The Science Behind NanoDays: Part 1

NanoDays™

The Biggest Event for the Smallest Science!

March 29 to April 6th 2014

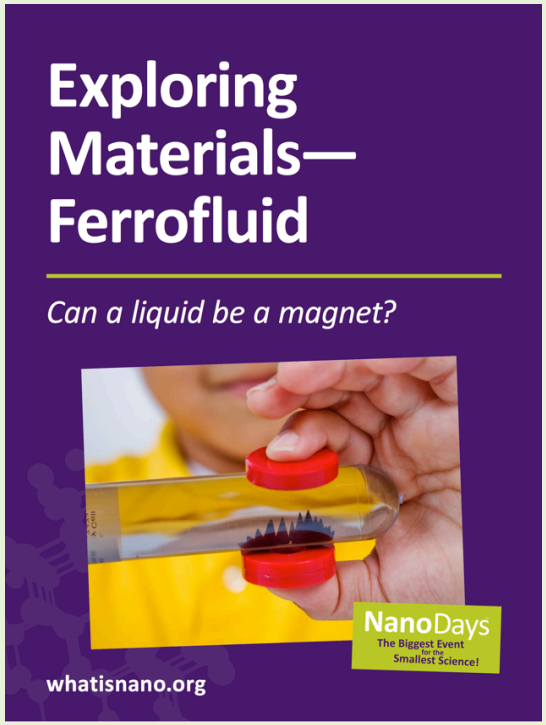
Digital kits available @
http://nisenet.org/nanodays/NanoDays-2014-digital-kit

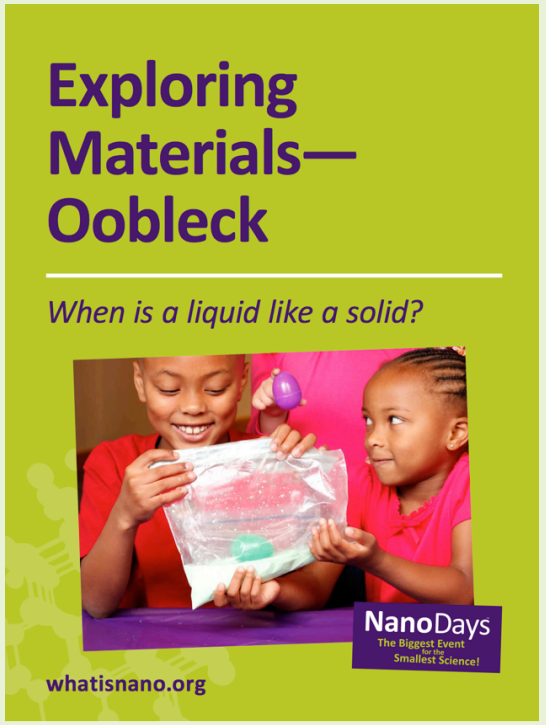
NISE network
NANOSCALE INFORMAL SCIENCE EDUCATION

NSF

February 19, 2014

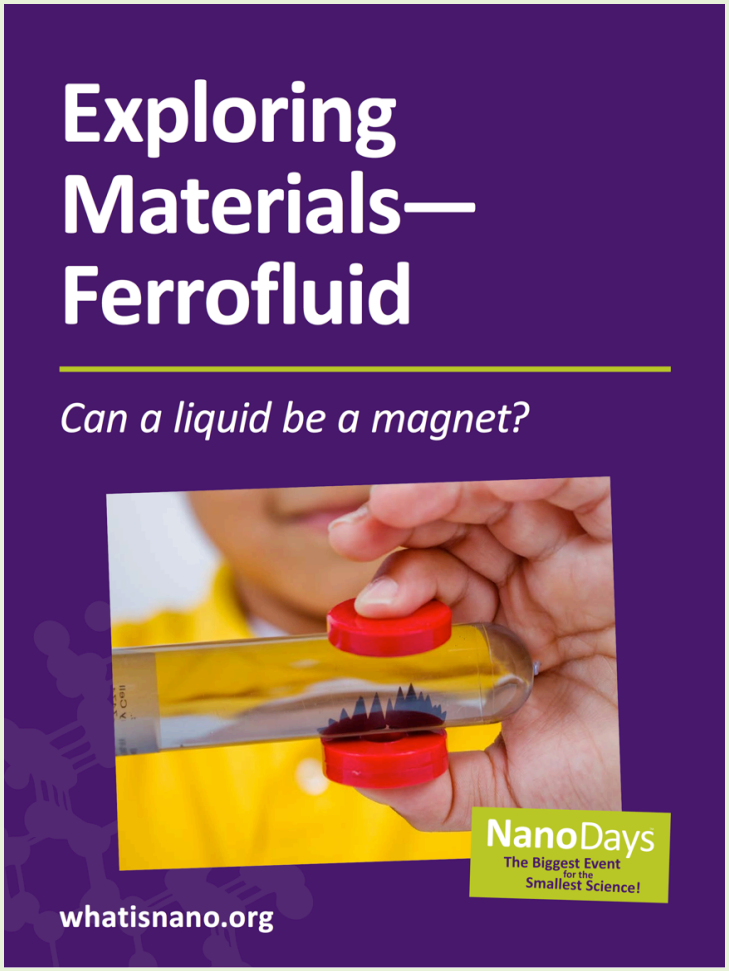
Activities We'll Cover Today



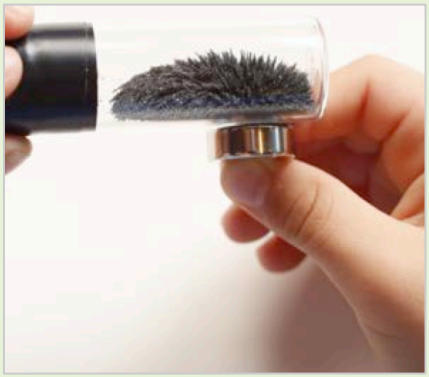


(What do you think these activities have in common?)

Ferrofluids



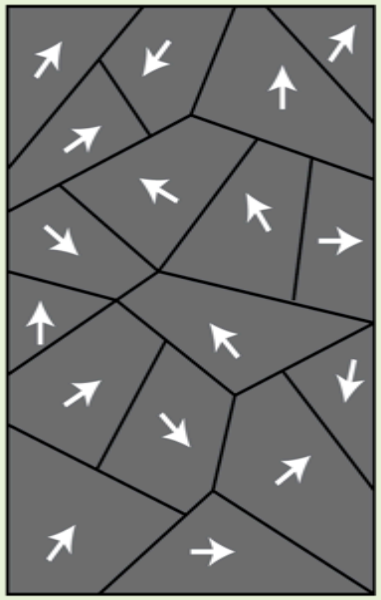
A **ferrofluid** is a unique material that acts like a magnetic solid *and* like a liquid.



Ferromagnets

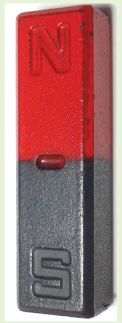
This schematic shows the ***magnetic domains*** in a ferromagnetic material.
A domain is a region where the magnetic fields of the atoms are aligned.

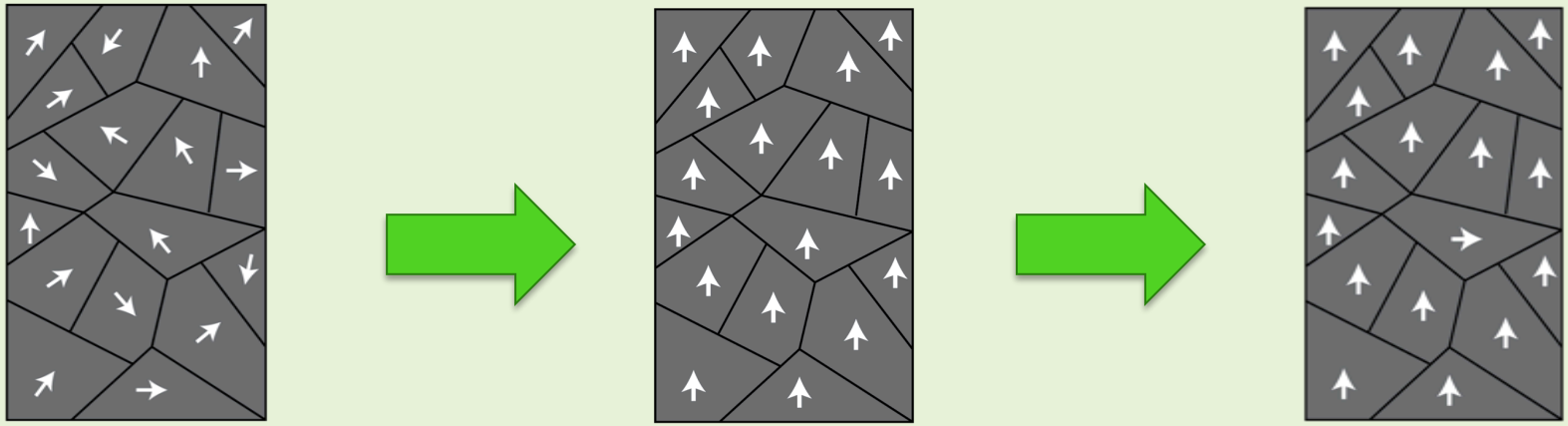
You can think of magnetic domains as miniature magnets within a larger magnet.



