#4 Physiology of the pancreas

objectives :

- Pancreatic acini
- Pancreatic secretion
- Pancreatic enzymes
- Control of pancreatic secretion
  - Neural
  - Hormonal
    - Secretin
    - Cholecystokinin

Doctors' notes

Extra

Important

Revised by
خولة العماري & هشام الغفيلي

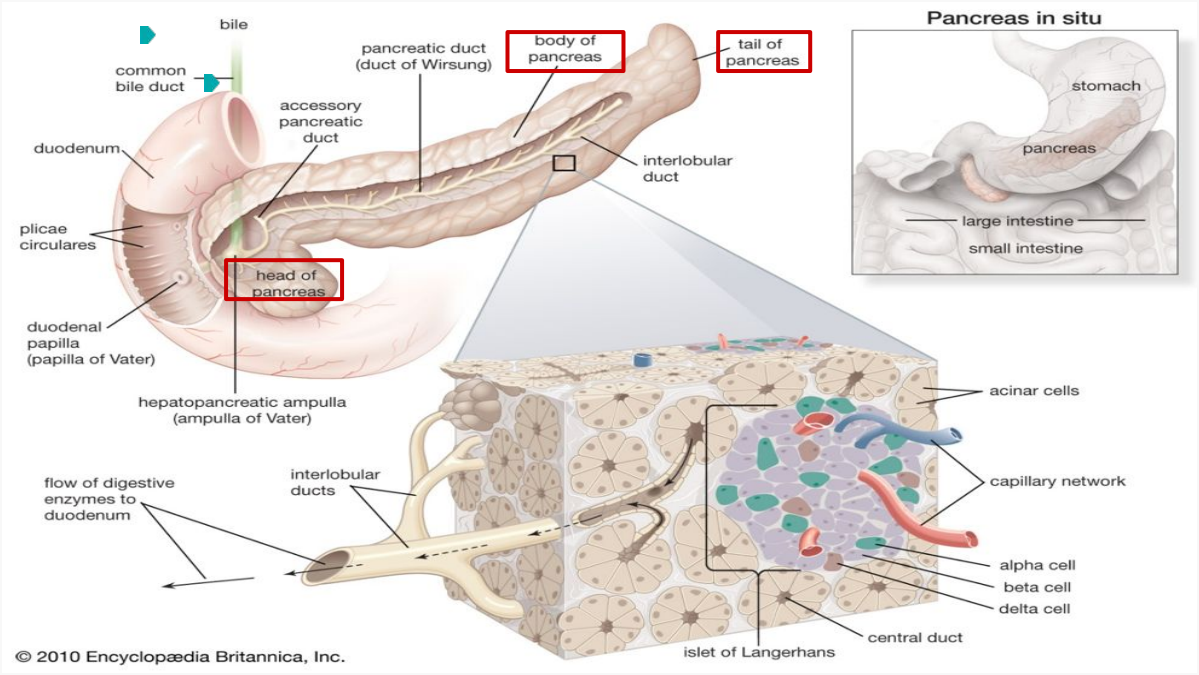
Resources: 435 Boys' & Girls' slides | Guyton and Hall 12th & 13th edition

Editing file

Physiology435@gmail.com

Anatomy of the pancreas :

For better understanding, study histology & Anatomy of pancreas



The pancreas, which lies parallel to and beneath the stomach is a large compound gland with most of its internal structure similar to that of the salivary glands

Histology of the pancreas

Acini (Exocrine) The digestive function

- Exocrine
- **99%** of gland

Islets of Langerhans (Endocrine) the regulatory function

- Endocrine
- **1%** of gland

Secrete :
1-insulin(Beta-cells;60%) which lowers the glucose level
2- glucagon(Alpha-Cells; 25%) rises the glucose level and both hormones are controlled by hormone called somatostatin (Delta cells; 10%)

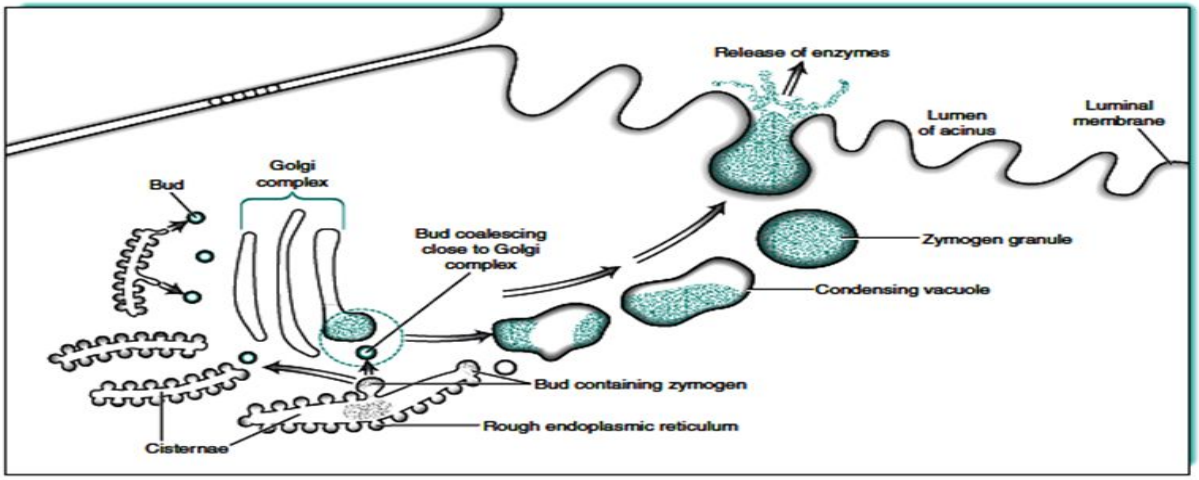


Fig. 5.9
Mechanism of enzyme secretion in the acinar cell.

Acinar cells are pyramid with basal nuclei and rich in RER and a lot of ribosomes and mitochondria in the base ,in the apex there's abundant secretory vesicles to make secretion easier , the nutrient we need will diffuse from the blood vessels and then the transcription of RNA take place then goes to ribosome to be translated which result in production of protein we need in formation of enzymes >> these protein goes to the Golgi apparatus which store and modify the inactive protein to make it active after that it will release some vesicles contain digestive enzymes called zymogen granules. these zymogen granules will condensate which result in low amount of water and high concentration of enzymes . once there's stimulus to this cells either neural (ACH) or hormonal (cholecystokinin) which is the main activator of enzyme synthesis . Then after stimulus has done there will be depolarization of membrane and the vesicles will fuse to the cell membrane >> exocytosis 80% of secretion of enzyme under the effect of CCK .

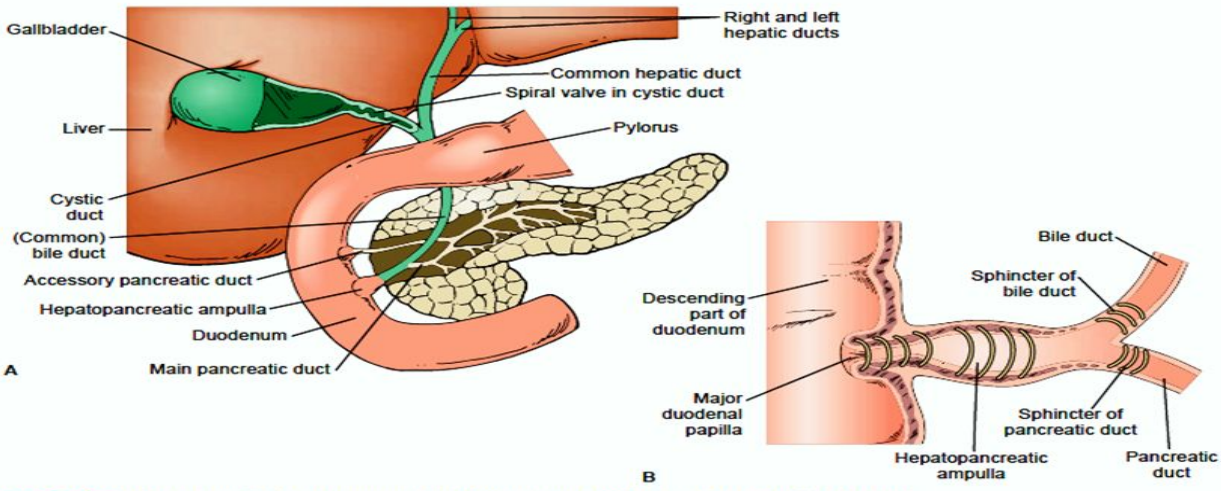


FIGURE 40-18 **(A)** Extrahepatic bile passages, gall bladder, and pancreatic ducts. **(B)** Entry of bile duct and pancreatic duct into the hepatopancreatic ampulla, which opens into the duodenum.

