Insulin & Diabetes

Avika Bansal
Carnegie Mellon University
Department of Biomedical Engineering

Background & Project Description

Diabetes is a highly prevalent disease that affects people of all ages in the United States. According to the Centers for Disease Control and Prevention, diabetes was the seventh leading cause of death in the United States in 2017. In 2018, around 10.5% of the US population had diabetes, which translates to about 34.2 million people of all ages. Out of this, around 34.1 million adults were aged 18 years or older. [5] Seeing that such a large percentage of adults around the age of 18 are affected, it is important to educate students and raise awareness regarding insulin, diabetes, and how the two are correlated.

Insulin is a peptide hormone composed of 51 amino acids produced by the beta cells in the pancreas, in order to regulate blood glucose levels and maintain homeostasis in the human body. Insulin was discovered in 1910 by Sir Edward Albert Sharpey-Shafer, extracted from the pancreas of a dog in 1921 by Frederick Banting, and first successfully administered to a 14 year old boy in 1922. Following this, companies like Eli Lilly began developing commercial insulin to put on the market. In the following years, many more properties and methodologies to analyze and administer insulin were discovered! [11]

This activity is intended to expose high school students who have taken at least general biology and general chemistry to the mechanisms of drug delivery, specifically insulin, for those affected by diabetes. The lesson can also be modified to fit course rigor and curriculum for AP Biology, Anatomy, and health classes. Students are expected to already know concepts such as diffusion, and the functions of different parts of the body such as the pancreas, circulatory system, and digestive system. The teachers will walk students through a PowerPoint presentation highlighting the background of diabetes, insulin, and different diabetes treatments. This lecture focuses more on insulin, including the history of how it was discovered and tested, and how the human body reacts to insulin under different situations. An important concept to reinforce to the students is that an oral administration (pill/capsule) of insulin is not effective enough for market distribution at the moment. Therefore, the purpose of the “Build Your Own Insulin Capsule” activity is for them to design their own capsule that fits a certain set of properties. They will also be provided with materials such as bath bombs, tissue paper, food coloring, plastic zipper bags, water etc. to build these capsules. Students will be able to apply concepts from the lecture during a hands-on engineering activity.

Objectives

- Demonstrate the mechanism of drug delivery in terms of insulin for diabetes treatment.
- Describe the science behind diabetes.
- Describe various insulin treatments and show how sustained versus immediate insulin reacts in the body.
- Students will apply engineering and problem solving skills to create their own slow or fast release “insulin capsules”

Materials

Materials required for lesson:

- “Insulin & Diabetes” PowerPoint Presentation
- Build Your Own “Insulin Capsule” Worksheet
- Computer and projector
- Classroom with lab capacity

Materials needed to make your own bath bombs:
(Total Time: 15 minutes to assemble, plus overnight for drying time)

- Baking soda
- Citric acid
- Food coloring (optional)
- Water
- Measuring cup, bowl, and whisk
- Mini muffin pan
- Wax paper

Recipe sourced from:
https://somethingturquoise.com/2013/07/12/diy-bath-bomb-favors/
https://www.popsci.com/how-to-make-your-own-bath-bombs/

Materials recommended to make “capsule”:

- Bath bombs
- Water
- Tissue paper
- Zipper storage bags
- Any other interesting and common household items that the teacher or student sees fit!

To Make Bath Bombs:

For this recipe, use 2 parts of baking soda to 1 part of citric acid. For example, 1 cup of baking soda to ½ cup of citric acid makes around 12 mini muffin bombs, while 2 pounds of baking soda to 1 pound of citric acid make around 48 bath bombs (total cost: $0.25 per bath bomb). In this demo, 1 cup of baking soda to ½ cup of citric acid, and ¾ tablespoons of water were used. Please adjust portions of the 3 ingredients to fit the number of bath bombs needed.

