INTRODUCTION TO THE ENDOCRINE SYSTEM

INTRODUCTION TO THE BLOOD

Taft College Human Physiology
Introduction to the Endocrine System

• The endocrine system, like the nervous system, is a system of communication.

• The endocrine system works in conjunction with the nervous system to integrate body functions.

• The endocrine system is a system of glands located throughout the body. These glands secrete chemicals into the bloodstream system and ultimately to extracellular fluid around the body.

• The chemicals are called hormones. They are shape specific and are only recognized by specific receptors on target cells where an action is taken in response their binding to their receptor.
## Endocrine Vs. Nervous System Communication

<table>
<thead>
<tr>
<th></th>
<th>Nervous</th>
<th>Endocrine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Origin</strong></td>
<td>Brain</td>
<td>Endocrine Gland</td>
</tr>
<tr>
<td><strong>Type of message</strong></td>
<td>Electrochemical = nerve impulses</td>
<td>Chemical only = hormones</td>
</tr>
<tr>
<td></td>
<td>Discrete - directly to target organ</td>
<td>nondiscrete - through-out body to target org.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with specific receptors</td>
</tr>
<tr>
<td><strong>Pathway</strong></td>
<td>Nerves</td>
<td>Via blood</td>
</tr>
<tr>
<td><strong>Time of onset</strong></td>
<td>Immediate – millisecs</td>
<td>Seconds, hours, days</td>
</tr>
<tr>
<td><strong>Message change/duration</strong></td>
<td>Immediate</td>
<td>longer</td>
</tr>
</tbody>
</table>

- The nervous system sends **electrochemical messages along discrete pathways** (neurons) **from the brain to specific target organs**.
- The endocrine system is a **system of glands** that produce hormones.
- The hormones serve as a **chemical message** to alter cellular metabolism.
  - Example: activate/deactivate enzymes, induce secretion, stimulate mitosis, trigger protein synthesis, cause changes in membrane permeability (e.g. smooth muscle contraction)
- The chemical message of the endocrine system travels **via the bloodstream** to all parts of the body where they will encounter specific receptors on cells.
- Even though the message goes to all parts of the body, **only certain target cells, tissues, or organs are capable of making sense of the message.**
Actions of Hormones

Specificity

- Hormones only act on specific target cells that have receptors on their membrane or inside the cell.
- Target tissues can regulate their responsiveness to their specific hormone by increasing the number of receptors (up-regulation) or decreasing the number of receptors (down-regulation).
- Blocking of these receptors will prevent the action of the hormone.
- Ex. RU486 (mifepristone) = (day after birth control pill) binds to progesterone receptors and prevents the effects of the hormone. If given to a pregnant women, the uterus cannot maintain the proper environment for embryonic development.

Actions

- There are 2 main chemical classes of hormones:
  1. Amino acid based (water soluble). Simple amino acids to peptides to proteins. Most hormones are this type.
  2. Steroid based (lipid soluble). Synthesized from cholesterol. Gonadal and adrenocortical hormones are examples.
Actions of Hormones

- Each hormone type has its own mechanism of triggering cell metabolism changes.
- Water soluble hormones cannot penetrate the lipid membrane of the target cell, so it must bind to a receptor in the membrane (first message). This triggers a secondary messenger in the cell to deliver the message and change cellular activities.
  - Example: FSH, LH

- Lipid soluble hormones can and do diffuse through the lipid membrane of the target cell and enter the nucleus of the target cell where it binds to its receptor, forming a hormone-receptor complex. This complex then turns on or off a gene(s) to induce or inhibit protein synthesis.
  - Example: Testosterone
The Enzyme Substrate Model

- The endocrine system message can be explained by something called the enzyme-substrate model.
- In the enzyme-substrate model many hormones (= enzyme) are secreted by the body and sent throughout the body via the blood. The target organ (= substrate) or target tissue can only understand the message of specific hormones, in this case, hormones A and B.
Endocrine vs. Exocrine Glands

There are actually 2 kinds of glands in the body:

1. **Endocrine glands** - are *ductless* and release hormones directly into the blood.
   - The endocrine glands include:
     - Pituitary, thyroid, parathyroids, adrenals, pancreas (in part) ovaries, testes, pineal, and thymus glands.
     - The placenta serves as a temporary endocrine gland.
     - The pituitary is often called the *master gland*, as it secretes many hormones that control many other endocrine glands.
     - The pituitary itself is controlled by the hypothalamus region of the brain. So this creates a brain-endocrine axis of control that regulates almost all aspects of growth, development, metabolism, and homeostasis.

