Carbohydrates

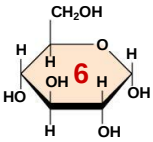
AICE Biology
Jones & Fosbery Chapter 2

Carbohydrates

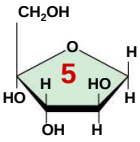
- Carbohydrates are composed of C, H, O
  - carbo - hydr - ate
  - CH_2O
  - $(CH_2O)_x \rightarrow C_6H_{12}O_6$
- Function:
  - fast energy
  - raw materials
  - energy storage
  - structural materials
- Monomer: sugars
- ex: sugars, starches, cellulose

Sugars

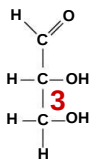
- Most names for sugars end in *-ose*
- Classified by number of carbons
  - 6C = hexose (glucose)
  - 5C = pentose (ribose)
  - 3C = triose (glyceraldehyde)



Glucose



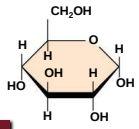
Ribose



Glyceraldehyde

Simple & complex sugars

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

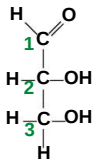


Glucose

Monosaccharides

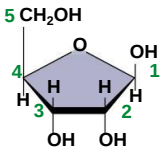
- Single Sugars
- Dissolve easily in water
- Sweet taste
- 3 forms: Sugars all end in "ose"
  - Triose (3C) $C_3H_6O_3$
    - (Gylceraldehyde)
  - Pentose (5 C) $C_5H_{10}O_5$
    - (Ribose, Deoxyribose = components of nucleic acids)
  - Hexose (6 C) $C_6H_{12}O_6$
    - (Glucose, Fructose, Galactose)

3-carbon sugar

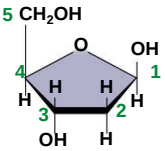


Glyceraldehyde

5-carbon sugars

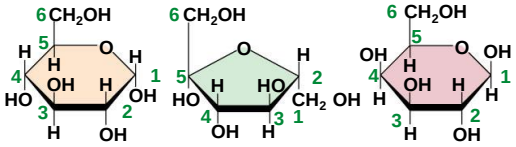


Ribose

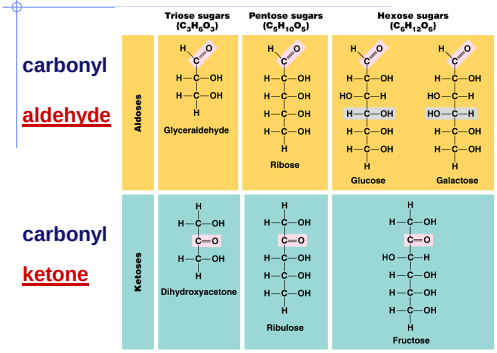


Deoxyribose

6-carbon sugars



Functional groups determine function

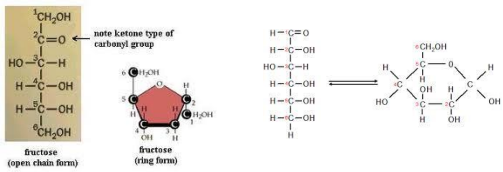


Chemical Formulae

- Molecular Formula (empirical formula) ie. $C_6H_{12}O_6$
- Structural Formula
  - Diagram showing the arrangement of atoms.
  - Glucose, fructose & galactose all have the same empirical formula, but have different structural formulae.

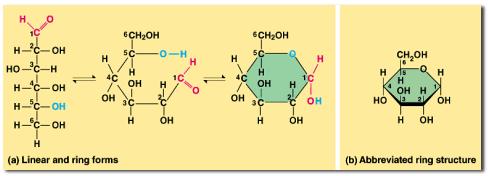
Structural Forms

- 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

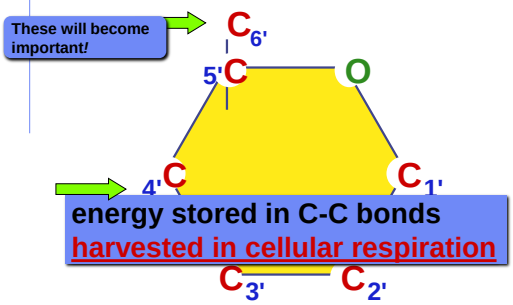
5C & 6C sugars form rings in solution



Carbons are numbered

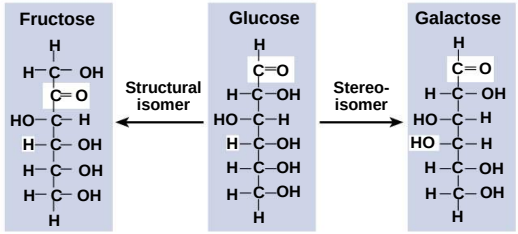
Numbered carbons

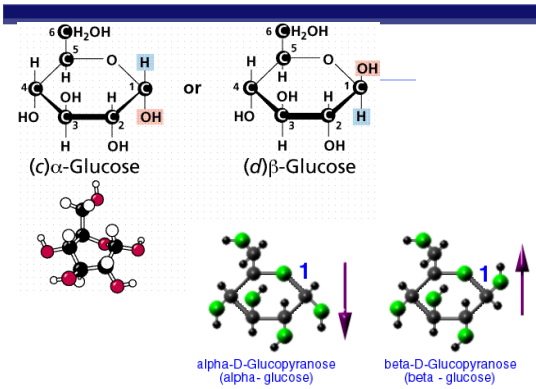
These will become important!



