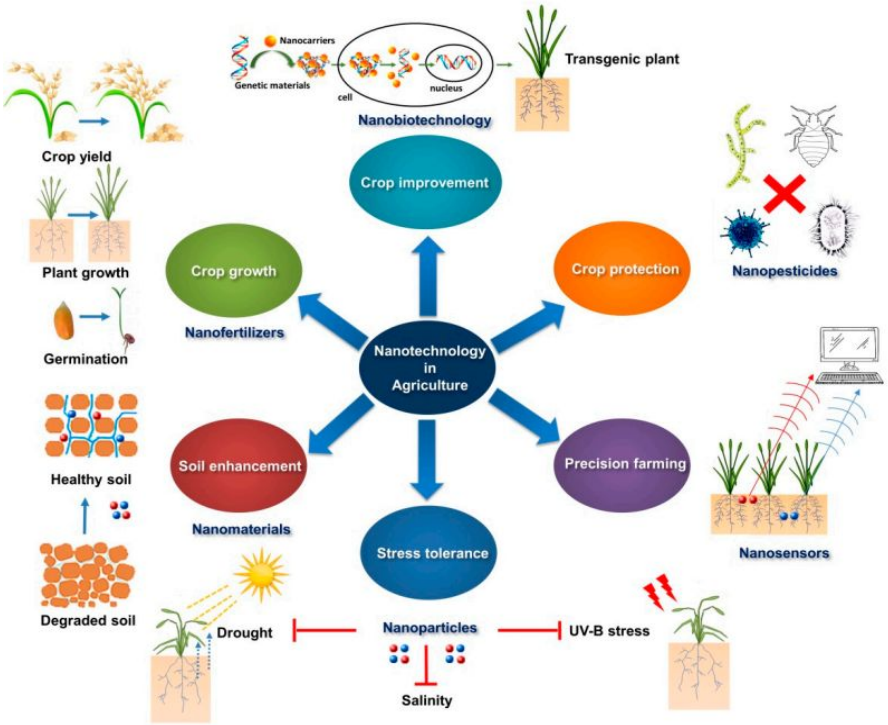


Image source: Swang et al. (2019)

- **Healthcare, emerging diseases/need for targeted treatment**

Targeted drug delivery, controlled release & enhancement of bioavailability

DNA scaffolds/nanocapsules-polymers for “coating” (slower rates of release)
Nanorobots & drug delivery vehicles for diagnosis and treatment
Nanotubes and nanowires for diagnosis (e.g. cancer)
Metal nanoparticles (Au, Ag, Cu) for antimicrobial, anticancer activities

- Bottom-up or top-down fabrication

(Jackson et al. 2021, Rothermund 2006)

- **Healthcare, emerging diseases/need for targeted treatment**

Covid diagnosis

- PCR method
  - Time-consuming
  - Labor-intensive
  - Tained laboratory workers needed

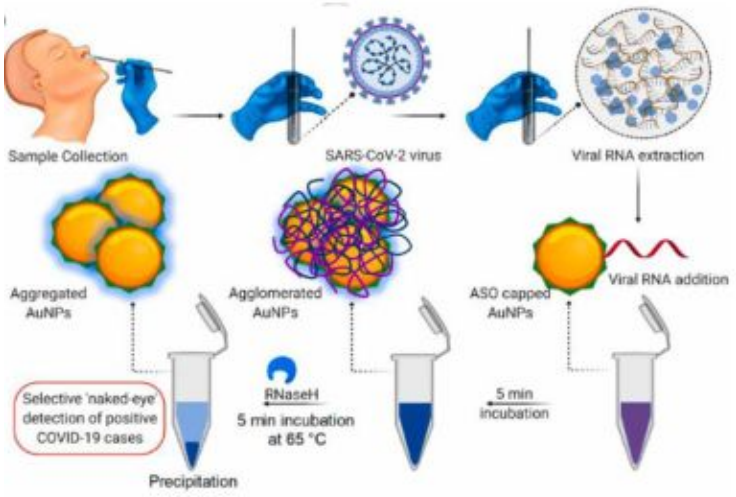


Image: Moitra et al. (2020)

Nano-biosensors

Au nanoparticles (mix) tend to disperse individually if not infected –while they are agglomerated and formed large clusters in the presense of SARS COVID 2 RNA.

