The Gastrointestinal System
Learning outcomes

- List two main components that make up the digestive system
- Describe the 6 essential functions of the GIT
- List factors (neurological, hormonal and paracrine mechanisms) that regulate GIT function and describe how they control GIT activities
- Describe components of the enteric nervous system. What are the major functions of the submucosal and myenteric nervous system
INTRODUCTION

Components of GI system are
1. motility
2. secretion
3. digestion
4. absorption
The Digestive system

• The digestive system can be divided into two groups:
  - gastrointestinal (GI) tract
  - accessory digestive organs

• Extends from mouth to anus, ≈ 9 m long

• Organs of the GI tract include: the oral cavity, pharynx, oesophagus, stomach, small intestine, large intestine

• The accessory digestive organs include the teeth, tongue, salivary glands, liver, gall bladder, and pancreas
The digestive system and functions of individual components
Functional organisation of GIT

1. Reception of food
2. Conduction and Storage
3. Early digestion
4. Final digestion and absorption
5. Elimination of undigested remains
1. Reception of food

- Involves mouth & associated appendages & cavity
- Food selection thru taste, olfaction, texture & sensory cues
- Oral glands secrete fluids
2. Conduction and Storage

- Occurs in oesophagus & anterior part of stomach

3. Early digestion

- Occurs in stomach
- Secretion of gastric juice containing enzymes
4. **Final digestion and absorption**
   - Occurs in posterior midgut & anterior intestine
   - Rich in digestive enzymes
   - Has microvilli for efficient absorption

5. **Elimination of undigested remains**
   - Takes place in terminal part of gut
   - Absorption of water from faecal material

- Nervous regulation is preponderant in initial & last stages of digestion whilst humoral factors become more vital in middle stages
Summary of digestive functions of different regions of the GIT
BLOOD SUPPLY

- Minimal blood flow is required for digestive glands to remain viable & GIT processes to continue unhindered.
- RCVs largest share of CO, though amount varies with its activity.
- Supplied by splanchnic circ
  - RCVs 30% of CO,
  - Blood flow of 1500ml/min,
  - Lowest total peripheral vascular resistance ($\approx 3.6$ mmHg/ml/sec)
Basic Principles

- Functions regulated & coordinated by hormones, paracrine agonists & neurons.

- Control mechanisms governed by volume and composition of luminal contents

- Reflexes elicited by following luminal stimuli:
  - Distension of wall ___ mechanoreceptors
  - Chyme osmolarity ___ osmoreceptors
  - Chyme acidity ___ chemoreceptors
  - Chyme [ ] of spc. digestion products
Secretion

- includes both *exocrine* and *endocrine* secretions
- Exocrine - the release of saliva, acids, digestive enzymes, buffers and salts by the epithelium of the digestive tract
- Endocrine – secretion of hormones that regulate the digestive system
- Receptors trigger reflexes that influence effectors – muscles and secretory glands
- Activities of oral & anal end of GIT are under conscious control whilst others proceed unconsciously
Histology Review

Small Intestine

Mucosa
Submucosa
Muscularis
Serosa
Inner Circular
Outer longitudinal
Fig. 37-1 The general organization of the layers of the gastrointestinal tract. (Redrawn from Ham AW: Histology, ed 3, Philadelphia, 1957, JB Lippincott.)
Neural Regulation

- **Enteric Nervous System (ENS),**
  - 2 nerve networks - Myenteric (Auerbach’s) plexus and Submucosa (Meissner’s) plexus
  - ENS has numerous sensory receptors & interneurons
    - also motor neurons innervating muscle, secretory cells & blood vessels
- **Myenteric plexus** - smooth muscle activity
- **Submucosa plexus** - secretory activity & blood flow
Fig. 37-4  Major neural plexuses of the small intestine. (A, Seen in whole mounts; B, seen in transverse section.) The two ganglionated plexuses are the myenteric and submucosal plexuses. Fibers originating in the myenteric and submucosal plexuses form the nonganglionated plexuses: the tertiary plexus (which innervates the longitudinal layer of muscularis externa), the deep muscular plexus (which supplies the inner dense circular muscle), and the mucosal plexus. Neurons and neuronal processes are shown in color. (Redrawn from Furness JB, Costal M: Neuroscience 5:1, 1980.)
**FIGURE 15–6**
Structure of the gastrointestinal wall in longitudinal section. Not shown are the smaller blood vessels and lymphatics, neural connections between the two nerve plexuses, and neural terminations on muscles, glands, and epithelium.
ENS releases - acetylcholine, serotonin, norepinephrine, NO, ATP, gastrin, CCK, several neuropeptides

