PHYSIOLOGY OF THE STOMACH & REGULATION OF GASTRIC SECRETION

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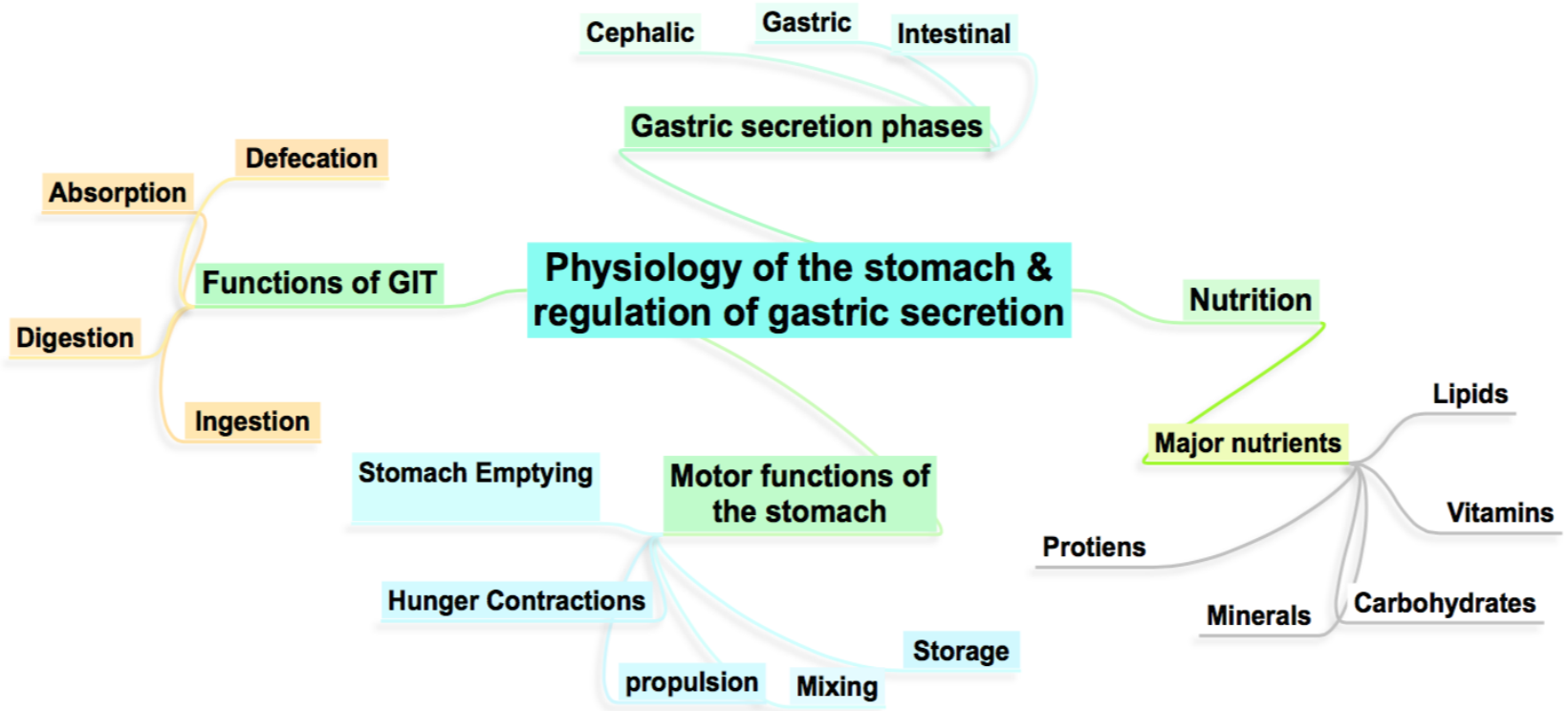
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NUTRITION

Nutrient: substance in food used to promote growth, maintenance, and repair

Major nutrients:

- **Carbohydrates**: sugars & starches
- **Lipids**: saturated/unsaturated fats
- **Proteins**: eggs, milk, meat (complete–all AA); legumes, nuts, cereals (incomplete)
- **Vitamins** :A, B, C, E, D, K
- **Minerals**: Ca, P, K, S, Na, Cl, Mg

FUNCTIONS OF GIT

1- Ingestion: mouth

2- Digestion:

A. Mechanical: fragment food into smaller particles (teeth, tongue, stomach, small intestine)

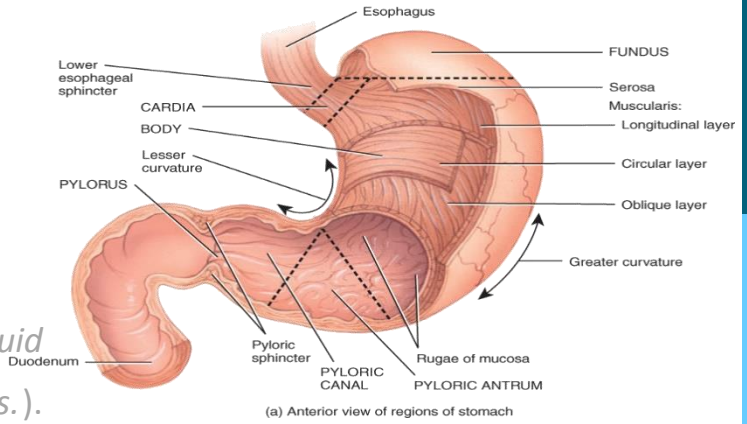
B. Chemical: enzymes

- Mouth = carbs (carbohydrates)
- Stomach = proteins
- SI (small intestine) = carbs, proteins, fats, nucleic acids

