Digestion, its types and functions. Role of oral cavity in digestion. Role of oral cavity in regulation of digestion.

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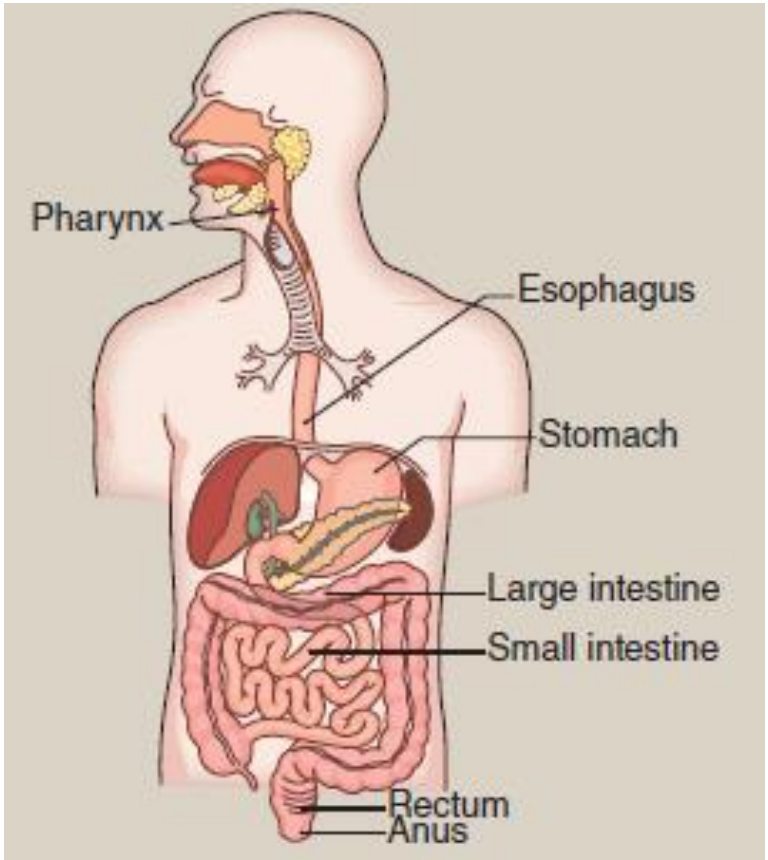
Digestion

- This is the process of breaking down (hydrolysis) food into simple chemical substances that can be absorbed and used as nutrients for the body.
- Digestive functions:

- Secretory (salivary glands, pancreas, liver, gastric, intestinal glands);
- Motility (chewing, swallowing, peristalsis, defecation);
- Absorptive (mucosal of the gastrointestinal tract).

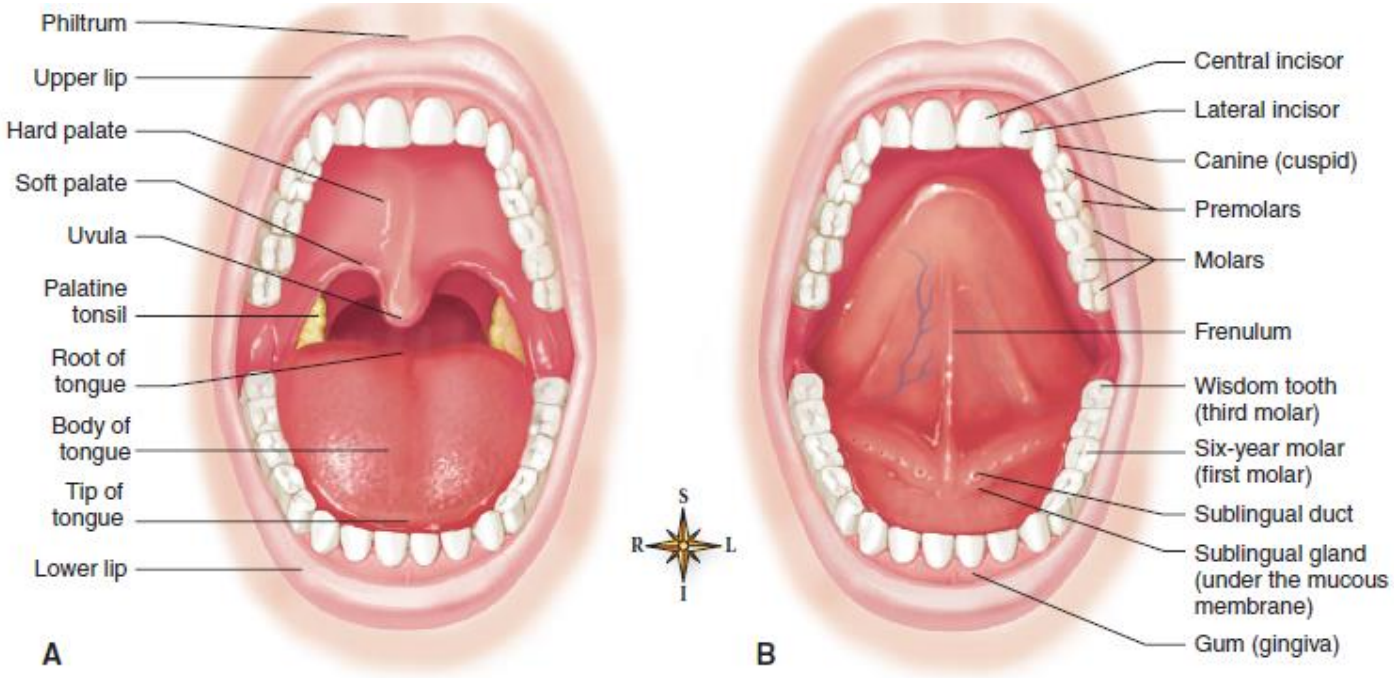
Digestive system

- The gastrointestinal tract extends from the mouth to the anus.
- It consists of the gastrointestinal tract (mouth, pharynx, esophagus, stomach, small intestine, large intestine) and accessory digestive organs (teeth, tongue, salivary glands, pancreas, liver with gall bladder).



Oral cavity

- It is formed by the cheeks, lips, palate, floor of the oral cavity with the tongue.
- It consists of the oral vestibule (between the teeth and lips, cheeks) and the oral cavity proper.
- Functions: food absorption, chewing, taste evaluation, swallowing, speech, communication.



Saliva

- Secretion volume – 1-1.5 l/day.
- The rate of secretion is ≈ 0.5 ml/min at rest, this is ≈ 30 ml/h, during stimulation (meals) it increases to 5-7 ml/min.
- The maximal secretion is 1ml/min/g of gland mass.
- Hypotonic relative to blood plasma (lower content of sodium and chlorine, but higher potassium and bicarbonate than in blood plasma).
- Specific gravity 1.002-1.012.
- pH 6.4-7.4 in the oral cavity.

Composition of saliva

- Water (99.5%);
- Solids (0.5%):

1. Inorganic (Na^+, Ca^{2+} , K^+, HCO_3^-, Cl^-, F^-, Br^-, PO_4^-);
2. Organic:

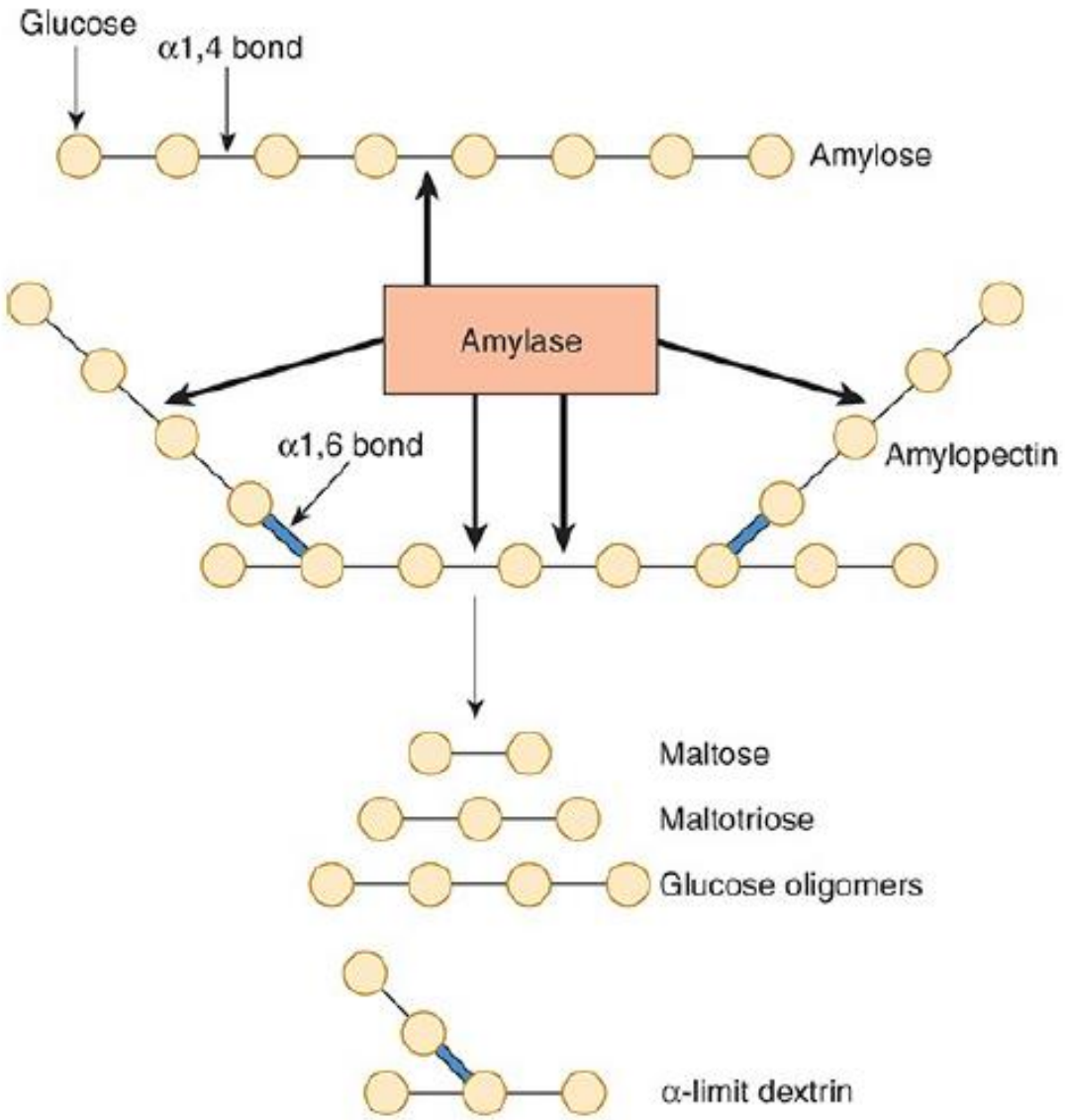
- Proteins (mucin, enzymes (amylase, maltase, lingual lipase, phosphatase, kallikrein, ribonuclease), proline-rich proteins, lysozyme, immunoglobulin A, lactoferrin, albumin, growth factors),
- Non-protein substances (amino acids, urea, creatinine, uric acid).

Functions of saliva

- Digestive (salivary amylase, lingual lipase);
- Moistening, helps in chewing and forming bolus and swallowing, speech;
- Taste evaluation (dissolves food substances);
- Cleansing (constant secretion);
- Protective (lysozyme, proline-rich proteins, mucin, lactoferrin, Ig A);
- Growth factors of the epidermis;
- Enamel mineralization;
- Water and electrolyte balance.
- Neutralization of the acidic chyme from the stomach in case of reflux.

