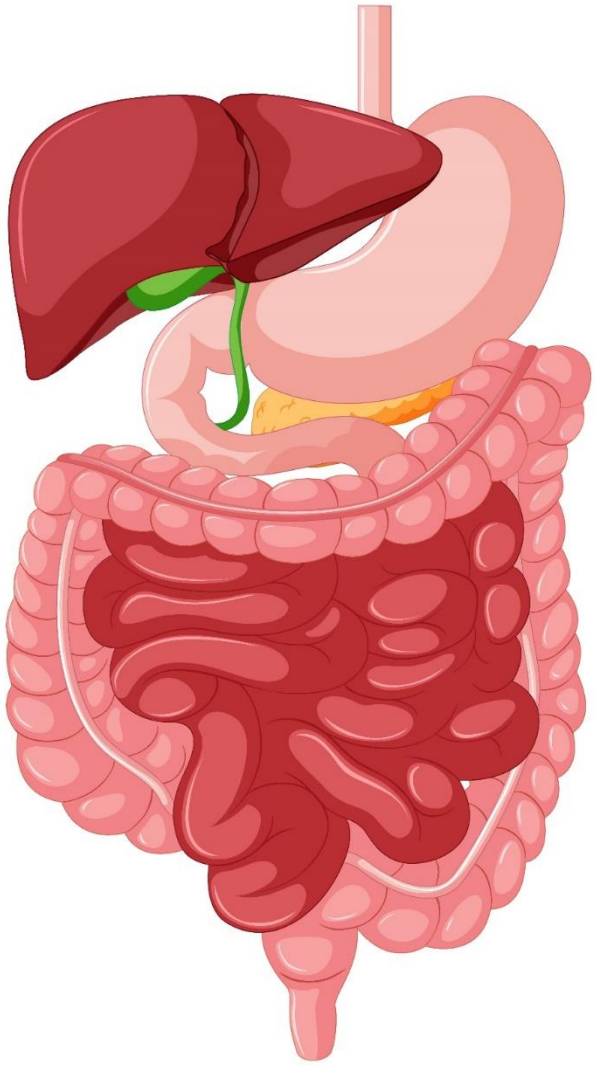


Gastrointestinal Motility

By: Khushal Khan

KMU-IPMS

Gastrointestinal (GI) motility

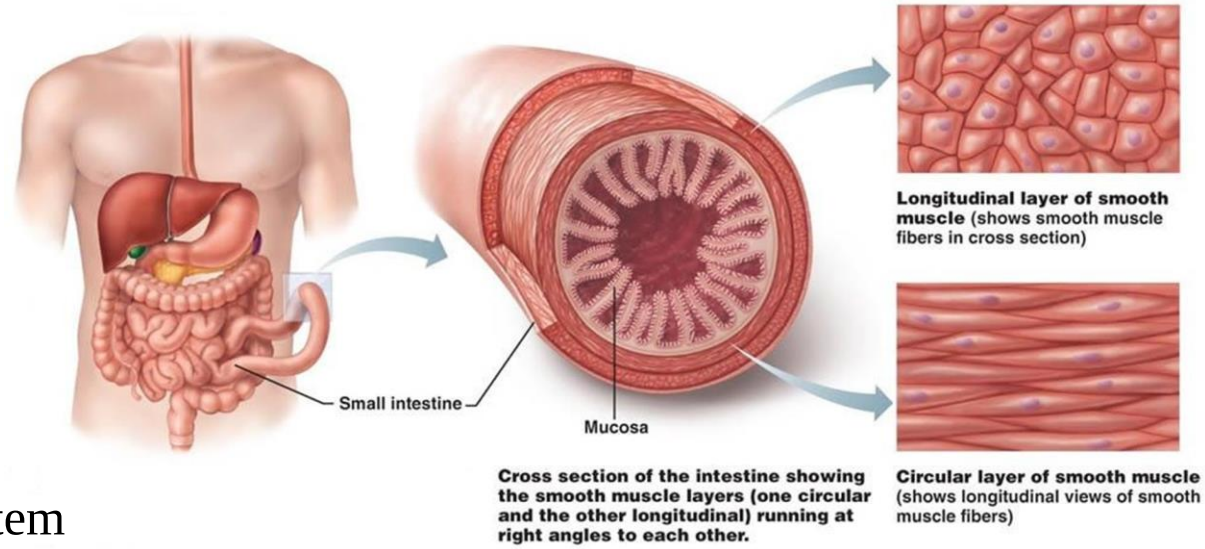
- GI motility refers to the **contraction and relaxation of the muscles** in the digestive tract **that move food and waste material through the system.**

- There are **several types of GI motility** that play different roles in the digestive process.

- Some of the **main types** are:
    1. **Swallowing**
    2. **Peristalsis**
    3. **Segmentation**
    4. **Mass movement**
    5. **Defecation**

Gastrointestinal Smooth Muscle

- Composed of **smooth muscle fibers**
- Arranged in **parallel bundles**
- **Length:** 200-500 micrometers
- **Diameter:** 2-10 micrometers



Function

- Responsible for **involuntary contractions**
- Propel **food and waste** through the digestive system

Control

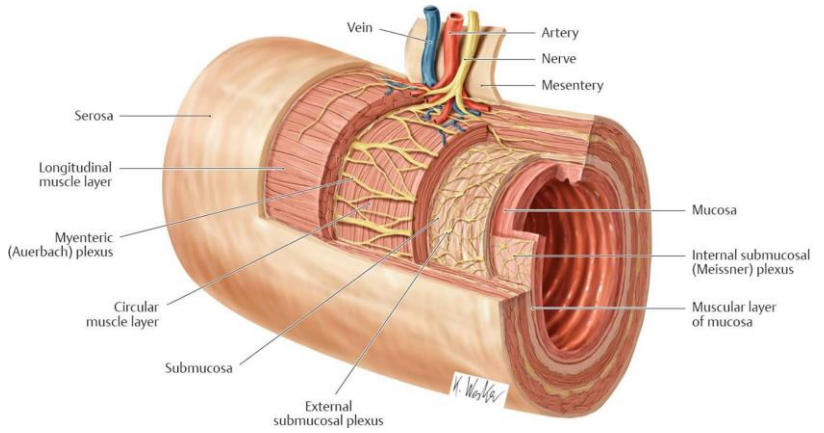
- Autonomic nervous system
  - **Sympathetic nerves:** inhibit contractions
  - **Parasympathetic nerves:** stimulate contractions

Gastrointestinal Smooth Muscle

- Smooth muscles in the GI tract are **arranged in two layers:**

1. **Outer Longitudinal muscle layer – fibers arranged longitudinally**
   - Runs parallel to the length of the GI tract
   - Responsible for shortening and lengthening the tube
   - Helps to move food along the tract

