NOTES
ANATOMY & PHYSIOLOGY

ANATOMY

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- *Alimentary/GI tract:* continuous muscular tube from mouth to anus
- Many digestive organs reside in abdominal, pelvic cavity; covered by mesentery

PERITONEUM

- Thin connective tissue composed of mesothelium, connective tissue supporting layer, simple squamous epithelium
- Lines abdominal, pelvic cavities; binds organs together, holds them in place
- Contains blood vessels, lymphatics, nerves innervating abdominal organs
  - *Parietal peritoneum:* lines abdominal, pelvic cavities
  - *Visceral peritoneum:* covers organ surfaces
  - *Peritoneal cavity:* potential space between parietal, visceral layers
- *Intraperitoneal organs:* digestive organs; keep mesentery during embryological development, remain in peritoneal cavity (e.g. stomach)
- *Retroperitoneal organs:* lose mesentery during embryological development, lay posterior to peritoneum (e.g. kidneys, pancreas, duodenum)
- *Mesentery:* double layer of parietal peritoneum on dorsal peritoneal cavity, provides routes for vessels, lymphatics, nerves to digestive organs

Omentum

- Visceral peritoneum layer covering stomach, intestines; contains adipose tissue, many lymph nodes
  - Expands during weight gain; "fat skin"
- *Lesser omentum:* double layer arises from lesser curvature of stomach, extends to liver
- *Greater omentum:* four layers (double sheet folds back upon itself); arises from greater curvature of stomach, covers intestines

GI tract layers

- Four basic tissue layers from esophagus to anus
- Serosa/adventitia
  - Outermost layer of intraperitoneal organs; also visceral peritoneum
  - Primarily composed of simple squamous epithelial cells, connective tissue
  - Secretes slippery fluid, prevents friction between viscera, digestive organs
  - Esophagus has adventitia instead of serosa
  - Retroperitoneal organs have serosa, adventitia
- Muscularis propria
  - Outer longitudinal, inner circular smooth muscle for involuntary contractions; regions of thickened circular layer forms sphincters
  - Skeletal muscle in esophagus for voluntary swallowing
  - Contains myenteric plexus (between longitudinal, circular layers of smooth muscle)
  - Myenteric plexus responsible for peristalsis, mixing
- Submucosa
  - Connective tissue that binds muscularis, provides elasticity, distensibility
  - Contains Meissner's plexus
  - Richly vascularized, innervated

- Mucosa
  - Innermost layer composed of epithelial membrane lining entire GI tract
  - *Functions:* exocrine glands secrete water, mucus, digestive enzymes, hormones; absorb digested nutrients; provides protective surface
  - *Muscularis mucosae:* smooth muscle layer responsible for mucosa movement; contains folds to increase surface area
  - *Lamina propria:* loose areolar connective tissue; contains blood, lymphatic vessels; contains MALT (lymphoid tissue that protects against pathogens)
  - *Epithelium:* mouth, esophagus, anus composed of stratified squamous cells; rest of GI tract simple columnar with mucus secreting cells

BLOOD CIRCULATION

- Splanchnic circulation
- *Celiac trunk:* supplies stomach, liver, spleen
- *Superior mesenteric artery:* supplies small intestine
- *Inferior mesenteric artery:* supplies large intestine

INNERVATION

- Supplied by autonomic nervous system (ANS)
- *Sympathetic component:* thoracic splanchnic nerves → celiac plexus
- *Parasympathetic component:* vagus nerve
- Enteric division provides local control of GI activity; "the brain in the gut"; can function independently of ANS

