Gastrointestinal Physiology
Lecture 5

Physiology of the Pancreas

Chapter 64; Pages: 799-802

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Learning Objectives

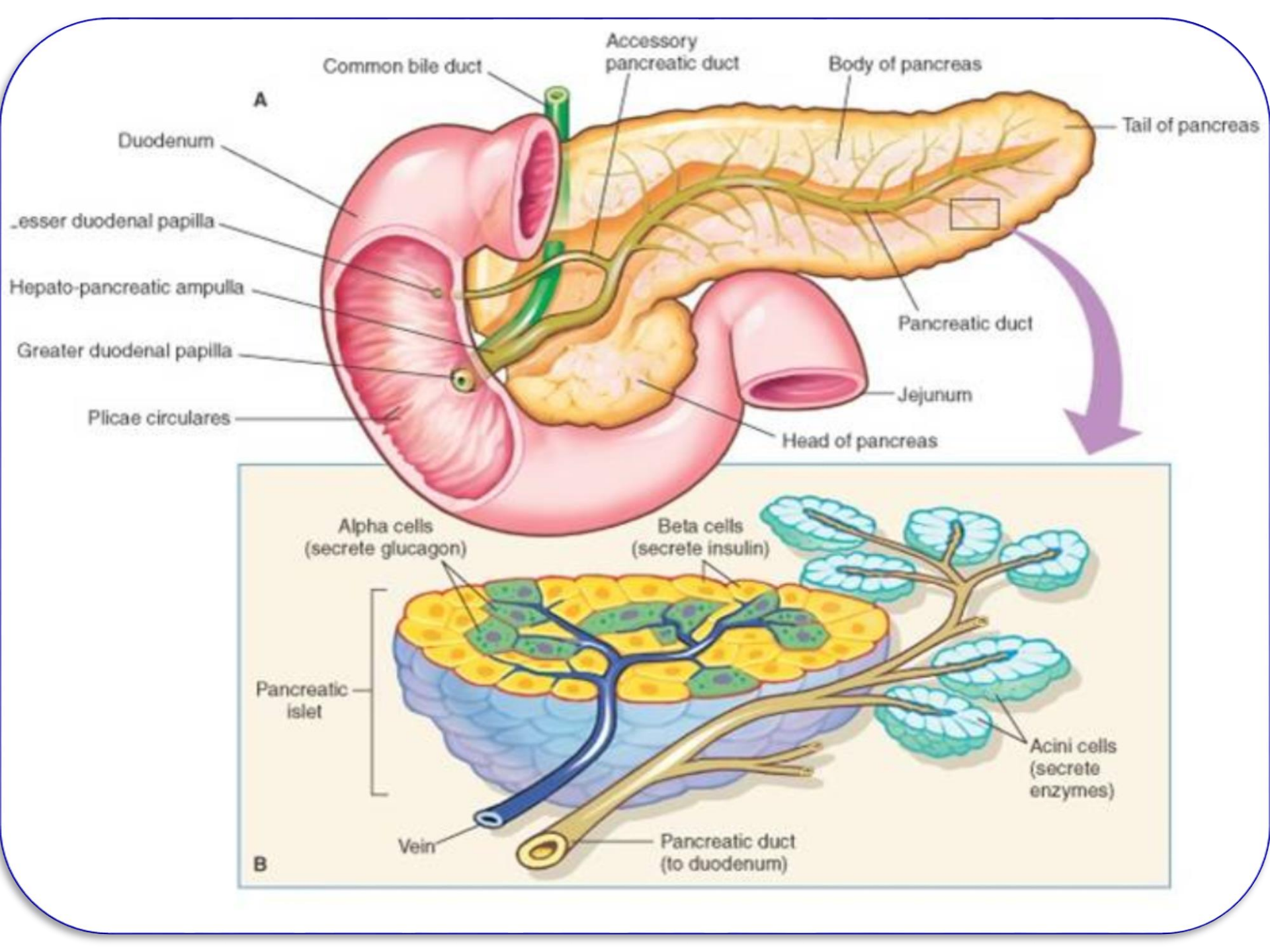
- Pancreatic Acini
- Pancreatic Secretion
- Pancreatic Enzymes
- Control of Pancreatic Secretion
  - Neural Control
  - Hormonal Control
    - Secretin
    - Choecystokinine

The exocrine pancreas

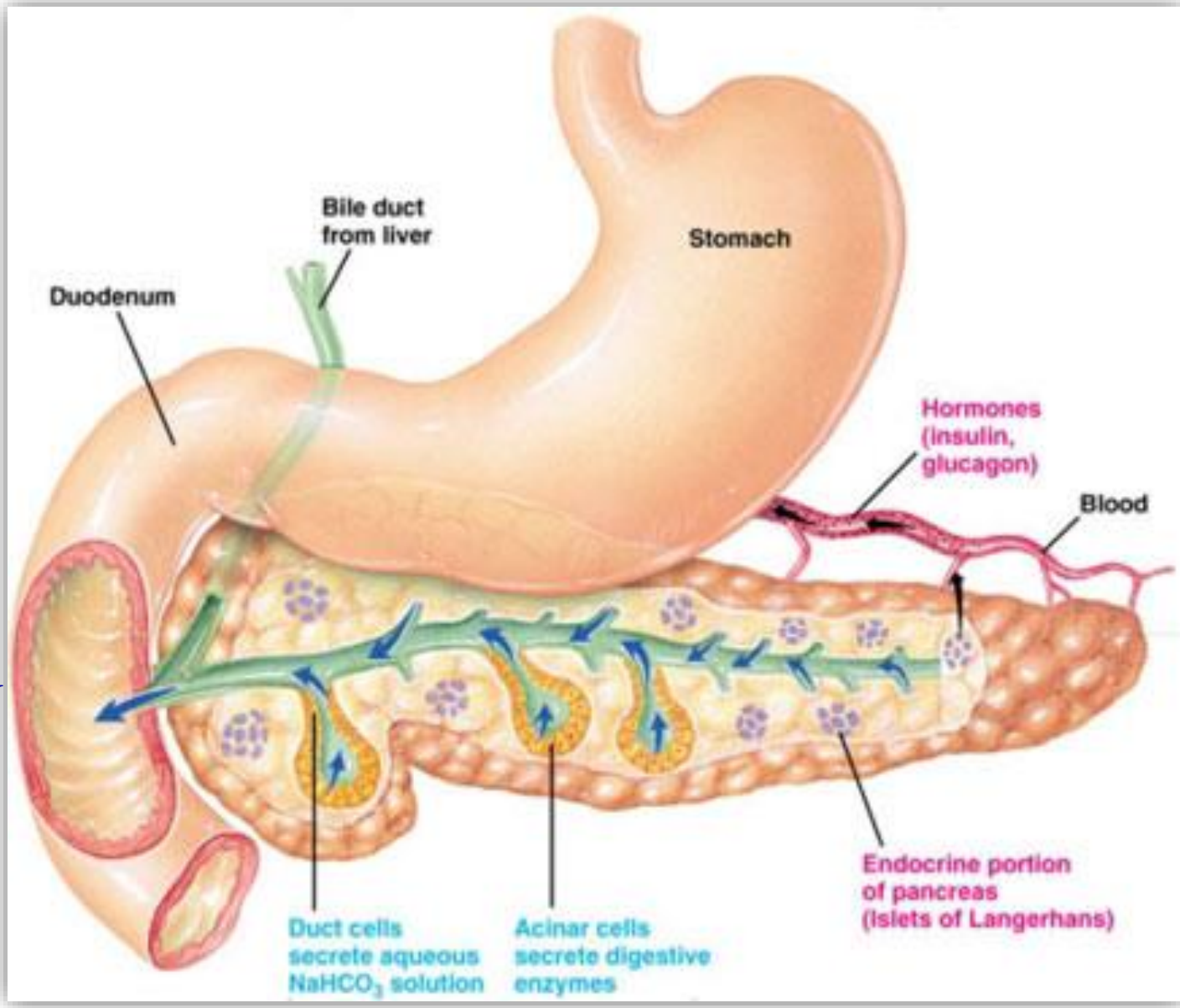
The pancreas, which lies parallel to and beneath the stomach is composed of:-

1) The endocrine islets of Langerhans which secrete insulin, glucagone and somatostatin.
2) Acinar gland tissues which produce pancreatic juice (the main source of digestive enzymes).

