Digestive system
Human Physiology 2007-2008

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Digestive system I

Basic structure, function and regulation of gastrointestinal organs, salivary glands
Basic function of GI

- Assimilation of food and nutrition
- Excretion of waste products (also kidney and liver)
- Fluid and electrolyte balance
- Immunity

Ingestion – initiates multiple endocrine, paracrine and neural pathways
Alimentary track in vertebrates

Figure 15-2 like
Oversigt over fordøjelsesorganene

Figure 15-1 like from Sand
The four processes carried out by the GI tract: digestion, secretion, absorption, and motility.

Figure 15-2
Mass balance of what comes in and out

Intake:
- 1200 ml water/day
- 800 g solids/day

Excretion:
- 100 ml water/day
- 50 g solids/day

Secretions:
- 1500 ml salivary secretion
- 2000 ml gastric secretion
- 1500 ml pancreatic secretion
- 1500 ml intestinal secretion

Absorption:
- 6700 ml absorbed
- 1400 ml absorbed

Figure 15-5 like
How long it takes

- Oral cavity (mouth): 10 s
- Pharynx (throat): 1-3 h
- Esophagus: 1-3 h
- Liver: 7-9 h
- Stomach: 25-30 h
- Small intestine: 30-120 h
Basic microanatomy of the tube

Enteriske Nervesystem (ENS)

Figure 15-6
Nervestyret regulering af fordøjelseskanalens aktiviteter
Korte (lokale) og lange reflexbuer

Figure 15-13
# Gastrointestinal hormones

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Source</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastrin</td>
<td>G-cells in antrum of stomach</td>
<td>parietal cells of stomach</td>
</tr>
<tr>
<td>Gastric-inhibitory peptide (GIP)</td>
<td>Vagal nerve endings</td>
<td>G-cells in antrum</td>
</tr>
<tr>
<td>(Glucose-dependent insulinotrophic peptide)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholecystokinin (CCK)</td>
<td>I-cells in duodenum</td>
<td>pancreas, gallbladder</td>
</tr>
<tr>
<td>Secretin</td>
<td>S-cells in small intestine</td>
<td>pancreas, stomach, bile ducts</td>
</tr>
</tbody>
</table>

*Table 15-4 like*
Phases of gastrointestinal control

**Cephalic**  
*(Hovedfasen)*  
PS, stimulus – sight, smell, thought

**Gastric**  
*(Ventrikelfasen)*  
various hormones, ENS and PS  
acidity, peptides, volume

**Intestinal**  
*(Tarmfasen)*  
various hormones, ENS and PS  
amino acids, fats

(PS parasympathetic nervous system; ENS enteric nervous system)
Motility - Divisions

Upper esophageal sphincter
Lower esophageal sphincter (cardiac sphincter)
Pyloric sphincter
Ileocecal sphincter
Internal and external anal sphincter

Figure 15-15 like
Motility - smooth muscles

Figure 15-23 like
Peristalsis and segmentation

Peristalsis (transport)

Segmentation (mixing)

Figure 15-22 and 15-32 like
Mouth phase
Major salivary glands

Function of saliva – taste

lubrication and dissolving of food
digestion of polysachharides by amylase
oral hygiene (antibacterial actions)
(temperature regulation)

Figure X and Table 15-1
Secretory endpieces and duct system of the human submandibular gland

Parasympathetic nerve terminal

Sympathetic nerve terminal

Acetylcholine

Noradrenaline

Acini

Mucous tubules

Duct system

Figure X

from Secretion by the Major Salivary Glands by J.A. Young et al. 1987
Digestive system II

Gastric, pancreatic and liver function
Regions of the stomach

- Fundus
- Corpus or body
- Antrum

Figure 15-16 like

Mavesækken
(Ventriklen)
Microanatomy of stomach

The mucosa is composed of surface epithelial cells and glands.
Gastric glands of the stomach secrete HCl and pepsinogen.

- **HCl**
- **Intrinsic factor**
- **Protective mucus and bicarbonate**
- **Pepsinogen**
- **Gastric lumen**
- **Gland region**
- **Muscularis mucosa**
- **Chief cell**
- **Parietal cell**
- **Mucus neck cells**

*Figure 15-17 and 15-21*
HCl secretion of parietal cells

Figure 15-18 like
HCl secretion of parietal cells

**Diagram Description:**
- **Lumen:** Food (FOOD) enters and exits through the lumen.
- **Cell:** HCl (Hydrochloric Acid) is secreted into the lumen. ATPase enzymes are present. CO₂ + H₂O → HCO₃⁻ + H⁺ reaction occurs.
- **Interstitium:** Cl⁻ and Na⁺ ions are transported into the interstitium from the cell. K⁺ ions are transported out of the interstitium into the cell.

