Anatomy and physiology of the small bowel

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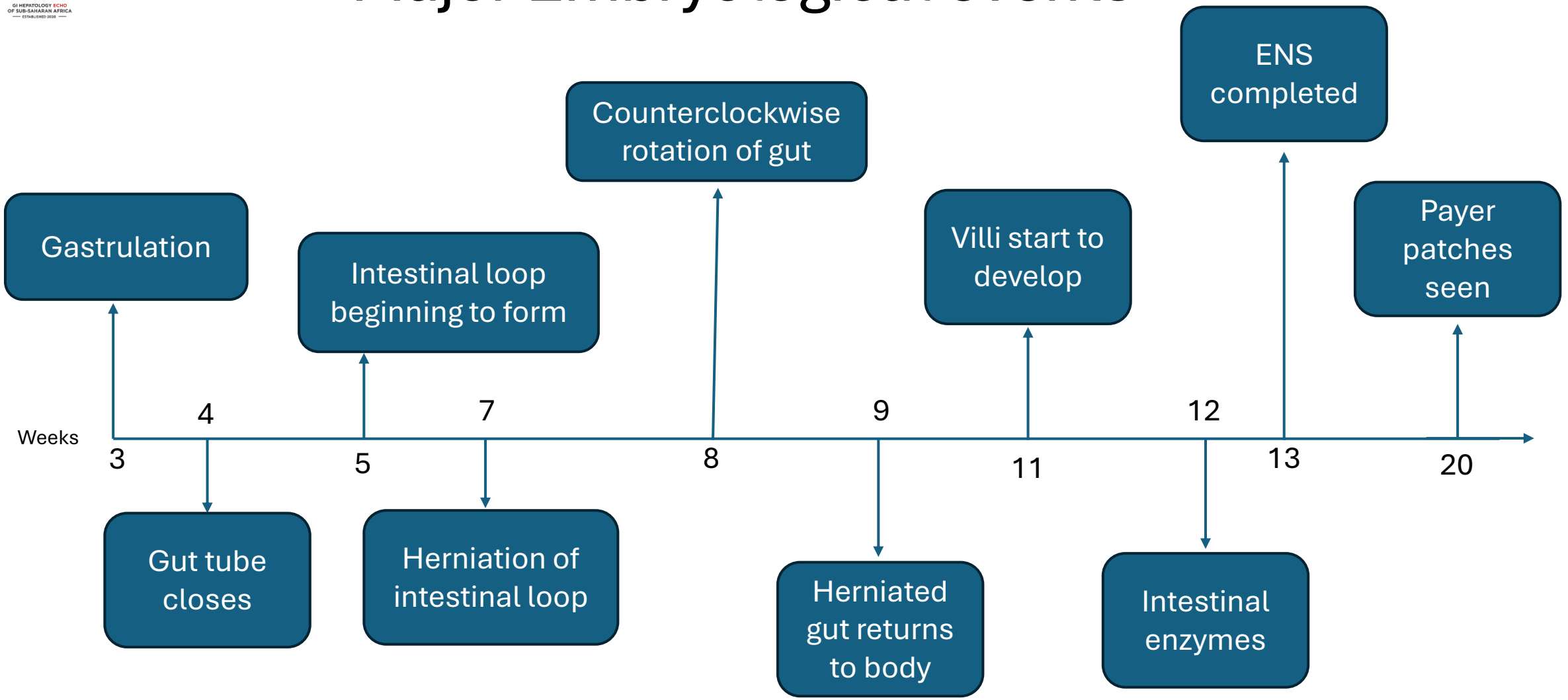
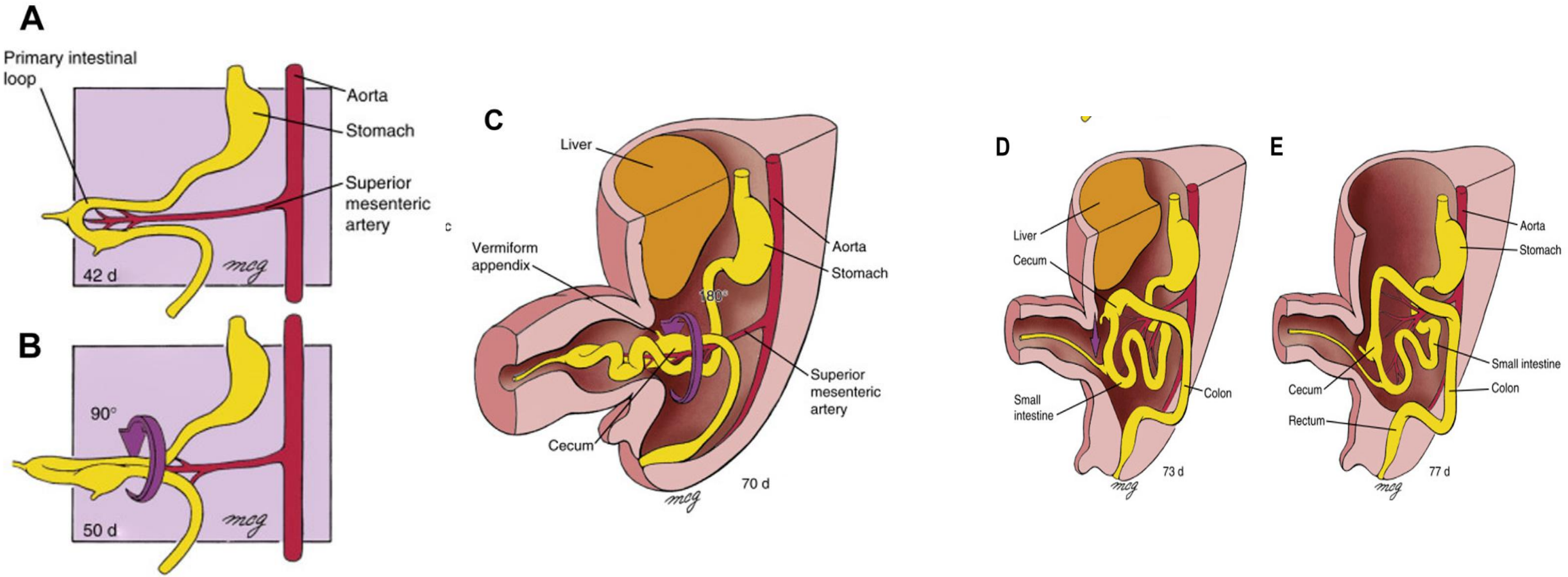
Outline

- Embryology/development
- Macroscopic & microscopic anatomy of small bowel
- Histology
- Physiology
  - Motility
  - Absorption

