Small Intestine
Duodenum
Jejunum & Ileum
Small Intestine

Three sections:

1. Duodenum
2. Jejenum
3. Ileum

Approximately 5-6m long & 2.5cm wide, dependent on level of tone, from pyloric sphincter (distal stomach at ~ L1, 3cm right of midline on transpyloric plane) to ileo-cecal valve (~Ant. To SIJt) of large intestine
Small Intestine

Duodenum:

- C-Shaped curve, concave left, embracing head of Pancreas
- ~25cm long, from pylorus to duodenoojejunal flexure, both areas covered by peritoneum
- Remainder is retro peritoneal
- Lies on posterior abdominal wall in epigastrium & umbilical regions
Small Intestine

Described in 4 parts:

1. ~5cm, passes up, posteriorly to right, down to part 2
2. ~8cm, passes down to part 3 at right side of L3
3. ~10cm, passes to left across post. abd. wall, turns up into part 4
4. ~3cm, passes upwards to duodenojejunal flexure at left side of L2
Fig. 28-8. The pancreas and portal vein. A, Anterior view showing the head of the pancreas within the cavity of the duodenum. B, Posterior view showing the formation of the portal vein behind the neck of the pancreas. The pancreas develops by the fusion of a dorsal with a ventral component, hence the frequency of two ducts (main and accessory) that open into the duodenum. 1 to 4, parts of the duodenum; G.B., gallbladder
Small Intestine

Duodenum Histology:

- Similar to Stomach's 4 layers
- Mucous membrane folded into Villi
- Some glands (duodenal mucus) extend through Muscularis Mucosa into Submucous layer
Small Intestine

- Extensive invaginations increase surface area:
  - Plicae Circulares, Villi & microvilli
  - Increased absorption & secretion
  - Increased Mucus, BB Enzyme, hormone production
- Mucus for lubrication & epithelial protection
- Brush Border Enzymes include:
- Hormones include: Gastrin, GIP, Secretin & CCK
Duodenal Relationships:

Part 1, Superior:

- Separated posteriorly from Pancreas by Omental Bursa
- Also posterior are the Bile Duct, Portal V & Gastroduodenal artery
- Inferiorly rests on Pancreas
- Separated anteriorly from Liver & Neck of Gallbladder by the Greater Sac
- Superiorly are Omental Bursa opening & free border of Lesser Omentum
Duodenal Relationships:

Part 2, Descending:

- Crossed anteriorly by attachment of Transverse Mesocolon
- Posteriorly in contact with Right Psoas, Suprarenal Gland & Hilus of kidney
- Left lie the Head of the Pancreas, Bile Duct & Pancreaticoduodenal vessels
- Superiorly in contact with Liver
- Inferiorly in contact with coils of the Jejenum & Ileum
- Halfway down posteromedial wall Common Bile Duct opens into Ampulla of Vater / Sphincter of Oddi
Duodenal Relationships:

Part 3, Horizontal:

- Inferior to Head & Uncinate process of Pancreas
- Anterior to, from right to left, right Ureter & Psoas, Gonadal vessels, IVC, Inf. Mesenteric Art. & the Aorta
- Anteriorly crossed by Sup. Mesenteric vessels & root of mesentary of small intestine,
- Anteriorly & Inferiorly covered by coils of Jejenum & Ileum

Small Intestine
Small Intestine

Duodenal Relationships:

Part 4, Ascending:

- Lies left of spine on Psoas
- Lies right of Inf. Mesenteric V, left Ureter & lower pole of left Kidney
- Medially in contact with Pancreas
- Anteriorly related to Root of Mesentary & coils of Jejenum & Ileum
Small Intestine

Jejenum & Ileum

- Proximal & distal portions of coiled small intestine, from distal Duodenum to Iliocecal valve ~ anterior to right SIJt
- Suspended from Post. Abd. Wall by the Mesentary making them highly mobile
- Mainly inferior to Transverse Colon and within Abd. Cavity
- Can travel into pelvis
- Jejunum wider & thicker walled vs Ileum
- Jejunal mucous membrane in circular folds with many Villi vs Ileum
- Jejunum less lymph nodes & fat in Mesentary vs Ileum
- Blood supply Superior Mesenteric Vessels
Jejenum & Ileum Peritoneal Relations.

The jejunum and ileum are suspended from the posterior abdominal wall by the mesentery (see fig. 26-4); they are highly mobile and occupy much of the abdominal and some of the pelvic cavity.