**Equations:**
- **HCl Secretion:** CO₂ + H₂O → H⁺ + HCO₃⁻

**Figure 15-18 like**
Regulation of parietal cells

- **Gastrin**
- **Histamine**
- **ACh**
- **Somatostatin**

**Second messengers**

- **HCl**
- **H^+**
- **ATPase**
- **K^+**

Figure 15-19 like
Where what is secreted

**Fundus**
- No parietal cells

**Corpus or body**
- Secretes acid
- Mucus
- Pepsinogen
- Intrinsic factor
- Bicarbonate

**Antrum**
- No parietal cells
- Secretes mucus, pepsinogen
- Endocrine cells release gastrin

*Figure 16-16 like*
Cephalic and gastric phase controlling acid secretion by the stomach

Figure 15-20
<table>
<thead>
<tr>
<th>STIMULI</th>
<th>PATHWAYS</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cephalic phase</strong></td>
<td>Parasympathetic nerves to enteric nervous system</td>
<td>$\uparrow$HCl secretion</td>
</tr>
<tr>
<td>Sight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smell</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chewing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gastric contents</strong></td>
<td>Long and short neural reflexes, and direct stimulation of gastrin secretion</td>
<td>$\uparrow$HCl secretion</td>
</tr>
<tr>
<td>(gastric phase)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\uparrow$Peptides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\downarrow$H$^+$ concentration</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intestinal contents</strong></td>
<td>Long and short neural reflexes; secretin, CCK, and other duodenal hormones</td>
<td>$\downarrow$HCl secretion</td>
</tr>
<tr>
<td>(intestinal phase)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\uparrow$H$^+$ concentration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\uparrow$Osmolarity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\uparrow$Nutrient concentrations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Gastric motility

- Fundus
- Corpus or body
- Antrum
- Chyme
- Membrane Potential (mV)
  - AP
  - Threshold Potential
  - Pacemaker Potential
- Muscle Tension
Intestinal-phase pathways inhibiting gastric emptying

Figure 15-24
Effects of chyme in small intestine

Acid chyme from stomach
Liver
Pancreas
Small intestine
Secretin
Cholecystokinin (CCK)
Acidic pH
Fatty acids
Bicarbonate
Enzymes

Figure 15-27 and 15-28 like
Pancreas and liver

Figure 15-25
Exocrine pancreas – two types of epithelia forming two types of secretion

**Exocrine cells (Acinus)**

- **NaHCO₃ + H₂O**
- **NaCl + Enzymes + H₂O**
Pancreatic enzymes

Proteolytic:
- Trypsin
- Chymotrypsin
- Elastase
- Carboxypeptidase A
- Carboxypeptidase B
- Aminopeptidase

Amyolytic (starch):
- \( \alpha \)-Amylase

Nucleolytic:
- Ribonulease
- Deoxyribonuclease

Lipolytic:
- Lipase
- Cholesterinesterase
- Phospholipase A

Table 15-6 like
Activation of pancreatic enzyme precursors in the small intestine

Figure 15-26
Hormonal regulation of bicarbonate secretion

Figure 15-27 like
(from Sand)
Hormonal regulation of enzyme secretion (and smooth muscle)

Figure 15-28 and 15.31 like (from Sand)
Liver – dual blood supply

Vena cava

Hepatic artery

Portal vein

Stomach

Spleen

Pancreas

Intestine
Liver functions

- Exocrine and digestive (bile salts and bicarbonate)
- Organic metabolism (carbohydrates, fats, urea)
- Endocrine function (T3 to T4, angiotensinogen)
- Clotting function (prothrombin and fibrinogen)
- Synthesis of plasma proteins
- Cholesterol metabolism
- Excretory and degradative function
Liver-portal triads and bile production
Bile and liver

- **Bile function:**
  - Promote digestion and absorption of lipids
  - Get rid of endogenous and exogenous waste products

- **Bile contains:**
  - Bile acids and salts
  - Lecithin
  - Cholesterol and phospholipids
  - Bicarbonate
  - Metabolic end products (bilirubin, medicaments)
  - Trace elements

- **Regulation of bile secretion**
  - Secretin stimulates bicarbonate secretion in bile canaliculi
  - CCK stimulates gallbladder contraction
Digestive system III

Small and large intestine, digestion and absorption
Small and large intestine

Functions:

Neutralization (small)
Further digestion (small)
Absorption of nutrients (small)
Salt and water balance (small and large)
Storage and concentration (large)
Microbial digestion (large)
Neutralization of acid chyme in small intestine

Acid chyme from stomach

Liver

Pancreas

Small intestine

$\text{HCO}_3^-$
Anatomy of small and large intestine

Figure 15-33 like
Small vs large intestine anatomy
Structure of villi in small intestine
Villi vs. microvilli

Figure 15-8 like
Na⁺-dependent absorption

Fluid movement is coupled with the movement of solute (nutrient or salt)

Intestine lumen

**Enzymes:**
- Amylases
- Peptidases
- Lipases

**Solute:**
- Glucose
- Amino acids
- Chloride
- Bicarbonate
- Lactose (glucose+galactose)

**Brush border enzymes:**

**ATPase**

**Na⁺**

**K⁺**

**H₂O**

**Interstitium**
Fat absorption in the small intestine

Big Droplets of Fat
↓
Small Droplets of Fat
↓
Micelles
↓
Fatty Acids and Monoglycerides
↓
Chylomicron Assembly
↓
Distribution and Processing

Figure 15-12
Large intestine

- Absorption of Na and Cl and water (but can also secrete)
- Bacterial digestion of carbohydrates and production of short chain fatty acids
- Absorption/secretion of K
- Sensitive to aldosterone
Intestine absorbs and secretes fluid

Intake: 1200 ml water/day
800 g solids/day

1500 ml salivary secretion

2000 ml gastric secretion

1500 ml pancreatic secretion

500 ml bile

6700 ml absorbed

1400 ml absorbed

Excretion: 100 ml water/day
50 g solids/day

Figure 15-5 like
Diarrheas

**Secretory diarrhea** (caused by endogenous secretions, e.g. toxins like cholera toxin), accompanied by metabolic acidosis

**Osmotic diarrhea** (caused by dietary nutrient that is not absorbed, e.g. lactose)