Pancreatic duct before it opens into the first part of duodenum it will join with the common bile duct is formed when common hepatic duct joins the common cystic duct (from gall bladder)(common hepatic duct is formed from right and left hepatic ducts which join together and form common hepatic duct). Then common bile duct will join the pancreatic duct to form hepatopancreatic ampulla which will open into duodenum by sphincter of oddi to control the secretion from the pancreatic duct and bile duct and also prevent the content of duodenum to go back , because pancreatic duct is sterile if there's infection it will lead into pancreatitis which is lethal .

Secretory function of pancreas :

Functional units:

1- Acinar cells of the exocrine pancreas

2- Duct cells of the exocrine pancreas

Secretory function of pancreas	
Pancreatic acini	• secrete the pancreatic digestive enzymes (Inactive enzymes)
The ductal cells	• secrete large volumes of sodium bicarbonate solution (Alkaline)

- Pancreatic juice is secreted in response to the presence of chyme in the upper portions of the small intestine.
- The combined product of enzymes and sodium bicarbonate solution then flows through a long pancreatic duct.
- Pancreatic duct joins the common hepatic duct to form hepatopancreatic ampulla.
- The ampulla empties its content through papilla of vater which is surrounded by sphincter of oddi.

Exocrine Pancreas

- Pancreatic enzymes originate in the acinar cells
- Secretion of water and electrolytes originates in the centroacinar and intercalated duct cells
- Final product is a colorless ,odorless عديم الرائحة, and isosmotic alkaline fluid that contains digestive enzymes (amylase, lipase, chymotrypsinogen and trypsinogen)

- Colorless compared to bile which has color.
- Isosmotic compared to saliva which was hypotonic.

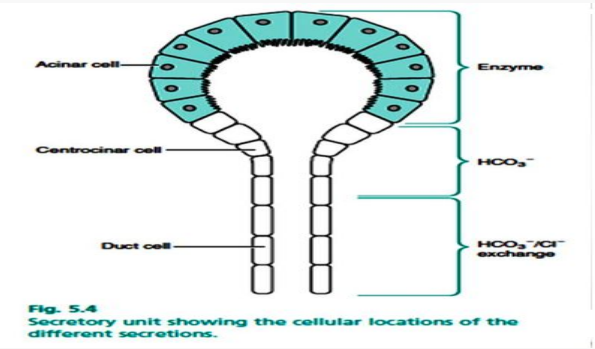


Fig. 5.4
Secretory unit showing the cellular locations of the different secretions.

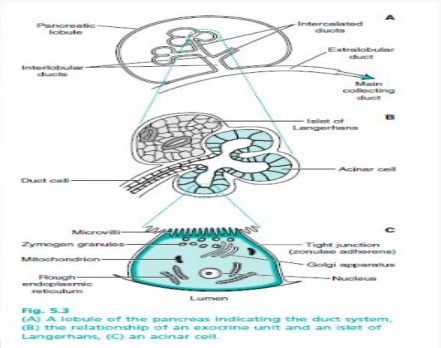
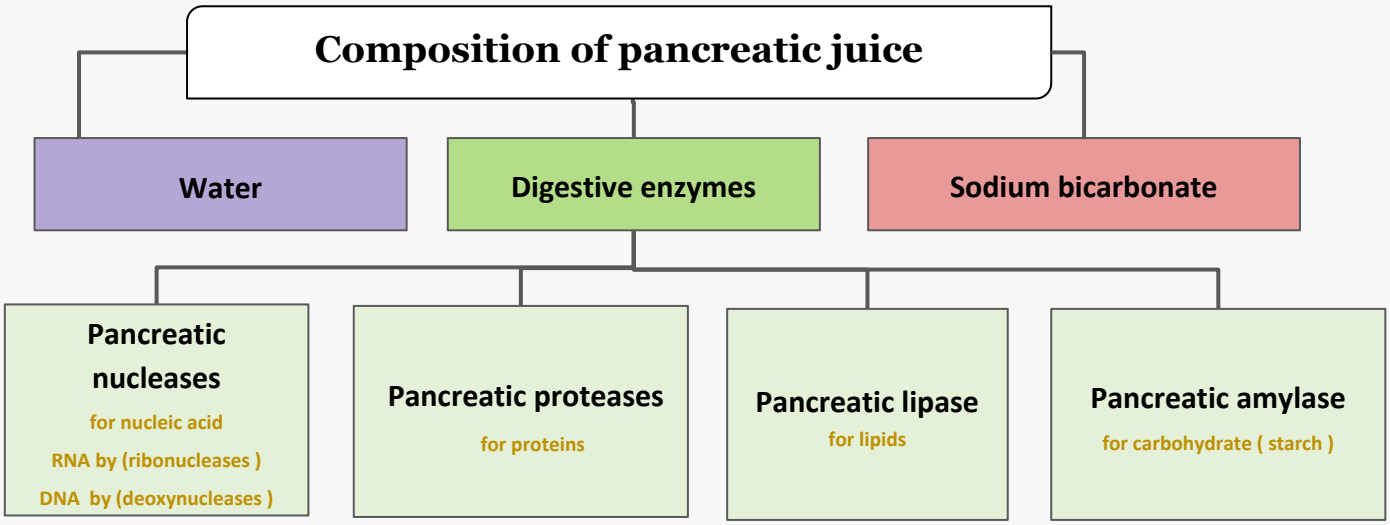


Fig. 5.3
(A) A lobule of the pancreas indicating the duct system, (B) the relationship of an exocrine unit and an islet of Langerhans, (C) an acinar cell.

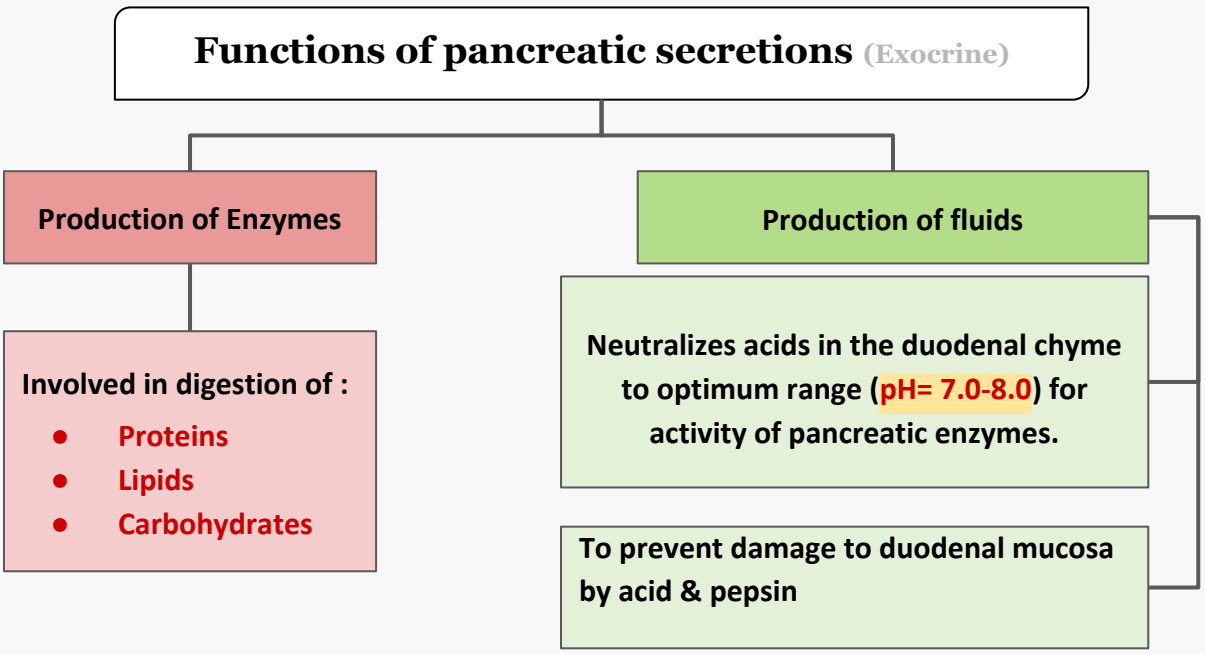
Guyton corner: The pancreatic digestive enzymes are secreted by *pancreatic acini,* and large volumes of sodium bicarbonate solution are secreted by the small ductules and larger ducts leading from the acini. The combined product of enzymes and sodium bicarbonate then flows through a long *pancreatic duct* that normally joins the hepatic duct immediately before it empties into the duodenum through the *papilla of Vater,* surrounded by the *sphincter of Oddi.*