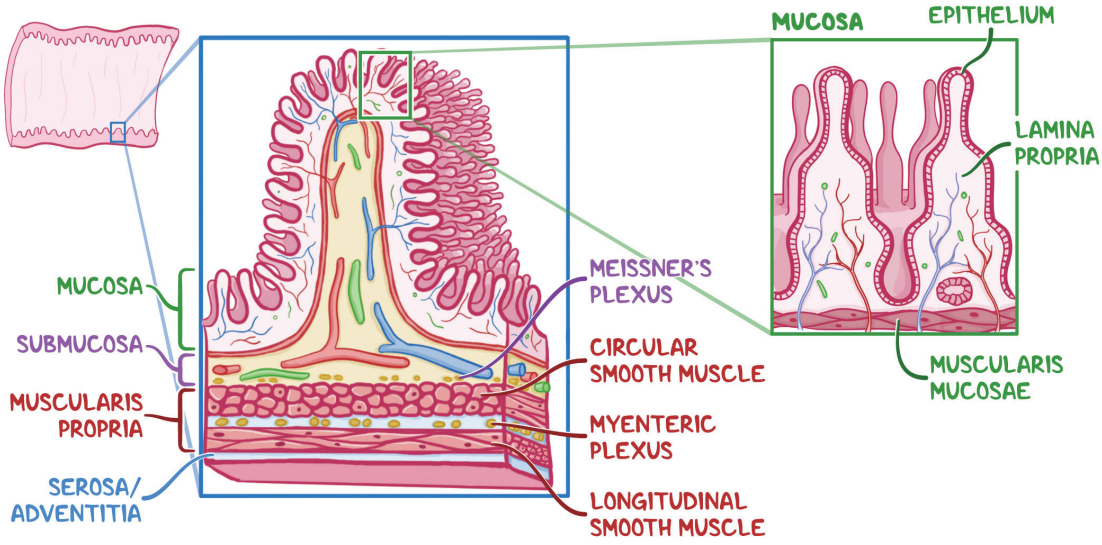

Figure 36.1 Cross section from small intestine showing the four basic tissue layers that line gastrointestinal tract: (from the outermost) serosa/adventitia, muscularis propria, submucosa, and mucosa.

STRUCTURES

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ORAL (BUCCAL) CAVITY

Function

- Ingestion, mechanical, chemical digestion, propulsion
- Saliva contains antibacterial properties that cleanses, protects oral cavity, teeth from infection
- *Propulsion:* swallowing (performed by tongue) propels food into pharynx, starts propulsion through GI tract
- *Mechanical digestion:* via mastication by teeth, tongue
- *Chemical digestion:* salivary amylase starts carbohydrate chemical breakdown

Secretions

- *Chemical digestion:* salivary amylase starts carbohydrate chemical breakdown; mucin, water provide lubrication
- *Lysozyme:* kills some microbes
- *Lingual lipase:* digests some lipids

ESOPHAGUS

- Muscular tube extending from laryngopharynx to stomach
- *Esophageal hiatus:* diaphragm opening where esophagus, vagus nerve pass through to abdominal cavity
- *Cardiac orifice:* junction of esophagus, stomach

Function

- Propulsion/peristalsis
- Epiglottis closes larynx, routes food into esophagus
- Lower end of esophagus contains mucous cells to protect esophagus from stomach acid reflux

Sphincters

- *Upper esophageal sphincter:* skeletal muscle; regulates movement from pharynx to esophagus
- *Cardiac sphincter:* AKA lower esophageal sphincter; smooth muscle at cardiac orifice that prevents acidic contents of stomach from moving upward into esophagus

Histology

- Mucosa
  - Nonkeratinized stratified squamous epithelium (simple columnar epithelium near cardiac orifice)
- Mucosa, submucosa form longitudinal folds when empty
- Submucosa
  - Mucus secreting glands
- Muscularis externa
  - *Superior ⅓:* skeletal muscle
  - *Middle ⅓:* skeletal, smooth muscle
  - *Inferior ⅓:* smooth muscle
- Adventitia instead of serosa

Secretions

- *Mucus:* lubrication, protection from gastric acid

STOMACH

- Located in upper left abdominal cavity quadrant
- Contains rugae (mucosa, submucosa) when stomach empty → expands to accommodate food

Function

- Churning, digestion, storage
- Beginning of chemical digestion turning food into chyme to be delivered into small intestine

Regions

- *Cardia:* most superior area surrounding cardiac orifice where food from esophagus enters stomach
  - Defined by Z-line of gastroesophageal junction
  - *Z-line:* epithelium changes from stratified squamous → simple columnar

- *Fundus:* area lying inferior to diaphragm, upper curvature
  - Food storage
- *Body:* central, largest area of the stomach
- *Pylorus:* connects to duodenum via pyloric sphincter
  - Controls gastric emptying, prevents backflow from duodenum into stomach

