The GEL BEAD Process: A Journey to *Jell-O Land*

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Introduction

Almost everyone knows the recipe to make Jell-O….a little powder in a lot of hot water, put the solution (yes, this IS a solution) in the fridge and a couple of hours later…voila…J-E-L-L-O! But what if you wanted to make a gel instantly? And what if you wanted to make a whole bunch of very small gel beads? How would you do it? And while we're at it, how did they make all those little beads in the silly ORBITZ DRINK they used to sell years ago?
And what is the connection between the ORBITZ DRINK and an artificial pancreas, that I heard Dr. Skip talking about?

Well, look no further ….just keep on reading and you'll learn all about your answers to these important questions….and have a FUN and EDUCATINAL time for kids from 5 to 80 yrs old. Guaranteed…or I'll eat my gel beads!
NOTE: And especially for our K-12 TEACHERS, we tie this learning activity to the *Science Benchmarks* to hopefully make it useful for your classroom use☺

GEL BEAD PROCESS

Overview

This activity introduces students to the concept of *polymers* and *gels*. Then it will provide students an understanding of how the *pancreas* works, and why it is important in the prevention of diseases such as diabetes. They will learn about how an engineer might go about creating an *artificial pancreas*, and how the pancreas is similar in ways to the ORBITZ drink.

Grade Level

K-12 (see end of document for benchmarks)

Activity Time

One hour for reading and discussion, and twenty minutes for laboratory activity.

Introduction to polymers and gels

A **polymer** is a long chain of repeating molecules. Think of a polymer like a long chain of paper clips. In this activity our polymer is called Sodium-Alginate and it is derived from algae. There are many common polymers derived from algae, such a carrageen, xanthan gum, and gelann gum. These are common in many foods.

A **gel** is when the polymers get crosslinked. Imagine if you took your paper clip chains and tied them together with wire. They make something like a mesh. A gel has qualities of both solid and a liquid. Jell-O is one gel with. which you are probably familiar, heat cross-links the polymer gelatin. Sodium Alginate is a chemically cross links the polymer. Calcium is the chemical that cross links Sodium Alginate to for the gel (see figure 1).

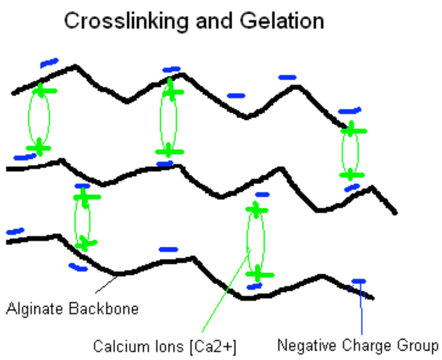

Figure 1. The process of turning a Sodium Alginate Solution into a Gel

ACTIVITY – Making Gel Beads

Making gel beads is a very simple process. It is as easy as dropping a 2 wt% Sodium Alginate (food grade product) solution into a 1 wt% Calcium Chloride solution. Beads are formed because drops are round and crosslinking (gelling – similar to making Jell-O) begins once the Sodium Alginate hits the Calcium Chloride solution.

Materials

The following is a list of required and suggested materials to make gel beads with a class of 30 students. Contact Dr. Skip Rochefort (skip.rochefort@oregonstate.edu) for supplies.

Expendable Materials	Reusable Materials
20g Sodium Alginate Powder	Blender or Electric Mixer
20 g. Calcium Chloride Powder	Balance
Water	2 x 2-liter bottles (soda bottles work well)
Food coloring (optional)	30 small cups
Zip-top baggies (optional)	12 small jars or cups
	Small droppers – disposable pasture pipettes work well
	Small strainers (optional)

Methods

To prepare for this activity, make all the solutions prior to the class period.

Sodium Alginate Solution

A 2wt% solution of sodium alginate is needed for this experiment. Weight percent (wt%) means that for every specific weight of water there is in a solution there is a specific weight of chemical. This sounds confusing but it's really not. To make a 2 wt% solution of Sodium Alginate we would need 2 grams of sodium alginate powder for every 100 grams of water (which is almost the same as 100 ml of water because the density of water is approximately 1.0 g/ml at room temperature). Therefore, 20 grams of sodium alginate are added to one liter of water. One liter of 2wt% sodium alginate solution should make more than enough gel beads for a class of 30 students.