2. **Exocrine glands** - are *ducted* glands that secrete their products into body cavities or onto its surface.
   - Examples: sweat glands, mammary glands, and pancreas (in part) to name a few.
5 Bonus Points on Exam 3

- Note: The rest of the material covered on the endocrine system is **optional!!!**
- There will be a bonus 5 point essay on exam 3 from the remaining uncovered endocrine material in the notes.
- Pay particular attention to:
  - A. Names of the glands
  - B. Hormone(s) produced by each gland.
  - C. The function or action of each hormone.
Introduction to the Blood

Taft College
Human Physiology
The Cardiovascular System: Blood

First, A Quick Review:
• **Transportation** is the key function of the cardiovascular system.
• 3 important components of the cardiovascular system are responsible for this transportation.
  • 1. A muscular pump = *heart*
  • 2. Tubing = *blood vessels*
  • 3. Transporting medium = *blood*

The Blood
• As cells specialize during development they become less capable of independent existence.
• The substances that bathe these cells and help to carry on some very protective functions are the **body fluids**.
• These body fluids have 3 names and differ slightly from each other depending upon where in the body they are found:
  1. If located in the blood vessels = *blood plasma*.
  2. If the fluid is in and about body tissues = *interstitial fluid or tissue fluid or extracellular fluid*.
  3. If the fluid is in the lymphatic system = *lymph*. 
2 Systems, 3 Important Fluids

Plasma, Tissue Fluid, Lymph

Cardiovascular System

Body Tissues

Lymphatic System

Review
Blood

The 3 primary functions of the blood are transportation and homeostasis and protection.

1. The blood serves in the transportation of:
   - Respiratory gases - oxygen & carbon dioxide
   - Nutrients
   - Metabolic waste products
   - Hormones
   - Heat - from cells to lungs and skin for removal
   - Excess body water - from cells to organs of excretion

2. The blood is of importance in homeostasis by:
   - Regulation of the volume of interstitial (tissue) fluid
   - Regulation of pH (acid-base balance).
   - Regulation of body temperature
   - Hemostasis, the prevention of blood loss

3. Protection against:
   - Blood loss by containing clotting or coagulation factors = hemostasis.
   - Infection:
     • By containing proteins (antibodies, interferon, complement) that serve to inactivate foreign microbes and toxins.
     • By containing phagocytic white blood cells that engulf & remove foreign substances & dead cells.
General Facts About Blood

- Blood is classified as a connective tissue.
- The matrix is a liquid with cells that contains:
  - Proteins, minerals, and water, just like bone, another connective tissue.
- Blood comprises about 7 - 8% of the body weight.
- Volume
  - Avg. male contains 5-6 liters of blood
  - Avg. female contains 4-5 liters of blood - simply due to smaller body size
- Analysis of the blood can give you a good idea of the status of body function.
- A good rule of thumb in drawing blood is that most animals can afford to lose 1% of their body weight in blood without any ill effects.
  - Example - 150 lb. person is about 70 kg and can afford to lose 0.7 kg in blood which is about 0.7 liters or approximately 1 pint.
  - A blood donation of a blood unit is about 1 pint (500 ml).
Components of the Blood

By drawing a sample of blood and adding an anticoagulant and letting it sit in a test tube (a centrifuge will speed this up), it will separate into 2 major components:

- **Plasma = liquid portion**
  - 55% of the total blood volume on top
  - Plasma – proteins = serum

- **Formed elements = cells**
  - 45% of the total blood volume on the bottom
Components of Plasma

- **92% H₂O**: solvent and suspending medium, carries heat
- **7% plasma proteins**: mainly made in the liver
  - **Albumins**: increases blood viscosity
  - **Globulins**: gamma globulin portion contain antibodies (immunoglobulins) that are important in your immune defenses against foreign agents (antigens).
  - **Fibrinogen**: important in clotting
- **1% electrolytes and other substances**: nutrients, gases, hormones, waste products, etc.
Formed Elements

(45% of blood) = cells

3 categories of formed elements:

1. **Erythrocytes** = rbcs or red blood cells
2. **Leukocytes** = wbcs or white blood cells
3. **Platelets** = thrombocytes (these are actually cell fragments)
Red Blood Cells

- **RBC – Erythrocytes**

- Mature RBCs are biconcave in shape and **without a nucleus** that provides for maximum surface area for the diffusion of gases and flexibility for moving through capillaries.