3- Absorption: transport from SI to blood

4- Defecation: eliminate indigestible residues (feces)

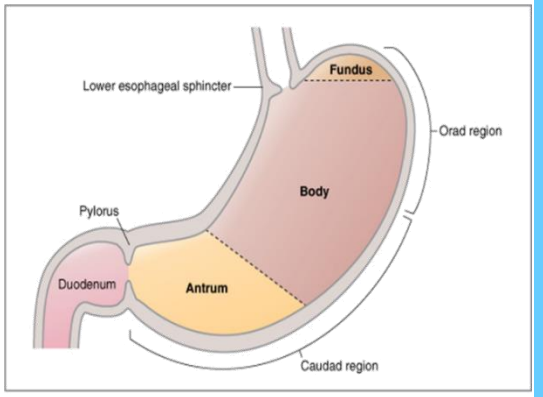
STOMACH



(a) Anterior view of regions of stomach

- ❖ **Stores & breaks down food**
- Mechanical : churn, mix
- Chemical : protein digestion
- ❖ **Gastric juice:** converts meal to acidic chyme (*Is a murky semi-fluid or paste composed of food that is thoroughly mixed with gastric secretions.*).
- *HCl:* pH 2, kills bacteria, denatures proteins
- *Pepsin*: enzyme breaks down proteins
- ❖ **Rugae**: large folds
- ❖ **Mucus**: protects lining of stomach

ANATOMY & PHYSIOLOGY OF THE STOMACH



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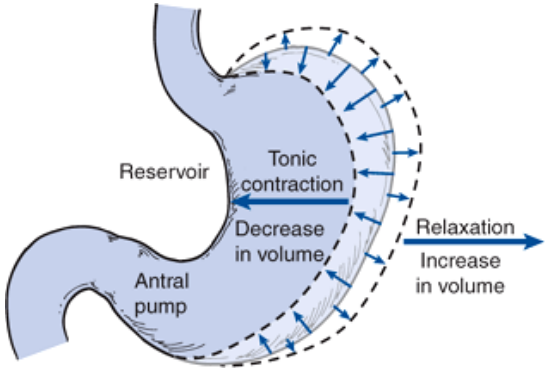
- ❖ **Anatomically : 1-** Body **2-**Antrum
- ❖ **Physiologically : 1-**Orad (Reservoir part (tonic contraction) **2-**Caudad (Antral pump (phasic contraction)).
- ❖ **Muscular wall: 1-**Longitudinal (outer) **2-**Circular (Middle) **3-**Oblique (inner)

TYPES OF RELAXATION IN GASTRIC RESERVOIR

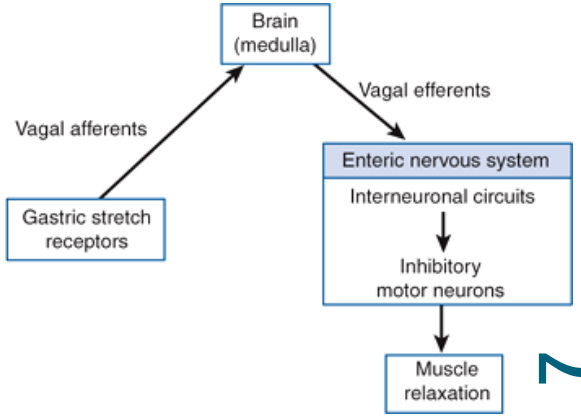
Based on males' slides

Receptive Relaxation Reflex:
Triggered by swallowing reflex.



Feedback Relaxation:
The presence of nutrients in the small intestine triggers feedback relaxation.

Adaptive relaxation:
Triggered by stretch receptors (vago-vagal reflex).
This reflex is lost in vagotomy.



MOTOR FUNCTIONS OF THE STOMACH

3 motor functions of the stomach:

1. Storage of large quantities of food
2. Mixing of food with gastric secretions to produce chyme
3. Slow emptying of chyme into the small intestine at a suitable rate for proper digestion & absorption

STORAGE FUNCTION:

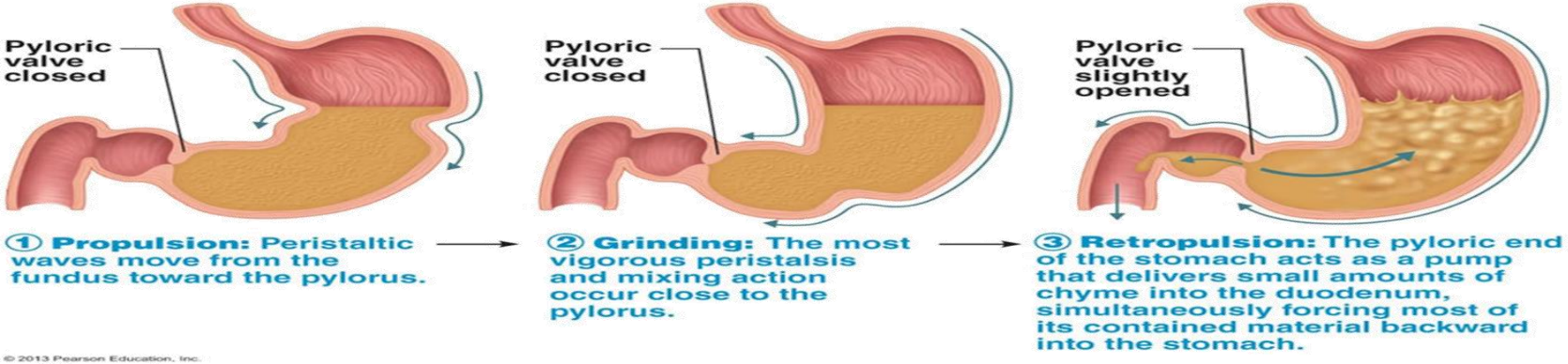
When food stretch the stomach a vagovagal reflex (Triggered by swallowing reflex) from the stomach to the brain stem Back to the stomach to reduce the tone in the muscular wall in the body of the stomach.

