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Tubular GI tract

Pharynx
Esophagus
Stomach
Small Intestine
Cecum and appendix
Large intestine
Rectum/Anus

J. Matthew Velkey
M1 – GI Sequence
Winter, 2009
Intestine - Functions

Small Intestine
- Digestion
- Absorption
- Endocrine secretion

Large Intestine
- Absorption of water [passive, follows sodium]
- Formation and propulsion of feces

Duodenum, Jejunum, Ileum
How to get the most out of your intestine

Start with a long tube

Convolute the absorptive surface of the tube

Add enzymes that break down luminal contents

Keep the tube moving, mix contents
Multiple strategies for convolution of small intestinal absorptive surface

Plicae

Villus

Microvilli

Original: Fig 14.16 from Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p262
Convolute the surface of the tube

Plicae circulares (circular folds) – aka valves of Kerckring: permanent transverse folds of mucosa with submucosal connective tissue core; extend halfway to two-thirds around circumference of lumen; function to slow movement of chyme & increase surface area.

Convolute the surface of the tube

Plicae circularis (Kerckring’s valves)

Primarily found in jejunum
Plicae are covered with villi, fingerlike projections of mucosa.

Plicae are covered with villi, fingerlike projections of mucosa.....
Villus cells have a "brush border"

Core of each villus contains lamina propria
The Brush border is composed of microvilli
Electron microscopic view of the brush border
Apical surface (luminal surface) of absorptive cells

Microvilli
Terminal web

~3000 microvilli/cell !!!

Sources Undetermined (All Images)
The microvilli have a well-developed surface glycocalyx

Source: Fig 26-6 from Fawcett and Raviola, *Bloom and Fawcett, a Textbook of Histology, 12th ed.* (1994), p622
Intestinal tube = 20 ft long

Plicae → Villi → Microvilli
(3 fold) (10 fold) (20-30 fold)

Total: 600-900 fold
(area 200 m²)!
How to get the most out of your intestine

Start with a long tube

Convolute the absorptive surface of the tube

Add enzymes that break down luminal contents

Keep the tube moving, mix contents
Enzymes/bile digest luminal contents:

“Chyme” enters from stomach, stimulates intestinal enteroendocrine cells in intestine to secrete:
- Secretin
- CCK (cholecystokinin)

Pancreatic secretion
Gall bladder contraction

Ampulla of Vater: intestinal segment of the common duct that delivers secretions to duodenum from pancreas (trypsin*, chymotrypsin*, amylase, lipase) from liver via gall bladder (bile-emulsifies fat)

Enzymes in small intestinal absorptive cell (enterocyte) membrane complete the process of digestion and absorb the breakdown products

*Secreted as inactive forms, activated by enterokinase cleavage (enterokinase produced in duodenum)
Enzymes/bile digest luminal contents:
activation of zymogens via enterokinase/trypsin

Enzymes

- Chymotrypsinogen
- Proelastase
- Procarboxypeptidase A
- Procarboxypeptidase B
- Prophospholipase A$_2$

Zymogens

- Trypsinogen

Active enzymes

- Chymotrypsin
- Elastase
- Carboxypeptidase A
- Carboxypeptidase B
- Phospholipase A$_2$

Enterokinase

Enterocyte

Regents of the University of Michigan

Keep the tube moving, mix contents

Location of Meissner’s plexus (Submucosal plexus)  Location of Auerbach’s plexus (myenteric plexus)

Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p261 Fig 14.15a
Submucosal plexus (Meissner’s plexus)

Controls contraction of muscularis mucosae, submucosal vascular tone, and secretory activity of mucosal epithelium
Keep the tube moving, mix contents

Location of Meissner’s plexus (Submucosal plexus)

Location of Auerbach’s plexus (myenteric plexus)

Muscularis externa & Myenteric plexus (Auerbach’s plexus)

Controls contraction of muscularis externa; wave-like contractions that move contents = peristalsis
Keep the tube moving, mix contents.

Smooth muscle cells run vertically from muscularis mucosae (MM) up the villi.

Contraction pumps villi; propels lymph, blood from core of villi.

L = lamina propria
V = villi
C = crypt

Epithelial cell types: Small intestine

**Enterocytes** (majority of cells): Absorption (and secretion, e.g. enterokinase)

**Goblet Cells**: Increase in number as you descend the GI tract. Produce acid glycoproteins (mucins). Lubrication. Stain with Alcian Blue or PAS.

**Enteroendocrine cells**: Part of the “diffuse neuroendocrine system”. Produce CCK, glucagon, secretin, motilin, etc. Hormone secretion.

**Paneth cells**: Located at base of crypts. Exocrine cells. Secrete lysozyme and α-defensins; Antibacterial activity.
Villus tip

Ly = Lymphocyte
P = Plasma cell
M = Muscle
C = Capillary

Blood vessel
Goblet cell
Enterocytes

Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p265 Fig 14.20a
Crypt region (H&E+Argentaffin stain)

- lamina propria
- stem cells located here
- Paneth cells
- muscularis mucosae
- enteroendocrine cells

Slide 247 of the University of San Francisco digital slide collection (UCSF247_40x.svs)
Villi & Crypts - Scanning electron microscopy

Villi project into the lumen

Crypts (glands) invaginate into underlying lamina propria.
Interpretation of cross-sections

- Crypts
- Villi

Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p265 Fig 14.19a
Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p265 Fig 14.20b
Stem cells (1-4/crypt) in crypt base give rise to four cell lineages. Cells differentiate as they migrate out of the crypts and up the sides of the villi. Cells at the apex slough off into the lumen. The entire villus epithelium turns over every 3-4 days!!