2. **Inner Circular muscle layer – fibers arranged in circular manner**
   - Runs perpendicular to the longitudinal layer
   - Responsible for constricting the lumen (inner space) of the GI tract
   - This helps to mix and break down food
   - Prevent backflow of digestive material

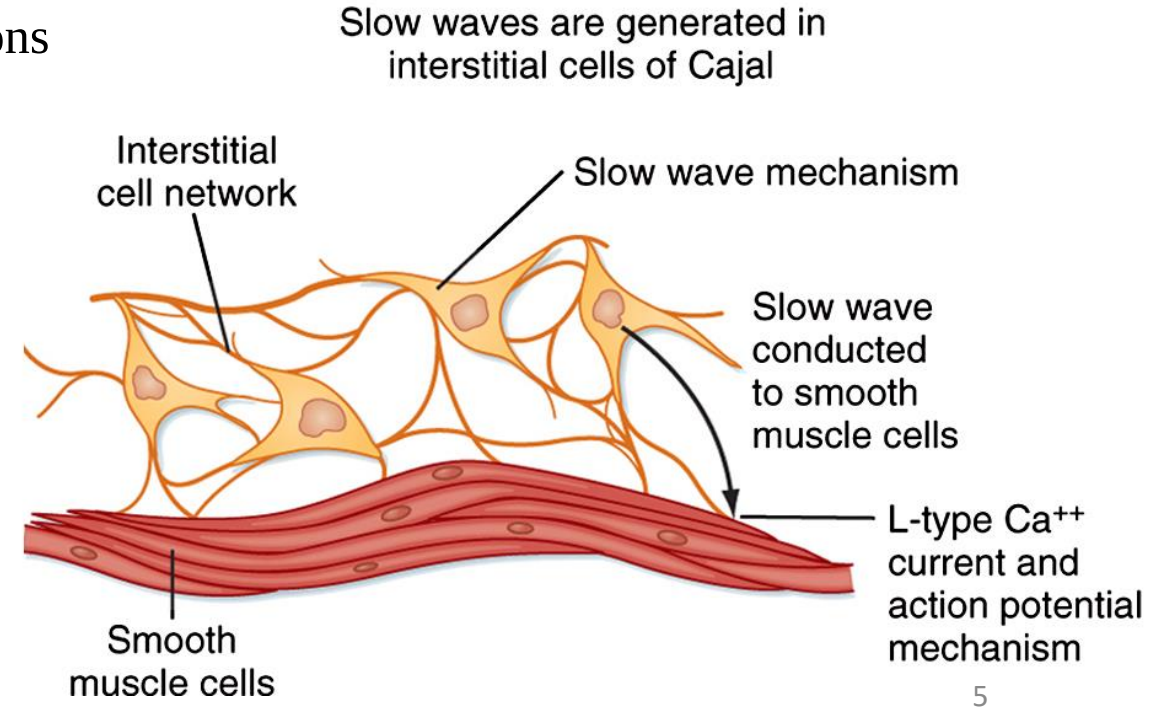


Interstitial Cells of Cajal (ICC)

- **Specialized cells** found throughout the GIT
- Key role in **regulating smooth muscle contractions**
- Located in muscle layers, **abundant near myenteric plexus**
- Act as **pacemakers,** generating **spontaneous electrical slow waves**
- **Electrical slow waves** trigger smooth muscle contractions
- Regulate **neurotransmission in the GI tract**
- Involved in release of:
  - **Acetylcholine (stimulates contractions)**
  - **Nitric oxide (inhibits contractions)**

Function:

- Proper functioning of GI tract
- Rhythmic smooth muscle contractions
- Modulating neurotransmission in GI wall



Gap Junctions

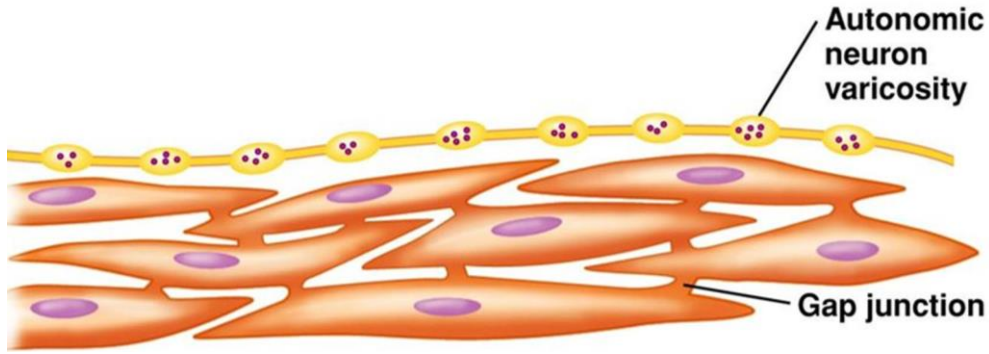
- Specialized channels for **direct cell-to-cell communication – ions and small molecules exchange**

Function in Smooth Muscles

- Allow rapid travel of electrical signals between cells
- Enable coordinated contraction of multiple cells

Role in GI Tract

- Electrical slow waves generated by ICC
- Spread through gap junctions to smooth muscle cells
- Lead to coordinated contractions (syncytium)
- Propel food and waste through the digestive system



Electrical Activity

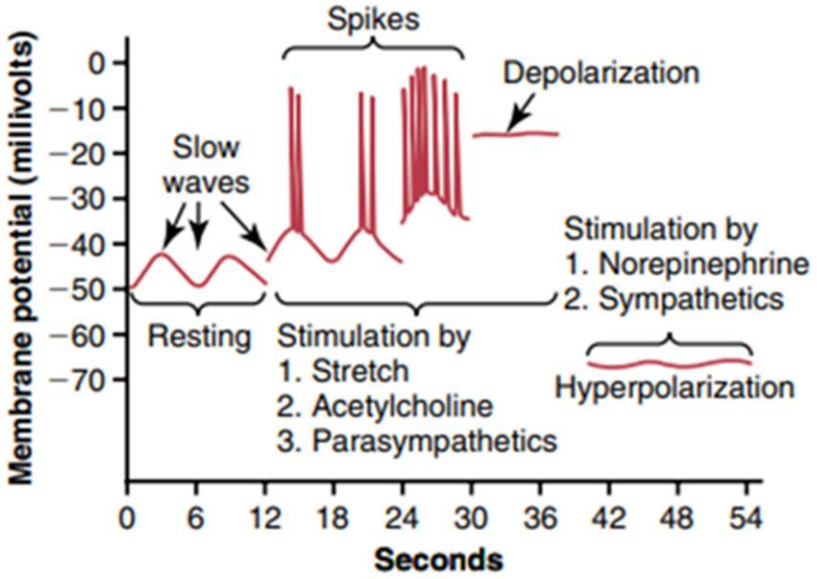
Excitation of GI Smooth Muscle

- Excited by continuous slow, intrinsic electrical activity

- **Two types of electrical waves:**

1. **Slow Waves**
   - Rhythmic, spontaneous fluctuations in ICC membrane potential

