Lecture 1+2

Gastrointestinal System (GIT)

By: Dr Safa Abdul Ghani

➢-Correlation between structure and function

➢- Gastrointestinal Motility:

I. Mastication and Swallowing
II. Mixing food in stomach
III. Gastric emptying
IV. Movement of small intestine
V. Defection

➢- Gastrointestinal Secretions

I. Salivary secretions
II. Esophageal secretion
III. Gastric Pancreatic secretion
IV. Bile secretion
V. Small and large intestine secretion

➢- Gastrointestinal Digestion

➢- Gastrointestinal Absorption



Functions of the Gastrointestinal tract (GIT)

1. Provides the body with a constant supply of water, electrolytes and nutrients.
   To do this it requires:
   a. Food enters the alimentary tract - INGESTION
   b. Movement of food through the alimentary tract - MOTILITY
   c. Secretion of digestive juices and digestion of food - SECRETION and DIGESTION
   d. Absorption of water, nutrients and digestive products - ABSORPTION
   e. Circulation of blood through the GI circulation to carry away the absorbed material - STORAGE AND ELIMINATION
   f. Control of these functions by local, humoral and nervous control
2. Mass balance - this is making sure there is equal daily input and output
3. Protection - killing bacteria in stomach acid

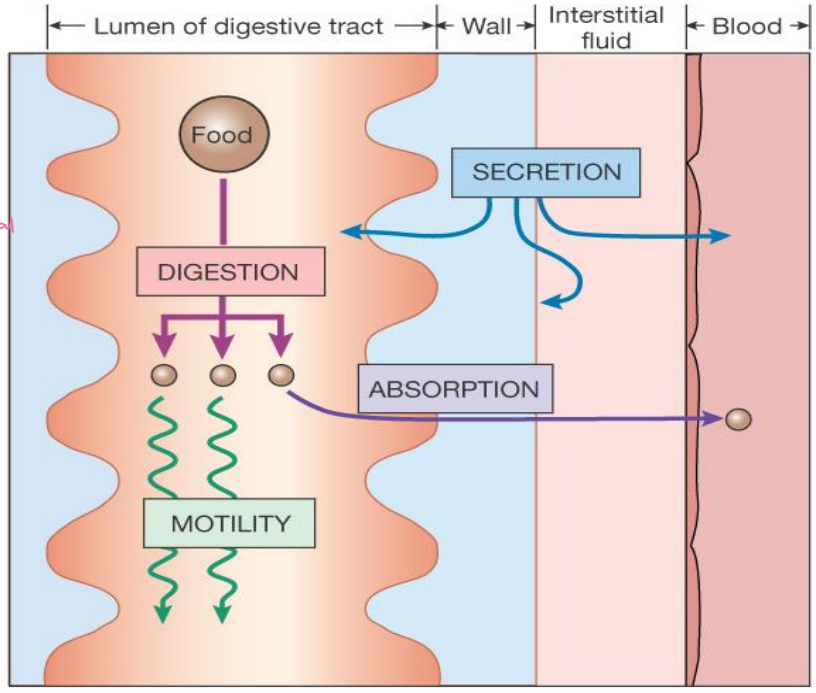
➢ *Each part of the GI system is adapted for a specialised function*

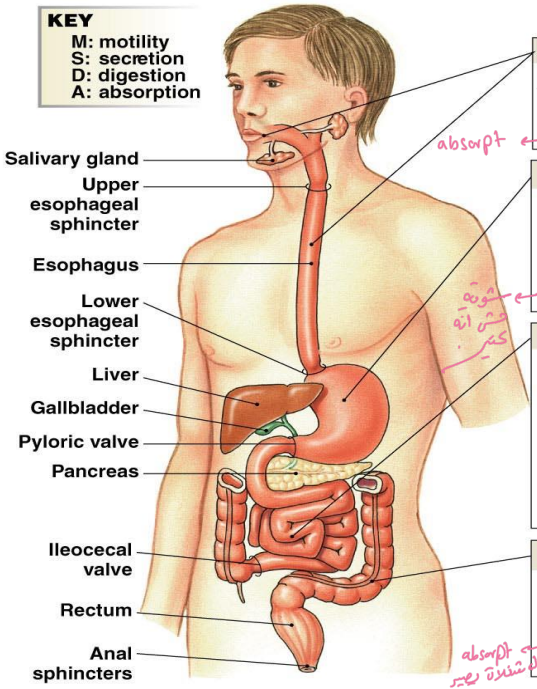
Processes of the Digestive System: Overview

- Ingestion
- Digestion:

  (Enzymatic) Chemical

  or mechanical-
- Motility:
- Secretion
- Absorption
- Elimination





ORAL CAVITY AND ESOPHAGUS

- M: swallowing, chewing
- S: saliva (salivary glands), lipase
- D: carbohydrates, fats (minimal)
- A: none

STOMACH

- M: peristaltic mixing and propulsion
- S: HCl (parietal cells); pepsinogen and gastric lipase (chief cells); mucus and HCO_3^- (surface mucous cells); gastrin (G cells); histamine (ECL cells)
- D: proteins, fats
- A: lipid-soluble substances such as alcohol and aspirin

SMALL INTESTINE

- M: mixing and propulsion primarily by segmentation;
- S: enzymes; HCO_3^- and enzymes (pancreas); bile (liver); mucus (goblet cells); hormones: CCK, secretin, GIP, and other hormones
- D: carbohydrates, fats, polypeptides, nucleic acids
- A: peptides by active transport; amino acids, glucose, and fructose by secondary active transport; fats by simple diffusion; water by osmosis; ions minerals, and vitamins by active transport

LARGE INTESTINE

- M: segmental mixing; mass movement for propulsion
- S: mucus (goblet cells)
- D: none (except by bacteria)
- A: ions, water, minerals, vitamins, and small organic molecles produced by bacteria

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Figure 21-22

Processes of the Digestive System: Overview

- Digestion: chemical and mechanical breakdown of foods into smaller units.
- Motility: movement of material in the GI tract as a result of muscle contraction.
- Absorption: active or passive transfer of substance from the lumen of the GI tract to the ECF
- Secretion: 1) transfer of water and ions from ECF to the lumen

  2) release of synthesized material by GI epithelial cells

Digestive Anatomy: Overview

The GI system is made up of:

1. The Alimentary canal

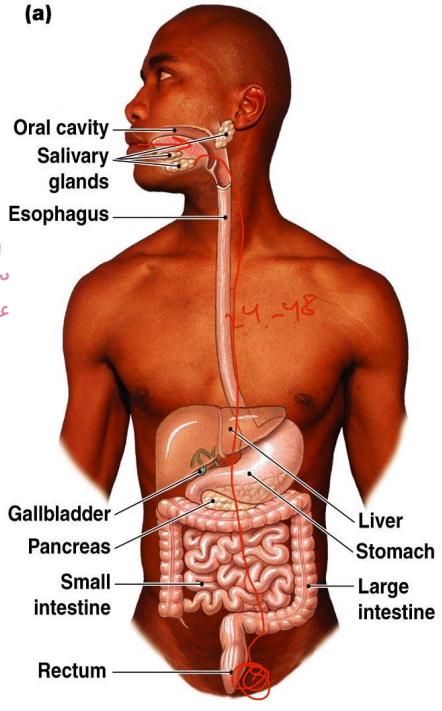
Mouth → Anus

The passage along which food passes through the body from mouth to anus during digestion.

(~24-48h)

1. Accessory organs of digestion

An organ that **helps** with digestion but is not part of the digestive tract. The accessory digestive organs are the (1) **salivary glands**, (2) **pancreas**, (3) **liver**, and (4) **gallbladder**.



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Digestive Anatomy: Overview

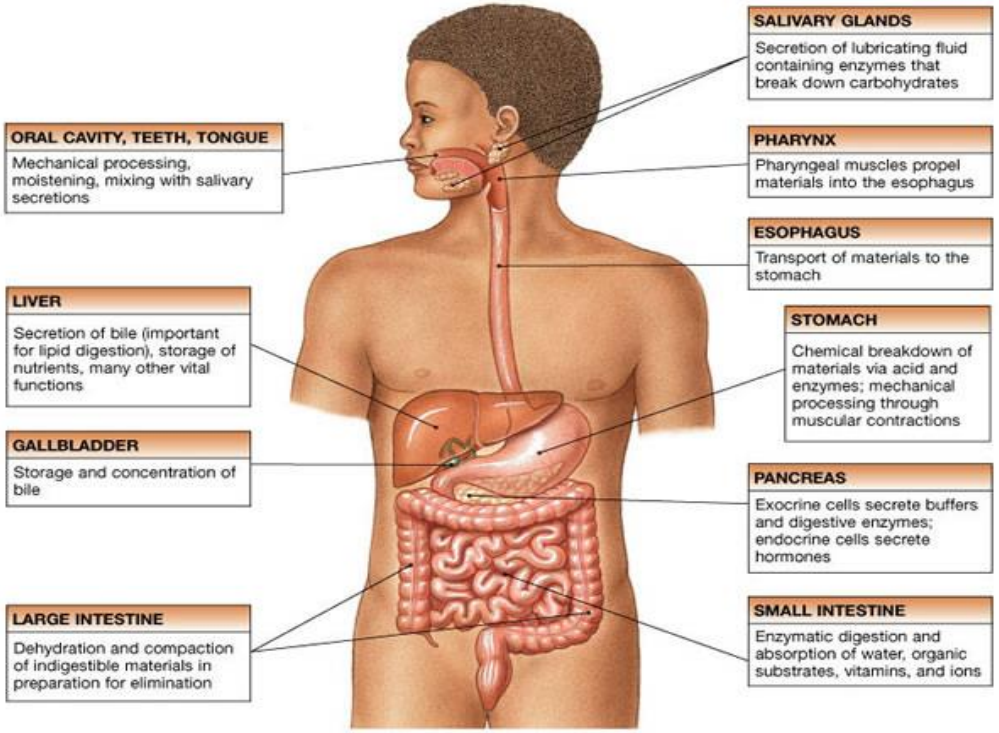
- Oral Cavity: 1st stage of digestion
- Salivary Glands: 3 pairs (Sublingual, submandibular, and parotid glands).
- Esophagus
- Stomach: hold up to 2-3L of food & fluids.
  - Fundus
  - Body
  - Antrum
  - Pyloris (pyloric valve)

More Digestive Anatomy

- Small intestine (complete digestion of food)
  - Duodenum (first 25 cm)
  - Jejunum
  - Ileum

  } (About 260 cm) (4~6 m)
- Pancreas
- Liver
- Large intestine (1.5L of chyme per day pass throught it)
  - Colon
  - Rectum
- Anus

Digestive Anatomy: overview



Sublingual, Submandibular parotid glands

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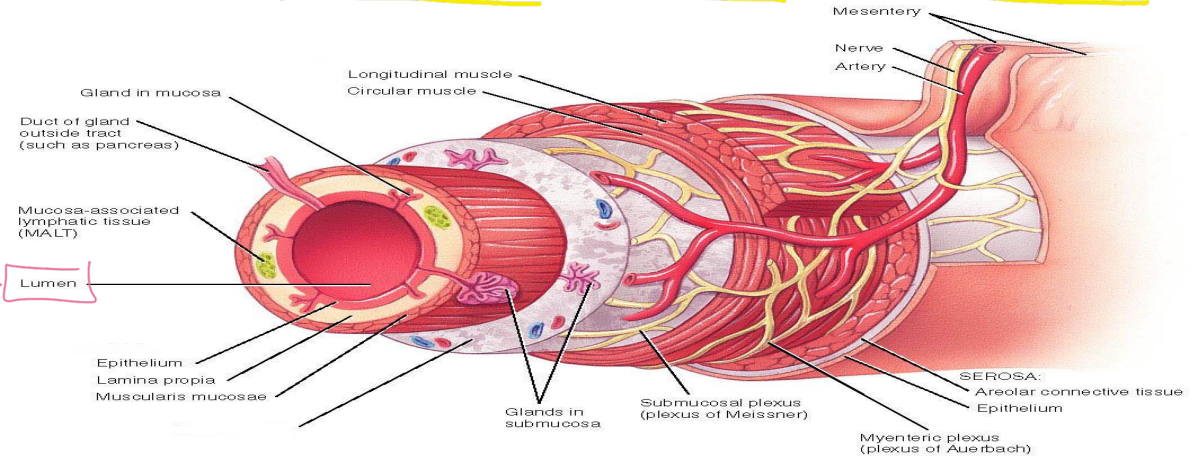
Layers of the GI tract

Tunics : الطبقة بالإنجليزية

GI الـ organs تمت لكل الـ له جدار

- The GI tract is composed of four layers or also know as **Tunics**.
- Each layer has different tissues and functions.
- From the inside out they are called:

Mucosa (inner) → submucosa → muscularis → serosa (outer layer)



هادا الموجود فيها اكل و Water

Layers of the GI Tract

(1) MUCOSA:- - Inner lining of the GI tract.

