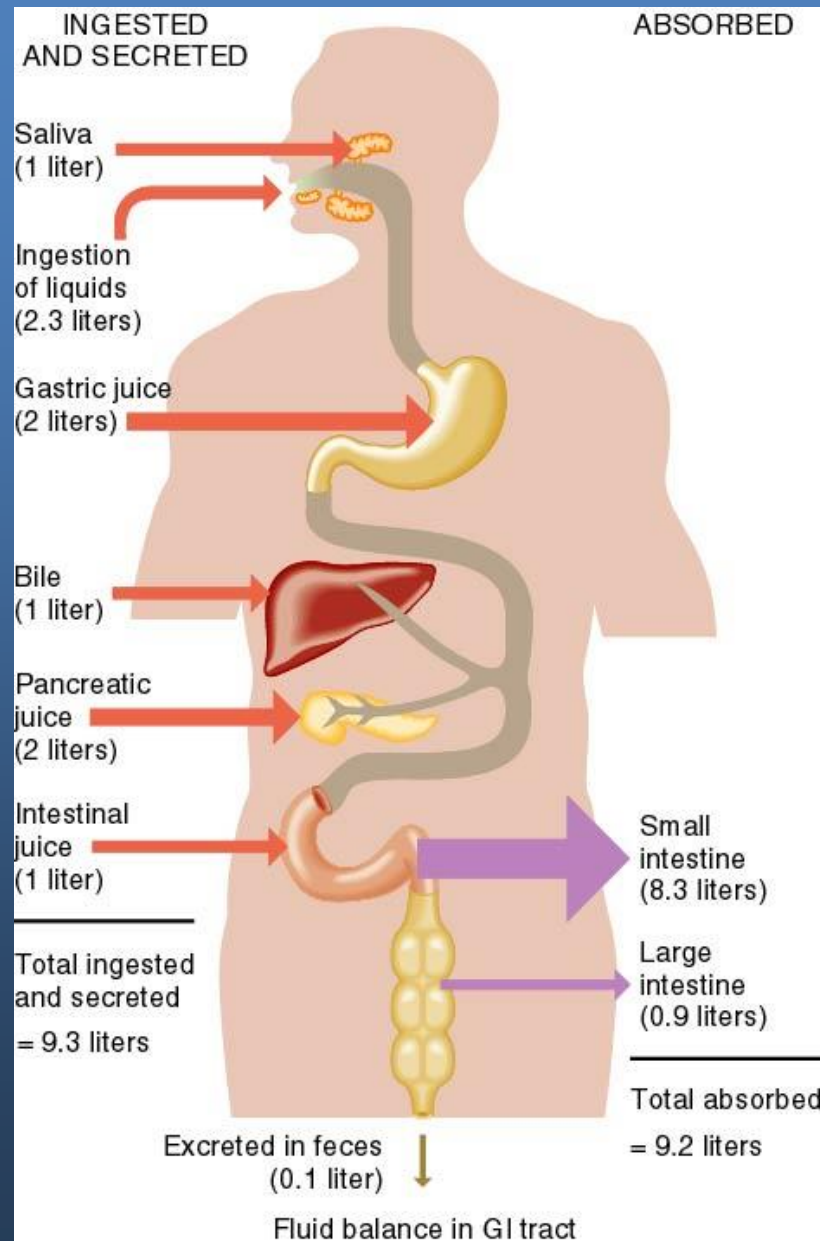


# Gastrointestinal Physiology

## Secretion

Fig. 24.26



# Functions

Provided by secretory glands which serve 2 functions:

- Digestive enzymes.
- Lubrication and protection of the mucosa.

# Types of secretory structures

The types of secretory glands:

- **Single-cell** secretory glands (goblet cells).
- **Pits** that represent invaginations of the epithelium in the submucosa in small intestine are known as crypts of Lieberkühn.
- **Complex glands** : in stomach and duodenum.
- **Organs**: salivary, pancreas and liver. Located outside the tubular structure of the GI.

# Control of secretion

## Neural Control

**ENS:**

**ANS:**

**Parasympathetic:**

**Sympathetic:**

- moderate increase →
- it reduces secretion by reducing blood → flow.

# Hormonal regulation

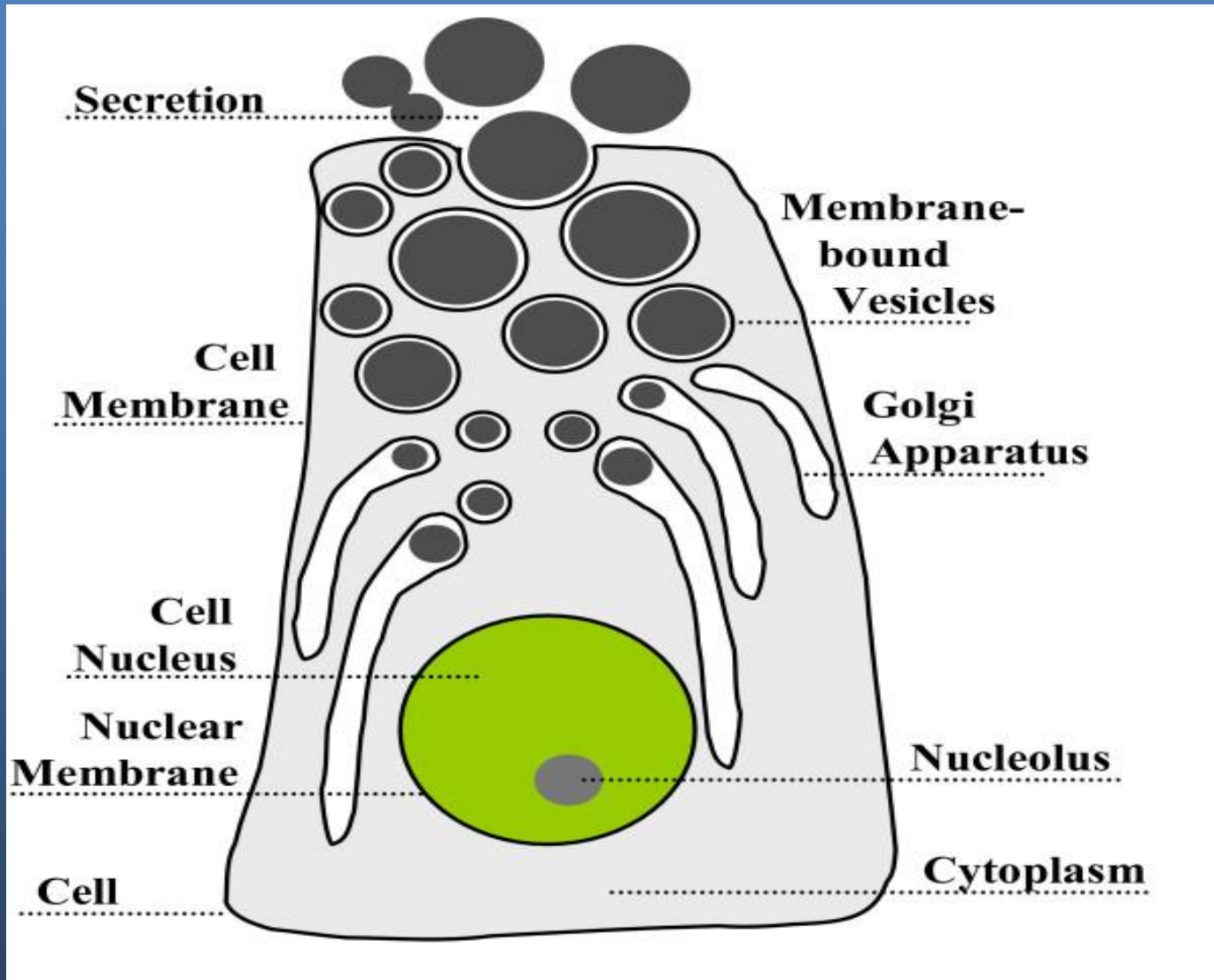
Some hormones are secreted by the presence of food or other local changes in the digestive organs.

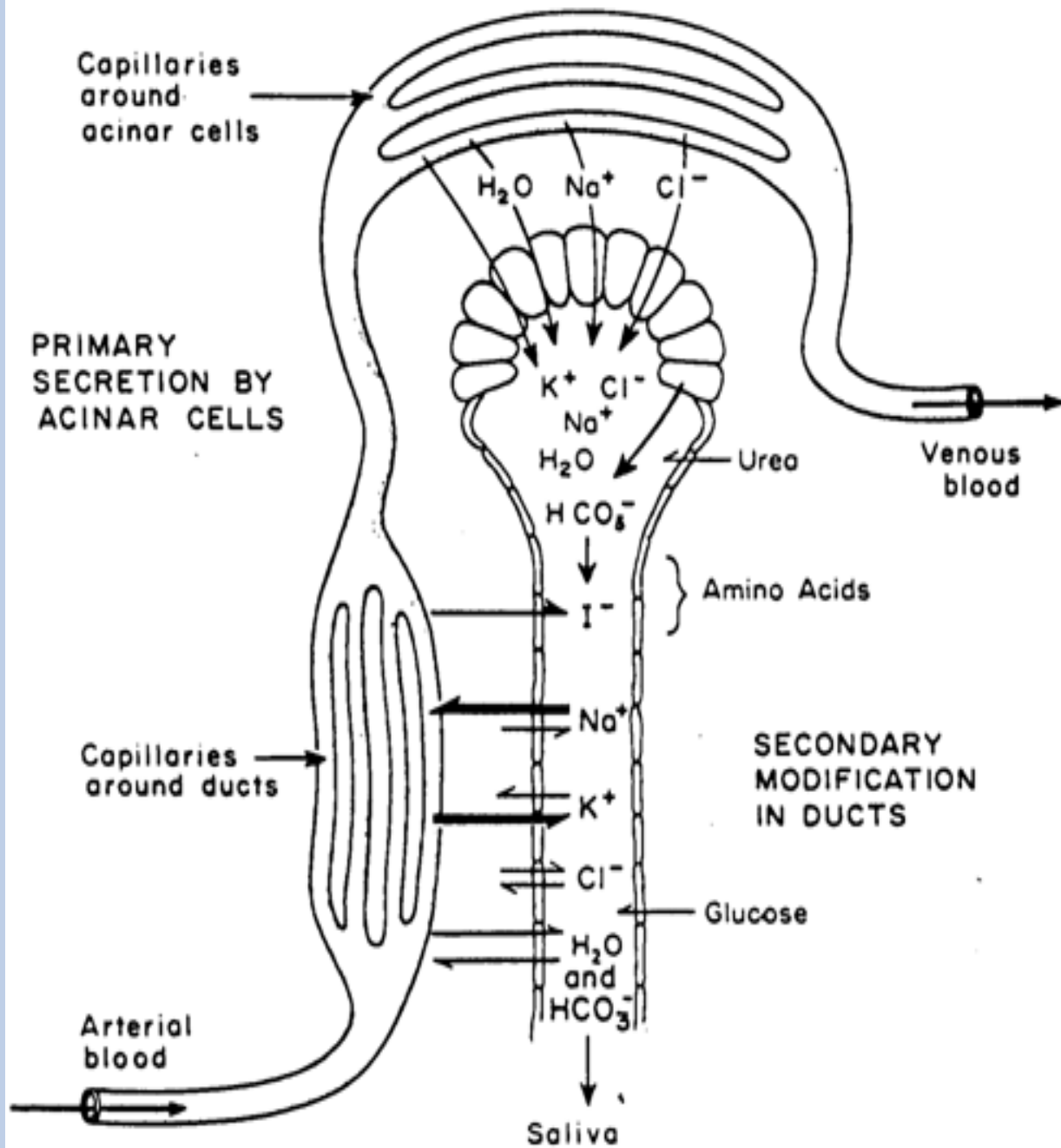
# Salivary Secretions

## Salivary Glands

| <b>Name of Gland</b> | <b>Type of Saliva</b> | <b>% of Total Saliva Secreted</b> |
|----------------------|-----------------------|-----------------------------------|
| Submandibular        | Mucous-serous         | 70                                |
| Parotid              | Serous                | 25                                |
| Sublingual           | Mucous                | 5                                 |

