Digestive System

University of Jordan

Faculty of Medicine

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Medical Committee
The University of Jordan

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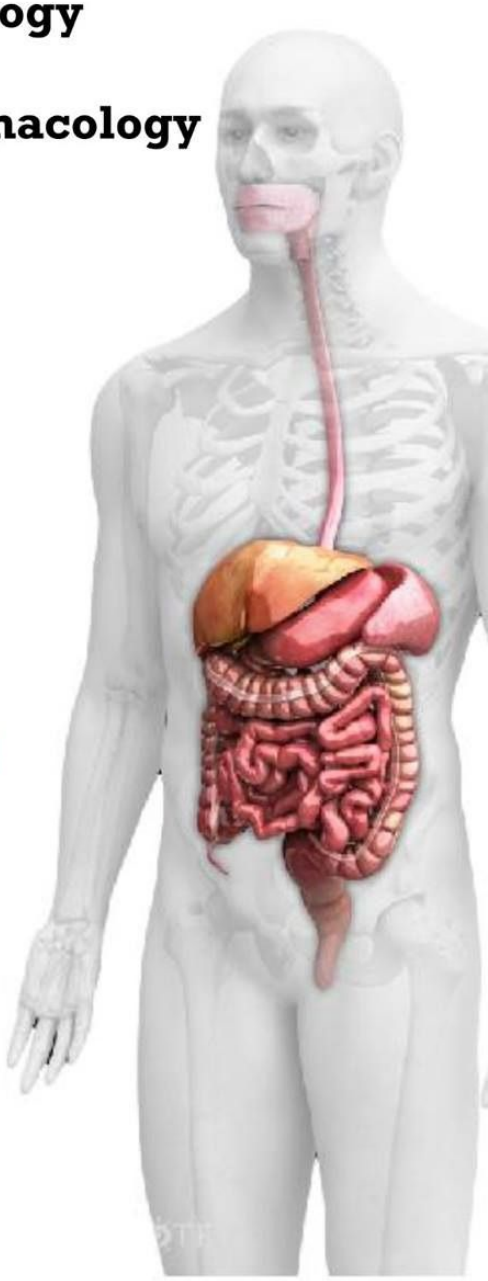

Sheet #: 7

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Secretion & Digestion

Secreatins of Liver - Bile Acids

Through the last lecture, we've started talking about the liver' secretions;

- The BILE which is composed of different bile salts, water, electrolytes, cholesterol, and phospholipids.
- Also the liver secretes BILIRUBIN which is a product of catabolism of hemoglobin.

Here, also remember the functional unit of the liver which is the hepatic lobule, a hexagonal shaped lobule with some branches of the portal vein at its edges and central veins at the center that will collect the blood and transfer it to the systemic circulation.
The blood actually travels from these peripherals to the center through sinusoids.

→ Each hepatocyte has one pole facing the blood and another one facing the bile canaliculii, so at any time, the hepatocyte can also transfer anything from blood to the canaliculii then to a network of ducts to be secreted finally with bile.
[You know, these ducts end up in two main ducts, Left & Right, then they unite and become the common bile duct. Where will the common duct go? It joins the duct that's coming from the pancreas before reaching duodenum.]

- That bile, before reaching duodenum, can be directed toward the known vesicular organ: the GALLBLADDER.
It reaches the gallbladder due to pressure difference, how? The gallbladder is a vesicular muscular organ that can contract and relax. Once it relaxes, the high pressure in the ducts will push the bile toward it.

Let's have some notes about **Bile Salts;**

- They are important in the processes of digestion and absorption.
- They are formed initially as bile acids from cholesterol molecules, then they're conjugated with glycine or taurine amino acids -at the level of hepatocytes.
- What happens to the bile after reaching the gallbladder? REABSORPTION of water and electrolytes occurs, resulting in more concentrated constituents in the salts about 5-20 times in gallbladder.
- The release of Bile from the gallbladder is controlled, How?