Major Embryological events

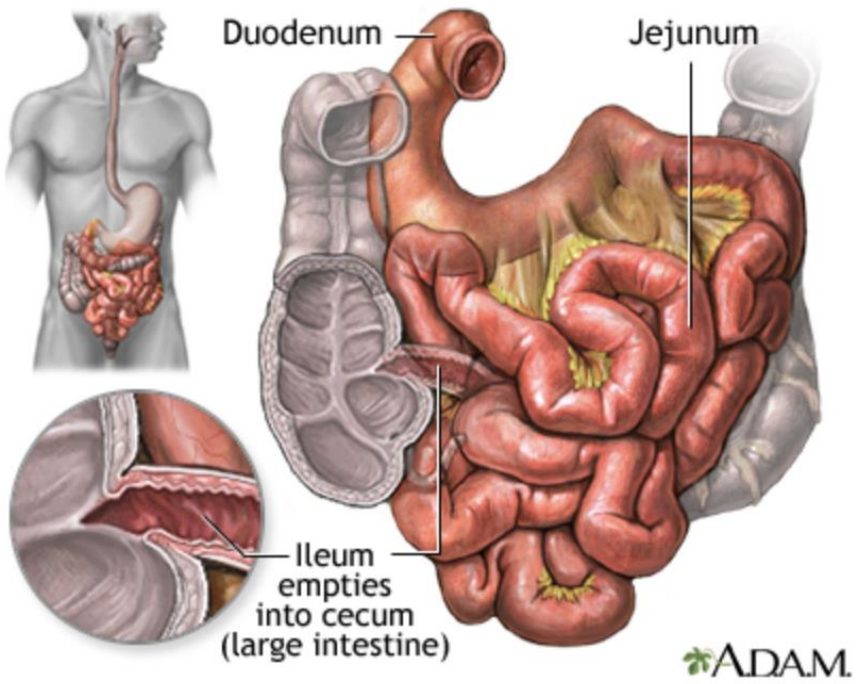


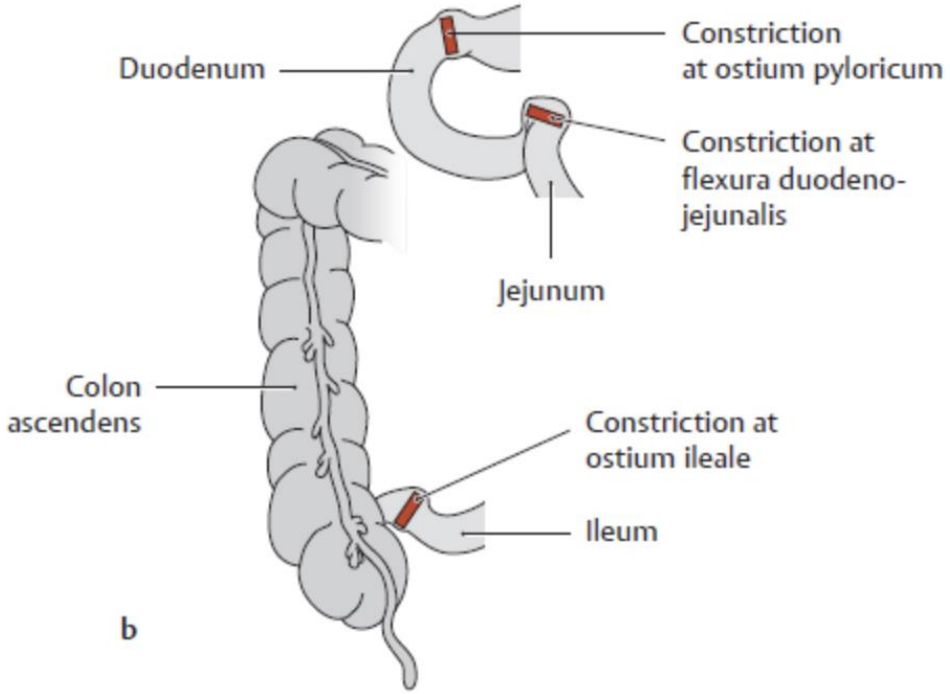
Herniation and rotation of gut



Abnormalities during embryogenesis

Abdominal wall	Vitelline duct	Malrotations	Duplications	Atresia & Stenosis	Enteric nervous system	Miscellaneous & Genetic
Omphalocele	Meckel's	Nonrotation	Tubular	Duodenal	Hirschsprung's disease	Microvillus inclusion disease
Gastroschisis	Cysts	Reverse	Spherical	Jejunal	Intestinal neuronal dysplasia	Intestinal epithelial dysplasia
	Bands	Malrotation			CIPO	Congenital Glucose malabsorption
	Patent					Sucrase & Lactase deficiency
	Remnant vessels					Chloridorrhea
						Sodium diarrhea





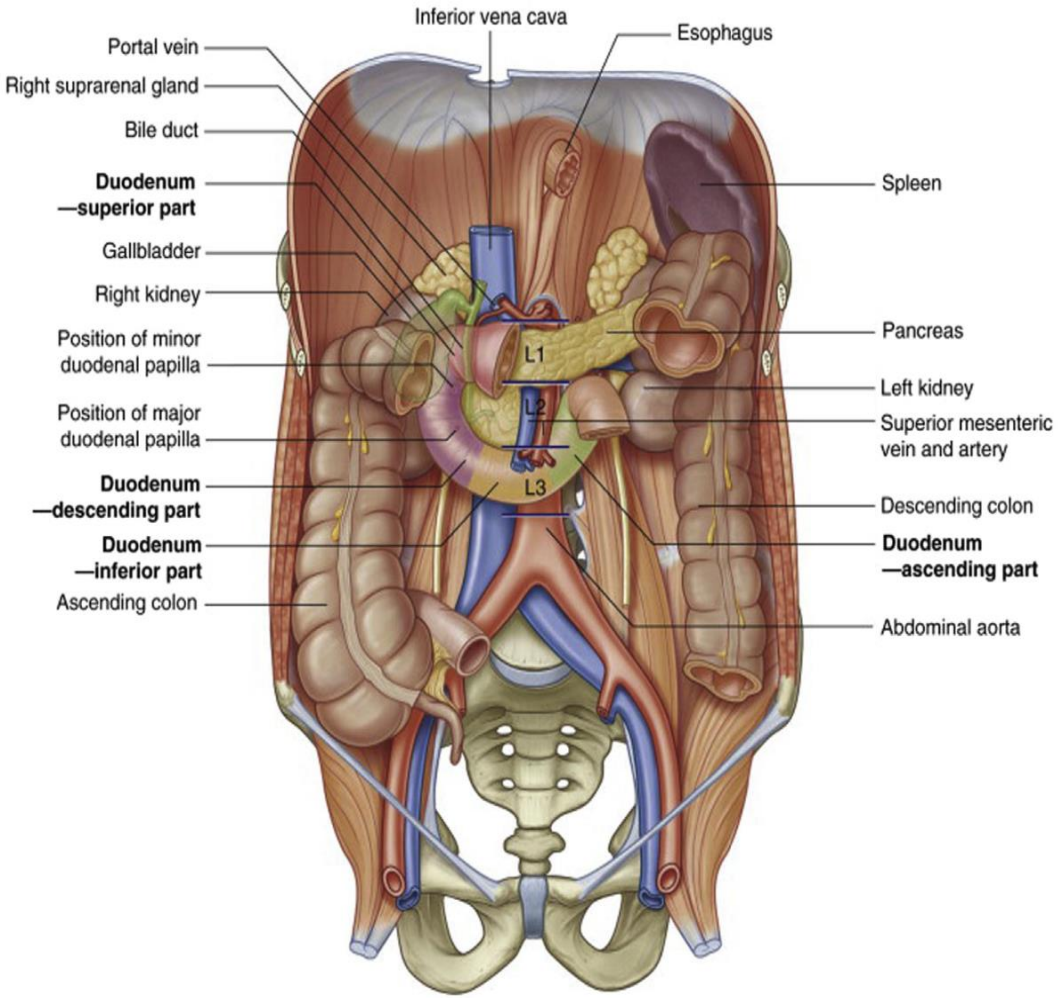
Anatomy: Macroscopic

- Length 6-7m
- Hollow tube
- Begins at Pylorus
- Ends at ileocecal valve

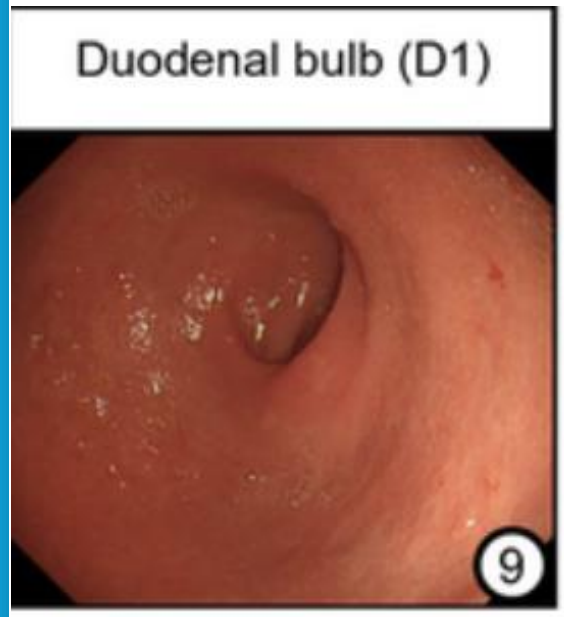
Anatomy: Macroscopic

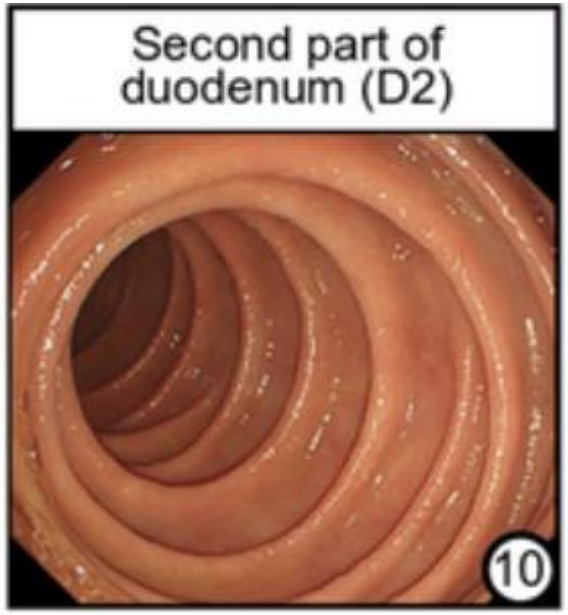
Proximal portion:

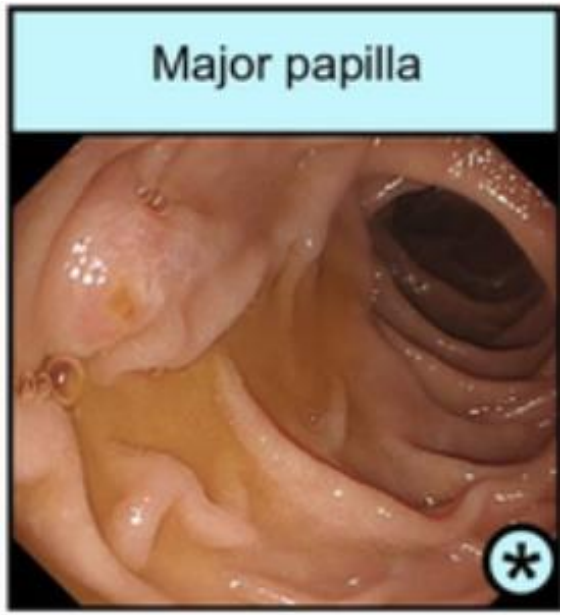
- Duodenum; 4 sections
- 1st part only portion not retroperitoneal
- Connected to liver by hepatoduodenal ligament
- Transverse retroperitoneally & wraps around head of pancreas
- Descending portion site of major ampulla
- Returns to peritoneal cavity at L2
- Fixed to retroperitoneum by suspensory ligament – Treitz
- Marks transition from duodenum to jejunum

