Cell Size Exploration 

Title: Why Do Cells Stay Small?
Estimated Time: 2-3 Periods

Core Ideas (GSE Standards):

S5L3. Obtain, evaluate, and communicate information to compare and contrast the parts of plant and animal cells.

a. Gather evidence by utilizing technology tools to support a claim that plants and animals are comprised of cells too small to be seen without magnification.

S7L2. Obtain, evaluate, and communicate information to describe how cell structures, cells, tissues, organs, and organ systems interact to maintain the basic needs of organisms.

a. Develop a model and construct an explanation of how cell structures (specifically the nucleus, cytoplasm, cell membrane, cell wall, chloroplasts, lysosome, and mitochondria) contribute to the function of the cell as a system in obtaining nutrients in order to grow, reproduce, make needed materials, and process waste.

(*Clarification statement:* The intent is for students to demonstrate how the component structures of the cell interact and work together to allow the cell as a whole to carry out various processes. Additional structures, beyond those listed, will be addressed in high school Biology.)

Science and Engineering Practices:

Asking Questions and Defining Problems:

Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.

Developing and Using Models

Use and/or develop a model of simple systems with uncertain and less predictable factors.

Constructing Explanations and Designing Solutions

Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.

Crosscutting Concepts

Models and System Models

Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
Models are limited in that they only represent certain aspects of the system under study.

Structure and Function

Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Authentic Scenario

The fact that you have about 30 trillion cells in your body gives us a good indication of how small most cells are. While cells come in a variety of shapes and sizes, most are extremely small. Cells are usually between 2 and 200 millionths of a meter. Fortunately, engineers are learning how to solve problems that occur with very tiny objects – including cells. The newly emerging field of Nanoengineering involves the design, creation, and control of materials or objects that are 1-100 nanometers in size. Cellular nanoengineers are working to solve a variety of problems that occur at the level of the cell. In this exploration, student investigate the question, "Why can't organisms be just one giant cell?" Since we don't have the equipment needed to work at the nano-level, we will have to use a model of a cell that is large enough for us to manipulate. As our cell model, we will make two cells in the shape of a cube that are made of gelatin. The gelatin works well as a model because it allows for materials (in this case vinegar) to diffuse slowly into it. The gelatin also contains some universal indicator solution that gives the cubes a purple color. As the vinegar diffuses into the gelatin cell, it will turn from green to red. This color change will allow you to measure how fast the diffusion occurs.

Guiding Question:
Why do cells stay small?

Part 1: Investigating Cell Size

5E Stage	**Student Activities** How will students engage actively in the three dimensions throughout the lesson?	**Teacher Activities** How will the teacher facilitate and monitor student learning?
Engage	• Students brainstorm ideas that could explain why cells have a tendency to stay very small. • Students discuss how the process of diffusion might be an important factor in limiting cell size. • Students generate questions based on their understanding of cells and diffusion. • Students predict what will happen when the gelatin cells are placed in vinegar.	• Encourage students to brainstorm multiple ideas • Share and discuss questions and predictions that are generated
Explore	• For younger students, students can make a small cell (.5cm sides) and a larger cell (1cm sides) and measure the time required for oxygen and carbon dioxide to move into and out of the cell. Discussion of surface area to volume ratios can wait. • In middle school, students begin by calculating the surface area and volume of two different cells that are cubic in shape. • Students use these calculations to determine the surface area to volume ratio of each of the cells. • In groups, students compare calculations and come to consensus as a group. • As a class, students discuss the importance of this ratio relative to the diffusion of nutrients and other materials into the cell. • In groups, students observe the gelatin cube and then carefully cut it into 2 different cell model sizes. Cube 1: .5 cm sides Cube 2: 1 cm sides • Students place cube into cup of vinegar, make and record observations, collect data, and measure the time required for nutrients to feed the entire cell.	• Encourage students to measure how long it takes oxygen move into a small cell vs a large cell. • Encourage students to make careful and detailed calculations. Scaffold as needed. • Surface area represents the space where diffusion can occur. • **Surface area of a cube = $6a^2$** • The volume represents the space that must receive needed materials & remove the unneeded materials. • **Volume of a cube = a^3** • Assist students in making careful observations and measurements.
Explain	• Students read/research about cell size and/or read **Why Do Cells Stay Small**?	• As needed, reiterate to students that one important

	• Students use their observations, data and research to evaluate the relationship between the surface area to volume ratio and the time required to feed each cell (rate of transport). • Students use their observations, data and evaluation to explain why cells stay small. • Students consider how the gelatin cell models are limited in how they represent real cells and actual systems.	skill of scientists is to construct explanations based on observations. • For older students, emphasize that the limitation in cell size can be represented mathematically by calculating the surface area to volume ratio of gelatin "cells" of different sizes. • Summary: The larger the cell, the slower the rate of diffusion (because surface area grows more slowly than volume).
Elaborate	Students graph the relationship between the size of the cell (represented by Surface Area/Volume ratio) and the rate of diffusion (time taken to turn red). Students use the graph to interpret the mathematical relationship between the variables.	Assist students in identifying the I.V. (Surface Area/Volume ratio) and the D.V. (time taken to turn red).
Evaluate	**Formative:** In groups, students present their explanations of why cells stay small using their evidence to support their explanations. **Summative:** Each group summarizes their explanations of why cells stay small based on their evidence and information obtained during reading/research. Students complete journal entries documenting observations, data, discussions, and conclusions.	**Formative:** Facilitate ongoing questioning & discussion Promote discussion of data and explanations. **Summative:** Evaluate group presentations Evaluate journal entries.