- Stomach wall bulges progressively.
- Stomach will accommodate up to 0.8-1.5 liters .
- Pressure in the stomach remains low.

CONT. MOTOR FUNCTIONS OF THE STOMACH

MIXING AND PROPULSION FUNCTION:

- As long as food is in the stomach , weak peristaltic (slow wave) constrictor waves (mixing waves) begin in the mid to upper portions of the stomach wall and move toward the antrum once every 15-20 seconds.
- It is **initiated** by the gut wall basic electrical rhythm (slow waves).
- As the constrictor waves move into the **antrum** they become **more intense.**
- Some become **extremely intense** providing peristaltic action potential-driven constrictor rings that force antral contents under higher pressure toward the pylorus.
- Constrictor rings play an important role in mixing the stomach contents:
- Each time it digs deeply into the food contents in the antrum
- The opening of the pylorus allows only a few mls of antral contents to be expelled into the duodenum with each wave
- As each wave approaches the pylorus the pyloric muscle contracts
- Most of the antral content are squeezed upstream through the peristaltic ring toward the body
- The moving peristaltic ring + upstream squeezing action called Retropulsion is an important mixing mechanism



MOTOR BEHAVIOR OF THE ANTRAL PUMP

*Based on males' slides

- The duration and strength of the phasic contractions of the antral pump are determined by gastric AP.
- They are initiated by a dominant pacemaker → Interstitial cell of cajal (ICC)
- The pacemaker region in humans generates action potentials and associated antral contractions at a frequency of **3/min**.
- The gastric action potential lasts about **5 seconds** and has a rising phase (depolarization), a plateau phase, and a falling phase (repolarization)

GASTRIC ACTION POTENTIAL

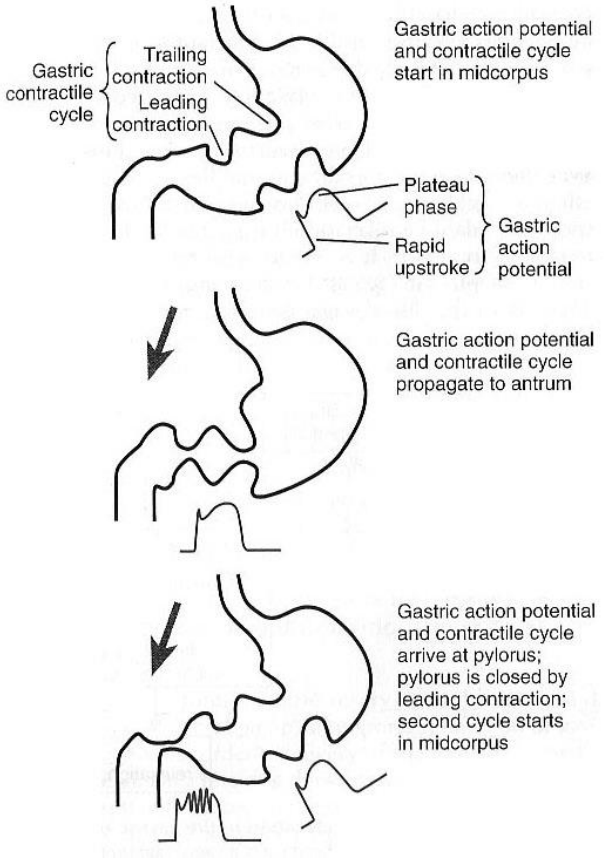
The gastric action potential is responsible for two components of the propulsive contractile behavior in the antral pump.

leading contraction

- relatively **constant** amplitude
- associated with the **rising phase**

trailing contraction

- **variable** amplitude
- associated with the **plateau phase**.



*Based on males' slides

CONT. MOTOR FUNCTIONS OF THE STOMACH

HUNGER CONTRACTIONS:

- Occurs when stomach is empty for several hours.
- They are rhythmical peristaltic contractions in the body of the stomach.
- When successive contractions become extremely strong they fuse into a **continuing tetanic contractions** that lasts for 2-3 min.
- Sometimes they cause mild pain (hunger pangs).
- They begin 12-24 hrs after last meal.
- In starvation they reach greatest intensity in 3-4 days.

STOMACH EMPTYING:

- Promoted by intense peristaltic contractions in the **antrum.**
- Empting is opposed by resistance to passage of chyme at the pylorus .