- **Transport oxygen**
- **5,000,000/ mm$^3$**
- **5.4 mil in males, 4.8 mil in females**

**Sickle cell anemia** = single amino acid mistake in hemoglobin. Why anemic? Why joint pain?

Sickle cell causes potassium to leak out of cell and kills malaria parasites, so confers a survival advantage in some regions.
Platelets

- Look like small purple specks.
- 150,000 – 400,000/mm$^3$
- 2-4 microns
- Important in clotting
White Blood Cells

• WBC – leucocytes
• Retain nuclei (irregular)
  – Granulocytes
    • Neutrophil
    • Eosinophil
    • Basophil
  – Agranulocytes
    • Lymphocytes
    • Monocytes

5,000 – 10,000/mm$^3$
WBC – Granulocytes  
(cytoplasm with granules)

- **Neutrophil**
  - Most abundant leucocyte 60-70% 10-12 microns
  - 3-5 lobed nucleus
  - Small granules
  - *Phagocytic (bacteria eaters)*
  - Stain purple/pink in Wright’s stain

- **Eosinophil**
  - 2-4% of leucocytes 10 – 12 microns
  - 2 lobed nucleus
  - Stain bright red in Wright’s stain
  - *Allergic response*

- **Basophil**
  - 0.5 -1% of leucocytes 8 – 10 microns
  - Nucleus regular, often bent in “S” shape
  - Few, but large granules
  - *Histamine relief and with heparin = anticoagulent*
  - Stain purpleish-blue – large purple granules
WBC – Agranulocytes
(cytoplasm without granules)

• Lymphocyte
  – 20 - 25% leucocytes  6-14 microns
  – Small cell with large nucleus
    • Leaves only small room for cytoplasm
  – Specific immunity
    • Produce antibodies = B Lymphoctes
    • Foreign cell killers = T Lymphoctes
  – Produced in lymph nodes

• Monocyte
  – 3-8% leucocytes  12-20 microns
  – Largest WBC  2=3x an RBC
  – Phagocytic cleaner
Summary of Formed Elements

<table>
<thead>
<tr>
<th>Name</th>
<th>#</th>
<th>Size</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (RBC)</td>
<td>5 x 10^6/mm³</td>
<td>7 - 8μm</td>
<td>transport oxygen</td>
</tr>
<tr>
<td>(actually 5.4 mill. In males &amp; 4.8 in females - more muscle means greater oxygen supply necessary)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets</td>
<td>250,000-400,000/mm³</td>
<td>2 - 4μm</td>
<td>clotting</td>
</tr>
<tr>
<td>Leukocytes (WBC)</td>
<td>5 x 10^3/mm³</td>
<td>6-20μm</td>
<td>5 types with different functions</td>
</tr>
<tr>
<td>Granulocytes: 3 types produced in the bone marrow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Neutrophil</td>
<td>60-70%</td>
<td>10-12μm</td>
<td>phagocytic</td>
</tr>
<tr>
<td>2. Eosinophil</td>
<td>2-4%</td>
<td>10-12μm</td>
<td>important in allergic response</td>
</tr>
<tr>
<td>3. Basophil</td>
<td>&lt; 0.5-1%</td>
<td>8-10μm</td>
<td>with heparin anticoagulant &amp; histamines</td>
</tr>
<tr>
<td>Agranulocytes: 2 types produced in the bone marrow. Some lymphocytes (T-cells) must undergo maturation steps in the thymus.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Lymphocytes</td>
<td>20-25%</td>
<td>6-14μm</td>
<td>specific immunity - antibodies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and cell killing directed at stimulating antigen</td>
</tr>
<tr>
<td>5. Monocytes</td>
<td>3-8%</td>
<td>12-20μm</td>
<td>phagocytic</td>
</tr>
</tbody>
</table>

- Neutrophils: Produce antibodies, regulate the immune response 10-44%
- Basophils: Engulf cellular debris, antigen processing 2-10%
- Eosinophils:
Granulocytes
- Neutrophils: 60-70%
- Eosinophils: 2-4%
- Basophils: 0.5-1%

Agranulocytes
- Lymphocytes: 20-25%
- Monocytes: 3-8%
Differential WBC Blood Count

• When blood is drawn, a differential WBC (leukocyte count) is performed, 100 wbc's are categorized by percentage (%).
  – Elevated neutrophils, lymphocytes, & monocytes means infection
  – Elevated eosinophils means allergic response or parasitic infection
  – Elevated monocytes & lymphocytes (some atypical) = mononucleosis, other viral infections

• In leukemia, WBCs may be extremely high, as high as 500,000/mm$^3$. This may depress RBC & platelet formation leading to anemia & bleeding.
RBC Life Cycle

Production

- The production of RBCs takes place in the red bone marrow in adults and is called **erythropoiesis**. When first produced, RBCs are nucleated but typically lose the nucleus by the time they move out and into circulation.

