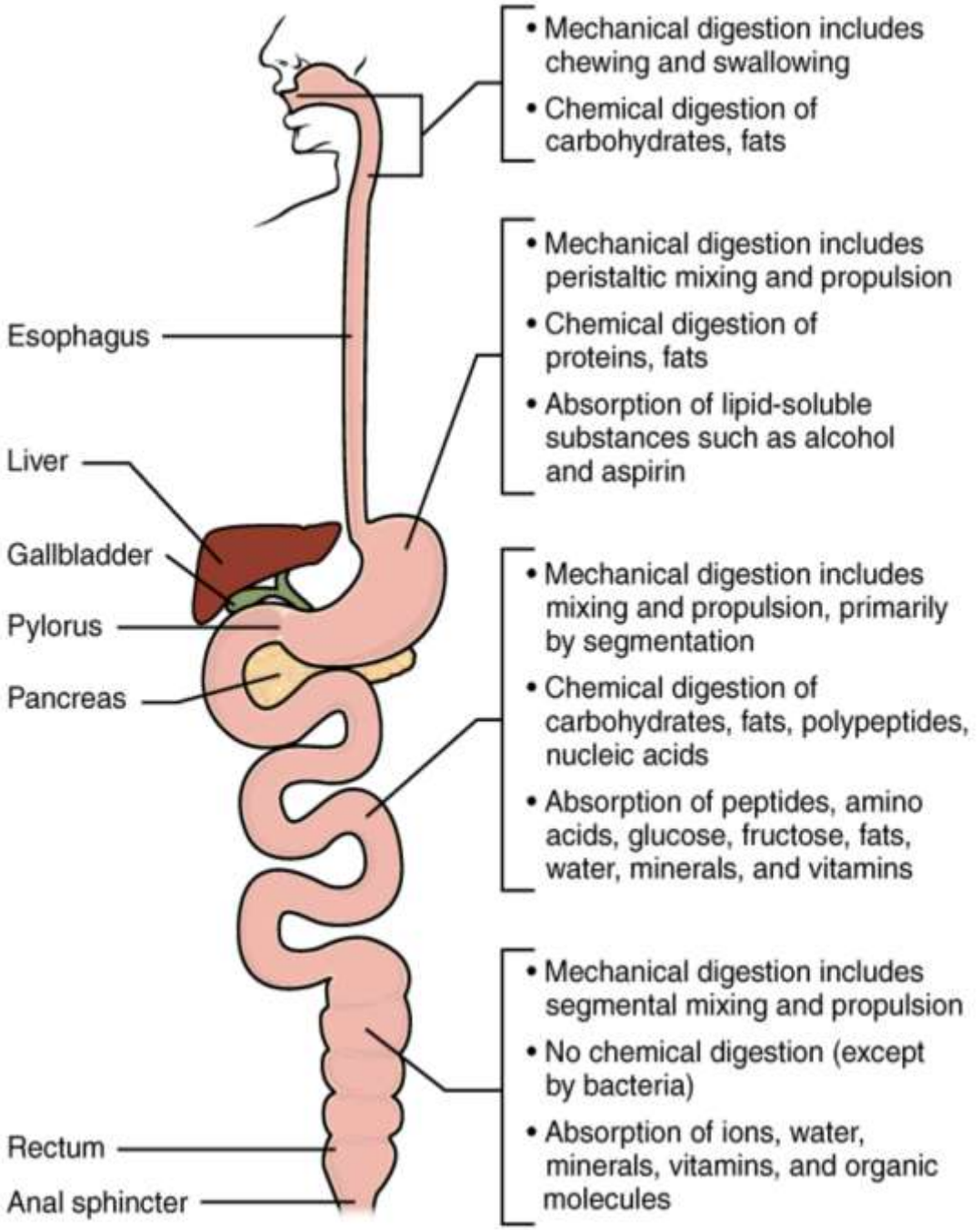
DIGESTION AND ABSORPTION OF FOOD

The process of digestion is accomplished by two processes,

- Chemical processes
- Mechanical processes



1. DIGESTION IN THE MOUTH

- Digestion by mechanical and chemical mean start in the mouth. Chewing (mastication) breaks up large food particles and mixes the food with the secretions of the salivary glands.
- Mucus in saliva helps in lubrication and adhering the masticated food particles into a bolus. The bolus is then propelled into the esophagus by the process of swallowing (or deglutition). This process is initiated by the voluntary action of collecting the oral contents on the tongue and propelling them backward into the esophagus.
- Inhibition of respiration and glottic closure are part of the reflex response.
- The bolus further passes down through the esophagus by successive waves of muscular contractions called peristalsis.
- The gastro-esophageal sphincter controls the passage of food into the stomach.

