PHYL2001: PHYSIOLOGY OF HUMAN BODY SYSTEMS

AUTONOMIC NERVOUS SYSTEM & ENDOCRINE SYSTEM

❖ These 2 systems monitor one's internal and external environments, making any appropriate adaptive changes.

Comparison of Nervous and Endocrine Systems

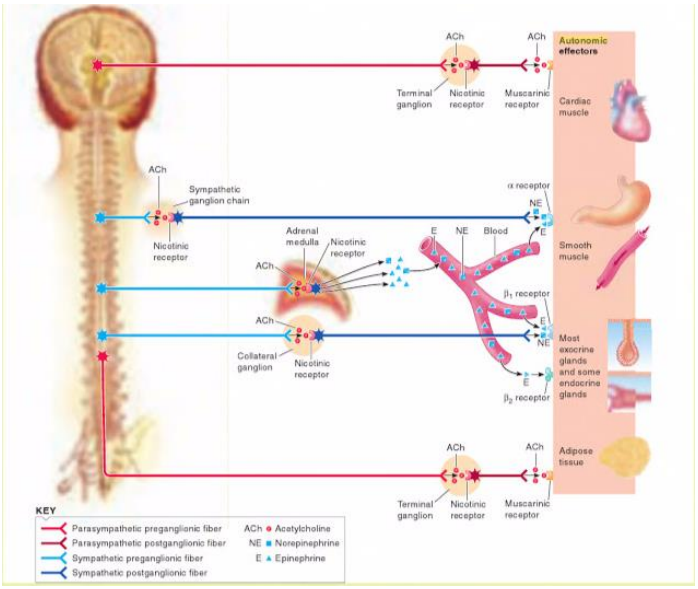
Property	Nervous System	Endocrine System
Anatomic arrangement	A "wired" system: A specific structural arrangement exists between neurons and their target cells, with structural continuity in the system	A "wireless" system: Endocrine glands are widely dispersed and not structurally related to one another or to their target cells
Type of chemical messenger	Neurotransmitters released into the synaptic cleft	Hormones released into the blood
Distance of action of the chemical messenger	Short distance (diffuses across the synaptic cleft)	Long distance (carried by the blood)
Specificity of action on the target cell	Dependent on the close anatomic relationship between neurons and their target cells	Dependent on the specificity of target cell binding and responsiveness to a particular hormone
Speed of response	Generally rapid (milliseconds)	Generally slow (minutes to hours)
Duration of action	Brief (milliseconds)	Long (minutes to days or longer)
Major functions	Coordinates rapid, precise responses	Controls activities that require long duration rather than speed

AUTONOMIC NERVOUS SYSTEM

The neurological system that acts to maintain *homeostasis in the body.
**(homeostasis: maintenance of a relatively stable internal environment despite fluctuations in the external environment)*

❖ The CNS controls muscles and glands by transmitting signals to these effector organs through the efferent division of the PNS. Two types of efferent output:

- **Somatic nervous system**
  - subject to voluntary control
  - supplies skeletal muscle.
- **Autonomic nervous system**
  - under involuntary control
  - supplies cardiac and smooth muscle (and most exocrine and some endocrine glands)
  - consists of 3 subdivisions – the sympathetic, parasympathetic, & enteric (gut) nervous systems. Separation of the ANS into either sympathetic and parasympathetic systems are based on anatomical differences and physiological differences.
  - consists of a two-neuron chain. The preganglionic fiber originates in the CNS and synapses with the cell body of the postganglionic fiber in a ganglion outside the CNS. Advantages of two neuron chain:
    - 1 preganglionic neuron can synapse onto many postganglionic neurons.
    - 1 preganglionic neuron can synapse both excitatory and inhibitory postganglionic neurons.
    - Information from sensory axons can have rapid reflex effects on output.
  - All preganglionic fibers and parasympathetic postganglionic fibers release acetylcholine (Ach). Sympathetic postganglionic fibers release norepinephrine.
  - Postganglionic fibers have numerous swellings, or varicosities, that simultaneously release neurotransmitter over a large area of the innervated organ.



The autonomic nervous system. The *sympathetic nervous system* (originate in thoracolumbar regions of spinal cord) has short cholinergic (acetylcholine-releasing) preganglionic fibers and long adrenergic (norepinephrine-releasing) postganglionic fibers. The *parasympathetic nervous system* (originates in brain and sacral region of spinal cord) has long cholinergic preganglionic fibers and short cholinergic postganglionic fibers. In most instances, sympathetic and parasympathetic postganglionic fibers innervate the same effector organs. The adrenal medulla is a modified sympathetic ganglion, which releases epinephrine and norepinephrine into the blood. Nicotinic cholinergic receptors are located in the automatic ganglia and adrenal medulla and respond to Ach released by all autonomic preganglionic fibers. Muscarinic cholinergic receptors are located at the autonomic effectors and respond to Ach released by parasympathetic fibers. α_1, α_2, β_1, β_2 adrenergic receptors are variably located at the autonomic effectors and differentially respond to norepinephrine released by sympathetic postganglionic fibers and to epinephrine released by adrenal medulla.