PYLORIC PUMP:

- Most of the time contractions are weak and cause mixing of food with gastric secretions.
- 20% of the time contractions in the form of tight ringlike constrictions cause stomach emptying .
- They are 6 times as powerful as mixing waves (the contraction which allow passage pf the food to jejunum).

ROLE OF PYLORUS IN CONTROLLING EMPTYING

- Pylorus is the distal opening of the stomach.
- Thickness of circular muscles is 50-100% greater than in the antrum.
- It is slightly tonically contracted almost all the time.
- It is named the **pyloric sphincter.**
- It is usually open enough to allow water & fluids.
- It is controlled by nervous and hormonal reflexes from the stomach and duodenum .

REGULATION OF STOMACH EMPTYING

More potent

By stomach

➢ **Gastric factors:**

- Gastric food volume: when volume increased it increased emptying due to stretch of stomach wall which initiate local myenteric reflexes causing:

1. Increase activity of pyloric pump
2. Inhibit the pylorus

- Gastrin (hormone secreted by G cells in the antrum): released from antral mucosa and enhance the activity of pyloric pump
- gastrin promotes the secretion of acidic gastric juices (ex. HCl) by the stomach gastric glands (or oxyntic glands)

By duodenum

➢ **Duodenal factors:** usually inhibitory

- Inhibitory enterogastric nervous reflexes mediated by:
  - Direct from duodenum to stomach via enteric nervous system
  - Extrinsic nerves to sympathetic ganglia
  - Vagus nerves to the brain stem

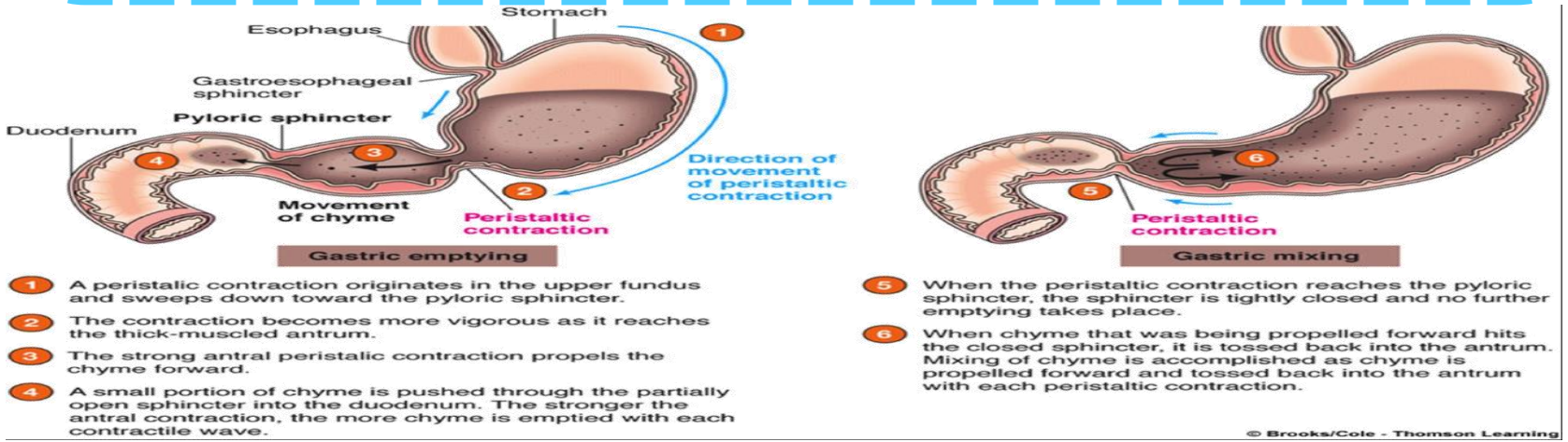
All these reflexes strongly inhibit pyloric pump & increase tone of the pyloric sphincter (it is like saying we have a lot of things to deal with them don't push anything ☺)

Factors that initiate these reflexes are:

Duodenal distention, irritation of mucosa, acidity of duodenal chyme, breakdown products such as proteins & fats