Hemoglobin

- RBCs contain hemoglobin, a **respiratory pigment with an affinity for oxygen 60x greater than blood without hemoglobin**.

- Hemoglobin has 2 parts:
  1. heme portion containing iron, and
  2. globin portion containing the protein chains.
Hemoglobin is partly recycled

- RBCs live for 120 days and are then phagocytized by macrophages in the liver, spleen, and bone marrow.
  - The membranes wear out from the constant squeezing through capillaries. No nucleus for repairs.
- Heme portion is split off and broken down into bilirubin and delivered to the liver and then secreted into bile and ultimately into intestines.
- When bile ducts are plugged, bilirubin backs up into the blood and deposits in tissue causing a yellowing (jaundice) and the stool may appear pale.
- Globin is broken down into amino acids.
- Iron is recycled.
RBC Life Cycle

- The replacement rate for RBCs is as high as 4 million /sec. The rate is largely controlled through a negative feedback loop of oxygen sensing and erythropoietin secretion.

- If the production of RBCs cannot keep up with the demand you end up with nucleated RBCs in blood which cannot carry \( O_2 \) as well.

- Appearance of nucleated RBC’s in the blood indicates the bone marrow is under great stress to produce RBCs.
Hemostasis

- **Hemostasis** is the prevention of blood loss by the stoppage of bleeding.

The body uses **3 reactions** to bring about hemostasis:

1. **Vasoconstriction** (vascular spasm) of blood vessels (smooth muscle) at the wound site triggered by direct damage or a reflex initiated by pain receptors. This lasts for several minutes and allows the other 2 mechanisms to form a plug.

2. **Platelet plug is formed** - platelets. Fig 19.9 p.647 Platelets become "sticky" and form a aggregation or platelet plug - especially when they contact collagen in the connective tissue of the skin.

3. **Blood coagulation or blood clotting**. Fig 19.11 p 649 Blood clotting proteins go from soluble protein to a semisolid gel (fibrinogen to fibrin) that separates from plasma and helps to form a plug with platelets.
Hemostasis

- 13 factors or chemicals are involved in the clotting process. These must be present for clotting to occur.
- We are not going to go through them. Disappointed?
- Simply stated: Soluble plasma protein fibrinogen is converted to insoluble protein fibers = fibrin threads. Fibrin forms a web across torn blood vessel that entangles platelets to form clot.
- This process is controlled by positive feedback and will continue until the stimulus is removed!
- Anticoagulant = anything that alters any of the 13 factors necessary for clotting to occur.
- Examples = Warfarin=(Coumadin), heparin, and aspirin.
  - Warfarin is slow acting and is used for long term therapy to prevent clotting on an outpatient basis.
  - Heparin is fast acting and used while a patient is in the hospital.
  - Aspirin inhibits platelet aggregation and vasoconstriction, so causes prolonged bleeding. Low doses are given to prevent strokes and MI.
- Thrombolytic (clot dissolving agent) agent: a chemical used to dissolve clots and restore circulation. They must be given soon after the clotting event (within 2 hours). Examples: (Streptokinase and tissue plasminogen activator (t-PA)).
Disorders of Clotting

• **Hemophilia (bleeders’ disease)** - a genetically determined condition where blood fails to clot. Many types of hemophilia exist.
  – Classic hemophilia is sex-linked recessive (males) and results in the absence of factor VIII.
  – Factor IX deficiency is the second most common hemophilia and is also sex-linked recessive.

• **Thrombus = blood clot**. This may be spontaneous due to a roughened vessel as in arteriosclerosis.

• **Thrombosis** = blocking of a vessel. Can be serious if it is a vital blood vessels such a coronary or cerebral artery. Will lead to ischemia and cell death.

• **Embolus** - floating clot (bubble or gas)

• **Embolism** - plugging of a vessel by an embolus

• **DIC (disseminated intravascular coagulation)** - in wide spread trauma, a condition where clotting is occurring so much throughout the body, all the clotting proteins are used up. The person will bleed at many body sites at one time. This dangerous condition must be stopped, usually by stopping the clotting trigger. It can be triggered by exposed brain tissue, complications in pregnancy, wide spread trauma, and other causes.

• **Vitamin K deficiency**. Although not directly involved in clotting, vitamin K is required for four clotting factors synthesized in the liver.
  – Vitamin K deficiency will lead to uncontrolled bleeding.
  – Vit K is made in the gut by bacteria absorbed along with fats.