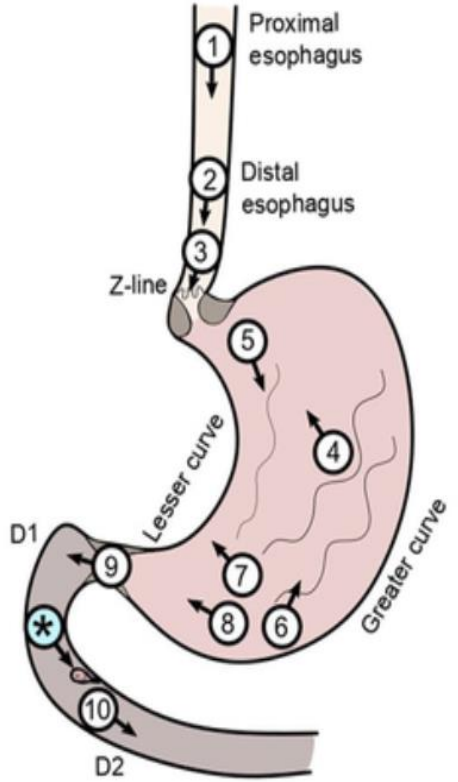


Endoscopic appearance





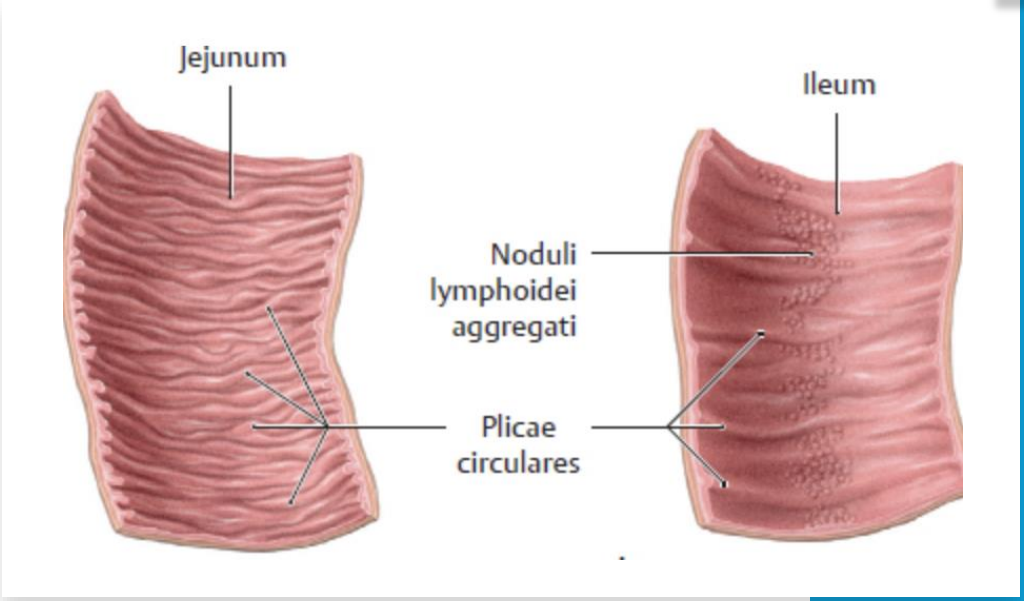


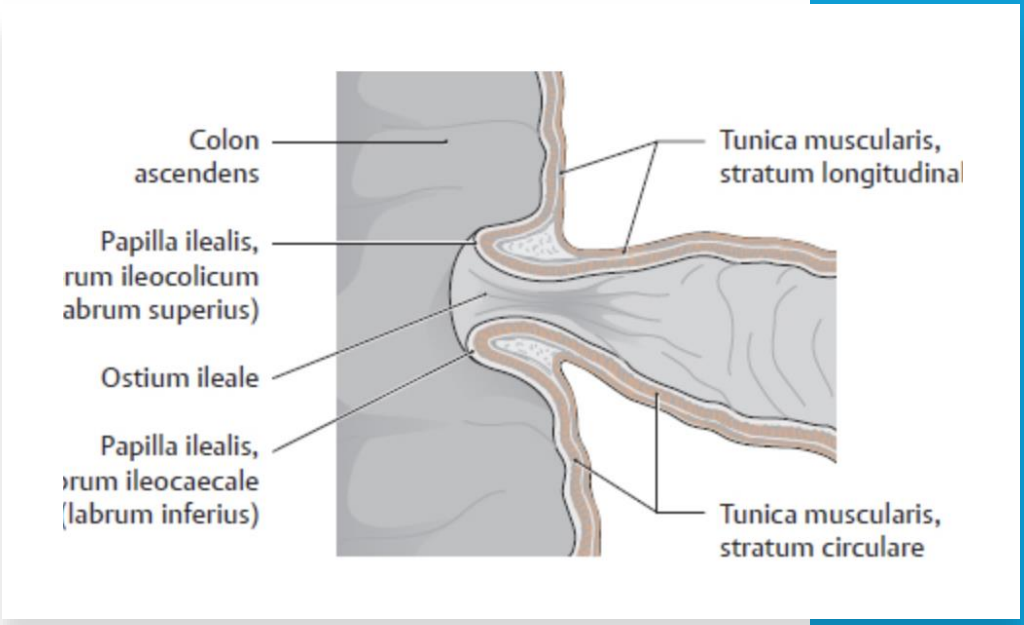


Anatomy: Macroscopic

Jejunum & Ileum:

- Resides in left upper quadrant
- ~ 2.5m in length
- Suspended in abdomen by thin mesentery attached to posterior wall
- Luminal surface, reveal plicae circulares = circular mucosa & submucosae folds > increases the surface area
- Decrease as move distally (anal), absent in terminal ileum
- Jejunum thicker mucosa folds
- Increased number of lymphoid follicles are found in ileum = Payers patches
- Ileocecal valve, 2 semilunar lips that protrude into caecum
- Suspended by superior and inferior ileocecal ligaments





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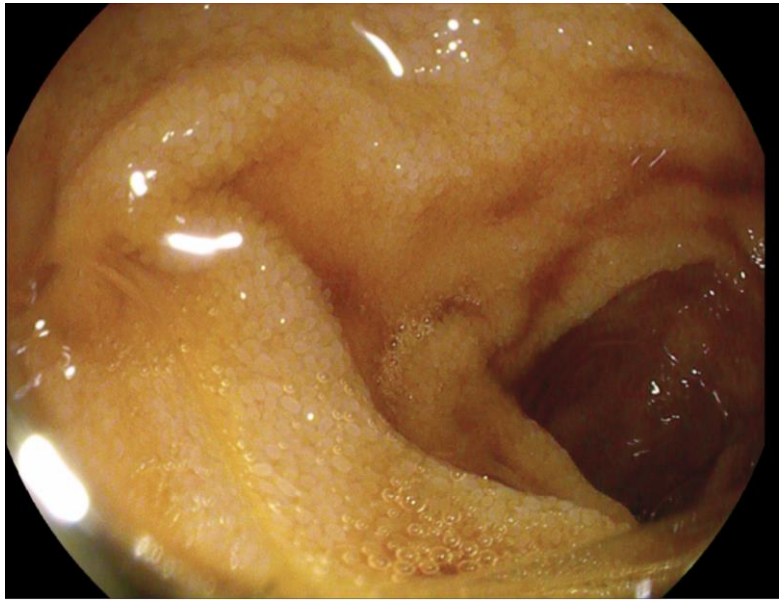
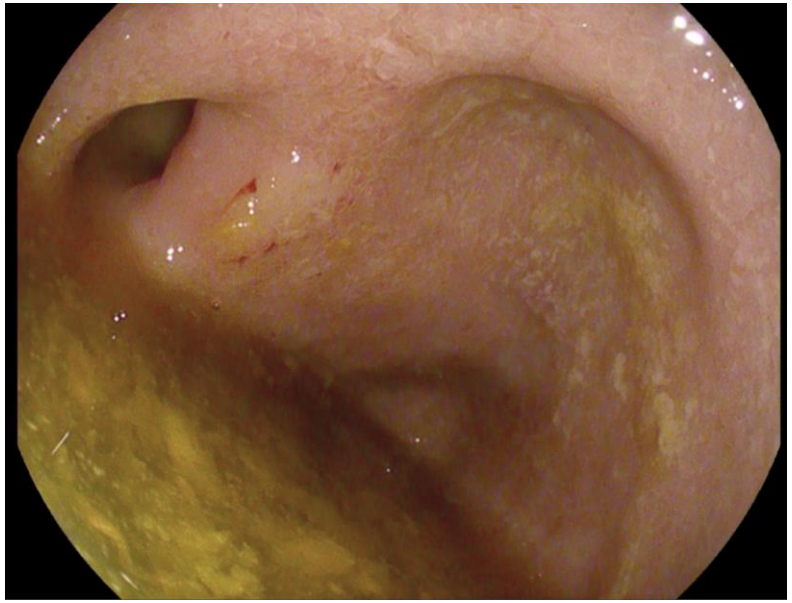
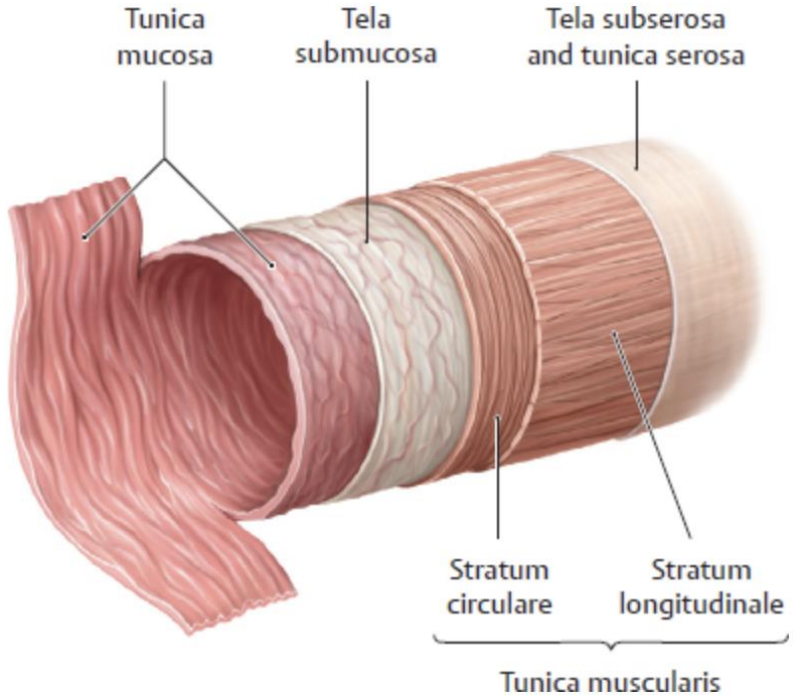
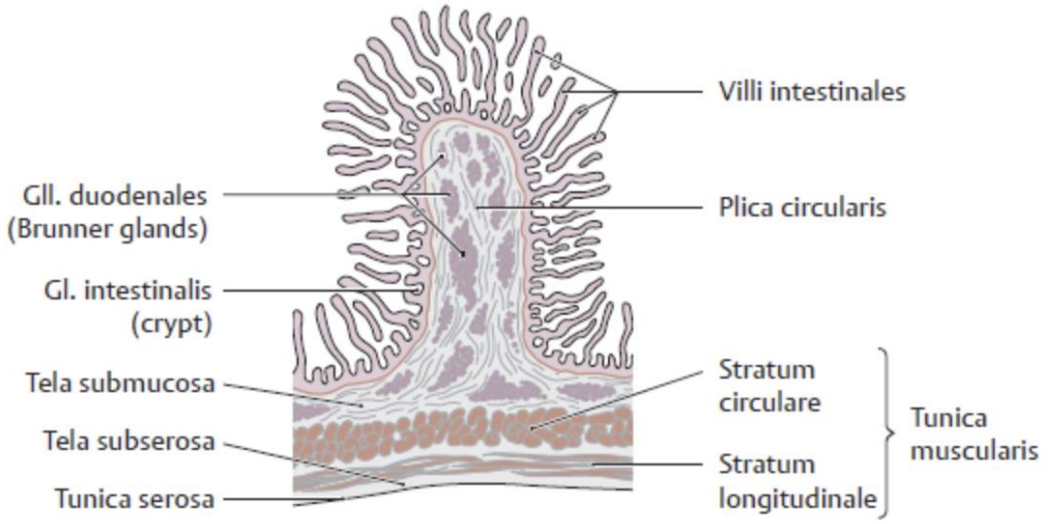








