Propulsion and Mixing of Food in the Alimentary Tract

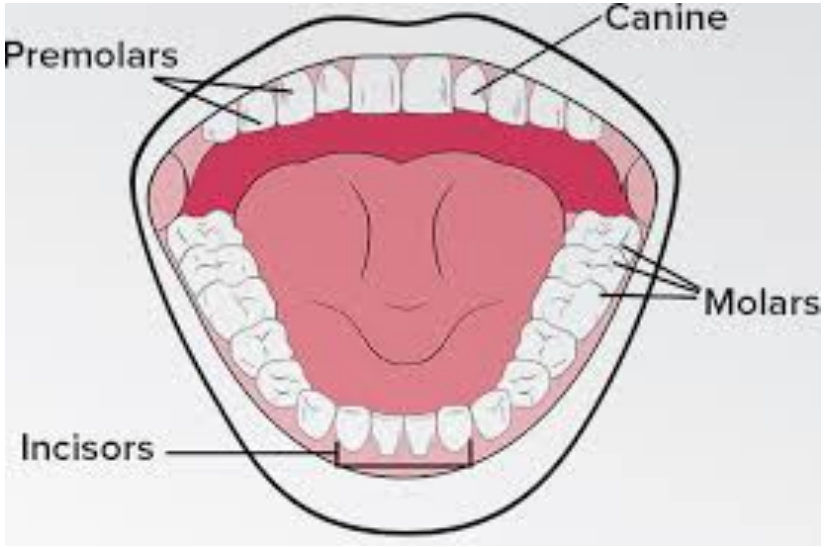
Dr. Iman Aolymat

imank@hu.edu.jo

Ingestion of food

- Hunger → Amount of food
- Appetite → Type of food

Chewing (mastication)

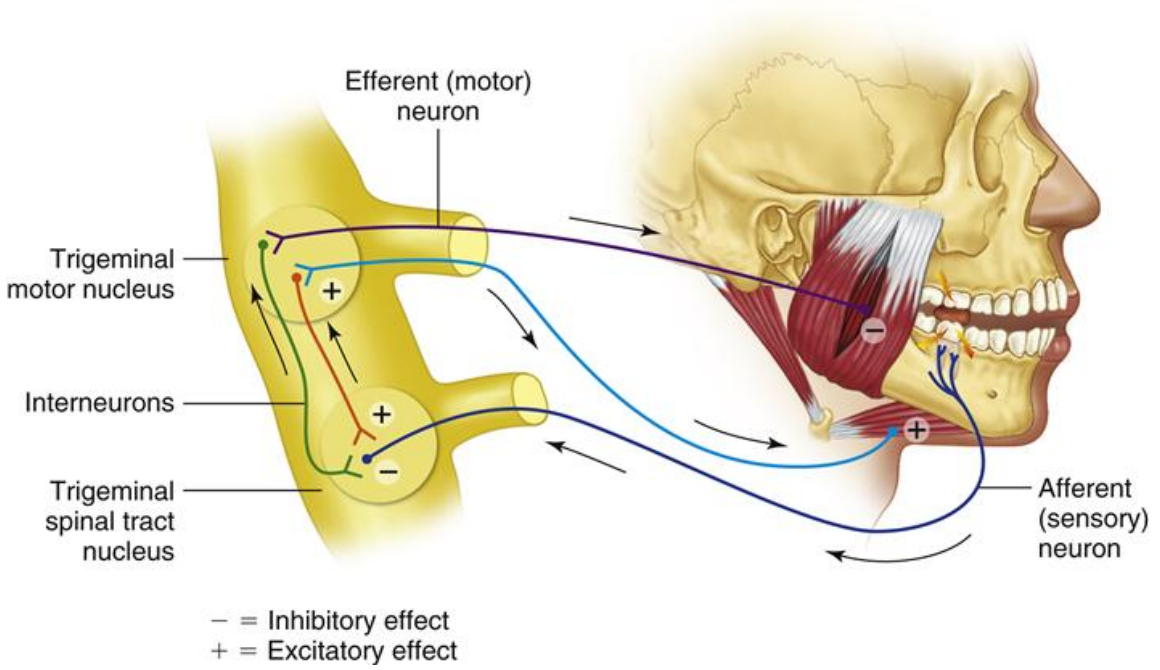


- Teeth
  - ✓Incisors-cutting
  - ✓Molars-grinding
- Jaw muscles

- **Purpose of Chewing -**
  - Breaks indigestible cellulose
  - ↑ surface area → ↑digestive enzymes act + ↑ digestion rate
  - Mixes food with saliva -
    - Begins digestion of starches (α-amylase, lingual lipase)
    - Lubricates food for swallowing
  - Prevents excoriation of GIT
  - Improves food emptying from stomach

Nervous Control of Chewing

- Innervation -
  - Controlled by nuclei in BS
  - 5th cranial nerve motor branch innervates muscles of mastication
  - Stimulation of reticular areas in BS taste centers → rhythmical chewing movements.
  - Stimulation of areas in hypothalamus, amygdala, & CC near areas for taste and smell → chewing.



