Mechanical and Chemical Events of Digestion of Food

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- The food we eat goes through ***five*** different processes in our body:

  (1) **Ingestion**: taking food into the body (eating).

  (2) **Digestion**: the breaking down of large complex food molecules into simple, soluble molecules.

  (3) **Absorption**: digested food from the alimentary canal diffuses into the blood stream.

  (4) **Assimilation**: the use of absorbed food to form new cells or part of cells.

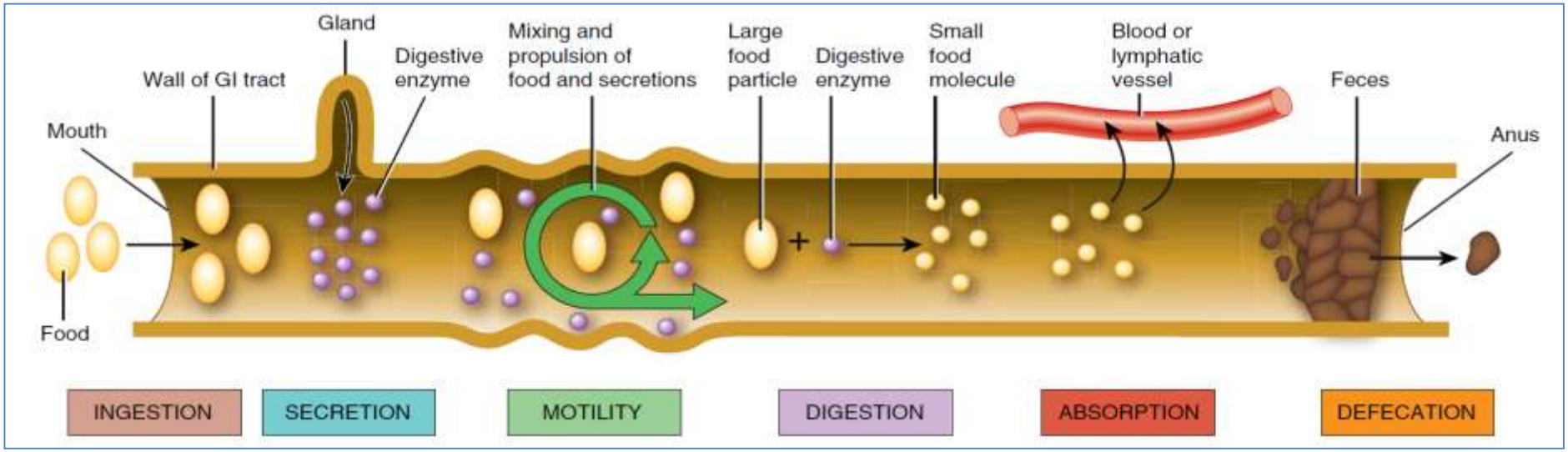
  (5) **Egestion**: passing out undigested food as faeces.

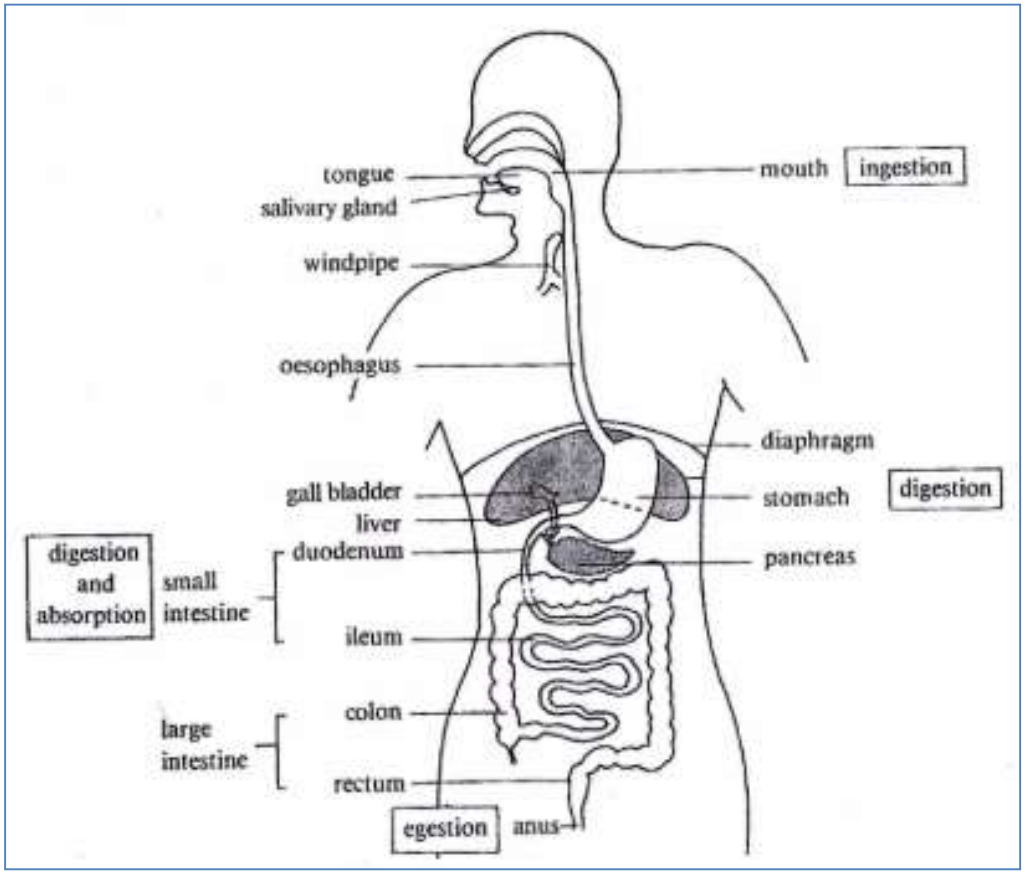
- The **alimentary canal** is the canal (tube) along which food passes to be processed.

  ✓ **Assimilation does not take place in the alimentary canal**.

  ✓ The human alimentary canal is **about 900cm (9 m) long**.

  ✓ The canal is able to fit into our bodies because it is **folded into loops**.


Gland
Wall of GI tract
Digestive enzyme
Mixing and propulsion of food and secretions
Large food particle
Digestive enzyme
Small food molecule
Blood or lymphatic vessel
Feces
Mouth
Anus
Food
INGESTION
SECRETION
MOTILITY
DIGESTION
ABSORPTION
DEFECATION


tongue
salivary gland
windpipe
oesophagus
mouth
ingestion
diaphragm
gall bladder
liver
duodenum
stomach
digestion
pancreas
digestion and absorption
small intestine
ileum
colon
large intestine
rectum
egestion
anus

Parts of the Human Alimentary Canal and the Associated Organs

(a) Mouth:

- **Ingestion takes place** in the mouth
- **Physical digestion starts here**
  (when teeth break the food into smaller pieces and the tongue roll the food to mix it with saliva)
- **Chemical digestion of starch starts** in the mouth (saliva contains enzyme **salivary amylase** to break down starch to maltose)

(b) Oesophagus:

- It is a tube through which **food is transferred from the mouth to the stomach**.
- This tube is muscular; it contracts and relaxes to push the food to the stomach. The contraction and relaxation of the muscular oesophagus is called **peristalsis**.

