People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
University Larbi Ben M'hidi Oum El Bouaghi
Institute of Sciences and Techniques of Physical and Sports Activities

Course of

General Physiology

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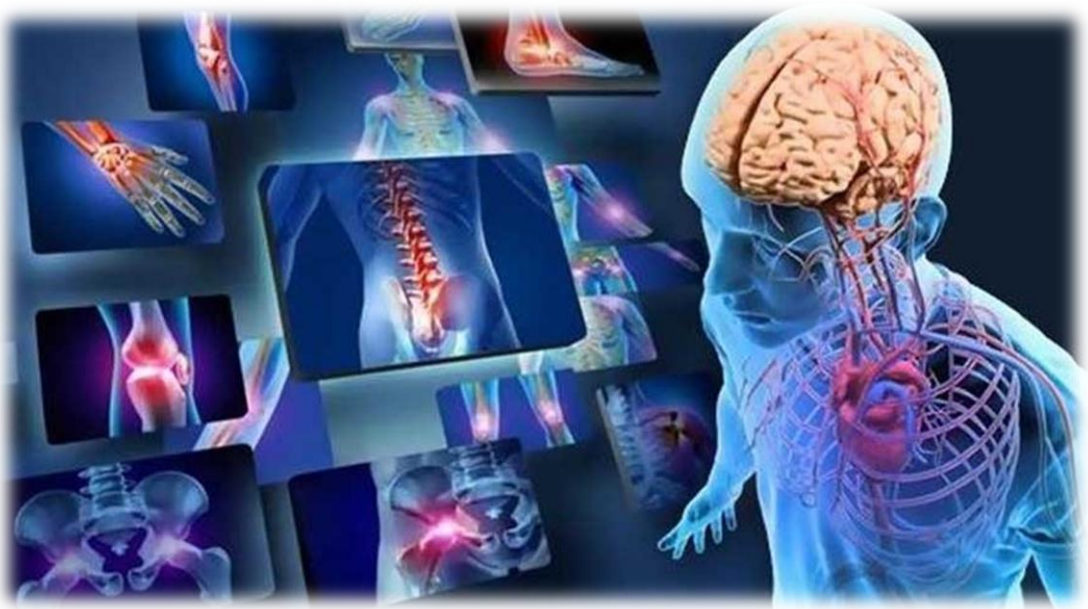
Courses for students **1st year Bachelor's degree**
Semester **2**



Academic year: 2024-2025

Content:

Introduction à la physiologie humaine générale

I. Definition and objectives of physiology

1. Definition of physiology

Physiology is the science that examines the functioning of the body and its components, that is, how they perform their functions to ensure the preservation of life.

It strives to understand how cells, tissues, organs, and systems work together to maintain life and internal balance..

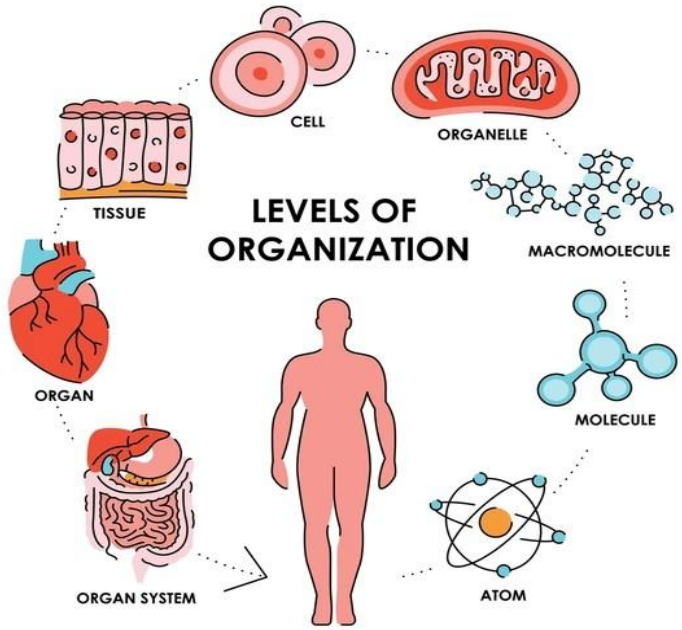
2. Objectives of physiology

1. Understanding the control processes within the human body.
2. Describing normal functioning for a better understanding of pathologies.
3. Forming the foundation of medicine, pharmacology, and health sciences.

