Test 5

Blood Conditioning Organ Systems

1. Kidneys – Blood Volume Homeostasis, Electrolyte (Na⁺, K⁺, H⁺) Homeostasis
   a) Blood volume influences blood pressure
   b) Long term maintenance of blood volume is essential for blood pressure

2. Liver – Chemical Homeostasis of the Blood

3. Respiratory System – Blood Gas and pH (acid/base) homeostasis
   a) Arterial Oxygen Pressure
   b) Arterial Carbon Dioxide Pressure
   c) Arterial pH

Blood Conditioning

- Kidneys receives 20-25% of resting cardiac output
  - Specifically designed capillary systems for FILTRATION of plasma from one set of capillaries and REABSORPTION of most filtrate solutes and water into a second second set of capillaries
  - Moves filtered solute and solvent to/from a set of tubes
  - Anything entering tubes that is not reclaimed is EXCRETED as urine
  - Regulated for fluid/electrolyte balance and maintenance of MEAN ARTERIAL PRESSURE
Blood Conditioning

- Liver – receives 25% of resting cardiac output
  - 6% directly from hepatic artery
  - 20+% from portal vein draining the DIGESTIVE SYSTEM (rich in nutrients due absorption of digested nutrient molecules)
  - “500” functions of the liver
    - metabolism of all nutrients
    - metabolism of transport proteins, cholesterol, hemoglobin
    - production of bile salts necessary for fat digestion
    - Inactivation of hormones, chemical messengers, metabolic end products
    - Blood detoxification
      - Alcohol
      - Therapeutic Drugs
      - Recreational Drugs

- Kidneys receive 20-25% of resting cardiac output
- Liver – receives 25% of resting cardiac output
- Pulmonary Circulation - receives 100% of cardiac output
  - Specifically designed for rapid diffusion of $O_2$ into blood, $CO_2$ into alveoli for excretion
  - Adjusts $CO_2$ level to influence blood pH
  - Respiratory system REGULATION designed for maintenance of blood gasses
    - Auxiliary function for communicating, temperature regulation, protection
Chapter 13

The Urinary System

Kidneys

- Overview of kidney functions
  1. Maintain $H_2O$ balance in the body
  2. Maintain proper osmolarity of body fluids, primarily through regulating $H_2O$ balance
  3. Regulate the quantity and concentration of most ECF ions
  4. Maintain proper plasma volume

1-4 ABOVE ARE RELATED TO ADEQUATE BLOOD VOLUME FOR FUNCTION OF THE CARDIOVASCULAR SYSTEM’s MEAN ARTERIAL PRESSURE
Kidneys

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     1-4 ABOVE ARE RELATED TO ADEQUATE BLOOD VOLUME FOR FUNCTION OF THE CARDIOVASCULAR SYSTEM’s MEAN ARTERIAL PRESSURE
  5. Help maintain proper acid-base balance in the body
  6. Eliminating the wastes of bodily metabolism
  7. Excreting many foreign compounds
  8. Producing erythropoietin
  9. Producing renin
  10. Converting vitamin D into its active form
Urinary System

- Consists of
  - Urine forming organs
    - Kidneys
  - Structures that carry urine from the kidneys to the outside for elimination from the body
    - Ureters
    - Urinary bladder
    - Urethra
(b) Longitudinal section of a kidney

(c) A greatly exaggerated nephron
Nephron: the functional unit of the kidney

- Smallest unit that can perform all kidney functions
- Approximately 1 million nephrons/kidney
- Each nephron has
  1. Vascular (blood containing) component
  2. Tubular (filtrate containing) component
     ◦ Filtrate is formed by filtration of plasma
  3. Combined vascular/tubular regulatory cells called Juxtaglomerular apparatus
     ◦ Secretes chemicals that influence kidney functions
Overview of Functions of Parts of a Nephron

Vascular component
- Afferent arteriole — carries blood to the glomerulus
- Glomerulus — a tuft of capillaries that filters a protein-free plasma into the tubular component
- Efferent arteriole — carries blood from the glomerulus
- Peritubular capillaries — supply the renal tissue; involved in exchanges with the fluid in the tubular lumen

Tubular component
- Bowman’s capsule — collects the glomerular filtrate
- Proximal tubule — uncontrolled reabsorption and secretion of selected substances occur here
- Loop of Henle — establishes an osmotic gradient in the renal medulla that is important in the kidney’s ability to produce urine of varying concentration
- Distal tubule and collecting duct — variable, controlled reabsorption of Na+ and H2O and secretion of K+ and H+ occur here; fluid leaving the collecting duct is urine, which enters the renal pelvis