Histology

- Muscularis contains regular GI tract layers with three-layered muscularis propria unique to stomach allowing for vigorous contractions, churning
  - Inner oblique layer
  - Middle circular layer (contains myenteric plexus)
  - Outer longitudinal layer

Glands

- Lined with simple columnar epithelium; forms gastric pits (tube-like opening for gastric glands)
- Cardia, pylorus glands mainly secrete mucus
- Fundus, body glands secrete majority of digestive stomach secretions
- Pyloric antrum glands mainly secrete mucus, hormones (mainly gastrin)

Secretions

- *Mucous cells:* neck, basal regions of glands; produce mucus that protects stomach lining, lubricates food
- *Parietal cells:* gland apical region amongst chief cells; produce HCl, intrinsic factor
- *Chief cells:* gastric gland base; produce pepsinogen (protein digestion)
- *Enteroendocrine cells (ECL cells):* located deep in glands; secretes histamine, somatostatin, serotonin, ghrelin
- *G-cells:* gastrin
- *D-cells:* somatostatin

SMALL INTESTINE

Function

- Primary organ of digestion, nutrient absorption; segmentation (localized mixing area), peristalsis
- *Absorption:* food breakdown products absorbed
- Contains circular folds, villi, microvilli to maximize absorption surface area
  - Circular folds are permanent, composed of mucosa, submucosa

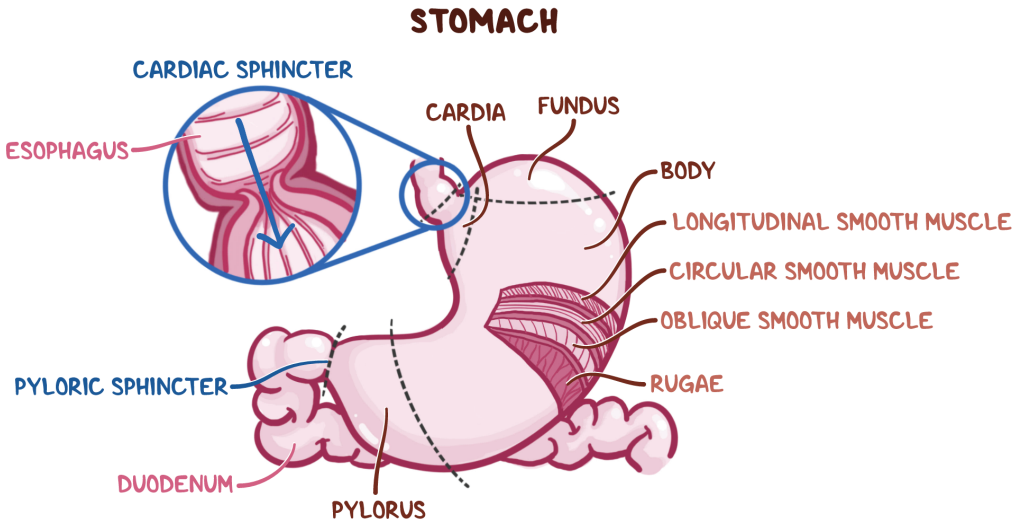

Figure 36.2 Stomach anatomy.

Innervation

- Relayed through celiac, superior mesenteric plexus
- *Sympathetic:* thoracic splanchnic
- *Parasympathetic:* vagus

Blood supply

- *Arterial:* superior mesenteric artery
- Veins from small intestine → hepatic portal vein → liver

Histology

- *Epithelium of villus:* simple columnar absorptive cells
  - Main function is absorbing nutrients
- Mucus secreting goblet cells in epithelium
- Mucosa contains pits called intestinal crypts
  - *Crypt cells:* secrete intestinal juice containing mucus
  - *Enteroendocrine cells:* within crypts, intraepithelial lymphocytes (T cells)
  - *Paneth cells:* located deep in crypts, release defensins, lysozyme to protect against pathogens