(c) Stomach:

- It is a **muscular** bag-like structure which stores ingested food for a few hours.
  - proteins and fats remains in the stomach for about 2 to 3 hours
  - carbohydrates remains in the stomach for only one hour
- Glands in the wall of the stomach produce **gastric juices** containing **hydrochloric acid** and **enzyme pepsin**.
- **Protein** is **digested** in the **stomach**.

(d) **Liver**:

- Produces bile. Bile does not contain any enzymes
- Bile breaks down bigger fat molecules to smaller fat molecules

(e) **Gall bladder**:

- Gall bladder is connected to liver.
- The bile produced by the liver is temporarily stored in the gall bladder
- The bile is then released to the duodenum (first part of the small intestine) when it is needed.

(f) **Pancreas**:

- Secretes pancreatic juice into the duodenum.
- Pancreatic juice contains enzymes for the digestion of carbohydrates, fats and proteins.

(g) Small intestine:

- It is about 6 metres long and consists of **duodenum** and **ileum**.

(i) Duodenum:

- First part of small intestine where acidic food from stomach is neutralized by the bile juice (released from gall bladder) and mix with pancreatic juice (released from pancreas)
- Bile not only neutralise the acidic food, it also helps to break down fats to smaller molecules. Pancreatic juice contain enzymes to break down proteins, carbohydrates and fats

(ii) Ileum:

- It is the long coiled part of the small intestine.
- It produces alkaline digestive juice (intestinal juice) that contains enzymes to **complete the digestion of food**.

(h) Large intestine:

- It is about 1.5 metres long and consists of **colon** and **rectum**.

(i) Colon:

- It absorbs water and minerals from undigested food.

(ii) Rectum:

- A short muscular tube which stores faeces before egestion.

(i) Anus:

- An opening through which the faeces is passed out.

Digestion

Digestion is the breaking down of large complex foods into smaller simpler food units.

📖 We must digest our food so that it is small enough to pass through the thin walls of the ileum into the blood.

📖 There are ***two*** types of digestion:

(1) Physical digestion
(2) Chemical digestion.

Physical Digestion

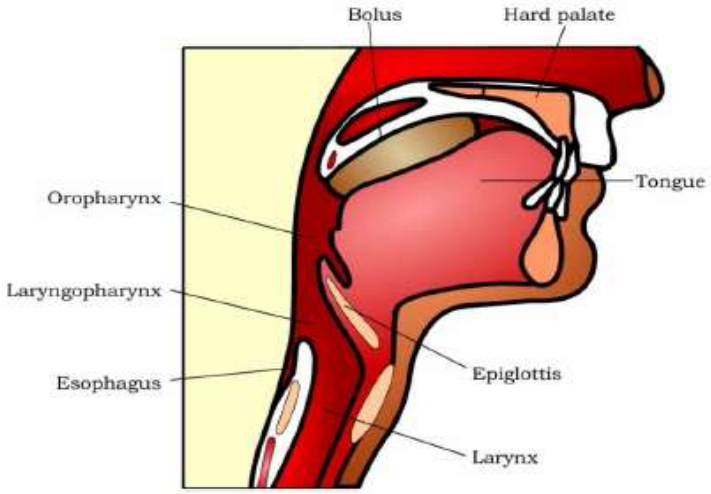
Physical digestion breaks down food into smaller pieces. It is sometimes called mechanical digestion. This type of digestion does not chemically change the food.

Chewing

- Example of physical digestion is chewing in our mouth with our teeth.
  - The functions of teeth are to **cut**, **tear** and **grind food** into smaller pieces.
  - It is **important to chew our food** because:
    (a) it breaks the food up into **smaller pieces** that are **easier to swallow**.
    (b) it makes **digestion by enzymes easier**. When food has been broken up into smaller pieces, there is a **larger surface area for the enzymes to act on**.
    (c) **chewing allows the food to be mixed with the saliva**. Saliva also contains mucus which helps food to move easily along the alimentary canal.

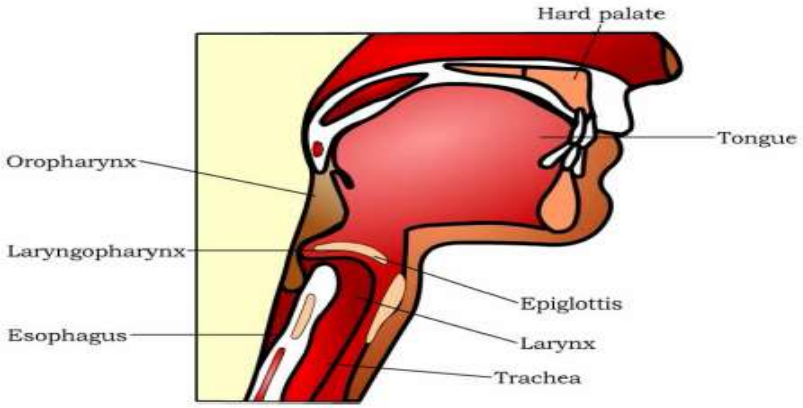
Mastication

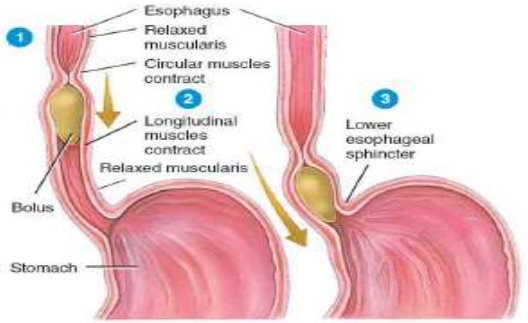
- Mastication or chewing, is a voluntary process, regulated by the CNS, and performed by muscles above and below the mandible.
- Skeletal muscles elevate the mandible , closing the mouth and moving the mandible side to side to chew.
- During chewing, food is :
  - Cut and ground by teeth.
  - Manipulated by the tongue, lips and cheeks.
  - Pushed toward the oropharynx.



Deglutition

- Swallowing occurs in three stages:
  - Voluntary stage in the mouth
  - Involuntary pharyngeal stage
  - Involuntary esophageal stage
- During the voluntary stage the tongue pushes the food bolus into the oropharynx.
- During the involuntary pharyngeal stage the bolus is moved through the laryngopharynx into the oesophagus.
- During the involuntary esophageal stage the bolus travels down the esophagus via **peristalsis**.
- Peristalsis is wave like movement of contractions and relaxations that propels the food down the GI tract
- Sphincters regulate the movement of food down the esophagus to the stomach.