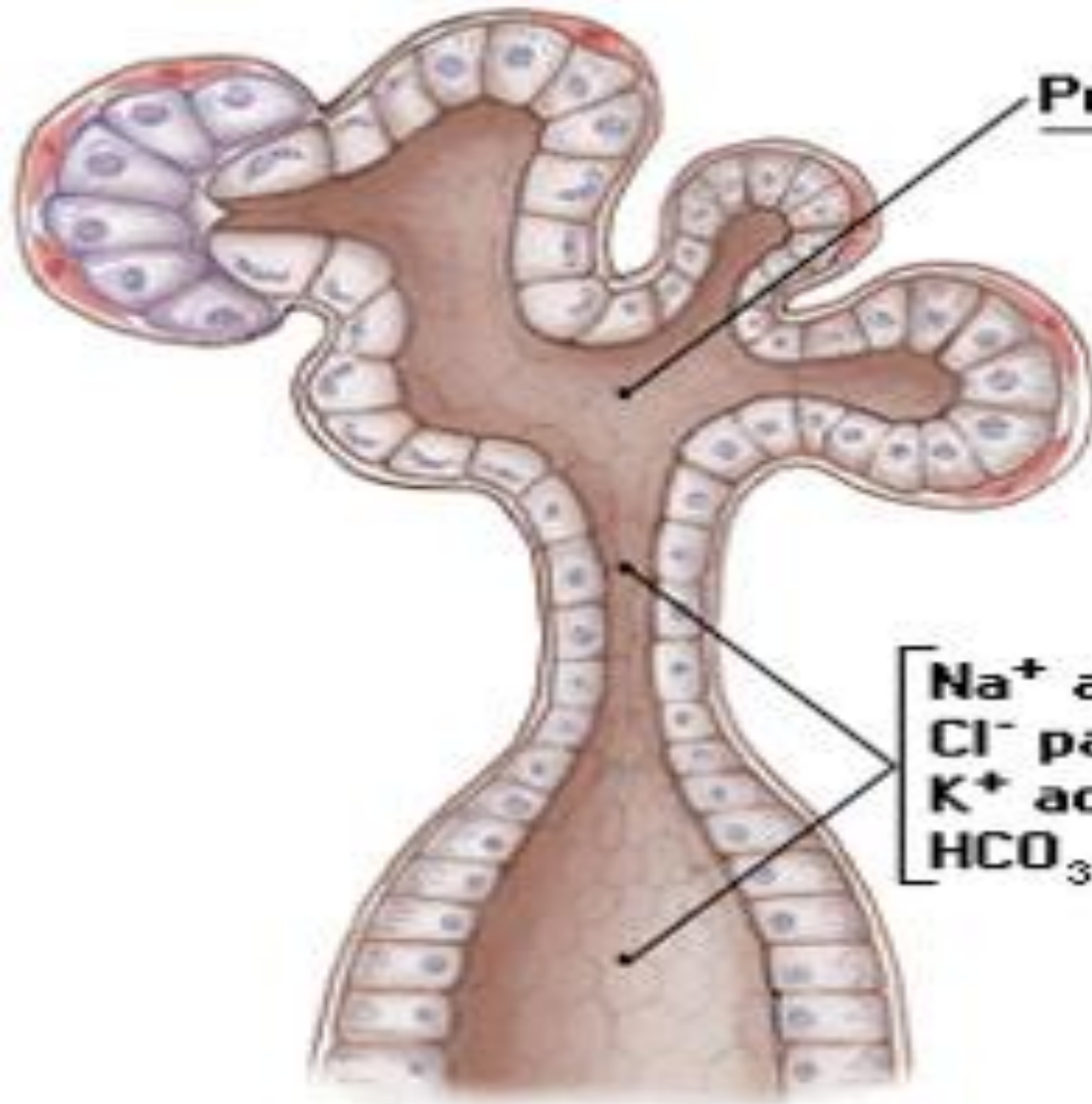






# Mechanism of Secretion

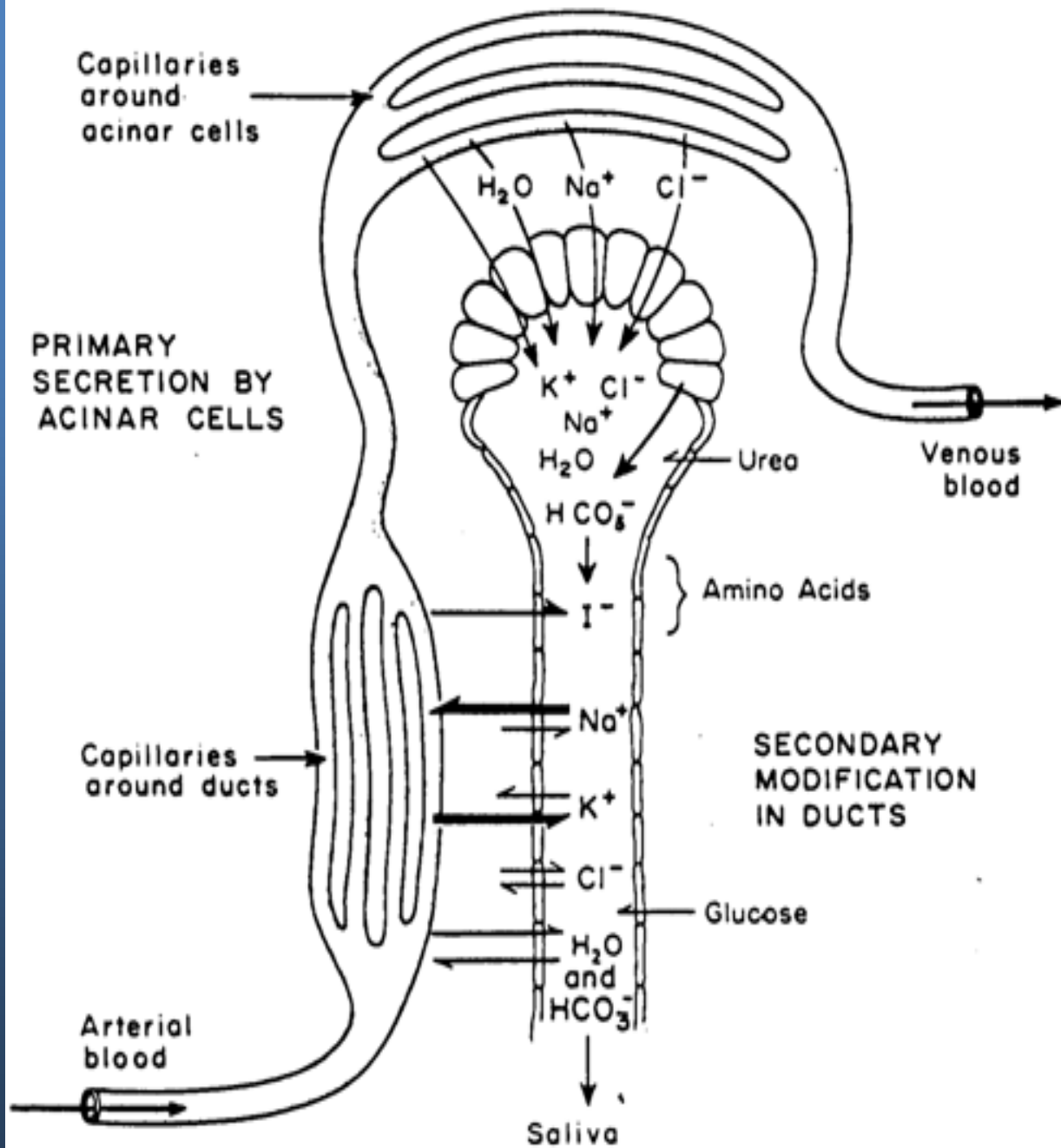
- **Active transport of Cl<sup>-</sup>** at the basal portion of the membrane.
- Increase in negativity of membrane potential which **attract the positive ion (Na<sup>+</sup>)**.
- Increase osmotic pressure inside the cell >> **pull water inside** >> increase hydrostatic pressure.
- This increase results in **minute ruptures at the luminal part** of the membrane which causes flushing of water,



**Primary Secretion**

- Amylase
- Mucus
- Extracellular fluid

- Na<sup>+</sup> active absorption**  
**Cl<sup>-</sup> passive absorption**  
**K<sup>+</sup> active secretion**  
**HCO<sub>3</sub> secretion**



# Changes in Composition in Final Saliva

↓ the Na<sup>+</sup> and Cl<sup>-</sup> concentration to the 1/10 of their plasma concentration

↑ 7 folds increase in K<sup>+</sup> concentration.

↑ HCO<sub>3</sub><sup>-</sup> concentration also increases 2-3 times.

# Rate of Secretion

The amount of salivary secretion is about 1500ml/day.

Resting secretion rate 0.025-0.5ml/min (during basal conditions).

The pH = 7.0

# DURING MAXIMAL STIMULATION

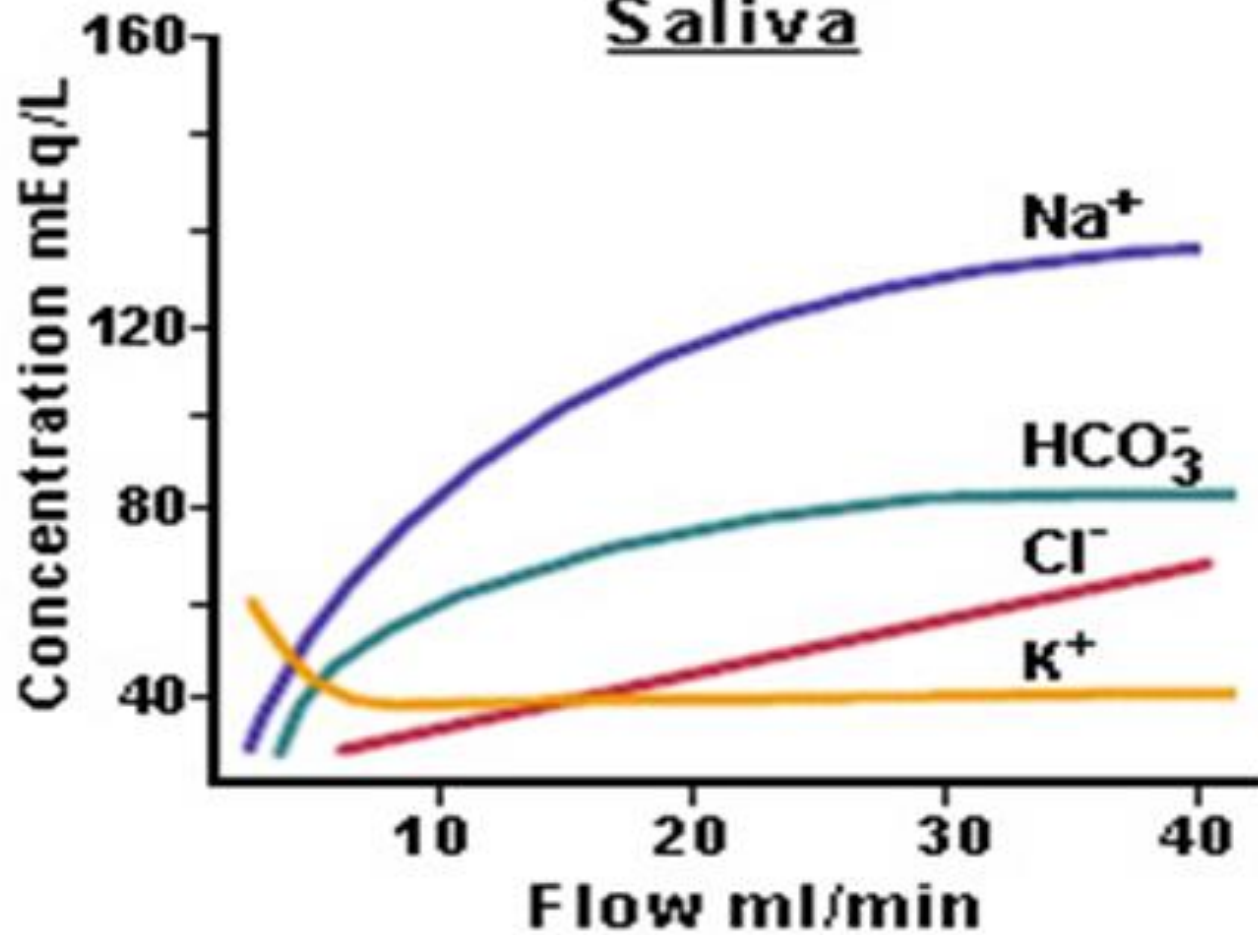
The primary saliva increasing 20 folds.

- Flow rate of saliva is increased

PH=8



## Saliva



# Control of salivary Secretion

## Autonomic nervous system.

- Both sympathetic and parasympathetic increase salivation but by different mechanisms

- **parasympathetic increase water and electrolyte secretion.**

- **Sympathetic increase mucin synthesis.**

An increase in the sympathetic activity → **reduces salivation**

# Control of salivary Secretion

Aldosterone:

Salivation is increased by:

- **Unconditioned** salivary reflex (dental procedures).
- **Conditioned** salivary reflex (learned — response).

# Functions of Saliva

- Saliva begins **digestion** of carbohydrates in the mouth:  
Saliva begins digestion of carbohydrates in the mouth:

Amylase that breaks polysaccharide into maltose (disaccharide consists of 2 glucose).

- **Facilitate swallowing** by:

Moistening the food particles.

Lubrication

# Functions of Saliva

## - Antibacterial actions:

Lysozyme: an enzyme that lyses or destroys certain bacteria.

## - Oral hygiene

keeping mouth and teeth clean by the constant flow and secretion of

IgA which helps in the destruction of bacteria

# Functions of Saliva

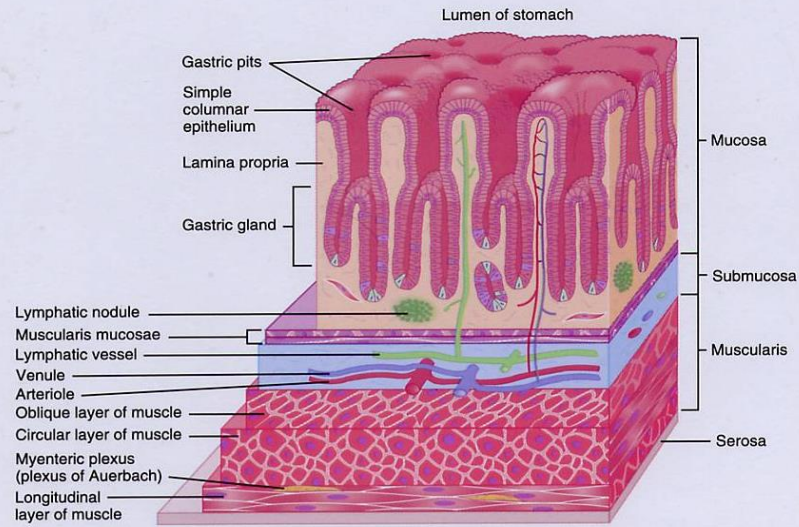
- **Solvent** for molecules that stimulate taste buds.
- **Aids speech.**
- Bicarbonate **neutralizes acids**
  - preventing cari

# Esophageal secretion

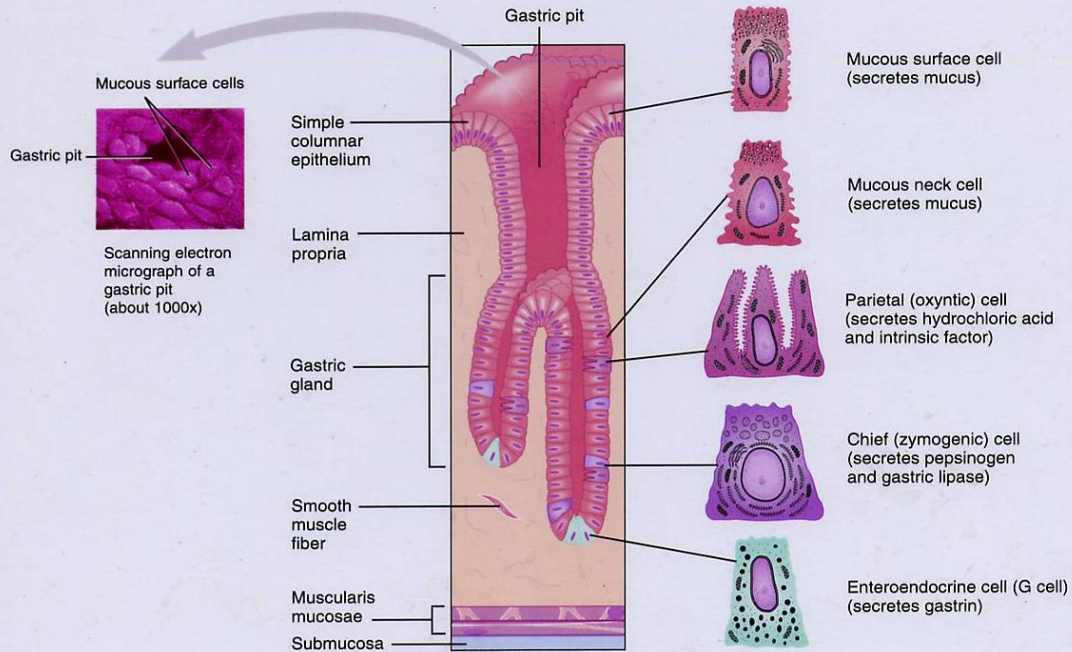
- **Simple mucus glands** and solitary cells (mucoïd character) help in lubrication and protection.
- **Compound mucus glands** near the esophago-gastric junction and protect the esophagus from reflux.

# Gastric Secretions





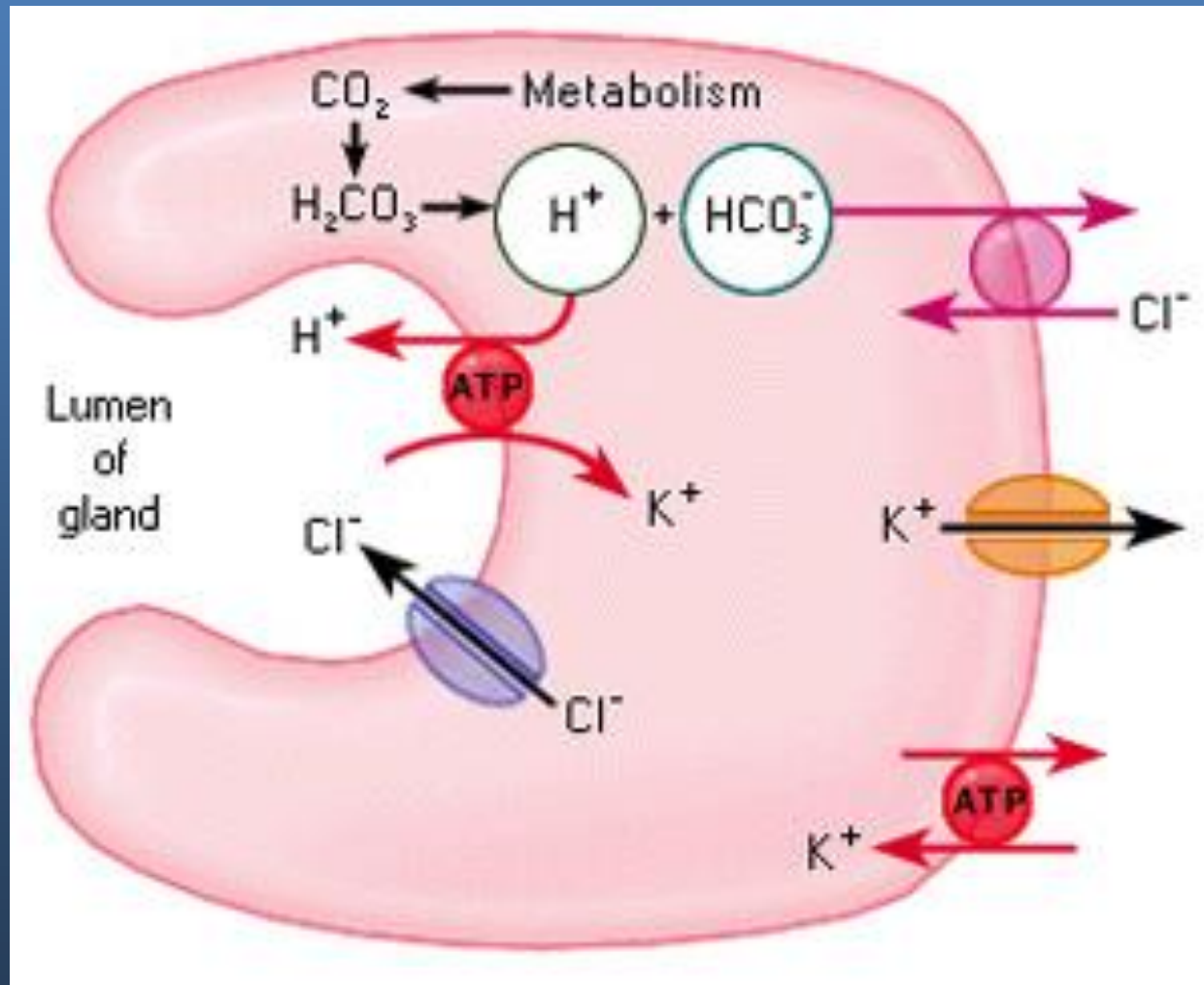
(a) Three-dimensional view of layers of the stomach