Table 1: Distinguishing features of sympathetic NS and parasympathetic NS

Feature	Sympathetic system	Parasympathetic system
Origin of preganglionic fiber	Thoracic and lumbar regions of the spinal cord	Brain and sacral region of the spinal cord
Origin of postganglionic fiber (location of ganglion)	Sympathetic ganglion chain (near the spinal cord) or collateral ganglia (about halfway between spinal cord and effector organs)	Terminal ganglia (in or near effector organs)
Length of fiber	Short preganglionic fibers Long postganglionic fibers	Long preganglionic fibers Short postganglionic fibers
Neurotransmitter released	Preganglionic: acetylcholine Postganglionic: norepinephrine	Preganglionic: acetylcholine Postganglionic: acetylcholine
Types of receptors for neurotransmitters	For preganglionic neurotransmitter: nicotinic For postganglionic neurotransmitter: α_1, α_2, β_1, β_2	For preganglionic neurotransmitter: nicotinic For postganglionic neurotransmitter: muscarinic
Dominance	Dominates in emergency 'fight-or-flight' situations; prepares the body for strenuous physical activity	Dominates in quiet, relaxed situations; promotes 'general housekeeping' activities such as digestion

CARDIOVASCULAR PHYSIOLOGY

THE BLOOD (11)

Blood consists of 3 types of cellular elements that are suspended in the liquid plasma

- Erythrocytes (red blood cells)
- Leukocytes (white blood cells)
- Platelets (thrombocytes)

NOTE: There are 5-5.5 L volume of blood in an adult

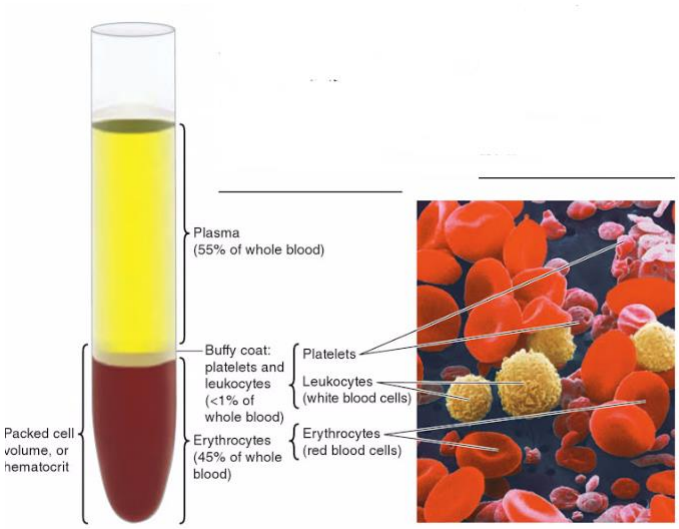


Figure 11-1 Hematocrit and types of blood cells. The values given are for men. The average hematocrit for women is 42%, with plasma occupying 58% of the blood volume. Note the biconcave shape of the erythrocytes.

PLASMA

- Plasma is a complex liquid consisting of 90% water that serves as a transport medium for substances being carried in the blood.
- The most abundant inorganic constituents in plasma are Na^+ and Cl^-, and the most plentiful organic constituents are plasma proteins.
- All plasma constituents are freely diffusible across the capillary walls except the plasma proteins, which remain in the plasma where they perform a variety of important functions.
- Plasma proteins include the albumins, globulins (α, β, γ), and fibrinogen.

