

Engineering matter at the Nanoscale

What could possibly go wrong?

Nanotechnology in context

Lecture 2 of 3

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Woodrow Wilson International Center for Scholars (in partnership with the Pew Charitable Trusts)



DESTROY CIVILIZATION WITH NANOTECHNOLOGY

...in just six amazing steps!



Now, we know what you're thinking ...

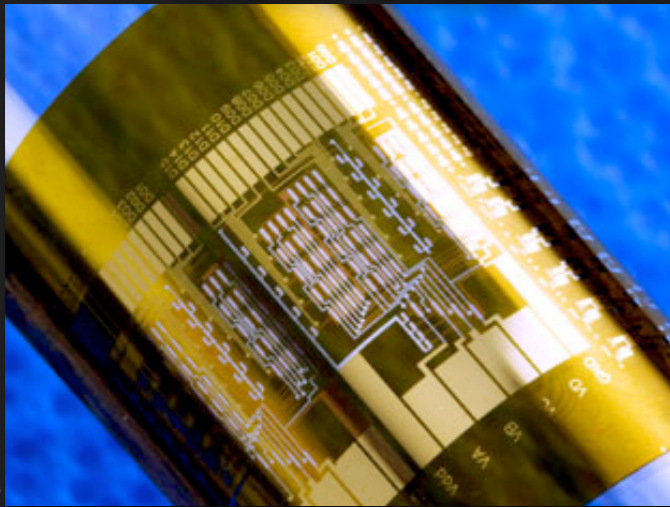
... sounds like a pretty big job. But don't worry, if you follow our easy to understand instructions, you will be amazing your friends and destroying the world in no time.



Ransom Riggs

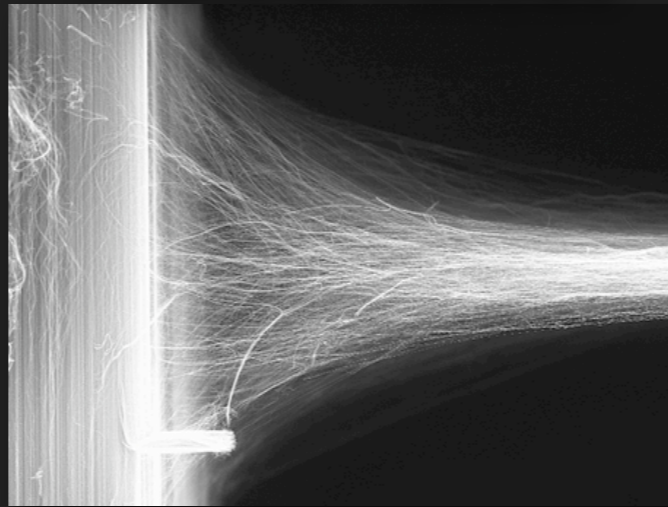
<http://www.mentalfloss.com/blogs/archives/23426>

Electronics



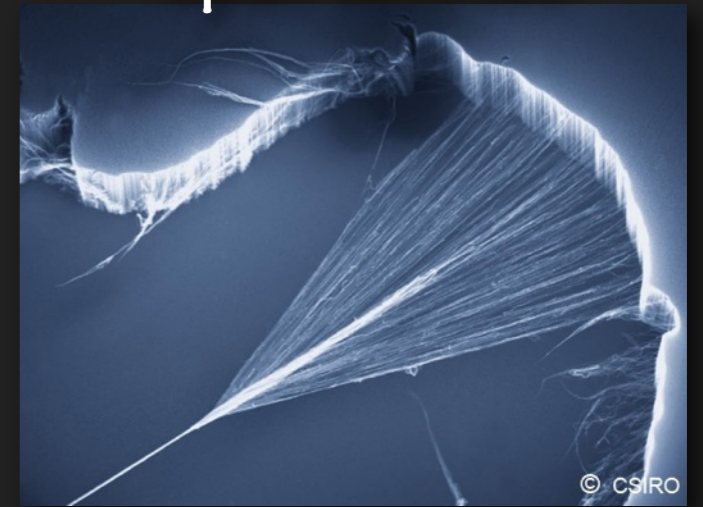
© Beckman Institute

Artificial muscles



blog.wired.com

Spun textiles



© CSIRO

Medicine

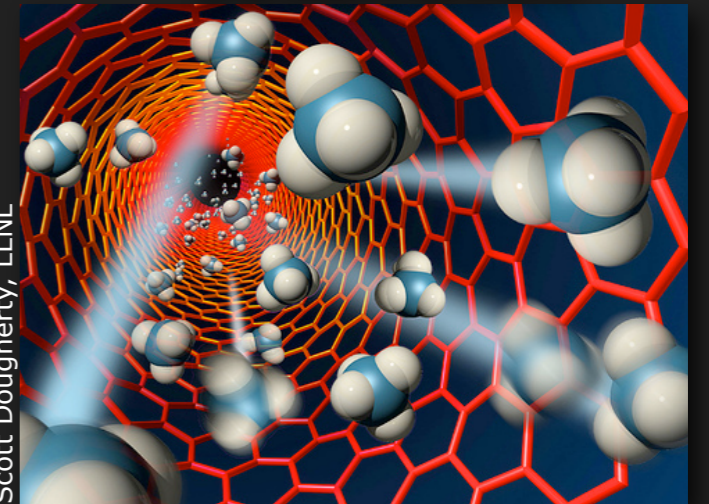


JPL



Chris Ewels, www.ewels.info

Desalination



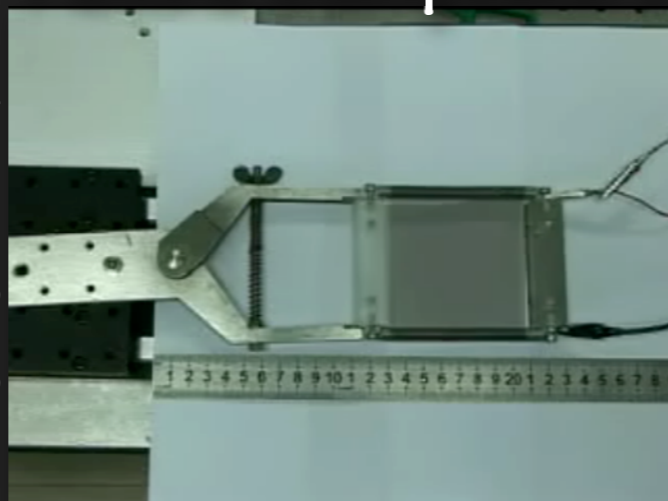
Scott Dougherty, LLNL

Strong materials



Easton

Flexible loudspeakers



Kaili Jiang, Tsinghua University

Space elevator

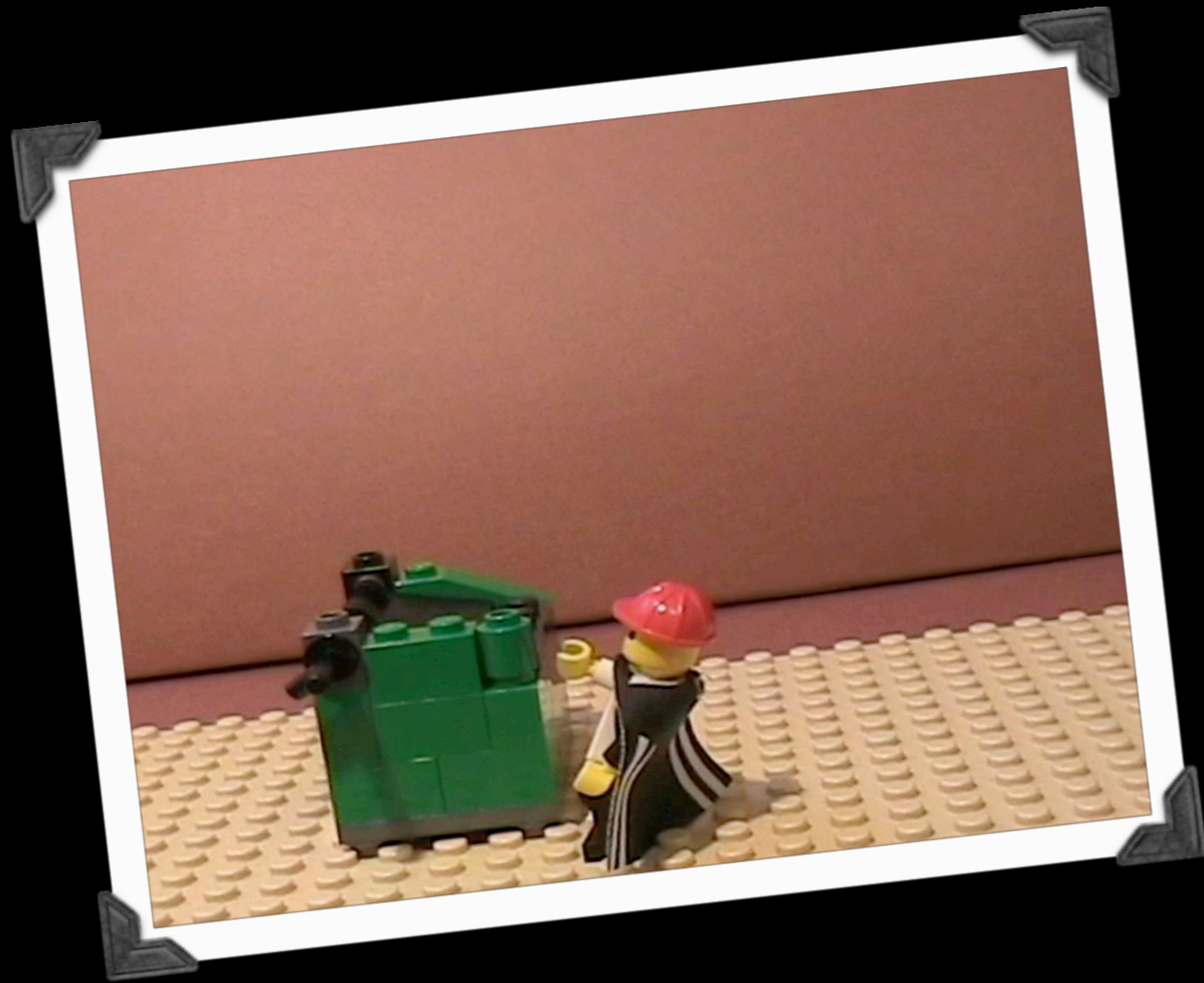


NASA

New Questions...

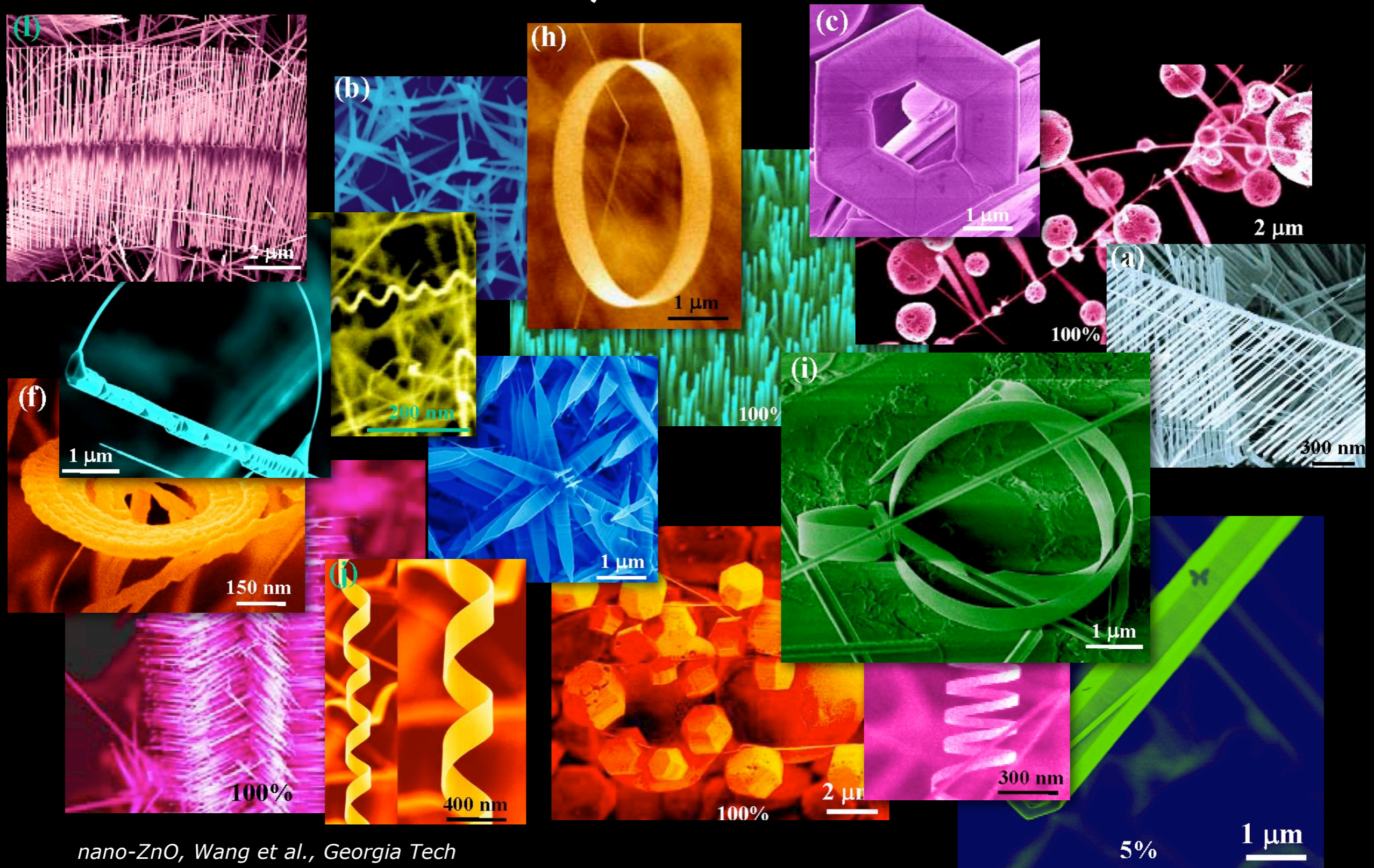
...but is nano
SAFE?

