

Pancreatic secretion

BY

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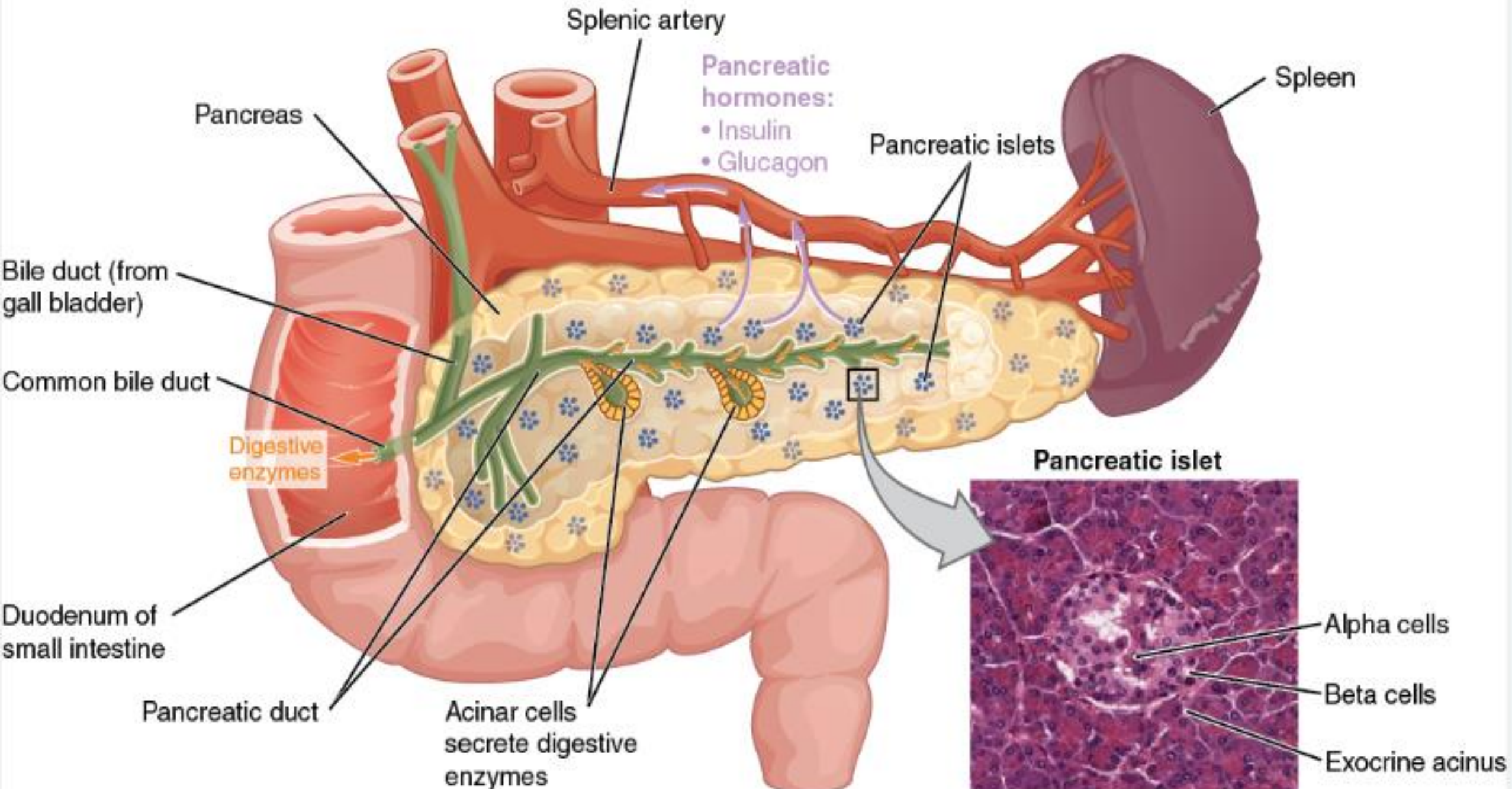
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Pancreas