Ferromagnets

Examples: nails, fridge doors, anything that sticks to a magnet

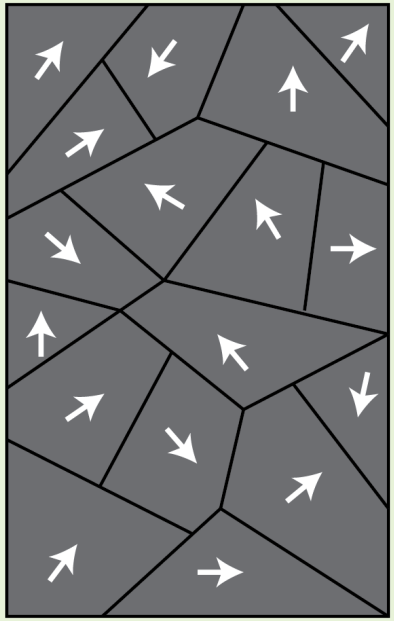




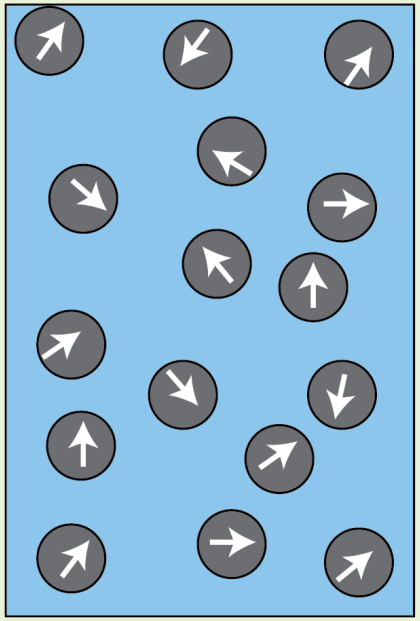
Basically, magnets are ferromagnetic materials that have been magnetized

Ferrofluids – How Do They Work?

The magnetic particles in a ferrofluid are so small that they each contain **only 1 magnetic domain**!

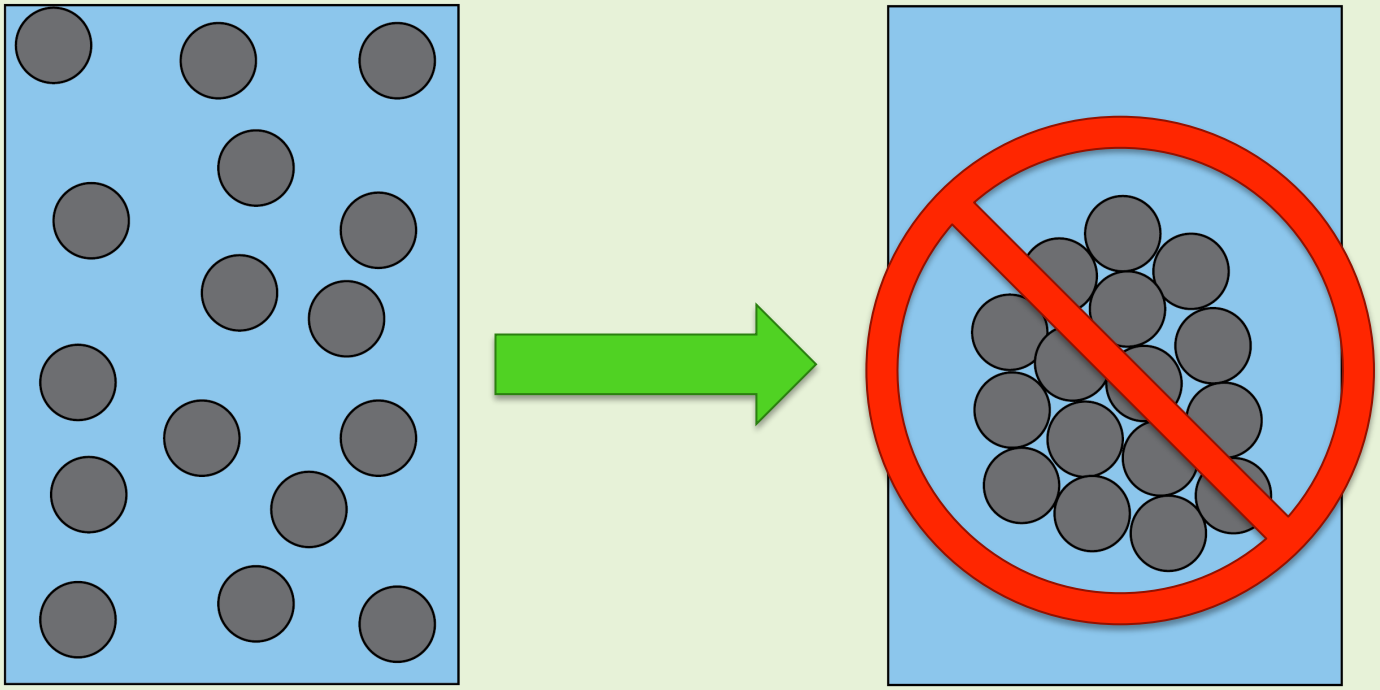


Bulk ferromagnetic material



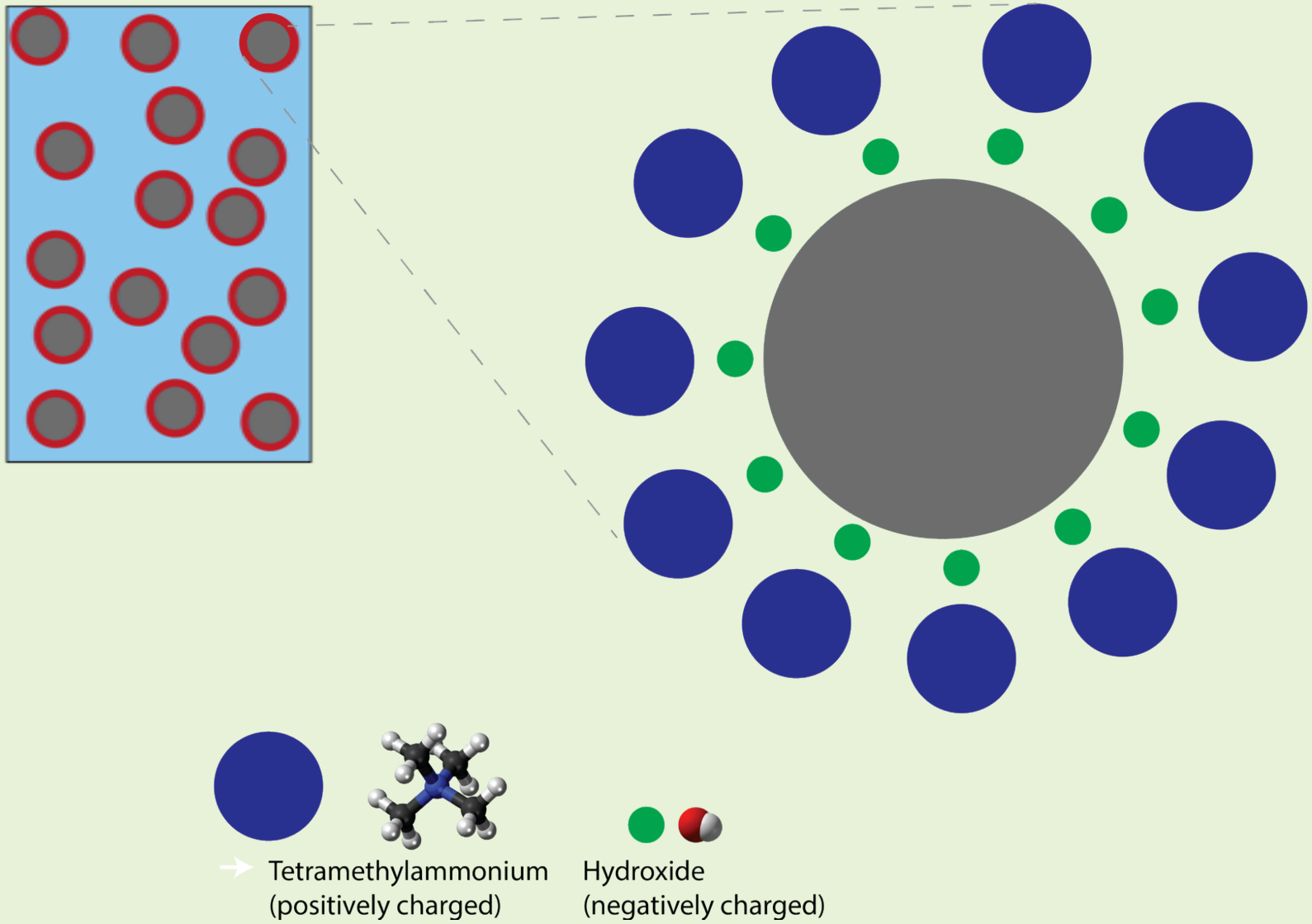
Ferromagnetic nanoparticles in a fluid

Ferrofluids – How Do They Work?



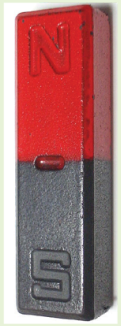
Need to prevent clumping/aggregation!

