### Large intestine

- **Overall functions**
  - Completion of absorption
  - Produce certain vitamins
    - Vitamin K produced by intestinal flora
  - Forms and rids the body of feces through the anus

### Anatomy of the large intestine

- Attached to abdominal wall by the mesocolon (omentum)
- Ileocecal sphincter between small and large intestine
- 4 major regions –
  - Cecum
  - Appendix is attached to cecum
  - Colon
  - Rectum
  - Anal canal
- Colon divided into ascending, transverse, descending and sigmoid

### The appendix—not so useless?

- A vestigial organ?
  - A shrunken remainder of an organ our ancestors required?
- Current research indicates that the appendix harbors symbiotic bacteria essential for health
- When our gut is ravaged by diseases like diarrhea and dysentery, the appendix repopulates the gut with beneficial bacteria

### Anatomy of the large intestine

- Two sphincters guard the opening of anal canal (anus)
  - Internal anal sphincter of smooth muscle
    - Involuntary
  - External anal sphincter of skeletal muscle
    - Under voluntary control
Large Intestine

Wall of large intestine has the same 4 layers
- Mucosa
  - Absorptive cells - absorb water
  - Goblet cells - secrete mucus
  - No circular folds or villi
- Submucosa
- Muscularis
- Serosa

Digestion in the Large Intestine

- Mechanical digestion
  - Ileocecal sphincter regulates passage of chyme from the ileum into cecum
  - After a meal, gastroileal reflex intensifies peristalsis in ileum and forces chyme into the cecum
- Movements of the colon
  - Haustral churning
    - The haustra fill up, then the walls contract and squeeze the contents into the next haustrum
  - Peristalsis
  - Mass peristalsis
    - A strong peristaltic wave that drives contents of colon into rectum
    - Initiated by food in the stomach

Digested in the Large Intestine

- Chemical digestion
  - Mucus is secreted by glands of large intestine
  - No digestive enzymes
  - Final stage of digestion via bacteria that inhabit the lumen
    - Bacteria ferment undigested carbohydrates and proteins → gases which contribute to flatulence
    - Produce several B vitamins and vitamin K
  - Remaining water absorbed
    - Helps maintain body’s water balance
    - Solidifies feces
  - Also absorbs ions (Na, Cl) and some vitamins

Feces formation

- Chyme remains in large intestine 3-10 hrs → becomes solid or semisolid because of water absorption
- Called feces
- Feces contain water, intestinal mucosal cells, bacteria, unabsorbed materials, etc.

The defecation reflex

- Mass peristalsis pushes fecal material into rectum
- Distension of rectal wall stimulates stretch receptors → initiates the defecation reflex
- Motor impulses from spinal cord → contraction of rectal muscles
- Pressure opens the internal anal sphincter
- External anal sphincter – voluntary control
- Defecation can be postponed
Diarrhea and constipation

- **Diarrhea** — increase in frequency, volume and fluid content of feces
  - Chyme passes too quickly thru GI tract, not enough time for absorption
  - Can result in dehydration and electrolyte imbalances
  - Causes: lactose intolerance, stress, infection

- **Constipation** — infrequent defecation caused by decreased motility of the intestine
  - Excessive water absorption → dry, hard feces

Other Colon & Rectal Disorders

- **Hemorrhoids**
  - Enlarged and inflamed blood vessels of the anus due to chronic constipation, pregnancy, anal intercourse

- **Irritable bowel syndrome (IBS)**
  - Muscularis layer contracts without its normal coordination, characterized by chronic diarrhea

- **Inflammatory bowel disease (IBD)**
  - A group of inflammatory disorders such as ulcerative colitis or Crohn’s disease

- **Polyp and cancer**
  - Small growths found in the mucosal lining
    - Benign or cancerous

Role of the GI tract in water absorption

- The small intestine must absorb massive quantities of water:
  - Water intake = 1 to 2 liters every day.
  - 6 to 7 liters as secretions from salivary glands, stomach, pancreas, liver and the small intestine itself.
  - Small intestine absorbs about 90% of the fluid, the rest is absorbed in large intestine.
  - Only a small amount (100 ml) excreted in feces.

Why is water balance important?

- Water is critical for body functions
  - The body is about 70% water
  - Found both inside and outside the cells

- Functions
  - Helps regulate body temperature
  - Transports nutrients
  - Excretion of waste products

Absorption of water and electrolytes

- Net movement of water across cell membranes always occurs by **osmosis**

- **Fundamental concept:** there is a tight coupling between water and electrolyte absorption.

- Absorption of water depends on absorption of sodium and other electrolytes.

Absorption of water and electrolytes

- Sodium is absorbed into the cell mainly by co-transport with glucose and amino acids.

- Absorbed sodium is rapidly exported from the cell via sodium pumps → a high osmolality in the spaces between enterocytes.

- Water diffuses into the intercellular space.