The **absorptive** and **secretory** layer.

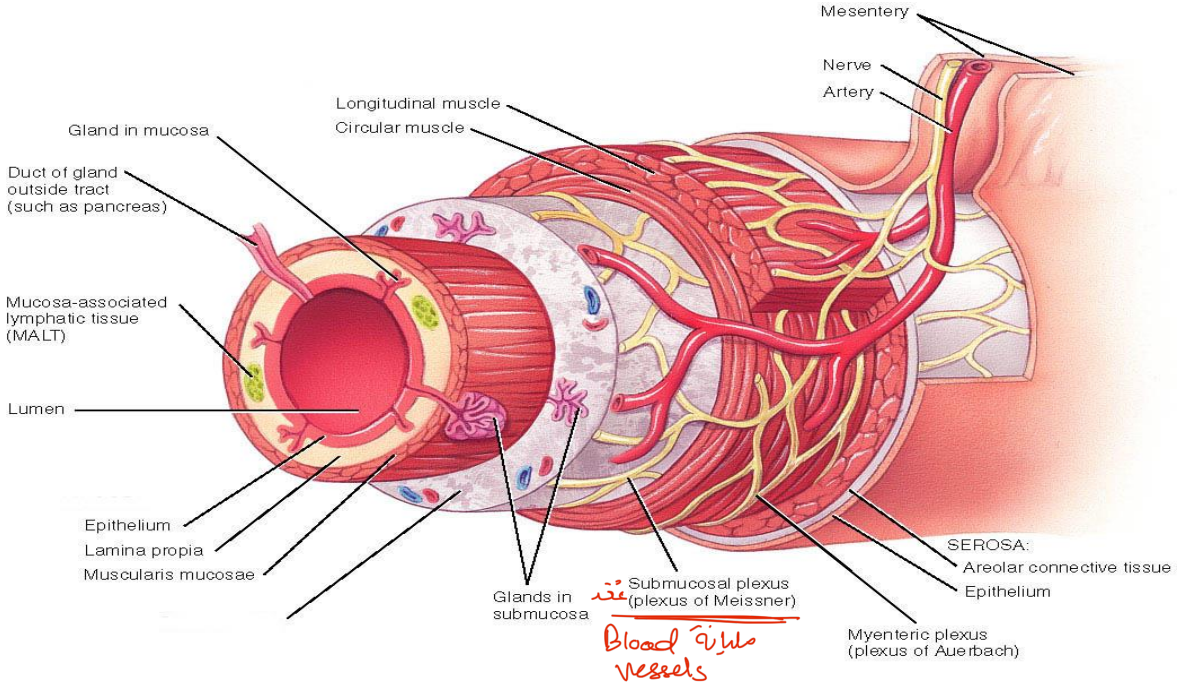
- It is composed of simple **epithelium cells** and a thin connective tissue.
- Contains specialized **goblet cells** that secrete **mucus** throughout the GI tract
- Some parts can contain **villi** and **microvilli** - e.g. in the small intestine!

- Made of 3 layers:

(A) A single layer of **epithelium** linning

(B) **The lamina propria** (subepithelium connective tissue that holds epithelium in place, contains nerves, small blood & lymph vessels, and immune cells).

(C) **The muscularis mucosa** (thin layer of smooth muscle)


Mesentery
Nerve
Artery
Longitudinal muscle
Circular muscle
Gland in mucosa
Duct of gland outside tract (such as pancreas)
Mucosa-associated lymphatic tissue (MALT)
Lumen
Epithelium
Lamina propia
Muscularis mucosae
Glands in submucosa
Submucosal plexus (plexus of Meissner)
Blood vessels
Myenteric plexus (plexus of Auerbach)
SEROSA:
Areolar connective tissue
Epithelium

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Layers of the GI Tract

(2) SUBMUCOSA:-

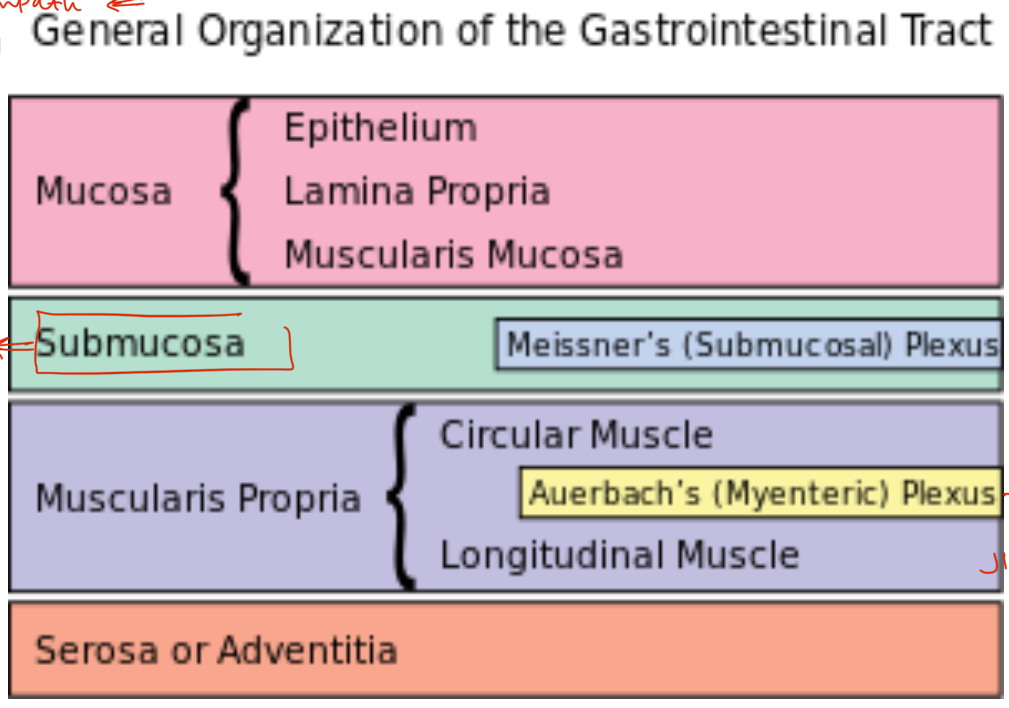
Middle layer, loose connective tissue, blood and lymph vessels and **submucosal plexus** (enteric nervous system).

Relatively **thick**, **highly vascular**, and serves the mucosa.

- The absorbed nutrients that pass through the mucosa are picked up in the **blood vessels** of the submucosa.
- The submucosa also has **glands** and **nerve plexuses.**
- Glands secrete **mucous** or **digestive enzymes**
- Different types of glands in different areas

(3) MUSCULARIS EXTERNA:-

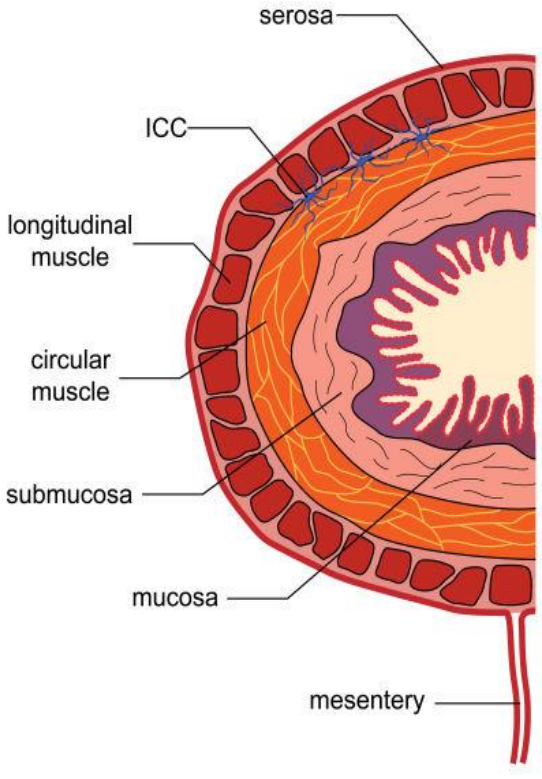
Outer layer, 2 layers of smooth muscle: inner circular and outer longitudinal layers for contraction.


General Organization of the Gastrointestinal Tract
Mucosa
Epithelium
Lamina Propria
Muscularis Mucosa
Submucosa
Meissner's (Submucosal) Plexus
Muscularis Propria
Circular Muscle
Auerbach's (Myenteric) Plexus
Longitudinal Muscle
Serosa or Adventitia

Layers of the GI tract

Muscularis: The muscularis is responsible for segmental contractions and peristaltic movement in the GI tract.

- The muscularis is composed of two layers of muscle:
  - An inner circular layer of smooth muscle - in a circle around the gut
  - An outer longitudinal layer of smooth muscle - arranged in long lines along the gut
  - These muscles cause food to move and churn with digestive enzymes down the GI tract



(4) SEROSA:- (peritonium)

Outer tough connective tissue membrane for protection, a continuation of the peritoneum.

The Functions of Secretory glands

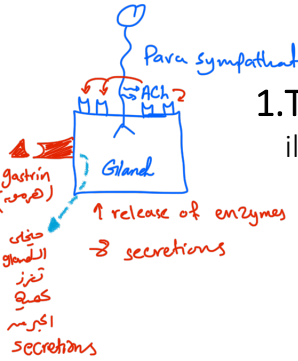
glands
- submucosa
- mucosa

nerve plexus
- submucosa
- muscularis

Secretory glands have 2 functions:

Submucosa , lamina propria of mucosa ← mucus [2] , digestive hormone ← إما إنه تفرز

secretions ← يتم افراز ال ← submucosa ← لو تم التنشيط ال nerves الموجودة في ← gastrin هي هرمون حث افرز.



حتى الغدد تفرز كمية اكبر من secretions

كل ما زادت كمية الهرمون ← أو عكس الـ Neuron inversion كل ما زاد الـ secretion

1. To secrete **digestive enzymes** (this occurs from the mouth to the terminal ileum)

حسب الكيمياء اللي اخذناها يتم افراز الـ enzymes في stomach ← pepsinogen & gastric lipase

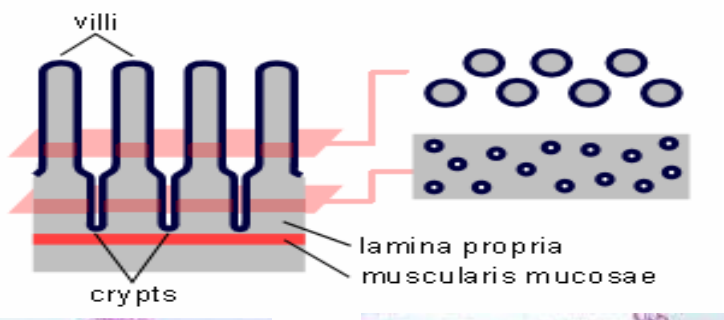
- These enzymes are released in response to **food in the alimentary tract - local control**
- The amount secreted is **very exact** (only the amount needed for proper digestion and no more)
- **Different types of secretions occur** depending on the type of food in the tract
- Secretions come from **different types of cells** انواع الخلايا
  - **Crypts** - cells with **small pits** in their surface. These are present in the ① **stomach** and in the ② **intestine**. In the intestine these are **"Crypts of Lieberkuhn"**
  - **Tubular glands** - in the **stomach** and **duodenum** ← Simple compound
  - **Complex glands** - **salivary, pancreas and liver**

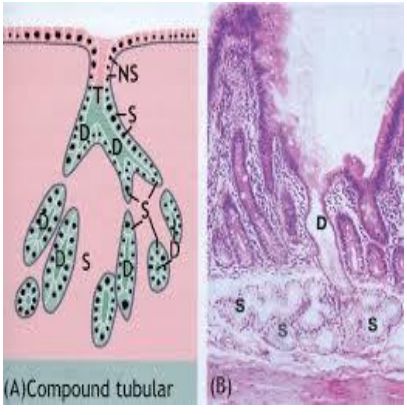
(Crypt of Lieber Kohn)

