

Introductory Physiology

Core Concepts of Physiology

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Med.phy)
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What is physiology?

Definition scope and concept of physiology

- Physiology (*phsis*, nature; *logos*, discourse) literally means the **knowledge of nature** or nature's philosophy.
- Hence for the first time the term Physiology was coined by **Thales Miletos** (600 BC).
- Physiology means the study of **processes and functions in living organisms**.
- It is concerned **how a state of health and wellness is maintained**.
- There are 10 body systems each with unique contribution to normal body functions in health.

- Is the study of biological function—of how the body works, from cell to tissue, tissue to organ, organ to system, and of how the organism as a whole accomplishes **particular tasks essential for life**.
- In the study of physiology, the emphasis is on **mechanisms** - with questions that begin with the word **how** and answers that involve **cause-and-effect** sequences.
- E.g. how it adapts to changing

- Physiology is fully experimental science
- In the modern sense, the first human physiologist was **William Harvey** (1578-1657). demonstrated that the heart pumps blood through a closed system of vessels.
- **Medical physiology** concentrates on human physiology.

- The Greek philosopher **Aristotle** (384–322B.C.) speculated on the function of the human body.
- French physiologist **Claude Bernard** (1813–1878), who observed that the ***milieu interieur*** (“*internal environment*”) remains remarkably constant **despite** **changing** **conditions** in the external environment.

Fields of physiology

- ❑ It ranges from simple viral physiology, bacterial physiology and cellular physiology to the most complex human physiology.
- ❑ Relationship between Physiology and other sciences...
- ❑ The science of physiology overlaps with Anatomy, biochemistry, pharmacology, physics and shares knowledge with the related sciences of pathophysiology and comparative physiology.

Fluid compartments of the body

ECF

- High amount of Na^+
- Nutrients
- Gases (O_2 , CO_2)
- Hormones
- Enzymes

ICF

- High amount of K^+ , Po_4^{3-} and Mg^{2+}

- Water

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- Minerals (High

The Study of Normal Variables

- ❖ These are essential to the understanding of disease processes. The knowledge of such variables helps in the understanding of pathophysiology and the development of treating techniques such as the artificial kidney, cardiac surgery, etc.
- ❖ In recent years there has been an increase in the use of physiology not only to provide greater diagnostic accuracy but also to guide treatment.

1. NORMAL VALUES IN PHYSIOLOGY

- ❖ The figures shown below give mean values for healthy young adult males (except where otherwise specified).
- ❖ Figures for clinical use should include the range, which is given in some cases. Variation of up to ± 20 from the mean is within normal limits. Figures marked with an asterisk should be memorized.

- **1.1. Blood, Plasma, Water, and Electrolytes**
- * Red blood cell counts in: adult = $5.5 \times 10^{12}/L$
- newborn = $7 \times 10^{12}/L$
- Life span of erythrocyte = 120 days
- * Hemoglobin content in: adult male = 15g/dl blood
- newborn = 20g/dl blood
- * Packed cell volume (PCV=haematocrit): male = 45% (43-49%)
- White blood cell count in: adult = 4000-11000 /mm³
- Platelet count = $(150-400 \times 10^3 \text{ cells/mm}^3)$

- Arterial blood oxygen carrying capacity = 20ml/dl
- 1gm hemoglobin combines with =1.36 ml oxygen at STP
- * PH of plasma = 7.35-7.45
- * Body water (male)= 60% of weight (varies with fat content)
- * Cellular water(approx.25 liters for 70kg man)
- * Plasma water=approx.3 liters for 70kg man
- * Blood content =8% of body weight (about 5 liters for in 70kg man)
- Body T. = 36.3 – 37.1°C

Body fluid volume = 40 Liters

- ECF = 15L
- ICF = 25L

Osmolality = 300 mosm/L, (285 – 300 mosm/L)

NORMAL VALUES

- * Plasma sodium (average) = 140 mM
- Range = 136-148 mM
- * Plasma potassium = 4 mmol/l
- Range = 3.5-5.0 mmol/l
- * Plasma calcium = 2.5mM or 10mg/dl
- Range = 2.12 to 2.62 mmol/l
- Plasma chloride = 105 mM
- Plasma bicarbonate = 25mM
- Plasma phosphate = 1mM

NORMAL VALUES

- *Plasma glucose (fasting) = 4 mmol/L (70-110 mg/dl)
- Plasma proteins (average) = 70gm/L (or 7gm/dl)
- *Plasma urea = 4mmol/L (8-25mg/100ml),
 - Range = 2.5 -6.0 mmol/l
- Creatinine(s) = 0.7 - 1.4 mg/dL
- Blood sedimentation rate=2-7mm per hour

NORMAL VALUES

- * Cardiac output at rest = 5L/min
- * (Exercise) = 30L/min
- * Stroke volume = 70ml
- * Systolic/diastolic pressure = 120/80(mmHg)
- * Pulse pressure = 40(mmHg)
- * Central venous pressure
- (mean right atrial pressure) = 2-5 (mmHg)

Physiological Variation

- Physiological variables differ with sex, age, weight, diet, degree of physical activity, and environment, among other things.
- Failure to consider such variation leads to **medical mistakes** such as overmedication of the elderly.

Electrolyte balance and Imbalance

Sodium

- Attracts water into the ECF
- Nerve impulse
- Muscle contractions

Hypernatremia

- Excess sodium in the blood
- Hypertension
- Muscle twitching
- Mental confusion
- Coma

Hyponatremia

- Deficiency of sodium in the blood
- Hypotension
- Tachycardia
- Muscle weakness
- Hypotonicity is always associated with hyponatremia

Potassium

- Attracts water into the ICF
- Nerve impulse
- Muscle contractions

Hyperkalemia

- Excess potassium in the blood
- Cardiac arrhythmias and cardiac arrest
- Elevated T wave
- Muscle weakness