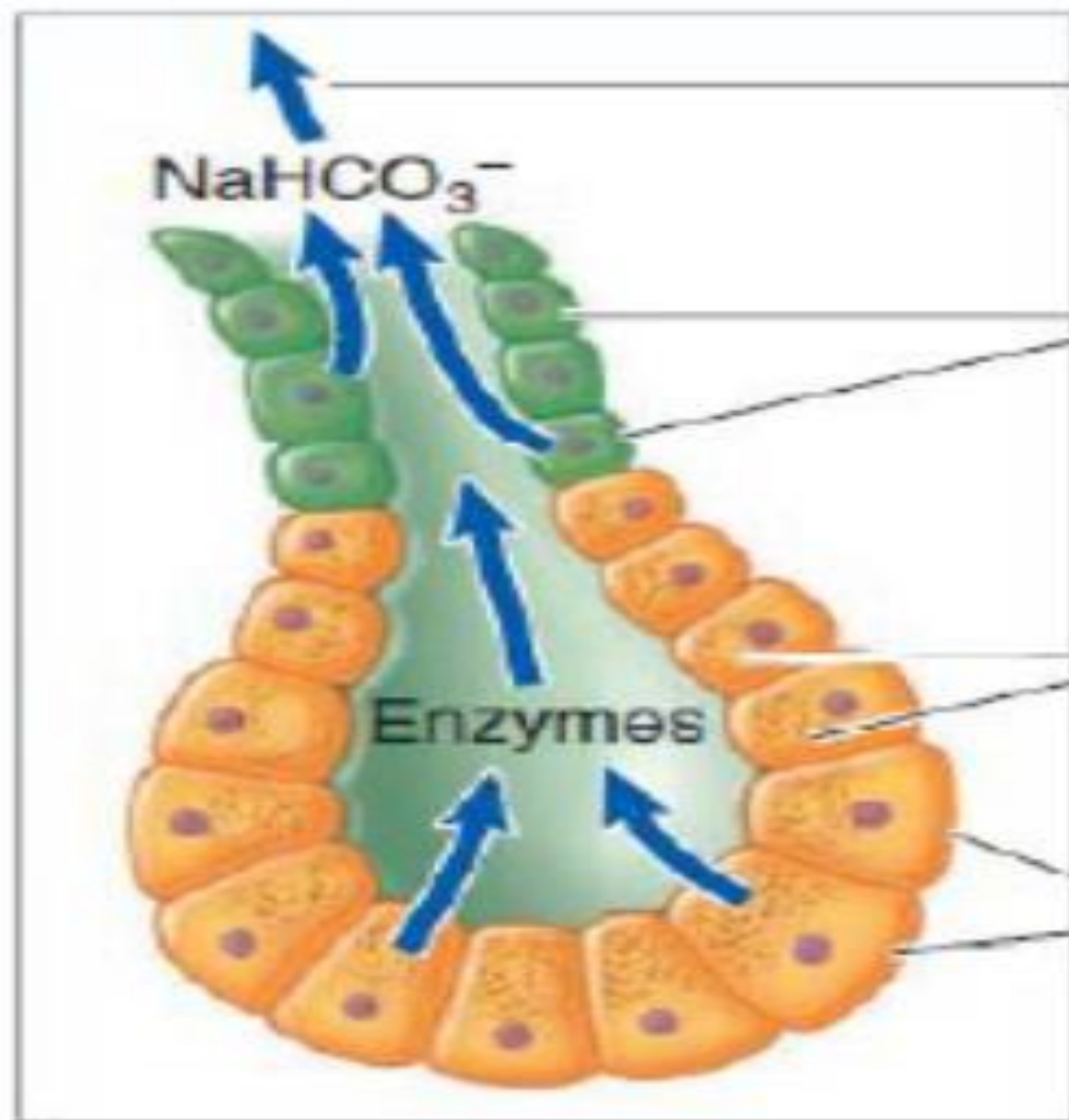
Pancreas is considered as an endocrine & exocrine gland.

- **The exocrine gland** secretes the pancreatic juice.
- The pancreatic juice consists of
 - 1- An aqueous component that is high in HCO_3^- . The **HCO_3^-** containing aqueous portion functions to neutralize the H^+ delivered to the duodenum from the stomach.
 - 2- An enzymatic component. The **enzymatic portion** functions to digest carbohydrates, proteins, and lipids into absorbable molecules.



Structure of the pancreatic exocrine glands:

- **The exocrine pancreas** resembles a bunch of grapes, with each grape corresponding to a single acinus.
- **The acinus** which is the blind end of a branching duct system. It is lined with acinar cells that secrete the enzymatic portion of the pancreatic secretion. **The ducts** are lined with ductal cells that secrete the aqueous HCO_3^- containing component of the pancreatic secretion.
- **The exocrine pancreas** is innervated by both the parasympathetic and the sympathetic nervous systems. Parasympathetic activity stimulates pancreatic secretion, while, sympathetic activity inhibits pancreatic secretion.



To pancreatic duct
and duodenum

Duct cells
(secrete aqueous
 NaHCO_3^- solution)

Zymogen
granules

Acinar cells
(secrete digestive
enzymes)

Pancreatic juice

Properties

- It is an alkaline secretion (pH about 8-8.3).
- The volume secreted per day is about 1000 to 2000 mL/day .

COMPOSITION OF PANCREATIC JUICE

Pancreatic juice contains 98.5% of water and 1.5% of solids. The solids are the organic and inorganic substances.

The inorganic constituents 1%: NaHCO_3 (mainly), K^+ , Ca^{++} , Mg^{++} , Zn^{++} , Cl^- , SO_4^{--} , HPO_4^{---}

Bicarbonate content is very high in pancreatic juice. It is about 110 to 150 mEq/ L, compared to the plasma level of 24 mEq/L. Water and bicarbonate are secreted by epithelial cells of pancreatic ducts.

The organic constituents 5%: secreted by the acini, include: Pancreatic enzymes

Pancreatic enzymes

I Proteolytic enzymes for protein digestion

Endopeptidase: (trypsinogen, chymotrypsinogen) it digests proteins into peptides.

Exopeptidase: (procarboxypeptidase), it digests peptides into amino acids.

II Lipolytic enzymes for fat digestion

Pancreatic lipase: it digests lipid

Prophospholipase A and B: it digests phospholipids.

Cholesteryl ester hydrolase: it digests cholesterol esters

III Pancreatic alpha amylase for carbohydrate digestion

IV pancreatic deoxy ribonucleases and ribonucleases: it digests DNA and RNA.

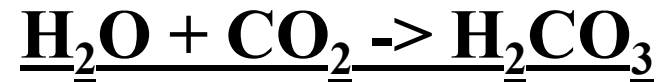
➤ **High bicarbonate content of pancreatic juice is important because of two reasons:**

i. High pancreatic bicarbonate content together with those in the intestinal juice and bile protects the intestinal mucosa from acid chyme of the stomach by neutralizing it. And so, it prevents development of duodenal ulcer.

ii. Bicarbonate ions provide the required optimum pH for the activation of pancreatic enzymes and intestinal enzymes.

Secretion of Bicarbonate and Water

- CO₂ diffuses to the interior of the cell from the blood. Then, carbonic is produced within ductal cells via **carbonic anhydrase**, which catalyzes the reaction between water (H₂O) and carbon dioxide (CO₂). This produces carbonic acid (H₂CO₃).