Salivary amylase

- Salivary amylase (amylolytic enzyme) is an enzyme that breaks down starch into dextrins (5-9 glucose residues), maltotriose and maltose. Optimal pH = 6.7. It destroys 1:4 α-glycosidic bonds.



Defensive factors

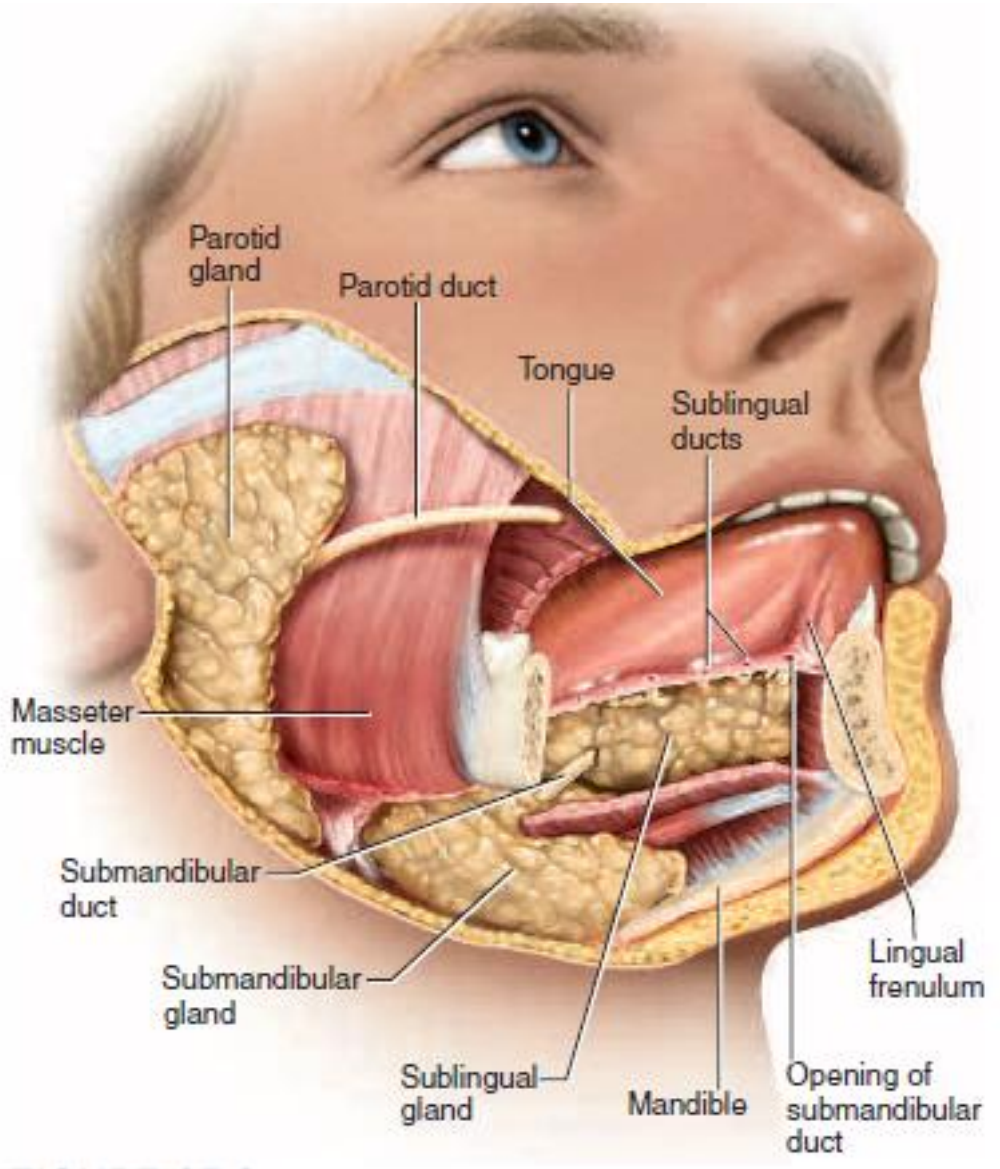
- Mucins moisturize the mucous membrane, protect against mechanical and thermal damage.
- Lysozyme (muramidase enzyme, which breaks down the bacterial wall) has a bactericidal effect on staphylococci and streptococci.
- Proline-rich proteins have antimicrobial action, create a pellicle, bind tannins.
- Lactoferrin has an antimicrobial effect (binds iron).
- Secretory Ig A has antibacterial action.

Salivary glands

I. Major:

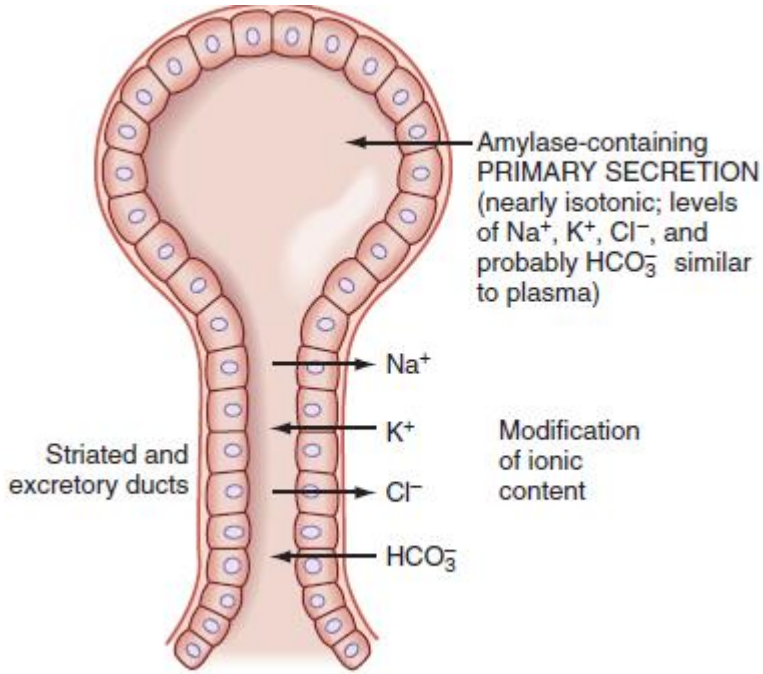
1. Parotid (25% of saliva) is the largest, the secretion is serous.
2. Submandibular (70% saliva) secretion is mixed.
3. Sublingual (5% saliva) secretion is mixed.

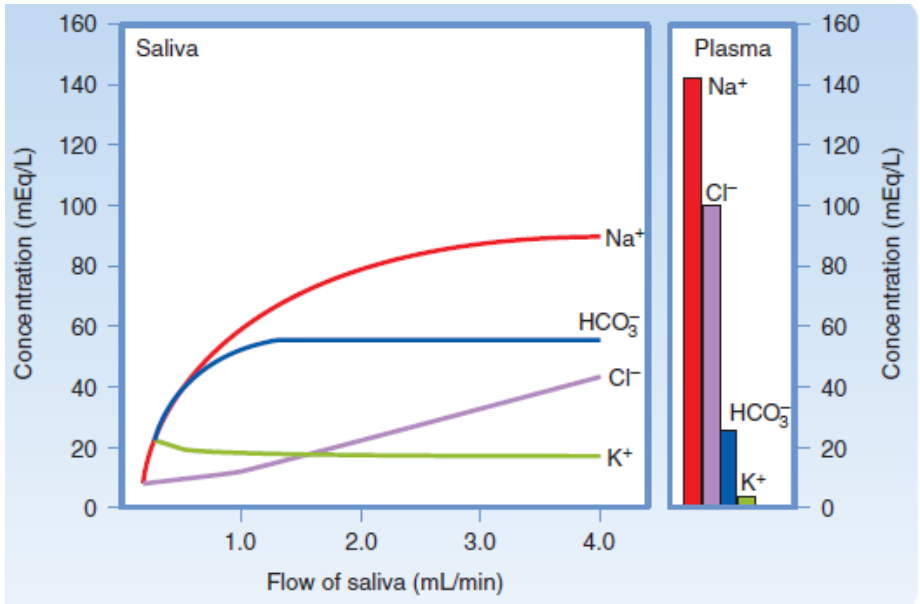
II. Minor: buccal, lingual (mucosal and serous), labial, palatal. Mucous secretion.



Mechanism of secretion

- Fluid enters by transudation of plasma, so primary saliva is isotonic.
- Reabsorption of Na^+ and Cl^- and secretion of K^+ and HCO_3^- occur in the ducts, so secondary saliva is hypotonic relative to plasma.

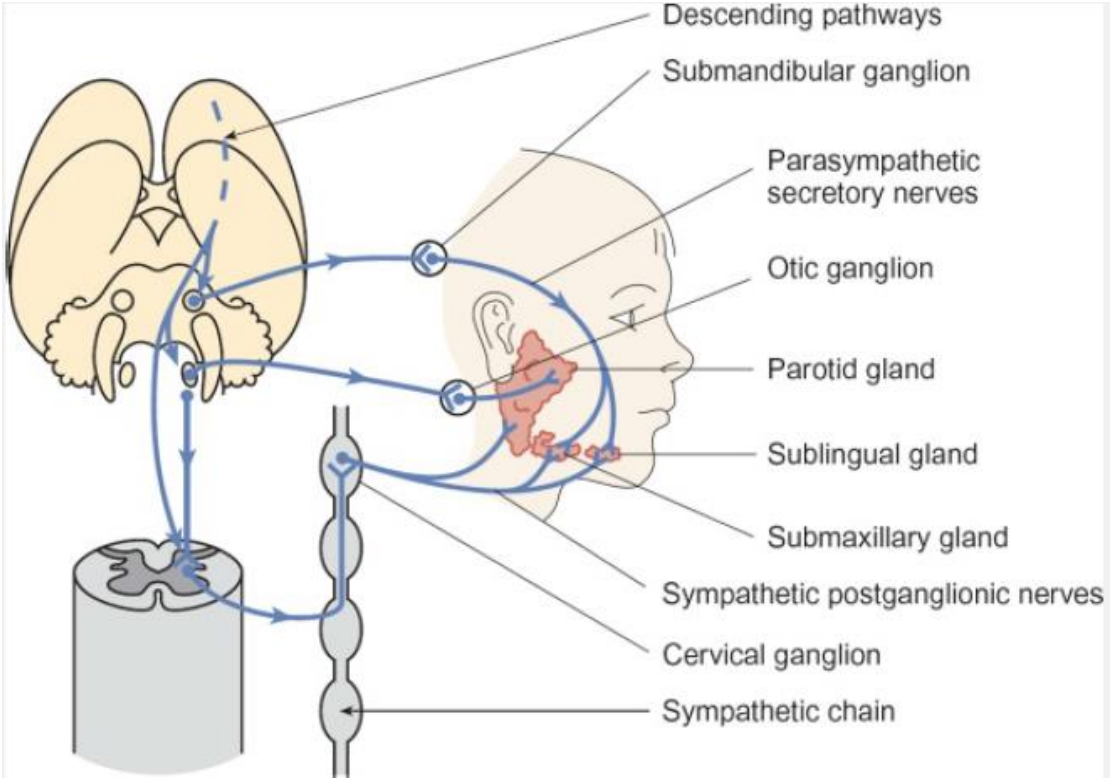




Innervation of salivary glands

I. Parasympathetic: superior salivary nucleus (pons), CN VII (chorda tympani), submandibular ganglion for submandibular and sublingual glands; inferior salivary nucleus (medulla oblongata), CN IX (n. petrosal minor), otic ganglion for parotid gland.