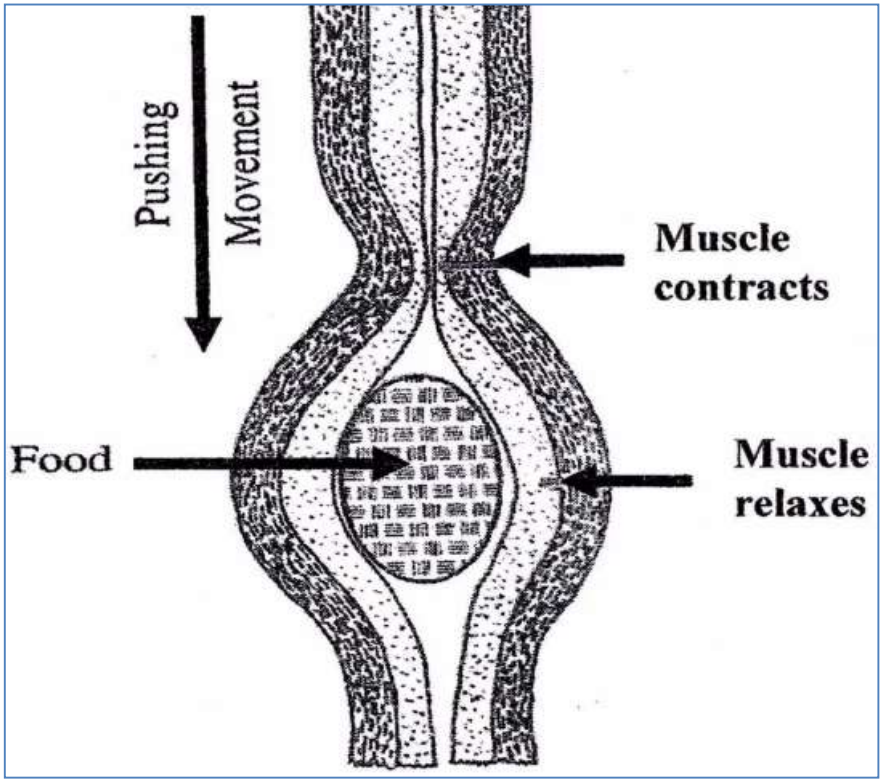


Esophageal stage of swallowing

Peristalsis

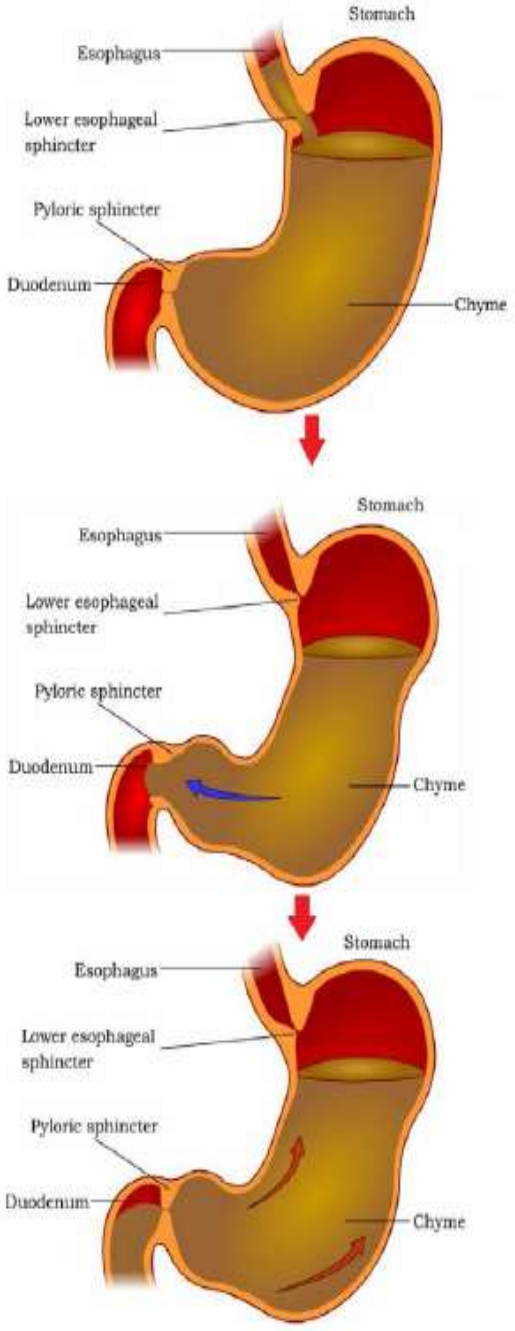
- The walls of the whole alimentary canal consist of layers of muscles and cells which secrete slimy liquid called **mucus**.
- The layers of muscles bring about wave-like contractions called **peristalsis** which push food along the alimentary canal.
- The slimy mucus makes it easier for the food to move along.

Below shows **peristalsis – wave-like contractions** which move food along the alimentary canal



Stomach peristalsis

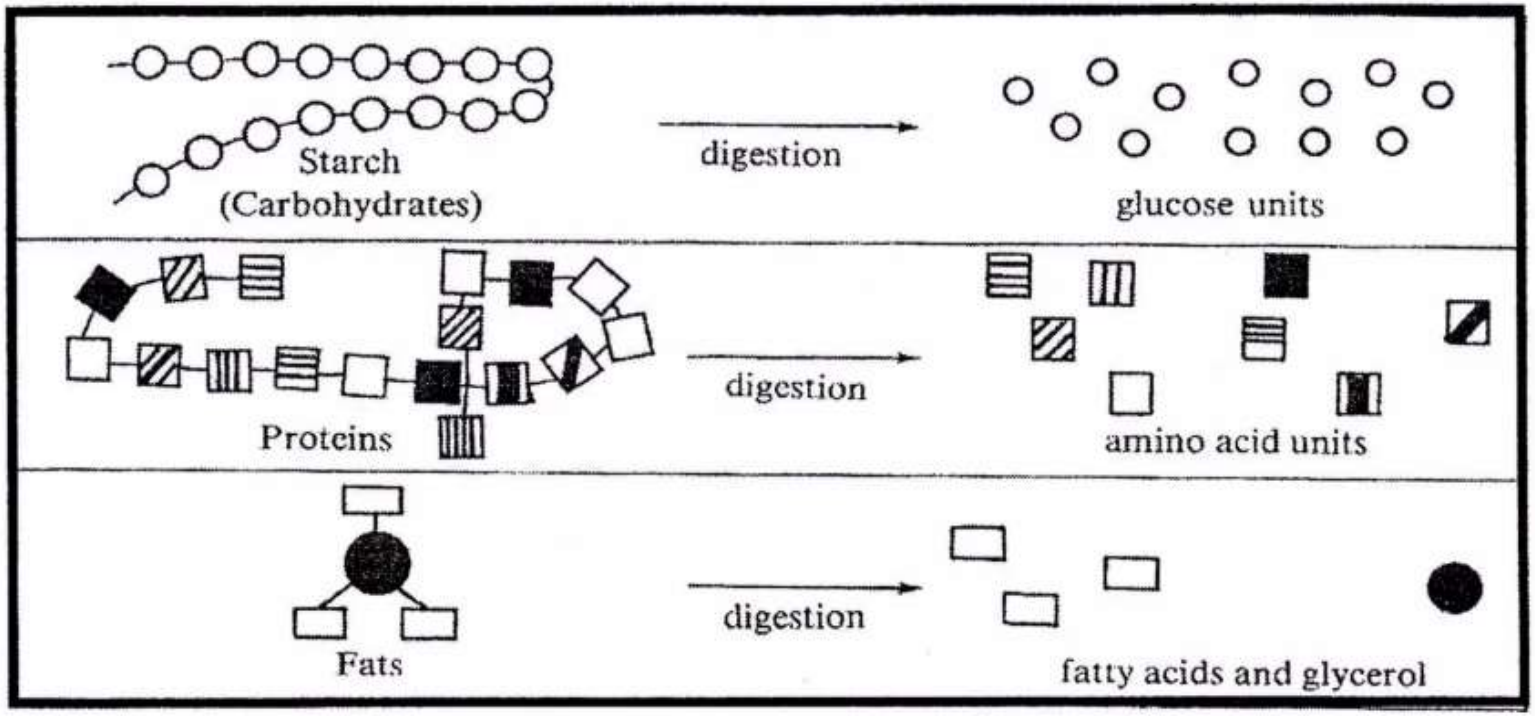
- Food enters, distending the stomach.
- Stretch receptors activate enteric reflexes that promote peristaltic movements.
- These movements , called mixing waves , begin to mix the food with stomach secretion.
- Mixing waves force the digestive food (chyme) toward and through the pyloric sphincter.
- Most food does not exit the stomach, so it moves back and forth in a churning digestive motion.
- The parasympathetic nervous system stimulates digestive movements in the stomach.



