Major types of nutrients and digestion

Lecture 1+2

Dr. Jehad Al-Shuneigat

- The 7 types of nutrients are Carbohydrates, Protein, Fats, Vitamins, Minerals, Water and Fibers

the major

every type of food has different serving.

We should have every day

examples of serving size:

* Grain products—1 slice of white bread or 1/2 cup of cooked rice;

* Vegetable group—1/2 cup cooked vegetables

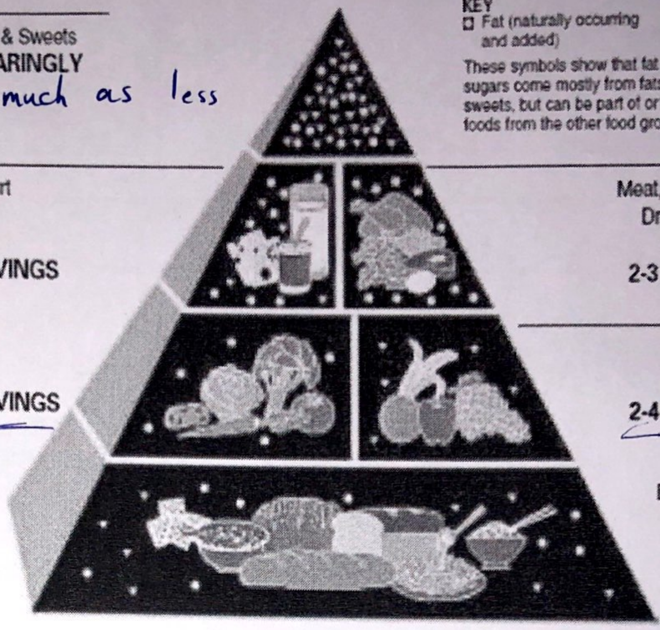
* Fruit group—1 apple or banana;

* Milk Group—1 cup of milk or 60g processed cheese;

* Meat and Beans Group—2–3 oz (60-80g) cooked lean meat or fish or 1 egg or 2 tbsp peanut butter. → table spoon

Food Guide Pyramid

A Guide to Daily Food choices



Fats, Oils, & Sweets
USE SPARINGLY
as much as less

KEY
☐ Fat (naturally occurring and added) ▣ Sugars (added)
These symbols show that fat and added sugars come mostly from fats, oils, and sweets, but can be part of or added to foods from the other food groups as well.

Milk, Yogurt & Cheese Group
2-3 SERVINGS

Meat, Poultry, Fish, Dry Beans, Eggs & Nuts Group
2-3 SERVINGS

Vegetable Group
3-5 SERVINGS

Fruit Group
2-4 SERVINGS

Bread, Cereal, Rice & Pasta Group
6-11 SERVINGS

1. Carbohydrates

Functions

- Energy
- Fibers (undigested carbs)
- Recognition and adhesion between cells
  Carbohydrate covalently attached to proteins or lipids examples: glycoproteins (bound to proteins), glycolipids (bound to lipids), these classes of molecules are called glycoconjugates.

الكربوهيدرات مصدرها الطبيعي هو plants

- Most foods derived from animals, such as meat or fish, contain very little carbohydrate except for small amounts of glycogen for example Liver contains 5% carbohydrates
- The major dietary carbohydrate of animal origin is lactose.

- Although all cells require glucose for metabolic functions, neither glucose nor other sugars are specifically required in the diet.

Oxidation

- 1g carbohydrates produces about 4 kcal/g,
- 1g proteins produces 4 kcal/g
- 1g fats produces 9 kcal/g. → this is why it the major thing for energy
- Energy is also expressed in joules. One kilocalorie equals 4.18 kilojoules (kJ).

لو الجسم بخزن السكر على شكل glycogen واي في الكبد, العضلات لكن يختفي بدقائق عند ال starvation ويبدأ حرق الدهون

Carbohydrates are classified into three groups:

1- Monosaccharide's: (simplest)

=Also called simple sugars

=Have the formula $(CH_2O)n$

=Cannot be broken down into smaller sugars.

2- Oligosaccharides:

= Consist of from **2 to 10 monosaccharides** molecules joined by a linkage called glycosidic bonds (covalent bond).

= The most abundant are the disaccharides

= Trisaccharides also occur frequently.

= All common monosaccharides and disaccharides have names ending with the suffix "-ose." اهم وحدة

3- Polysaccharides: are polymers of monosaccharide's. (more than 10)

They may be either linear like cellulose or branched like glycogen. Polysaccharides may contain hundreds or even thousands of monosaccharide units.

2 monosaccharides

Disaccharides

the building block of it is glucose but different in site of bond

1- **Maltose** Consist of two glucose units joined by **α-1,4**. → carbon number 1 + C4 of next glucose
Comes from the hydrolysis of starch

2- Cellobiose, is a two glucose disaccharide joined by **β-1,4** obtained from the acid hydrolysis of cellulose

3- Isomaltose consists of two glucose units linked by **α-1,6**. obtained from the hydrolysis of some polysaccharides like dextran

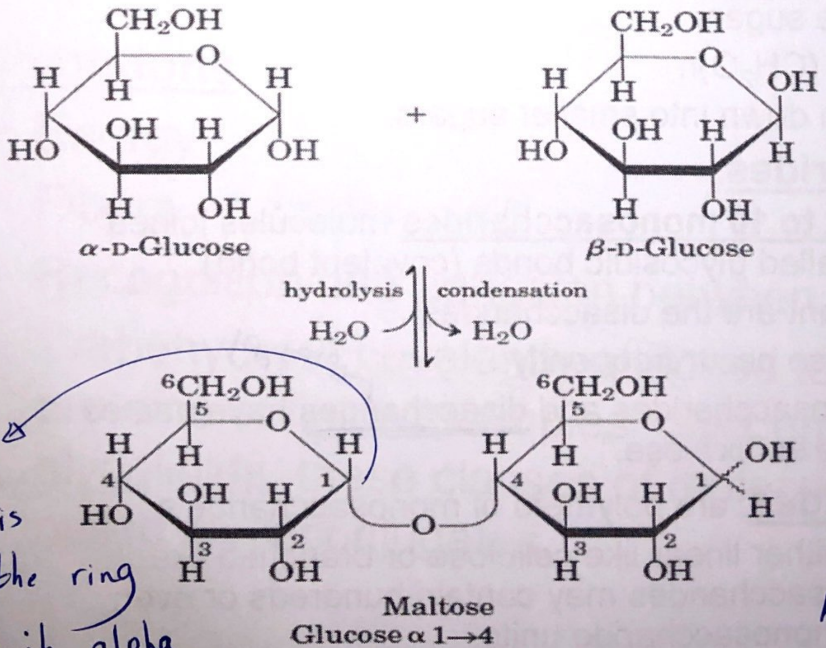
4- **Trehalose** two glucose units linked by an α-bond (α-1,1)

5- **Lactose** Milk sugar, Composed of Galactose & Glucose joined by (β-1,4) link.

6- **Sucrose** Composed of (glucose-α-1,2-fructose) obtained from cane or beet commonly known as table sugar

Glycosidic bond in maltose

Glycosidic bond the covalent bond between the anomeric carbon atom of a saccharide and some other group or molecule with which it forms a glycoside.



alpha 1,4 glycosidic bonds are formed when the OH on the carbon-1 is below the glucose ring while beta 1,4 glycosidic bonds are formed when the OH is above the plane

If the bond is down the ring we call it alpha
If it above the plane of ring called Beta.