II. Sympathetic: T1-T3 of the spinal cord, upper cervical ganglion, carotid plexus, n.petrosus profundus.



Sympathetic regulation of secretion

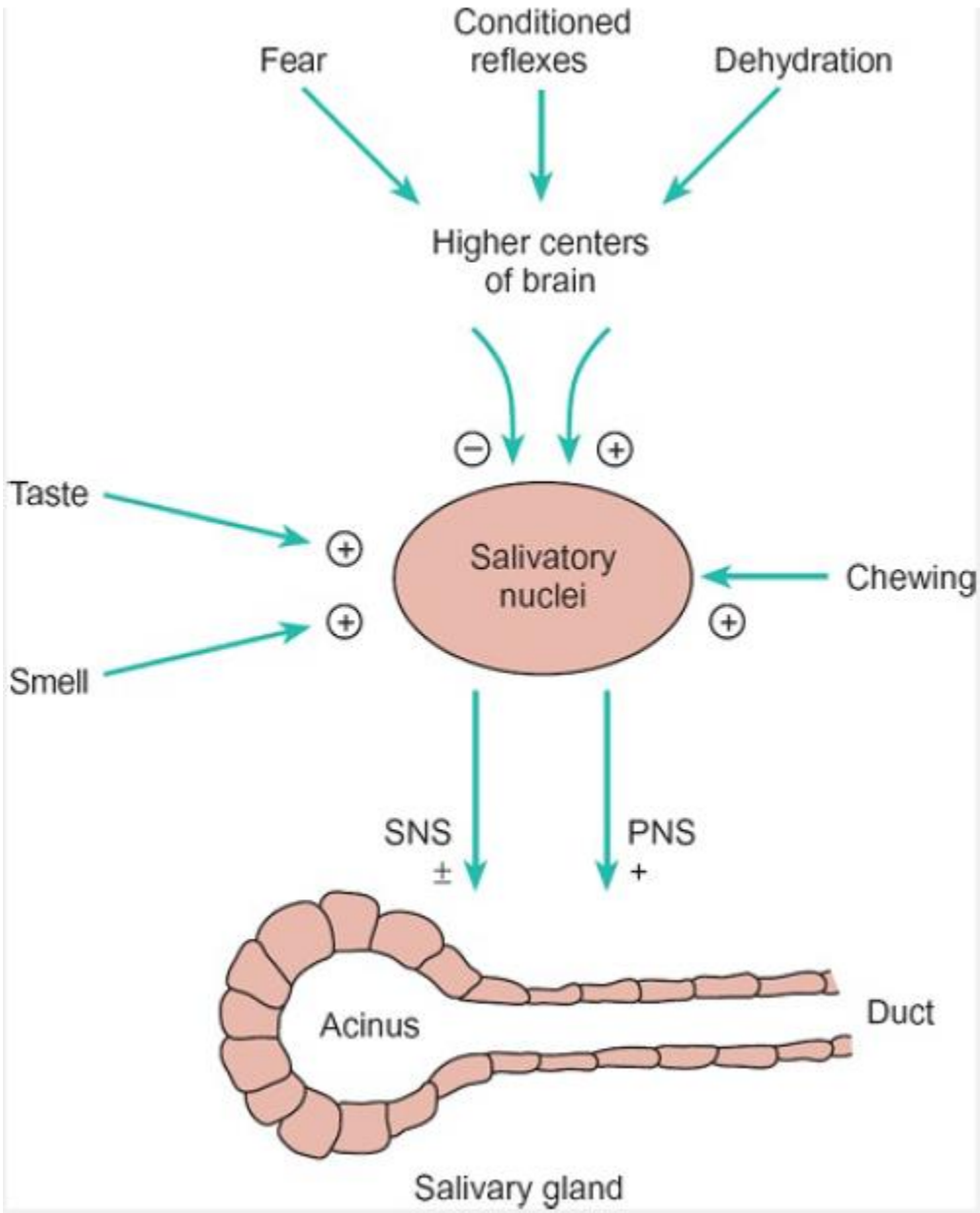
- Glands produce a little viscous saliva, rich in mucus.
- The neurotransmitter is norepinephrine.
- Vasoconstriction reaction (activation of α_1 adrenoceptors);
- Formation of more enzymes and mucins (activation of β_2 adrenoceptors).

Parasympathetic regulation of secretion

- Glands produce a lot of watery saliva.
- The neurotransmitter is acetylcholine.
- Local vasodilatation (the mediator is the vasoactive intestinal peptide VIP, which is released together with acetylcholine).
- Acetylcholine via muscarinic cholinoreceptors stimulates bicarbonate secretion and reduces sodium reabsorption and potassium secretion.
- Stimulates the secretion of kallikrein, which cleaves kininogens into kallidin, which dilates blood vessels and increases their permeability.

Regulation of salivation

- Salivatory reflex: unconditional (activation of mechanoreceptors and chemoreceptors of the oral cavity by food);
- conditional (thought about food).
- The salivatory center is in the medulla oblongata.



Mastication

- This is a mechanical process, as a result of which the food is crushed and turns into a food bolus.
- Function: grinding food into small pieces, mixing food with saliva (moistening and starting digestion), increasing salivation, evaluating the taste of food.
- The number of chewing movements depends on the food (25-30 times is optimal).
- Types of chewing movements:

- Opening and closing the mouth;
- Rotation of the jaw;
- Protraction and retraction of the jaw.

Mastication

- A complex reflectory act that has voluntary and involuntary components.
- It is activated by the mechanoreceptors of the oral cavity (the presence of food reflexively lowers the jaw, stretching the proprioceptors of the masticatory muscles raises it).
- The afferent nerve is the mandibular branch of the trigeminal nerve.
- Chewing center in medulla oblongata and cerebral cortex.
- Efferent nerve – trigeminal (CN V).

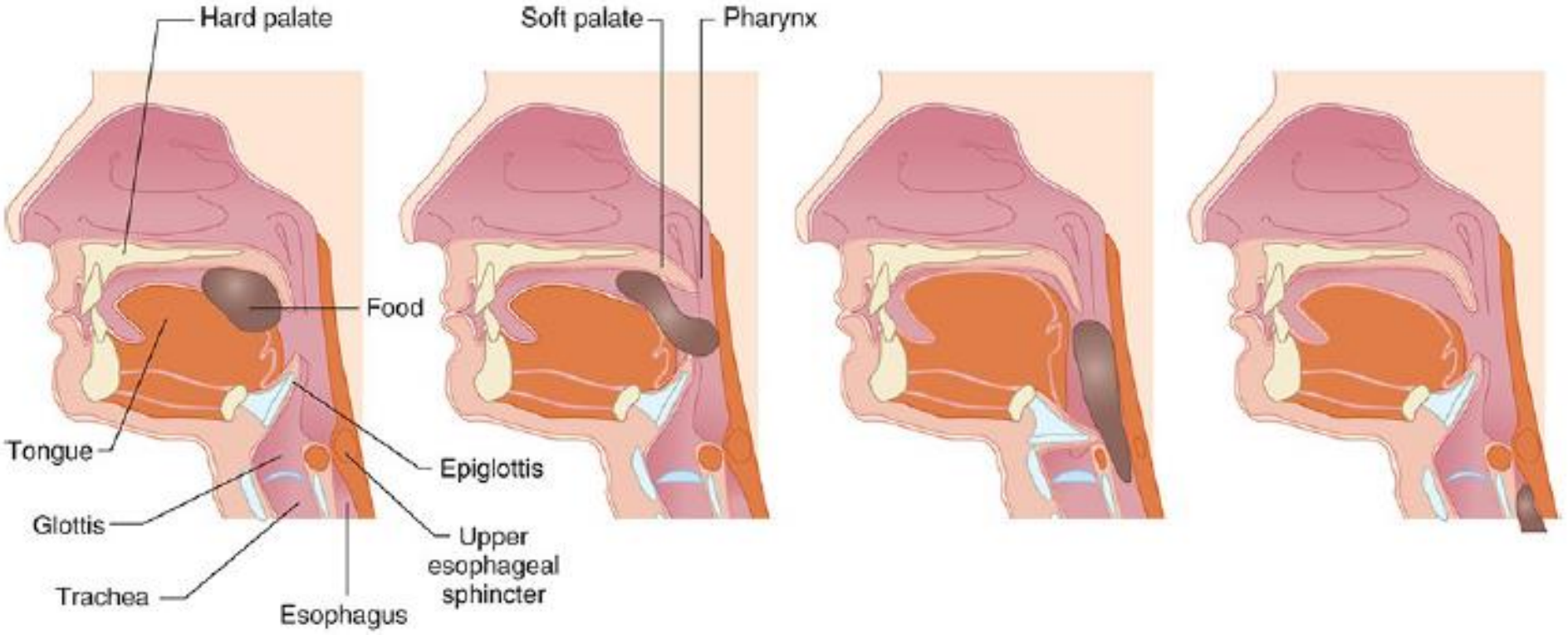
Swallowing

- This is the process of food passing from the oral cavity to the stomach.
- Swallowing disorder - dysphagia.
- Stages:

Oral (from the mouth to the pharynx);

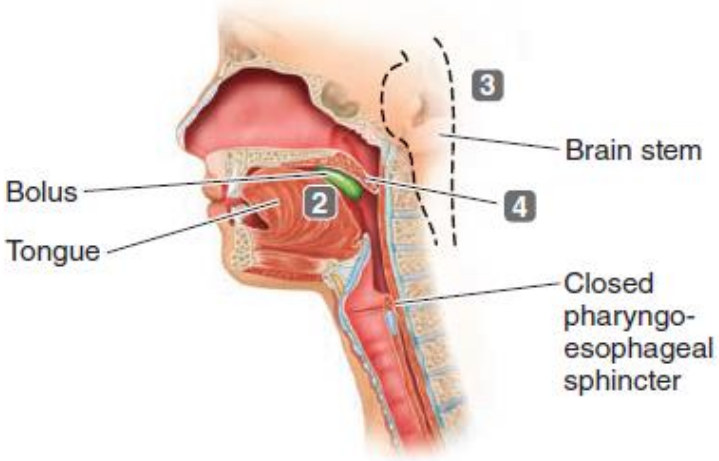
Pharyngeal (from the pharynx to the esophagus);

Esophageal (from the esophagus to the stomach).



Swallowing (oral phase)

- Voluntary;
- The mouth is closed;
- The tongue places a bolus on the middle line, the front part of the tongue rises to the palate;
- A bolus is placed on the root of the tongue (preparatory position);
- The back of the tongue rises to the hard palate, which pushes the bolus into the pharynx;
- Contraction of the tongue creates positive pressure in the back of the mouth, which also pushes food into the pharynx.