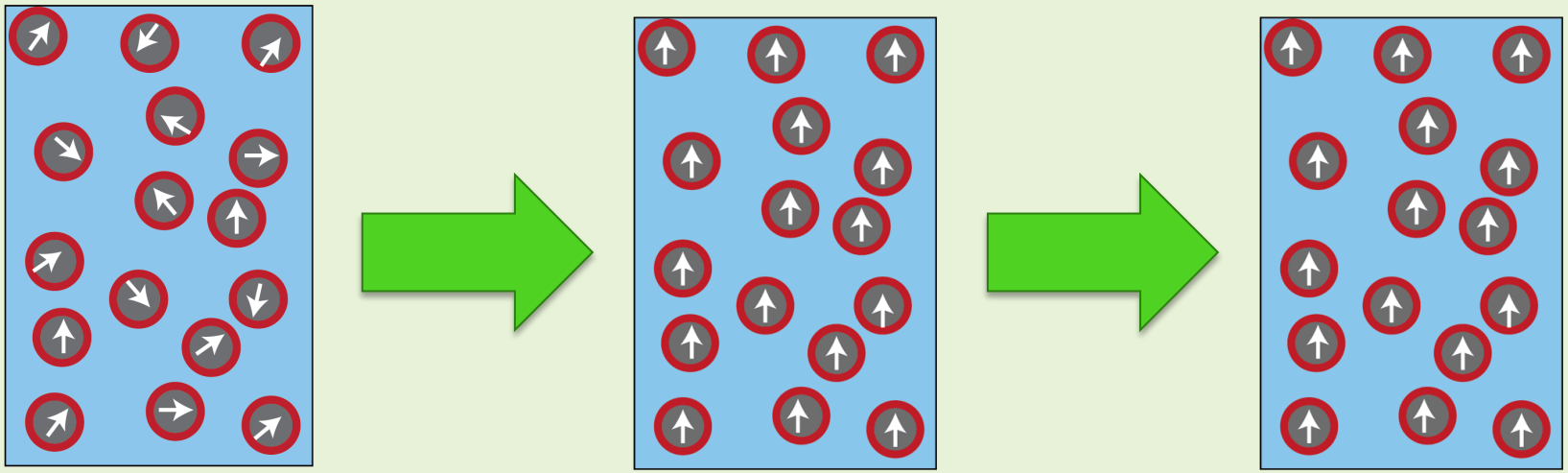
Ferrofluids – How Do They Work?



Ferrofluids – Why Are They Special?

Ferromagnetic nanoparticles respond to a magnet the same way a bulk ferromagnetic material does





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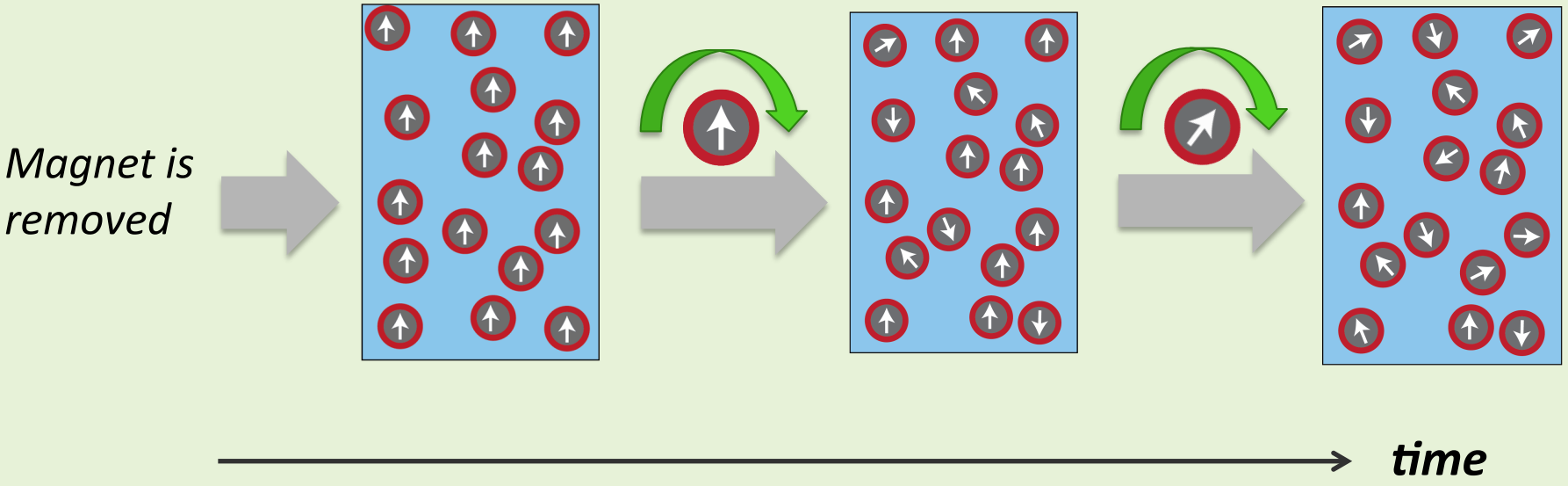
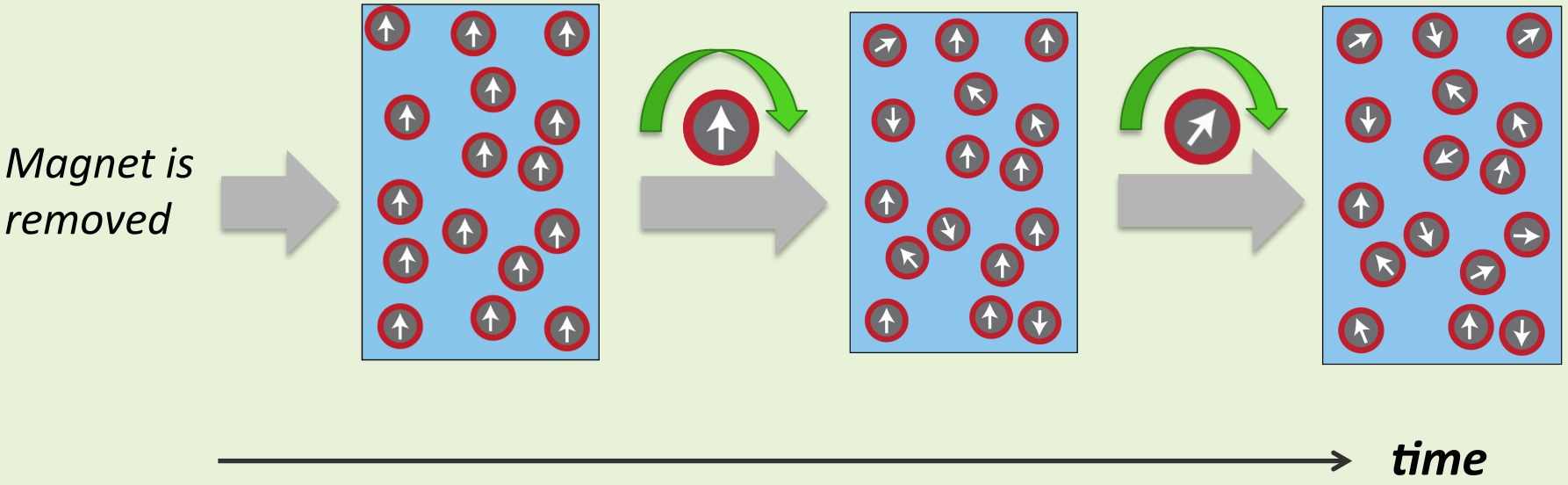


Unlike domains in large magnets, nanoparticles suspended in solution can rotate due to Brownian motion (which is always happening)

Ferrofluids – Why Are They Special?



It only takes 10-100 micro-seconds (10-100 μs) for the magnetization directions to change

Ferrofluids – Paramagnets!

Because ferrofluids don't retain their magnetization for long, they don't follow the definition of a ferromagnet

So, what are they??