...New Answers



<http://www.youtube.com/watch?v=NmxHRuf6q-0>

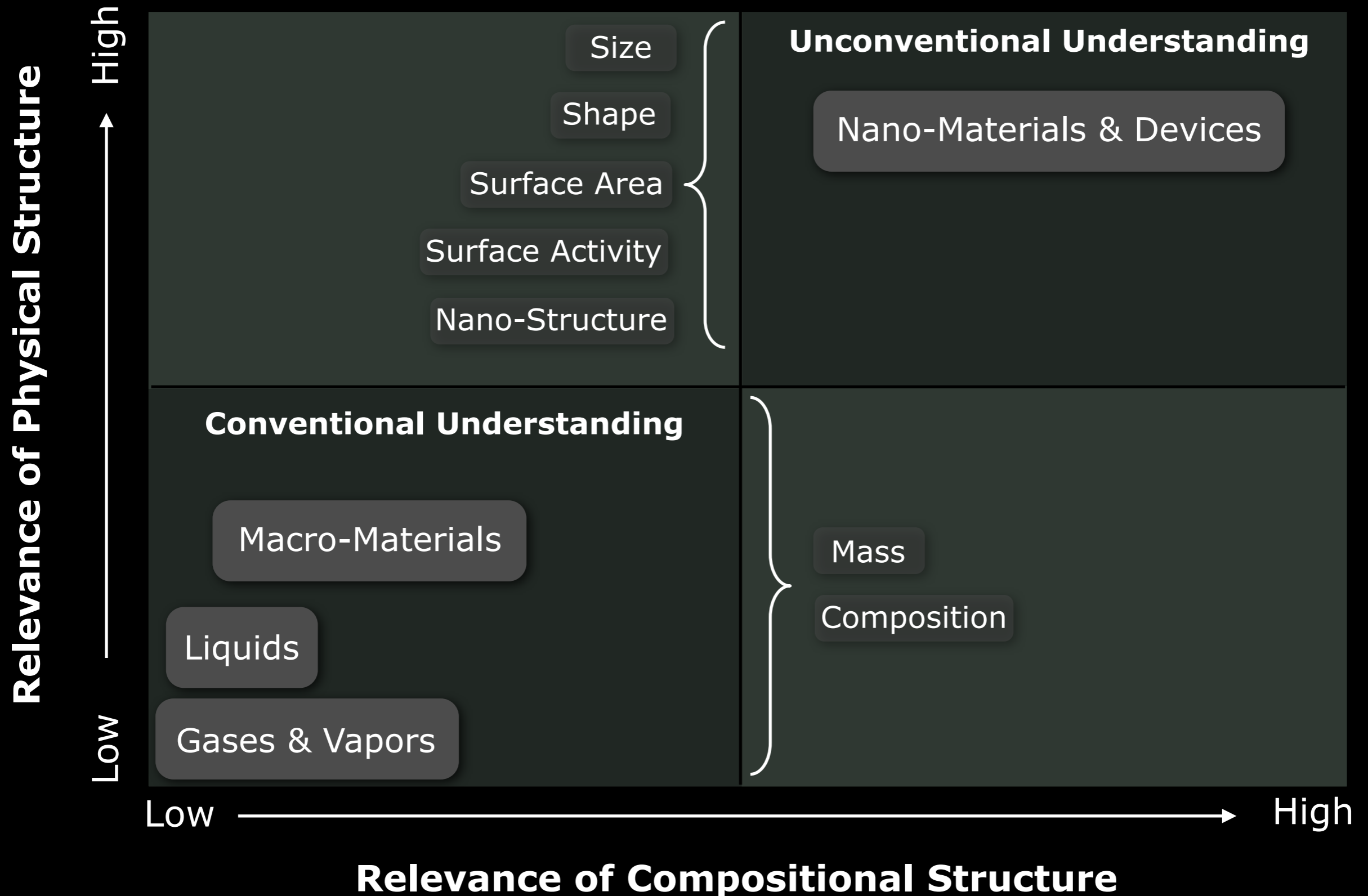
Similar Chemistry



Potentially Different Risks

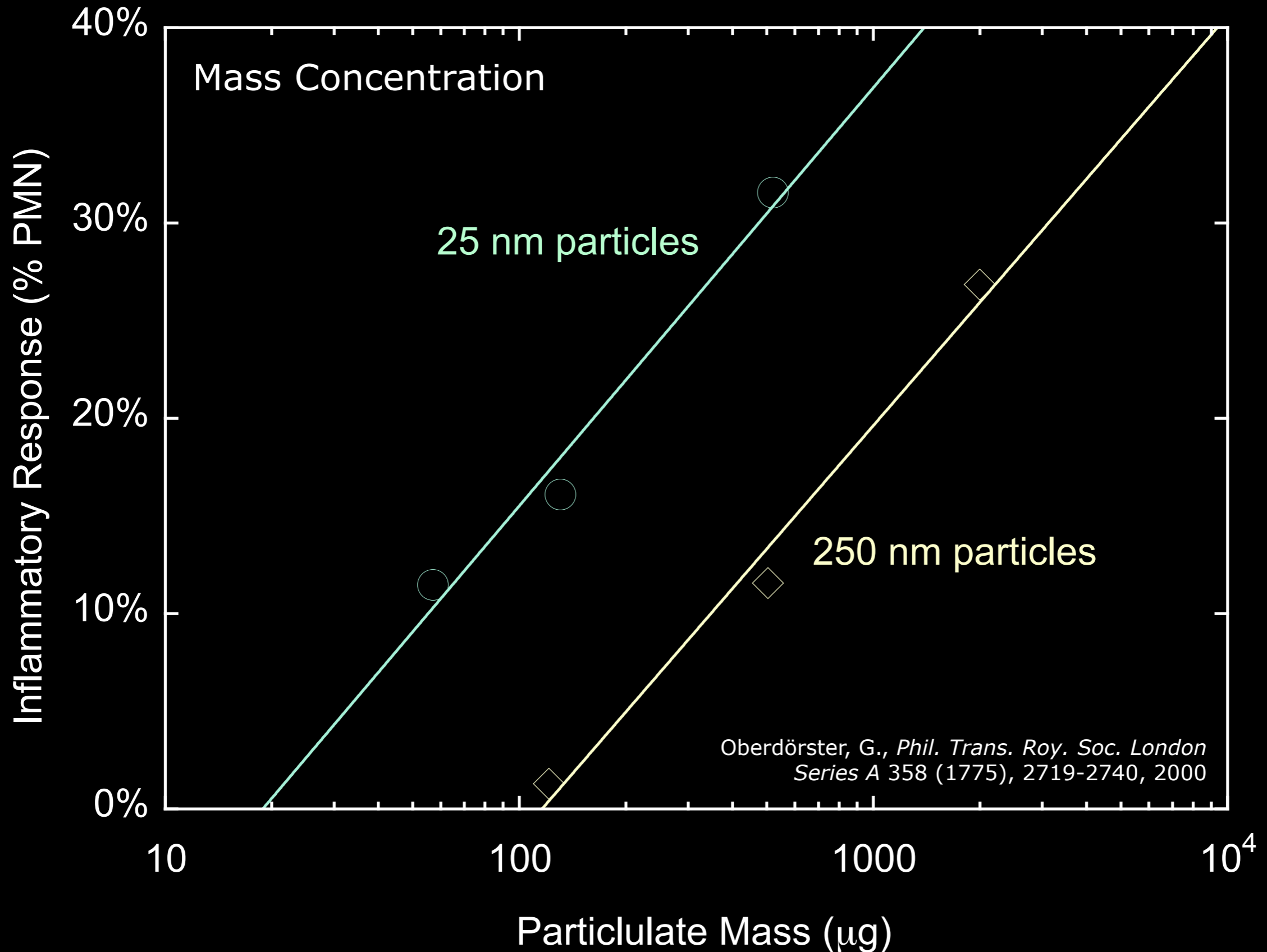
A thought experiment

The potential significance of structure on nanomaterial impact



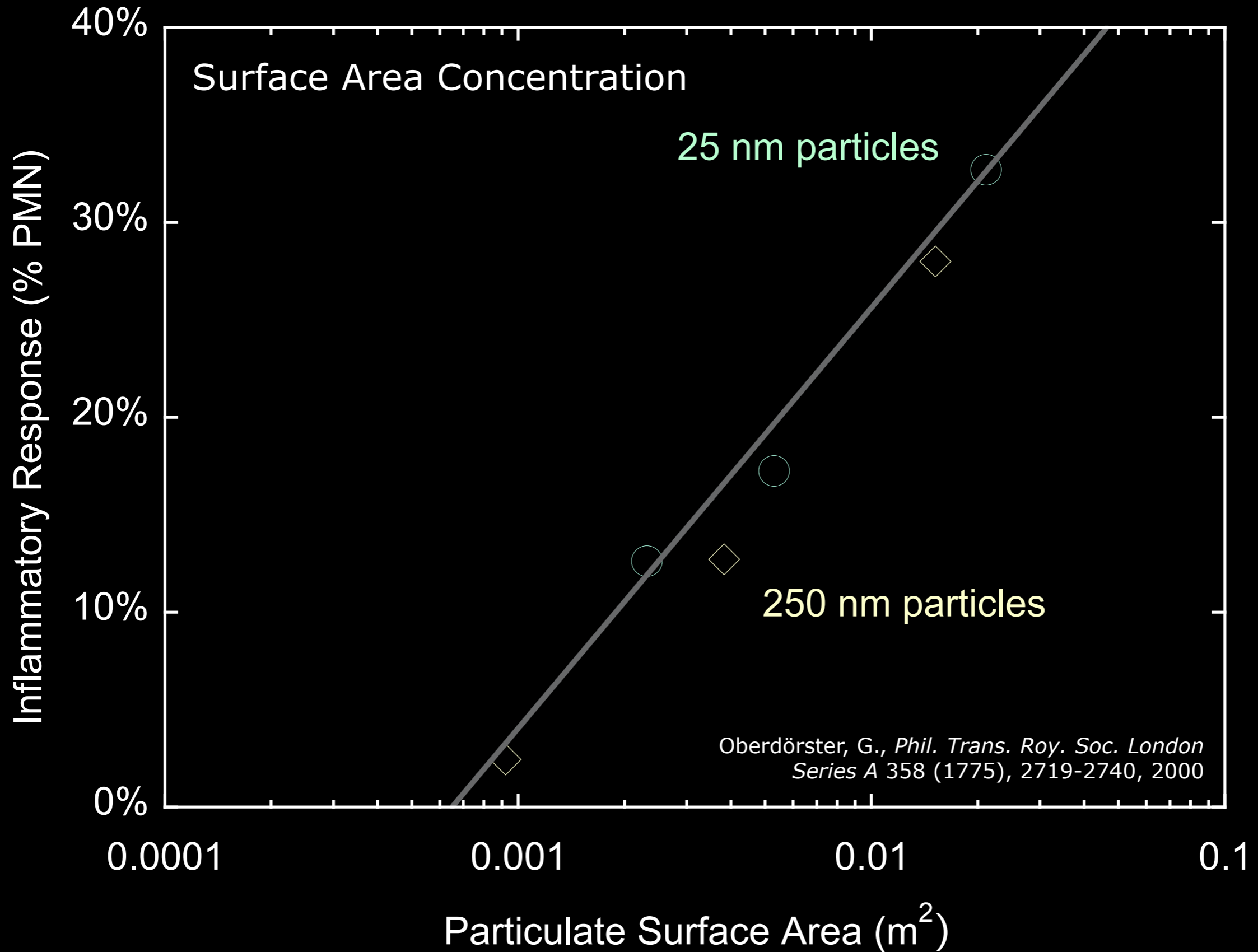
Scale-specific hazard: Particle Size

TiO₂ Instillation in Rats



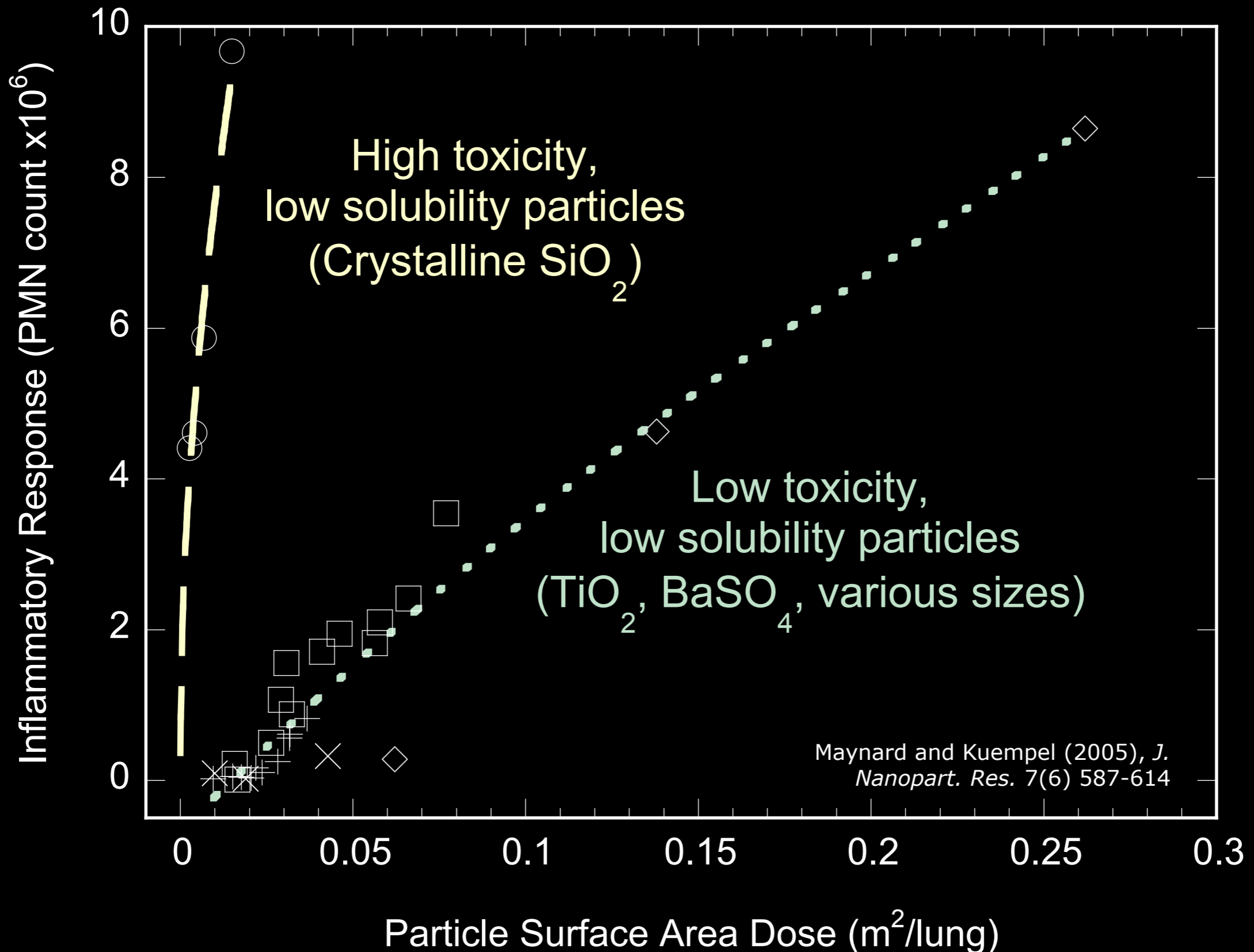
Scale-specific hazard: Particle Size

TiO₂ Instillation in Rats



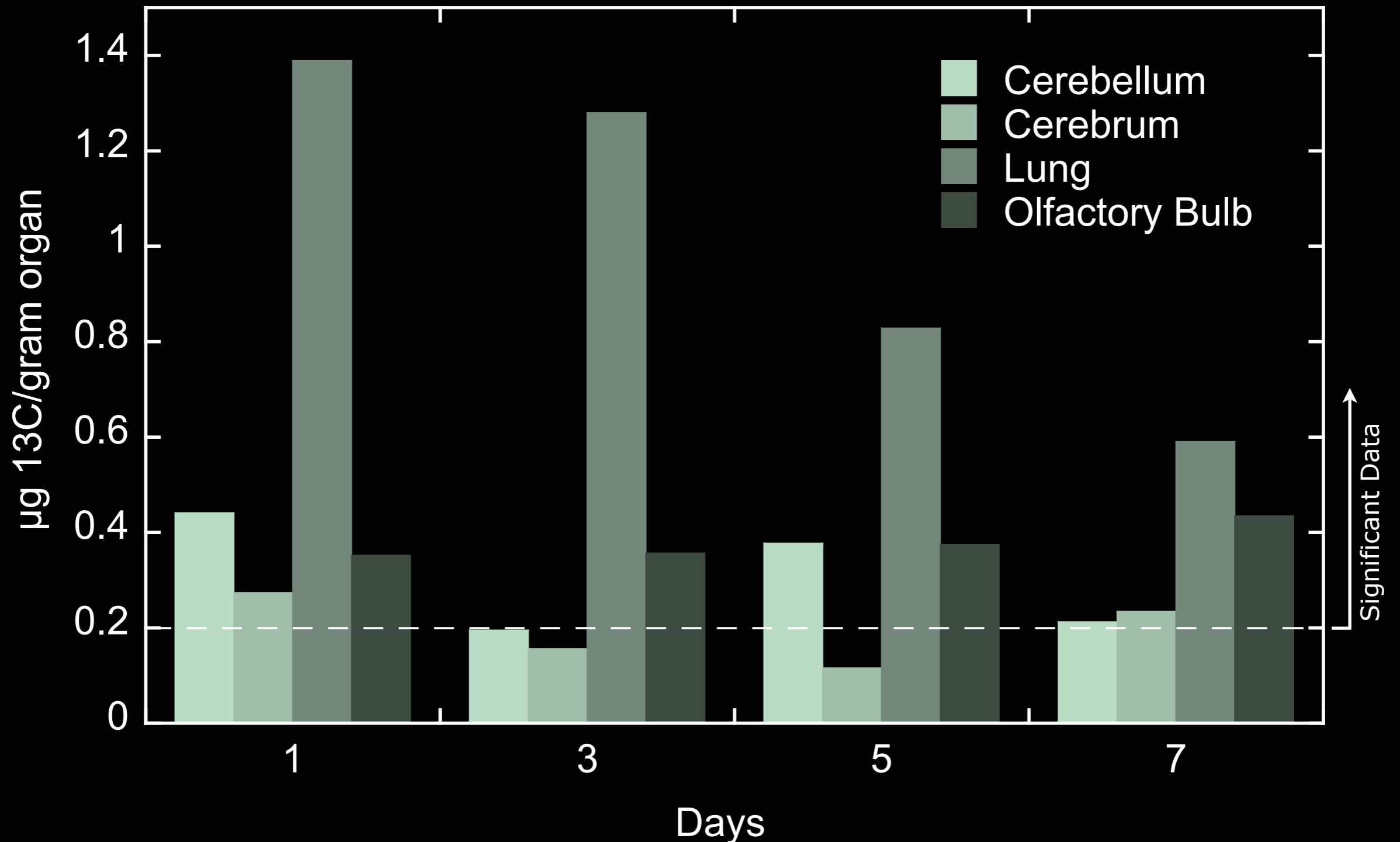
Scale-specific hazard: Particle Surface