Composition of pancreatic juice :



Guyton corner : **Pancreatic secretion** contains multiple enzymes for digesting all of the three major types of food: proteins, carbohydrates, and fats. It also contains large quantities of bicarbonate ions, which play an important role in neutralizing the acidity of the chyme emptied from the stomach into the duodenum.The most important of the **pancreatic** enzymes for digesting proteins are *trypsin, chymotrypsin,* and *carboxypolypeptidase*. By far the most abundant of these is trypsin.

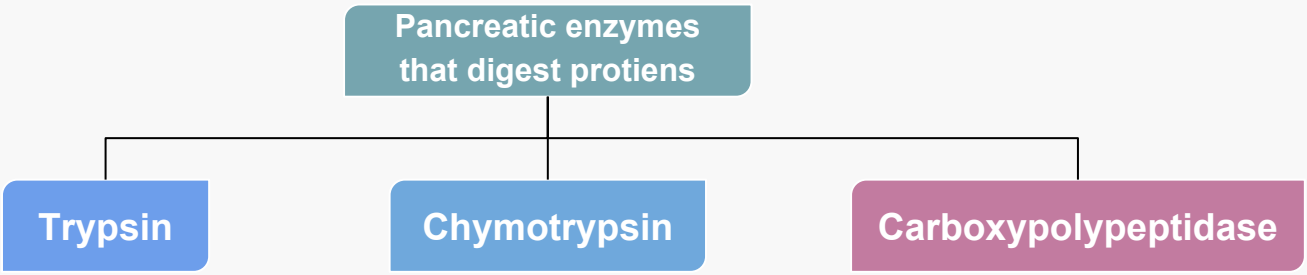
Functions of pancreatic secretions :



Pancreatic secretions are alkaline because it will face high acidity coming from the stomach so they will neutralize the acidity of the stomach .They act as vehicle ناقل to carry enzymes because enzymes are thick substances that need some fluid to carry it, without fluid and bicarbonate we can't carry enzyme to ducts.

Pancreatic secretion:

The most important pancreatic enzymes for digesting proteins are:



- **Trypsin and chymotrypsin split whole and partially digested proteins into peptides of various sizes but do not cause release of individual amino acids.**
- **Carboxypolypeptidase splits some peptides into individual amino acids, thus completing digestion of some proteins to amino acids.**

What protect pancreas from digestive enzymes:

- **Pancreatic enzymes are secreted in inactive form:**
  - **Trypsinogen**
  - **Chymotrypsinogen**
  - **Procarboxypolypeptidase.**

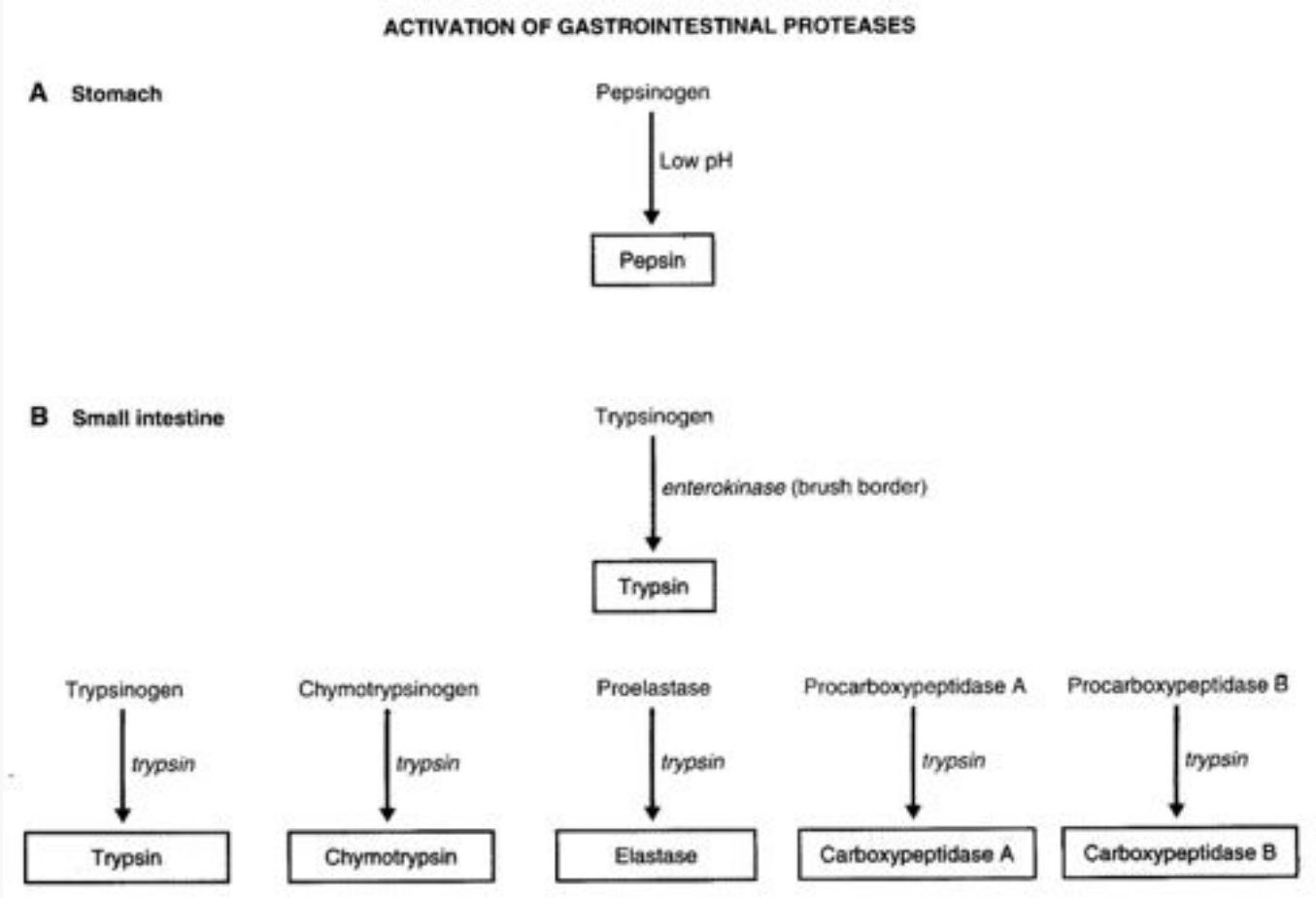
- **They will be activated by:**

1. **enterokinase enzyme an enzyme secreted by the intestinal mucosa when chyme comes in contact with the mucosa** (release from duodenum wall)
2. **Trypsinogen, Chymotrypsinogen and Procarboxypolypeptidase can be autocatalytically activated by trypsin formed from previously secreted trypsinogen.**

- **The acinar cells that secrete the enzymes secretes trypsin inhibitor which prevent activation of trypsin inside acini and ducts. When a duct is blocked , the trypsin inhibitor can not inhibit activation of accumulated enzymes which will be activated and digest the pancreas in few hours !**

Table 5.1
Activation of enzyme precursors in the small intestine

Precursor		*Active enzyme*
Trypsinogen	*enterokinase, trypsin* →	trypsin + peptide
Chymotrypsinogen	*trypsin* →	chymotrypsin + peptide
Proelastase	*trypsin* →	elastase + peptide
Procarboxypeptidase	*trypsin* →	carboxypeptidase + peptide
Prophospholipase A	*trypsin* →	phospholipase A + peptide



Enterokinase	• is an enzyme that is secreted by brush border of small intestine and **activate** pancreatic enzymes.
Trypsin inhibitor	• is secreted by acinar cells to **prevent activation** of the enzymes inside the cells ,in the acini and in the ducts.