Causes

- decreased renal excretion of K^+
- exogenous source of K

Diagnosis

- Serum K^+ /level
- ECG

Hyperkalemia

$K = 6.0-7.0$ mEq/L



"tented" T wave

$K = 7.0-8.0$ mEq/L



QRS widening

$K = 8.0-9.0$ mEq/L



PR interval lengthening

$K = 9.0-10.0$ mEq/L

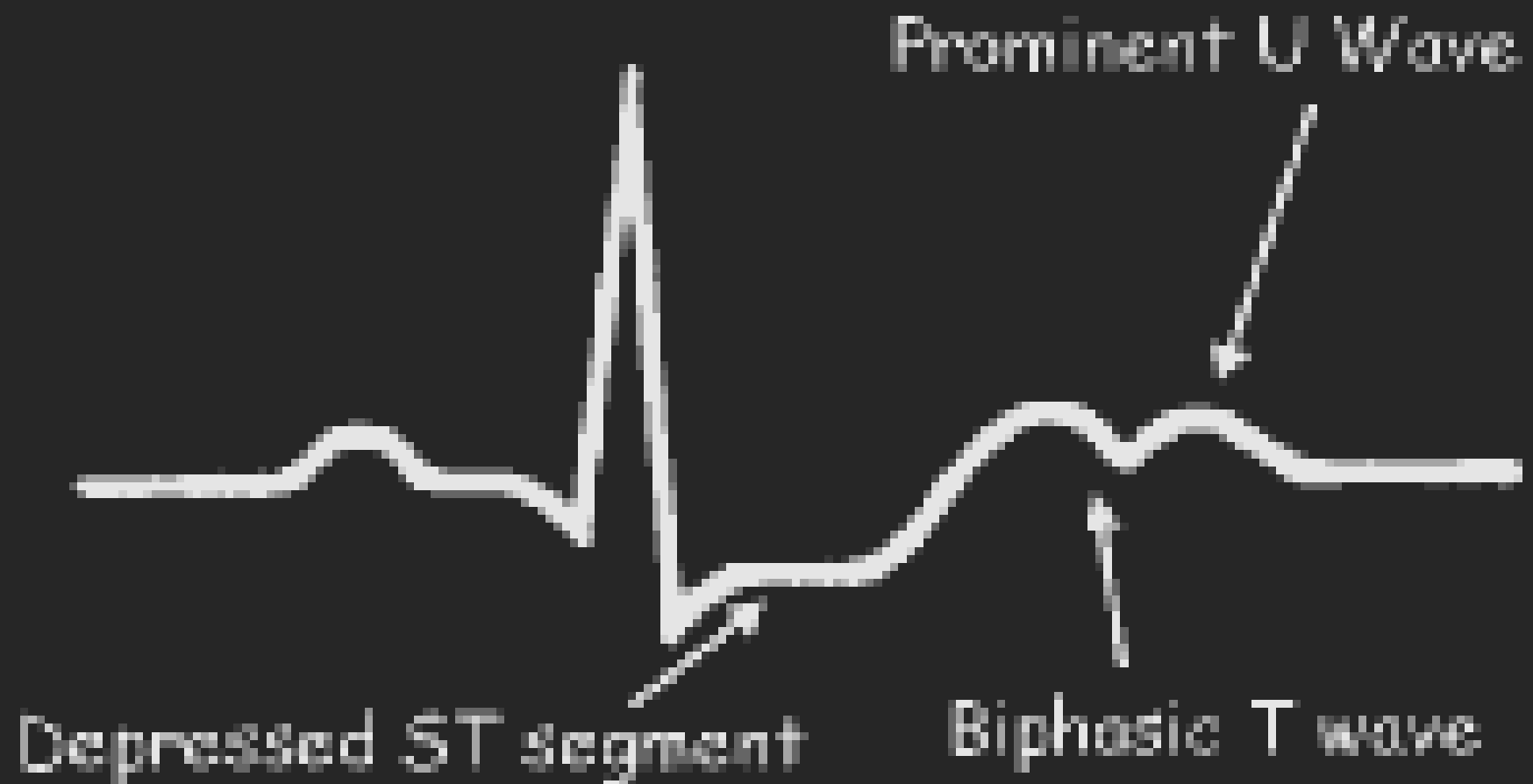


atrial arrest

Hypokalemia

- Deficiency of potassium in the blood (< 3.5 meq/l)
- Cardiac arrhythmias and cardiac arrest
- Flattened T wave
- Muscle weakness

ECG Pattern of Hypokalemia



Calcium

- Most in bones and teeth
- Blood clotting
- Nerve impulse
- Muscle contraction

Hypercalcemia

- Excess calcium in the blood
- Kidney stones
- Bone pain
- Cardiac arrhythmias

Hypocalcemia

- Deficiency of calcium in the blood
- Tetany/ **Spasms** - muscle of the extremities and face
- Weak heart muscle
- Increased clotting time

Causes

- Bed rest in elderly person with osteoporosis is hazardous because impaired Ca metabolism with increased bone resorption is associated with immobilization
- Inadequate Vitamin D

Homeostasis

- The term homeostasis is used by physiologists to mean that maintenance of static or constant conditions in the internal environment (ECF).
- For a person to remain healthy, physiological conditions in the body must be kept at optimal levels and closely regulated. Eg.
- Lungs - maintain concn. of respiratory gases in blood.
- CVS- transports substances and removes waste products,
- Kidneys- maintain constant ionic concentration

GIC - maintain constant

Homeostasis

- The internal environment of the organism is actively maintained constant by the function of cells, tissues, and organs organized into negative feedback systems.
- The role of negative feedback in regulating the functions of the body is a particularly powerful core concept in physiology.

Regulatory systems of homeostasis:

1. The nervous system and the endocrine system are the two controlling bodies of homeostasis

- The endocrine system functions closely with the nervous system in regulating and integrating body processes and maintaining homeostasis.

1.1 The nervous regulatory mechanism

- The nerves system is composed of three major components
 - **sensory** portion
 - **integrative** portion
 - **motor** portion.
- The sensory receptor detects any change in the body (BGC, BT, BP, Pain etc) and send impulse to the brain, spinal cord (CNS).
- The CNS associate the information store, generate thought and send appropriate response to the effector

1.2 The hormonal regulatory mechanism

- Hormones are chemical messengers secreted by endocrine glands, and transported in blood to the target gland (organs).

E.g. PTH $\rightarrow$ the kidney, bone, GIT $\rightarrow$
 $\rightarrow [Ca^{2+}]$

ADH $\rightarrow$ the kidney $\rightarrow$ $\rightarrow [H_2O]$

NB. An organism is said to be in homeostasis when its internal environment contains an optimum amount of nutrients, gases, electrolytes,

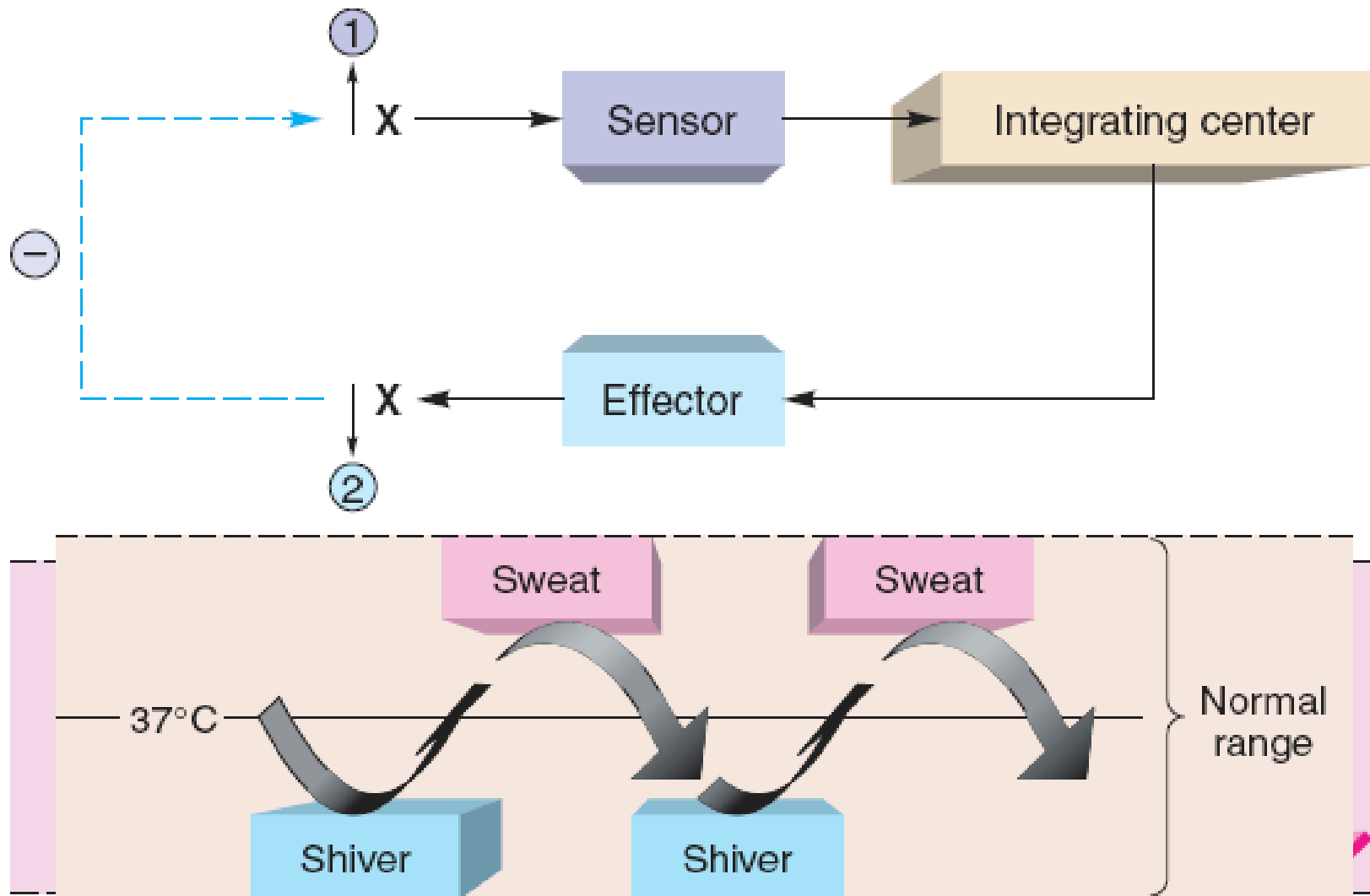
2. Feedback control system of the homeostatic mechanisms:-