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
  - ∂ glucose (OH below the plane)
  - ß glucose (OH above the plane)



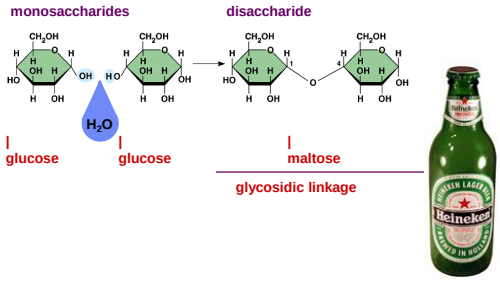


Roles of Monosaccharides

- **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

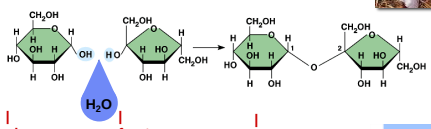
- **2 hydroxyl (-OH) groups line up with one another**
- **One combines with a hydrogen from the other to form a water molecule: HENCE, DEHYDRATION/ CONDENSATION**
  - Forms an oxygen bridge "glycosidic bond"
  - Any two hydroxyl groups can line up & bond
  - Large variety of possible disaccharides

Building sugars

- Dehydration synthesis

monosaccharides

disaccharide



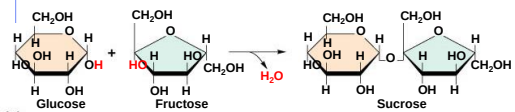
glucose

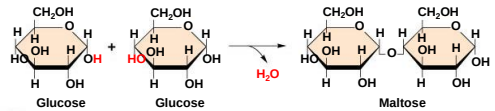
fructose

sucrose (table sugar)

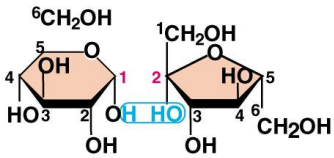
Disaccharides

- Two monosaccharides joined by a covalent bond





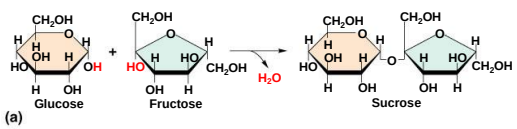
Glucose + Fructose

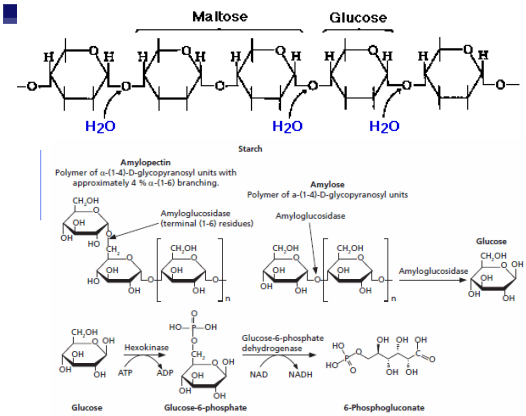


MONOSACCHARIDES

Breaking Bonds: Hydrolysis

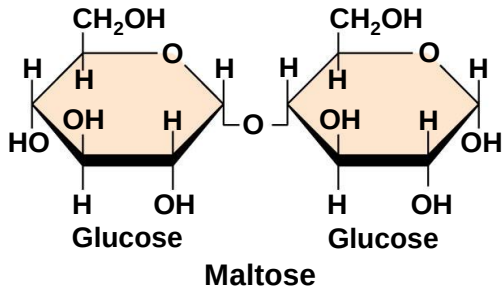
- Hydrolysis: When polysaccharides break apart to form smaller molecules.
  - Hydro = water
  - Lysis = breaking apart
- Breaking a molecule apart by adding water
- Both Condensation & hydrolysis are controlled by enzymes.

