

**13<sup>th</sup>** International Conference on the  
**SCIENTIFIC AND CLINICAL  
APPLICATIONS OF  
MAGNETIC CARRIERS**

LONDON, UNITED KINGDOM  
JUNE 14-17, 2022

# Short Review of the Last Four Years of Magnetic Carriers / 2018-2022

Urs Häfeli



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London, U.K.



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Krems, Austria



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# First Names – Please

*Sie*

**vd**

**Vous**

**Du**

**You**

# First Names – Please

13<sup>th</sup> International Conference on the  
Scientific and Clinical Applications of Magnetic Carriers  
London, UK — June 14-17, 2022 — [magneticmicrosphere.com](http://magneticmicrosphere.com)

Yevhen

Ablets

Technical University of Darmstadt -  
Germany

Just: You!

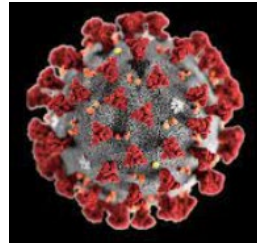
# Thank You





# Covid-19

- Unfortunately, this pandemic is not over yet
- Yesterday, 4766 people tested positive, 4 died
- The mayor of London recommends
  - Get vaccinated and boosted as soon as possible
  - Consider wearing a face covering, especially indoors and in poorly ventilated spaces
  - Stay at home and avoid contact with others for 5 days if you test positive for COVID-19
  - If you have symptoms of COVID-19 or other respiratory illness, stay at home until you no longer feel unwell
  - Remember good hygiene, including covering your mouth and nose with a tissue or your sleeve when you cough or sneeze and washing or sanitizing your hands regularly



# Our Special JMMM Issue – NOW ONLINE Since Yesterday

- **Editors:**

Silvio Dutz, Maciej Zborowski, Lucia Gutierrez

- We need your help in reviewing the papers – please say “yes” when we ask for your assistance. Thanks!

- And you can now submit:

**VSI: Magnetic Carriers 2022**

- *Limit: 1 per lab*



# DISCLAIMER

- This presentation is rather incomplete, opinionated, one-sided, and might NOT mention your research
- But that's why you have to stay around for the next 4 days ...



# The Relative Size of Particles

## THE RELATIVE SIZE OF PARTICLES

From the COVID-19 pandemic to the U.S. West Coast wildfires, some of the biggest threats now are also the most microscopic.

A particle needs to be 10 microns ( $\mu\text{m}$ ) or less before it can be inhaled into your respiratory tract. But just how small are these specks?

Here's a look at the relative sizes of some familiar particles »



MNPs

SOURCES: Cleanstream; David Lovett; EPA; Financial Times; News Medical; Science Direct; SCMP; Susan Sokolowski; Petrocenter, U.S. Dept. of Energy  
COLLABORATORS: RESEARCH • WRITING: Carolyn Ang, Imran Ghosh | DESIGN • ART DIRECTION: Harrison Schell

VISUAL  
CAPITALIST

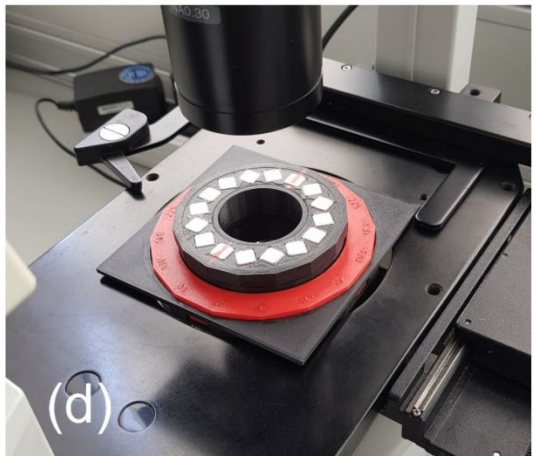
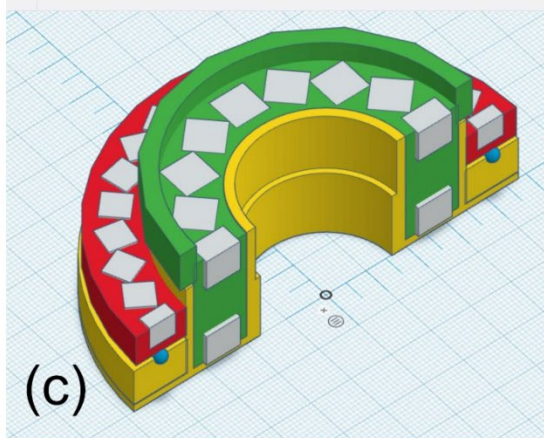
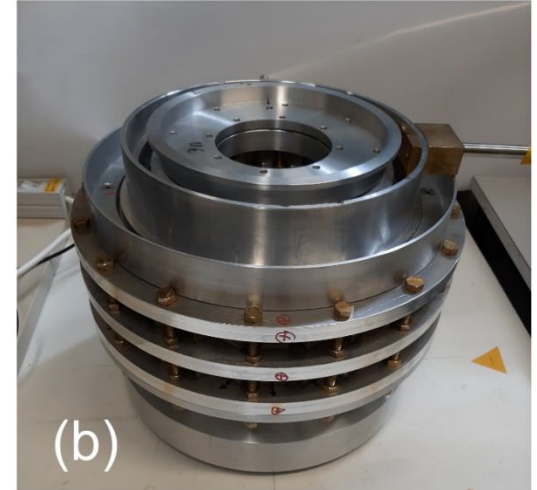
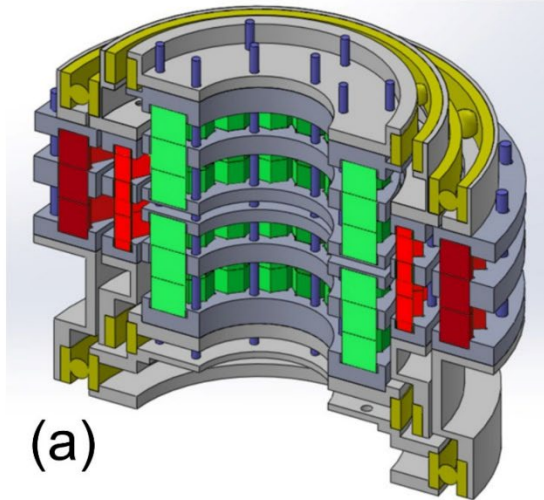
f /visualcapitalist @visualcap visualcapitalist.com

# Technical Applications



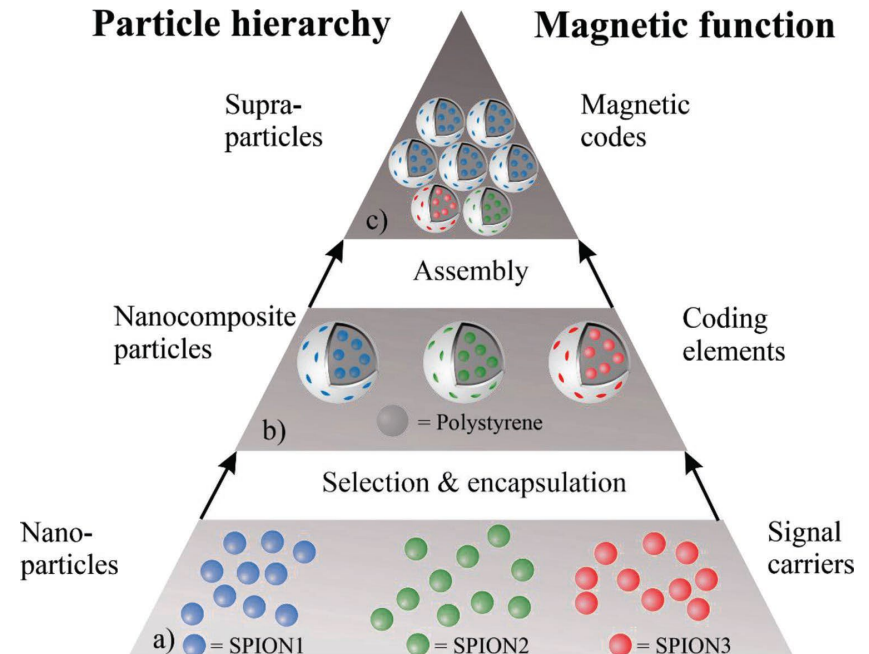
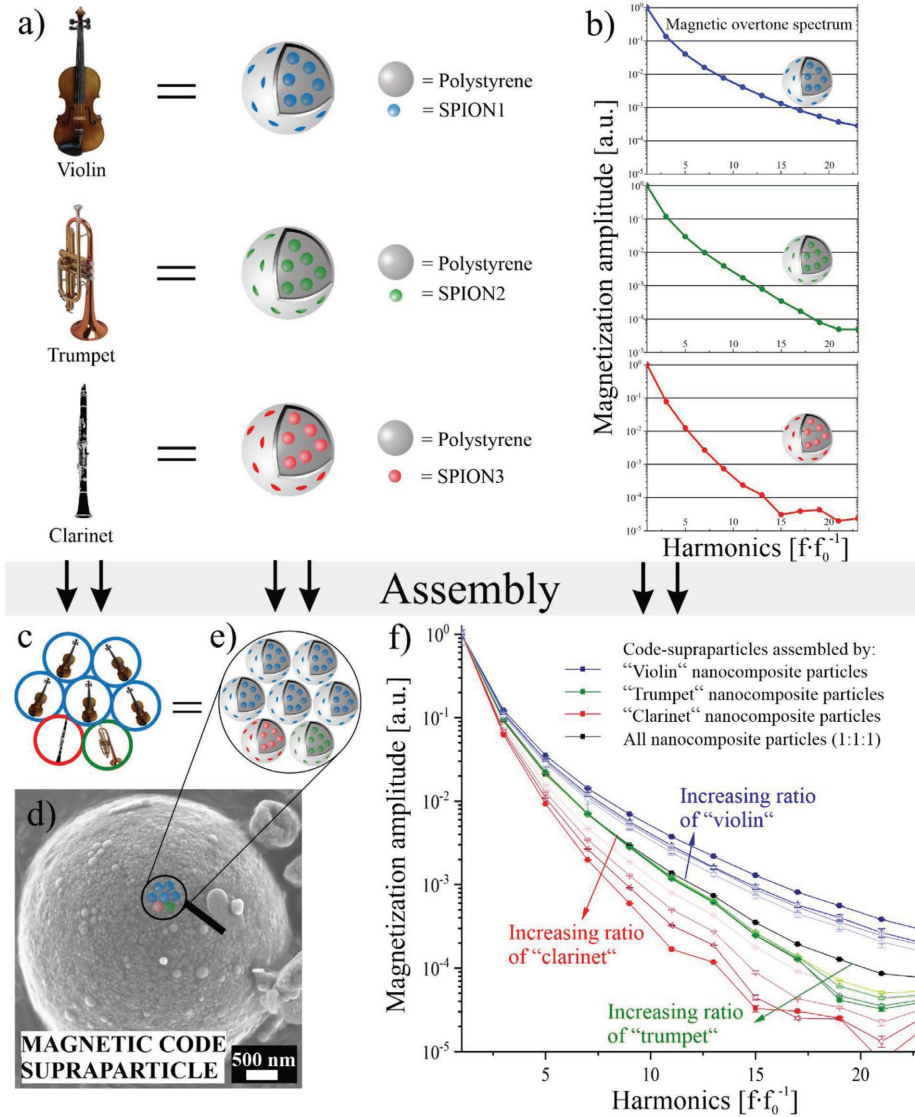
# Magnetic Guiding with Permanent Magnets

- Good review
- Application of Halbach arrays



Blümler Peter, Cells 2021, 10(10), 2708;  
<https://doi.org/10.3390/cells10102708>

# Encoding (+ Reading out) of 77 Billion Magnetic Codes in One Particle

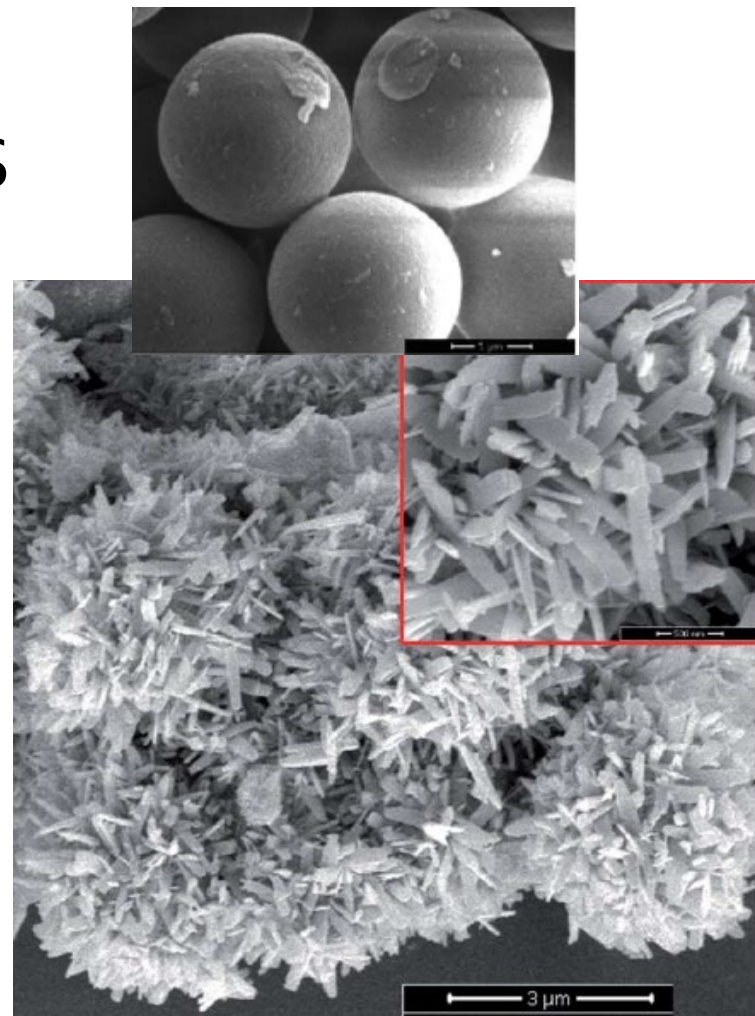
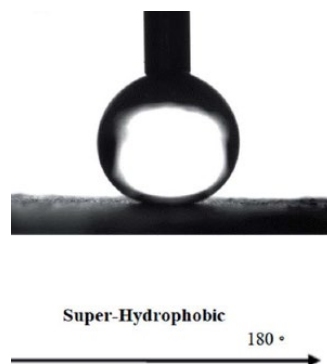


# Synthesis

# Prickly Shaped Iron-Carbonyl Particles

- Hydrothermal reaction to grow superhydrophobic MMS
- Central composite design method
- The optimal glucose concentration, temperature, and time were 0.75 Mol/L, 170 °, and 4 h, respectively