- Chewing reflex mechanism –(inhibitory & excitatory)

  -Food in mouth → relax muscles of mastication → jaw drops → stretch reflex → rebound contraction → jaw rise, teeth closure & pushes food against lining of mouth → repetitive action

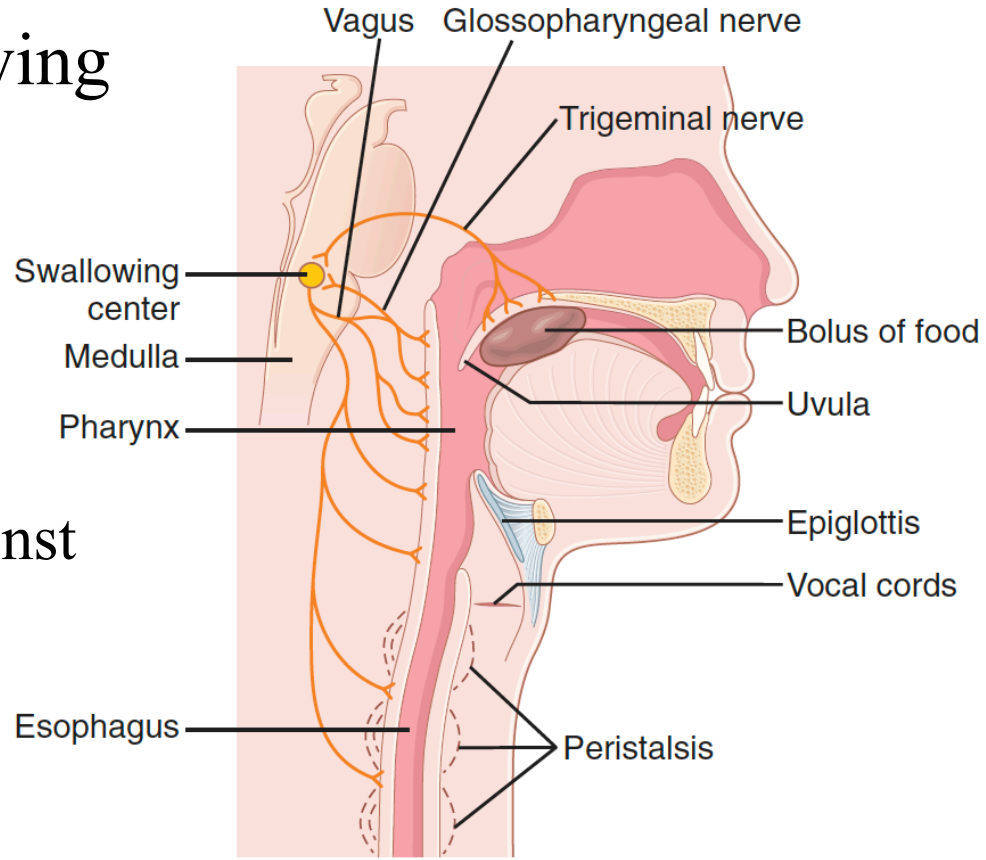
Swallowing (deglutination)

- Pharynx subserves respiration and swallowing

Three stages -

- Voluntary

- Initiates swallowing process
- Food is pulled upward & backward to pharynx against palate by tongue



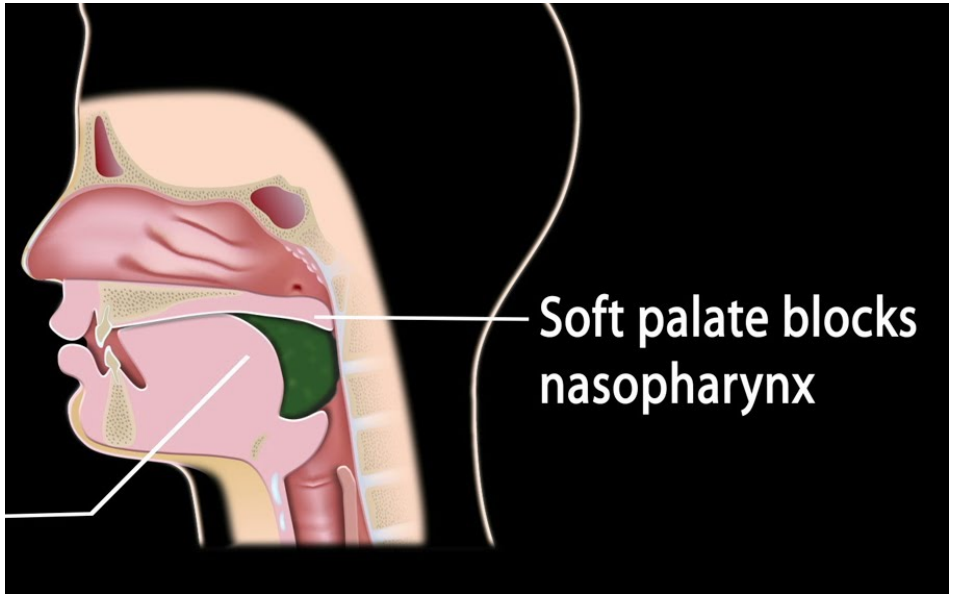
Swallowing (deglutination)

- Involuntary
  - Pharyngeal - passage of food through pharynx into esophagus
  - Esophageal - passage of food from pharynx to stomach