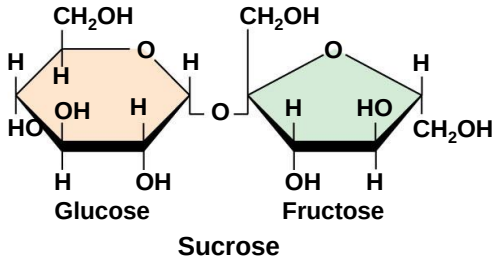


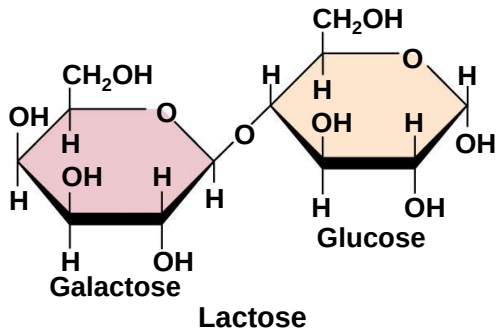


Transport Disaccharides

- 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.
  - ∂ Glucose + fructose = sucrose
  - Glucose + galactose = lactose
  - Glucose + glucose = maltose





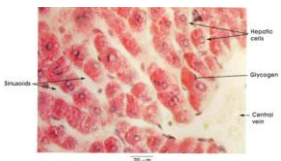


Polysaccharides

- *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)

Storage Polysaccharides

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



Linear vs. branched polysaccharides

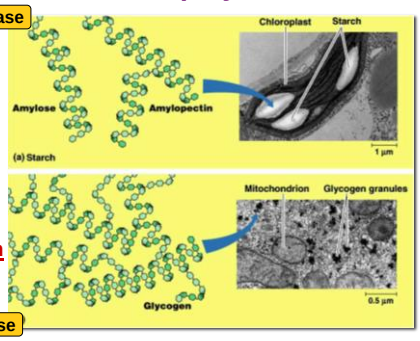
slow release

starch (plant)

energy storage

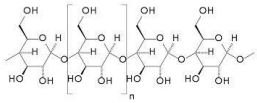
glycogen (animal)

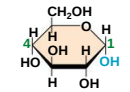
fast release



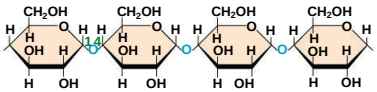
Starches: Amylose

- **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 insoluable in water**
  - **Potato starch ~ 20% amylose**





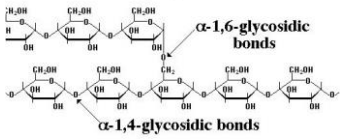
α form of glucose

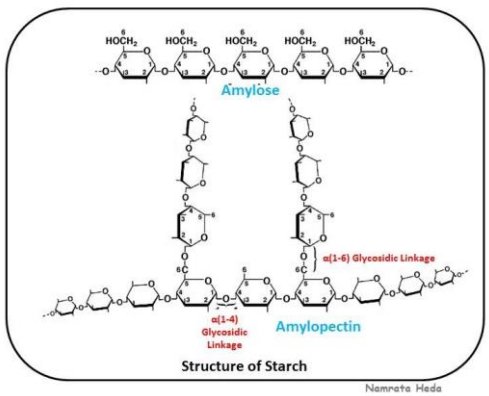


Starch: chain of α–glucose subunits

Starch: Amylopectin

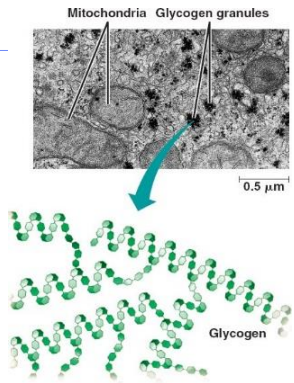
- **Most plant starch is amylopectin.**
  - **Also made of many 1,4 linked glucose, but also have 1,6 branching linkages Only 20-30 glucose subunits.**
  - **Mixtures of amylose & amylopectin build up as starch grains in chloroplasts & storage vacuoles.**

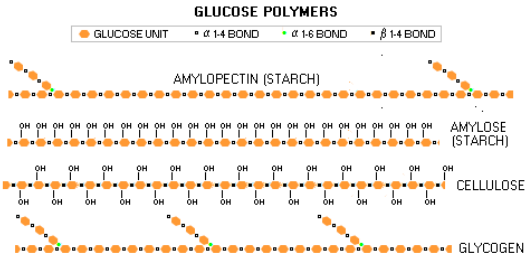




Glycogen

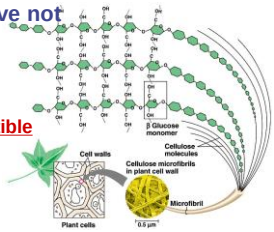
- **"Animal version of starch."**
- **Insoluble polysaccharide of branched amylose chains**
- **Average chain much longer and greater # of branches than plant starch.**
- **Animal form of energy storage.**





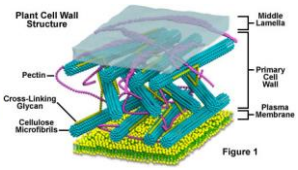
Structural Carbohydrates: Cellulose

- **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



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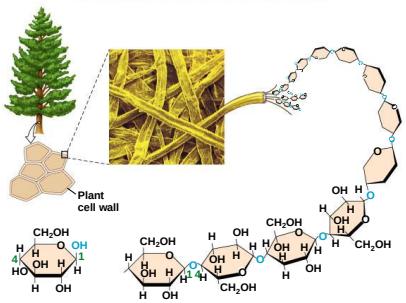

β form of glucose

Cellulose: chain of β–glucose subunits