Carbohydrates

Carbohydrates are one of the four major biomolecules/macromolecules/organic molecules (3 popular names all mean the same thing).

- The four major biomolecules include carbohydrates, lipids, proteins, and nucleic acids. This page of notes is just focusing on carbohydrates.
- Carbohydrates always contain carbon, hydrogen, and oxygen, and usually there are twice as many hydrogens as oxygens.
- Polysaccharides "many sugars" are built from monosaccharides "one sugar".

Monomers, or building blocks, of large carbohydrate molecules:

- monosaccharide simple sugar carbohydrates, most notably glucose
- In the watery environment of the body, sugars form into ring structures.
- Simple sugars usually have the formula $C_6H_{12}0_6$. 6 carbons, 12 H's, and 6 oxygens.
- Dextrose is the term used for glucose in the purified form administered in IVs or other medical settings.
- The two other main 6 carbon monosaccharides are fructose and galactose.
- Ribose and deoxyribose are the 5 carbon sugars in the sugar-phosphate backbone nucleic acids, but they are rarely discussed when talking about carbohydrate roles in the body.

Disaccharides

- two simple sugar monosaccharides put together, usually making the formula $C_{12}H_{22}O_{11}$. The pattern of 2:1 Hydrogen to Oxygen is typical.
- Sucrose (table sugar) is formed by linking one glucose to one fructose. Lactose (milk sugar), and maltose are the two other well-known disaccharides.

Polysaccharides

- Very large biomolecules that are built with many many simple sugars.
- Plant starch
    - Starch is digestible by us using the enzyme amylase, which is made by our pancreas and our salivary glands.
        - Amylase breaks down complex carbohydrates such as starch into many many individual molecules of glucose. This occurs in the intestine, and then these glucose molecules are absorbed into the bloodstream.
    - Potatoes and grains are well-known examples of starches.

Animal Glycogen

- Animals store their carbohydrates as long branching chains called glycogen.
- We can store limited quantities of glycogen in our liver and our muscle cells.
    - Liver and skeletal muscle are the primary "sinks" to store glycogen. The fitter you are, the more you can store in your skeletal muscles.

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Plant cellulose

- highly structured polysaccharide that makes up all plant cell walls.
- Completely indigestible for us as humans.
    - Cellulose provides us with insoluble dietary fiber.
    - Other indigestible fiber carbohydrate parts of a plant that are more soluble in water include pectin and the gums of certain plants; these we would call soluble fiber.
- Only animals that contain certain kinds of stomachs and bacterial populations are able to extract any calories from cellulose; we call these types of animals herbivores.

Peptidoglycan

- combination of carbohydrate and proteins - makes up bacterial cell walls.
- Protein cross-links hold together many layers of simple sugars.
- Gram negative bacteria have relatively thin peptidoglycan layers, and stain pink
- Gram positive bacteria stain purple because of their thick peptidoglycan layers.

Blood glucose or blood sugar.

- The ideal range in the blood remains quite steady, even between meals. As people lose metabolic flexibility or become pre-diabetic, they may vary more and more widely from the ideal range of between 70 - 120mg/dL.
    - Above 125mg/dL fasting levels is diagnostic for type II diabetes
    - A random blood sugar at any time over 200mg/dL is diagnostic for type II diabetes
- Hyperglycemia literally means too much sugar in the blood. It is most commonly seen when people damage their metabolism and begin to develop Type II diabetes.
- Hypoglycemia is the opposite problem, not enough sugar in the blood. It is most commonly seen in diabetics that inject more insulin than they needed.
- Normoglycemia means normal amounts of sugar in the blood.

Insulin's role in glucose entry to cells

- The protein hormone insulin binds to insulin receptors on cells.
    - Insulin binding stimulates glucose channels to be inserted into the cell membrane
    - polar glucose molecules can then passively enter the cells through these glucose channels, moving down their concentration gradient.
- Insulin allows glucose to enter cells. Thus, insulin decreases blood sugar.

Glucose as Fuel

- Once inside the cell, glucose is broken down in the cytoplasm in the process of **glycolysis**, into 2 3-carbon molecules called pyruvate.
- Pyruvate enters the mitochondria, where complete breakdown of the carbon molecules is finished with many enzymatic reactions of the Citric Acid Cycle.
- The electron transport chain, on this inner mitochondrial membrane, then generates ATP energy for cellular activities.
- Glucose is a key source of ATP production for many cells.

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Glycoproteins

- part protein, and part sugar.
- They serve to identify a cell as part of you, or not!
    - Think of them as ID tags.
- An antigen is the name we give to glycoproteins that provoke an immune response.
    - The spike protein of Sars-CoV-2 is a glycoprotein, for example.

    - If our antibodies respond to antigens on our body cells, that is what we call an autoimmune reaction.

The liver monitors blood glucose levels in the blood

- glucose is absorbed from the intestine, and immediately enters the liver through the hepatic portal vein.
- The liver allows just the right amount (ideally about 100mg/dL) to exit the liver and return to the circulation through the hepatic vein.
- The liver modifies carbohydrates by storing or releasing glucose in order to keep blood sugar steady.
    - If excess glucose was in the meal, then the liver stores the excess glucose as glycogen in a process that is called **glycogenesis**.
    - Once the glycogen stores are maxed out, the liver must store additional excess glucose and all excess fructose as triglycerides; we call this **lipogenesis**.
        - Once the liver stores too much fat, inflammation can begin in the liver, leading to **non-alcoholic fatty liver disease (NAFLD)**, a disease that was virtually unheard of 50 years ago but has become very common.
    - In between meals, glycogen stores can be broken down via **glycogenolysis**, releasing glucose into the blood so hypoglycemia doesn't occur.
    - Given enough hours between meals, the liver can also start breaking down triglycerides by performing **lipolysis**.
    - The liver is even capable of building new glucose molecules from amino acids in a process called **gluconeogenesis**.