Chemical digestion is a process by which complex food molecules are broken down into simple soluble substances. Enzymes are used to produce these chemical changes.

Most of the food we ingest is insoluble and made up of molecules that are too large and complex to pass through the wall of the small intestine (ileum) into the blood vessels.

Below shows digestion reduces complex food substances into simple units



✦ In most animals, digestion is **extracellular**.
(**Extracellular** means that **digestion takes place outside the body cells**. In most animals, digestion takes place in the alimentary canal.)

✦ Example of extracellular digestions are:

(a) **Mouth**: starch —***salivary amylase***→ maltose

(b) **Stomach**: protein —***pepsin***→ polypeptide (peptones)

(c) **Duodenum**: fats —***bile*** *(no enzyme)*→ emulsified fats

starch —***pancreatic amylase***→ maltose

(d) **Ileum**: maltose —***maltase***→ glucose

polypeptide (peptones) —***peptidase***→ amino acids

fats —***lipase***→ fatty acids and glycerol

CHEMICAL DIGESTION

Introduction

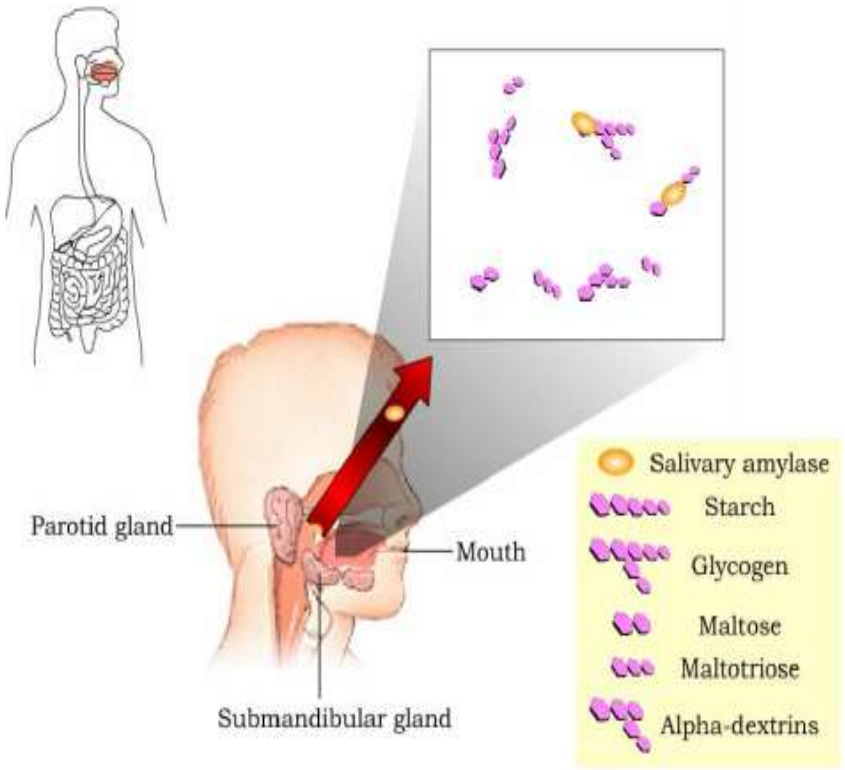
- Chemical digestion breaks down food as it moves through the digestive tract.
- Using enzymes and other digestive chemicals, the process reduces food particles into nutrient molecules that can be absorbed.

Digestive chemicals - Types

- Most chemical digestion is done by the actions of digestive enzymes.
- Other important digestive chemicals are needed to maintain a proper environment for enzymatic reactions, as well as other functions.
- These chemicals are: **water, Bile , Gastric acid, Bicarbonate**.
- **Digestive chemicals - Enzymes**
- The reactions in chemical digestion are enzyme mediated **hydrolysis reactions**.
- Water and enzymes break down the substrate into products.
- Most enzymes are identified by the substrate that they break down.
- For example, the enzyme **dipeptidase** breaks down dipepetide.

Carbohydrate digestion

- Digestion of complex carbohydrates (starches and glycogen) involves:
  - Amylases produced by the salivary glands and pancreas.
  - Brush-border enzymes in small intestine.



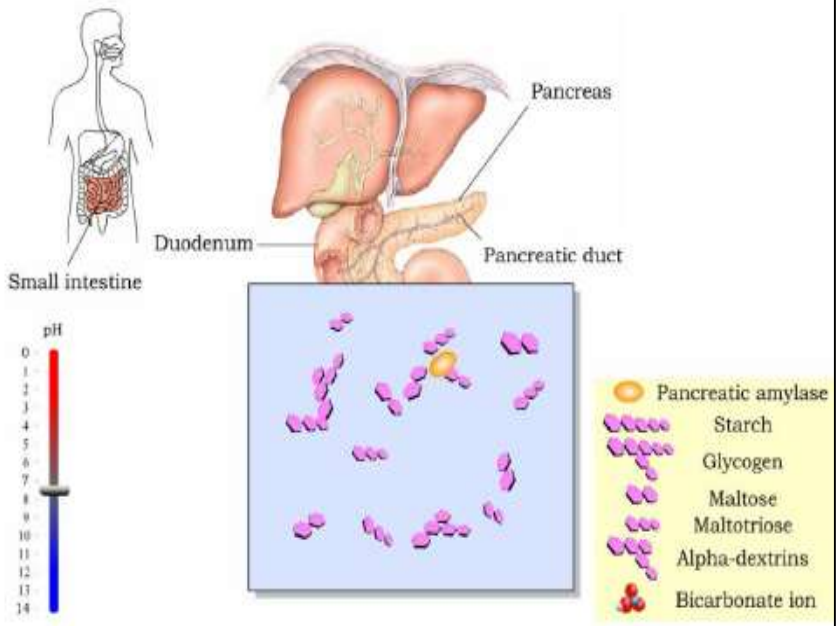
Carbohydrate digestion – mouth and stomach

- **In the mouth, amylase** from the **parotid** and **submandibular salivary glands** begins carbohydrate digestion.
- Salivary amylase converts starch and glycogen into following products :
  - Maltose (disaccharide)
  - Maltotriose (trisaccharide)
  - Alpha-dextrins (starch fragments)

- However, only a few starch or glycogen molecules are completely digested into maltose before they enter the small intestine.
- The stomach's acidic pH destroys **salivary amylase**.