Sections

- Duodenum
  - Mostly retroperitoneal
  - Curves around head of pancreas, receives bile from liver via bile duct, pancreatic secretions from pancreas via main pancreatic duct
  - *Ampulla of vater:* bulb-like point where bile duct, main pancreatic duct unite, deliver secretions into duodenum
  - *Major duodenal papilla:* ampulla opening into duodenum releasing bile/pancreatic secretions
  - *Hepatopancreatic sphincter:* controls bile entry, pancreatic secretions
  - Duodenal glands (Brunner's) in duodenal submucosa secrete alkaline mucus to neutralize acidic chyme
- Jejunum
  - Intraperitoneal
  - Suspended from posterior abdominal wall by mesentery
- Ileum
  - Intraperitoneal
  - Joins large intestine at ileocecal valve
  - Suspended from posterior abdominal wall by mesentery
  - *Peyer's patches:* lymphatic tissue sections composed predominantly of proliferating B lymphocytes, mostly located in ileal lamina propria as protection against pathogenic bacteria; B lymphocytes release IgA

Secretions

- Brush border enzymes on microvilli complete food digestion (e.g. mucus, water, peptidases, disaccharidases)
- Pancreas, liver contribute to most small intestine digestion

LARGE INTESTINE

- Retroperitoneal except for transverse, sigmoid parts
  - Intraperitoneal transverse, sigmoid sections anchored to posterior abdominal wall by mesocolon (mesentery)
  - Connects ileum via ileocecal valve, sphincter

Function

- Digestion, absorption, propulsion, defecation
- *Digestion:* enteric bacteria digests remaining food
  - Bacteria also produce vitamin K, other B vitamins
- *Absorption:* absorbs mainly water, electrolytes, vitamins to concentrate, form feces
- *Propulsion:* propels feces towards rectum
- *Defecation:* stores, eliminates feces from body

Unique features

- *Tenia coli:* three longitudinal ribbons of smooth muscle on ascending, transverse, descending, sigmoid colons that contract to produce haustra
- *Haustra:* small pouches/segments of large intestine created by tenia coli
- *Epiploic appendages:* small pouches of peritoneum filled with fat

Regions

- Cecum → ascending colon → right colic/hepatic flexure → transverse colon → left colic/splenic flexure → descending colon → sigmoid colon → rectum → anal canal → anus
  - *Cecum:* pouch that lies below ileocecal valve at large,small intestine junction; beginning of large intestine
  - *Appendix:* pouch of lymphoid tissue (part of MALT) located in cecum, harbors bacteria to recolonize gut when needed
- Anal canal has two sphincters
  - *Internal anal sphincter:* involuntary, composed of smooth muscle
  - *External anal sphincter:* voluntary, composed of skeletal muscle

Histology

- Muscularis mucosae consists of inner circular, outer longitudinal layers
- *Large intestine mucosa:* simple columnar epithelium
- *Anal canal:* stratified squamous epithelium
- Does not contain folds, villi, microvilli as in small intestine
- Many crypts with goblet cells

Pectinate line

- Divides upper ⅔ from lower ⅓ of anal canal where many distinctions made
- Embryological origin
  - *Above:* endoderm
  - *Below:* ectoderm
- Epithelium
  - *Above:* columnar epithelium
  - *Below:* stratified squamous epithelium
- Innervation
  - *Above:* inferior hypogastric plexus
  - *Below:* inferior rectal nerves
- Lymph drainage
  - *Above:* internal iliac
  - *Below:* superficial inguinal lymph nodes
- Vascularization
  - *Above:* superior rectal artery, superior rectal vein (drains into inferior mesenteric vein → hepatic portal system)
  - *Below:* middle, inferior rectal arteries; middle, inferior rectal veins

Flora

- Large intestine contains largest bacterial ecosystem in body
- Function of bacteria
  - Synthesize vitamins (vitamin K, some B vitamins)
  - Ferment indigestible carbohydrates (e.g. cellulose)
  - Metabolism/digestion of certain molecules (e.g. hyaluronic acid, mucin)
  - Live symbiotically with host
  - Present pathogens to nearby lymphoid tissue (MALT)