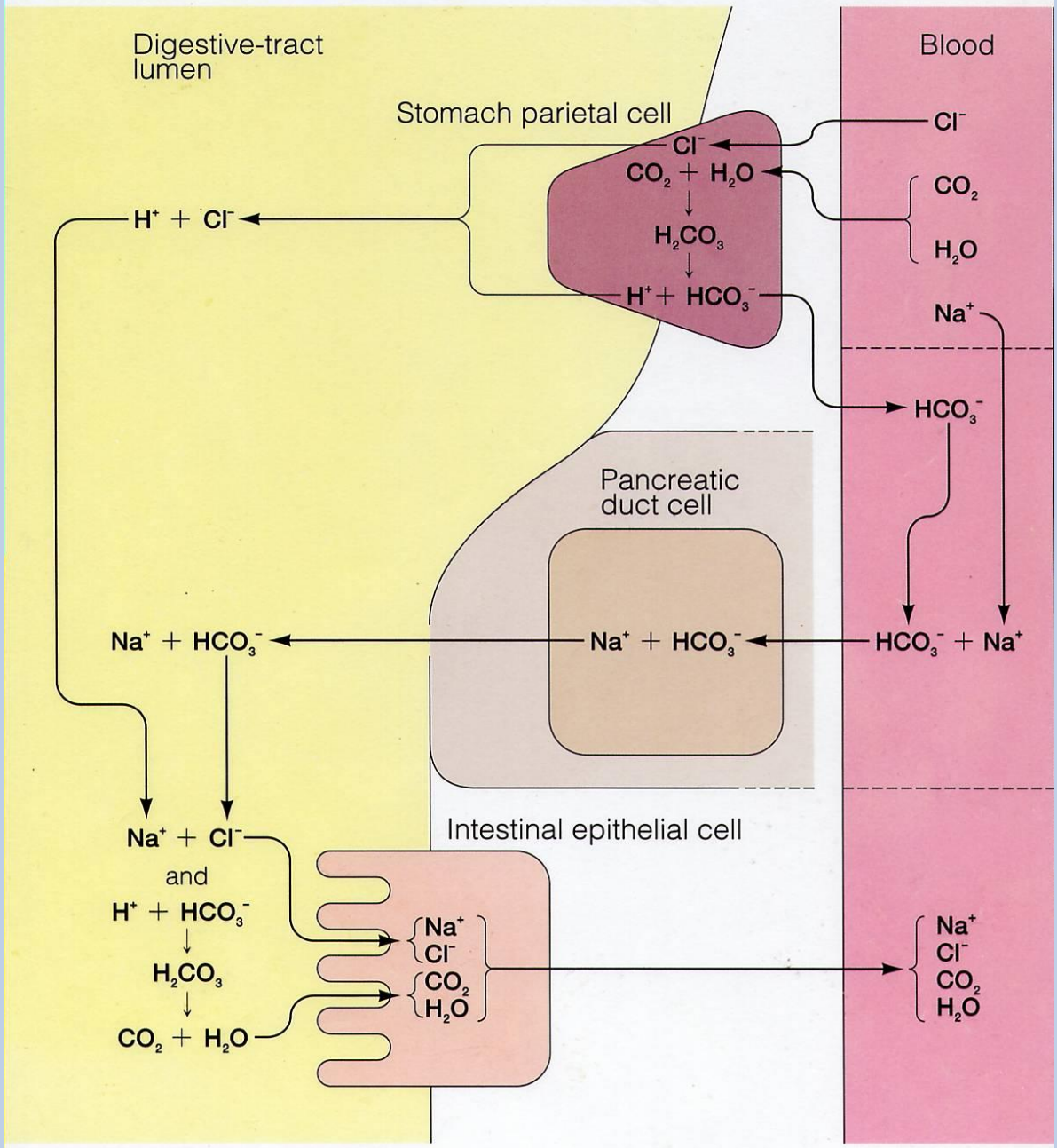
(b) Sectional view of the stomach mucosa showing gastric glands

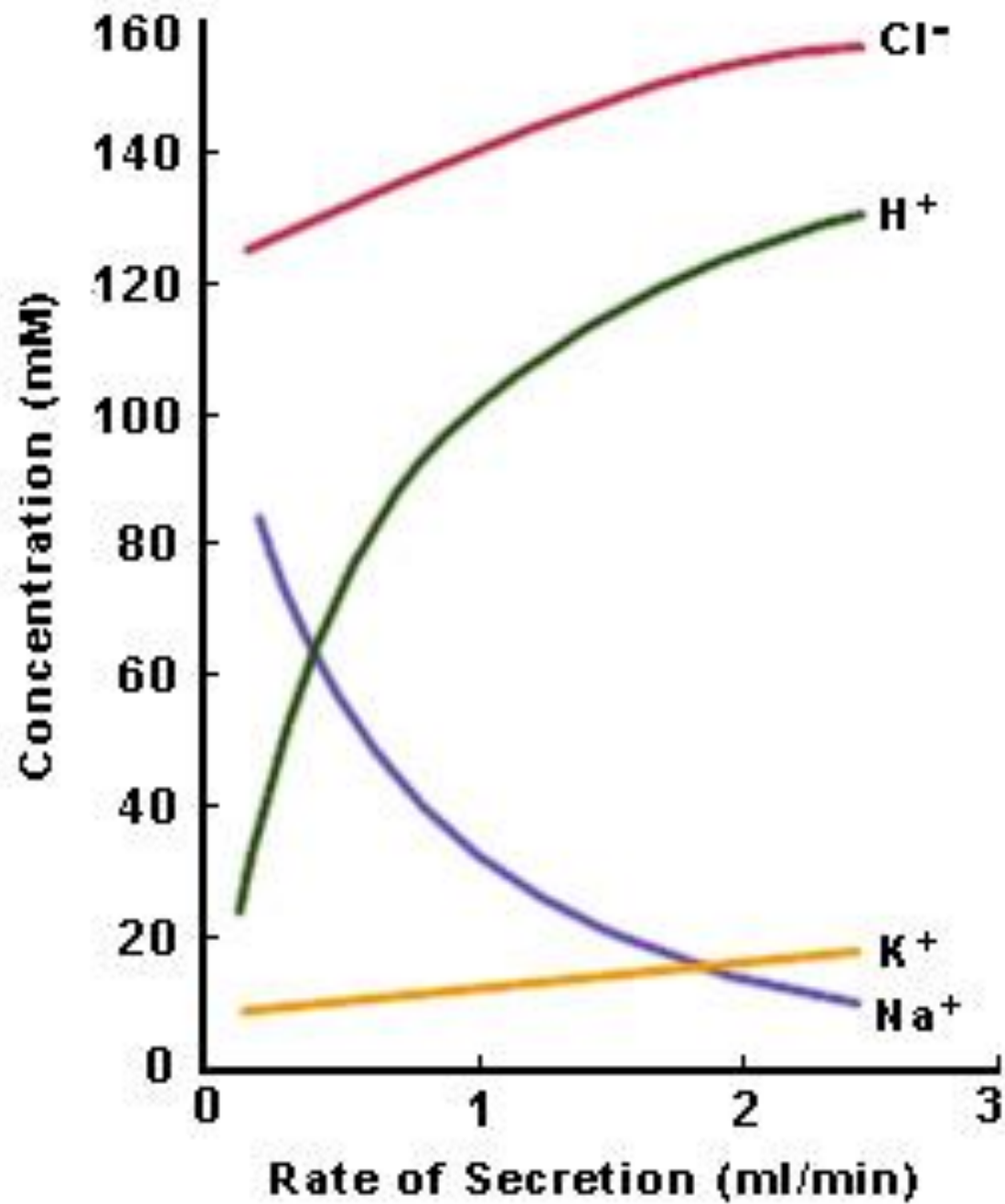
**Histology of the Stomach: Layers of the Stomach and the Stomach Mucosa, Fig# 24.12a-b**

# Mechanism of HCl Secretion

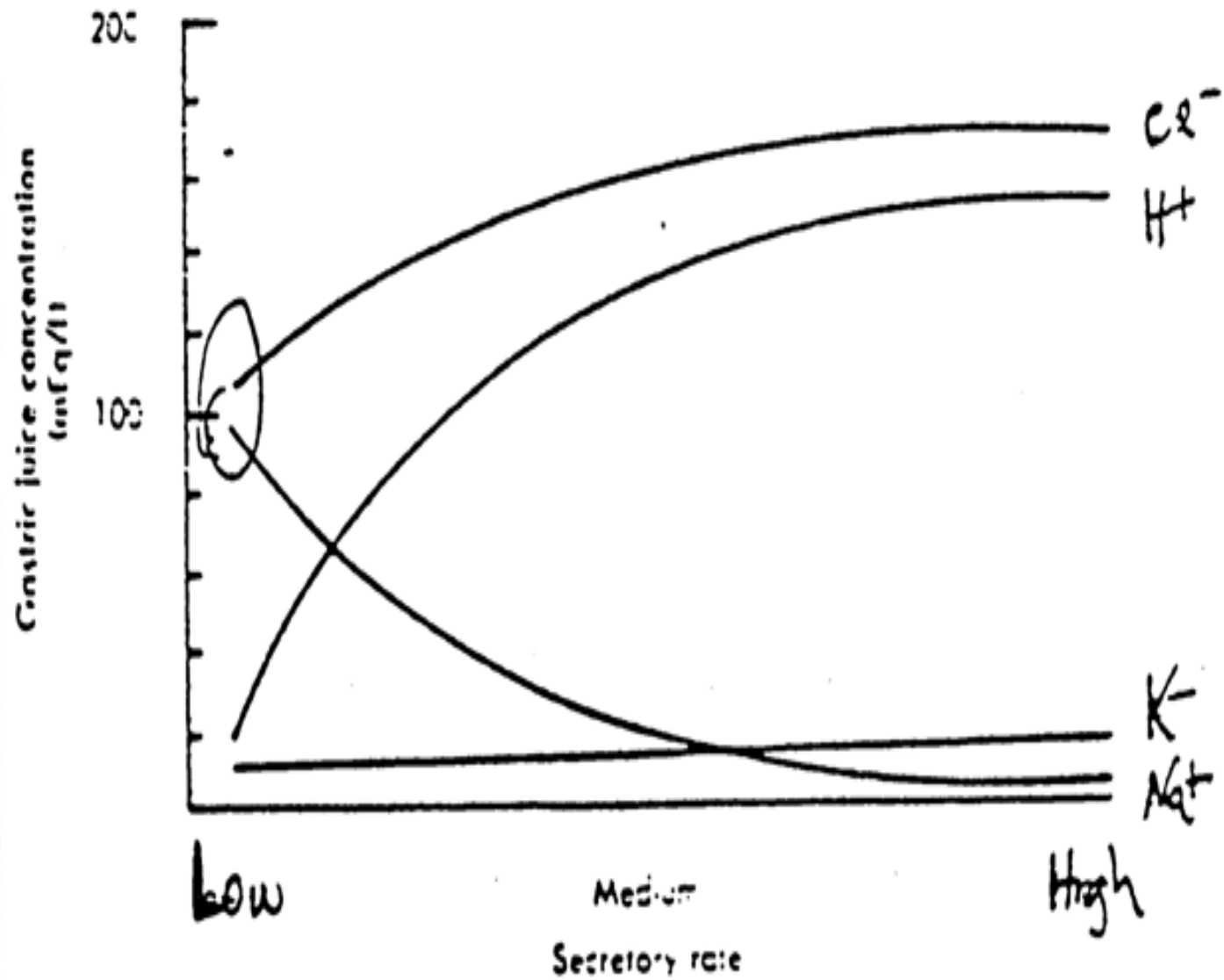


# Biochemical Balance Among the Stomach, Pancreas, and Small Intestine









# Functions of HCl

- Conversion of pepsinogen to pepsin
- Helps in the decomposition of connective tissue.
- Defense (killing most microorganisms ingested with food).

# Secretion of **pepsinogen**

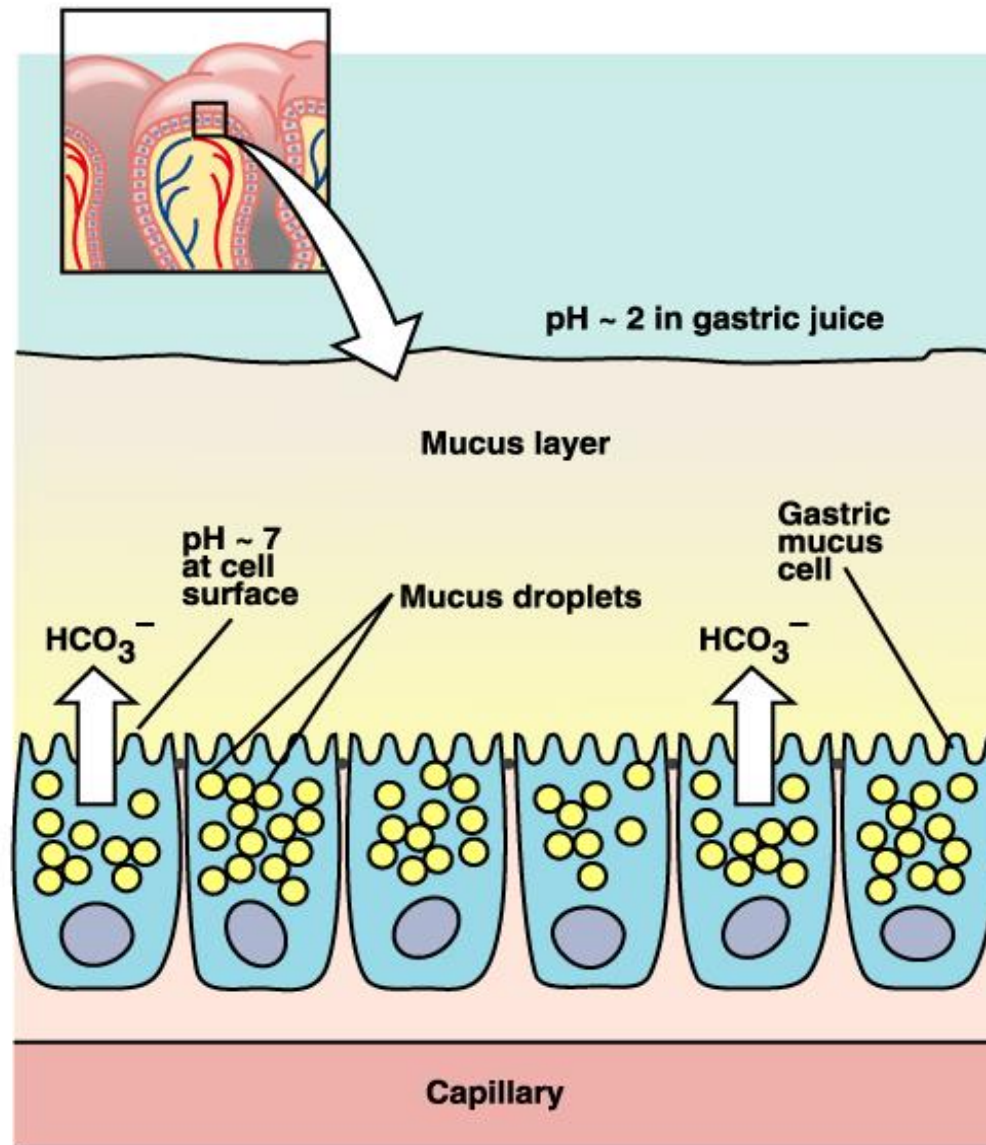
Secreted by peptic (chief) and mucous cells.

- Optimal activity at pH (1.8-3.5).

## **Function:**

- Pepsin cleaves the peptide linkage protein → into smaller peptide fragments.

# Mucus secreting cells





# Mucus secreting cells

Function:

- Lubricating functions.
- Protect the mucosa from the chemical injury by:
  - Preventing the activity of the proteolytic enzymes to act on the mucosa
  - Neutralizing HCl by its alkaline character.

# Gastrin Secretion

Secreted by G cells

stimulated by:

- gastric distention.
- presence of proteins in chyme.
- vagal stimulation.

## Functions:

- Increases HCl and pepsinogen secretion.
- trophic effect on gastric mucosa to maintain growth of mucosal cells.