TiO₂ Instillation in Rats



Size-related hazard: Translocation

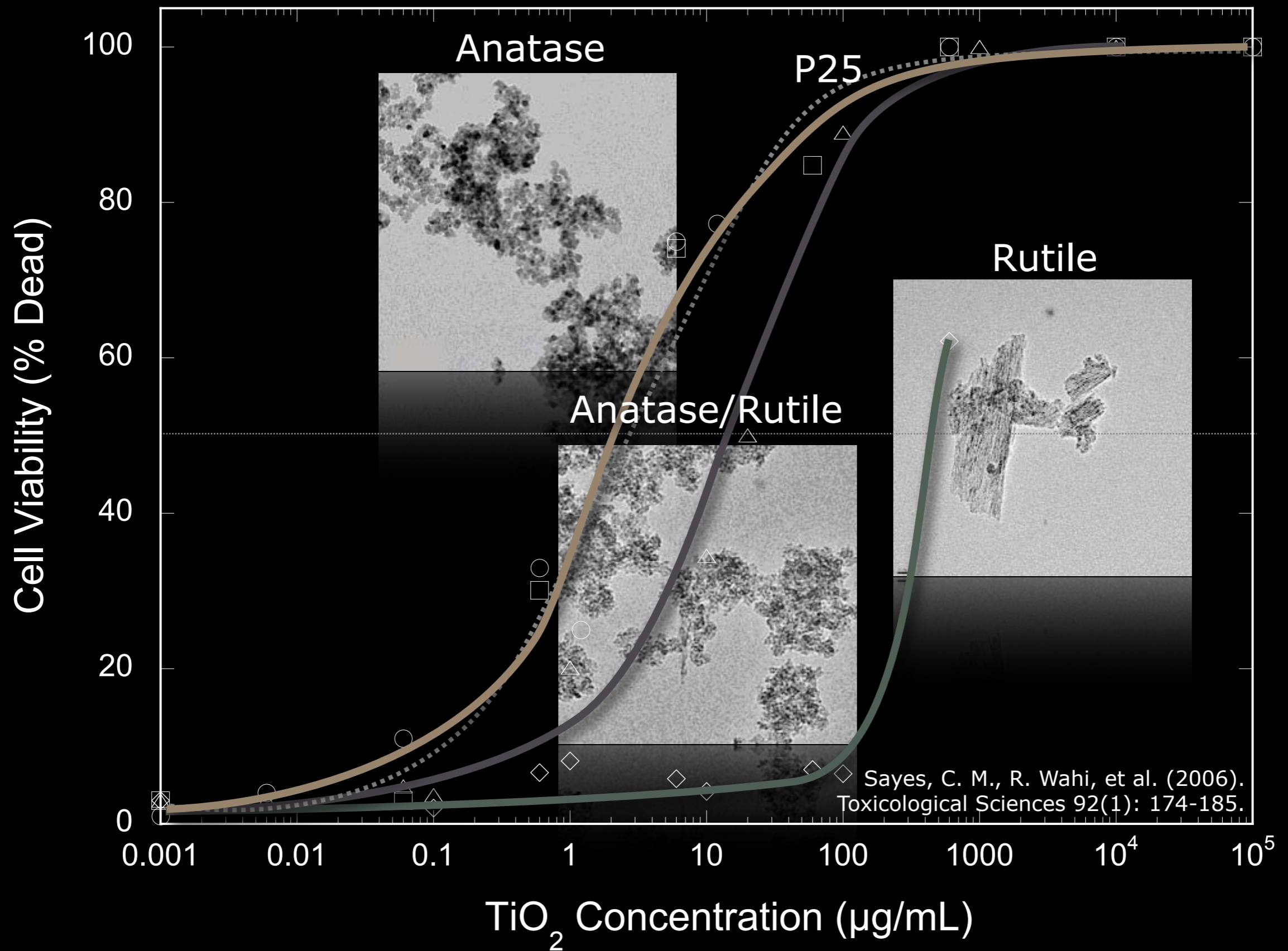
Translocation following inhalation - Nose to Brain



(Based on Oberdörster, G., et al. (2004), *Inhal. Toxicol.* 16 (6-7), 437-445)

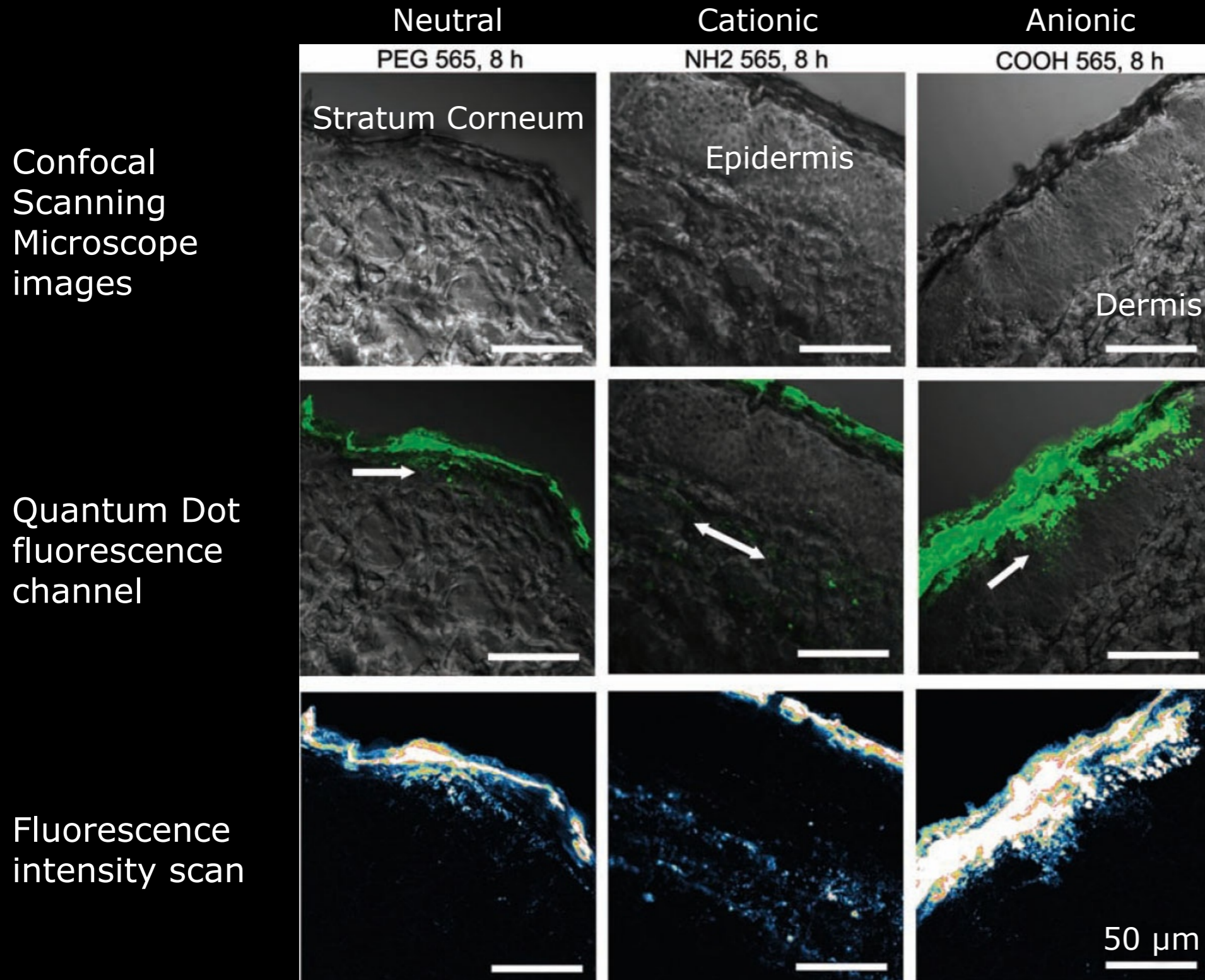
Structure-related hazard: Crystallinity

In vitro studies - Human Dermal Fibroblasts



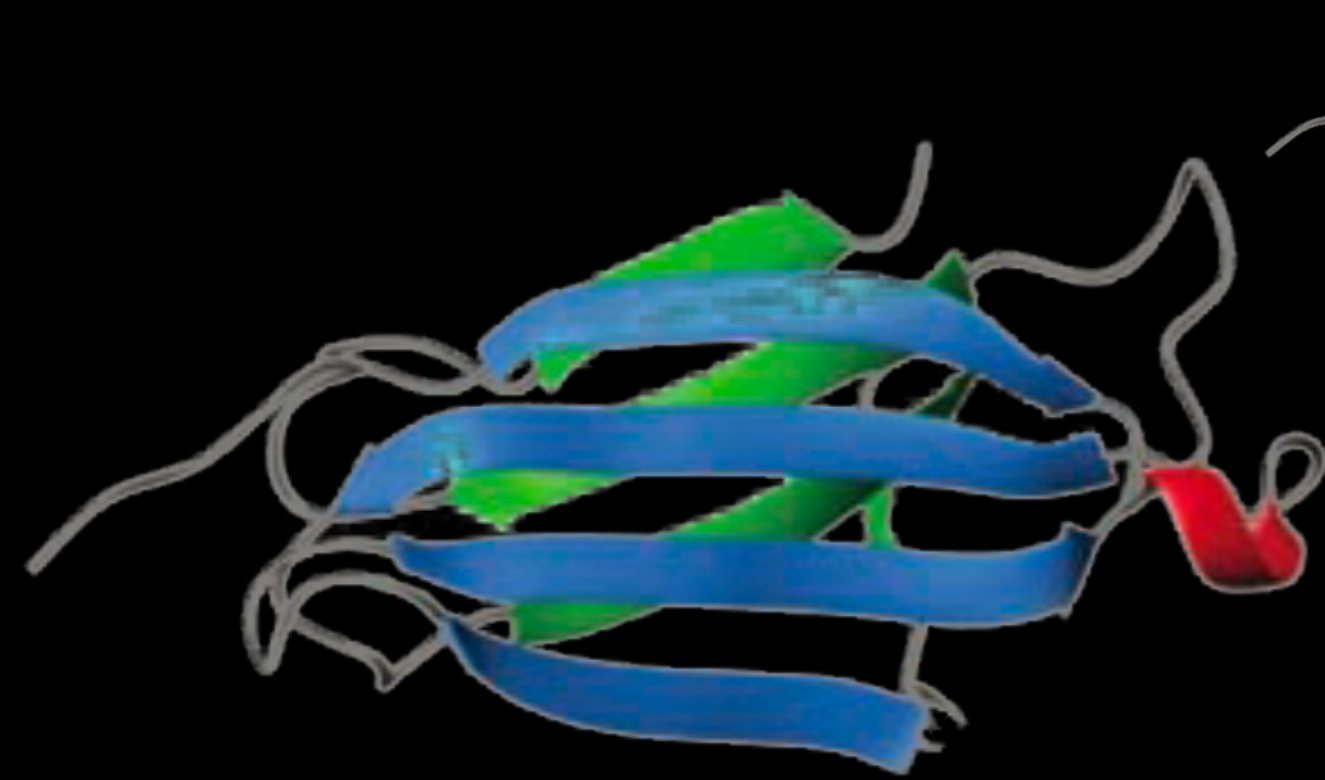
Scale-specific hazard: Skin Penetration

4.6 nm spherical Quantum dots in porcine skin flow-through cell

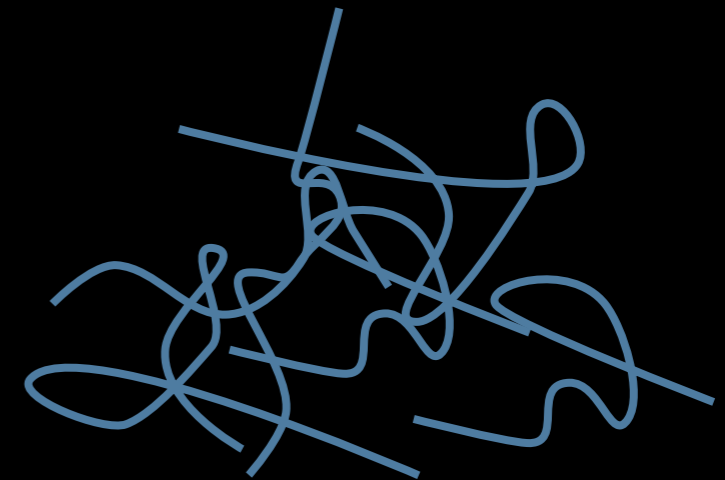
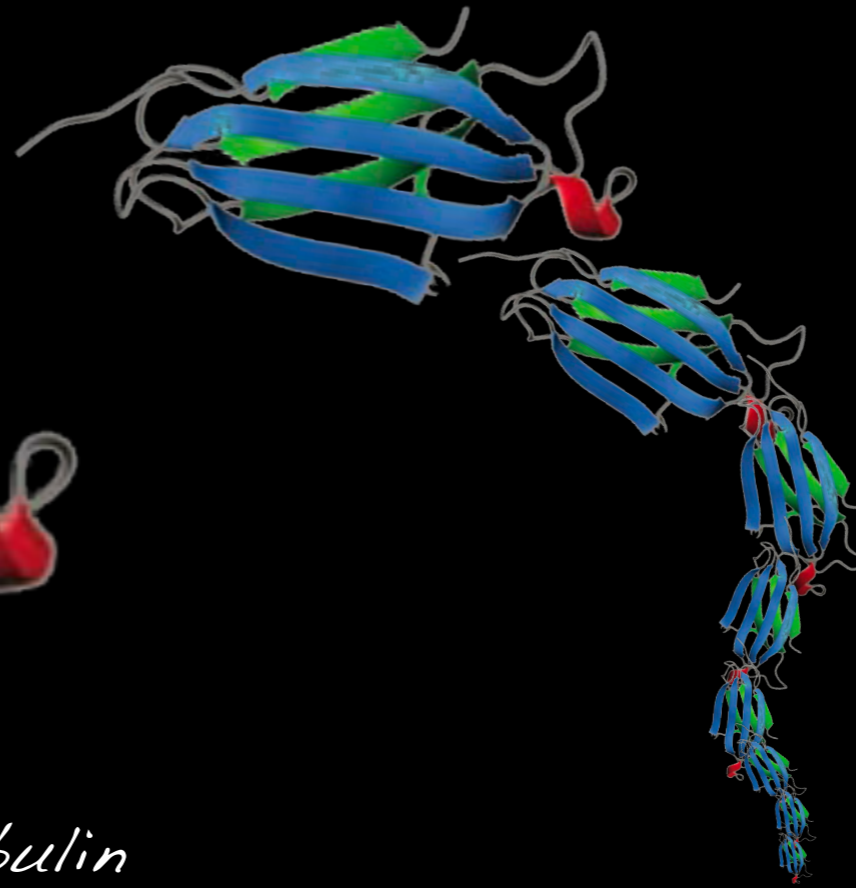