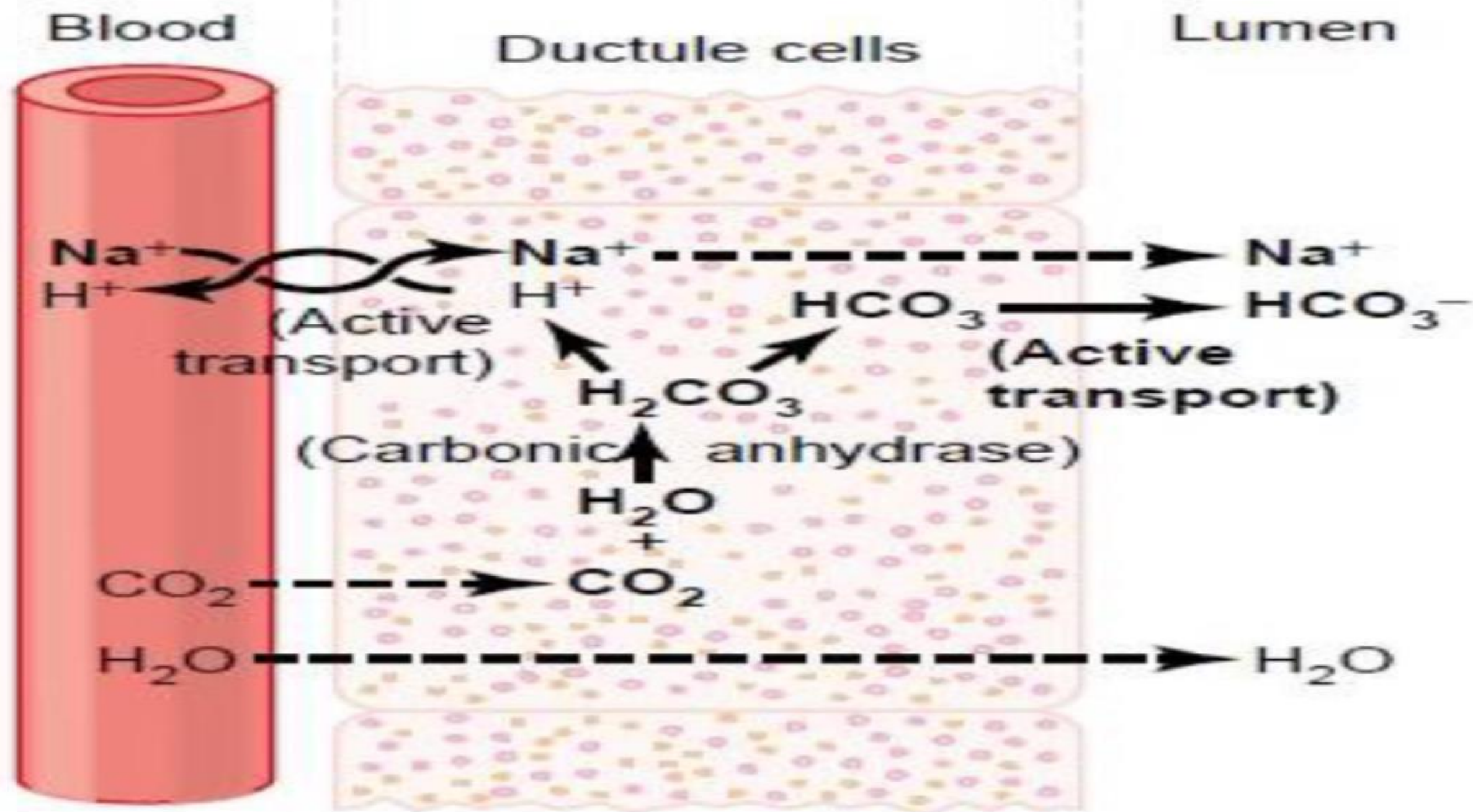


- **Carbonic acid** then dissociates into hydrogen ions (H⁺) and bicarbonate ions (HCO₃⁻).



- The bicarbonate ions (HCO₃⁻) are actively transported in association with Na ions through the luminal border into the lumen of pancreatic duct. Na⁺ provides electrical neutrality for the secreted bicarbonate ions.

- Meanwhile, the hydrogen ions are removed by exchanging for sodium ions (Na^+) in the blood through the basolateral border of the ductal cell of pancreas via a **H^+/Na^+ antiporter..**
- Overall, the movement of sodium and bicarbonate ions into the lumen creates an **osmotic gradient** pulling water into the ducts of pancreas forming the bicarbonate solution.
- The HCO_3^- ions, Na^+ ions and water then are ready for secretion into the duodenum upon an appropriate stimulus.
- **The postprandial acid tide:** The entry of H^+ into blood decreases pH of pancreatic venous blood. This neutralizes the alkaline tide of the gastric venous blood, restoring the normal pH of venous blood as leaving GIT. .



Function of pancreatic enzymes

- Pancreatic enzymes are considered **the most powerful enzymes in the alimentary canal** (the pancreas is the only gland which secretes a complete set of digestive enzymes for all types of food substances that is sufficient for complete digestion of carbohydrates, proteins and fats even in absence of salivary amylase, gastric pepsin and bile salts).
- **Pancreatic enzymes include:**
 1. Proteolytic enzymes (i.e. Digest proteins): e.g. Trypsin and chymotrypsin.
 2. Lipolytic enzymes (i.e. Digest lipids): e.g. Pancreatic lipase and colipase.
 3. Saccharolytic enzymes (i.e. Digest polysaccharides): e.g. Pancreatic amylase.
- **In addition to the proteases, lipase and amylase**, the pancreas produces a host of other digestive enzymes, including ribonuclease, deoxyribonuclease, gelatinase and elastase.