# Secretion of Intrinsic factor

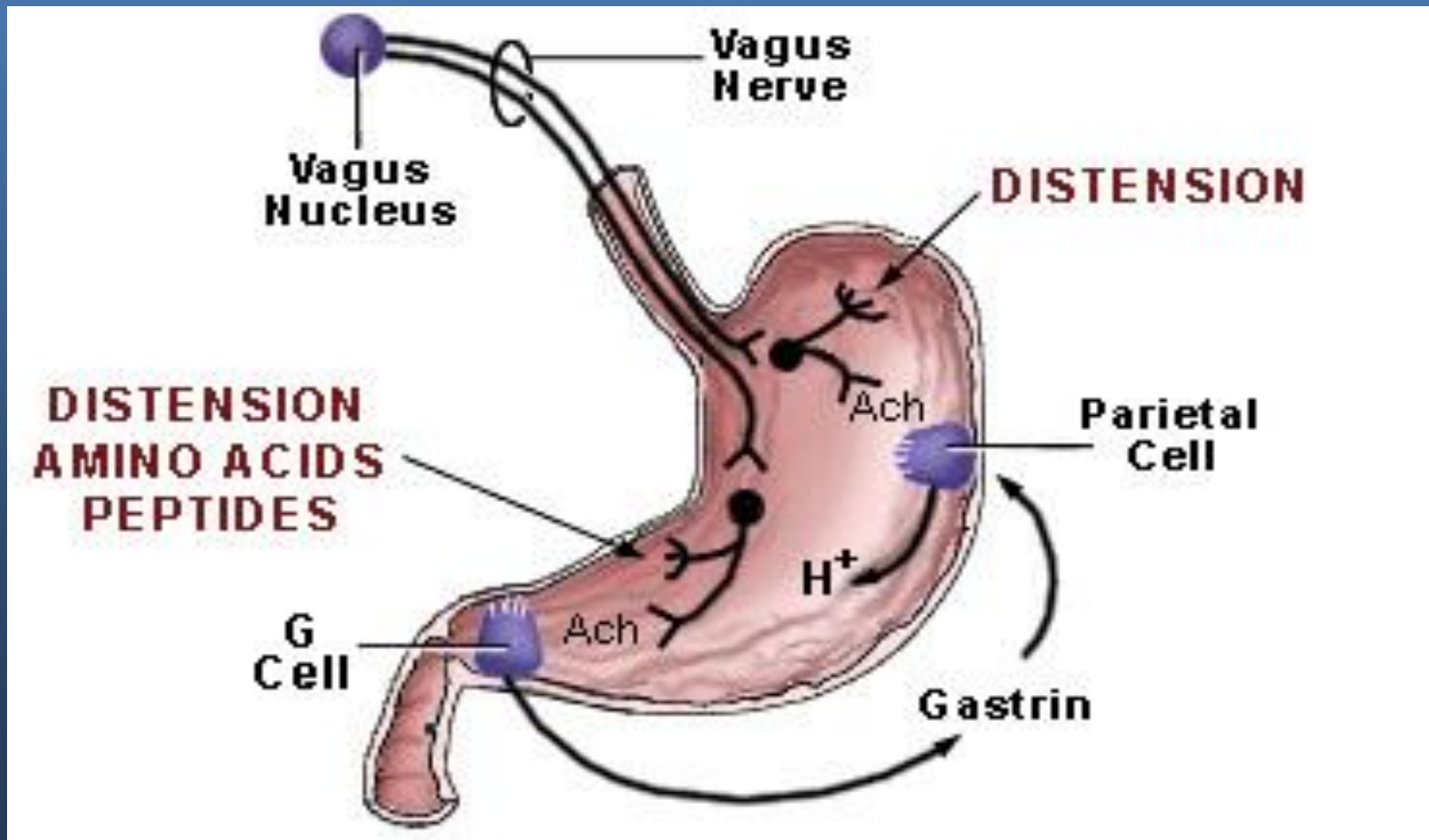
Is secreted by parietal cells  
(**oxyntic cells**).

**Essential for B12 absorption**

# Control of Gastric Secretion

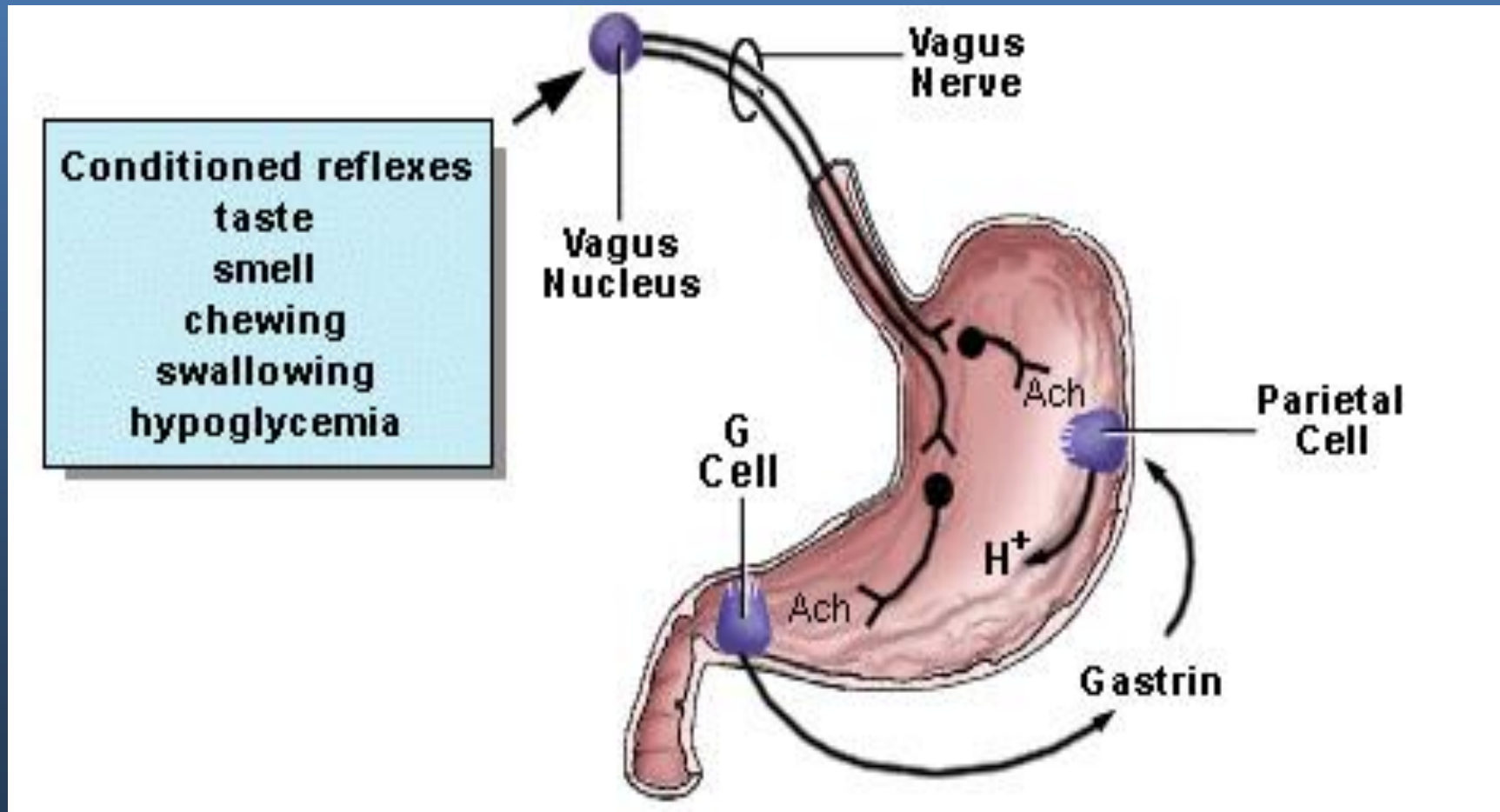
# Neural Control

**ENS:** Ach neurons → parietal and peptic cells.



# Neural Control

**ANS** (Parasympathetic): vagal activation during cephalic and gastric phases ( via long arc reflex)



# Neural Control

**ANS (Parasympathetic):** vagal activation during cephalic and gastric phases ( via long arc reflex)

- **enteric excitatory** neurons to release **Ach.**

- **enteric neurons** → enterochromaffin-like cells → **Histamine.**

- **enteric neurons** that release GRP → Gastrin Releasing Peptide → G Cells → **Gastrin.**

# Control of Gastric Secretion

## Hormonal control

Gastrin → parietal cells → increase HCl secretion.

Gastrin stimulate CCK-B receptor on oxyntic cells to secrete HCl.

This receptor can also be activated by CCK (cholecystokinin).



# Control of Gastric Secretion

## Paracrine

**Histamine** (secreted by enterochromaffin-like cells) → H<sub>2</sub> receptors on parietal cells → increased cAMP → increased HCl secretion.

**Somatostatin (SS)** → SS receptors on parietal cells decrease cAMP → decrease HCl secretion.

# Role of HCl in controlling secretion

- HCl acts indirectly by initiating enteric reflexes that causes an increase in pepsinogen secretion by peptic cell.

- **Excess of acids**

- causes feed back inhibition of gastric secretions by 2 ways:

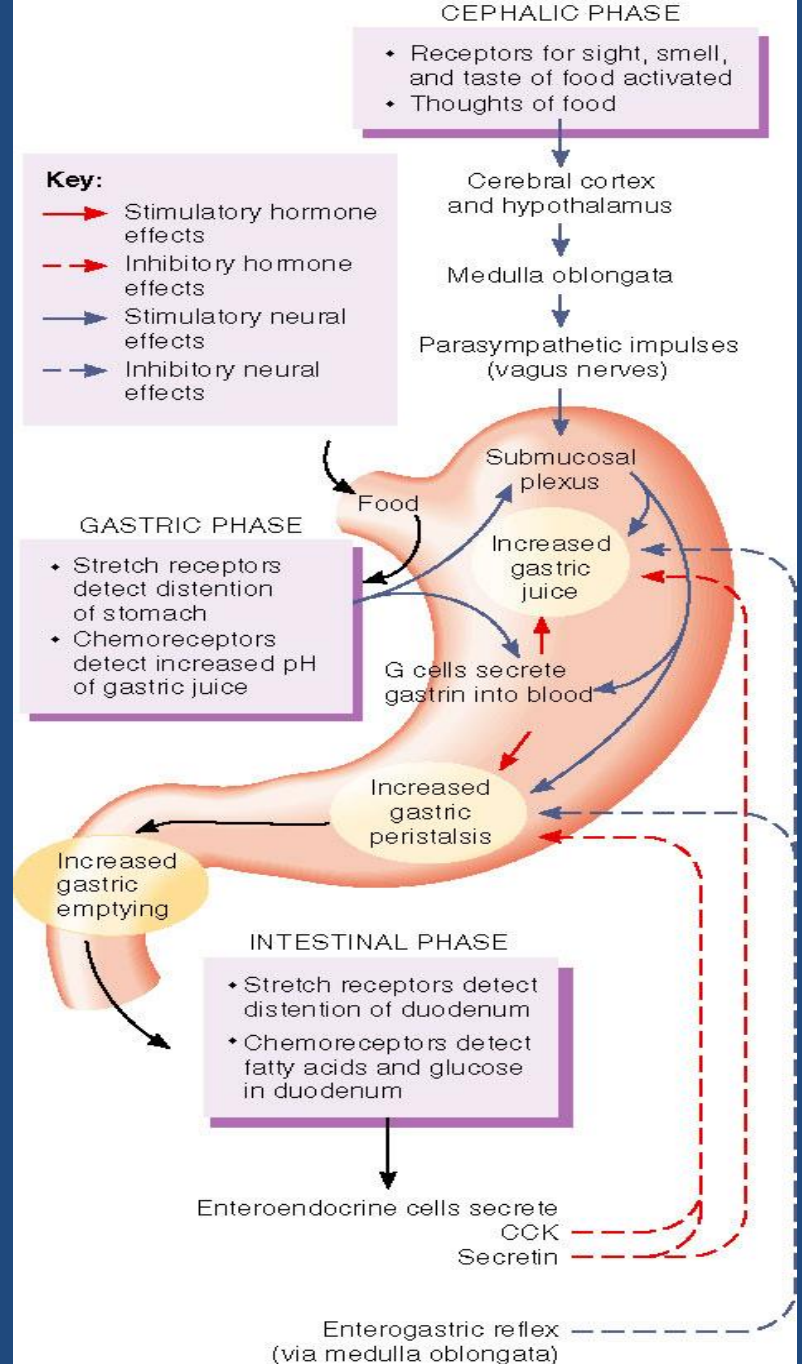
  - \* Reduction of gastrin release

  - \* Initiation of inhibitory reflexes.

This maintains the pH from falling below 3.

# Summary of Control

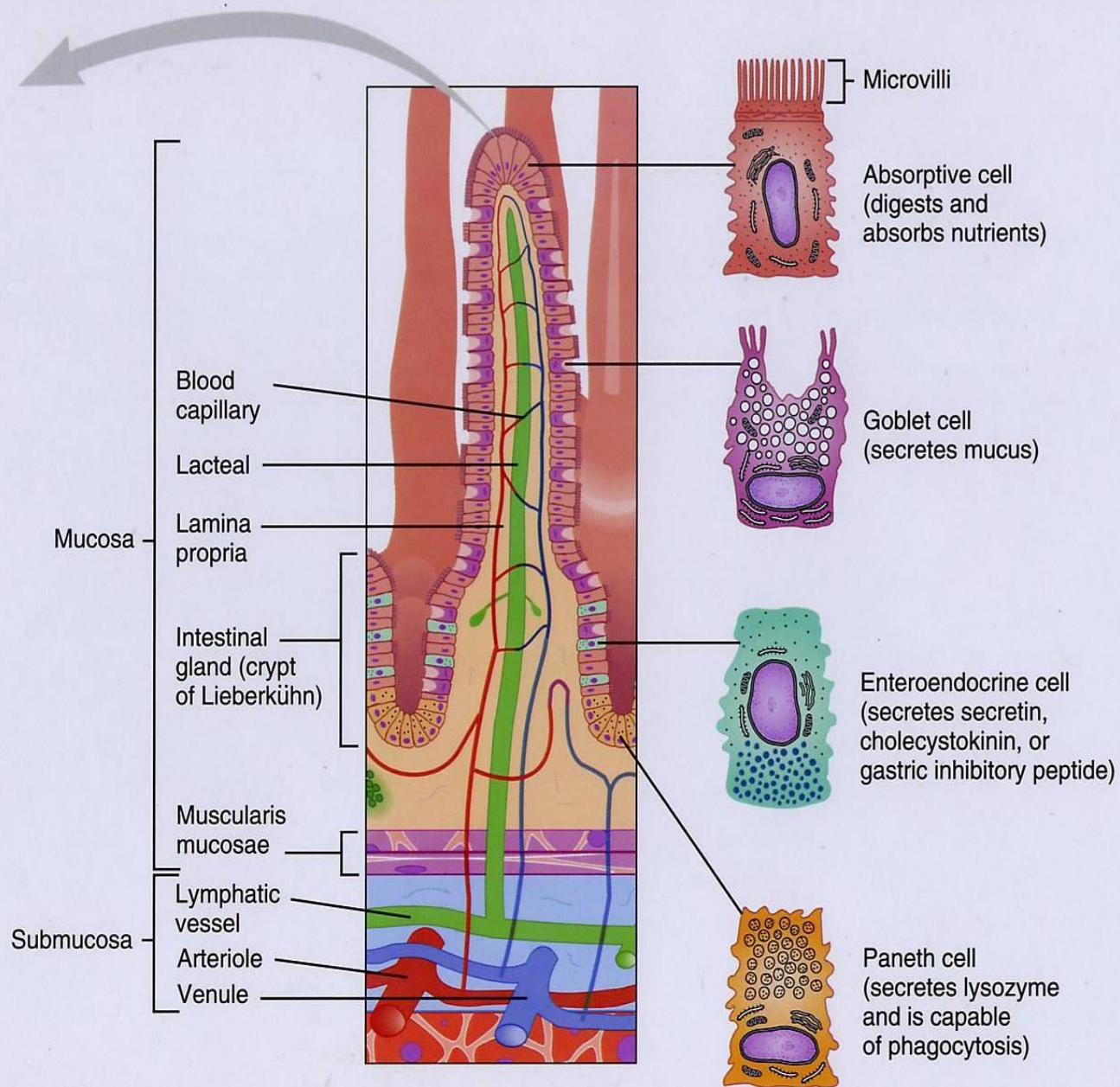
- Cephalic phase
- Gastric phase
- Intestinal phase



# 3 phases of control of gastric secretions

- **Cephalic phase:** stimuli before food reaching the stomach via parasympathetic NS
- **Gastric phase:** Food in stomach
  - Distension and the presence of proteins local and long reflexes increased gastric secretion.
  - Caffeine and alcohol also stimulate acid secretionsvia ENS, ANS and Hormones
- **Intestinal phase:**
  - Excitatory
  - **Inhibitory**

# Intestinal Secretions



Enlarged Villus Showing Lacteal, Capillaries and Intestinal Gland, Fig# 24.23b

# Small Intestinal Secretions

(1500ml/day)

- Cells of mucosal epithelium secrete mucus, water and electrolytes.

Tubular glands (crypts of Leiberkuhn) secrete serous secretion.