- These feedback systems alter the function of organs by increasing or decreasing their activities.
- There are two types of feed back mechanisms:

2.1 The Negative Feedback Mechanism (NFM)

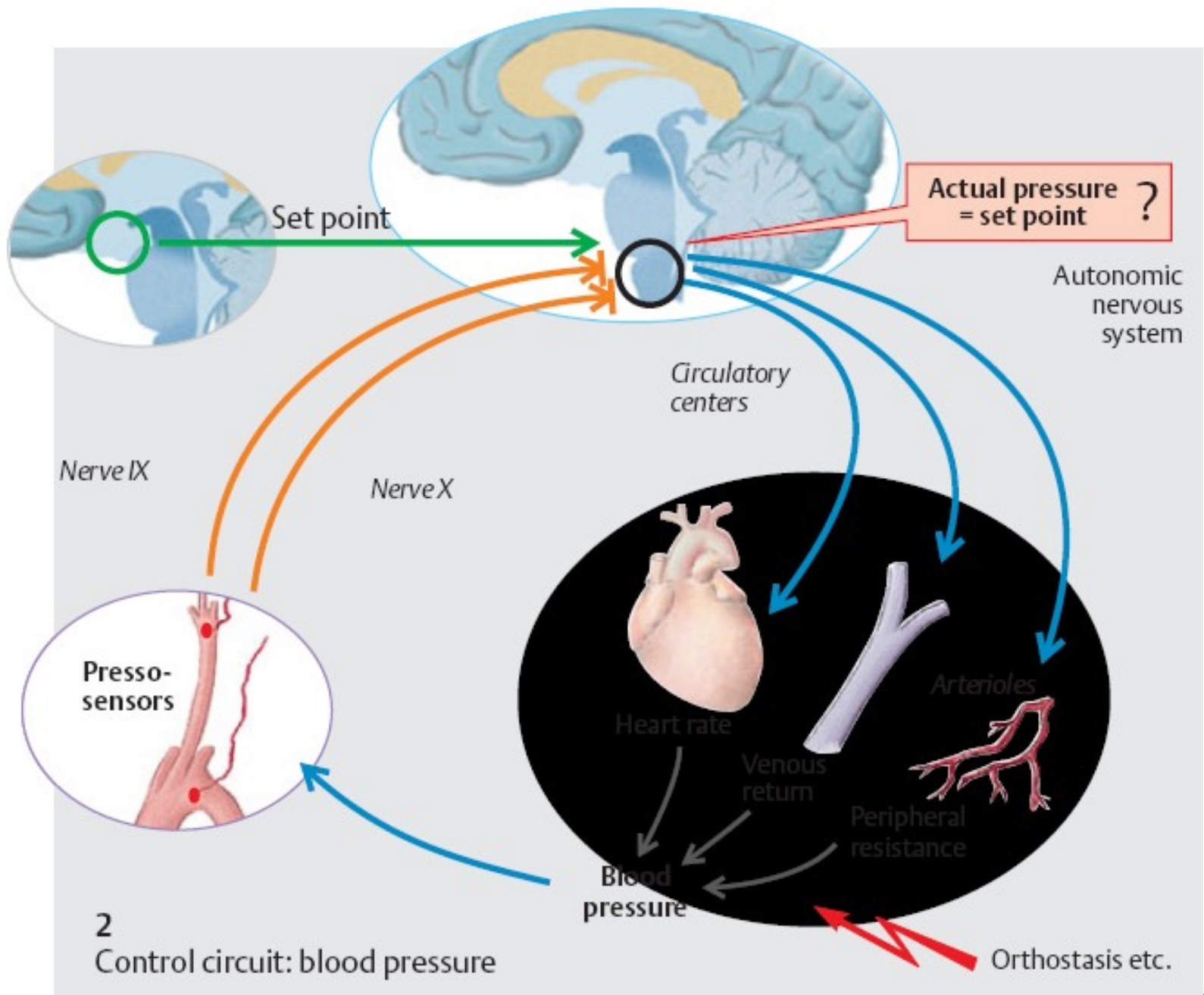
- It works by producing an effect which opposes the previous condition (the initiating stimulus) of the organ.

Negative feedback loop



Negative feedback control

- Change in variable being controlled induces a counter deviations of response that pushes the variable opposite to the original value.
- The components of negative feed back includes
 - **Set point:** the center of normal range of controlled variable
 - **Sensor:** Continuously monitor the controlled variable
 - **Effectors:** Restores the set point to its normal level



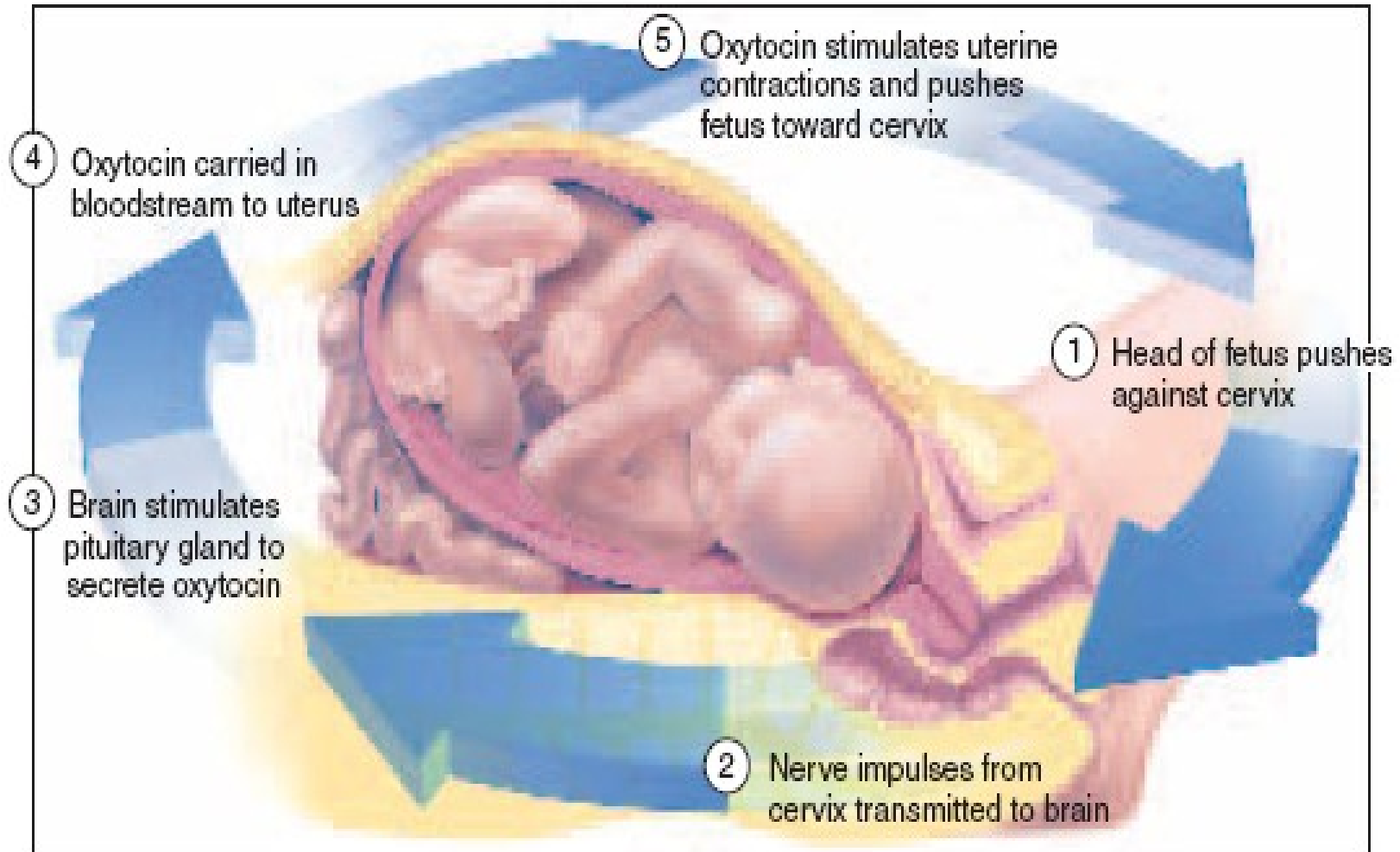
2.2 The Positive Feedback Mechanism(PFM)

