HOW BIG IS A CELL?

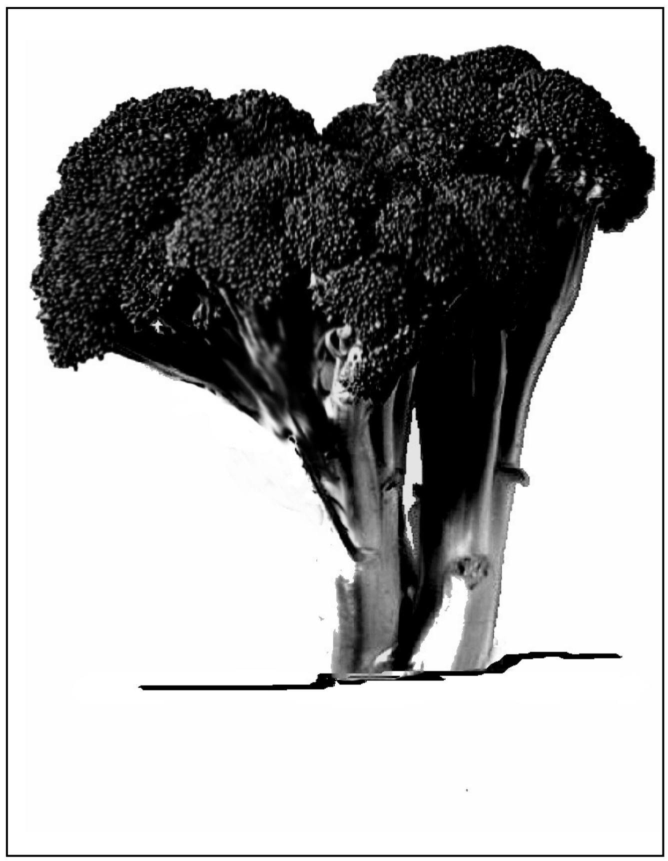
By: Alice Dennis

There is no easy answer to this question. This is like asking how big a plant is. Are plants as big as the giant sequoia redwoods? Or are they as small as a piece of duckweed? This activity will introduce students to a range of cell sizes.

Part 1: Scale. What is "big"?

WARM-UP ACTIVITY:

1. Look at the two pictures on this page.
2. Approximately how big do you think these objects are? Are they the same size?
3. What makes you think this?
4. Turn to the next page.



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 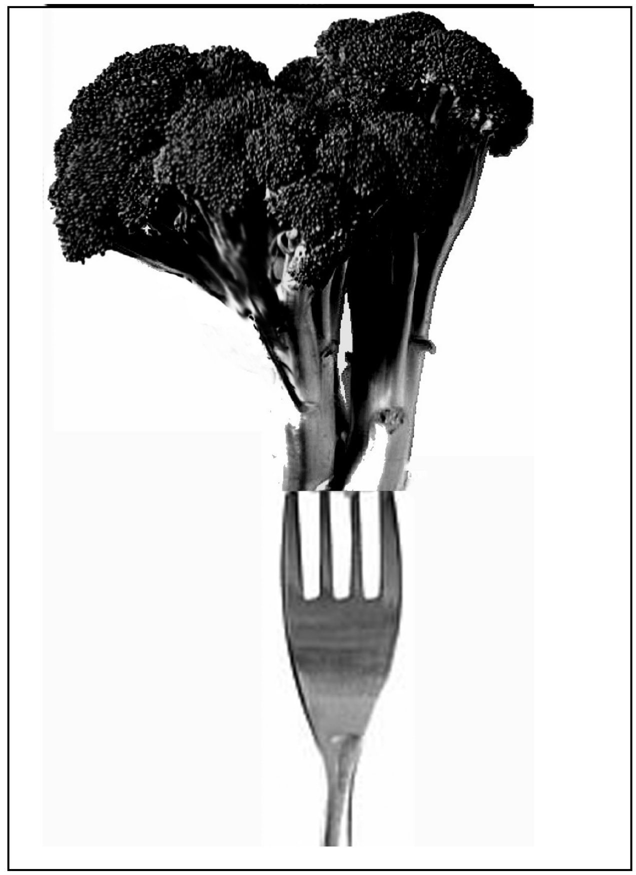

5. Look at the same pictures again (above).

6. Now how big do you think each object is?

7. How do your answers change when you see these pictures again here? Why?

The things you use a microscope to view may be less familiar than a tree or a piece of broccoli. Without some measure of scale, you have no idea how big they are.

