The goal of this lecture is to discuss basic gastrointestinal physiology associated with motility, secretion, digestion, absorption and their control.

The sections for this lecture are:

**Introduction**
- Motility, secretion, digestion, absorption
- Neuroendocrine control of this GI tube
- Overall GI structure and attached organs

**Basic GI functions**
- Structure / function, muscle, BER, control
- Glands, control & neuroendocrine mechanisms

**Physiopathology of some GI processes**
- Ulcers, vomit, gallstones, lactose intol., diarrhea

Life is a series of chemical reactions occurring in compartmentalized environments.

The main purpose of life is to keep itself alive

Physiology, the study of how life works, is based on the simultaneous occurrence of the following three concepts:
- Levels of organization
- Structure / function relationship
- Homeostatic regulation

**Gastrointestinal Tract Processes**

- Heart
- Liver
- Heparic portal vein
- Anus
- Rectum
- FECES
- FOOD AND WATER
- DIGESTION
- SMALL INTESTINE
- LARGE INTESTINE
- STOMACH
- ESOPHAGUS
- MOTILITY

**Introduction**
- Motility, secretion, digestion, absorption
- A tube with its lumen outside the body
- Neuroendocrine control of this GI tube
- Overall GI structure and attached organs
Introduction

Motility, secretion, digestion, absorption

A tube with its lumen outside the body

Neuroendocrine control of this GI tube

Overall GI structure and attached organs

Major Functions of Saliva
1. Moisture and lubricate food
2. Digestion of polysaccharides by amylase
3. Dilute food
4. Antimicrobial actions
Introduction

Motility, secretion, digestion, absorption

A tube with its lumen outside the body

Neuroendocrine control of this GI tube

Overall GI structure and attached organs

Summary of Liver Functions

1. Synthesis of plasma proteins (Chapter 15), such as those involved in blood clotting.
2. Synthesis of serum albumin (Chapter 15), which is essential for maintaining blood volume and pressure.
3. Synthesis of lipoproteins, which are involved in the transport of lipids (Chapter 15).
4. Synthesis of bile acids (Chapter 15), which are essential for the absorption of fats and fat-soluble vitamins.
5. Synthesis of hormones (Chapter 15), such as estrogen and testosterone.
6. Synthesis of vitamin D (Chapter 15), which is essential for the absorption of calcium and phosphorus.
7. Synthesis of glucose (Chapter 15), which is essential for energy production.
8. Synthesis of amino acids (Chapter 15), which are essential for protein synthesis.
9. Synthesis of fatty acids (Chapter 15), which are essential for energy production.
10. Synthesis of ketone bodies (Chapter 15), which are essential for energy production in the absence of glucose.

Overall, the liver plays a crucial role in maintaining homeostasis and supporting various physiological processes.
Introduction

Motility, secretion, digestion, absorption

A tube with its lumen outside the body

Neuroendocrine control of this GI tube

Overall GI structure and attached organs

Motility, secretion, digestion, absorption

A tube with its lumen outside the body

Neuroendocrine control of this GI tube

Overall GI structure and attached organs

Spontaneous electrical activity

Distance from LES or pylorus
Introduction

Motility, secretion, digestion, absorption

A tube with its lumen outside the body

Neuroendocrine control of this GI tube

Overall GI structure and attached organs
Introduction

Motility, secretion, digestion, absorption

A tube with its lumen outside the body

 Neuroendocrine control of this GI tube

Overall GI structure and attached organs

S
S → E
Introduction

Motility, secretion, digestion, absorption

A tube with its lumen outside the body

Neuroendocrine control of this GI tube

Overall GI structure and attached organs

example (endocrine role of pancreas will be expanded in the metabolism lecture)
Motility, secretion, digestion, absorption

A tube with its lumen outside the body

Neuroendocrine control of this GI tube

Overall GI structure and attached organs

example

(duodenal - gastric interactions will be used as a model for secretory interactions in the next section)