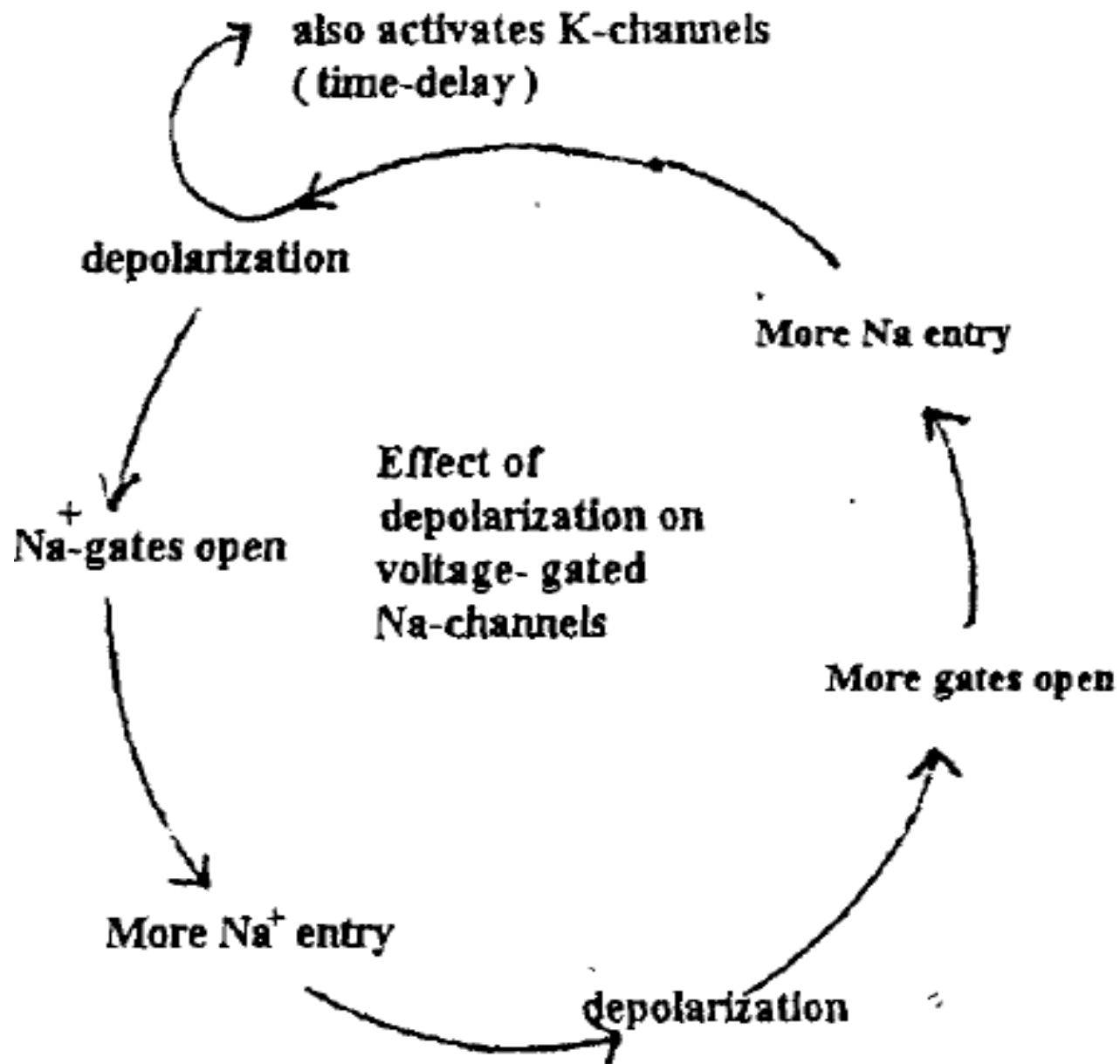
- It works by producing an effect which enhances or repeats the same action like that of the starting stimulus.
- The PFM also called **viscous circle**.
- Most of the action of this mechanism **disturbs** the internal environment and cause disease and death.
- Is a closed loop control system in which the output **accelerates** the control system.
- The action of effectors **amplifies** those changes that stimulated the effectors. It is some times important

Positive feedback control

- Changes in the variable being controlled causes the effect to drive further away from the initial value
- Makes the control system unstable
- Common in disease states
- Physiologic examples are
 - Ovulatory hormonal level
 - Blood clotting
 - Opening of voltage gated Na^+ ion channel
 - Parturition reflex
 - Child birth (labor)

PFM- e.g. OT





Tonicity

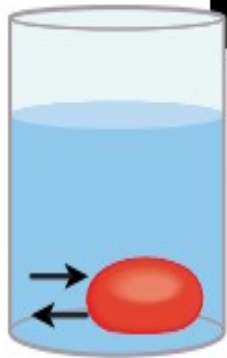
- When body cells are placed in a solution having a different osmotic pressure than cytosol, the shape and volume of the cells change.
- A solution's **tonicity**; *tonic* tension is a measure of the solution's ability to change the volume of cells by altering their water content. Eg. RBC maintains its normal shape and volume is an **isotonic solution**
- The concentrations of solutes that cannot cross the plasma membrane are the same on both sides of the membrane. For instance, a 0.9% NaCl solution (0.9 gram of NaCl in 100 mL of solution), called a *normal*

- **Hypotonic solution-** a solution that has a *lower* concentration of solutes than the cytosol inside the RBCs.
- In this case, water molecules enter the cells and causing the RBCs to swell and eventually to burst. The rupture of RBCs in this manner is called **hemolysis**
- A **hypertonic solution:** a solution that has *higher* concentration of solutes than does the cytosol inside RBCs
- Example- 2% NaCl solution. In such solution water molecules move out of the cells and causing the cells to **shrink**. Such shrinkage of cells is called **crenation**