2. **Spike Potentials**
   - Rapid, transient changes in membrane potential
   - Occur in response to ICC membrane depolarization



Electrical Activity

Slow Waves

- Most GI **contractions occur rhythmically** – brought by slow waves.
- These waves **are not action potentials.**
- They are **slow, wave like changes in the resting membrane potential.**
- Intensity: **5 and 15 mv**
- Frequency: **3 to 12/min**

Spike Potentials

- The spike potentials **are true action potentials.**
- They occur automatically when the **RMP (−50 and -60 mv)** of the GI smooth muscle becomes more positive than about **−40 mv.**
- Frequency: **1-10 spikes / sec**
- AP Duration: **10-20 ms**
- In GI smooth muscle fibers, the channels responsible for the action potentials are : **calcium-sodium channels.**

Factors

↑ Excitability of Membrane

- Stretching of the muscle
- Stimulation by **acetylcholine** released from parasympathetic nerves
- Stimulation by several specific gastrointestinal hormones

↓ Excitability of Membrane

- Norepinephrine
- Epinephrine
- Stimulation of the **sympathetic nerves** that secrete norepinephrine

Mechanism of Smooth Muscle Contraction

1. **Calcium entry:**
   - SM contraction initiated when **Ca2+ enter SM cell from ECF or sarcoplasmic reticulum.**
   - **Ca2+ entry** triggered by stimuli such as **neurotransmitters, hormones, mechanical stretch.**

2. **Calcium binding to calmodulin:**
   - **Ca2+** that enter the SM cell **bind to a protein called calmodulin.**
   - This binding activates an **enzyme** called **myosin light chain kinase (MLCK).**

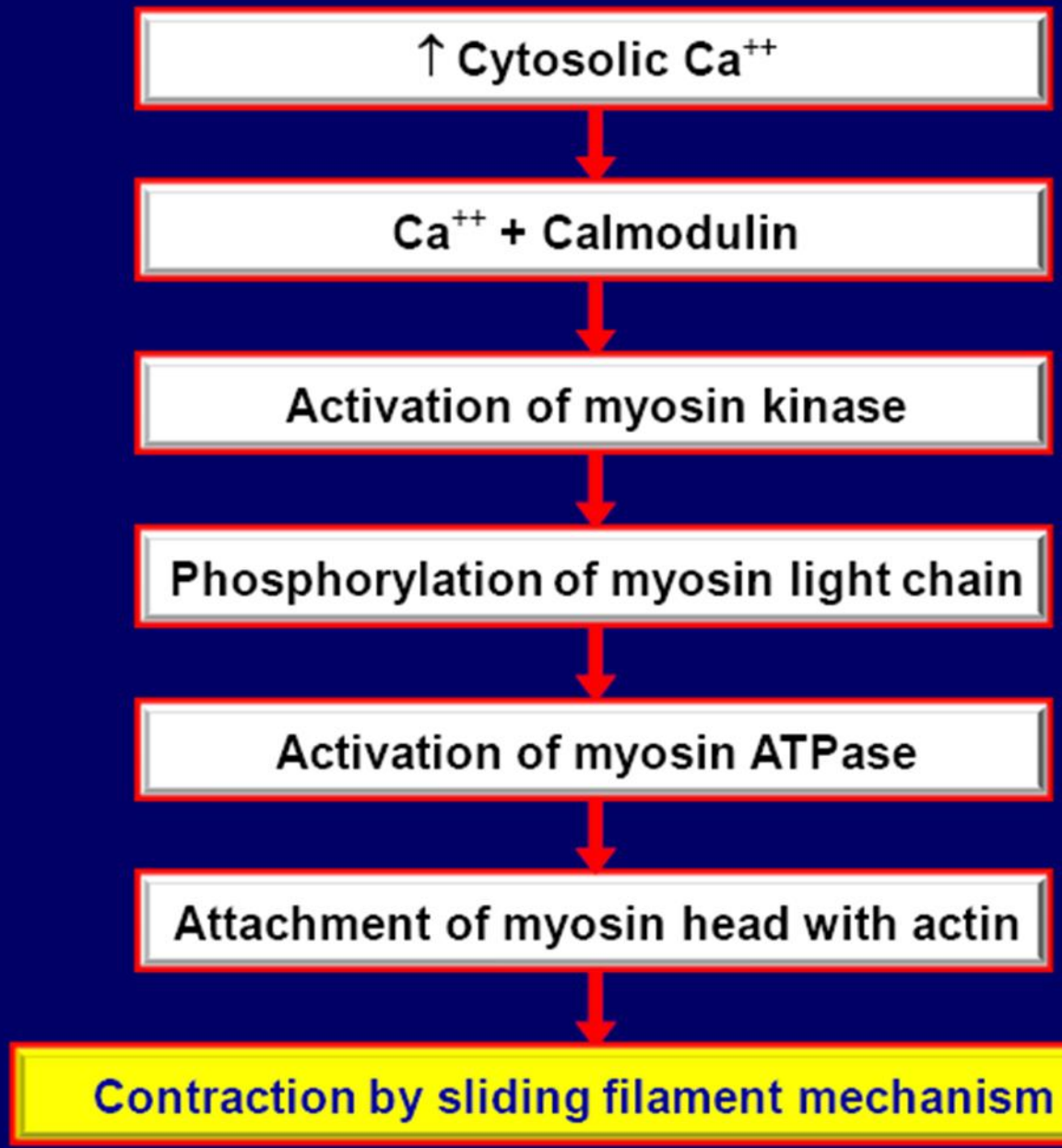
3. **Activation of myosin light chain kinase:**
   - Activated **MLCK phosphorylates** the **myosin light chains of the myosin filaments** in the smooth muscle cell.