Introduction
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

motility

GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Neuro-muscular junction

motility
GI functions

Gastrointestinal Hormone Properties

<table>
<thead>
<tr>
<th>Chemical class</th>
<th>Carbohydrate</th>
<th>Lipid</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site of production</td>
<td>Stomach</td>
<td>Small intestine</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Stimulated by</td>
<td>Amino acids, fatty acids, and nutrients</td>
<td>Amino acids, fatty acids, and nutrients</td>
<td>Amino acids, fatty acids, and nutrients</td>
</tr>
<tr>
<td>Target organs</td>
<td>Acid in small intestine, glucose, fat in small intestine</td>
<td>Acid in small intestine, glucose, fat in small intestine</td>
<td>Acid in small intestine, glucose, fat in small intestine</td>
</tr>
</tbody>
</table>

Glands, control phases and neuroendocrine mechanisms

Food Carbohydrates

<table>
<thead>
<tr>
<th>Carbohydrate</th>
<th>Examples</th>
<th>Made of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>Cellulose</td>
<td>Glucose</td>
</tr>
<tr>
<td>Glycogen</td>
<td>Glucose</td>
<td>Glucose</td>
</tr>
<tr>
<td>Dextrin</td>
<td>Maltose</td>
<td>Glucose</td>
</tr>
<tr>
<td>Maltose</td>
<td>Maltose</td>
<td>Glucose-6-phosphate</td>
</tr>
</tbody>
</table>

Control of HCl During a Meal

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Pathways</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chyme</td>
<td>Gastric emptying</td>
<td>Stomach contraction, 1HCl secretion</td>
</tr>
<tr>
<td>Taste</td>
<td>Gastric distension</td>
<td>Stomach contraction, 1HCl secretion</td>
</tr>
<tr>
<td>Sight</td>
<td>Gastric distension</td>
<td>Stomach contraction, 1HCl secretion</td>
</tr>
<tr>
<td>Sound</td>
<td>Gastric distension</td>
<td>Stomach contraction, 1HCl secretion</td>
</tr>
</tbody>
</table>

Gastric secretion
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Gastric lumen
Gastric pit
Mucus neck cells
Chief cell
Parietal cells
Muscularis mucosa

Regulation of Gastric Secretion
Vagal efferent fibers
Parietal cell
Ach → HCl
Internal neuron
G cell
Gastrin

Taste, smell sight, chewing

gastric secretion
GI functions

- Structure / function, muscle, BER, control
- Glands, control phases and neuroendocrine mechanisms

gastric secretion
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Stomach regions

Gastric secretion

GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Pepsinogen Conversion

Gastric lumen

Pepsinogen

HCl

PROTEIN

PEPSINOGEN

PEPSIN

PEPTIDES

INTRINSIC FACTOR

Chief cell

Parietal cell

Secretion
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

motility / secretion

motility / secretion

GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

motility / secretion

cephalic phase

gastric phase
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Gastric Emptying

Small intestine

Stimulate secretion of enterogastrones
Stimulate neural receptors

ACID, I FAT, HYPERTONIC SOLUTIONS, DISTENSION

1 SYMPATHETIC / PARASYMPATHETIC DISCHARGE
SHORT NEURAL REFLEXES VIA ENTERIC NEURONS

CNS

gastric emptying

GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Pancreas

pancreatic secretion
GI functions

Pancreatic Enzymes

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SUBSTRATE</th>
<th>ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trypsin</td>
<td>Proteins</td>
<td>Breaks peptide bonds in proteins to form peptide fragments</td>
</tr>
<tr>
<td>Carboxypeptidase</td>
<td>Proteins</td>
<td>Splits off terminal amino acids from the carboxyl end of proteins</td>
</tr>
<tr>
<td>Lipase</td>
<td>Fats</td>
<td>Splits triglycerides to form free fatty acids and monoacylglycerols</td>
</tr>
<tr>
<td>Amylase</td>
<td>Polysaccharides</td>
<td>Splits polysaccharides into glucose and maltose</td>
</tr>
<tr>
<td>Ribonuclease</td>
<td>Nucleic acids</td>
<td>Splits nucleic acids into free nucleotides</td>
</tr>
</tbody>
</table>