NOTE: Sodium Alginate tends to form gel-like particles with gentle stirring in water, with the outside of the particles "gooey" and the inside still powder. The easiest way to make a nice solution is to put it into a kitchen blender and give it a good whirl. Once you no longer see any globs of powder you are done. The sodium lginate solution should have the thickness of a shake (because that's how they make shakes at McDonald's and Burger King, folks!), and be nice and smooth (no lumps). Store the 2 wt% sodium alginate solution in a one or two liter bottle in the fridge until ready for use. To make the gel beads easier to see, and more interesting for the kids (and adults), food coloring may be added. Put the Alginate solution into small jars or lidded containers (baby food jars work great) and add a few drops of food coloring and mix. If no small jars are available it would work to mix the color in once you have poured the alginate into the cups for use.
NOTE: The Sodium Alginate used is a food grade product, so "accidental ingestion" is not a problem.

Calcium Chloride Solution
A 1 wt% solution of calcium chloride ($CaCl_2$) is need for this experiment. Calcium Chloride can be obtained from any chemical supply house or any other source. 2 liters of calcium chloride are recommended for 30 students. This means 20g of calcium chloride powder are needed (NOTE: Other divalent salts may also be used,but $CaCl_2$ is best). Fill a two-liter bottle with water and add the 20g of calcium chloride. Cap the bottle and mix until all powder goes into solution. This is stable and does not need to be refrigerated.

Making Gel Beads
Pour the 2 wt% sodium alginate solution into small cups and add food coloring (if not already done) or open the small jar (or containers). Put a few pipettes into each container of 2wt% sodium alginate. Set-up one container of each color 2 wt% sodium alginate solution per group of students. Each student should have a small cup of calcium chloride (approximately ½ inch of liquid in the container). Students can use the pipettes to drop the 2wt% sodium alginate solution into the 1wt% calcium chloride to make gel beads. (NOTE: Students quickly learn that "other forms" can also be made…snakes, tadpoles, kidney beans, silly string, etc. but altering the "squirting process"!). If the students are not familiar with how to use the pipettes, a quick demonstration can be very useful.

The beads will quickly form a gel on the outside and remain liquid in the middle. After students have made a few beads have them reach into the cup and pick out a bead and squeeze it to observe what happens (be careful…they squirt). The students should observe that a "shell" has formed. Wait a few minutes and try this again. The shell gets bigger until the entire bead is a gel. This happens because the calcium ions diffuse from the outside of the bead towards the middle, gelling the outside first and then the inside. After approximately 5 minutes the bead will be completely gelled, such that they can be bounced like little balls. Be careful…..this activity often leads to "lots of fun" for the students! REMINDER: The sodium alginate is a food grade products, so nothing will happen if ingested….but this is not encouraged or recommended.

"Harvesting" the Gel Beads
Once the activity is over the students can take their gel beads (and whatever else they have made) home. They can either use their fingers to strain the beads or small kitchen strainers work well if "harvesting" large quantities of beads. These can be stored in a small plastic bag or any other container. They should not be stored in water or the calcium chloride solution with water because the food coloring will leach out of the beads, rendering them all "white" and the solution

an ugly brown color. The beads, like any food product, keep well in the fridge or in a cool dry place.

Clean-up and Storage

Clean-up is easy. The calcium chloride can be store indefinitely or poured down the drain (it is a salt). The sodium alginate will keep for several weeks in the refrigerator or it can be poured down this drain as well.

To obtain HANDOUTS for the GEL BEAD and ARTIFICIAL PANCREAS activity, visit Dr. Skip's web site, listed below, and look in the folder titled MOMENTUM. http://che.oregonstate.edu/~rochefsk

For more information on this activity or to ask QUESTIONS contact:
***Dr. Skip Rochefort*, Chemical Engineering Department, Oregon State University**
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GEL BEADS – Many uses from silly drinks to bioreactors

Gel beads are fun to make and play with but they also serve useful purposes. They were once popular in a drink called ORBITZ (sales discontinued in 1996, although you can still buy some bottles on EBay). They are now being used to encapsulate cells in the development of an artificial pancreas to help people with diabetes and for the production of high value pharmaceuticals in bioreactors.

Background – The Pancreas

The Role of the Pancreas

The pancreas is located between the stomach and small intestine. Figure 2 shows an illustration of a pancreas.

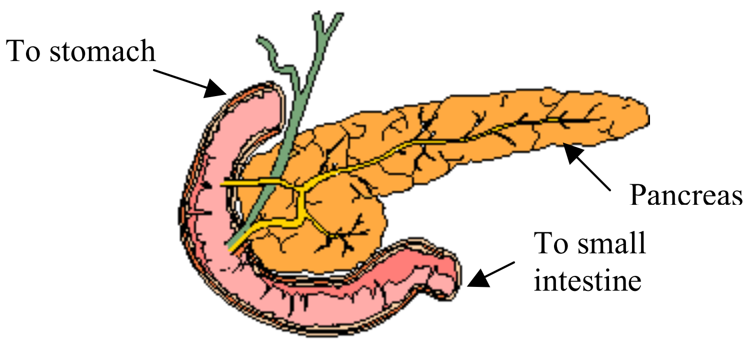

Figure 2: Diagram of the Pancreas (Norman, 2002)

The pancreas serves two main purposes. One of the major responsibilities of the pancreas is to secrete digestive enzymes into the small intestine, which help break down food that has been eaten. The role of the pancreas that will be focused on in this activity is the production of the hormones glucagon and insulin.