The nanoparticles in ferrofluids are made of a *ferromagnetic* material

But the ferrofluid – a collection of these nanoparticles – is *paramagnetic*

Imaging and Disease Treatment

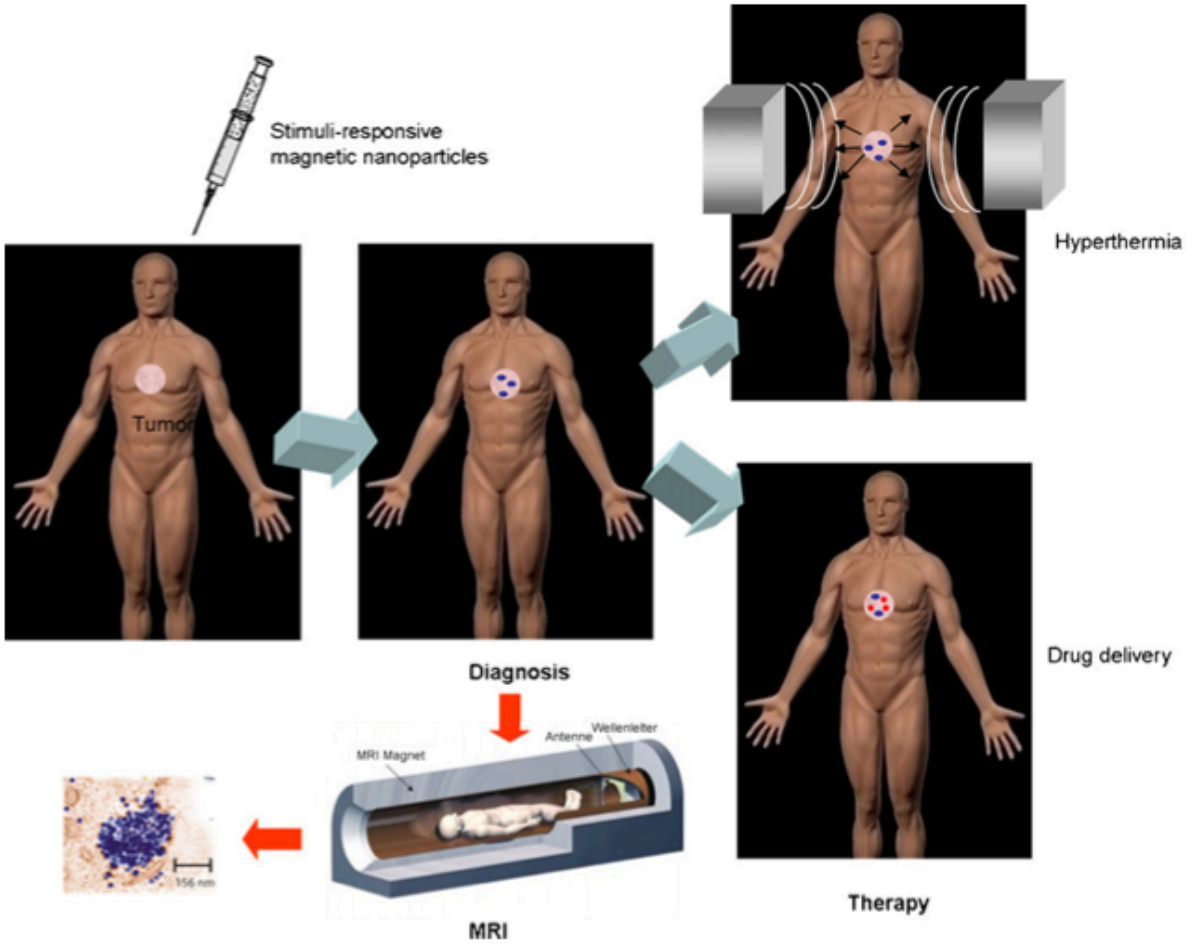
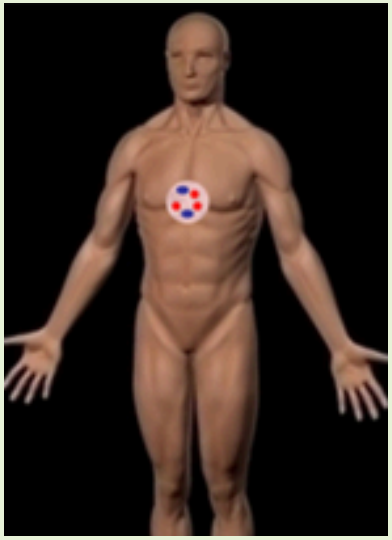
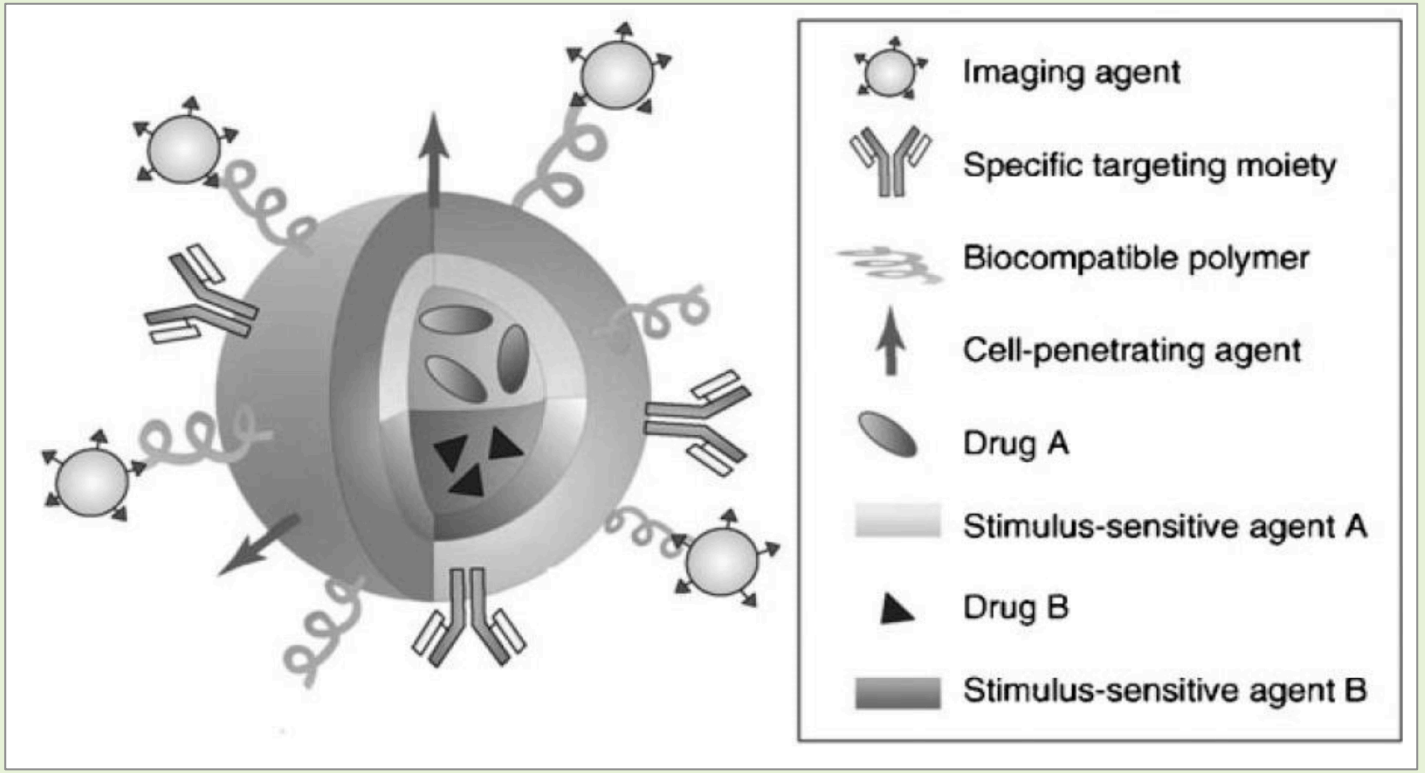


Fig. 15. Schematic representation of the drug-loaded magnetic nanoparticles localization by MRI followed by the treatment of the tumour either by hyperthermia or by the drug release.

