UNIVERSITY OF BASRAH
AL-ZAHRAA MEDICAL COLLEGE

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

The module: Metabolism

Session 2, Lecture 2

Duration : 1 hr

Carbohydrate Metabolism 1.

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Marks Essentials of Medical Biochemistry.
Ganong's Review of Medical Physiology .
For more discussion, questions or cases need help please post to the session group

Learning outcomes (LO)

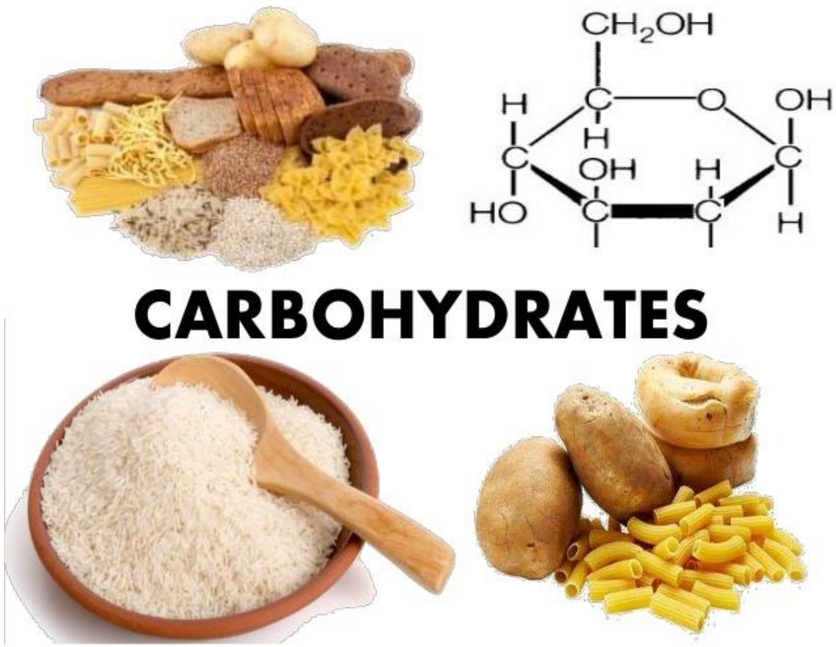
1. General structures and functions of carbohydrates.
2. How dietary carbohydrates are digested and absorbed.
3. Why cellulose is not digested in the human gastrointestinal tract.
4. The glucose-dependency of some tissues.
5. The key features of glycolysis.
6. Why lactic acid (lactate) production is important in anaerobic glycolysis.
7. How the blood concentration of lactate is controlled.

General structure of carbohydrates : LO 1

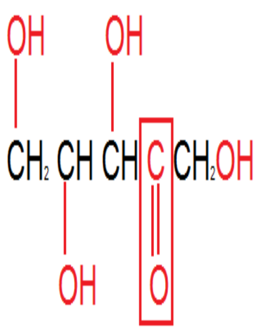
- **Carbohydrate:** Is a Large class of compounds that are **polyhydroxy aldehyde**, **polyhydroxy ketone** or substances that yield such compounds on acid hydrolysis.

- The empirical formula is **$C_n(H_2O)_n$**

- E.g. **Glucose $C_6H_{12}O_6$**

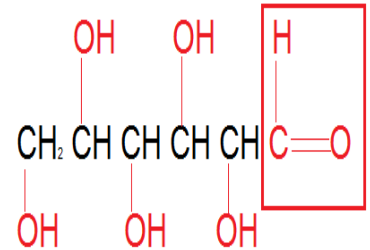


- CHO usually involves only **two functional groups**:
  - **The carbonyl group of an aldehyde or ketone.**
  - **The alcohol hydroxy group.**



carbonyl group of a ketone

KETOPENTOSE



carbonyl group of an aldehyde

AN ALDOHEXOSE

The classification of CHO:

LO1

- carbohydrate
  - Sugars
    - Monosacch.
      - Aldoses
      - Ketoses
    - Oligosacch.
      - Disacch.
      - Trisacch.
      - Tetrasacch.
  - Non-sugars
    - Homopoly Sacch.
    - Heteropoly Sacch.

The importance of CHO.

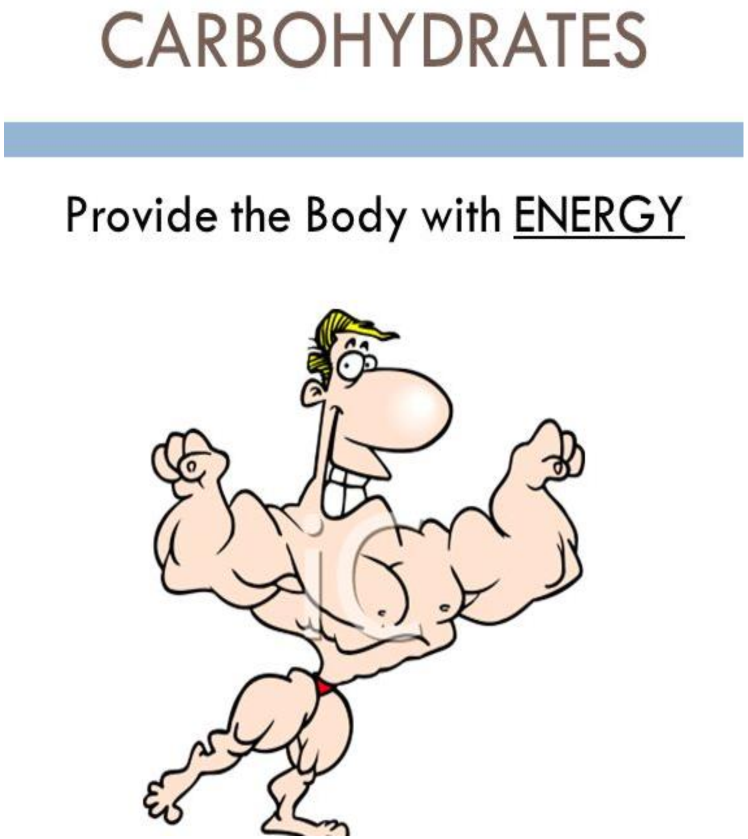
LO 1

1. Polysaccharides serve for the storage of energy e.g. **starch (in plants), glycogen (in human).**

2. Structural components e.g.

   Cellulose in plants

   Chitin in arthropods



3. 5-carbon monosaccharide ribose is an important component of :

a) coenzymes e.g. **ATP** (Adenosine triphosphate),
FAD (Flavin adenine dinucleotide)
NAD (Nicotinamide adenine dinucleotide

b) The backbone of the genetic molecule RNA and DNA.

4. Saccharides and their derivatives play key roles in the:

Immune system, Fertilization, Blood clotting and development.

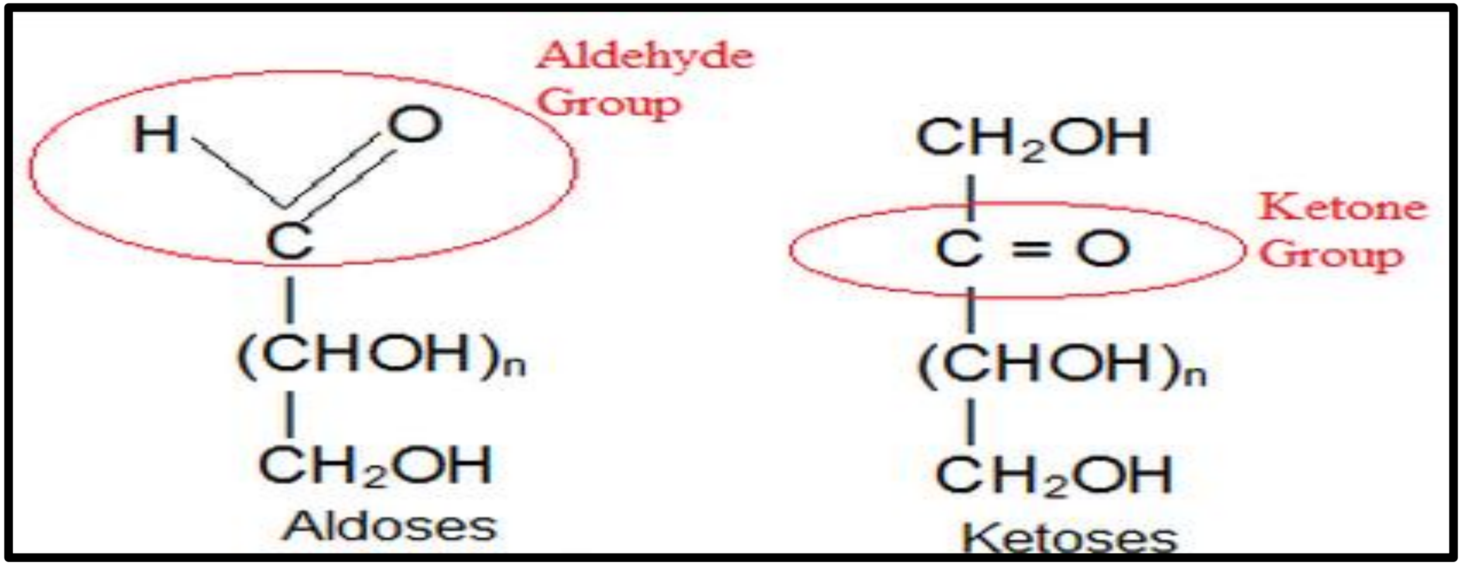
	Monosaccharide	Disaccharide	Polysaccharide
Subunits	One	Two	Many
Main Function	Energy Source	Transport Form	Storage Form
Examples	**G**lucose **G**alactose **F**ructose	**L**actose **S**ucrose **M**altose	**C**ellulose **G**lycogen **S**tarch
Mnemonic	**G**ives **G**ood **F**lavour 	**L**ength **S**upports **M**ovement 	**C**an **G**et **S**tored 

http://ib.bioninja.com.au/standard-level/topic-2-molecular-biology/23-carbohydrates-and-lipids/sugar-subunits.html

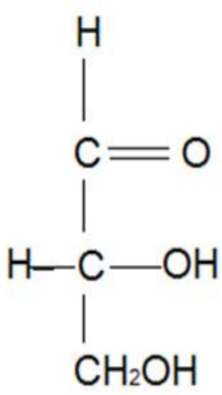
Monosaccharides (simple sugar molecules)

LO 1

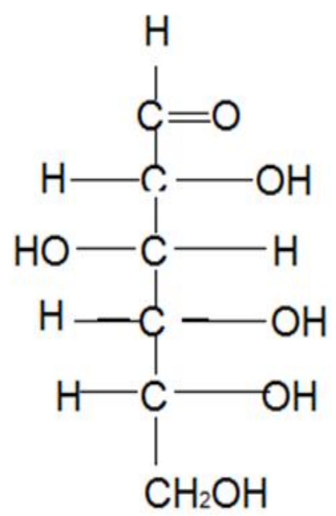
- These can contain from 3 to 9 C-atoms.
- They are either :
  - aldoses (derived from glyceraldehyde).
  - ketoses (derived from dihydroxyacetone).