Inside of the pancreas, there are hundreds of thousands of cell clusters called *Islets of Langerhans*. One particularly important function of the *Islets of Langerhans* is the production of hormones **glucagon** and **insulin**. These hormones enter the bloodstream and balance the body's glucose (sugar) level. Cells in the body burn glucose to produce energy. When there are high levels of glucose in the blood the pancreas releases insulin, which allows glucose to be stored in the liver. When there are low levels of glucose in the blood the pancreas releases glucagon, which causes the liver to release glucose into the blood.

Diabetes

When the pancreas does not produce enough insulin, the amount of glucose in the blood becomes too high. This is one cause of diabetes (specifically it is the cause of Type 1 diabetes), which is a disorder in which the level of glucose in the blood is consistently high. In the United States, nearly six percent of the population has diabetes, and it is the seventh leading cause of all deaths Diabetes may cause blindness, kidney failure, and heart disease . Individuals with Type 1 diabetes must use a meter several times a day to check how much glucose is in a drop of blood that is usually obtained by pricking a finger. In order to keep a safe level of glucose in their blood, a person with diabetes must inject insulin two to four times a day to make up for the insulin that their body does not produce (reference Microsoft, n.d.).

Introduction to the Orbitz Drink

How Does This Relate to the Orbitz Drink?

The Orbitz drink is a type of clear soda pop that contains colored gel beads floating in it. Figure 3 shows a picture of the Orbitz drink.

Figure3: Orbitz Drink (BevNET, 1998)

The clear liquid in the drink is made up of water, sugar, and xanthan gum, while the gel beads are made of gellan gum (Rochefort, 2002). Xanthan gum and gellan gum are polymers. Xanthan gum and Gellan Gum are combined with water and sugar in the liquid of the Orbitz drink, and act synergistically to produce a weakly crosslinked network of polymer molecules, which if magnified would look like a "spider web" in the. This spider web acts as a net to hold up the spheres of gellan gum, and so the gel beads stay suspended. If the drink is shaken, the weak network is broken and the gel beads are free to move slowly around, until the "spider web" network reforms and traps them once again.

The Orbitz is similar to the pancreas, in that it is made up of a glass container with clear fluid inside that contains gel beads, where a pancreas is basically a sack that contains Islets of Langerhans. One main difference is that the pancreas sack is semi-permeable (species can go in and out across the sack), while of course a glass bottle does not allow this.
This is illustrated in Figure 4.

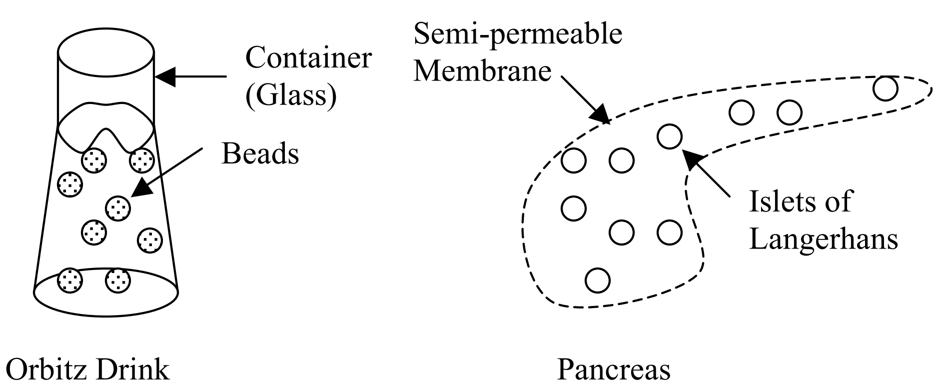

Figure 4: How the Orbitz Drink and the Pancreas are Similar

The pancreas container is called a semi-permeable membrane in Figure 4, because it lets insulin out when it senses high amounts of glucose, but does not let out the *Islets of Langerhans*. When something allows one species to pass through it, but not another, it is called a *semi-permeable membrane*.