Carbohydrates as monosaccarides
Aldoses → Aldyhide (functional group) → in C1
Ketoses → Keton → in C2

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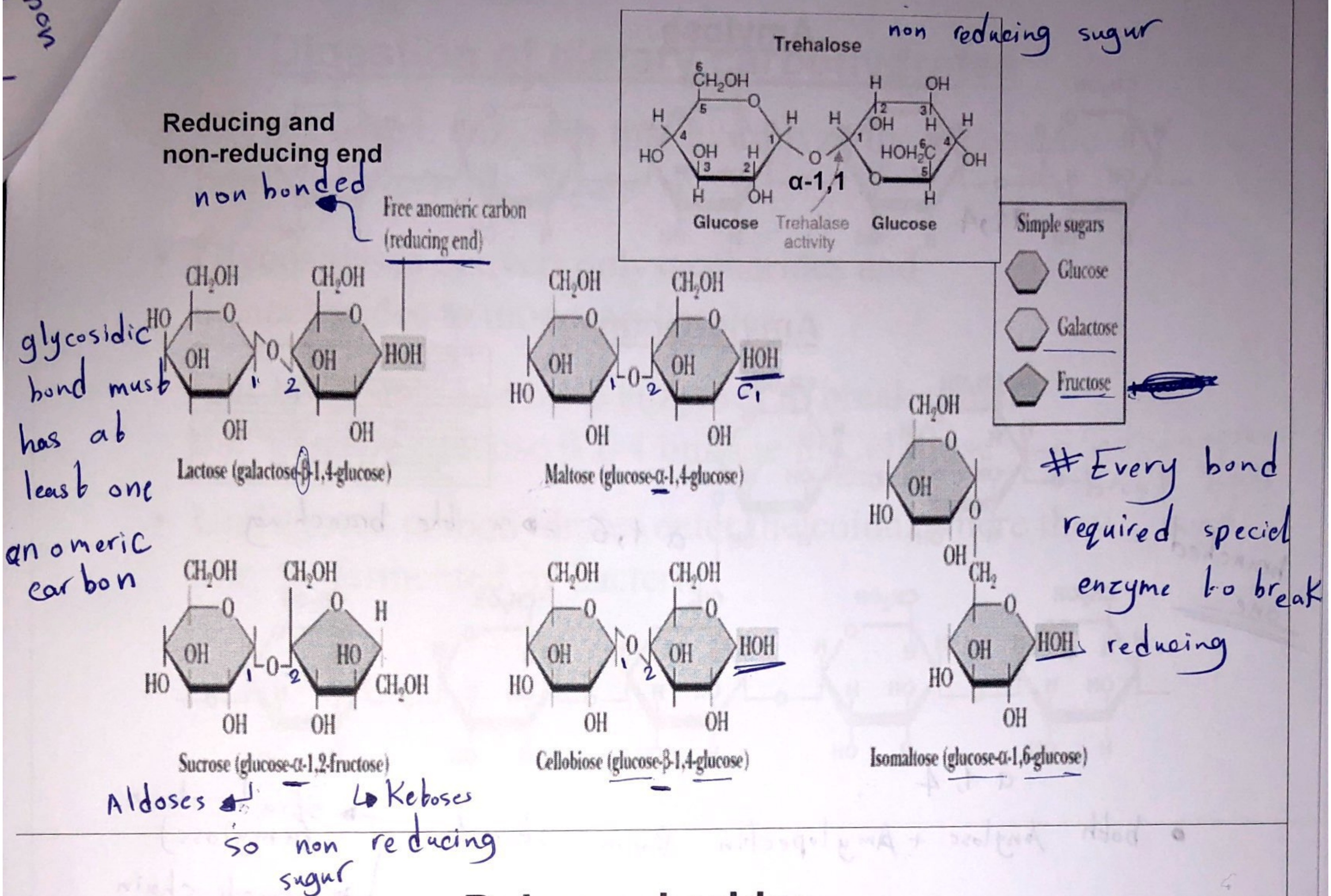
Reducing and non-reducing end



Polysaccharides

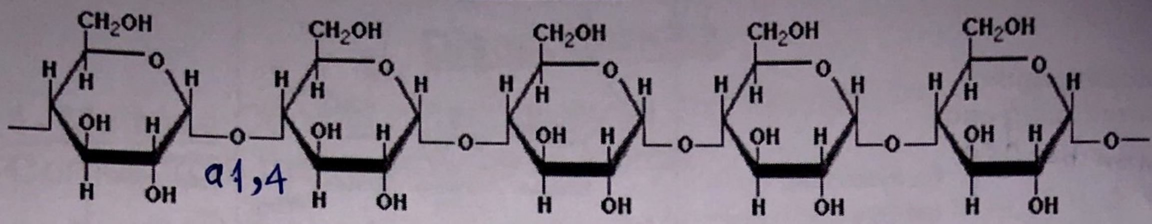
- **Starch** Starch represents the main type of digestible polysaccharides. Found in cereal grains (wheat, rice, corn, oats, and barley) and tubers such as potatoes.
- Starch is made up of :- glucose mainly

1- Amylose (about 20% of starch) strait chain of glucose which is linked by α-1,4 glycosidic bonds

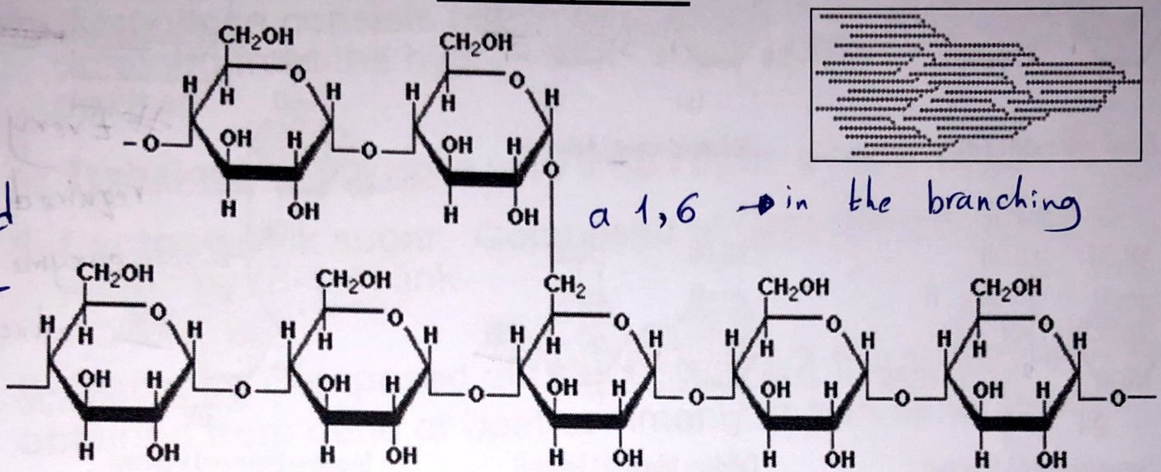
2- Amylopectin (about 80% of starch) (branched) the α-1,4 chains contain branches connected via α-1,6 glycosidic bonds

- **None starch polysaccharides are the main component of dietary fibers which include:** Cellulose, hemicellulose, pectin's and gum.

Amylose



Amylopectin



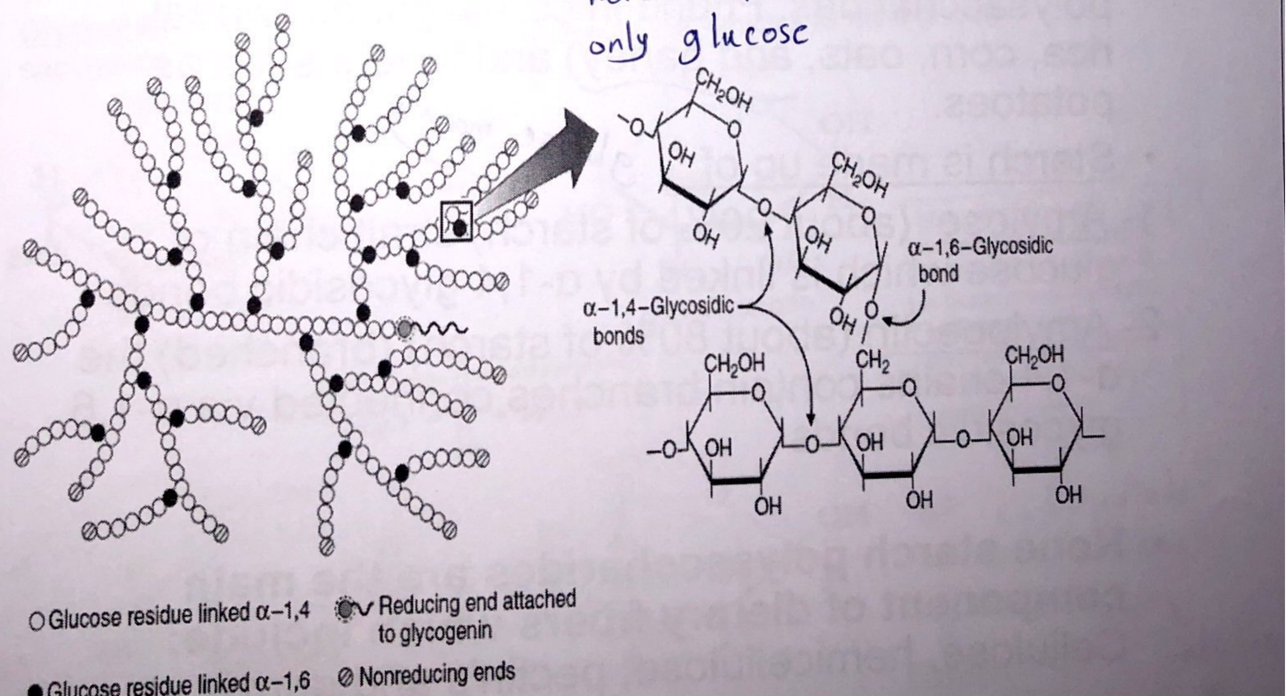
branched one

a 1, 4

- both Amylose + Amylopectin form starch → strait chain (amylose)
  → branch chain (Amylopectin)