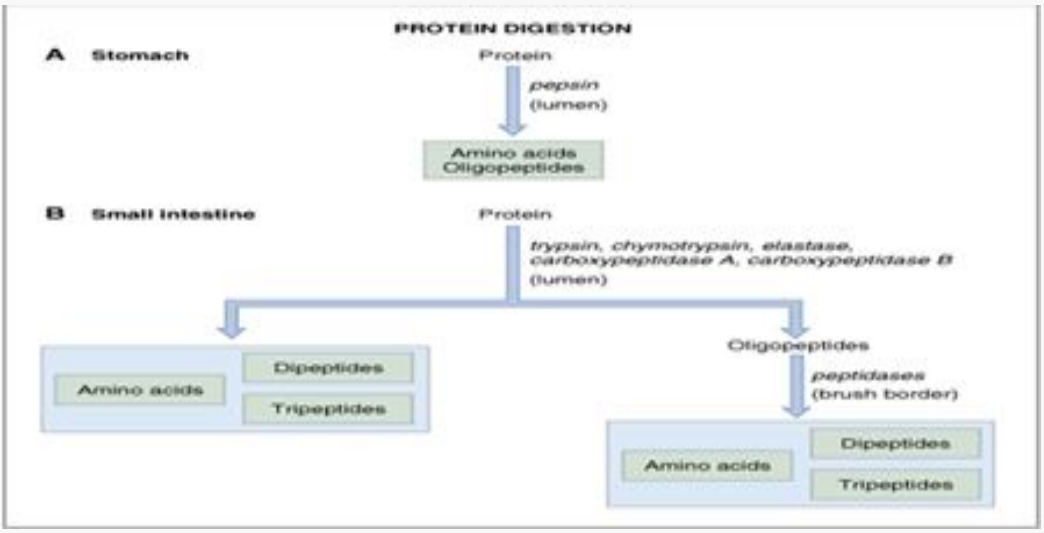
Trypsin inhibitor فقط لأن أول مايحصله تحفيز لتربيسن يسوي ستميوليشن لكل الانزايم الاخرى وايضا ستميوليشن لنفسه

When the pancreatic ducts are obstructed by tumor or by stones from gallbladder or common bile duct. it will obstruct the hepatopancreatic ampulla. so the pancreatic enzymes will accumulate and there will be continuous stimulation of CCK and nervous system (ACH) and more enzyme accumulated. trypsin inhibitor مايقدر يلحق عليهم so most of the enzymes will be activated. this condition is lethal it's called acute pancreatitis witch pancreas digest it self. when they test the blood they will find high concentration of activated enzymes in the blood which indicate pancreatitis. but in chronic pancreatitis like alcoholic patients fibrosis and more damage of pancreatic cells. Also Langerhan cells will be affected so he may develop diabetes mellitus.

Guyton corner : Trypsin Inhibitor is formed in the cytoplasm of the glandular cells, and it prevents activation of trypsin both inside the secretory cells and in the acini and ducts of the pancreas. and, because it is trypsin that activates the other pancreatic proteolytic enzymes, trypsin inhibitor prevents activation of the others as well. When the pancreas becomes severely damaged or when a duct becomes blocked, large quantities of pancreatic secretion sometimes become pooled in the damaged areas of the pancreas. Under these conditions, the effect of trypsin inhibitor is often overwhelmed, in which case the pancreatic secretions rapidly become activated and can literally digest the entire pancreas within a few hours, giving rise to the condition called acute pancreatitis. This is sometimes lethal because of accompanying circulatory shock; even if not lethal, it usually leads to a subsequent lifetime of pancreatic insufficiency.

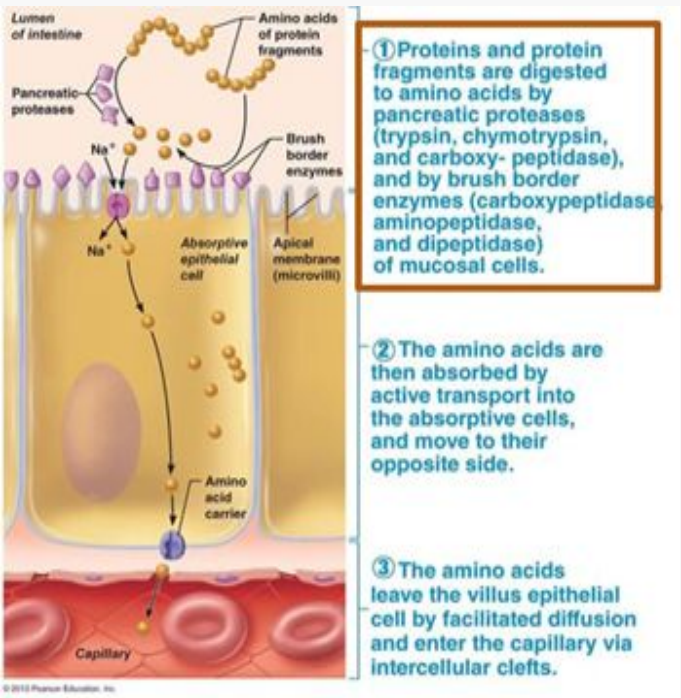
Protein digestion:

(A)in stomach (B) in small intestine.

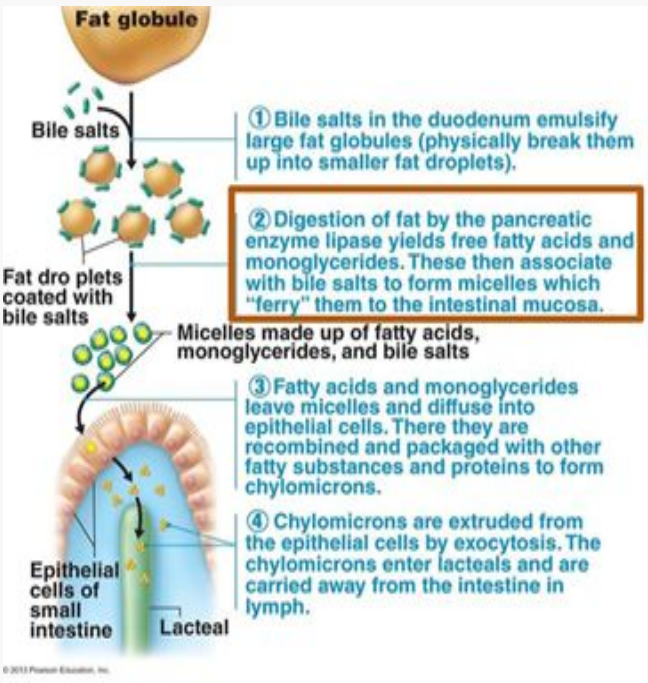


The pancreatic secretion plays important role in protein digestion

We know pepsin in stomach digest 20% of protein but when rest of protein reaches the small intestine the pancreatic enzymes digest protein into oligopeptide and amino acids these enzyme known as trypsin chymotrypsin elastase and carboxypeptidase but some of these protein are not completely digested it will continue digestion in small intestine by brush border enzyme peptidase (will be discussed later).