Histology

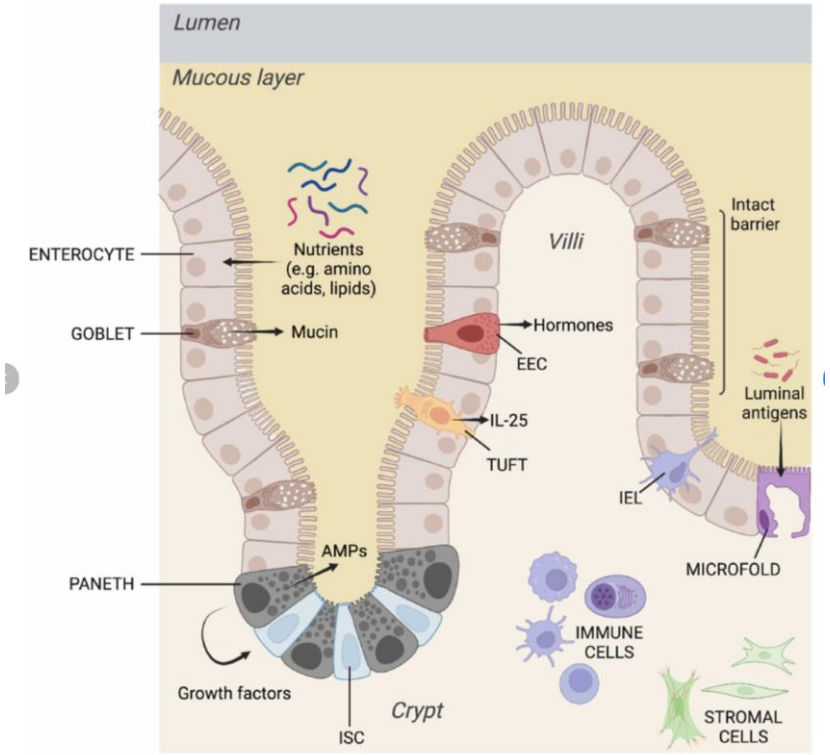
Small intestine 4 layers

- Mucosa
- Submucosa
- Muscularis propria
- Serosa

Histology: Mucosa

Mucosa: 3 distinct layers

- Epithelium, lamina propria(LP), muscularis mucosae (MM)
- Predominant cell, absorptive cell = enterocyte
- Each enterocyte >3000 microvilli
- Organised in grypt-vili axis
- Constantly proliferate and differentiate
- Stem cells located base of crypts
- Differentiate into 7 distinct cells
- Zona occludens holds cells together
- Lamina propria, provides connective tissue base
- Lymphocytes & mast cells present in LP
- MM thin layer of smooth muscle that plays minor role in peristalsis



Histology: Mucosa cell types and function

Cell type	Major known function	Structure	Location
Enterocytes	Main absorptive cell	Tall columnar cells with microvilli on apical side	Predominant cell of epithelium
Paneth cell	Defense against bacteria = secretes lysozymes and defensing	Large, pyramidal cells; eosinophilic granules at apical ends	Base of crypt of Lieberkuhn
Enteroendocrine cells	Locally regulate intestinal activity; CCK, secretin, GIP	Granules close to base	Crypts
Goblet cells	Mucin secreting cells = cytoprotective	Large granules; apical surface	Throughout; high concentration in jejunum & ileum
Tuft cells	Chemoprotection	Microfilaments connected to long vili	Throughout; high concentration jejunum & ileum
Cup cells	No known function	Braod apex, tapers	ileum
M cells	Antigen sampling cells	Epithelial cells lack brush border, many vesicles	Overlie Peyer patch

Histology: Submucosa, muscularis propria & serosa

Submucosa:

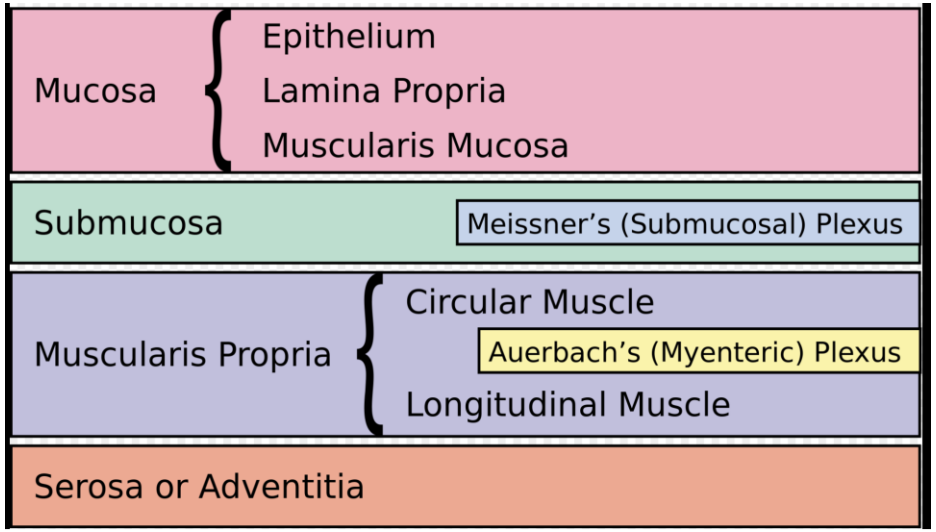
- Connective tissue layer
- Mass cell and fibroblast
- Aids in absorptive function of mucosa
- Collection of ganglions = Meissner's plexus, helps co-ordinate peristalsis

Muscularis propria:

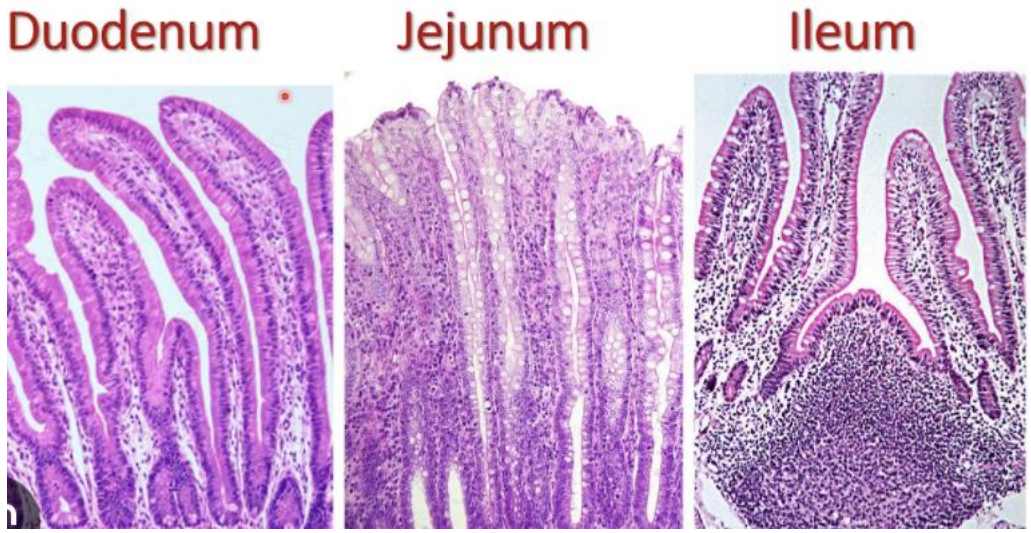
- Peristalsis
- 2 layers inner circular and outer longitudinal
- Auerbach plexus situated in-between

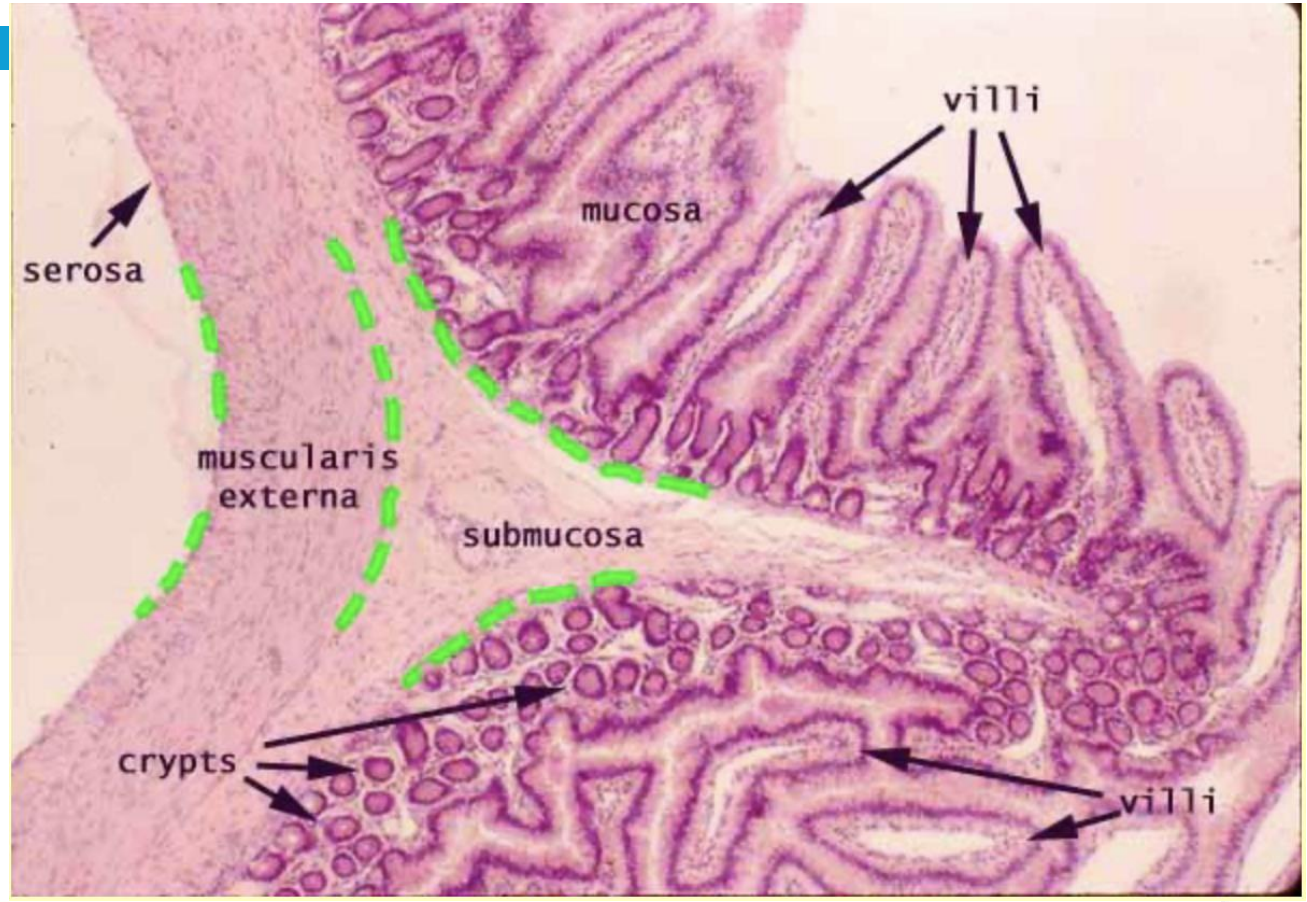
Serosa:

- Thin layer of mesothelial cells, underlying loose connective tissue structure



Histology slides





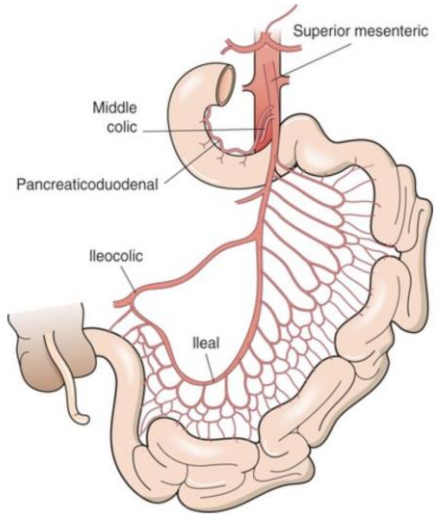
Blood supply & lymphatics

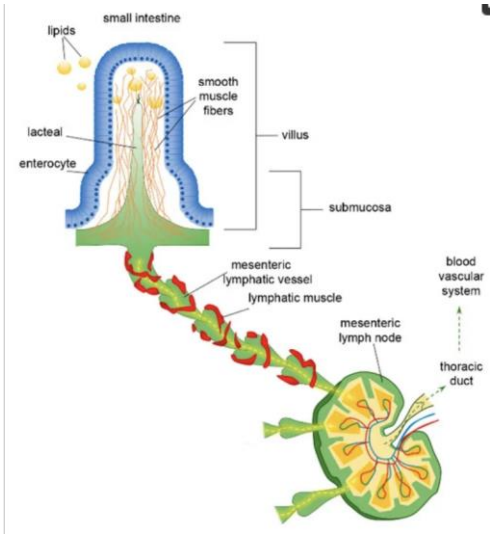
Blood supply:

- Oxygenated blood, from superior mesenteric artery (SMA)
- Duodenum secondary supply from branch of gastroduodenal artery
- Venous blood drains via superior mesenteric vein which joins splenic vein to form portal system - liver

Lymphatics:

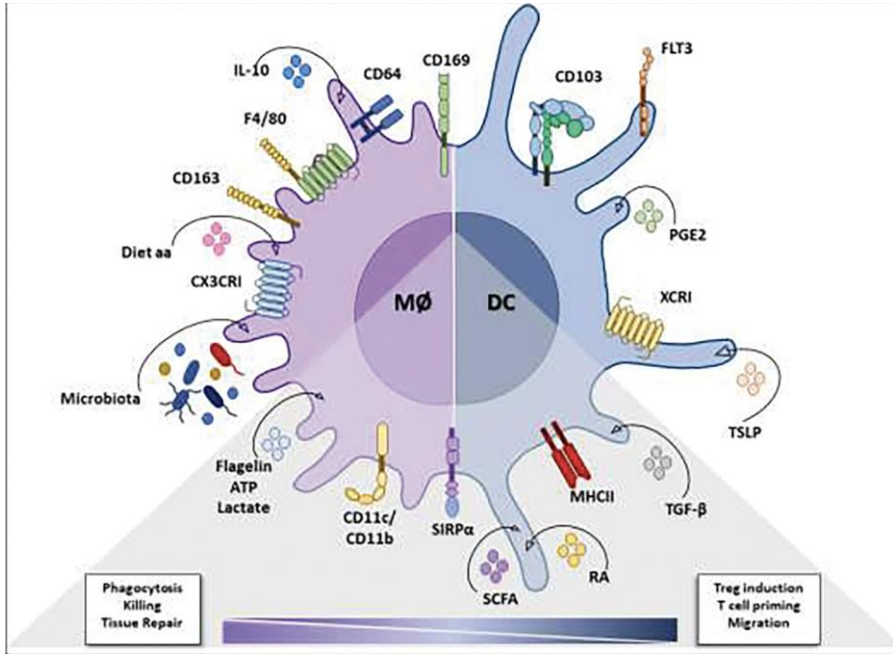
- Villus lacteals
- Drain into mesenteric lymph nodes, located along SMA
- Drain into thoracic duct
- Enters vena cava at subclavian vein on left