2 Tongue propels bolus to pharynx.

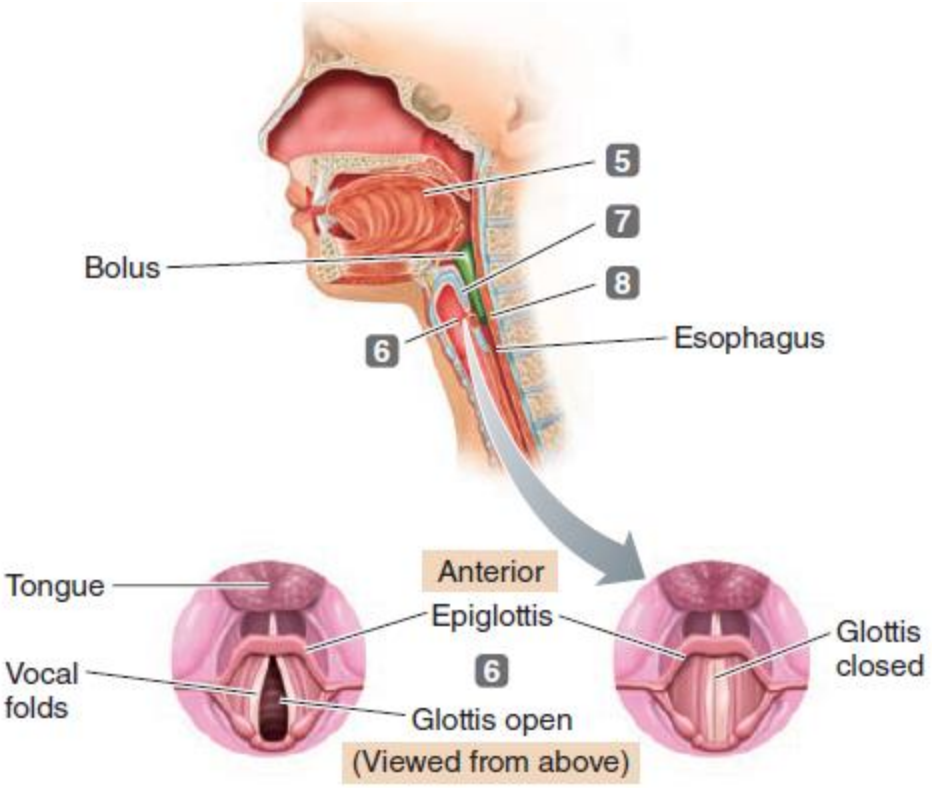
3 Swallowing center inhibits respiratory center in brain stem.

4 Elevation of uvula prevents food from entering nasal passageways.

Swallowing (pharyngeal phase)

- Involuntary, lasts 1-2 seconds.
- Food is pushed into the esophagus because:

1) the oral cavity is closed due to the position of the tongue and pressure in the oral cavity (closure of the palatopharyngeal arch);
2) The nasopharynx is closed due to the elevation of the soft palate with the uvula;
3) The larynx is closed due to closure of the vocal cords, it moves up and forward (this also stretches the opening of the esophagus), closure of the epiglottis – stopping breathing (swallowing apnea);
4) The upper esophageal sphincter relaxes;



5 Position of tongue prevents food from reentering mouth.

6 Tight alignment of vocal cords prevents food from entering trachea.

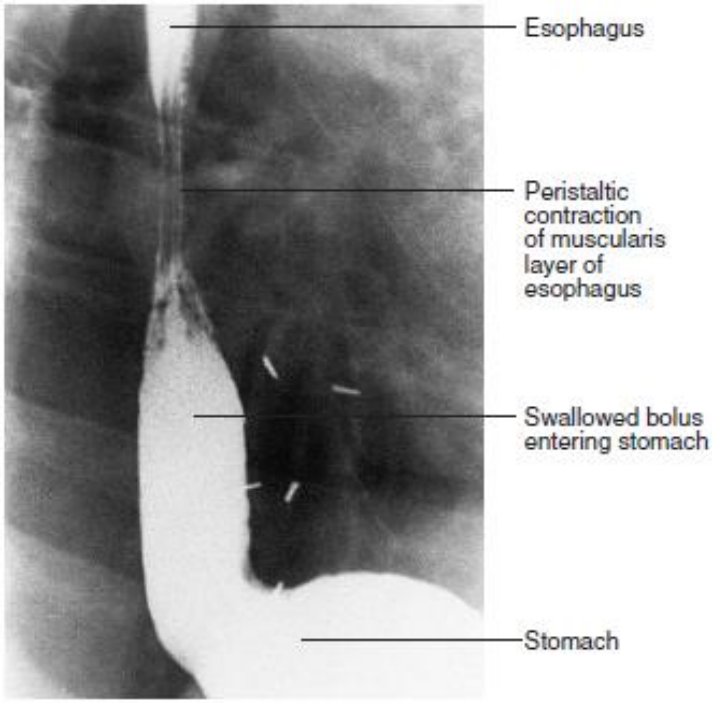
7 Epiglottis folds over closed glottis.

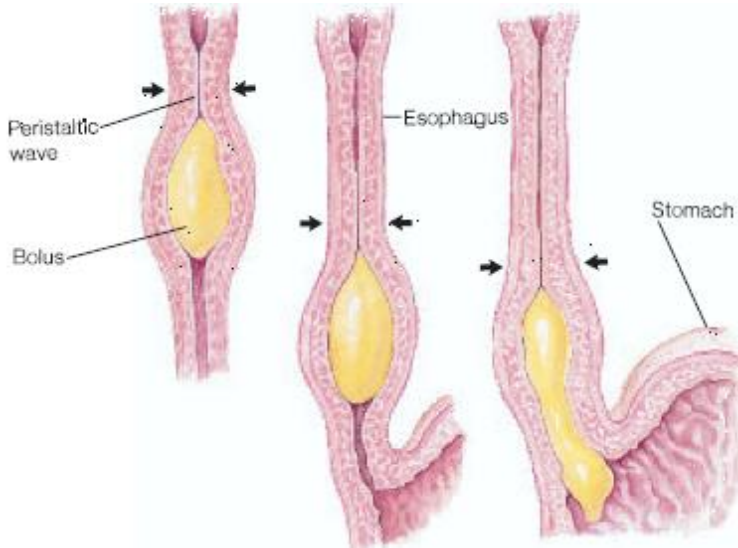
8 Contraction of pharyngeal muscles pushes bolus through opened pharyngoesophageal sphincter into esophagus.

Swallowing (esophageal phase)

- Involuntary;
- Gravity + peristalsis (stronger, so swallowing is possible even while standing on the head);
- Peristaltic waves of the esophagus (speed 3-5 cm/second):

- Primary (begins in the pharynx and goes down the esophagus).
- Secondary (starts in the esophagus, when the wall is stretched, vago-vagal reflex, continues until the bolus is pushed to the stomach.
- Acetycholine provides peristalsis, VIP and NO - relaxation of sphincters.

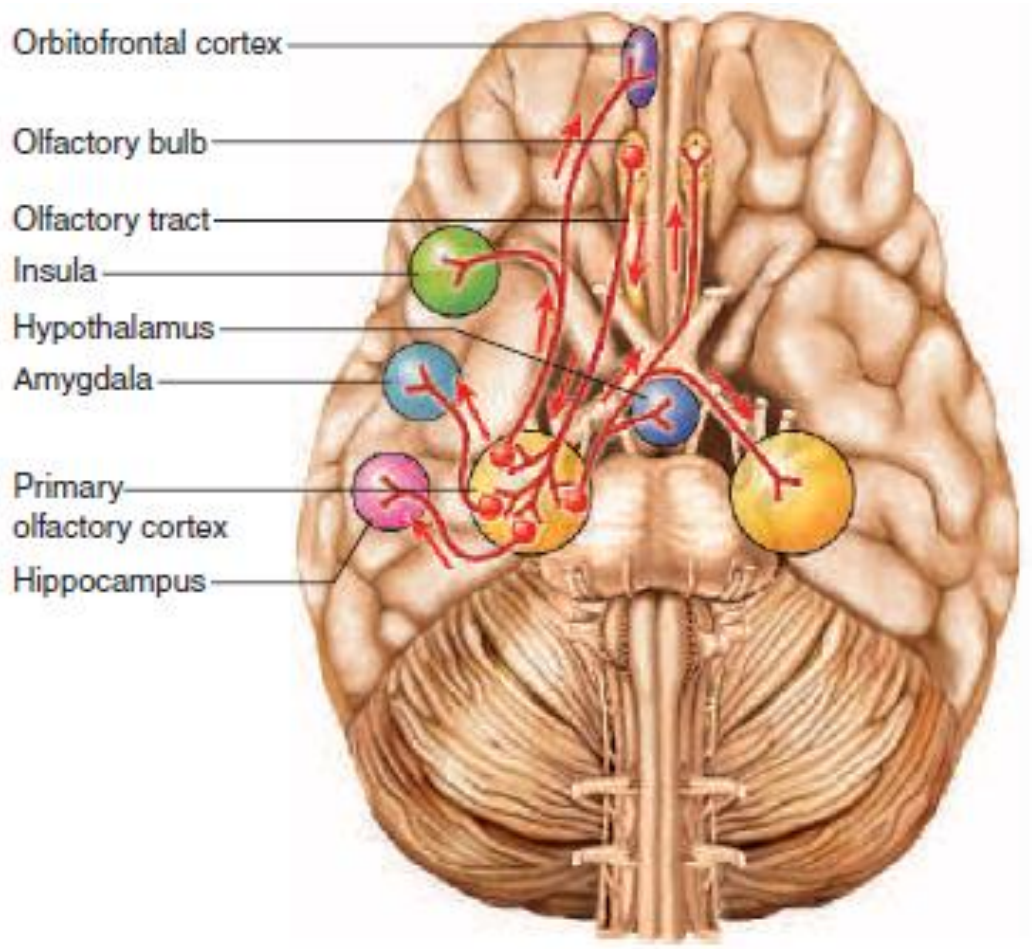




Olfactory and gustatory systems

- They help to find food, evaluate quality and safety.
- The olfactory system identifies dangerous and irritating substances in the environment.
- Odor information influences social interactions, defensive responses, reproduction, feeding behavior.
- The taste system is involved in the regulation of digestion.

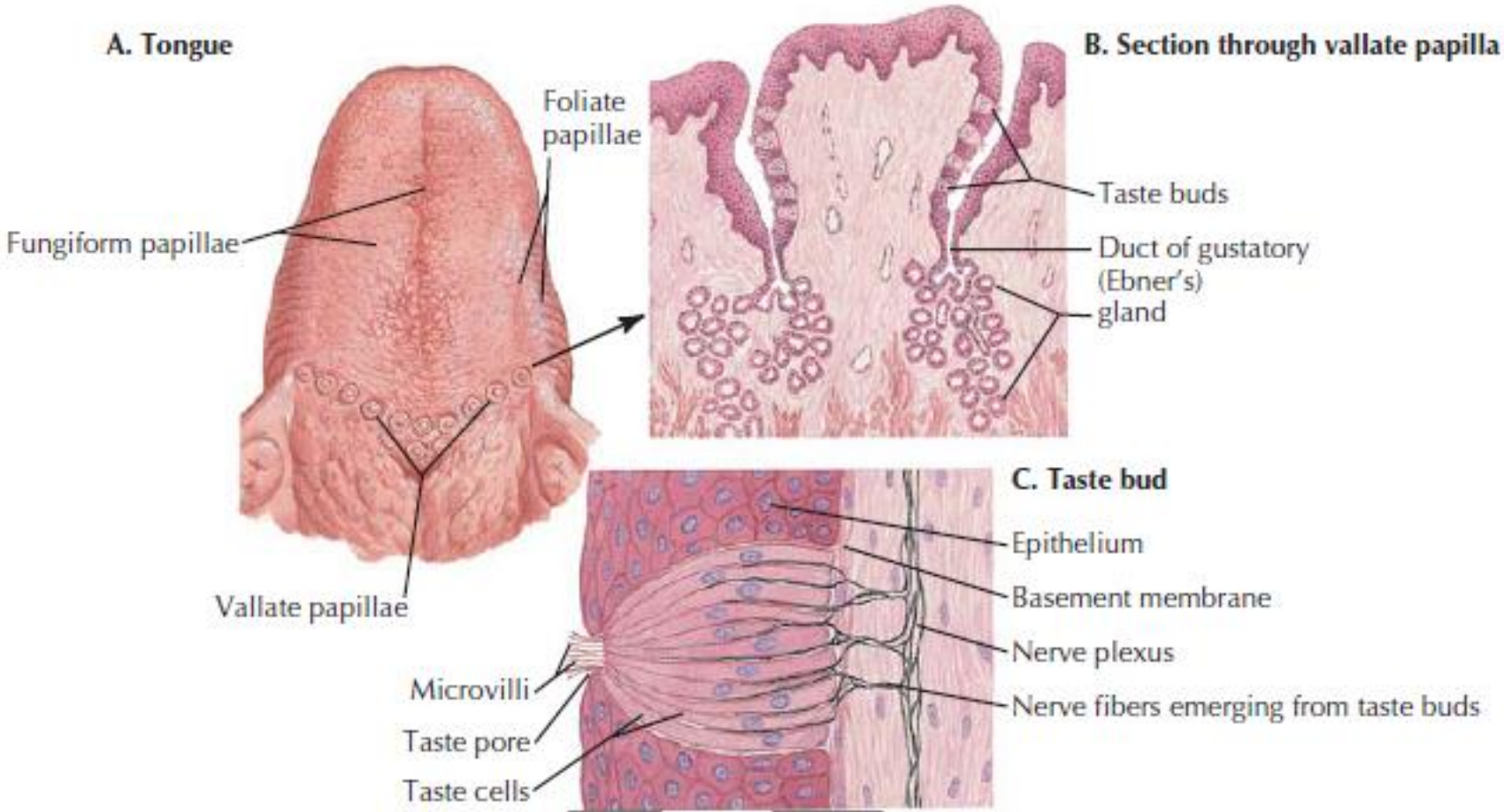
Olfactory sensory system



- Olfactory receptors;
- Olfactory nerve (CNI);
- Olfactory bulbs;
- Olfactory tract;
- Primary olfactory cortex (piriform);
- Orbitofrontal cortex;
- Projections to amygdala, parahippocampal gyrus, hypothalamus.