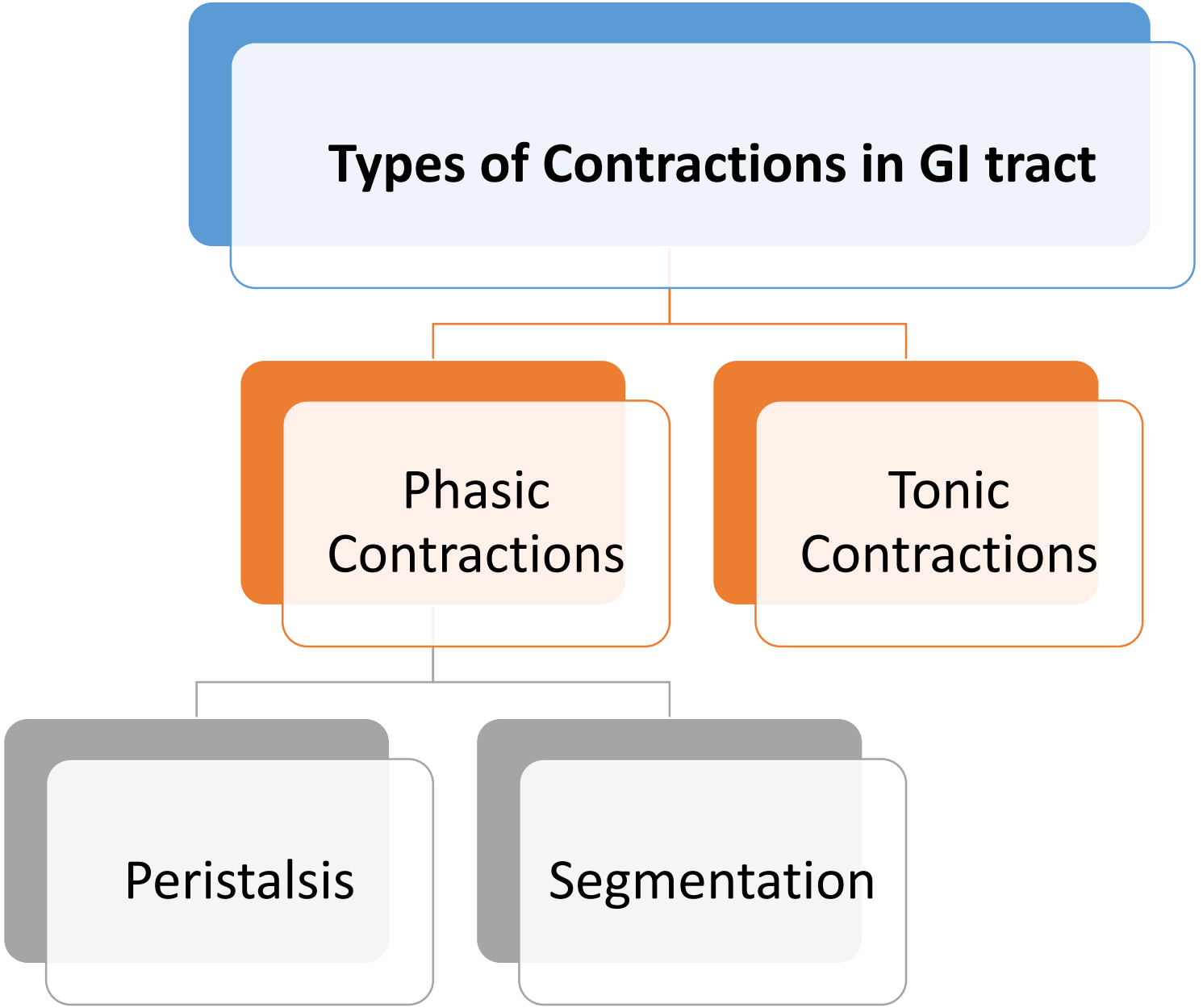
- **Cross-bridge cycling:**
  - Phosphorylation of the myosin light chains **causes the myosin heads to bind to actin filaments in the smooth muscle cell, forming cross-bridges.**
  - The myosin heads then undergo **a conformational change**, pulling the actin filaments towards the center of the sarcomere and causing contraction of the smooth muscle cell.

- **Calcium removal:**
  - Once the calcium ions have triggered smooth muscle contraction, **they need to be removed from the smooth muscle cell to allow for relaxation.**
  - Calcium removal is achieved by a variety of mechanisms, including **calcium uptake into the sarcoplasmic reticulum and extrusion from the cell via calcium pumps.**

- **Dephosphorylation of myosin light chains:**
  - As the calcium ions are removed from the smooth muscle cell, **the myosin light chain kinase is deactivated,** leading to **dephosphorylation of the myosin light chains**.
  - This causes the **myosin heads to release from the actin filaments** and allows for **relaxation of the smooth muscle cell.**

Mechanism of smooth muscle contraction




Types of Contractions in GI tract
Phasic Contractions
Tonic Contractions
Peristalsis
Segmentation

Types of Contractions in GIT

Phasic Contractions

- Rhythmic, cyclical SM contractions
- Occur in response to food or other stimuli in the GI tract
- Propel food and waste through the GI system
- Regulated by ICC-generated electrical slow waves

Tonic Contractions

- Sustained SM contractions over a prolonged period
- Maintain tone and tension of the GI wall
- Essential for proper functioning of GI sphincters
  - Lower oesophageal sphincter
  - Pyloric sphincter

Phasic Contractions

Peristalsis

- Coordinated contraction and relaxation of smooth muscle
- Propels food and waste through the GI tract
- Involves wave-like contractions along the GI tract
- Relaxation phase follows each contraction, allowing forward movement of contents

Segmentation

- Occurs in the small intestine
- Localized smooth muscle contractions
- Mix and knead intestinal contents
- Aid in digestion and nutrient absorption

Hormonal Control of Gastrointestinal Motility

The gastrointestinal hormones are released into the **portal circulation** and **exert physiological actions on target cells** with specific receptors for the hormone.

Hormone	Stimuli for Secretion	Site of Secretion	Actions
Gastrin	Protein Distention Nervous *(Acid inhibits release)*	G cells of the antrum, duodenum, and jejunum	Stimulates Gastric acid secretion Mucosal growth
Cholecystokinin	Protein Fat Acid	I cells of the duodenum, jejunum, and ileum	Stimulates Pancreatic enzyme secretion Pancreatic bicarbonate secretion Gallbladder contraction Growth of exocrine pancreas Inhibits Gastric emptying
Secretin	Acid Fat	S cells of the duodenum, jejunum, and ileum	Stimulates Pepsin secretion Pancreatic bicarbonate secretion Biliary bicarbonate secretion Growth of exocrine pancreas Inhibits Gastrin release and gastric acid secretion
Glucose-dependent insulinotropic peptide *(also called gastric inhibitory peptide)*	Protein Fat Carbohydrate	K cells of the duodenum and jejunum	Stimulates Insulin release Inhibits Gastric acid secretion
Motilin	Fat Acid Nervous	M cells of the duodenum and jejunum	Stimulates Gastric motility Intestinal motility

Basic movement

1. **Mixing movement** – Keep the intestinal contents thoroughly mixed at all times.
2. **Propulsive movement** (peristalsis)– Food move forward along the tract at an appropriate rate to accommodate digestion and absorption.