Intestinal macrophages

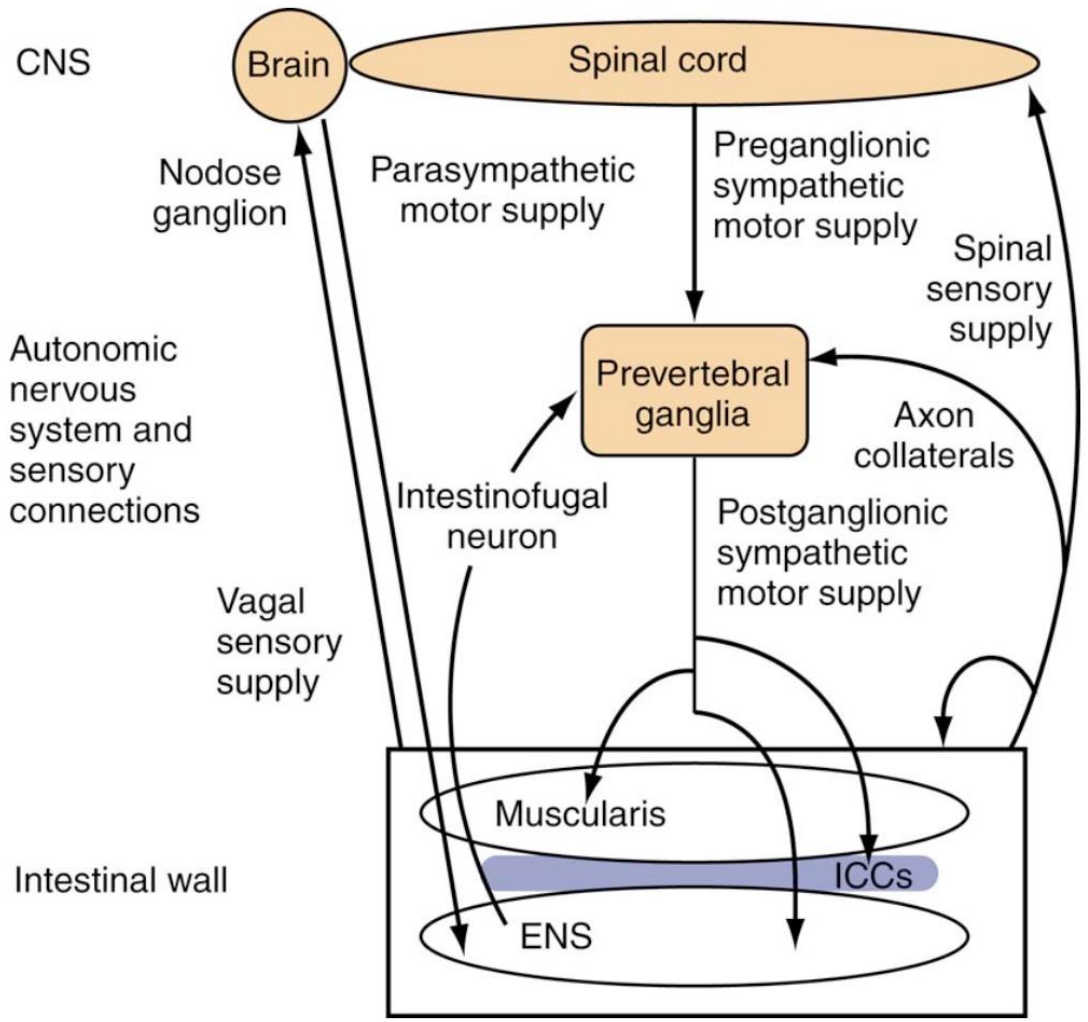
- Largest number of immune cell concentration
- Intestine direct surface to epithelium interface
- Role, both antigen presenting, immunotolerance
- 3 distinct types:
  - Lamina propria macrophages (LpMs)
  - Payer's patches macrophages (PpMs)
  - Muscularis mucosae macrophages (MMs)
- Interlinking role with dendritic cells
- Found in Lymphoid follicles and specilised tissue



Neuronal innervation

Extrinsic innervation (ANS):

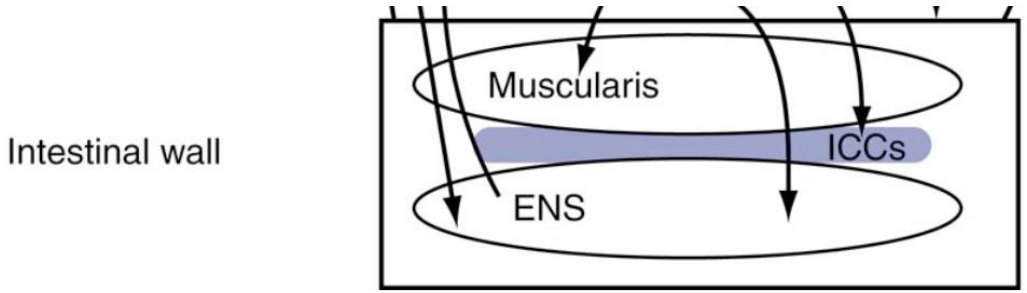
- Sympathetic innervation: T5-T11
- Preganglionic fibers pass uninterrupted through sympathetic trunk and terminate in celiac ganglion, NE primary mediator
- Parasympathetic innervation: Vagus nerve, Ach primary mediator
- Although present, not absolutely required



Neuronal innervation

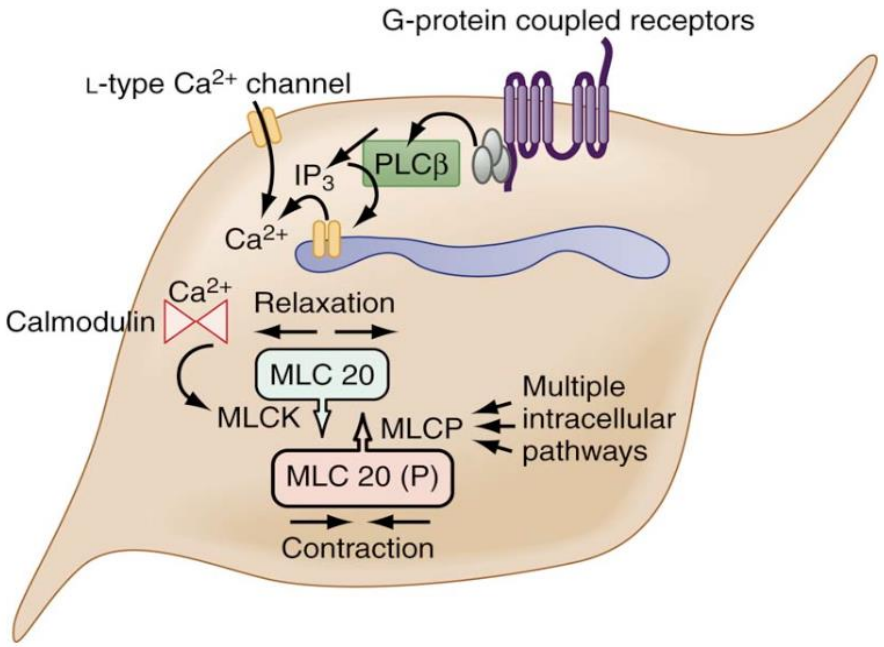
Intrinsic innervation (ENS):

- Nerve cell bodies and processes embedded in wall of gut
- Contains ~ 200-600 million neurons
- Three classes of neurons: IPANs; Interneurons; motor neurons
- Intimately involved in:
  - Motility, Secretion, Blood flow
- Two major enteric complexes:
  - Myenteric (involves motor innervation)
  - Submucosal plexus (secretory cells; endocrine cells; blood flow)
  - IPANs communication between 2 plexuses



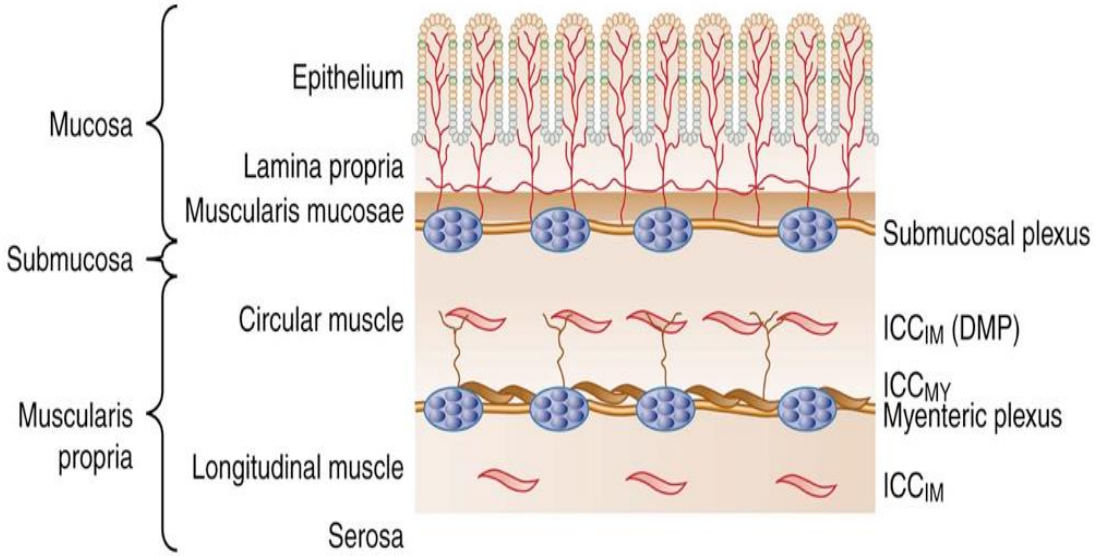
Motility, Smooth muscle

- Continuous fluctuations in membrane potential
- Occur ~ 11-12/min; Terminal ileum ~ 7-8/min
- Spike burst, results in contractions spread circumferentially