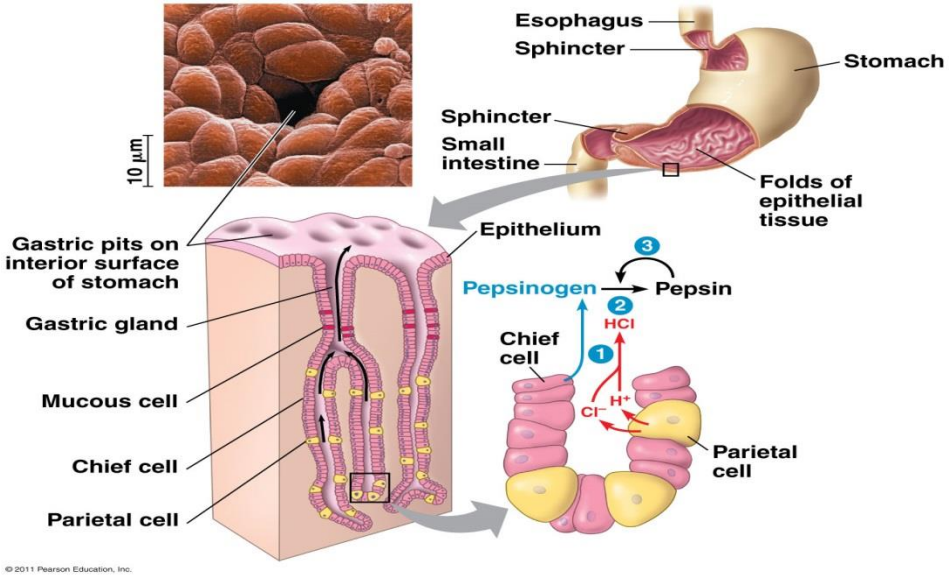
CONT. REGULATION OF STOMACH EMPTYING

- **Duodenal factors:**
- **Hormonal feedback:**
  - The main stimulus for releasing these inhibitory hormones is fat in the duodenum.
  - Through receptors on epithelial cells .
  - Released hormones carried by blood to the stomach.
  - They inhibit pyloric pump & increase contraction of pyloric sphincter .
  - The most potent hormone, CCK released from **duodenum and jejunum** by **fat**.
  - Secretin released from duodenal mucosa in response to **acid** .
  - Gastric inhibitory peptide (GIP) from upper small intestine **mainly by fat** in chyme and carbohydrates.



GASTRIC SECRETION

- Gastric mucosa has numerous openings called gastric pits and **Gastric glands** empty into bottom of pits
- 4 functionally different cell types compose glands:
  - Mucous cells
  - Chief cells
  - Parietal cells
  - Enteroendocrine cells



SECRETORY FUNCTIONS OF THE STOMACH

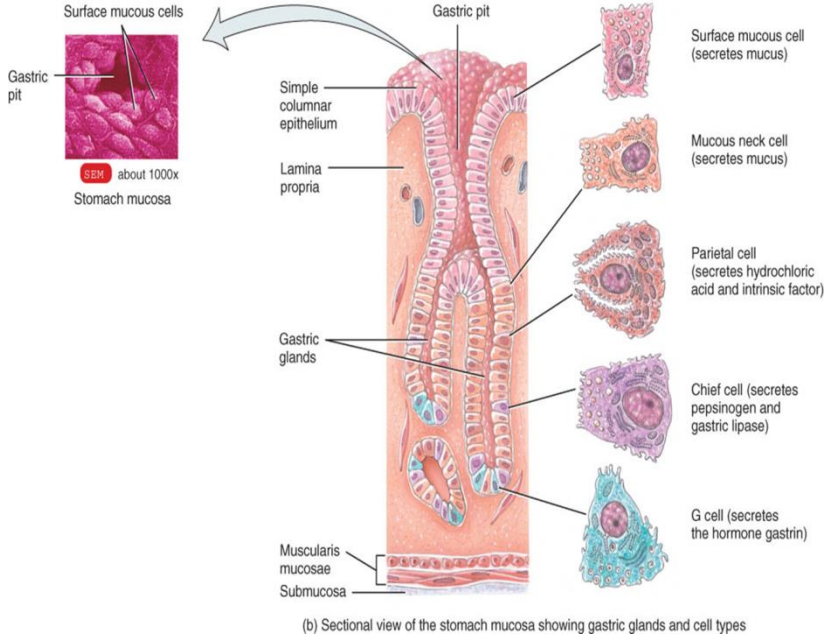
- In addition to mucus secreting cells that line the stomach and secrete alkaline mucus, there are two important types of tubular glands:

oxyntic (gastric) glands

- Secrete:
  Hydrochloric acid
  Pepsinogen
  Intrinsic factor
  Mucus
- Located in body & fundus
  In proximal 80%of stomach

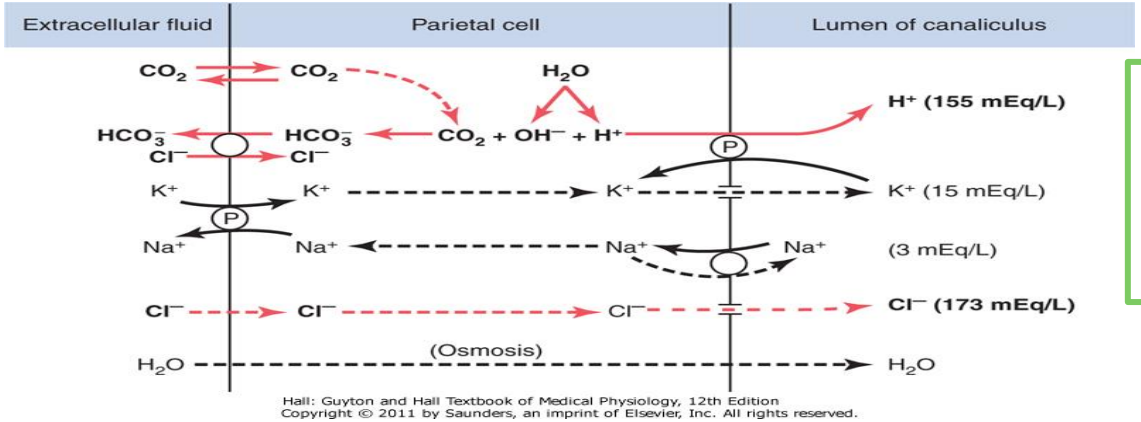
Pyloric glands

- Secrete:
  •Mucus- protection
  •Gastrin
  •Small amount of Pepsinogen
- Located in the antrum
  In the distal 20% of stomach



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

MECHANISM OF HCL SECRETION



Males' lecture

Mechanism of HCl production:

- Depends on H/K ATPase
- Inhibited by: omeprazole
- H/K pump depends on $[K]_{out}$
- [HCl] drives water into gastric content to maintain osmolality
- During gastric acid secretion: amount of HCO_3^- in blood = amount of HCl being secreted
- Alkaline tide

Water inside the parietal cell becomes dissociated into H^+ and OH^- in the cell cytoplasm The H^+ is then actively secreted into the canaliculus in exchange for K^+

most of the K^+ and Na^+ in the canaliculus is reabsorbed into the cell cytoplasm, and hydrogen ions take their place in the canaliculus.