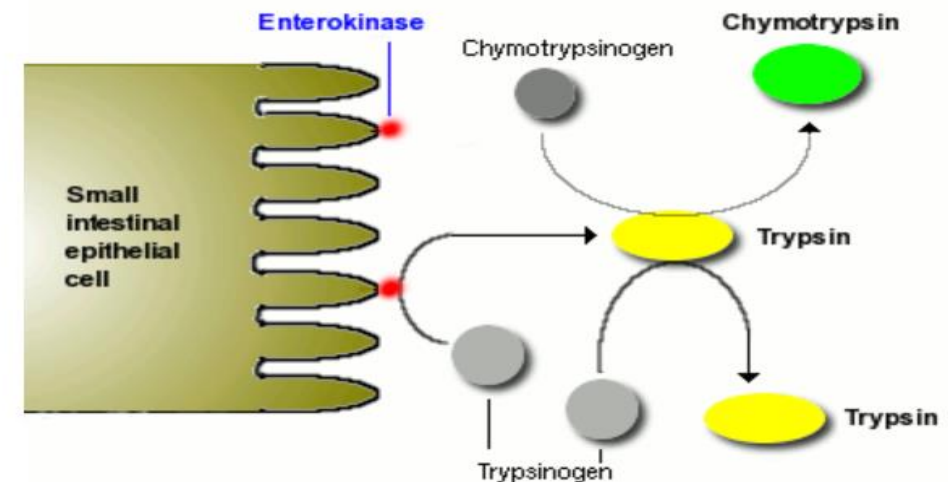
Proteolytic enzymes

- These proteolytic enzymes are secreted inactive.
- These inactive proteolytic enzymes include
 - Endopeptidase: (trypsinogen, chymotrypsinogen, proelastase).
 - Exopeptidase: (procarboxypeptidase).
- Trypsinogen is activated into trypsin in the duodenal lumen by enterokinase which is secreted from duodenal mucosal cells. Then, trypsin activates the other proteolytic enzymes in the duodenal lumen.

Chemotrypsinogen $\rightarrow\rightarrow\rightarrow$ chemotrypsin.

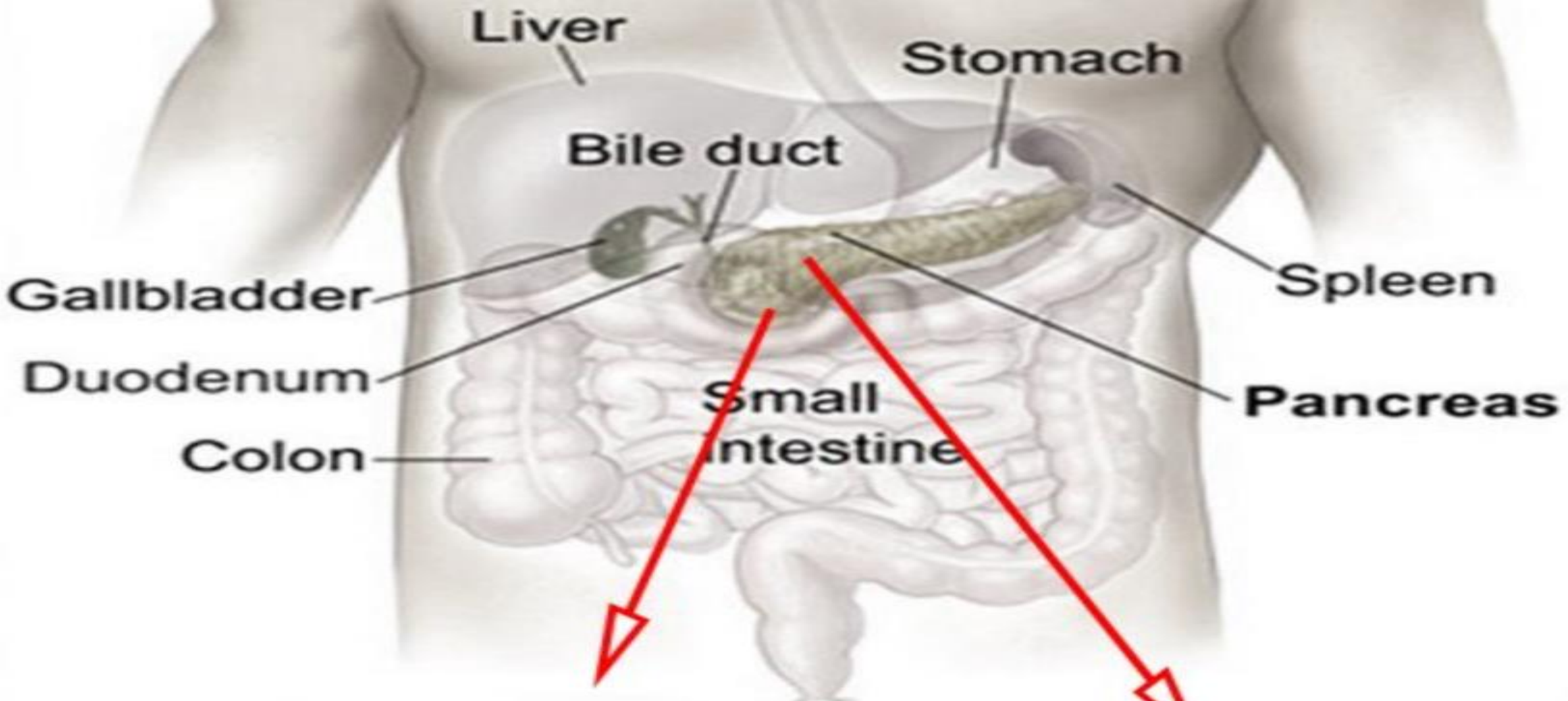
Proelastase $\rightarrow\rightarrow\rightarrow$ elastase.