Scale-specific hazard: Form

Interfering with biology at the nanoscale



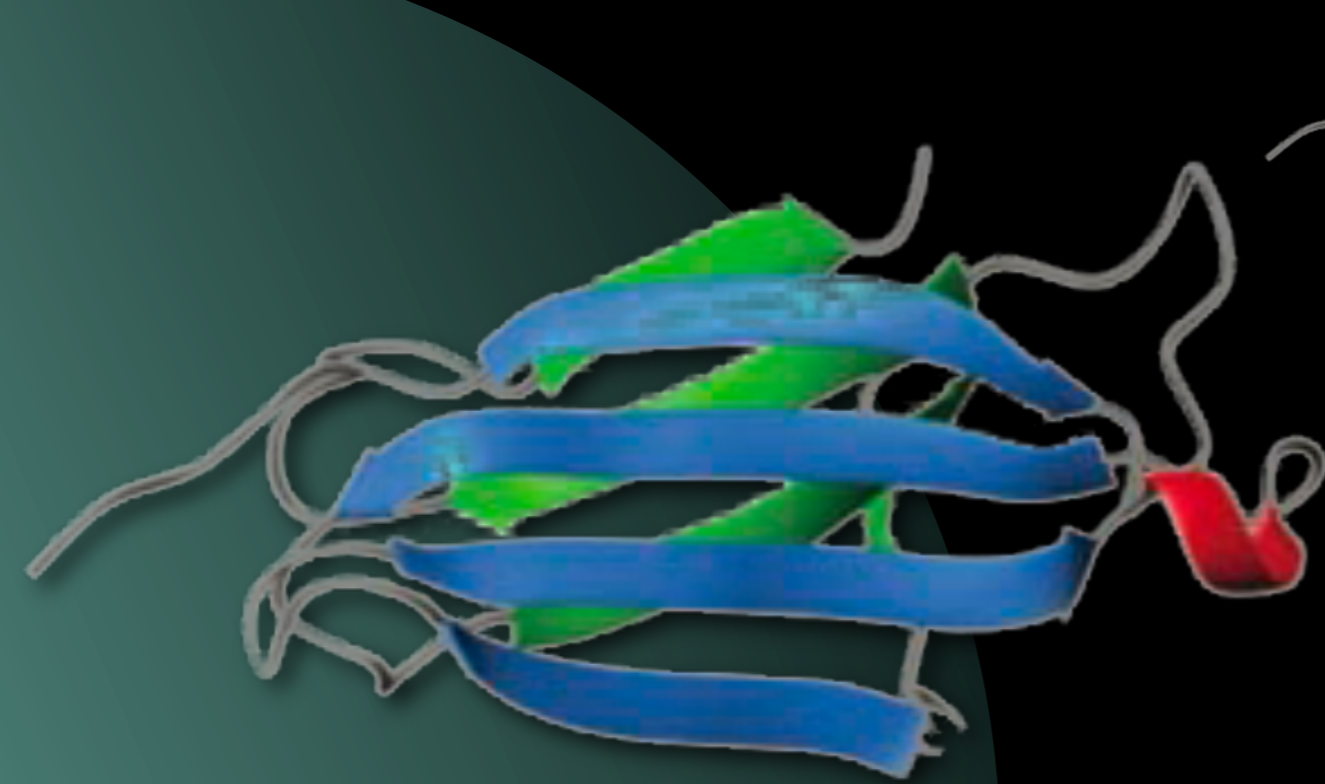
beta-2 microglobulin



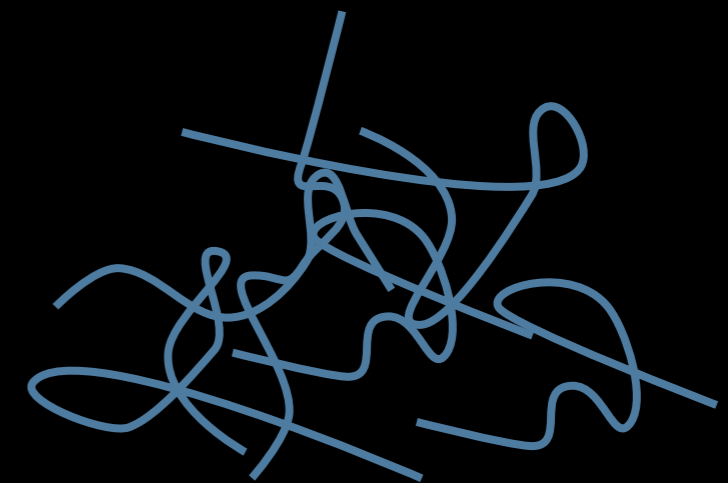
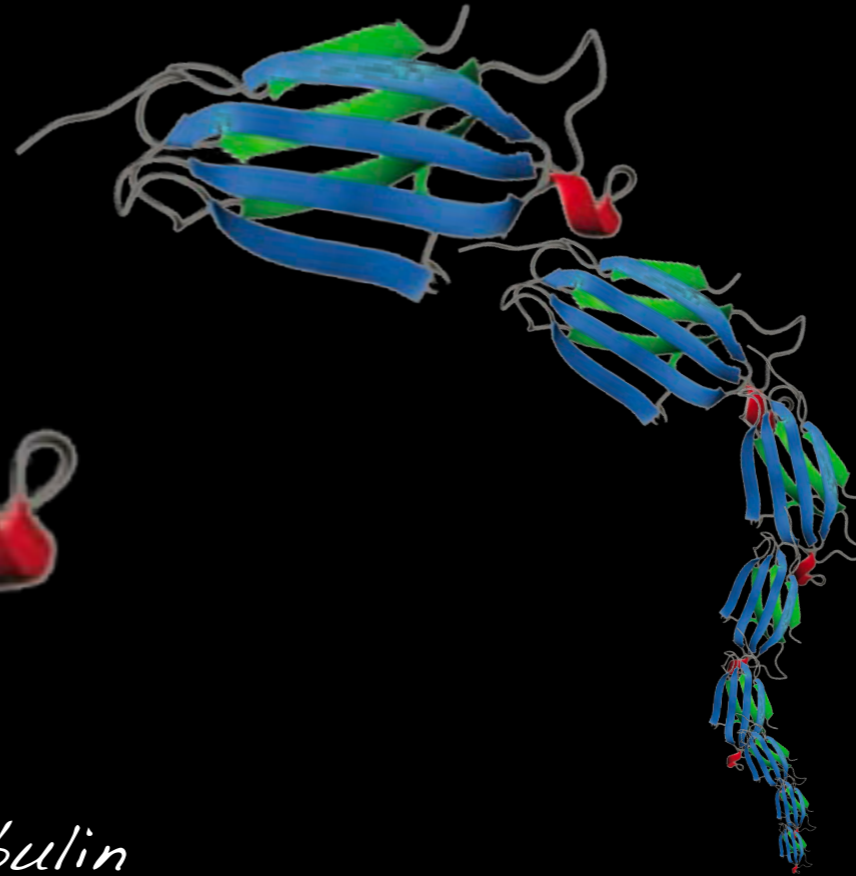
fibrillated protein

Scale-specific hazard: Form

Interfering with biology at the nanoscale



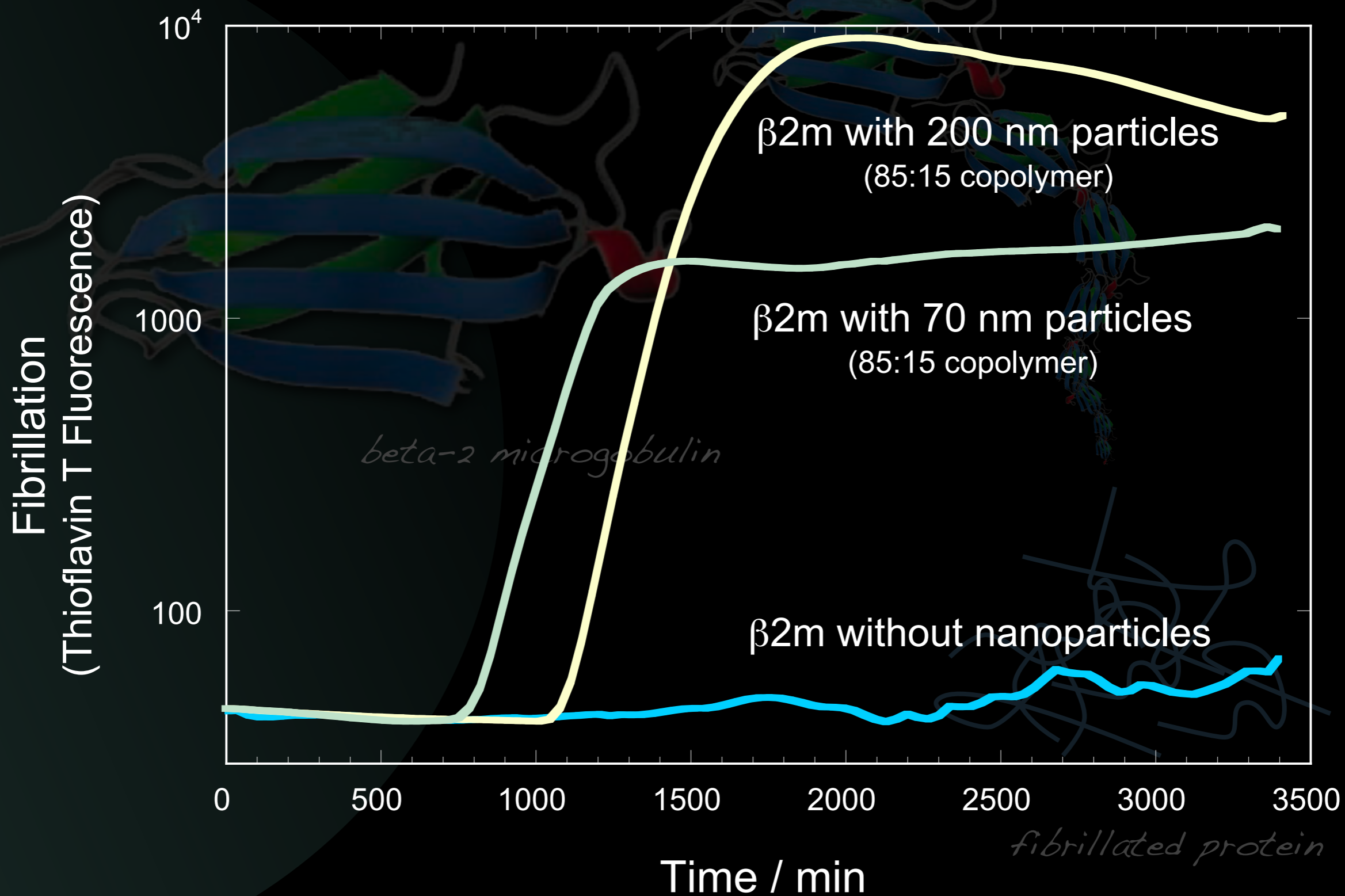
beta-2 microglobulin



fibrillated protein

Scale-specific hazard: Form

Interfering with biology at the nanoscale

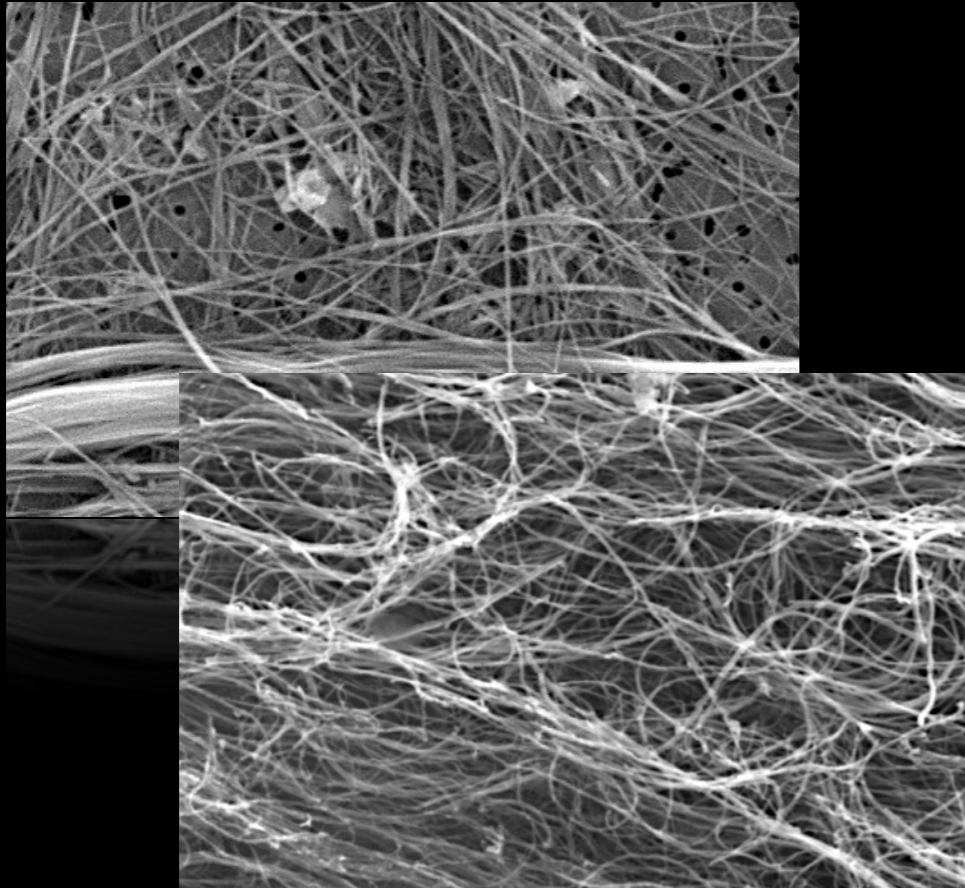


Structure-related hazard: Things we already know

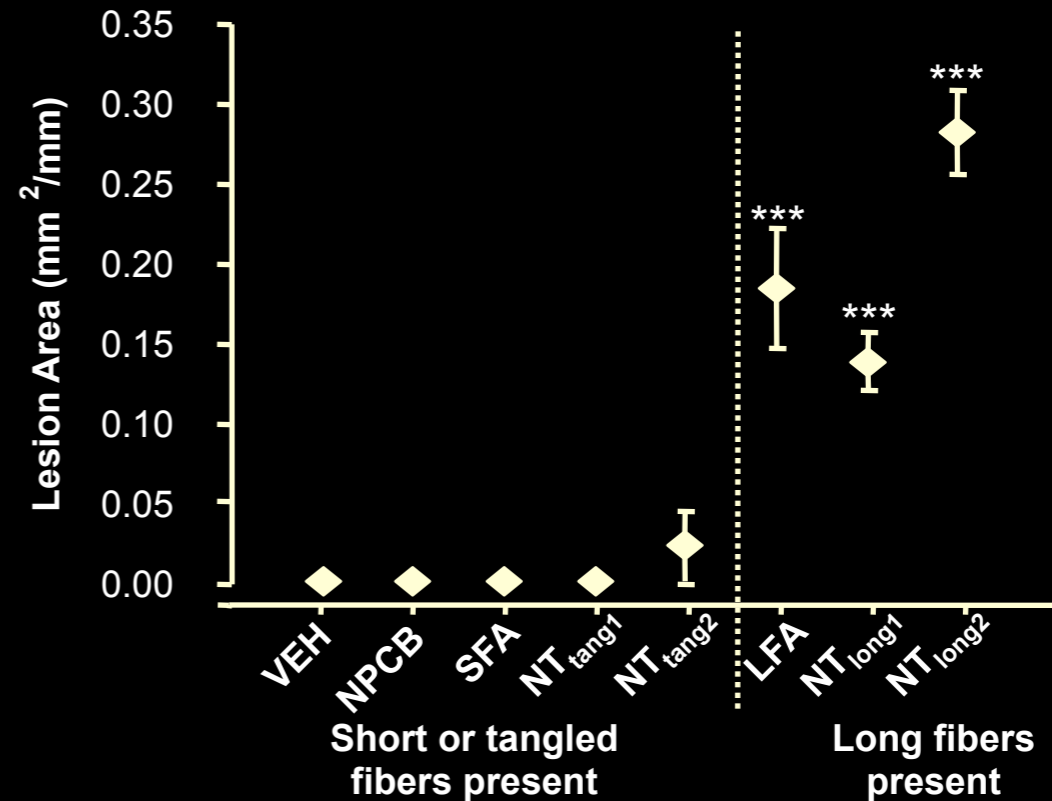
Does the fiber paradigm hold for fiber-like nanomaterials?

Asbestos

5 μm



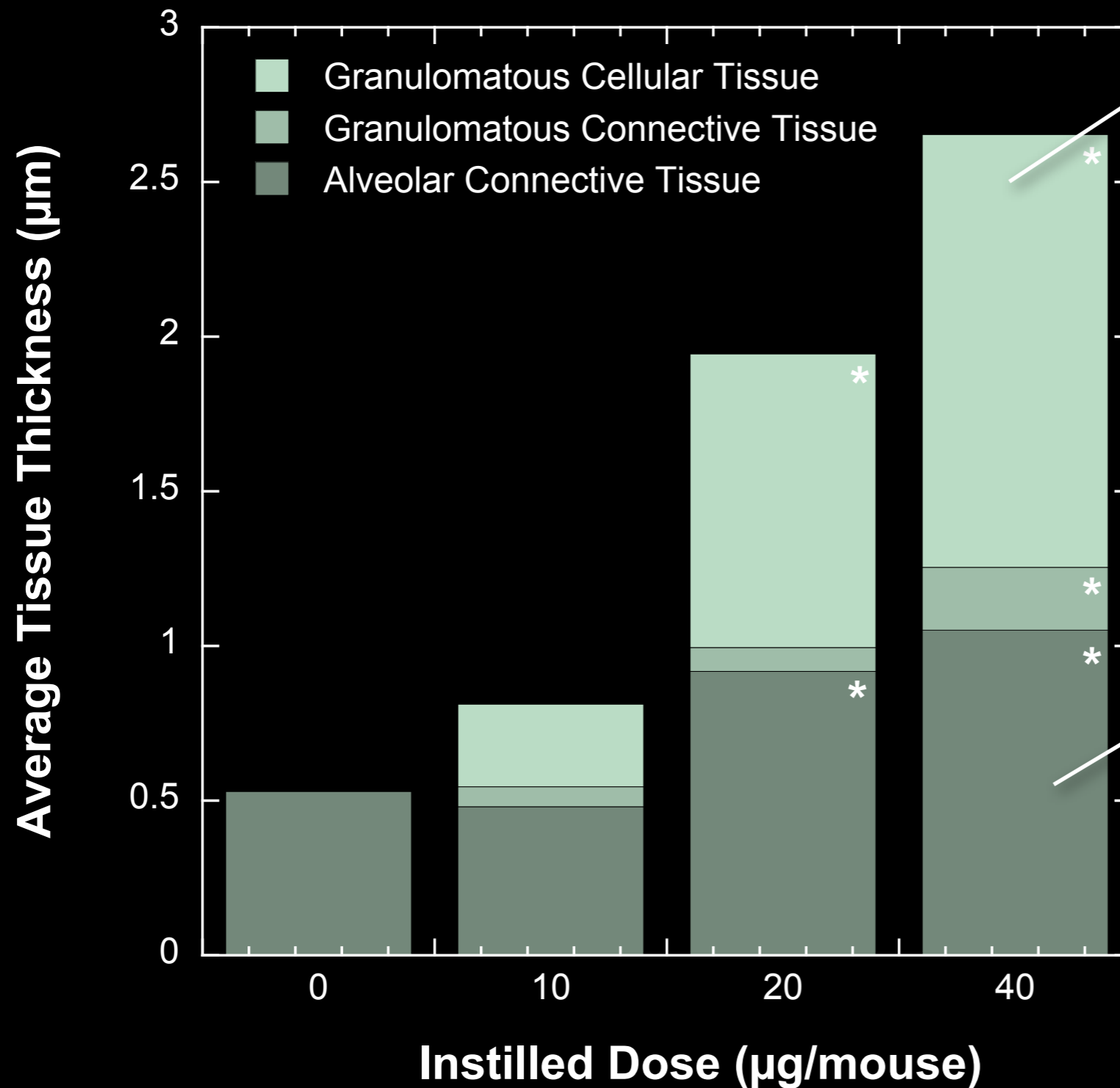
Carbon Nanotubes



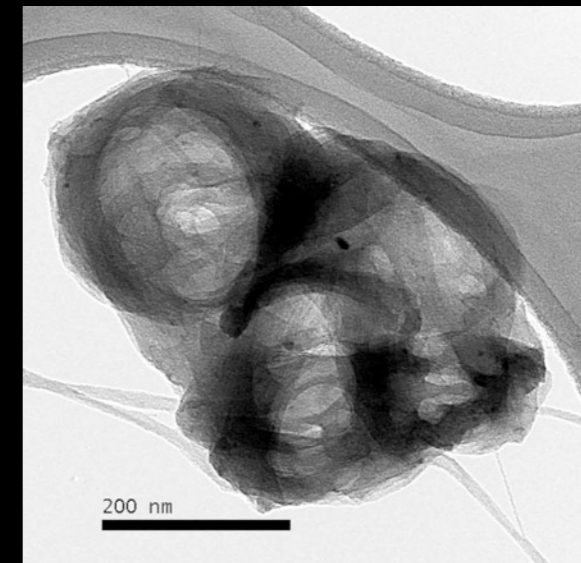
Carbon nanotubes that look like harmful asbestos fibers, behave like harmful asbestos fibers