Taste buds

- There are 4 types of papillae on the tongue: fungiform, circumvallate, foliate, and filiform (this type doesn't contain taste buds).
- Taste buds consist of ≈ 100 taste receptors (types I-III).



Tastes

1. Sour (acids) caused by hydrogen ions, receptors are ionotropic.
2. Salty (salts) cause sodium ions and other cations, the receptors are ionotropic.
3. Sweet (sugars, alcohols, aldehydes, ketones, ethers, some amino acids and metals), receptors are metabotropic.
4. Bitter (alkaloids, some inorganic substances), metabotropic receptors.
5. Umami (glutamate), metabotropic receptors.

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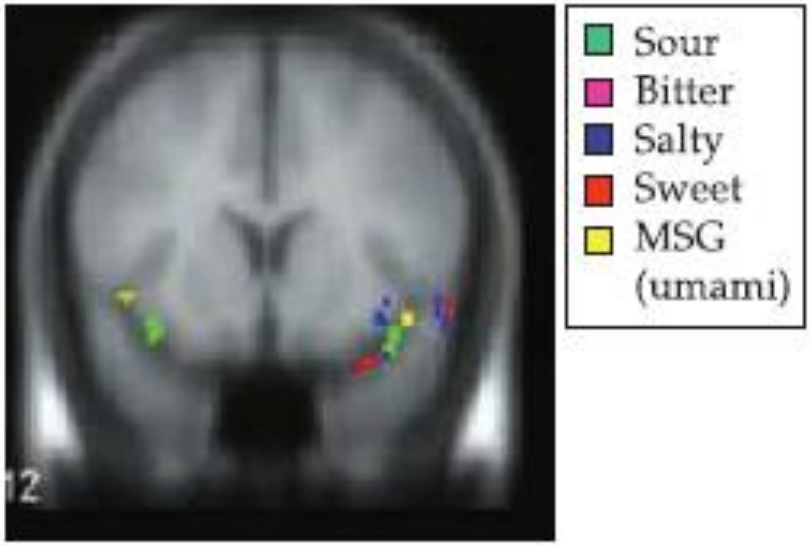
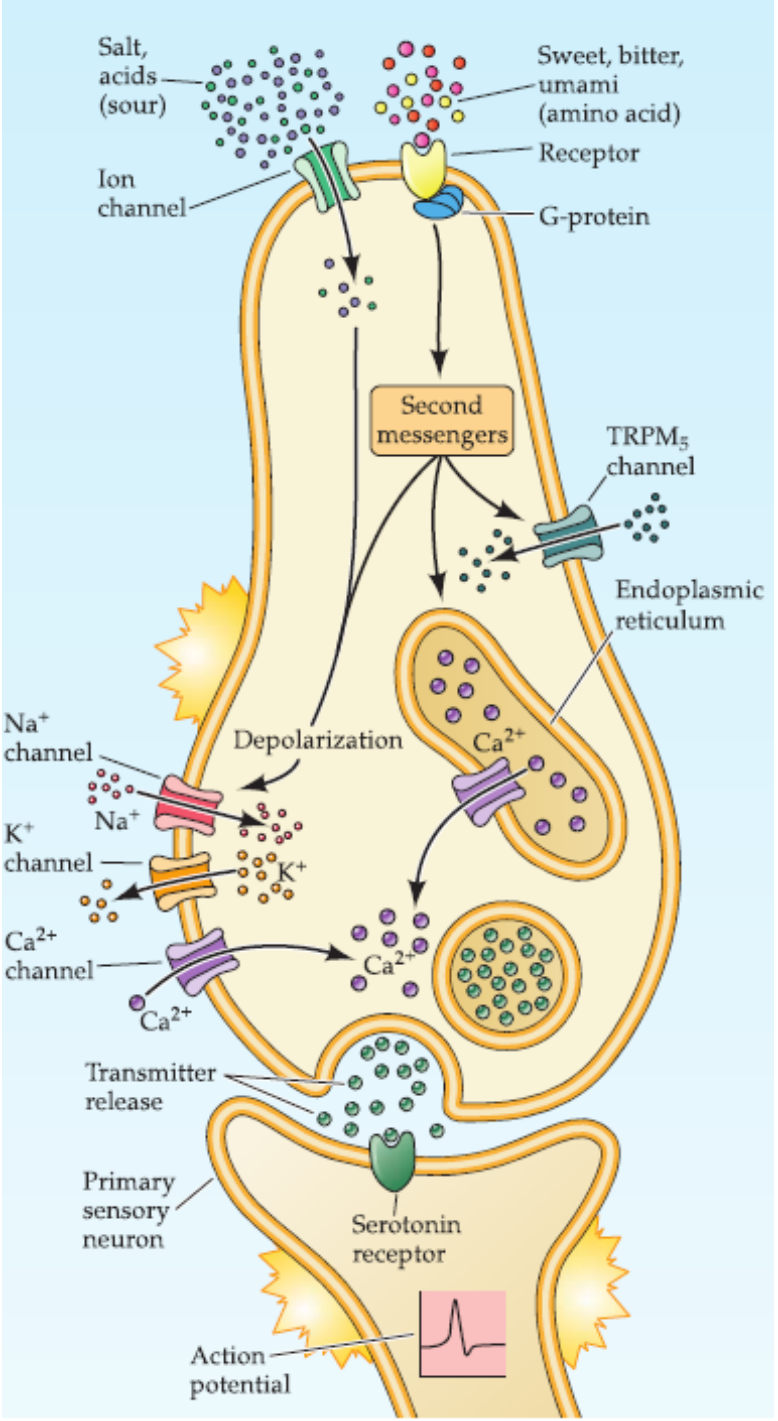
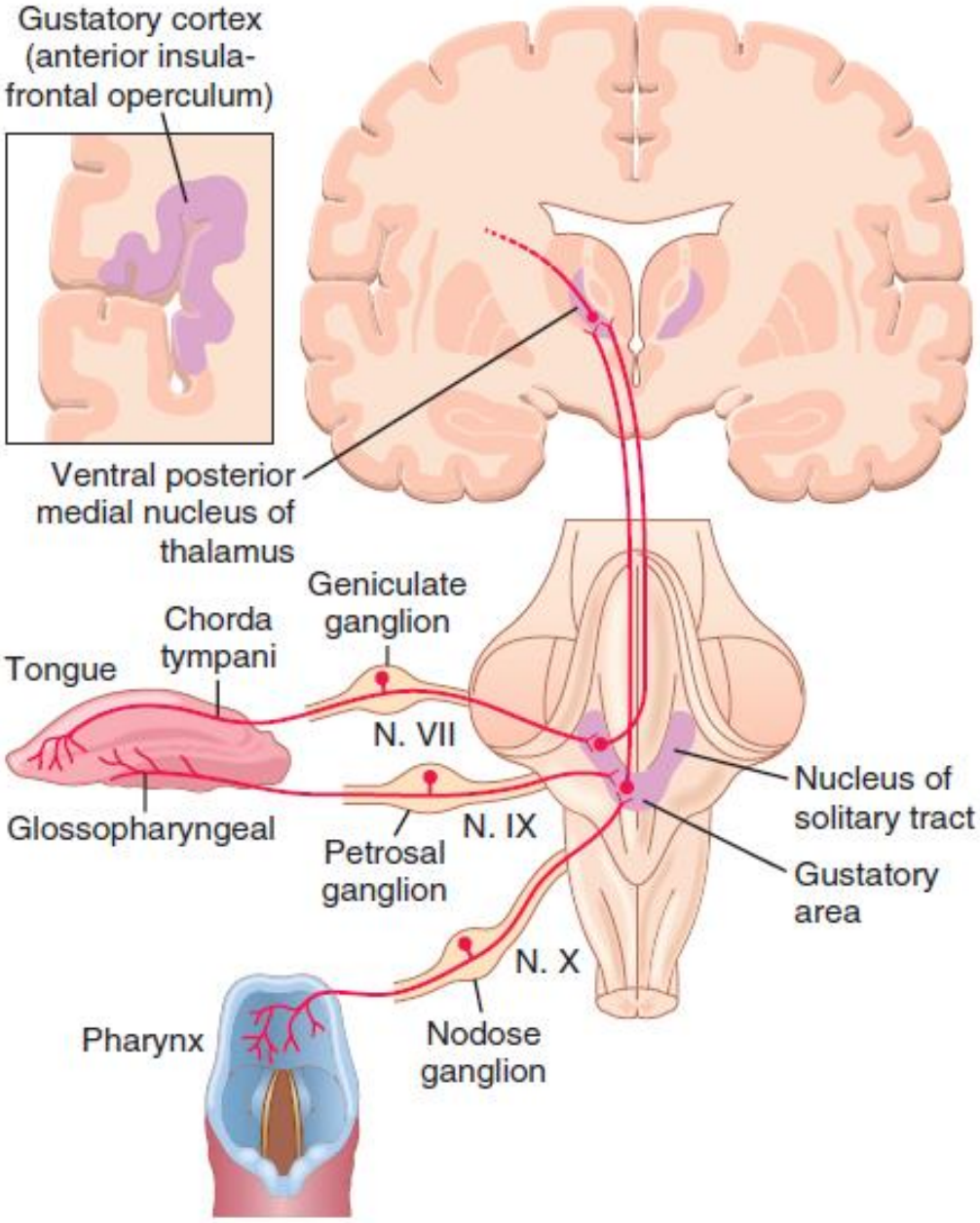




Transduction

- Tastant binding to its receptors activates receptors: ionotropic receptors generate depolarization due to ions flux, metabotropic receptors use G protein gustducin which leads to production of secondary messengers and release of transmitter (serotonin).