(Pishva, & Yüce 2021)

- **Healthcare, emerging diseases/need for targeted treatment**
  - Organ implantation is restricted by the shortage of accessible donors and expensive processes

NST & Tissue Engineering: acceleration of the recovery of damaged issues

- Optimise characteristics of scaffolds and tune their biological functionality
- Provide scaffolds by delivering loaded drugs

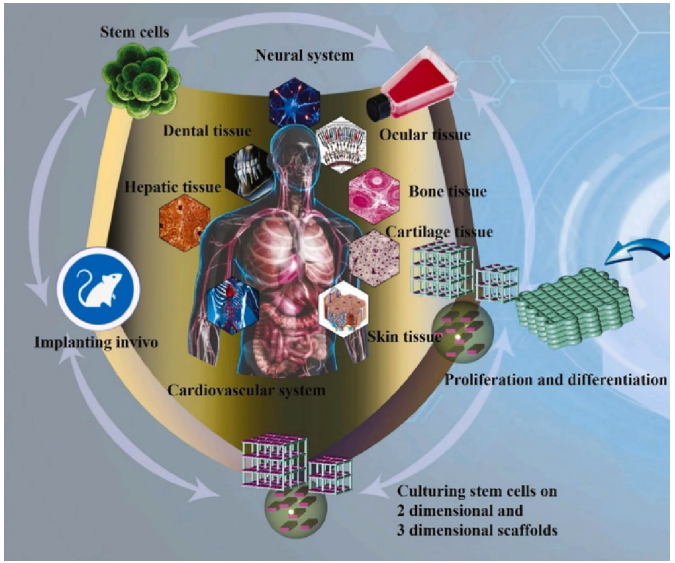


Image: Abdolahiyan et al. (2021)

(Abdolahiyan et al. 2021)

- **Healthcare**

Bacterial adhesion and biofilm formation on biomedical surfaces for public health

Antivacterial sharkskin-mimetising surface deflects accumulation of vacteria/algae/barnacles

Applications: medical equipment, railings, door handles in hospitals

(Tan et al. 2020, Ball 1999)

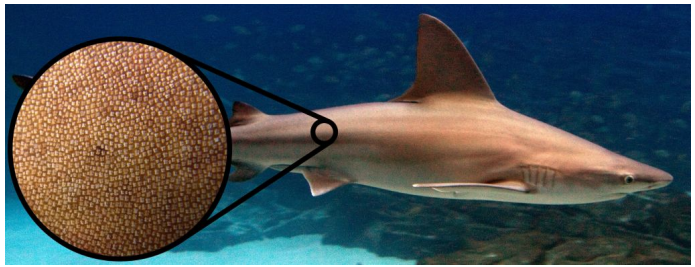


Image: https://sustainable-nano.com/2013/12/03/natures-nanotechnology-bio-mimicry-and-making-the-superpowers-of-your-dreams-a-reality-4 /

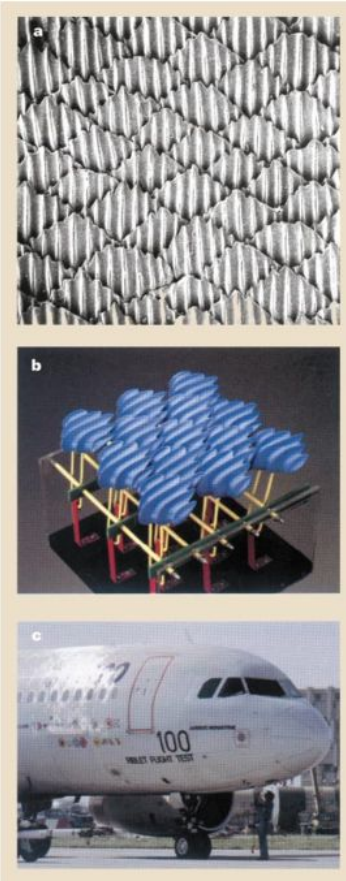


Image: Ball (1999)