Cells are very small and we measure them with very small metric units, usually µm (pronounced: ˈmī-krō-ˌmē-tər). This is one *millionth* (0.000001 or $1x\ 10^{-6}$) of a meter and a *thousandth* (0.001 or $1x\ 10^{-3}$) of a millimeter. How big is 1µm? A mm is about the width of the tip of a ball point pen, and it takes 1,000 µm to equal 1mm*.

**For more information on scale, see the SOAR lesson plan titled "Measure Up" (see references).*

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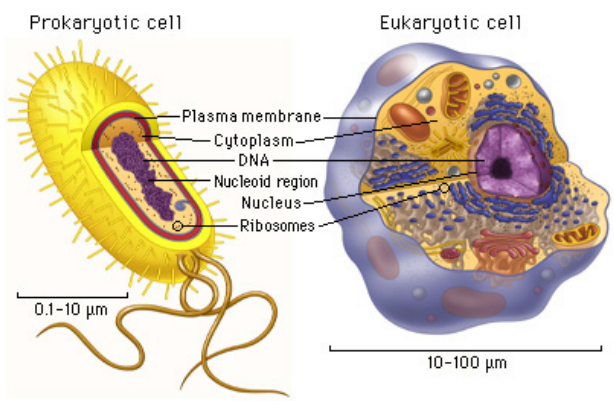
Part 2: How big is a cell?

There is not one single answer to this question. Why? Cell size varies depending on where it comes from and what it does. This means that a bacterial cell is smaller than an animal cell, a human red blood cell is smaller than a human nerve cell and all of these are smaller than the single-celled, 15cm long ostrich egg!

Two basic cell types:

Prokaryotes: Meaning 'before the nucleus' these cells usually do not keep their DNA or other organelles sealed in membranes. This group includes some of the smallest cells and all bacteria *of which only a small fraction make us sick.* Bacteria come in three basic shapes: spheres, rods and spirals. These small cells require a high magnification to be seen [>400X], so are not usually seen with SOAR.

Eukaryotes: This more complex type of cell is found in many groups, including animals, fungi, and plants. These cells contain a nucleus and many other special structures (organelles) that perform specific functions. Examples of these functions are: producing energy (mitochondria), directing materials around the cell (golgi bodies) and digesting waste (lysosome). If you stain your sample, the nucleus can be seen as a spot within the cell using Scope-On-A-Rope [>200X]. A higher magnification is needed to see most other structures.



Why do we need bacteria?

The average person has about 10 times more bacterial cells in their body than they have of their own cells! What are they doing? Breaking down our food, living in our skin, and just hanging out.

Now, don't go scrubbing your hands too hard. Most of these bacteria are either beneficial or harmless. Without bacteria to help us digest food, we would starve and die! Most bad bacteria come from outside your body (or human waste). It has been said that if you took away everything on earth except for the bacteria, you would see a fine outline of everything we know (buildings and mountains for example) because of the layer of bacteria covering them.

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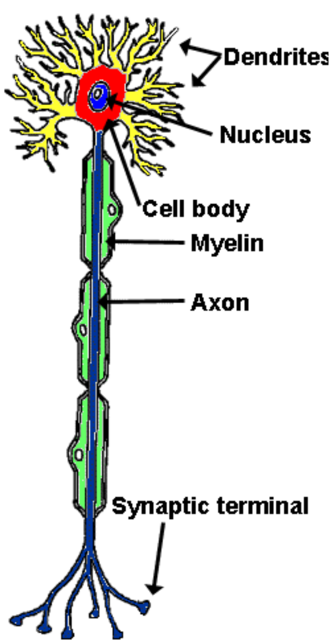
Some cells sizes and how to view them

Type of cell	Average Size	How can it bee seen?
Virus	0.03 – 0.8 µm	Electron microscope (EM)
Bacteria cell (prokaryote)	0.5 – 5.0 µm	Light microscope or EM
Smallest human cell (sperm cell)	2.3 – 3.5 µm	Light microscope
Human red blood cell	7.5 µm	
Human cheek cell	60 µm	Light microscope or Scope-On-A-Rope!
Mature human ovum	120 – 150 µm	
Amoeba	300 µm	
Grain of salt	300 µm	
Onion skin cell	400 µm	
Largest human cell (neuron)	Up to 1m long ! (=1,000,000 µm)	