Digestion of carbohydrates

- Digestion of carbohydrates involves **hydrolysis of glycosidic bonds** of by addition of water.
- Digestion of carbohydrates starts from the mouth.
- When food is chewed, it is mixed with saliva, which contain the digestion enzyme **ptyalin (an α-amylase)** secreted mainly by the parotid glands.
- The optimal pH for this enzyme is 6.7.α-amylase is an endoamylase. This enzyme **hydrolyzes amylopectin of starch into the disaccharide maltose**; the trisaccharide maltotrioseand α-limit dextrins and unbranched amylose into maltose and maltotriose.
- Only α1-4 glycosidic bond is hydrolysed by α-amylase and the α1-6 glycosidic bond at branching point remain intact. About 30 percent of starch is hydrolysed in the mouth by this enzyme.

Digestion of lipids

- The most abundant lipids of the diet are **triglycerides (or triacyglycerol)**.
- Each molecule of triglyceride is composed of a glycerol and three fatty acids. Fatty acids have varying length and may be unsaturated or saturated. Triglycerides can be distinguished as fat and oil on the basis of physical state at room temperature.
- Fats, which are solid at room temperature, contain a large proportion of saturated fatty acids. Oils are liquid at room temperature because of their relatively high unsaturated fatty acid content. The usual diet also includes small quantities of phospholipids, cholesterol esters.
- A lingual **lipase** is secreted by **serous lingual gland** (Ebner's gland) of the tongue. This enzyme becomes activated in the acidic environment of the stomach.
- A small amount of triacylglycerols (or triglycerides) is digested in the stomach by lingual lipase that is secreted in the mouth and swallowed with the saliva.

2. DIGESTION IN THE STOMACH

- Digestion by both mechanical and chemical mean occur in stomach. Churning movement of the stomach makes food break down in size and responsible for mixing food with gastric juice.
- The stomach stores the food for 4 to 5 hours. Several minutes after food enters the stomach, gentle and rippling, peristaltic movement called mixing waves pass over the stomach every 15 to 25 seconds.
- These waves macerates food , mix it with secretions of the gastric gland to produce to produce a thick semifluid mass of partially digested food known as chyme.
- In stomach, enzyme mediated chemical digestion of proteins and lipids occurs.

Digestion of proteins

- Digestion of proteins involves **hydrolysis of the peptide bonds** of proteins by addition of water.
- Protein digestion begins in the stomach. Pepsin, the important protease of the stomach, initiates the process of protein digestion.
- Pepsins are secreted in the from of inactive precursors called pepsinogens and are activated by gastric acid. It is most active at pH~ 2.0 and is inactive at a pH above 5.0.

Digestion of lipids

- The chief cells of stomach secrete **gastric lipase**. It is active under acidic condition and shows optimum activity at pH~6.
- Gastric lipase, together with lingual lipase, comprise the two acidic lipases.
- These lipase **split triglycerides into fatty acids and monoglycerides.**

3.DIGESTION IN THE SMALL INTESTINE

Small intestine completes the digestion of carbohydrates, proteins, nucleic acid and lipids

Digestion of carbohydrates:

Pancreatic secretion, like saliva, contain a large quantity of α-amylase called pancreatic amylase (almost identical in its function with the α-amylase of saliva). Pancreatic amylase **hydrolyzes starch into the maltose, maltotriose and α- limit dextrins.**

Hydrolysis of disaccharides and small glucose polymers into monosaccharides occur by brush-border enzymes (such as lactase, sucrose, maltase and α-dextrinase) produced by enterocytes.

Lactase hydrolyzes β-1,4 glycosidic bond of disaccharide lactose into glucose and galactose. The inability to digest lactose in adults and children due to insufficient level of lactase synthesis is called lactose intolerance.

Sucrase catalyzes the hydrolysis of α1-2β glycosidic bond of disaccharide **sucrose and fructose.**

Maltase catalyzes the hydrolysis of α1-4β glycosidic bond of **maltase and maltotriose into glucose molecules**

α-dextrinase (or limit dextrinase or isomaitase) catalyses the hydrolysis of α-1,6 glycosidic bond in isomaltase and limits dextrins produced by starch by α-amylase. **The monosaccharides are the final products of carbohydrate digestion.** In the ordinary diet, which contains mostly starches than other carbohydrates, glycose represent more than 80 percent of the final product of carbohydrate digestion.

Digestion of proteins

- Most protein digestion occurs in the small intestine, (mainly in the duodenum and jejunum), by the proteolytic enzymes of the pancreas and intestinal mucosa.
- Major proteases present in pancreatic enzymes are **trypsin, chymotrypsin, carboxpolypeptidase and prolastase**.
- Enteropeptidase (also called enterokinase) is an enzyme produced by cells of the small intestine, enteropeptidase converts **trypsinogen (a zymogen) into its active from tryspin**, resulting in the subsequent activation of pancreatic digestive enzymes.
- The last stage in intestinal lumen is achieved by enzymes synthesized by enterocytes. Two types of peptidases are present.
- **Aminopeptidase (cleaves off amino acid at the amino end of a peptide)**
- **Dipeptidase (splits dipeptides into single amino acids).**
- Proteolytic enzymes in the small intestine split the polypeptides into tripeptides, dipeptides and amino acids.