Medical Uses of Isotonic, Hypertonic, and Hypotonic Solutions

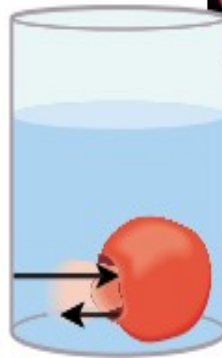
- RBCs and other body cells may be damaged or destroyed if exposed to hypertonic or hypotonic solutions. For this reason, most **intravenous (IV) solutions**, liquids infused into the blood of a vein, are isotonic.
- Eg isotonic saline (0.9% NaCl) and D5W, which stands for dextrose 5% in water.
- Sometimes infusion of a hypertonic solution such as mannitol (sugar alcohol) is useful to treat patients who have **cerebral edema**, excess interstitial fluid in the brain. Infusion of such a solution relieves fluid overload by

Isotonic
solution



(a) Normal RBC
shape

Hypotonic
solution

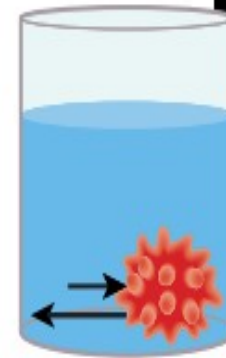


(b) RBC undergoes
hemolysis

Hypertonic
solution



15,000x SEM



(c) RBC undergoes
crenation

Levels of structural organization:

- Levels of organization: An understanding of physiological functions requires understanding the behavior at every level of organization from the molecular to the social.
- As the science of physiology has advanced, our understanding of physiological phenomena has expanded to encompass many different levels of organization.
- While we cannot yet explain everything at the molecular level, we are rapidly expanding the list of phenomena understood at that level

Levels of Organization



Levels of structural organization:

Cell

- From single cell to organ system cells are the basic units of living organisms.
- The cells are the building blocks of the body.
- The cell is the smallest functional unit of a living organism.
- In other words, a cell (and no smaller unit) is able to perform essential **vital functions** such as metabolism,⁴⁸

Tissue

- Cells that have similar functions are grouped into categories called *tissues*.
- The body is composed of four primary tissues:
 - (1) Muscle,
 - (2) Nervous,
 - (3) Epithelial, and
 - (4) Connective tissues.
- There are three types of muscle tissue: skeletal, cardiac, and smooth muscle.
- Groupings of these four primary tissues into anatomical and functional units are

Organs

- Organs, in turn, may be grouped together by common functions into systems.
- Each organ is an aggregate of many different cells held together by intercellular supporting structures.
- Organs are composed of two or more primary tissues that serve the different functions of the organ.

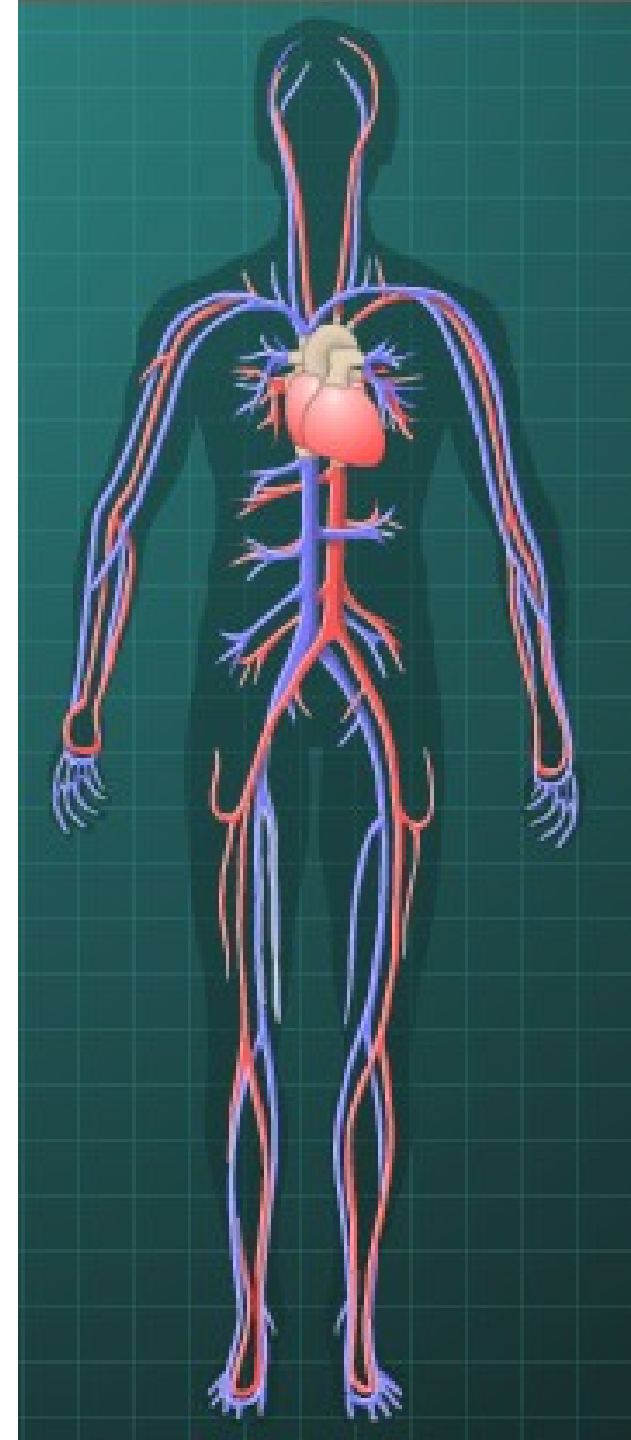
Eg. Heart

Systems

- Combination two or more organs
- The ***nervous system*** made of organs such as brain, spinal cord, ganglia and peripheral nerve. It subserves the functions of controlling other organ-system, receiving sensory information, storing memory, initiating & controlling behavior.
- There are 10 systems that controls body functions

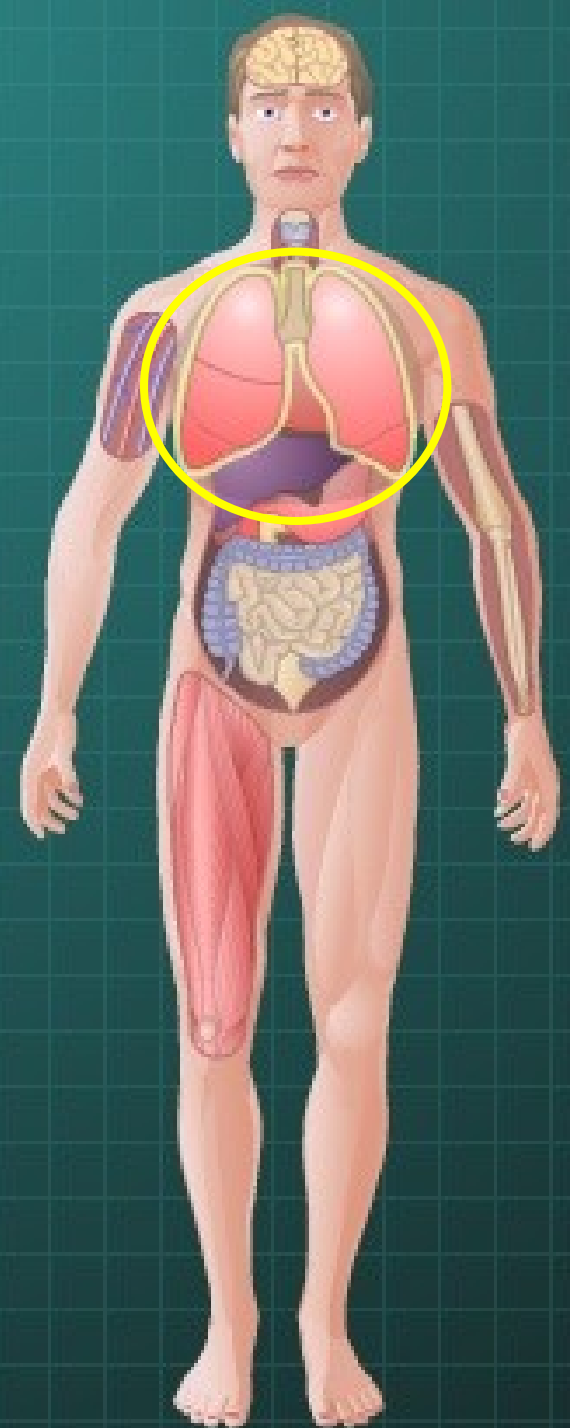
Functions

- **Cardiovascular system**
- **Respiratory system**
- **Digestive system**
- **Renal system**
- **Reproductive system**
- **Musculo-skeletal system**
- **Nervous system**
- **Endocrine system**
- **Immune system**