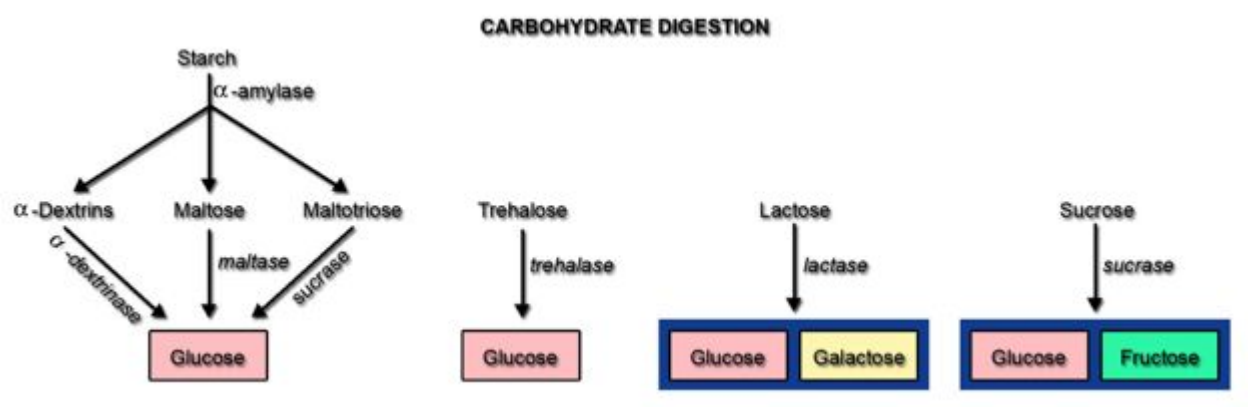
Proteins are digested by pancreatic enzyme and continue digestion by brush border.



Digestion of fat is by pancreatic enzyme called lipase and break fat into fatty acid and monoglyceride and those fatty acid will be absorbed in micelle.

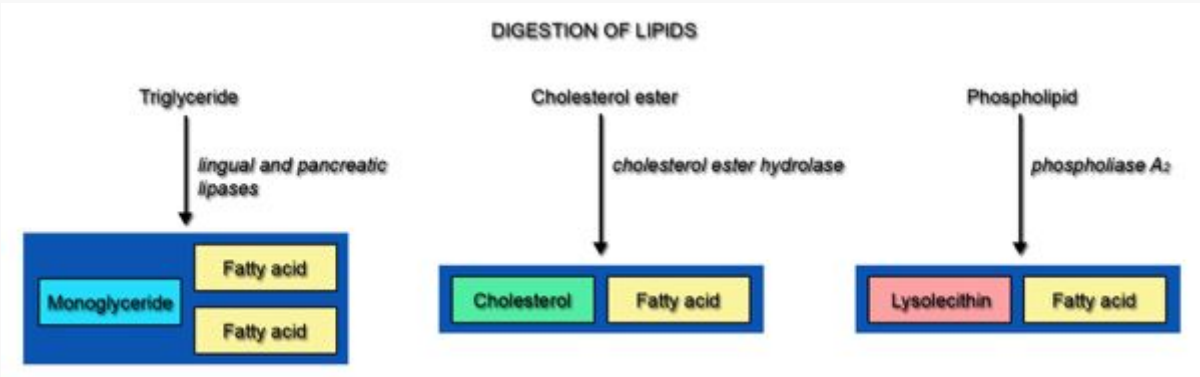
Pancreatic secretion:

- The pancreatic enzyme for digesting carbohydrates is pancreatic amylase, which hydrolyzes starches, glycogen, and most other carbohydrates (except cellulose) to form mostly disaccharides and a few tri-saccharides.



- The main enzymes for fat digestion are:

1. Pancreatic lipase
2. Cholesterol esterase
3. Phospholipase



Characteristics of Pancreatic Enzymes

Proteolytic	Amylolytic	Nucleolytic
• Endopeptidases • Trypsinogen • Chymotrypsinogen • Proelastase • Exopeptidase • Procarboxypeptidase	• a-Amylase • Lipases • Prophospholipase A2 • Carboxylester hydrolase (cholesterol esterase)	• Ribonuclease • Deoxyribonuclease

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

Mechanism of bicarbonate ions (HCO_3^-) secretion:

Apical membrane of ductal cells	Basolateral membrane of ductal cells
• **Contains :** Cl^- - HCO_3^- exchanger	• **Contains :** 1. Na^+-K^+ ATPase 2. Na^+-H^+ exchanger

1

CO_2 and H_2O combine in cells to form H^+ and HCO_3^-

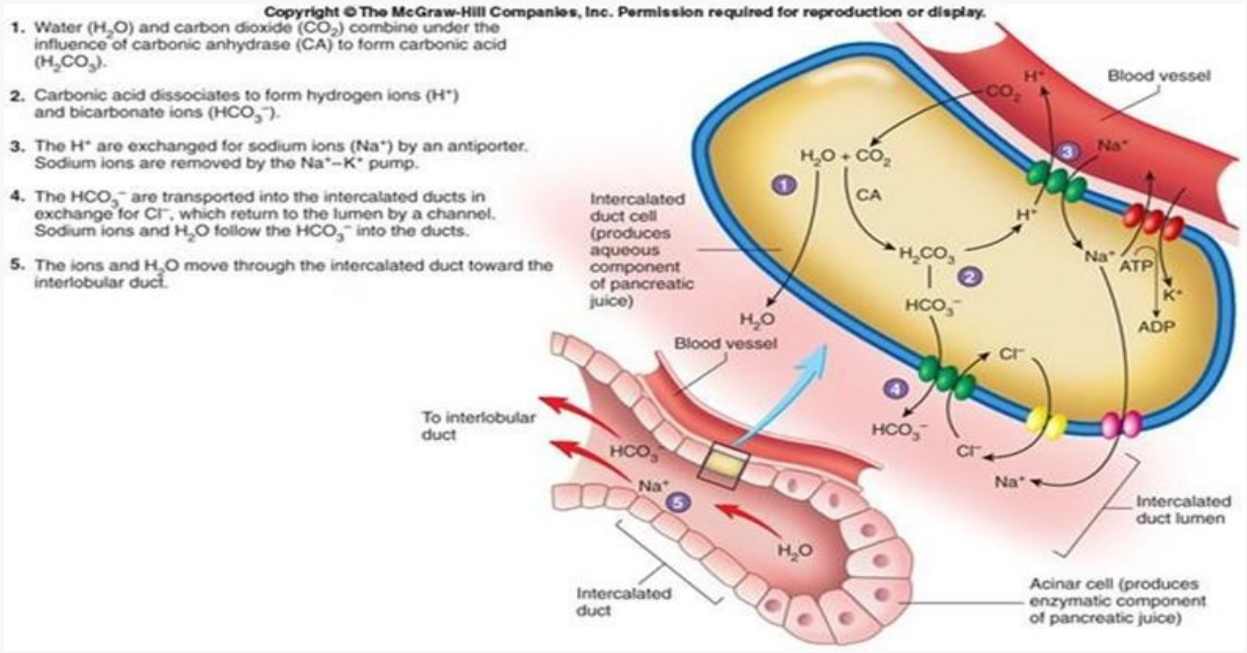
2

HCO_3^- is secreted into pancreatic juice by Cl^-- HCO_3^- exchanger

3

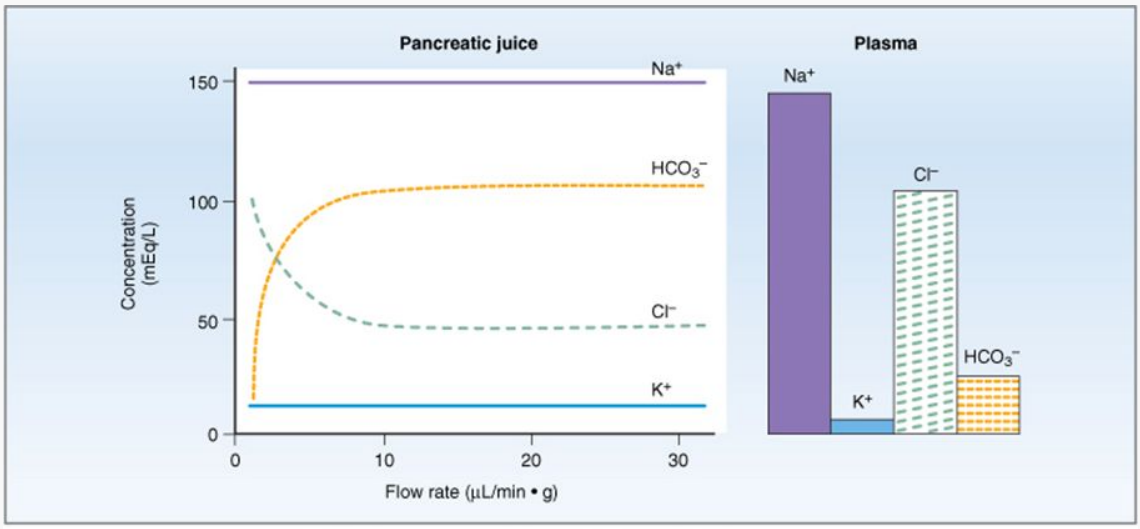
H+ is transported into <u>blood</u> by Na^+- H^+ exchanger