The cells lining the acini are serous cells containing zymogen granules.


A
Common bile duct
Accessory pancreatic duct
Body of pancreas
Tail of pancreas
Duodenum
Lesser duodenal papilla
Hepato-pancreatic ampulla
Greater duodenal papilla
Plicae circulares
Pancreatic duct
Jejunum
Head of pancreas
B
Alpha cells (secrete glucagon)
Beta cells (secrete insulin)
Pancreatic islet
Acini cells (secrete enzymes)
Vein
Pancreatic duct (to duodenum)

The main pancreatic duct joins into bile duct at ampulla of vater that is surrounded by sphincter of Oddi



Pancreatic Secretion

- Pancreatic juice is secreted in response to the presence of chyme in the upper portions of the small intestine.
- ***The major functions of pancreatic secretion:***
  - To neutralize the acids in the chyme
  - To produce enzymes involved in the digestion of dietary carbohydrate, fat, and protein.

Pancreatic Secretion

Volume: 1.2-1.5 l/day.

The osmolarity of pancreatic fluid is equal to that of plasma (isotonic)

PH= 8 alkaline.

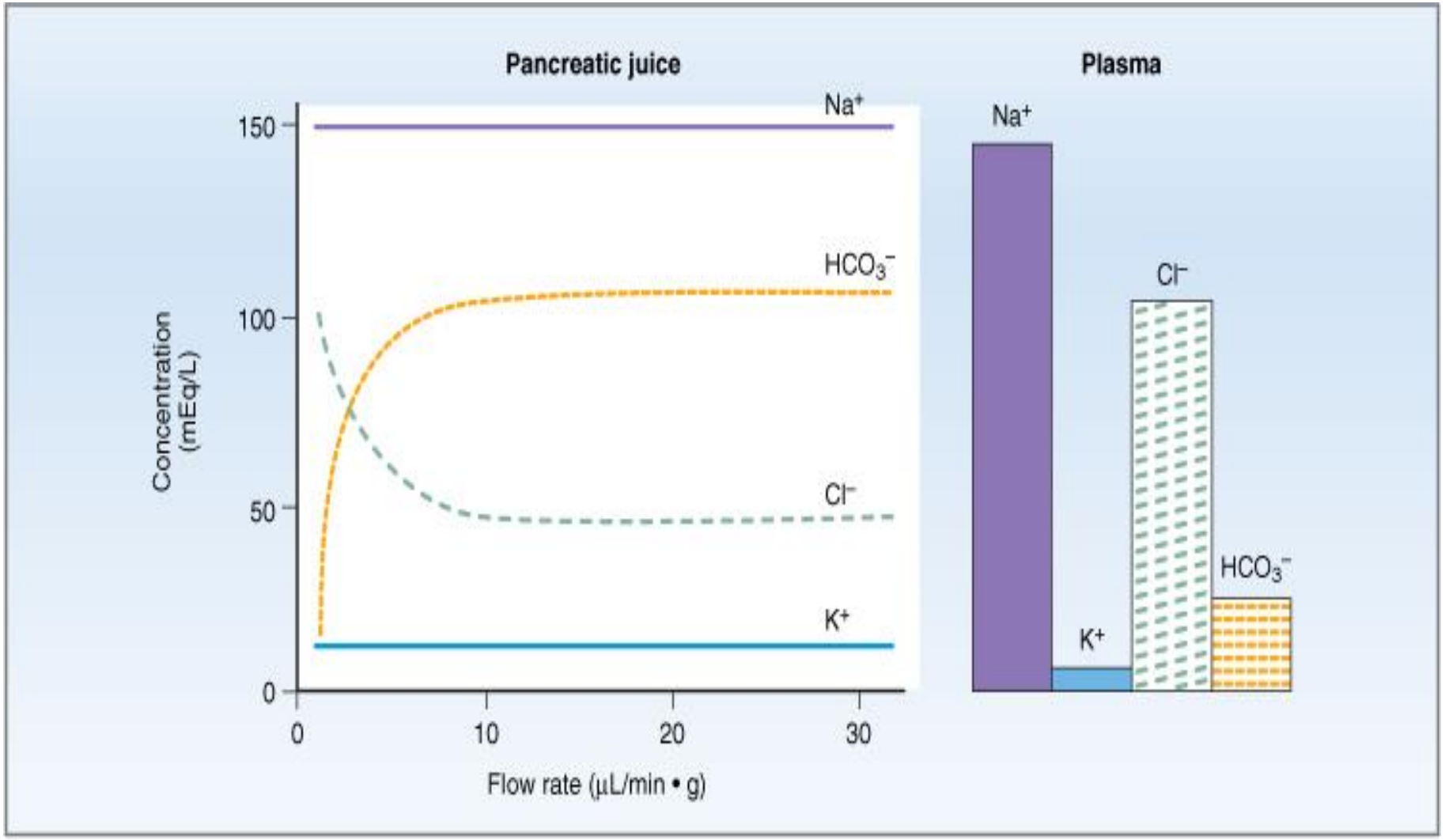
Composition: 1 % inorganic materials (electrolytes)

1-2 % organic materials mostly enzymes.

