Lymphatic System and Immunity

Functions of the Lymphatic System

- network of vessels that assist in circulating fluids
- transports excess fluid away from interstitial spaces
- transports fluid to the bloodstream
- aids in absorption of dietary fats
- help defend the body against disease

Lymphatic Pathways

[Diagram of lymphatic pathways]
Lymphatic Ducts

- Thoracic duct – drains left side of body above diaphragm and all lower body
- Right lymphatic duct – drains right side of body above diaphragm and right arm

Lymph
- Tissue fluid that has entered a lymphatic capillary
- Contains lymphocytes, interstitial fluid, and plasma proteins

Lymph Movement
- Action of skeletal muscles
- Respiratory movements
- Smooth muscle in larger lymphatic vessels
- Valves in lymphatic vessels

Anatomical and physiological mechanisms similar to veins!!

Lymphatic Tissues

- Aggregations of lymphocytes in the connective tissues of mucous membranes and various organs
  - Diffuse lymphatic tissue (scattered, rather than densely clustered), e.g., in respiratory, digestive, urinary, and reproductive tracts. Known as MALT (mucosa-associated lymphatic tissue)
  - Lymphatic nodules (follicles) – densely clustered cell masses in lymph nodes, tonsils, appendix, small intestine (Peyer’s patches)
Lymphatic Tissues

- Lymph nodes filter the lymph, carry out immune surveillance, and serve as an early warning system for pathogens
  - The structural unit of the LN is the nodule
  - Some tissues contain isolated nodules
- Lymph nodes are usually located in clusters/chains
  - Cervical, axillary, inguinal, pelvic, abdominal, thoracic, and supratrochlear
- The thymus is the site of ‘education’ of T lymphocytes
- The spleen is the filter of the blood; destroys worn out RBCs

Innate (Nonspecific) Defenses

- Species Resistance
  - resistance to certain diseases to which other species are susceptible
- Mechanical Barriers
  - skin
  - mucous membranes
- Chemical Barriers
  - enzymes in various body fluids
  - pH extremes in stomach
  - high salt concentrations
  - interferons
  - defensins
  - collectins

These are not specific to a particular pathogen (disease causing agent)

Innate Defenses (continued)

- Natural Killer Cells
  - type of lymphocyte
  - lysis of viral-infected cells and cancer cells
- Phagocytosis
  - neutrophils
  - monocytes
  - macrophages
  - ingestion and destruction of foreign particles
- Complement System
  - ‘complements’ the action of antibodies
  - helps clear pathogens

These are not specific to a particular pathogen

- Inflammation
  - tissue response to injury
  - helps prevent spread of pathogens
  - promotes healing
  - blood vessels dilate
  - capillaries become leaky
  - white blood cells attracted to area
  - clot forms
  - fibroblasts arrive
  - phagocytes are active

- Fever
  - inhibits microbial growth
  - increases phagocytic activity

These are not specific to a particular pathogen
Adaptive (Specific) Immunity

- resistance to particular pathogens or to their toxins or metabolic by-products
- ** based on the ability of lymphocytes to distinguish “self” from “non-self”
- antigens = cell surface proteins that can provoke immune responses
- Adaptive (Specific) Immunity demonstrates:
  1) specificity and 2) memory
- T cells – cell-mediated immunity; B cells – humoral immunity

The Immune Response – A Summary

![Immune Response Diagram]

Types of Immunoglobulins (Ig)

Immunoglobulins are the ‘gamma globulins’ in plasma

**IgM**
- located in plasma; too large to escape
- reacts with naturally occurring antigens on RBCs following certain blood transfusions
- activates complement

**IgG**
- located in tissue fluid and plasma
- activates complement
- defends against bacteria, viruses, and toxins
- can cross the placenta

**IgA**
- located in exocrine gland secretions
- defends against bacteria and viruses in membranes
- can cross the placenta
Types of Immunoglobulins

**IgD**
- located on surface of most B lymphocytes
- plays a role in B cell activation

**IgE**
- located in exocrine gland secretions
- promotes inflammation and allergic reactions

**Actions of Antibodies**
- agglutination
- precipitation
- neutralization
- activation of complement

The Complement Cascade

Activation of the complement cascade stimulates inflammation, attracts phagocytes, and enhances phagocytosis

Immune Responses

A primary immune response produces a lesser concentration of antibodies than does a secondary immune response

Primary response (IgM, IgG)
- 4-5 days

Secondary response (anamnestic) (IgG)
- 1-2 days

Know this
Practical Classification of Immunity

Immunity

- Natural
  - Passive (maternal Ig)
- Artificial
  - Active (vaccination)
  - Passive (Ig or antitoxin)

Know this

Allergic Response

IgE mediates allergic reactions by binding to mast cells
Mast cells release histamine and heparin

Anaphylaxis is a severe allergic reaction involving the whole body caused by histamine release.