Rabbani Y et al., RSC Adv., 2022, 12, 12760–12772

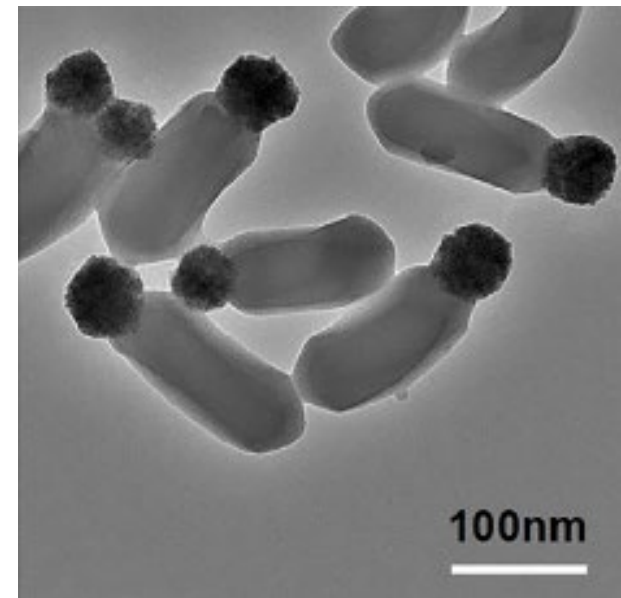
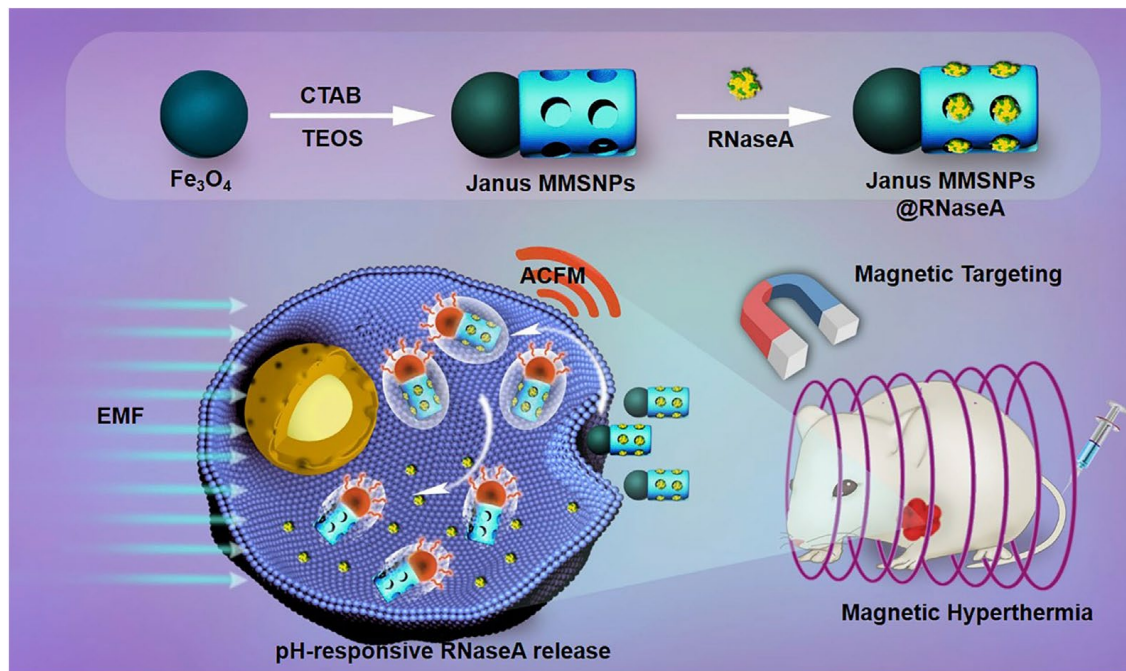




# RNaseA Loaded Janus Particles

- Magnetic hyperthermia
- Release of RNaseA protein
- Together effective in cancer model

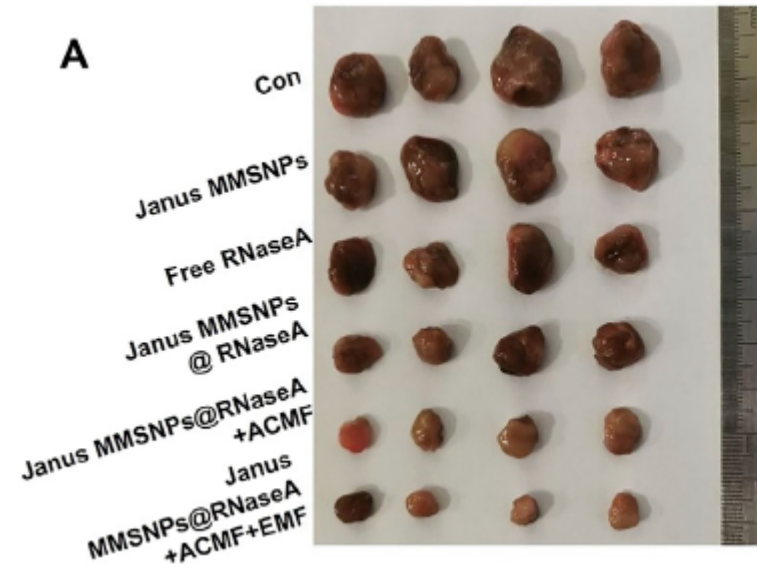
Zuo S et al., Front. Bioeng. Biotechnol. 9:763486. doi: 10.3389/fbioe.2021.763486



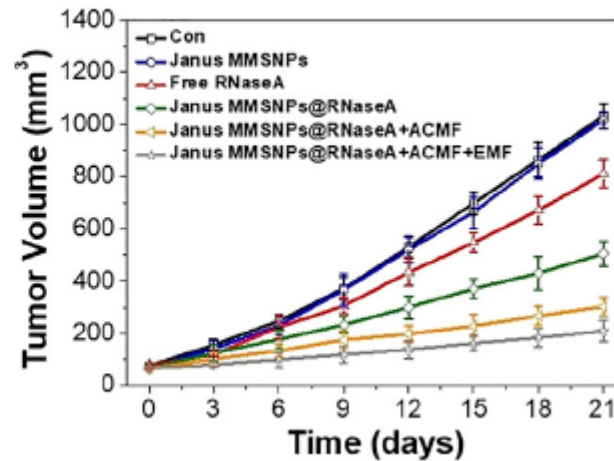


# RNaseA Loaded Janus Particles

A

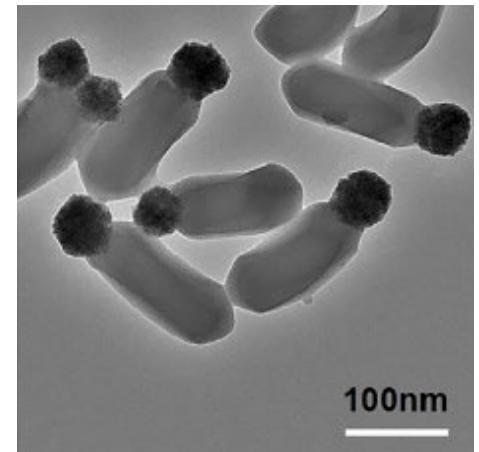
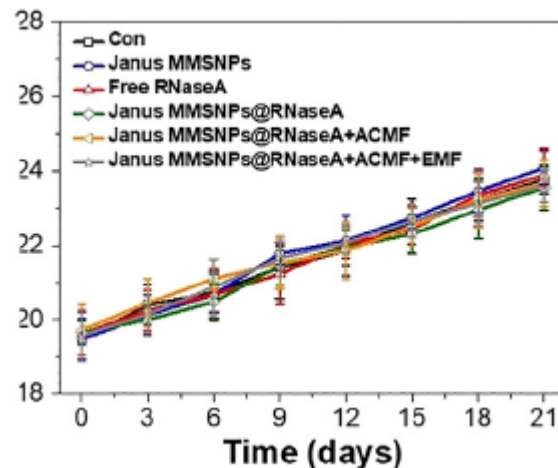


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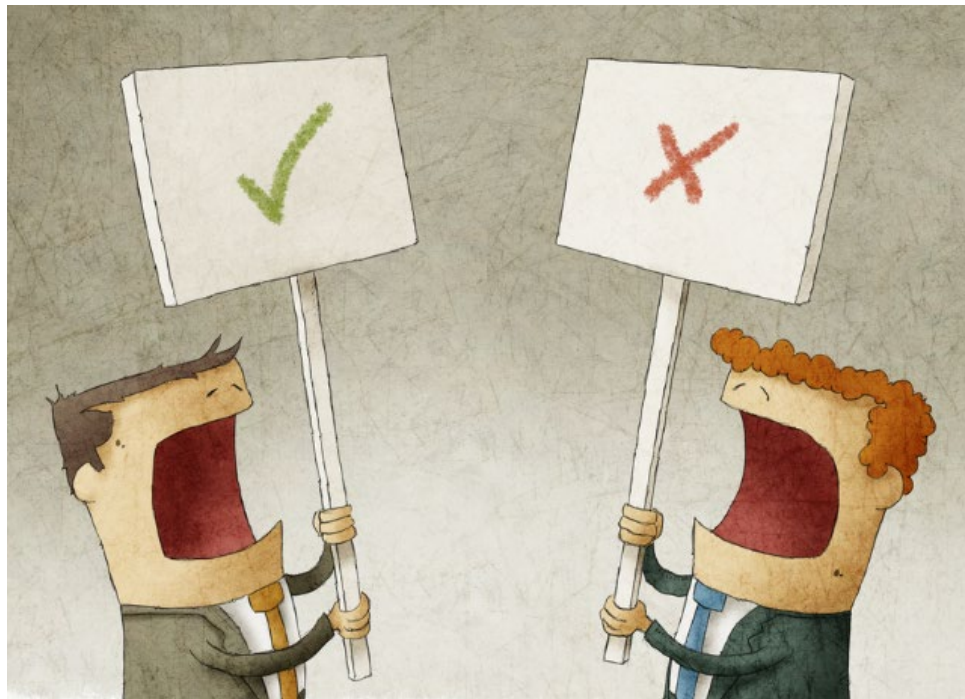
Zuo S et al., Front. Bioeng. Biotechnol. 9:763486

D



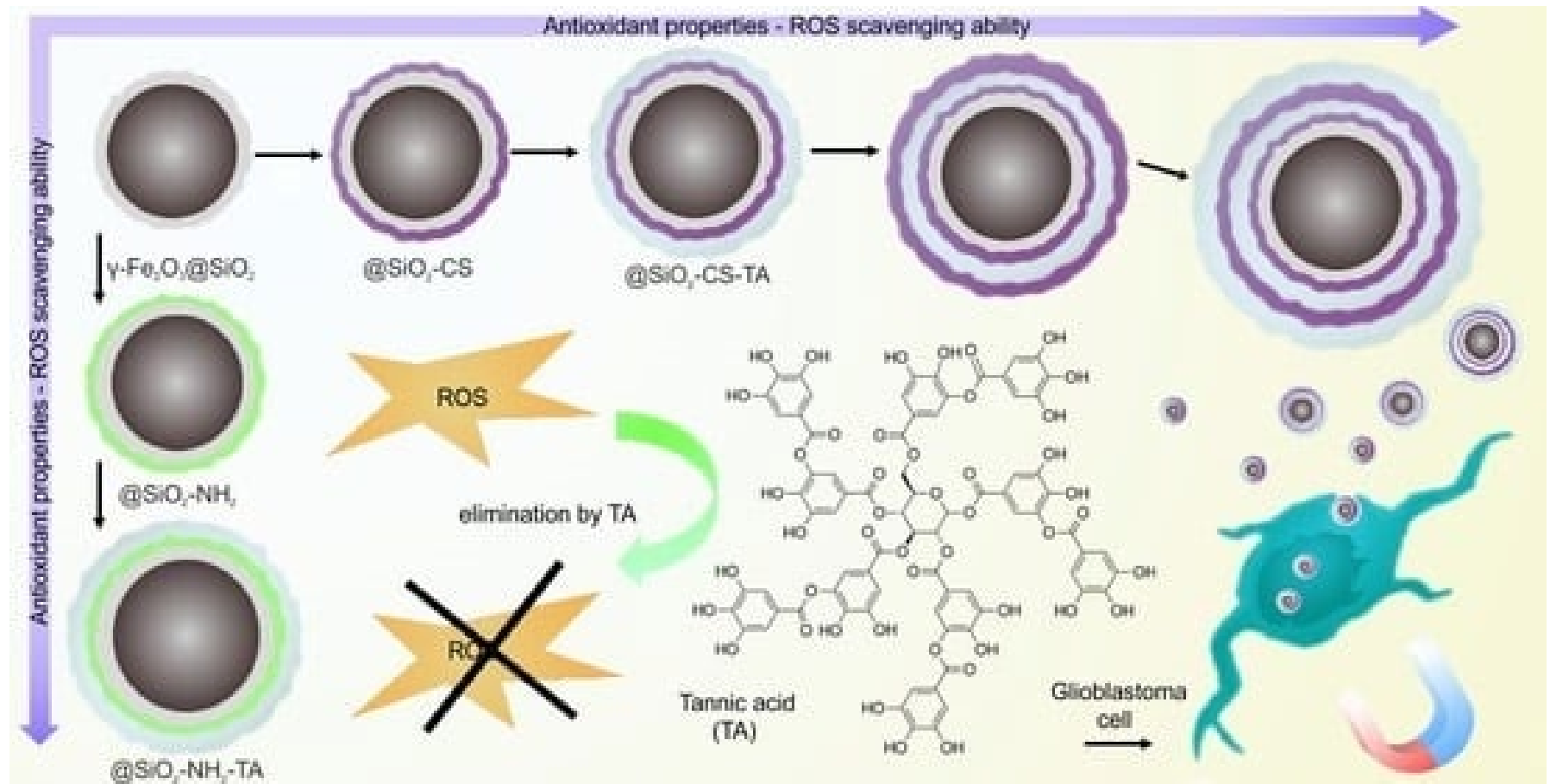
# New Magnetic Particles

- Discussion later this afternoon: Do we really still need new magnetic nanoparticle types?