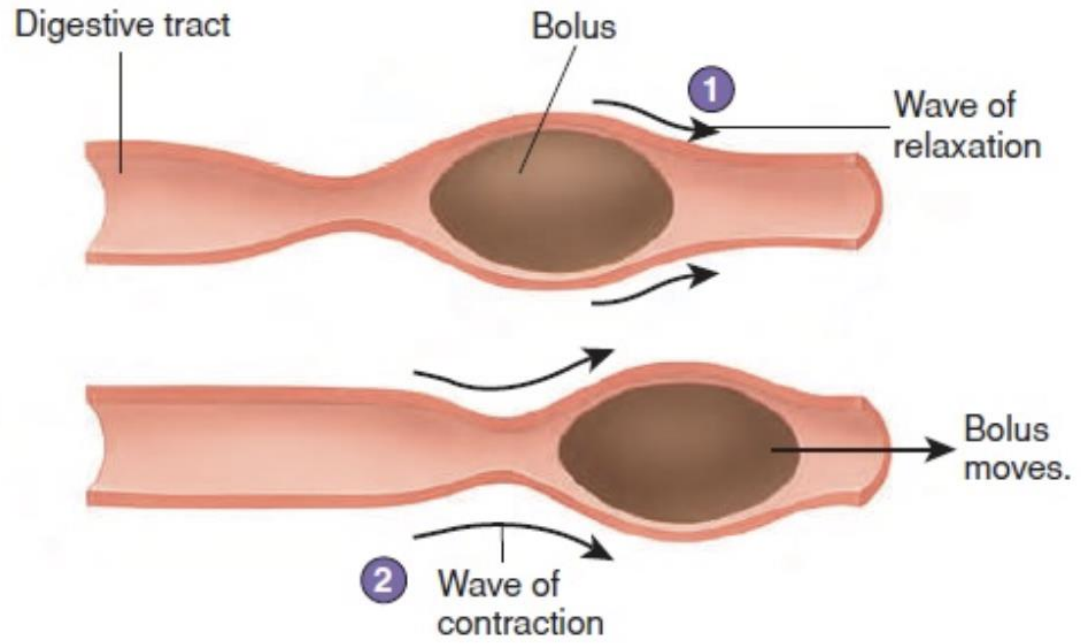
Motility, Interstitial cells of cajal

- Specialised cell within smooth muscle
- Lie in close proximity to nerve axons and myocytes
- Two roles:
  - Pacemaker cells
  - Transduce both inhibitory and excitatory signals
- Three functional groups
  - ICC_{MY}
  - ICC_{IM}
  - ICC (DMP)
- Input from excitatory neurons are mediated by M2/M3
- Input from inhibitory neurons are mediated by VIP & NO



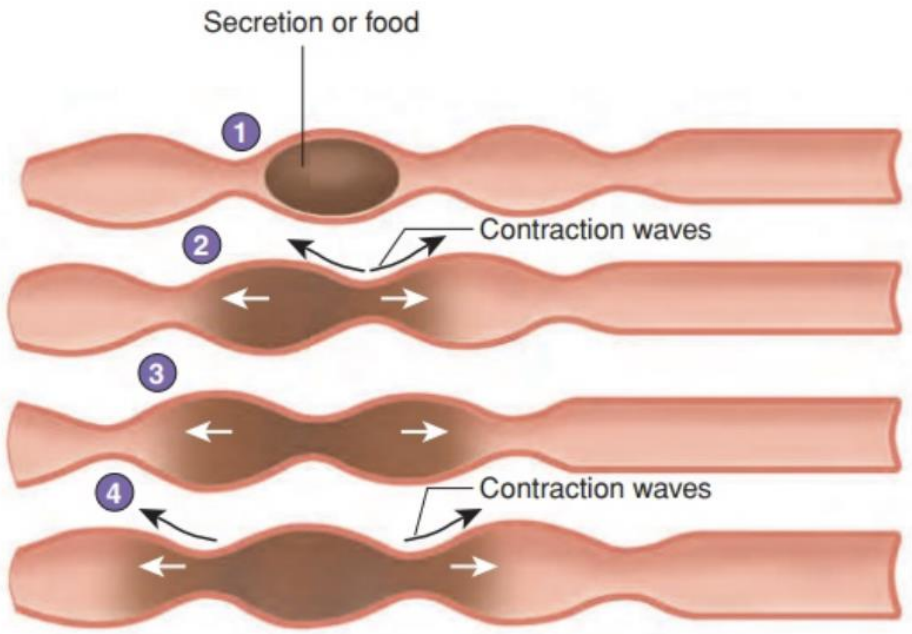
Motility, Peristalsis

- Progression of contractile activity in an aboral direction
- Coordinated entirely by ENS
- Initiated by mechanical, chemical stimuli
- Sensory and motor aspects
- IPANs
- Reverse peristalsis – mechanism for emesis



Motility, Interdigestive Motor complex

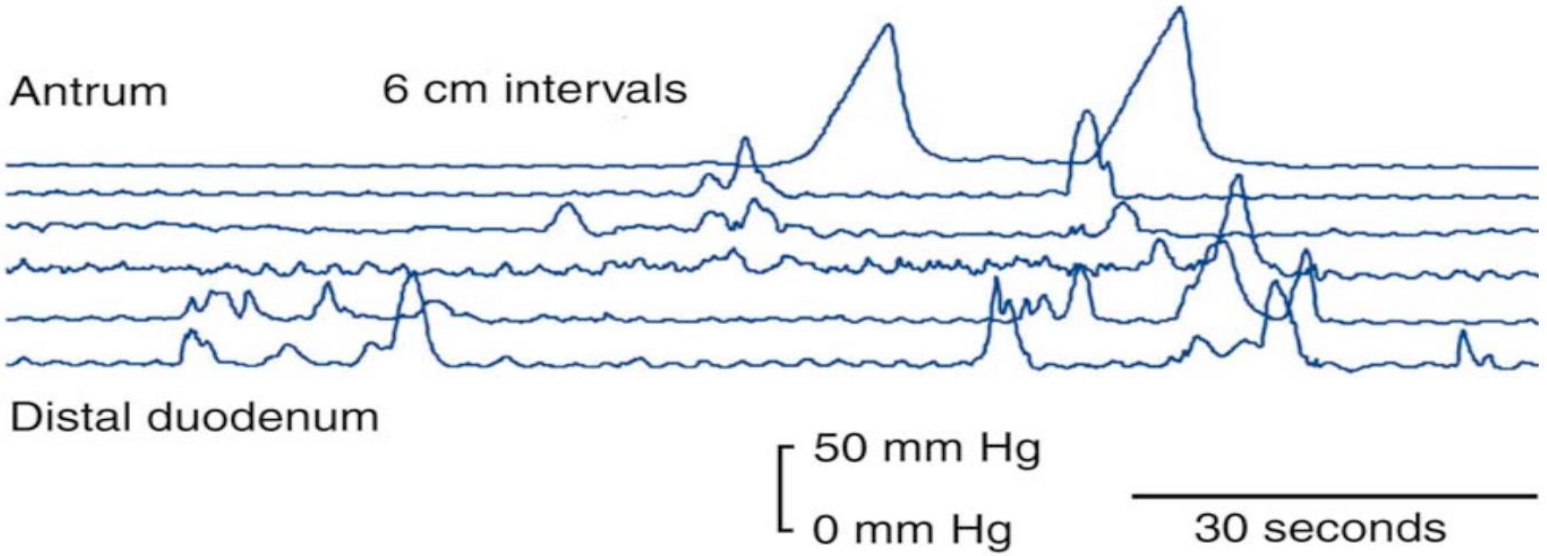
Migrating Motor Complex	
Phase I	Quiesant phase, ~45min – 2Hours
Phase II	Chaotic phase, 20-30min; Irregular contractions and amplitude
Phase III	Regular high amplitude contractions 5-7minutes



- Transit time affected by; distention, osmolality & pH
- Absorption occurs during phase I

