seeing scale

GOAL:

Visitors will appreciate the magnitude of different metric scales and recognize that different tools are required to see objects at each level.

MATERIALS:

- Meter stick, unfolded with metric units displayed
- 4 butterfly cards (butterfly, wing, scales, fine structure)
- 4 cell phone cards (phone, processor, circuit, transistor)
- 4 visualization tool cards (eye, magnifying glass, light microscope, scanning electron microscope)
- Magnet board

PROCEDURE:

Set-up:

1. Lay out the meter stick with metric units displayed.

2. Prop up the magnet board and post the butterfly cards at the top in order of decreasing scale.

3. Have the visualization tool cards and cell phone cards accessible, with each set shuffled out of scale order.

Doing the demonstration:

1. Show visitors the 4 butterfly cards and explain that each card has a picture of a monarch butterfly's wing, zoomed in closer and closer and closer. Then give them the set of visualization tool cards. Tell visitors to identify the tool that would be used to see the butterfly at each scale by posting each tool card underneath the corresponding butterfly card.

2. Once the visitor has matched all of the pictures, turn each pair of cards over. If the color outlines on the backs of the cards match, then the matches are correct.

3. Review the information on the backs of the cards with visitors, beginning with the centimeter scale. The whole butterfly is on the centimeter scale; you can point out

its size range on the meter stick as reference for younger children who may not have a good sense of scale. We are able to see this scale very easily with the naked eye.

4. The details of a butterfly's wing are on the millimeter scale. Ask the visitor to find a millimeter on the meter stick. We can still see things on this scale with our eyes, but we can observe finer details with a magnifying glass.

5. The scales on a butterfly wing are on the micrometer scale. There is no micrometer measurement on the meter stick because it is too small to see with our eyes. While we can see individual objects on the micrometer scale (like the edge of a sheet of paper), we need a light microscope to be able to distinguish between things that are this small.

6. The fine structure of the butterfly scales is at the nanometer scale. Scales in the center of the wing are shown here, but the structure varies between different types of scales in the wing, e.g. along a vein vs. in the wing center. We cannot see things at this level with our eyes or even a light microscope; we need a Scanning Electron Microscope (SEM), a large, powerful tool, to see things that are this small.

7. Once you have reviewed each of the scale sizes with the visitors, remove the butterfly cards and flip the tool cards back to the image side. Then give visitors the set of cell phone cards. Tell them that things exist on the nano-scale not only in nature, but also in the technology that they use everyday. As a second challenge, ask the visitor to match these images with the correct visualization tools as they did for the butterfly cards. See if the visitor can remember each scale before they flip the cards over to check their matches.

Clean-up:

1. Gather all materials and return to storage.

EXPLANATION:

Scale represents the measured relationship between objects. The metric system provides a convenient frame of reference for scale based on powers of ten. A centimeter is one hundredth of a meter; a millimeter is one thousandth of a meter. A micrometer is one millionth of a meter – the diameter of a human hair is about 60 micrometers. A nanometer is invisible to the eye and is one billionth of a meter. On average, atoms are about 0.1 nm and molecules are about 1-2 nm wide.

Various visualization tools allow us to make observations that we may not see with the naked eye. Magnifying glasses have a single convex lens that refracts light to make the image of an object appear bigger. Optical microscopes also use visible light and combine multiple lenses to magnify objects to a resolution of up to 0.2 micrometers. The Scanning Electron Microscope (SEM) does not rely on visible light; rather, it emits a beam of electrons and detects the pattern of their interaction with the surface of the sample. This method yields images with a three-dimensional appearance at nanometer-scale resolution.

Observation of objects in nature at the nano-scale has inspired new technologies for consumer goods. For example, butterflies with iridescent wings (not monarchs) have nanostructures called photonic crystals that reflect light and regulate temperature. Scientists are now developing manmade photonic crystals that could provide thermal protection for humans in extreme environments.

In addition, the development of nanotechnology has enabled the miniaturization of popular consumer electronics. For example, a cellular phone contains large numbers of nano-scale silicon transistors that control the resistance to flow of electrons within a circuit. To manufacture these transistors in bulk at relatively low cost, materials are first deposited in layers – each just a few atoms thick – on a substrate. Nano-scale features are then defined by imprinting, and finally excess material is etched away. Current research is focusing not only on better, cheaper production techniques but also on new materials with novel nano-scale properties, such as carbon nanotube transistors.