Secretions

- Mucus

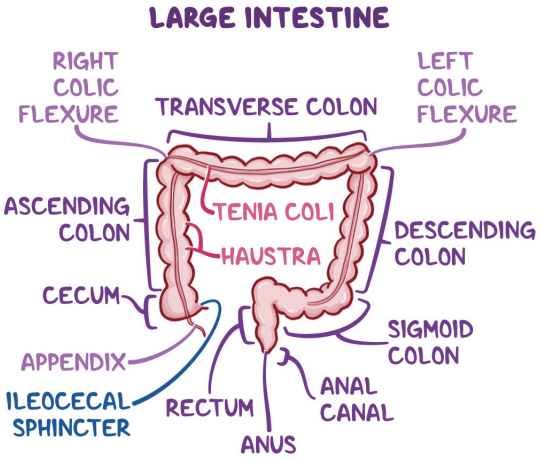

Figure 36.3 Large intestine anatomy.

ACCESSORY ORGANS

- Gallbladder, liver, pancreas
- Liver
  - Hepatocytes produce bile which emulsifies lipid globules, aids in absorption
  - Stores glucose in form of glycogen
- Gallbladder
  - Bile storage; releases bile into small intestine in response to hormonal stimulus
- Pancreas
  - *Exocrine function:* acini secrete various digestive enzymes; "pancreatic juice;" e.g. secretin, cholecystokinin (CCK)
  - *Endocrine function:* islets produce glucagon, insulin to maintain normal glucose levels; somatostatin, pancreatic polypeptide production

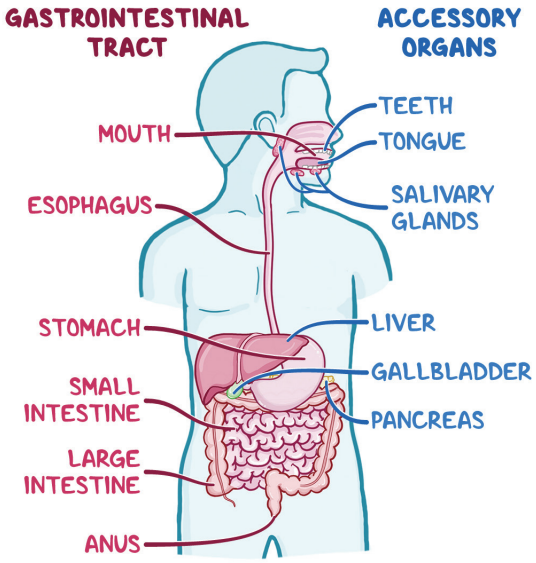

Figure 36.4 Overview of gastrointestinal tract, accessory organs structures.

PHYSIOLOGY

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PROCESSING OF FOOD

1. Ingestion
2. Mechanical digestion
   - Carried out by teeth; increases surface area to facilitate enzymatic digestion
3. Propulsion
   - Movement, mixing of food through GI tract, starts with swallowing
4. Secretion
   - Exocrine glands secrete various digestive juices into digestive tract lumen
5. Digestion
   - Complex food broken down via enzymes
6. Absorption
   - Digested nutrients absorbed by GI mucosal cells into blood/lymph
7. Elimination
   - Indigestible substances eliminated via anus in form of feces

GI MUSCLE PROPERTIES

- Smooth muscle of GI tract acts as syncytium
  - Muscle fibers connected by gap junctions allowing electrical signals to initiate muscle contractions from one muscle fiber to next rapidly along length of bundle
- Normal resting membrane potential of GI smooth muscles: -50mV to -60mV
- Two types of electrical waves contributing to membrane potential

Slow waves

- Generated, propagated by interstitial cells of Cajal (pacemaker cells)
- *Slow-wave threshold:* potential that must be reached by slow wave to propagate smooth muscle
- Does not cause smooth muscle contraction
- Slow-wave threshold reached → L-type calcium channels activated → calcium influx → motility initiation

- Occur at 12 cycles/minute in duodenum, decreases towards colon
- Regulated by innervation, hormones
  - Excitatory stimulants (e.g. acetylcholine, substance P), inhibitory stimulants (e.g. VIP, nitric oxide)

Spikes

- True action potentials occurring automatically when GI smooth muscle potential becomes more positive than -40mV
- Digestive activity controls
  - Involves regulation by autonomous smooth muscle, intrinsic nerve plexuses, external nerves (ANS), GI hormones