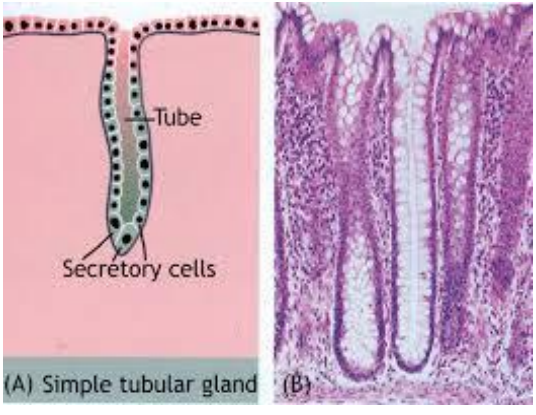


← خلايا مخزنة

Types of glands







The Functions of Secretory glands

Goblet cells اسم هذه الخلايا التي تفرزها هي

2. To secrete **mucous** for **lubrication** and **protection** of the alimentary tract

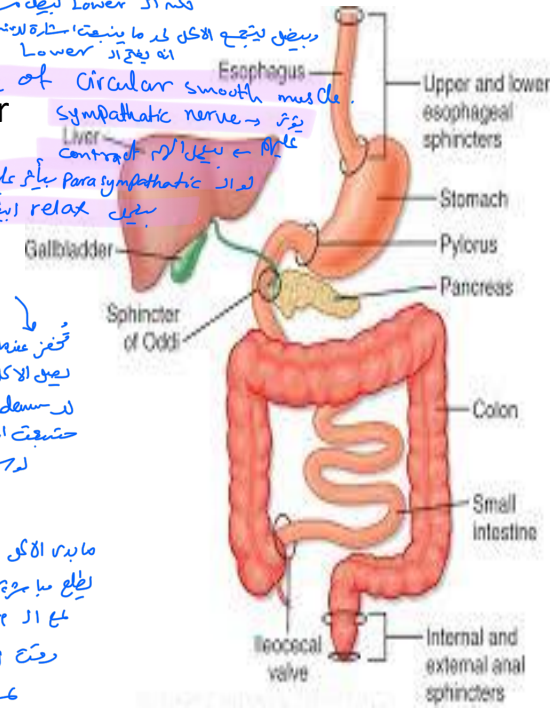
① ② Bicarbonate مثبط

كل ما المنطقة كانت كبيرة كل ما كان الـ irritation في الجدار كان اكثر ⇐ كل ما الـ goblet cell افرزت اكثر mucus.

- Secreted from **mucous cells** (also called **goblet cells**) which are located on the surface of the epithelium
- They release mucous in response to **direct irritation**

Sphincters of the GI tract

- **Oesophageal Sphincter:** upper / lower
- **Pyloric sphincter:** A muscle sphincter which separates the pylorus of the **stomach from the duodenum**
- **Sphincter of Oddi:** A muscular **valve** that controls the flow of **digestive juices** (bile and pancreatic enzymes) into the second part of the **duodenum**
- **Ileocaecal valve:** A muscle sphincter which separates the **small intestine from the large intestine**
- anal sphincter
  - internal
  - external



Functions of the GI tract - Mastication

- Food is ingested - the amount of food is stimulated by the desire of HUNGER
- The type of food a person seeks is determined by APPETITE

Teeth: Designed for chewing also called MASTICATION

- Anterior incisors = cutting action
- Posterior teeth (molars) = grinding action
- Jaw muscles (muscles of mastication) = open and close the teeth with force
- Muscles of mastication are innervated by the 5th cranial nerve (trigeminal)
- The process of chewing is stimulated by the **brainstem**



CHEWING REFLEX-

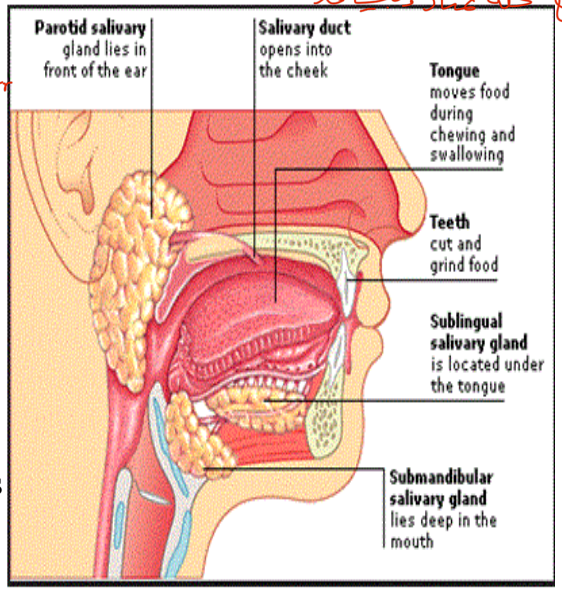
- Once the food bolus enters the mouth the **chewing reflex** is stimulated
- Initially this inhibits the muscles of mastication so that our jaw opens
- When our jaw drops this stimulates a **stretch reflex** and stimulates contraction of the muscles of mastication
- This closes the teeth as the jaw closes and compresses the food bolus against the walls of our mouth→ repeated cycle!
- Chewing helps digestion by increasing the surface area that can be exposed to enzymes

Accessory organs of digestion

Salivary glands:

- These are the **parotid gland, submandibular gland, sublingual gland**
- Exocrine glands that produces saliva
- Approximately 800-1500 mL saliva is made/day

- Saliva contains 2 protein secretions
  - **Mucous** → for lubrication and protection of epithelial surfaces
  - Saliva moistens food for chewing and swallowing and prevents mucous membranes from drying out
  - **Amylase** → for digestion of starches (carbohydrates)
- Saliva also helps to prevent against tooth decay by removing pathogens



Source - http://www.infoplease.com/dk/encyclopedia/mouth.html

Tongue:

1. Manipulates food for chewing/swallowing
2. Main taste organ, covered in taste buds

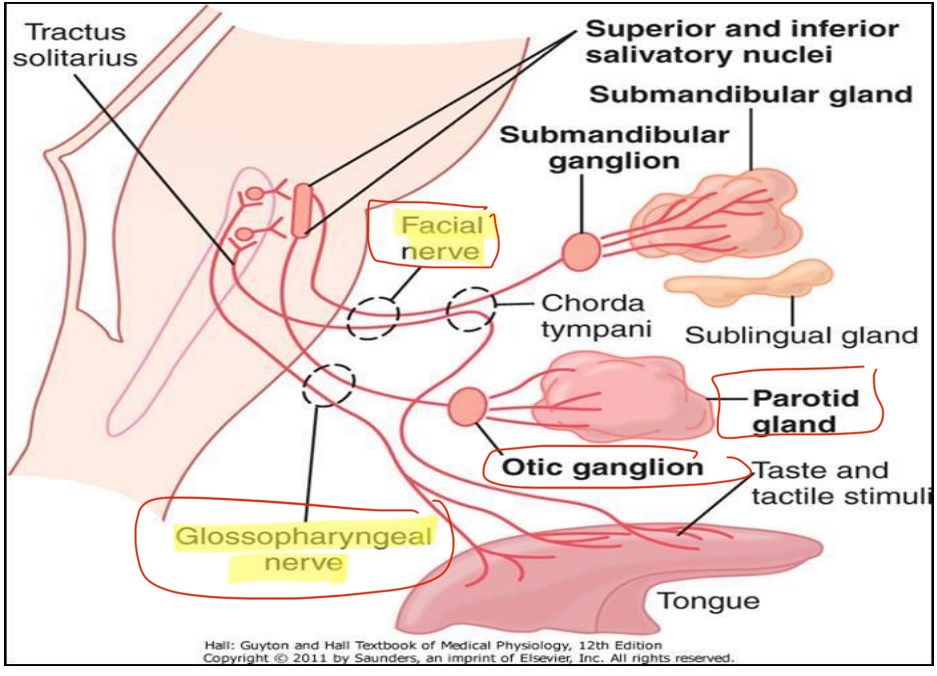
SALIVARY SECRETIONS

Function:-

The main functions of saliva in digestion include:

1. Lubrication and moistening of food for swallowing by secreting musin
2. Solubilization of material for taste
3. initiation of carbohydrate digestion (amylase) and lipid (Lingual lipase)
4. Neutralization of refluxed gastric secretions in the oesophagus.
5. Antibacterial actions by secreting Lysozyme
6. Secretion of Kallikrein, which convert plasma protein into bradykinin (**vasodilator**)

- **Regulation of salivary secretion is exclusively neural; parasympathetic innervation is most important in the response to food.** *Sympathetic → سيالة secretion.



