Digestion and Absorption in the Gastrointestinal Tract

Hydrolysis of Macronutrients

- Hydrolysis means the breakdown of a substance by the addition of water.
- All three major types of food (Carbohydrates, protein, & fat) have the same basic process of hydrolysis and it is a reversible process.

The only difference is the types of enzymes required to promote the hydrolysis reactions.

- Carbohydrates (*polysaccharides* or *disaccharides)*: monosaccharides
- Proteins (*amino acids* that are bound together by *peptide linkages*: amino acids
- Fats (triglycerides) : Free fatty acids and glycerol.

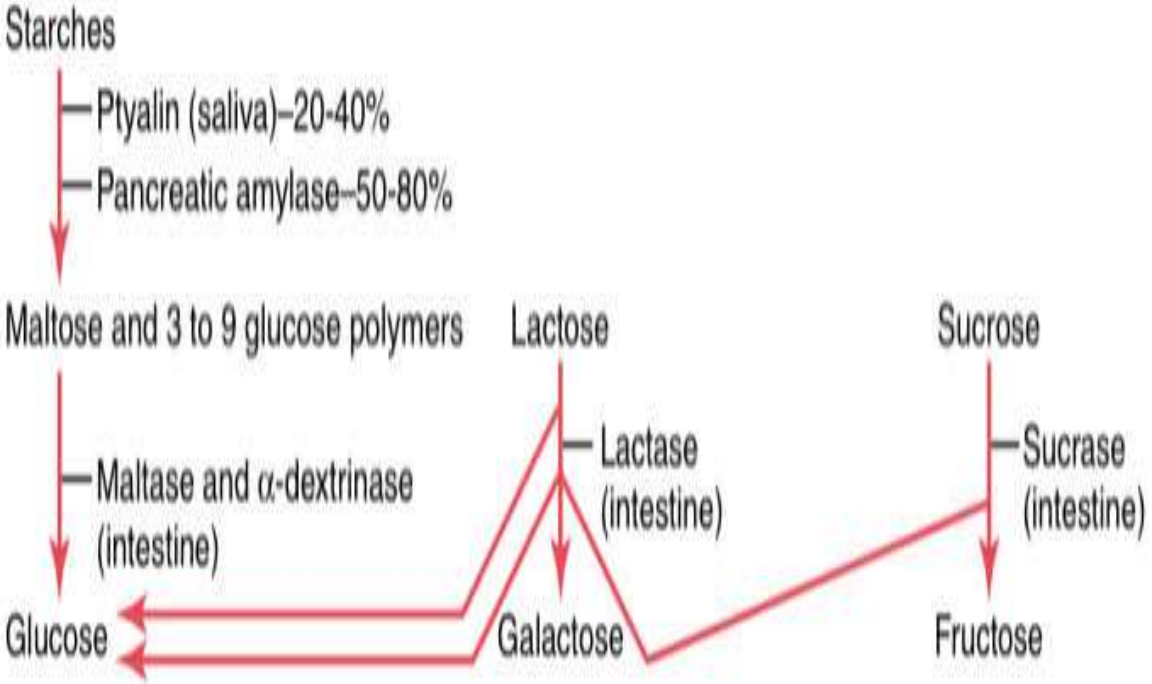
Digestion of Carbohydrates

- The major 3 sources of carbohydrates in human diet that the body can digest are: *sucrose (cane sugar), lactose (milk), and starches (grains).*
- Cellulose is a carbohydrate but no enzymes capable of hydrolyzing it so it cannot be considered a food for humans.
- It starts in the saliva in the mouth that contains the digestive enzyme ***ptyalin*** (an **α-amylase**).
- ***Ptyalin*** enzyme hydrolyzes starch into the disaccharide ***maltose*** and **3-9 glucose molecules polymers.**
- It is continued with the **pancreatic secretion** which contains a large quantity of **α-amylase (powerful).**
- All the carbohydrates will be digested in 15 to 30 minutes after the chyme empties from the stomach into the duodenum.

Digestion of Carbohydrates

- The digestion occurs on the *brush border* of small intestine which contain four enzymes (***lactase, sucrase, maltase*, and α-*dextrinase***) which split the disaccharides lactose, sucrose, and maltose, & other glucose polymers into **monosaccharides**.
- Lactose splits into a molecule of *galactose* and a molecule of *glucose*.
- Sucrose splits into a molecule of *fructose* and a molecule of *glucose.*
- Maltose and other small glucose polymers all split into *multiple molecules of glucose*.
- Thus, the final products of carbohydrate digestion are all **monosaccharides.**
- They are all water soluble and are absorbed immediately into the portal blood. Glucose represents more than 80 percent of the final products of carbohydrate digestion, and 10 % galactose , 10 % fructose.

