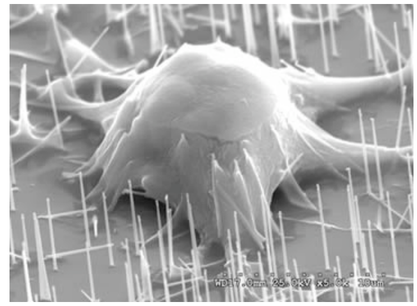
Sizing Up the Nanoworld

The actual size of objects at the nanoscale is a difficult concept to grasp, and misconceptions about how nanoscale objects compare to micro- and macro-scopic objects can lead to misunderstandings of many concepts. For example how viruses infect cells and how the various nanoscale approaches to disease prevention and treatment might work.



A scanning electron microscope reveals individual mouse embryonic stem cells penetrated by silicon nanowires.

Purpose

In this activity, students will "scale up" various nanoscopic and microscopic objects using a scale in which 1 nm = 1mm. Students will then identify objects in the classroom that have nearly same dimensions. As they practice their math skills and the use of the metric system, they will find that the nanoworld holds big surprises!

Materials

- Index cards listing item and its actual size
- Data table, one per student
- Meter sticks, one per pair
- Metric rulers
- String (optional)

Preparation

- Select some or all item from the attached list that you find most useful for your class.
- Write the names of the items and their actual dimensions on an index card; one item per card.
- Prepare a data table (see sample at the end of this activity) that includes your selections, but leave the "scaled up" and "object" boxes blank.

To Do and Notice

Be sure that your students are familiar with the metric system, and very small units. In particular, review the following, or include on their data table:

Unit	Abbreviation	Decimal	Scientific Notation
Meter	m	1.0 m	1×10^{0} m
Kilometer	km	1000 m	1×10^{3} m
Centimeter	cm	0.01 m	1×10^{-2} m
Millimeter	mm	0.001 m	$1 \times ^{10-3}$ m
Micrometer	µm	0.000001 m	1×10^{-6} m
Nanometer	nm	0.000000001 m	1×10^{-9} m

- Pass out cards to students, one or two per pair, or whatever works for your class. It's fine if more than one group receives the same item.

- Provide each group with meter sticks and metric rulers. Have string available as a tool for measuring long distances, if needed.
- Instruct the students to "scale up" their items by multiplying the dimensions of each by one million times – that is, multiply by 1×10^{6}. In our conversion, 1 nanometer (nm) scaled up one million times is 1 millimeter (mm). One micrometer (µm) scaled up one million times is one meter (m).

- Students then use the measuring devices to find an object in the classroom that approximates their dimensions of the scaled up item.

- Students share their results with the class. Are the students surprised by any of their results? If so, why? Lead a discussion on the significance of the relative sizes