What is the...	
World's largest cell (by volume)?	A fresh **ostrich egg**, which can weigh up to 3lbs.
World's longest cell?	**Nerve cells** from the spinal cord of can be up to a meter long.
World's smallest cell?	**Mycoplasma** are the smallest known cells. These tiny, single celled bacteria don't have cell walls. Why are they important? Members of this group include pneumonia and other human pathogens.

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Part 3: Viewing Cells

Note: This activity works best after completing the "Measure Up" activity, found on the SOAR website (http://www.scopeonarope.lsu.edu/).

Materials needed:

- Scope-On-A-Rope with 200x lens
- salt
- an onion
- ballpoint pens
- small Petri dishes
- stain solution (gentian violet, an antibiotic found at most drug stores, or iodine)
- dropper bottle or pipette
- copies of worksheet on pages 7-8

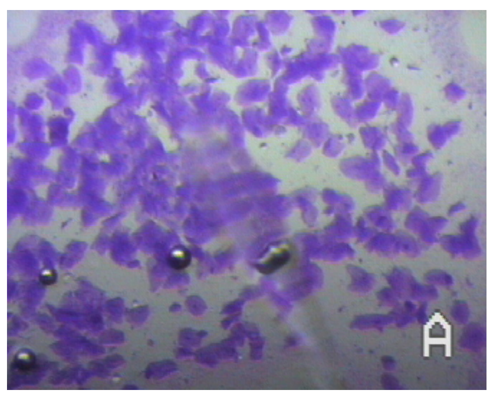
A. Viewing small objects for scale reference

1. **Salt**: prepare a slide of salt using glue or a glue dot. View the exposed side of the salt using the 200X lens. Draw what you observe on the worksheet (pages 7-8), paying attention to the portion of the viewing field each grain of salt occupies.

2. **Pen tip**: hold a ballpoint pen to the 200X lens. Move it to bring it into focus. Snap a picture and draw the scale of this relative to the salt grains. Then scope a metric ruler to show the field of view of the 200x lens.

B. Viewing Animal Cells: Human cheek cells (Activity by Cindy Henk)

1. Prepare stain solution by mixing 1 drop of gentian violet with 10 ml water.
2. Draw a ~1cm diameter circle on the outside of the large half of the Petri dish with a marker.
3. With a clean finger, touch the inner cheek inside your mouth. **Do not scrape, just touch!** Then touch the inner lid inside the circle. Do this 2 more times. You are attaching your own cells to the lid.



4. Wait 3-5 minutes for the cells to dry.
5. When the cells are dry, put a drop of stain about the diameter of a pencil eraser inside the circle on the lid.
6. Now place the small half of the Petri dish inside the large half, on top of your drop. This should enlarge the drop. (See tip with diagram on next page.)

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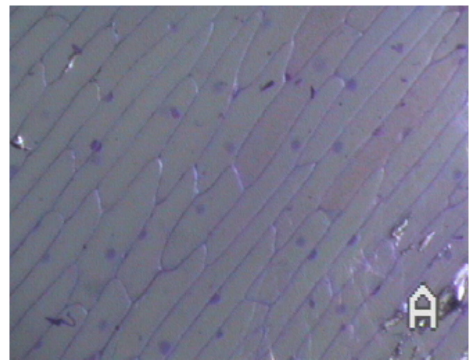
7. View your Petri dish ‘slide’ with the 200X lens in the inverted setup on the SOAR. Make sure that the circle is centered over the hole in the lens tip. Use the lamp above the scope to achieve a ‘brightfield’ effect.

8. Look at your cells. Can you see the slightly darker dot in their center? This is the cell nucleus. Record what you see on the activity worksheet. Compare the cell you see to a textbook illustration of a cell. What can you see? What can’t you see?

Note: An example of a large clump of cells is in the SOAR snapshot on the previous page. Each independent purple shape is one cheek cell!