Structure-related hazard: Carbon Nanotubes

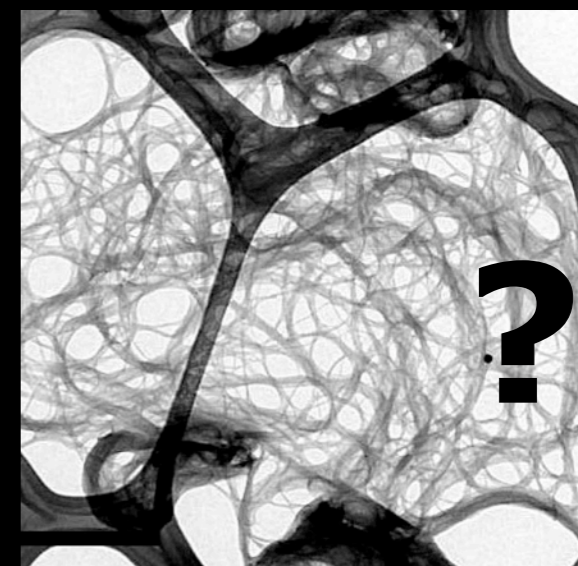
Non fiber-like behavior

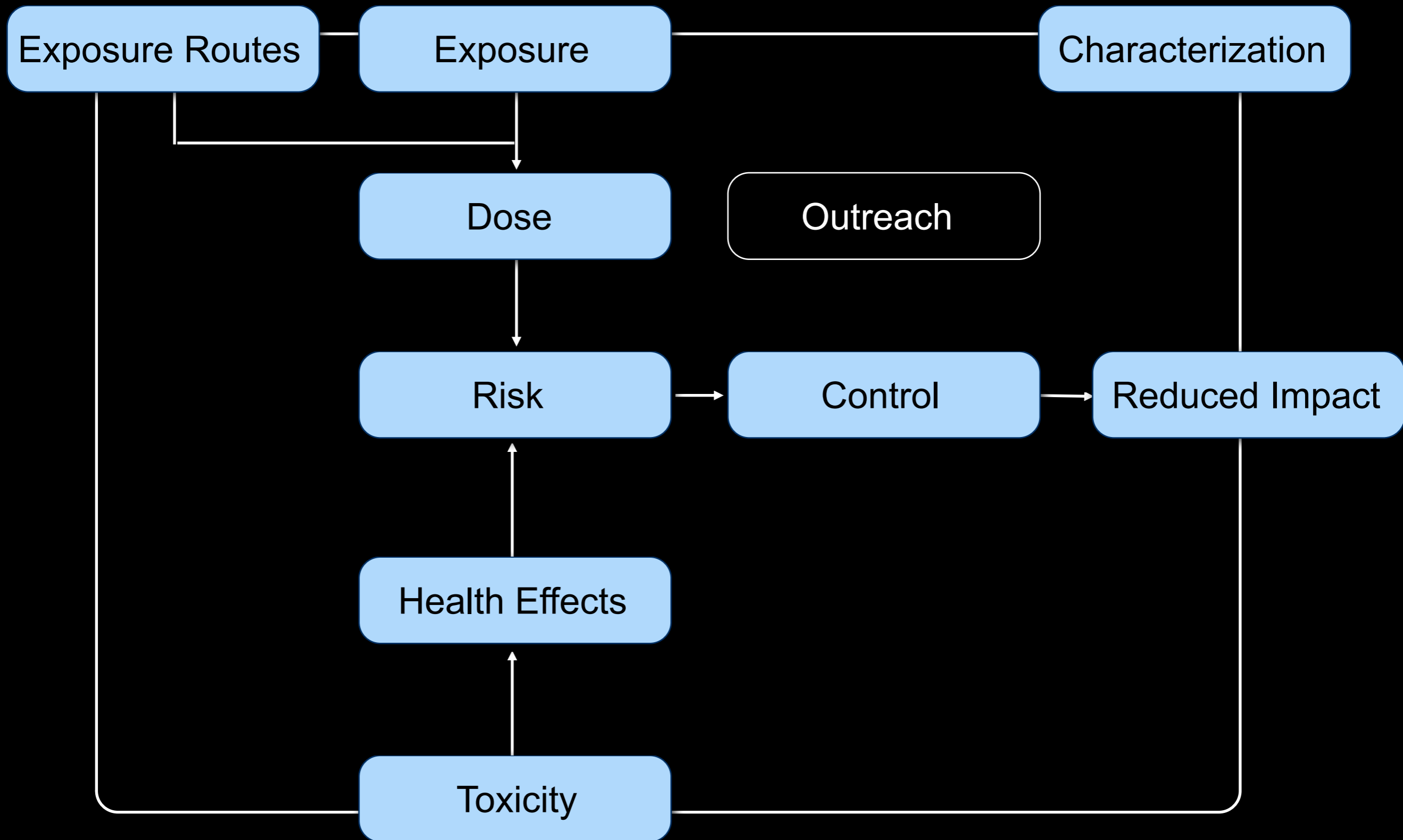


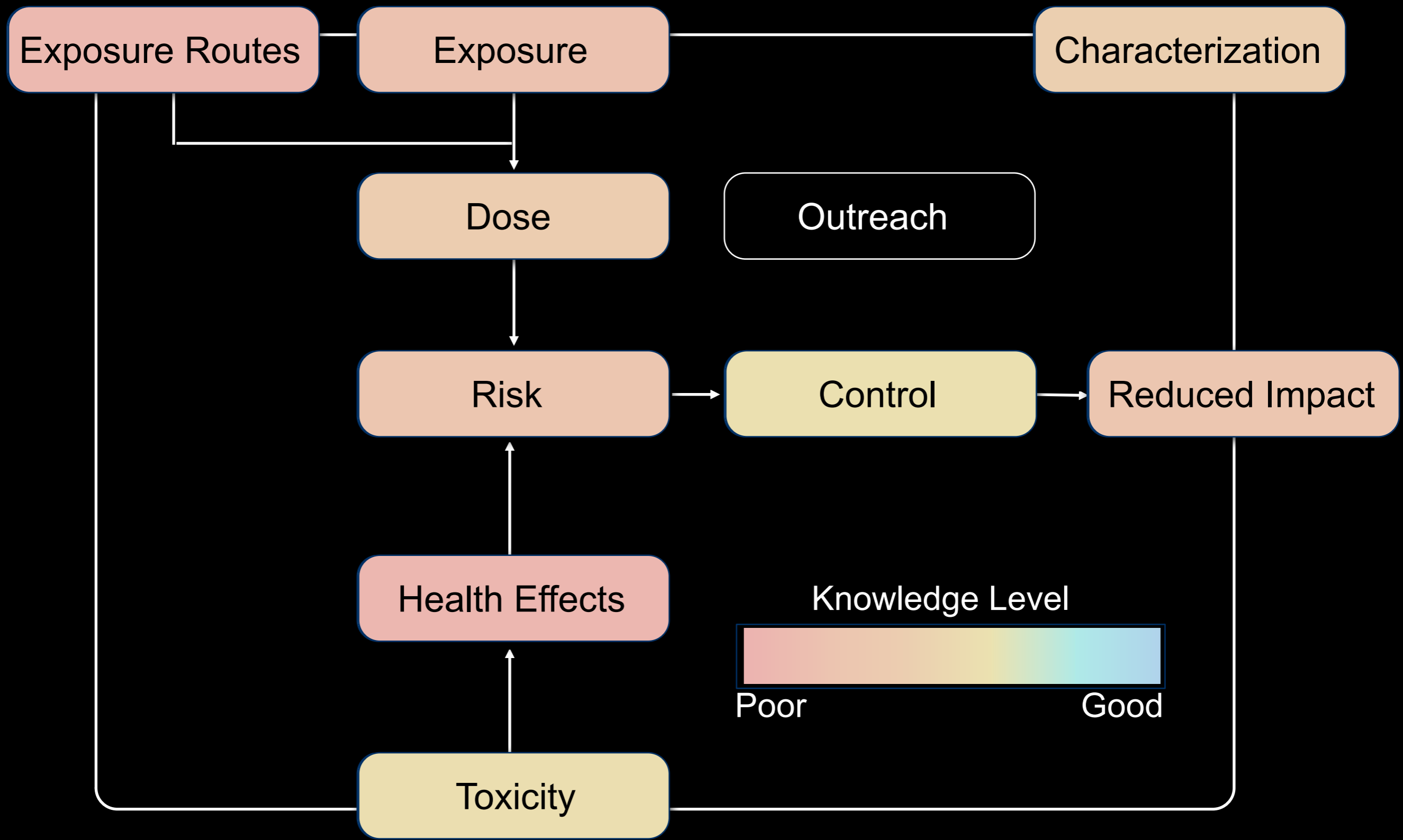
Proximal region of lung
Visible SWCNT clumps

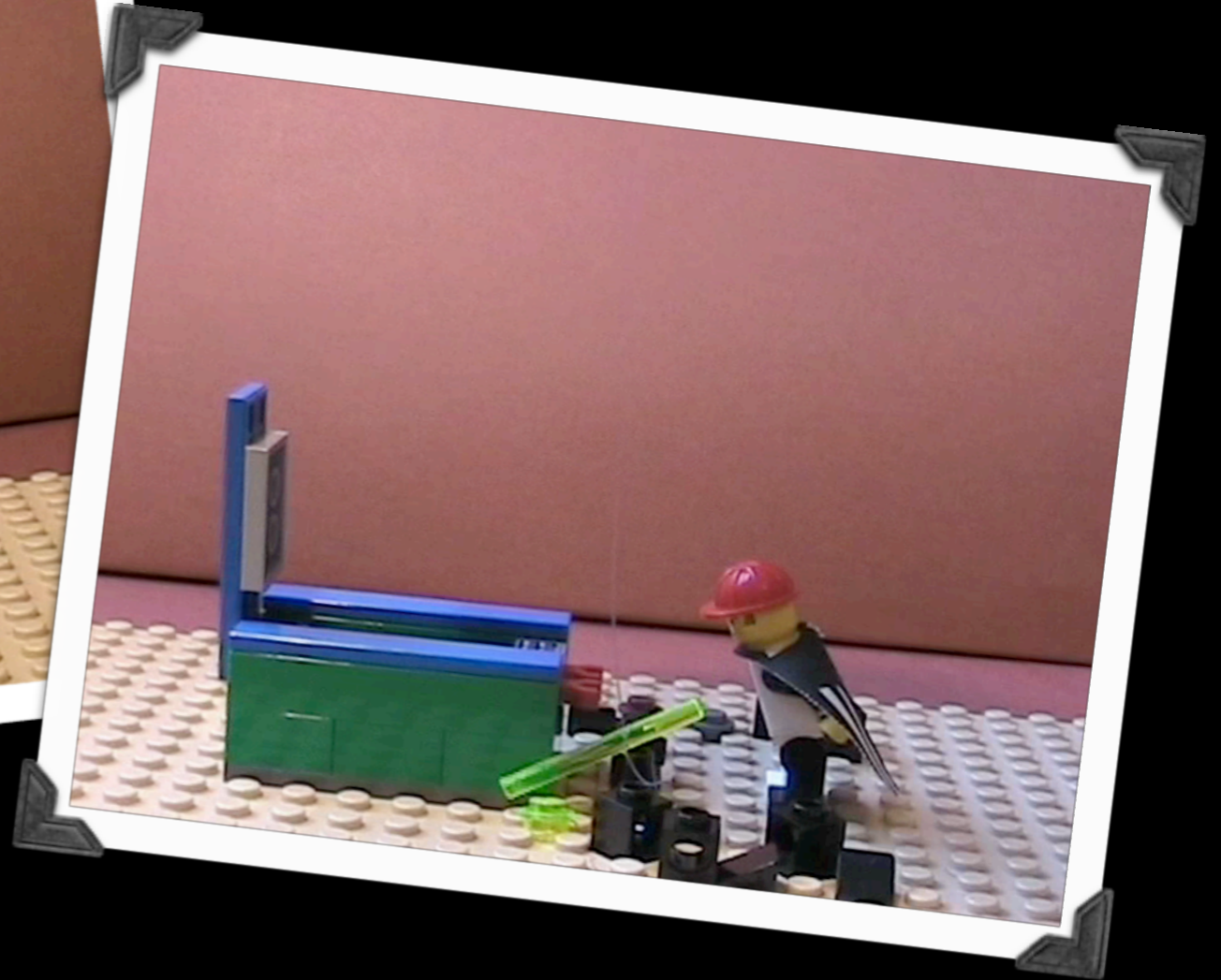
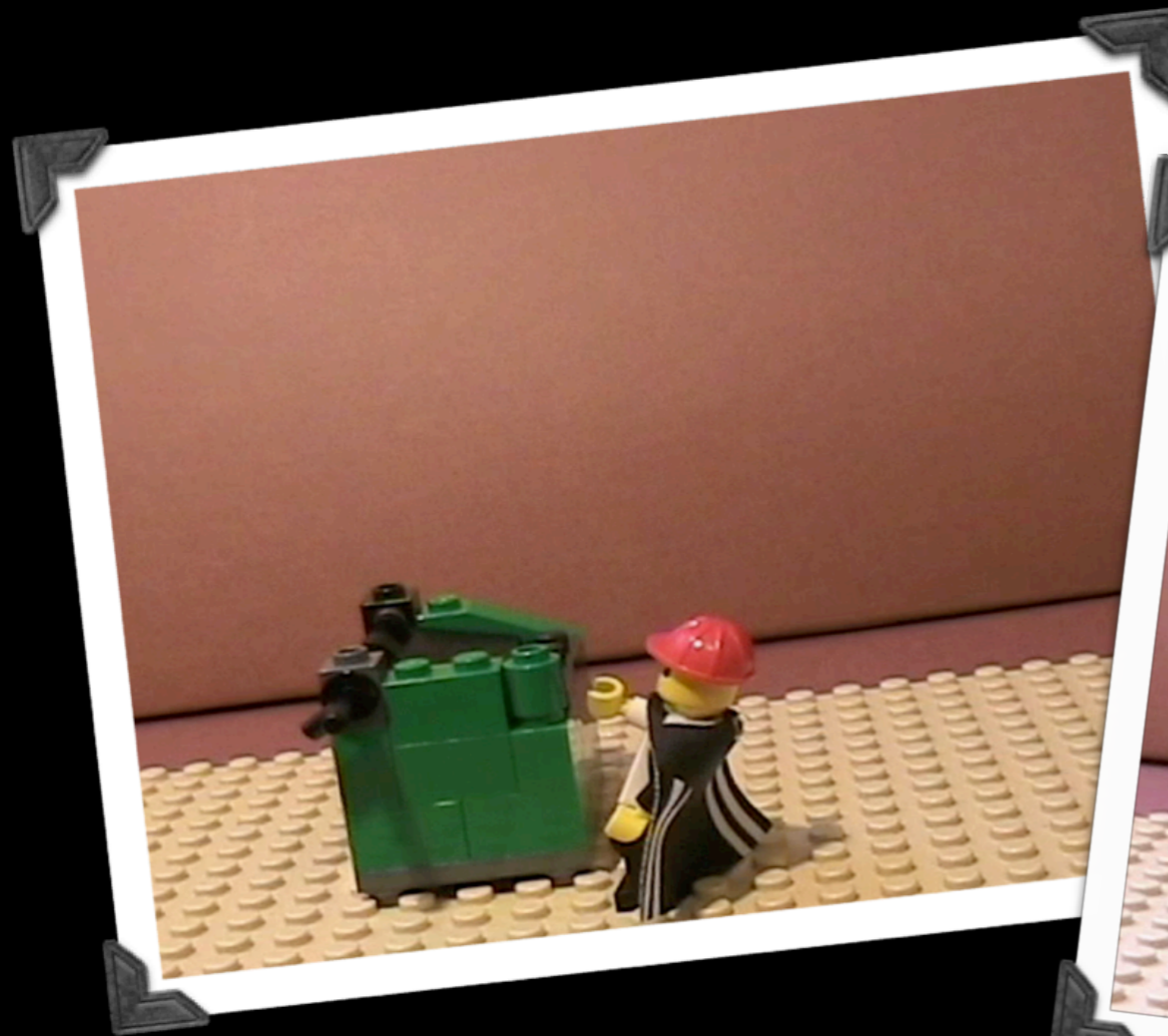