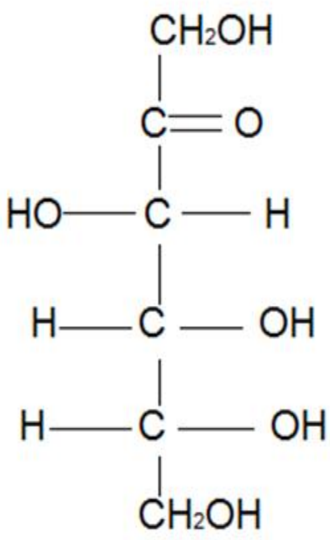
- Since the monosacch. Can exist in several different forms. So it's important to provide the complete name.



TRIOSE
ALDOTRIOSE
D-GLYCERALDEHYDE

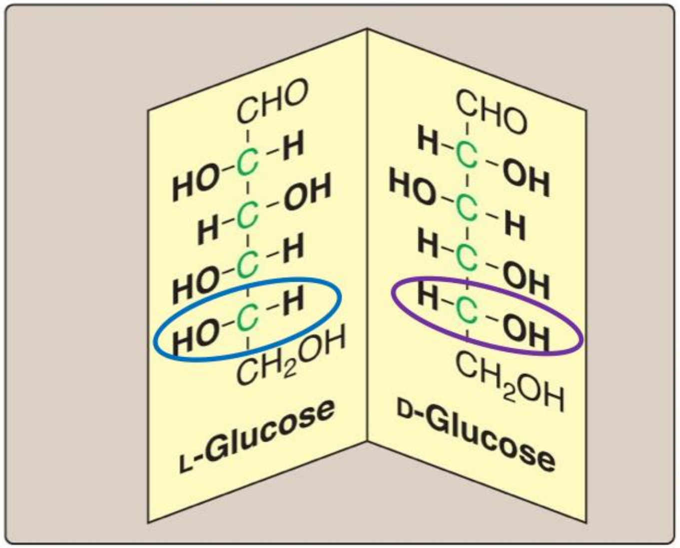


HEXOSE
ALDOHEXOSE
D-GLUCOSE



HEXOSE
KETOHEXOSE
D-FRUCTOSE

D-glucose & L-glucose: same chemical formula $C_6H_{12}O_6$



D enantiomer → asymmetric C farthest from carbonyl has OH on right

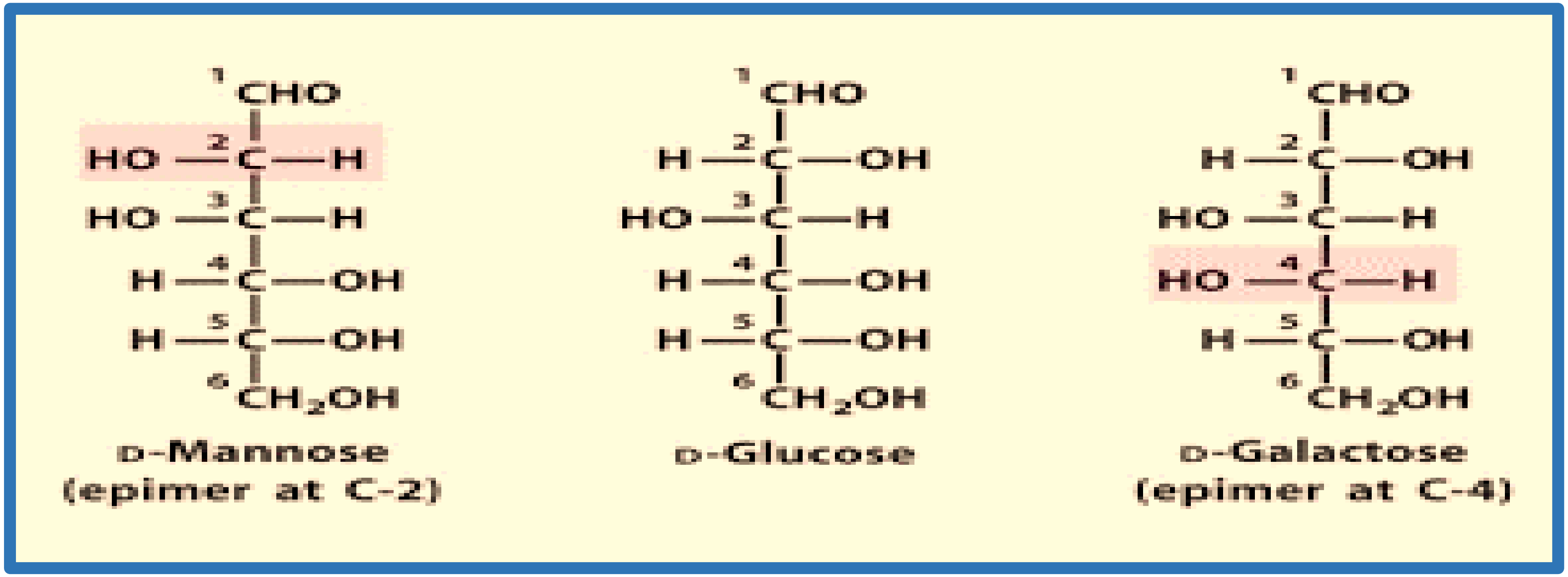
L enantiomer → asymmetric C farthest from carbonyl has OH on left

- Almost all sugars occurring in humans are D enantiomers

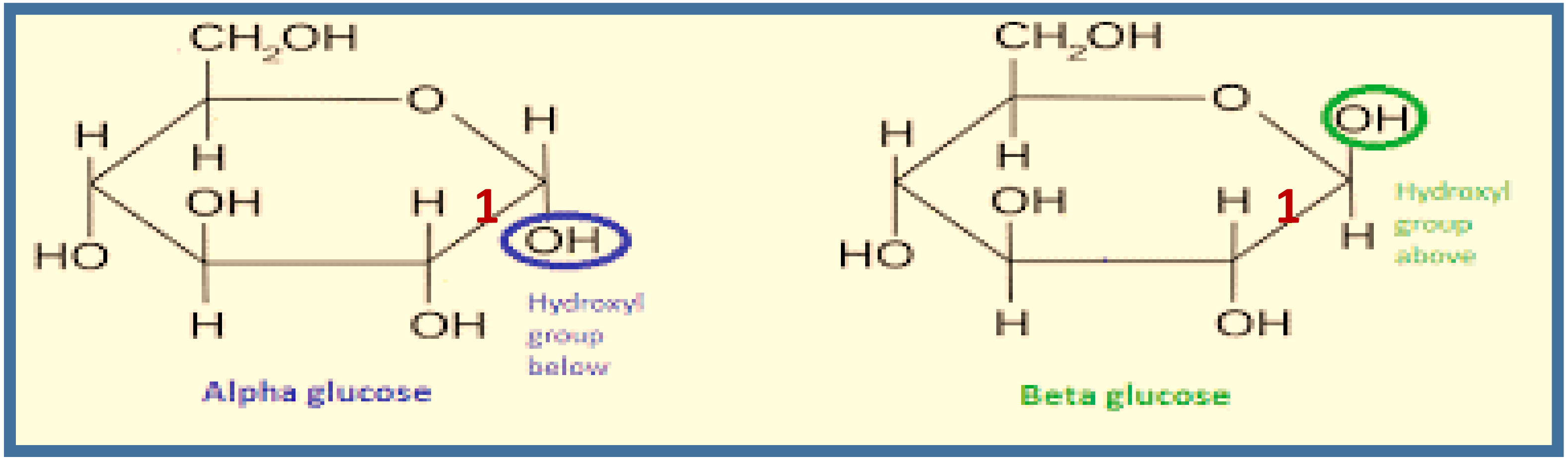
Epimers of glucose

LO 1

A.