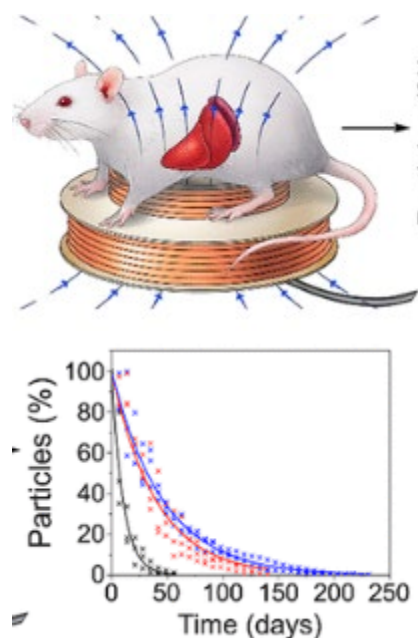


# Coatings

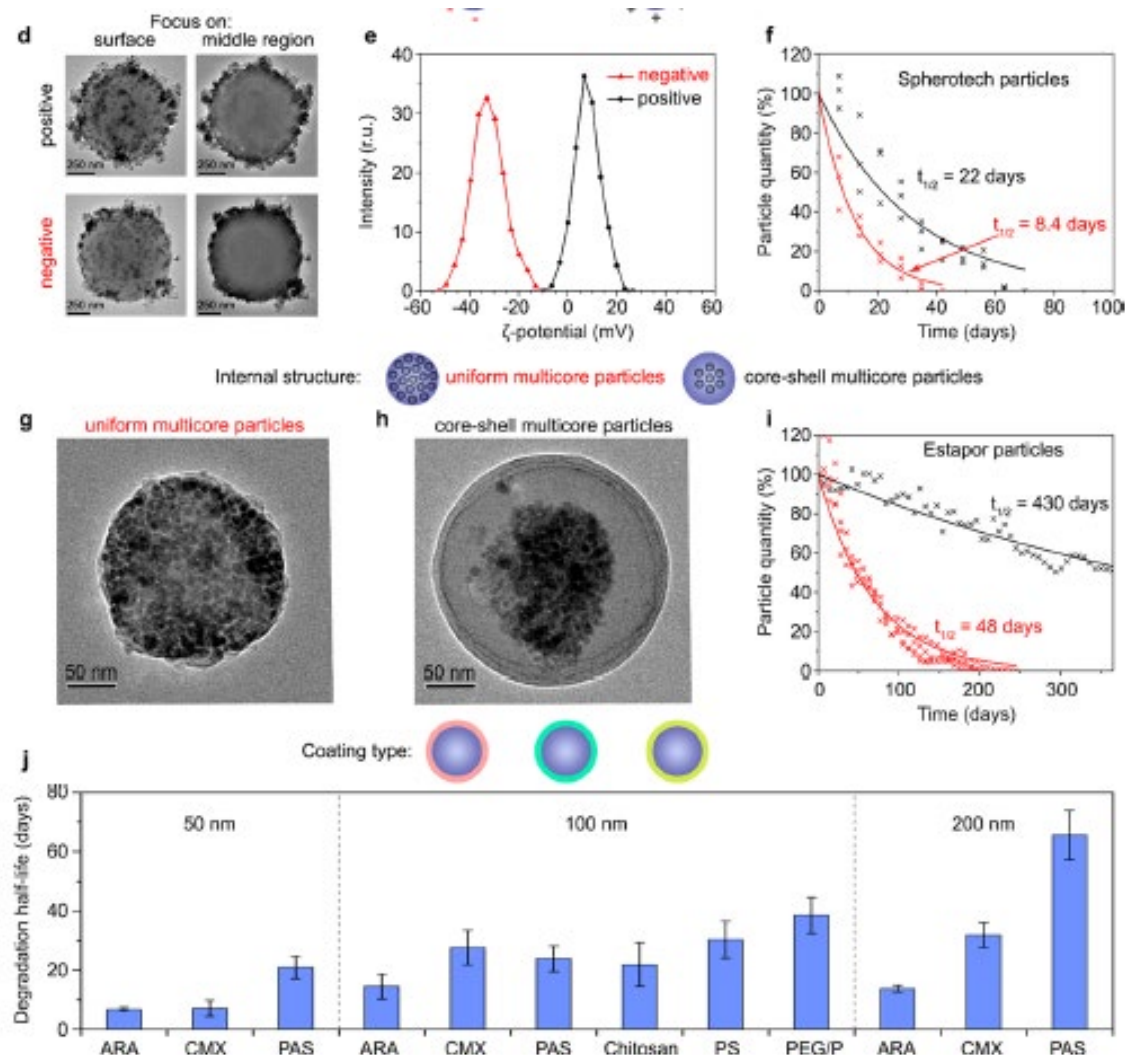
# Gallate Coating Makes Antioxidant MNPs and Enhances Internalization



# Biodegradation Is Coating Dependent



Zelepukin IV, ... Nikitin Petr & Maxim  
(2021). ACS Nano **15**, 11341-11357

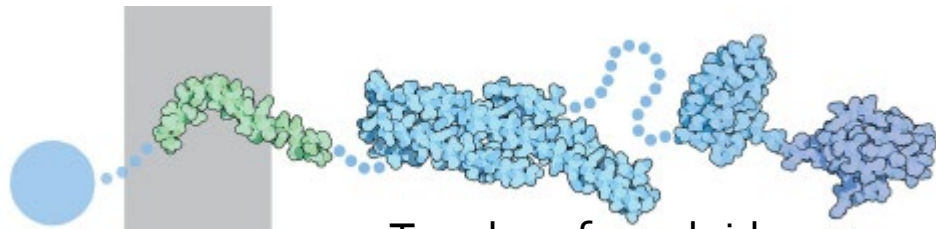
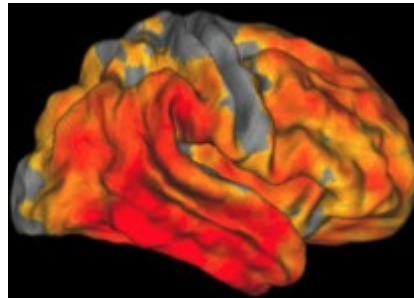




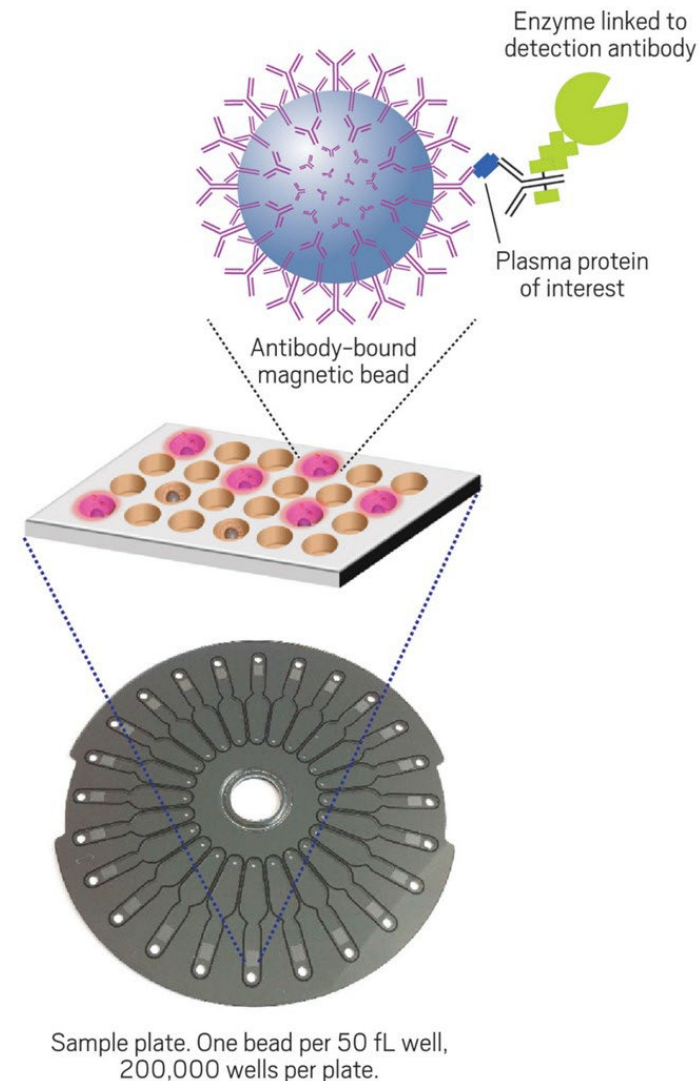
# Assays and Diagnostics

# Alzheimer's Diagnosis in Blood

- P-tau181 analysis in blood is as sensitive as PET or cerebrospinal fluid biomarker analysis
- Antibody-based assay Simoa<sup>®</sup> by Quanterix, got breakthrough device designation by FDA at the end of 2021



Tangles of amyloid precursor protein



# Humans May Sense Earth's Magnetic Field

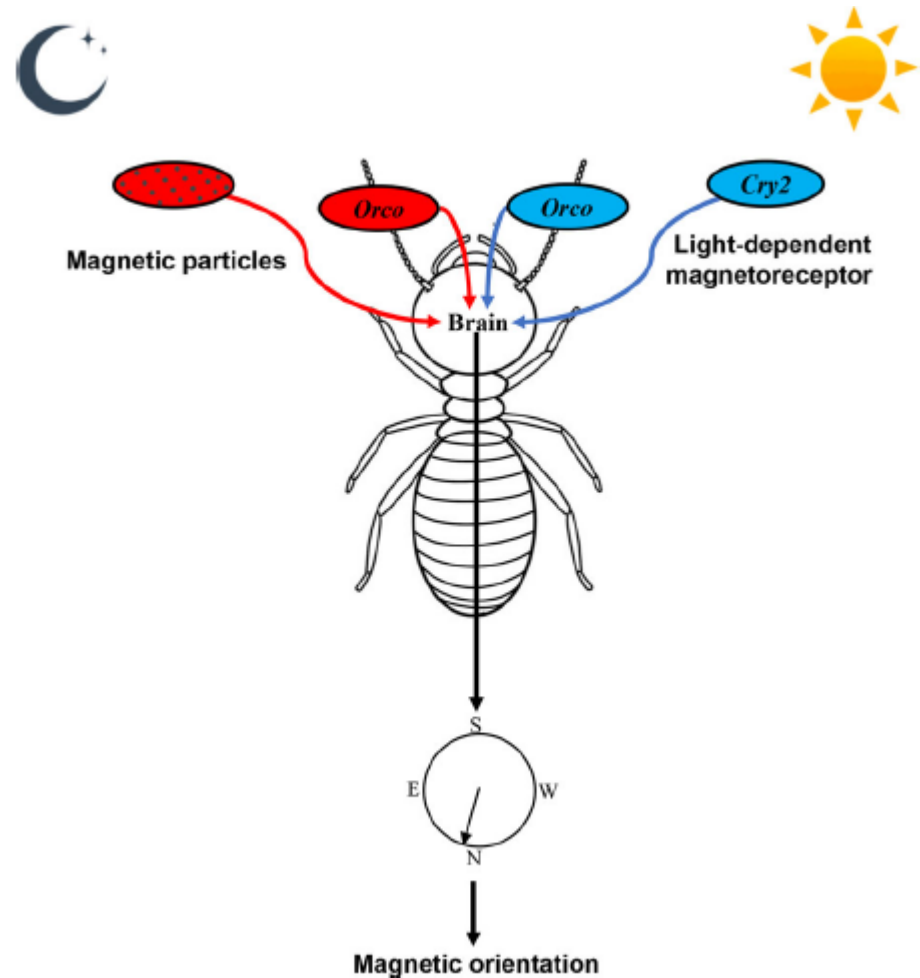
- "I think this paper will make quite a splash," says **Peter Hore**, a physical chemist at the University of Oxford
- The effect showed up in less than a third of participants, which could indicate that genetic factors or past experiences influence a person's sensitivity to a magnetic field, says cognitive neuroscientist **Shinsuke Shimojo**

"I'm not surprised there's an effect," says Margaret Ahmad



# Termites Certainly Do And Use Geomagnetic Fields for Orientation

- In an interplay of light sensitive magnetoreceptors, olfactory co-receptors and MNPs in the brain
- Seen in fire ants and leafcutter ants too