Movements of different parts of GIT:

1. **Oral cavity** : i) Mastication
   ii) Deglutition
2. **Pharynx**: i) Deglutition
3. **Esophagus** : i) Deglutition
   ii) Peristalsis

Movements of different parts of GIT:

4. **Stomach–** i) Mixing movement
   ii) Peristalsis
   iii)Stomach emptying
   iv) Hunger contraction
5. **Small intestine**– i) Segmentation
   ii) peristalsis
6. **Large intestine** – i) Haustration
   ii) Mass movement
7. **Rectum and anal canal--** Defecation

Motility in Esophagus

Peristalsis (Propulsion):

- Primary function of esophagus
- Alternating wave of contraction and relaxation
- Moves food and fluids along the GI tract

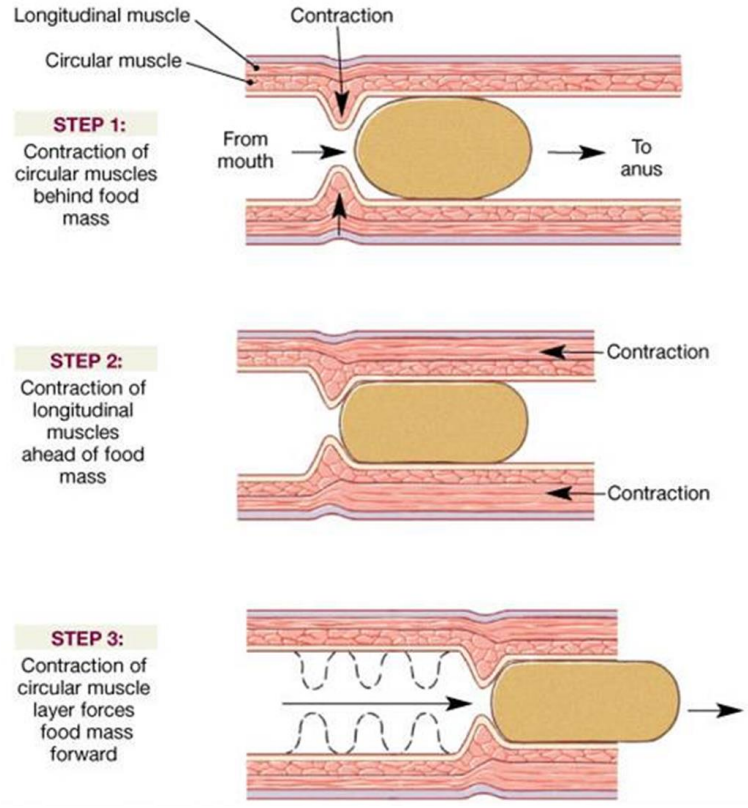
Esophagus:

- Contraction behind bolus, relaxation ahead
- Distension activates stretch receptors

Myenteric Plexus (Auerbach's plexus) between muscular layers

During peristalsis:

- Longitudinal muscular layer contracts, widening esophagus lumen
- Circular muscular layer contracts, narrowing esophagus lumen



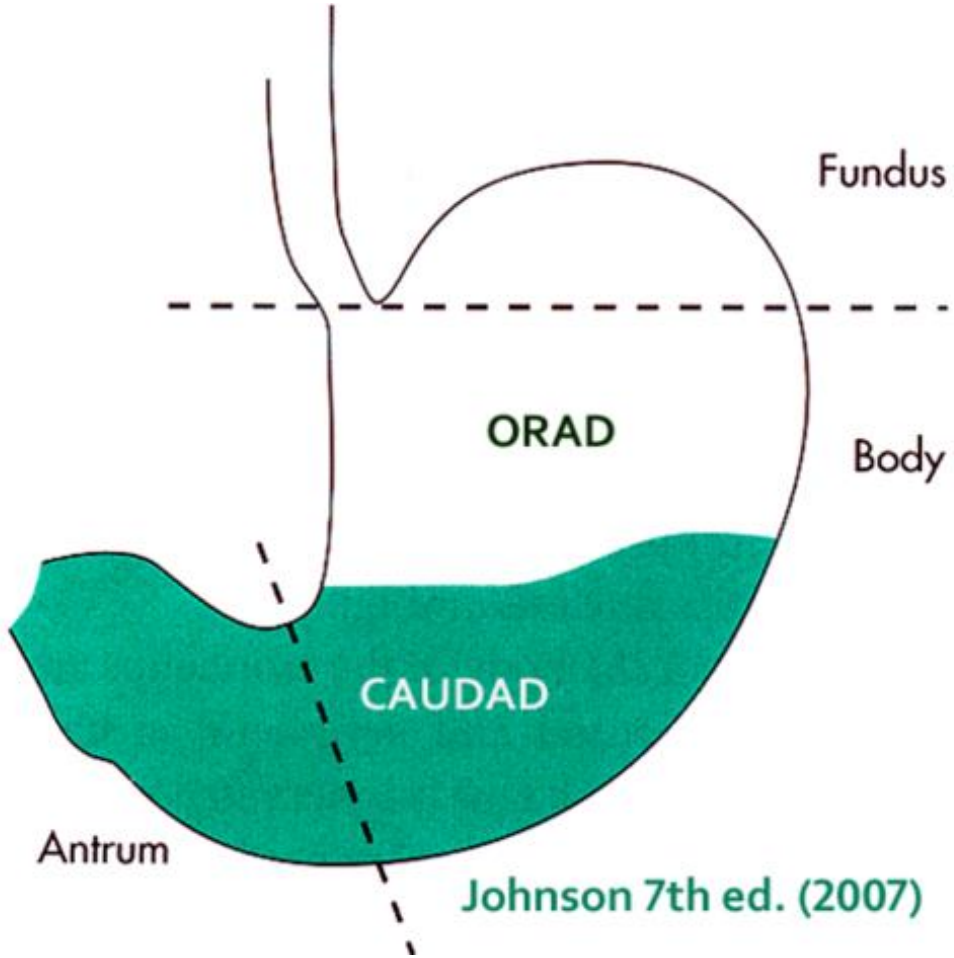
Motility in Stomach

Functions of the Stomach:

1. Reservoir for food storage
2. Mixing (churning) of food
3. Emptying of the stomach

Physiological Parts of the Stomach:

1. **Orad Portion:**
   - Includes fundus and first 2-3rd part of the body
   - Role in food storage
2. **Caudad Portion:**
   - Comprises the remainder of the body and antrum
   - Role in food churning and emptying