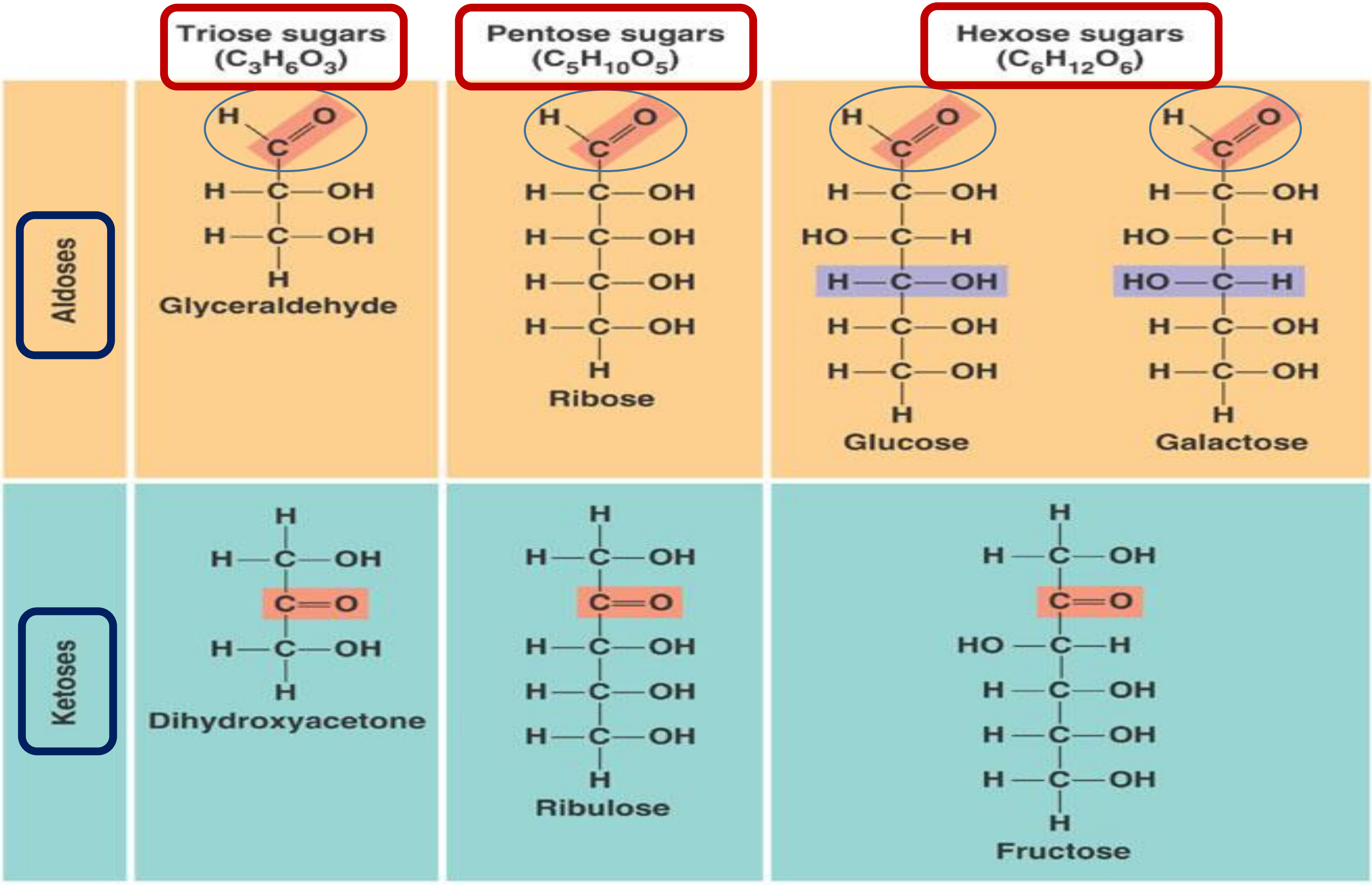


B.



Monosaccharides (simple sugar molecules)

LO 1



Disaccharides :

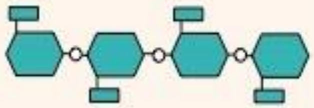
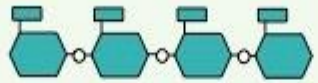
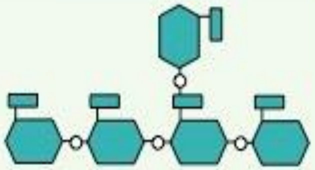
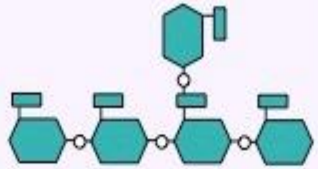
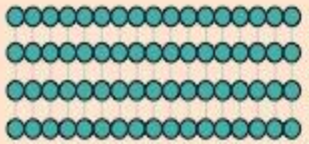
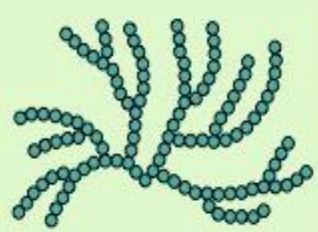
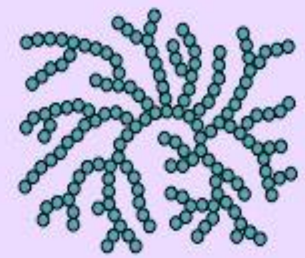
LO 1

Glucose | Fructose → SUCROSE

Glucose | Galactose → LACTOSE

Glucose | Glucose → MALTOSE

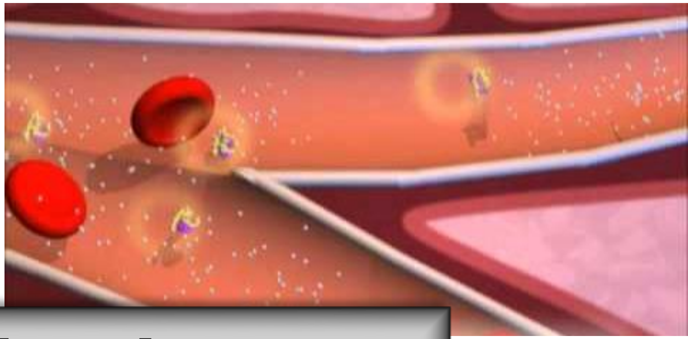
Polysaccharides : LO 1

	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Subunit	β-glucose	α-glucose	α-glucose	α-glucose
Bonds	1-4	1-4	1-4 *and* 1-6	1-4 *and* 1-6
Branches	No	No	Yes (~per 20 subunits)	Yes (~per 10 subunits)
Diagram				
Shape				

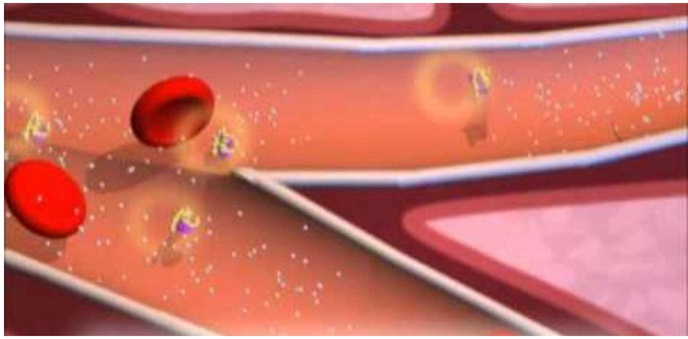
https://www.creative-proteomics.com/services/polysaccharide-analysis.htm

LO 1

What is the main suger in blood ?



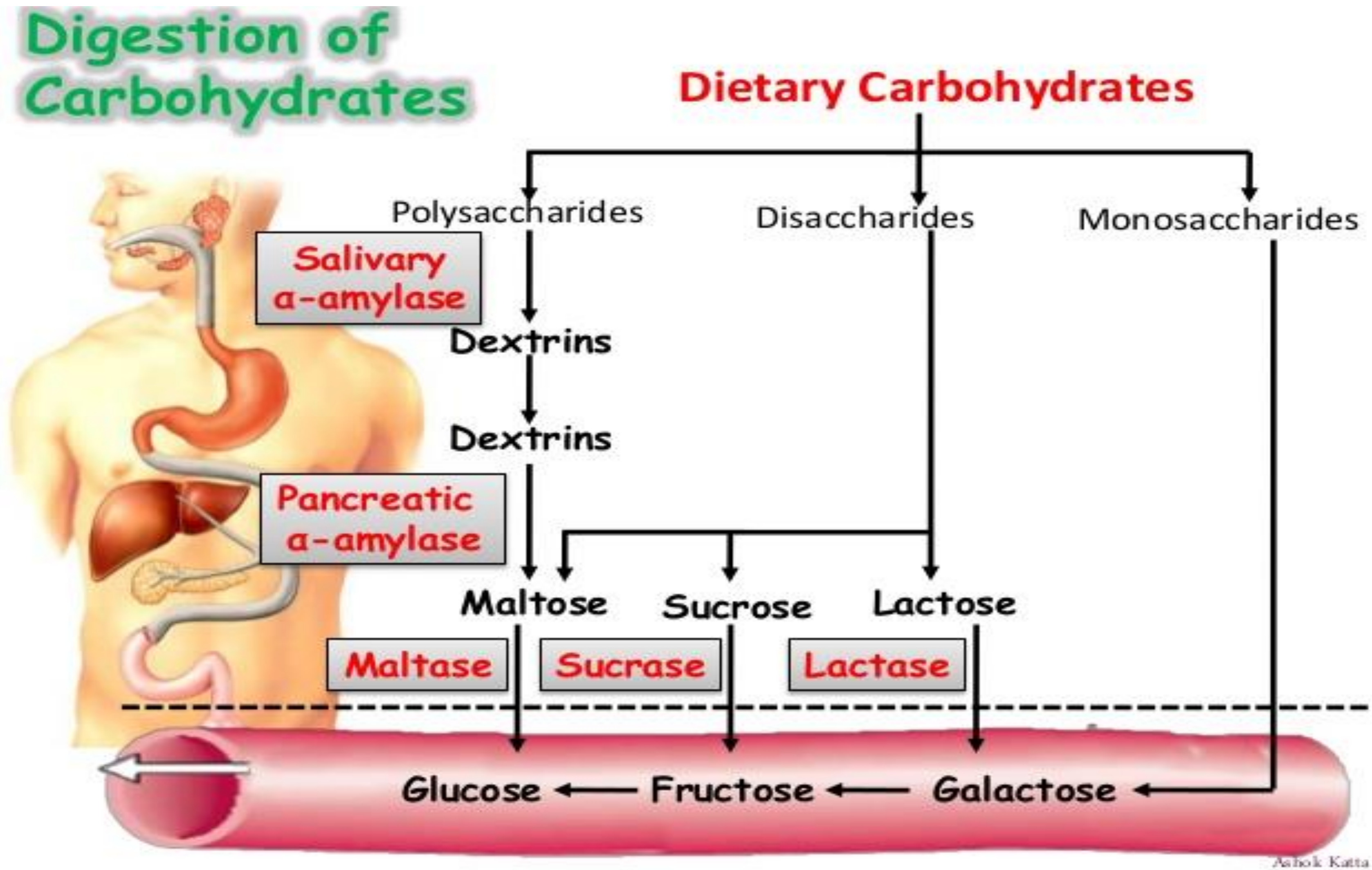
- The major sugar found in blood is glucose.
- In addition, fructose and galactose may appear for short periods depending on the dietary intake of fruit and dairy products.