Distal region of lung
No SWCNT visible





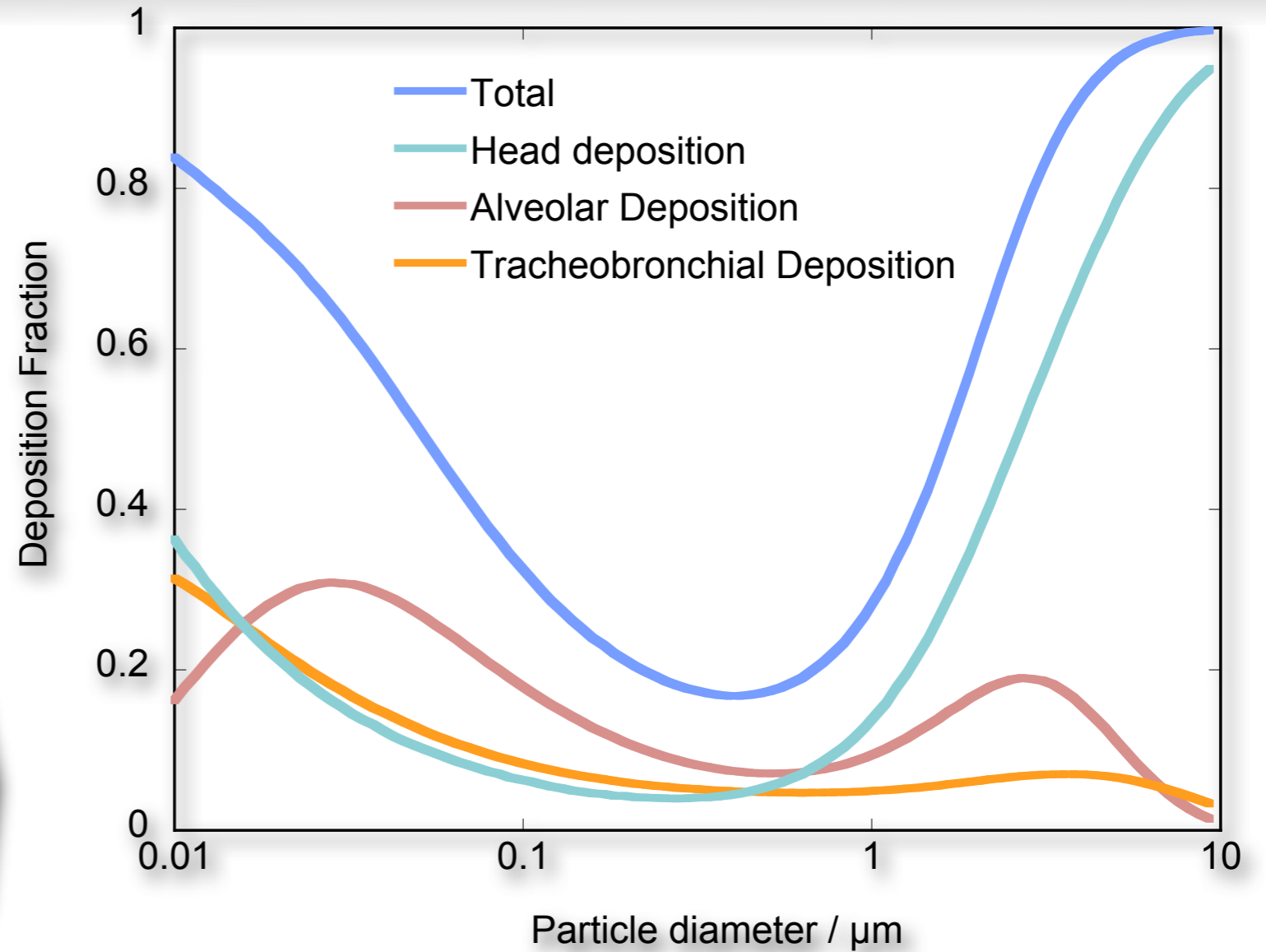
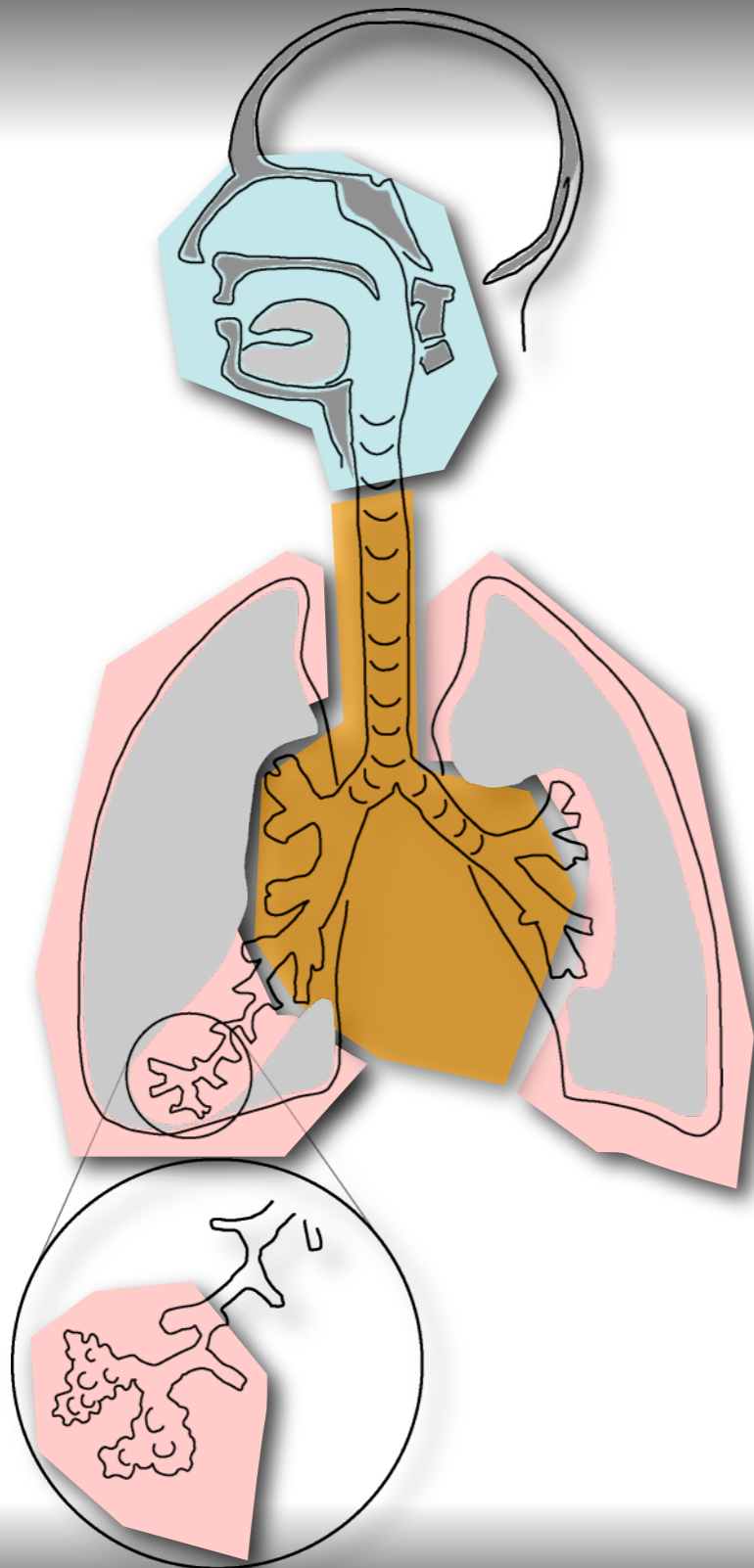




<http://www.youtube.com/watch?v=mGj5idMYMzw>

Particle deposition in the lungs

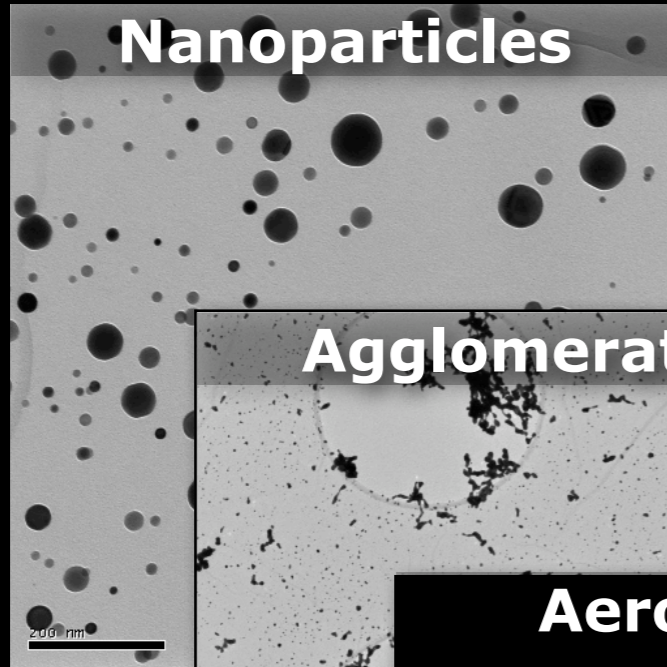
Modeled lung deposition. Mouth and nose breathing, person at rest.