GI functions

Pancreas: Bicarbonate Secretion
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Pancreatic secretion

Pancreatic Enzymes in Small Intestine

secretin > CCK
CCK > secretin

Pancreatic Bicarbonate Secretion

Pancreatic Enzyme Secretion

Glands, control phases and neuroendocrine mechanisms

pancreatic secretion

Pancreas: Regulation of Exocrine Secretion

Stomach

Duodenum

Protein and fat digestion products

(+)

HCl

Secretin

Bicarbonate

Cholecystokinin

Intercalated duct cells

Acinar cell

Pancreas
**GI functions**

**Secretion**
- Ach
- Histamine
- Gastrin
- Proglumide
- Cimetidine
- Secretin
- CCK

**Oxyntic cell**
- HCl

**Common intermediate**
- Ca
- Ca

**Pancreatic cell**
- HCO3
- Enz

**Digestion / Absorption**
- Galactose
- Lactose
- Lactase
- Amylase
- Maltase
- Glucose
- Sucrose
- Fructose
- Digestion and Absorption of Carbohydrates

- Luminal vs. mucosal digestion
- Similar pattern for sugars and proteins
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Intracellular Concentration

C_{i} = constant extracellular concentration

C_{i} = intracellular concentration

Time

absorption

- luminal vs mucosal digestion
- similar pattern for sugars and proteins

GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Assortment of Movements of Solutes

absorption

sugars and aminoacids
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

GL functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

hepatic secretion
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Bile Salt

hepatic secretion

secret / digest / absorb
GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Gastric, pancreatic, liver secretion have 3 phases, cephalic, gastric, intestinal

Secretin increases pepsinogen secretion and decreases acid chloride secretion

Ach, muscarinic, calcium influx; histamine, H2, cAMP, PKA; gastrin, G, Ca up; antagonists, PGE, PGI, SS, EGF; activate Gi and decrease adenyl cyclase

Motility / secretion

GI functions

Structure / function, muscle, BER, control

Glands, control phases and neuroendocrine mechanisms

Large intestine

Water absorption

Increased water permeability vesicles with water channels fuse with membrane ATP

Protein phosphorylation

CAMP-dependent protein kinase

GTPase activity of the α subunit is blocked by Cholera toxin

ECF

H

R

Ga

GDP

replaced by GTP

AC

cAMP

PK

ICF

H

R

Gs

GTP

AC

cAMP

PK

H

R

Ga

Gs

GTP

ECF

H

R

Gs

GTP

AC

cAMP

PK

GTPase activity of the α subunit is blocked by Cholera toxin
simple diffusion, diffusion of solutes if membrane is permeable, Fick’s first law of diffusion
\[ J = -DA \frac{dc}{dx} \]
- net rate diffusion, moles or g/cm² per unit time
- \( A \): area of the plane
- \( \frac{dc}{dx} \): concentration gradient across plane

osmosis, water diffusion through memb, impermeable to ions, van’t Hoff’s law for osmotic pressure
\[ p = iRTm \]
- \( p \): osmotic pressure
- \( i \): # of ions formed by dissociation of a solute
- \( R \): ideal gas constant
- \( T \): absolute temperature
- \( m \): solute molal conc (moles solute / kg water)

facilitated diffusion, diffusion of solutes through a transporter
\[ V = \frac{V_{max} [S]}{K_m + [S]} \]
- \( V \): rate of transport
- \( [S] \): substrate concentration
- \( V_{max} \): max. rate of transport (in flux = efflux)
- \( K_m \): substrate concentration for half \( V_{max} \)

e.g., when \( K_m \) for flux = 0.5 mM and \( K_m \) for efflux = 5 mM, equilibrium is reached at an internal concentration 10x that of the external concentration

active transport, transport against concentration / electrical gradient
\[ V = \frac{V_{max} [S]}{K_m + [S]} \]
- \( V \): rate of transport
- \( [S] \): substrate concentration
- \( V_{max} \): max. rate of transport (in flux = efflux)

Gastrointestinal Tract Processes
Physiopathology

Ulcers, vomit, gallstones, lactose intolerance, diarrhea

Summary