Medeiros, *Int. J. Pharm.*, 2011

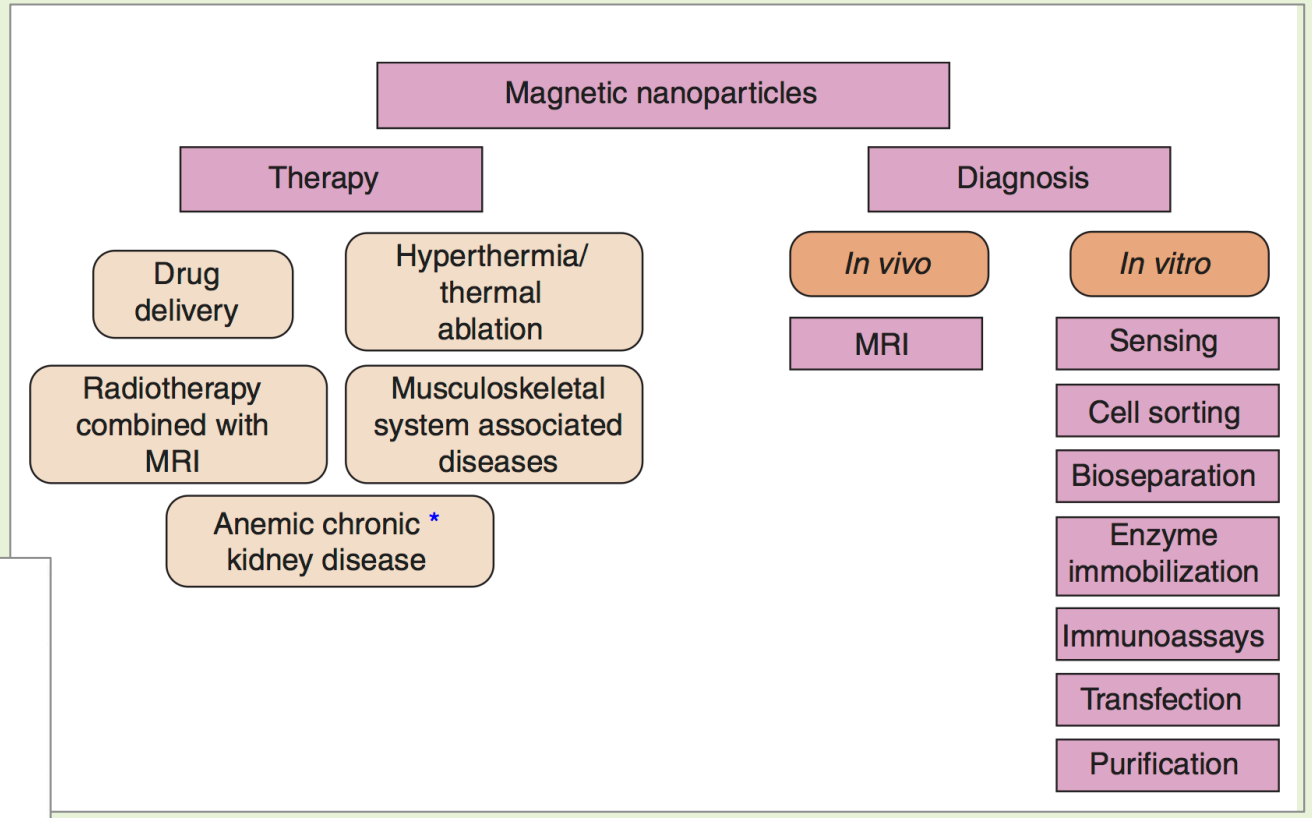
Ferrofluids for Cancer Treatment

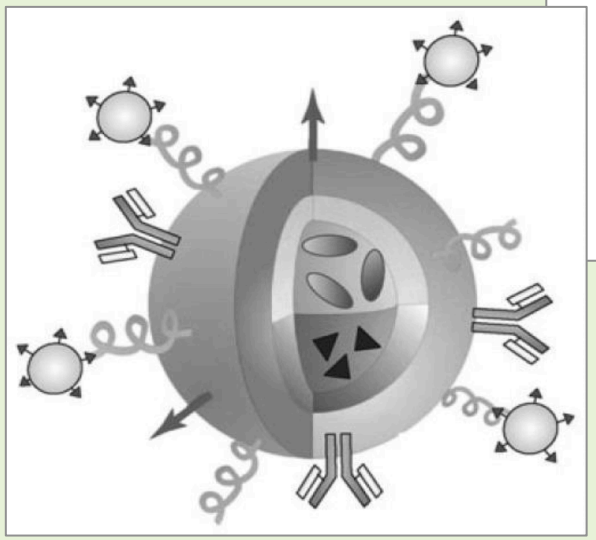




Mahapatro and Singh, *J Nanobiotechnology,* 2011

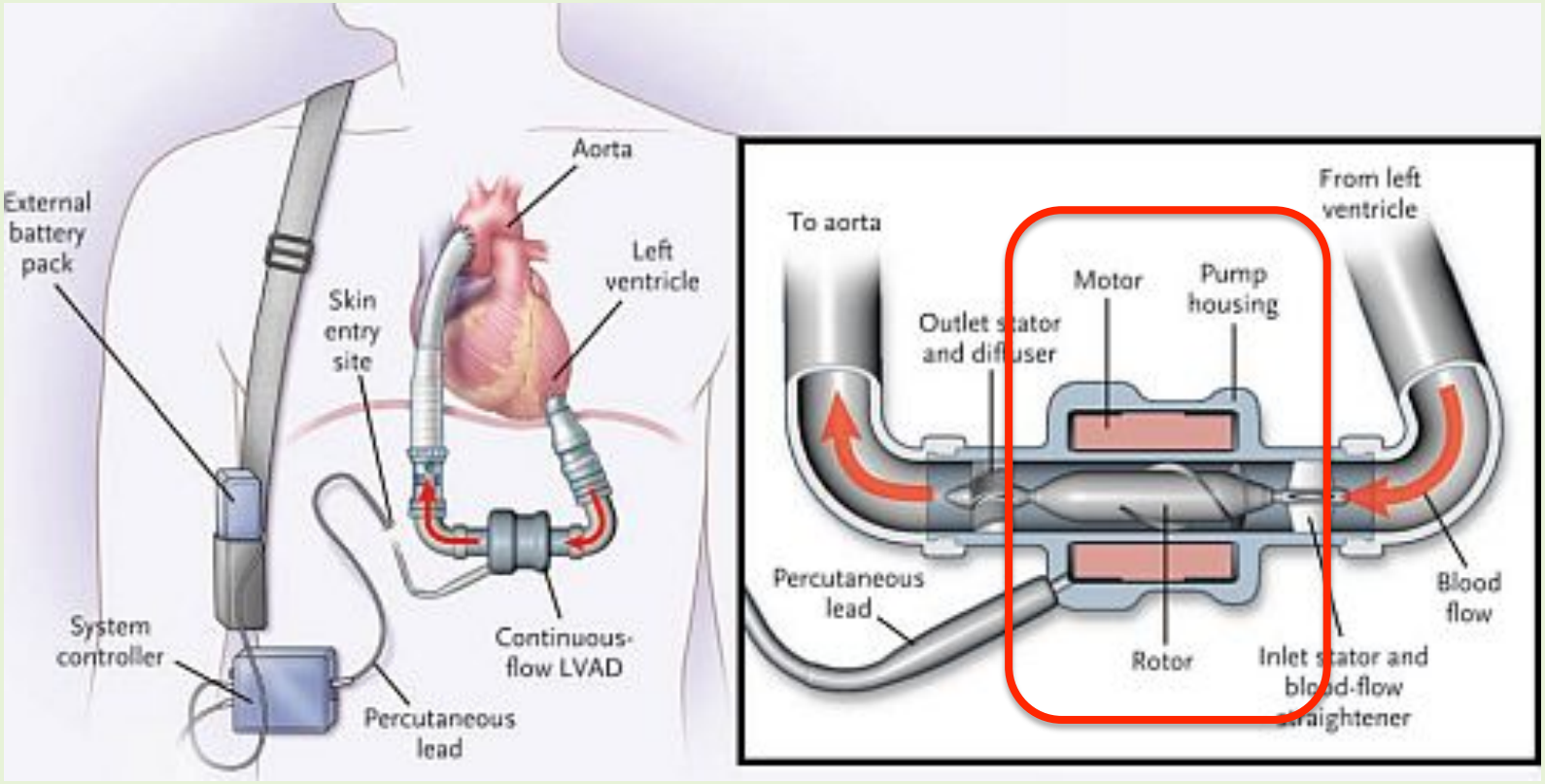
Ferrofluids for Cancer Treatment





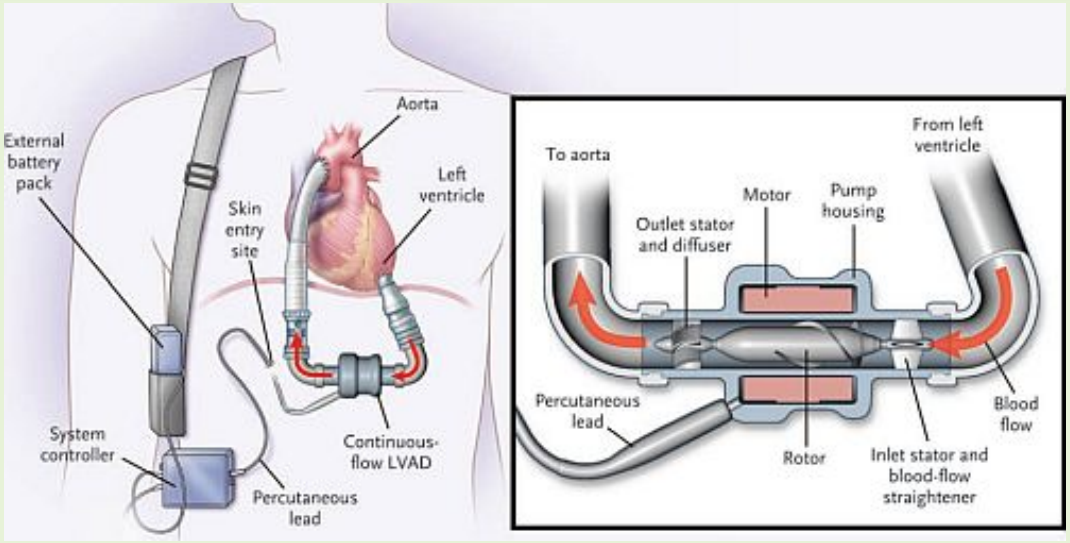
Arruebo et al, *Nano Today,, 2007*
Mahapatro and Singh, *J Nanobiotechnology,* 2011

Applications of Ferrofluids: Artificial Heart (?)

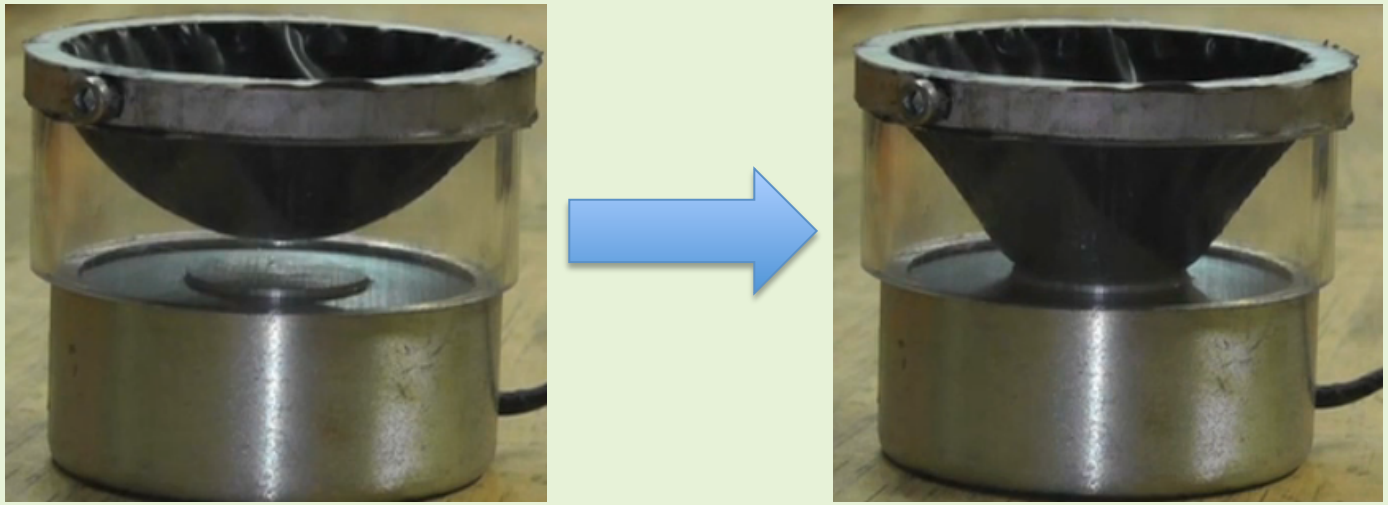


Slaughter, *et al.*, *New Engl. J. Med.*, 2009

Applications of Ferrofluids: Artificial Heart (?)