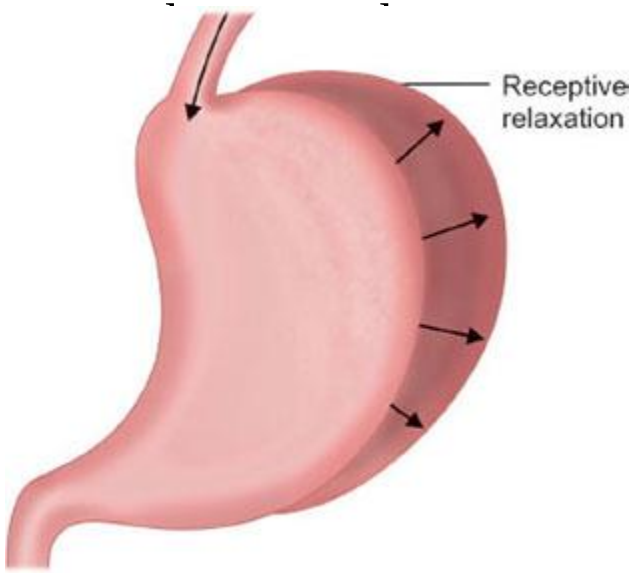


Storage

- Can hold food from **0.8 to 1.5 liters.**

Cephalic Phase:

- Triggered by **sight, thought, smell, and taste.**
- Vagus nerve stimulates neurons near the fundus to **release VIP (vasoactive intestinal peptide) and NO (nitric oxide).**
- Causes the orad portion to relax **(receptive relaxation)** before food



Gastric Accommodation:

- Entry of bolus increases stomach volume, causing wall distension.
- Triggers a **local reflex (vagovagal reflex)** and **releases NO and VIP.**
- Promotes further relaxation **(adaptive relaxation)** to accommodate food.

Receptive and Adaptive Relaxation:

- Both play vital roles in **gastric accommodation.**
- Allow **intragastric volume to increase with food intake** while **maintaining stable intragastric pressure until capacity is reached.**

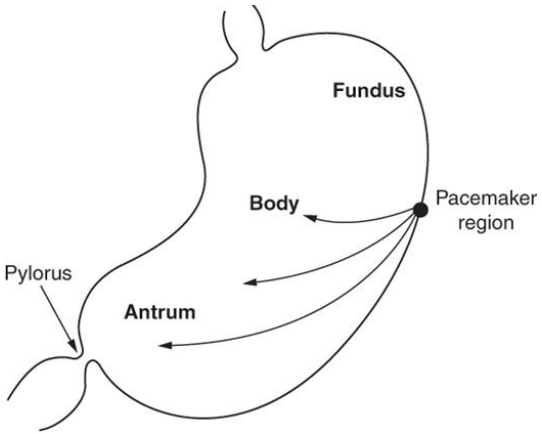
Mixing (Churning)

Mid-Body of the Stomach:

- Contains Pacemaker cells (interstitial cells of Cajal) that generate action potentials, causing **smooth muscle contraction.**

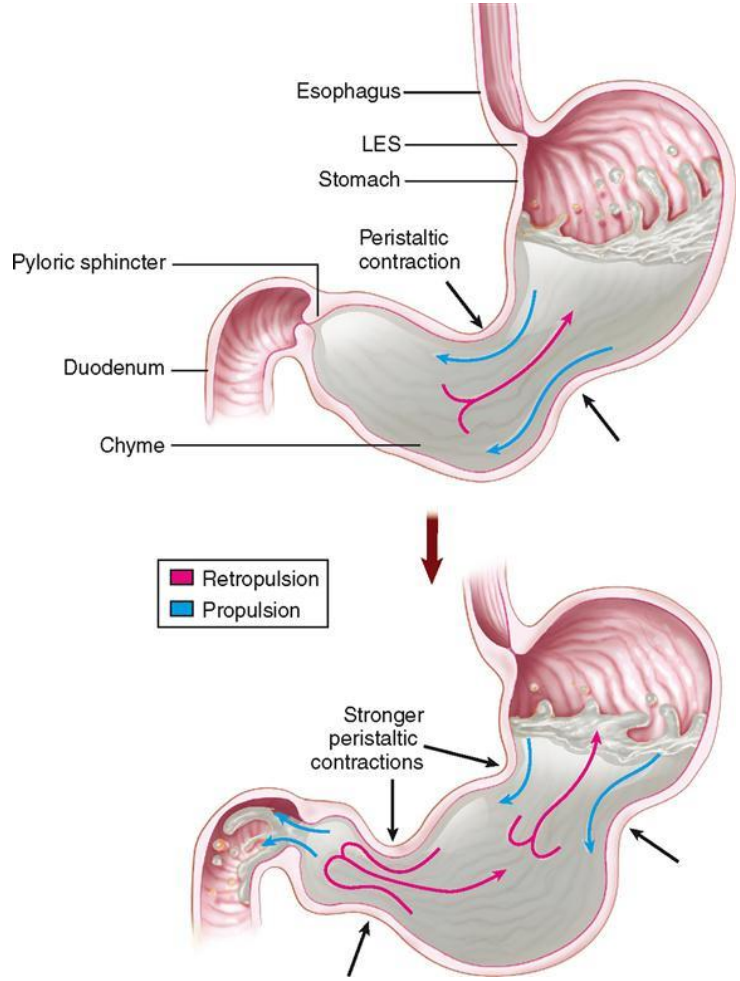
Contraction Pattern:

- Contraction begins in the **upper part of the body.**
- Intensity and force of contraction increase as they move towards the pylorus.
- These contractions create **potential-driven constrictor rings,** which force antral contents toward the pylorus under increasing pressure.



Mixing Mechanism:

- Each peristaltic wave **passes down the antral wall,** digging deeply into the antral contents.
- The **pylorus opening is small,** allowing only a few milliliters or less of contents to be expelled into the duodenum per wave.
- As the peristaltic wave approaches, **the pyloric muscle often contracts, further impeding emptying.**
- Most antral contents are **squeezed upstream through the peristaltic ring towards the body of the stomach,** not through the pylorus.



Retropulsion:

- This upstream squeezing action, combined with the moving peristaltic constrictive ring, is termed **"retropulsion."**
- **Retropulsion is a crucial mixing mechanism,** ensuring thorough mixing of stomach contents for effective digestion.