submax

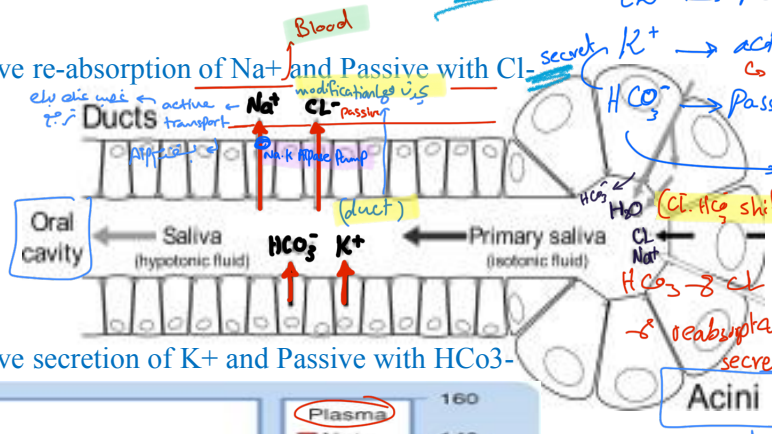
Salivon

High conc of K+ and HCO3-

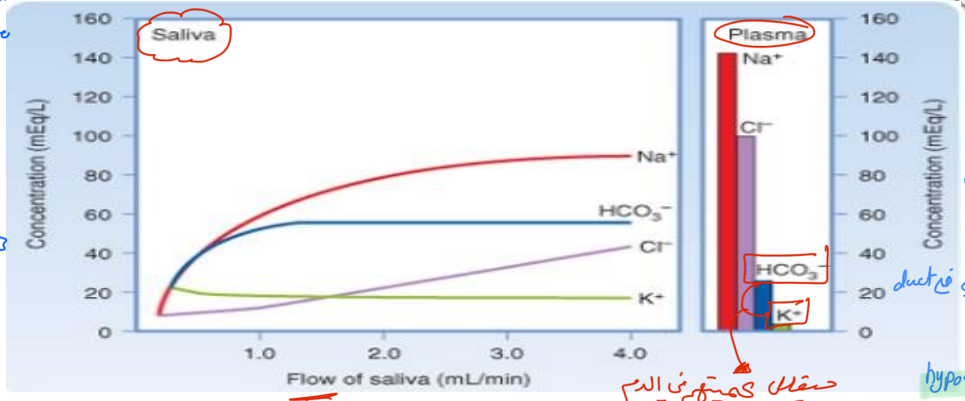
Low conc of Na+ and Cl-

Volume= 1.5-1.8L

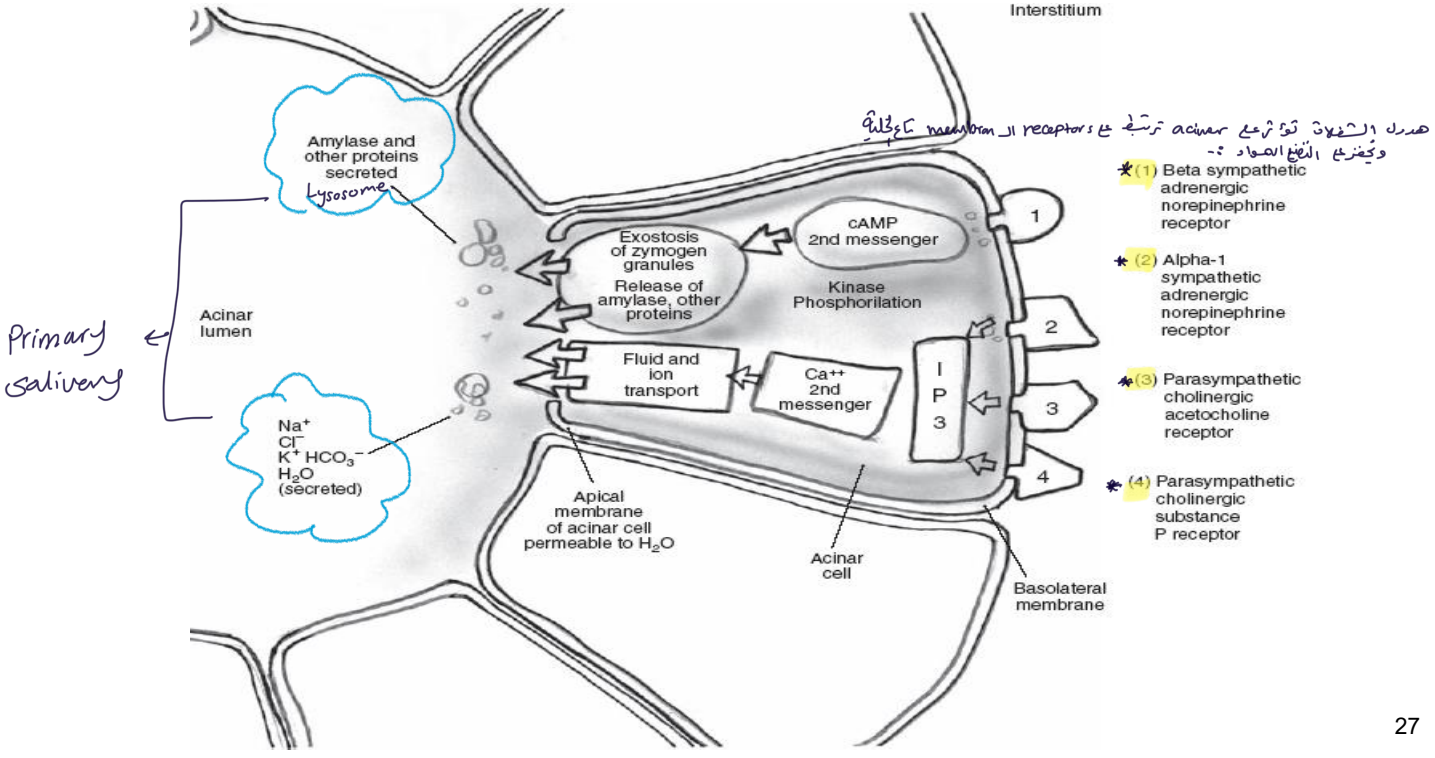
Active re-absorption of Na+ and Passive with Cl-



Active secretion of K+ and Passive with HCo3-



ACINAR CELL


Interstitium
Amylase and other proteins secreted
Lysosome
Acinar lumen
Primary saliva
Na+
Cl−
K+ HCO3−
H2O
(secreted)
Exostosis of zymogen granules
Release of amylase, other proteins
cAMP 2nd messenger
Kinase Phosphorilation
Fluid and ion transport
Ca++ 2nd messenger
IP3
1
2
3
4
(1) Beta sympathetic adrenergic norepinephrine receptor
(2) Alpha-1 sympathetic adrenergic norepinephrine receptor
(3) Parasympathetic cholinergic acetocholine receptor
(4) Parasympathetic cholinergic substance P receptor
Apical membrane of acinar cell permeable to H2O
Acinar cell
Basolateral membrane

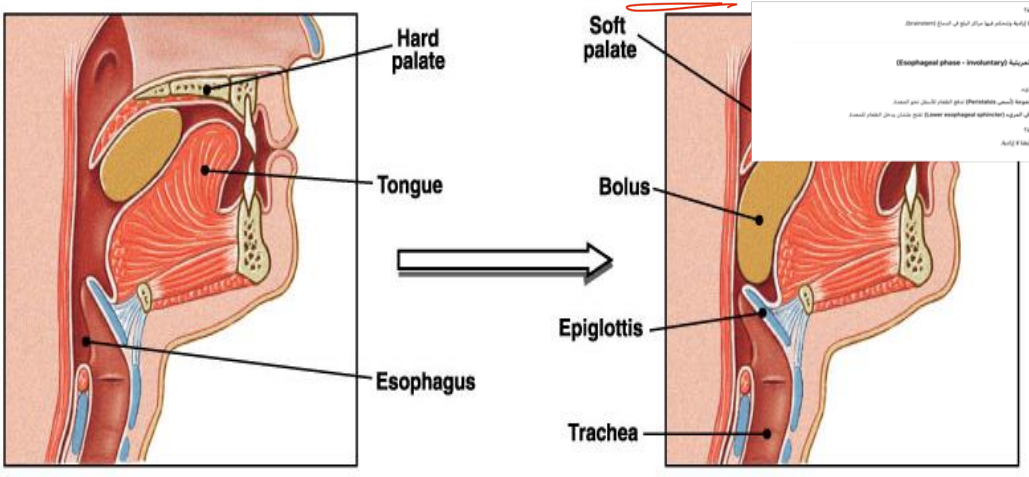
Regulation of saliva secretion

- Controlled mainly by **parasympathetic stimulation** → Stimulation of glossopharyngeal and facial nerve → increases secretion by increasing the blood supply to the glands through vasodilation
- Afferent signals are sent to the **superior and inferior salivary nuclei in the brain stem** (located between the medulla and pons)
- **Positive modulation:**
  - Whenever food *touches* the mouth, tongue or pharynx (tactile stimulus)
  - *Taste* stimuli are sent to the brainstem also and increase salivation → especially if the taste is sour
  - *Smell* → if we like a food this stimulates salivation
  - In response to irritation in the stomach and upper parts of the intestines → increases salivation. This is to remove the irritating factor
- **Negative modulation**:
  - Sleep, Fatigue, dehydration and fear inhibit
- **Sympathetic stimulation** can increase salivation a little also but not as much as there is no vasodilation of the blood supply to the glands
- **Hormones** e.g. bradykinin cause vasodilation of the blood supply to the glands and therefore increase salivation

Swallowing reflex: Soft Palate & Esophagus

Swallowing has 3 stages:

- **Voluntary stage** - when food ready for swallowing is pushed to the back of our mouths into the pharynx by the movement of our tongue upwards.

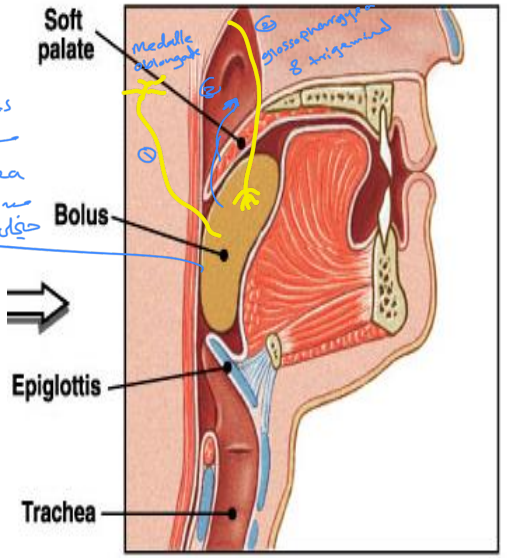


Tongue pushes bolus of food from oral cavity into oropharynx

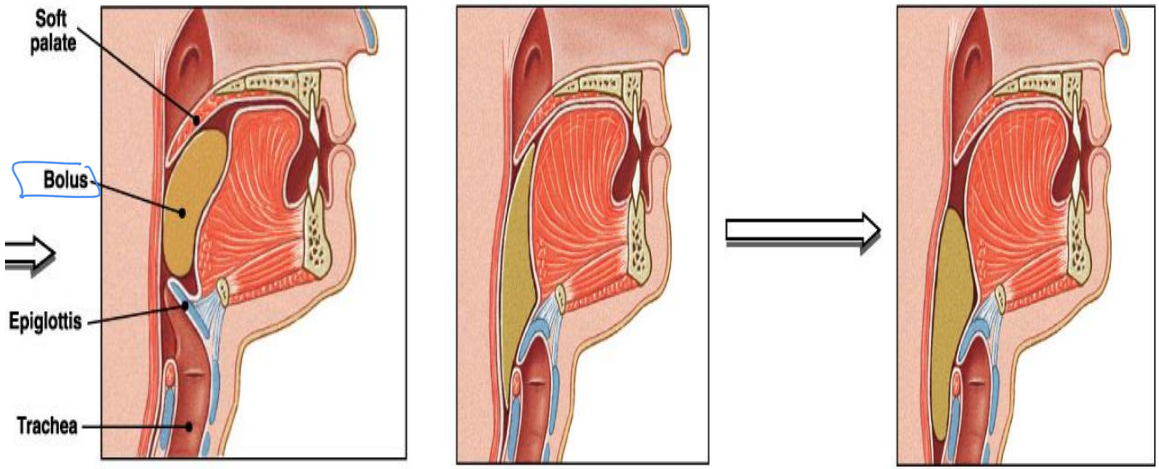
Sensory input: pressure against soft palate, signal to medulla

Swallowing reflex: Soft Palate & Esophagus

- **Pharyngeal stage - involuntary** As the **food bolus enters** the pharynx it stimulates the epithelial swallowing receptor areas at the opening of the pharynx → impulses go to the brainstem swallowing center (**medulla oblongata**) to cause:
  - Automatic **contraction of the pharynx** via the trigeminal and glossopharyngeal nerves→ pushes food into the oesophagus
  - Efferent impulses cause the **soft palate up move up** and to close the posterior nares. This prevent food entering the nasal cavities



- The larynx is pulled up and forward by neck muscles and the **epiglottis moves down** to cover the opening to the larynx → prevents food entering the lungs
- The larynx moving up also closes the glottis which prevents food entering the lungs

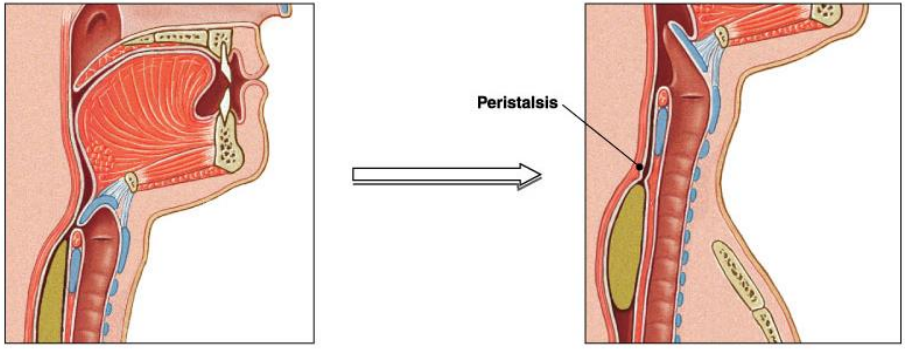


Swallowing continued → pharyngeal phase

The whole process lasts less than 2 seconds هذه العملية

During each swallow the swallowing center in the brainstem inhibits the respiratory center to allow the swallowing to proceed

* لما احكي لشخص الي بيأكل خد نفس وانت بتاكل ع زوه وقت ما صو
شغال ال (swallowing center) بيكون ال Respiratory center واقف (مضبط) مش شغال



ESOPHAGEAL PHASE

Upper esophageal sphincter open

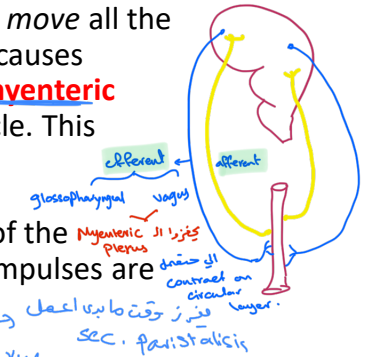
Peristalsis propels bolus down esophagus toward stomach

Phase 3 - the esophageal phase

- The oesophagus runs from the pharynx to the stomach
- It pushes the food from the pharynx into the stomach **by peristalsis**
  - It does this by primary or secondary peristalsis

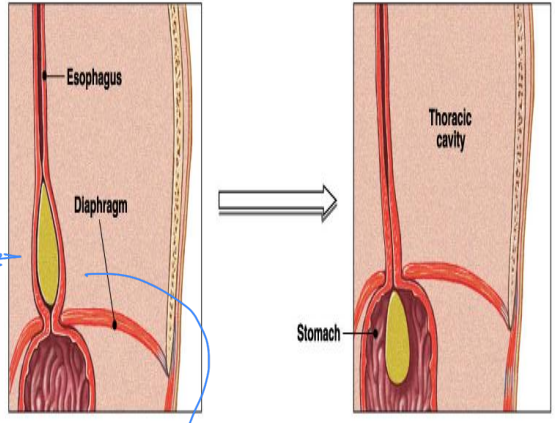
- Primary peristalsis is a continuation of the way of muscle contraction from the pharynx to the stomach

- Secondary peristalsis is *when the primary peristaltic wave fails to move* all the food into the stomach. The food remains in the oesophagus and causes stretch of the oesophagus. **Contraction is then initiated by the myenteric** nervous system to cause contraction of the circular smooth muscle. This causes a new wave of peristalsis

