Overview of Gastrointestinal Function

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The gastrointestinal system
Functions of the gastrointestinal system

- Digestion
- Absorption
- Secretion
- Motility
- Immune surveillance and tolerance
Histology of the GI tract

Blood or Serosal Side

Lumenal or Mucosal Side

- Submucosa
- Muscularis mucosa
- Gland
- Myenteric plexus
- Submucosal plexus
- Lymph node
- Circular muscle
- Longitudinal muscle
- Epithelium
- Lumen
- Villi
- Lamina propria
Structure of a villus

- Villus
- Lamina propria
- Epithelial cells
- Capillary network
- Lacteal
- Intestinal crypt
Movement of substances across the epithelial layer

- **Lumen**
  - Apical membrane
  - **transcellular**

- **Blood**
  - Basolateral membrane
  - **paracellular**

**Tight junctions**
Histology of the GI tract

Blood or Serosal Side

Lumenal or Mucosal Side

Gland
Myenteric plexus
Submucosal plexus
Lymph node
Circular muscle
Longitudinal muscle
Submucosa
Muscularis mucosa
Epithelium
Lumen
Villi
Lamina propria
Motility in the gastrointestinal system

- **Propulsion**
  - net movement by peristalsis

- **Mixing**
  - for digestion and absorption

- **Separation**
  - sphincters

- **Storage**
  - decreased pressure
Intercellular signaling in the gastrointestinal system

- Neural
- Hormonal
- Paracrine
Neural control of the GI system

- **Extrinsic nervous system**
  autonomic central nervous system

- **Intrinsic (enteric) nervous system**
  entirely with the GI system
The extrinsic nervous system
The intrinsic nervous system forms complete functional circuits

- Sensory neurons
- Interneurons
- Motor neurons
  (excitatory and inhibitory)
Parasympathetic nerves regulate functions of the intrinsic nervous system
Reflex control of gastrointestinal functions

Vago-vagal reflex

Longitudinal Muscle

Circular Muscle

Muscularis Mucosa

Mucosa

Endocrine Cells

Parasympathetic Nerves

Myenteric Plexus

Submucosa Plexus

Higher Centers
Salivary Glands
Composition of Saliva

- **Proteins**
  - α-amylose
  - lactoferrin
  - lipase
  - RNase
  - lysozyme
  - et al
  - mucus

- **Electrolyte solution**
  - water
  - Na⁺, K⁺
  - HCO₃⁻
Functions of saliva

- **Oral protection**
  buffering of hot, cold, acid, base

- **Oral hygiene**
  bacteriostatic

- **Lubrication**
  swallowing

- **Digestion**
  carbohydrates and lipids
Structure of the esophagus

- Pharynx
- Upper Esophageal Sphincter (UES)
- Diaphragm
- Lower Esophageal Sphincter (LES)
- Skeletal muscle
- Skeletal and smooth muscle
- Smooth muscle
- Stomach
Regulation of the UES during a swallow

- Reflex relaxation (neural)
- Reflex contraction (neural)
- Persistalsis
Regulation of the UES during a swallow

Reflex contraction (myogenic)

Reflex relaxation (neural)

VIP (NO ?)
Anatomical and functional divisions of the stomach

G cell

Gastrin

pylorus

Pyloric gland area

Orad

Gastric juice

Oxyntic gland area

Caudad

LES

Fundus

duodenum

Body (Corpus)

Pyloric gland area

Antrum

Body (Corpus)

Gastrin

G cell

LES

Oxyntic gland

Antrum

Body (Corpus)
Mechanism of acid secretion by the parietal cell

H_2O + H^+ + OH^- → H_2O

Cl^- + H^+ + K^+ + Na^+ → HCO_3^- + Cl^- + H_2O

Carbonic anhydrase

Blood
Stimulation of acid secretion in parietal cells

Receptors → Histamine (H2) → Gastrin → ACh

H+ → Lumen

GI-S-13
Stimulation of acid secretion in parietal cells

Receptors → Histamine (H2) → Gastrin → ACh →

- cAMP → Protein kinase A → Substrates
- IP₃ + DAG → Protein kinase C → Ca²⁺ → Protein kinase C

Sequestered H⁺ / K⁺ pumps
Membrane-exposed H⁺ / K⁺ pumps

Lumen
A Simple Recipe For Heartburn-Free Chili

Take Pepcid AC first and you can be heartburn-free
Cephalic phase of acid secretion

thought, sight, smell, taste, or chewing of food

Vagal nucleus
Vagus nerve

G cell
GRP

ECL cell
Histamine

Parietal cell

Gastrin

H⁺

Efferent pathways

Circulation
Gastric phase of acid secretion

distension in the stomach, presence of amino acids and peptides

distension sensed by mechanoreceptors

vagal nucleus

vagus nerve

Efferent pathways

Afferent pathways

G cell

ECL cell

Parietal cell

Gastrin

Histamine

H^+

Amino acids and peptides

Gastrin

GRP

ACh

Histamine

circulation

GI-S-06
Protection of the epithelial lining of the stomach

Gastric lumen

Mucus layer

Mucus
Motility in the stomach

- **Reservoir**
  
  storage without increased pressure

- **Grinding and mixing**

  mechanical disruption for digestion and absorption

- **Regulated pumping**

  optimal delivery to duodenum
The gastrointestinal system

Small Intestine

Digestion
Absorption
Secretion
Motility
Pancreatic Secretion

Aqueous Component (ductule cells)
- water
- bicarbonate
  Function: acid neutralization