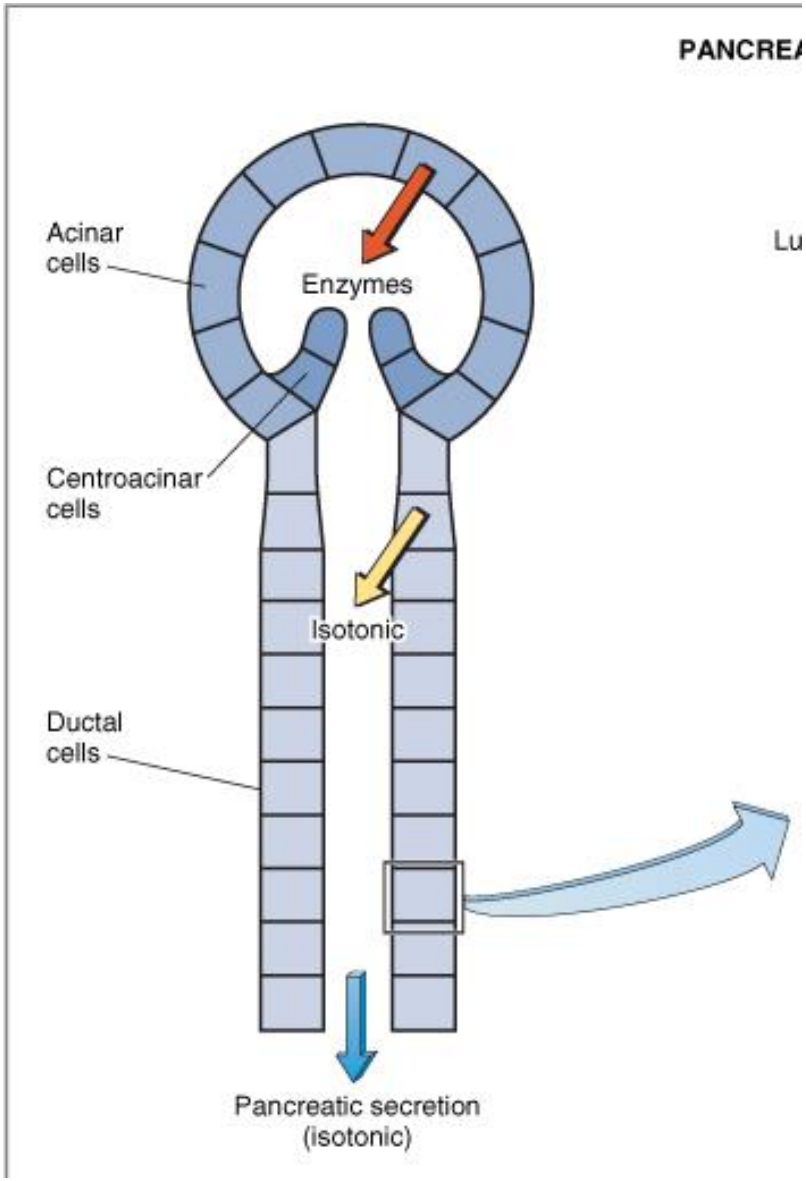
The electrolytes

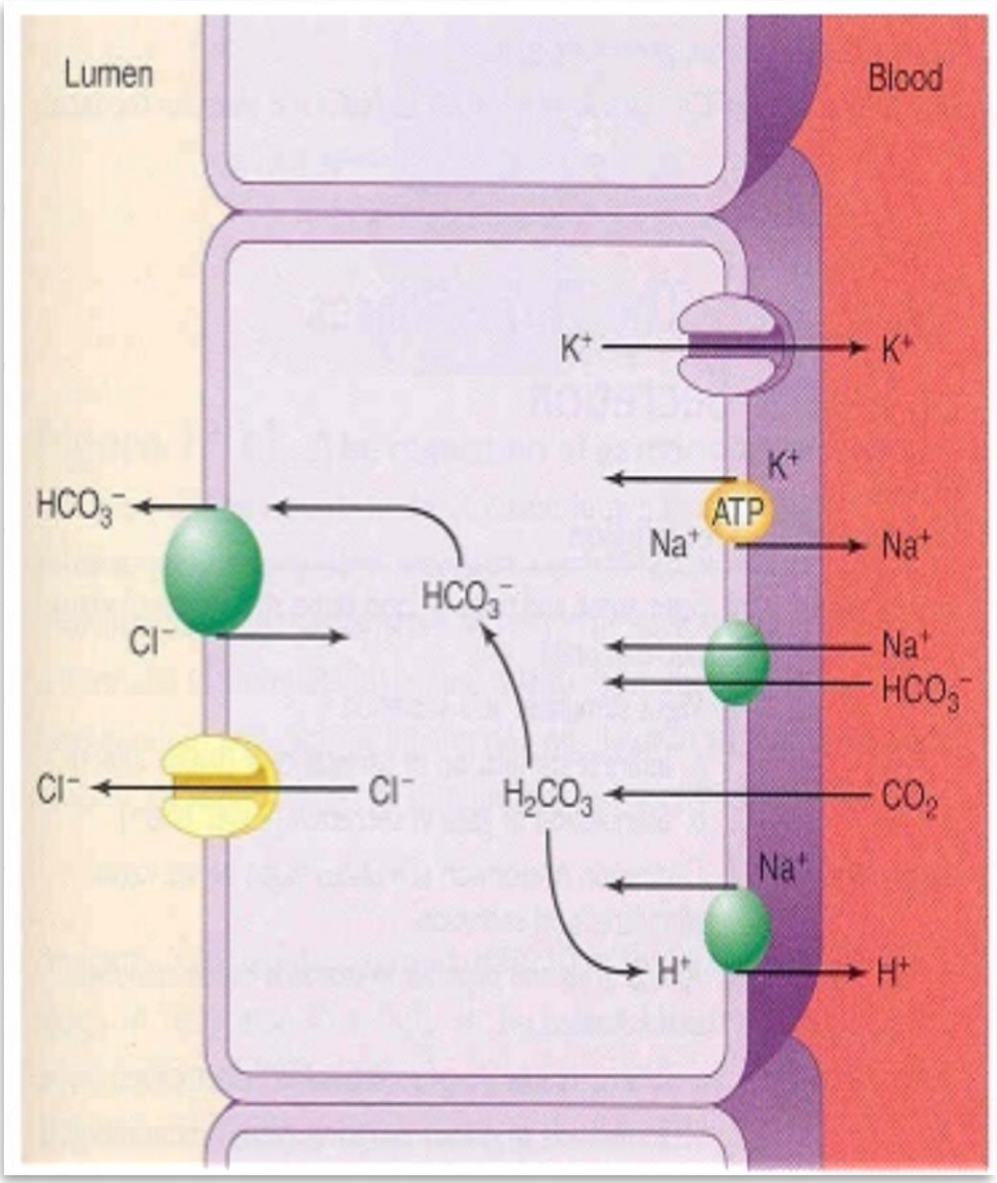
- They are produced from the epithelial cells of the ductules and ducts and include cations Na^+, K^+, Ca^{++} and anions HCO_3^- and Cl^-.
- The greater bulk of electrolytes is in the form of $NaHCO_3$.
- HCO_3^- concentration increases with increasing secretion rate.

Flow Rate and pancreatic secretion



Secretion of Bicarbonate Ions into Pancreatic Juice





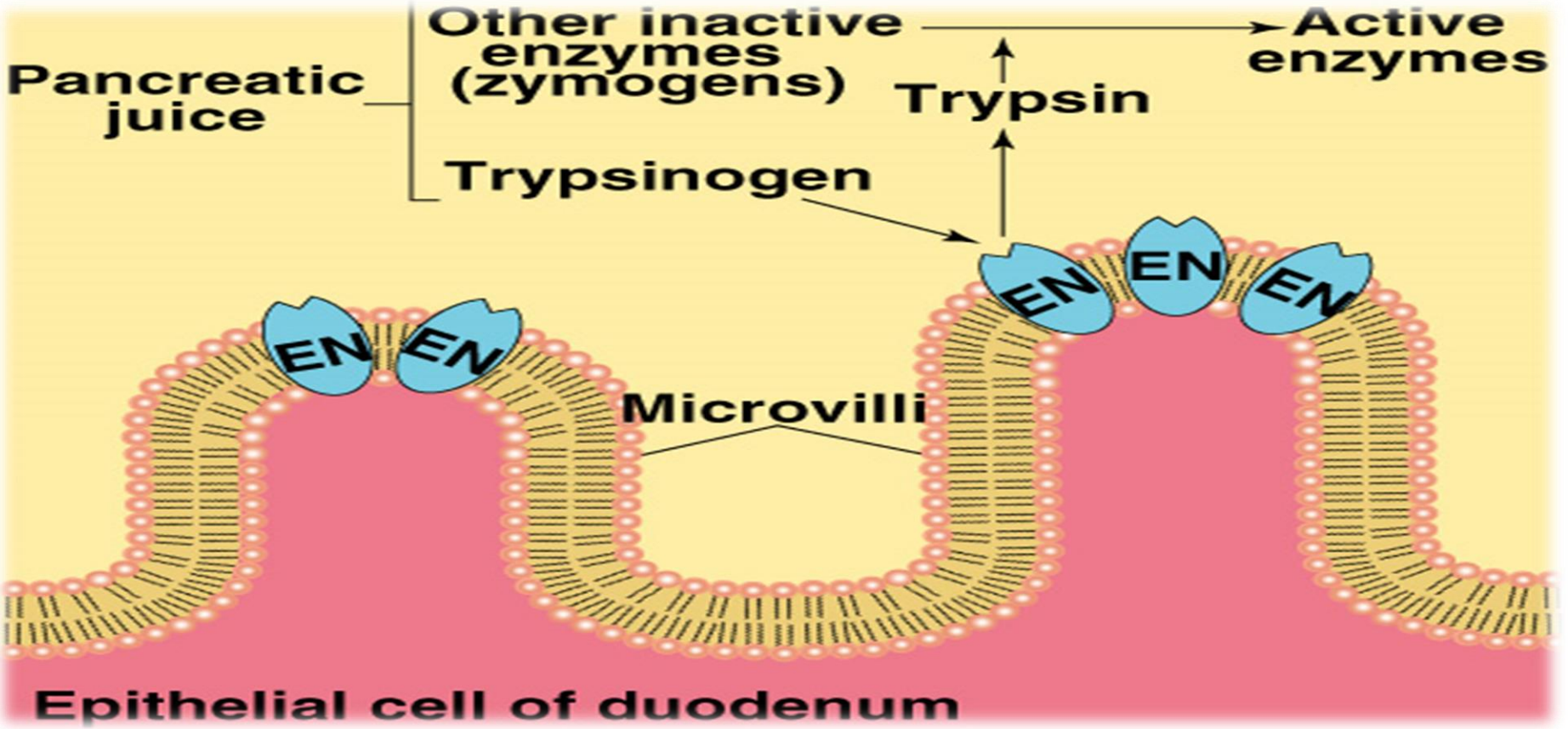
Pancreatic enzymes

The pancreas secrets enzymes that act on all major types of food stuffs.