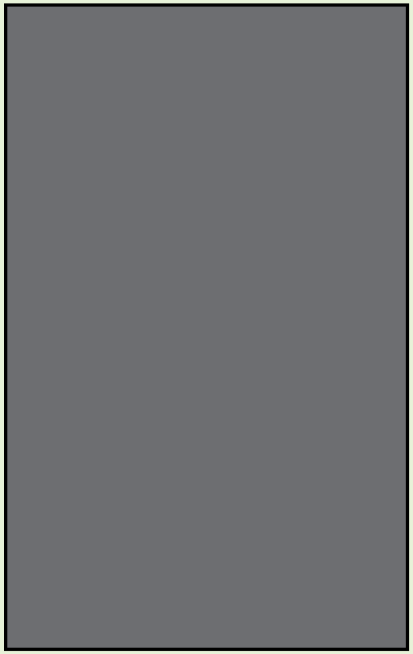


http://www.popsci.com/technology/article/2012-08/new-artificial-heart-pump-acts-real-thing

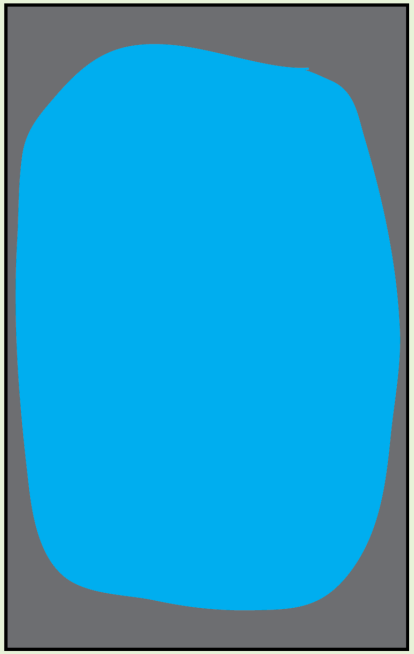


Imaging Magnetic Domains

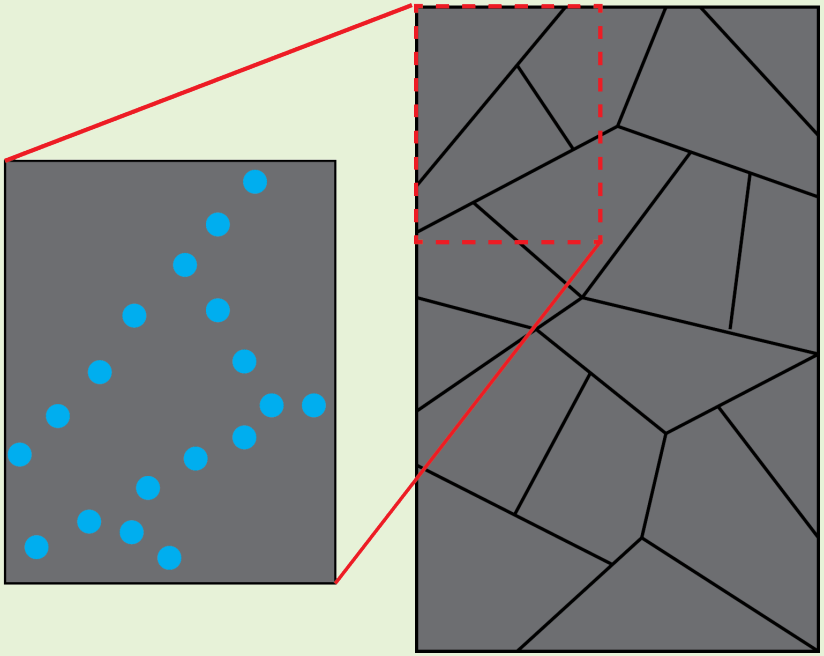
Sample with unknown magnetic structure



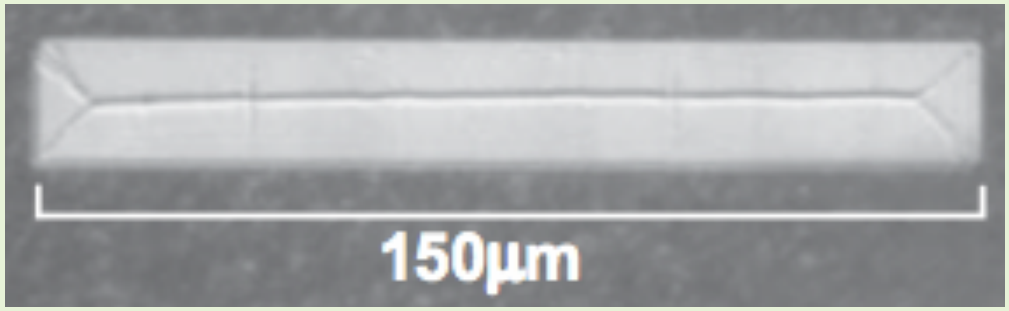
Drop ferrofluid on sample, then wait for solvent to evaporate

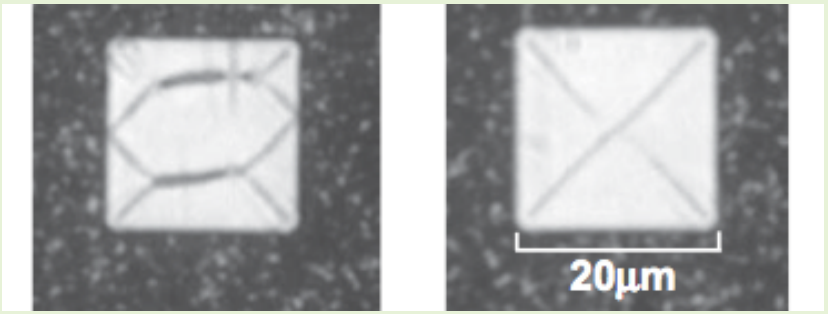


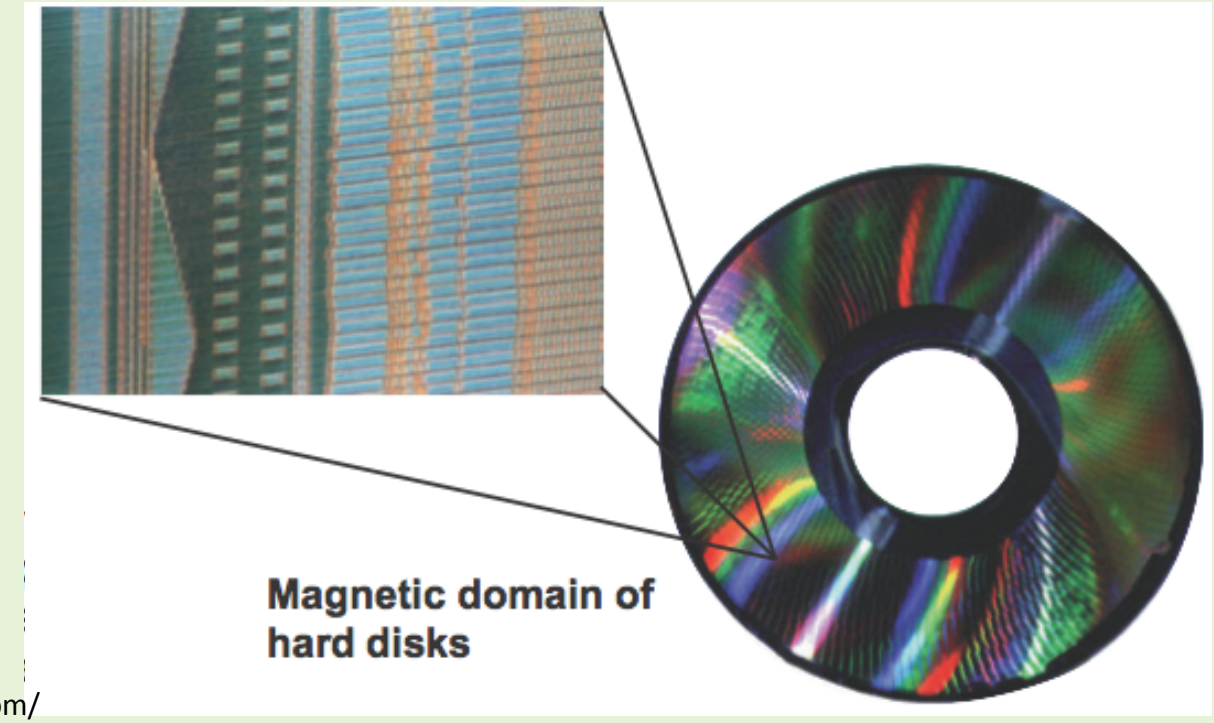
Magnetic particles congregate at boundaries, indicating domains