Procarboxypeptidase $\rightarrow\rightarrow\rightarrow$ carboxypeptidase



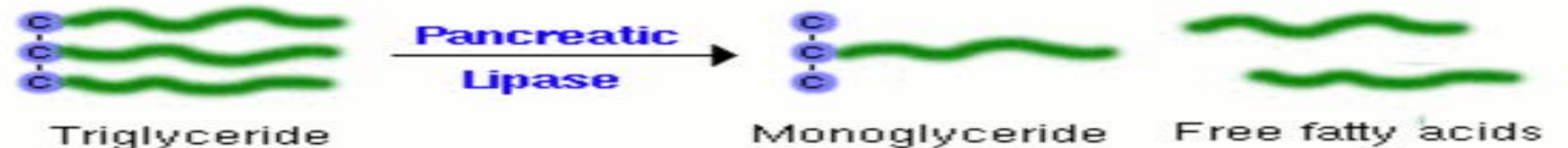
- These active proteolytic enzymes include endopeptidase and exopeptidase become ready to digest protein.
- The active endopeptidase include trypsin, chymotrypsin and elastase. They act on the internal peptide bonds and so digest the proteins into peptides. While, The active exopeptidase which include carboxypeptidase, act on the peripheral peptide bonds (C- terminus or N- terminus) and so digest the peptides into amino acids.
- All pancreatic proteolytic enzymes are secreted inactive and activated only in the duodenum to prevent autodigestion of pancreas and development of pancreatitis with subsequent death.
- Normally, the cells that secrete the proteolytic enzymes into the acini of the pancreas, secrete simultaneously **the trypsin inhibitor** which prevents activation of trypsinogen inside pancreas and also block the action of some activated trypsin that escaped from duodenum into pancreas or normally small amount activated with in the pancreas. So, trypsin inhibitor protect the pancreas from autodigestion by pancreatic proteolytic enzymes.

- Obstruction of the main pancreatic duct may result in acute pancreatitis. This occurs due to the level of activated trypsin inside the pancreas may increase to a high level that exceeds the capacity of trypsin inhibitors to inactivate it. This level of activated trypsin is enough to activate other proteolytic enzymes. And all these activated proteolytic enzymes attack the pancreatic tissue leading to autodigestion which is fatal due to the accompanying hemorrhagic shock.



Lipolytic enzymes

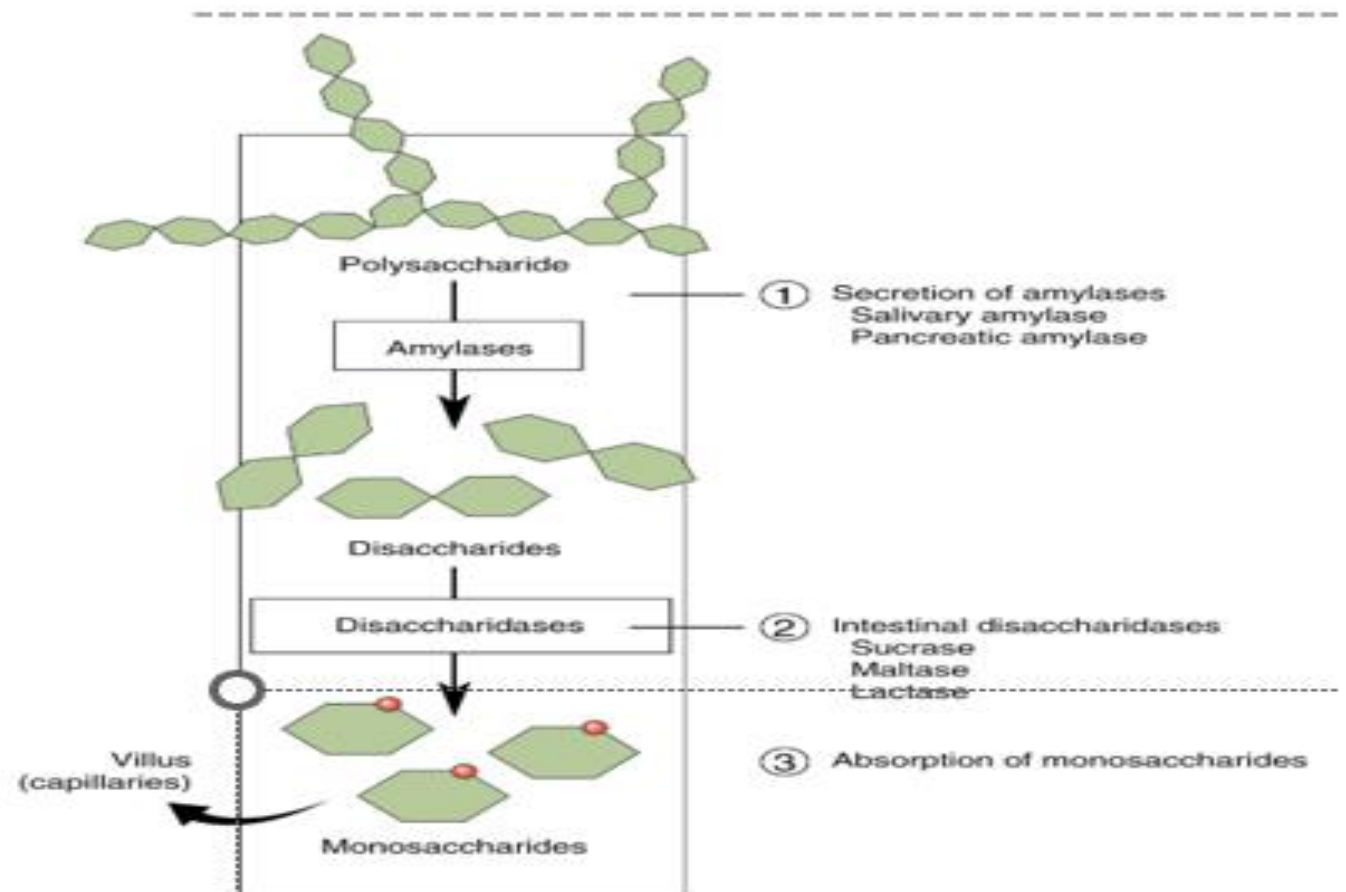
- They include pancreatic lipase, phospholipase and cholesteryl ester hydrolase.
- Pancreatic lipase is an active enzyme that hydrolyzes triglycerides into monoacylglycerol and fatty acids. This action is facilitated by the emulsifying action of bile salts.
- Phospholipase A2 is an inactive enzyme which is activated by trypsin into phospholipase A2 which acts on phospholipids resulting in formation of fatty acids and lysophospholipids.
- Cholesteryl ester hydrolase hydrolyzes cholesteryl ester leading to liberation of cholesterol.
- Pancreatic lipase has recently been a target for treatment of obesity. The drug orlistat is a pancreatic lipase inhibitor that prevents the digestion of triglyceride and thereby reduces absorption of dietary fat.