<u>C. Viewing Plant Cells: Onion cells</u>



1. Cut a small piece off of the onion (a few cm square). Take this piece in your fingers and peel off the thinnest layer possible. This should be about 1 cell thick.

2. Place this slice flat inside the larger half of a small Petri dish. Add a drop of stain. Diluted iodine is best used for this, but gentian violet works as well (and has been used in the sample preparation shown on this page).

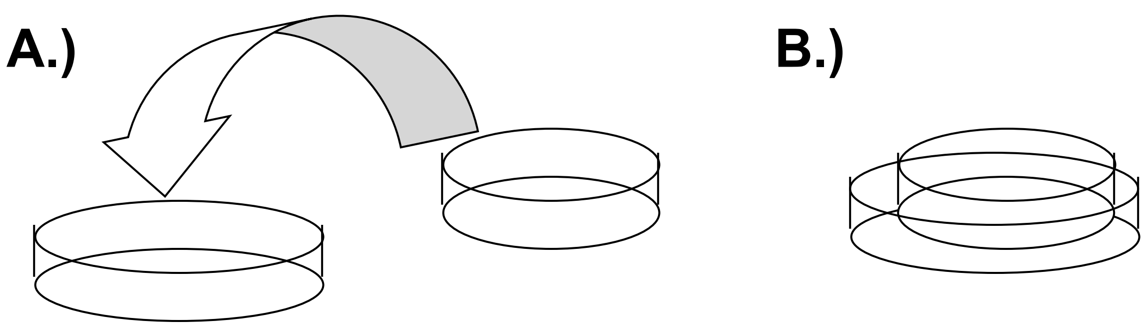
3. Flatten the preparation by placing the small half of the Petri dish on top of the onion sample.

4. View your onion cell prep using the 200X lens in the inverted setup (as in #7 above).

5. Look for the dark nucleus of the cells. The geometric plant cell walls should appear different from the animal cells. Again, record your observations on the worksheet.

Note: An example of an outer onion skin is shown in the SOAR snapshot above. The cell nucleus and other, large organelles are visible as the darker purple shapes seen within each cell.

<u>Tip: Using a small Petri dish to prepare samples</u>



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Part 4: Activity Worksheet

Use the 200X lens of SOAR to look at the following items. Draw what you see in each box.

1. Salt grains

2. The tip of a pen

3. Onion skin cells

4. Human cheek cells

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Questions

Use your observations from the previous page to answer the following.

5. How many onion cells would fit on the tip of a pen? ________

6. How many cheek cells would fit there? ________

7. What differences do you see between onion skin (a plant cells) and a cheek sample (animal cells)?

8. What do you see that is the same in the two cells?

9. How do the salt grains differ from the cells you viewed? Is each grain the same size and shape?

10. Describe a cell for someone who has never seen one.

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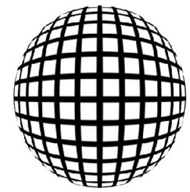
Part 5: Math Extensions



Surface to volume ratio.

Why aren't cells bigger?