Neural pathways



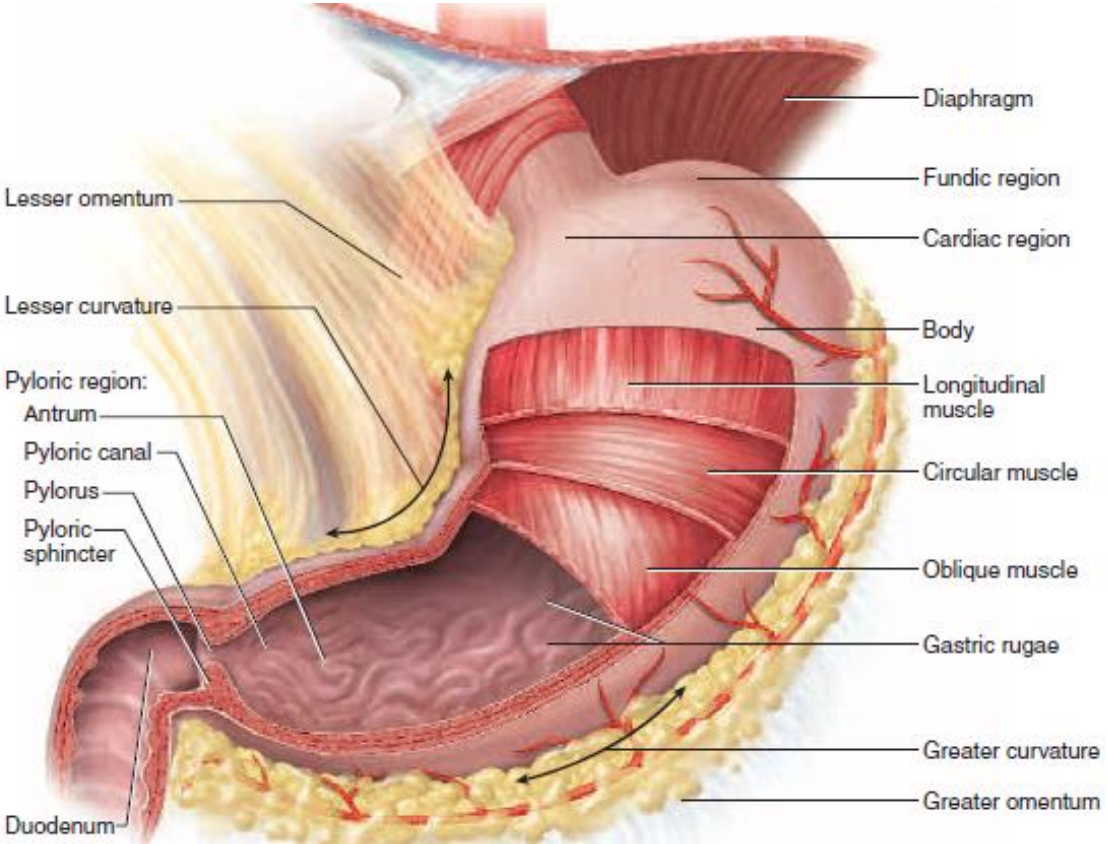
- Inn. of tongue: anterior 2/3 – CN VII, posterior 1/3 – CN IX, pharynx – CN X.
- 1 ordered neuron – ganglions of CN VII, IX, X.
- 2 ordered neuron – nucleus of solitary tract.
- 3 ordered neuron – ventral posterior medial nucleus of thalamus.
- Gustatory cortex.

Functions of stomach

- Digestive (proteins), bolus → chyme.
- Mixing, storing, and evacuation of chyme.
- Defensive (hydrochloric acid kills bacteria).
- Excretory function.
- Production of intrinsic Castle (gastric) factor (effect on haematopoiesis).

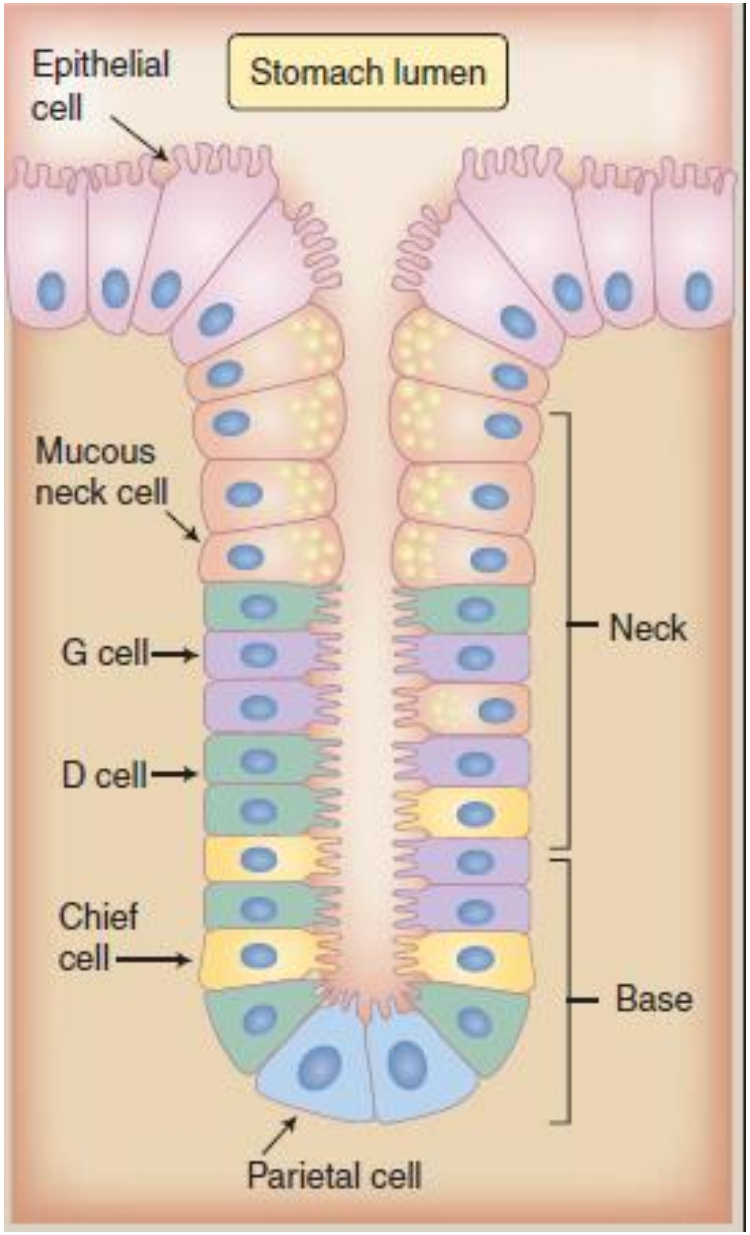
Stomach structure

- The hollow organ lies under the diaphragm on the left.
- The empty volume is 50 ml, after a meal up to 1-1.5 liters, a maximum of 3-4 liters.
- Parts: cardia, fundus, body, antrum, pylorus.



Gastric glands

- Fundic glands (fundus and body): parietal (oxyntic) cells, chief cells, mucous neck cells, enterochromaffin cells (EC-cells), enterochromaffin like cells (ECL-cells).
- Pyloric glands: chief cells, mucous neck cells, G-cells, D-cells, EC-cells , ECL-cells.
- Cardiac glands: chief cells, mucous neck cells, EC-cells , ECL-cells.



Types of cells in stomach

Cells	*Secretion*
Chief	*Pepsinogen, gastric lipase, gelatinase*
Parietal (oxyntic)	*Hydrochloric acid, intrinsic factor*
Mucous neck cells	*Mucus*
G-cells	*Gastrin*
D-cells	*Somatostatin*
EC-cells	*Serotonin*
ECL-cells	*Histamin*

Gastric juice

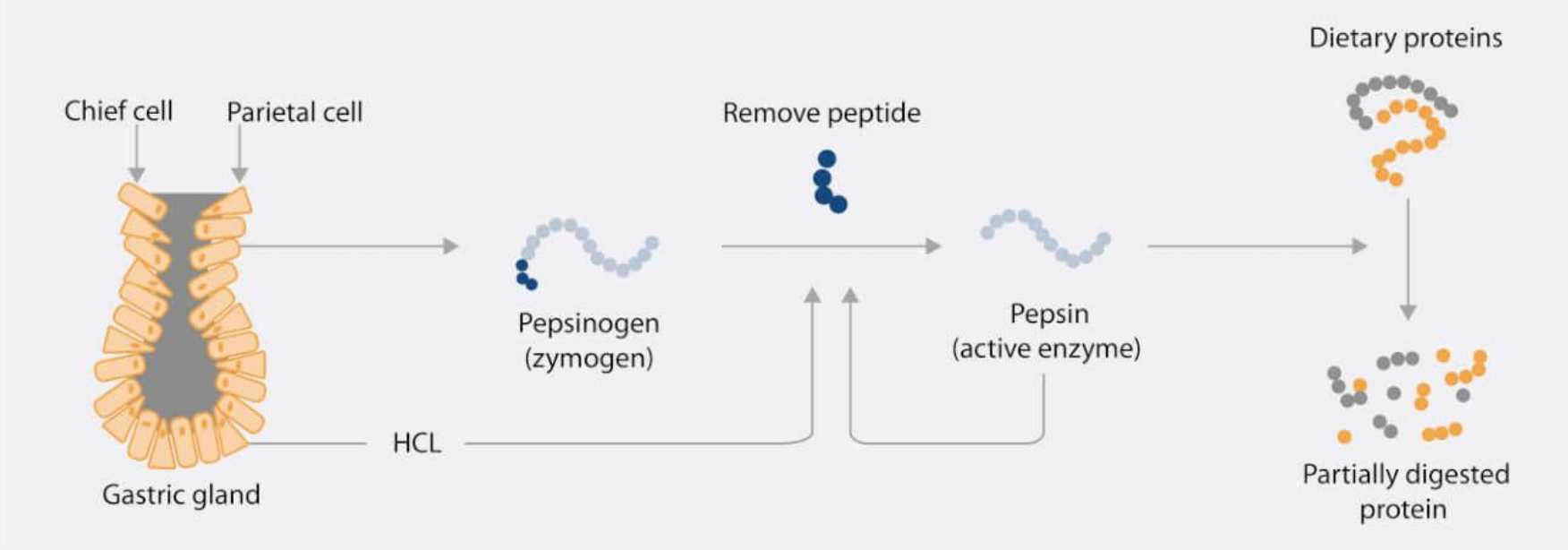
- 1.2-1.5 l/day.
- pH 0.9-1.2.
- Specific gravity 1.002-1.004.
- Composition: 99.5% - water, solids:

- Organic: enzymes (pepsin, gastric lipase, gelatinase), mucins, Castle's intrinsic factor.

- Inorganic: hydrochloric acid (HCl), sodium, potassium, calcium, phosphates, sulfates.