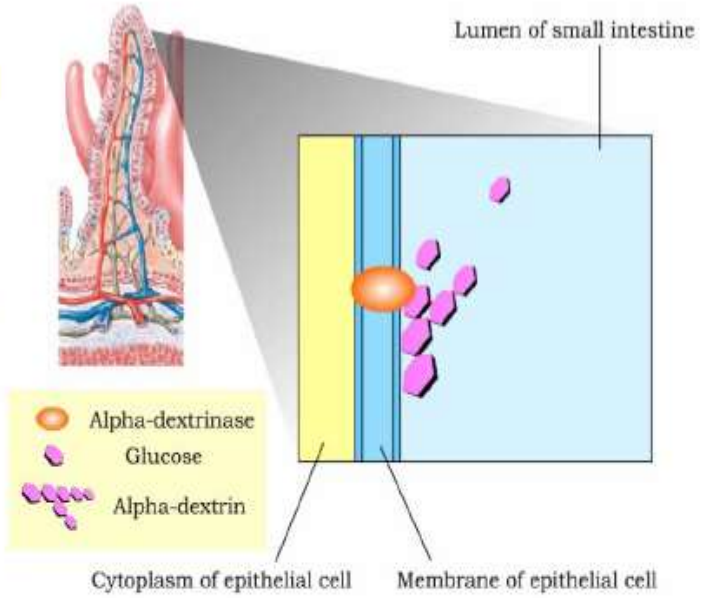
Carbohydrate digestion – Pancreas and small intestine

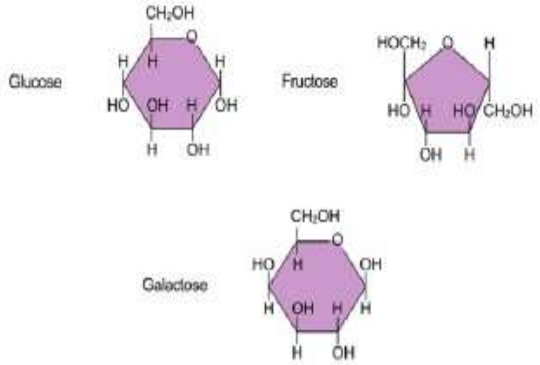
- The **pancreas** secretes **amylase** into the **duodenum**.
- In the small intestine, bicarbonate ions from pancreatic juice neutralizes gastric acid.
- Amylase continues the breakdown of starches and glycogen into maltose, maltotriose, and alpha dextrins.
- **Amylase** does **not** act on **cellulose** an indigestible plant fiber.



Carbohydrate digestion – brush border enzymes

- Carbohydrate digestion concludes in the microvilli of the small intestine, in brush border epithelial cells.
- Four brush border enzymes are involved:
  - **Alpha dextrinase** breaks down alpha-dextrin chains by removing glucose units.
  - **Sucrase** breaks sucrose into glucose and fructose.
  - **Maltase** breaks maltose and maltotriose into glucose.
  - **Lactase** breaks lactose into glucose and galactose.
- The **final** end **products** of **carbohydrate digestion** are **glucose, fructose,** and **galactose.**



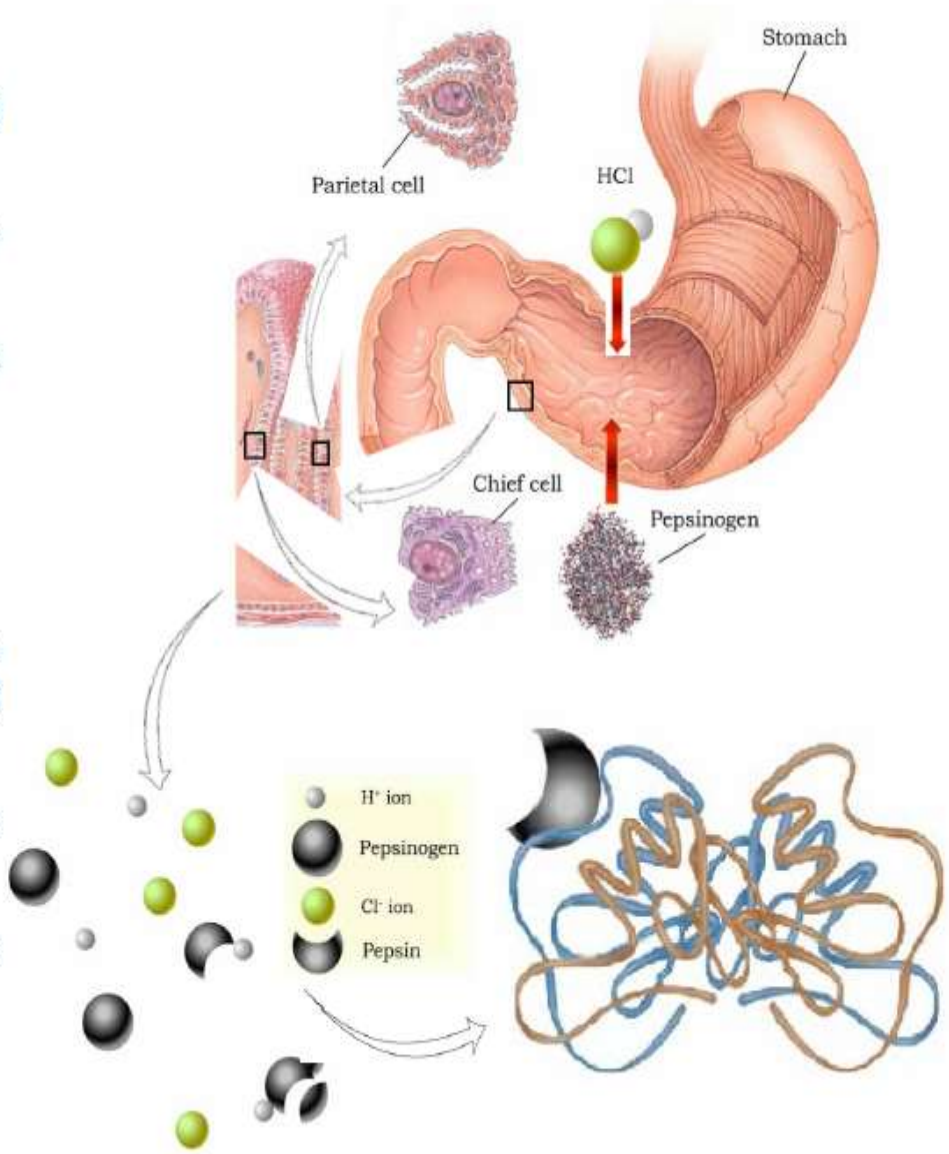


Protein Digestion

- Protein digestion occurs in the stomach and small intestine.
- The stomach enzyme pepsin initiates the process.
- Pancreatic and intestinal brush border enzymes complete the digestive process.

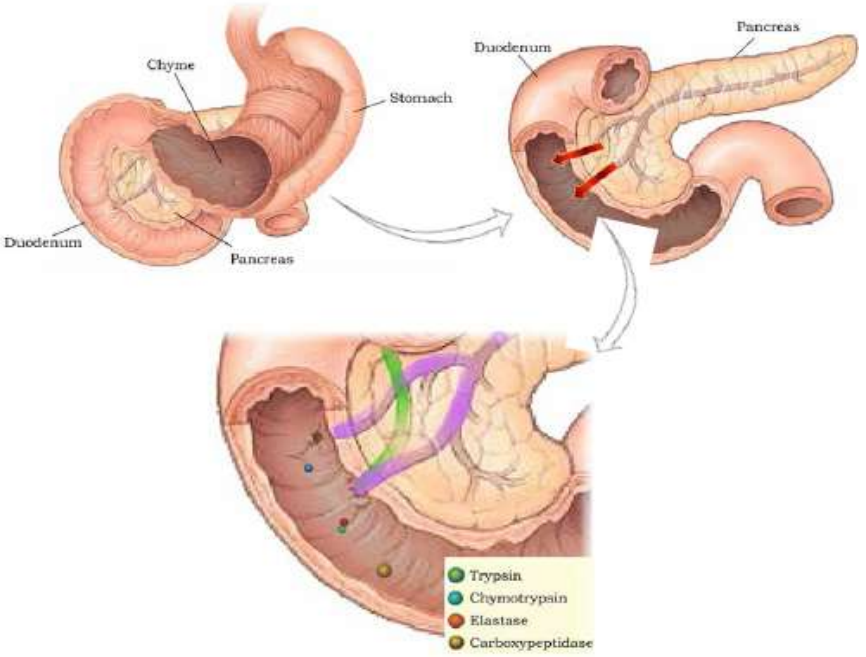
Protein Digestion - Stomach

- In the stomach, pepsin is created from pepsinogen in the presence of pH- lowering hydrochloric acid (HCl).
- Newly produced pepsin molecules then catalyze the production of more pepsin.
- Pepsin molecules begin to break down proteins into peptides.