1- Pancreatic proteolytic enzymes (proteases)

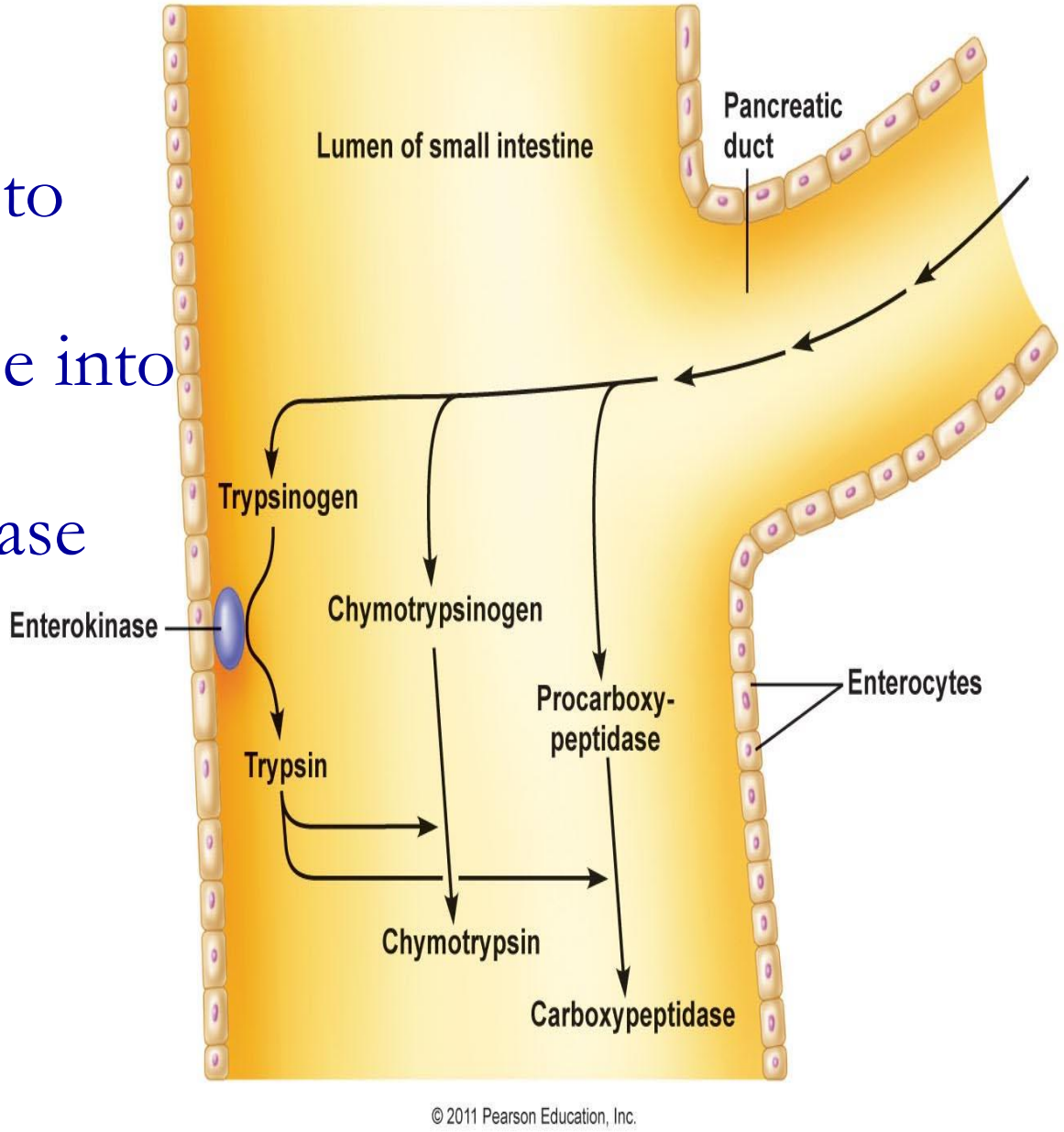
- Trypsin, chymotrypsin, elastase, carboxypeptidase.
- They are secreted in inactive form and activated in intestinal lumen.

- Trypsinogen is activated into trypsin by the enzyme *enteropeptidase (enterokinase)*, secreted by duodenal mucosal cells.