II. The levels of organization of the human body

The organization of the human body follows a hierarchy of increasing complexity, progressing from the most basic to the most sophisticated. At the molecular level, we find chemical elements as well as molecules essential to life, such as water, proteins, lipids, and DNA. These molecules combine to create cells, which constitute the fundamental structural and functional unit of every living organism. Similar cells, assembled to perform a shared function, constitute tissues (for example, muscle tissue or nervous tissue). Several types of tissues then combine to form an organ, such as the heart, lung, or kidney, each with a specific function.

A set of organs working together to perform a physiological function constitutes a system, such as the digestive, nervous, or respiratory systems. Ultimately, this combination of interconnected and integrated systems forms the human entity, a complete living organism capable of maintaining its internal balance while interacting with its environment.

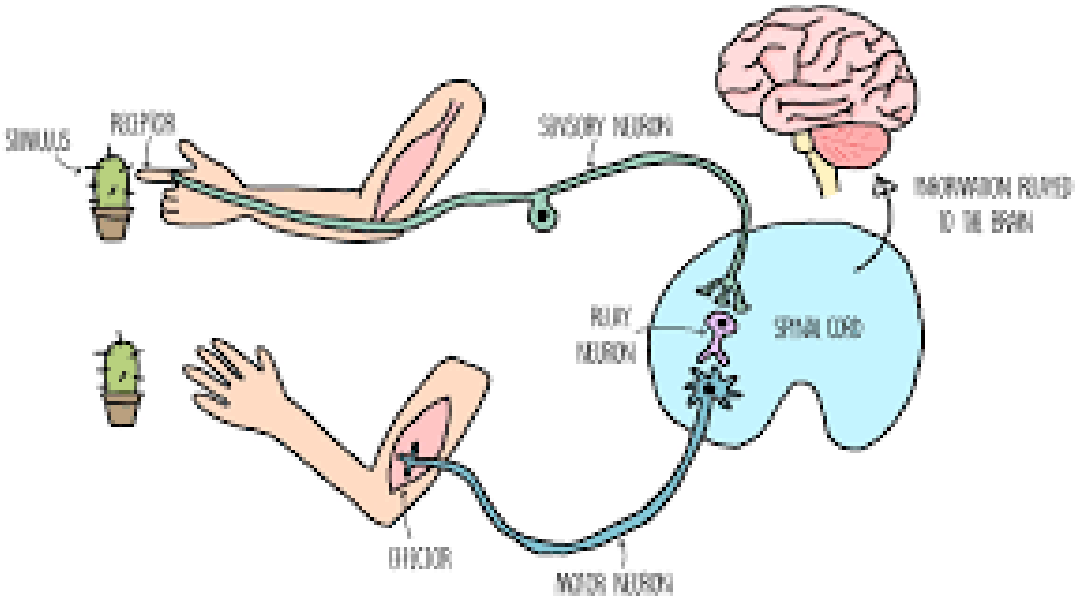


III. Regulatory Mechanisms

Each physiological parameter is regulated by:

- Receptors: detect changes.
- Regulatory center (often the brain or spinal cord).
- Effectors: organs or cells that restore balance.

Example: temperature regulation by the hypothalamus.



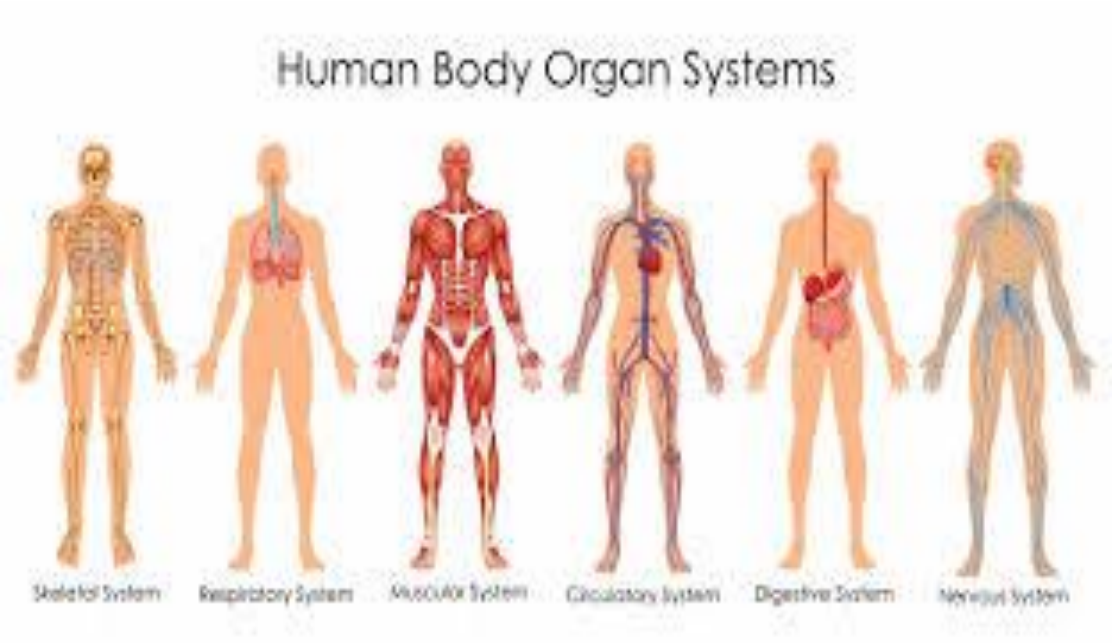
IV. Systems and Organs:

A set of dissimilar organs that participate in the same function; In the human body, three orders of systems are distinguishe :

- Systems of Relational Life:
- Nutritional Systems:
- Reproductive System:

This system is composed of 11 systems and organs. It is the most complex level of organization. It represents the sum of all levels working in synergy to ensure the maintenance of life.

None of the systems works completely independently; they all collaborate for the well-being of the entire organism.



1. **Systems of Relational Life:**
   - Locomotor System: includes the skeletal, articular, and muscular systems.
   - Nervous System: includes the central, peripheral, and autonomic nervous systems.
   - Sensory System: includes the five senses: touch, taste, smell, sight, and hearing.
2. **Nutritional Systems:**
   - Digestive System: Includes the digestive tract and associated glands.

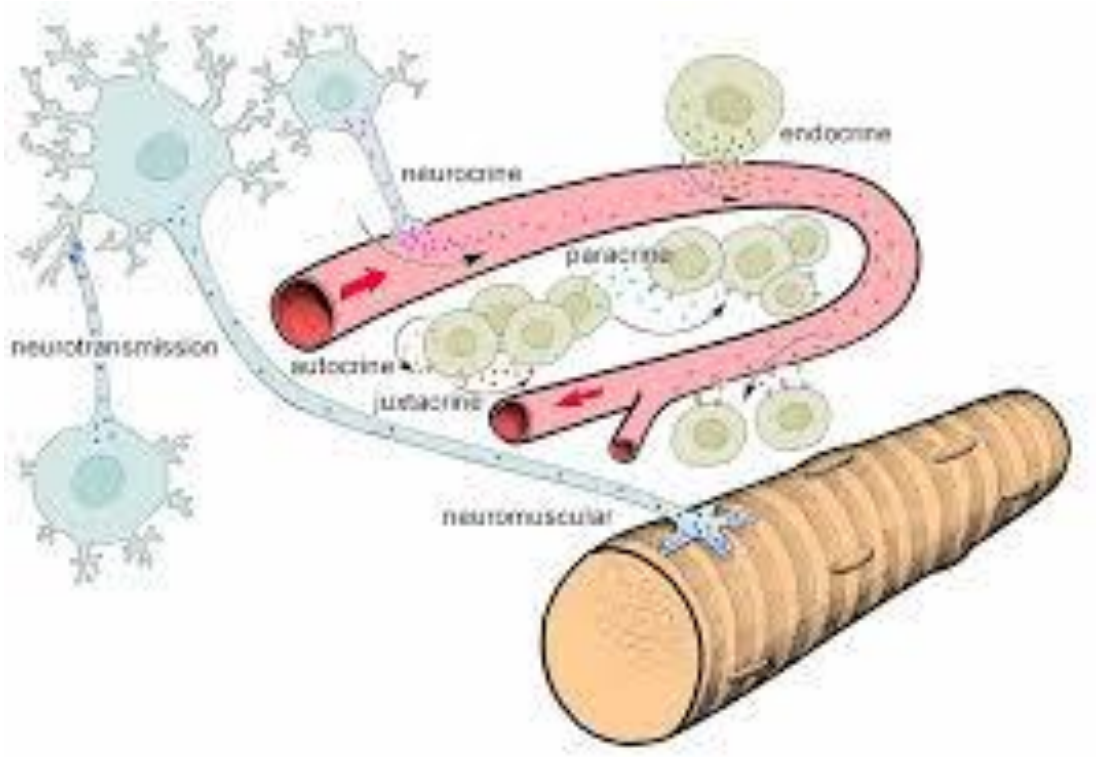
- Circulatory System: Includes the heart and the arterial, venous, and lymphatic systems.
- Respiratory System: Includes the respiratory tract and lungs.
- Urinary System: Includes the kidneys and urinary tract.
- Endocrine System: Represented by the endocrine glands.