Pharyngeal Stage of Swallowing

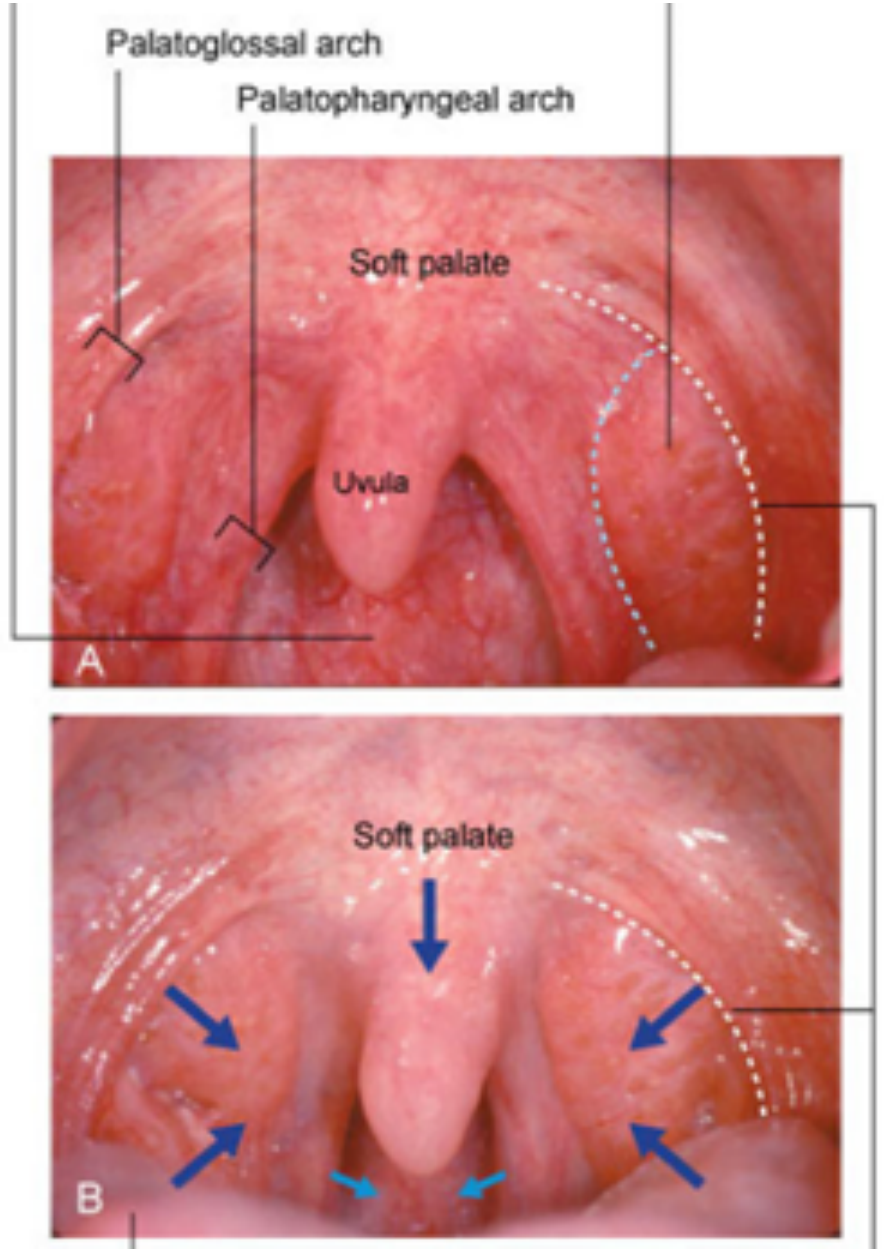
Food in pharynx - tactile stimulation of epithelial swallowing receptors around opening of pharynx → BS → **several automatic pharyngeal muscle contractions**:

1. Soft palate pulled upward → close the posterior nares



Pharyngeal Stage of Swallowing

2. Palatopharyngeal folds pulled together → food must pass into posterior pharynx

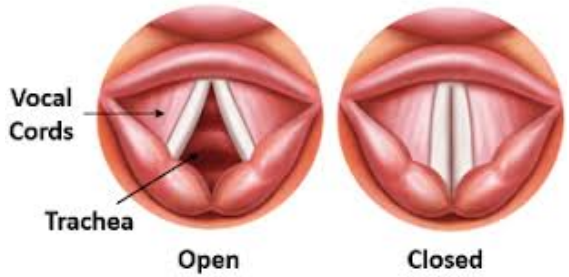


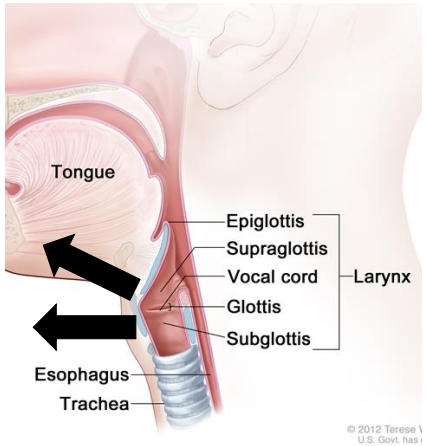
Pharyngeal Stage of Swallowing

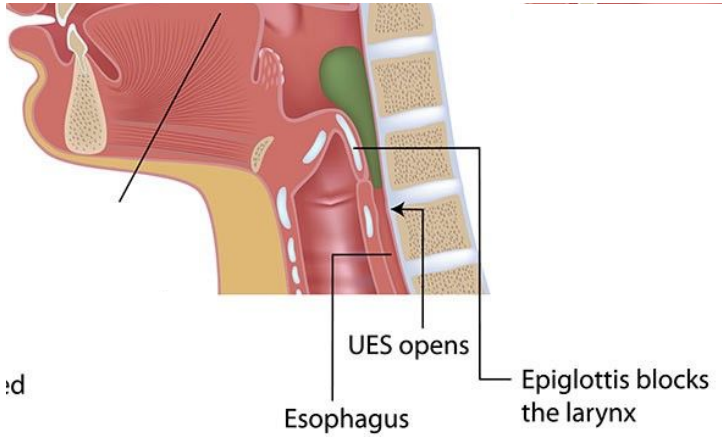
3. Trachea is closed (respiration inhibited)
   - Vocal cords approximated
   - Larynx pulled upward & anteriorly
   - Epiglottis covers larynx

4. Relaxation of UES →food movement from posterior pharynx into upper esophagus
   - ➢UES strongly contracted between swallows preventing air from entering esophagus during respiration

5. Peristaltic contraction of pharynx → pushing food into esophagus







Swallowing (deglutination)

Nervous Control of Swallowing reflex

- Pharyngeal phase -starting with voluntary food movement, ending with involuntary swallowing reflex - < 6 sec

  - **Afferent**-tactile areas of posterior mouth & pharynx (most sensitive on tonsillar pillars) → sensory portions of trigeminal & glossopharyngeal nerves → medulla oblongata (tractus solitarius)

  - **Efferent**- swallowing center (reticular substance of medulla & lower portion of pons) → V,IX,X,XII, sup. Cervical nerves → pharynx & upper esophagus