Major Organs of Digestive System

Digestion is the mechanical and chemical breakdown of food into a small enough form that cells can absorb

Organs can be divided into:
- Digestive tract (primary) (alimentary canal); tube extending from mouth to anus (about 30 ft.); in contact with food
- Accessory organs (secondary); teeth, tongue, salivary glands, liver, gallbladder, and pancreas; provide secretions for digestion

- Two major movements stimulating digestion: 1) segmentation and 2) peristalsis
**Innervation of the Alimentary Canal**

The alimentary canal has extensive sympathetic and parasympathetic innervation:
- mainly in the muscularis externa
- regulates its tone and the strength, rate, and velocity of muscular contractions
- submucosal plexus – controls secretions/blood flow
- myenteric plexus – controls gastrointestinal motility/sphincters
- parasympathetic division of ANS – increases activities of digestive system and relaxes sphincters
- sympathetic division of ANS – generally inhibits digestive actions and contracts sphincters

**Palate**

- roof of oral cavity

Important in separating the nasopharynx from the pharynx during swallowing

Epiglottis prevents food from entering trachea during swallowing
Secondary (Permanent) Teeth

Total of 32 secondary (permanent) teeth; total of 20 primary (baby, milk) teeth

Be able to label this diagram

I C Big Molars!!!

Pharynx

Pharynx aids swallowing by grasping food and moving it toward the esophagus.

Three Phases of the Swallowing Reflex

Only voluntary phase is the buccal (oral) phase, i.e., the initiation of swallowing, then...

- soft palate and uvula raise
- hyoid bone and larynx elevate
- epiglottis closes off top of trachea
- longitudinal muscles of pharynx contract
- inferior constrictor muscles relax and esophagus opens
- peristaltic waves push food through pharynx

Esophagus conveys food from pharynx to stomach by peristalsis
**Stomach Review**

- **Stomach (know all these)**
  - Cardia, fundus, body, pylorus
  - Mixes food and begins digestion of protein
  - Limited absorption (alcohol)
  - Moves food into small intestine
  - Pyloric sphincter (entrance to small intestine); opens when liquidified stomach contents (chyme) exerts enough pressure
    - Ragae (flatten as it fills) and gastric pits → gastric juice
  - Gastric glands
    - Mucous cells (goblet) – secrete mucus
    - Chief cells (peptic) – secrete pepsinogen
    - Parietal cells (oxyntic) – secrete HCl (Parietal, pH); Intrinsic factor for absorption of vitamin B₁₂
    - G cells -> gastrin (Go hormone!); D cells -> Somatostatin (Stop hormone!)

**Three Phases of Stomach Control**

- **Cephalic phase**
  - triggered by smell, taste, sight, or thought of food
  - begin secretion and digestion

- **Gastric phase**
  - triggered by distension, presence of food, and rise in pH in stomach
  - enhance secretion and digestion

- **Intestinal phase**
  - triggered by distension of small intestine and pH change
  - controls rate of gastric emptying; may slow emptying; the more fat in the chyme, the slower the emptying

**NOTE** that all the phases control activity in the **STOMACH**

Know what each phase does (shown in red)
Pancreatic Juice

- **pancreatic amylase** – splits glycogen into disaccharides
- **pancreatic lipases** – break down triglycerides
- **pancreatic nucleases** – digest nucleic acids
- **bicarbonate ions** – make pancreatic juice alkaline (pH = 8) and neutralize acid (chyme) coming from stomach
- Pancreatic proteolytic enzymes...

Pancreatic Proteolytic Enzymes

**Enteropeptidase** (Enterokinase) (brush border of small intestine)

Trypsinogen → Trypsin
Chymotrypsinogen → Chymotrypsin
Procarboxypeptidase → Carboxypeptidase
Proelastase → Elastase

Dipeptides, tripeptides, amino acids → Proteins

Purpose of proteolytic enzymes is to continue the breakdown of proteins that began in the stomach

Regulation of Pancreas/Intestinal Digestion
Liver Functions (over 200!)