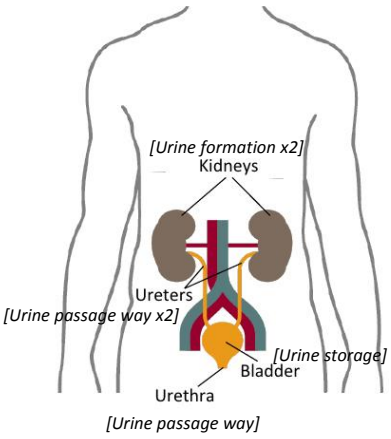
ERYTHROCYTES (RED BLOOD CELLS

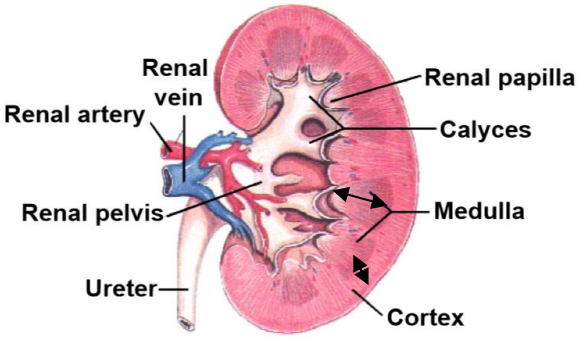
- Erythrocytes arte specialized for their primary function of O_2 transport in the blood. Their biconcave shape maximizes the surface area available for diffusion of O_2 into cells of this volume. Erythrocytes do not contain a nucleus or organelles (these are extruded during development) but instead are packed full of haemoglobin, an iron-containing molecule that can loosely and reversibly bind with O_2. Because O_2 is poorly soluble in blood, haemoglobin is indispensable for O_2 transport. Each haemoglobin molecule can carry 4 O_2 molecules.
- Haemoglobin also contributes to CO_2 transport and buffering of blood by reversibly binding with CO_2 and H^+.
- Unable to replace cell components, erythrocytes are destined to a short life span of about 120 days.
- Undifferentiated pluripotent stem cells in the red bone marrow give rise to all cellular elements of the blood. Erythrocyte production (erythropoiesis) by the red marrow normally keeps pace with the rate of erythrocyte loss, keeping the red cell count constant. Erythropoiesis is stimulated by erythropoietin, a hormone secreted by the kidneys in response to reduced O_2 delivery.
- The major ABO blood types depend on the presence of specific antigens on the surface of erythrocytes. The red blood cells of type A have antigen A; those of type B blood have B antigen, those of type AB blood have both A and B antigen, and those of type O blood have no A or B antigen. Type A blood has anti-B antibodies, type B blood has anti-A antibodies, type AB blood has no anti-A or anti-B antibodies, and type O blood has both anti-A and anti-B antibodies. These antibodies cause the RBCs with the corresponding antigens to agglutinate (clump) or rupture causing a transfusion reaction if incoming donor cells are exposed to corresponding antibodies in recipient blood.

RENAL PHYSIOLOGY

KIDNEYS: FUNCTIONS, ANATOMY AND BASIC PROCESSES

Renal/Urinary system organs:





Urine pathway: nephron (*medulla + cortex)* → renal papilla → calyces (major, then minor) → renal pelvis → ureter

Blood pathway: renal artery → *nephron (medulla + cortex)* → renal vein

Urinary system consists of urine forming organs (kidneys) and the structures that carry urine from kidneys to outside for elimination from the body.

Kidneys are a pair of bean-shaped organs (10-12 cm long) lying behind abdominal cavity, and on either side of vertebral column.

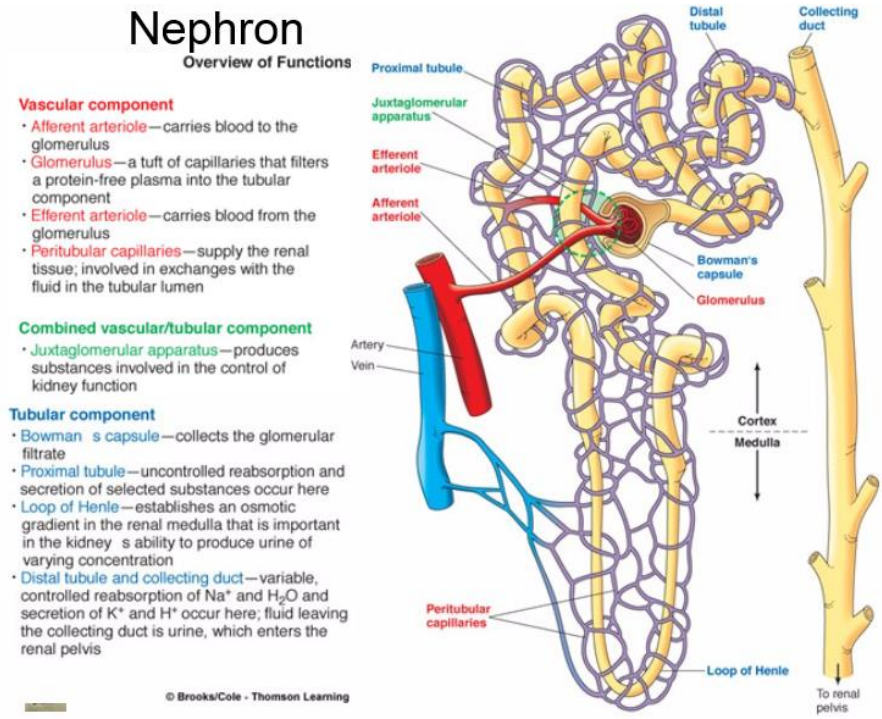
KIDNEY FUNCTIONS

- **Overview:** Forming urine & eliminating unwanted plasma constitutes in urine while conserving materials of value to the body. Primarily responsible for maintaining the stability of ECF (extracellular fluid) volume, electrolyte composition, and osmolarity (solute concentration).
- Maintain water (H_2O) balance in body.
- Regulate ECF volume and concentration of ECF ions (K^+, Na^+, Cl^-, HCO_3^-, Ca^{2+}, Mg^{2+}, SO_4^{2-}, PO_4^{3-}, & H^+).
- Maintain plasma volume and osmolarity.
  - Plasma volume – important in long terms regulation of arterial blood pressure.
  - Osmolarity – important to prevent osmotic fluxes into or out of the cells (which leads to detrimental swelling or shrinking of cells, respectively).
- Control acid-base balance.
- Excretion of waste products.