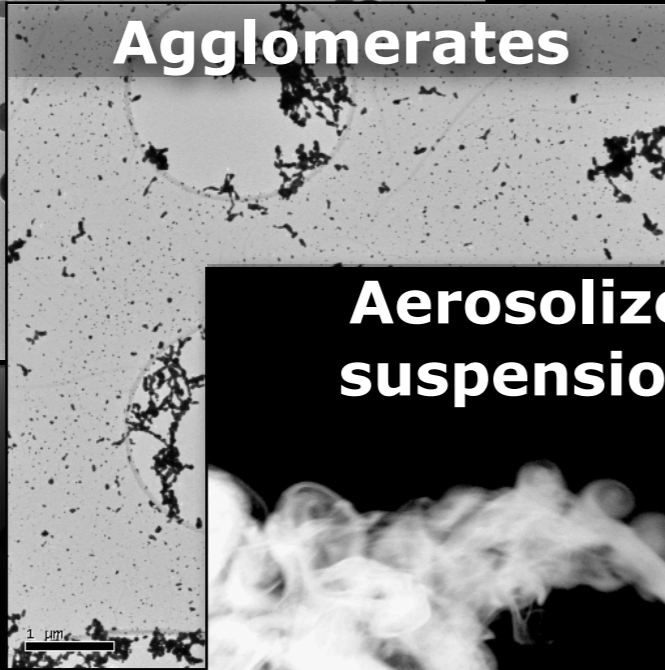
Setting Boundaries

Engineered nanomaterials which potentially present new challenges

Nanoparticles



Agglomerates



Aerosolized suspensions



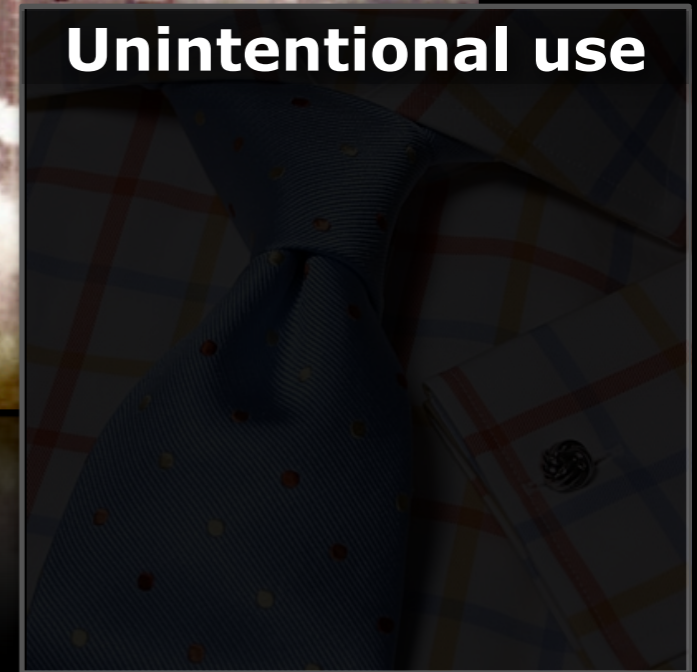
Comminution



**Degradation/
Failure**

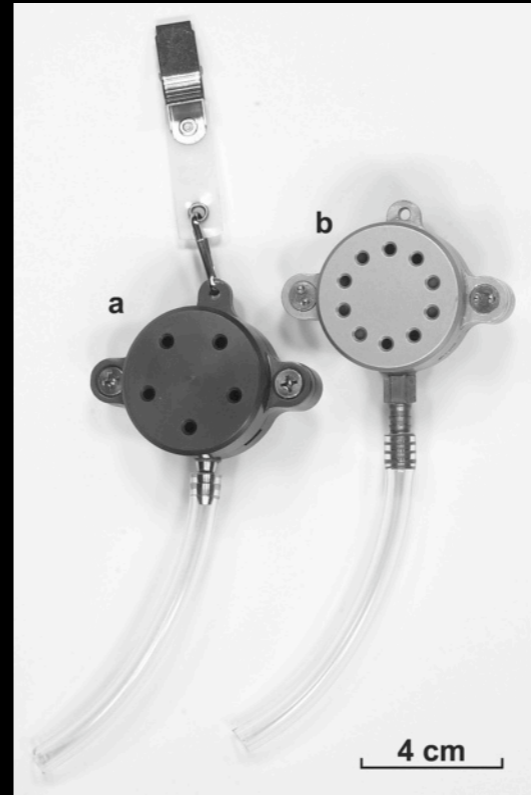


Unintentional use





<http://www.youtube.com/watch?v=AohjUkNxR5U>



Monitoring nanoscale aerosol exposures

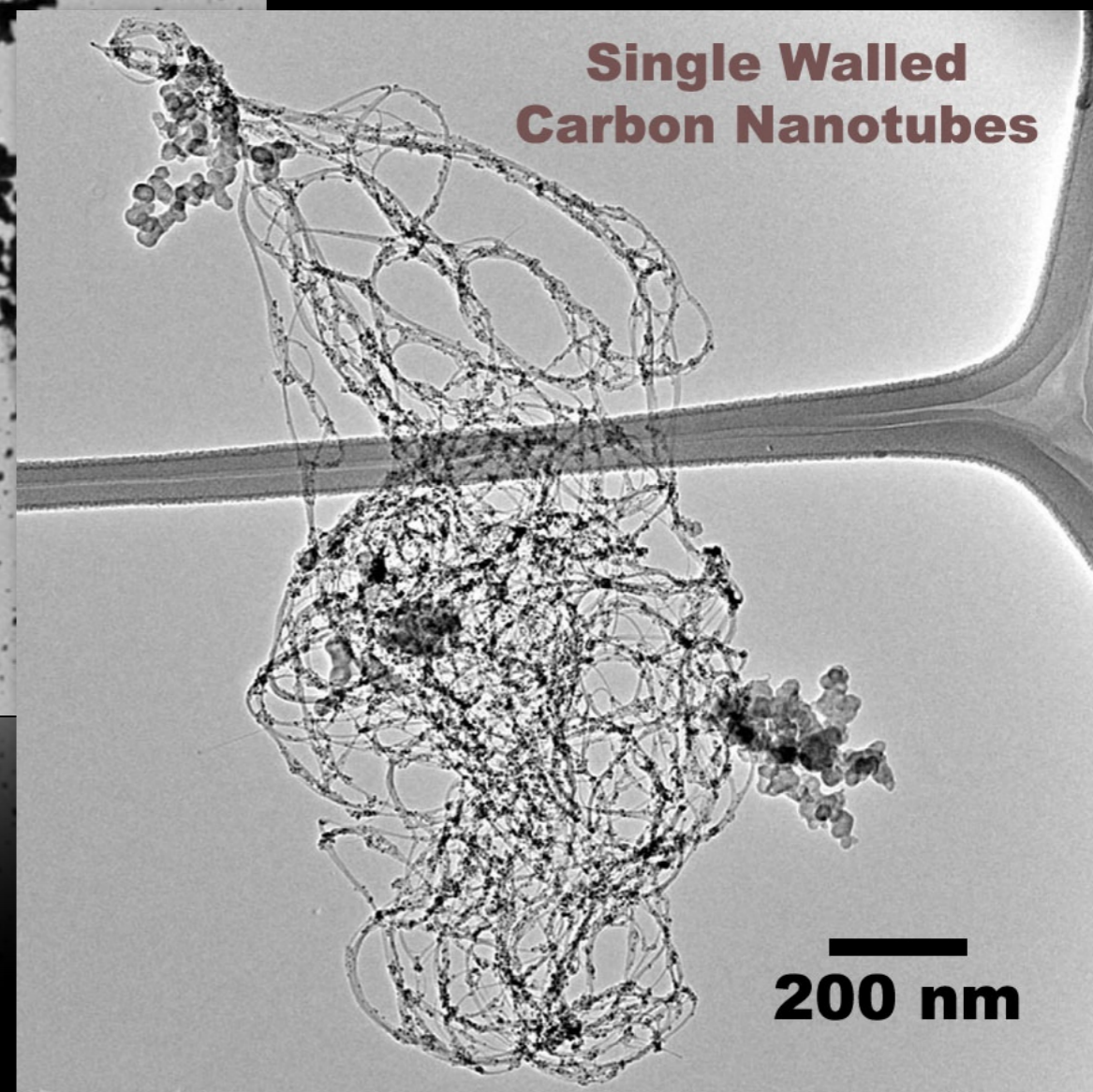
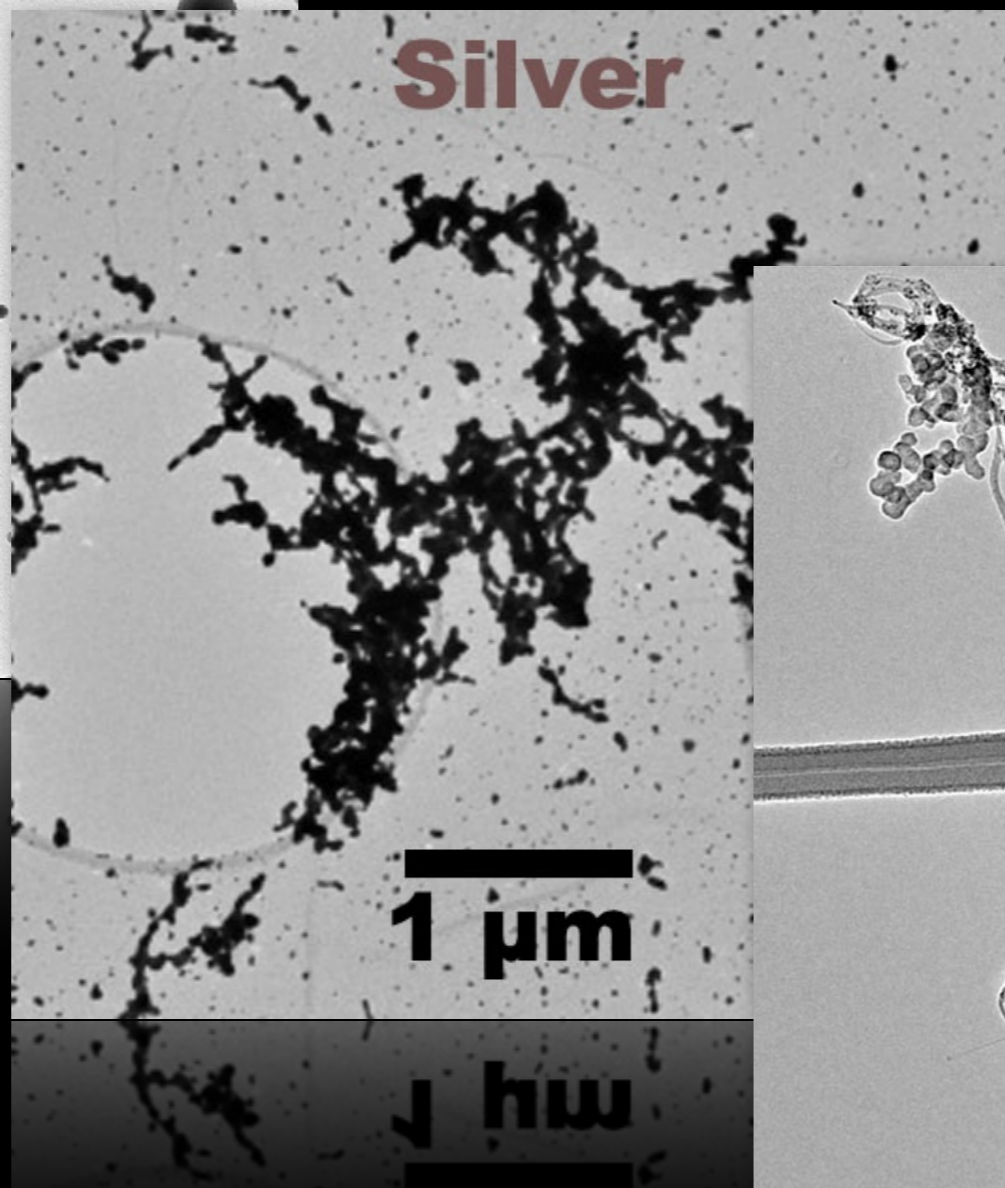
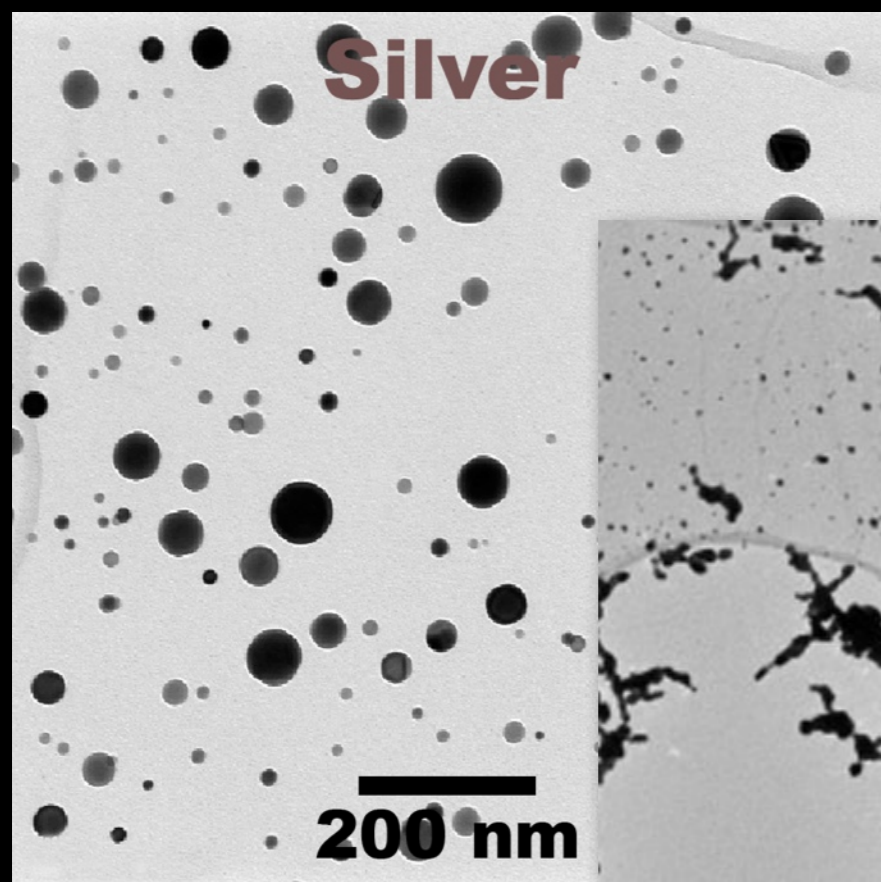
Options



Or...

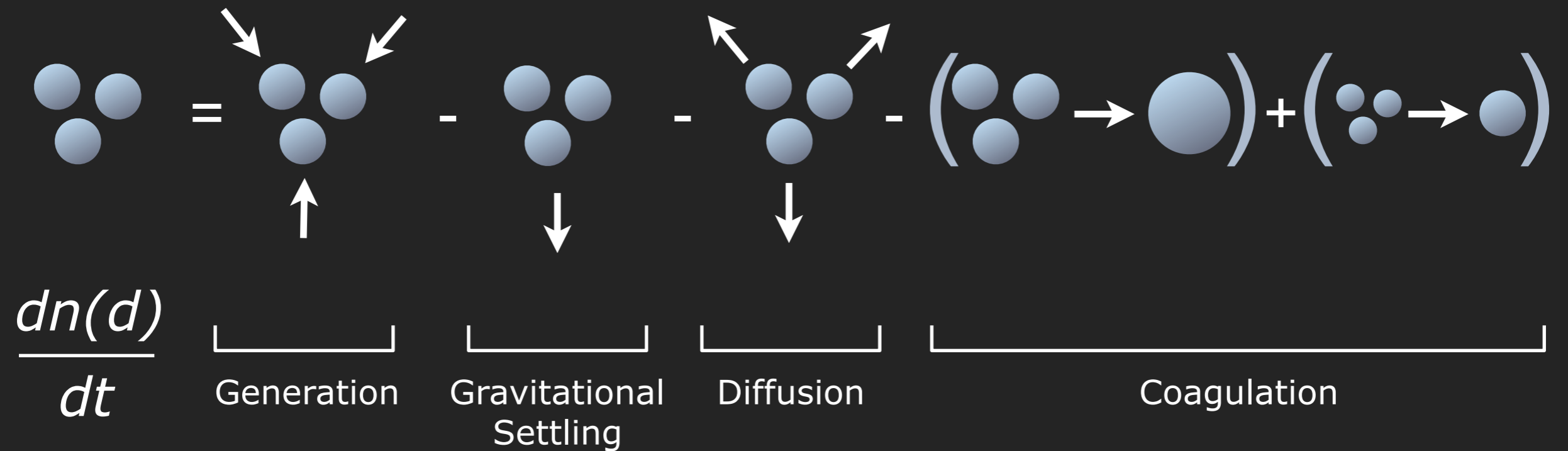


Agglomeration



Modeling Agglomeration...

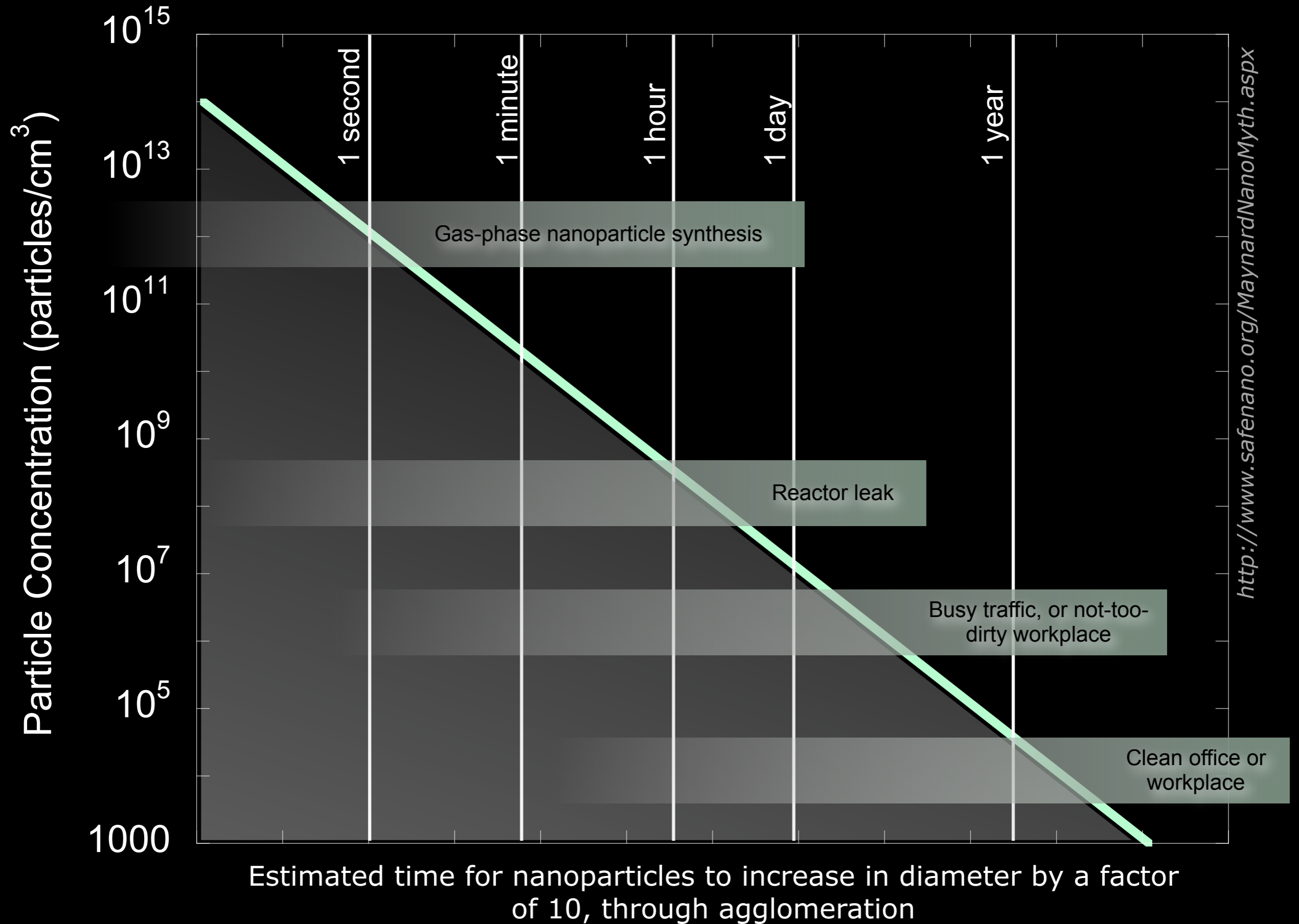
The hard way



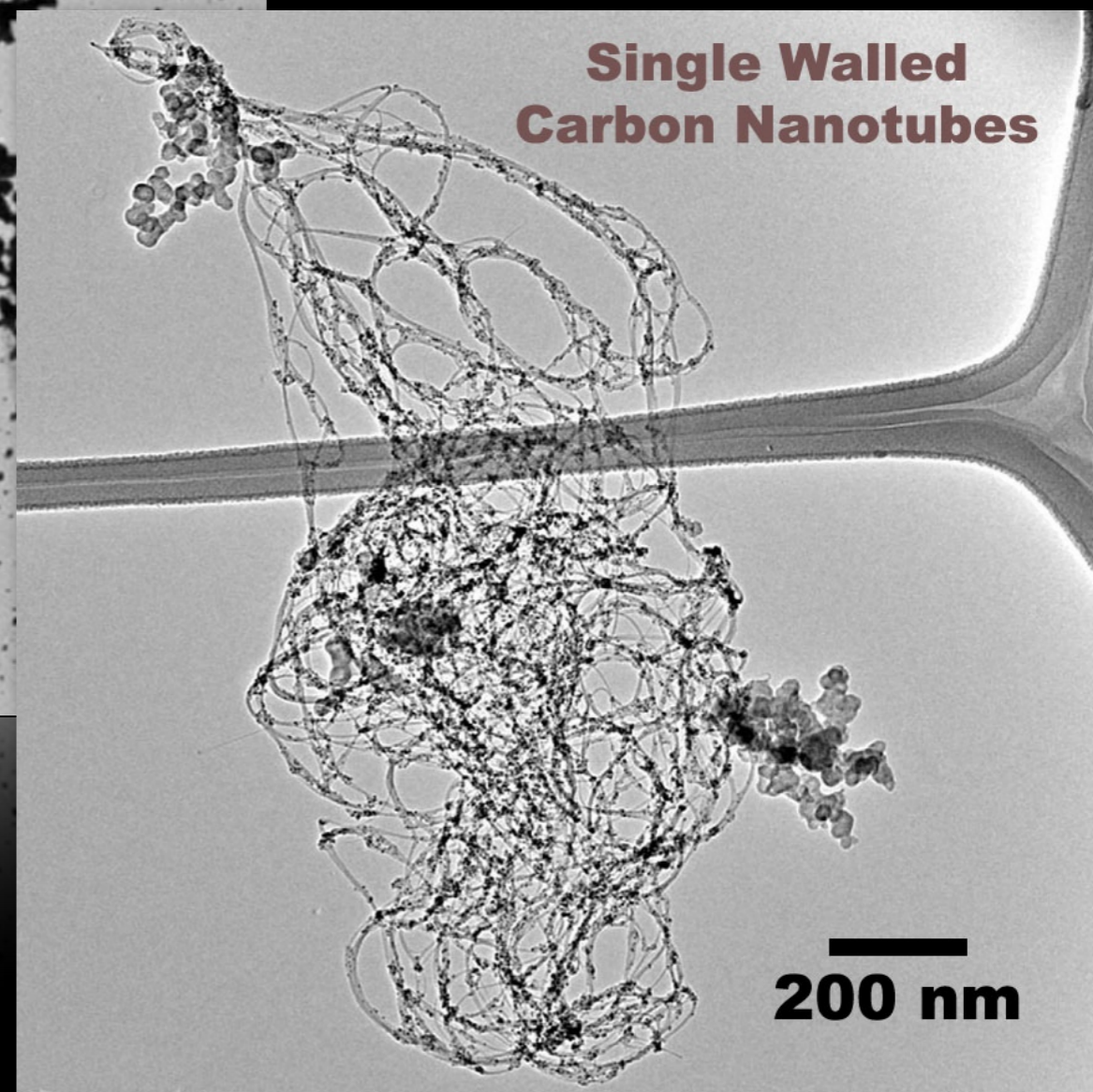
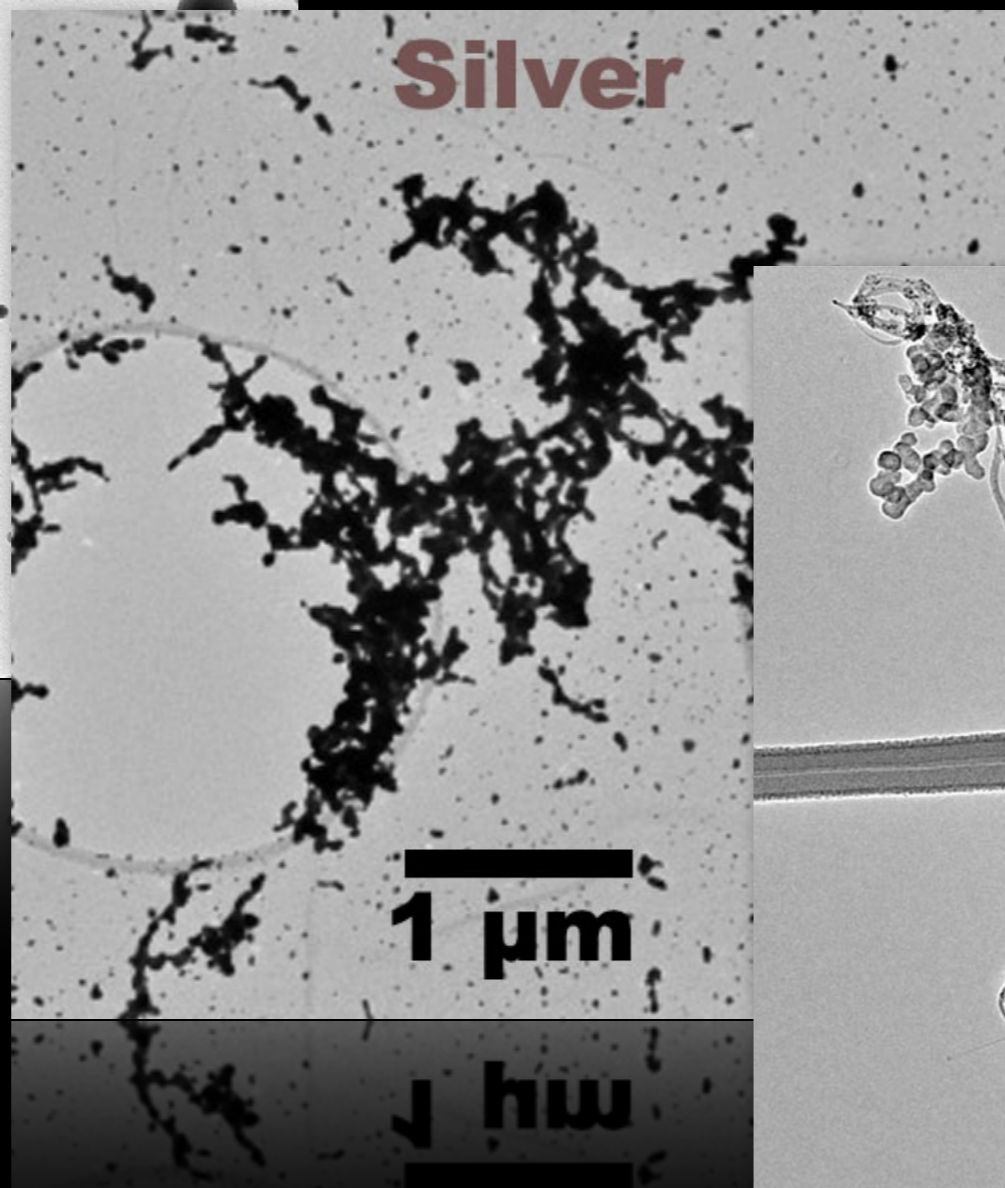
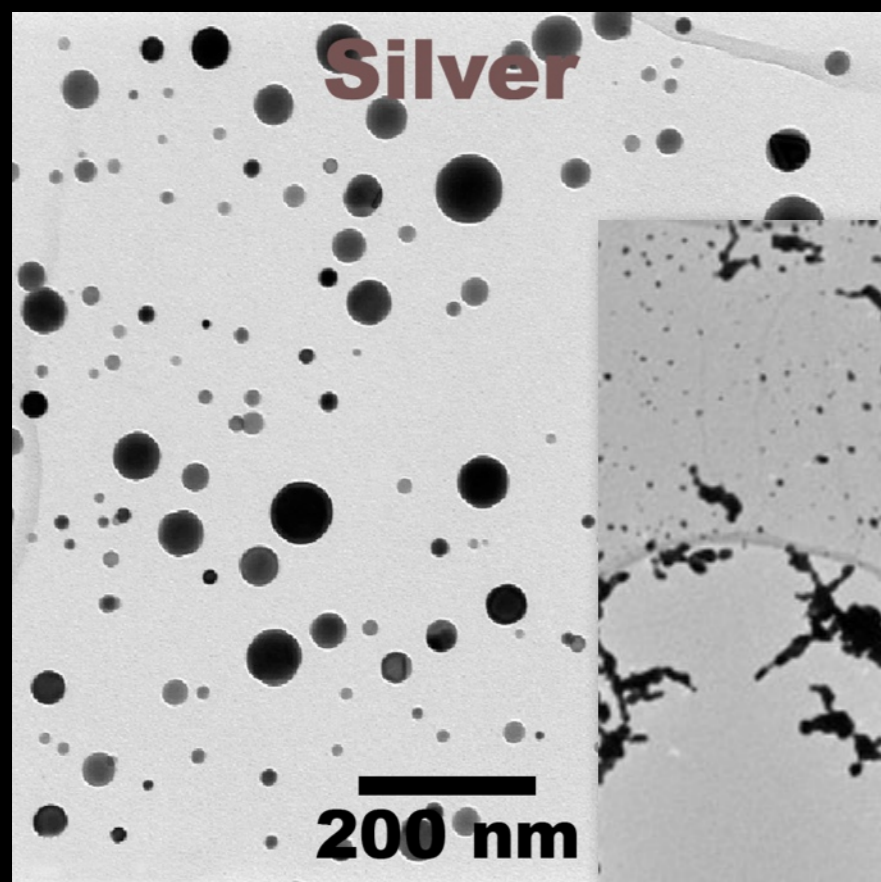
The easy way