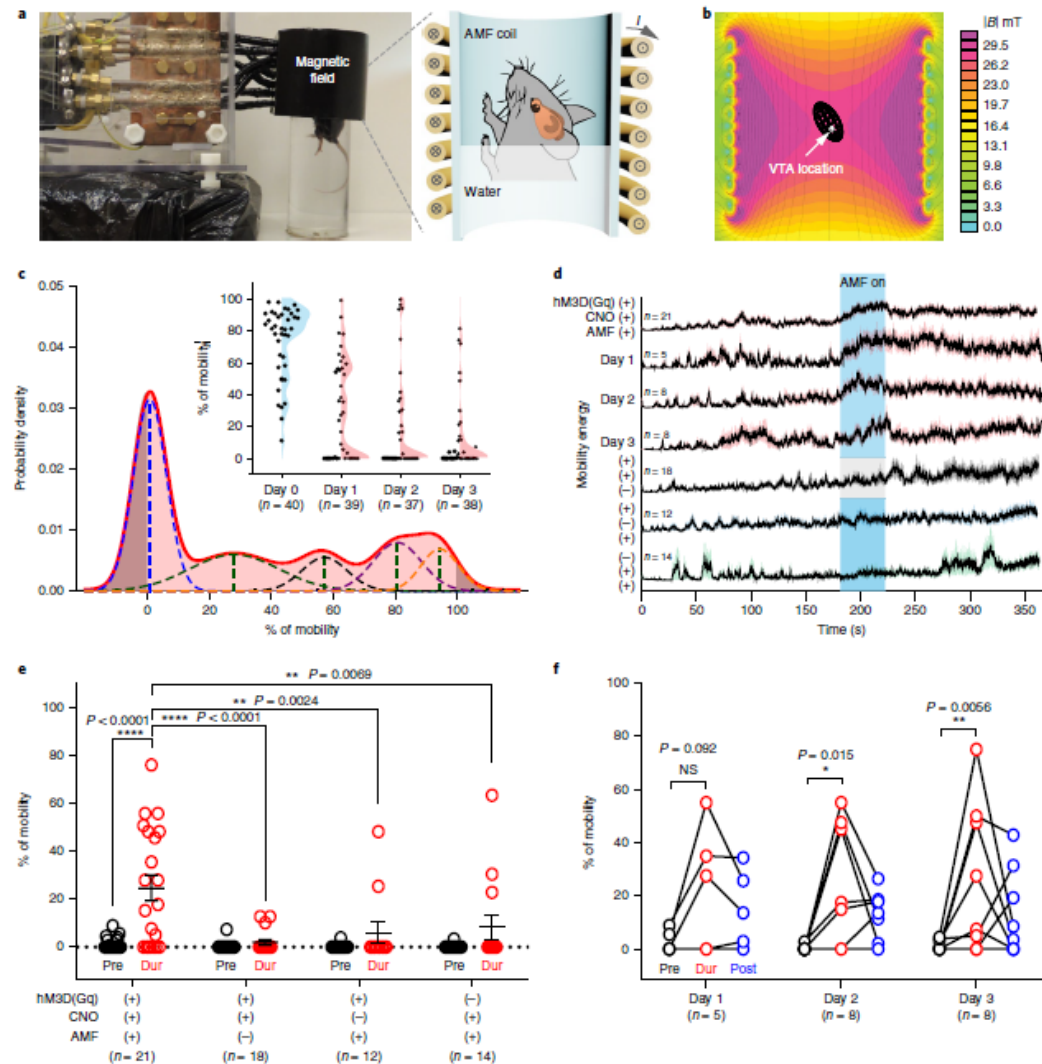
# Biological Applications



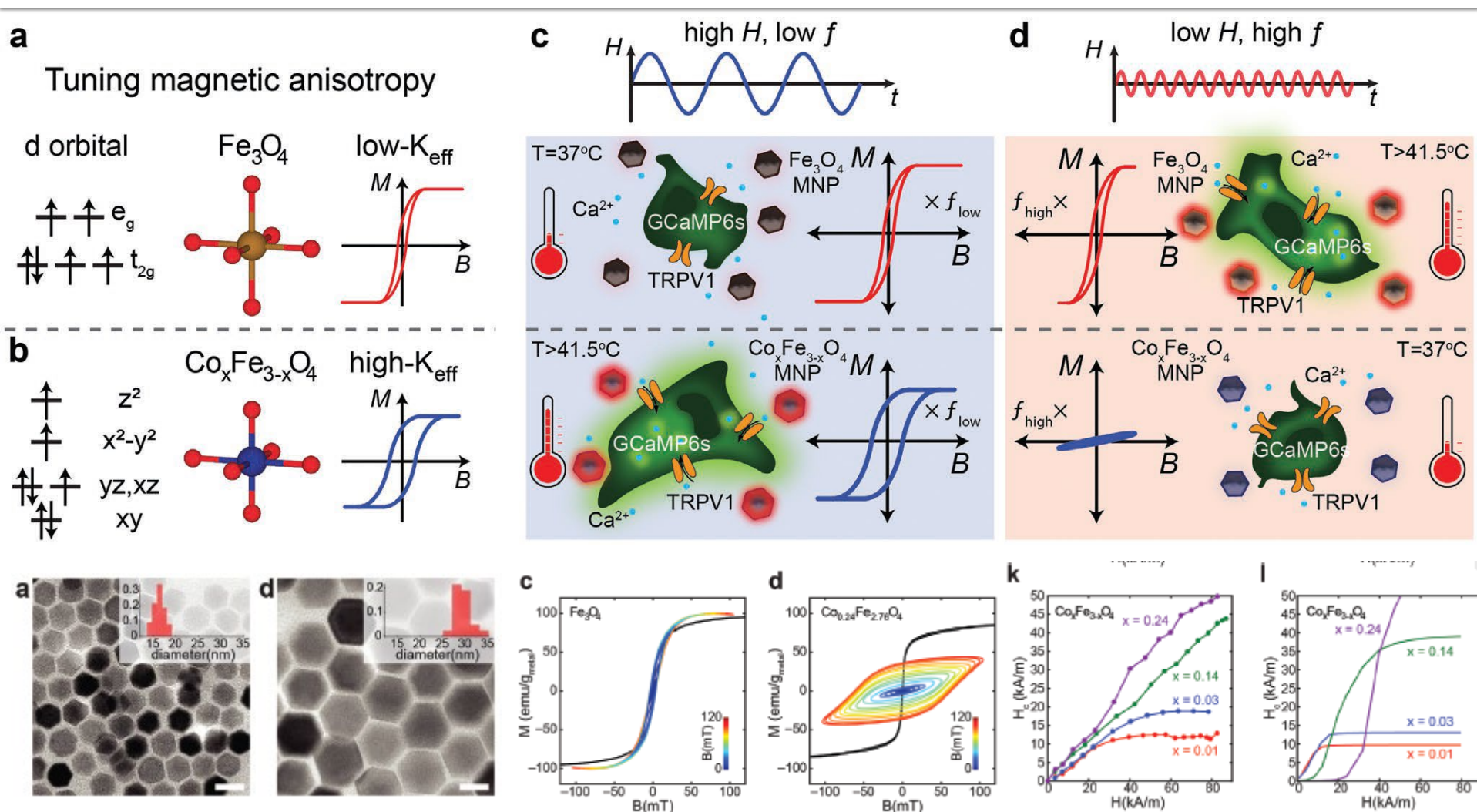
# Chemomagnetic Nerve Modulation

- Thermosensitive magnetic liposomes were able to release neurostimulatory drugs in an AMF and then modulate motivational behavior in mice
- Receptors that exemplify the chemogenetic principle are called **DREADDs** (designer receptors exclusively activated by designer drugs)

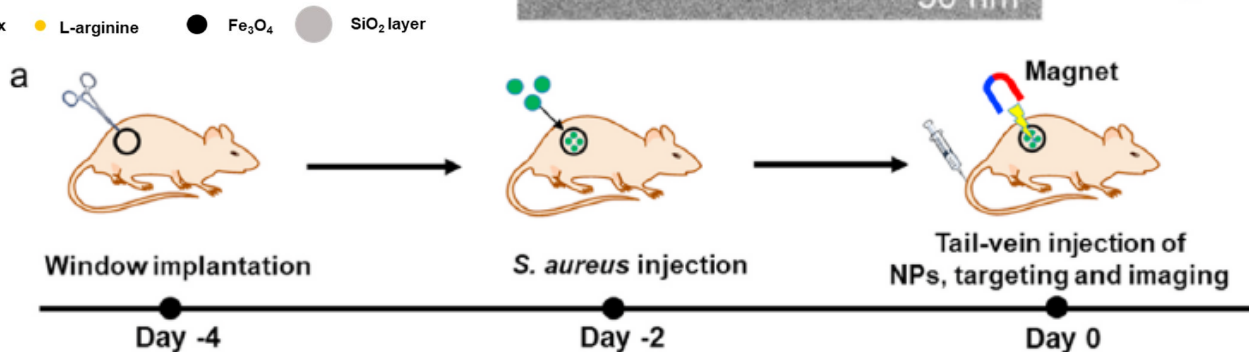
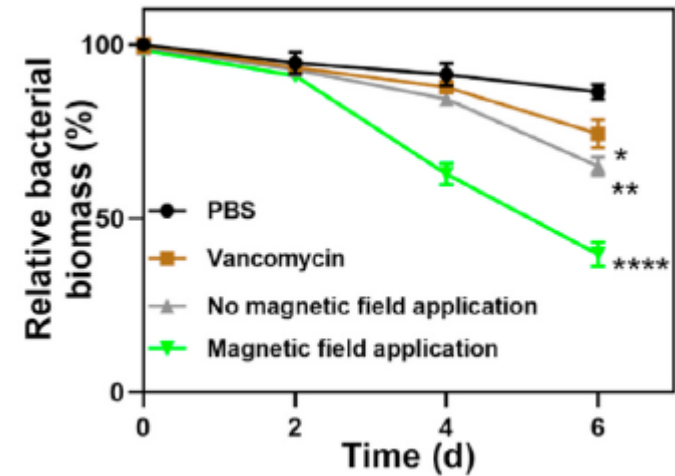
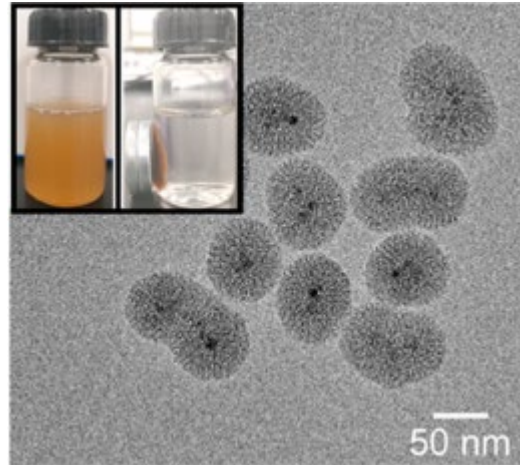
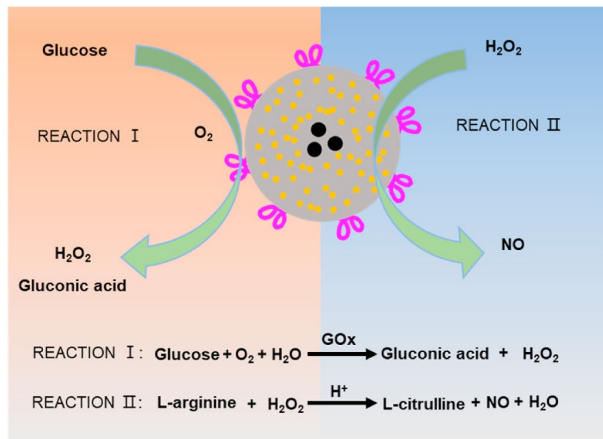
Rao S ... Anikeeva P (2019). Nature Nanotechnology **14**, 967-973



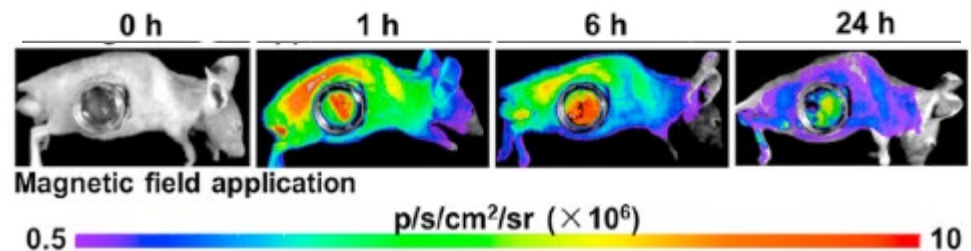
# Design of Multiplexed Control of Cell Signaling Using Selective Magnetothermal Stimulation



# Biofilm Fighting MNPs That Release NO



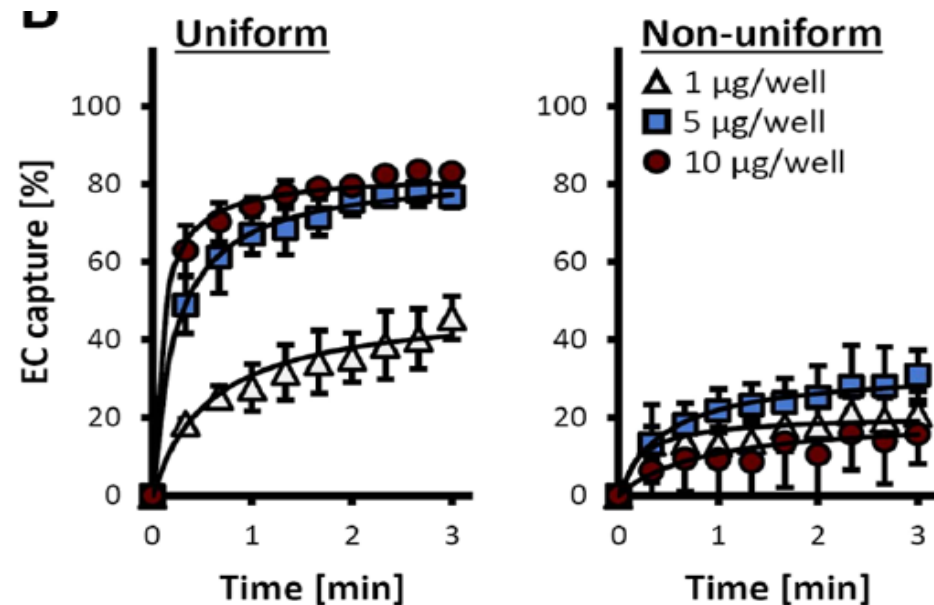
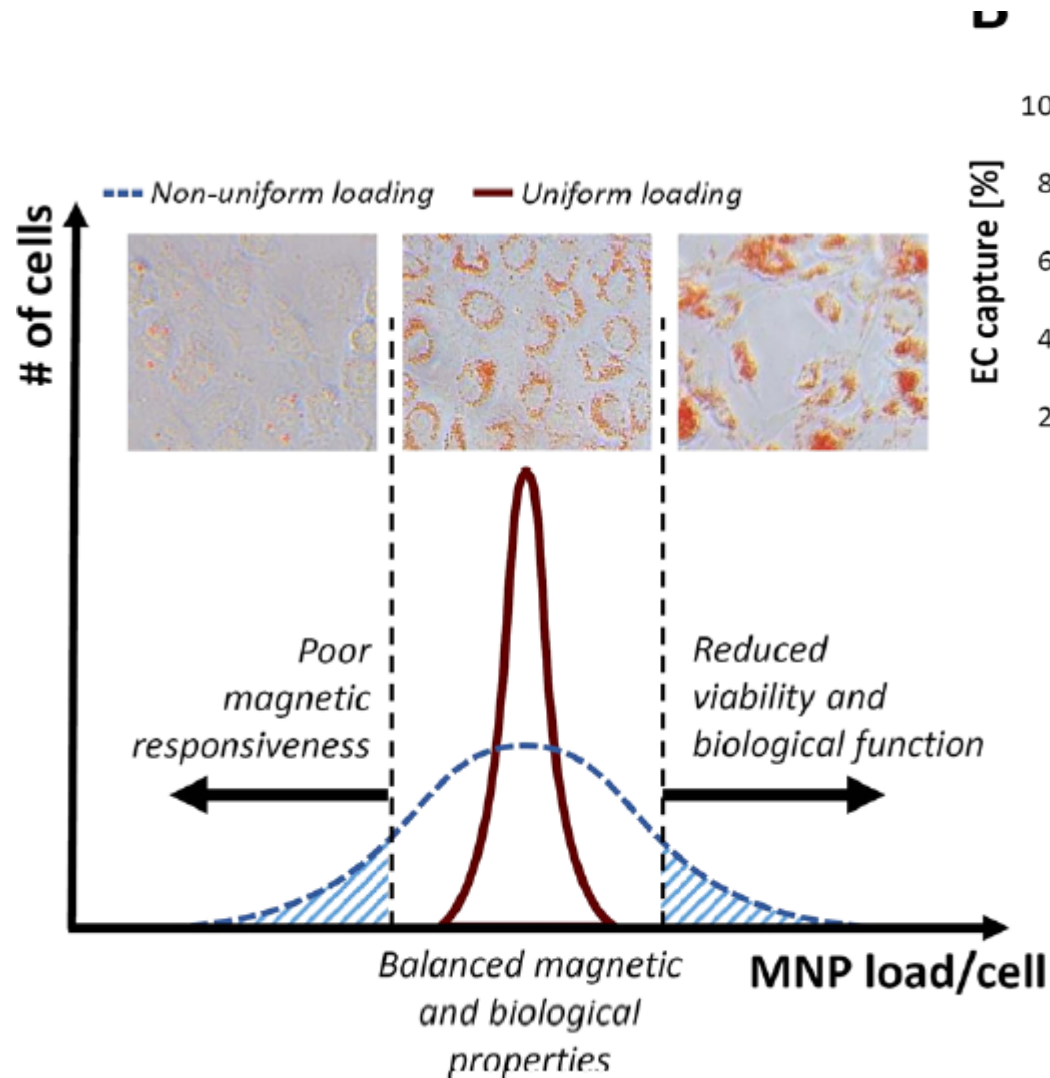
Yang G et al., Bioactive Materials 14 (2022) 321–334