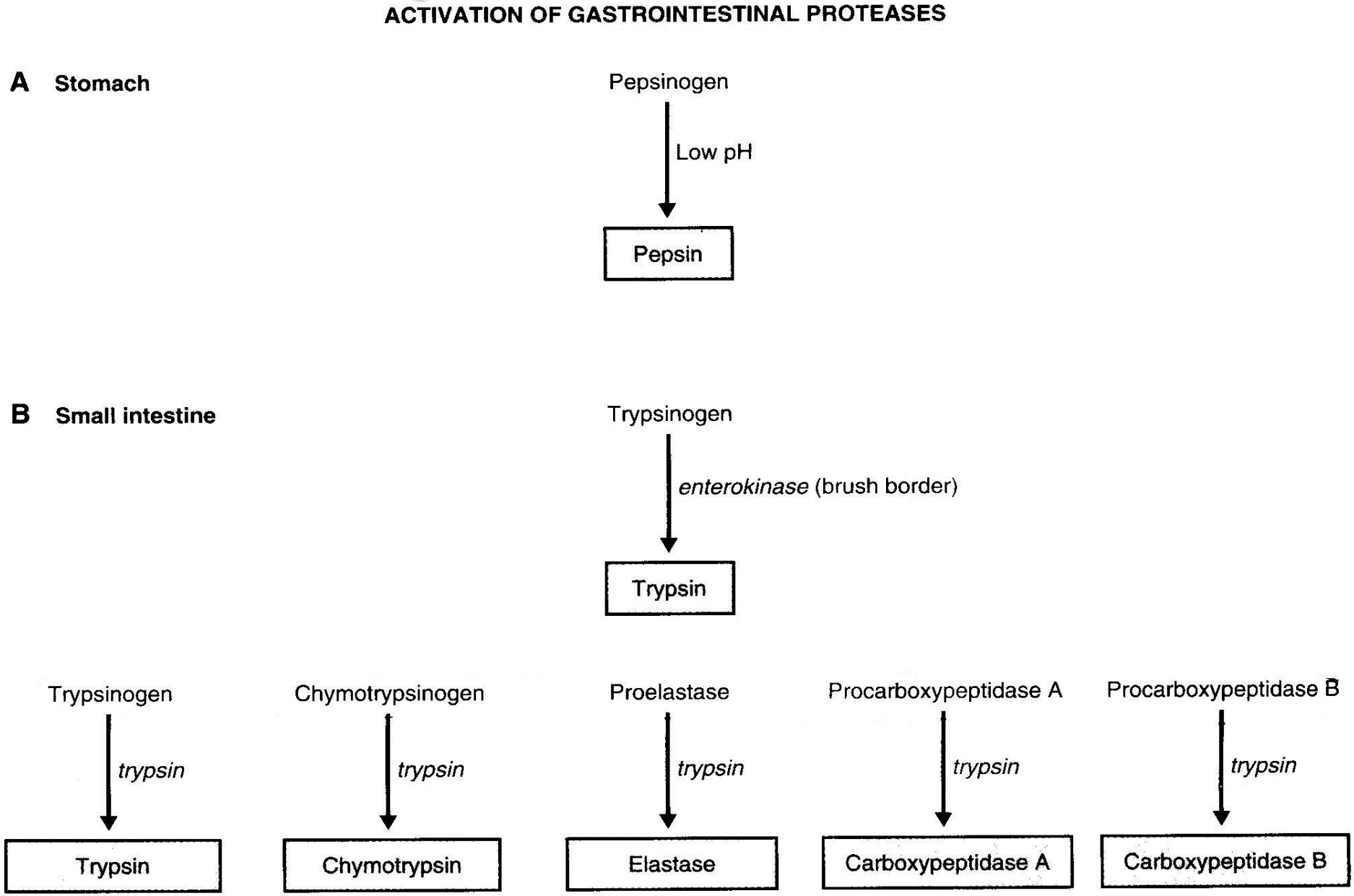


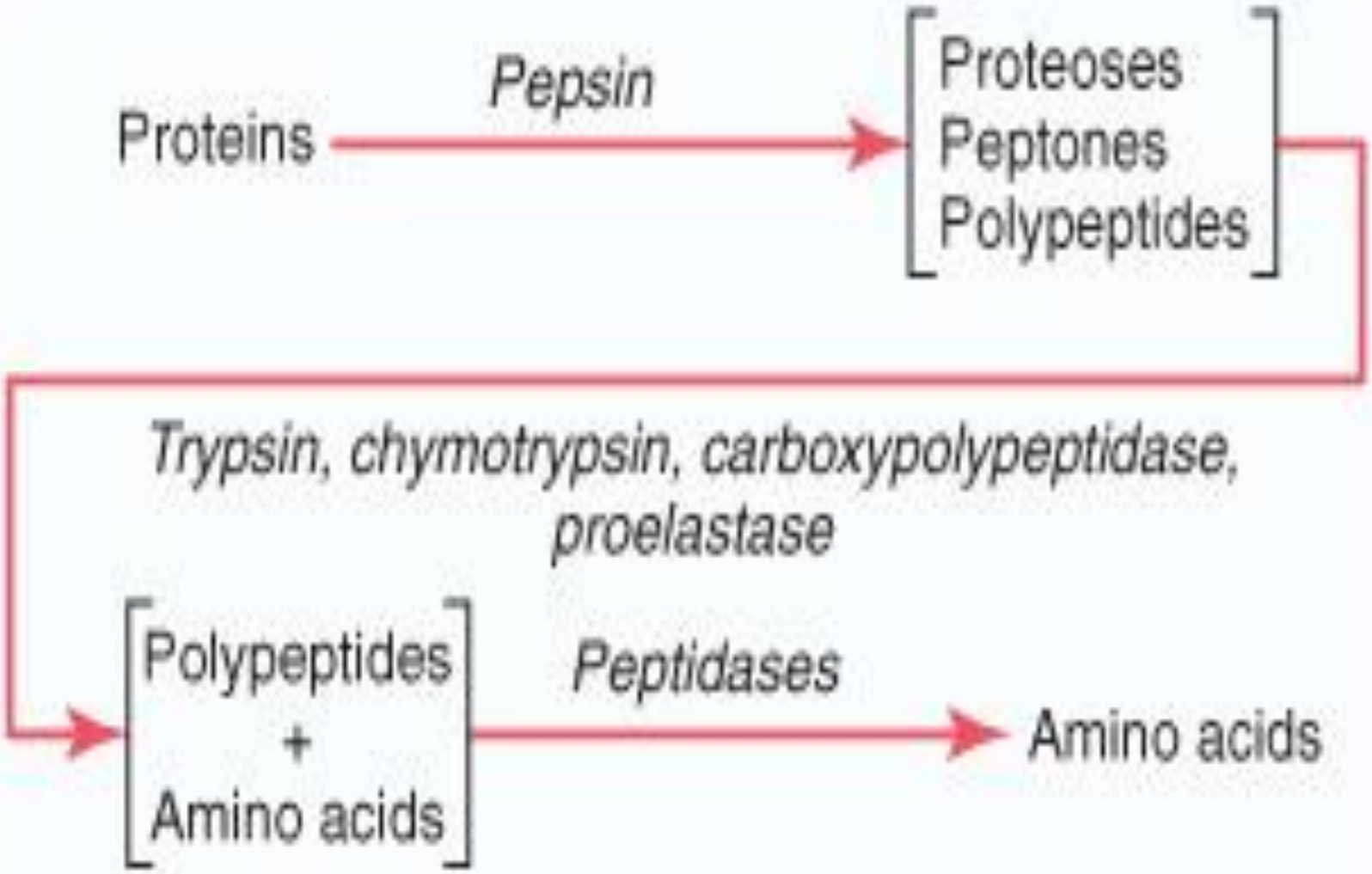
Trypsin activates:

- Chymotrypsinogen to chymotrypsin
- Procarboxypeptidase into carboxypeptidase.
- Proelastase to elastase

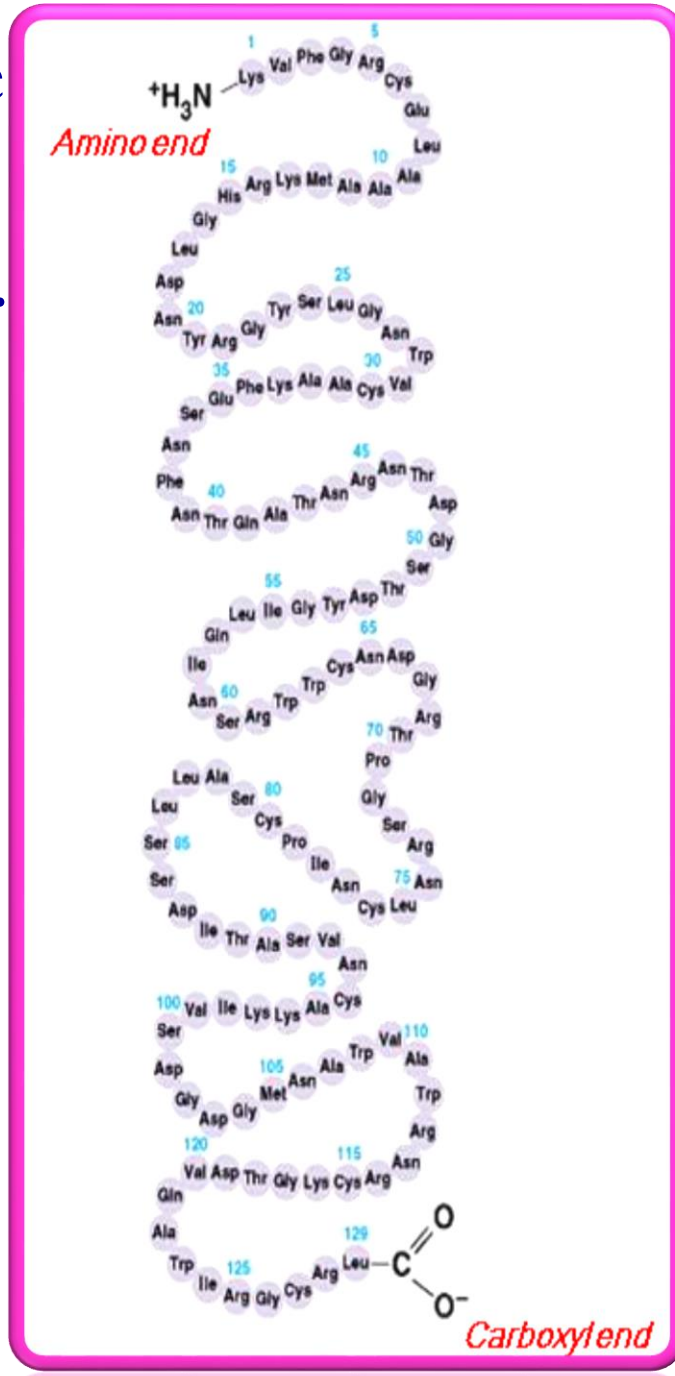


Activation of Gastrointestinal Proteases




Proteins
Pepsin
Proteoses
Peptones
Polypeptides
Trypsin, chymotrypsin, carboxypolypeptidase, proelastase
Polypeptides
+
Amino acids
Peptidases
Amino acids