The muscles of the wall of the gallbladder contract, then the concentrated bile will be going in the ducts then to the duodenum.
The Contraction is controlled by:
1- Parasympathetic activation.
2- Hormonally by some enzymes, And MAINLY the Cholecystokinin –**CCK**, it's the only hormone that is acting directly and causing contractions of the gallbladder.
[CCK is released when we have high fat contents in the chyme; **Fats** stimulate the release of CCK → release of **Bile acids and salts** because they help in fats' emulsification and absorption.]

➔ Another hormone that shares in the release is: **Secretin**; it controls the secretions of ductal cells (the lining cells of the ducts of biliary trees), and stimulates the release of water and electrolytes.

The Fate of Bile Salts

Once they complete their function in the small intestine, most of them are reabsorbed and collected by the portal vein → to liver cells again → re-secretion. #RECYCLING
But in every cycle (meal), we are losing about 20% of the salts, they are not reabsorbed, but you are recovering about 80% of these salts.

Then? We replace the lost amount by DE-NOVO synthesis of new bile salts. (new synthesis).
- That circulation of bile salts between intestines to gallbladder then again to the intestines is called → the Enterohepatic circulation of bile salts.

- In the **intestine**, some **modifications** take place, like converting the cholic acid to deoxycholic acid, and converting Chenodeoxycholic acid to lithocholic acid.

Digestion & Absorption

General notes:

- NO Absorption takes place in the esophagus; the food goes very fast through it.
- The **Small Intestine** is the specialized organ for **Absorption**.
  - High surface area.
  - Certain enzymes at the mucosa (important for continuing the process of digestion).

- Most Nutrients are absorbed at the upper part of the intestine; before reaching the ileum.
- The lower part of the intestine is responsible for removal of fluids.
- Some absorption occurs at the level of colon for final fluids' removal.

➔ 85% of the reabsorption occurs in the small intestine, while only 15% in the colon.

But, what makes the small intestine specialized for absorbing different materials?
It's folded, with papillary-like structures (Villi) on the top of each fold.

- Each villus is highly **vascularized (has a lot of capillaries)**; this aids in the absorption of nutrients.
- **Lymphatic vessels** (central lacteals) in the center of each villus; these vessels help in absorption of lipids.
- The cells that are lining the villus (Absorptive cells) have folded luminal membranes to form a **brush border** (microvilli). Absorptive cells also synthesize some enzymes at the level of brush border, these enzymes are called: "**Brush Border Enzymes**".

e.g: Enterokinase enzyme, a brush-border enzyme, helps in the activation of Trypsinogyn.

➔ All this increases the surface area around 600 times; so if you're taking 1cm^2 of the upper part of small intestines, it, functional wise, resembles 600 cm^2 in absorption.

تقول الأسطورة أن من أفضل الأشياء في حياة طالب الطب بعد محاضرة ال 10 هي صفحة فارغة في وسط شيت (:

Digestion Of Carbohydrates

- We are ingesting carbohydrates in the form of:
  - Starch
  - Sucrose (fruit)
  - Lactose (milk products)
  - Cellulose [pay attention, we're talking about ingestion not digestion]
  -
- Starch → Polymer of glucose residues connected together by (alpha,1-4) glycosidic bonds. And at the branching points, there are (alpha,1-6) bonds.

- One important enzyme that's involved in the digestion of carbohydrates is the **Amaylase.**
  - Amaylase is secreted first by salivary gland' cells to the oral cavity, but the optimal activity for this enzyme needs an alkaline pH; that's why this enzyme in not active when it reaches the acidic stomach with the food.
  - Once we have emptyed the contents into the duodenum, the enzyme can continue digestion, so it's re-released from the pancreas to the duodenum when the chyme leaves to there too, and it can function well for the higher pH in the intestine.
  - Amylase, once released, starts digestion of starch (not sucrose or lactose) and resulting of dimers (maltose) and trimers of glucose (Dextrin; 2 glucoses with a third one at the branching point)

- Now, in the intestine, we have sucrose/lactose/maltose/dextrin, they are not absorbable and they need more digestion by some certain brush-border enzymes: sucrase/lactase/maltase/dextrinase, respectively. After that we have all these molecules as monomers.