- Excessive amounts of galactose and fructose in the blood are associated with a number of clinical problems (e.g. Galactosaemia, Fructose intolerance)

- As are the persistently high levels of glucose seen in untreated diabetes.

Stage 1 of Carbohydrate metabolism: LO 2



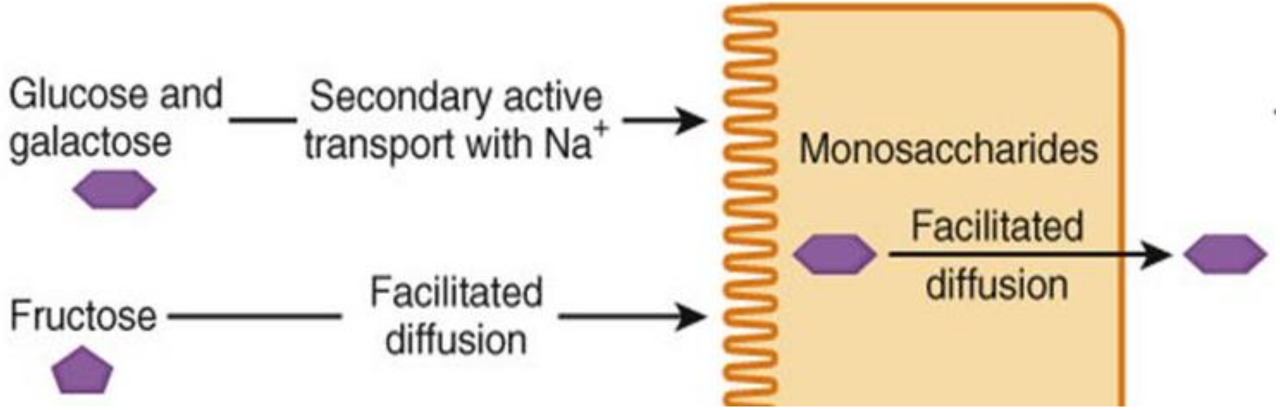
https://www.slideshare.net/ashokktt/digestion-and-absorption-of-carbohydrates-36695573

<u>Sugar absorption</u> :

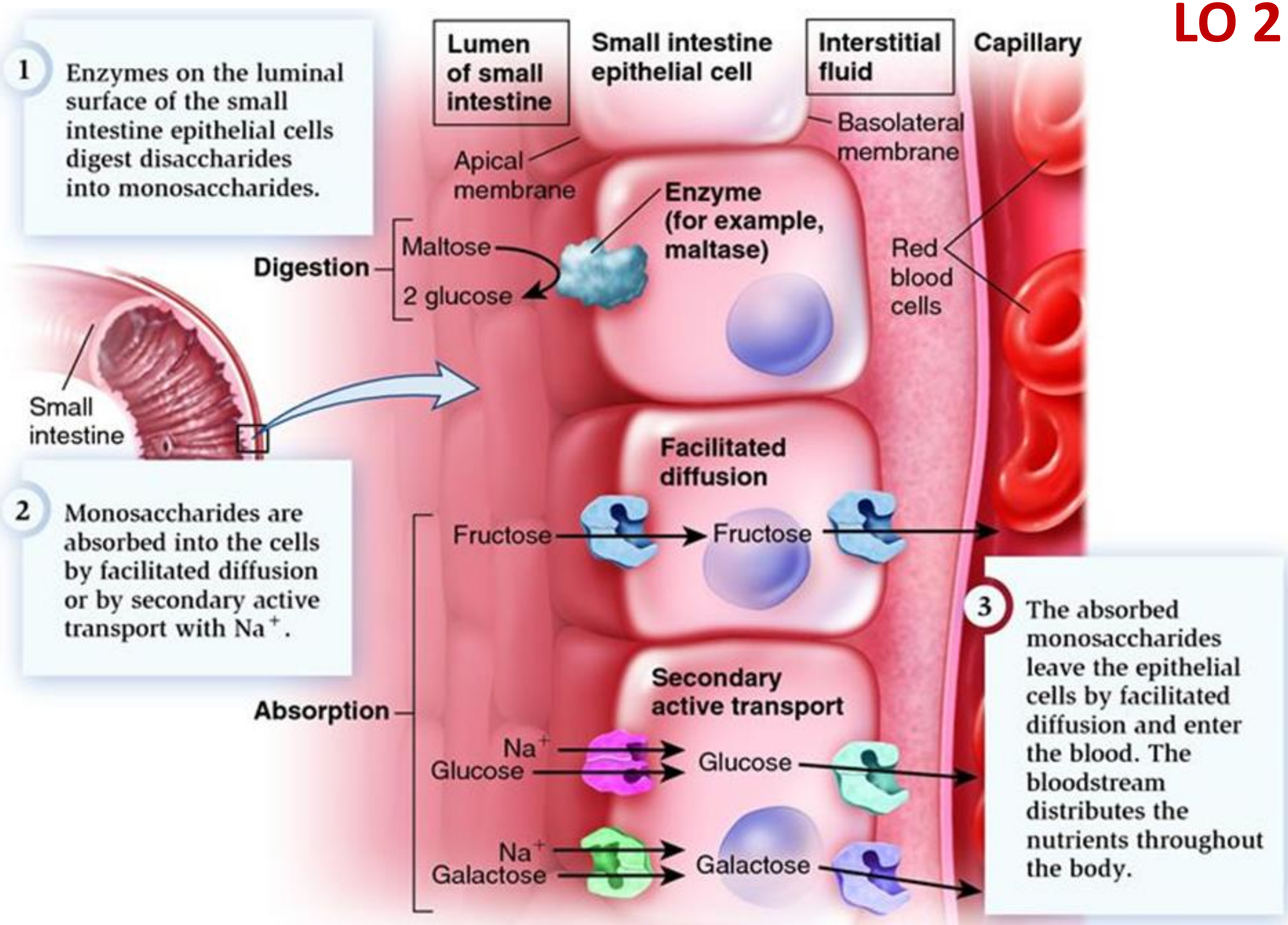
LO 2

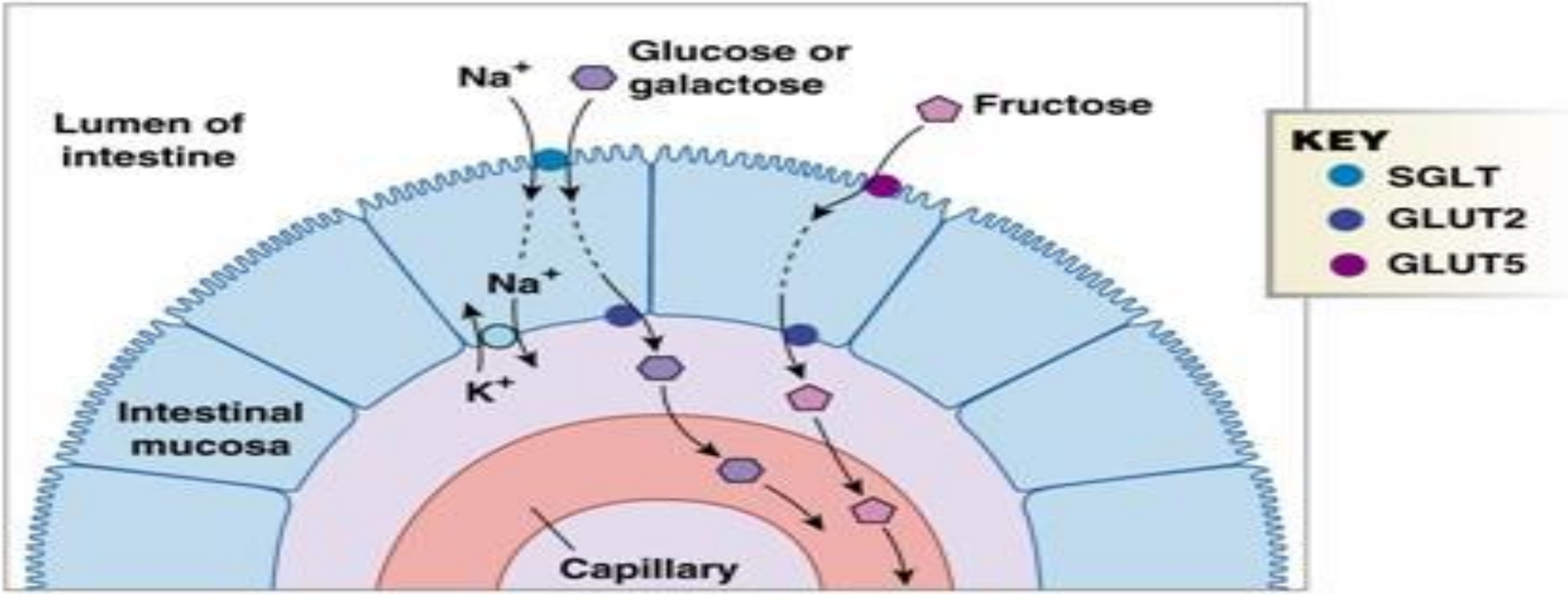
- Essentially all CHO are absorbed in the form of monosaccharides.
  - 80% glucose
  - 20% fructose and galactose

- Glucose and galactose are transported by sodium co-transport mechanism.
- Fructose transported by facilitated diffusion.
- The absorbed monosaccharides leaves the epithelial cells by facilitated diffusion and enter the blood.