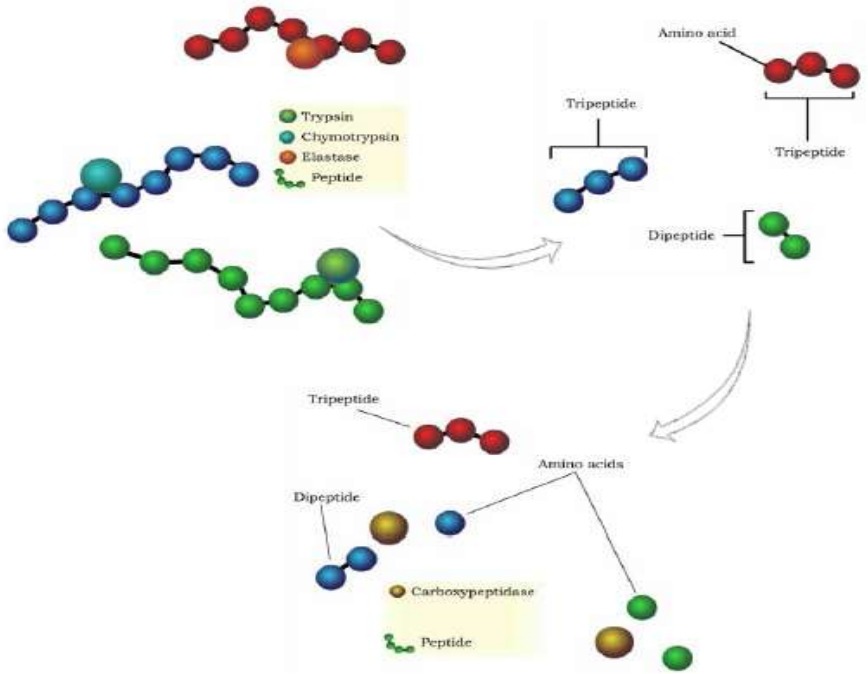


Protein Digestion – Small Intestine

- Protein continues to be broken down in the small intestine.
- In the duodenum , chyme interacts with pancreatic juice, a mixture of fluid and several enzymes.
- Protein digesting enzymes in pancreatic juice are:
  - Trypsin
  - Chymotrypsin
  - Elastase
  - Carboxypeptidase.



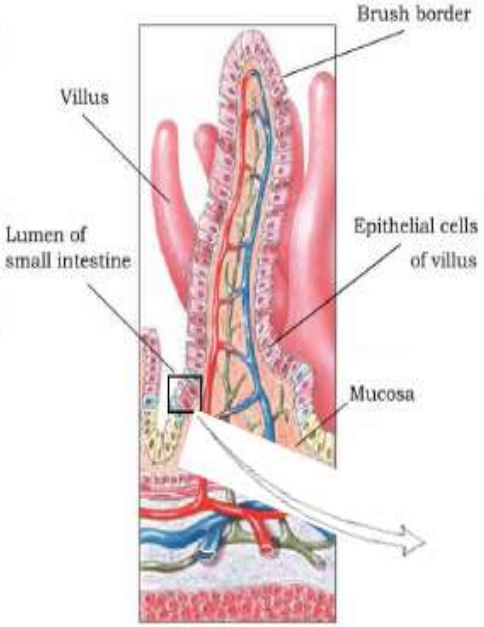
- Each enzyme effectively breaks a particular peptide bond to produce smaller peptides or amino acids.
- **Trypsin, chymotrypsin, and elastase** help break down larger peptides into smaller peptides.
- **Carboxypeptidase** breaks the bond between the terminal amino acid and the carboxyl end of the peptide .

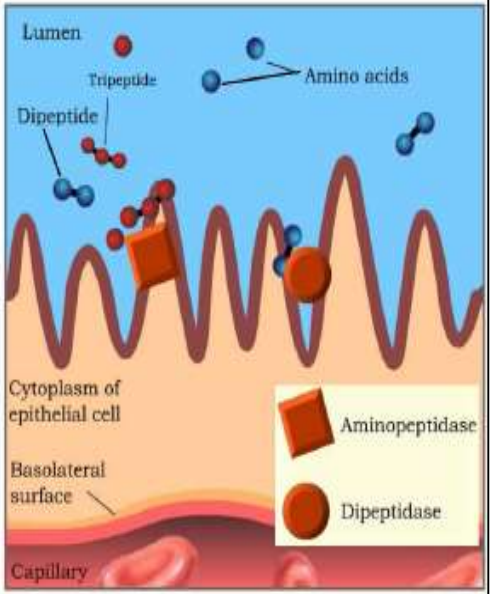


Protein Digestion – brush border enzymes

- Digestion is completed in the brush border by two active enzymes:
  - **Aminopeptidase-** breaks peptide bond that attaches terminal amino acid to the amino end of the peptide.
  - **Dipeptidase-** splits dipeptides into single amino acids.

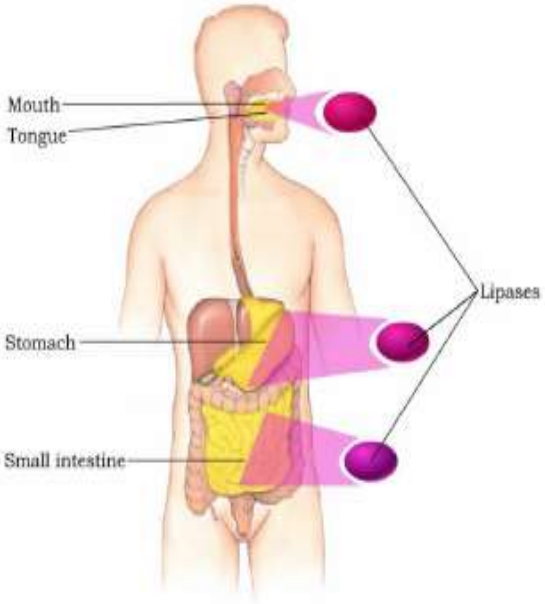
- End product of protein digestion
  - amino acids
  - Dipeptide
  - tripeptides