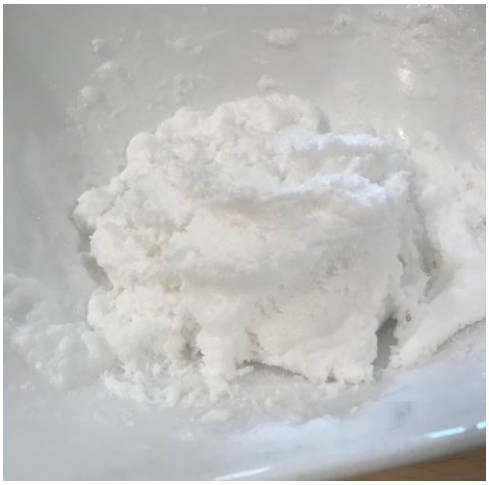
1. Gather all materials. You may want to use a silicon ice cube mold in place of the muffin pan.

2. Measure 1 cup of baking soda and pour it into a large bowl.

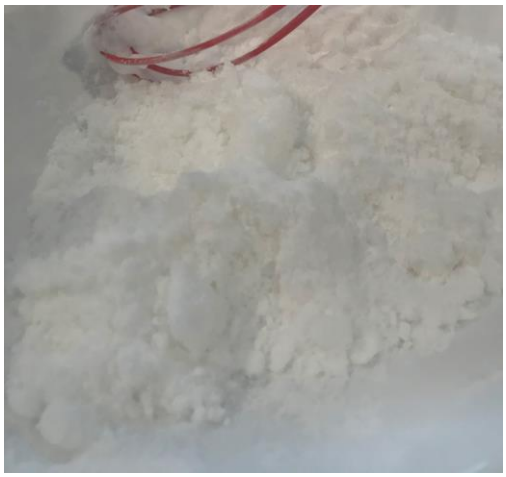
3. Measure ½ cup of citric acid and pour it into the same bowl as the baking soda.

4. Thoroughly mix the baking soda and citric acid with a whisk, making sure there are no lumps.

5. Measure 1 tablespoon of water. Do not use it all! Slowly pour in very tiny amounts of water. You will notice that the citric acid will start to bubble up. If you have a spray bottle, it would be helpful to use that instead. You should end with a mixture that resembles damp sand, and barely clumps together. Below are examples of a mixture when too much water is added. It looks and feels like wet sand, and if left alone for a few minutes, will bubble up a lot. This is the citric acid being activated by the water!!



← We do not want these!! Instead, the mixture should resemble the image at the top of the next page.



← We want this! Feel free to mix with your hands as well.

6. Finally, distribute the mixture into the mini muffin pans, and pack them down as hard as possible. Instead of putting pressure on the wrists, it is easier to use the tablespoon measure to pack them down.

7. Let the pan of bath bombs sit for 10 minutes to dry.

8. Then, flip it onto wax paper or foil and let it dry overnight. Pop them out and voila!
9. Carefully store the bath bombs in sealed container so they don't crumble or excessively dry out.

Final product!

Safety Considerations

It is important to advise students not to ingest any of the residue from the bath bombs, and to keep a clean work space. Due to the fizzy nature of the bath bombs, it could also be an option to have the students wear lab goggles. Please clean hands and work space thoroughly after activity to ensure that baking soda and citric acid components are removed.

Vocabulary

- **Insulin** → a naturally occurring energy storage hormone produced by the pancreas, that helps cells to consume/use the carbs, fats, proteins after eating. [1]
- **Diabetes** → when the amount of glucose in the blood is higher than normal due to the lack of insulin, or insulin resistance, in the human body. [3]
- **Insulin kinetics** → describes the change in levels of insulin in the body during the day. [2]
- **Homeostatic regulation** → describes the regulation of several hormones in the body when blood sugar is high or low. [2]
- **Onset** → length of time before insulin reaches the bloodstream and begins lowering blood sugar. [2]
- **Peak time** → the time during which insulin is at maximum strength in terms of lowering blood sugar. [2]
- **Duration** → how long insulin continues to lower blood glucose. [2]