NEPHRON

A **nephron** is a basic functional unit of the kidney, in which their main function is to filter blood (and produce urine).

- Approximately 1 million nephrons per kidney.
- Arrangement of nephrons within kidneys give rise to 2 distinct regions:
  - Outer region
    - *Renal cortex* (granular in appearance).
  - Inner region
    - *Renal medulla.*
    - Made up of striated triangles called renal pyramids.
- Each nephron has two components:
  - Vascular component
  - Tubular component
- Two types of nephrons:
  - Juxtamedullary nephrons
    - 15-20% of total (humans).



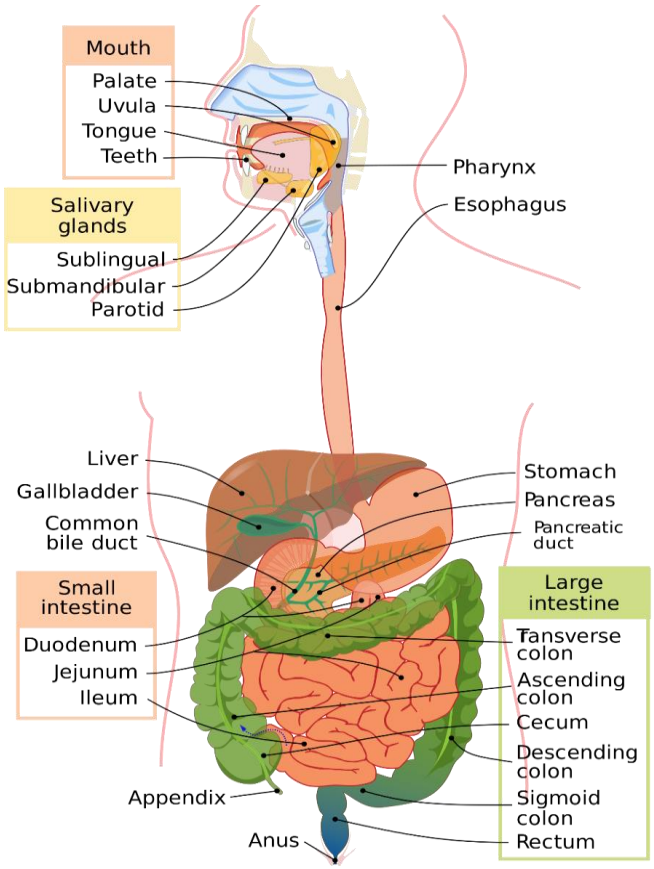
- Glomeruli in inner renal cortex.
- Loop of Henle (LoH) descends fully into medulla.
- Peritubular capillaries near LoH form straight vessels known as vasa recta.

- Cortical nephrons:
  - ~ 80% of total (humans).
  - Glomeruli in outer renal cortex.
  - Loop of Henle dips only slightly into medulla

GASTROINTESTINAL PHYSIOLOGY

Normal gastrointestinal tract (GIT or Gut) function

- ***Motility:*** to mix (propulsive) and deliver (non-propulsive) food to appropriate sites at an appropriate rate.
- **Secretion:** system produces exocrine and endocrine secretions to assist with the smooth passageway of food through digestive tract by lubricating, liquefying, & digesting.
- ***Digestion:*** to chemically break down the structurally complex foodstuffs in our diet into smaller, absorbable units at the appropriate sites into nutrients.
- **Absorption:** movement of nutrients out of digestive tract into cells.



- The digestive system consists of the digestive tract (mouth → pharynx → oesophagus → stomach → small intestine → large intestine) AND accessary digestive organs (liver, gall bladder, & pancreas for small intestine).

MOUTH

MOTILITY

- Mastication (chewing) by **teeth** (mechanical breakdown) as it's mixed with saliva.

SECRETION

- Saliva by medulla, mediated by autonomic nerves to the salivary glands.
  - Amylase – begins to digest polysaccharides into the disaccharide maltose
  - Mucus
  - Lysosome

DIGESTION

- Carbohydrate digestion begins. I.e. same as 'secretion'.

ABSORPTION

- N/A

PHARYNX & OESOPHAGUS