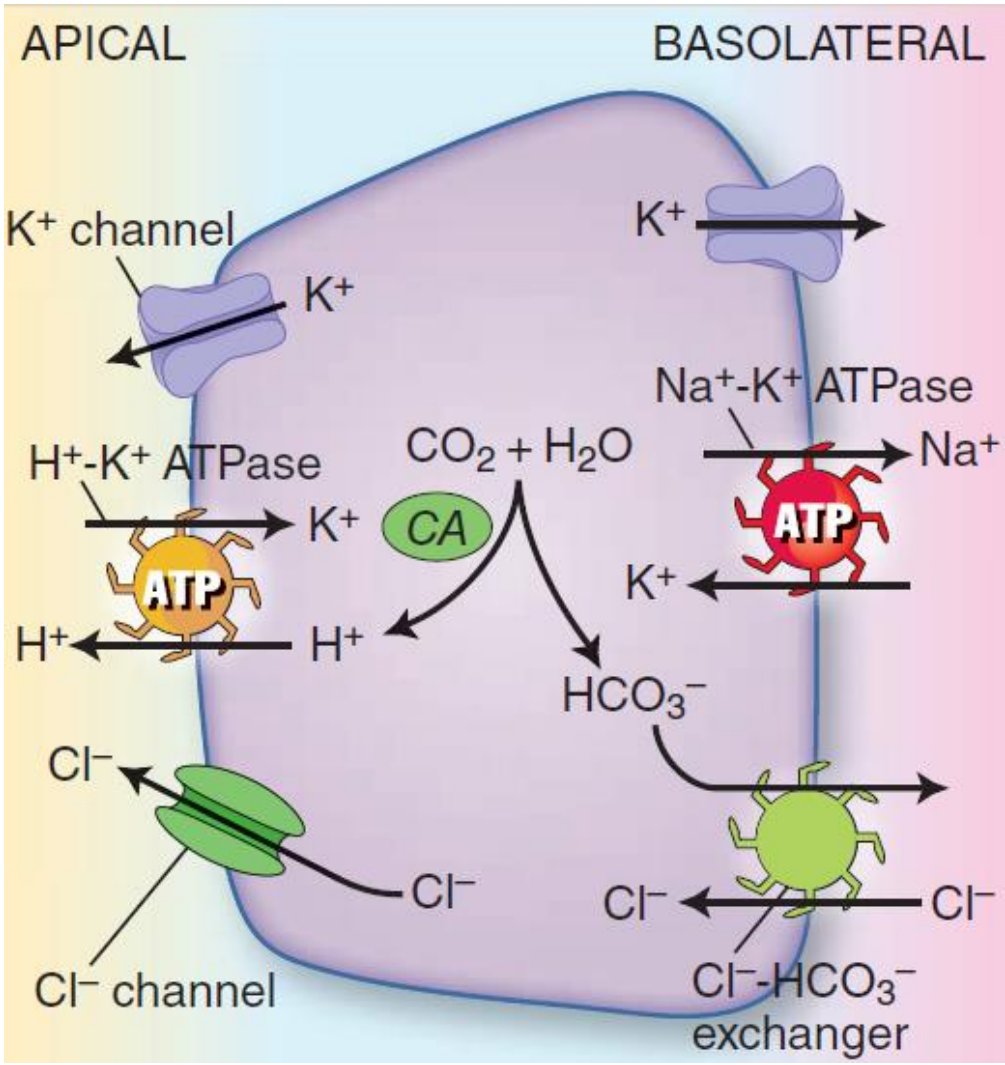
Pepsinogen

- Zymogen is activated by hydrochloric acid.
- Optimal pH 1,5-2.
- There are 2 major types of pepsinogens (pepsinogen I is produced mainly by chief cells in fundus and pepsinogen II is synthesized mostly by antral mucosa).
- Endopeptidase has cleavage specificit: cleavage of peptide bonds of aromatic amino acids (tyrosine, tryptophan, phenylalanin).
- Products of hydrolysis – peptons and peptides.



Secretion of hydrochloric acid

- Carbonic anhydrase converts H_2O and CO_2 into carbonic acid H_2CO_3, which dissociates into bicarbonate, which goes into the blood (alkaline tide) in exchange for chloride ions, which go into the lumen of the stomach through chloride channels.
- Hydrogen ions are secreted by H^+-K^+ ATPase (proton pump) into the lumen of the stomach.
- The proton pump is blocked by blockers (omeprazole).



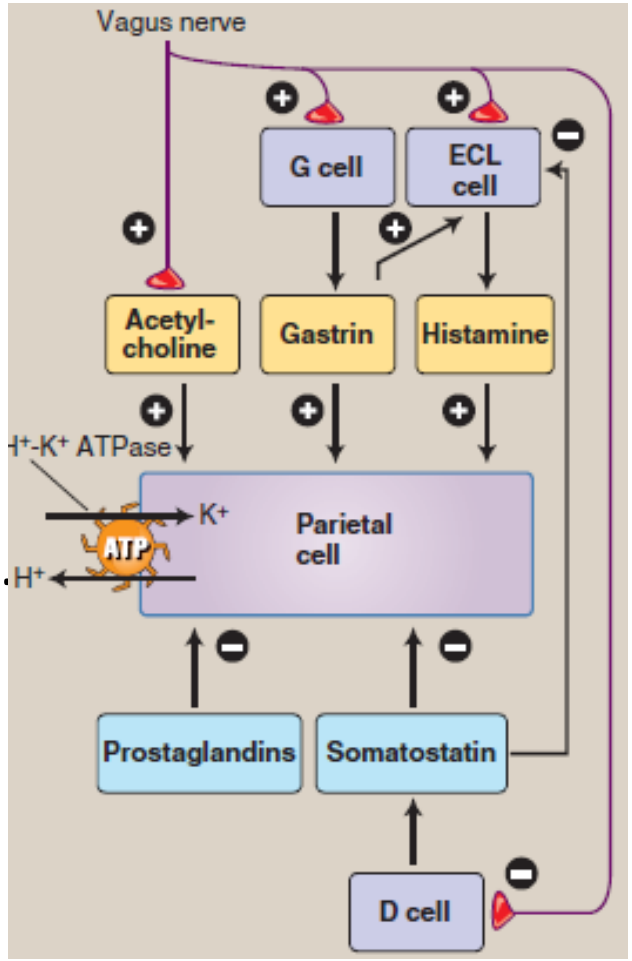
Regulation of HCl secretion

- Stimulation:

1. The vagus, transmitter is acetylcholine, M_3 cholinergic receptors (muscarinic), the second messenger IF_3, calcium activates the proton pump. Blocked by atropine.
2. Gastrin, gastrin (CCK_B) receptors, second messenger cAMP, calcium activates the proton pump. Blocked by proglumide.
3. Histamine, histamine (H_2) receptors, secondary messenger cAMP, calcium activate sthe proton pump. They are blocked by ranitidine, cimetidine.

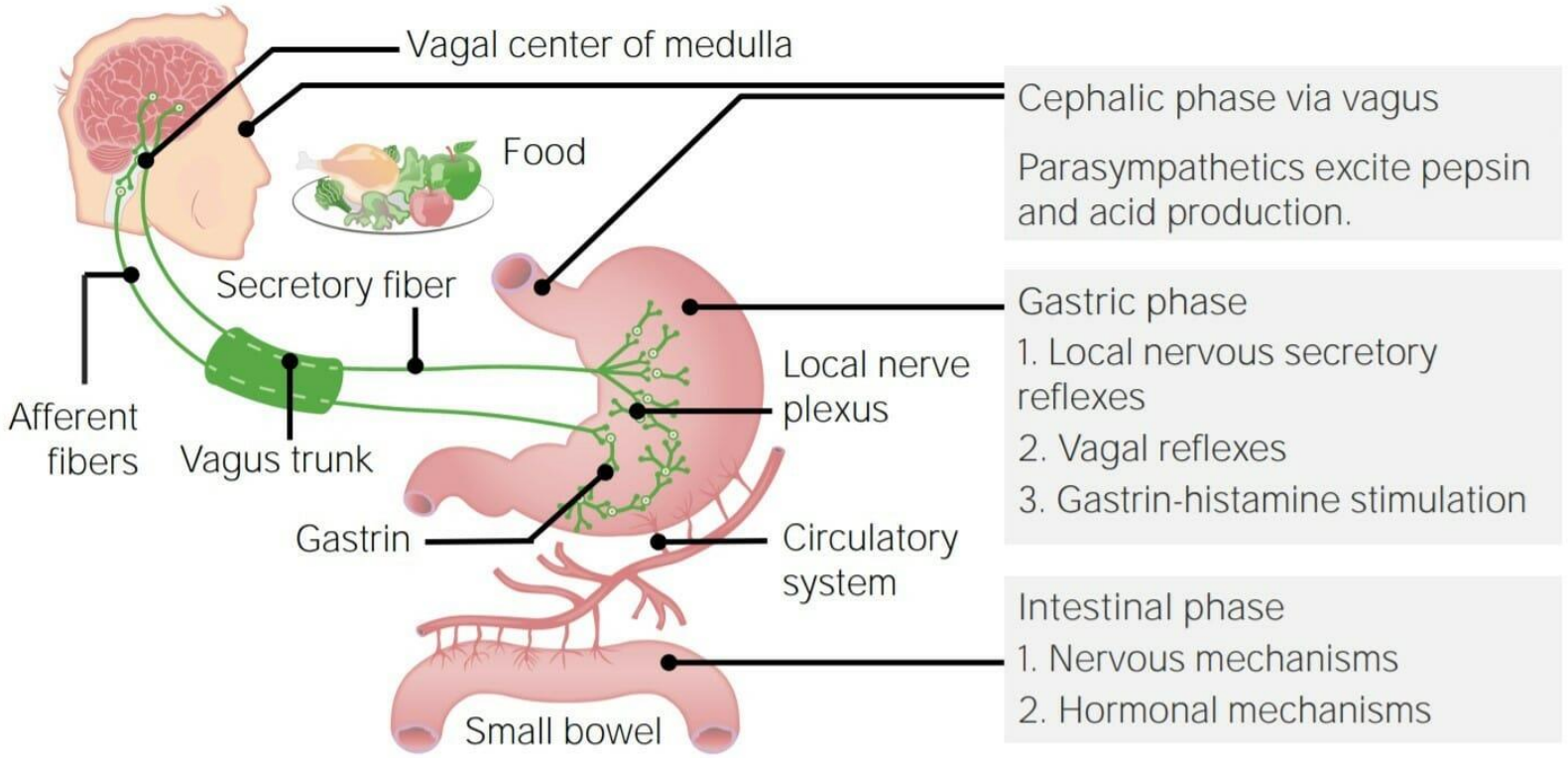
- Inhibition:

1. Somatostatin, G_i-coupled receptors (reduce cAMP levels).
2. Prostaglandins (E_2) potentiate the action of somatostatin.
3. Cholecystokinin, secretin, gastric inhibitory peptide.



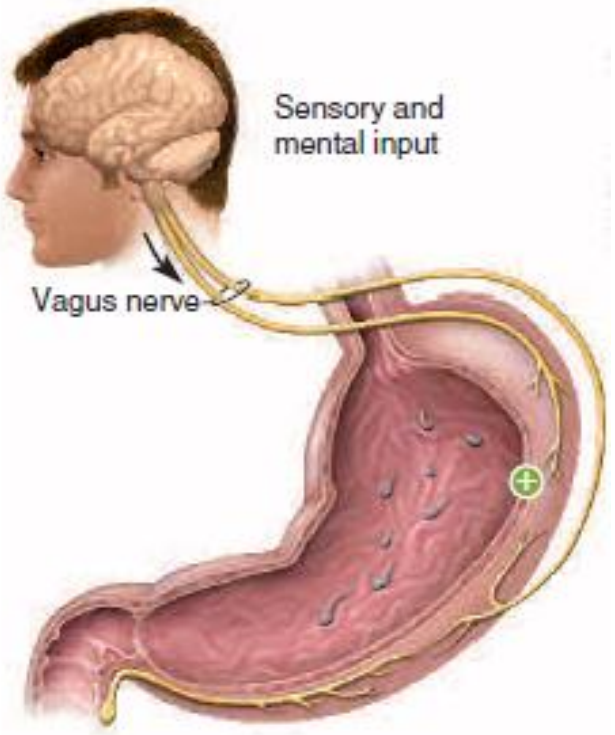
Phases of gastric secretion

1) Cephalic: 20-30% of secretion, occurs before food enters the stomach.
2) Gastric: 60% of secretion, occurs when chyme in the stomach.
3) Intestinal: 10% of secretion, occurs when chyme in the duodenum.