Combined vascular/tubular component
- Juxtaglomerular apparatus — produces substances involved in the control of kidney function

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**Nephron**

- **Vascular component**
  - renal artery, inflowing blood passes through afferent arterioles which deliver blood to the glomerular capillaries in the glomerulus
  - Dominant part is the glomerulus which is a ball-like tuft of **glomerular capillaries**
    - Water and solutes are **filtered** through glomerulus capillaries as blood passes through them (**filtrate enters tube system**)
  - Efferent arteriole transports remaining unfiltered blood and plasma from glomerulus to a second set of reabsorbing capillaries
    - Efferent arteriole runs to **peritubular capillaries** which surround tube part of nephron
  - Peritubular capillaries join into venules which transport blood into the renal vein, which then drains the “conditioned” blood back into the systemic circulation via vena cava

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Fig. 13-2, p. 384
Nephron

- Tubular component
  - Hollow, fluid-filled tube formed by a single layer of epithelial cells
  - Components
    ◇ Bowman’s capsule
    ◇ Proximal tubule
    ◇ Loop of Henle
      ◦ Descending limb
      ◦ Ascending limb
    ◇ Juxtaglomerular apparatus
    ◇ Distal tubule
    ◇ Collecting duct or tubule

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**FILTRATION:**
Outward pressures across capillary wall exceed inward pressures

GF = Glomerular filtration — nondiscriminant filtration of a protein-free plasma from the glomerulus into Bowman’s capsule
TR = Tubular reabsorption — selective movement of filtered substances from the tubular lumen into the peritubular capillaries
TS = Tubular secretion — selective movement of nonfiltered substances from the peritubular capillaries into the tubular lumen

GF
80% of the plasma that enters the glomerulus is not filtered and leaves through the efferent arteriole
20% of the plasma that enters the glomerulus is filtered

To venous system (conserved for the body)

Urine excretion (eliminated from the body)

Fig. 13-4, p. 385
Basic Renal Processes: (1) Glomerular Filtration

- Fluid filtered from the glomerulus into Bowman’s capsule pass through three layers of the glomerular membrane
  - Glomerular capillary wall
    - Single layer of endothelial cells
    - More permeable to water and solutes than capillaries elsewhere in the body
  - Basement membrane
    - Acellular gelatinous layer
    - Composed of collagen and glycoproteins
  - Inner layer of Bowman’s capsule
    - Consists of podocytes that encircle the glomerulus tuft

Fig. 13-5, p. 386
Glomerular Capillary Blood Pressure

- Fluid pressure exerted by blood within glomerular capillaries
- Depends on
  - Contraction of the heart producing normal mean arterial pressure
  - Resistance to blood flow by arterioles
    - afferent arterioles (filling pressure for glomerulus)
    - efferent arterioles (drain for glomerulus)
  - Major force producing glomerular filtration is 55 mm Hg blood pressure in glomerular capillary
    - There is no change in pressure along length of glomerular capillaries because they are not drained by venules which have high capacitance

Glomerular Filtration is a special type of normal capillary filtration

<table>
<thead>
<tr>
<th>Force</th>
<th>Effect</th>
<th>Magnitude (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glomerular Capillary Blood Pressure</td>
<td>Favors filtration</td>
<td><img src="image" alt="55" /></td>
</tr>
<tr>
<td>Plasma-Colloid Osmotic Pressure</td>
<td>Opposes filtration</td>
<td><img src="image" alt="30" /></td>
</tr>
<tr>
<td>Bowman's Capsule Hydrostatic Pressure</td>
<td>Opposes filtration</td>
<td><img src="image" alt="15" /></td>
</tr>
<tr>
<td>Net Filtration Pressure (difference between force favoring and forces opposing filtration)</td>
<td>Favors filtration</td>
<td>$55 - (30 + 15) = 10$</td>
</tr>
</tbody>
</table>
**Glomerular Filtration Rate**

- Net filtration pressure = glomerular capillary blood pressure – (plasma-colloid osmotic pressure + Bowman’s capsule hydrostatic pressure)
  - e.g. 55 mm Hg – (30 mm Hg + 15 mm Hg) = 10 mm Hg
- Glomerular filtration rate (GFR)
  - 180 liters per day
  - 125 ml per minute

99% reabsorbed = 123.75 reabsorbed per minute
1% = urine formation = 1.25 ml/minute x 60 minutes x 24 hours

= 1800ml (1.8 Liters) urine formed per day