Imaging Magnetic Domains

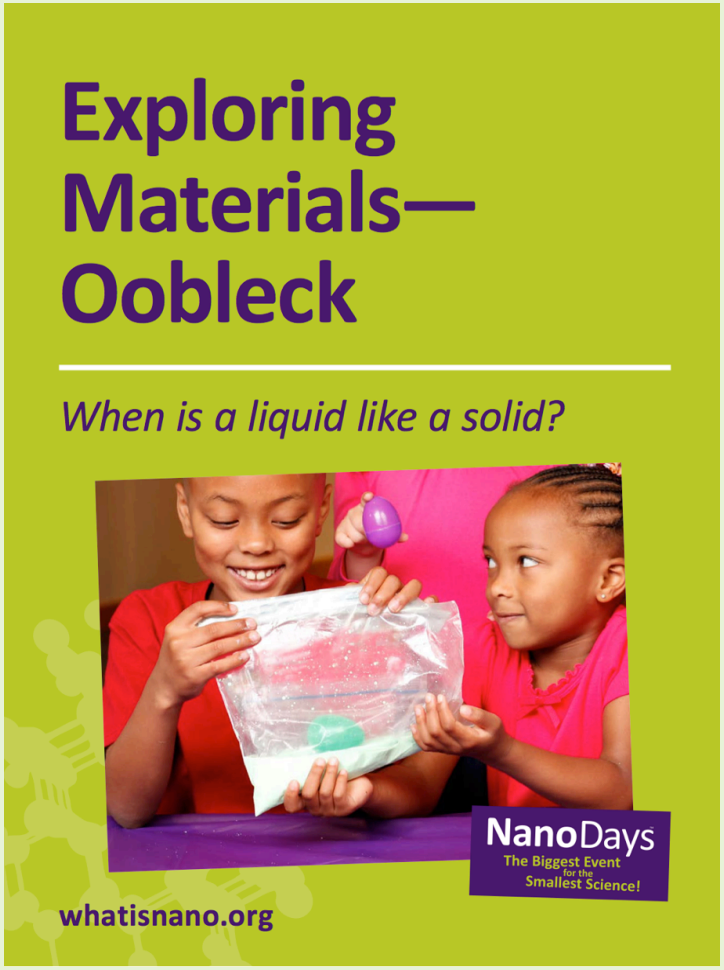






https://ferrofluid.ferrotec.com/downloads/domain_detection.pdf

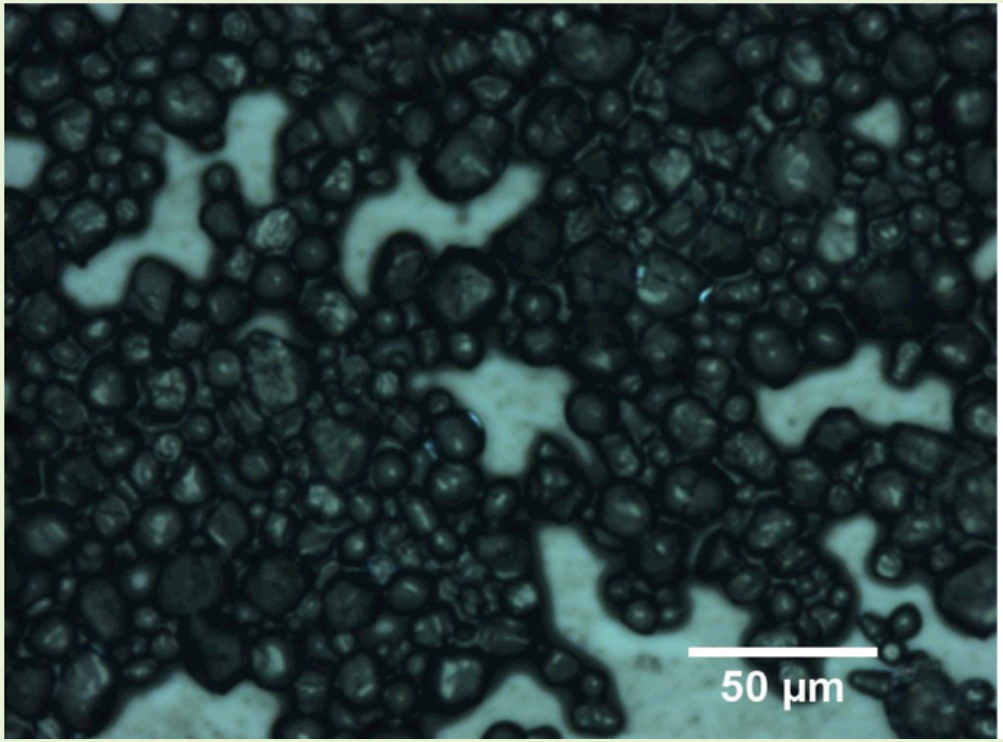
Shear Thickening Fluids (Oobleck)



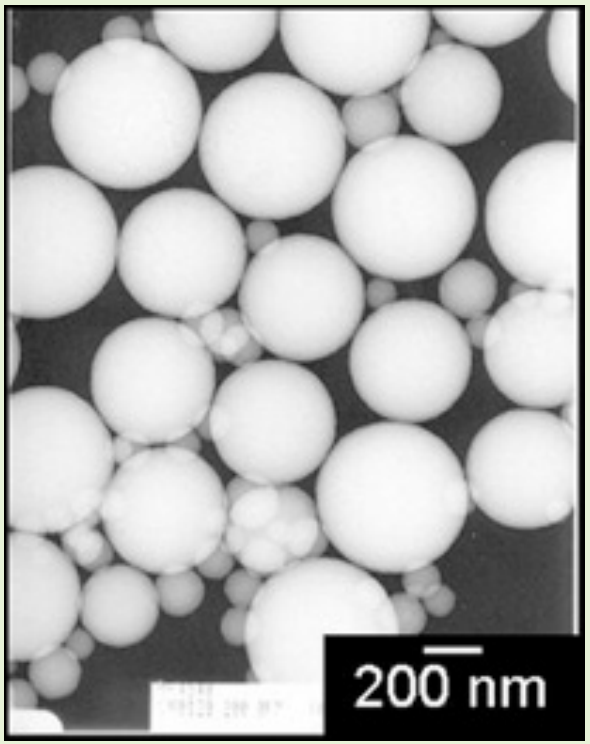
When you quickly apply a lot of pressure to Oobleck, like by tapping or squeezing, it firms up like a solid.

When no pressure is applied, it flows like a liquid.

What Fluids does Liquid Armor Use?



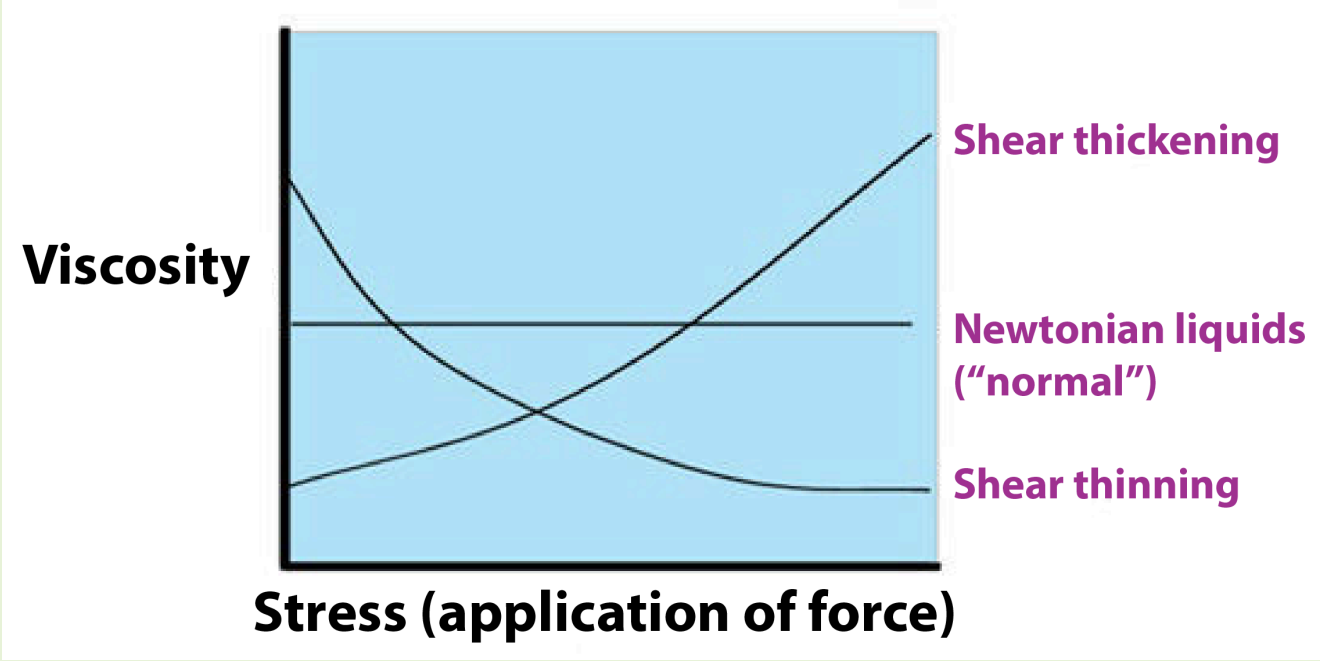
Oobleck (cornstarch and water)



Silica nanoparticles in ethylene glycol

Dounas-Frazer *et al.,* http://arxiv.org/pdf/1203.2682.pdf,
http://www.nanooze.org/main/Nanooze/More_Nano/Entries/2010/5/10_Liquid_Armor.html