The pumping of H^+ out of the cell by the H^+-K^+ ATPase permits OH^- to accumulate and form HCO_3^- from CO_2

This reaction is catalyzed by *carbonic anhydrase.* The HCO_3^- is then transported across the basolateral membrane into the extracellular fluid in exchange for chloride ions

Cl secreted through chloride channels into the canaliculus, The hydrochloric acid is then secreted outward through the open end of the canaliculus into the lumen of the gland.

NEURAL & HORMONAL CONTROL OF GASTRIC SECRETION

Vagus nerve (neural effector) either by releasing Ach (direct activation of parietal cells) or by releasing Gastrin releasing peptide, GRP (indirect activation).

Gastrin (hormonal effector)

Enterochromaffin-like cells release Histamine→ activates H_2 receptor (parietal cells) → increases acid secretion

Cimetidine (H_2 receptor blocker)→ peptic ulcer and gastroesophageal reflux

*the ECL cells are stimulated to secrete histamine by the hormonal substance gastrin, which is formed almost entirely in the antral portion of the stomach mucosa in response to proteins in the foods being digested.

PHASES OF GASTRIC SECRETION

Cephalic phase: The cephalic phase of gastric secretion occurs even before food enters the stomach, especially while it is being eaten

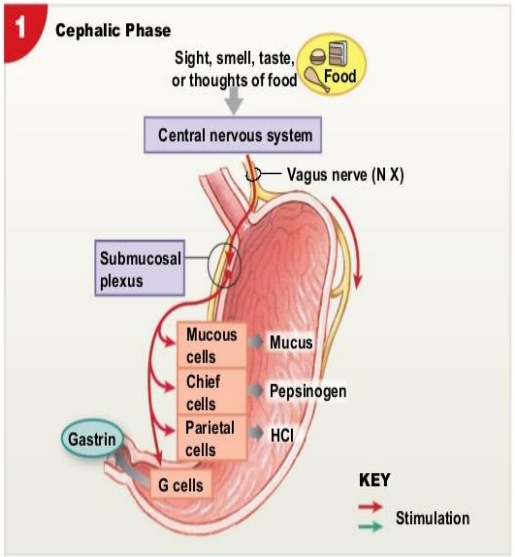
It results from the sight, smell, thought, or taste of food, and the greater the appetite, the more intense is the stimulation. This normally accounts for about 30 percent of the gastric secretion associated with eating a meal.

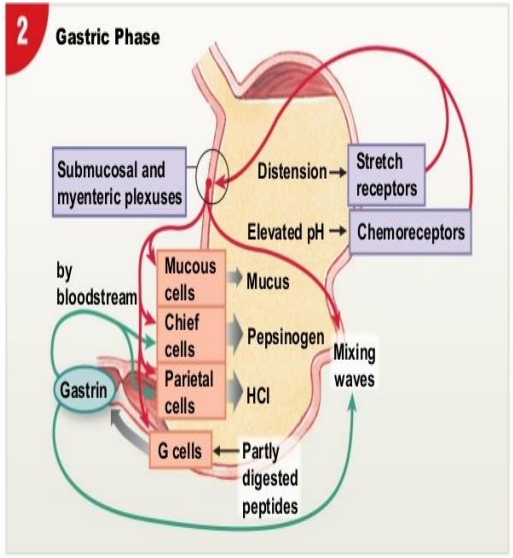
Neurogenic signals originate in the cerebral cortex and in the appetite centers of the amygdala and hypothalamus.thence through the vagus nerves to the stomach.

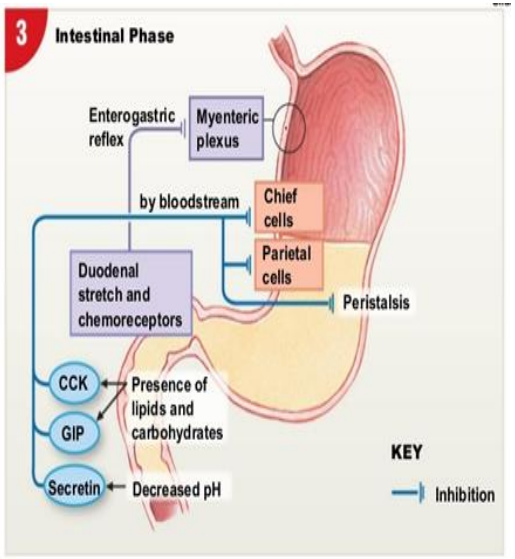
Gastric Phase: Once food enters the stomach, it excites:(1) long vagovagal reflexes from the stomach to the brain and back to the stomach, (2) local enteric reflexes, and (3) the gastrin mechanism, all of cause secretion of gastric juice during several hours while food remains in the stomach. The gastric phase of secretion accounts for about 60 percent of the total gastric secretion associated with eating a meal .