Enzymatic Component (acinar cells)
- proteases
- lipases
- saccharidases
  Function: digestion
Intestinal phase of pancreatic secretion

Acid and digestion products in the duodenum

- I cells
- S cells
- Enzymes
- Ductule cells
- Acinar cells
- Pancreas
- Vagal nucleus
- Vagus nerve
- Afferent pathways for vagal reflex
- Efferent pathways for vagal reflex
- CCK
- Secretin
- HCO₃⁻
- H₂O
- Ach
- Protein
- Amino acids
- Peptides
- Fat
- H⁺

Circulation
Secretion from the liver and gallbladder

Liver

Secretin

HCO$_3^-$
Na$^+$
H$_2$O

HCO$_3^-$
Cl$^-$
Na$^+$
H$_2$O

Sphincter of Oddi

Duodenum

Gallbladder

Portal circulation

Ileum

Bile acids

Bile acids

CCK

Ach

Figure 15

Figure 14

Figure 11
Functions of Bile

- **Emulsification** of dietary lipids required for lipid digestion

- **Solubilization** of lipid digestion products required for lipid absorption

- **Excretion** of waste products bilirubin and cholesterol
Organic components of bile

- Bile acids / bile salts 70%
- Phospholipids 20%
- Cholesterol 5%
- Bilirubin 1%
- Everything else 4%
Components of bile

**Primary Bile Acids**
- Cholic Acid
- Chenodeoxycholic Acid

**Secondary Bile Acids**
- Deoxycholic Acid
- Lithocholic Acid

**Bile Salts**
- Glycine (pKa ~ 3.7)
- Taurine (pKa ~ 1.5)

**Cholesterol**

**Lecithin**

\[
(CH_3)_3NCH_2CH_2OPO_3CH_2
\]
Bile acids package products of lipid digestion into mixed micelles for absorption

Products of lipid digestion

- Free fatty acid
- Lysolecithin
- Cholesterol
- Monoglyceride

Mixed micelle

GI-SILPGB-36
Digestion and absorption in the small intestine

**Proteins**
- degradation to amino acids and peptides
- combined action of luminal and membrane-bounds proteases
- absorption by multiple transporters

**Carbohydrates**
- degradation to monosaccharides
- combined action of luminal and membrane-bounds proteases
- absorption by several transporters

**Lipids**
Absorption of monosaccharides in the small intestine

- **SGLT1**: Sodium-glucose cotransporter 1
- **Glucose / Galactose**: Absorbed into the cell via SGLT1.
- **Fructose**: Absorbed into the cell via GLUT5.
- **Na+/K+ ATPase**: Pump for sodium and potassium ions.
- **Glut 2**: Exports glucose to the blood.
- **Glut 5**: Exports fructose to the blood.
- **Blood (Basolateral)**: Site for glucosuria and fructosuria.
- **Lumen (Apical)**: Site for absorption of monosaccharides.

**Equations**:
- $\text{ATP} \rightarrow \text{ADP}$
- $\text{Na}^+ / \text{K}^+$ ATPase
Lactaid Ultra

Dietary Supplement

Works naturally to make dairy foods easy to digest.

Just 1 Caplet Per Serving

32 Caplets 32 Single-Serve Packets
Fluid balance in the GI tract

- Ingest 2000 ml/day water
- Saliva 1500 ml/day
- Gastric secretions 2000 ml/day
- Small intestine absorbs 8500 ml/day
- Colon absorbs 400 ml/day
- Intestinal secretions 1500 ml/day
- Bile 500 ml/day
- Pancreatic juices 1500 ml/day

Volume entering intestines: 9000 ml
Volume absorbed by intestines: 8900 ml
Volume excreted: 100 ml

~ 20% total body water!
Important Principle

The absorption of water is dependent on and proportional to the absorption of solutes.
Bad things happen when solutes are not absorbed

**Jejunum**
- Lactose → glucose + galactose → H₂O → Na⁺

**Ileum**
- H₂O

**Colon**
- H₂O

**Normal**
- Lactose → lactose → SCFA → CO₂ → H₂O → Diarrhea

**Lactase deficiency**
- Lactose → lactose → H₂O → Diarrhea