Carbohydrates

AICE Biology
Jones & Fosbery Chapter 2

Carbohydrates

- Carbohydrates are composed of C, H, O
  \[ \text{carbo - hyd - ate} \]
  \[ \text{CH}_2\text{O} \rightarrow \text{C}_n\text{H}_m\text{O}_q \]

- Function:
  - fast energy
  - energy storage
  - raw materials
  - structural materials

- Monomer: sugars
- ex: sugars, starches, cellulose

Simple & complex sugars

- Monosaccharides
  - simple 1 monomer sugars
  - glucose
- Disaccharides
  - 2 monomers
  - sucrose
- Polysaccharides
  - large polymers
  - starch

Sugars

- Most names for sugars end in -ose
- Classified by number of carbons
  - 6C = hexose (glucose)
  - 5C = pentose (ribose)
  - 3C = triose (glyceraldehyde)

- Monosaccharides
  - Single Sugars
  - Dissolve easily in water
  - Sweet taste
  - 3 forms: Sugars all end in “ose”
    - Triose (3C) \( \text{C}_3\text{H}_6\text{O}_3 \)
      - (Glyceraldehyde)
    - Pentose (5 C) \( \text{C}_5\text{H}_{10}\text{O}_5 \)
      - (Ribose, Deoxyribose = components of nucleic acids)
    - Hexose (6 C) \( \text{C}_6\text{H}_{12}\text{O}_6 \)
      - (Glucose, Fructose, Galactose)
Chemical Formulae
- Molecular Formula (empirical formula) ie. \( \text{C}_6\text{H}_{12}\text{O}_6 \)
- Structural Formula
  - Diagram showing the arrangement of atoms.
  - Glucose, fructose & galactose all have the same empirical formula, but have different structural formulae.

Functional groups determine function
- carbonyl
- aldehyde
- ketone

Structural Forms
- Chain Form: Carbon backbone with oxygen & hydrogen forming side bonds.
- Ring Form: In aqueous solution, the molecule closes upon itself to form a more stable ring form.

Sugar structure
5C & 6C sugars form rings in solution

Numbered carbons
energy stored in C-C bonds harvested in cellular respiration
Isomers of Sugars

- **Structural Isomers**: different arrangement of bonds.
  - eg glucose & fructose (See O=C Bonds)
  - Your taste buds can tell the difference fructose much sweeter
  - Form different polymers (repeating subunits)

- **Stereoisomers**: Same bond structure but different orientations of molecule groups.
  - eg. Glucose & galactose: Hydroxyl groups are mirror images of one another
  - α glucose (OH below the plane)
  - β glucose (OH above the plane)

Roles of Monosaccharides

- **Source of energy in respiration**.
  - C-H bonds release lots of energy when broken—used to convert ADP to ATP.
  - Glucose is the most important, metabolically.

- **Building blocks of larger molecules**.
  - glucose → starch, glycogen, cellulose
  - ribose → RNA (ribonucleic acid) & ATP
  - deoxyribose → DNA (deoxyribonucleic acid)

Building sugars

- **Dehydration synthesis**

Dehydration synthesis

- 2 hydroxyl (-OH) groups line up with one another
- One combines with a hydrogen from the other to form a water molecule: HENCE, DEHYDRATION/CONDENSATION
  - Forms an oxygen bridge “glycosidic bond”
  - Any two hydroxyl groups can line up & bond
  - Large variety of possible disaccharides
**Building sugars**

- Dehydration synthesis

Disaccharides

- Two monosaccharides joined by a covalent bond

Breaking Bonds: Hydrolysis

- Hydrolysis: When polysaccharides break apart to form smaller molecules.
  - Hydro = water
  - Lysis = breaking apart
- Breaking a molecule apart by adding water
- Both Condensation & hydrolysis are controlled by enzymes.
**Transport Disaccharides**

- In humans, glucose can circulate in the blood
- In plants & many other organisms, glucose must be converted for transport to keep glucose from being “used up” while in transport
  - The bond breaking enzymes are only located in tissue where glucose is meant to be used.
  - \( \text{Glucose + fructose} \rightarrow \text{sucrose} \)
  - \( \text{Glucose + galactose} \rightarrow \text{lactose} \)
  - \( \text{Glucose + glucose} \rightarrow \text{maltose} \)

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**Polysaccharides**

- *Polymers of sugars* (NOT sugars)
  - costs little energy to build
  - easily reversible = release energy
- **Function:**
  - *energy storage*
    - starch (plants)
    - glycogen (animals)
      - in liver & muscles
  - *structure*
    - cellulose (plants)
    - chitin (arthropods & fungi)

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**Storage Polysaccharides**

- Transport disaccharides may be linked together as polysaccharides for storage within cells.
- Plant polysaccharides = starches.
- Animal polysaccharides = glycogen
Linear vs. branched polysaccharides

Starches: Amylose
- Amylose = simplest starch, hundreds / thousands of linked, unbranched alpha glucose molecules.
  - #1 carbon links to #4 of next molecule = long chains of maltose.
  - Long chains coil up in water making it insoluble in water
  - Potato starch ~ 20% amylose

Starch: Amylopectin
- Most plant starch is amylopectin.
  - Also made of many 1,4 linked glucose, but also have 1,6 branching linkages Only 20-30 glucose subunits.
  - Mixtures of amylose & amylopectin build up as starch grains in chloroplasts & storage vacuoles.

Glycogen
- "Animal version of starch."
- Insoluble polysaccharide of branched amylose chains
  - Average chain much longer and greater # of branches than plant starch.
  - Animal form of energy storage.
Structural Carbohydrates: Cellulose

- Most abundant organic compound on Earth
  - herbivores have evolved a mechanism to digest cellulose
  - most carnivores have not
- that’s why they eat meat to get their energy & nutrients
- cellulose = undigestible roughage

Cellulose

- Unbranched chains of beta glucose
- Several chains are cross-linked by H-bonding to form fibrils
- Several fibrils crosslink to form fibres
- Forms cell walls of plants