ENTERIC NERVOUS SYSTEM

- Intrinsic nervous system of the GI system
- Division of ANS
- Provides major nerve supply to GI tract controlling GI function, motility
  - Parasympathetic system activates digestion
  - Sympathetic system inhibits digestion
  - Also capable of self-regulation, autonomous function

Receptors and plexus

- Chemoreceptors respond to chemicals from food in gut lumen
- Stretch receptors respond to food distending GI tract wall
- Two plexus consist of motor neurons, interneurons, sensory neurons
  - *Submucosal (Meissner's) nerve plexus:* innervates secretory cells → controls digestive secretions
  - *Myenteric nerve plexus:* innervates smooth muscle layers of muscularis → controls GI motility
- Segmentation, peristalsis mostly automatic mediated by pacemaker cells, reflex arcs

Reflex mediation

- *Short reflexes:* intrinsic control (enteric nervous system)
- *Long reflexes:* extrinsic control outside of GI tract (e.g. CNS, autonomic nerves)

GASTROINTESTINAL MOTILITY

Gastric motility

- Peristaltic contractions originate in upper fundus, move to pyloric sphincter
- Moves gastric chyme forward → gastric emptying into duodenum

Small intestinal motility

- Mix chyme, digestive enzymes, pancreatic secretions, bile → digestion
- Expose nutrients to mucosa → maximize absorption
- Advance chyme along small intestine via segmentation actions → ileocecal valve → ileocecal sphincter → large intestine

Large intestinal motility

- Unabsorbed small intestine material → large intestine
  - Contents now feces (destined for excretion)
- Segmental contractions (cecum, proximal colon) associated with haustra (sac-like segments characteristic of large intestine) mixes contents
- Mass movements
  - *Function:* move contents long distances (e.g. transverse → sigmoid)
  - Occur 1–3 times daily
  - *Water absorption:* fecal contents → increasingly solid (hard to mobilize)
  - Final mass movements propel contents to rectum → stored until defecation
- Gastrocolic reflex
  - Stomach distension → ↑ colonic motility → ↑ mass movements
  - Afferent limb (from stomach) → parasympathetic nervous system mediates → efferent limb → CCK, gastrin production → ↑ colonic motility

- Defecation
  - Rectum 25% full → defecation urge
  - Rectum fills with feces → rectal wall distends → stretch receptors send afferent signals to spinal cord → to brain (awareness of need to defecate) + afferent signals to myenteric plexus → peristaltic waves → move feces forward → internal anal sphincter relaxes → external anal sphincter remains tonically contracted (striated skeletal muscle under voluntary control) → when appropriate, external anal sphincter relaxed voluntarily → rectal smooth muscle contracts → ↑ pressure → Valsalva maneuver (expire against closed glottis) → ↑ intra-abdominal pressure → ↑ defecation pressure → feces forced out through anal canal

SECRETORY PRODUCTS OF THE GASTRIC MUCOSA GLANDS

	STIMULUS FOR SECRETION	SECRETORY PRODUCTS	FUNCTION
CHIEF	Gastrin Acetylcholine	Pepsinogen (converts to pepsin in presence of HCl) Gastric lipase	Breaks down protein into peptide chains Initiates lipolysis
D	HCl	Somatostatin (paracrine)	Modulates HCl secretion by inhibiting gastrin, histamine release
ECL	Gastrin Acetylcholine Surges before meals (cephalic stimulation)	Histamine Ghrelin	Primary stimulator of HCl secretion by parietal cells Stimulates appetite Increases gastric secretion, motility
G	Partially digested protein	Gastrin	Increases secretion of HCl Relaxes ileocecal valve
MUCOUS	Mechanical stimulation by stomach contents	Mucus Bicarbonate	Protective alkaline barrier for gastric epithelium Lubrication
PARIETAL	Gastrin (endocrine) Histamine (paracrine) Acetylcholine (neural)	HCl Intrinsic factor	Activates pepsinogen Inactivates amylase Denatures proteins - Kills microorganisms Binds with vitamin B12 for intestinal absorption