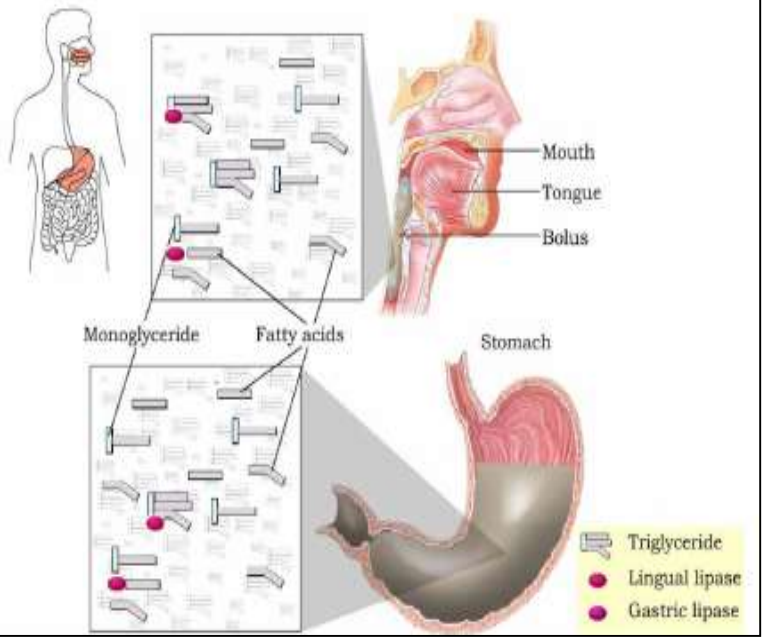




Lipid Digestion

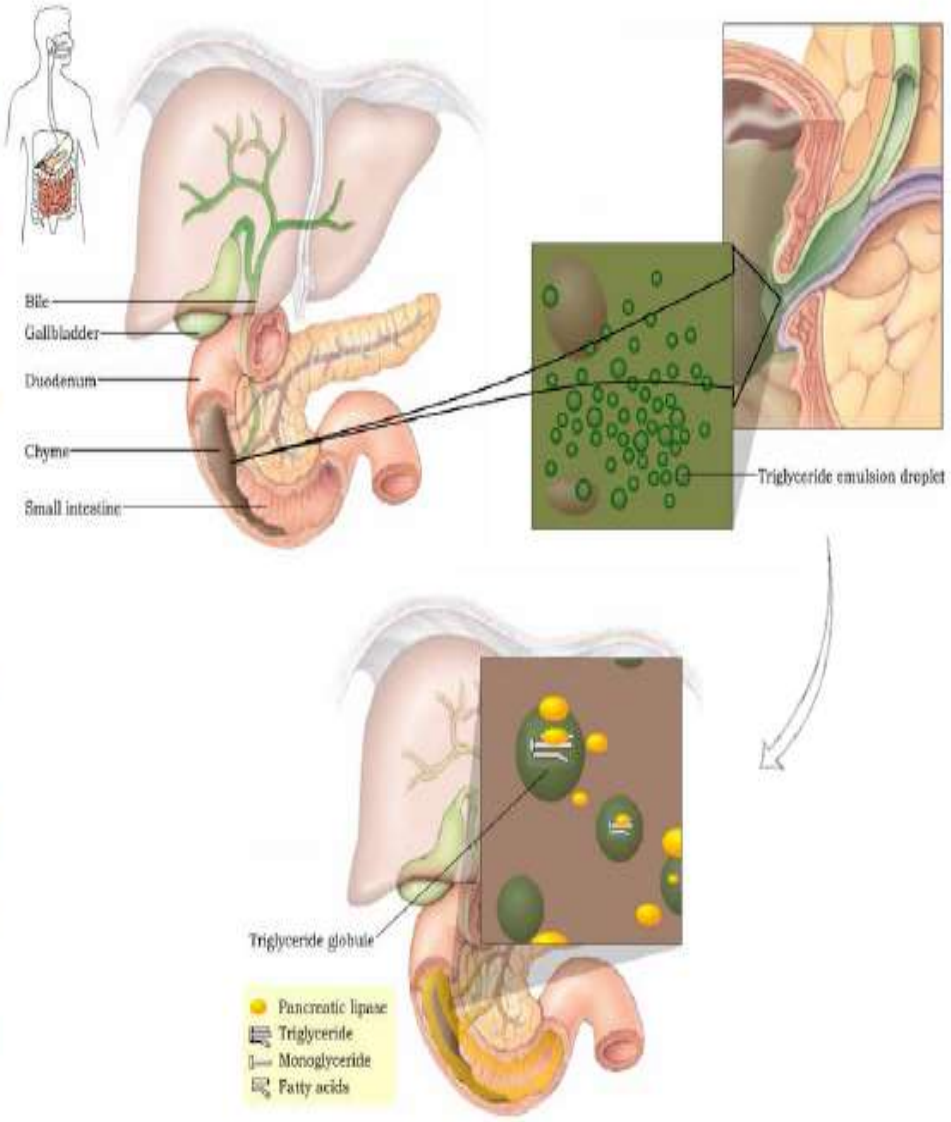
- Lipid digestion takes place primarily in the **small intestine** :
- **some** occurs **in the mouth and stomach.**
- Lipases are enzymes that break down triglycerides ad phospholipids.
- Lingual and gastric lipases hydrolyze a small amount of triglycerides.
- End products are fatty acids and monoglycerides.





Lipid Digestion - small intestine

- In the duodenum, triglycerides interact with bile salts and pancreatic juice.
- Bile salts cling to mono, di, and triglycerides of fat globules.
- The breakup of the fat globules results in triglyceride emulsion droplets.
- **Pacreatic lipase:**
  - is produced by pancreatic acinar cells.
  - Attaches to triglyceride molecules of the emulsion droplets.
  - Catalyze the breakup of the triglyceride of molecules into monoglycerides ad fatty acids.
  - Break down most triglycerides in the duodenum of the small intestine.