- Trypsin, chymotrypsin and elastase are endopeptidases, splitting protein into shorter peptide chains.
- Carboxypeptidase is an exopeptidase which splits off AA at the carboxyl terminus of the peptide.
- Trypsin inhibitor is present in cytoplasm of glandular cells. It inhibits activation of trypsin in acini and ducts of the pancreas.



2- Pancreatic amylase

It splits starch to maltose, maltotriose and dextrins.

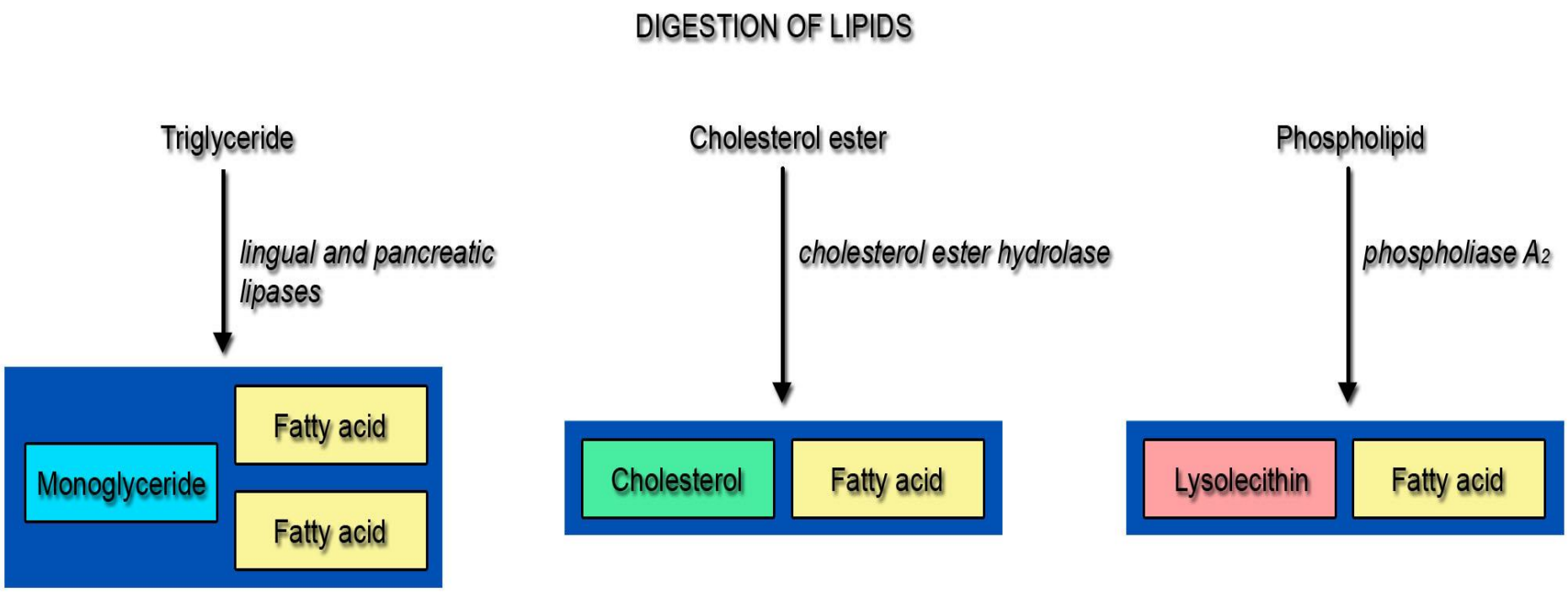
3- Enzymes for fat digestion

a. Pancreatic lipase is the most important fat splitting enzyme. It breaks TG into MG and FA in the presence of bile salts and colipase.

b. Cholesterol esterase which liberates cholesterol.

c. Phospholipase A_2 which splits phospholipids into lysolecithin & FA.

End Products of Fat Digestion



Characteristics of Pancreatic Enzymes

Enzyme	Specific Hydrolytic Activity
Proteolytic	
Endopeptidases	
Trypsin(ogen)	Cleaves peptide linkages in which the carboxyl group is either arginine or lysine
Chymotrypsin(ogen)	Cleaves peptides at the carboxyl end of hydrophobic amino acids, e.g., tyrosine or phynylalanine
(Pro)elastase	Cleaves peptide bonds at the carboxyl terminal of aliphatic amino acids
Exopeptidase	
(Pro)carboxypeptidase	Cleaves amino acids from the carboxyl end of the peptide
Amylolytic	
α-Amylase	Cleaves α-1,4-glycosidic linkages of glucose polymers
Lipases	
Lipase	Cleaves the ester bond at the 1 and 3 positions of triglycerides, producing free fatty acids and 2-monoglyceride
(Pro)phospholipase A_2	Cleaves the ester bond at the 2 position of phospholipids
Carboxylesterhydrolase (cholesterol esterase)	Cleaves cholesteryl ester to free cholesterol
Nucleolytic	
Ribonuclease	Cleaves ribonucleic acids into mononucleotides
Deoxyribonuclease	Cleaves deoxyribonucleic acids into mononucleotides