Digestion of lipid

- Although some lipid digestion occurs in stomach, most occurs in the small intestine through the action of pancreatic lipase. **Triglycerides are broken down by pancreatic lipase into fatty acids and monoglycerides.**
- First step is the **emulsification of fat by bile salts and phospholipid lecithin.** Most of the emulsification occurs in the duodenum.
- Important enzyme for digestion of triglycerides is pancreatic lipase. A protein colipase iss required for optimal enzyme activity of pancreatic lipase.
- **Colipase** is secreted by pancreas in an inactive form procolipase and activated in intestinal lumen by trypsin.
- Colipase binds to the bile salt covered emulsion droplet and anchors lipase at the surface of emulsion droplet.
- After digestion, monoglycerides and fatty acids associate with bile constituents (bile salts, phospholipid lecithin, cholesterol) to form **micelles.**

Digestion of nucleic acids:

- **Nucleic acids are split into nucleotides** in the intestine by pancreatic nucleases.
- Pancreatic juice contains two nucleases: ribonuclease (digest RNA) and deoxyribonuclease (digests DNA).
- Nucleotides are further digested by brush border enzymes called nucleosidases and phosphatases into pentoses, phosphates and nitrogenous bases.
- **Phosphatases split nucleotides into nucleosides and phosphoric acid.**
- **Nucleosidases split nucleosides into their constituent sugars and purine and pyrimidine bases.**

4.DIGESTION IN LARGE INTESTINE

- The final stage of digestion occur in the colon of large intestine through the activity of bacteria that inhabit the lumen.
- Mucus is secreted by the glands of the large intestine, but no digestive enzymes are secreted. Bacteria ferment remaining carbohydrates present in the chime and release gases such as hydrogen, carbon dioxide and methane.
- These gases contribute to flatus (gas) in the colon, termed flatulence when it is excessive.
- The smell is largely due to sulfides such as hydrogen sulfide.
- Bacteria also convert any remaining proteins to amino acids and break down the amino acids into simpler substances.

ABSORPTION OF FOODS

- The chemical and mechanical digestion from the mouth to the small intestine, changing food into simpler forms that can absorb through the absorptive epithelial cells of the mucosa.
- Absorption of materials occurs via simple diffusion, facilitated diffusion, active transport.
- About 90% of all absorption of nutrients occurs in small intestine, the other 10% occurs in large intestine.

Absorption in small intestine

Carbohydrates:

- All carbohydrates are absorbed as monosaccharides. Monosaccharides enter into the cells through the apical membrane via facilitated diffusion or active transport.
- Fructose is transported through facilitated diffusion whereas glucose and galactose are transported through secondary active transport.
- The transport of glucose and galactose is dependent on presence of Na+ in intestinal lumen.
- Because the intracellular Na+ concentration is low in intestinal cells, Na+ moves into the cell along its concentration gradient. Glucose moves with the Na+ and is released in the cell.

Lipids

- All dietary lipids are absorbed via simple diffusion. Fatty acids and monoglycerides enter the enterocytes by simple diffusion. Once inside the enterocyte, monoglycerides and fatty acids are re-synthesized into triglycerides.
- The triglycerides are packaged, along with cholesterol into chylomicrons. Chylomicrons are released by exocytosis at the basolateral surface of the enterocytes.
- They are too large to enter into the typical capillaries.
- Instead they enter into the lymphatic capillaries (lacteals) present in the center of each villus.
- Chylomicrons then flow into the circulation via lymphatic vessels.

Proteins

- Normally, 95-98% of the protein present in the small intestine is digested and absorbed. In intestine, proteolytic enzymes split the larger polypeptides into tripeptides, dipeptides and amino acids.
- Most amino acids, tripeptides, dipeptides are absorbed via active transport processes, mainly in the duodenum and jejunum.
- The dipeptides and tripeptides are transported into enterocytes and their amino acids are released due to intracellular hydrolysis.
- Small amounts of undigested proteins are also absorbed.

Vitamins

- The fat – soluble vitamins A, D, E and K are carried in the micelles and absorbed passively with the end products of fat digestion.
- Most water-soluble vitamins, such as most B vitamins and vitamin C, are absorbed via simple diffusion.
- Vitamin B12 combines with intrinsic factor produced by the stomach, and the complex is absorbed in the ileum via an active transport mechanism.

Absorption in large intestine

- When chyme pass through the ileocecal valve into the large intestine, most of the water and electrolytes in this chyme are absorbed in the colon.
- Most of the absorption in the large intestine occurs in the proximal one half of the colon, giving this portion the name absorbing colon, whereas the distal colon functions principally for storage of feces and is therefore called the storage colon.
- The large intestine can absorb a maximum of 5 to 8 liters of fluid and electrolytes each day.