  - Swallowing center inhibits respiratory center (medulla)

Esophageal Stage of Swallowing

- **Primary peristalsis** - continuation of pharyngeal swallowing peristalsis, 8-10 sec
- Gravidity aids in food pulling to stomach
- **Secondary peristalsis** -
  - Failure of primary peristalsis
  - Induced by distention
  - Repeats until bolus is cleared
  - Initiated partly by myenteric NS & partly by vagal reflexes starting in pharynx → medulla → glossopharyngeal & vagal nerves → esophagus
- Upper esophagus - upper 1/3 is striated muscle (glossopharyngeal & vagal nerves)
- Lower esophagus - lower 2/3 is SM (myenteric NS (enough) + vagus)

Receptive Relaxation of the Stomach

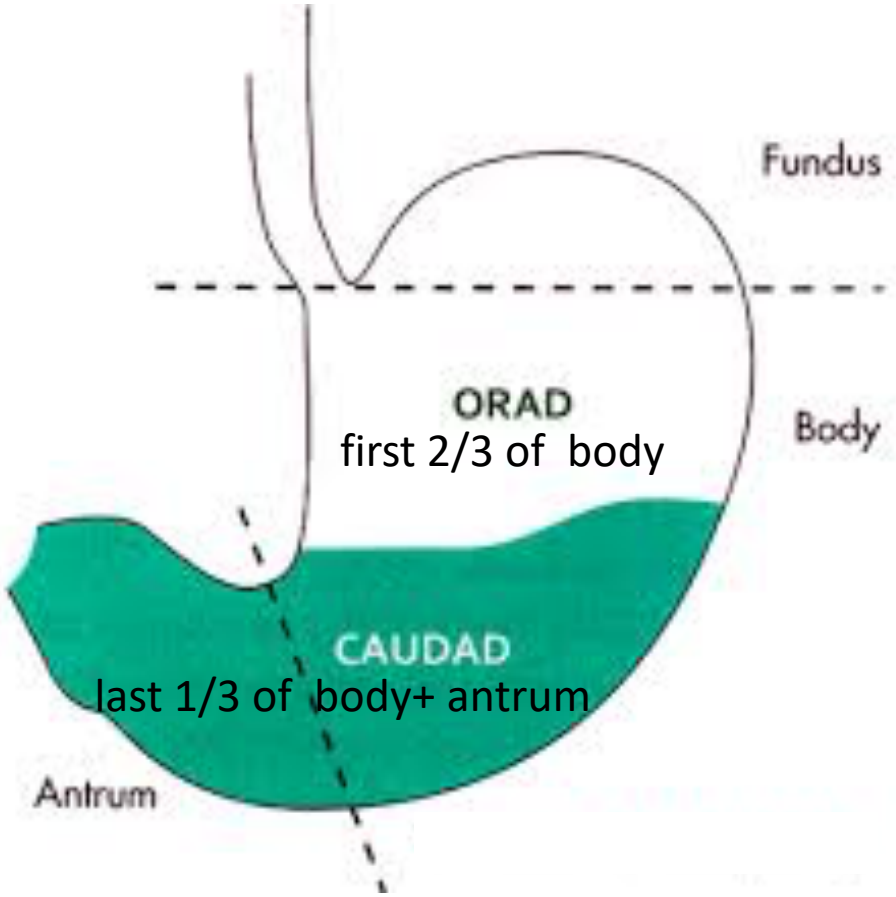
- **LES/GES**

- Tonically constricted (30 mm Hg) + valvelike closure of lower esophagus →prevents acid reflux into esophagus

- Receptive relaxation of LES ahead of peristaltic wave → propulsion of food into stomach

- Esophageal peristaltic wave approaches stomach → myenteric relaxation of stomach & duodenum → to receive food from esophagus

Motor functions of the stomach

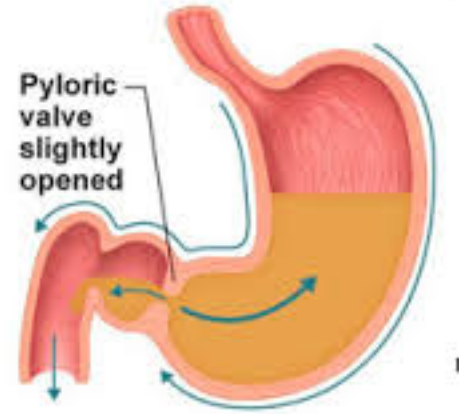


Motor functions of stomach

- Functions of gastric SM-
  - ➢ Storage of food - orad area
  - Food stretching → vagovagal reflex –stomach → BS → stomach → stomach relaxation & outward bulging
  - Stomach capacity 0.8-1.5 L
  - Pressure in stomach remains low until this limit approached

Motor functions of stomach

- Functions of gastric SM-
  - ➢ Mixes food with gastric juice from gastric glands = **chyme**
  - ➢ **Chyme fluidity**-amount of food, H2O, secretions, degree of digestion
  - ✓ Mixing waves (weak peristaltic constrictor waves) → beginning in mid-upper stomach & progress to antrum (every 15-20 sec)
  - ✓ Initiated by **slow waves** → more intense toward antrum → powerful peristaltic AP→ pushing chyme toward pylorus
  - ✓ Contracted antrum → **retropulsion** = squeezed back toward body of stomach



③ **Retropulsion:** The pyloric end of the stomach acts as a pump that delivers small amounts of chyme into the duodenum, simultaneously forcing most of its contained material backward into the stomach.