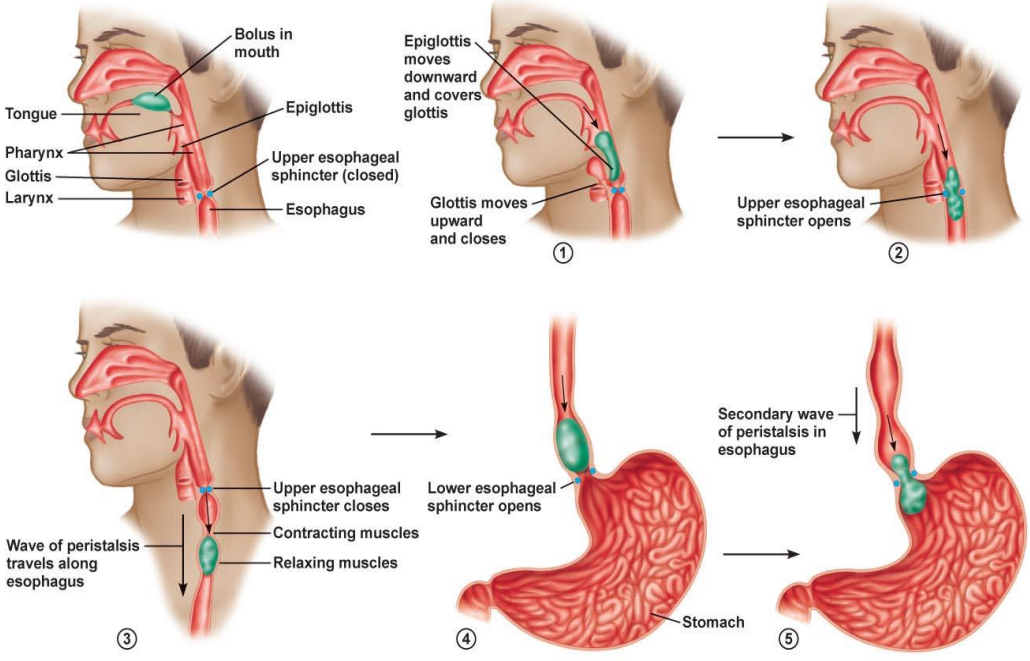


- Secondary peristalsis is controlled by afferent nerves in the wall of the oesophagus which send afferent impulses to the brain. Efferent impulses are sent **from the brain to the myenteric nervous system** via the **glossopharyngeal and vagus nerves → contraction**

- When the food reaches the opening to the stomach the **lower esophageal sphincter** which is normally contracted (to keep the stomach contents from moving up the oesophagus) **relaxes** as the myenteric nervous system sends inhibitory signals
- There is also relaxation of the stomach wall and the duodenum to allow for the food that will be coming into them



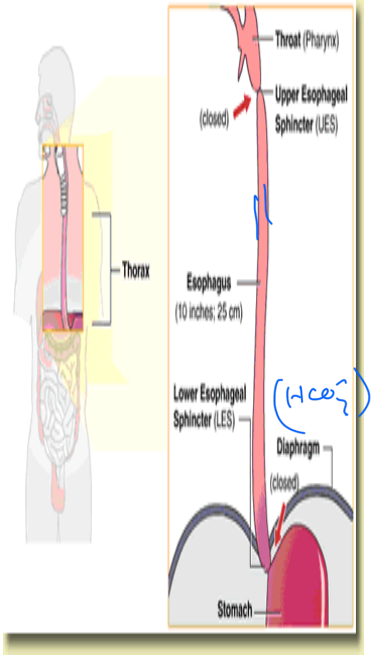
ESOPHAGEAL PHASE



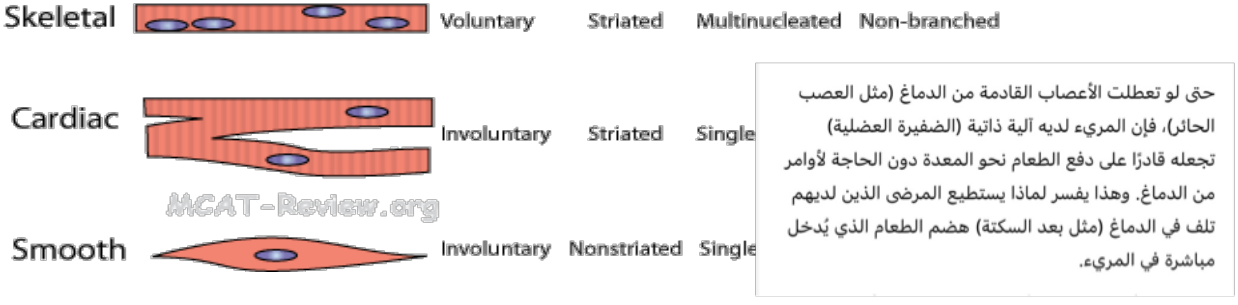
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The oesophagus

- Muscular organ connecting the laryngopharynx to the stomach
- A passage for swallowed food and fluid
- In an adult 25-30cm long
- Protected at each end by an oesophageal sphincter (the upper and lower oesophageal sphincters)
- When we are not eating both these sphincters are closed
- Has the 4 layers → mucosa, submucosa, muscularis and serosa
- Contains glands:
  - Mucous glands : Secrete extra mucus to lubricate the tract to keep food moving
    - Protect against scratching of the lining of the oesophagus
  - Bicarbonate to keep the pH of the oesophagus normal (to protect against the acidic secretions from the stomach)



- The pharynx is made from striated (skeletal muscle)
- The oesophagus is made of striated muscle for the first ⅓ (voluntary)
- Areas of striated muscle have greater glossopharyngeal innervation
- The final ⅔ of the oesophagus is made of smooth muscle → this is innervated more by the vagus nerve though the myenteric nervous system → involuntary.
- The difference between the different types of muscles



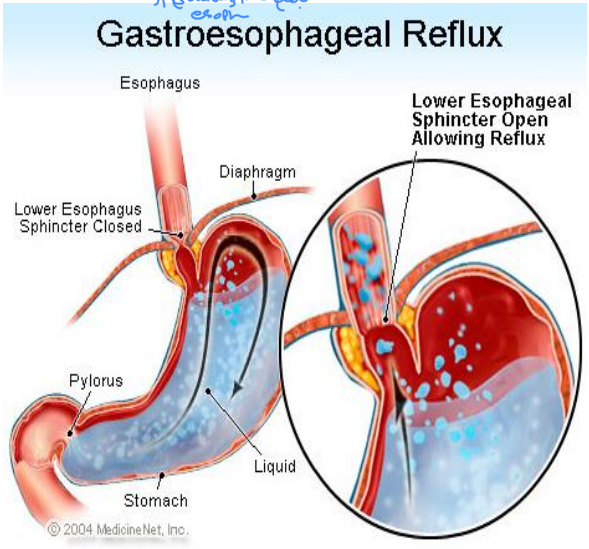
حتى لو تعطلت الأعصاب القادمة من الدماغ (مثل العصب الحائر)، فإن المريء لديه آلية ذاتية (الضفيرة العضلية) تجعله قادرًا على دفع الطعام نحو المعدة دون الحاجة لأوامر من الدماغ. وهذا يفسر لماذا يستطيع المرضى الذين لديهم تلف في الدماغ (مثل بعد السكتة) هضم الطعام الذي يُدخل مباشرة في المريء.

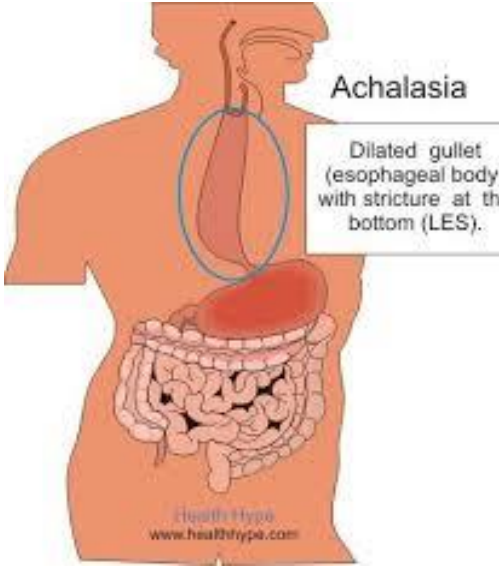
●If vagus nerves to the oesophagus are cut → the myenteric plexus can take over without stimulation to cause secondary peristaltic waves even without efferent input from the brain → if you have problems with the brainstem (e.g. stroke) → food fed by a tube into to oesophagus still moves to the stomach!!!

Problems with the lower oesophageal sphincter

Problems with the lower oesophageal sphincter:

- If it doesn't relax food can't get in = achalasia
- If it doesn't contract you get reflux of the acidic gastric contents = heartburn/reflux



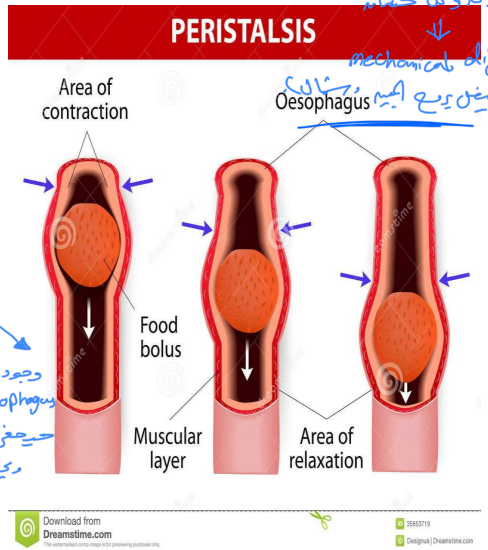


There are 2 types of movements:

1. **Peristaltic movements** which push food along the GI tract at a rate that allows maximum digestion and absorption.
2. **Mixing movements** - keep the contents of the intestinal mixed at all times

Peristalsis

- There is **contraction of the the circular smooth muscle** in the GI wall -- > this **pushes** food/contents forward and **contraction of longitudinal muscles** which **shortens the length of the tube**
- The contraction occurs again further along the GI wall → process repeated until the contents are pushed along
- The stimulation for the contraction is **distension** of the GI wall → this stimulates the **enteric nervous system which causes parasympathetic stimulation**
- Can also be stimulated by **irritants**
- Requires a **myenteric plexus** for it to occur



Mixing movements

Occur in different ways in different parts of the GI tract

In some areas the contractions that occur during **peristalsis** can cause mixing also

This tends to occur if there is a **valve or sphincter which stops the movement** created by peristalsis - e.g. at the opening to the small intestine. Here the food can be moved as far as the "blockage" but the distension caused by the contents of the GI tract mean the peristalsis waves continue as they want to push the food further but cannot. The contractions end up **"churning"** the food in this situation

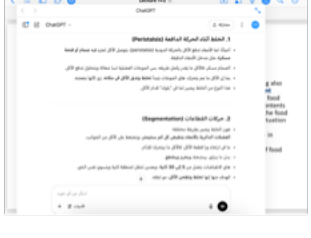
In other areas there are contractions of the gut wall every few centimeters - in **segments**

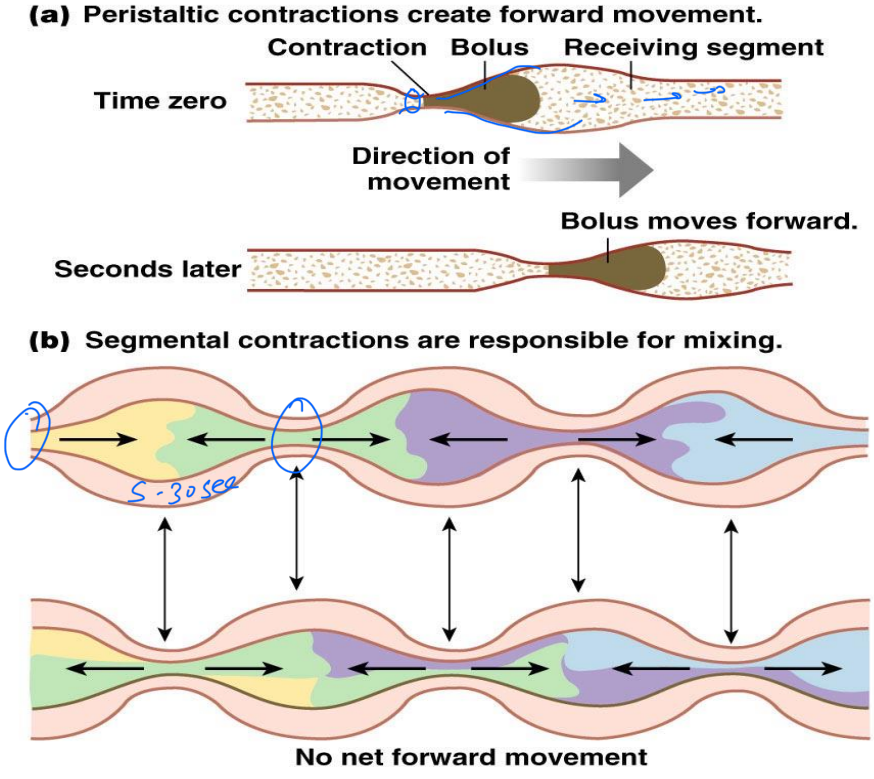
There is **no relaxation of the circular muscles after the bolus** so the bolus of food **doesn't move** → it just gets **compressed**