Intestinal Phase: The presence of food in the upper portion of the small intestine, particularly in the duodenum, will continue to cause stomach secretion of small amounts of gastric juice, probably partly because of small amounts of gastrin released by the duodenal mucosa. This accounts for about 10 percent of the acid response to a meal.

PHASES OF GASTRIC SECRETION







Cell type	Mucous neck cell	Parietal cells	Enterochromaffin -like cells	Chief cells	D cells	G cells
Substance secreted	Mucus Bicarbonate	Gastric acid (HCl) Intrinsic factor (Ca absorption)	Histamine (stimulates acid)	Pepsin Gastric lipase	Somatostatin (inhibits acid)	Gastrin (stimulates acid)

Cephalic phase

- stimulated by:

1. the taste or smell of food
2. Tactile sensation of food
3. Thought of food

- Before food enters the stomach
- The greater the appetite the more intense the stimulation
- Originates in the cerebral cortex and in the appetite centers of the amygdala and hypothalamus.
- Transmitted through dorsal motor nuclei of the vagi.
- stimulate secretion of HCl and pepsin
  release of gastrin lower part

Gastric phase

- Stimulated by: stomach distention
- Excites:

1. long vagovagal reflexes from the stomach to the brain and back to the stomach
2. local enteric reflexes
3. gastrin mechanism

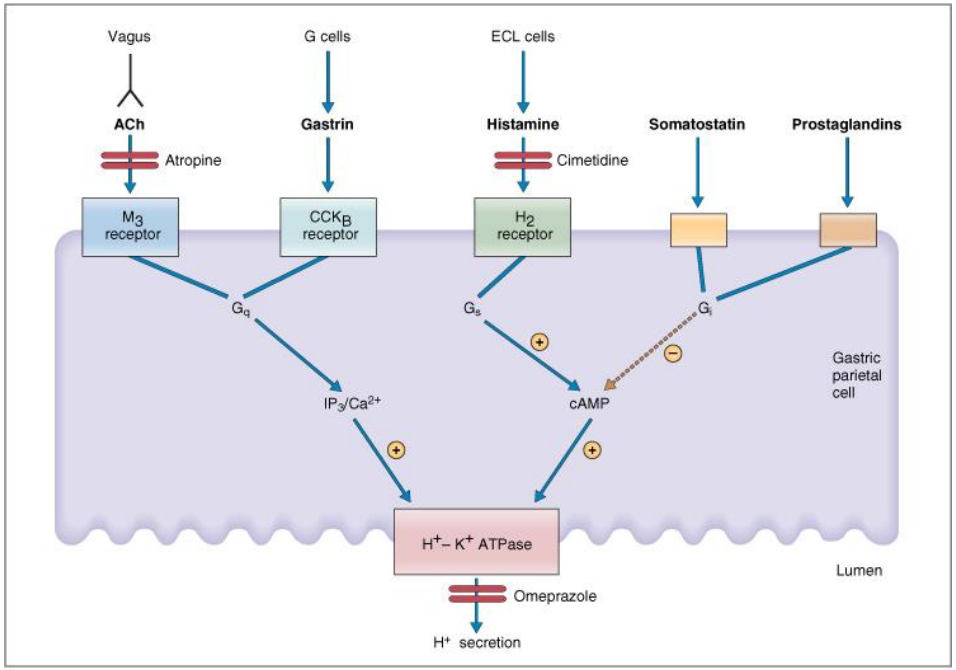
- Continued secretion of HCl and pepsin

*The slide is based on guyton and the video linked previously

Intestinal phase

- Chyme enters the duodenum
- Gastric secretions are inhibited
- Lipids and hydrogen ions decrease gastric secretion by inhibiting parasympathetic activity of the gastric glands
- CCK, GIP, and secretin are released and cause inhibition of gastric secretions.
- Duodenal stretch leads to local reflexes that inhibit gastric secretions as well

AGENTS THAT STIMULATE AND INHIBIT H^+ SECRETION BY GASTRIC PARIETAL CELLS



DIGESTION & ABSORPTION

Digestion of	Carbohydrates	Proteins	
Location	Mouth and small intestine	Stomach	
Enzymes used	**Ptyalin** (an **α amylase**) Secreted by: parotid gland and pancreas	**Pepsin** Secreted by: chief (peptic) cells	**Hydrochloric acid** Secreted by: parietal (oxyntic) cells
Enzymes info.	▪ It hydrolysis starch to maltose. ▪ Gastric acid deactivate it.	▪ It is active at pH **2-3** and inactive at pH **5** ▪ Initiate protein digestion (10-20% of protein digestion) ▪ Can digest collagen	———

Stomach is a poor absorptive area of GIT :