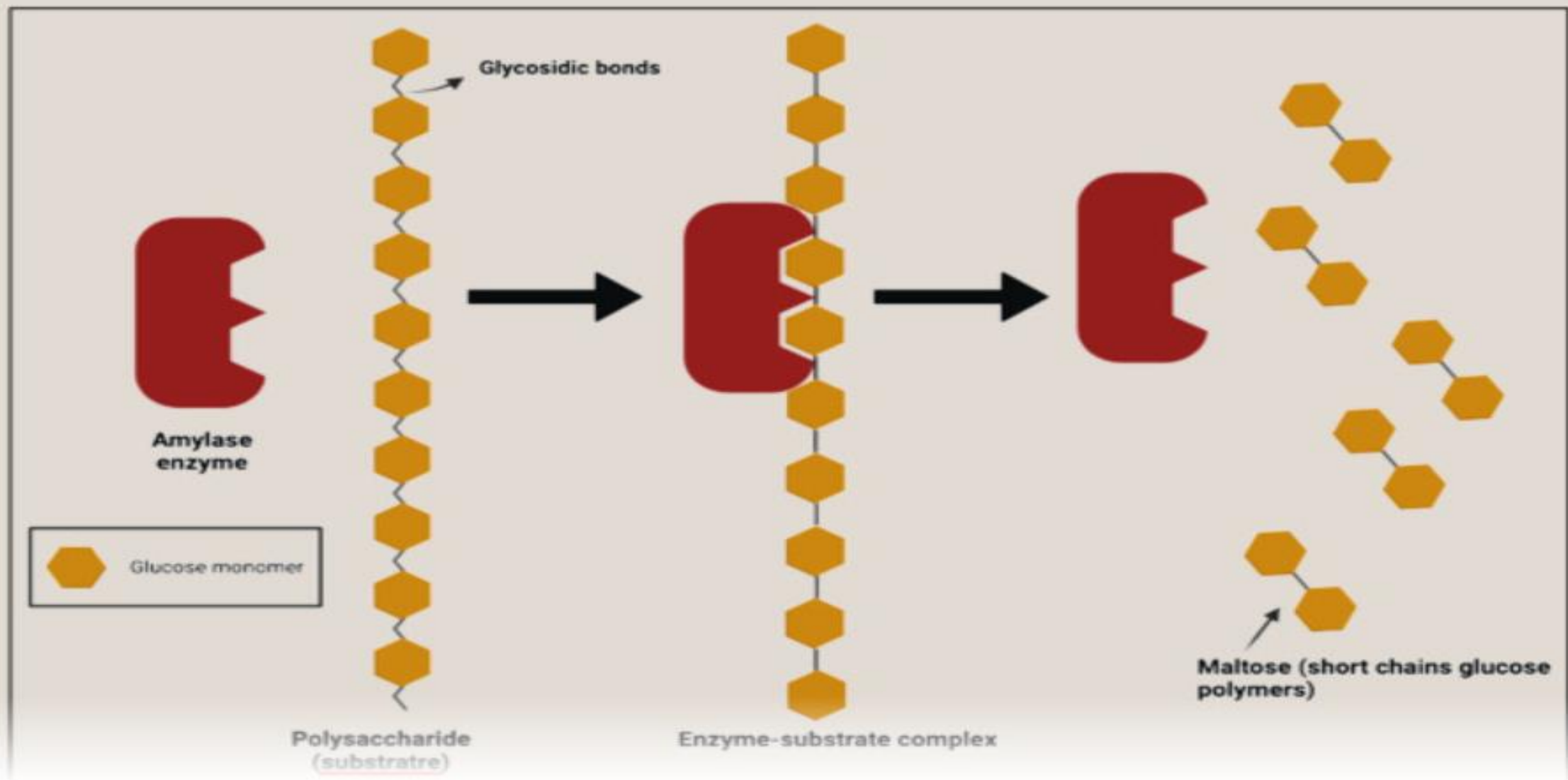
Saccharolytic enzymes (i.e. Digest polysaccharides): Pancreatic Amylase

Pancreatic Amylase completes the action of salivary amylase, but it is more potent as it acts on cooked and uncooked starch. it hydrolyses starch to maltose (a glucose-glucose disaccharide),

as well as the trisaccharide maltotriose and small branchpoints fragments called limit dextrins..



Hydrolysis of long-chain polysaccharides to short chains of glucose polymers by α -amylase enzymes



Regulation of exocrine pancreatic secretion

□ (I) **Nervous mechanism:**

It accounts for about **30%** of pancreatic secretion. It is produced by parasympathetic (vagus nerve) which stimulates acinar cells producing a secretion rich in digestive enzymes and poor in fluid. This occurs through cephalic phase and gastric phase

□ Cephalic phase (conditioned and unconditioned reflex)

A) **Conditioned reflexes:**

1) **Stimulus:** Seeing, smelling, and hearing the preparation of food.

2) **Reflex pathway:**

Receptors: in the eye, nose, and ear.

Afferent: cranial nerves (optic, olfactory & auditory).

Center: cerebral cortex □ vagal nucleus in MO.

Efferent: vagus nerve.

Effector organ: pancreas (**acini**).

3) **Response:** Pancreatic secretion, which is; Small in volume, Poor in alkalies and Rich in enzymes.

B) Unconditioned (simple) reflexes:

1) Stimulus: Food in mouth, esophagus or stomach

2) Reflex pathway:

Receptors: taste buds in mouth, other receptors in GIT.

Afferent:

7th, 9th C.N. from mouth & pharynx

10th C.N. from esophagus & stomach.