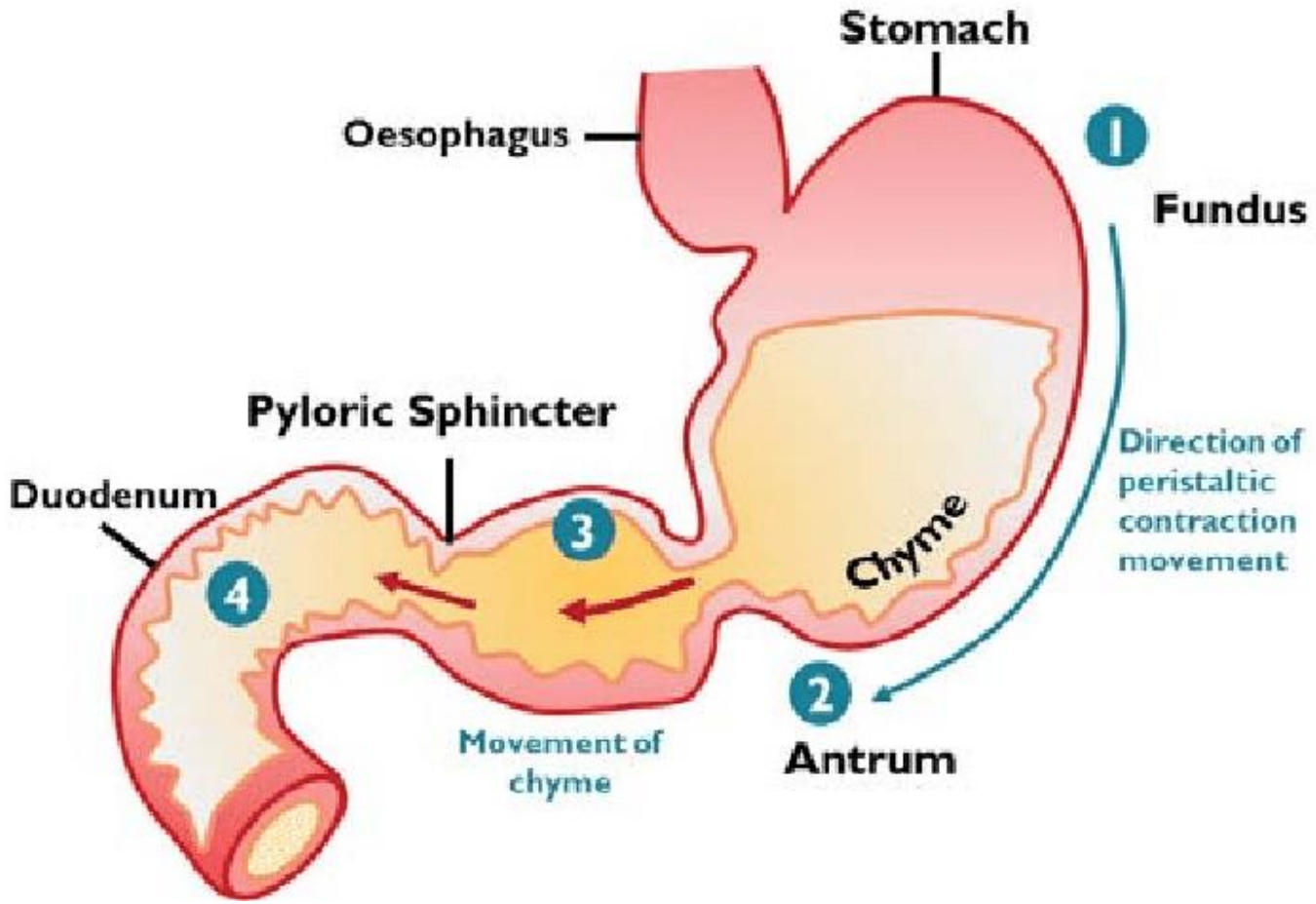
Emptying

Intense Peristaltic Contractions:

- Occur in the stomach antrum, promoting stomach emptying.
- About **20% of contractions become intense,** beginning in midstomach and spreading through the caudad stomach.
- These contractions are **strong, tight, ring-like constrictions** capable of causing stomach emptying.
- Generate pressures of **50 to 70 cm of water, about six times as powerful as usual mixing peristaltic waves.**

Pyloric Pump:

- When pyloric tone is normal, **each strong peristaltic wave forces up to several milliliters of chyme into the duodenum.**
- Besides mixing stomach contents, these peristaltic waves **also create a pumping action** called the **"pyloric pump,"** which facilitates the movement of chyme into the small intestine.



Regulation of Stomach Emptying

1. **Increased food volume in the stomach promotes increased emptying.**

2. **Gastrin:**
   - Gastrin causes the secretion of highly acidic gastric juice by the stomach glands.
   - Gastrin also has mild to moderate stimulatory effects on motor functions in the body of the stomach, enhancing the activity of the pyloric pump.
   - Thus, gastrin promotes stomach emptying.

3. **Duodenum Enterogastric Nervous Reflexes:**
   - These reflexes inhibit stomach emptying, regulating the rate at which chyme enters the duodenum.

Inhibition of Stomach Emptying

Duodenal Reflexes:

- When food enters the duodenum, multiple nervous reflexes are initiated from the duodenal wall.
- These reflexes pass back to the stomach **to slow or stop stomach emptying if the volume of chyme in the duodenum becomes too high.**

- These parallel reflexes have two main effects:
  1. **Strongly inhibit the “pyloric pump” propulsive contractions.**
  2. **Increase the tone of the pyloric sphincter.**

Factors

1. **Distention of the Duodenum:**
    - Increased volume stretches the duodenal wall.
2. **Irritation of the Duodenal Mucosa:**
    - Presence of irritants triggers inhibitory reflexes.
3. **Acidity of Duodenal Chyme:**
    - High acidity levels initiate reflexes to slow emptying.
4. **Osmolality of Chyme:**
    - Changes in osmolality signal the need to regulate emptying.
5. **Breakdown Products of Proteins and Fats:**
    - Presence of these products also triggers inhibitory reflexes to manage the digestive process.

Motility in Small Intestine

Mixing Contractions (Segmentation Contractions)

- Sluggish, short-lived contractions
- Primarily function as mixing of chyme – with **bile, pancreatic & intestinal enzymes**
- Antegrade and retrograde moments – **Mixing**
- Increases the contact time with chyme and mucosal surface – **absorption**

Propulsive Moments (Peristalsis)

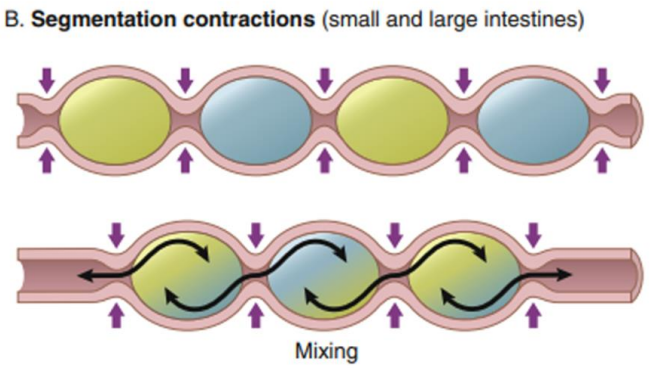
- It is the alternative wave of contraction and relaxation
- Move the chyme from small intestine toward the long intestine

Segmentation

- Chyme causes intestinal distension, stretching the intestinal wall.
- This induces localized concentric contractions lasting less than a minute.