Figure 65-1 Digestion of carbohydrates.



Absorption of Carbohydrates

- All the monosaccharides are **bsorbed** by an active transport.
- Glucose & Galactose are **transported** by a **sodium co-transport mechanism**, no glucose can be absorbed without it. It is provides the motive force for moving glucose & Galactose through the basolateral membranes of the intestinal epithelial cells.
- Fructose is transported by **facilitated diffusion** all the way through the intestinal epithelium.
- Fructose becomes phosphorylated then converted to glucose after entering the cells.

Digestion of Proteins

- ***Pepsin***, the important **peptic enzyme** of the stomach.
- The stomach juices must be **acidic** as Pepsin is most active at a pH of **2.0 to 3.0** and is inactive at a pH above about 5.0; which means stomach juices must be acidic.
- Pepsin has the ability to digest the protein ***collagen*** that is affected little by other digestive enzymes. In persons who lack pepsin in the stomach juices, the ingested meats may be poorly digested.
- Pepsin only initiates the process of protein digestion; providing only 10 to 20 percent of the total protein digestion to convert the protein to **proteoses, peptones, and a few polypeptides.** This happens as a result of hydrolysis at the peptide linkages between amino acids.

Digestion of Proteins

- The Proteolytic enzymes **(*trypsin, chymotrypsin, carboxypolypeptidase,* and *proelastase)*** from the pancreatic secretion are responsible for the **protein digestion** in the **small intestine**.
- Trypsin and chymotrypsin split protein molecules into small polypeptides.
- Carboxypolypeptidase cleaves individual amino acids from the carboxyl ends of the polypeptides.
- Proelastas is converted into elastase, which then digests elastin fibers that partially hold meats together.

Digestion & absorption of Proteins

- **The last digestive stage** is in the enterocytes of the small intestine at **the *brush border*** that consists of hundreds of ***microvilli***. These microvilli have many ***peptidases***.
- Two types of **peptidase enzymes** are important: ***aminopolypeptidase*** **and** ***dipeptidases***.
- They split the remaining larger polypeptides into tripeptides and dipeptides and a few into amino acids, and after digestion they pass on through to the enterocyte and then into the blood.
- The final protein digestive products that absorbed are **99% individual amino acids**, with only rare absorption of peptides and whole protein molecules.
- **Absorbed** through the intestinal epithelial cells in the form of dipeptides, tripeptides, and a few free amino acids by **sodium co-transport .**
- Few amino acids do not require this sodium co-transport mechanism but are **transported by facilitated diffusion.**