Center: vagal nucleus in medulla oblongata (MO).

Efferent: vagus nerve.

Effector organ: pancreas (acini).

3) Response:

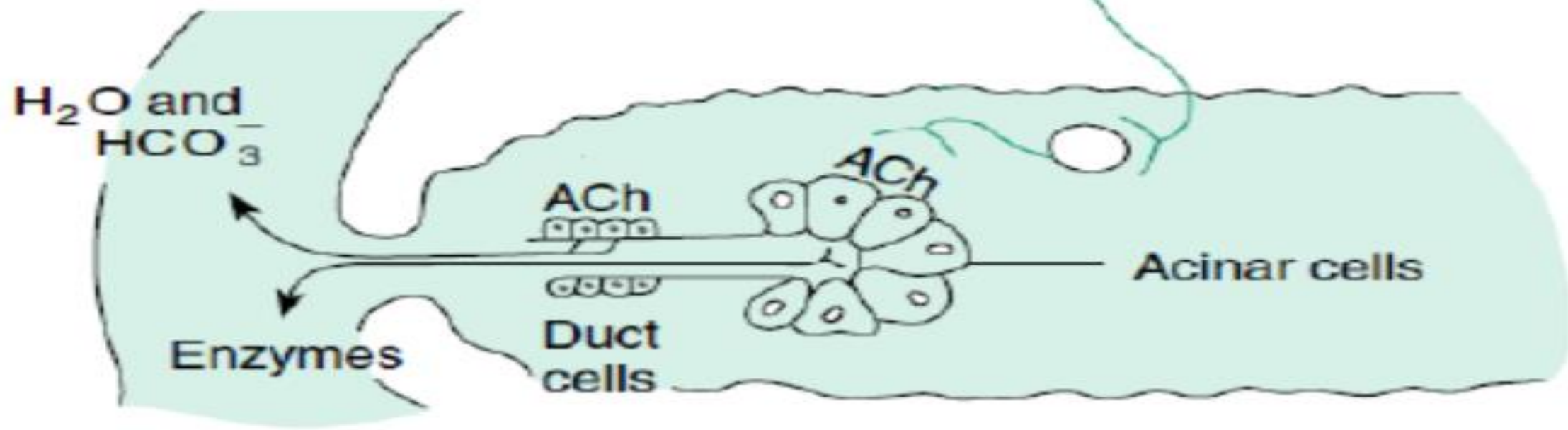
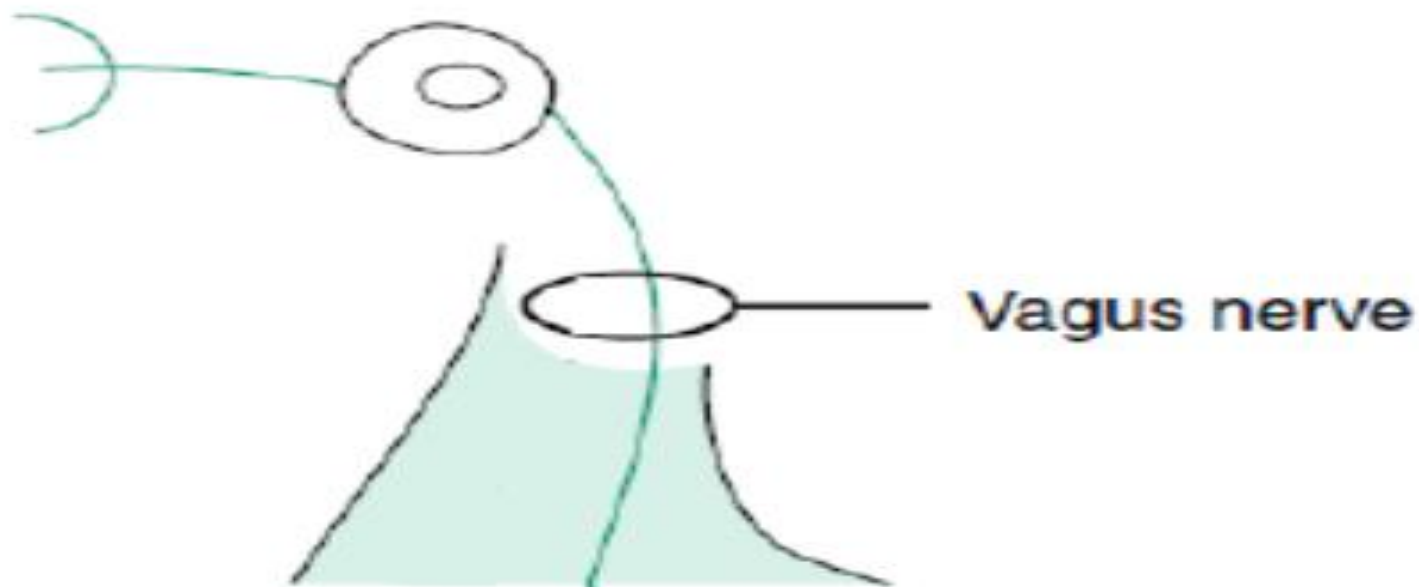
- Pancreatic secretion, which is;

Small in volume.

Poor in alkalies.

Rich in enzymes.

Conditioned stimuli
Smell, taste
Chewing
Swallowing
Hypoglycemia



(II) Hormonal mechanism: It is account for about **70%** of pancreatic secretion. It is the slowest control mechanism but the most important one. This occurs by secretin and cholecystokinin hormones.

I] Secretin hormone:

Site of release: Mucosa of upper part of small intestine.

Stimulus of release: Presence of acid chyme (semi-fluid material produced by gastric digestion of food)

Actions:

- **A) Pancreatic actions:** Pancreatic secretion (*ductular* secretion):

Large in amount.

Rich in alkalies (NaHCO_3).

Poor in enzymes.

B) Extra pancreatic actions:

1- Stimulation of bile secretion rich in H_2O (hydrocholertic).