- Three general categories of function
  1) Metabolic regulation
     - Interconversion of carbohydrates, lipids, amino acids
     - Removal of wastes
     - Vitamin and mineral metabolism
     - Drug inactivation
     - Storage of fats, glycogen, iron, vit A/B/D/E/K
  2) Hematological regulation
     - Phagocytosis and antigen presentation; ab removal
     - Synthesis of plasma proteins
     - Removal of circulating hormones
     - Removal of worn-out RBCs (Kupffer cells)
     - Removal or storage of toxins
  3) Synthesis and secretion of bile (digestion)

Paths of Blood and Bile in Hepatic Lobule

Yellowish-green liquid continually secreted by hepatocytes

- water
- bile salts (bile acids)
  - derived from cholesterol
  - emulsification of fats (increases surface area for digestive enzymes; large fat blobs become smaller blobs)
  - absorption of fatty acids, cholesterol, and fat-soluble vitamins
  - 80% are recycled (reabsorbed and reused) – enterohepatic circulation of bile
  - 20% excreted in feces (disposes of excess cholesterol)
- bile pigments (bilirubin and biliverdin from breakdown of RBCs)
- electrolytes

The hormone secretin, released by the small intestine, stimulates the hepatocytes to produce a bicarbonate-rich bile that neutralizes acidic chyme coming from the stomach
Main function is to store and concentrate bile between meals, and release concentrated bile under the influence of CCK.

- Fatty chyme entering duodenum stimulates the GB to release bile (via CCK).
- Secretin causes the bile ducts (and pancreatic ducts) to secrete bile rich in HCO₃⁻.

Actions of Cholecystokinin (CCK) on Digestion:
- Contraction of Gallbladder
- Secretion of pancreatic enzymes
- Reduced emptying of stomach
- Relaxation of hepatopancreatic sphincter

Protein, CHO, lipid absorption and digestion
Matching of nutrient delivery to digestive and absorptive capability.
Small Intestine

- Three major parts
  - Duodenum – mixing chamber; mucus, buffers, enzymes
  - Jejunum – digestion and absorption
  - Ileum – connects to cecum of large intestine
- Blood supply and drainage via superior mesenteric artery/vein
- Surface area greatly increased, especially in the jejunum, by
  - Plicae
  - Villi
  - Microvilli

Small Intestine (cont’d)

- Secretions
  - mucus secretion (protective) stimulated by presence of chyme in small intestine
  - distension of intestinal wall activates nerve plexuses in wall of small intestine
  - motility/secretion stimulated by gastroenteric reflex
  - parasympathetics trigger release of intestinal enzymes
- Absorption
  - Protein, CHO, electrolytes –> to hepatic portal vein into liver
  - Fats via chylomicrons and lacteals -> circulation (2nd pass)
- Movements
  - Local via myenteric plexuses
  - Long distance via stomach filling
    - Gastroenteric reflex
    - Gastroileal reflex

Secretions of Small Intestine

- peptidase – breaks down peptides into amino acids
- sucrase, maltase, lactase – break down disaccharides into monosaccharides
- intestinal lipase – breaks down fats into fatty acids and glycerol
- enterokinase – converts trypsinogen to trypsin
- gastrin/somatostatin – hormones that stimulate/inhibit acid secretion by stomach
- cholecystokinin (CCK) – hormone that inhibits gastric glands, stimulates pancreas to release enzymes in pancreatic juice, stimulates gallbladder to release bile, and relaxes hepatopancreatic sphincter (of Oddi)
- secretin – stimulates pancreas to release bicarbonate ions in pancreatic juice; stimulates gall bladder to release bicarbonate-rich bile

See Table 17.9 in Hole for summary of digestive enzymes
Absorption of Fats in the Small Intestine

- fatty acids and glycerol
- several steps
- absorbed into lymph into blood

Functions of Large Intestine

- little or no digestive function
- absorbs water, bile salts, and electrolytes
- secretes mucus (lubrication, binding, protection, pH)
- conversion of bilirubin (uro- and stercobilinogen)
- houses intestinal flora (~800 species of bacteria) and absorbs vitamins liberated by bacterial action (K, B6, and Biotin); produces intestinal gas (flatus)
- forms and stores feces
- carries out defecation

Large Intestine

Blood supply/drainage via superior mesenteric arteries/veins
**Movements of Large Intestine**