- Water, as well as sodium, then diffuses into capillary blood within the villus.
Overview of digestion

Neural and hormonal regulation of digestion

Phases of digestion

Cephalic phase of digestion

Gastric phase of digestion

Neural regulation of gastric motility and pH
Hormonal regulation of gastric secretion

- **Gastrin**
  - Hormone released by G cells when presence of chyme in stomach lowers its acidity
  - Stimulates HCl secretion by parietal cells of stomach
  - Aids in gastric motility

Intestinal phase of digestion

- **Intestinal phase**
  - Begins when food enters the small intestine
- **Neural & hormonal regulation**:
  - Slows exit of chyme from stomach
  - Stimulates flow of bile and pancreatic juice

The intestinal phase of digestion

- **Reflexes initiated during cephalic and gastric phases** stimulate stomach secretion and motility
- **Reflexes during the intestinal phase** slow the release of chyme from stomach
  - Prevents duodenum from being overloaded

Neural regulation of the intestinal phase

- **Distension of the duodenum by chyme** causes the enterogastric reflex
  - Stretch receptors in duodenal wall send nerve impulses to medulla
  - ↓ parasympathetic stimulation
  - ↑ sympathetic nerves to the stomach
  - Result – decreases gastric motility and slows emptying of stomach

Hormonal regulation of the intestinal phase

- **Intestinal phase of digestion**: regulated by 2 major hormones secreted by small intestine
  - Cholecystokinin (CCK) and secretin
- **Functions of CCK**
  - Stimulates secretion of pancreatic enzymes
  - Causes contraction of the gall bladder
- **Roles of secretin**
  - Stimulates flow of pancreatic juice rich in bicarbonate – buffers chyme entering the duodenum
  - Slows the production of acid in the stomach

Recap: Hormonal regulation of digestion

- **Major gut hormones**
  - **Gastrin** (stomach)
    - Stimulates HCl secretion
    - Aids in gastric motility
  - **Cholecystokinin** (CCK)
    - Secretion of pancreatic enzymes
    - Bile release
    - Induces satiety (feeling full)
    - Secretin
    - Secretion of bicarbonate (buffers the chyme in duodenum)
    - Inhibits secretion of gastric HCl
The intestinal tract: a role in immunity

- Foods contain bacteria and other pathogens
- The immune system must prevent pathogens from crossing the digestive tract & entering into blood
- Microorganisms are neutralized by:
  - Enzymes in the saliva and bile.
  - The low pH of the stomach
  - Mucus – contains antibodies
  - “Good” intestinal bacteria prevent the overgrowth of potentially harmful bacteria in the gut.
  - GI immune system or gut-associated lymphoid tissue (GALT).

Gut-associated lymphoid tissue (GALT)

- GALT – the digestive tract’s immune system
  - Much of the GI tract is populated with potentially pathogenic microorganisms
  - About 70% of the body’s immune system is found in the digestive tract.
  - GALT works to protect the body from pathogens
- Peyer’s patches
  - Areas of lymphoid tissue found in small intestine
  - Help generate an immune response within the mucosa

Innate defenses of the intestinal mucosa

- gastric acidity
- bile acids
- Secretion of antimicrobial peptides, mucus and water
- peristaltic movements of the intestine

Water secretion

- A simple method of responding to the presence of intestinal pathogens
- Rapid flow of fluid across the intestinal epithelium flushes organisms from the intestinal lumen and prevents attachment
- The presence of bacterial toxins initiates intestinal secretion of electrolytes and water.

Water secretion into the intestinal crypt

- Crypt cells pump Na and Cl ions into crypt – increases osmolarity and pulls water into intestine
- Some bacteria, such as cholera, cause this pump system to lock in the “ON” position → massive diarrhea

Chapter 25: Metabolism and Nutrition
Living cells and automobile engines use the same basic process—they use oxygen to harvest the chemical energy of fuel molecules.

Cells use chemical energy to do work.

Most cells receive energy in a form they can’t use directly:
- Energy from the sun (plants)
- Energy from food (all organisms)

This energy has to be converted into a usable form of energy:
- ATP or Adenosine TriPhosphate

ATP = adenosine plus a ‘tail’ of three phosphate groups
- Where is the energy in ATP?
  - It’s trapped in the bonds between the phosphate groups
  - High-energy bonds
    - Phosphates are negatively charged, it takes lots of energy to hold them together

ATP is broken down to ADP, accompanied by the release of energy:
- ATP → ADP + P + energy

The cell uses this energy to drive other reactions in the cell.

The energy in ATP is used to drive cellular work:
- Movement
- Transport
- Chemical reactions

It takes about 10 million ATP molecules per second to power an active muscle cell.
The ATP Cycle
- ATP acts like an energy shuttle – it stores energy obtained from food and releases it as needed at a later time.

Metabolism
- Metabolism – all chemical reactions occurring in body
  - Anabolic reactions – synthesis
    - e.g. synthesis of glycogen from glucose
  - Catabolic reactions – break down
    - e.g. cell respiration – breaks down glucose and produces ATP energy

Metabolism in a nut shell – anabolic and catabolic reactions

Cellular respiration
How Cells make ATP from Food

We use the energy that plants capture from the sun
Food as Fuel

- Cells
  - Break down food molecules in cellular respiration.
  - Generate many molecules of ATP.

Where Is the Energy in Food?

- Stored in chemical bonds
- Cellular respiration
  - the process of harvesting energy from food and converting it to ATP
  - Series of catabolic reactions – break down complex molecules and transfer the energy to ATP

How is energy transferred to ATP?

- Oxidation-reduction reactions
  - Oxidation: Removal of electrons
  - Reduction: Addition of electrons
  - The liberated H atoms are transferred to the coenzymes NAD or FAD and used to synthesize ATP

Mechanisms of ATP synthesis

- Substrate-level phosphorylation
  - Direct
  - Transferring high-energy phosphate group from an intermediate directly to ADP
- Oxidative phosphorylation
  - Remove electrons and pass them through electron transport chain to oxygen
  - Occurs in the mitochondria
- Photophosphorylation
  - Only in chlorophyll-containing plant cells

The Overall Equation for Cellular Respiration

- Glucose is a common fuel molecule for cellular respiration.

An overview of cellular respiration

- Cells break down glucose and capture the released energy as ATP
  - 3 steps
  1. Glycolysis
     - occurs in the cytoplasm
     - Produces ATP
  2. Krebs cycle
     - occurs in mitochondria
     - Produces ATP
  3. Electron transport
     - generates most ATP