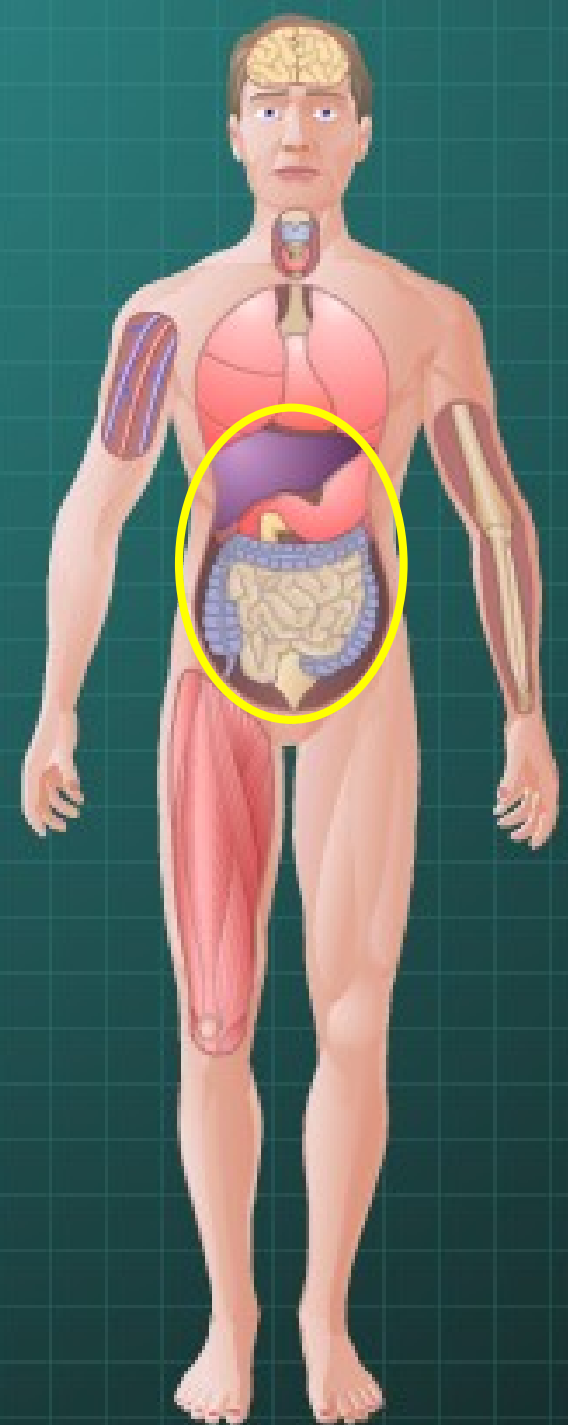
Functions...cont'd

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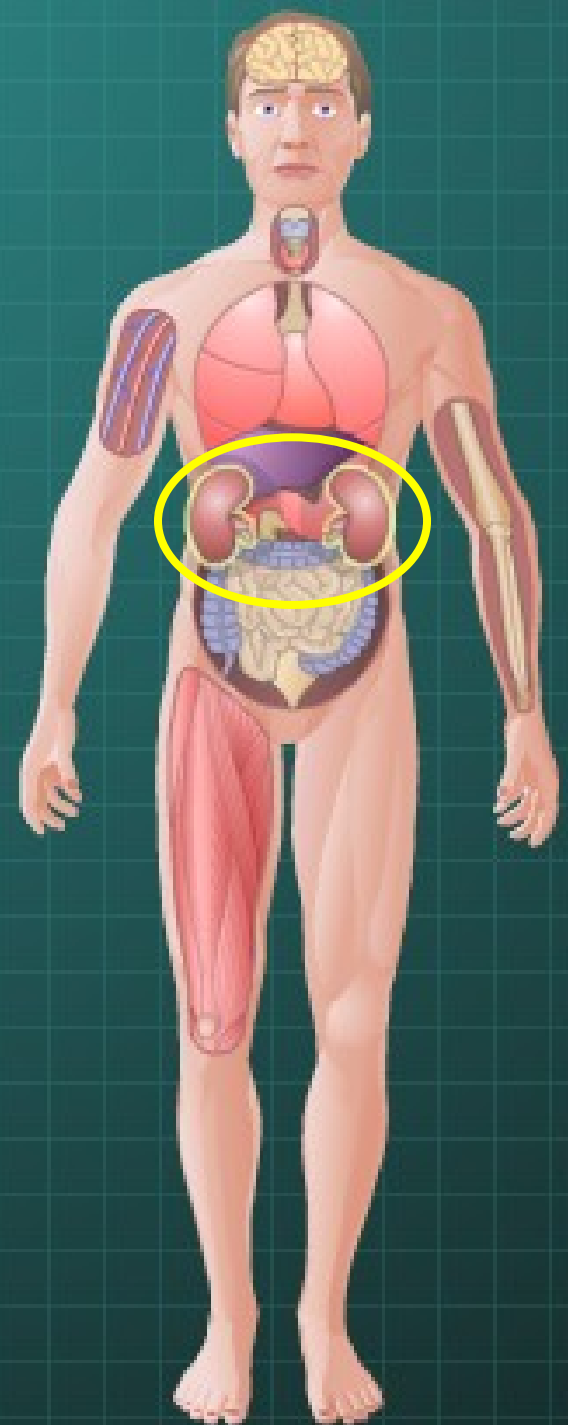
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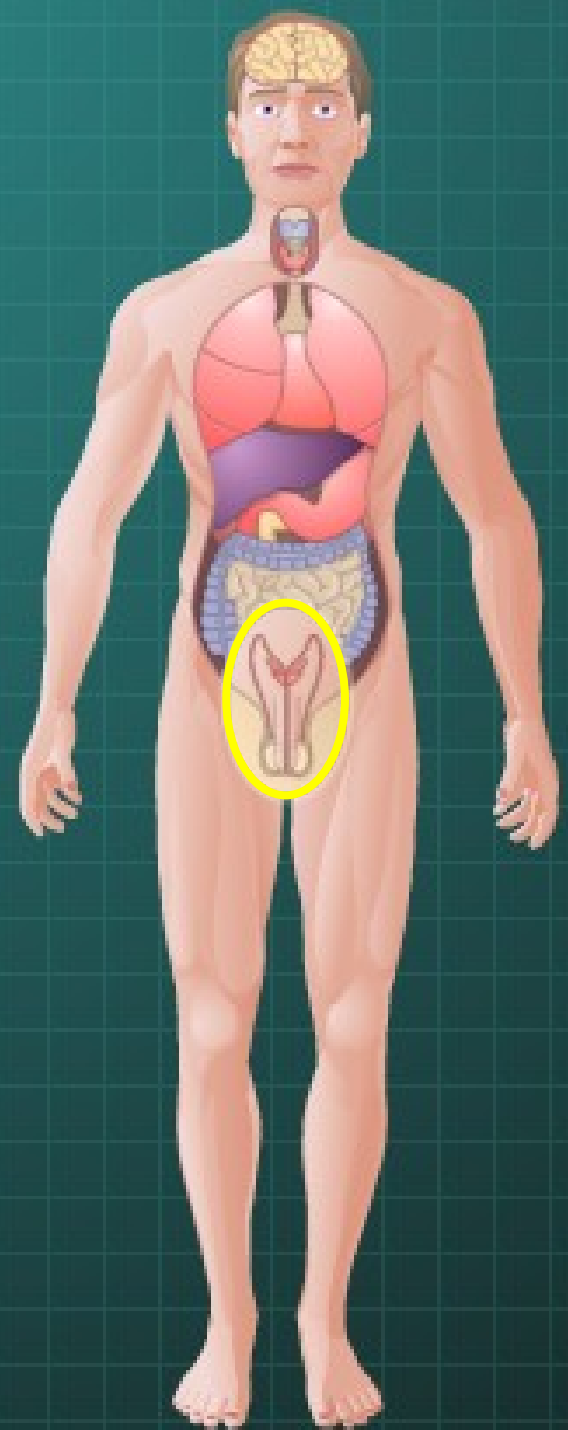
Functions...cont'd