It lacks the villous type of absorptive membrane

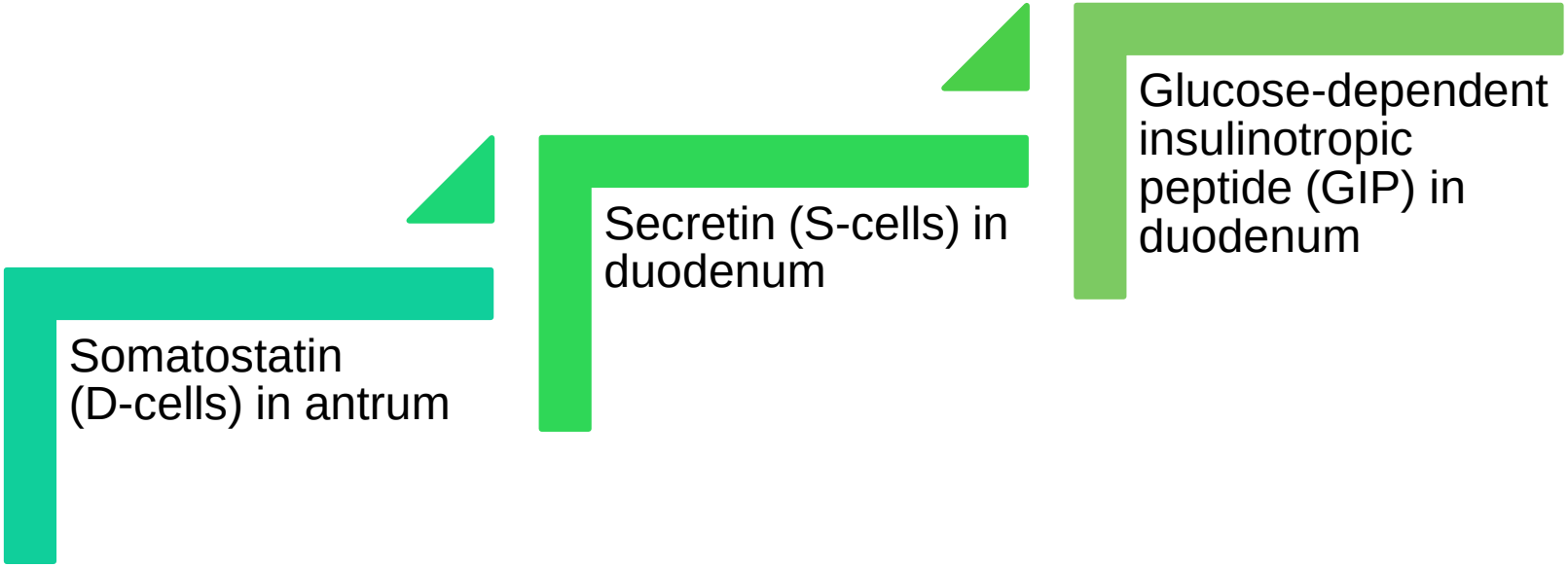
It has tight junctions between epithelial cells

Only a few highly-lipid soluble substances can be absorbed such as:

- Alcohol
- Aspirin

INHIBITION OF ACID SECRETION

Inhibitory hormones (Enterogastrones):



Based on males' lecture

MCQs

Answer key: 1:E 2:A 3:B 4:B 5:B 6:C 7:D

1- Which of these conditions causes inhibition of gastric secretion?
A. hypotonic or hypertonic solution in the duodenum
B. distention of the duodenal wall
C. pH less than 2 in the duodenum.
D. fats in the duodenum
E. all of these

2-Which of these inhibits secretion and motility of the stomach?
A. enterogastric reflex
B. parasympathetic stimulation
C. gastrin
D. intrinsic factor
E) distention of stomach wall

3-The "pyloric pump" describes
A. food movement through the esophagus into the stomach.
B. chyme moving from the stomach into the small intestine.
C. undigested food moving through the ileocecal valve.
D. feces moving through the internal anal sphincter.
E. gastrin, HCl, and pepsinogen being secreted from duodenal glands.

4-Sometimes they cause mild pain
A. Stomach Emptying
B. hunger pangs
C. Pyloric pump:
D.Mixing and propulsion.

5- Hydrochloric acid is secreted by:
A. Peptic .
B. parital .
C. Mucous cells.
D. Enteroendocrine cells.

6- Hormone released from antral mucosa and enhance the activity of pyloric pump.
A. Gastric inhibitory peptide (GIP).
B. Secretin .
C. Gastrin.
D. Cholecystokinin.

7-Which of the following occurs during the cephalic phase of gastric secretion?
A)Gastrin begins to be secreted by the lower part of the stomach.
B)Hydrochloric acid and pepsin secretion is stimulated in the upper and middle parts of the stomach.
C)Tactile sensation of food in the mouth sends nervous impulses to the medulla oblongata.
D)all of the above
E)none of the above

Q1: What is the function of HCL and Pepsin ?

Ans:

HCl: pH 2, kills bacteria, denatures proteins

Pepsin: enzyme breaks down proteins

Q2: What Are the Mediated Inhibitory enterogastricnervous reflexes ?

Ans:

1. Direct from duodenum to stomach via enteric nervous system
2. Extrinsic nerves to sympathetic ganglia
3. Vagus nerves to the brain stem

Q3: What are the Pyloric glands and oxyntic cells secrete?

Ans:

Pyloric glands secrete : Mucus-protection – Gastrin – small amounts of Pepsinogen

oxyntic cells secrete: Hydrochloric acid - Pepsinogen -Intrinsic factor -Mucus

Q4: What are the Phases of gastric secretion?

Ans:

cephalic phase-Gastric Phase -Intestinal Phase

Thanks for checking our work

Good Luck

Done by:

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