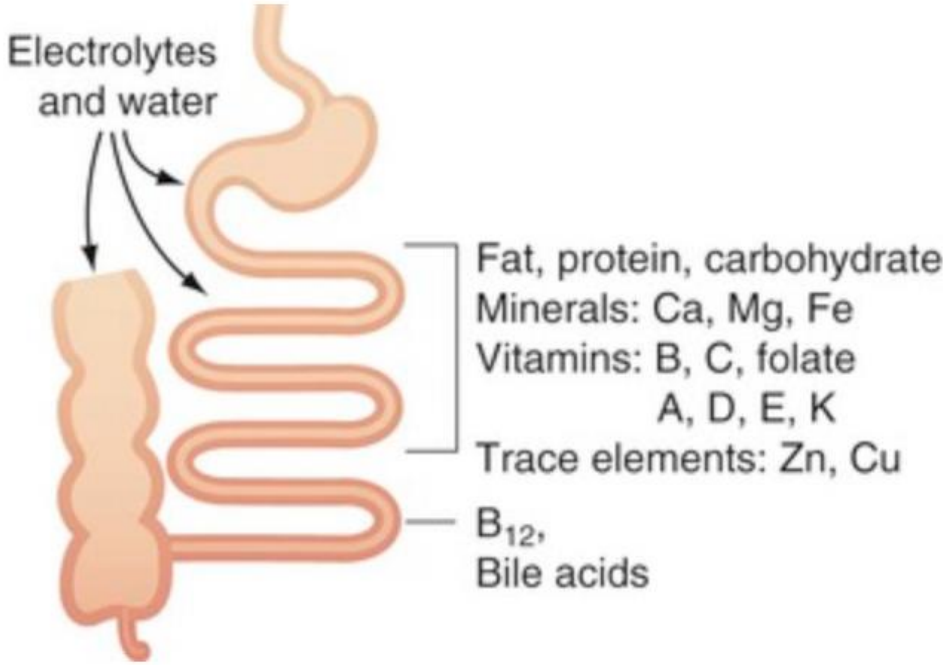
Tools to assess small bowel motility

Tool	
Manometry	Direct measurement of contractile forces. Sensor limitation and length
MRI	Non-invasive, lacks radiation, cost and availability



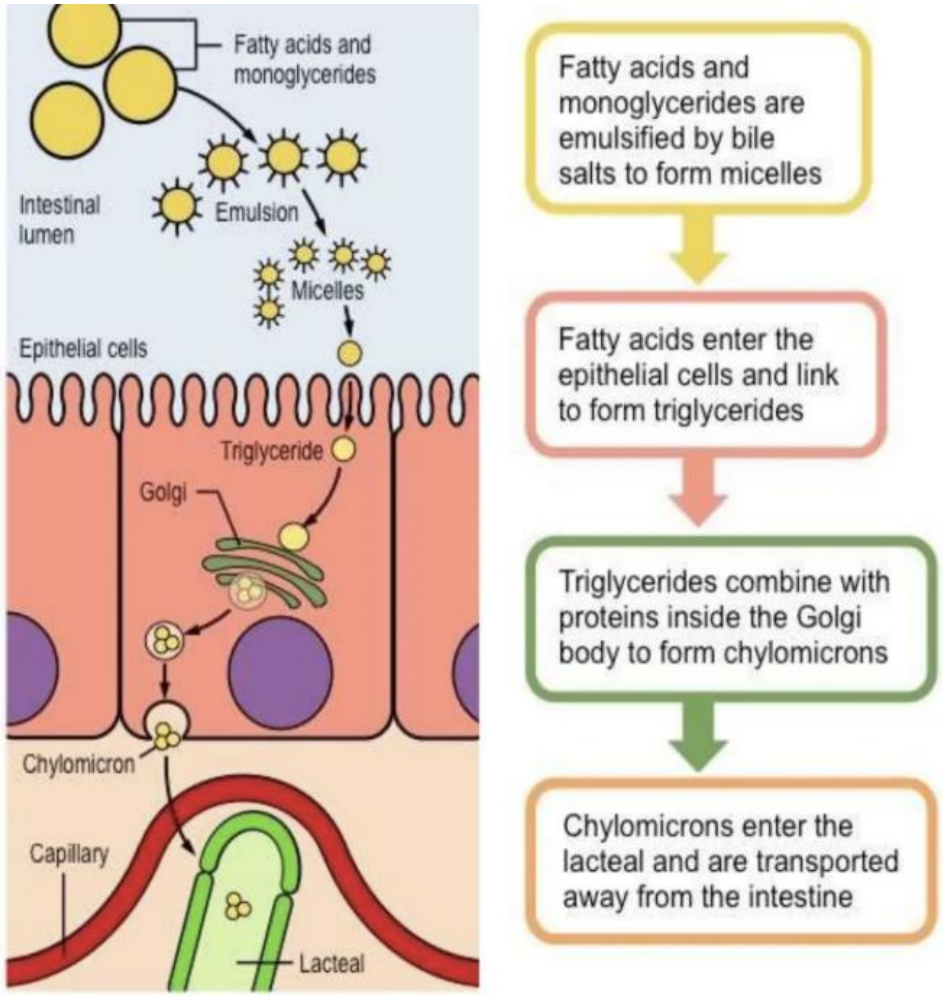
Absorption

- Most chemical absorption occurs within the small intestine
- Digestion relies on complex interplay of entire GI tract



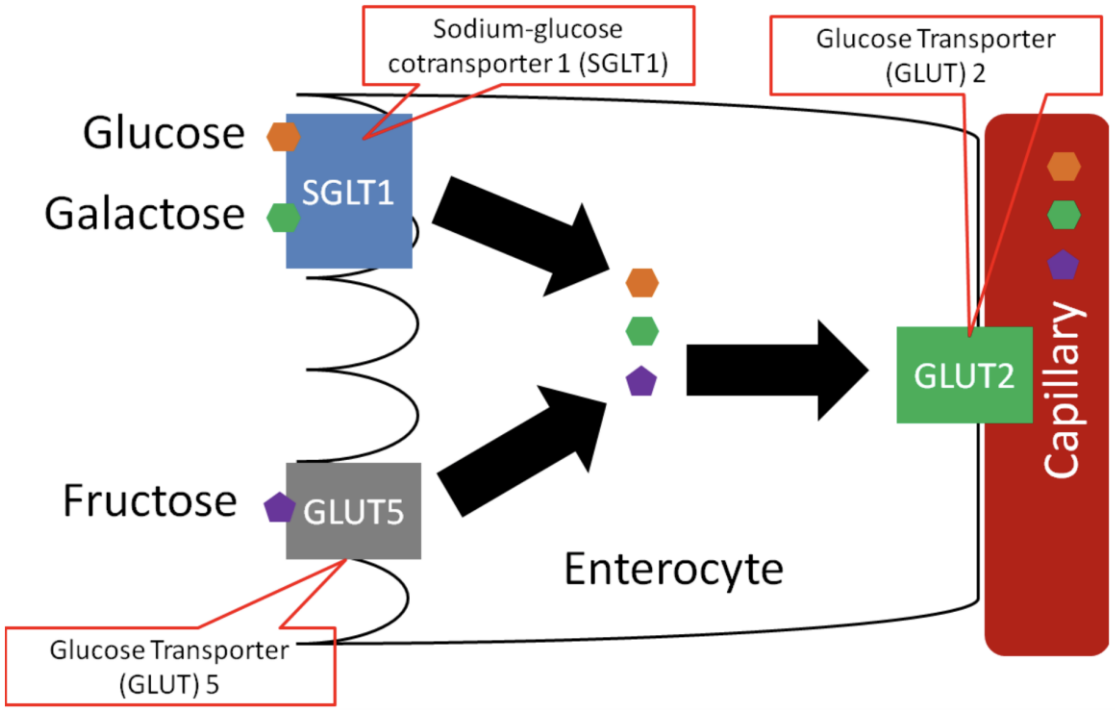
Absorption, Lipids

- Absorbed in upper 2/3 of jejunum
- Multiple digestive steps
- Most Lipolysis occurs within small intestine
- Pancreatic lipases enter gut via pancreatic duct
- Bile salts serve as emulsifiers
- Transport via micelles
- Absorption into enterocyte via fatty acid transport proteins
- Once in the enterocyte, bind to FABP, then transported for processing



Absorption, Carbohydrates

- Multistep process, many depending on small bowel unique properties
- Hydrolyses of starch within the lumen via Pancreatic amylase initiates
- Resulting products undergo further hydrolyses by apical carbohydrase's



Major brush border carbohydrase's		
Substrate	Enzyme	End Product
α-1,4-Linked oligosaccharides	Maltase	Glucose
Lactose	Lactase	Glucose & Galactose
Sucrose	Sucrase	Glucose & Fructose
α-Limit dextrins	Isomaltase	Glucose

Absorption, Proteins

- Degraded to small peptides and amino acids before absorption
- Pepsin activity inactivated in small bowel
- Pancreatic proteolytic enzymes continue process

Pancreatic proteolytic enzymes and their function	
Proteolytic Enzyme	Function
Trypsin	Cleaves bonds at lysine or arginine
Elastase	Cleaves bond at aliphatic amino acid
Chymotrypsin	Cleaves bond at aromatic or neutral amino acids
Carboxypeptidase A	Cleaves aromatic amino acids at terminal ends of peptides
Carboxypeptidase B	Cleaves arginine or lysine from terminal ends of peptides

Absorption, Micronutrients

Folate

- Absorbed in duodenum & upper jejunum
- Hydrolysed by glutamate carboxypeptidase II at brush border

Vitamin B12

- Bind to R-protein in gastric lumen
- Binds intrinsic factor in small intestine lumen
- B12-IF complex binds to AML receptors in terminal ileum

Vitamins A,D & E

- Passive absorption in small bowel

Vitamin K

- K_1 Dependent on bile salts and carrier mediated diffusion
- K_2 absorbed passively

Absorption, Water

Water

- 9L delivered to GI tract
- ~7L of water absorbed by small bowel
- 60-80% efficient
- Mechanism not well explained
    - Aquaporins; osmotic gradients all discovered

Conclusion

- A Concise understanding of the mechanism of small intestinal, motility, absorptive function and microenvironment is essential in management of gastrointestinal disorders
- Facilitates digestions and absorption of nutrients and water
- Continuously replenishes its epithelial surface
- It has a brain of its own!

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