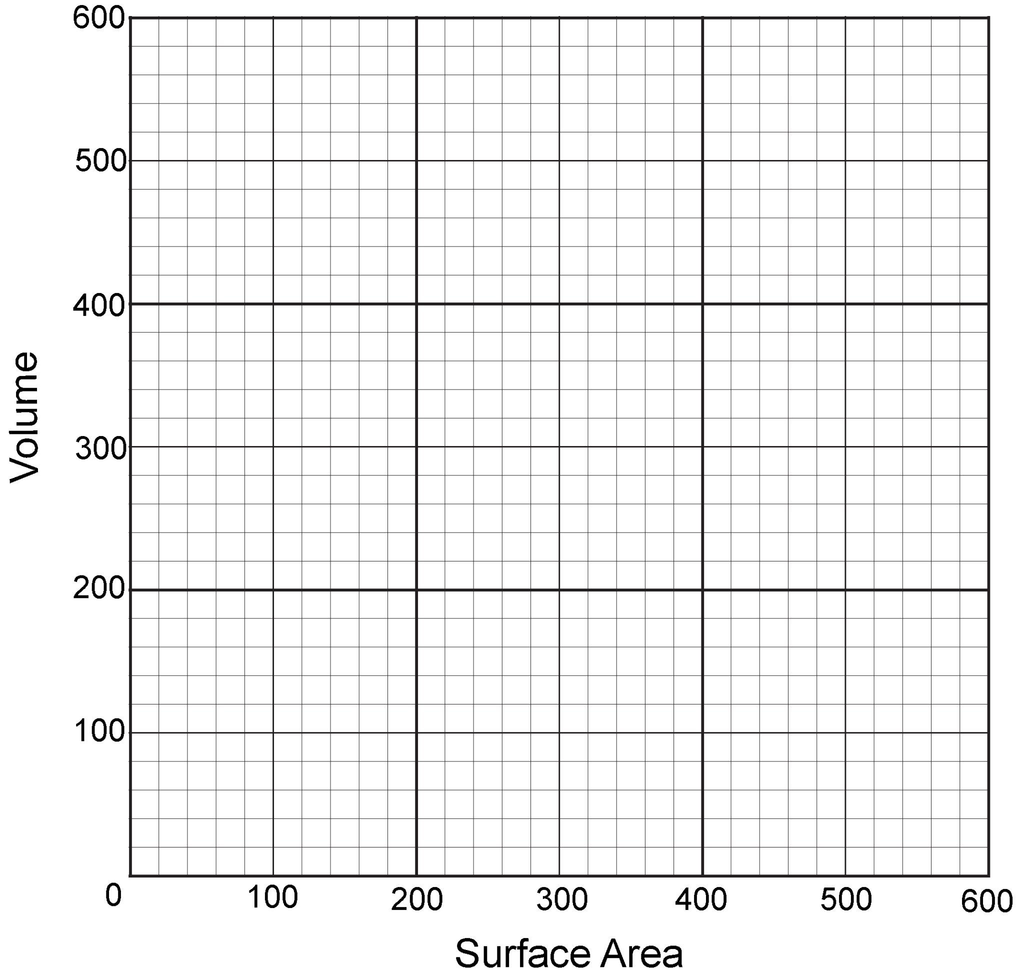
They're limited by the ratio of surface area to the volume of the cell. Think of a balloon--the surface area is the two-dimensional area of the balloon. The volume is the three-dimensional amount of air inside the balloon.

Try for yourself. Graph the surface to volume ratio using the radii provided below.

Use these formulas to calculate volume and surface area:
(Answer key is on page 13.)

$$V = \frac{4\pi}{3}r^3 \qquad S = 4\pi r^2$$

Radius	1µm	2µm	3µm	4µm	5µm
Volume					
Surface Area					



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Look at the graph you made on the previous page. As the surface area increases, how does the volume increase? (circle one)

FASTER **SLOWER** **THE SAME**

Why does this matter?
Most transportation in a cell is by diffusion. If there isn't enough surface area, essential nutrients like oxygen can't get into the cell fast enough--especially to the organelles in the middle. Think of how far the exit of a football stadium is from the center and compare this to the distance from the door to the center of your classroom.

Additional Math Activities:

1. Experimental measurements- they can vary.
   a. Using the method described in the SOAR *Measure Up* activity, estimate the size of each object you measure. As you will see in this activity, the field of view using the 200X lens is about 1mm.
   b. Graph or list each person's estimates.
   c. Compare the measurements among groups. This will demonstrate the expected range in any set of measurements.

2. Conversions of the metric measurements you just made. Go back to page 7 to estimate your sizes. [1 mm = 0.03937inch]

How big are the objects you've just measured? Use your class resources to approximate their measurements in inches. What common objects are about this size? (e.g. sugar crystals, seeds, etc.) *Add your own objects to the blank rows.*

	Metric measurement	English measurement	How many of these could line up across a penny?
Penny diameter	19mm	0.75 inches	
Salt Grain			
Onion cell			
Cheek cell			

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Part 6: Vocabulary

Scale: The relative size of an object

Size: The measurement of how big (or small) an object is.

Measurement: An estimation of the physical quantity of something.

Virus: DNA with a protein coat. These particles require a living host cell to replicate.

Cell: The smallest metabolically functional unit of life.

Prokaryote: 'Primitive' types of cell without membrane-bound nuclei or organelles. These are found only in the domains Bacteria and Archaea.

Eukaryote: The more complex of the two cell types (the other being prokaryotic cells). These cells have membranes around their organelles. They are found in many organisms, including animals, plants, fungi and single celled protozoans.