Further Discussion

The gel beads that are formed by dripping sodium alginate and water into calcium chloride are held together by cross-linking. If *Islet of Langerhans* cells are added to the mixture of water and sodium alginate, then when it is dripped into calcium chloride, gel beads will form that have *Islets of Langerhans* cells trapped inside. The cross-linking in these gel beads looks something like a fishnet, and this fishnet is what traps the large *Islets of Langerhans* inside, while the glucagon and insulin produced are free to leave the beads. A close up view of one of these gel beads might look something like Figure 5.

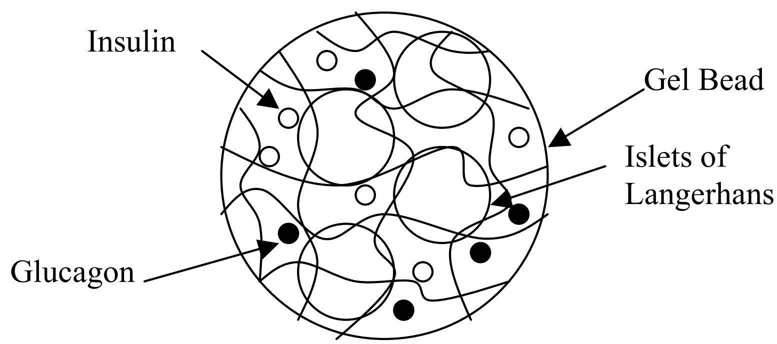

Figure 5: Close up of a Gel Bead

It would be desirable to make these gel beads so that their diameter was only a few micrometers. There are 1 million micrometers in a meter, and so that means that the beads would be very small. To illustrate how small a micrometer is, the thickness of a pencil is a little under 0.01 meters, or 10,000 micrometers. It is necessary to make the gel beads small so that many of them can fit into a small semi-permeable membrane, and thus the necessary amounts of glucagon and insulin can be produced.

One type of ***semi-permeable membrane*** that is popular with people who enjoy outdoor activities is Gore-Tex. Gore-Tex is a material that is in many hiking boots, rain jackets, and other clothing. It is designed so that water from the outside will not be absorbed and get the person wearing the clothing wet, but at the same time, it allows moisture from the person to escape through the clothing to the outside. This keeps the person dry and warm. Since Gore-Tex is popular and easy to get, it might be used as the semi-permeable membrane for the artificial pancreas.

Now the gel beads containing the *Islets of Langerhans* could be placed inside a Gore-Tex bag, which could then be sewn up to make an artificial pancreas. From this discussion, it can be seen how important it is when engineers solve a problem that they understand the purpose and function of whatever it is they are designing. In the case of the pancreas, it was important to understand that it produces glucagon and insulin, and that this glucagon and insulin are important to prevent diseases such as diabetes. Next, it can be helpful for engineers to simplify the object they are designing and relate it to something that they are already familiar with. For the artificial pancreas, it was useful to relate it to the Orbitz drink. Later, it is necessary for engineers to brainstorm what materials they might need to use for different parts of their design, and how easy these materials are to find, or how they might be produced in a simple manner. The materials considered for the artificial pancreas were gel beads and Gore-Tex. Gore-Tex is easy to get, but for the gel beads, it was necessary to think of how they might be made. Later on, there would probably be tests that the engineers would have to do on the artificial pancreas, in order to make sure that it works correctly, and is safe for patients (biocompatible). As can be seen from this discussion, there are many things for engineers to consider when trying to solve a problem, such as the ***design of an artificial pancrea***s.

BENCHMARKS

Science:

Level I (Grade K-2):

Standard 8: Understands the structure and properties of matter.

Benchmark 1: Knows that different objects are made of many different types of materials (e.g., cloth, paper, wood, metal) and have many different observable properties (e.g., color, size, shape, weight).

Level II (Grade 3-5):

Standard 8: Understands the structure and properties of matter.

Benchmark 4: Knows that materials may be composed of parts that are too small to be seen without magnification.

Level III (Grade 6-8):

Standard 5: Understands the structure and function of cells and organisms.

Benchmark 4: Knows that multicellular organisms have a variety of specialized cells, tissues, organs, and organ systems that perform specialized functions for survival (e.g., digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, protection from disease).

Benchmark 8: Knows that disease in organisms can be caused by intrinsic failures of the system or infection by other organisms.

Standard 8: Understands the structure and properties of matter.

Benchmark 8: Knows that substances react in characteristic ways with other substances to form new substances (compounds) with different characteristic properties.

Level IV (Grade 9-12):

Standard 8: Understands the structure and properties of matter.

Benchmark 5: Knows that the physical properties of a compound are determined by its molecular structure (e.g., constituent atoms, distances and angles between them).

Standard 13: Understands the scientific enterprise.

Benchmark 6: Knows that creativity, imagination, and a good knowledge base are all required in the work of science and engineering.