Glycogen structure

made of only glucose

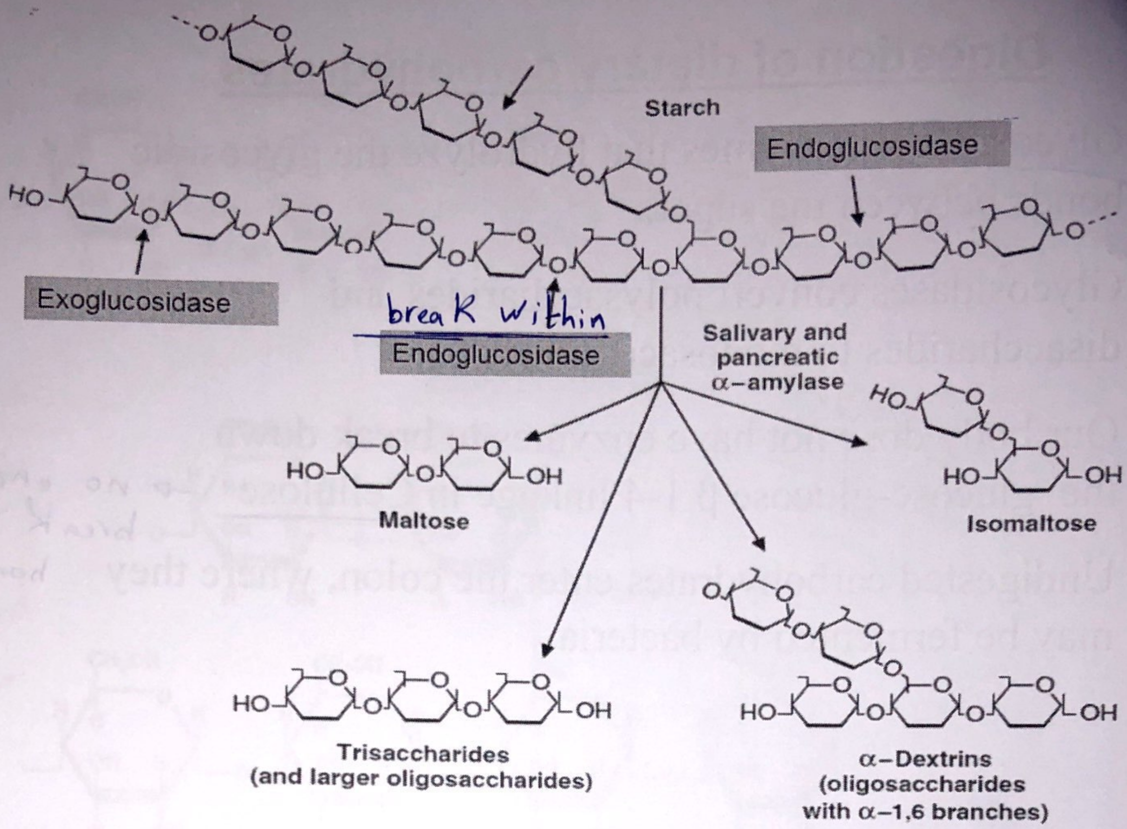


Digestion of dietary carbohydrates

- Glycosidases: enzymes that hydrolyze the glycosidic bonds between the sugars
- Glycosidases convert polysaccharides and disaccharides to monosaccharides
- Our body dose not have enzymes to break down the glucose-glucose β 1-4 linkage in Cellulose → no enzyme break this bond
- Undigested carbohydrates enter the colon, where they may be fermented by bacteria

- **A. Salivary α-amylase**
- The digestion of starch begins in the mouth.
- The salivary glands secrete approximately 1 liter of liquid per day into the mouth (pH 6.4 - 7) containing salivary α-amylase.
- α-Amylase is an endoglucosidase, which means that it hydrolyzes internal α-1,4 bonds between glucose residues at random intervals in the polysaccharide chains.
- Requires Cl^- ion for activation with an optimum pH of 6.7 قريبة لل ph تاعة اللعاب
- Digestion of starch and glycogen in the mouth gives maltose, isomaltose and α-dextrins
- In the stomach: Carbohydrate digestion stops temporarily, salivary α-amylase may be largely inactivated by the acidity of the stomach.

-If the enzyme start to break from last molcule → Exoglucosidase



- <u>Digestion in the Stomach</u>

- Gastric juice does not contain enzyme for carbohydrate digestion. due to high acidity

- Hydrochloric acid in the stomach may hydrolyze sucrose into glucose and fructose.

Digestion in Small Intestine

A. Pancreatic Secretions

- Secretions from the exocrine pancreas (approximately 1.5 L/day) enter the duodenum which contain

1- Bicarbonate (HCO_3^-), which neutralizes the acidic pH of stomach contents → increse the number of ph to creat aproper environment for enzymes

2- **Pancreatic α-amylase**. similar to salivary amylase

Pancreatic α-amylase (optimum pH=7.1) also activated by chloride ions, continues to hydrolyze the starches and glycogen, forming the disaccharide maltose, isomaltose, the trisaccharide maltotriose (three glucose molecules linked with α-1,4 glycosidic bonds), and oligosaccharides.

- These oligosaccharides, are usually 4-9 glucose units long linked by α 1-4 and contain one or more α-1,6 branches.
- α-Amylase has no activity toward sugar containing polymers other than glucose linked by α-1,4 bonds.

Digestion in Small Intestine

B. Disaccharidases of the intestinal brush-border membrane

1. Glucoamylase

- It has two catalytic sites with similar activities.
- Glucoamylase is an exoglucosidase that is specific for the α–1,4 bonds between glucose residues.
- It begins at the non-reducing end of saccharides
- The glucoamylase is heavily glycosylated with oligosaccharides that protect it from digestive proteases.
- α-amylase split of large polysaccharides molecule and thus supplying new substrate molecules for glucoamylase

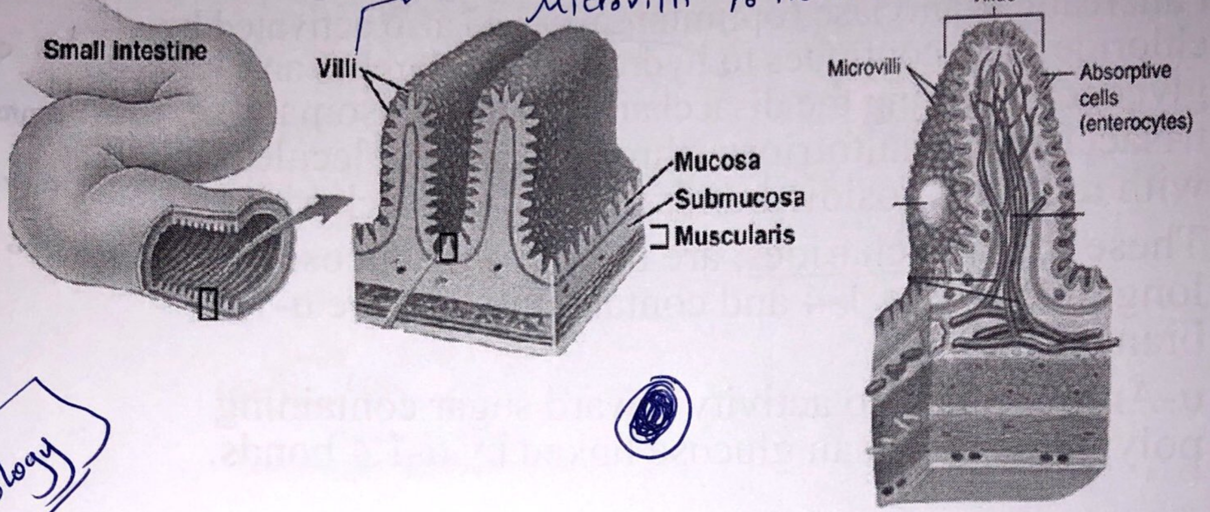
α-amylase of pancrease and saliva functional mainly on polyssacarides (starch) into di or tri ssacarides or short chain of oligossacarides

but glucoamylase breaks the short chain → di or trissacarides

Location of disaccharide complexes in intestinal villi

- The **villi** are finger like projections of the mucosa into the lumen of the small intestine.
- A villus has thousands of **microvilli.**
- Collectively, microvilli known as a "brush border".