Bacteria: Single celled, prokaryotic microorganisms. They are found in every habitat on earth. The vast majority of these cells are harmless to humans.

Animal cells: The cells found in all animals. These are eukaryotic cells and do not have chloroplasts, cell walls or vacuoles.

Plant cells: Unique to plants, these eukaryotic cells contain a visible cell wall, a large vacuole, plasmodesmata and chloroplasts.

Cell Membrane: The thin covering on all cells that controls what goes into and out of the cell.

Cell Wall: A rigid support layer around a plant cell, outside of the cell membrane. Animals do not have this, but fungi do.

Organelles: Cellular structures with specific functions. Examples of these are: nuclei, mitochondria, chloroplasts and the endoplasmic reticulum.

Nucleus (pl. nuclei): A large organelle within the cell that contains the DNA within a membrane.

DNA: Short for **D**eoxyribose **N**ucleic **A**cid. This molecule contains the genetic instructions for the development and maintenance of life.

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Part 7: References

Web Links:

1. "*Measure Up* with SOAR". This invaluable lesson plan will introduce students to the idea of scale and magnification. *Highly recommended* before looking at cell sizes: www.scopeonarope.lsu.edu

2. The scale of cells and their parts: www.cellsalive.com/howbig.htm

3. The Charms of Duckweed: www.mobot.org/jwcross/duckweed

4. The Universe in Powers of 10: micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10

5. Insights on Bacteria: www.stephenjaygould.org/library/gould_bacteria.html

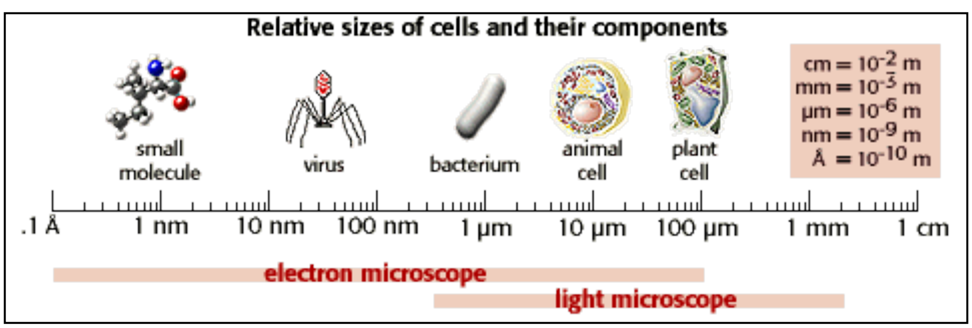
6. Math: www.ugrad.math.ubc.ca/coursedoc/math100/notes/zoo/cell.html

Books:

7. *Cells are Us.* (1994). Author: Frances R. Balkwill. Illustrator: Mic Rolph. Publisher: Carolrhoda Books.
   Note: This book illustrates the function and diversity of cells in the human body.

Journal articles:

8. Sears C (2005). "A dynamic partnership: Celebrating our gut flora". *Anaerobe* **11** (5): 247 – 51.



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Part 8: Louisiana Grade Level Expectations (GLE's)

Grade 4: Science as Inquiry: 2, 4, 6, 8, 9, 10, 12, 14, 17, 18 and 23.
Math 2, 21 and 22

Grade 5: Science as Inquiry: 2, 3, 6, 7, 8, 11, 19, 28 and 31.
Physical Science: 15, 16 and 17.
Math: 15, 18, 19, 20, 22 and 28.

Grade 6: Science as Inquiry: 2, 3, 6, 7, 8, 11, 19, 28 and 31.
Math: 7, 18, 23 and 30.

Grade 7: Science as Inquiry 2, 6, 7, 8, 11, 19, 28 and 31.
Life Science: 2 and 4.
Math: 1, 20, 26, 27 and 28.

Grade 8: Science as Inquiry: 2, 6, 7, 11, 19, 28 and 31.
Math: 4, 17 and 20.

Answer Key for Part 5: Math Extensions

Surface to volume ratios:

Radius	1µm	2µm	3µm	4µm	5µm
Volume	**4.2**	**33.5**	**113.1**	**268.1**	**523.6**
Surface Area	**12.6**	**50.3**	**113.1**	**201.1**	**314.2**

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