Diffusion in Agar Cells

Bigger Isn't Necessarily Better

Introduction

Diffusion and osmosis are among the most commonly studied topics in biology. Virtually all living cells are, to varying degrees, dependent on these processes. This activity will enable students to explore the relationship between diffusion and cell size by experimenting with model "cells."

Concepts

- Cell size
- Diffusion

Materials (for each setup)

Agar powder, 20 g
Phenolphthalein indicator solution, 1%, 10 mL
Sodium hydroxide solution, 0.1 M, NaOH, 200 mL
Water, distilled or deionized, 1 L
Beaker, 400-mL
Heat source
Metric ruler
Plastic knife
Spoon or tongs
Tray for casting gel (see *Preparation* section)

Safety Precautions

Phenolphthalein solution is an alcohol-based solution and is a flammable liquid. Keep from heat and sources of ignition. Sodium hydroxide solutions are corrosive, skin burns are possible, very dangerous to eyes. Wear chemical splash goggles and chemical-resistant gloves and a chemical-resistant apron. Please review current Safety Data Sheets for additional safety, handling and disposal information.

Preparation

1. Mix 20 g of agar with one liter of distilled or deionized water. *Note:* Recipe based on 15 groups of students working in pairs.
2. Heat almost to a boil. Stir frequently until solution is clear.
3. Remove from heat. As the agar mixture cools add 10 mL of 1% phenolphthalein solution (1 g phenolphthalein in 100 mL 95% ethyl alcohol) and stir. *Note:* If the mixture is pink, add a few drops of dilute hydrochloric acid until the pink color disappears.
4. Pour agar into a shallow tray to a depth of 3 cm and allow it to set (overnight). A tray measuring 12 cm × 25 cm that is at least 3 cm deep will accommodate one liter of agar mixture. Volume adjustments may be necessary depending on the tray used.
5. Cut the agar into 3 cm × 3 cm × 5 cm blocks, one per lab group.

Procedure

1. Each group will cut three agar cubes: 3-cm cube, 2-cm cube and 1-cm cube. Cut as accurately as possible.
2. Pour 200 mL of 0.1 M sodium hydroxide solution into the 400-mL beaker. Note the time and immerse the three blocks in the sodium hydroxide solution. Let them soak for 10 minutes with periodic gentle stirring and turning.
3. After 10 minutes, use a spoon or tongs to remove the blocks and blot dry with a paper towel.
4. Promptly cut each block in half and measure the depth to which the pink color has penetrated. Sketch each block's cross section.

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5. Set up and complete the following data table:

Cube	Surface Area (cm^2)	Volume (cm^3)	Surface-to-Volume Ratio	Diffusion Depth (mm)	Diffusion Rate (mm/min)
1-cm					
2-cm					
3-cm					

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Agar blocks can be disposed of in the trash according to Flinn Suggested Disposal Method #26a. The sodium hydroxide solution should be disposed of according to Flinn Suggested Disposal Method #10.

Discussion

The primary objective of this lab is to demonstrate a potential limitation on cell size. Diffusion is a fairly slow process and a cell that relies primarily on diffusion to transport essential molecules into and throughout its interior—and to carry waste products out—could conceivably grow too large for this process to work efficiently.

Have the students fill out the first three columns of the table before running the experiment and use those numbers to predict the outcome. Some will assume that the "cell" with the largest surface area will be the most efficient at moving materials in and out.

When the blocks are cut students will discover that the penetration depths and diffusion rates are equal for all three sizes. What is dramatically different is how much of the interior volume of each cube has been affected. Mathematically inclined students can calculate the percentage of each cell's interior volume that has turned pink. This will give a fairly direct indication of which cell is most likely to "survive."

The key characteristic of the blocks is not total surface area, but their surface-to-volume ratio. The table shows that cube size and surface-to-volume ratio are inversely proportional and that the cube with the highest ratio is the most efficient. One obvious conclusion is that smaller cells are better able to move materials in and out. A cell could eventually reach a size at which materials could not diffuse in fast enough to meet requirements, and waste products could build up to toxic levels.

Two optional activities could easily be added to demonstrate the effect of temperature on diffusion rate, and the effect of concentration on diffusion rate. To study temperature effects, assign a few of the lab groups to heat or chill their sodium hydroxide solution 10 degrees above or below room temperature prior to immersing their agar cubes. To study concentration effects, assign a few lab groups to use a 1.0 M or 2.0 M sodium hydroxide solution.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-LS1 From Molecules to Organisms: Structures and Processes
LS1.A: Structure and Function

Disciplinary Core Ideas: High School
HS-LS1 From Molecules to Organisms: Structures and Processes
LS1.A: Structure and Function

Science and Engineering Practices
Asking questions and defining problems
Planning and carrying out investigations
Constructing explanations and designing solutions

Crosscutting Concepts
Scale, proportion, and quantity
Structure and function

Materials for *Diffusion in Agar Cells* are available from Flinn Scientific, Inc.

Catalog No.	Description
A0012	Agar Powder, 100 g
A0013	Agar Powder, 500 g
P0020	Phenolphthalein Indicator Solution, 1%, 500 mL
S0074	Sodium Hydroxide, Pellets, 100 g
S0149	Sodium Hydroxide Solution, 0.1 M, 500 mL
FB1638	Cell Size and Diffusion Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.