1. The nanoscale: Solutions

In order to understand the scale we are dealing with when talking about nanotechnology, **Figure 1** explains the different size ranges for materials from the millimetre to the nanoscale. DNA (deoxyribonucleic acid) is an amazing example of a biological device functional at the nanoscale. The diameter of this double helical molecule is as small as 2-12 nm. At the nanoscale, we encounter various other highly functional moieties like red blood cells, plant cells, animal cells, bacteria and viruses which are just several nanometers big. At the extreme left end of the scale, molecules and atoms are present. These are less than 1 nm in size and are the most fundamental constituent of all matter around us.

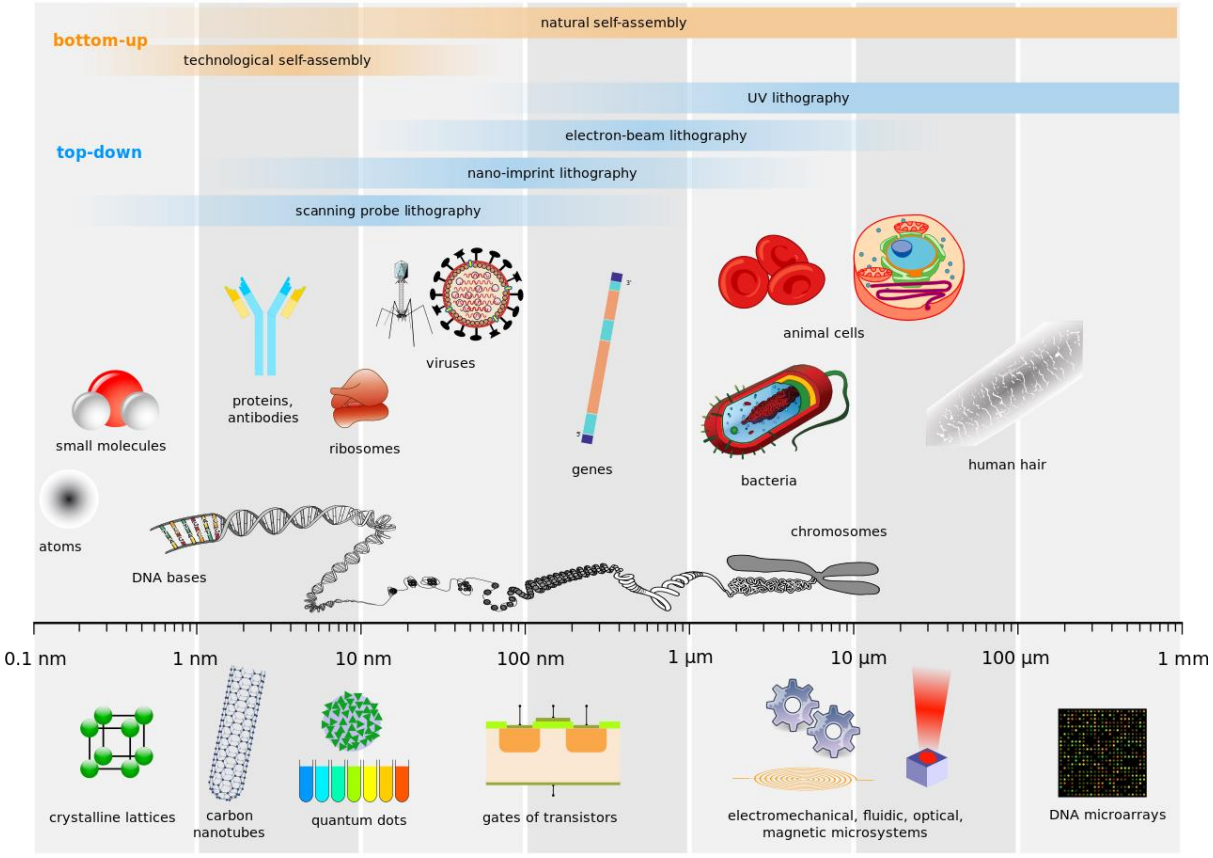

Figure 1: Scale-bar to explain materials in the nanodimension
https://commons.wikimedia.org/wiki/File:Biological_and_technological_scales_compared-en.svg
Credit: Guillaume Paumier, Philip Ronan, NIH, Artur Jan Fijałkowski, Jerome Walker, Michael David Jones, Tyler Heal, Mariana Ruiz, Science Primer (National Center for Biotechnology Information), Liquid_2003, Arne Nordmann & The Tango! Desktop Project
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These examples point us to the fact that the sizes of the most functional materials in nature lie in the nanoscale region.

Why is the nanoscale so significant?

Nanomaterials have a much higher surface area to volume ratio in comparison to their bulk counterparts. This high value of surface area to volume ratio increases the interaction of nanomaterials with their surroundings. Surface area occupies a very important place in deciding the final applications of nanomaterials because it is directly proportional to the number of atoms exposed on the surface of a material. It means that materials with a higher surface area have a greater number of atoms exposed on their surface. The increase in surface area to volume can be explained with the help of **Figure 2**