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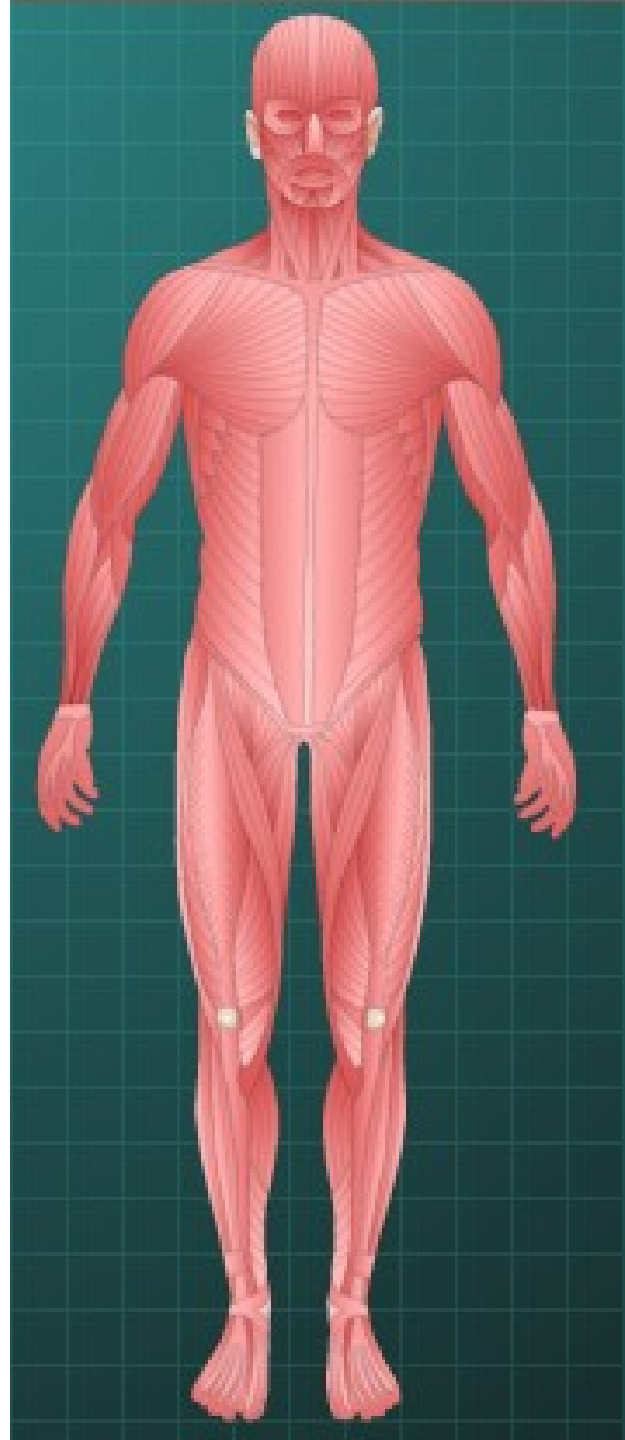
Functions...cont'd

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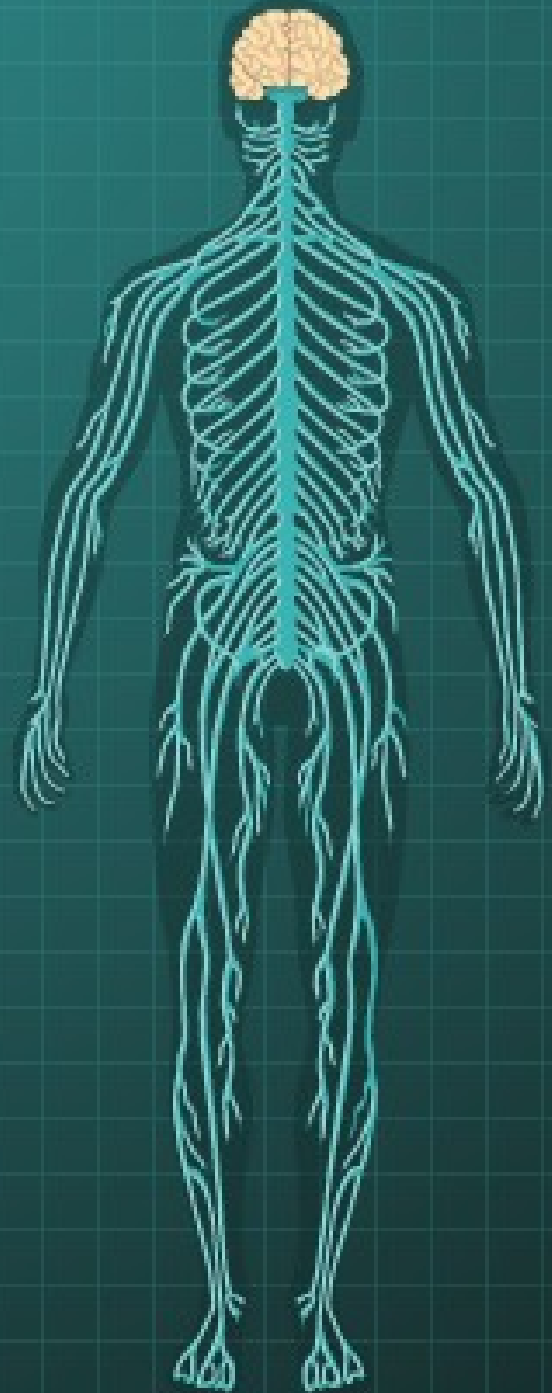
Functions...cont'd