These contractions last 5-30 seconds

They then move to another part of the wall and contract again

This **chops and shears** the food up





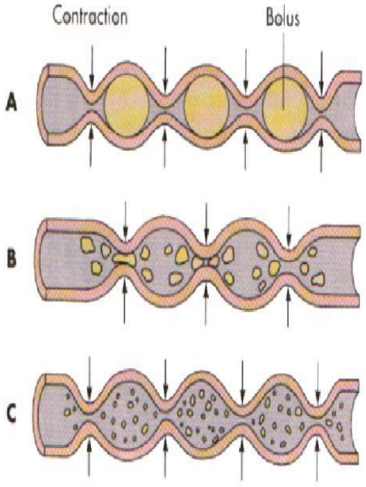
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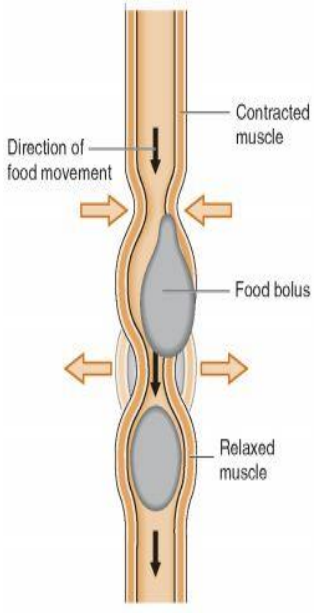
Figure 21-4 - Overview

peristalsis movements - contraction of the circular muscle before the food and relaxation after

Mixing movements →

Contraction of segments - not pushing food along but simply breaking it up into smaller portions - no relaxation of circular muscle after the bolus

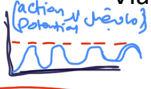




Electrical activity of gastrointestinal smooth muscle

Electrical activity of the Gastrointestinal smooth muscle

Via 2 types of electrical waves



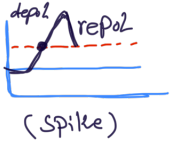
1. **Slow waves**
2. **Spikes**

Slow waves

Most GI contractions occur rhythmically and the **rhythm** is determined by **SLOW WAVES**

These are small wave like changes in the resting membrane potential of the smooth muscle cells by 5-15 mV

THEY ARE NOT ACTION POTENTIALS

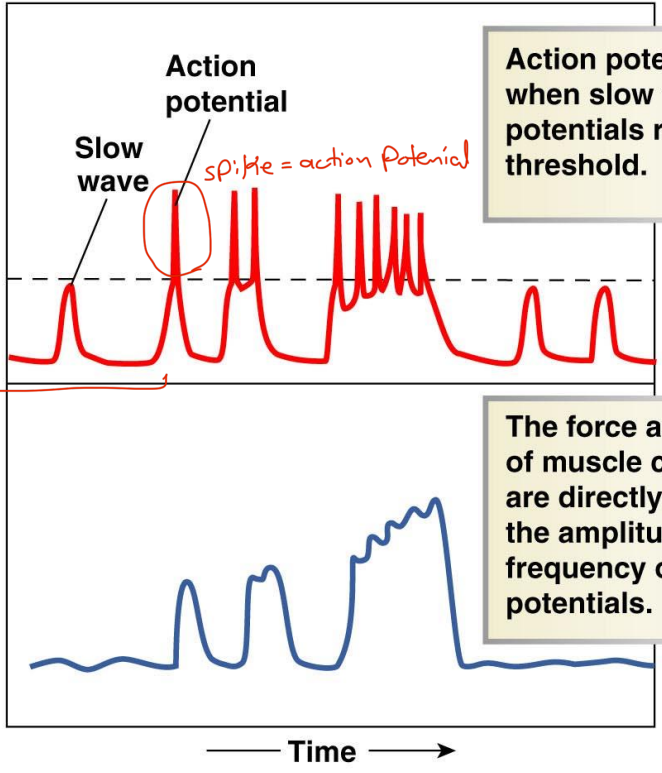


Occurs at a range of 3-12 waves per minute –

- 3 waves per minute in the stomach
- 12 waves per minute in the duodenum
- 9 waves per minute in the ileum

Exact cause of these waves is unknown - by likely to be due to pacemaker type cells called **CAJAL CELLS** that have ion channels which open - particularly Na channels which allow ions into the cell and K+ out of the cell

NO CALCIUM IONS MOVE INTO/OUT OF THE CELLS DURING SLOW WAVES



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Figure 21-3

Electrical activity of gastrointestinal smooth muscle

Spike waves or spike potentials

THESE ARE ACTION POTENTIALS - because there is **depolarisation** of the cell membrane

Occur when the membrane potential of the smooth muscle cell becomes more positive

When the charge of the **slow wave rises above -40mV** - this **stimulates an action potential** and therefore a spike wave

The ion channels which cause the action potential in GI smooth muscle are **calcium-sodium channels** (this means Ca and Na ions move into the cell to change the charge from -ve to +ve. This is different from "normal" action potentials when only Na ions move into the cell)

These cause **long action potentials** (like in the heart) because of the slower Ca channels and therefore prolonged contraction of GI muscle

Spike waves occur when there is **stimulation via efferent nerves directly from the enteric plexus** to increase the membrane potential of the cells - called a **reflex mechanism**

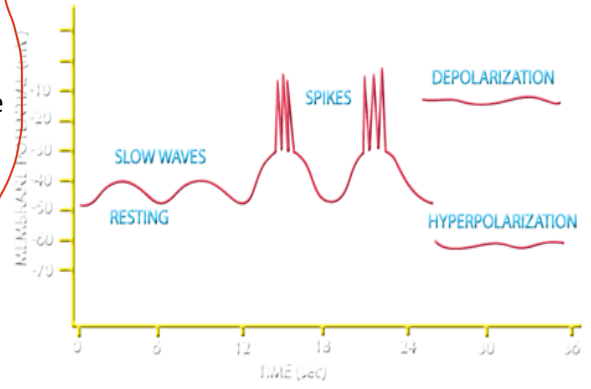
Can be under control of the higher brain centers and autonomic nervous system

Depolarisation: When the action potential becomes **less negative** and the cells become **excitable**

Hyper polarisation: When the membrane potential becomes **more negative** and the cells become **less excitable**

Factors that make cells **excitable** (cause depolarisation):

1. **Stretching of the muscle**
2. **Parasympathetic stimulation (acetylcholine)**
3. **Stimulation by acetylcholine directly**
4. **Stimulation by certain GI hormones**



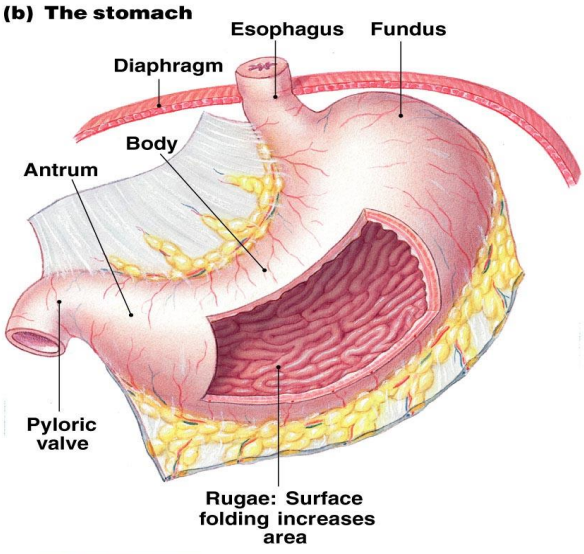
Things that make the cells **less excitable** (hyper polarisation)

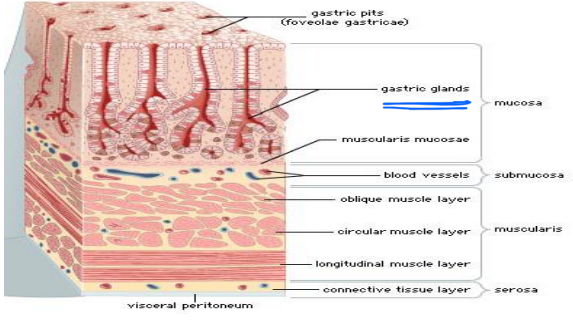
1. **Adrenaline or noradrenaline**
2. **Sympathetic stimulation**

Stomach

Cardia
Fundic < Fundus
Body
antrum
Pylorus sphincter.

- A J shaped muscular organ → remember our 4 layers!!!
- Has a lesser and greater curve
- <u>Divided into 4 regions:</u>
  - Cardia
  - Fundus
  - Body - the biggest part of the stomach
  - Antrum
  - Pyloric → this eventually reaches the pylorus and pyloric sphincter before the start of the duodenum





The stomach

1. Storage
2. Secretions & Mixing
3. emptying

The functions of the stomach are:

- **Storage** of large quantities of food until it can be processed
- **Mixing** of good with gastric secretions
- **Slow emptying of CHYME** from the stomach to the small intestine to allow proper digestion and absorption

Functions of the stomach

Store large quantities of food until it can be processed

- It takes approximately *4 hours* to remove a meal from the stomach
- The stomach expands with a meal because as the new food enters the stomach the old food is pushed towards the walls of the stomach → stimulates stretch receptors which send impulses to the brain via the vagus nerve. The brain increases the *parasympathetic stimulation* to allow the walls of the stomach to relax

Mixing of food with gastric secretions

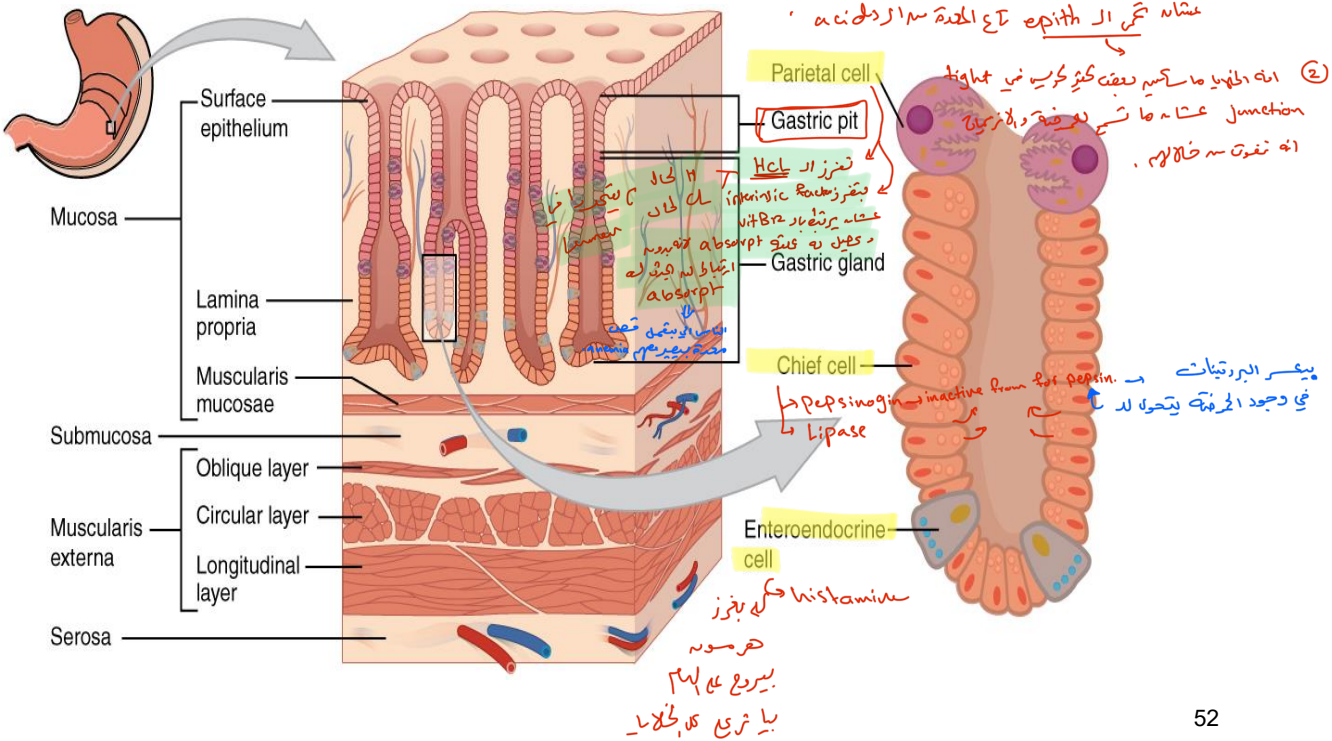
- **Mechanical digestion** → this is when the muscular walls of the stomach break up food **through peristaltic mixing waves**.
    - Occurs in the mid section of the stomach and force of waves become more intense towards the antrum.
    - This helps force food through the pyloric structure (at high pressures)
- **Chemical digestion** → by **digestive juices** released from gastric glands in the stomach

Functions of the stomach

Slow emptying of CHYME from the stomach into the small intestine at a rate suitable for digestion (this occurs via the pyloric sphincter) + gastric pump.