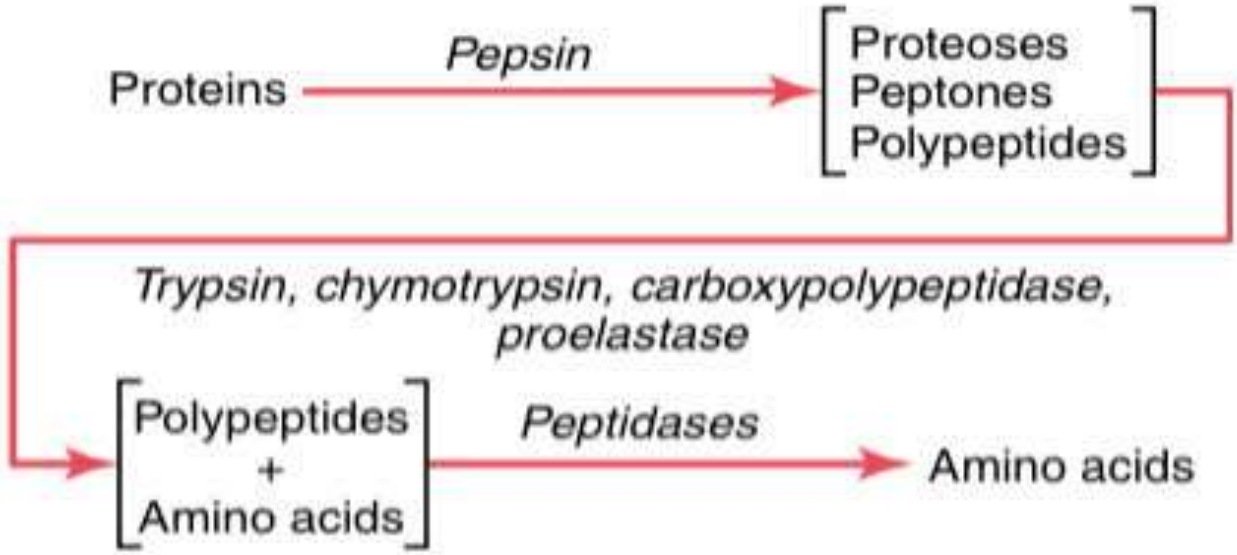


Figure 65-2 Digestion of proteins.

Digestion of Fats

- **Fats of the Diet** are *triglyceride which* consists of a glycerol nucleus and three fatty acid mostly from animal origin.
- Also diet may contain small quantities of **phospholipids and cholesterol ester** which can be considered fats because they **contain fatty acids**.
- Cholesterol is a sterol compound that contains no fatty acid but metabolized similarly t o fats so it considered as fat.

- All fat digestion occurs in the small intestine as follow:

1- Emulsification of the fat: large aggregates of dietary triglyceride are broken down.

- **It happens in the** duodenum by the influence of ***bile which secreted from the liver.***
- Bile contains a large quantity of *bile salts,* and the phospholipid *lecithin.*
- A major function of the bile salts and lecithin is to make the fat globules easily fragmentable by agitation with the water in the small intestine.

2- By Pancreatic Lipase: digest within 1 minute all triglycerides that it can reach.

3- End Products of Fat Digestion are *free fatty acids* and *2-monoglycerides.*

The bile salts *micelles that* **speed up the fat digestion and remove** the end products of fat from the vicinity.

Absorption of Fat:

- About 95 percent of lipids are absorbed after entering the epithelial cell of small intestine through the microvilli of the intestinal cell. Which there by the endoplasmic reticulum , *Fatty acids* and *monoglycerides* *are* converted into triglycerides to form *chylomicrons* and then transported from the lymph duct and empty into the circulating blood.
- Small Short- and medium-chain fatty acids are absorbed **directly** into the portal blood.

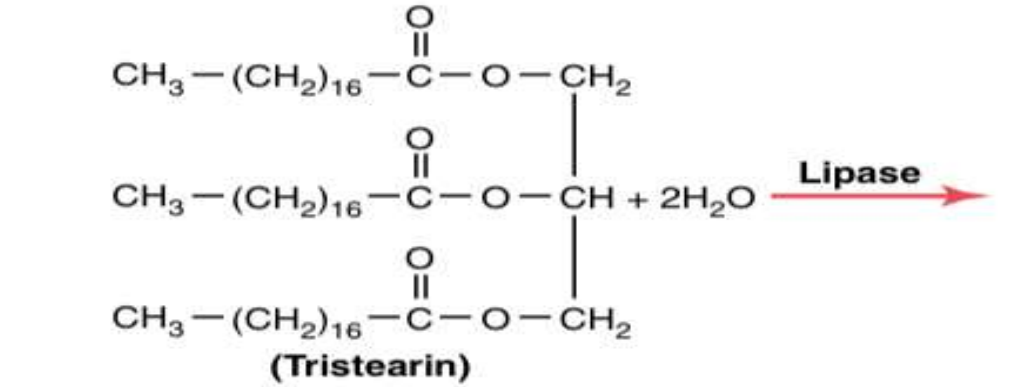


Figure 65-3 Hydrolysis of neutral fat catalyzed by lipase.

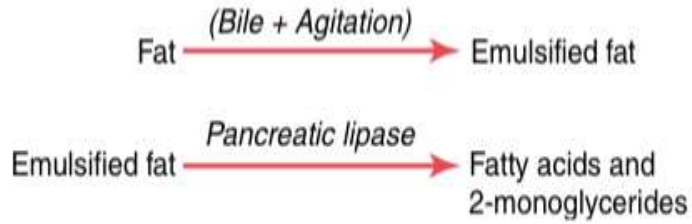


Figure 65-4 Digestion of fats.

Absorption in the Small Intestine

The total quantity of fluid that must be absorbed each day by the intestines is 8-9 liters.