Absorption of H^+ causes acidification of pancreatic venous blood

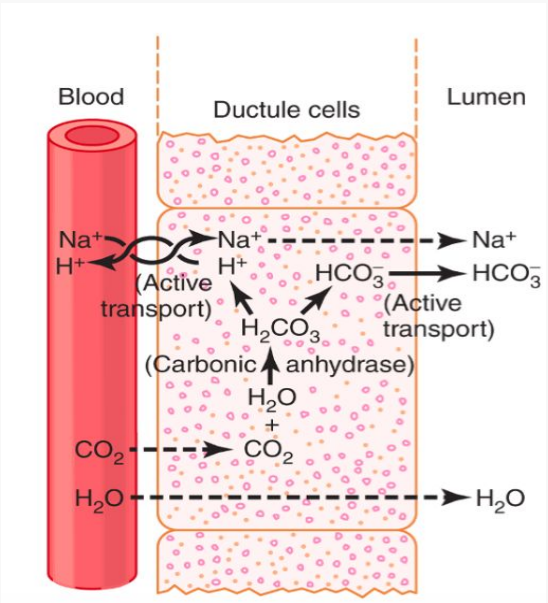


(HCO_3^-) secretion :

- Pancreatic secretions are rich in bicarbonate ions , secrets about 1 L/day of HCO3 –rich fluid from the epithelial cells of the ductules and ducts.
- The osmolarity of pancreatic fluid is equal to that of plasma
- HCO3 concentration increases with increasing secretion rate



What happen inside the cell ? We have H2O and CO2 join to form the carbonic acid which dissociate into H and bicarbonate the H ions will be absorbed in exchange with Na and the HCO3 they're secreted actively into the lumen in exchange with Cl- (Secretin increases rate of exchange). Influxed Na will be secreted into lumen and the water will follow the Na by osmosis so the result is sodium bicarbonate and water which flow carrying enzymes with it .



Guyton corner : We are 100% sure that you will understand the whole process after reading this :)
1.Carbon dioxide diffuses to the interior of the cell from the blood and, under the influence of carbonic anhydrase, combines with water to form carbonic acid (H2CO3). The carbonic acid in turn dissociates into bicarbonate ions and hydrogen ions (HCO3 − and H+). Then the bicarbonate ions are actively transported in association with sodium ions (Na+) through the luminal border of the cell into the lumen of the duct.
2. The hydrogen ions formed by dissociation of carbonic acid inside the cell are exchanged for sodium ions through the blood border of the cell by a secondary active transport process. This supplies the sodium ions (Na+) that are transported through the luminal border into the pancreatic duct lumen to provide electrical neutrality for the secreted bicarbonate ions.
3. The overall movement of sodium and bicarbonate ions from the blood into the duct lumen creates an osmotic pressure gradient that causes osmosis of water also into the pancreatic duct, thus forming an almost completely isosmotic bicarbonate solution.
The pancreas also secretes insulin, but this is not secreted by the same pancreatic tissue that secretes intestinal pancreatic juice. Instead, insulin is secreted directly into the blood—not into the intestine— by the islets of Langerhans that occur in islet patches throughout the pancreas.

Phases of pancreatic secretion:

Cephalic phase	Gastric phase	Intestinal phase
• Stimulated by smell, taste, chewing and swallowing. • Mediated by ACh through vagus nerve. • 20% of pancreatic enzymes.	• Stimulated by proteins, gastric distention. • Mediated by vago-vagal reflex. • 5-10% of pancreatic enzymes.	• Stimulated by acid in chyme and fatty acids. • Mediated by secretin, CCK and vago-vagal reflex. • 70-75 % of pancreatic enzymes & fluid.

- Cephalic phase when we think about food or tasting the food this result in CNS stimulation of vagus nerve the impulses will be transmitted into pancreas the ach mainly stimulate acinar cells so we can say ach stimulate enzymes
- Gastric phase in pancreatic sections is opposite to gastric secretions (gastric phase in gastric secretion as we know it's high stimulation for secretion but in pancreatic secretion the gastric phase has slight stimulation 5%-10% and this stimulation is due to vagus stimulation, cuz when food reaches stomach there's some local stimulation and goes all the way into CNS and through the vagus nerve this stimulation will reach the pancreas and cause secretion of enzyme but in slight amount (5%-10%).
- Intestinal phase When the food is moving in the intestine in this it's mainly hormonal by secretin and CCK at this time its enzyme and fluid

Guyton corner: Phases of Pancreatic Secretion

Pancreatic secretion occurs in three **phases**, the same as for gastric **secretion**: the *cephalic phase,* the *gastric phase,* and the *intestinal phase*. Their characteristics are as follows.

Cephalic and Gastric Phases.

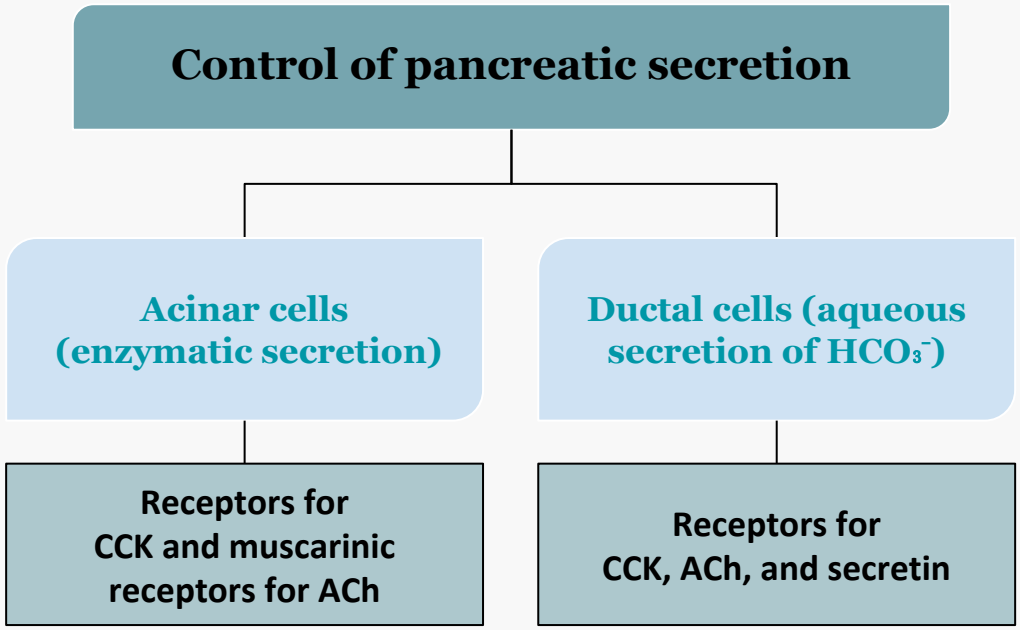
During the cephalic phase **of pancreatic secretion**, the same nervous signals from the brain that cause **secretion** in the stomach also cause acetylcholine release by the vagal nerve endings in the pancreas. This causes moderate amounts of enzymes to be secreted into the **pancreatic** acini, accounting for about 20 percent of the total **secretion of pancreatic** enzymes after a meal. But little of the **secretion** flows immediately through the **pancreatic** ducts into the intestine because only small amounts of water and electrolytes are secreted along with the enzymes.

During the gastric phase, the nervous stimulation of enzyme **secretion** continues, accounting for another 5 to 10 percent **of pancreatic** enzymes secreted after a meal. But, again, only small amounts reach the duodenum because of continued lack of significant fluid **secretion**.

Intestinal Phase.