# Small Intestinal Secretions

## Regulation

**Neural** mechanisms (mediated by Ach and VIP).

## Hormonal:

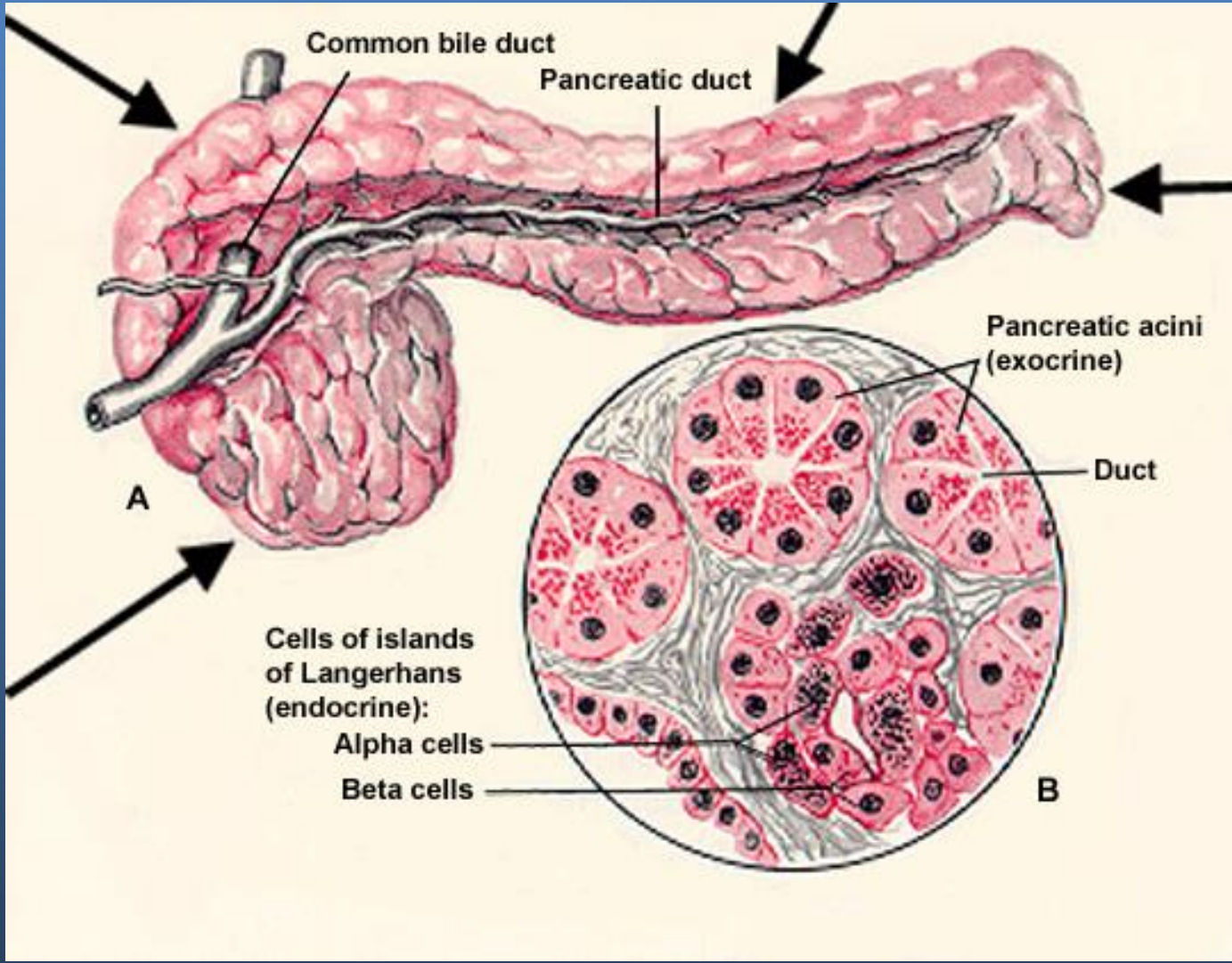
Secretin: increases duodenal secretion.



# Colonic secretions

- Mostly **mucus** secretion
- Small amount of **serous** secretions which is high in  $K^+$  and  $HCO_3^-$ .

# Pancreatic Secretions



# Exocrine portion

- Enzymes: secreted by **acinar** cells.
- Water and bicarbonate are secreted by **duct** cells.

## Schematic Representation of Exocrine and Endocrine Portions of the Pancreas

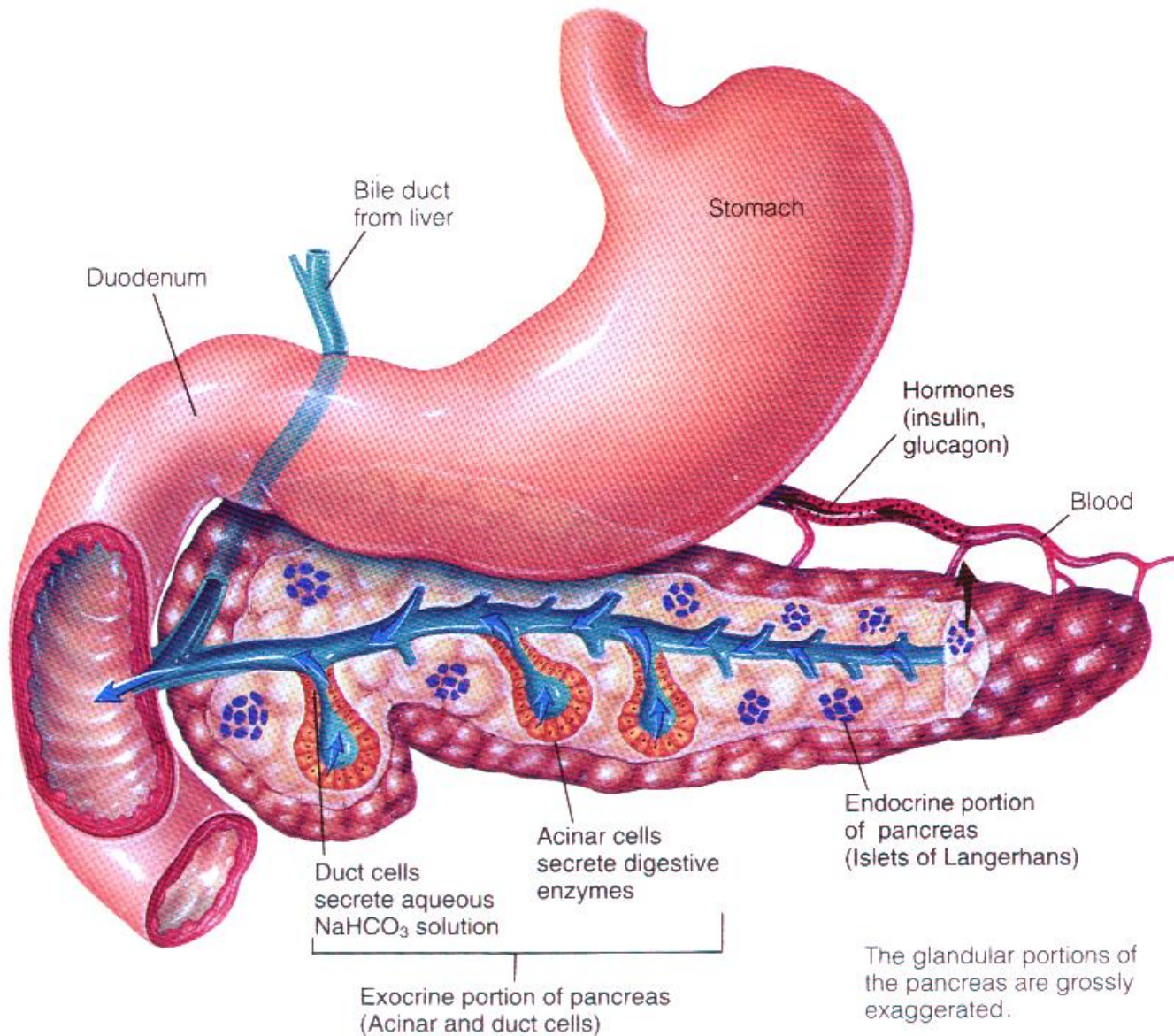
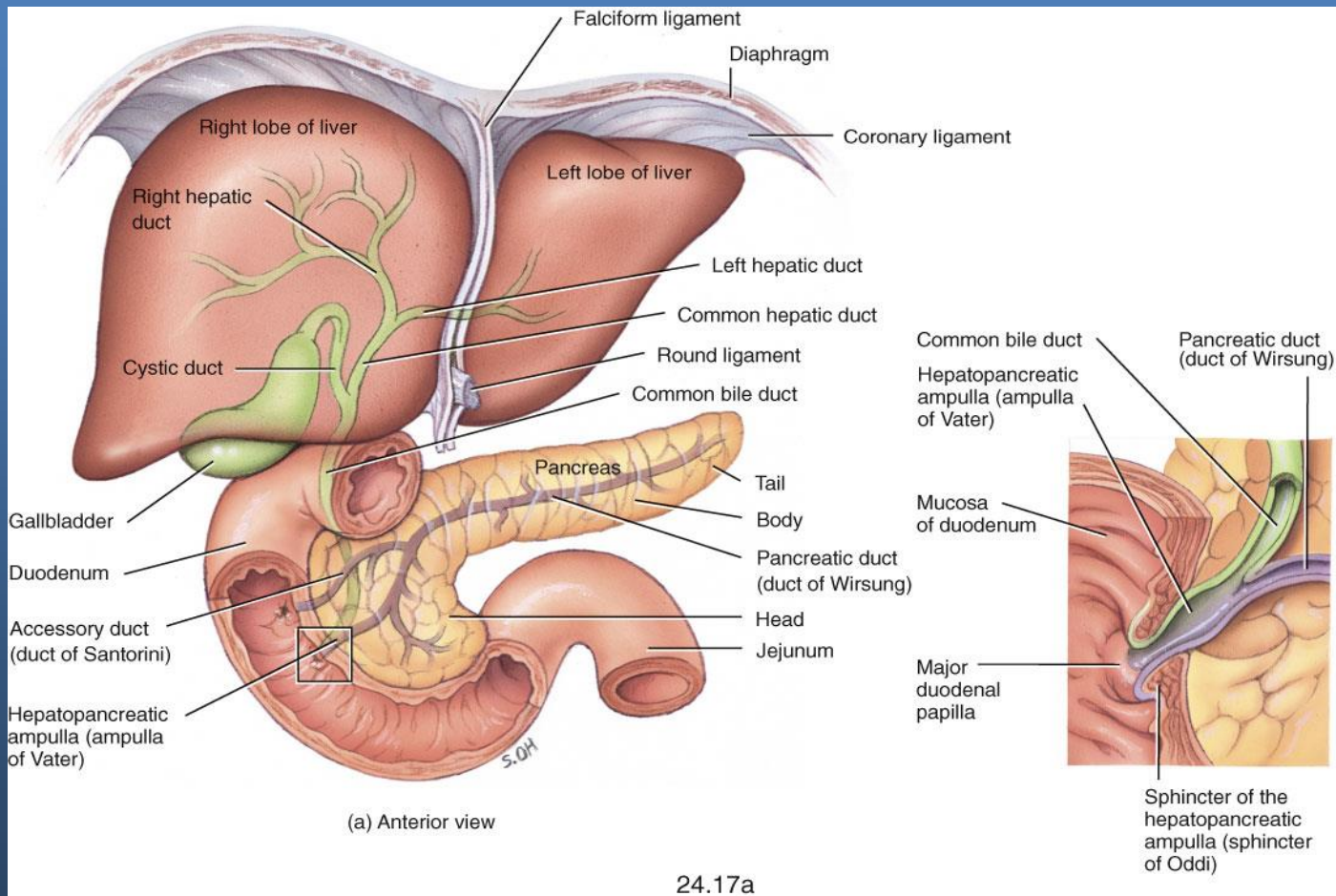