Absorption from the small intestine each day consists of :

- Several hundred grams of carbohydrates
- 100 or more grams of fat,
- 50 to 100 grams of amino acids
- 50 to 100 grams of ions
- 7 to 8 liters of water

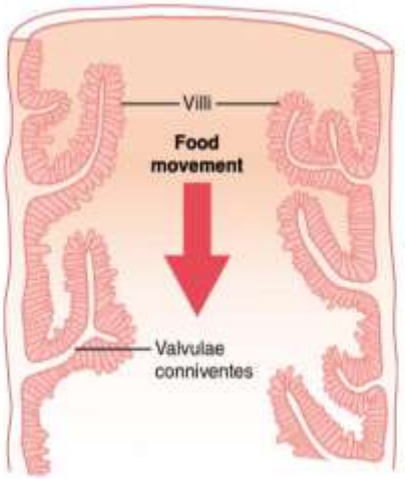


Figure 65-5 Longitudinal section of the small intestine, showing the valvulae conniventes covered by villi.

The absorptive *capacity* of the normal small intestine is far greater than these numbers

Absorption of Water by Osmosis

- Water is transported through the intestinal membrane by *diffusion*.
- When the chyme is dilute enough, water is absorbed through the intestinal mucosa into the blood by osmosis.
- Water can also be transported in the opposite direction from plasma into the chyme when needed.

Absorption of Sodium & Cholride

- *Sodium* absorption is provided by **active transport** of sodium from inside the epithelial cells into paracellular spaces.
- Twenty to 30 grams of sodium are secreted in the intestinal secretions each day.
- To prevent net loss of sodium into the feces, the intestines must absorb 25 to 35 grams of sodium each day.
- Sodium plays an important role in helping to absorb sugars and amino acids
- Sodium is also **co-transported** through the brush border membrane specific carrier proteins:
- (1) sodium-glucose co-transporter (2) sodium-amino acid co-transporters
- (3) sodium-hydrogen exchanger.
- They provide more sodium ions to be transported by the epithelial cells into the paracellular spaces.
- They also provide secondary active absorption of glucose and amino acids.

Absorption of Sodium & Cholride

Absorption of Chloride Ions in the Small Intestine in the upper part of the small intestine by diffusion and chloride ions move along with electrical gradient to follow the sodium ions.

Aldosterone Greatly Enhances Sodium Absorption

- When a person becomes dehydrated, large amounts of aldosterone are secreted by the adrenal glands. Within 1 to 3 hours this aldosterone causes increased activation of the enzyme and transport mechanisms for all aspects of sodium absorption by the intestinal epithelium. The increased sodium absorption in turn causes secondary increases in absorption of chloride ions, water, and some other substances. It serves to conserve sodium chloride and water in the body when a person becomes dehydrated.

- The toxins of cholera and of some other types of diarrheal bacteria can cause the loss of 5 to 10 liters of water and sodium chloride as *diarrhea* each day.
- Within 1 to 5 days, many severely affected patients die from this loss of fluid alone. The life of a cholera victim can be saved by giving large amounts of sodium chloride solution to make up for the loss. It is providing rapid flow of fluid along with the salt. All this excess fluid washes away most of the bacteria.

Active Absorption of Calcium, Iron, Potassium, Magnesium, and Phosphate

- *Calcium ions* are actively absorbed into the blood, especially from the duodenum
- The amount of calcium ion absorption is exactly controlled to supply the daily need of the body for calcium.

Important factors controlling calcium absorption:

- *Parathyroid hormone* secreted by the parathyroid glands
- *Vitamin D.*
- Parathyroid hormone **activates** vitamin D, and the activated vitamin D in turn greatly enhances calcium absorption.
- *Iron ions* are actively absorbed from the **small intestine**; *Potassium, magnesium, phosphate* are actively absorbed through **the intestinal mucosa.**

Absorption in the Large Intestine

- Most of the water and electrolytes in this chyme are absorbed in the colon.
- The proximal half of the colon responsible for absorption
- The distal colon responsible for storage until feces exerted

Bacterial Action in the Colon

- Colon bacilli in the proximal absorbing colon.
- They are capable of digesting small amounts of cellulose, in this way providing a few calories of extra nutrition for the body of animals.
- Other substances formed as a result of bacterial activity are vitamin K, vitamin B_{12}, thiamine, riboflavin, and various gases
- The bacteria-formed vitamin K is important because the amount of this vitamin in the daily ingested foods is normally insufficient to maintain adequate blood coagulation.

References

- Hall, J. E. 1. (2011). *Guyton and Hall textbook of medical physiology* (12th edition.). Philadelphia, PA: Elsevier.

Thank you

Any questions?