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  Applications: medical equipment, railings, door handles in hospitals

(Tan et al. 2020, Ball 1999)

- **Technological development**

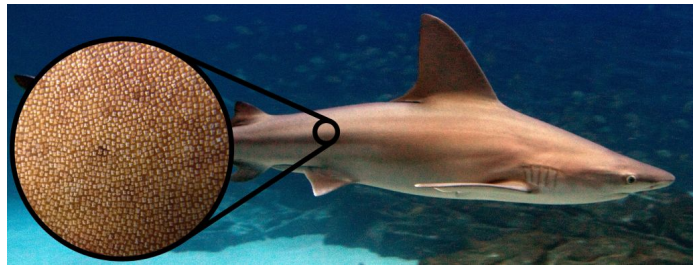
  Drag reduction in high speed due to ridges at the surface

  Contact area between vortices and surface is reduced (turbulent flow regime)

  Applications: aircrafts, boats, swimsuits

❑Nano or micro scale?

(Dai et al. 2019)



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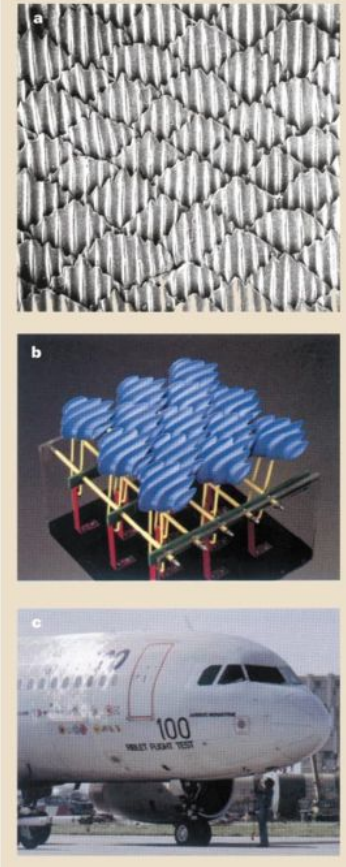

Image: Ball (1999)

- **Technological development**

NST & daily life

Sports: seeking for competitive performances!

- Tennis rackets (modulus graphite with carbon nanotubes), tennis balls
- Football shin pads (light, strength) , footballs (retain pressure)
- Golf balls (redistribute weight on the fly-change direction)
- Yacht sails (waterproof), yacht masts (carbon nanotubes: light & strength)

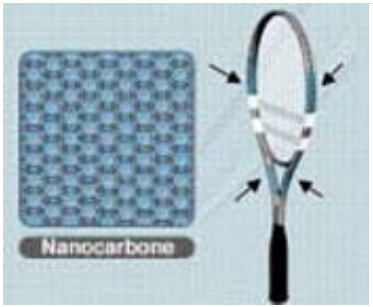

Image: www.nanotechproject.tech/

Image: www.cafepress.com
https://nano-magazine.com/news/2017/7/7/228q4lr8rr5orforgaord750aqs26b

Photo: https://www.nano4life.co/nano4-marinetextile-en

- **Technological development**

NST & everyday life

- Clothing (hydrophobicity)
- Cosmetics
    - perfumes,
    - sunscreens,
    - moisturizers,
    - anti-aging formulations,
    - nails and hair care

Image: Ngô & Van de Voorde (2014)

(Ngô & Van de Voorde 2014)

Overview: Contemporary problems/challenges:

- Environmental pollution & Climate change
- Energy crisis/global need for fuel
- Overpopulation/increased grobal need for food
- Healthcare, emerging diseases/need for targeted treatment
- Economical welfare & technological development

- **Guide 1 (20 min)**

Please read and answer the questions found in the document titled “Guide 1”

- **Reflection**

Please share and discuss your answers with the group

- **Reflection**

Discuss the following question:

Can you identify any commonalities among the aforementioned STEM disciplines?

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