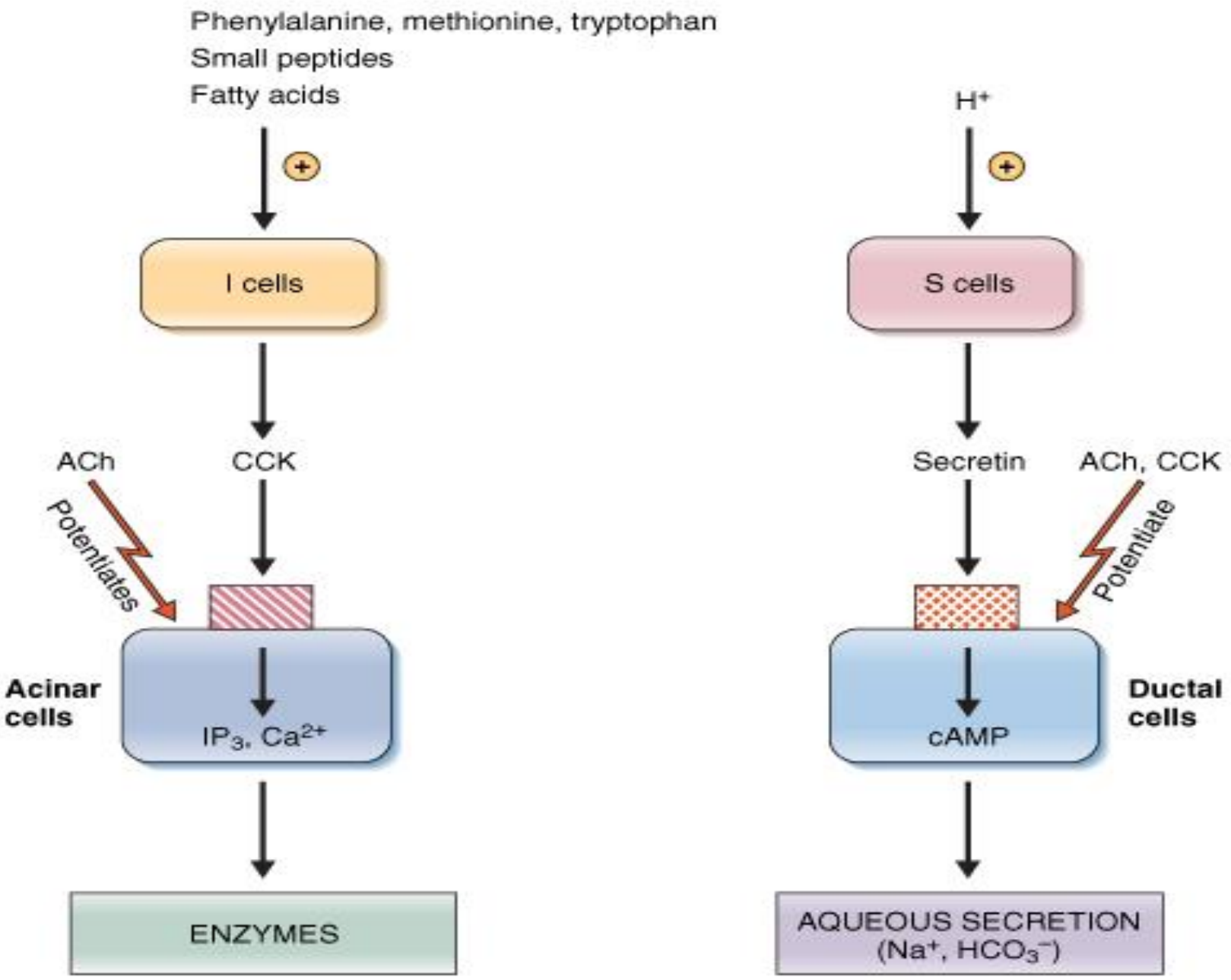
The suffix –ogen or prefix pro- indicates the enzyme is secreted in an inactive form

Pancreatic Secretion is Under Neural and Hormonal Control

- ☆Parasympathetic stimulation (through Ach on acinar cells) results in an increase in enzyme secretion-fluid and HCO_3^-
- ☆Secretin tends to stimulate a HCO_3^- rich secretion by activating ductal cells.
- ☆Cholecystokinin (CCK) stimulates a marked increase in enzyme secretion by stimulating the acinar cells.
- ☆Pancreatic secretion normally results from the combined effects of the multiple basic stimuli, not from one alone (potentiate each other).

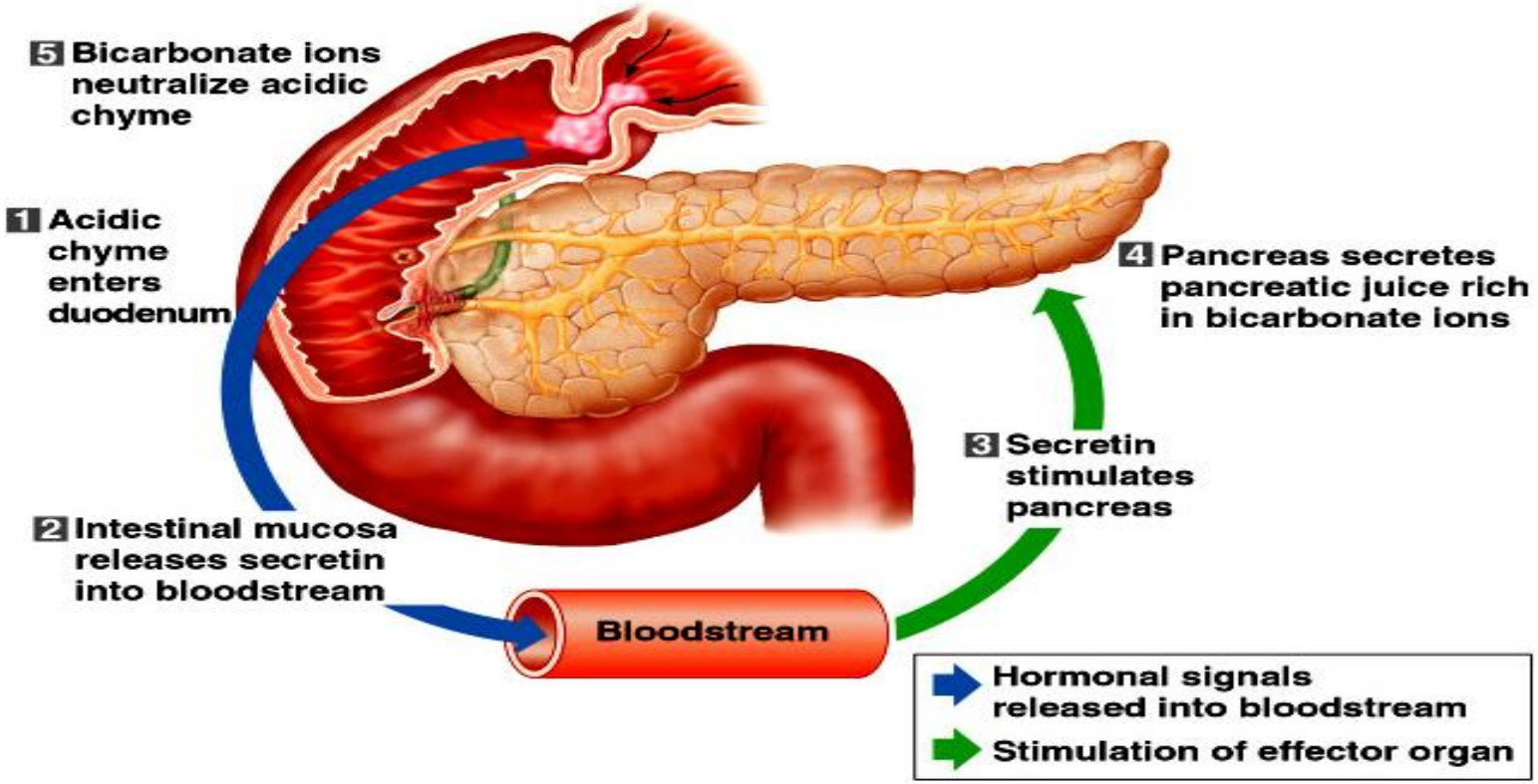
Phases of Pancreatic secretion

Phase	stimulus	Mediators
Cephalic phase	Smell, taste, chewing and swallowing	Release of Ach and gastrin
Gastric phase	Protein, gastric distention	Vago-vagal reflex
Intestinal phase	Acid in chyme, fatty acids	Secretin, CCK and vago-vagal reflex


REGULATION OF PANCREATIC SECRETION
Phenylalanine, methionine, tryptophan
Small peptides
Fatty acids
H+
I cells
S cells
ACh
CCK
Secretin
ACh, CCK
Potentiates
Potentiate
Acinar cells
IP3, Ca2+
cAMP
Ductal cells
ENZYMES
AQUEOUS SECRETION
(Na+, HCO3−)

Secretin hormone

- ✓ It is a peptide released into the blood from "S" cells in upper intestinal mucosa.
- ✓ Stimuli for its release:
  - Mainly acids (pH 4 or less)
  - To a less extent AA and FA.