Interneurons in plexuses connect afferent sensory fibres with efferent neurons to smooth muscles & secretory cells

- reflex acts wholly within GIT wall
- can coordinates activity in absence of extrinsic innervation
Sensory neurons respond to:

- Mechanical deformation
- Particular chemical stimuli
- Pain
- Temperature
Myenteric Neurons

- Mostly motor neurons – both excitatory & inhibitory
  - Excitatory release acetylcholine onto muscarinic receptors
    1. ↑ tonic contraction, ‘tone’, of gut wall
    2. ↑ intensity & rate of rhythmical contractions
    3. ↑ velocity of conduction of excitatory waves along gut wall
      - more rapid movement of peristalsis
Inhibitory release Vasoactive Intestinal Polypeptide (VIP) & NO

Useful for inhibiting intestinal sphincters

E.g

- pyloric sphincter & sphincter of the ileocecal valve that controls emptying into caecum
Submucosa Neurons

- Mostly regulate glandular, endocrine & epithelial cell secretion
  - Controls local intestinal secretion
  - local absorption
  - local contraction of submucosal muscles

- Release acetylcholine & VIP
Autonomic Nervous System

- Extensive sympathetic & parasympathetic innervations primarily project onto ENS

  - Extrinsic innervation influences the motor & secretory functions of GIT via ENS
Sympathetic Innervation

- inhibits motor & secretory activities of GIT
- Mostly terminate on neurons of ENS
- Some vasoconstrictor innervate directly blood vessels and glandular structures
- contraction of muscularis mucosae & some sphincters
Parasympathetic Innervation

- Vagus nerve down to level of transverse colon whilst pelvic nerves remainder of colon, rectum & anus
- Fibres are preganglionic & predominantly cholinergic
- Mostly terminate on ENS
- stimulates motor & secretory activities of GIT
Fig. 37-3  Major features of the autonomic innervation of the gastrointestinal tract. In most cases the autonomic nerves influence the functions of the gastrointestinal tract by modulating the activities of neurons of the enteric nervous system.
Enteric Nervous System

- Myenteric plexus
- Submucosal plexus
- Motor neurons:
  - Longitudinal and circular smooth muscle layers of the muscularis
  - Sensory neuron:
    - Mucosal epithelium

Connections to ANS and CNS neurons
NEURAL REFLEXES

- Afferent fibres in GIT provide afferent limbs of both local & central reflex arcs
- Afferent sensory fibres can be stimulated by:
  
  i. Irritation of gut mucosa
  
  ii. Excessive distension of gut
  
  iii. Presence of specific chemical substances in gut
Sensory fibres terminate in:

i. ENS

ii. Prevertebral sympathetic ganglia, that’s celiac, mesenteric & hypogastric ganglia

iii. Multiple areas of spinal cord & brain stem
GI Reflexes

1. Reflexes that are integrated entirely within ENS, include those that control:
   a. GI secretion
   b. Peristalsis
   c. Mixing contractions
   d. Local inhibitory effects
2. Reflexes from gut to prevertebral sympathetic ganglia & back to GIT
   a. Gastrocolic reflex – signal from stomach → evacuation of colon
   b. Enterogastric reflex – signal from colon & S. intestine → inhibit stomach motility and secretion
   c. Colonoileal reflex – signal from colon to inhibit emptying of ileal contents to colon
3. Reflexes from gut to spinal cord & brain stem
   a. Reflexes from stomach & duodenum to brain stem & back to stomach thru vagus nerves to control gastric motor & secretory activity
   b. Pain reflexes that cause general inhibition of entire GIT
   c. Defecation reflexes from colon & rectum to spinal cord & back again to produce powerful colonic, rectal & abdominal contractions required for defecation
Central reflexes are required to coordinate activities located far from each other.