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Biological Structure	ACTUAL SIZE	SCALED SIZE Multiplied by 1 million or 1 x 10^6
DNA: average length in one human chromosome	2 nm diameter 2 x 10^{-9} m 60 mm length 60 x 10^{-3} m	2 x 10^{-3} m diameter, or 2 mm 60 x 10^3 m length, or 60 km
Human Red Blood Cell	8 µm diameter 8 x 10^{-6} m	8 x 10^0 m, or 8 m
Human T lymphocyte	12 µm diameter 12 x 10^{-6} m	12 x 10^0 m, or 12 m
Human ovum (egg)	150 µm diameter 150 x 10^{-6} m	150 x 10^0 m, or 150 m
Human sperm	4 µm diameter 4 x 10^{-6} m	4 x 10^0 m, or 4 m
Escherichia coli Common gut inhabitant; some strains are sources of gastrointestinal disease	1 µm width x 2µm length 1 x 10^{-6} m by 2 x 10^{-6} m	1 x 10^0 m width by 2 x 10^0 m length, or 1 m by 2 m
Viruses	ACTUAL SIZE	SCALED SIZE Multiplied by 1 million or 1 x 10^6
HIV virus particle; causative agent of AIDS	110 nm diameter 110 x 10^{-9} m	110 x 10^{-3} m, or 110 mm (11 cm or 0.11m)
Rhinovirus; one of the causative agent of colds	230 nm diameter 230 x 10^{-9} m	230 x 10^{-3} m diameter, or 230 mm (23 cm; 0.23 m)
Parainfluenza; one of the causative agents of the flu	220 nm diameter 220 x 10^{-9} m	220 x 10-^{3} m diameter, or 220 mm (22 cm; 0.22 m)
Astronomy/Geology	ACTUAL SIZE	SCALED SIZE Multiplied by 1 million or 1 x 10^6
Interstellar Dust Grain	1 µm or 1 x 10^{-6} m	1 x 10^0 m or 1m
Micrometeorite	200 µm or 200 x 10^{-6} m	200 x 10^0 m or 200m
Gold Nanoparticle	4nm diameter 4 x 10^{-9} m	4 x 10-^{3} m diameter, or 4 mm (4 cm; 0.40 m)
Physics	ACTUAL SIZE	SCALED SIZE Multiplied by 1 million or 1 x 10^6
Wavelength of yellow light	500 nm or 500 x 10^{-9} m	500 x 10-^{3} m diameter, or 500 mm (50 cm; 0.50 m)
Wavelength of Extreme Ultraviolet Light (EUV)	10 nm to 120 nm or 10 x 10^{-9}m to 120 x 10^{-9}m	10 x 10^{-3} m to 120 x 10^{-3} m or 10 mm to 120 mm
Magnetic nanoparticles in ferrofluids	10 nm	10 x 10^{-3} m or 10 mm

Variations

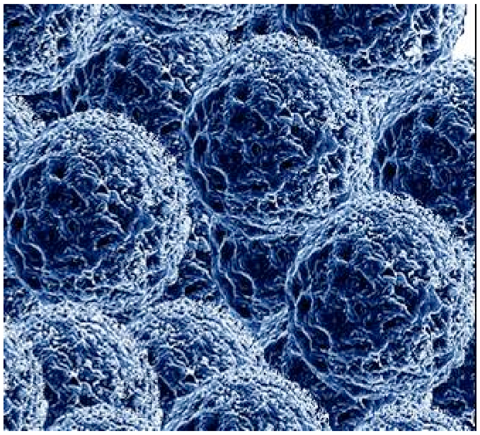
- With younger students, you may wish to supply the "scaled up" sizes of the cells and structures, and have the students find objects that are similarly sized.
- This activity is easily adapted to by conducted outside, or can be made to fit in a classroom even better by scaling up by 100,000 (1×10^5) rather than one million.

Going Further

- Consider a human being who is 1.8 meters tall. Multiply by this height by one million times to see how large a person would be, relative to some of these objects.
- Provide the students with inexpensive materials (paper, Styrofoam packaging, pipe straws, etc. to make models of selected cells.

Acknowledgement

This activity is a modification of an exploration originally developed by Margaret Till and Cynthia Surmacz of the Dept. Biological and Allied Health Sciences, Bloomsburg University and revised by Karen Kalumuck of the Exploratorium.



Silver nanoparticles

Example of Student Data Sheet – Life Science

ITEM	ACTUAL SIZE	Scaled Size	Scaled Object
DNA: average length in one human chromosome	2 nm diameter 2×10^{-9} m 60 mm length $60 \times 10^{--3}$ m		
Human Red Blood Cell	8 µm diameter 8×10^{-6} m		
Human T lymphocyte	12 µm diameter 12×10^{-6} m		
Human ovum (egg)	150 µm diameter 150×10^{-6} m		
Human sperm	4 µm diameter 4×10^{-6} m		
Escherichia coli Common gut inhabitant; some strains are sources of gastrointestinal disease	1 µm width x 2µm length 1×10^{-6} m by 2×10^{-6} m		