- slower and less frequent than those of small intestine
- mixing movements (haustral churning every 30 min)
- mass movements - usually follow meals (stimulated by distension of stomach and duodenum)
  - gastrocolic reflex
  - duodenocolic reflex
  - peristaltic wave from transverse colon through rest of large intestine

**The Rectum, Anal Canal, and Anus**

- Temporary storage of fecal material in rectum triggers the urge to defecate
- Internal anal sphincter is usually contracted but relaxes in response to distension. External sphincter must be tensed to retain feces

**Parasympathetic Defecation Reflex**

- Note that this reflex: 1) relaxes (opens) the internal sphincter and 2) constricts (closes) the external sphincter
- Need voluntary relaxation of the external sphincter for defecation
Nutrients

Nutrients – chemical substances supplied by the environment required for survival (used for growth, repair, or maintenance of the body)

- Macronutrients
  - carbohydrates
  - proteins
  - fats

- Micronutrients
  - vitamins
  - minerals

- Essential Nutrients
  - human cells cannot synthesize
  - include certain fatty acids, amino acids, vitamins

Nitrogen Balance

Variety of compounds in the body contain nitrogen (N):
- amino acids, purines, pyrimidines, creatine, porphyrins.

The body neither stores nor maintains reserves of N. There’s only about 1 kg of N in body at any one time. During starvation, N-containing compounds, like skeletal muscle, are conserved; CHO and fats are metabolized first (protein-sparing effect)

- nitrogen balance - amount of nitrogen taken in is equal to amount excreted
- negative nitrogen balance develops from starvation
- positive nitrogen balance develops in growing children, pregnant women, or an athlete in training

Body Mass Index

- occurs when caloric intake in the form of food equals caloric output from BMR and muscular activities
- positive energy balance leads to weight gain
- negative energy balance leads to weight loss

**Body Mass Index (BMI)**: Wt (kg) / Height² (m)

<table>
<thead>
<tr>
<th>Condition</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin</td>
<td>&lt; 18.5</td>
</tr>
<tr>
<td>Healthy or Normal</td>
<td>18.5 – 24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25.0 – 29.9</td>
</tr>
<tr>
<td>Obese</td>
<td>30.0 – 39.9</td>
</tr>
<tr>
<td>Morbidly Obese</td>
<td>≥ 40.0</td>
</tr>
</tbody>
</table>

* Source: World Health Organization
Calculations of RDA/Maximums

• Energy yields:
  – Protein, CHO = 4 Kcal/gm
  – Fats = 9 Kcal/gm
  • No more than 30% of calories from fat

• RDA for protein = 0.8 g/kg body weight
  – Recall: (2.2 lbs/kg)

Example Calculations - Fat

What is the maximum number of grams of fat to be consumed per day for a patient on a 1500 calorie diet?

1) Find maximum number of CALORIES from fat:

\[ 1500 \text{ calories} \times 30\% = 450 \text{ calories/day max from fat} \]

2) Calculate number of GRAMS of fat in 450 calories

\[ \frac{450 \text{ calories/day}}{9 \text{ calories/gram}} = 50 \text{ grams fat/day} \]

Example Calculations - Protein

What is the minimum number of grams of protein recommended that should be consumed per day for a 175 lb patient?

1) Find patient’s weight in Kg.

\[ 175 \text{ lbs} \times \frac{1 \text{ Kg}}{2.2 \text{ lbs}} = 79.5 \text{ Kg} \]

2) Calculate number of GRAMS of protein required per day

\[ \frac{79.5 \text{ Kg} \times 0.8 \text{ g protein/day}}{\text{Kg}} = 63.5 \text{ grams protein/day} \]
Summary of Lipoproteins

<table>
<thead>
<tr>
<th>Designation</th>
<th>Origin</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chylomicron</td>
<td>GI tract</td>
<td>Transports dietary fats (mainly triglycerides) to liver for processing</td>
</tr>
<tr>
<td>Very Low Density Lipoprotein (VLDL)</td>
<td>Liver</td>
<td>Transports triglycerides from liver to adipose cells</td>
</tr>
<tr>
<td>Low Density Lipoprotein (LDL)</td>
<td>Liver</td>
<td>Transports cholesterol from liver to cells in body</td>
</tr>
<tr>
<td>High Density Lipoprotein (HDL)</td>
<td>Liver</td>
<td>Removes excess cholesterol from cells and transports to liver</td>
</tr>
</tbody>
</table>