Materials:
2 Packets Unflavored gelatin (Knox)
3 beakers or plastic cups per group
Universal Indicator Solution (6-7 ml per 2 pouches of gelatin)
Household ammonia (6-7 ml per 2 pouches of gelatin)
Cutting utensil (plastic knife works fine)
Calculators (optional)
Vinegar
Stop watch or timer

Recipe to make Universal Indicator Gelatin (for about 25 student groups)
This can be made several days in advance. This recipe should be enough for 50 students working in pairs.

1. Place 1 cup (230 ml) of water in a wide beaker or bowl.
2. Sprinkle 2 pouches gelatin(Knox) to the water. Let stand for 1 minute
3. Add 1 cup (230 ml) boiling water to the mixture. Stir until the granules are completely dissolved – it will become clear again – okay if you have some small clumps.

4. If needed, microwave for about 30 seconds to help in the dissolving process.
5. Add 6-7 ml of universal indicator solution and mix.
6. Add 6-7 ml of household ammonia and mix. Mixture should turn deep green to purple.
7. If the mixture is not a deep green-purple yet, add 1-2 more ml of indicator solution and/or ammonia.
8. Pour the gelatin into ice cube trays -- enough for 1 ice cube per student group. It will gel in about 2 hours or less if refrigerated.
9. After gelling, the cubes can be removed from the tray using a plastic knife or similar utensil. Store in plastic bag and refrigerate if you plan to keep more them more than 1-2 days.

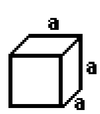
Teacher Notes:

Substances are moving in and out of the cell continuously. For the cell to thrive, these materials must be able to move back and forth quickly and efficiently. While the cell membrane provides an important barrier that can regulate which materials move in and out, the process of simple diffusion is also super important. In this case, substances move naturally from where they are more concentrated to where they are less concentrated. Water, carbon dioxide, and oxygen, are three small molecules that move by diffusion into the cell. So, in a very real sense, cells breathe when oxygen and carbon dioxide move into and out of the cell.

One factor that impacts the speed (rate) of diffusion is the size of the cell. The large the cell, the lower the rate of diffusion. As a cell grows, it becomes more and more difficult for key substances like oxygen and carbon dioxide to get into and out of cell. The bigger the cell, the more difficult it becomes for it to breathe effectively.

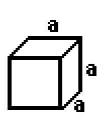
For more advanced students, you can discuss the mathematics that can explain this phenomenon in more detail. The specific rate of diffusion for a cell depends on the surface area of the cell compared to the volume of the cell. The surface area of the cell represents the space where diffusion can occur since it serves the boundary between the inside and the outside of the cell. The surface area of a cube is the area of the six squares that cover it. The area of one of them is a x a or a^2 and, since these are all the same, the area of a cube is 6 times the area of one surface. Area is measured in square units like cm^2.

Surface area of a cube = $6a^2$



The volume of the cell represents the space that must receive needed substances and remove the unneeded substances. If the cell doesn't receive and remove needed and unneeded materials at a fast enough rate, it will quickly die. The volume of a cube is equal to a x a x a (side x side x side). Volume is measured in cubic units like cm^3.

Volume of a cube = a^3



Cells are limited in size because the outside (the plasma membrane) must transport oxygen and carbon dioxide into and out of the cell. As a cell gets bigger, the outside (surface area) is unable to keep up with the inside (volume), because the 3-D inside grows at a faster rate than the 2-D outside. Diffusion works faster over short distances and takes longer over long distances. So if a cell grows larger instead of dividing, diffusion will be too slow and the cell will not be able to obtain oxygen and get rid of wastes efficiently, which ultimately would kill the cell. Thus, cells divide so that an organism as a whole can get bigger despite the fact that cell size is limited. The limitation in cell size can be represented mathematically by calculating the surface area to volume ratio of gelatin “cells” of different sizes. As a cell gets larger, this ratio gets smaller, meaning the cell membrane cannot supply the inside with what it needs to survive.

Sample Data Table (complete)

	Length of Side (cm)	**Surface Area of Cell (cm^2)**	**Volume of Cell (cm^3)**	**Surface Area/Volume Ratio**	**Time required to turn red (feed cell).**
Cell 1	.5	1.5	.125	12	(9-10 min)
Cell 2	1	6	1	6	(25-27 min)
Cell 3 (optional)	1.5	13.5	3.37	4	

Safety Concerns:
Always wear appropriate protective gear while conducing science demonstrations.
Safety goggles should be worn for this experiment
Although the gelatin cubes are considered to be safe to cut and handle, you should never put chemicals (including the cubes) in your mouth, eyes, ear, or nose.
Wash hands after completing this experiment.