3. **Reproductive System:**
   - Male Reproductive System: Includes the testicles, prostate gland, and spermatic cords.
   - Female Reproductive System: Includes the ovaries and reproductive tract.

V. Communication and Integration within the Body

- Nervous communication: rapid, electrical impulses.
- Hormonal communication: slow, via the blood.

Both systems cooperate to maintain homeostasis.

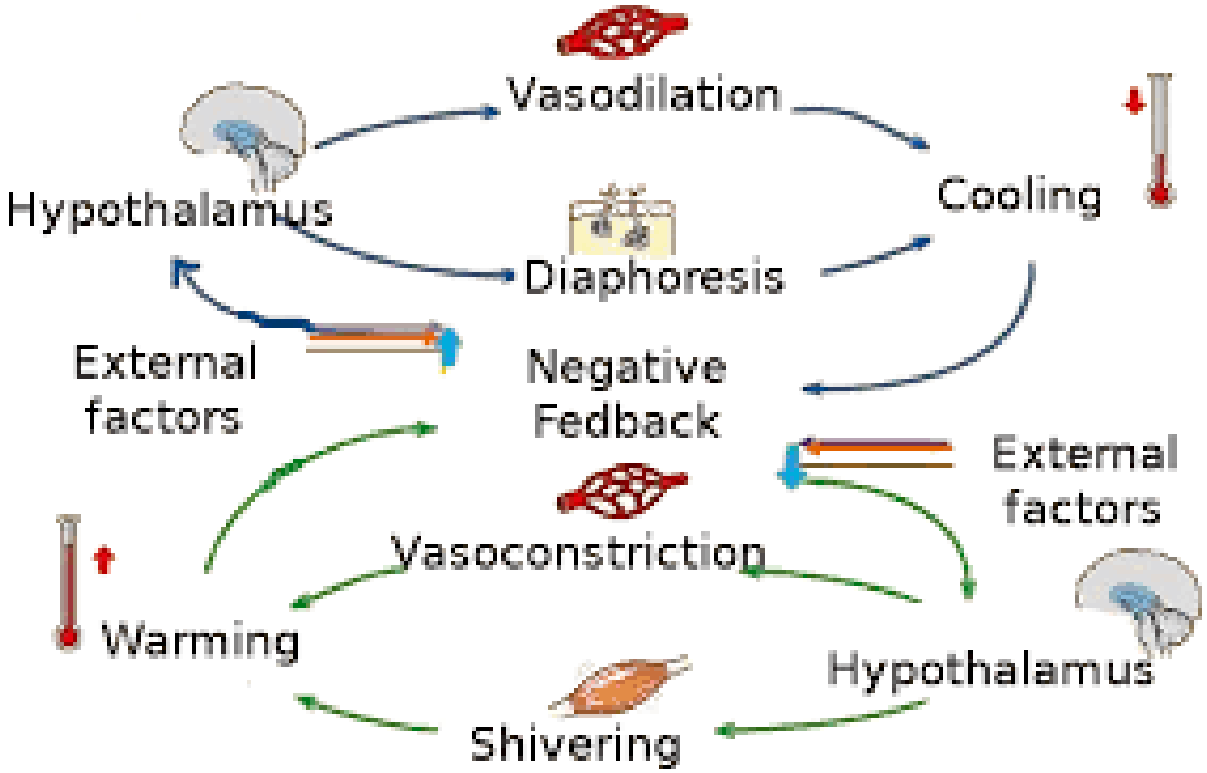


VI. Fundamental Principles of Physiology

- Structure and function are linked (e.g., lung shape adapted for gas exchange).
- Flow of energy and matter (nutrition, respiration, excretion).

VII. Regulation and Feedback:

- Negative feedback: stabilizes (e.g., blood glucose regulation).
- Positive feedback: amplifies (e.g., childbirth, coagulation).
- Adaptation and plasticity of the body to external variations.



VIII. Conclusion

The integration of cell biology, anatomy, and biochemistry makes human physiology a unifying science, aiming to understand the overall functioning of the human body.