Science Behind Shear Thickening Fluids

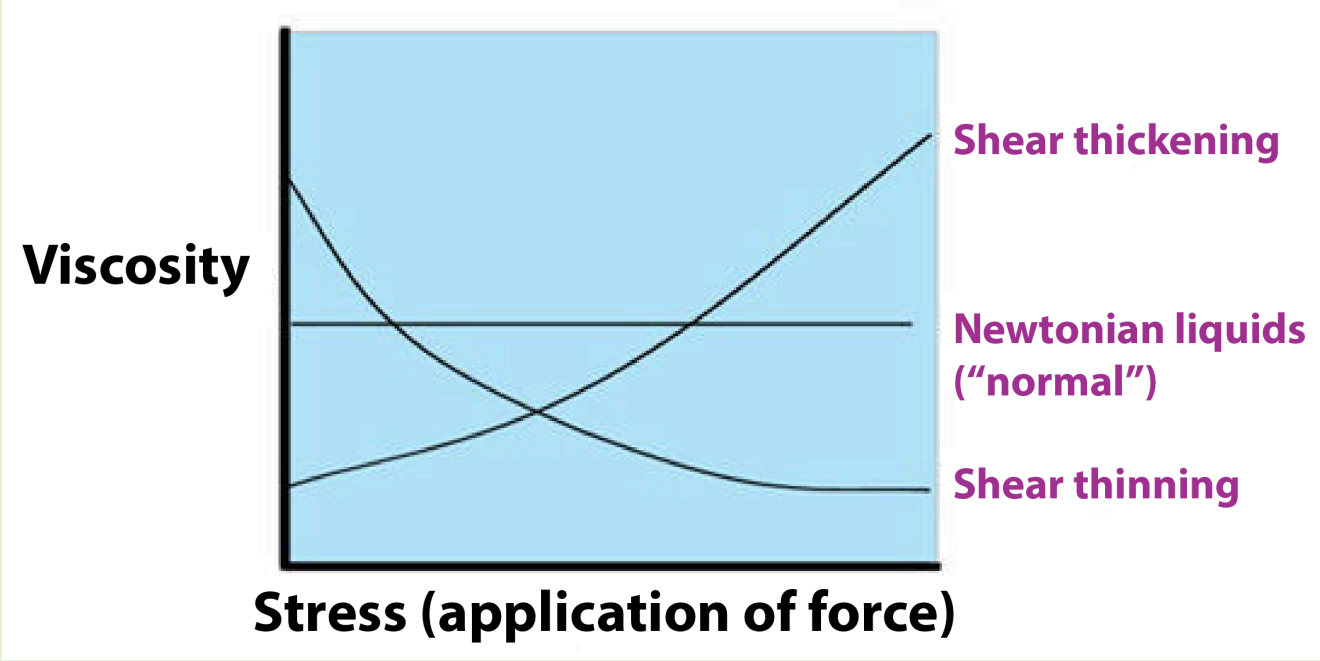


The viscosity of certain fluids depends on whether they're under shear stress

Viscosity = resistance to flow → more viscous = thicker

http://sciencelearn.org.nz/Science-Stories/Strange-Liquids/Sci-Media/Images

Science Behind Shear Thickening Fluids



Newtonian:
water, milk, mineral oil, kerosene

Shear thinning:
ketchup, paint, blood, nail polish

Shear thickening:
Oobleck, Silly Putty, wet beach sand

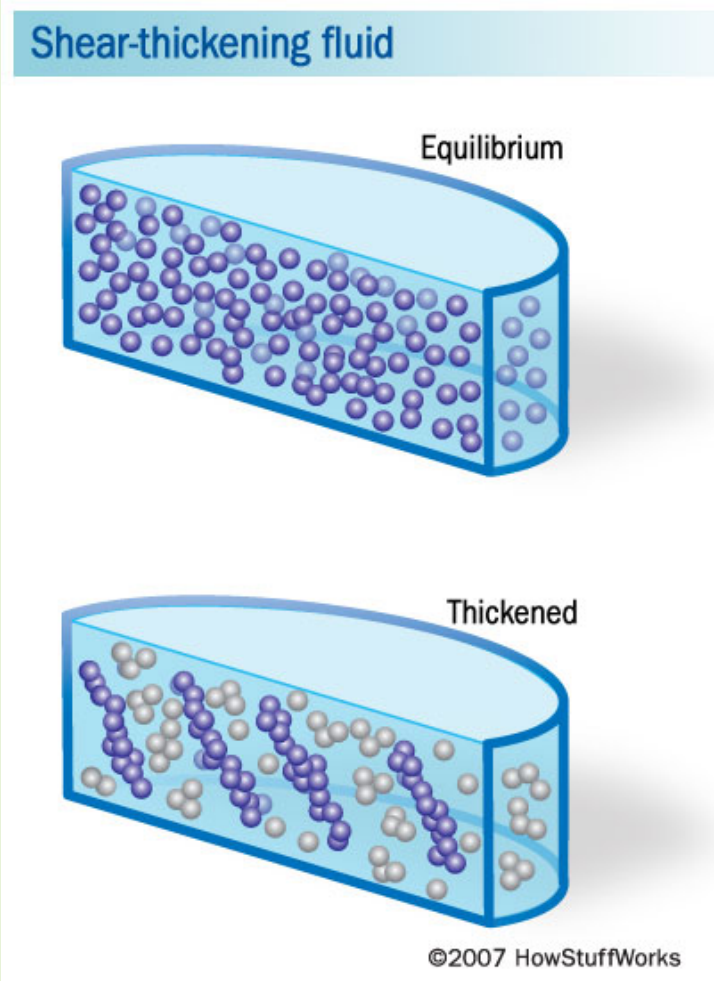
http://sciencelearn.org.nz/Science-Stories/Strange-Liquids/Sci-Media/Images

Science Behind Shear Thickening Fluids

Suspensions become thicker when…

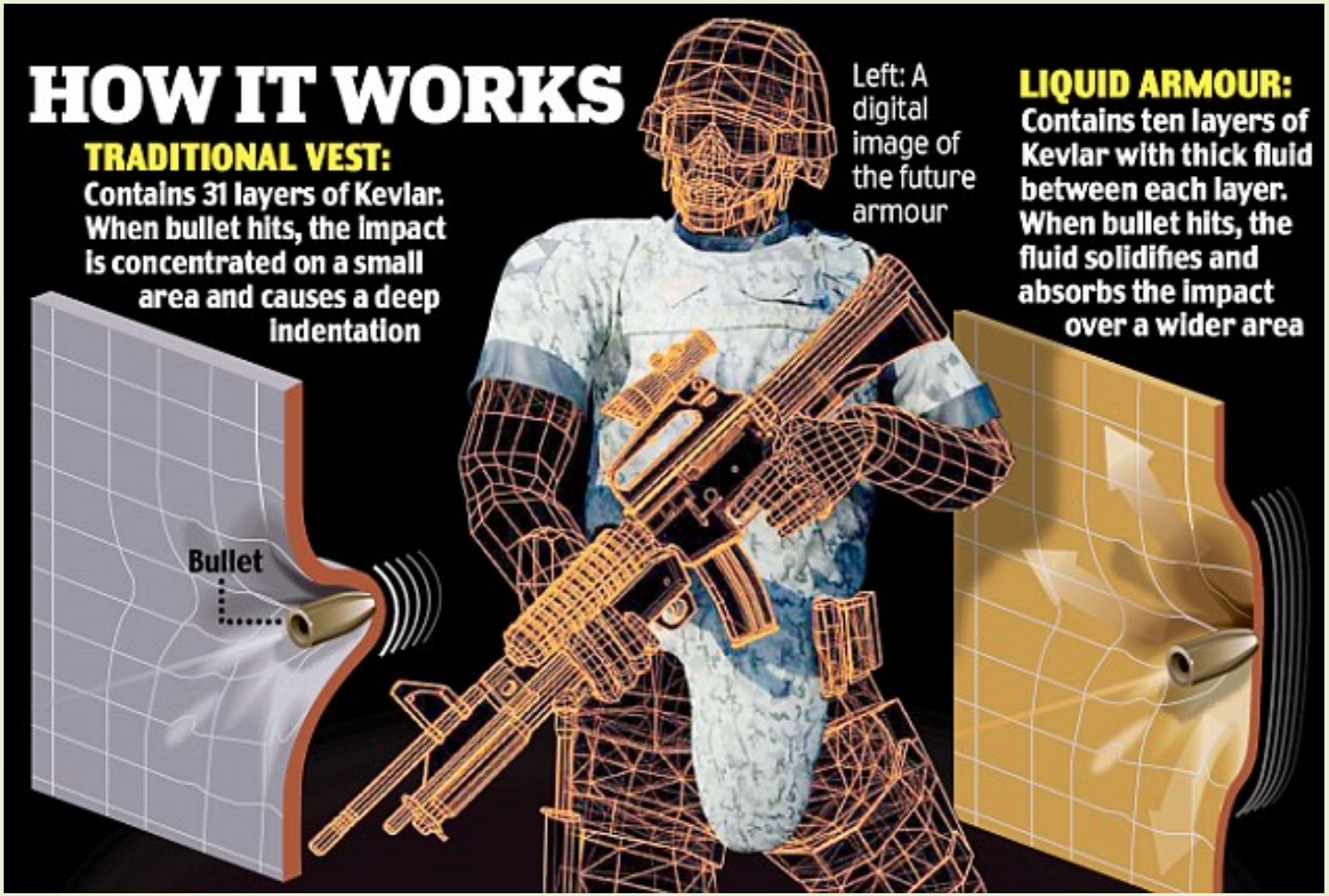
- (For certain fluids) A shear stress is applied
- The volume fraction of particles is increased
- The volume fraction is kept constant, but smaller particles are used

More particle-particle interactions = higher viscosity (thicker fluids)



http://www.azom.com/article.aspx?ArticleID=5542
http://www.howstuffworks.com/liquid-body-armor1.htm

Liquid Armor



http://www.dailymail.co.uk/sciencetech/article-1346877

Horse Boots and Hip Protectors

http://www.popsci.com/beanie/article/2006-02/better-headgear-through-chemistry

Ski cap

http://files.mcrsafety.com/specs/products/gloves/ZB100L.php

Safety gloves – *applications include* impact tools, jack hammer, vibrating tools, carpentry, demolition, grinding, heavy equipment operators

Safety Gloves and Protective Footwear

http://www.d3o.com/markets/footwear/

Protective footwear

http://www.popsci.com/entertainment-gaming/article/2008-03/pumas-crazy-chemistry-ball

Soccer ball

Pointe (Ballet) Shoes

As featured in *Popular Science*

http://www.popsci.com/score/article/2008-05/modern-twist-ancient-shoe

After hundreds of years, there's finally a new way to make pointe shoes!

http://www.capuletworld.com/pointe_d3o_evolution.htm

Other Applications

Shear thickening fluids can also

- Limit vibration during an earthquake or windstorm
- Protect power and phone lines from being cut or punctured

Future Applications

Issues with Liquid Body Armor

Basically, the shear thickening fluid can evaporate and leak out of the fabric

Drawbacks:

- Evaporation
- Sensitivity to humidity
- Reduced permeability

Related Topics

- **Magnetism (related to Ferrofluid)**
  - Exploring Products – Computer Hard Drives (2014)
  - Exploring Tools – Mystery Shapes (2013)
  - Exploring Tools – Special Microscopes (2011)

- **Colloidal solutions (related to both)**
  - Exploring Materials: Nano Gold (2012)

- **Smart Materials (related to both)**
  - Exploring Properties: Electric Squeeze (2014)
  - Exploring Products: Liquid Crystal Display (2013)
  - Exploring Materials: Memory Metal (2013)

Science Behind NanoDays: Part 2
March 18th, 10am PST

Check out the NanoDays 2014 Training Videos:
http://www.nisenet.org/blog/nanodays/nanodays_2014_training_videos_now_available

Cool! Ferrofluid Soap Bubbles

https://vimeo.com/28304264

Ferrofluids: Other Applications

- Damping vibrations and dissipating heat (in loud speakers)
- Seals for computer hard drives
- Adaptive liquid lenses

Horse Boots and Hip Protectors

http://www.d3o.com/markets/sports/

Horse boots

http://www.d3o.com/markets/industrial-and-medical/

Flexible and comfortable hip protectors