- After food is mixed well with the stomach secretions the mixture is now called CHYME
  - lipid
  - digestived Protein
  - acids
- "Hunger contractions" occur when the stomach has been empty for several hours
- These are peristaltic contractions that start in the body of the stomach = mild pain
- Sometimes these contractions can "join" together to last for 2-3 minutes at a time
- These are felt most in young, healthy people as the muscles in their stomach are strong (good muscle tone)
- Also felt when a person's blood sugar is low

Gastric secretion: Gastric Glands

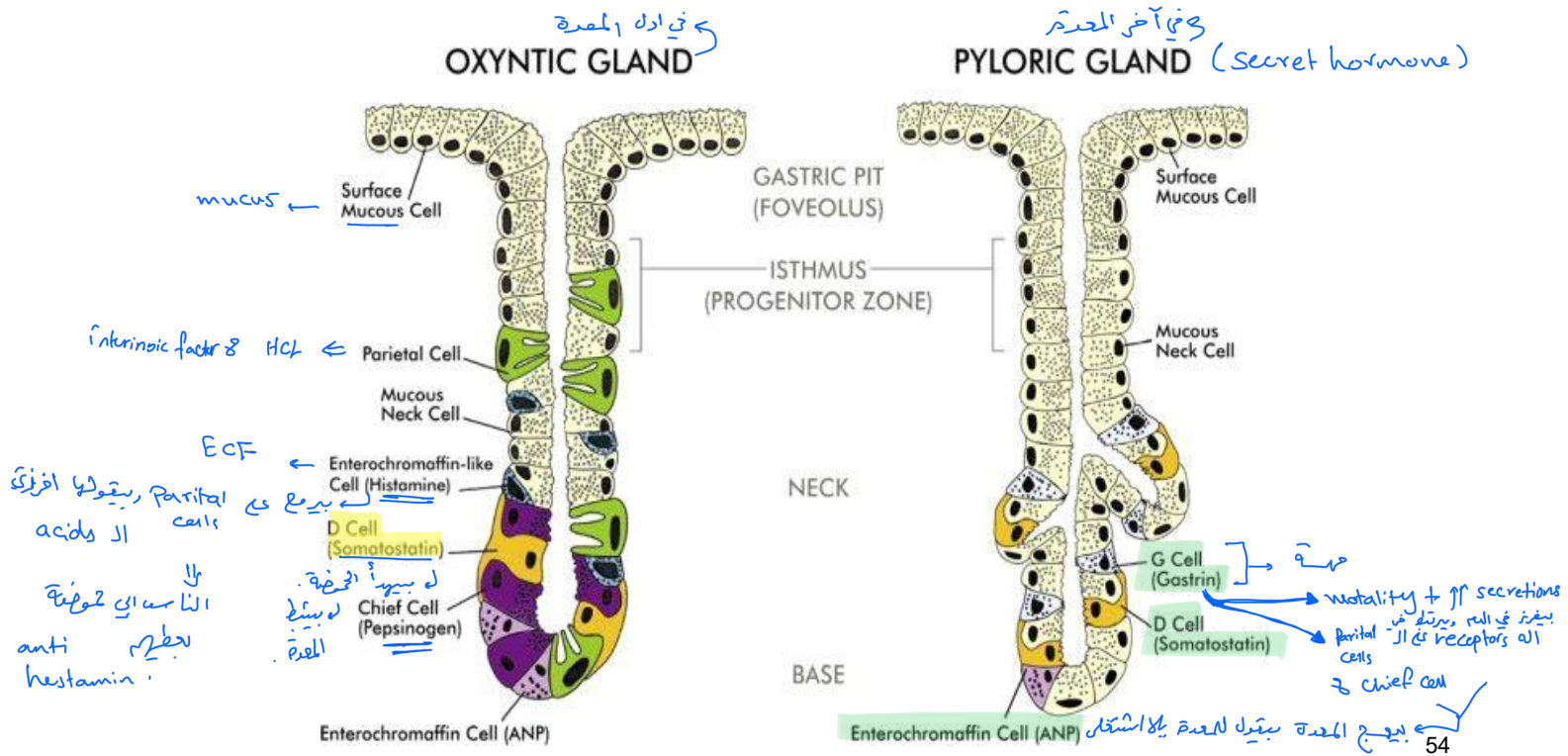


Gastric secretion

- The stomach also contains 2 types of tubular glands
- The tubular glands are called:
  - OXYNTIC GLANDS → Fundus , Body .
    - Contain mucous neck cells which secrete mucous (alkaline mucous)
    - Contain chief cells which secrete *pepsinogen*
      - Pepsinogen is activated to pepsin when it comes into contact with hydrochloric acid
      - Pepsin is an enzyme that breaks down proteins in an acidic environment
    - Contain parietal cells which secrete *hydrochloric acid* and *intrinsic factor* (necessary for the absorption of B12)
    - Located in the body and fundus of the stomach
  - PYLORIC GLANDS في آخر المعدة
    - Secrete mucous (alkaline mucous)
    - Secrete the hormone GASTRIN from G cells in response to proteins
    - Located in the antrum

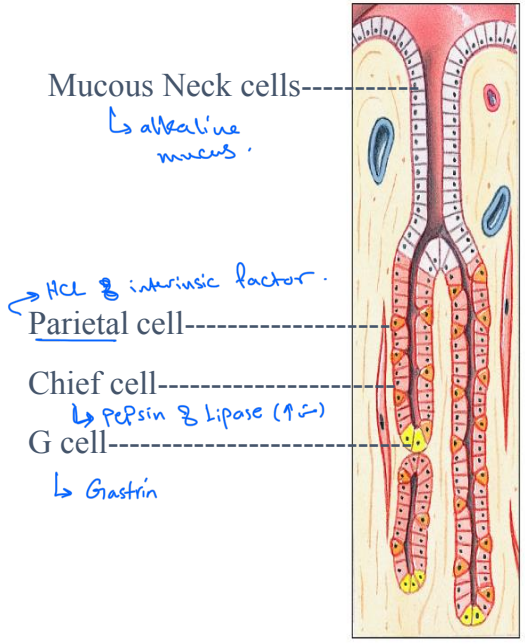
يختلفوا في نوع الخلايا المشاركة في تكوين العصارة

Gastric secretion



GASTRIC GLANDS: SECRETIONS

- Gastric glands
  - Mucous neck cells secrete protective mucus and $HCO3^-$
  - Parietal cells secrete hydrochloric acid and intrinsic factor
  - Chief cells secrete pepsinogen and gastric lipase
  - G cells secrete hormone gastrin which stimulates gastric secretions



GASTRIC GLANDS: SECRETIONS

- **Gastric acid (HCl)**:
  1. - Kills bacteria and other organisms
  2. - Denatures proteins by destroying tertiary structure & breaking bonds
- **Pepsin (protease)**: initial digestion of proteins (esp. meat)
- **Gastric lipase**: (10% of fat digestion)
- **Carbohydrates digestion** continues in the stomach (salivary amylase is inactivated at low pH)

Gastric secretion

Concentration of hydrochloric acid (HCL) is very strong enough to cause tissue damage but the stomach is protected by:

- the mucosal cells
- the tight junctions between the cells



هناك شغلات تتحكم في افرازات HCL تزوده أو تقلله

The control of HCL secretion from the parietal cells **via 1) nervous control** and 2) **substances** released into the stomach from **Enterochromaffin like cells (ELC).**

Para sympath

ELC release histamine. → ↑ HCL

Histamine is released in response to:

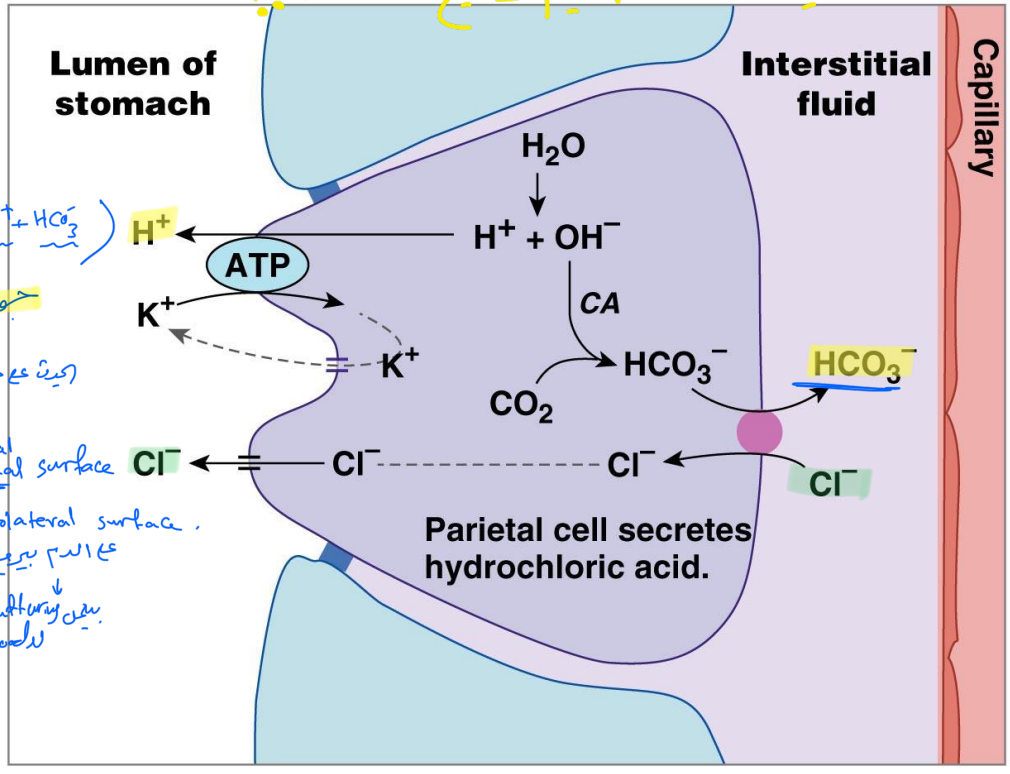
- Gastrin - causes increased histamine release which increases acid release from parietal cells → ↑ HCL.
- Parasympathetic stimulation

Pepsinogen is released by exocytosis in response to:

parasympathetic stimulation or when there is acid in the stomach

Cell Types of the Gastric Mucosa

source	Substance secreted	stimulus	function
Mucous neck cell	mucus	Irritation of mucosa	barrier
	bicarbonate	Secreted with mucous	Buffers gastric acid
Parietal cells	Gastric acid	Acetylcholine, gastrin, histamine	Activates pepsin, kills bacteria
	Intrinsic factor		Complex with vit. B12 to permit absorption
D cells	Somatostatin	Acid in the stomach	Inhibit gastric acid secretion
G cells	Gastrin	Acetylcholine, peptides, AA	Stimulate gastric acid secretion
Enterochromaffin-like cell	histamine	Acetylcholine, gastrin	Stimulate gastric acid secretion
Chief cells	Pepsin(ogen)	Acetylcholine, acid, secretin	Digest proteins
	Gastric lipase		Digest fats