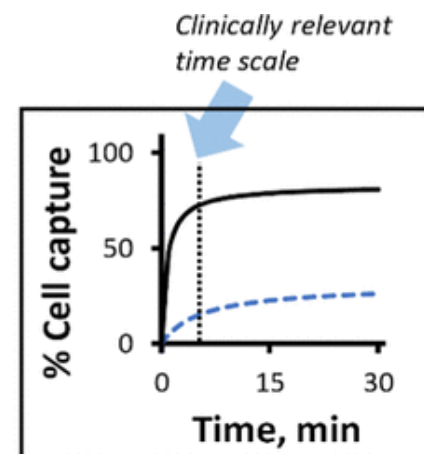
# Medical Applications



# Best Approach to Load Cells with Magnetic Particles

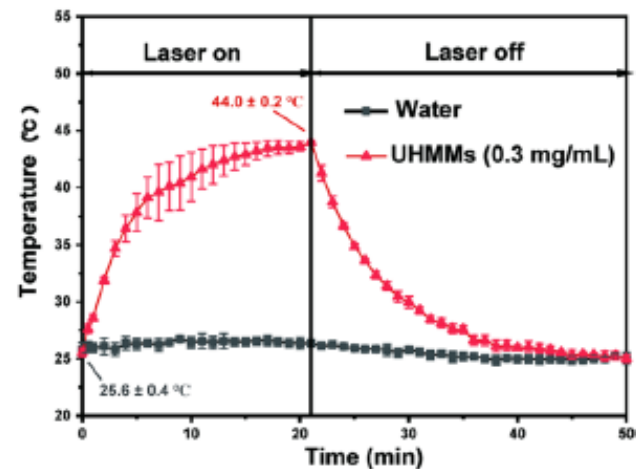
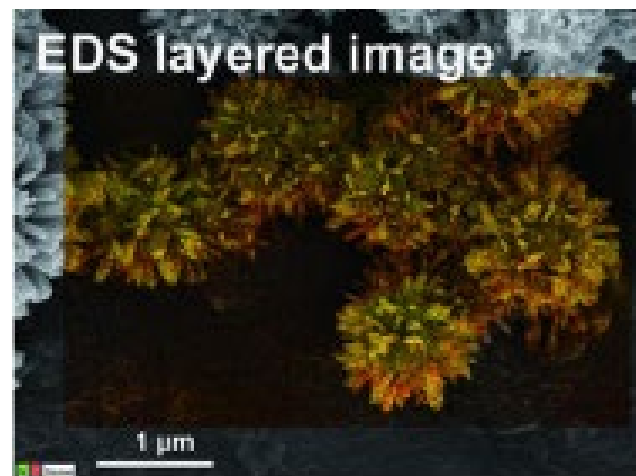
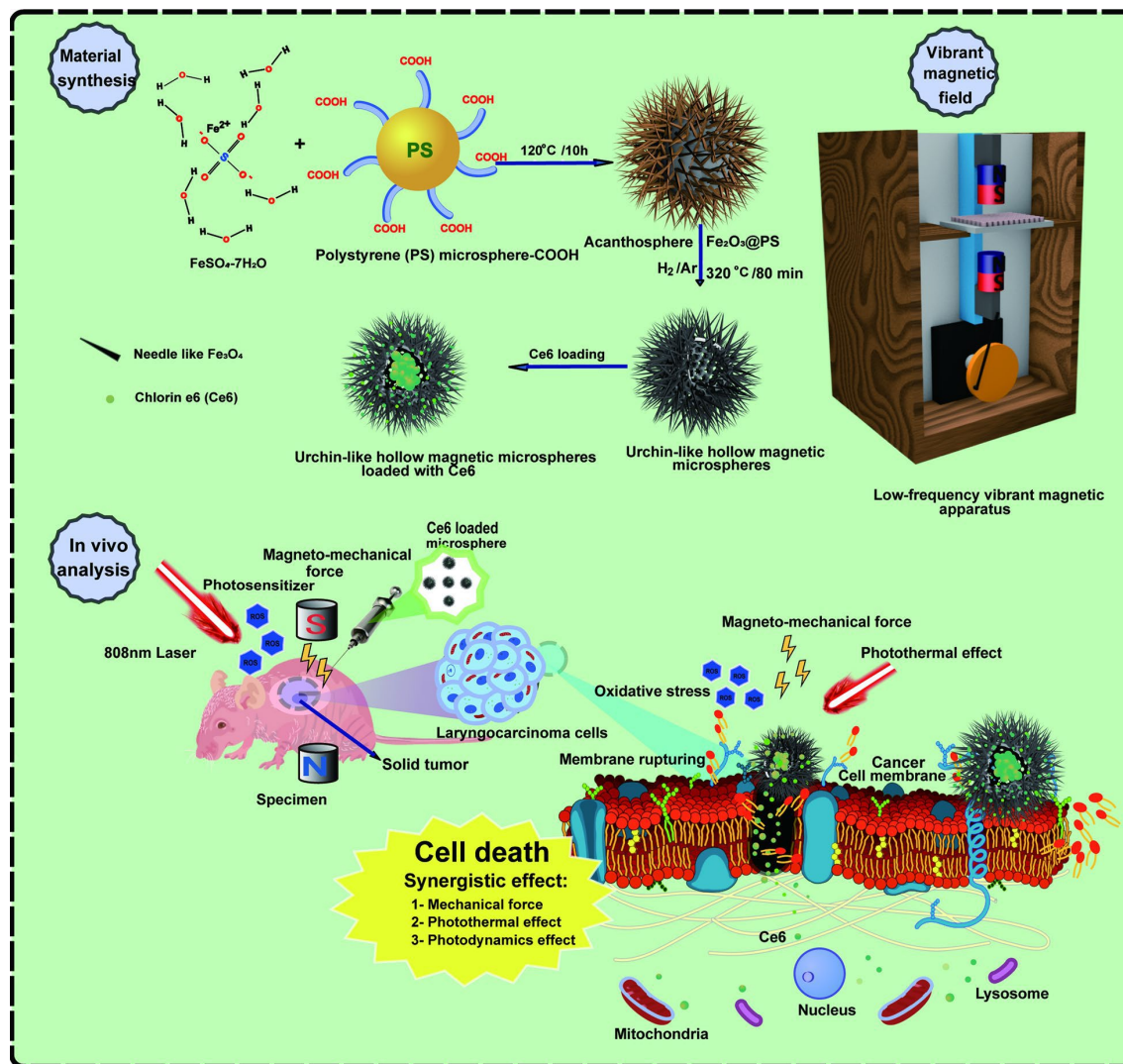


Battig MR et al.  
(2020). ACS Appl  
Bio Mater 3, 3914-  
3922.



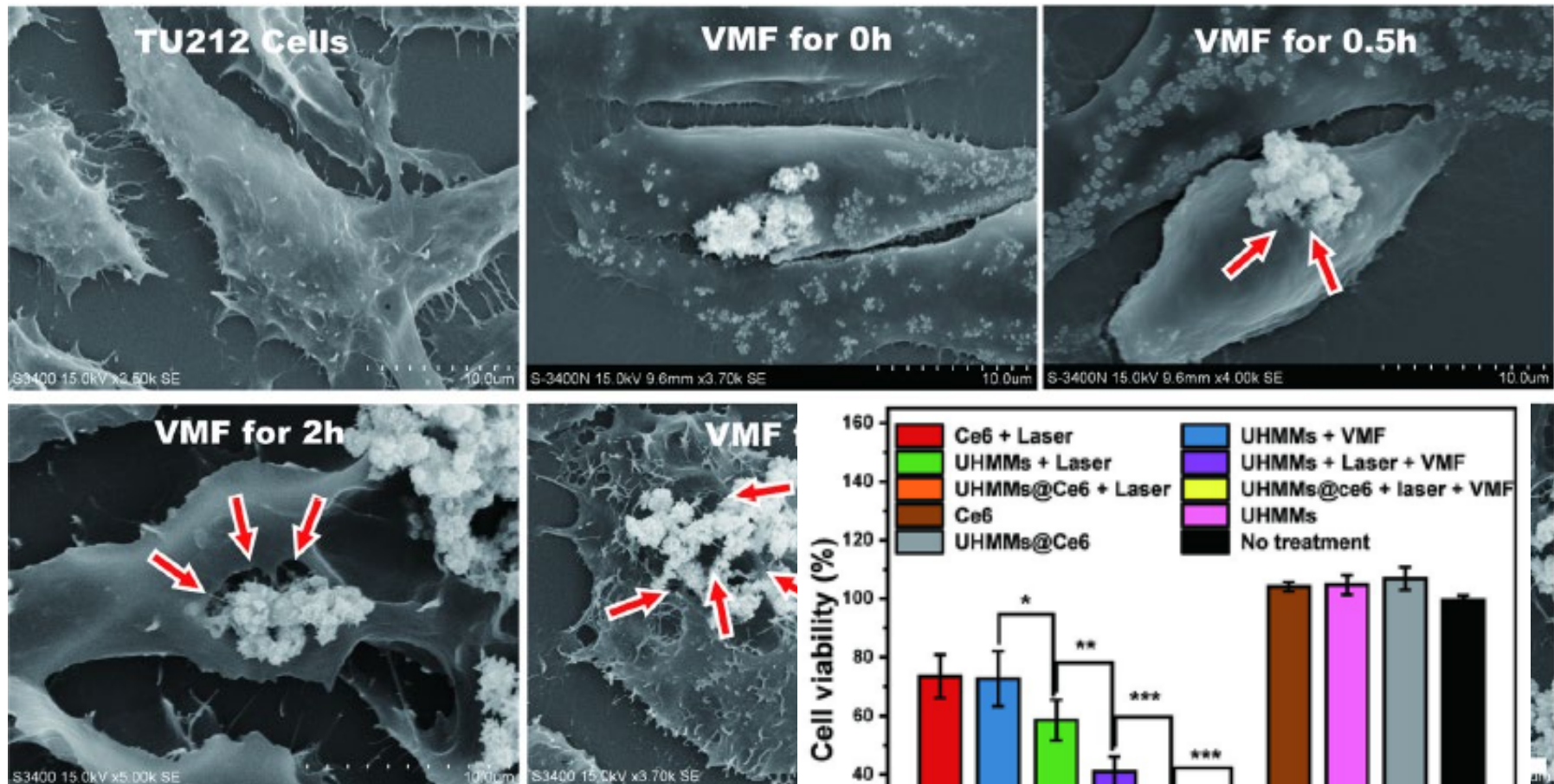


# Urchin-Like Magnetic Microsphere Cancer Therapy



Wu et al. *J Nanobiotechnol* (2022) 20:224.  
<https://doi.org/10.1186/s12951-022-01411-y>

# Urchin-Like Magnetic Microsphere Cancer Therapy

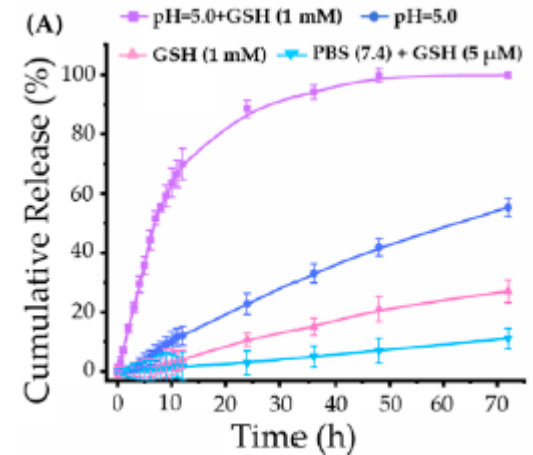
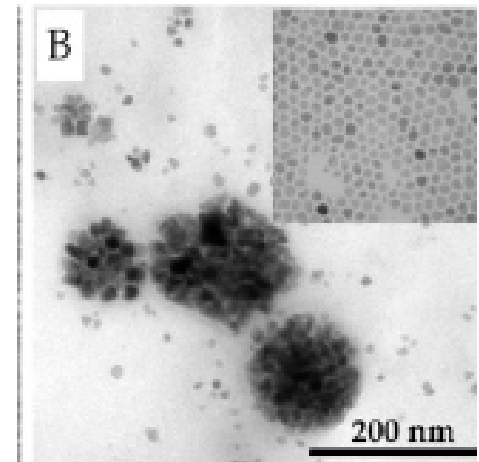
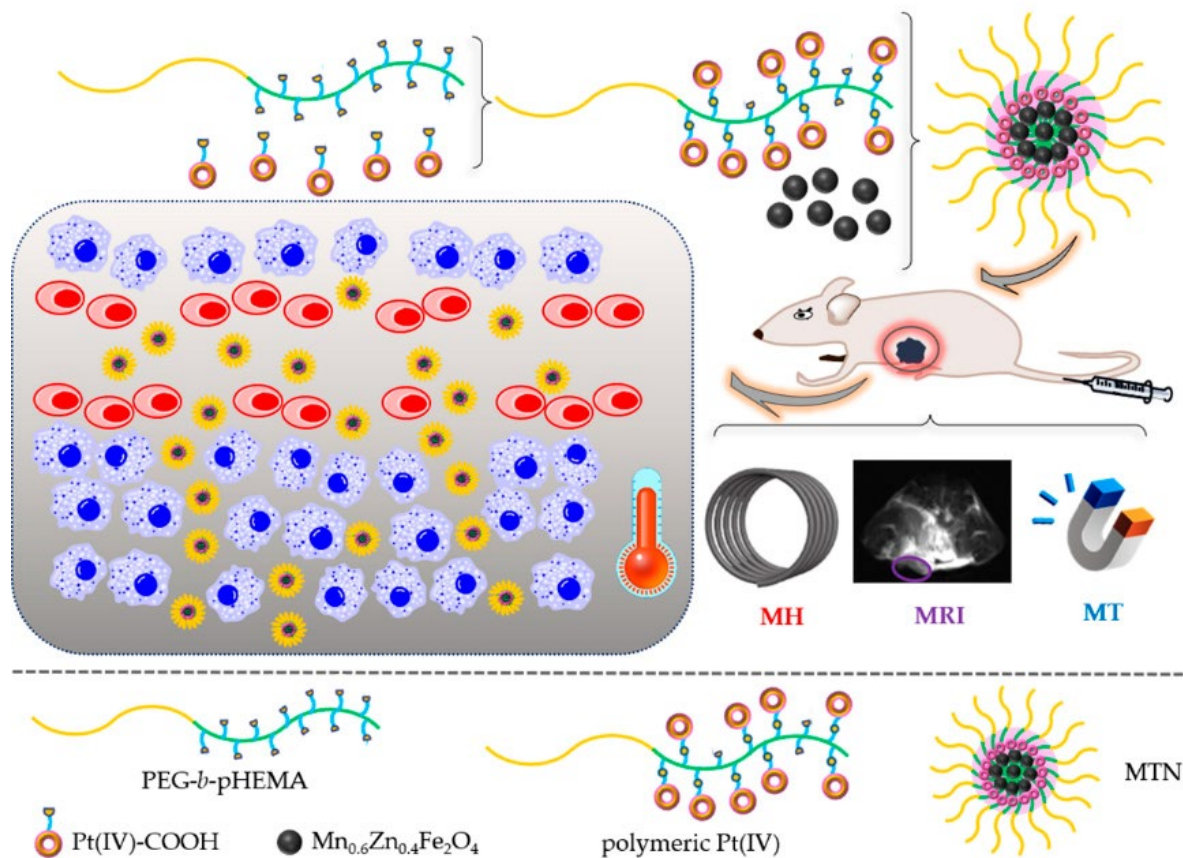