- Some disorders result in **defectaive lactase** enzyme; this results in decreased absorption of lactose → the lactose will attract more water → irritation in small intestines and increasing motility, and we'll be having a case of **osmotic diarrhea**.

- This (Mal-absorption and mal-absorption) can happen also transiently with infants who had experienced any type of colitis or inflammation in the GI followed by shedding of cells. The shedding is followed by fast replacement of new cells but these new cells lake the lactase enzyme. Then? Diarrhea continues with those infants, but the main problem is that the infant depends exclusively on milk, and that's why we need to give them "Lactose-free milk" for a period of time (2weeks-1month), until their intestines re-function normally.

- Go back to the last points, after degrading the dimers to monomers, the monomers are absorbed by enterocytes. One important monomer: Glucose.

- **How different monomers are transported to cells?**
  - **Glucose**: Sodium-dependent glucose carriers → Secondary active co-transport mechanism.
    At the basolateral membranes of cells, we have Na^+/K^+ pumps which are pumping Na^+ all the time out to the interstitial fluid, maintain low Na^+ concentration inside the cells; and this favors the transport of glucose.
  - **Galactose**: Sodium-dependent carriers also, but different ones than those for glucose.
  - **Fructose**: Sodium-Independent carriers → Passive Facilitated transport.
    It's transported from the area of high concentrations (lumen of intestine) to the low concentrations inside of cells.

- Then everything is removed at the basolateral membranes by carriers that are transporting materials now from high concentrations inside to the low concentrations in the interstitial fluid.
- All materials in food are water-soluble so they can be carried from villi by blood capillaries to other parts of body.

- Some literatures mention that some glucose molecules are transported by a mechanism know as: **Solvent drag absorption.**
  - We are absorbing water between cells (Paracellular space; between cells).
  - If we have high concentrations of glucose between cells with the water, some glucose can be absorbed just like water and enter the cells toward the interstitial fluid through the paracellular spaces.

Digestion & Absorption of Proteins

- Proteins are long chains of amino acids without branching.
- We start digestion of proteins at the level of **stomach** with the help of enzymes like pepsin (which works optimally at acidic pH), and degrades the long chains to shorter peptides.
- The contents of chyme are released into the **duodenum**, and there, we continue the process of digestion by proteolytic pancreatic enzyme [Trypsinogen (activated Trypsin), Chemotrypsin, Procarboxypeptidase (exo- /endo- peptidases)).
  - Note: Exo-peptidase: it will remove a single amino acid each time from the carboxylic end.
  - Endo-peptidase: works somewhere in the middle of the peptide.

- The activity of Pepsin decreases after reaching the duodenum with chyme (again, due to high pH), and that's why we need different proteolytic enzymes to work, they are released from pancreas.
- More Digestion occurs at the **brush-border** level (third level of digestion where we have digestion or hydrolysis of peptides):
  - Brush border has many amino peptidases (exo-peptidases that work on the amino end) enzymes.
- After all these levels of digestion, we still have short peptides (mono, di, tri, tetra-peptides) and these short peptides can be absorbed by special carriers.

- **Inside the absorptive cells**, a fourth level of digestion takes place to convert these short peptides to single amino acids, by intracellular peptidases.
- We then remove these amino acids from cells.

➔ Absorption of small peptides occurs by Sodium-dependent carriers (secondary active transport).

➔ Absorption of amino acids occurs by Sodium-dependent carriers (Active) and Sodium-independent carries (Facilitated).
So, we have these 3 different mechanisms that you need to know,
with 5 or 6 subtypes for transporting different amino acids, but you don't need to memorize these subtypes.

THE END

Thanks to Muhannad Haddadin and all members of correction team ☺