Motor functions of the stomach

❖ **Hunger Contractions**

- Intense contraction caused by empty stomach
- Rhythmical peristaltic contractions in body of stomach
- Successive strong contractions → tetanic contraction (2-3 m)
- Can cause pain= hunger pangs (12 -24 h after last meal, max. intensity 3-4 days & gradually ↓ after)

Motor functions of the stomach

- Functions of gastric SM-

  ➢ Propels chyme into duodenum - caudad area

- Thick pyloric sphincter -tonically constricted (Still leaky for water and other fluids to empty from stomach to duodenum
  - ✓Pyloric sphincter contraction ↑ or ↓ by nervous & hormonal mechanisms
- Strong gastric peristaltic waves > closing pressure of pylorus muscle (pyloric pump)
- Pushing chyme into duodenum & mixing in stomach

Regulation of Gastric Emptying

- **Moderate** degree by stomach factors-

1. ↑ **Food in stomach**→ ↑ gastric emptying (stretch mediated myenteric reflexes→ ↓ pylorus & ↑ pyloric pump)

2. **Gastrin** -stretching of stomach → ↑ gastrin from G cells of the antral mucosa → ↑ gastric juice & enhance activity of pyloric pump.

Regulation of Gastric Emptying

- More important control from the **duodenum**

1. Inhibit pyloric pump
2. Increase tone of pyloric sphincter

Stimulated by:

- Distention of duodenum
- Too much acidic chyme (pH< 3.5-4) in SI (quick within 30 sec)→neutralized by pancreatic and other secretions
- Too much unprocessed protein /fat
- Hypotonic/hypertonic chyme
- Irritation

Regulation of Gastric Emptying

- Inhibitory Enterogastric reflexes:

- **Intrinsic ENS** (Direct form doudernum to stomach)
- **Extrinsic nerves**

1. Prevertebral sympathetic ganglia →inhibitory SN fibers to stomach
2. Vagus nerves to BS → inhibit normal excitatory signals transmitted to stomach through vagi

Regulation of Gastric Emptying

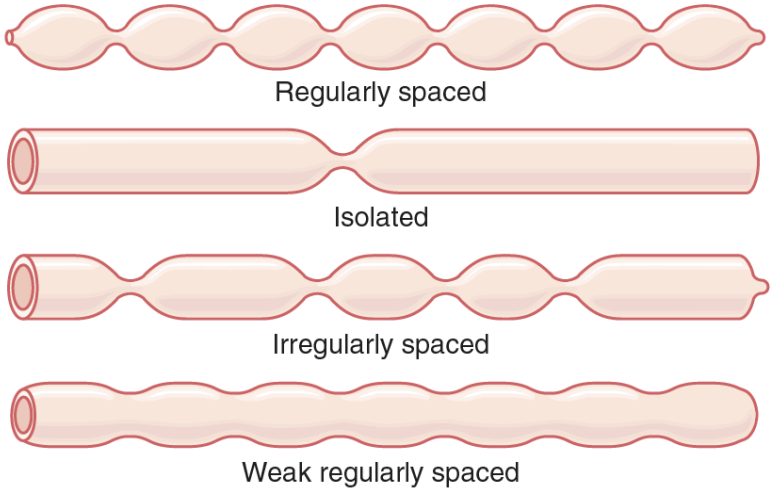
➢ **Hormonal**-stimulated mainly by fats in duodenum

- **CCK**- from mucosa of jejunum → block stomach motility caused by gastrin
- **Secretin** -from duodenal mucosa in response to gastric acid passed from stomach through pylorus
- **Glucose-dependent insulinotropic peptide/ gastric inhibitory peptide (GIP)-**

✓From upper SI mainly
✓ Stimulated by fat, lesser extent by carbohydrates.
✓General but weak effect -↓ GI motility.
✓ Stimulate secretion of insulin by the pancreas (main function)

SI Motility

- Two types of movements in SI:



  - **Segmentation & Peristalsis**

  - **<u>Segmentation</u>** - a mixing movement + cause propulsion

- Stimulus: stretching of SI
- Localized concentric contractions spaced at intervals → chain of sausages appearance → chyme chopping
- Frequency of segmentation is determined by frequency of **slow waves**-12/min duodenum & prox. Jejunum, 8-9/min T. ileum.

- Blocked by atropine
- Excitation from myenteric nerve plexus is mandatory for mixing movements

SI Motility

- **Peristalsis** - weak propulsive movement, die out after 3-5 cm
- Stimului:

1. Chyme entry into duodenum
2. Distention of stomach (**Gastroenteric reflex:** mediated by myenteric plexus)

- Slowly propelling chyme toward ileocecal valve & spread out the chyme along the intestinal mucosa.
- **Velocity** - 0.5-2.0 cm/sec, faster in proximal intestine, slower in terminal intestine
- 3-5 h required for passage of chyme from pylorus to ICV

- Upon reaching ICV chyme is blocked for several hours until person eats another meal →**gastroileal reflex** → ↑peristalsis in ileum → pushing chyme through ICV to cecum

Peristaltic Rush

- Intense irritation of intestinal mucosa (e.g. infectious diarrhea) →powerful & rapid peristalsis
- Mediated by nervous reflexes (ANS & BS) + intrinsic ↑ myenteric plexus reflexes
- Travel long distances in SI within minutes→ sweeping contents of intestine into colon → relieving SI irritation.

Control of Small Intestinal Motility

- Hormonal factors -
  - -Gastrin, CCK, insulin, motilin & serotonin → ↑peristalsis
  - -Secretin & glucagon → ↓peristalsis

Movements caused by muscularis mucosae & muscle fibers of villi.

Muscularis mucosae function:

1. Folding of intestinal mucosa →↑ surface area & ↑ absorption
2. Contraction of intestinal villi →lymph flow from central lacteals to lymphatic system

Mucosal & villous contractions are mediated by submucosal nerve plexus in response to chyme in SI.