VMF= low frequency vibrating magnetic field



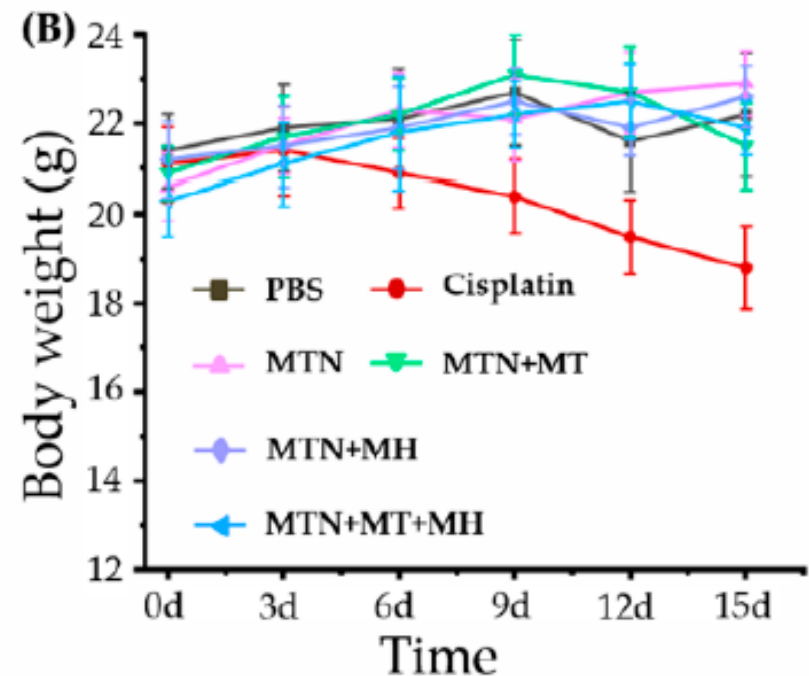
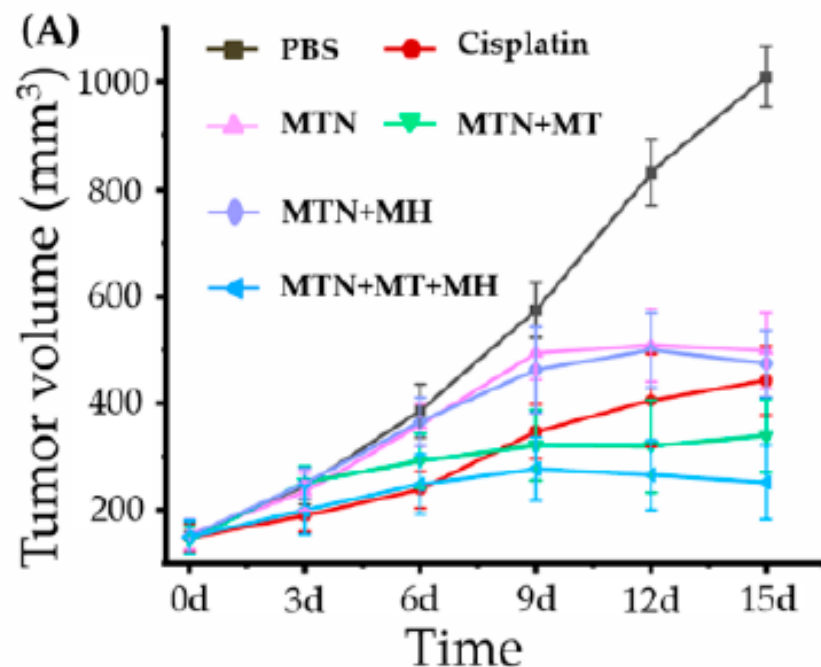
# Magnetic Cisplatin Prodrug

- Pt(IV) prodrug with 104 emu/g

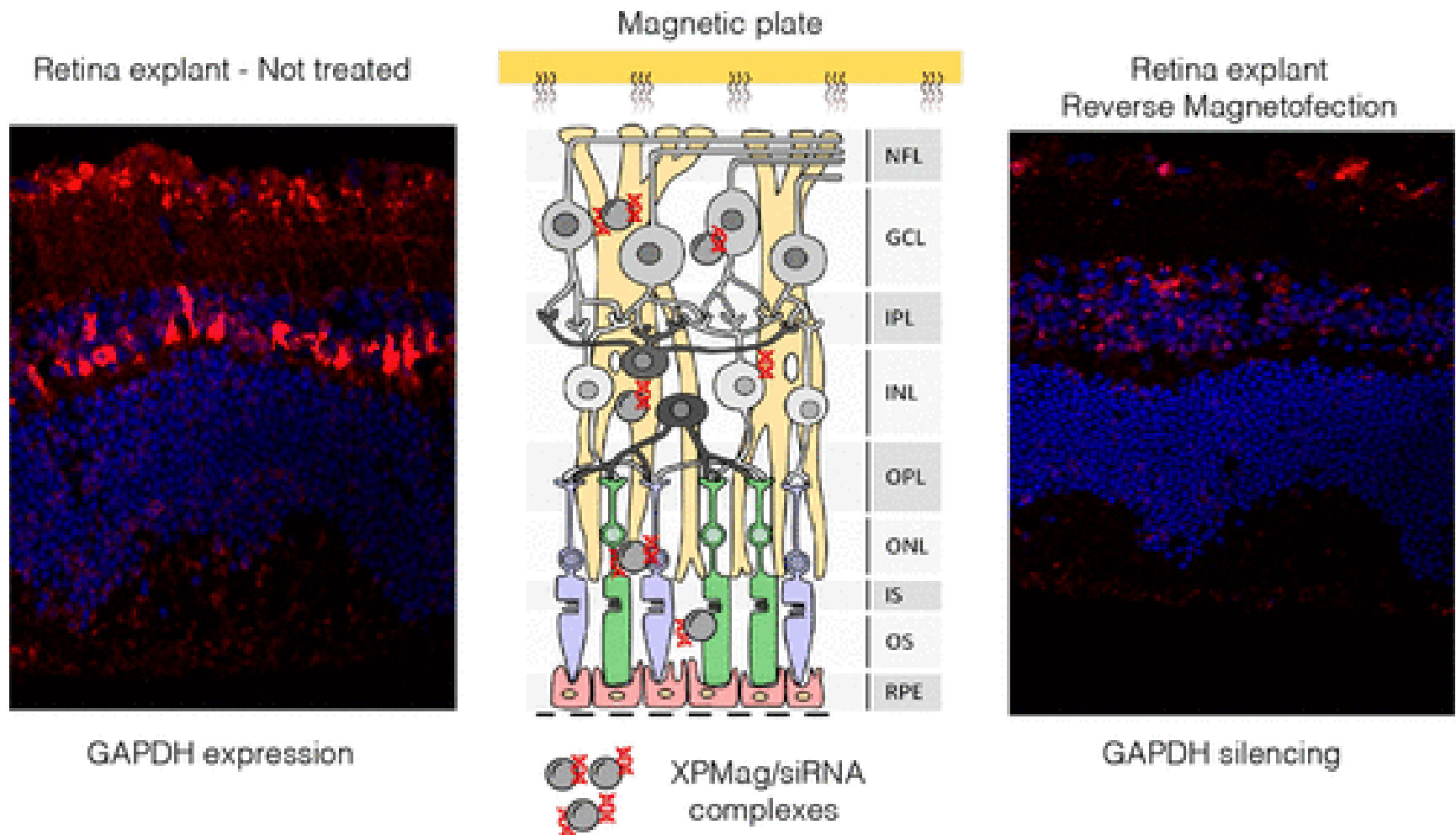


# Magnetic Cisplatinum Prodrug

- Clearly less toxic and more effective than the parent drug cisplatin



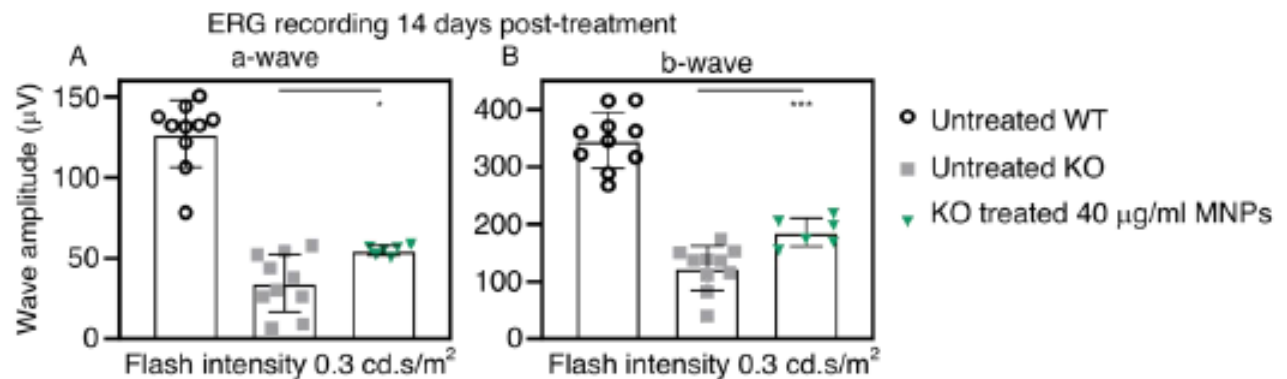
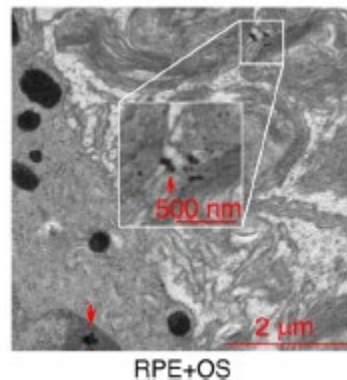
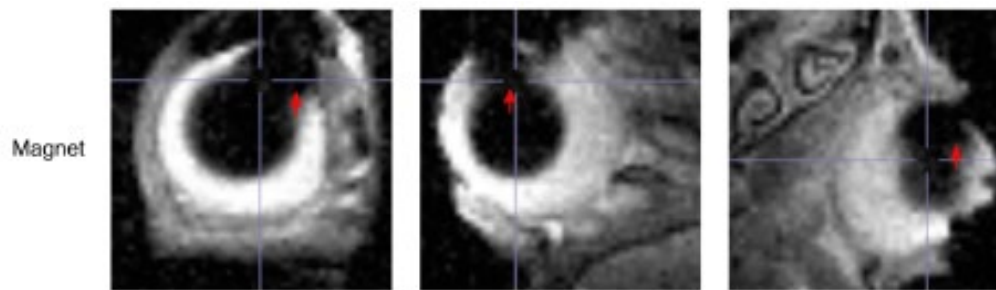
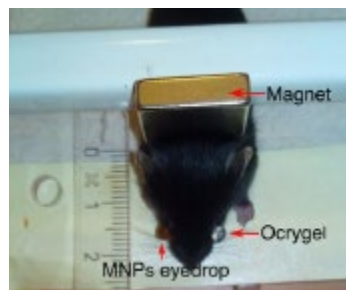
# Reverse Magnetofection with siRNA Delivery to the Retina





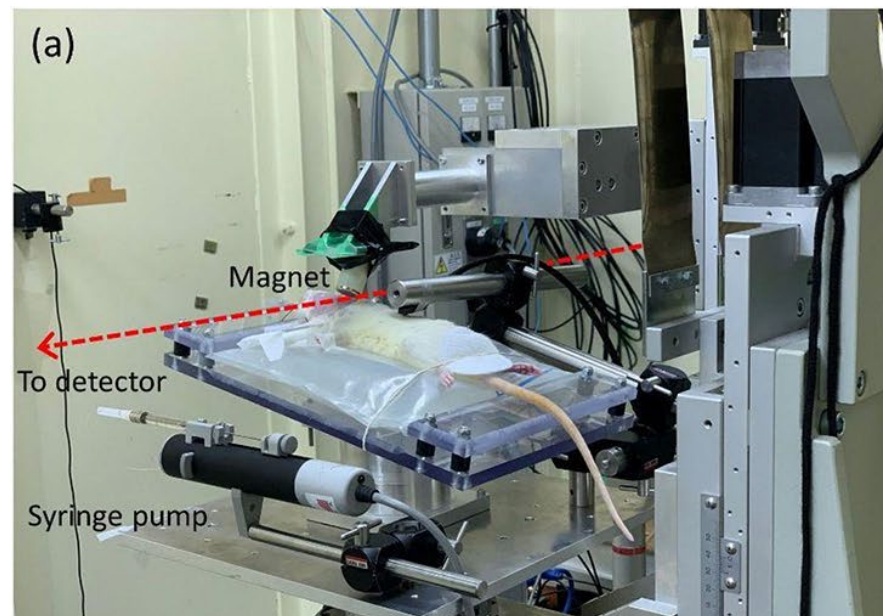
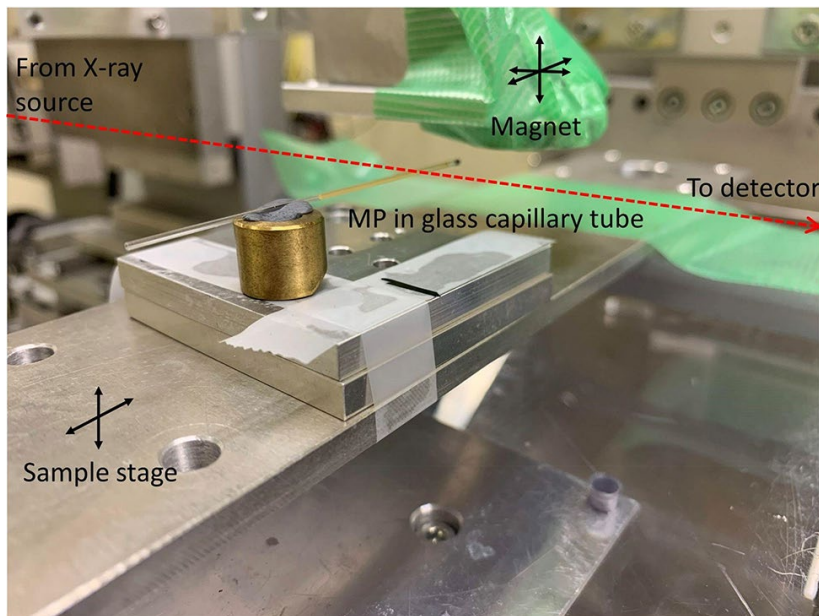
# Drug Delivery from Topical Eye Drops to Maintain Retinal Function

- Bardet-Biedl syndrome (BBS) is a rare genetic disorder of the retina
- Magnetic delivery of two drugs guanabenz and valproic acid
- Electroretinograms showed beneficial effect in BBS-/- KO mice