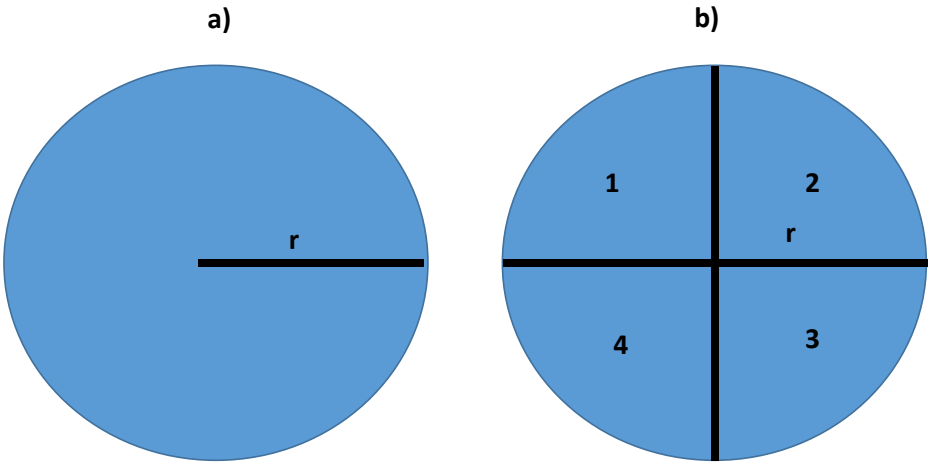

Figure 4: a) A sphere of radius r; b) a sphere of radius r divided in 4 segments
Drawn by Sukanya Datta

In **Figure 2a**, surface area of the sphere is given by: $4\pi r^2$

Volume of the sphere is $4/3\ \pi r^3$
Surface area/volume ratio is $(4\pi r^2)/\ (4/3\pi r^3) =$ **$\underline{3/r}$**

It is important to note that the surface area to volume ratio is inversely proportional to the radius of the sphere. This means that the smaller the particle, the higher the surface area to volume ratio. Because of this property, the way nanomaterials interact with their environment is much more effective than the way that bulk materials do. At the nanoscale, quantum confinement effects also come into play, determining the space coordinates in which the electrons are able to interact. Characteristics of materials are size-dependent in this scale range. Properties such as melting point, fluorescence, electrical conductivity, magnetic permeability, and chemical reactivity change as a function of the size of the particle and can't be explained by classical mechanics.

*1) Which dissolves more quickly in water? Explain your answer. See **Figure 3** for reference.*

a) Powdered sugar
b) Sugar cubes

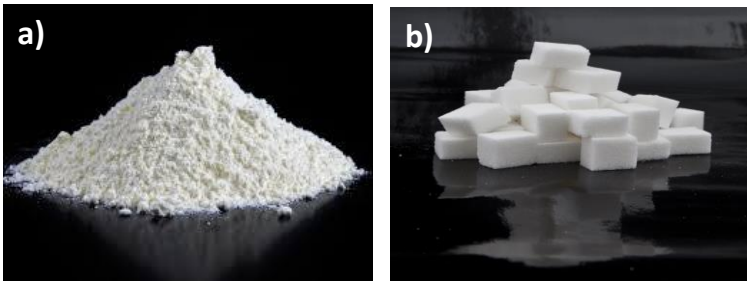

Figure 3: a) Powdered sugar, b) Sugar cubes
https://pxhere.com/en/photo/550876
https://commons.wikimedia.org/wiki/File:Sugar_Cubes_(7164573186).jpg
Credit: David Pacey. Creative Commons Attribution 2.0 Generic license.
Letters added by Sukanya Datta

Powder sugar will dissolve in water more quickly than sugar cube because of the small particle size. It has a higher surface area to volume ratio in comparison to sugar cubes.

2) Look at Figure 4 below. Which one of these statements is correct? Explain why.

a) All of the vials contain gold nanoparticles
b) None of the vial contains gold nanoparticles
c) Vial number 5 contains gold nanoparticles
d) Another vial contains gold nanoparticles.

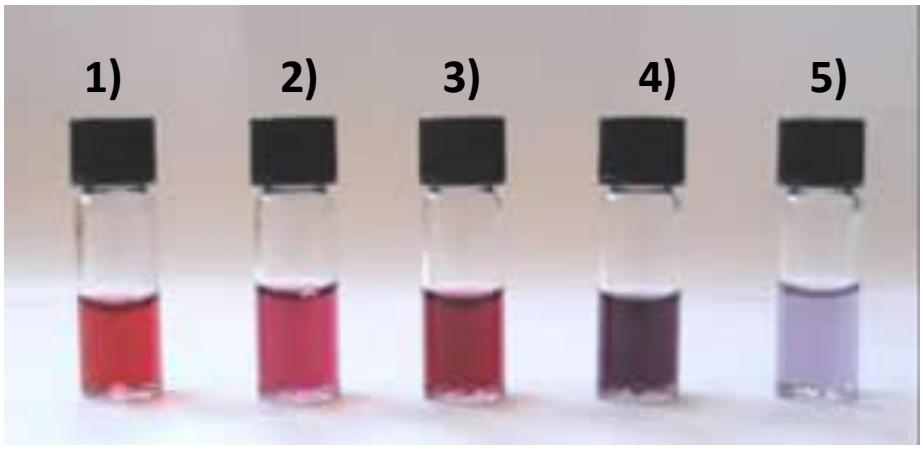

Figure 4
https://commons.wikimedia.org/wiki/File:Gold255.jpg
Credit: Aleksandar Kondinski, GNU Free Documentation License
Numbers added by Sukanya Datta

a) All of the vials contain gold nanoparticles. The colour of the gold nanoparticle changes as its size changes. This change in colour is due to a difference in the light-electron interaction.

Resources for further reading:
https://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials/search?key=&field_topic_tid%5B%5D=20