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Figure 21-6

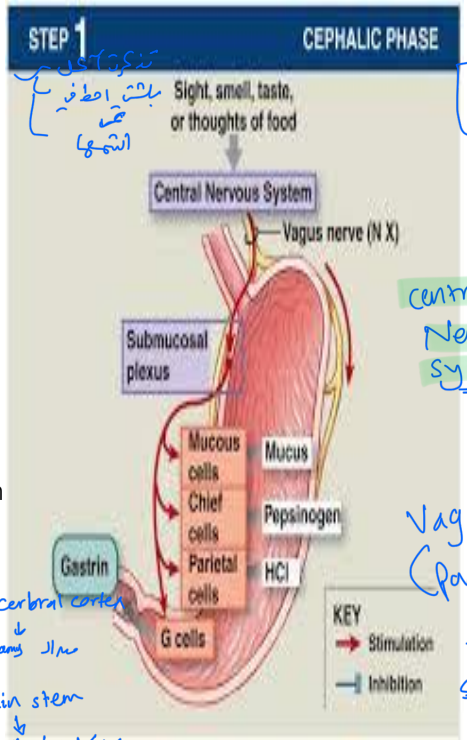
Phases of gastric secretion

There are 3 phases to gastric secretion:

- Cephalic phase (Pre - gastric)
- Gastric phase
- Intestinal phase (Post - gastric)

Cephalic: This secretion occurs before the food enters the stomach - especially as it is being eaten

- It results from **sight, taste, smell** or thought of food
- Stimulus for secretion comes via parasympathetic signals via the vagus nerve which receive signals from the *cerebral cortex or appetite centres* (hypothalamus) of the brainstem and via *submucosal plexus (enteric nervous system)*
- This makes up 20% of the total gastric secretions that occur during a meal
- Stimulation of gastrin release by G cells



Duration: Long (3-4h)

- This occurs one food enters the stomach - due to the stretch of the stomach

Mechanism:

Neural:

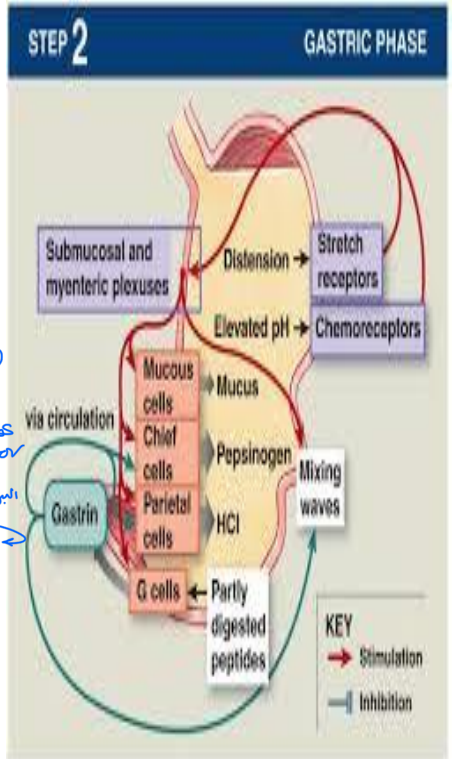
- Stretch receptor: Food stimulates parasympathetic signals to be sent from the brain via the vagus nerve. It also causes stimulation of the local myenteric and submucosal plexus to stimulate parasympathetic nerves
- Stimulation of chemoreceptors as PH changes.

Hormonal: stimulation of gastrin

Local: release of histamine

Action: Increase acid and pepsinogen production, increase motility and initiation of mixing wave

This forms 70% of the total gastric secretions that occur with a meal



Phases of gastric secretion

Intestinal Phase

Function: Control rate of chyme entry to duodenum

Duration: Long(hours)

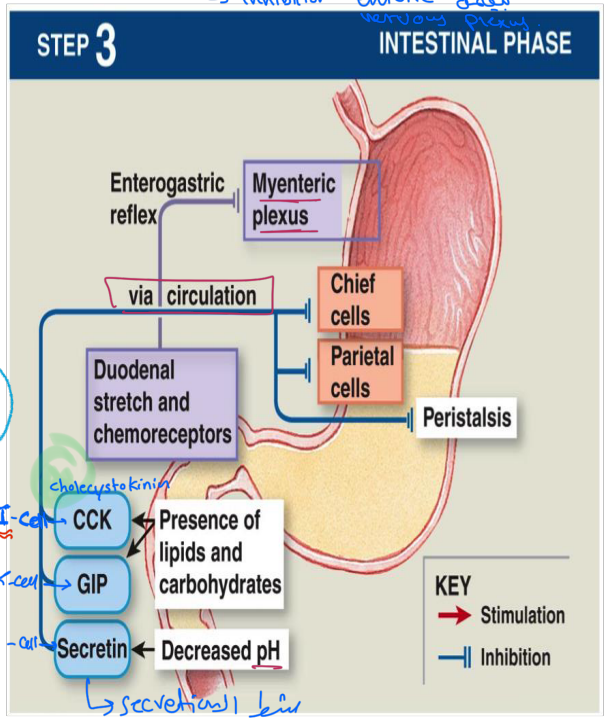
Mechanism: (Control)

Neural: short refluxes (**enterogastric reflex**)
triggered by extension of duodenum

Hormonal: Primary stimulation of CCK, GIP and secretin release by presence of acid, carb and lipids

Action:

Feedback inhibition of gastric acid and pepsinogen production, reduction of gastric motility



Inhibition of gastric secretion

- Occurs due to the presence of food or acid in the SMALL INTESTINE
  - Turns off secretion through a reflex called the reverse enterogastric reflex which causes the myenteric plexus to *increase sympathetic* stimulation to the stomach
- Also can occur due to irritation of the intestinal mucosa or the presence of acid, fat or protein breakdown products in the small intestine
  - This causes the release of intestinal hormones such as secretin which stops stomach secretion
  - Gastric inhibitory peptide, vasoactive intestinal polypeptide (VIP) and somatostatin can also be released which help to inhibit gastric secretion

Stomach Emptying

The amount of chyme that exits the stomach is controlled by several factors:

- The pyloric pump - This is the increasing peristaltic contractions from the antrum of the stomach that forces chyme through the tight pyloric sphincter at high pressure
    - Increased food in the stomach = increase emptying from the stomach.
    - Increased emptying is caused by stretching of the stomach which **stimulates the myogenic nerves** and increases the pyloric pumps working
- The pyloric sphincter
    - This is normally contracted - so only a small lumen for food to move through is present
    - This small lumen still allows water and other fluids to exit the stomach easily
    - The contraction means that food cannot exit the stomach until the food particles have become properly mixed in the chyme to a fluid like consistency
    - The pylorus is supplied by ***both sympathetic and parasympathetic*** nerves and can be made to constrict further or dilate
    - When there is increased stretch of the stomach the myogenic nerves prevent the pylorus from constricting → therefore dilates and increases the lumen for food to pass

relaxation = inhibitory vagal fibers (mediated by VIP & NO)
contriction: cholinergic vagal fibers, sympathatic fiber, hormone → secretin, gastric inhibitory peptide, CCK



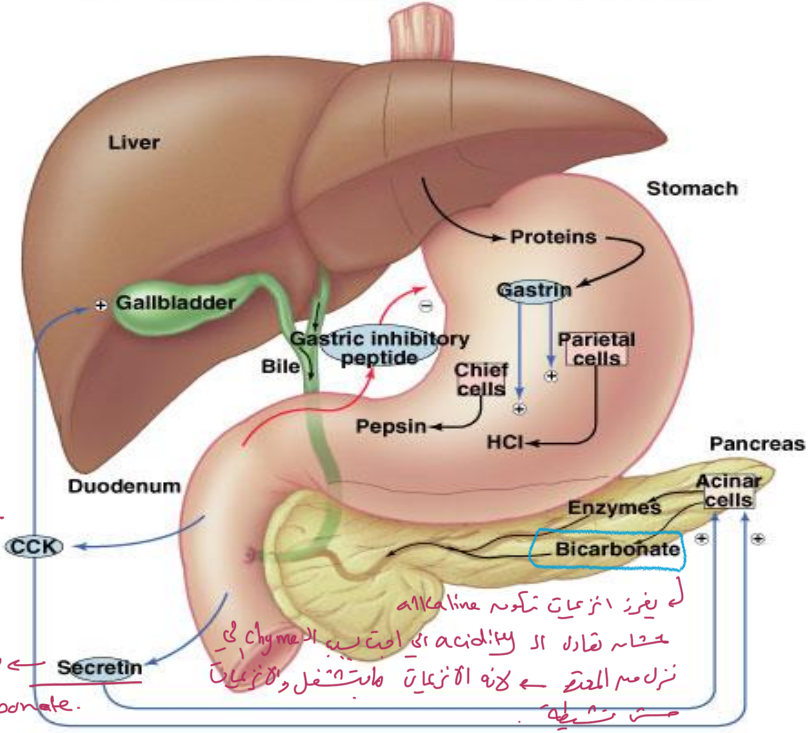
Stomach emptying

Stomach emptying can also be decreased

- This occurs if the **volume of chyme entering the duodenum** is too much, the duodenal mucosa becomes irritated or the chyme has a low pH due to a lot of gastric secretions.
- Neural control
  - Sending **local inhibitory signals** from the duodenal nerves directly to the stomach nerves
  - By **sending afferent signals to the brainstem** which sends back efferent inhibitory signals

- Hormones can also affect emptying
  - **Cholecystokinin (CCK)** is released from the jejunum when there is a lot of fatty substances in the chyme. This **decreases the work of the pyloric pump** and **increases the constriction of the pyloric sphincter**. (Gastrin increases the pyloric pump and cholecystokinin decreases it)
  - **Secretin** and **GIP** also decrease emptying

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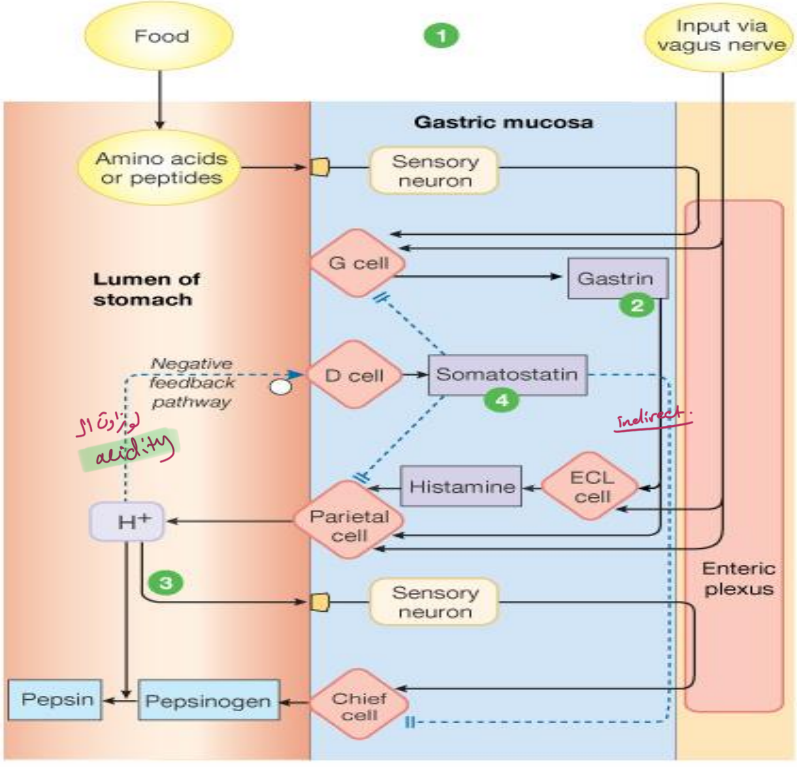


بيروح على Pancrease بيخلي يفرز juceses rich Lipase عشان يكسر الـ fat
بيروح على gall bladder بيسبب انقباض وبيخلي تفرز Bile اللي بتتمم عملية الـ lipid digestion

بيروح على الـ Pancrease وبيخلي يفرز juceses rich in bicarbonate.

بيفرز انزيمات تكون alkaline عشان تقادل الـ acidity في الـ chyme اللي اتنزل من المعدة ← لانه الانزيمات هاتشتغل في الانزيمات

Regulation of the Stomach Digestive Activities



1. Food or cephalic reflexes initiate gastric secretion.
2. Gastrin stimulates acid secretion.
3. Acid stimulates short reflex secretion of pepsinogen.
4. Somatostatin is the negative feedback signal.