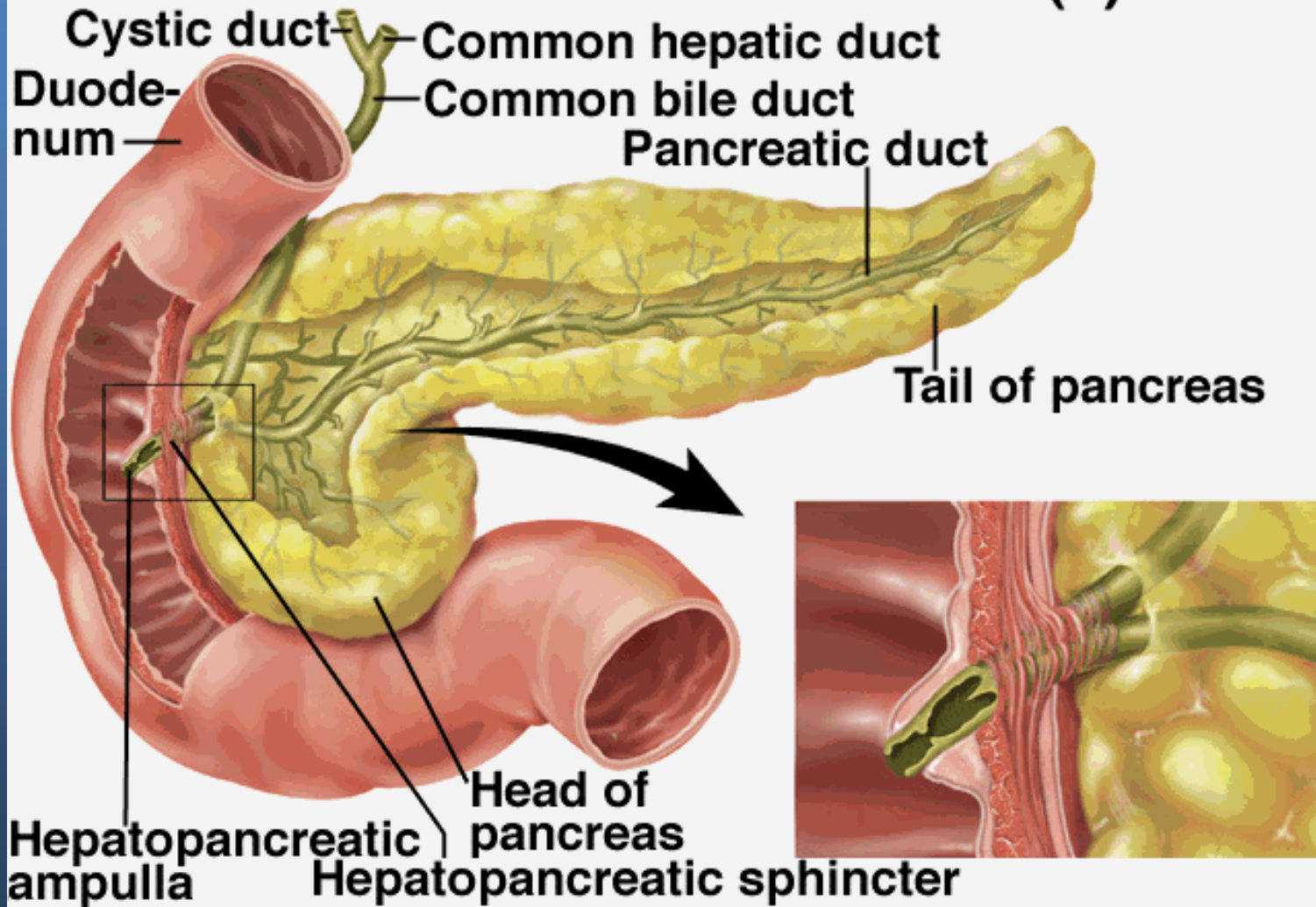


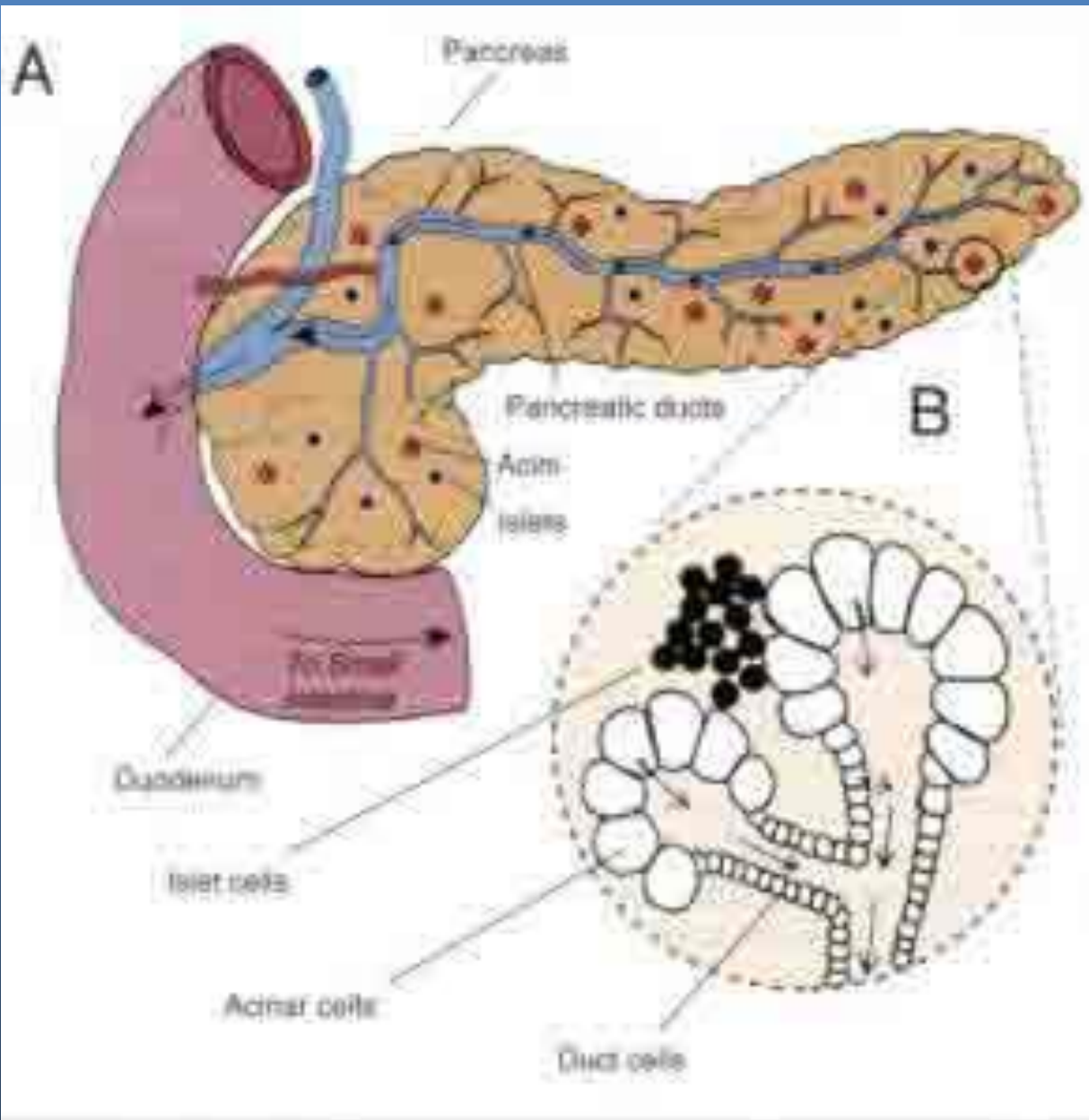
Fig. 24.17a



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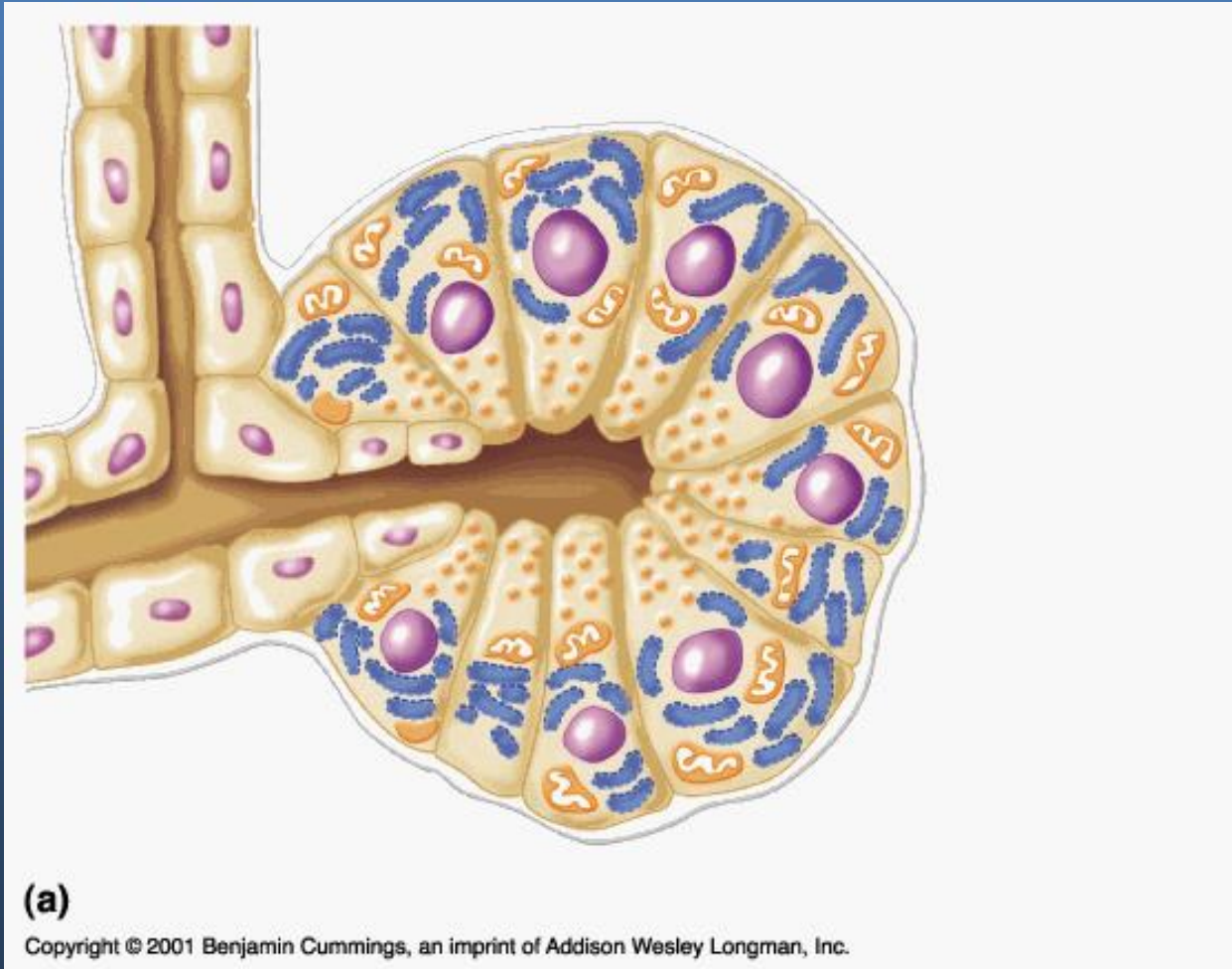
# Pancreas and Duodenum (1)







# Enzyme Secretion by acinar cells



# Protolytic enzymes:

- **Trypsin (ogen)**: activated by **enterokinase** from the duodenum acts as (endopeptidase. As long as this enzyme is in pancreas remains inactive by trypsin inhibitor.
- **Chemotrypsin(ogen)**: activated by trypsin and acts as endopeptodase.
- **(Pro) carboxypeptidase**: activated by trypsin and acts as exopeptidase.

# Enzyme for Digestion of Carbohydrates

## **Pancreatic amylase:**

secreted as active enzyme to convert  
Starch (polysaccharide) → disaccharides.

# Lipolytic enzymes

- **Lipase** that split

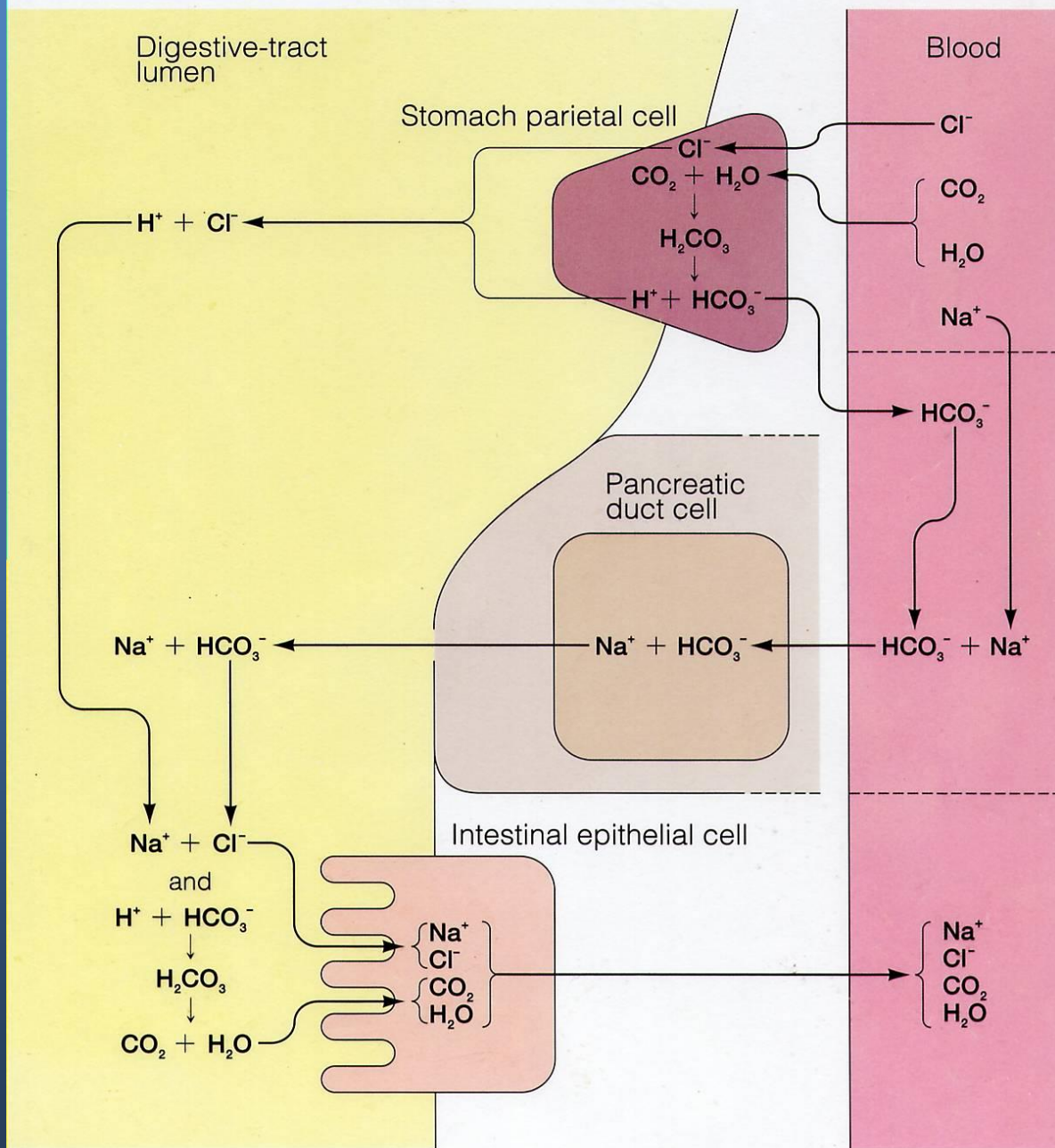
Triglycerides → monoglyceride + free fatty acids.

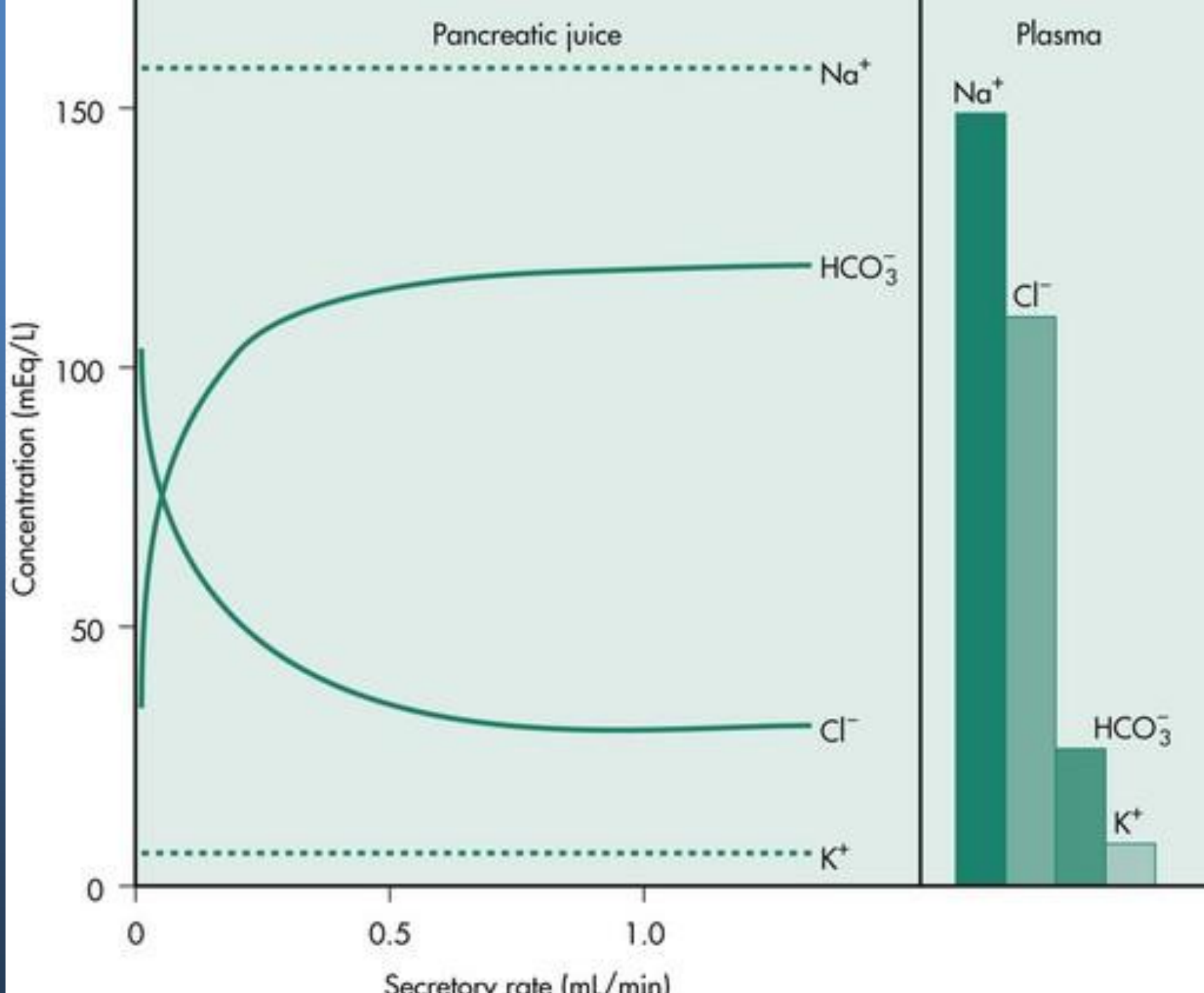
Their activity requires an oil/water interface, bile salts (secreted by liver) and other **co-lipase** secreted by the pancreas.

- **Phospholipase.**

- **Cholesterol ester hydroxylase.**

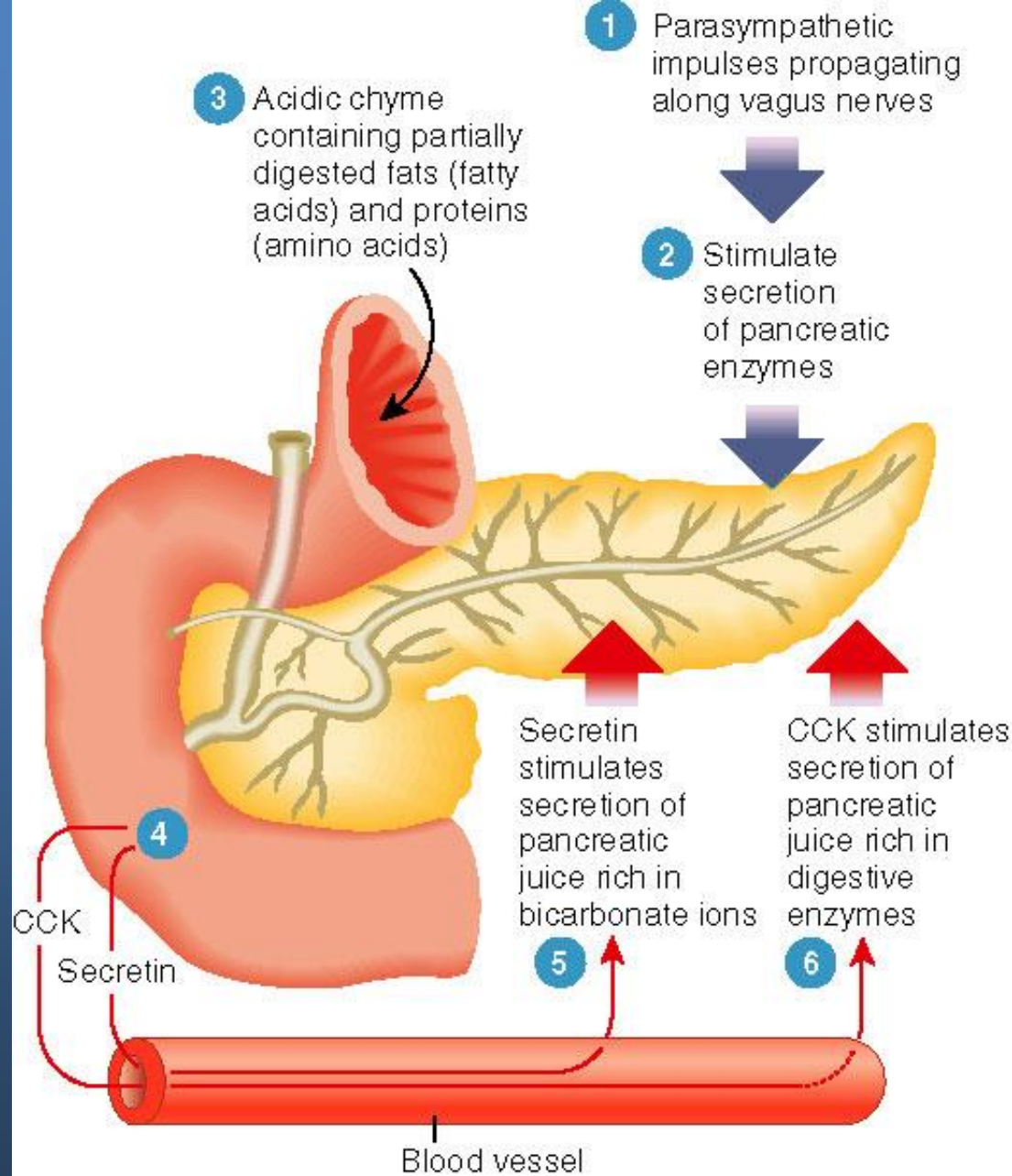
Water and bicarbonate secretion by duct cells.