Note: villi and crypts are arranged such that each crypt contributes cells to a small stripe on multiple villi.

Cormack, Ham's Histology 9th ed. (1987) p505 Fig 18-29
Regional Morphology: Pyloric junction

Duodenum (villus epithelium)

Stomach Epithelium (flat)

Pyloric Sphincter

Brunner’s glands (submucosal)
Secrete alkaline mucous neutralize stomach acid
(Brunner’s glands are diagnostic for duodenum....)
Duodenum: Periodic Acid Schiff Stain (PAS)

Stains complex carbohydrates (mucins) and negative charges strong magenta

Brunner’s Glands (secrete bicarbonate-rich, alkaline mucus)

Villi

Goblet Cells

Crypts of Lieberkühn

Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p263 Fig 14.17b
Jejunum, Ileum: no Brunner’s glands
Jejunum has pronounced plicae circularis

Image is from Slide 246 of the Univ of San Francisco School of Medicine Histology Collection
Jejunum/ileum

Villus tips

Crypts of Lieberkühn (glands)
Contain stem cells
Jejunum/ileum

lymphoid follicles

Sr = Serosa

Young & Heath, Wheater Functional Histology, 4th ed. (2000), p261 Fig 14.15b
GALT: Gut Associated Lymphoid Tissue
(approximately 1/4 of mucosa)

- Plasma cells, macrophages, lymphocytes located in lamina propria and submucosa
- Also “intraepithelial” lymphocytes – specialized T cells found between columnar epithelial cells
- Lymph nodules (or follicles): aggregations of lymphocytes usually in lamina propria, sometimes extending into submucosa
  - activated leukocytes go to nearby lymph nodes, activate T+B cells, which “home” to GI mucosa.
  - plasma cells develop from activated B cells in follicles and migrate into lamina propria to secrete antibodies (secretory IgA, which can be selectively transported across enterocytes into the gut lumen)

- “Peyer’s patches:” large aggregates of nodules (technically this term applies to aggregates found in ileum)
  - covered by M cells (specialized for uptake & presentation of antigen to underlying macrophages and lymphoid cells)

Similar large aggregates also found in the APPENDIX
Peyer’s patch histology - TEM

Junquiera and Carneiro. *Basic Histology, 10th ed.* (2003), p317 Fig 15-31
**Sprue:** Immune reactivity to gliadin (a protein in most wheat cereals). Pathology primarily in jejunum. Diagnostic biopsy.

-Therapy: Gluten-free diet
Ileo-cecal junction (SI/LI)

Ileum (mucosa has villi & crypts)

Colon (mucosa has crypts ONLY)

Cecum/Appendix

Ileocecal Valve (extension of muscularis mucosae)

Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p267 Fig 14.26
Appendix

Blind sac extending from the caecum

- “Colonic” mucosa (crypts only)

- Note prominent lymphoid infiltrate in lamina propria (LP) and submucosa (SM)

- Muscularis externa has complete inner and outer smooth muscle layers (outer layer interrupted in colon)
Appendix - Lymphoid nodule/follicle
Colon - whole mount

Outer longitudinal muscle: three discontinuous bands (Teniae coli, TC)

Semilunary folds (arrows) caused by contraction of TC

Sacculations of external surface = Haustra coli (HC)

Small fatty projections of the serosa = omental appendices (OA)

Colon

Flat epithelium (no villi)

Thick muscularis mucosae

Thick inner circular muscle

Three bands of longitudinal muscle (discontinuous) = teniae coli

Two types of muscle contraction by muscularis externa:
Segmentation: local contraction, mixes contents
Peristalsis: moves feces down the tube
Colonic epithelium

Rich in goblet cells; no villi (flat surface); tightly packed glands; stem cells at base of glands (arrows).
Colonic epithelium

T = intraepithelial T lymphocytes
LP = Lamina Propria

Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p261. Fig 14.28b
Susceptibility to disease is regional in the small and large intestine

Predominant location of pathology:
Sprue - jejunum
Crohn’s disease - ileum
Ulcerative colitis - colon/rectum
Hirschsprung’s disease - colon
Bacterial colitis - SI and/or LI

Cancer is a disease of the large bowel and is rarely seen in the small intestine
Recto-Anal junction

- Transition from columnar epithelium to stratified squamous epithelium (stratified epithelium is non-keratinized proximal, keratinized distal)
- Internal and external anal sphincters: smooth and skeletal m., respectively
- Note also dermal sebaceous glands and adipose tissue in wall of anal canal
Recto- Anal Junction: anal sphincters

internal: smooth muscle

external: skeletal muscle
Recto-Anal junction

Rectal mucosa - Columnar epithelium

Anal canal - stratified squamous epithelium

mm=muscularis mucosae; Ly=lymph nodule

dilated submucosal vessels = “internal” rectal hemorrhoids
Recto-Anal junction

Young & Heath, Wheater’s Functional Histology, 4th ed. (2000), p271. Fig14.31h
Learning Objectives

• Be able to identify and describe the function of the layers AND COMPONENT CELLS/TISSUES in the wall of the digestive tract (mucosa, submucosa, muscularis externa and adventitia/serosa), and be aware of how the layers may differ in the small and large intestine.

• Be able to identify and know the general functions of the following regions of the GI tract:
  – Duodenum
  – Jejunum/ileum
  – Colon
  – Appendix
  – Rectum
  – Anal canal
Additional Source Information

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