Fig. 26-4. Median section through the abdomen to show the peritoneal cavity. The lesser sac is situated behind the stomach and in front of the pancreas. The caudate lobe invaginates the lesser sac. Below the liver, the stomach, transverse colon, and small intestine are seen in section. The greater omentum and transverse mesocolon are fused posteriorly. The arrows indicate surgical approaches to the lesser sac.
Innervation of the Small Intestine

Small Intestine:
PNS: CNX Vagus N
ANS: T6-T9 via Splanchnic N
Both via Celiac & Superior Mesenteric Ganglion

Fig. 27-8. Functional components of the nerve supply of the small intestine. Sympathetic fibers are shown as continuous black lines, parasympathetic fibers as dashed black lines, and sensory fibers in blue.
Small Intestine Functions

Forward propulsion of contents

Major site of digestion

90% of nutrient absorption

Production of B-SCFAs (& Colon)

Intake of Bile / Pancreatic Juice & Enzymes: Trypsin & Chymotripsin, Pancreatic Lipase & Amylase

Small Intestine Microvilli Brush Border cell enzyme secretion: Dextrinase & Glucoamylase, Sucrase, Maltase & Lactase

Protection against infection: GALT & Bacterial Flora

Hormone secretion: CCK & Secretin, GIP & Motilin
Small Intestine Functions

Digestive Breakdown Products

**Carbohydrate** → monosaccharides (glucose, galactose, fructose)

**Protein** → amino acids, di & tripeptides

**Lipids** → fatty acids, glycerol & monoglycerols
Small Intestine Functions

Carbohydrates

- α-dextrins - polysaccharide of glucose (5-10 molecules)
- Maltose - disaccharide of glucose
- Sucrose - disaccharide of glucose & fructose
- Lactose - disaccharide of glucose & galactose
Small Intestine Functions

Protein

Trypsinogen → Enterokinase → Trypsin → Polypeptides → Tri/Di/Mono-Peptides

Chymotrypsinogen → Chymotrypsin → Polypeptides → Tri/Di/Mono-Peptides
Small Intestine Functions

Fat

- Reliant on lecithin and lipases
- Lecithin secreted by gallbladder in bile salts
- Lipases secreted by pancreas
Small Intestine Functions

Macro & Micro Nutrient Sites of Absorption:

**Duodenum**: Absorption of carbohydrates, lipids, amino acids, Calcium, magnesium, selenium, chromium, iron, manganese, zinc

**Jejuneum**: Absorption of carbohydrates, lipids, amino acids, Calcium, magnesium, Vitamins B1, B2, B3, B5, B6, B12, Biotin, Vitamin C, Choline, inositol

**Ileum**: Absorption of bile salts, vitamin B12, water electrolytes, Vitamins A, D, E, K
Luminal Nutrition and Intestinal Conditioning

- G.I tract mucosa is only body tissue with a systemic and luminal nutritional source
- Over 50% of nutrition of small and large intestinal mucosa is luminal

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Glucose</th>
<th>Glutamine</th>
<th>Butyrate</th>
<th>Aspartate</th>
<th>Acetate</th>
<th>Propionate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duodenum</td>
<td>30%</td>
<td>60%</td>
<td>-</td>
<td>10%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Jejunum</td>
<td>20%</td>
<td>70%</td>
<td>-</td>
<td>10%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Colon</td>
<td>5%</td>
<td>5%</td>
<td>60%</td>
<td>-</td>
<td>20%</td>
<td>10%</td>
</tr>
</tbody>
</table>
Short Chain Fatty Acid Production and the Colon

- Approximately 30g of SCFA produced by colonic flora/day
- SCFA’s are easily absorbed across the colonic epithelium
- Relatively stable ratio of SFCA:
  \[
  \text{Acetate : Propionate : Butyrate} \quad 55 : 20 : 20
  \]
- 95% of all SCFA’s produced in colon are utilised by host; up to 5% is excreted in faeces

- **Acetate** - Metabolised in brain, heart and skin tissue
- **Propionate** - Probably excluded by the liver but could be involved in lowering blood cholesterol
- **Butyrate** - Inhibits DNA synthesis
  - Induces differentiation in cancer cells
  - Decreases neoplastic cell growth
Butyrate is a controller of cell replication in the colon. If deficient, it will mediate slowing of cell turnover, but eventually atrophy and gut permeability result.

When deficient, colon cells are unable to use other energy sources.

Butyrate slows DNA replication and proliferation of human cancer cell lines and stimulates differentiation.
Stomach
Alcohol

Duodenum
Calcium/magnesium
selenium
chromium
iron
manganese
zinc

Jejunum
B1, B2, B3, B5, B6, B12
Biotin
Vitamin C
Choline, inositol
Calcium/magnesium

Ileum
Vitamin A
Vitamin D
Vitamin E
Vitamin K
Protection against infection:

- GALT is the largest lymphoid organ in the body comprising approximately two thirds of the body’s entire immune system.