# Control of pancreatic secretion:

- Neural
- Hormonal





# Neural Control

- **Parasympathetic:**

Vagal stimulation → enteric nervous system → release of Ach, VIP, and GRP (Gastrin releasing peptide).

- **Sympathetic:** indirect inhibition via vasoconstriction



# Hormonal Control

- **Secretin** (duodenal mucosa) → blood → ductal cells → increase water and HCO<sub>3</sub>-secretion.

- **CCK (Cholecystokinin):**

\* → CCK-A receptors (acinar cells) → enzyme secretion.

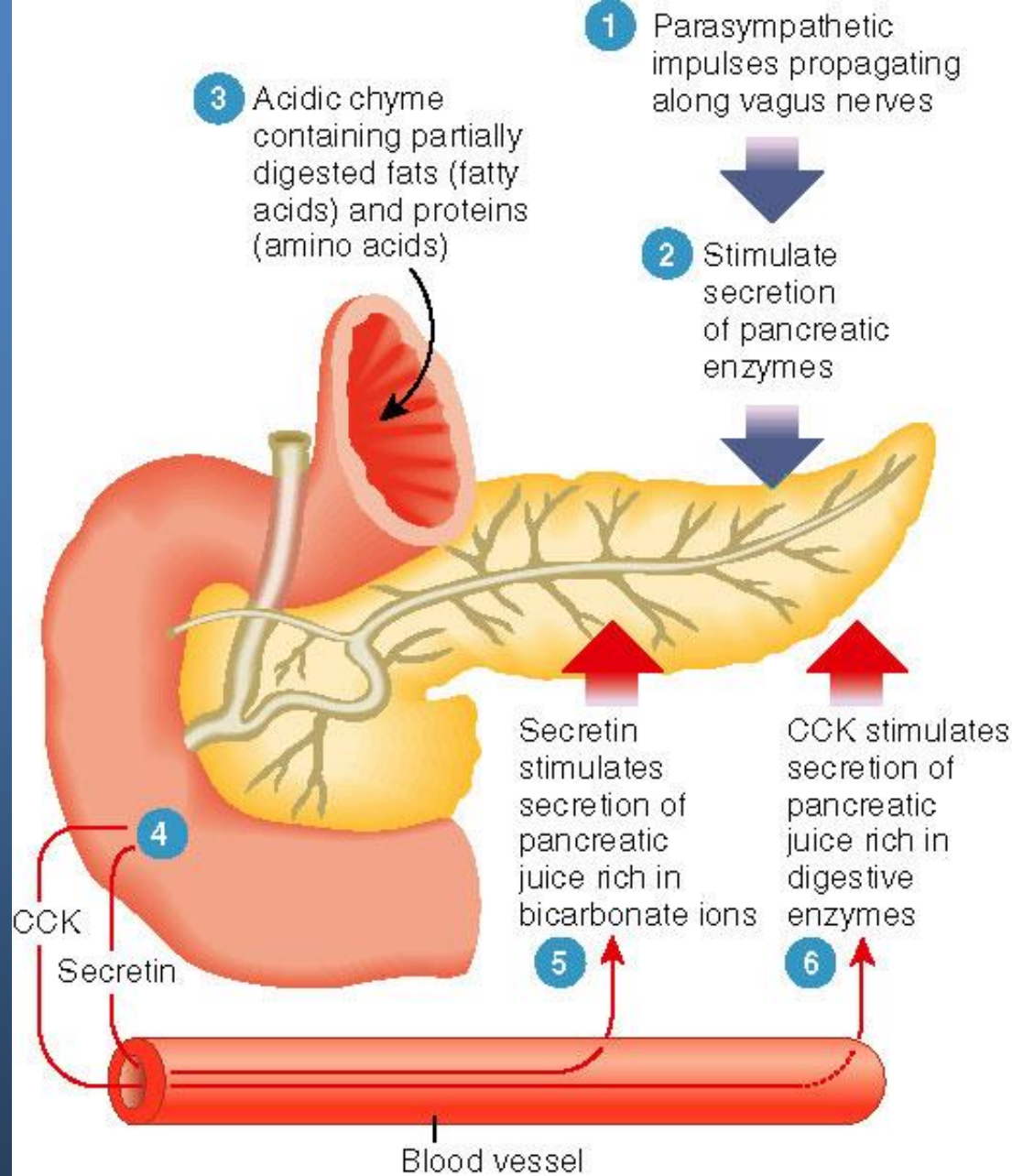
\* → vago-vagal reflex to stimulate enzyme secretions.

# Hormonal Control

- **Pancreatic polypeptide:** inhibits the release of enzymes by its inhibitory effect
  - \*- Inhibits Ach release from enteric nervous system.
  - \*- Inhibits vagal output of the CNS.

# Control of pancreatic secretion:

- Cephalic phase
- Gastric phase
- Intestinal phase



# 3 phases of control of pancreatic secretions

**Cephalic phase:** sight, smell, taste or hearing.  
Mediated by vagus.

**Gastric phase:** Distension.  
Mediated by vagus.

**Intestinal phase:** Aminoacids (aa), Fatty acids, H<sup>+</sup>, Distension.  
Mediated by CCK, secretin, enteropancreatic reflexes, other hormones.

# Liver Secretions

# Liver functions

- Metabolic processing: Process all nutrients after their absorption.
- Detoxification of body wastes, hormones, drugs, and other foreign bodies.
- Synthesis of plasma proteins, including clotting factors (their synthesis requires vit. K), hormone transporters.
- Storage organ of glycogen, iron (ferritin), copper, and vitamins.
- Removal of bacteria and foreign materials by reticuloendothelial cells (Kupffer cells).
- Excretion of cholesterol and bilirubin.

# Bile secretion

- Bile acts as detergent to emulsify lipids and make them soluble.

Bile is composed of **bile salts**, water & - electrolytes, cholesterol, phospholipids and wastes intended for excretion, (bilirubin).

# Liver functions

- Metabolic processing: Process all nutrients after their absorption.
- Detoxification of body wastes, hormones, drugs, and other foreign bodies.
- Synthesis of plasma proteins, including clotting factors (their synthesis requires vit. K), hormone transporters.
- Storage organ of glycogen, iron (ferritin), copper, and vitamins.
- Removal of bacteria and foreign materials by reticuloendothelial cells (Kupffer cells).
- **Excretion of cholesterol and bilirubin.**



# Excretion of bilirubin in the bile

Bilirubin results from the catabolism of hemoglobin → Heme + Globin

Heme ring → iron + biliverdin

Biliverdin → bilirubin secreted with bile as conjugated (glucoronide, sulfate, other substances).

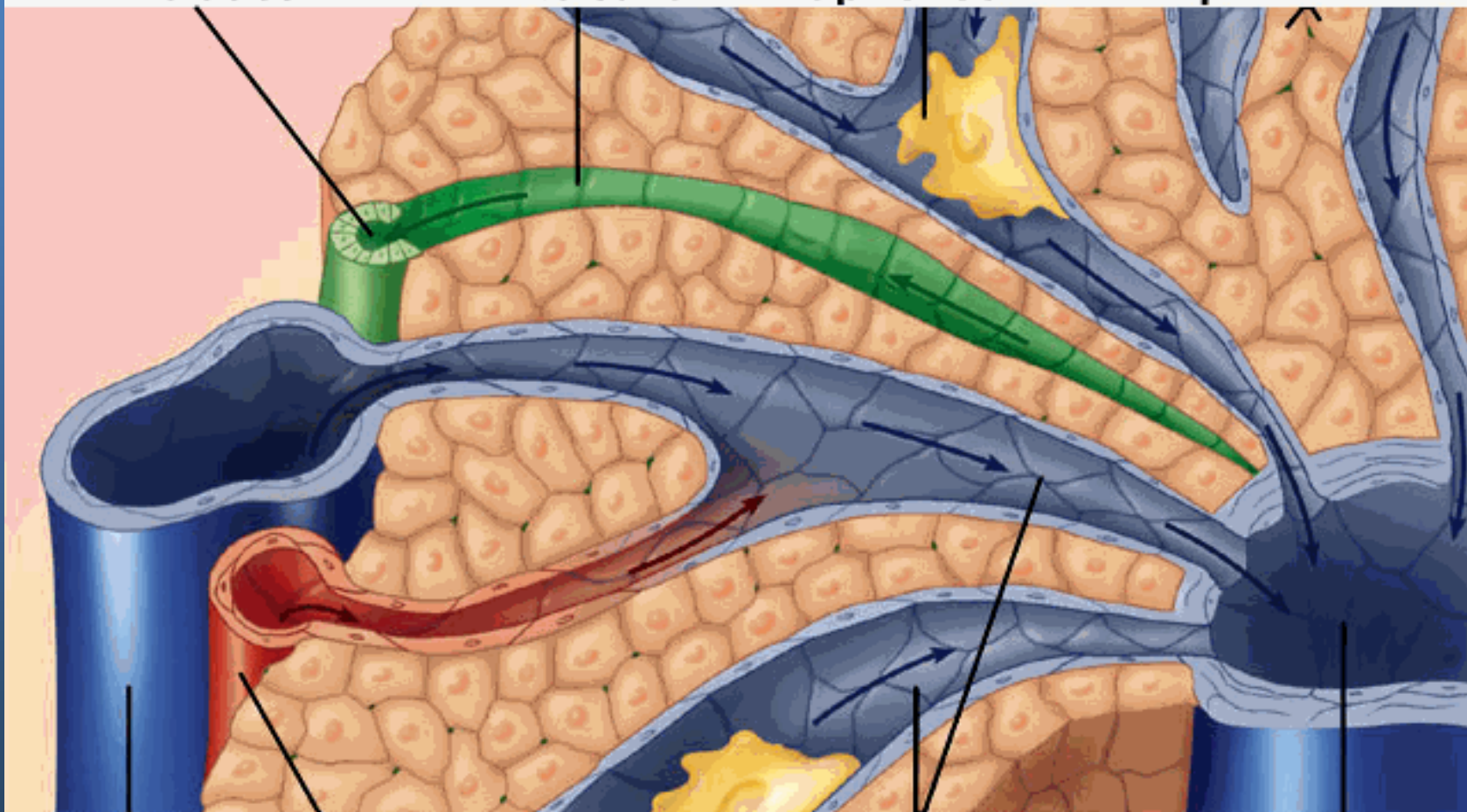
# Hepatic Lobule—Blood and Bile Paths

Bile duct

Bile canal

Kupffer cell

Hepatic cells



Branch of hepatic portal vein

Branch of hepatic artery

Blood flow into liver

Hepatic sinusoids

Central canal (blood flow out of liver)

# bilirubin

Bilirubin (by bacterial action) → urobilinogen → reabsorbed and secreted in urine (urobilin).

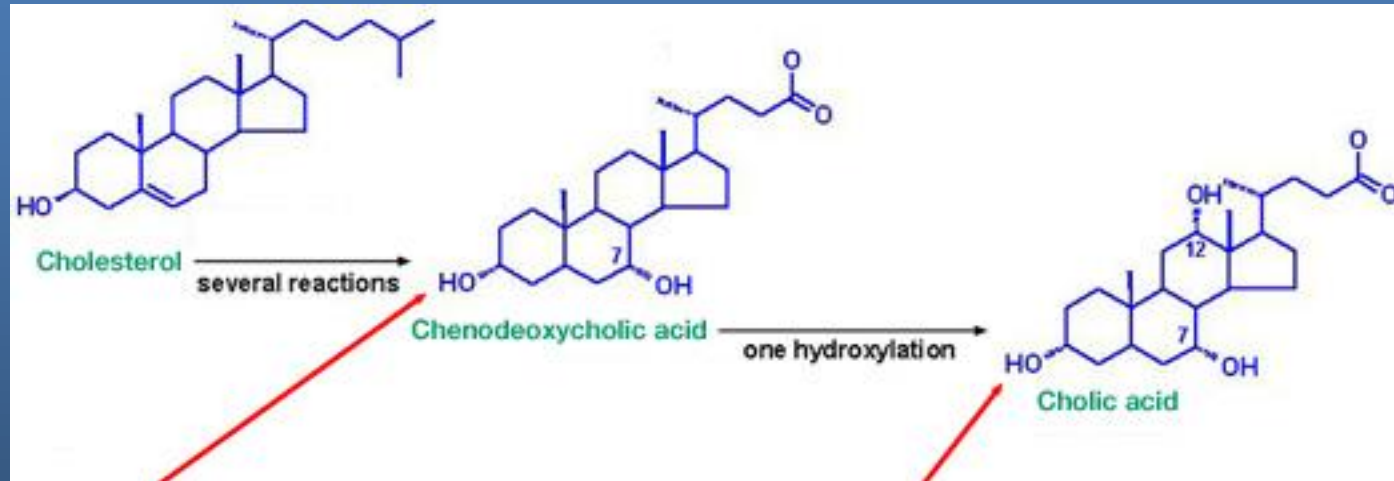
Or in feces → stercobilin.

**Jaundice is caused by large quantity of bilirubin in the extracellular space.**

# Bile formation

- Bile salts are synthesized by the liver, concentrated in the gallbladder and modified in the lumen.
- Synthesized as primary bile acids from cholesterol (*cholic and chenodeoxycholic acid*)

# Bile salts



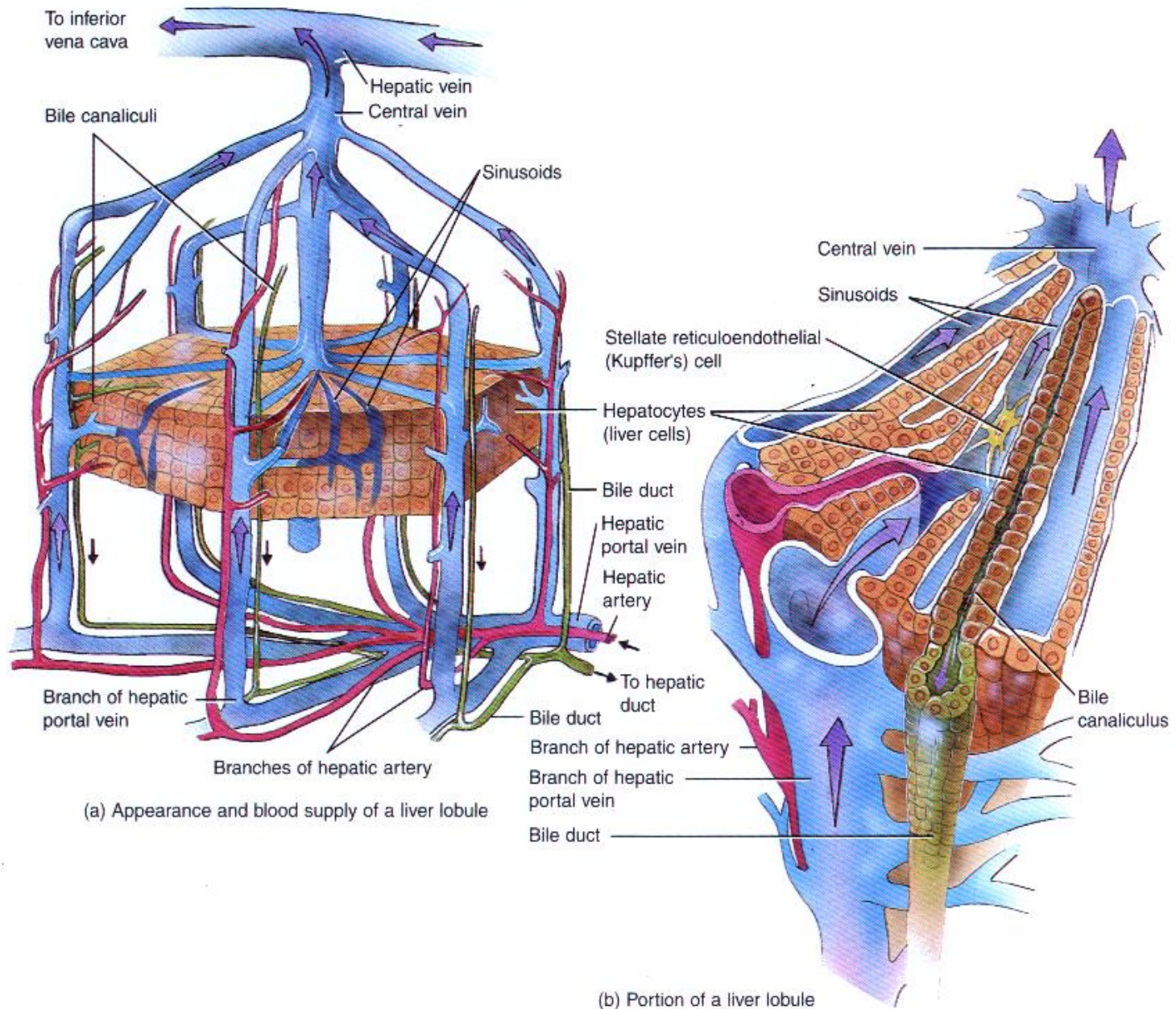
Bile acids → Conjugated to Glycine or Taurine

→ Bile salts

# Bile

- Between meals, bile → gallbladder where it is stored. The epithelium of the gallbladder removes water and electrolytes → 5-20 fold concentration of bile.