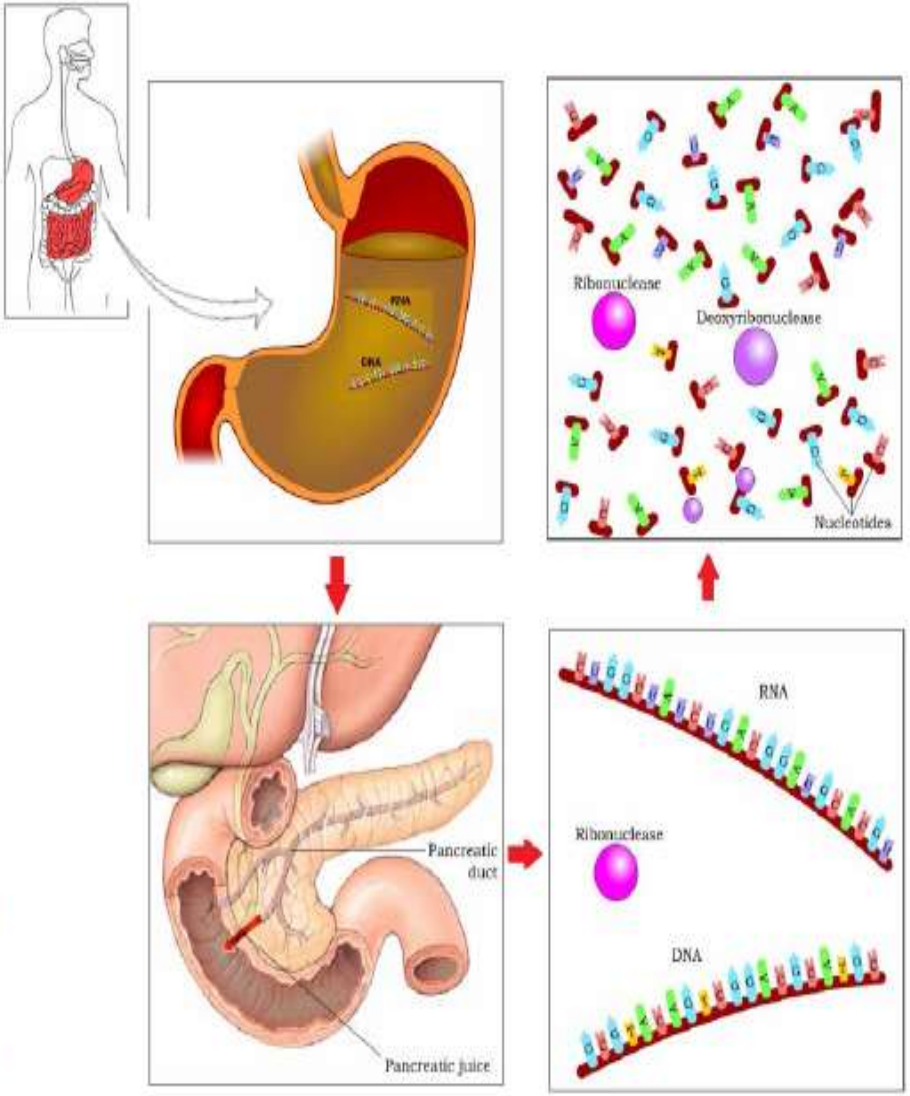


Nucleic Acid Digestion

- Nucleic acid digestion, which takes place in the small intestine, involves:
  - Pancreatic nuclease,
  - Brush border enzymes in the small intestine.

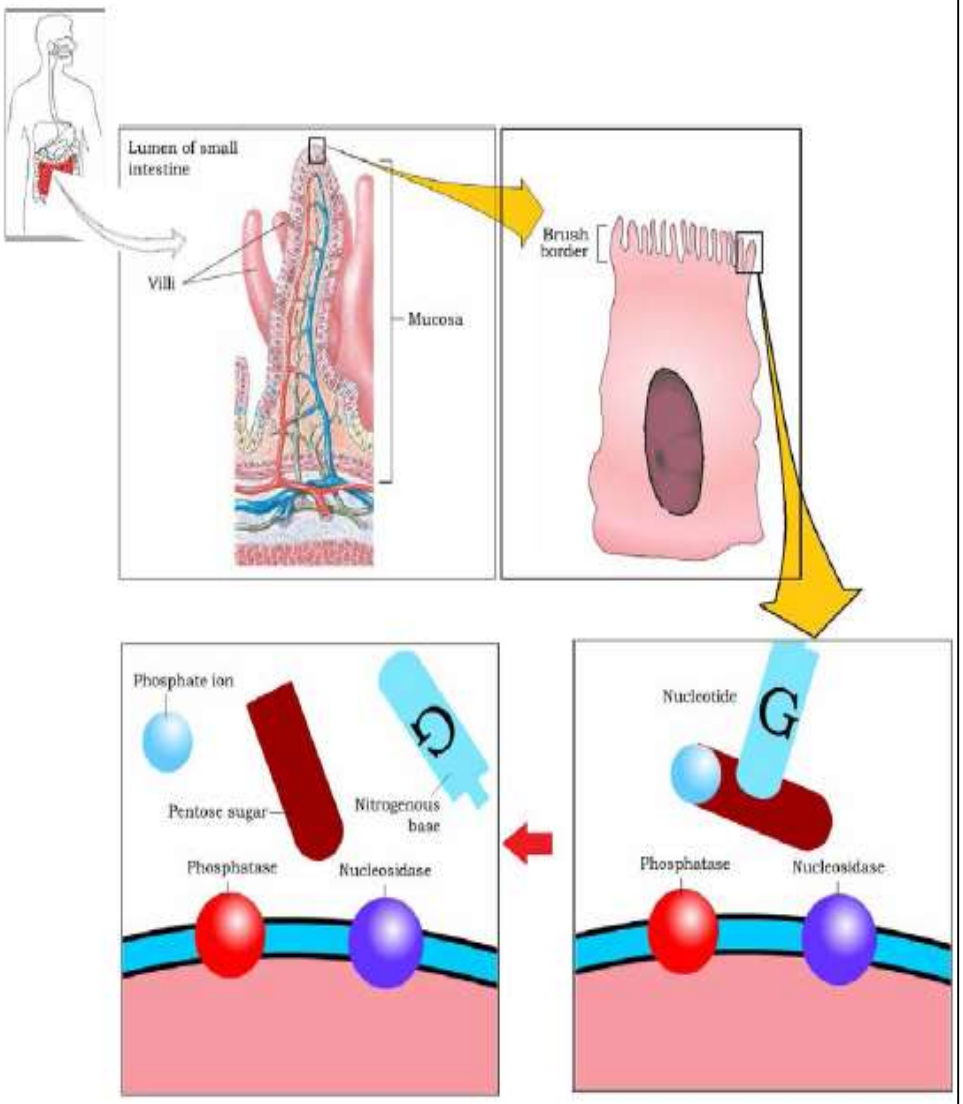
Nucleic Acid Digestion – small intestine

- Nucleic acids enter the small intestine dissolved in gastric chyme.
- As gastric chyme enters the duodenum of the small intestine, pancreatic juice also delivers two nucleases
  - **Ribnuclease,** which catalyzes the breakdown of RNA into ribonucleotides.
  - **Deoxyribouclease**, which catalyzes the breakdown of DNA into deoxyribonucleotides.



Nucleic Acid Digestion – brush border enzymes

- Further digestion occurs at the microvilli of the epithelial cells of the villi in the small intestine.
- Two brush border enzymes completes nucleic acid digestion
  - **Phosphatases** which catalyzes the cleavage of a phosphate to form a nucleoside(nitrogenous base and pentose sugar).
  - **Nucleosidases**, which catalyze the breaking of the covalent bond that holds the nitrogenous base to the pentose sugar.
- The final end products of nucleic acid digestion are
  - Nitrogeous base
  - Pentose sugars (Ribose and Deoxyribose sugar)
  - Phosphate ions.



A Summary of Digestion of Carbohydrates, Proteins and Lipids

	(a) Carbohydrate digestion	(b) Protein digestion	(c) Nucleic acid digestion	(d) Fat digestion
Oral cavity, pharynx, esophagus	Polysaccharides (starch, glycogen) ↓ **Salivary amylase** Smaller polysaccharides, maltose			Lingual lipase
Stomach		Proteins ↓ **Pepsin** Small polypeptides		Gastric lipase
Lumen of small intestine	Polysaccharides ↓ **Pancreatic amylases** Maltose and other disaccharides	Polypeptides ↓ **Trypsin, Chymotrypsin** Smaller **Aminopeptidase, Carboxypeptidase** Amino acids	DNA, RNA ↓ **Nucleases** Nucleotides	Fat globules ↓ **Bile salts** Fat droplets (emulsified) ↓ **Lipase** Glycerol, fatty acids, glycerides
Epithelium of small intestine (brush border)	↓ **Disaccharidases** Monosaccharides	Sm **Aminopeptidase,** ↓ **Dipeptidases** Amino acids	↓ **Nucleotidases** Nucleosides ↓ **Nucleosidases** Nitrogenous bases, sugars, phosphates	