Not all neural reflexes are initiated within tract as hunger, the sight or smell of food, & emotional state of person can have vital effects on GIT - effects mediated by CNS via autonomic neurons.
Hormonal Regulation

- Hormones secreted by endocrine cells scattered throughout GIT
- secretin, cholecystokinin (CCK), gastrin, & glucose-dependent insulinotropic peptide (GIP)
  - each hormone is involved in feedback mechanisms to regulate GI luminal environment
  - each hormone affects > 1 type of target cell
hormones have stimulatory, inhibitory and tropic effects
latency & duration of hormonal effects are much prolonged as compared to neural influences
hormonal effects are potentiated in the presence of neural activity

- GIT has immunocytes that secrete inflammatory mediators such as histamine, prostaglandins, leukotrienes, cytokines e.t.c
  - involved in GI disorders such as Celiac, inflammatory bowel diseases and Crohn’s disease
<table>
<thead>
<tr>
<th></th>
<th>GASTRIN</th>
<th>CCK</th>
<th>SECRETIN</th>
<th>GIP</th>
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</thead>
<tbody>
<tr>
<td><strong>Chemical class</strong></td>
<td>Peptide</td>
<td>Peptide</td>
<td>Peptide</td>
<td>Peptide</td>
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<tr>
<td><strong>Site of production</strong></td>
<td>Antrum of stomach</td>
<td>Small intestine</td>
<td>Small intestine</td>
<td>Small intestine</td>
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<tr>
<td><strong>Stimuli for hormone release</strong></td>
<td>Amino acids, peptides in stomach; parasympathetic nerves</td>
<td>Amino acids, fatty acids in small intestine</td>
<td>Acid in small intestine</td>
<td>Glucose, fat in small intestine</td>
</tr>
<tr>
<td><strong>Factors inhibiting hormone release</strong></td>
<td>Acid in stomach; somatostatin</td>
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**Target Organ Responses**

**Stomach**
- Acid secretion: Stimulates, Inhibits, Inhibits
- Motility: Stimulates, Inhibits
- Growth: Stimulates

**Pancreas**
- Bicarbonate secretion: Potentiates secretin’s actions, Stimulates
- Enzyme secretion: Stimulates
- Insulin secretion: Stimulates
- Growth of exocrine pancreas: Stimulates

**Liver (bile ducts)**
- Bicarbonate secretion: Potentiates secretin’s actions, Stimulates

**Gallbladder**
- Contraction: Stimulates

**Sphincter of Oddi**
- Relaxes

**Small intestine**
- Motility: Stimulates ileum
- Growth: Stimulates

**Large intestine**
- Stimulates mass movement
Phases of GI Control

- 3 phases according to location of stimuli
- **Cephalic phase**
  - receptors in head stimulated by sight, smell, taste and chewing & various emotional states
  - efferent pathways mediated by parasympathetic fibres in vagus nerve
  - affect secretory and contractile activity
2. **Gastric phase**

- initiated in stomach by distension, acidity, amino acids & peptides

- responses mediated by short & long reflexes and release of gastrin
3. **Intestinal phase**

- initiated in intestinal tract by distension, acidity, osmolarity and various digestive products
- responses mediated by short & long reflexes and release of secretin, CCK & GIP
FIGURE 15-13

Long and short neural reflex pathways activated by stimuli in the gastrointestinal tract. The long reflexes utilize neurons that link the central nervous system to the gastrointestinal tract. Chemoreceptors are stimulated by chemicals, osmoreceptors are sensitive to changes in osmolarity (salt concentration), and mechanoreceptors respond to distention of the gastrointestinal wall.
Fig. 37-5  Local and central reflex pathways in the gastrointestinal system.