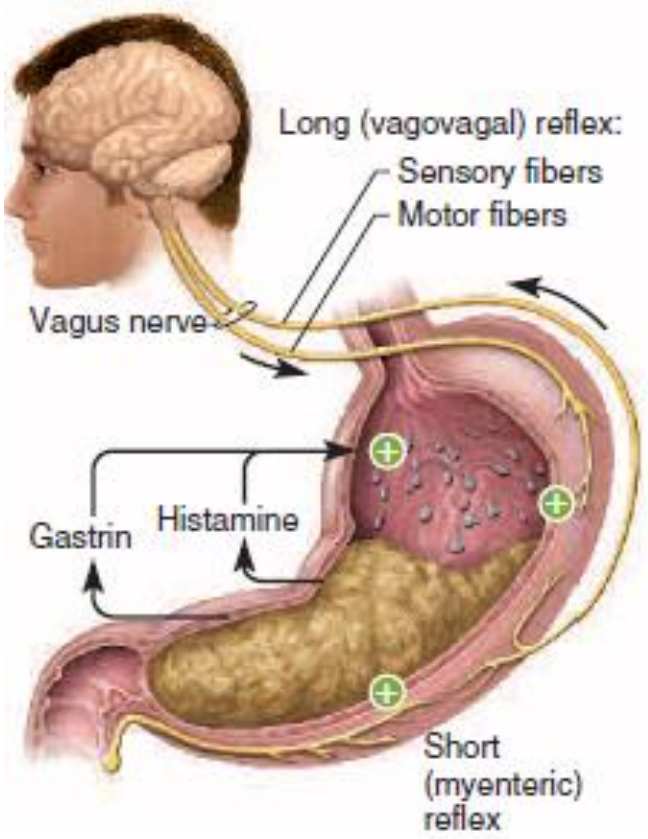
Cephalic phase

- Unconditioned reflex: irritation of the receptors of the oral cavity → afferent fibers CN V, VII, IX, X → nucleus of solitary tract → dorsal motor nucleus of the vagus → efferent fibers of the vagus → parietal cells (HCl) or G cells → gastrin → parietal cells (HCl), or ECL cells → histamine → parietal cells (HCl).
- Conditioned reflex: sight of food → cortex → hypothalamus → dorsal motor nucleus of the vagus → vagus ...
- Sympathetic nervous system (stress response) inhibits secretion.



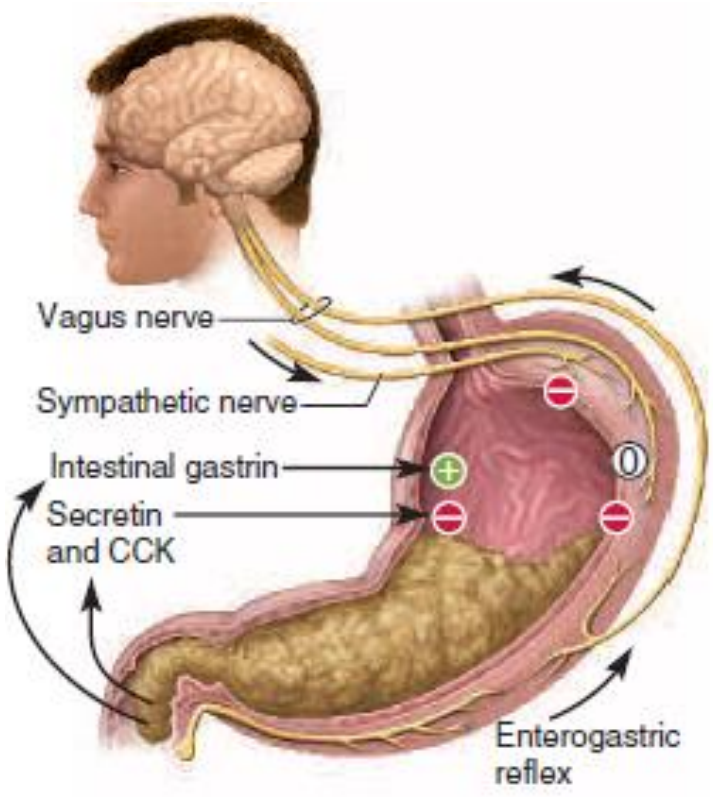
Gastric phase

- Distension of the stomach activates mechanoreceptors → afferent fibers of the vagus → dorsal motor nucleus of the vagus → efferent fibers of the vagus → parietal cells (HCl) – vago-vagal reflex.
- Irritation of the mucous membrane activates the receptors of the neurons of Meissner's submucosal plexus (enteric system).
- Peptides and extractive substances activate G-cells → gastrin → parietal cells (HCl).
- Protons activate D-cells → somatostatin → inhibits secretion (negative feedback).
- Sympathetic nervous system inhibits secretion.



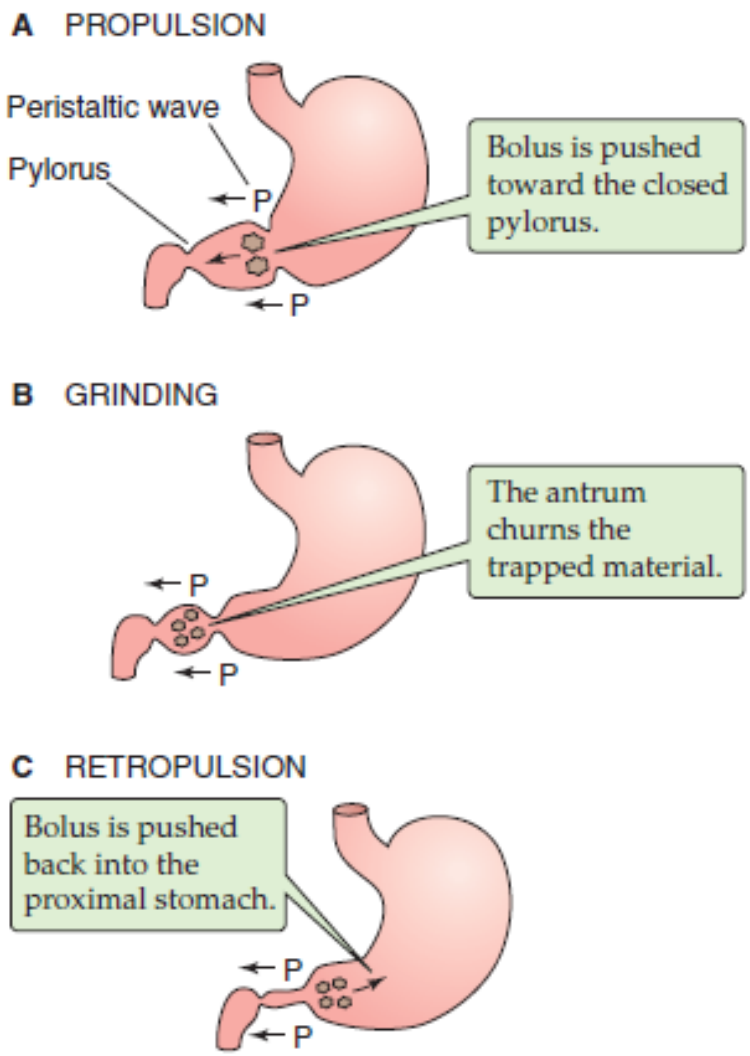
Intestinal phase

- Protons in chyme activate duodenal G cells → intestinal gastrin → parietal and chief cells.
- S-cells → secretin → inhibits parietal cells, but stimulates chief cells.
- Gastric inhibitory peptide, VIP, cholecystokinin inhibit gastric secretion.
- Enterogastric reflex (local, Auerbach's nerve plexus) suppresses motility and secretion of the stomach.



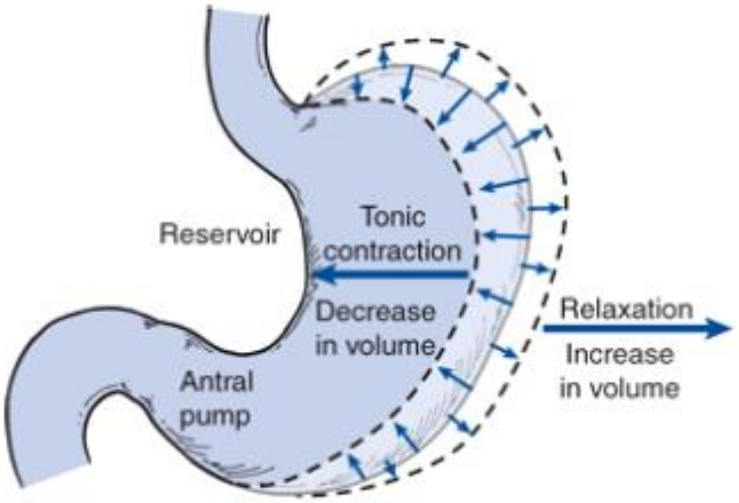
Motility of the stomach

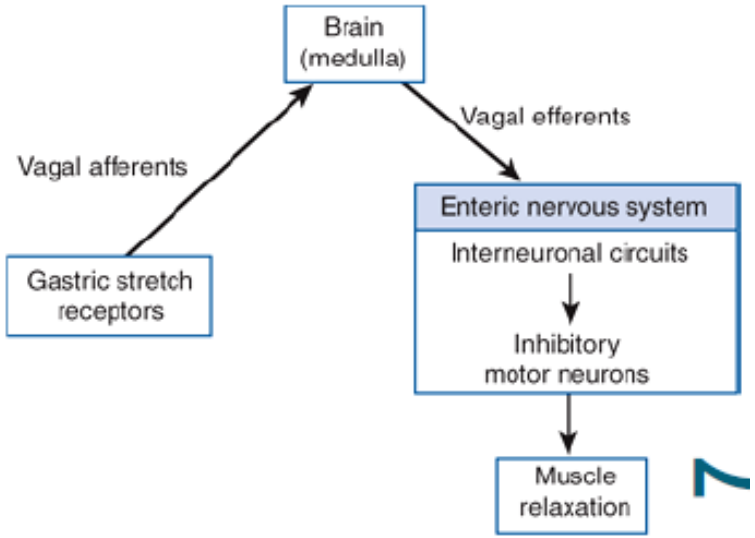
- Accepting food (receptive relaxation).
- Storing food.
- Mixing food with gastric secretion, grinding of bolus.
- Emptying chyme to the small intestine.
- Hunger contractions.



Receptive relaxation

- Accommodation of the stomach to a change in volume (from 50 ml to 1-3 l) without a significant increase in intragastric pressure.
- Stretching of the stomach wall causes reflex relaxation (vago-vagal reflex).
- Transmitters – VIP and NO.
- The peptones in the chyme activate G cells, which secrete gastrin, which causes relaxation.





Emptying of the stomach

- At a time - 3-5 ml of chyme, takes 3-4 hours, with fatty food, the time increases to 6-9 hours.
- Factors affecting:
- The rate of evacuation of isotonic liquid is proportional to the volume (stretching) of the stomach;
- Osmolality (hypertonic and hypotonic content is evacuated more slowly than isotonic)
- pH: the lower the pH, the slower the evacuation;
- Content consistency: large particles slow down evacuation (liquid chyme speeds it up);
- Chemical composition (carbohydrates are faster than proteins, and proteins are faster than lipids);
- The difference in intragastric and duodenal pressure;
- Pyloric sphincter resistance.

Hunger contractions

- The function is cleaning of food residues, gastric juice and exfoliated epithelium.
- Migrating motor complex (MMC), pacemaker - smooth muscles of the circular layer of the stomach.
- Activated by motilin (Mo cells).
- Occurs every 90 minutes.
- Cycle: phase I - no contractions, phase II - irregular contractions, phase III - regular strong contractions.