LO 2

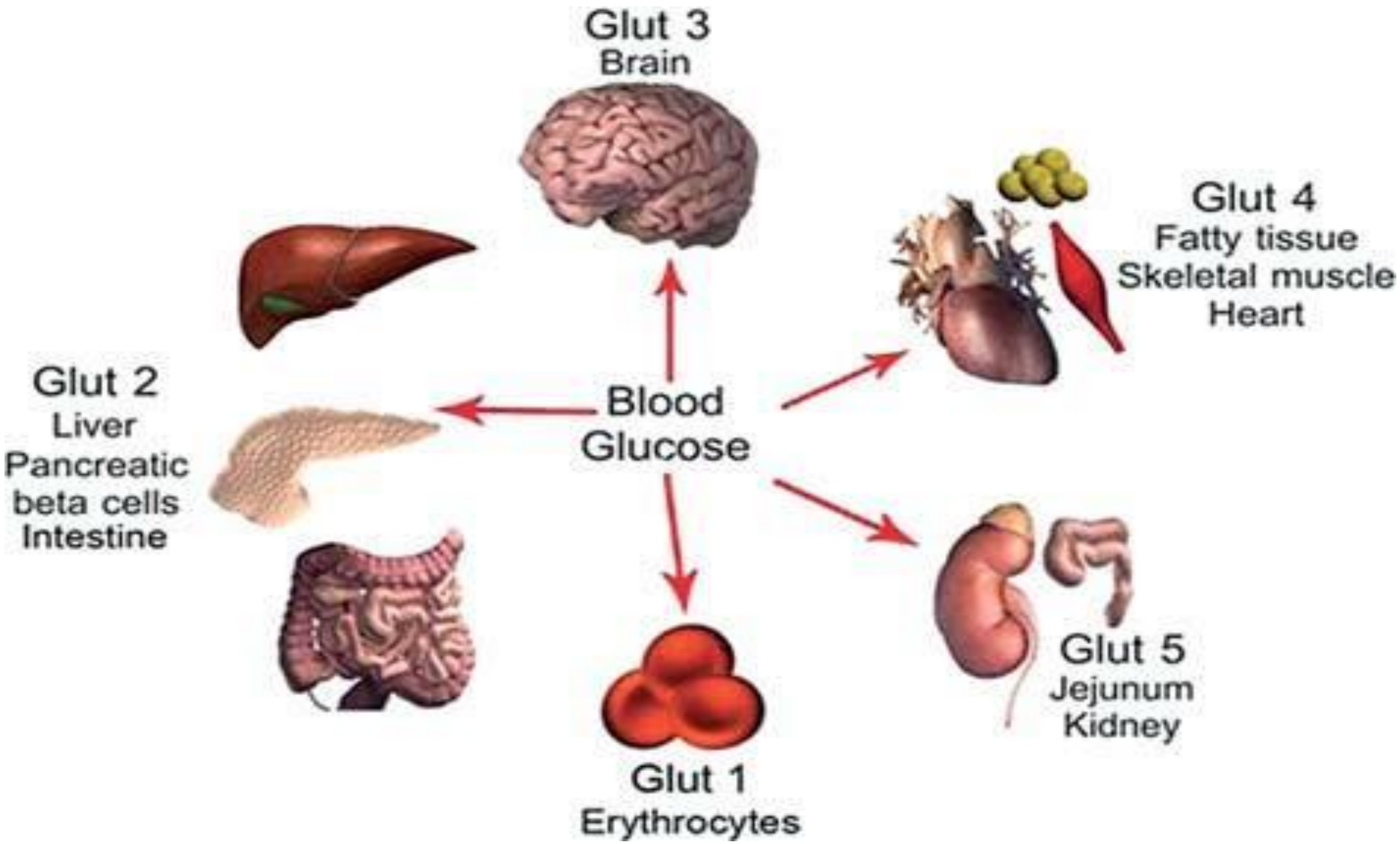

1 Enzymes on the luminal surface of the small intestine epithelial cells digest disaccharides into monosaccharides.
Lumen of small intestine
Small intestine epithelial cell
Interstitial fluid
Capillary
Apical membrane
Basolateral membrane
Enzyme (for example, maltase)
Red blood cells
Digestion
Maltose
2 glucose
Small intestine
Facilitated diffusion
Fructose
Fructose
2 Monosaccharides are absorbed into the cells by facilitated diffusion or by secondary active transport with Na^+.
Absorption
Secondary active transport
Na^+
Glucose
Glucose
Na^+
Galactose
Galactose
3 The absorbed monosaccharides leave the epithelial cells by facilitated diffusion and enter the blood. The bloodstream distributes the nutrients throughout the body.



Glucose enters the cell with Na^+ on the SGLT symporter and exits on GLUT2. Fructose enters on GLUT5 and exits on GLUT 2.

- Transport from the absorptive cells into the blood and from the blood into tissues is by **facilitated diffusion** and involves a family of **glucose transport proteins (GLUT 1-GLUT 5).**

- Synthesis of some transporters is enhanced by **insulin**, e.g, **GLUT4** in **muscles and adipose tissues** .



http://www.namrata.co/digestion-and-absorption-of-carbohydrates-a-quick-revision/

Cellulose is not digested in the human gastrointestinal tract. Why?

- It is not digested by the human or the bacteria of the human gut because absence of the cellulase enzyme.
- It provides the fiber necessary for the process of defecation.
- It can be digested in herbivores, such as cows and horses at which the intestinal bacteria have cellulase that can breakdown (β-1,4) glucosidic bond.

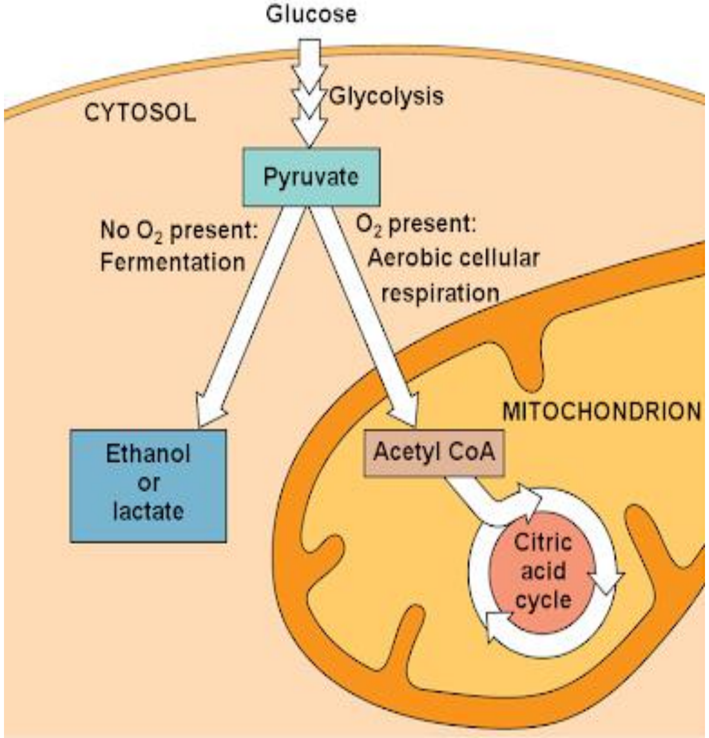
<u>Glucose requirements of tissues</u> : LO 4

The minimum amount of glucose required by a healthy adult on a normal diet is **~180 g/day**:

- ~40 g for RBCs, WBCs, kidney medulla and lens of the eye (Only use Glucose).
- 140 g for NS (Prefer Glucose for energy production).
- Variable amounts are required by some tissues for example adipose tissue to synthesize Triacylglycerols

Glycolysis :

- Glycolysis is a series of reactions that extract energy from glucose by splitting it into two three-carbon molecules called pyruvates.
- Glyco = sugar lysis = break
- Glycolysis takes place in the cytosol of a cell.
- Glycolysis is the ONLY source of ATPs in:
    - Cornea and lens of the eye.
    - Renal medulla and.
    - RBCs.



LO 5

❖Glycolysis is one of the main processes involved in cellular respiration.

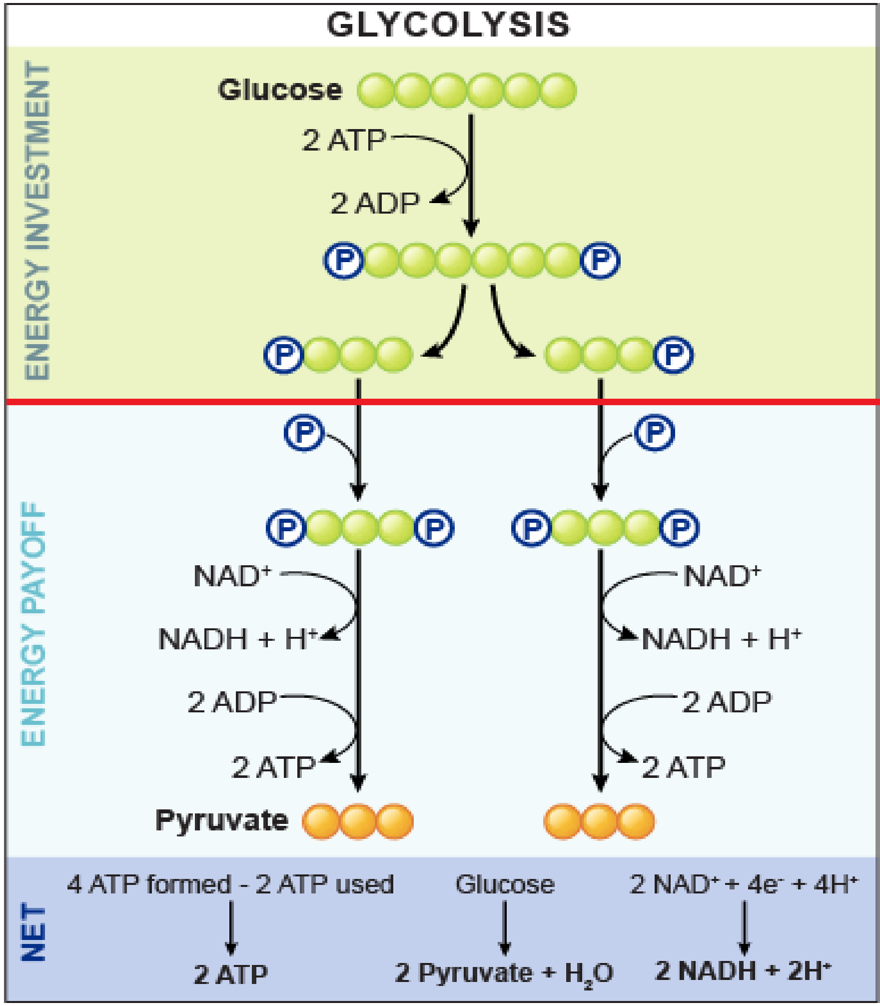
❖Cellular respiration is a set of metabolic reactions to yield ATP in the mitochondria