has thaosands of Microvilli to increase the surface



cardiology

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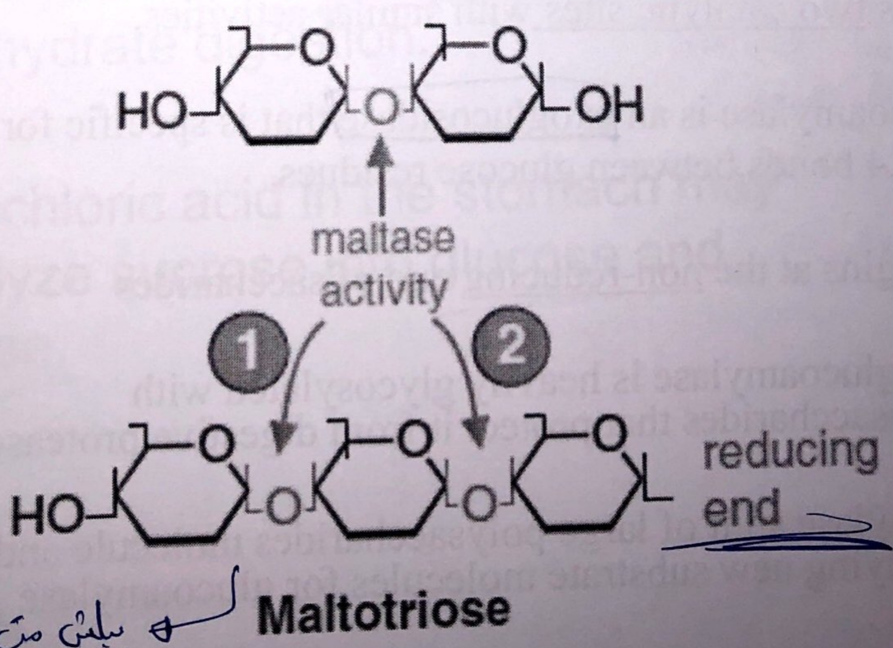
مراجعة

Glucoamylase activity. Glucoamylase is an α-1,4 exoglycosidase, which initiates cleavage at the nonreducing end of the sugar.



villi

2. Sucrase–isomaltase complex

- Sucrase–isomaltase has two catalytic sites that differs in substrate specificity from the other (Intestinal protease clips it into two separate subunits)

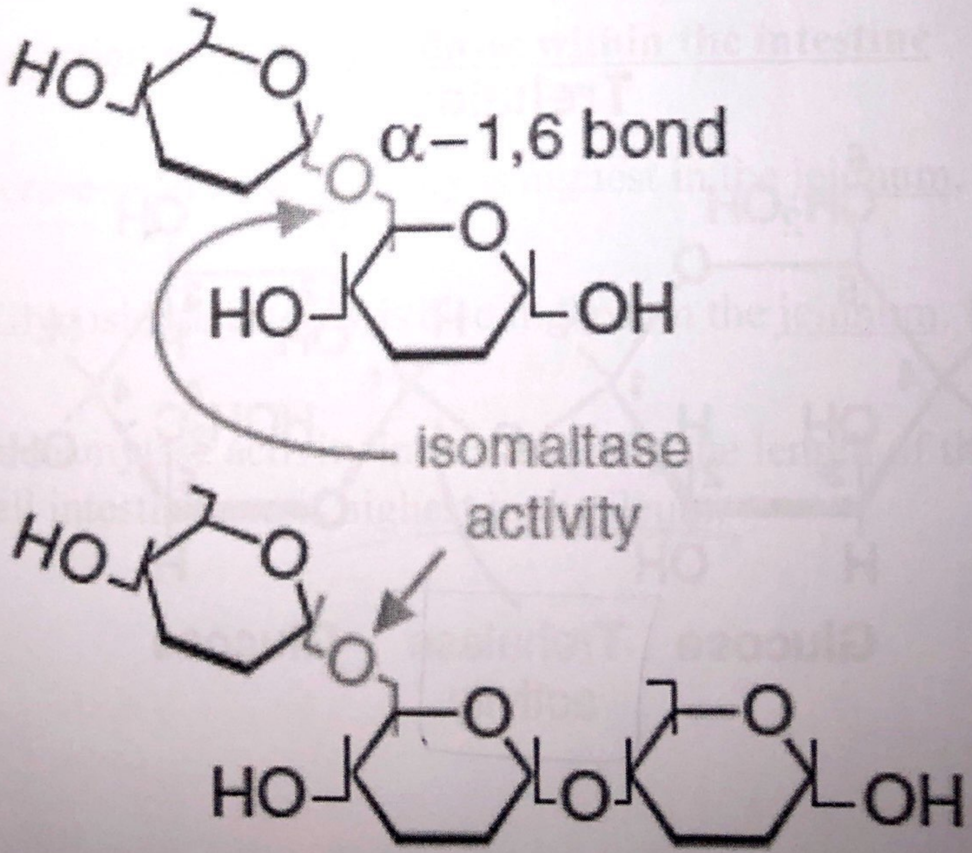
The two catalytic sites are:

A-) The sucrase–maltase site
= Nearly 100% of sucrose hydrolyze (glucose-α-1,2-fructose)
= Maltase activity. degradation

B-) The isomaltase–maltase site
= All α-1,6-glucose-glucose bonds
= Maltase activity.

80% of the maltase is by these complex (maltose: glucose α-1,4 glucose) activity of the small intestine. The remainder of the maltase activity is found in the glucoamylase complex.

20% breaked by glucoamylaze



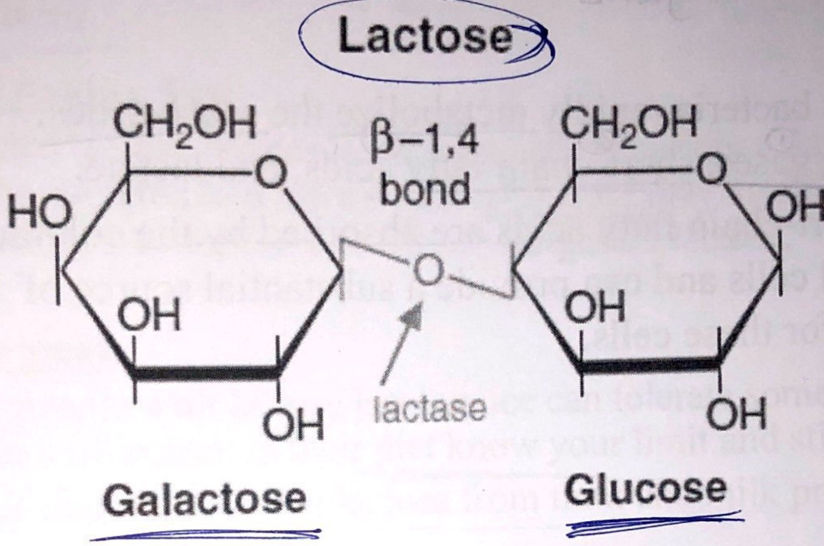
always we takes the function of ezyme by it's name.

4. β-glycosidase complex (lactase-glucosylceramidase) → lipids

- Has two catalytic sites

1- The lactase catalytic site hydrolyzes the β-bond connecting glucose and galactose in lactose (also splits the β-1,4 bond between some cellulose disaccharides).

2- The β-bond between glucose or galactose and hydrophobic residues ceramide in glycolipids



Location of disaccharidases within the intestine

A- Sucrase–isomaltase activity is highest in the jejunum,

B- β-Glycosidase activity is also highest in the jejunum.

C- Glucoamylase activity increases along the length of the small intestine and is highest in the ileum.

• Metabolism of Sugars by Colonic Bacteria

- Starches high in amylose, or less well hydrated (e.g., starch in dried beans), are resistant to digestion and enter the colon. undigested
- Colonic bacteria rapidly metabolize the saccharides, forming gases, short-chain fatty acids, and lactate.
- The short-chain fatty acids are absorbed by the colonic mucosal cells and can provide a substantial source of energy for these cells.

Lactose Intolerance

not normal (disease)

- The small intestine does not make enough of the enzyme lactase.
- The lactose that is not absorbed is converted by colonic bacteria to lactic acid, methane gas (CH4), and H_2 gas that result in: abdominal pain, gases, and diarrhea.

Lactase deficiency may be

(i) **Congenital**: complete deficiency of lactase enzyme since birth (rare).

(ii) **Acquired**: which occurs later on in life. which include:

a. Primary lactase deficiency develops over time and begins after about age 2 when the body begins to produce less lactase with a possible genetic link.

b. Secondary lactase deficiency results from injury to the small intestine, gastrointestinal diseases, including exposure to intestinal parasites.

How is lactose intolerance diagnosed?