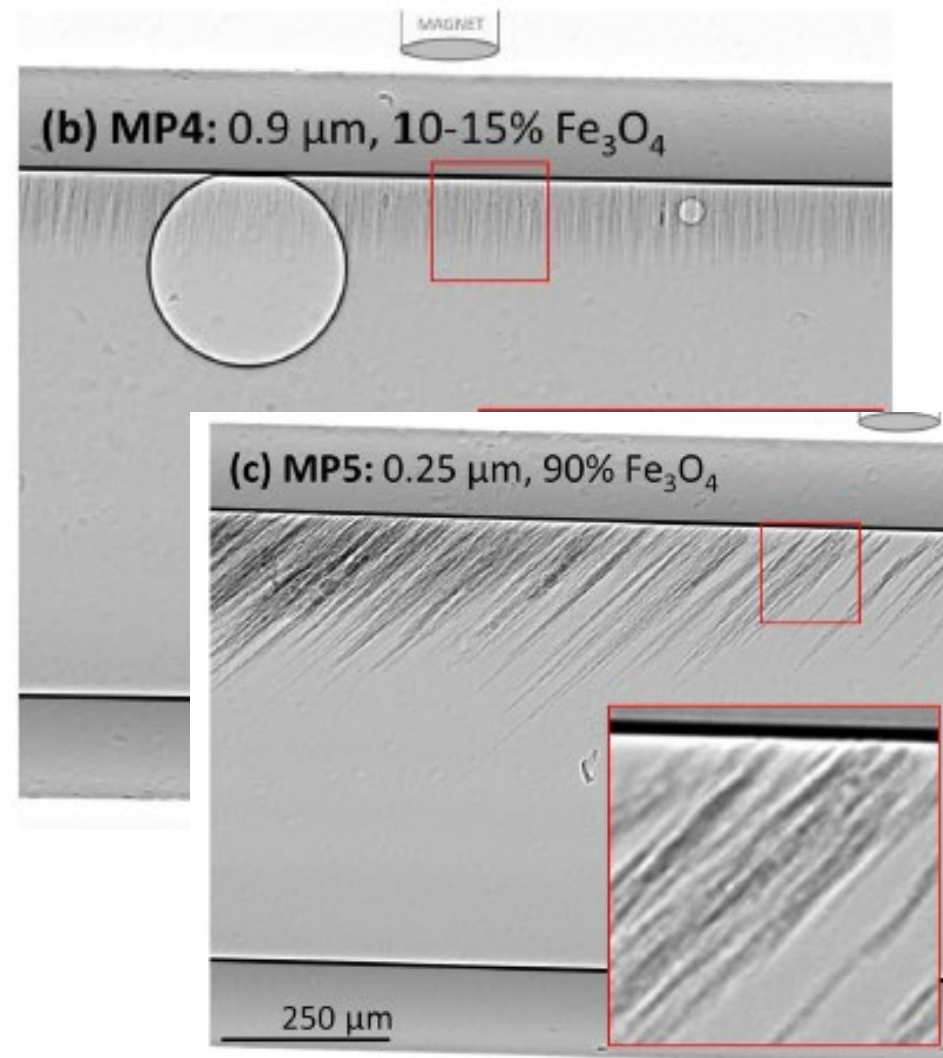
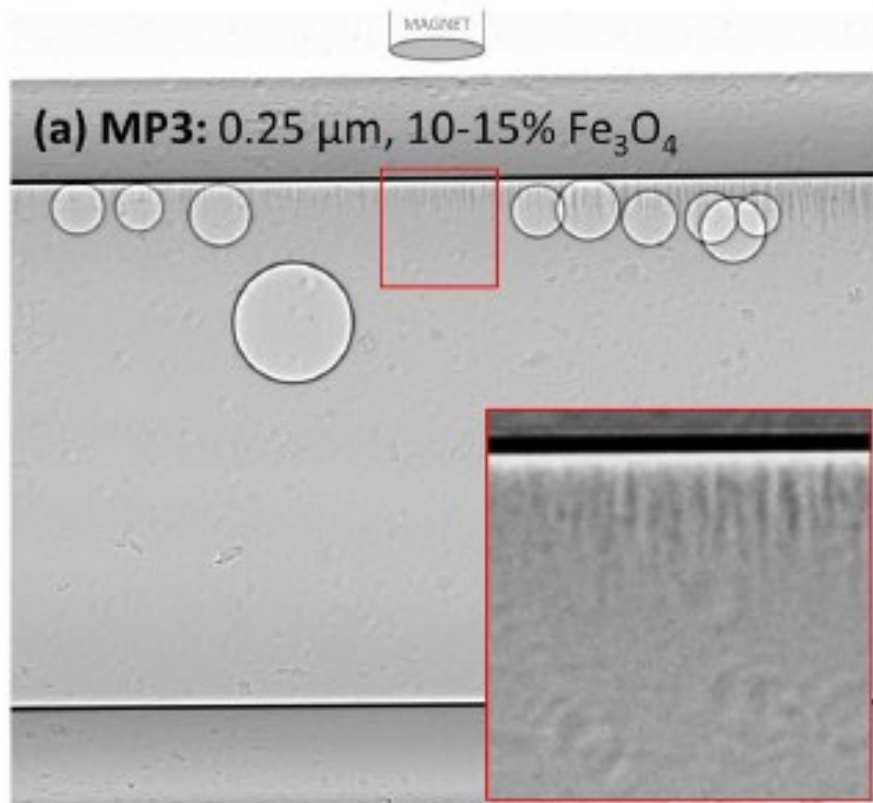


# Gene Delivery to the Lungs

- Synchrotron x-ray beam investigation
- Gene delivery with magnetic particles to lungs, with the aim of treating cystic fibrosis



# Gene Delivery to the Lungs



Donnelley M, Cmielewski P, et al. (2022).  
Scientific reports **12**, 9000.



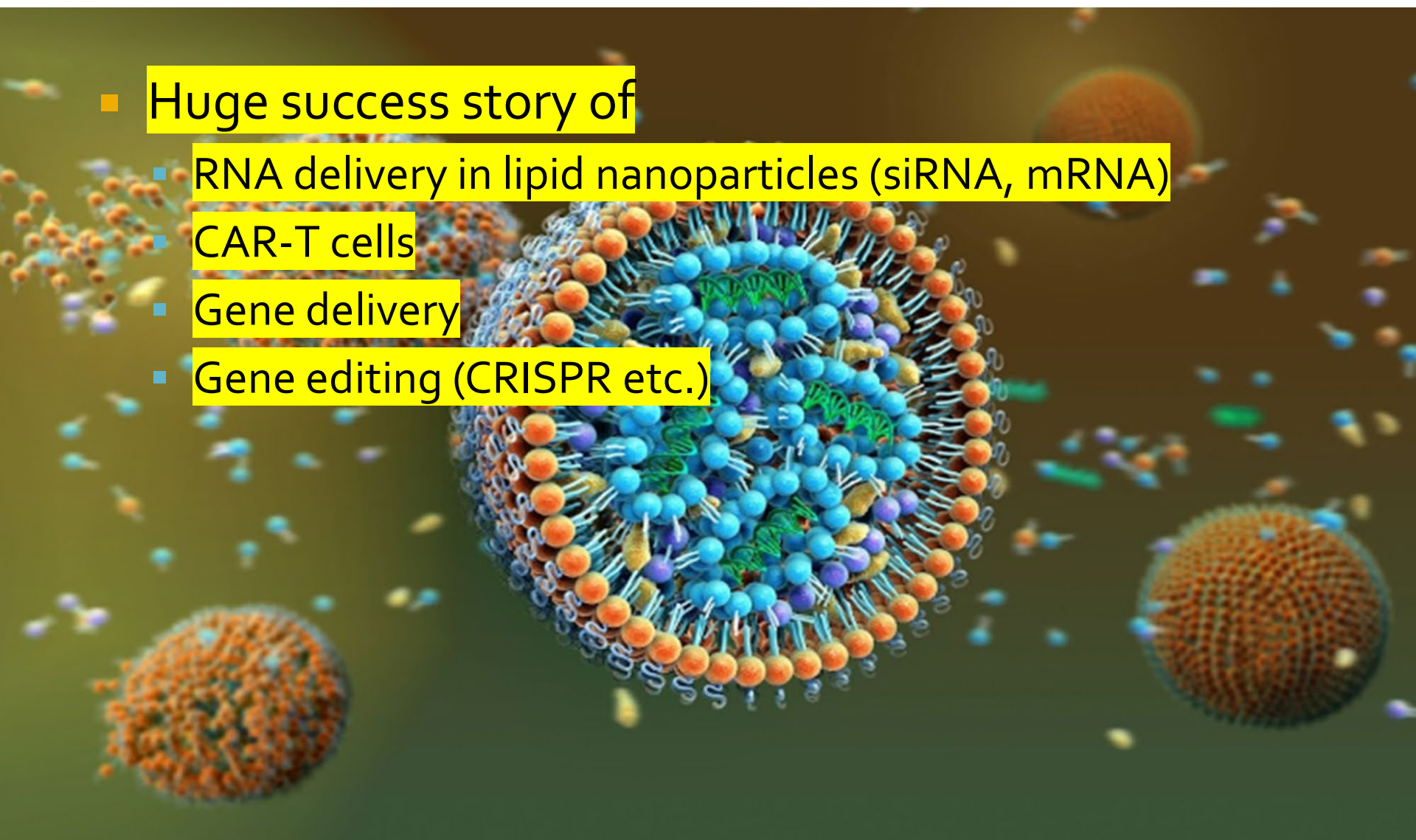
# Gene Delivery to the Lungs



Donnelley M, Cmielewski P, et al. (2022). Scientific reports **12**, 9000.

# What Is Next Step in Nanomedicines?

- Huge success story of
  - RNA delivery in lipid nanoparticles (siRNA, mRNA)
  - CAR-T cells
  - Gene delivery
  - Gene editing (CRISPR etc.)



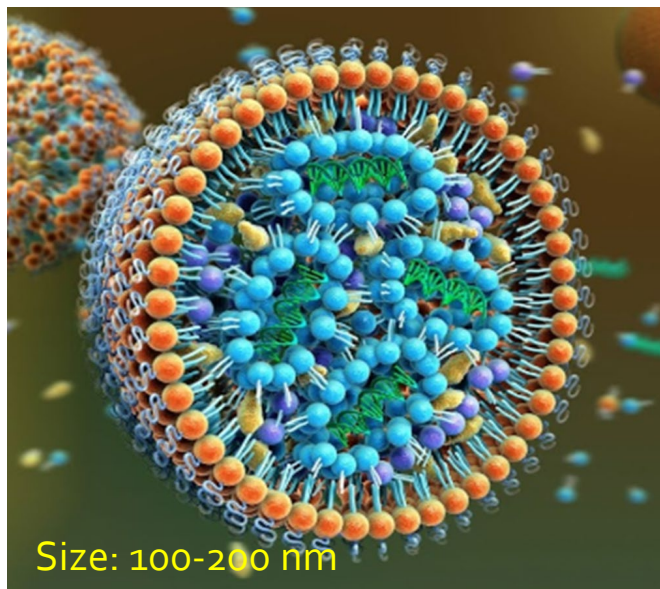


# Magnetic Delivery of Lipid Nanoparticles



- Still needed
- Hottest topic at the moment

**But Vaccine Applications are Just the Tip of the Iceberg, LNP mRNA Technology Will Enable a Multitude of Gene Therapies**



Size: 100-200 nm

## Infectious Diseases (Vaccines):

- COVID-19
- Universal influenza vaccine
- HIV
- Zika
- Malaria, etc

## Chronic diseases

- Cancer
- Heart disease
- Alzheimer's, etc

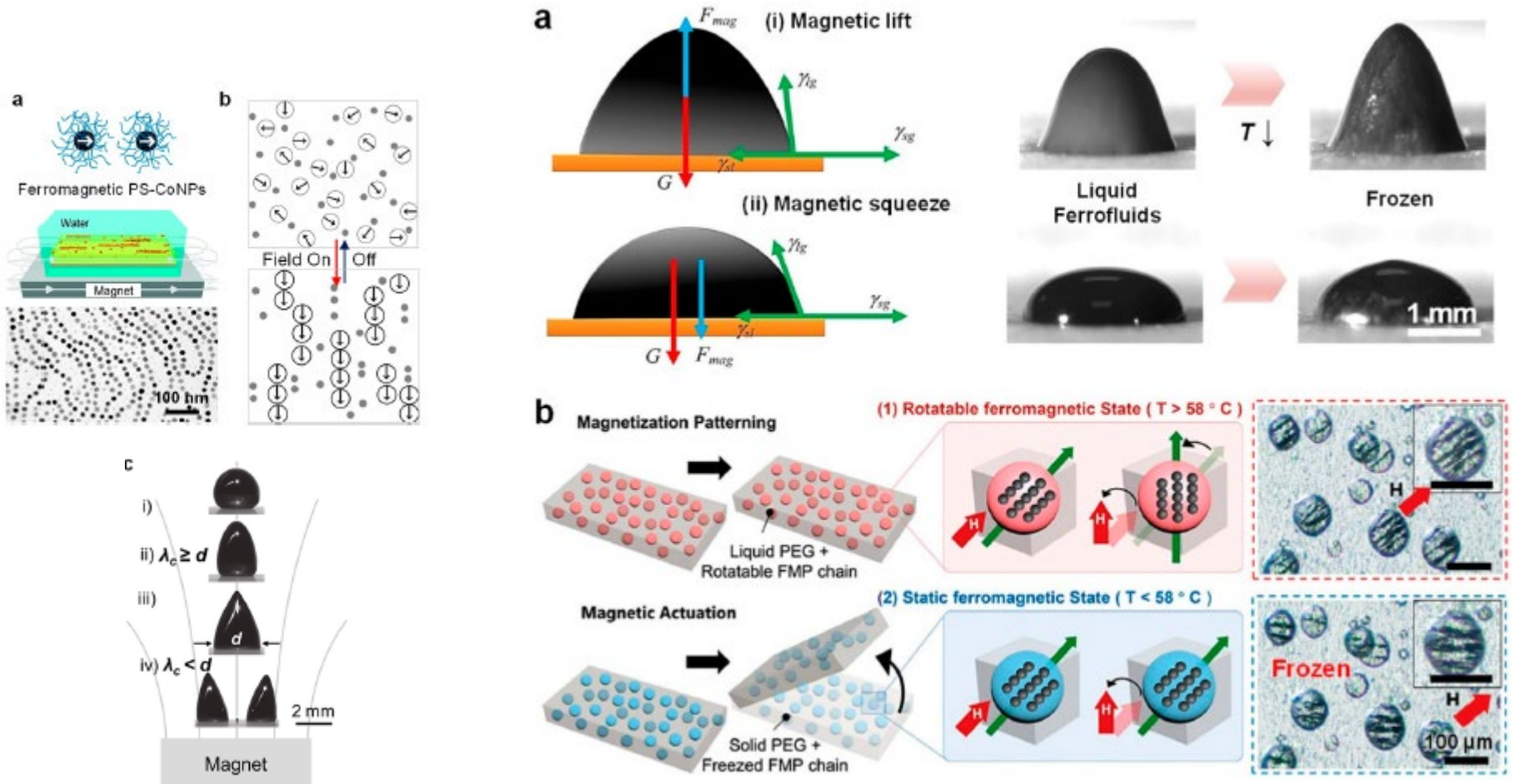
## Inherited diseases

- Sickle cell anemia
- Huntington's disease
- Cystic fibrosis, etc

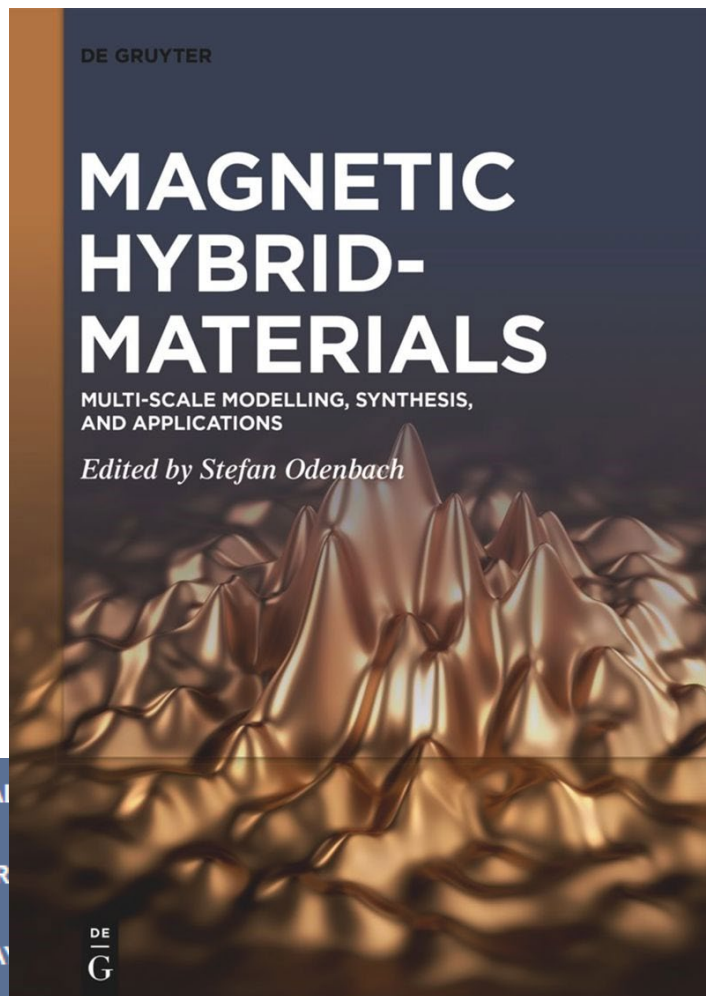
Pfizer/BionTech  
Moderna

Slide from Pieter Cullis, University of British Columbia, Vancouver, Canada

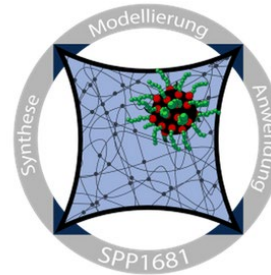
# Ferrofluids



# New Ferrofluids Books



- Multi-scale Modelling, Synthesis, and Applications
  - *Edited by: Stefan Odenbach*
  - <https://doi.org/10.1515/9783110569636>
  - Published: November 8, 2021
  - 812 pages