❖**Cellular respiration:**

1. glycolysis.
2. Pyruvate oxidation.
3. Citric acid cycle.
4. Oxidative phosphorylation.

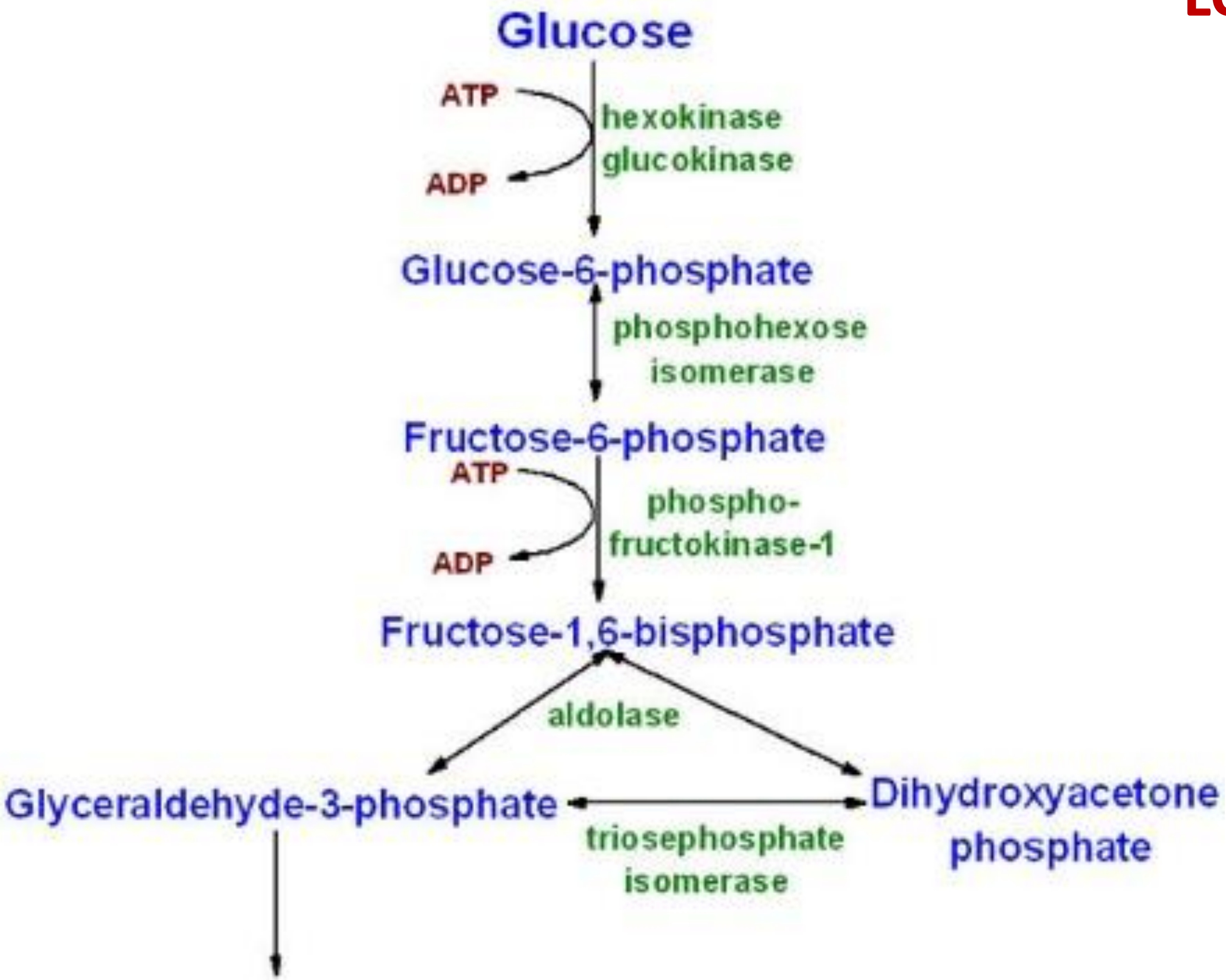
❖ **Two main phases in Glycolysis:**

1. the energy investment phase.
2. the energy-releasing phase.