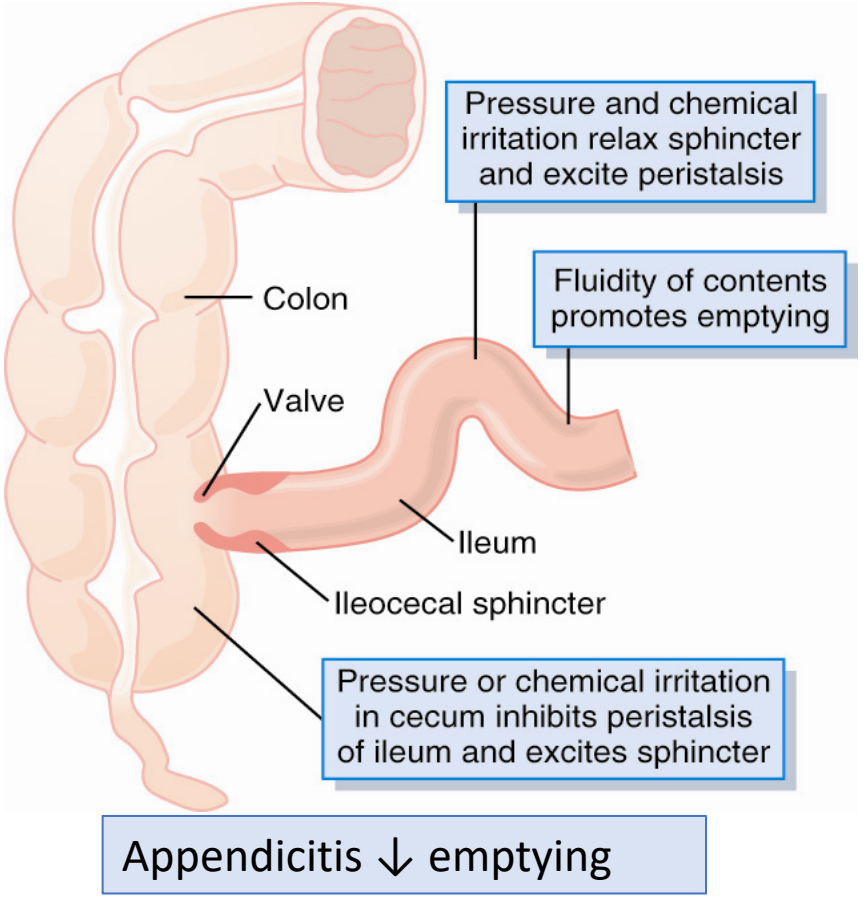
Ileocecal Junction

- Functions as a valve and a sphincter
- Valvular function

  - Prevents backflow into small intestine mechanically

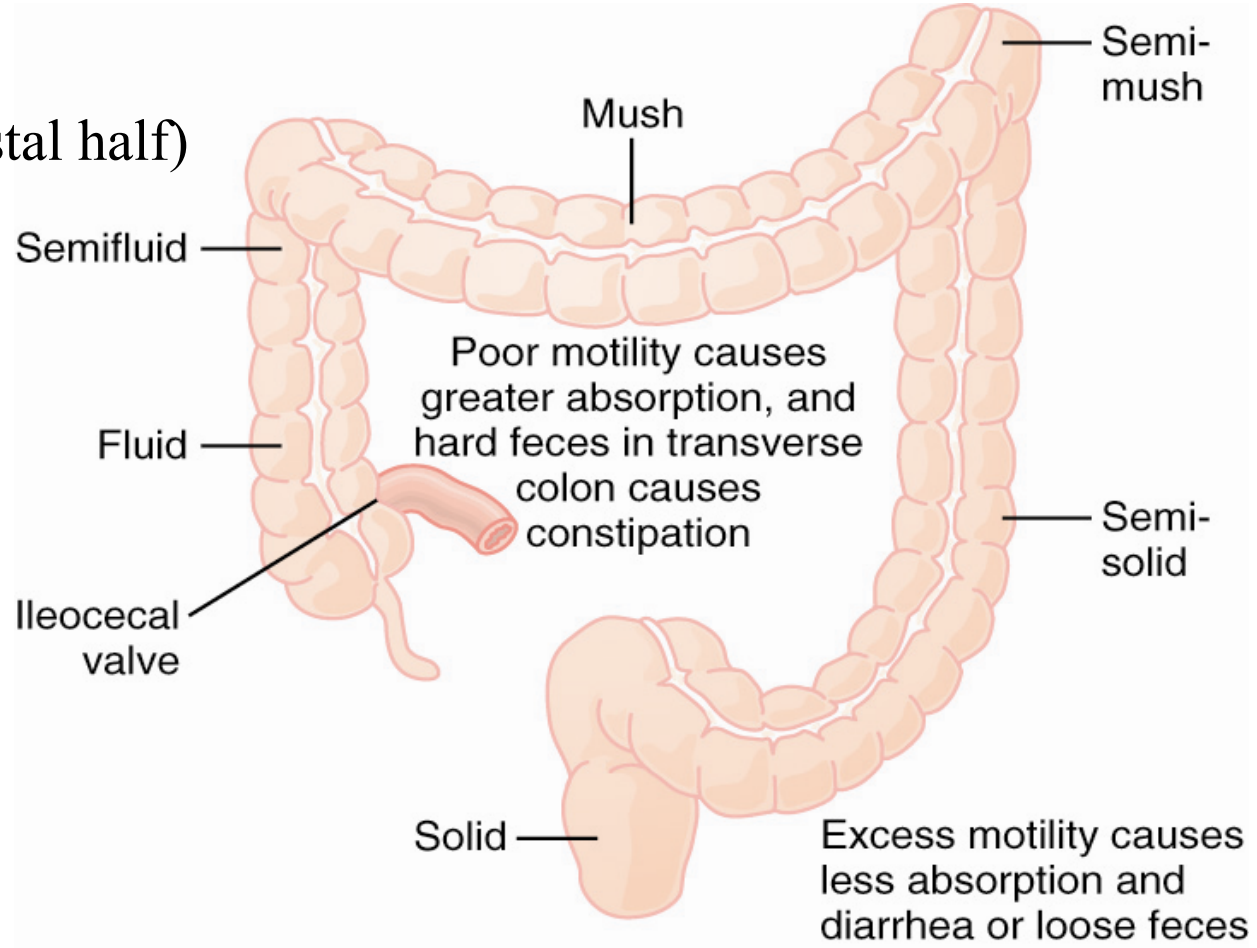
- Sphincter function -

  - Regulates movement of ileal contents into large intestine.
  -1.5- 2 L of chyme empty into cecum each day
  -Regulated by: ENS and prevertebral sympathetic ganglia



