Carnegie Mellon University Biomedical Engineering + Leonard Gelfand Center

Insulin & Diabetes

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This educational resource for high school audiences was developed as a project by Carnegie Mellon student, Avika Bansal, for the course *Experiential Learning through Projects*, Section O, taught by Dr. Conrad Zapanta and Dr. Judith Hallinen during the summer of 2020.

<u>CAUTION</u>: If you are attempting an experiment, it is important to make sure that you are following all safety steps. All experiments should be completed with supervision of a adult. Weather permitting, we recommend taking messy experiments outside. Remember to wear safety gear like gloves, aprons, and goggles, especially for experiments with chemical reactions!

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Be SAFE and enjoy the modules!

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What is Insulin?

- A naturally occuring energy storage hormone released by the pancreas

 helps cells to consume and use the carbs, fats, proteins after eating
- When food is consumed:
 - Digestive system converts carbohydrates into glucose molecules which are released into the bloodstream
 - More glucose in blood = higher blood sugar levels = pancreas secretes insulin to return blood glucose levels to homeostasis

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More About Insulin...

- If there is a lack of insulin in the blood or if cells are not using insulin properly, glucose levels remain high!
- This is also called insulin resistance:
 - Misshapen insulin cannot bind to cell receptors
 - Cells do not have enough insulin receptors
- Effects of insulin malfunctioning
 - o Hypoglycemia
 - Long term complications kidney, eye, nerve, heart damage

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Insulin **Kinetics**



Credit for this image to Dr. Steven Chase of the Biomedical Engineering Department at Carnegie Mellon University. Also found on https://en.wikipedia.org/wiki/Blood sugar level

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Homeostatic Regulation of Blood Glucose



Credit for this image to Dr. Steven Chase of the Biomedical Engineering Department at Carnegie Mellon University

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Homeostatic **Regulation of** Blood Glucose

Stimulates glucose uptake Effector by cells Insulin **Tissue cells** Stimulates er glycogen formation Pancreas Glycogen Glucose Blood eptor glucose falls to normal Liver range Stimulus: Imbalance **Rising blood** alucose level Homeostasis: Normal blood glucose level (about 90 mg/100 ml) Imbalance Stimulus: Declining blood alucose level Blood alucose rises to normal range Pancreas Stimulates Glycogen Carnegie Mellon glycogen breakdown Glucagon Liver University

Credit for this image to Niroshini Nirmalan through the Anaesthesia & Intensive Care Medicine Journal.

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Insulin Receptor Tyrosine Kinase Interaction



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insulin-resistance

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What is Diabetes?

When body blood sugar levels are too high OR Blood glucose levels are higher than normal due to improper use by cells

Type 1

- Genetic (diagnosed in young children and adults)
- Body is not able to produce its own insulin
- Beta cells in pancreas that produce insulin are attacked by immune system
- Daily insulin supplements to digest glucose from meals

Type 2

- A developed condition over time
- The body is less able to develop insulin
- Some causes:
 - Age 45+
 - Family history of diabetes
 - Lack of physical activity

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Existing Diabetes Treatments

Other than insulin, there are a few ways to manage diabetes:

- 1. Bariatric surgery
- 2. Artificial pancreas
- 3. Pancreatic islet transplantation

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In 2017, diabetes was the 7th leading cause of death in the US

Figure 3. Age-adjusted, county-level prevalence of diagnosed diabetes among adults aged 20 years or older, United States, 2004, 2008, and 2016



Note: Data were unavailable for some US territories.

Data sources: US Diabetes Surveillance System; Behavioral Risk Factor Surveillance System.

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Diabetes in the US

According to the CDC, in 2018...

- An estimated 34.2 million people of all ages—or 10.5% of the US population—had diabetes
- 34.1 million adults aged 18 years or older or 13.0% of all US adults—had diabetes

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Characteristics of Insulin

- Onset → length of time before insulin reaches the bloodstream and begins lowering blood sugar
- Peak time → the time during which insulin is at maximum strength in terms of lowering blood sugar
- Duration → how long insulin continues to lower blood glucose

Types of Insulin and How They Work

| Insulin type | How fast it starts to work (onset) | When it peaks | How long it lasts (duration) |
|-----------------------------------|------------------------------------|------------------|---------------------------------|
| Rapid-acting | About 15 minutes after injection | 1 hour | 2 to 4 hours |
| Short-acting, also called regular | Within 30 minutes after injection | 2 to 3 hours | 3 to 6 hours |
| Intermediate-acting | 2 to 4 hours after injection | 4 to 12 hours | 12 to 18 hours |
| Long-acting | Several hours after injection | Does not peak | 24 hours; some last longer |

Source: Insulin basics. American Diabetes Association website. C Last edited 2015. Accessed August 25, 2016.

Existing Insulin Delivery Techniques

- Needle and Syringe
- Pen
- Pump
- Inhaler
- Injection port
- Jet Injector
- **Oral medication

NOW...

Build Your Own Insulin Capsule!!!

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Build Your Own Insulin Capsule!!!

Instructions:

Using your knowledge about the different types of insulin, create different types of capsules

- Draw a sketch of your capsule
- Explain how it works
- Test your capsule
- Record the onset, duration, and peak time of your capsules
- Explain how you would improve your capsule and why?

Materials:

× Bath bombs, water, tissue paper, zipper storage bags

& anything else you can find!

Activity Scenario Examples:

Create a rapid acting capsule with an onset of 15 seconds and a duration of 3 minutes
 Create an intermediate acting capsule with an onset of 3 minutes and duration of 3 minutes
 Other scenarios as determined by the instructor or students

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Insulin and Diabetes

- Questions?
- Hardest part of activity?
- Interesting discoveries?

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