- Cardiovascular system
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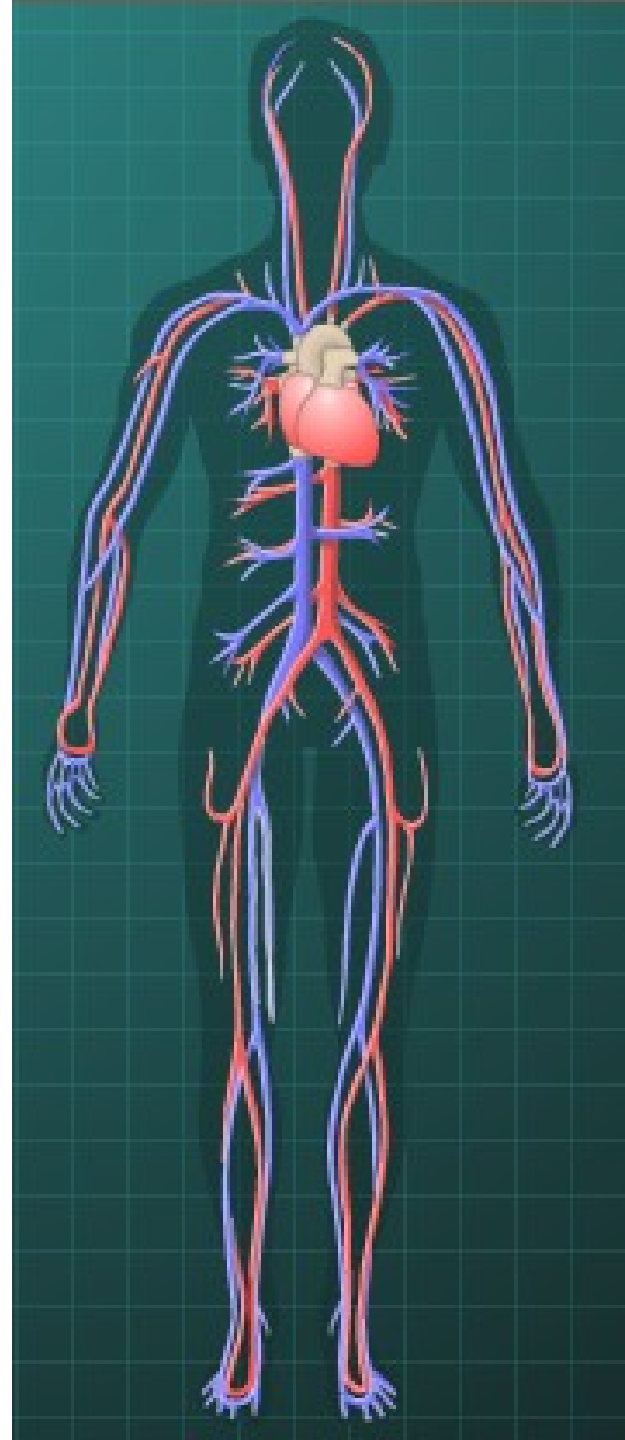
Functions...cont'd

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Functions...cont'd

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- **Respiratory system**
- **Digestive system**
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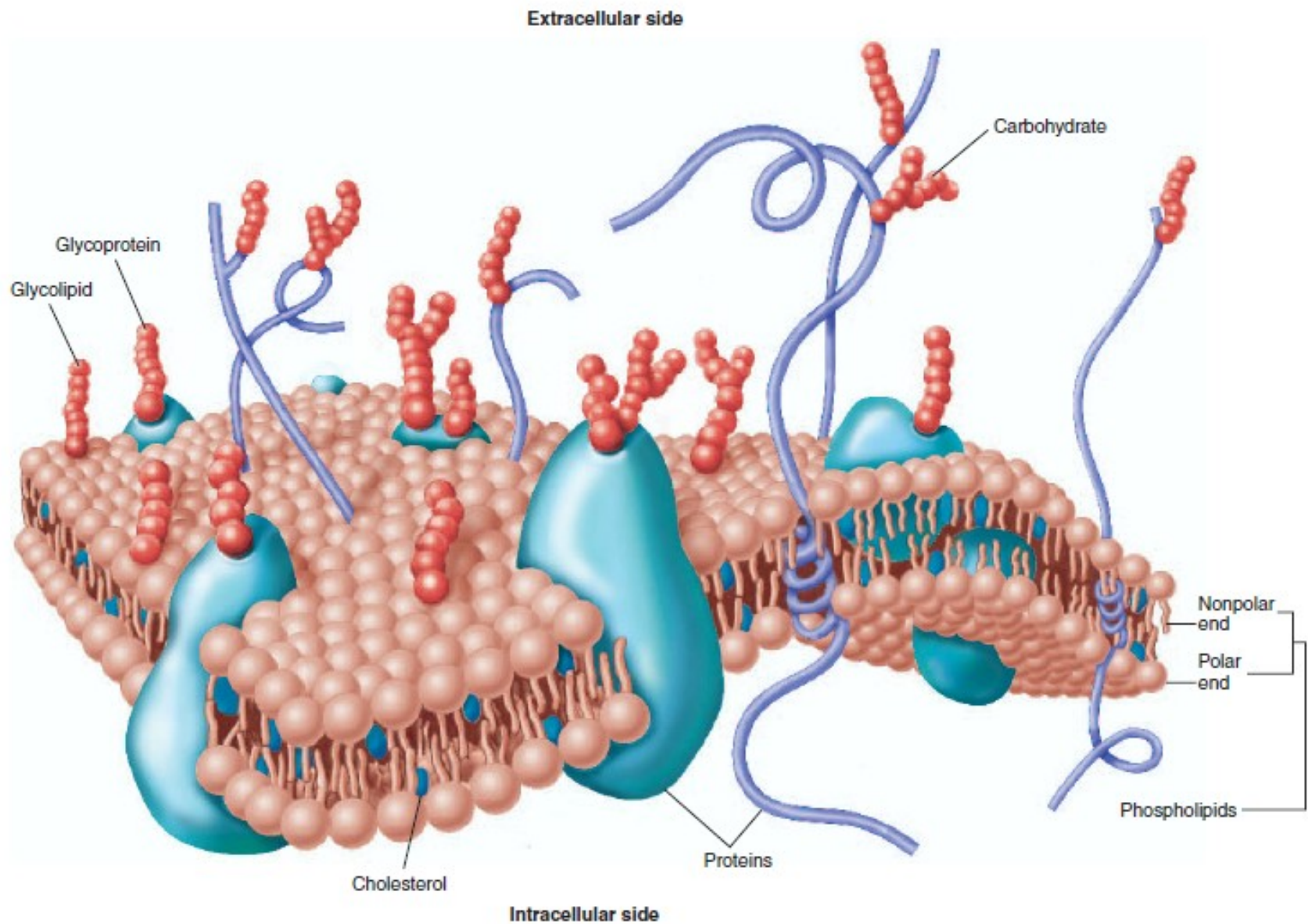
Functions...cont'd

- **Cardiovascular system**
- **Respiratory system**
- **Digestive system**
- **Renal system**
- **Reproductive system**
- **Musculo-skeletal system**
- **Nervous system**
- **Endocrine system**
- **Immune system**
- **Integumentary system**



The plasma membrane

- Cell plasma membranes are complex structures that determine what substances enter or leave the cell. They are essential for cell signaling, transport, and other processes.
- Every cell has a membrane separating the constituents of the cell from the extracellular compartment. The properties of membranes are thus an important **determinant** of the functions of the cell.
- It serves as a **mechanical barrier**
- It is **selectively permeable**
- It is entirely composed of **proteins** and **lipids**, 55:43 respectively, and 3% of **carbohydrates**



Cell Membrane Carbohydrates

- Is known as **Cell coat** or “**Glycocalyx**”
- Carbohydrates occur almost invariably in combination with proteins or lipids in the form of *glycoproteins* or *glycolipids*.
- In addition to lipids and proteins, the plasma membrane also contains carbohydrates, which are primarily attached to the outer surface of the membrane as glycoproteins and glycolipids.
- These surface carbohydrates have numerous **negative charges** and, as ⁶³a

- The carbohydrate moieties attached to the outer surface of the cell have several important functions:

- ❑ Short-chain carbohydrate on the outer membrane surface serves as **self-identity marker** enabling cells to identify and interact with each other in the following ways:

- Recognition of “**self**” and **cell-to-cell** interactions.
- Carbohydrate-containing surface markers are important in growth. Cells do not overgrow their own