Thus the intestine contains:

- 80% of the immunoglobulin producing cells in the body (30 billion)
- 75% of entire T-cell population (60% above basal membrane)
- 40mg/kg body weight/day of secretory IgA is passed into intestinal lumen, i.e. 2.8g -5g for average adult male
- Total daily production of IgG in the body is 30mg/kg/day (Hansen, 2000)
Gut Flora: **Small Intestine Immunity**

400-1000 species of bacteria
100-140 Trillion bacteria

Lactobacillus & bifidobacterium are major human GIT bacteria e.g L.acidoph.

Form a defensive layer on the luminal surface
Prevent pathogens adhering to lumen
Acid forming bacteria (e.g. Acidophilus) against pathogens
Tolerance means inflammatory response blunted to GIT contents
Produce B-SCFAs and vitamins
Partially digest consumed fibre
Help maintain integrity of GIT lining
GALT can be divided anatomically into organised and diffuse components:

**ORGANISED GALT**
- Peyer’s Patches (aggregated lymphoid follicles) - 250 per GI tract
- Mesenteric lymph nodes
- Isolated follicles (3 follicles per cm$^2$ in colon)

**DIFFUSE GALT**
- Two distinct populations of cells above and below the basement membrane:
  - Intraepithelial lymphocytes
  - Lamina propria lymphocytes
Organised GALT: Mainly composed of precursor B and T lymphocytes

Diffuse GALT: Mainly mature effector T-lymphocytes and immunoglobulin-producing plasma cells.

Examples of GALT in GIT include:

Tonsils & Adenoids
Peyer’s Patches (Small Intestine)
Appendiceal and Large Intestinal aggregates
Small Intestine Functions

Small Intestine Hormones:

Exocrine:

CCK - Cholecystokinin stimulates release of Pancreatic Enzymes & Bile into Duodenum
Secretin - Stimulates Pancreas to release Bicarbonate
GIP - Glucose-dependent Insulinotropic Peptide stimulate Pancreas to release Insulin
Motilin - Stimulates Peristalsis

Endocrine:

Serotonin - Stimulates peristalsis
Substance P - Pain related
Small Intestinal Ecosystem

- Great length (25 ft) and immense surface area (= a doubles tennis court)
- Enzyme/bile acid gradient
- Bacterial gradient
- Intense immune activity
  - Intraepithelial lymphocytes (CD8)
  - Peyer’s patch lymphocytes (CD4)
Enteric Ecosystem Disruptors

- Loss of beneficial flora (Lactobacilli)
- Bacterial overgrowth/fermentation
- Exuberant immune responses
- Mucosal hyperpermeability
- Altered motility
- Malnutrition (systemic and local: parenteral feeding, low fiber diets)
- Infection
CAUSES OF UPPER GI BACTERIAL OVERGROWTH

- Achlorhydria/hypochlorhydria
- Surgical resection/blind loops
- Stasis from abnormal motility
- Strictures
- Fistulas
- Diverticulosis
- Immune deficiency
- Intestinal giardiasis
- Tropical sprue
- Malnutrition
EFFECTS OF UPPER GI BACTERIAL OVERGROWTH

• Carbohydrate/fiber intolerance, bloating, altered bowel habit, fatigue
• Vitamin B12 deficiency
• Bile salt dehydroxylation
  – Impairs formation of micelles
• Bile salt deconjugation
  – Increases colonic water secretion
  – Inhibit monosaccharide transport
EFFECTS OF UPPER GI BACTERIAL OVERGROWTH
(continued)

• Inhibition of folate conjugases
• Increased fecal nitrogen, hypoalbumenemia
• Bacterial degradation of CHO
• Villi: blunted and broadened
• Lamina propria: increased mononuclear cells
EFFECTS OF UPPER GI BACTERIAL OVERGROWTH
(continued)

• Mucosal damage by bacterial enzymes
  – Loss of brush border
• Endotoxemia/antigenemia
• Liver damage
• Joint disease
BACTERIAL OVERGROWTH IS MORE COMMON THAN SUSPECTED

• 202 patients with IBS underwent hydrogen breath testing
• 157 (78%) had SBBO and were treated with antibiotics
• 25/47 patients had normal breath tests at follow-up
• Diarrhea and abdominal pain were significantly improved by treatment
Elimination of SBBO eliminated IBS in 12/25 of patients:
  48 % of patients with IBS and abnormal breath tests who responded to antibiotics with normal breath tests no longer met Rome criteria for IBS

Pimentel M et al, AM J Gastroenterol 2000