**DFG**

CH. AI

M. GR

S. MA

A.TSCHÖPE

J.WAGNER

TH.WALLMERSPERGER

A.WASKE, J.ECKERT

H.WENDE

K.ZIMMERMANN

BRAND, H. PLEINER

J. CLEMENT, F. V. EGGELING

S. DUTZ

B. FISCHER

S. KLAPP

R. V. KLITZING

M. KRUTYEVA

H. LÖWEN

F. LUDWIG

T. SCHEIBEL

A.SCHMIDT

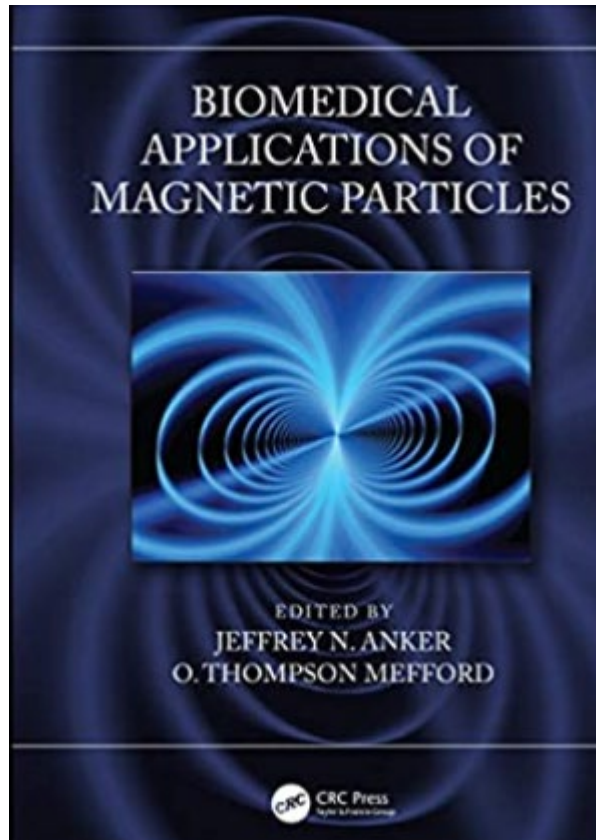
M.SCHRÖDNER

R. STANNARIUS

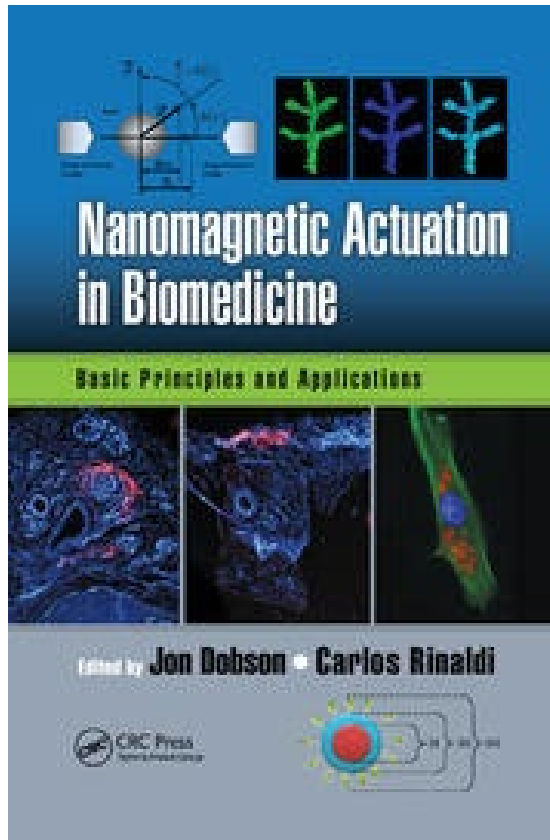
L.TRAHMS



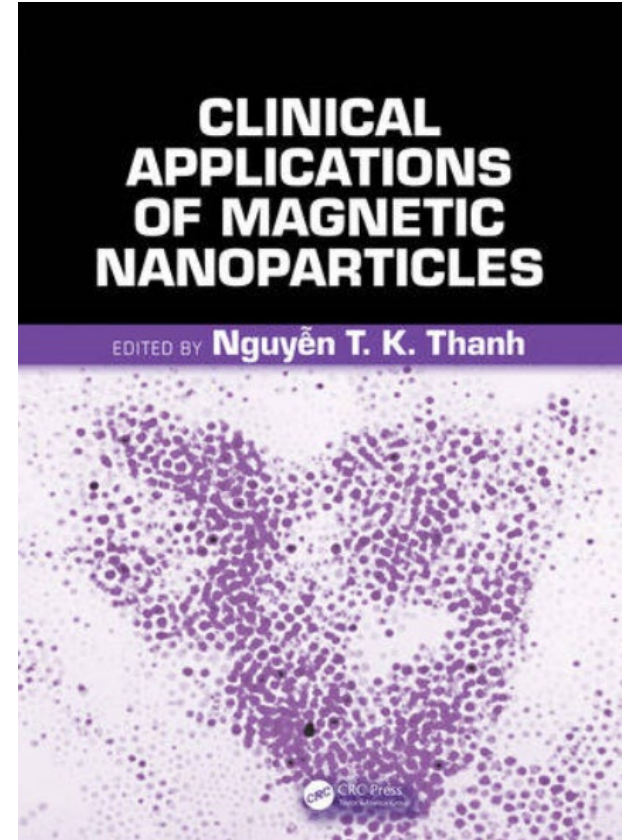
# Other New Books



2022

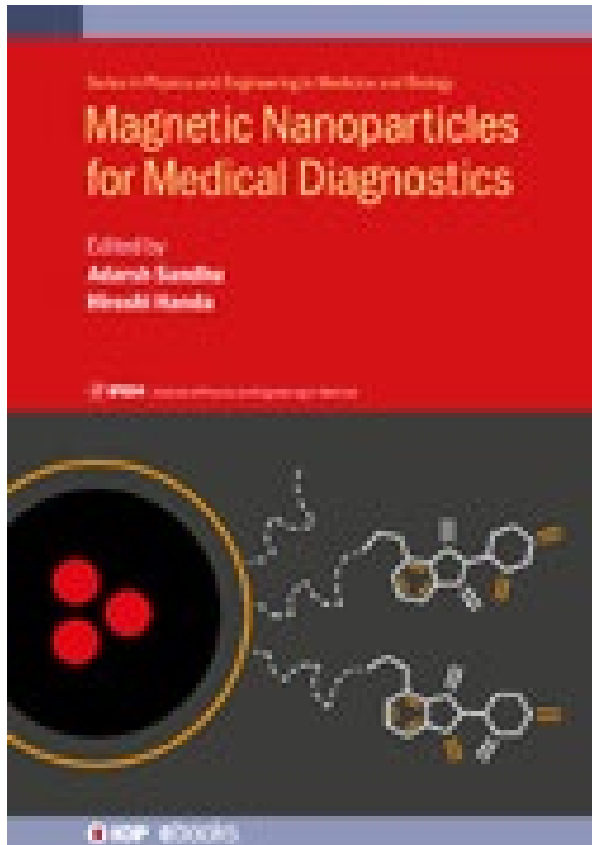


2019

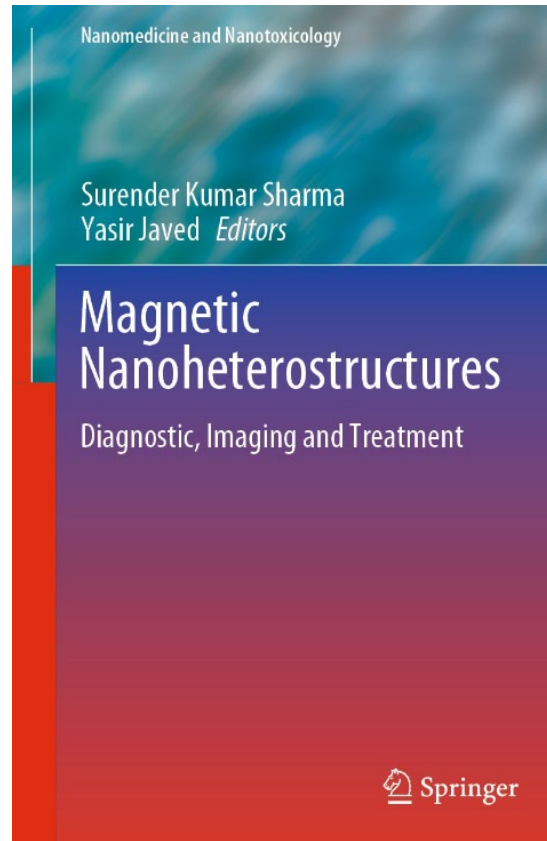


2018

# Other New Books



2018



2020

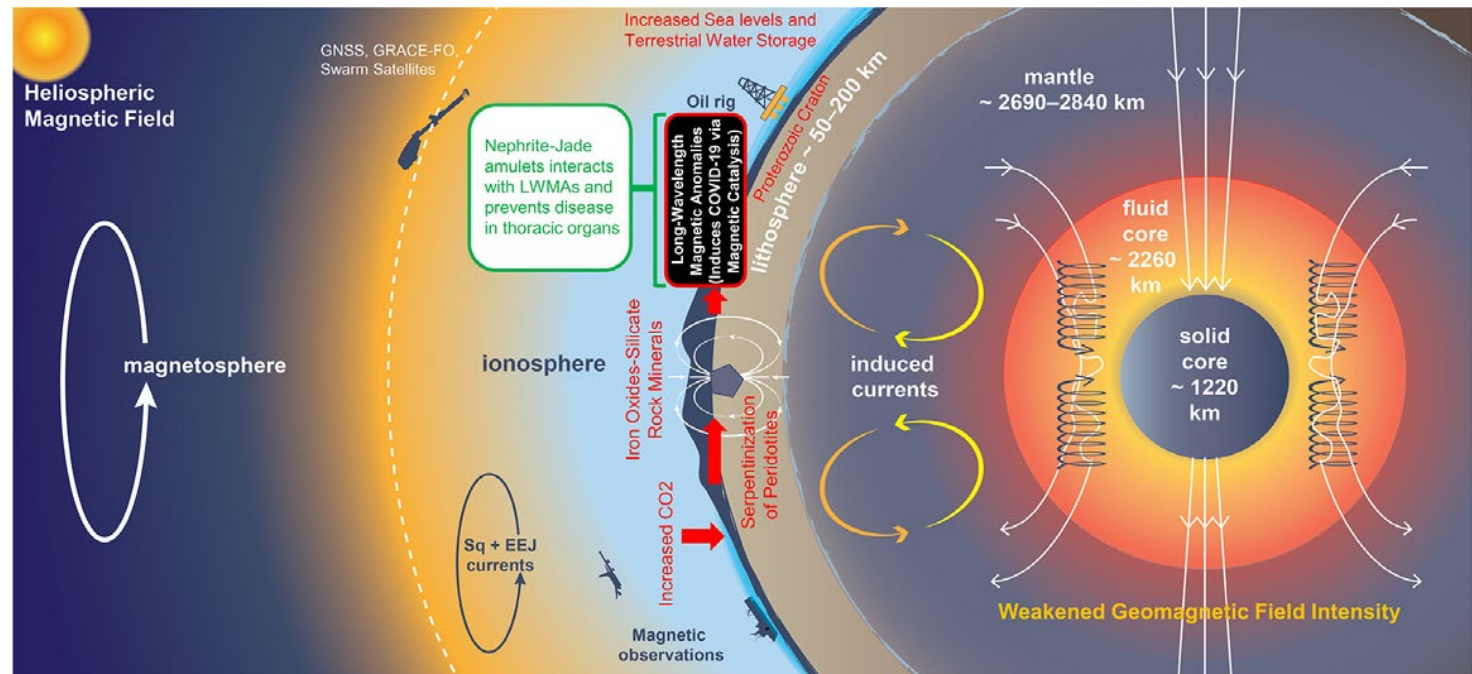


# Worth Reading ?????

I guess not – it was withdrawn in the meantime

Can Traditional Chinese Medicine provide insights into controlling the COVID-19 pandemic: Serpentinization-induced lithospheric long-wavelength magnetic anomalies in Proterozoic bedrocks in a weakened geomagnetic field mediate the aberrant transformation of biogenic molecules in COVID-19 via magnetic catalysis

Moses Turkle Bility <sup>a,\*</sup>, Yash Agarwal <sup>a</sup>, Sara Ho <sup>a</sup>, Isabella Castronova <sup>a</sup>, Cole Beatty <sup>a</sup>, Shivkumar Biradar <sup>a</sup>, Vanshika Narala <sup>a</sup>, Nivitha Periyapatna <sup>a</sup>, Yue Chen <sup>a</sup>, Jean Nachega <sup>a,b</sup>



Bility MT,  
Agarwal Y, et al.  
(2020). Sci Total  
Environ, 142830.

# There is Much More ....

**13<sup>th</sup> International Conference on the  
SCIENTIFIC AND CLINICAL  
APPLICATIONS OF  
MAGNETIC CARRIERS**

LONDON, UNITED KINGDOM  
JUNE 14-17, 2022



... from your colleagues during  
the next few days here at the  
meeting !

*And don't forget to check (and  
contribute) to our website:*

<http://www.magneticmicrosphere.com>

# Thank You

- Participants / Reviewers
- Local organizer Thanh and her students
- Exhibitors / Sponsors

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**MSI AUTOMATION**

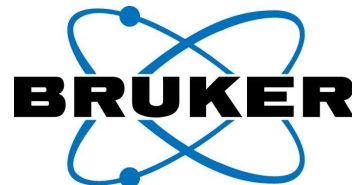
**magnetsales**

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**nB**  
nanoScale  
Biomagnetics  
Experts in Magnetic nanoHeating





# A Very Special Thank You

- Lydia
- Ben