(a) Appearance and blood supply of a liver lobule

(b) Portion of a liver lobule

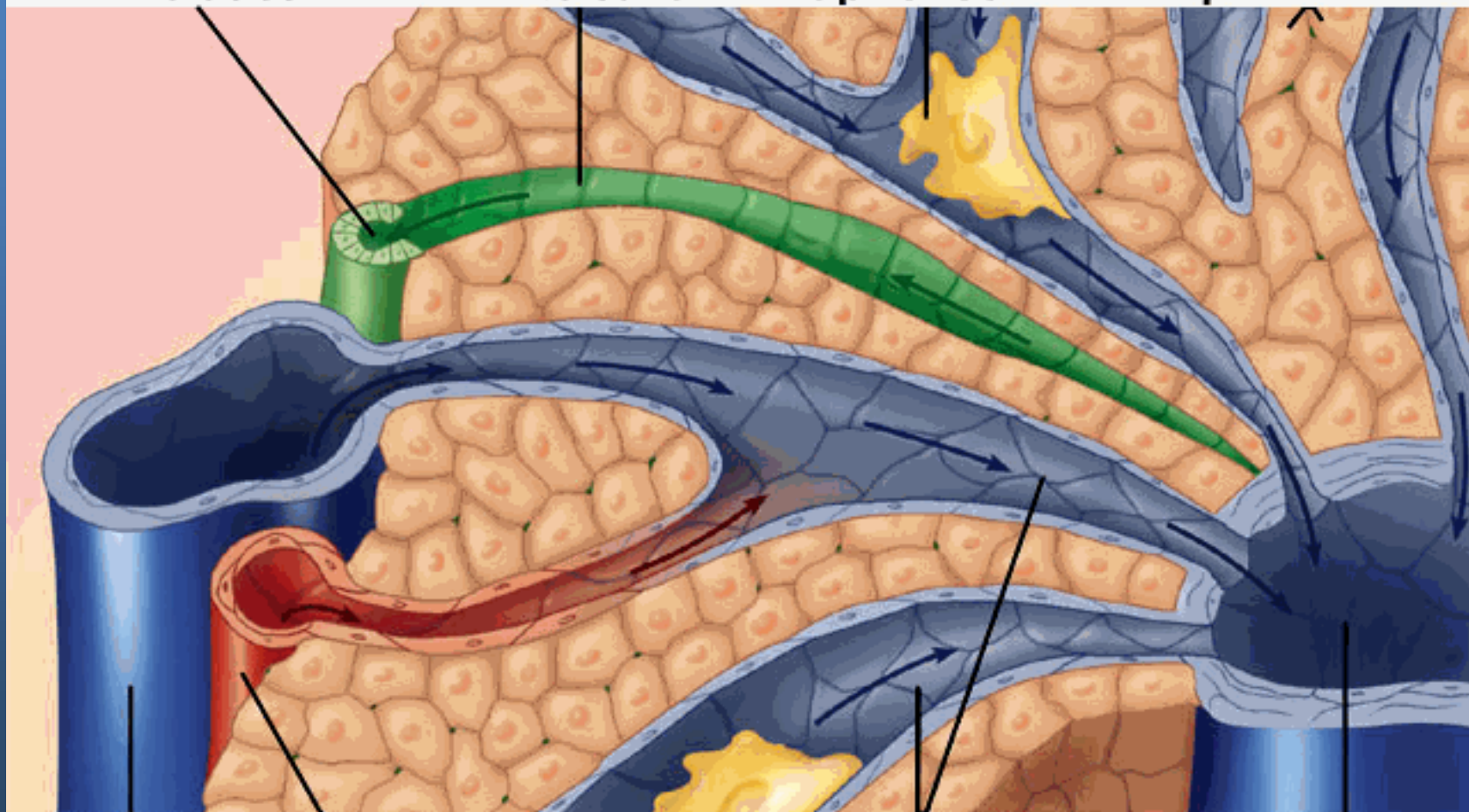
# Hepatic Lobule—Blood and Bile Paths

Bile duct

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Kupffer cell

Hepatic cells



Branch of hepatic portal vein

Branch of hepatic artery

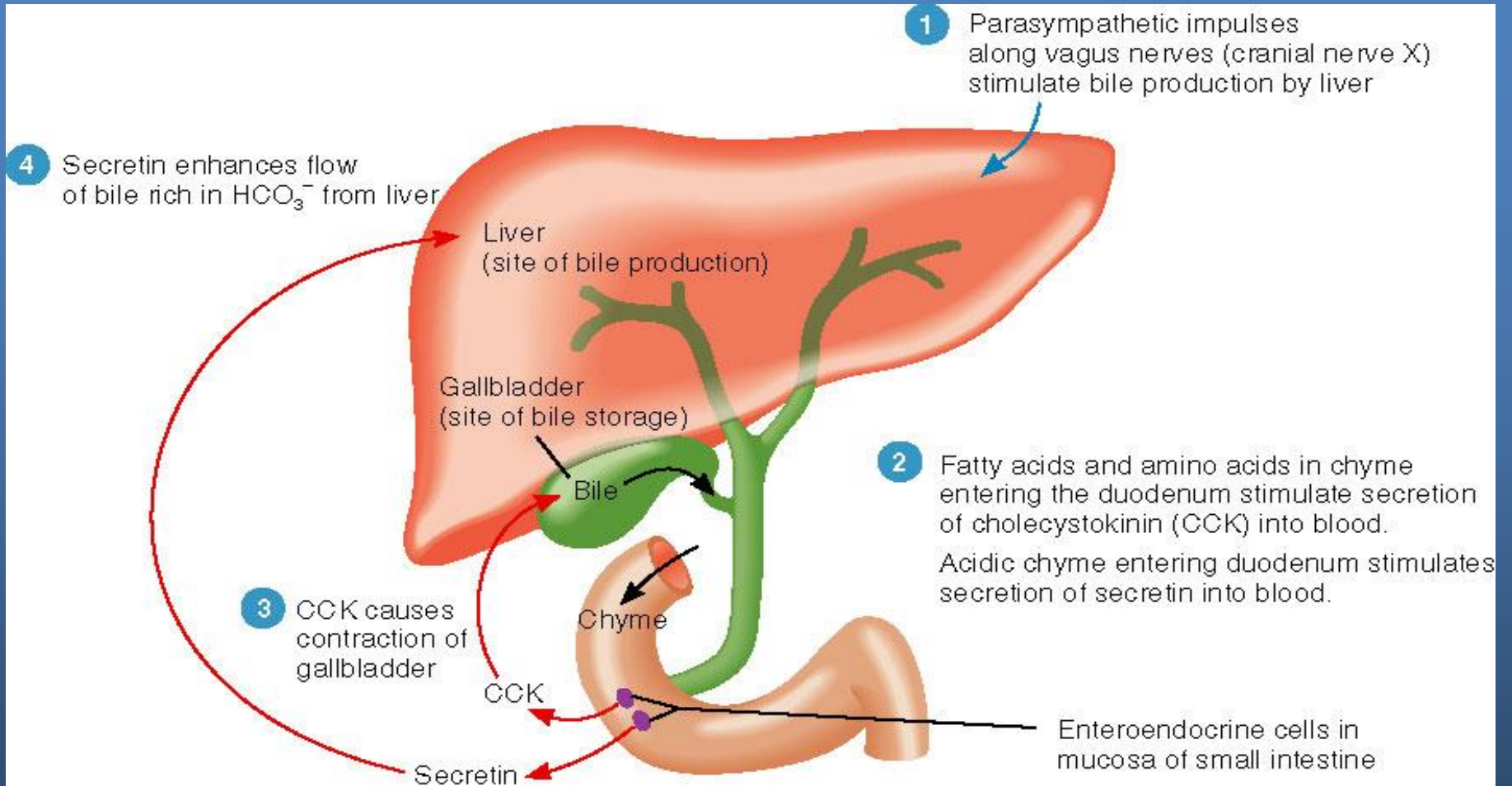
Blood flow into liver

Hepatic sinusoids

Central canal (blood flow out of liver)

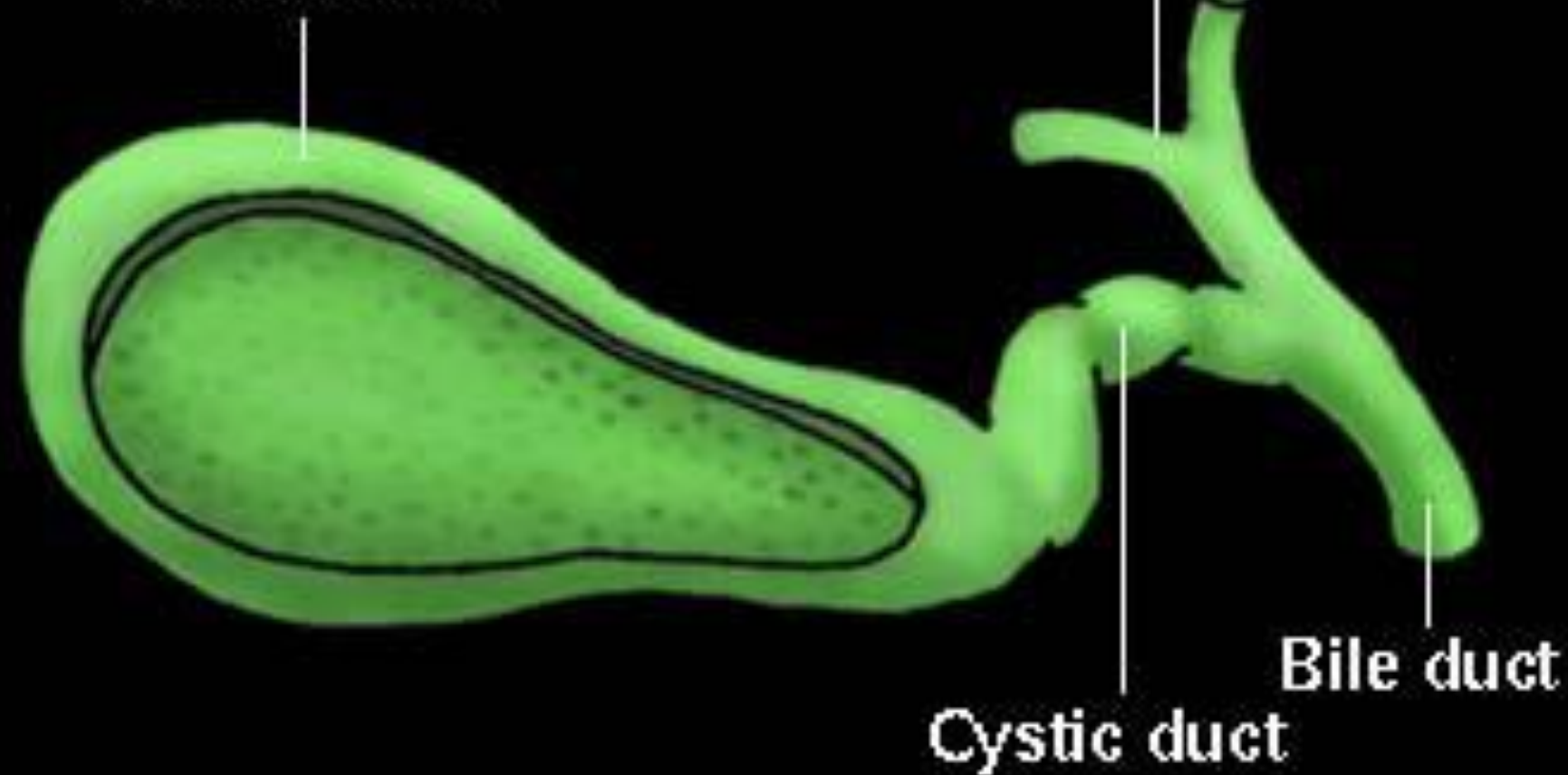


Fig. 24.21



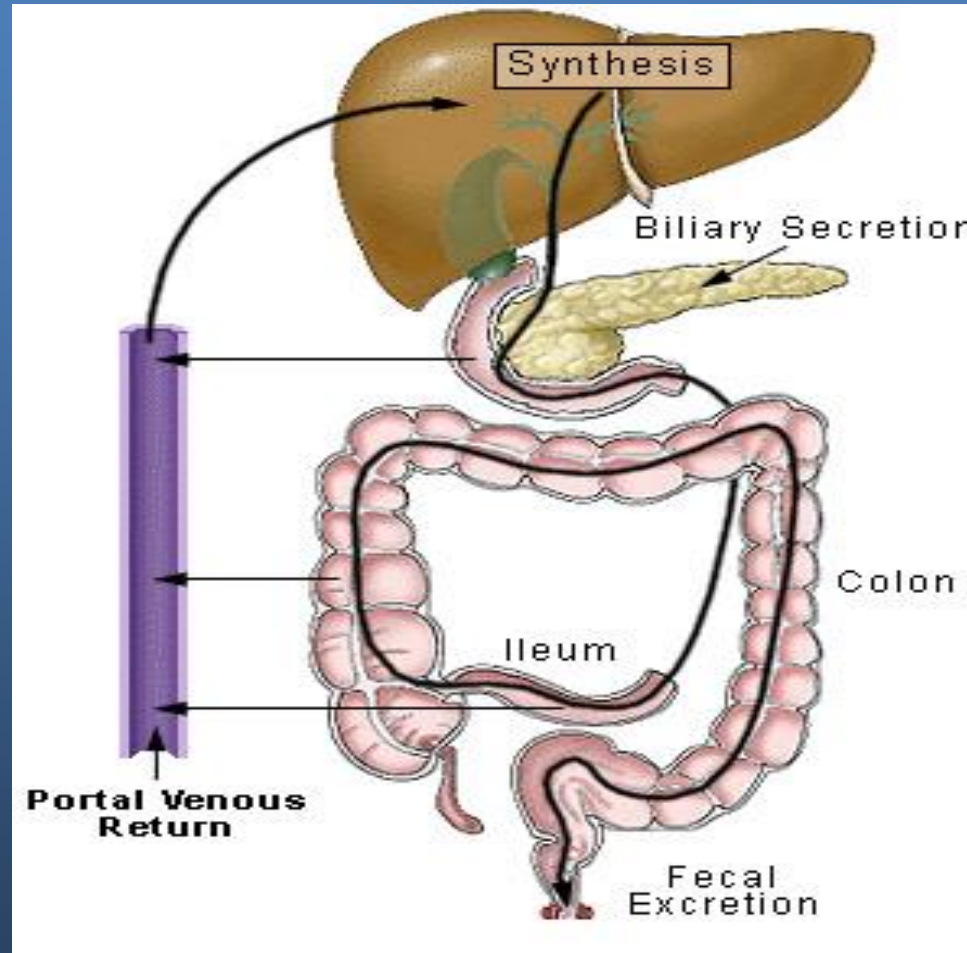
Hepatic ducts

Gall bladder



|                                    | <b>LIVER<br/>BILE</b> | <b>GALLBLADDER<br/>BILE</b> |
|------------------------------------|-----------------------|-----------------------------|
| <b>Water</b>                       | <b>97.5 gm/dl</b>     | <b>92 gm/dl</b>             |
| <b>Bile Salts</b>                  | <b>1.1 gm/dl</b>      | <b>6 gm/dl</b>              |
| <b>Bilirubin</b>                   | <b>0.04 gm/dl</b>     | <b>0.3 gm/dl</b>            |
| <b>Cholesterol</b>                 | <b>0.1 gm/dl</b>      | <b>0.3 to 0.9 gm/dl</b>     |
| <b>Fatty Acids</b>                 | <b>0.12 gm/dl</b>     | <b>0.3 to 1.2 gm/dl</b>     |
| <b>Lecithin</b>                    | <b>0.04 gm/dl</b>     | <b>0.3 gm/dl</b>            |
| <b>Na<sup>+</sup></b>              | <b>145 mEq/liter</b>  | <b>130 mEq/liter</b>        |
| <b>K<sup>+</sup></b>               | <b>5 mEq/liter</b>    | <b>12 mEq/liter</b>         |
| <b>Ca<sup>++</sup></b>             | <b>5 mEq/liter</b>    | <b>23 mEq/liter</b>         |
| <b>Cl<sup>-</sup></b>              | <b>100 mEq/liter</b>  | <b>25 mEq/liter</b>         |
| <b>HCO<sub>3</sub><sup>-</sup></b> | <b>28 mEq/liter</b>   | <b>10 mEq/liter</b>         |

# Enterohepatic circulation



# Modification in the intestine

Modified to **secondary** bile acid:

Cholic acid → deoxycholic acid.

Chenodeoxycholic acid → lithocholic acid



Fig. 24.21