1. **Hydrogen Breath Test.**

The person drinks a lactose-loaded beverage and then the breath is analysed at regular intervals to measure the amount of hydrogen. Normally, very little hydrogen is detectable in the breath, but undigested lactose produces high levels of hydrogen.

2. **Stool Acidity Test**

Undigested lactose creates lactic acid and other fatty acids that can be detected in a stool sample. Glucose may also be present in the stool as a result of undigested lactose.

Management:

1- Most people with lactose intolerance can tolerate some amount of lactose in their diet know your limit and stick to it.

2. Decreasing or removing lactose from milk and milk products.

- Glycemic index
- Not all complex carbohydrates are digested at the same rate within the intestine, and some carbohydrate sources lead to a near-immediate rise in blood glucose levels slowly raise blood glucose levels

- The glycemic index of a food is an indication of how rapidly blood glucose levels rise after consumption.

- Glucose has the highest glycemic indices (142) with white bread defined as an index of 100.
- The glycemic response to ingested foods depends not only on the glycemic index of the foods, but also on the fiber and fat content of the food, as well as its method of preparation.

Glycemic Index of Selected Foods, with Values Adjusted to White Bread of 100

Breads	normal
Whole wheat	100
Pumpernickel (whole grain rye)	88
Pasta	
Spaghetti, white, boiled	67
Cereal grains	
Barley (pearled)	36
Rice (instant, boiled 1 min)	65
Rice, polished (boiled 10–25 min)	81
Sweet corn	80
Breakfast cereals	
All bran	74
Cornflakes	121
Muesli	96
Cookies	
Oatmeal	78
Plain water crackers	100
Root vegetables	
Potatoes (instant)	120
Potato (new, white, boiled)	80
Potato chips	77
Yam	74

needs more time to digest (Rice, polished)

Legumes	
Baked beans (canned)	70
Butter beans	46
Garden peas (frozen)	85
Kidney beans (dried)	43
Kidney beans (canned)	74
Peanuts	15
Fruit	
Apple	52
Apple juice	45
Orange	59
Raisins	93
Sugars	
Fructose	27
Glucose	142
Lactose	57
Sucrose	83
Dairy Products	
Ice cream	69
Whole milk	44
Skim milk	46
Yogurt	52

because it need least much time to digest (Glucose)

• مهمة عشان نعرف كم بده وقت لحتى السكر يصل الدم.

hypoglys = لما يتعرض تعطي المريض glucose drink لأنه بعمل sudden increase في مستوى السكر.

Absorption of sugars

Two mechanisms are responsible for absorption of monosaccharides: active transport and facilitated diffusion.

Features	Facilitated diffusion	Active transport
Concentration gradient	Down the concentration gradient from high to low.	Against a concentration gradient from low to high
Energy expenditure	none	Energy expenditure is in the form of ATP
Carrier protein/ transporter	required	required
Speed	Fast	Fastest mode
Monosaccharides	**Fructose and mannose**	**Glucose and Galactose**

Note: Glucose and other monosaccharide's are polar molecule. It cannot pass through lipid bilayer of cell therefore passive diffusion doesn't apply for sugar.

Glycemic Index of Selected Foods, with Values Adjusted to White Bread of 100

Breads	
Whole wheat	100 (normal)
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needs more time to digest (rice, polished)

because it need least much time to digest (glucose)

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Absorption of sugars

Two mechanisms are responsible for absorption of monosaccharides: active transport and facilitated diffusion.

(Na) ion dependent

Features	Facilitated diffusion	Active transport
Concentration gradient	Down (with) the concentration gradient from high to low.	Against (opposite) a concentration gradient from low to high
Energy expenditure	none	Energy expenditure is in the form of ATP
Carrier protein/ transporter	required	required
Speed	Fast	Fastest mode
Monosaccharides	**Fructose and mannose**	**Glucose and Galactose**

Note: Glucose and other monosaccharide's are polar molecule. It cannot pass through (can't pass alone) lipid bilayer of cell therefore passive diffusion doesn't apply for sugar.

الامعاء لا تمتص الا بصورة monossacaride اما oligo + poly تهضم الى mono

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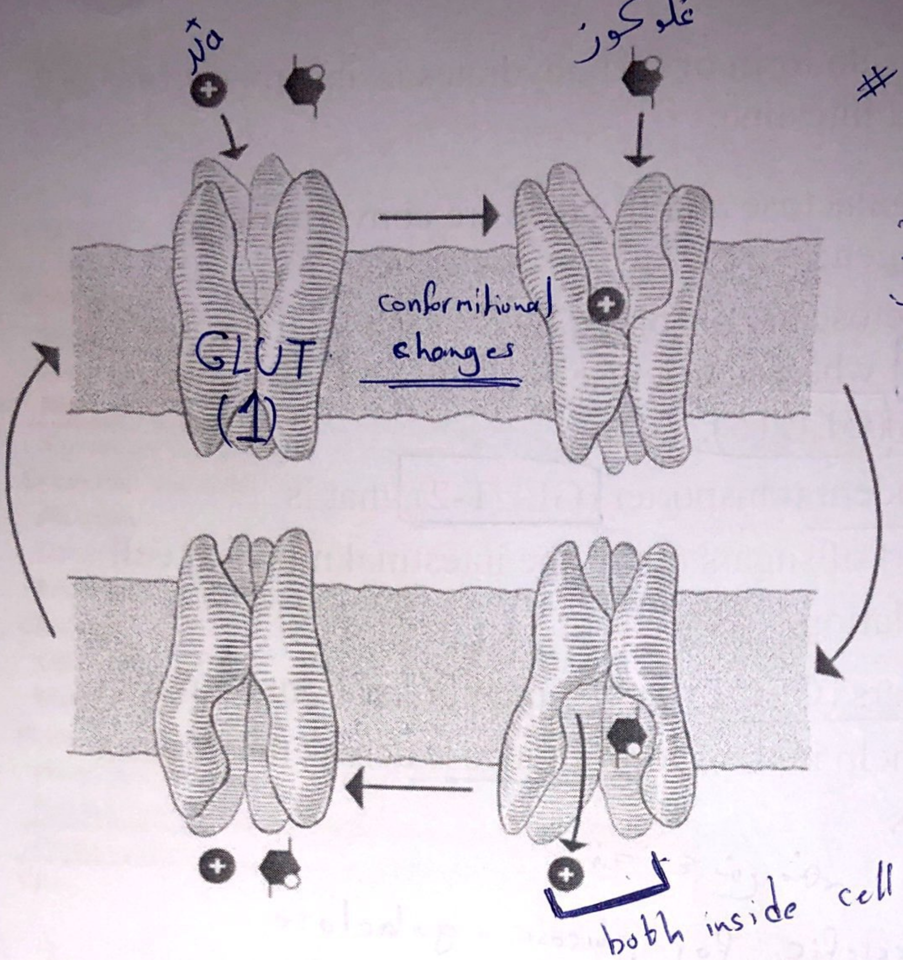
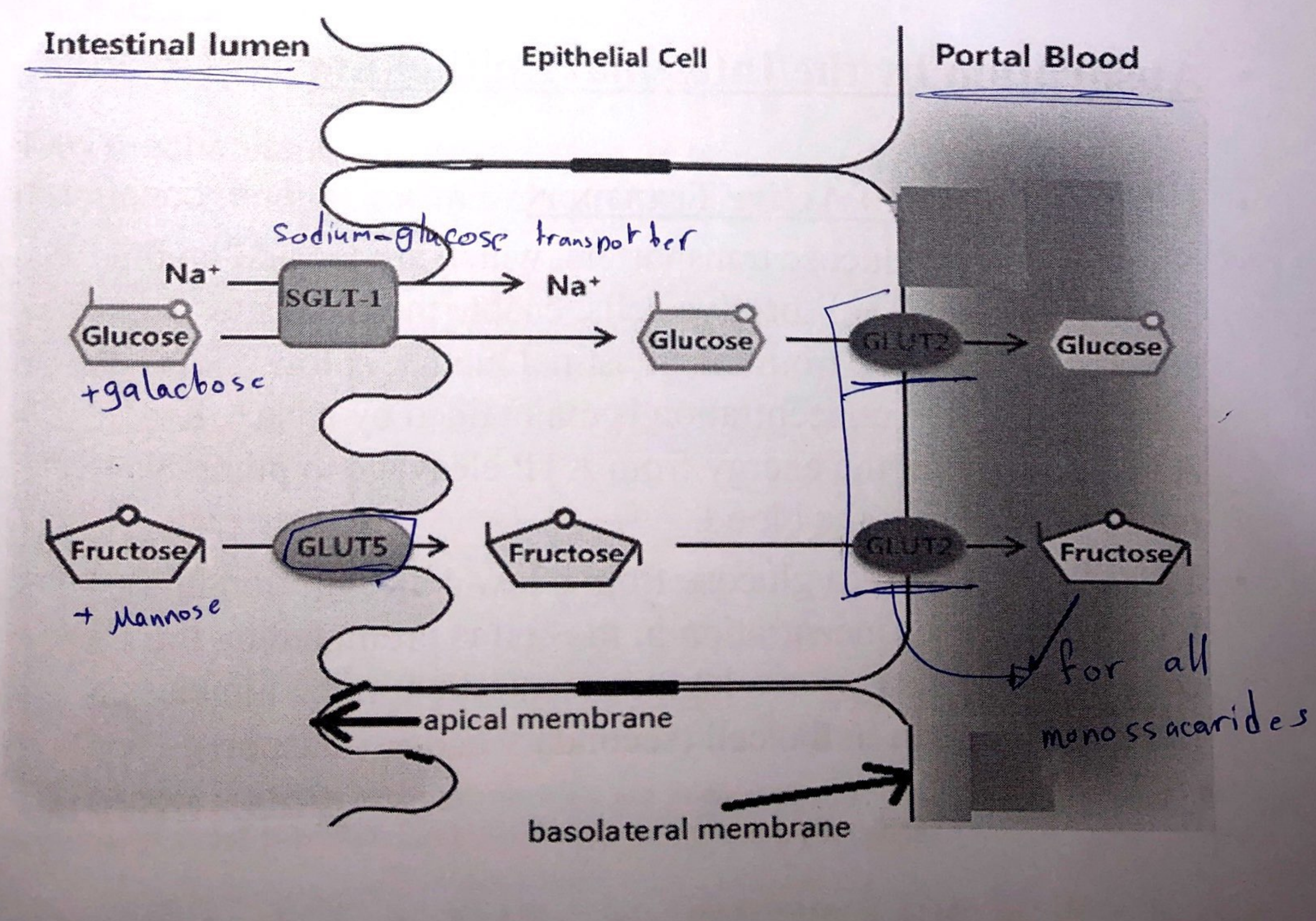