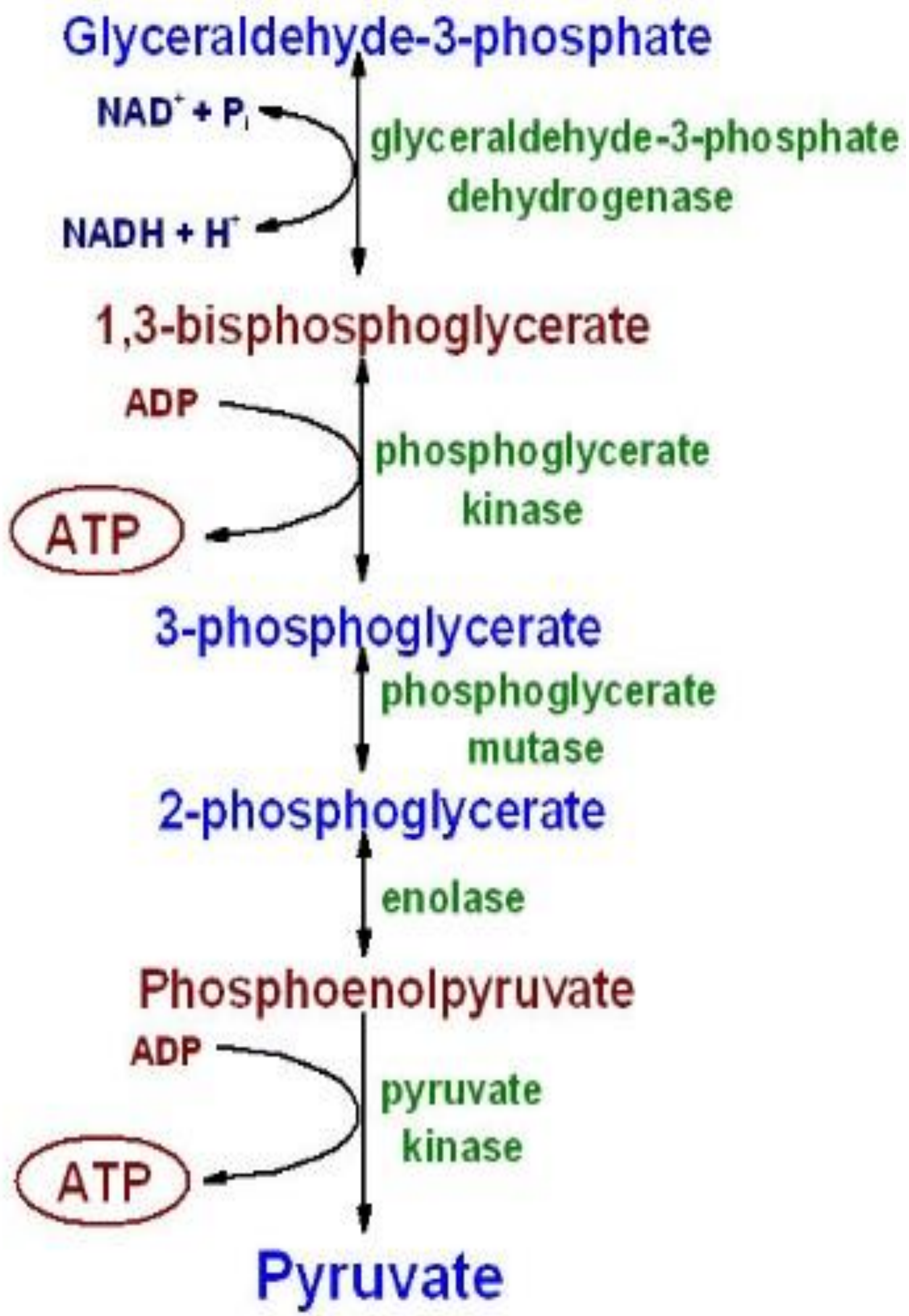


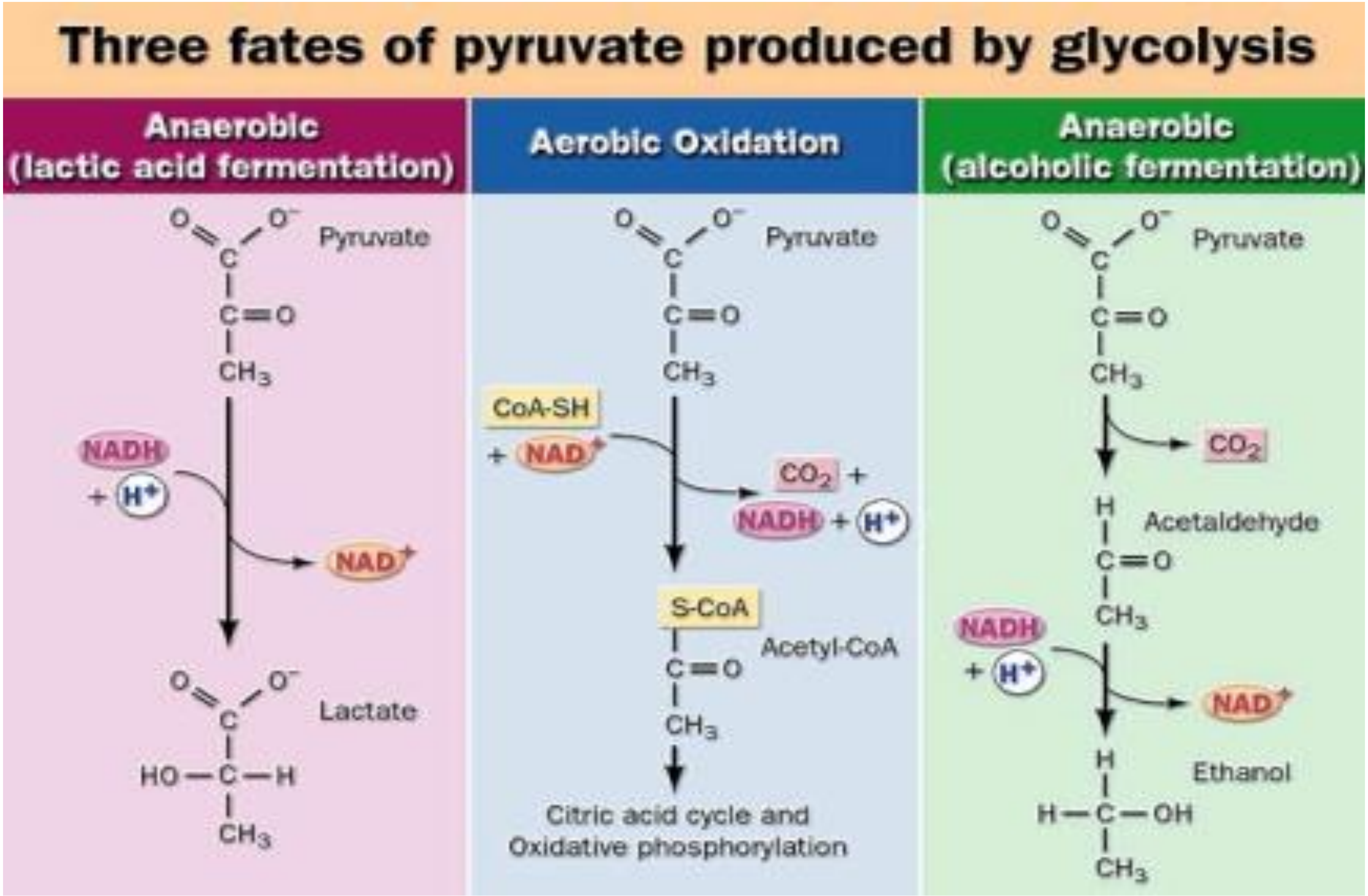
http://hyperphysics.phy-astr.gsu.edu/hbase/Biology/celres.html

LO 5


Glucose
ATP
ADP
hexokinase
glucokinase
Glucose-6-phosphate
phosphohexose
isomerase
Fructose-6-phosphate
ATP
ADP
phospho-
fructokinase-1
Fructose-1,6-bisphosphate
aldolase
Glyceraldehyde-3-phosphate
Dihydroxyacetone
phosphate
triosephosphate
isomerase

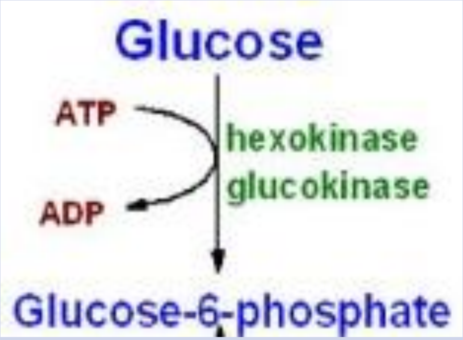
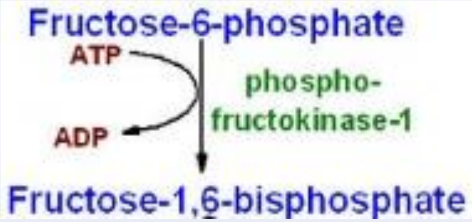
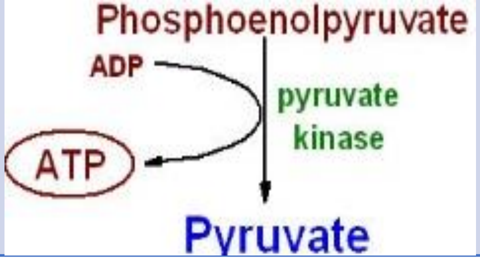
LO 5


Glyceraldehyde-3-phosphate
NAD+ + Pi
NADH + H+
glyceraldehyde-3-phosphate dehydrogenase
1,3-bisphosphoglycerate
ADP
ATP
phosphoglycerate kinase
3-phosphoglycerate
phosphoglycerate mutase
2-phosphoglycerate
enolase
Phosphoenolpyruvate
ADP
ATP
pyruvate kinase
Pyruvate

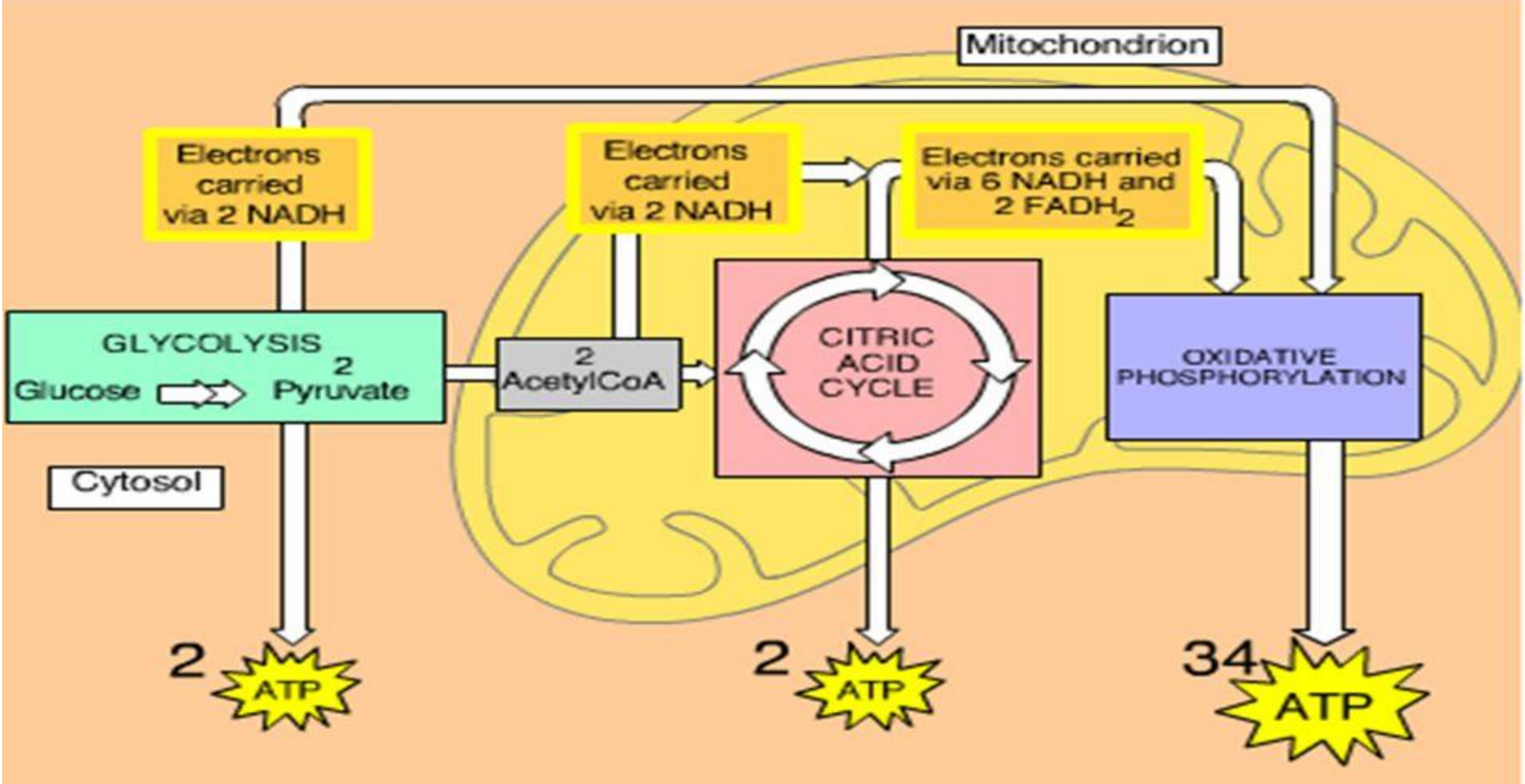

Three fates of pyruvate produced by glycolysis
Anaerobic
(lactic acid fermentation)
Aerobic Oxidation
Anaerobic
(alcoholic fermentation)
Pyruvate
NADH
+ H+
NAD+
Lactate
CoA-SH
+ NAD+
CO2 +
NADH + H+
S-CoA
Acetyl-CoA
Citric acid cycle and
Oxidative phosphorylation
CO2
Acetaldehyde
Ethanol