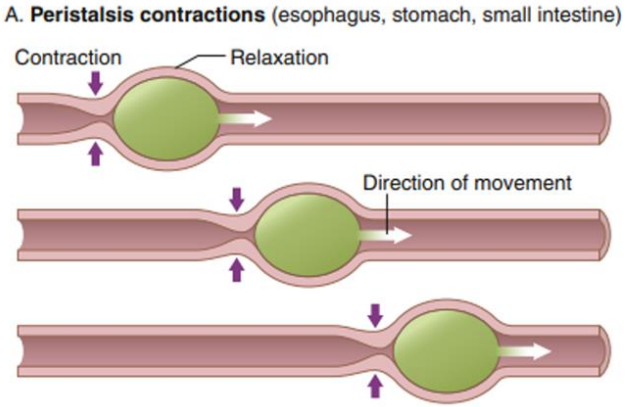
Segmentation:

- These contractions cause segmentation, dividing the intestine into spaced segments, resembling a chain of sausages.
- When one set of segmentation contractions relaxes, a new set begins at new points between the previous contractions.
- This results in chopping of chyme 2-3 times per minute.
- Frequency: Occurs at a rate of about 12 contractions per minute.



Peristalsis

- Chyme is propelled through the small intestine by peristaltic waves.
- These waves can occur in any part of the small intestine and move toward the anus.
- Velocity ranges from 0.5 to 2.0 cm/sec.
- Faster in the proximal intestine and slower in the terminal intestine.



Characteristics of Peristaltic Waves:

- Normally weak and often die out after traveling 3 to 5 cm.
- Rarely travel farther than 10 cm, resulting in very slow forward movement of the chyme.
- Net movement averages only 1 cm/min.
- It takes approximately 3 to 5 hours for chyme to pass from the pylorus to the ileocecal valve.

Control of Peristalsis

Stimulation

1. **Entry of chyme into the duodenum,** causing stretch of the duodenal wall.

2. **Neuronal - Gastroenteric reflex**
   - Initiated by the distention of the stomach.
   - Conducted principally through the myenteric plexus from the stomach along the wall of the small intestine.
   - Causes stretching of the duodenal wall upon chyme entry.

3. **Hormonal**
   - Gastrin, CCK, insulin, motilin, serotonin

Inhibition

- Secretin
- Glucagon

Motility in Large Intestine

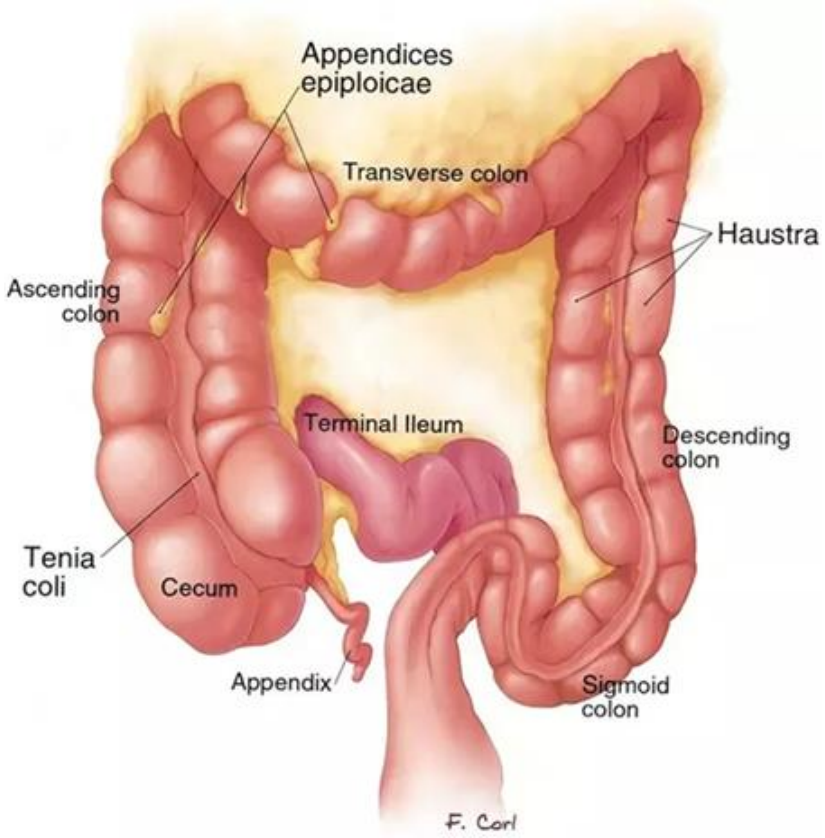
- The principal **functions of the colon are:**
  1. **Absorption of water and electrolytes** from the chyme to form solid feces.
  2. **Storage of fecal matter** until it can be expelled.
- Colon
  - **Proximal half – absorption**
  - **Distal half – storage**
- Movements in colon are sluggish. Divided into:
  1. **Mixing movements –** Haustrations
  2. **Propulsive movements** - Mass Movements

Taenia Coli:

- **Bands of smooth muscle** running the length of the large intestine.
- Shorter than the intestine, causing the colon to form **sac-like pouches called haustra.**

Haustra:

- Small pouches formed by **sacculation,** giving the colon its segmented appearance.



Mixing Movements – Haustral Contractions

- Slow, segmenting movements that mix chyme.
- Chyme fills a haustrum, causing **distension.**
- The smooth muscle layer **(taenia coli) contracts,** creating constriction points.
- These contractions **bring faecal residue into close contact with the mucosal wall.**
- This process aids in the **absorption of electrolytes (e.g., Na+, Cl-), water, and B vitamins.**

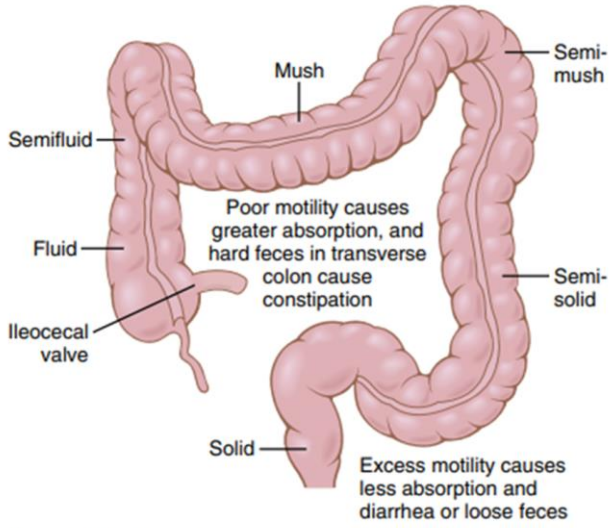


Figure 64-5. Absorptive and storage functions of the large intestine.

Propulsive Movements “Mass Movements”

- Slow, powerful contractions that move undigested waste to the rectum for defecation via the anus.
- Much **stronger and sustained peristaltic contractions.**
- **3–4** times a day.
- Mainly occurs in the **transverse, descending, and sigmoid colons.**
- Produced by **circular layer (smooth muscle) contractions.**

Thank You