The Fat-soluble Vitamins

• Absorbed with fats in digestive tract
• Function/Other sources
  – Vitamin A; structural component of retinal (night vision)
  – Vitamin D
    • increases absorption of calcium and phosphorus from intestine
    • skin and UV light
  – Vitamin E
    • stabilizes internal cellular membranes
    • antioxidant
  – Vitamin K
    • Clotting (‘K’lotting)
    • bacteria in intestine and green, leafy vegetables

Water-soluble Vitamins

• Rapidly exchanged between fluid compartments of digestive tract and circulating blood
• Excesses excreted in urine
• Vitamins B₁₂ and C are stored in larger quantities than other water-soluble vitamins
  – B vitamins [know these functions]
    • as a group, are coenzymes used to harvest energy
    • Vitamin B₁₂ is important in hematopoiesis and maintenance of myelin sheath and epithelial cells
  – Vitamin C (ascorbic acid) [know these functions]
    • collagen production
    • Antioxidant / immune system booster
    • ↑ absorption of iron
**Minerals**

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Symbol</th>
<th>Major/Trace</th>
<th>Primary Location</th>
<th>Major Functions</th>
<th>Major Sources</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>Major</td>
<td>Bones &amp; Teeth</td>
<td>Major Functions: bone/teeth; nerve impulse conduction; muscle contraction</td>
<td>Milk; + kidney stones</td>
<td>- stunted growth</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
<td>Major</td>
<td>Bones &amp; Teeth</td>
<td>Major Functions: bone/teeth; ATP; Nucleic acid &amp; proteins</td>
<td>Meats; Cheese; Milk</td>
<td>+ none; - stunted growth</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
<td>Major</td>
<td>Intracellular Fluid</td>
<td>Major Function: maintenance of resting membrane potential (RMP)</td>
<td>Avocados; Bananas; Potatoes</td>
<td>+ none; - muscular &amp; cardiac problems</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>Major</td>
<td>Extracellular Fluid</td>
<td>Major Functions: maintenance of RMP, electrolyte, water, &amp; pH balance</td>
<td>Table salt; Cured Ham</td>
<td>+ Hypertension, Edema; - cramps, convulsions</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>Major</td>
<td>Extracellular Fluid</td>
<td>Major Functions: maintenance of RMP, electrolyte, water, &amp; pH balance</td>
<td>Table salt; Cured Ham</td>
<td>+ Vomiting; - muscle cramps</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
<td>Major</td>
<td>Bones, needed in mitochondria for cellular respiration; ATP/ADP conversion</td>
<td>Milk; Dairy; Legumes</td>
<td>+ Diarrhea; - neuro-muscular problems</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>Trace</td>
<td>Blood</td>
<td>Major Function: part of hemoglobin</td>
<td>Liver; + Liver damage</td>
<td>- Anemia</td>
</tr>
<tr>
<td>Iodine</td>
<td>I</td>
<td>Trace</td>
<td>Thyroid</td>
<td>Major Function: essential in the synthesis of thyroid hormones (thyroid hormone)</td>
<td>Iodized Salt; Iodine</td>
<td>+ Thyroid hormone imbalance; - goiter</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn</td>
<td>Trace</td>
<td>Liver, kidneys, Brain</td>
<td>Major Function: wound healing; part of several enzymes</td>
<td>Meats; Cereals</td>
<td>+ Slurred speech; - decreased immunity</td>
</tr>
</tbody>
</table>

**Metabolism**

- Glycolysis – metabolism of glucose to pyruvate (Fed)
- Gluconeogenesis – metabolism of pyruvate to glucose (CHO from non-CHO source) – (Fasted)
- Glycogenesis – metabolism of glucose to glycogen (Fed)
- Glycogenolysis – metabolism of glycogen to glucose (Fasted)
- Lipogenesis – creation of new triglyceride (fat) – (Fed)
- Lipolysis – breakdown of triglyceride into glycerol and fatty acids (Fasted)

Major purpose of BOTH states is to maintain homocastic levels of glucose in blood.
Basal Metabolic Rate

Basal metabolic rate (BMR)
- rate at which body expends energy at rest (kcal/hr)
- primarily reflects energy needed to support activities of organs
- varies with gender, body size, body temperature, and endocrine function

Energy needed
- to maintain BMR
- to support resting muscular activity
- to maintain body temperature
- for growth in children and pregnant women

BMR is proportional to body weight

Body’s basal metabolic rate (BMR) falls 10% during sleep and about 40% during prolonged starvation

BMR is profoundly affected by circulating thyroid hormone levels