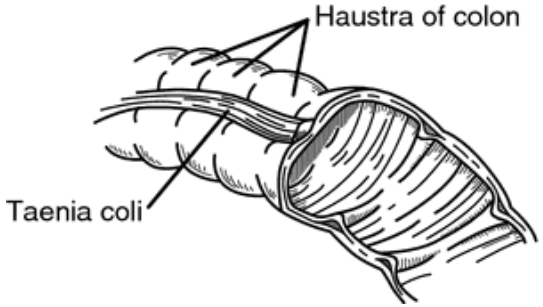
• Motility of Colon

Absorptive (proximal half) & fecal storage (distal half) functions of the large intestine



Motility of Colon

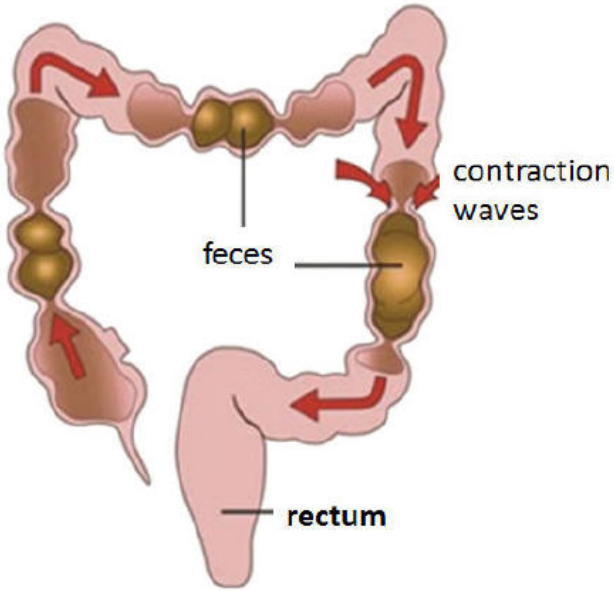
- Movements of the colon are sluggish
- **Mixing and propulsive movements**



1. Mixing Movements "Haustrations"

- ✓ Combined contractions of circular & longitudinal strips (teniae coli) of muscle → haustration
- ✓ Move slowly toward anus during contraction
- ✓ Provide minor forward propulsion of colonic contents (mainly cecum & ascending colon)→8-15 h to move chyme from ICV through colon
- ✓ Enhances fluid/electrolyte absorption

Motility of Colon



2. Propulsive/Mass Movements

- Propels fecal material (80 -200 ml/day)
- From cecum →sigmoid
- Freq: 1-3/day after eating breakfast

- Distention or irritation of colon (T. colon)→ constrictive ring →loss of haustrations distal to constrictive ring & contract as a unit → propelling feces distally
- Series of mass movements continue for 10-30 min, diminish, return half day later

- Gastrocolic and duodenocolic reflexes (ANS) initiate mass movement (distention of stomach & duodenum

Defecation

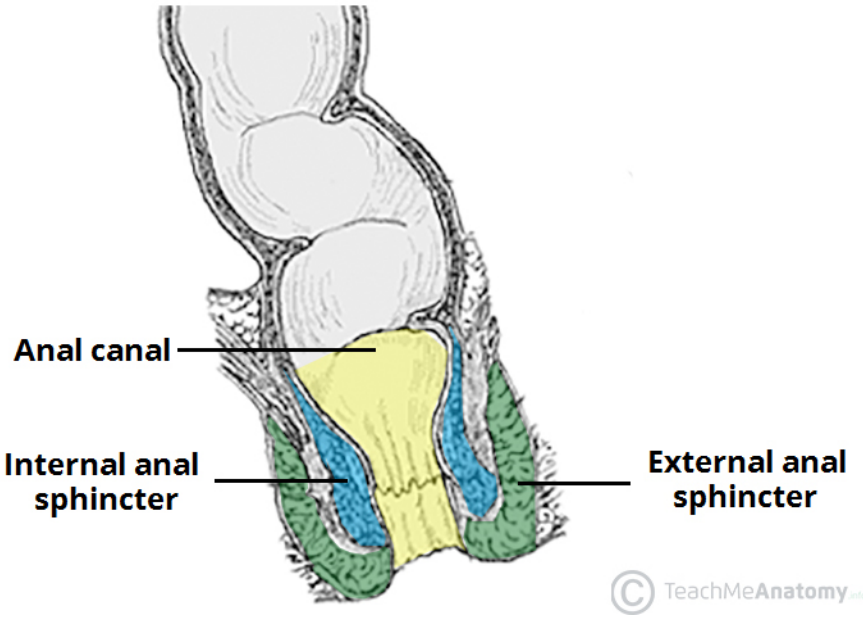
- Mostly, rectum is empty of feces

- Weak functional sphincter (at juncture between S. colon & rectum) + sharp angulation
- Feces reached rectum by mass movement→ desire for defecation →reflex contraction of rectum & relaxation of anal sphincters.
- **Internal anal sphincter** → thickening of circular SM in anus
- **External anal sphincter** → striated voluntary muscle surrounding internal sphincter & extends distal to it.

✓ Controlled by pudendal nerve (somatic NS)

✓ Under voluntary, conscious, subconscious control

✓ Continuously constricted unless conscious signals inhibit the constriction.