Agglomeration - simple model



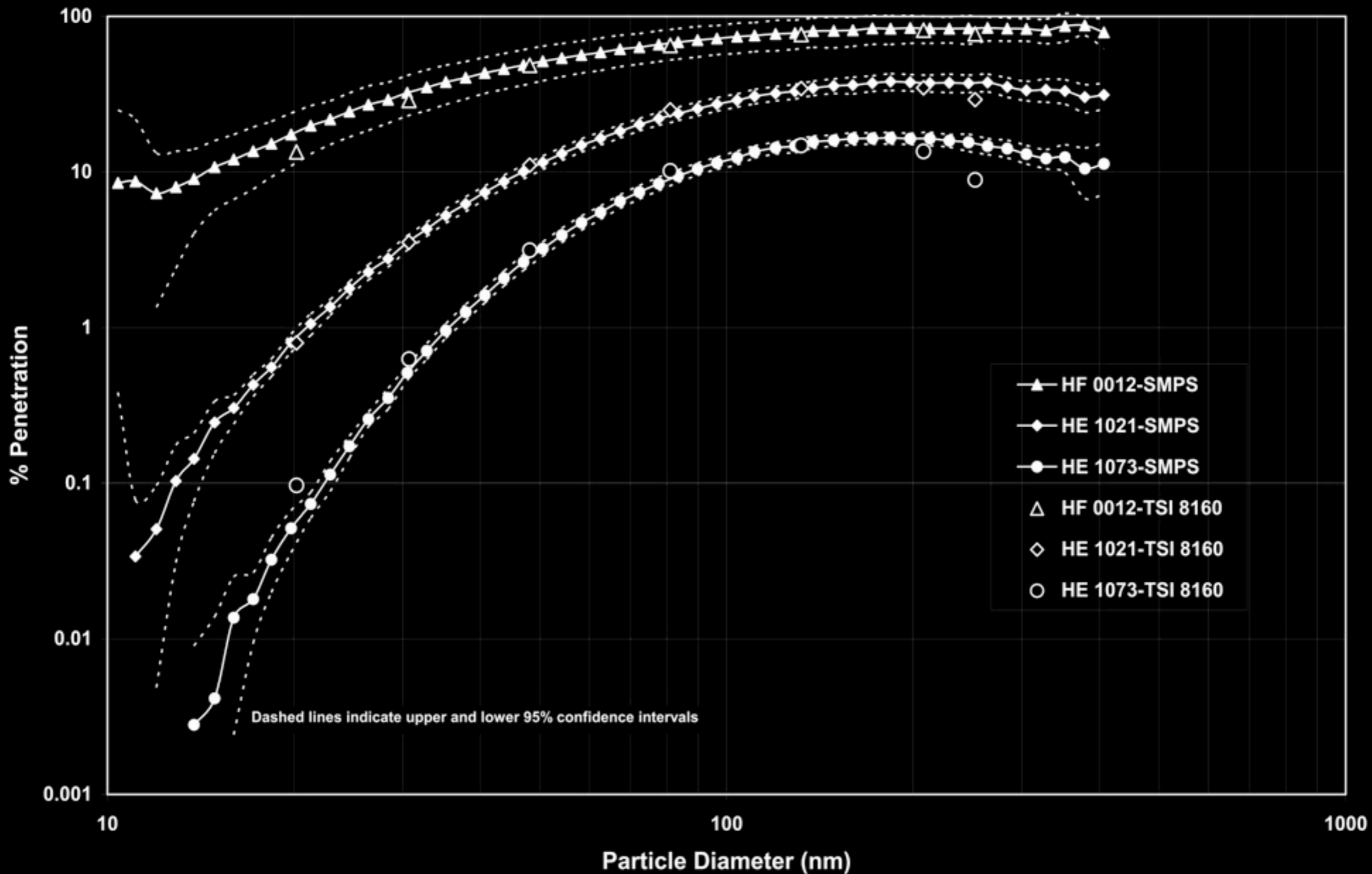
Agglomeration

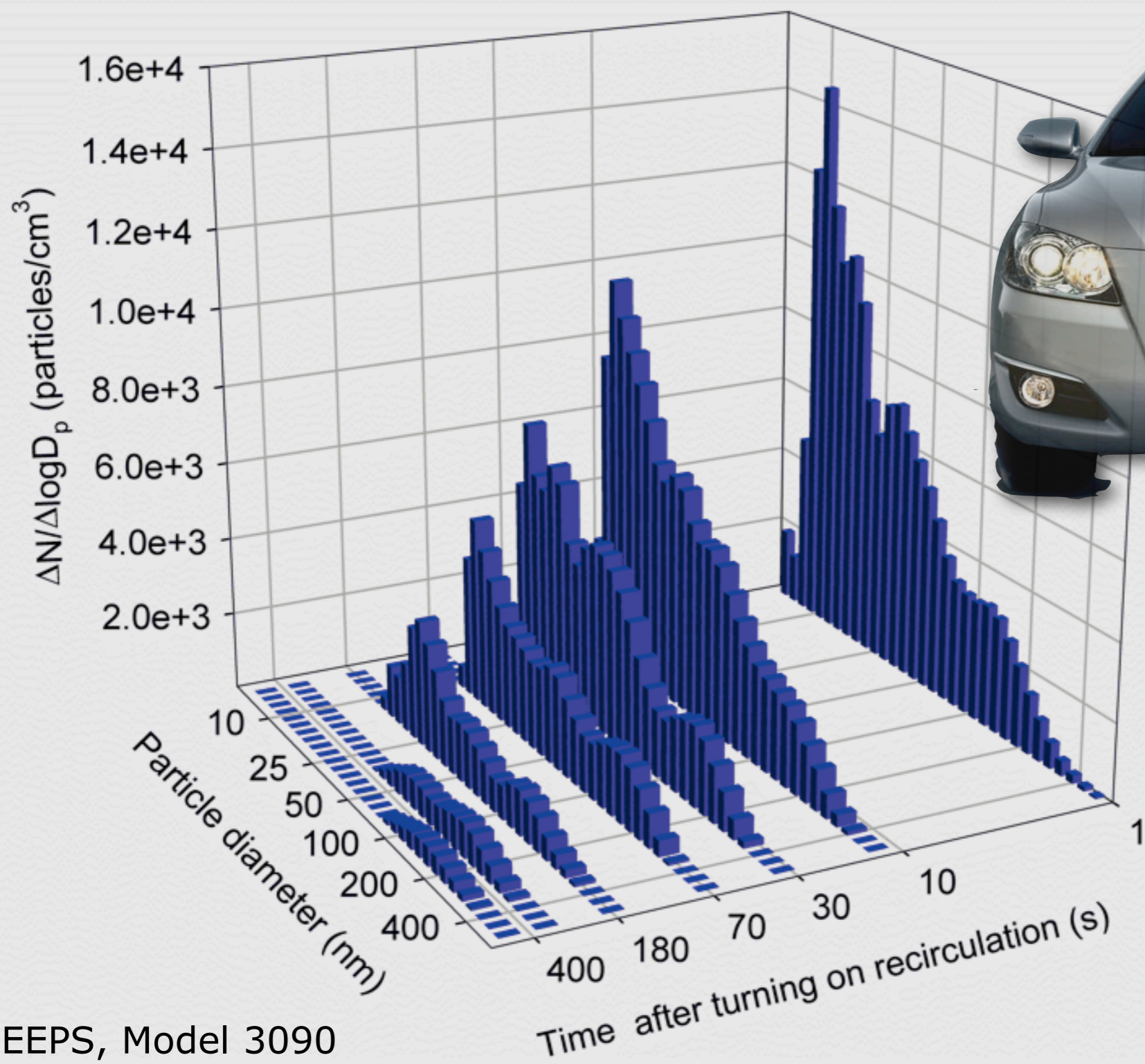


Protection



Filter penetration





EEPS, Model 3090

Min efficiency ~ 20%

Driving in heavy traffic, air recirculation on.

In-cabin aerosol < 4000 particles/m³ within 3 minutes

Pui, D. Y. H., Qi, C., Stanley, N., Oberdörster, G. and Maynard, A. (2008). Recirculating Air Filtration Significantly Reduces Exposure to Airborne Nanoparticles. Environ Health Perspect doi:10.1289/ehp.11169.

Novel Risks (*potential*): Engineered Nanomaterials

Concerns:

- ⌈ Might get to normally inaccessible places
- ⌈ Might cause harm in unusual ways
- ⌈ Harm might not be predictable from chemistry alone

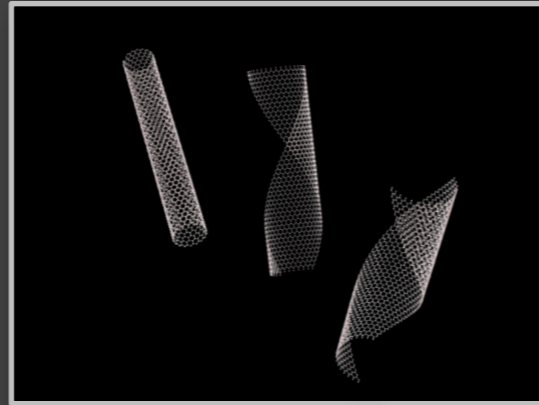
Cautions

- ⌈ Few generic principles of behavior
- ⌈ Not all nanomaterials will present novel risks
- ⌈ Existing risk management approaches *may* work



House Science Subcommittee on Research & Science Education
October 31 2007

Managing Risks
A thought exercise



Novel
Exposure:

Medium

Low

High

Novel
Toxicity:

High

Medium

High

Suggested
Precautions:

High

Low

High

COMMENTARY

Safe handling of nanotechnology

The pursuit of responsible nanotechnologies can be tackled through a series of grand challenges, argue **Andrew D. Maynard** and his co-authors.

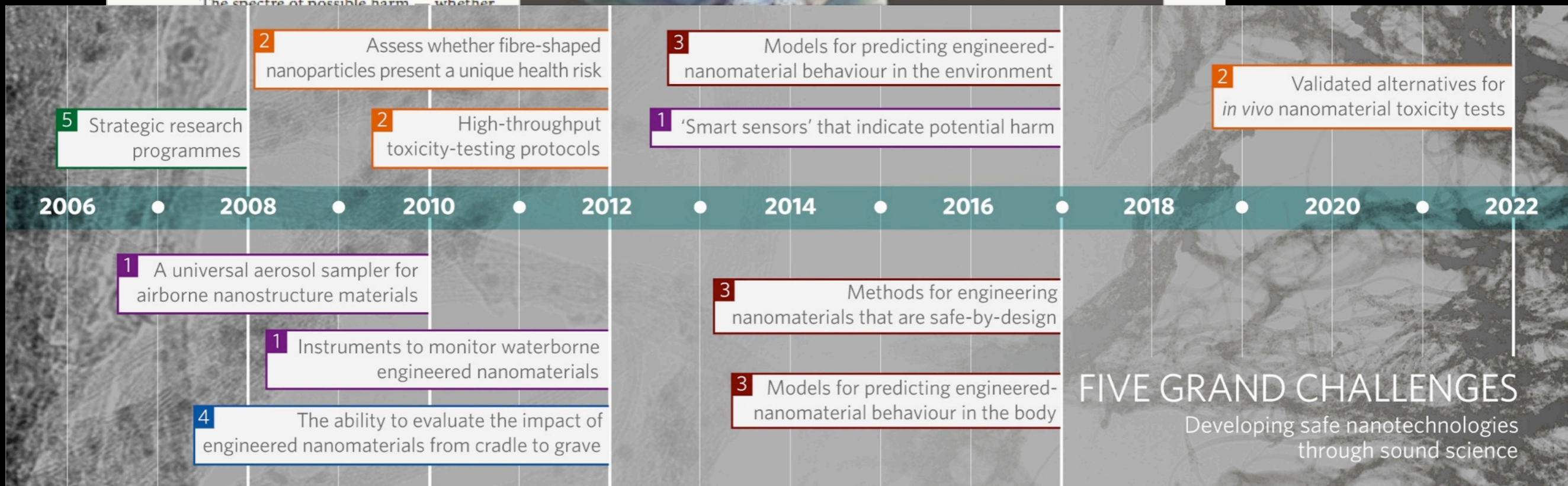
When the physicist and Nobel laureate Richard Feynman challenged the science community to think small in his 1959 lecture 'There's Plenty of Room at the Bottom', he planted the seeds of a new era in science and technology. Nanotechnology, which is about controlling matter at near-atomic scales to produce unique or enhanced materials, products and devices, is now maturing rapidly with more than 300 claimed nanotechnology products already on the market¹. Yet concerns have been raised that the very properties of nanostructured materials that make them so attractive could potentially lead to unforeseen health or environmental hazards².

The spectre of possible harm — whether



D. RAMSEY

Nature Vol.
444/16
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not made enough progress on reducing the uncertainties surrounding the health and both what they are made of and their physical nature. For instance, small particles of inhaled The science community needs to set how a strategic research is to support sustainable nano-



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Writing on emerging technologies at:

<http://2020science.org>