Regulation of glycolysis

LO 5

Enzyme	Activator	inhibitor	
Hexokinase	AMP/ ADP	G6P	
Phosphofructokinase	AMP/ ADP Insulin	ATP Citrate Glucagon	
Pyruvate kinase	AMP/ ADP	ATP AcetylCoA	

Overview of Aerobic Respiration Diagram



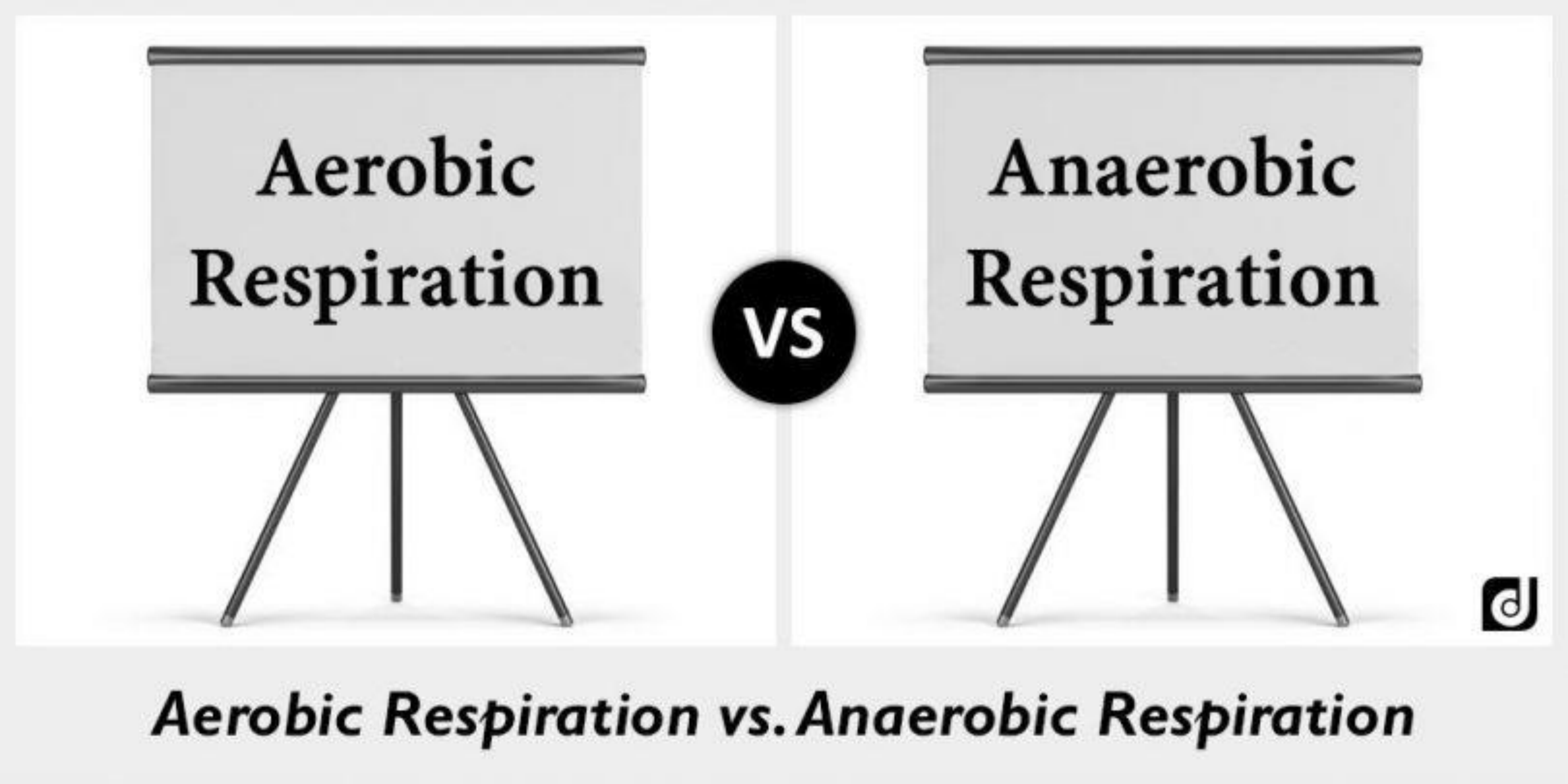
https://www.quora.com/How-36-ATP-are-formed-in-aerobic-respiration

Total energy yield of aerobic glycolysis

LO 5

Stage	Source	Number of ATP
Glycolysis	Direct 2 NADH	2 6
Pyruvate Oxidation	2NADH	6
Citric Acid Cycle	Direct 6 NADH 2 FADH2	2 18 4
Total		38

- All NADH and FADH2 converted to ATP during Electron Transport Chain (ETC) and Oxidative Phosphorylation stage of cellular respiration.
- Each NADH converts to 3 ATP.
- Each FADH2 converts to 2ATP
  (enters the ETC at a lower level than NADH).


Aerobic Respiration
VS
Anaerobic Respiration
Aerobic Respiration vs. Anaerobic Respiration

LO 5

	Anaerobic	Aerobic
Reactants	Glucose	Glucose **and** oxygen
Combustion	Incomplete	Complete
Energy Yield	Low (2 ATP)	High (36 – 38 ATP)
Products	**Animals:** Lactic acid **Yeast:** Ethanol + CO_2	CO_2 and H_2O
Location	Cytoplasm	Cytoplasm **and** mitochondrion
Stages	Glycolysis Fermentation	Glycolysis Link reaction Krebs cycle Electron transport chain

Importance of lactate production.

LO 6

Production of lactate is essential to continue glycolysis when oxygen supply is insufficient for example during contraction of muscle.

About 50g/day of lactate are produced from RBCs, muscle under anaerobic conditions.

Go to the liver for synthesis of glucose or the heart muscle to be oxidized to pyruvate then CO_2

LO 7

Situations in which there may be a marked increase in plasma lactate due to:

Increased production include:

1.strenuous exercise (up to 10 g/min)

2. sepsis

3.shock

4. congestive heart disease.

Decreased utilization occur:

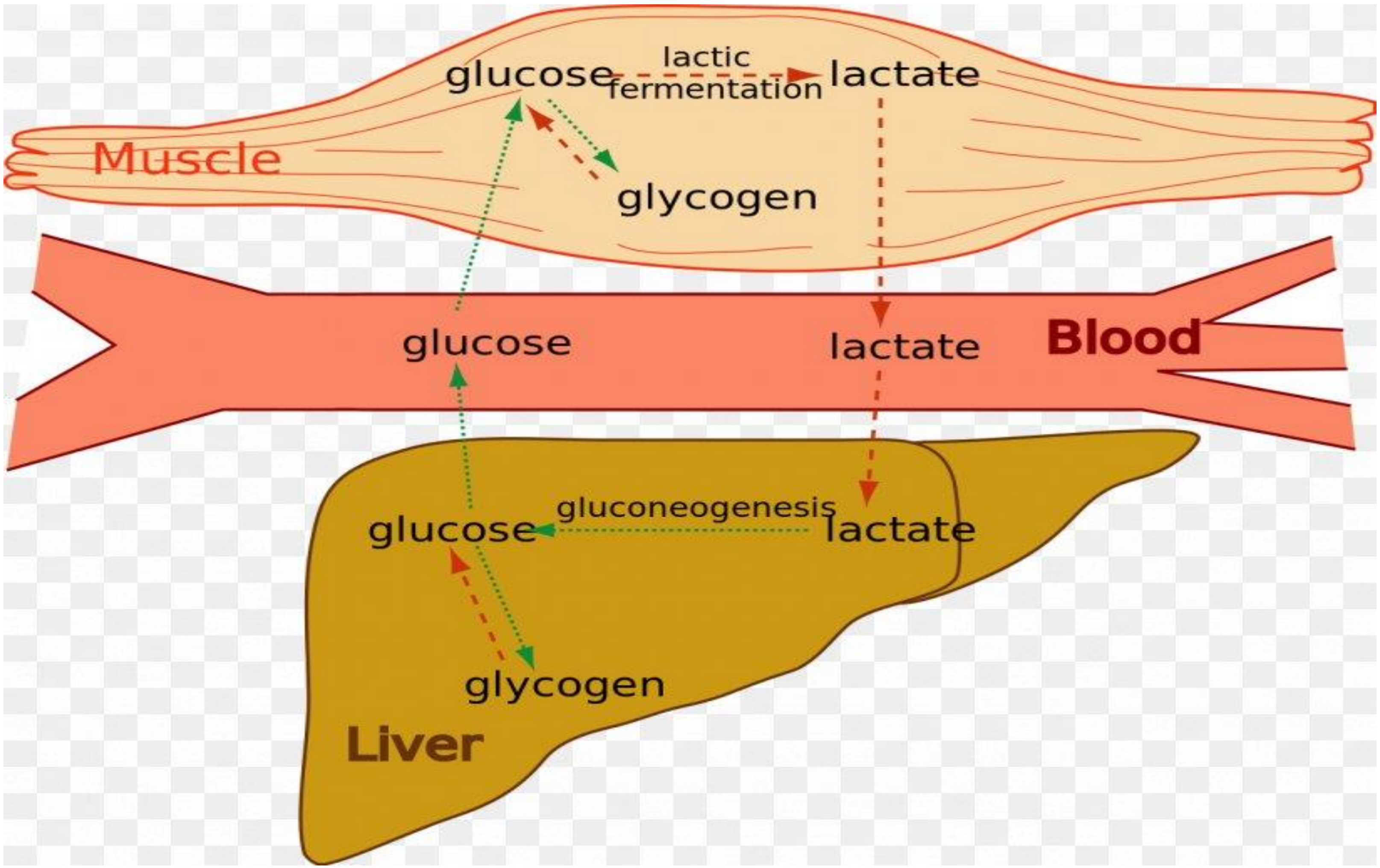
1. liver disease

2. thiamine deficiency

3. alcohol metabolism.

Significance of lactate production

LO 7



Cellular Respiration


THANKS!