Lesson Overview & Procedure

1. Make or buy bath bombs
    a. *Please refer to Materials section for how to make bath bombs*
2. Collect appropriate amount of materials for class size
3. Present lecture to students (Note to instructor: please edit lecture details/difficulty as needed pertaining to class level and depth. Information presented is sourced within presentation file)
    a. What is Insulin?
        i. How Insulin interacts with the body
        ii. Insulin kinetics
        iii. Homeostatic regulation of blood glucose
        iv. Insulin Receptor Tyrosine Kinase Interaction
    b. What is Diabetes?
        i. Type 1 vs Type 2
        ii. Existing Diabetes Treatments
        iii. Important Statistics
    c. Insulin Pertaining to Diabetes Treatment
        i. Characteristics of insulin
        ii. Types of Insulin and How they work
        iii. Existing Insulin Delivery Techniques
    d. Introduce Activity!
4. Split students into groups of 2-3, and provide them with materials, and distribute one "Build Your Own Insulin Capsule" worksheet per student
    a. Prior to activity, please feel free to edit the worksheet and add more scenarios as needed. You might see that "Scenario 3" and "Scenario 4" have been left blank.
    b. Explain prompts to students, and instruct them to collect data regarding peak time/onset/duration of the capsules they created
5. Closing remarks- An instructor-led discussion with students at the end of the activity
    a. Questions or thoughts from the class?
    b. What did they think was the hardest part of this activity and why?
    c. Can they recognize why it is so difficult to create an oral (pill/capsule) medication that delivers insulin?
6. *Optional* homework activity
    a. Instruct groups of students to analyze the combinations of materials they used to build each capsule and how that affected their onset/peak time/duration for each pill. Have them write more thorough explanations for how their capsule works, how they would adjust their capsule for a subsequent iteration, and why.

Next Generation Science Standards

1. **HS-PS1-6.** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*
2. **HS-ESS3-2.** Evaluate competing design solutions for **developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.***
3. **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
4. **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
5. **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Author

This educational resource was developed as a project by Carnegie Mellon student, Avika Bansal, for the summer 2020 course *Experiential Learning through Projects [99-520]*. All images in this document were developed by Avika Bansal unless otherwise specified. Inspired by Spring 2020 project presented by Donggyun Chris Yang for *BME in Everyday Life* course, taught by Dr. Conrad Zapanta.

References & Additional Resources

1. https://www.verywellhealth.com/how-insulin-works-in-the-body-1087716
    a. Detailed overview of insulin (what is insulin, how does it interact in body etc)
2. https://www.diabetes.org/diabetes/medication-management/insulin-other-injectables/insulin-basics
    a. Insulin basics (defines different types of insulin)
3. https://www.niddk.nih.gov/health-information/diabetes/overview/what-is-diabetes
    a. Detailed overview of diabetes (type 1, type 2, treatments etc)
4. https://www.niddk.nih.gov/health-information/diabetes/overview/insulin-medicines-treatments
    a. Detailed overview of of diabetes treatments, including the different types of insulin
5. https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf
    a. CDC 2020 Diabetes report
6. https://www.diabetes.org/diabetes/medication-management/oral-medication
    a. How oral medication for diabetes works.
7. https://www.diabetes.co.uk/body/glycogen.html
    a. Describe the relationship between glucose, glycogen, and glucagon.
8. https://en.wikipedia.org/wiki/Blood_sugar_level
    a. Describes the process of insulin kinetics.
9. https://www.dietdoctor.com/a-new-paradigm-of-insulin-resistance
    a. Image regarding Insulin receptor tyrosine kinase interaction
10. https://www.healthline.com/health/diabetes/medications-list#takeaway
    a. Lists common diabetes medications as well as treatment options
11. https://www.diabetes.org/blog/history-wonderful-thing-we-call-insulin
    a. History of insulin