Na+ binds to the cotransporter, which results in a conformational change that permits glucose to bind to the glucose-binding site.
The cotransporter undergoes a new conformational shift, placing Na+ and glucose near the inner surface of the membrane.



- **2. Facilitative glucose transporters (Na⁺ independent transporter)**
- Glucose moves via the facilitative transporters from the high concentration inside the cell to the lower concentration in the blood without the need of energy. In addition to the Na+-dependent glucose transporters, facilitative transporters for glucose also exist on the luminal side of the absorptive cells.
- The various types of facilitative glucose transporters found in the plasma membranes of cells referred to as GLUT 1 to GLUT 14.
- One common structural theme to these proteins is that they all contain 12 membrane-spanning domains.

- Because glucose leaves the intestine via the hepatic portal vein, the liver is the first tissue it passes through. The liver extracts a portion of this glucose from the blood.

they are insulin dependent

Dietary fiber

undigested polysaccharides

- Are components of food cannot be digested by human digestive enzymes they are mainly polysaccharide derivatives and lignan **(Noncarbohydrate, polymeric derivatives of phenylpropane).**
- There are several kinds of dietary fiber.
- **Water insoluble fiber:** Cellulose, lignin and hemicellulose are materials that stimulate regular function of the colon.

function

- **Water-soluble fiber** Pectins and gums are materials that form viscous gel-like suspensions in the digestive system slowing the rate of absorption of many nutrients, including carbohydrates, and lowering serum cholesterol in many cases.

mainly small intestine

getting energy

Benefits of fibers

1- Soluble fibers are fermented by bacteria and produce small chain of FA. 10% of our total calories we get from compounds produced by bacterial digestion of substances in our digestive tract.

2- Fiber is thought to "soften" the stool, thereby reducing pressure on the colonic wall and enhancing expulsion of feces this specificlly beneficial effect to diverticular disease, in which sacs or pouches may develop in the colon because of a weakening of the muscle and submucosal structures.

because the fiber keep water in it

لما البراز يكون قاسي بيشكل ضغط على colon ال

3- Disease prevention for example:

pectins=may lower blood cholesterol levels by binding bile acids
=beneficial for diabetes by slowing the rate of absorption of simple sugars and preventing high blood glucose levels after meals. → slow degradation of fat and their absorption is the same

β-glucan (obtained from oats) reduce cholesterol levels through a reduction in bile acid degradation in the intestine.

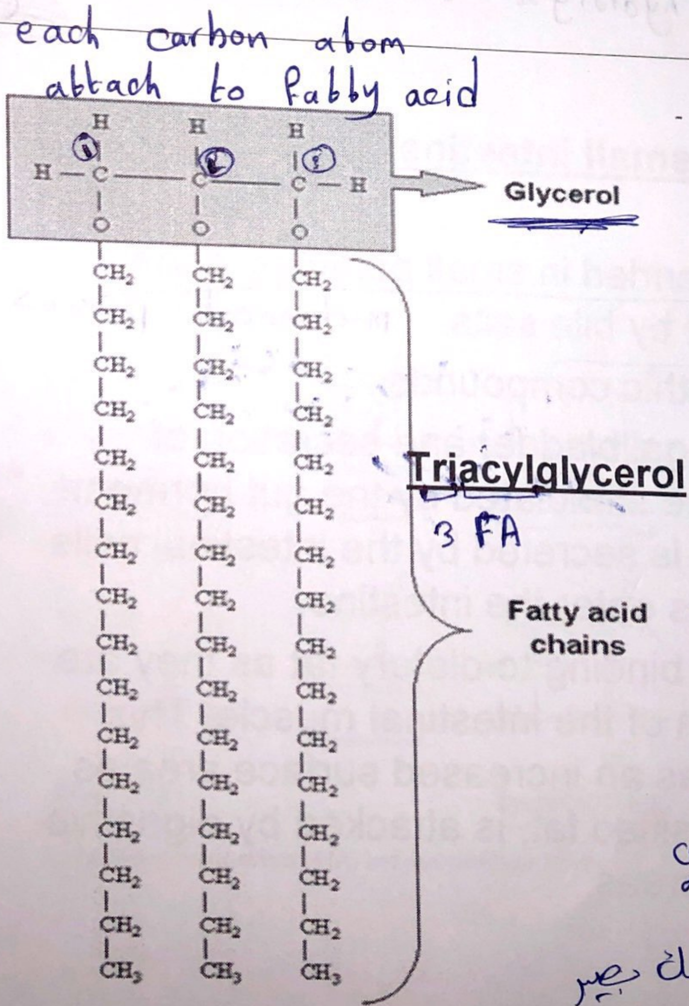
← مهم لمرضى السكري ← لمنع ال sudden increase in suger + slow absorption rate of suger

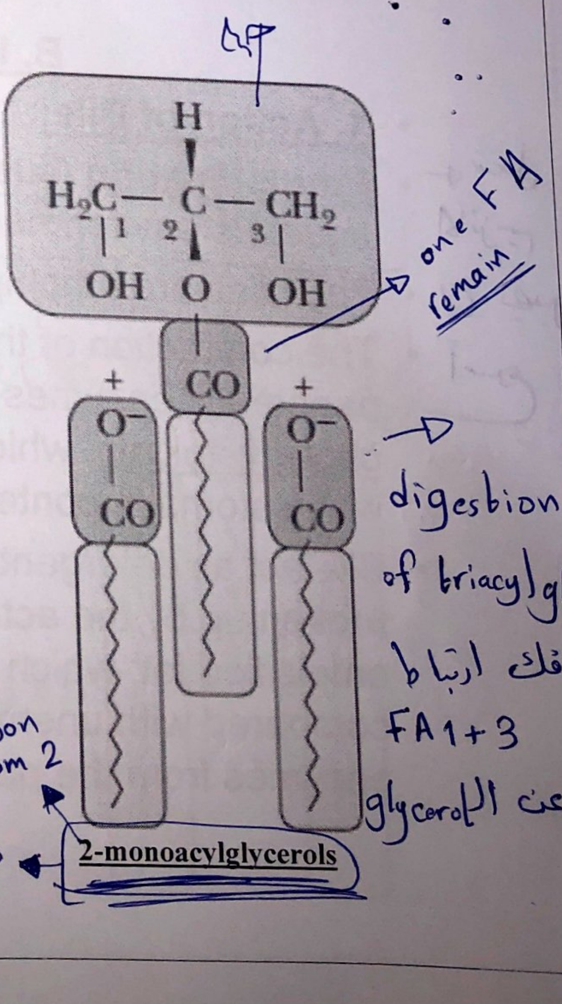
2. Fats

- Functions: 1- Cell structure, 2- fuel storage, 3- hormone (all steroid hormones from cholesterol)
- Essential fatty acids and nonessential fatty acids
- Nonessential fatty acids can be synthesized in our body essential fatty acids we get them from food (We can't synthesize it.)
- The essential fatty acids α-linoleic and α-linolenic acid are supplied by dietary plant oils.
- More than 300 different **fatty acids** are known however only 20–25 of them are widely distributed in **nature**

Triacylglycerols

- Triacylglycerols are the major fat in the human diet because they are the major storage lipid in the plants and animals that constitute our food supply.
- The remainder of the dietary lipids consists primarily of cholesterol, phospholipids, and free fatty acids.
- Triacylglycerols contain a glycerol backbone to which three fatty acids are esterified.
- The main route for digestion of triacylglycerols involves hydrolysis to fatty acids and 2-monoacylglycerols in the lumen of the intestine. However, the route depends to some extent on the chain length of the fatty acids.