After chyme leaves the stomach and enters the small intestine, **pancreatic secretion** becomes copious, mainly in response to the hormone *secretin.*

Control of pancreatic secretion:



On acinar cells it has receptors for CCK and muscarinic for Ach both are responsible for enzymatic secretion but the CCK is more important than nervous control (Ach) because it stimulate a lot of pancreatic enzymatic secretions

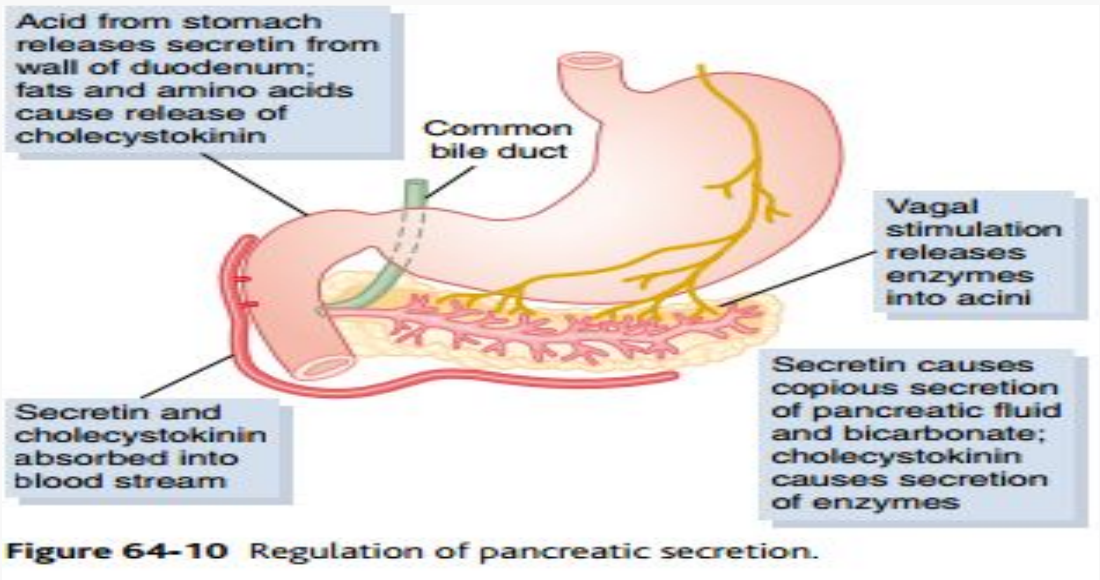


Figure 64–10 Regulation of pancreatic secretion.

Control of pancreatic secretion cont. :

	CCK	ACh	Secretin
Actions	**Most important enzyme secretion stimulant through stimulating acinar cells** the I cells are stimulated to release cck when fatty acid and amino acid present in the chyme àthe hormone travel through blood to pancreas à CCK binds to its receptors on acinar cells and stimulate enzyme secretion.	**Also stimulates enzyme secretion** The most important in aqueous bicarbonate secretion is secretin but cck and ach are potentiating (helping)	• Major stimulant • Cause the pancreas to secrets large quantities of fluid containing a high concentration of HCO3(up to 145 mEq/L = ~5X normal) but a low concentration of Cl. HCL + NaHCO3 → NaCl + H2CO3 • Stimulates secretion of large quantities of H_20 and $NaHCO_3$ solution (in contrast of the first two stimulants "CCK and ACh"). • Tends to stimulate a HCO_3-rich secretion by activating ductal cells. • Effects of secretin are potentiated by both CCK and ACh (READ the corner) • Has protective mechanism to prevent development of duodenal ulcers
	Both CCK and ACh stimulate the acinar cells to produce large quantities of pancreatic digestive enzymes and relatively small amounts of water and electrolytes.		**Guyton corner :** Multiplicative Effects of Different Stimuli. When all the different stimuli of pancreatic secretion occur at once, the total secretion is far greater than the sum of the secretions caused by each one separately. Therefore, the various stimuli are said to "multiply," or "potentiate," one another. Thus, pancreatic secretion normally results from the combined effects of the multiple basic stimuli, not from one alone.
Secreted from	I cells in the mucosa of the duodenum and upper jejunum.	**Parasympathetic vagus nerve endings and other cholinergic nerves in the enteric nervous system**	**from S cells in the mucosa of duodenum and jejunum**
Secreted in response to	**presence of amino acids and fatty acids in intestinal lumen**	–	**When highly acidic chyme (pH<4.5-5) enters the small intestine** H^+ and hydrochloric acid

Multiplicative or potentiation effects:

- Pancreatic secretion normally results from the combined effects of multiple basic stimuli, not from one alone.
- When all different stimuli of pancreatic secretion (ACh, CCK and secretin) occur at once, then the total secretion is far greater than the sum of the secretions caused by each stimulus separately. The stimuli "multiply" or "potentiate" one another.

Control of pancreatic secretion cont. :

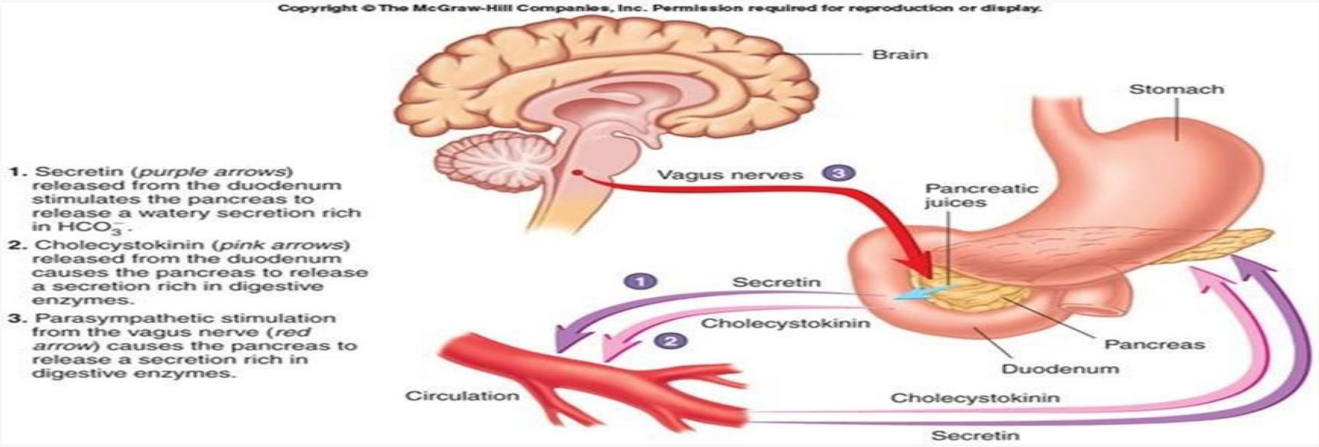
Guyton corner : Regulation of Pancreatic Secretion

Basic Stimuli That Cause **Pancreatic Secretion**

Three basic stimuli are important in causing **pancreatic secretion**:

1. *Acetylcholine,* which is released from the parasympathetic vagus nerve endings and from other cholinergic nerves in the enteric nervous system
2. *Cholecystokinin,* which is secreted by the duodenal and upper jejunal mucosa when food enters the small intestine
3. *Secretin,* which is also secreted by the duodenal and jejunal mucosa when highly acidic food enters the small intestine

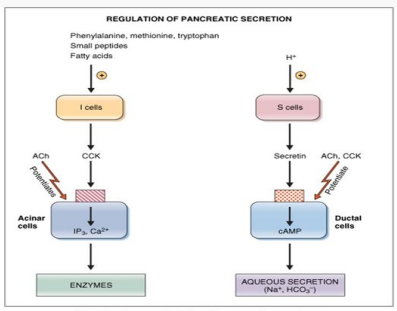
The first two of these stimuli, acetylcholine and cholecystokinin, stimulate the acinar cells of the pancreas, causing production of large quantities **of pancreatic** digestive enzymes but relatively small quantities of water and electrolytes to go with the enzymes. Without the water, most of the enzymes remain temporarily stored in the acini and ducts until more fluid **secretion** comes along to wash them into the duodenum. Secretin, in contrast to the first two basic stimuli, stimulates **secretion** of large quantities of water solution of sodium bicarbonate by the **pancreatic** ductal epithelium.