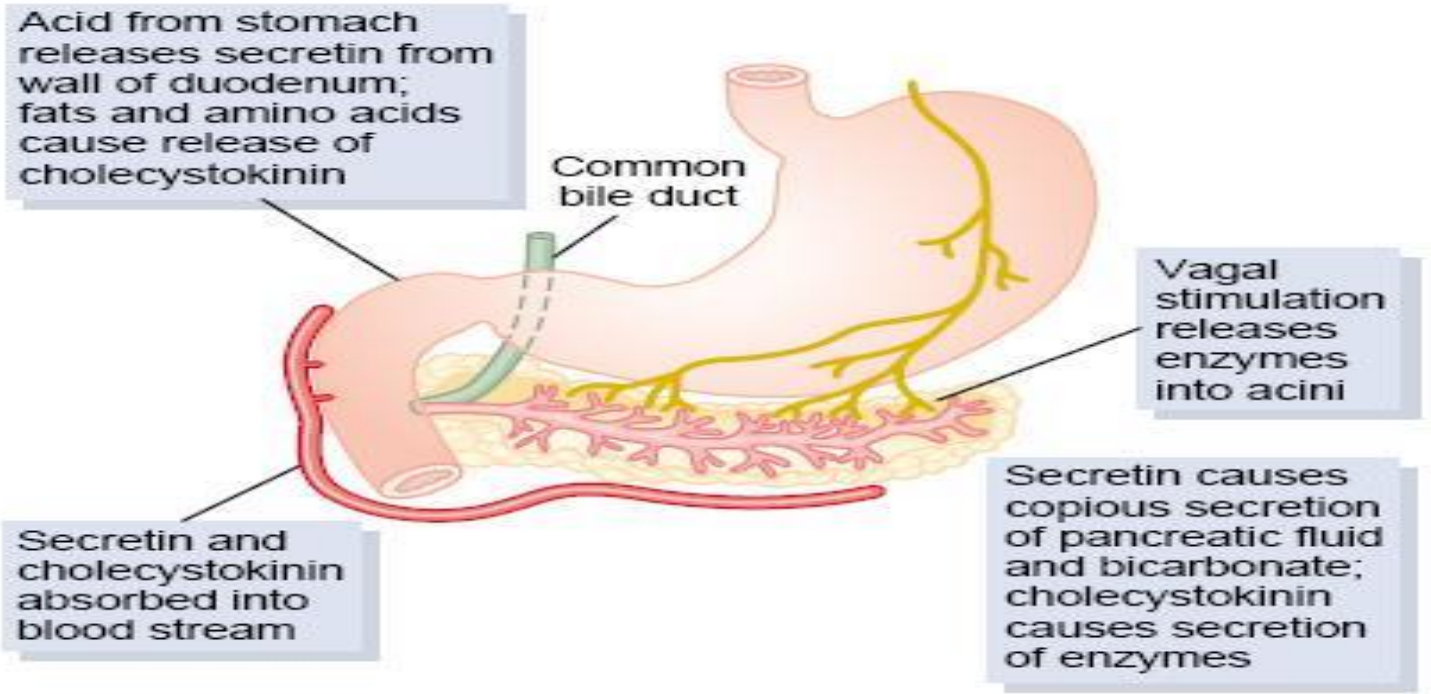


Functions

- It acts on pancreatic duct cells to stimulate secretion of HCO_3^- and H_2O.
- It acts on biliary duct cells to stimulate hepatic bile flow and HCO_3^- secretion.
- It augments the action of CCK in stimulating pancreatic enzyme secretion.
- It inhibits gastric acid secretion and gastrin release, but it stimulates pepsin secretion.
- It inhibits gastric motility, contracts pylorus and slows gastric emptying.
- It relaxes LES.
- It inhibits intestinal motility and contracts ileocecal sphincter.

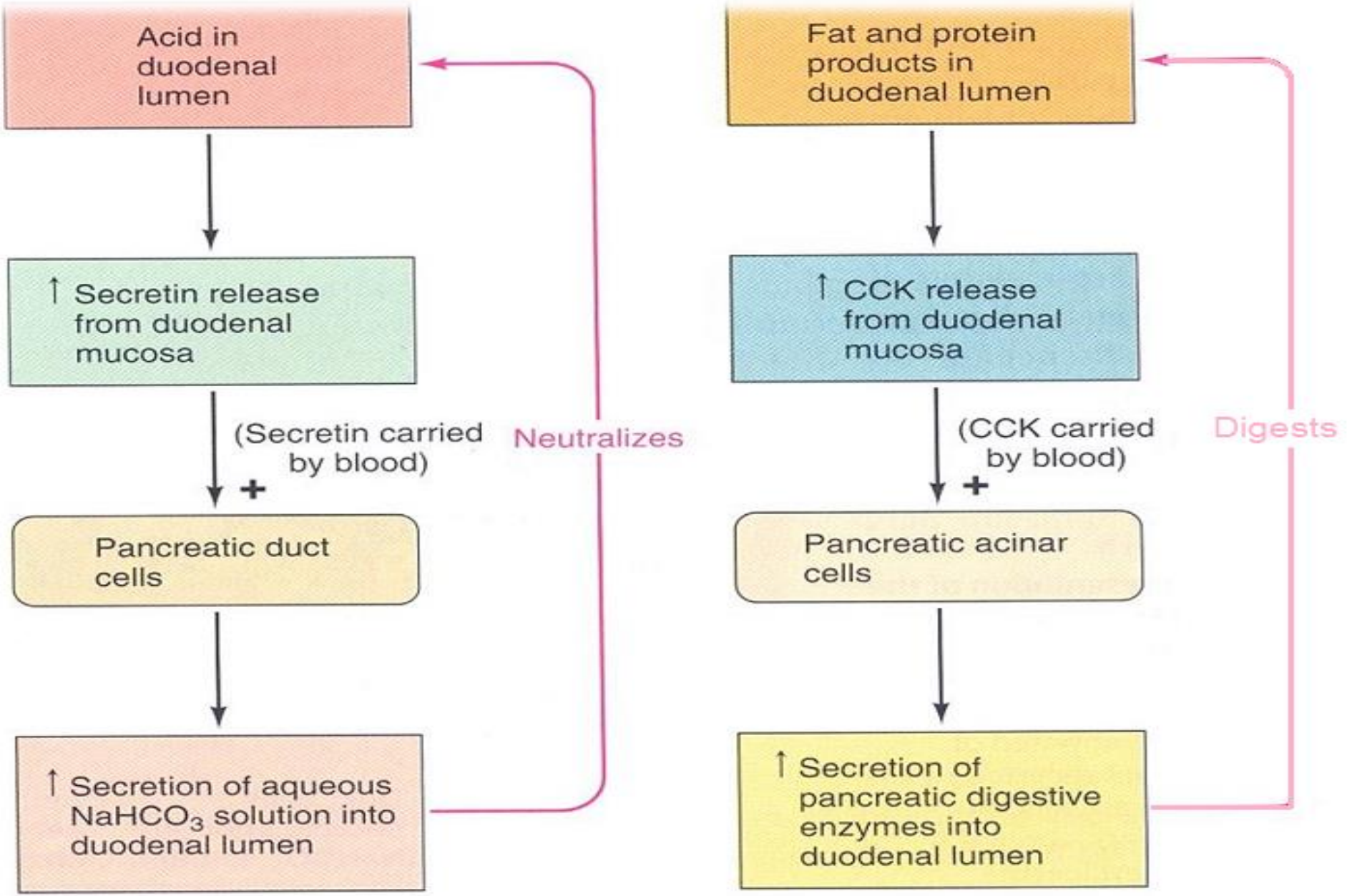
Cholecystokinin (CCK)

- ✓ It is a peptide released from "I" cells in the upper intestine.
- ✓ Stimuli of release:-
  - Mainly by AA and FA
  - To a lesser extent by HCl.



✓Functions

- It stimulates pancreatic *enzyme* secretion.
- It augments stimulation of H_2O and HCO_3^- secretion by secretin.
- It has trophic effect on pancreas.
- It contracts gall bladder, relaxes sphincter of Oddi and causes bile discharge into intestine.
- It stimulates gastric motility, contracts pylorus thus slows gastric emptying.
- It relaxes LES.
- It stimulates intestinal motility.
- It may be concerned with the mechanism of satiety.



Hormonal control of pancreatic exocrine secretion