Digestion of fat

A. Mouth and stomach

Limited digestion of lipids occurs in the mouth **and stomach because of the low solubility.**

1. Lingual lipase produced by cells at the back of the tongue
2. Gastric lipase produced by stomach

- Same function for both enzymes: they hydrolyze short- and medium-chain fatty acids triacylglycerols (containing 12 or fewer carbon atoms).
- Lingual and gastric lipases hydrolyse 25–30% of ingested triglycerides (n-3) into diglycerides and free fatty acids.

only hydrolyse one FA in C3

B. In small intestine

- **1. Action of Bile:**
- **Emulsification** (suspended in small particles in the aqueous environment) by bile salts. mechane cal prosses
- The biles are amphipathic compounds
- The contraction of the gallbladder and secretion of pancreatic enzymes are stimulated by the gut hormone cholecystokinin, which is secreted by the intestinal cells when stomach contents enter the intestine.
- Bile act as detergents, binding to dietary fat as they are broken up by the action of the intestinal muscle. This emulsified fat, which has an increased surface area as compared with unemulsified fat, is attacked by digestive enzymes from the pancreas.

ح شغل الانزيم ح يصير أسرع

2. Action of Pancreatic secretion

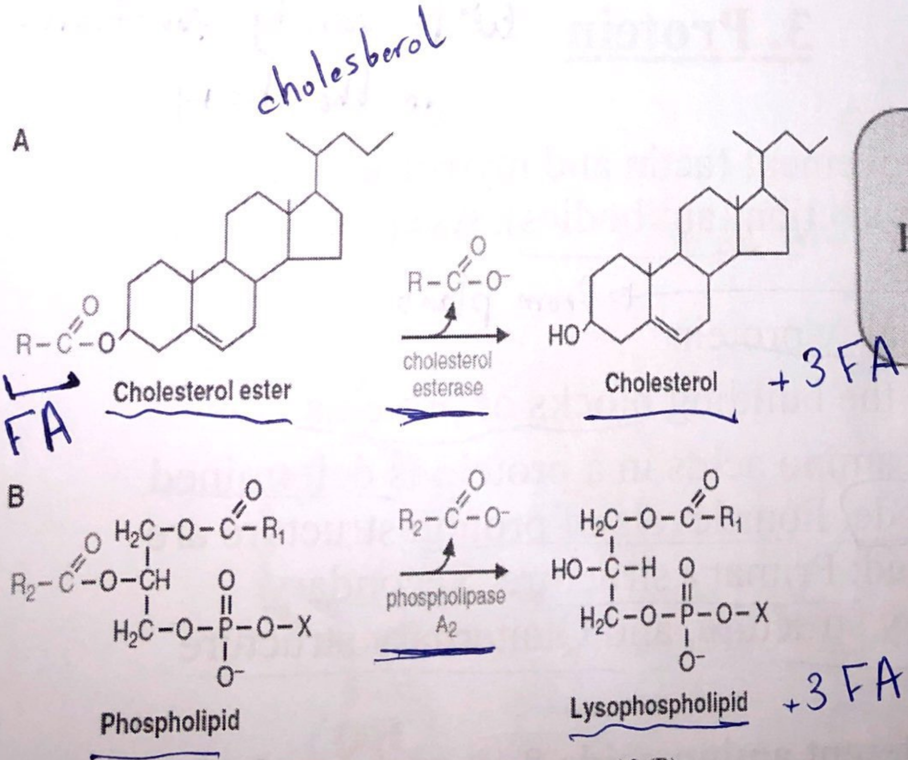
A- Bicarbonate (hormone secretin released from the intestine when acid enters the duodenum) raises the pH of the contents of the intestinal lumen into a range (pH ~ 6.5).

B-Lipase digests dietary triacylglycerols producing 2 free fatty acids and 2-monoacylglycerol

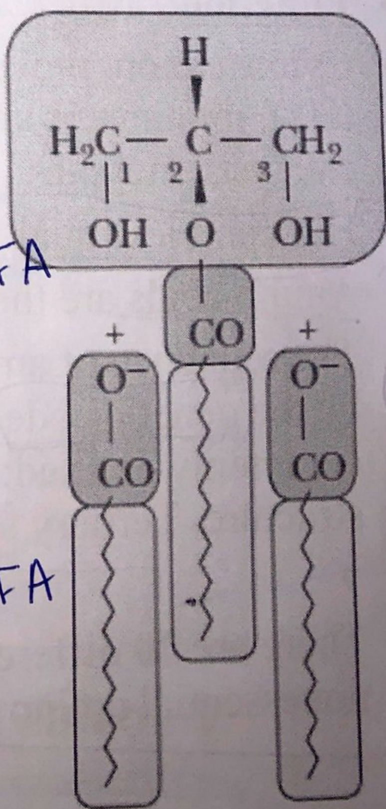
C- Colipase it binds to the dietary fat and to the lipase, thereby increasing lipase activity.

D- Esterases remove fatty acids from compounds such as cholesterol esters (The ester bond is formed between the carboxylate group of a fatty acid and the hydroxyl group of cholesterol.)

E- phospholipase A2 digests phospholipids to a free fatty acid and a lysophospholipid



Action of pancreatic esterases (A) and phospholipase A2 (B).



- **Absorption of digested fats**
- Short- and medium-chain fatty acids (C4 to C12) are absorbed directly into intestinal epithelial cells, they enter the portal blood and are transported to the liver bound to serum albumin. hydrophopic تحتاج ناقل لانها
- The digested fatty acids and 2-monoacylglycerols are resynthesized into triacylglycerols in intestinal epithelial cells, then packaged in lipoprotein particles chylomicrons because they are insoluble in water, and secreted by way of the lymph into the blood. اذا دخلت بدون ناقل الى الدم تعمل blockage

تترجع تكون بسبب intestinal epithilium cells

synthesize by

- If triacylglycerols directly entered the blood, they would come together, impeding blood flow.
- Chylomicrons transport lipids to adipose tissue, heart, and skeletal muscle. The fatty acids of the chylomicron triacylglycerols are stored mainly as triacylglycerols in adipose cells.

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3. Protein

Wide variety functions in the body

- **Function**:
- Cytoskeleton, movement (actin and myosin), transport (Hb), immune protection (antibodies), receptors and as catalysts enzymes
- High and low quality protein

from animals (they contain all essential Amino acid) — from plants

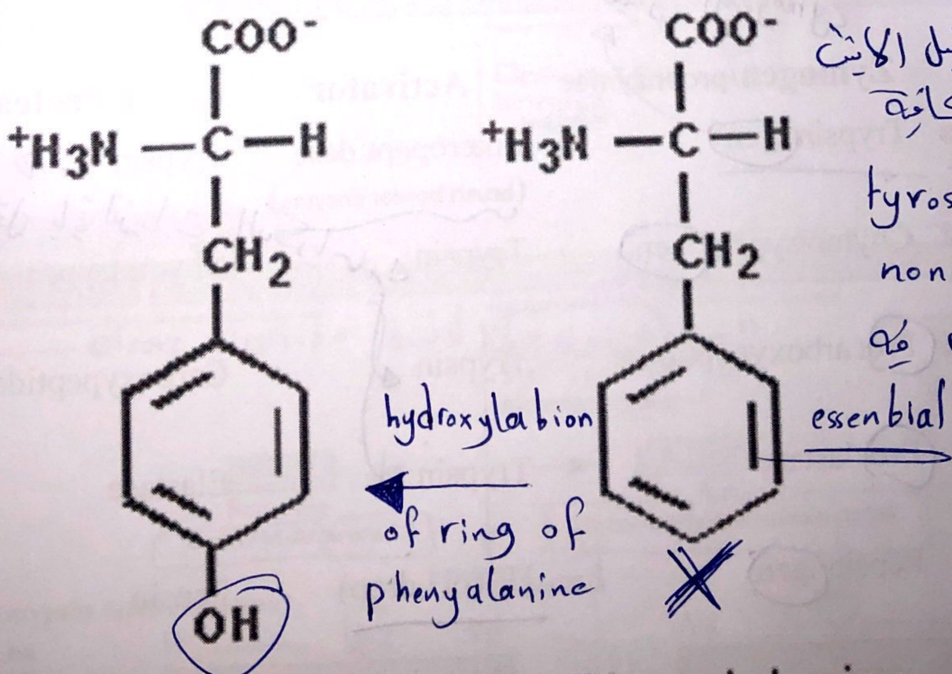
- Amino acids are the building blocks of proteins.
- The sequence of amino acids in a protein is determined by the genetic code. Four levels of protein structure are commonly defined: Primary structure, Secondary structure, Tertiary structure, and Quaternary structure
- There are **20** different amino acids **8** essential and **12** nonessential amino acids that form human proteins.