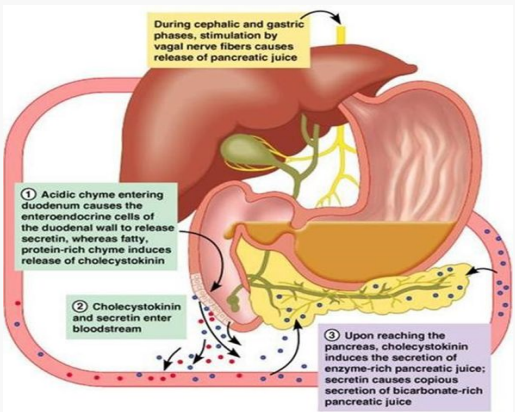
- The purple arrow shows the secretin release in response to acidity present in chyme (acidity stimulates cells to release secretin).
- Secretin is present in an inactive form as prosecretin in S cells in the mucosa of duodenum and jejunum
- The secretin travel through blood and reach pancreas to the ductal cells >> causes the pancreas to release large quantities of fluid containing large a high concentration of HCO_3 (up to 145 mEq/L which 5 times more than normal) and low concentration of Cl^-
- $HCl + NaHCO_3 \rightarrow NaCl + H_2CO_3$ (then H_2CO_3 is dissociated into $H_2O + CO_2$)
- The pink arrow shows CCK which is stimulated in presence of proteoses and peptones (products of partial protein degradation) and long-chain fatty acid stimulate I cells in duodenum and upper jejunum >> CCK released and travel through blood to pancreases >> binds to its receptors on acinar cells >> A lot of pancreatic enzymes is secreted (**has similar effect to that caused by vagal stimulation but even more prominent, responsible for 70%-80% of total secretion of pancreatic enzymes after a meal**).
- Red arrow shows parasympathetic stimulation through vagus nerve will go to pancreas and potentiate the release of aqueous fluid with secretin but mainly it stimulate release of enzymes
- So we can say :

  Ach – CCK >> enzymatic.

  Secretin >> fluid and bicarbonate.



Regulation of pancreatic secretion. ACh, Acetylcholine; cAMP, cyclic adenosine monophosphate; CCK, cholecystokinin; IP_3, inositol 1,4,5-triphosphate



- This figure demonstrate the cephalic and gastric phase which is due to nervous stimulation in both phases stimulate pancreas through the vagus nerve which will stimulate release enzyme.
- And when the acidic chyme reaches the duodenum it will stimulate S cells to release secretin and I cells (due to amino and fatty acid) stimulate CCK >> bind to their receptors
- Secretin receptors on ductal cells >> aqueous fluid
- CCK bind to its receptors and cause >> abundant release of enzymes

Hormonal control of GIT:

شايفين كيف هالجدول يتكرر بكل محاضرة؟ مما يعني إن حفظه أحد أساسيات هالبلوك

Hormone	Stimuli of Secretion	Site of Secretion	Action	
			Stimulates	inhibits
Gastrin	• Protein •Distention •Nerve •(Acid inhibits release)	G cells of pyloric antrum, duodenum and jejunum	• gastric acid secretion • mucosal growth.	–
Cholecystokinin (CCK)	•Protein • Fat •Acid	I cells of duodenum, jejunum and ileum	• Pancreatic enzyme • Pancreatic bicarbonate secretions. • Gall bladder contraction • Growth of exocrine pancreas	gastric emptying.
Secretin عشان نحفظ الsecrtin action هو حساس للacidity فشغله بيكون انه يحاول يعادل الحامضية فبيحاول انه يحفز البايكروبنيت سيكريشن سواء من البنكرياس او البلياري سيكريشن	•Acid •Fat	S cells of duodenum, jejunum and ileum	•Pepsin •pancreatic bicarbonate •Biliary bicarbonate secretions •growth of exocrine pancreas	gastric acid secretion.
Gastric Inhibitory peptide (GIP)	•Protein • Fat •Carbohydrate	K cells of duodenum and jejunum	•insulin release وجدوا له تأثير على الانسولين لذلك سموه glucose-insulinotropic peptide GIP يعني يروح للبيتا سيلز يحفزها تطلع انسولين	gastric acid secretion.
Motilin	•Fat •Acid • Nerve	M cells of duodenum and jejunum	•Gastric •intestinal motility.	–
	Motilin during fasting this hormone is released and stimulate gastric and intestinal motility which helps in emptying the stomach between meals causing hunger pain			

SUMMARY

- The pancreas secretes two important hormones Insulin & Glucagon.
- Pancreatic juice is secreted in Response to the presence of Chyme in the upper portions of the small intestine.
- Trypsinogen is activated into trypsin by enzyme Enteropeptidase (enterokinase), if Chyme comes in contact with the mucosa.
- Trypsin, chymotrypsin and elastase are endopeptidases, while Carboxypeptidase is an Exopeptidase.
- Secretion of Trypsin Inhibitor prevents digestion of The Pancreas Itself.
- The pancreatic enzyme for digesting carbohydrates is pancreatic amylase, for fat Digesting is pancreatic lipase which is the most important fat enzyme.
- Ach, Secretin, CCK mediators (potentiate each other) to get a huge amount of pancreatic juices.

MCQs

1- Stimulation of the acinar cells of the pancreas causing production of large quantities of pancreatic digestive enzymes and little quantities of water and electrolytes occurs by?

A. Cholecystokinin
B. Ach
C. Secretin
D. A&B

2- Pancreatic juice is released in response to:

A. Hypoglycemia
B. Hyperglycemia
C. Presence of chyme in the intestine
D. Presence of chyme in the stomach

3- The presence of long-chain fatty acids in the duodenum will stimulate which of the following?

A. I cells
B. S cells
C. C cells
D. G Cells

4- Increased HCO3 exchange with Cl occurs by:

A. Increased secretion of cholecystokinin
B. Decreased secretion of cholecystokinin
C. Increased secretion of secretin
D. Decreased secretion of secretin

5- Which of the following does NOT have a direct effect on acinar cells?

A. Parasympathetic
B. Secretin
C. Cholecystokinin
D. None of them

6-The most important pancreatic enzymes for digesting proteins are :

A. Trypsin.
B.Chymotrypsin.
C.Carboxypolypeptidase.
D.All above

7-Which of the following enzymes splits some peptides into individual amino acids :

A.Trypsin.
B.Chymotrypsin.
C.Carboxypolypeptidase.
D.Trypsin and Chymotrypsin

8-Which one of The following pancreatic enzyme released for digesting carbohydrates :

A. a-Amylase
B.Trypsinogen
C.Ribonuclease
D.Non above

9-Which of the following is true about the secretion from exocrine pancreas:

A - It has higher Cl concentration than does plasma
B - It is stimulated by the presence of HCO in the duodenum
C - Pancreatic HCO secretion is decreased by gastrin
D - Pancreatic enzyme secretion is increased by cholecystokinin

10-Which of the following enzymes activate the other inactive enzymes involved in protein digestion:

A- Trypsinogen
B- Trypsin
C- Chymotrypsin
D- Carboxypolypeptidase

Answer key: 1: D - 2: C - 3: A - 4: C - 5: B-6:D - 7:C - 8:A - 9:D - 10:B.

خولة العمَّاري
نجود الحيدري
نورة الطويل
لولوة الصغير
لجين السواط
رزان السبتي
ربى السليمي
ديما الفارس
خولة العريني
ملاك الشريف
منيرة الحسيني
مروج الحربي
أفنان المالكي
دلال الحزيمي
رناد القحطاني
سارة الخليفة
فرح مندوزا
مي العقيل
نورة الخراز
سارة الخليفة
نورة الخيال
رغد النفيسة
منيرة السلولي
نوف العبدالكريم
سها العنزي
نورة القحطاني

عمر آل سليمان
عبدالعزيز الحماد
عبدالرحمن السياري
محمد أبونيان
عبدالرحمن البركه
إبراهيم النفيسه
محمد البشر
عمر العتيبي
حمزة الفعر
عبدالله الجعفر
عبدالله الضحيان
حسن البلادي
حسن الشماسي
عبدالله الضبيب
محمد الفواز
محمد السحيباني
وائل العود
رواف الرواف
عمر الشهري