Control of Defecation

- There are three levels of control -
  - Intrinsic reflex
  - Parasympathetic reflex
  - Involvement of higher centers

Intrinsic Defecation Reflex

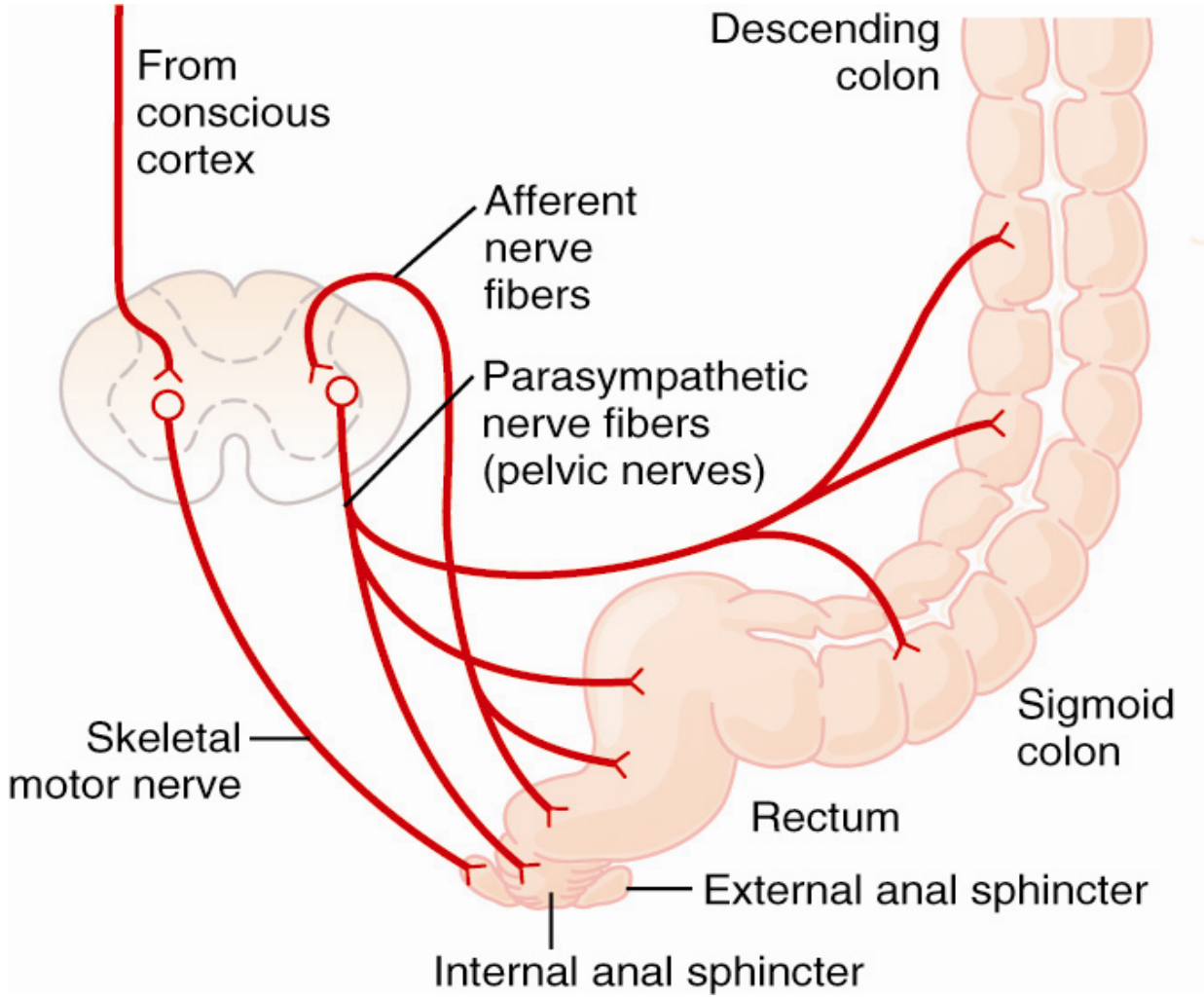
- Intrinsic reflex mediated entirely by ENS-weak reflex
- Initiated when feces enters rectum via mass movements

- Rectal distention → afferent signals that spread through myenteric plexus→ peristalsis in descending and sigmoid colon, and rectum → force feces toward anus →internal anal sphincter **relaxation** and if external anal sphincter is <u>voluntarily</u> relaxed, defecation occurs.

Parasympathetic defecation (sacral) reflex

- Parasympathetic cord reflex greatly intensifies intrinsic reflex
- Effective in emptying the LI all the way from splenic flexure of colon to anus
- Nerve endings in rectum are stimulated →afferent signals →SC → parasympathetic fibers in pelvic nerves →descending and sigmoid colon, and rectum→ ↑peristalsis & internal anal sphincter relaxation

- The lower neurons S2-S4 provide sensory and motor fibers for defecation reflex. They are intact when spinal cord is injured at higher levels.


From
conscious
cortex
Descending
colon
Afferent
nerve
fibers
Parasympathetic
nerve fibers
(pelvic nerves)
Skeletal
motor nerve
Sigmoid
colon
Rectum
External anal sphincter
Internal anal sphincter

Defecation Reflex - Higher Centers

- Afferent signals entering SC initiate:
  - deep breath, closure of glottis, contraction of abdominal wall muscles & increased abdominal pressure, pelvic floor relaxation
  - all work to move fecal contents downward
- Newborn babies & people with transected SC, the defecation reflexes cause automatic emptying
- Cord defecation reflex can be excited (either digitally or with enema)

Other autonomic reflexes that affect bowel activity

- **Peritoneointestinal reflex** : irritation of peritoneum (e.g peritonititis); strongly inhibits excitatory enteric nerves⟶ intestinal paralysis,

- **Renointestinal reflex → inhibit intestinal activity due to kidney irritation.**

- **Vesicointestinal reflex** → inhibit intestinal activity due bladder irritation.