2- Inhibit gastric motility & secretion.

II) Cholecystokinin hormone: (CCK)

Site of release: Mucosa of upper part of small intestine.

Stimulus of release: Presence of digestive products of proteins & fat.

Actions:

A) Pancreatic actions: Pancreatic secretion (*acinar* secretion):

Small in volume.

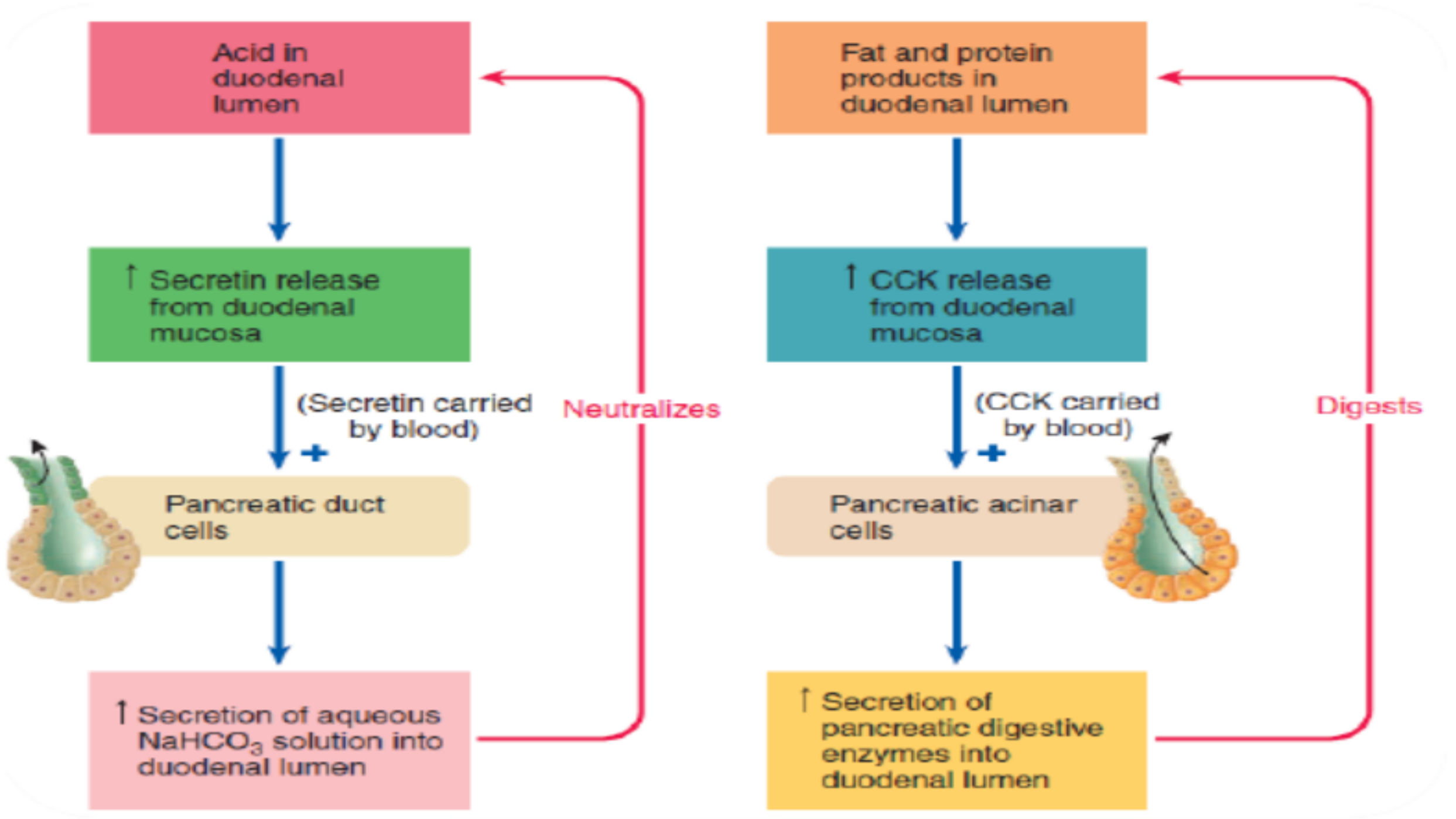
Poor in alkalies (NaHCO₃).

Rich in enzymes.

B) Extra pancreatic actions:

1- Evacuation of gall bladder (cholagogue).

2- Inhibit gastric motility & secretion.



Effects of damage of pancreas

1- Diabetes mellitus due to lack of insulin.

2- Digestive and nutritional disturbances

this is due to unproper digestion of various food constituents and so deficient absorption and loss of considerable amount of ingested protein and fat in the stool.

Fat loss causes steatorrhea (fatty diarrhea) in which feces become bulky, pale, loose and greasy with subsequent undernutrition.

3- Loss of fat soluble vitamins (A, D, E and K).

Causes of Steatorrhea

Any condition that causes indigestion or malabsorption of fat leads to steatorrhea. It leads to appearance of fat in stool which becomes pale, greasy, foul smelling. It is also associated with loss of fat soluble vitamins (K, E, D, A) important causes of steatorrhea include:

- **1. *Lack of pancreatic lipase:*** Since most of the fat is digested only by pancreatic lipase, its deficiency leads to steatorrhea
- **2. *Liver disease affecting secretion of bile:*** Bile salts are essential for the digestion of fat by lipase and absorption of fat from intestine. Absence of bile salts results in excretion of fatty stool
- **3. *Celiac disease:*** Atrophy of intestinal villi leads to malabsorption, resulting in steatorrhea

A vibrant watercolor illustration of a butterfly, centered on a white rectangular background. The butterfly's wings are painted with a variety of colors including purple, blue, yellow, pink, orange, and red, with soft, blended edges. Small, dark brown speckles are scattered around the butterfly, particularly on the left and right sides, adding a delicate, artistic touch. The overall composition is set against a light beige background.

Thank
you