Conditionally essential amino acids

normally they are non essential but become essential under some conditions

- Children and pregnant women have a high rate of protein synthesis to support growth, and require more of arginine and histidine than their body synthesise.

- Tyrosine is also considered conditionally essential. Tyrosine is synthesized from phenylalanine (by hydroxylation of phenylalanine), and it is required in the diet if phenylalanine intake is inadequate, or if an individual is congenitally deficient in an enzyme required to convert phenylalanine to tyrosine (the congenital disease phenylketonuria).



Tyrosine

Phenylalanine

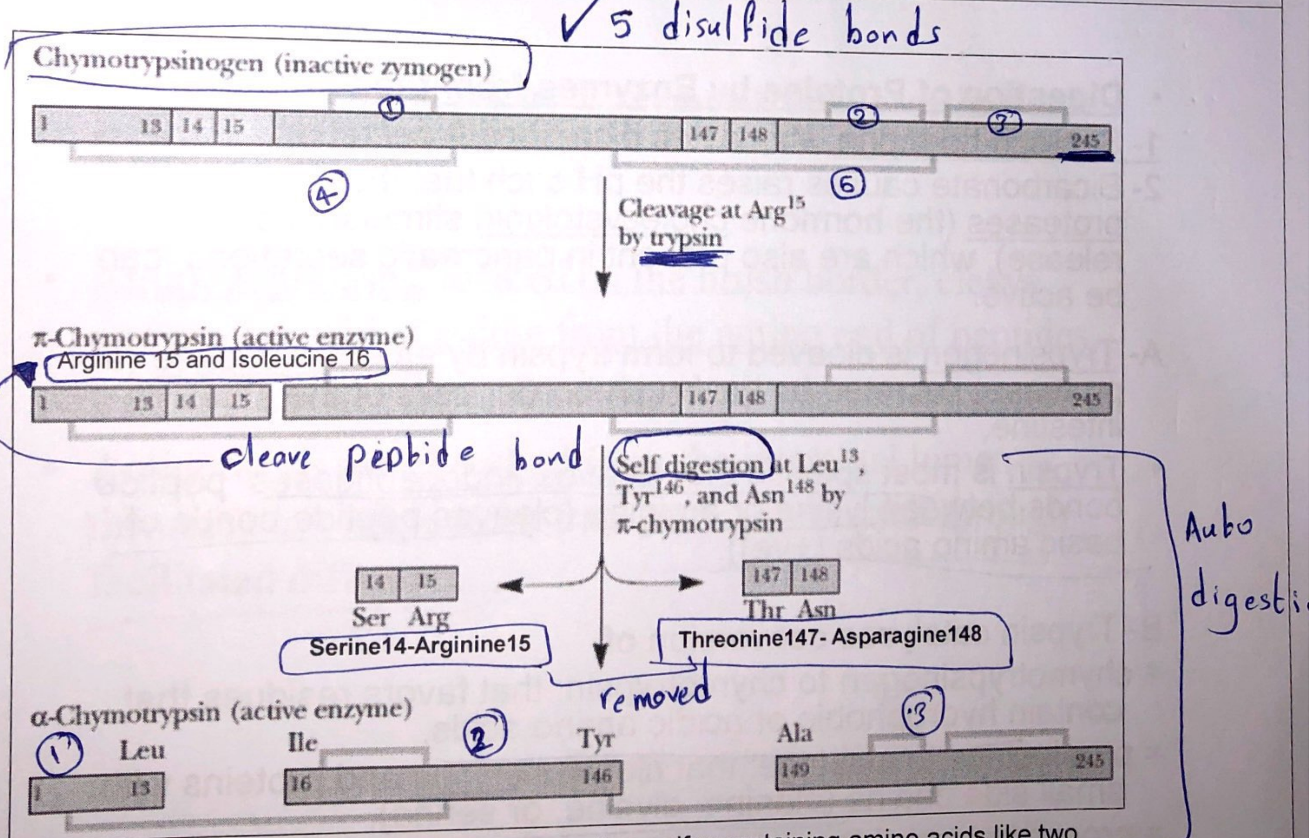
لما يكون الفينيل الالنين في كميات كافية يكون tyrosine nonessential لما اذا كان فيه نقص يصير essential proteases → break down the proteins, very active and powerfull (If it work all the time it will digest our body) → so keep it inactive only if needed

- **Zymogens**
- Inactive enzymes precursors are called **zymogens** or **proenzymes**,
- It only acquire full activity upon specific proteolytic cleavage of one or several of their peptide bonds.
- Zymogen activation by specific proteolysis is an irreversible process.
- Important to switch on processes at the appropriate time and place
- The synthesis of zymogens as inactive precursors prevents them from cleaving proteins prematurely at their sites of synthesis or secretion.

لتمييز الـzymogen

Origin	Zymogen/proenzymes	Activator	Active Protease
Pancreas	Trypsinogen	Enteropeptidase (brush border enzyme)	Trypsin → بس يتنشط ينسحب ويفعّل باقي انزيمات البنكرياس
Pancreas	Chymotrypsinogen	Trypsin	Chymotrypsin
Pancreas	Procarboxypeptidase	Trypsin	Carboxypeptidase
Pancreas	Proelastase	Trypsin	Elastase
Stomach	Pepsinogen	H^+ (pH drop)	Pepsin

- **Activation of chymotrypsinogen**
- **Chymotrypsinogen** is a 245-aa cross-linked by five disulfide bonds.
- Chymotrypsinogen is converted to an enzymatically active form called π-chymotrypsin when trypsin cleaves the peptide bond joining Arginine 15 and Isoleucine 16.
- The enzymatically active π-chymotrypsin acts upon other π-chymotrypsin molecules, removing two dipeptides, Serine14-Arginine15 and Threonine147- Asparagine148.
- The end product of this processing pathway is the mature protease **α-chymotrypsin,** in which the three peptide chains.
- A (residues 1 through 13), B (residues 16 through 146), and C (residues 149 through 245), remain together because they are linked by two disulfide bonds, one from A to B, and one from B to C.



A **disulfide bond** is a covalent **bond** between two sulfur containing amino acids like two cysteine molecules

3 polypeptide separated join together by disulfide bond.

- **Digestion of Proteins in the Stomach**

 # Gastrin hormone (gastric mucosa) stimulates the secretion

A- Pepsinogen by the chief cells of the gastric glands.

B- Hydrochloric acid by the parietal cells

A- **Pepsinogen** is activated to its active form **pepsin** by acidic gastric juice (pH 1.0 to 2.5) that alters the conformation of so that it can cleave itself, producing the active pepsin.

- **Pepsin** acts as an endopeptidase, cleaving peptide bonds at various points within the protein chain.

B- Stomach acidity: causes dietary proteins denaturation, this serves to inactivate the proteins and partially unfolds them such that they are better substrates for proteases.

- Smaller peptides and some free amino acids are produced.

- **Digestion of Proteins by Enzymes from the Pancreas**

1- Secretin hormone: stimulates bicarbonate secretion

2- Bicarbonate causes raises the pH such that the pancreatic proteases (the hormone cholecystokinin stimulate its release), which are also present in pancreatic secretions, can be active.

A- Trypsinogen is cleaved to form trypsin by enteropeptidase (a protease) secreted by the brush-border cells of the small intestine.

- Trypsin is most specific that cleaves endopeptidases peptide bonds between lysine or arginine (cleaves peptide bonds of basic amino acids (+ve)).

B- Trypsin catalyzes conversion of

= chymotrypsinogen to chymotrypsin: that favors residues that contain hydrophobic or acidic amino acids.

= proelastase to elastase: that cleaves elastin and proteins with small side chains (alanine, glycine, or serine).

= procarboxypeptidases to carboxypeptidases.