It is an essential foundation for addressing pathology, pharmacology, and clinical medicine.

Homeostasis of The internal environment and Its Indicators

I. Definitions:

1. The internal environment

It is in direct contact with the body's cells; its composition must allow each cell to obtain the elements it needs. Similarly, it is in the internal environment that the waste products of cellular activity are eliminated and transported to the elimination sites. The internal environment constitutes the true living environment of the body's cells.

2. Homeostasis

Internal homeostasis refers to the organism's ability to maintain relatively constant physical and chemical conditions within its internal environment, despite fluctuations in the external environment. The concept of homeostasis, introduced by Claude Bernard, primarily concerns the extracellular fluids (blood plasma and interstitial fluid) that surround cells and supply them with the substances essential for their survival. To maintain the equilibrium of this environment, the organism employs complex regulatory systems involving receptors (which detect changes), control centers (such as the hypothalamus or brainstem), and effectors (organs or cells responsible for correcting deviations).

For example, the regulation of body temperature, blood glucose levels, blood pH, and blood pressure illustrates these homeostatic mechanisms. These regulations generally operate based on a negative feedback mechanism, where any deviation of a parameter from its standard value triggers a reaction aimed at restoring it to its equilibrium state. Therefore, homeostasis of the internal environment is vital for survival, as it ensures the proper functioning of cells and, consequently, that of the entire organism.

II. Characteristics of the internal environment:

1. Stable physicochemical characteristics:

- Concentration (molarity and molality).
- Osmotic pressure.
- pH.
- Temperature.
- Electrical charge.

2. Dynamic nature:

Constant renewal of its homogeneity.

III. Maintenance of the internal environment's constant:

1. Composition of the internal environment:

The internal environment consists of 3 compartments:

- Plasmatic
- Interstitial
- Lymphatic

2. Blood:

Blood is a liquid tissue that circulates throughout our body via blood vessels. It is composed of red blood cells, white blood cells, and platelets suspended in a liquid called plasma. Blood plays a vital role in transporting oxygen, nutrients, antibodies, and hormones.

In an adult, the blood volume is approximately 5 liters, but this volume varies depending on the individual's weight, height, and sex.

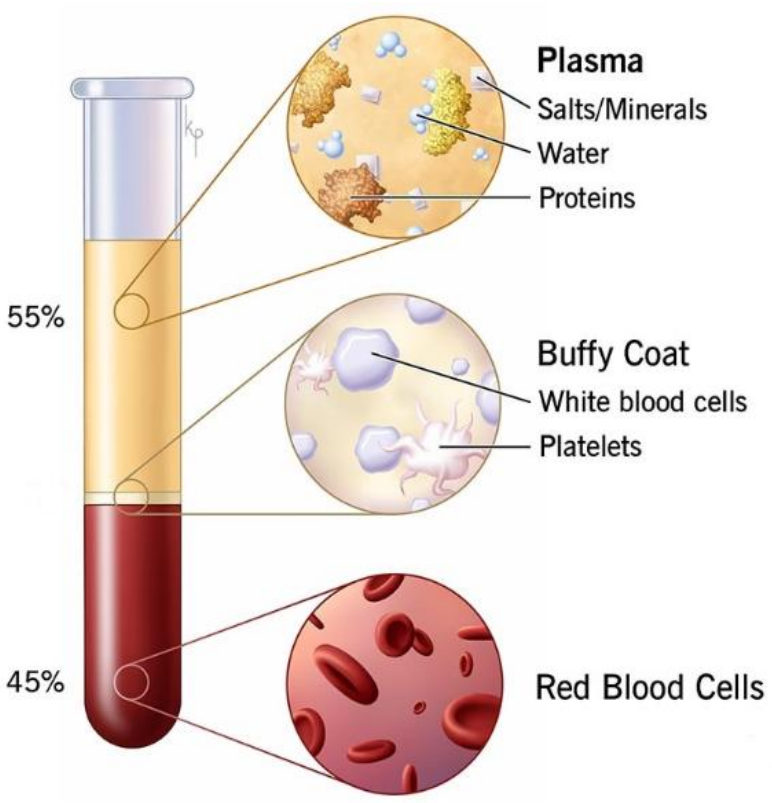
The composition of blood is as follows:

- 45% cells (red blood cells, white blood cells, and platelets)
- 55% plasma (liquid portion)

3. Plasma:

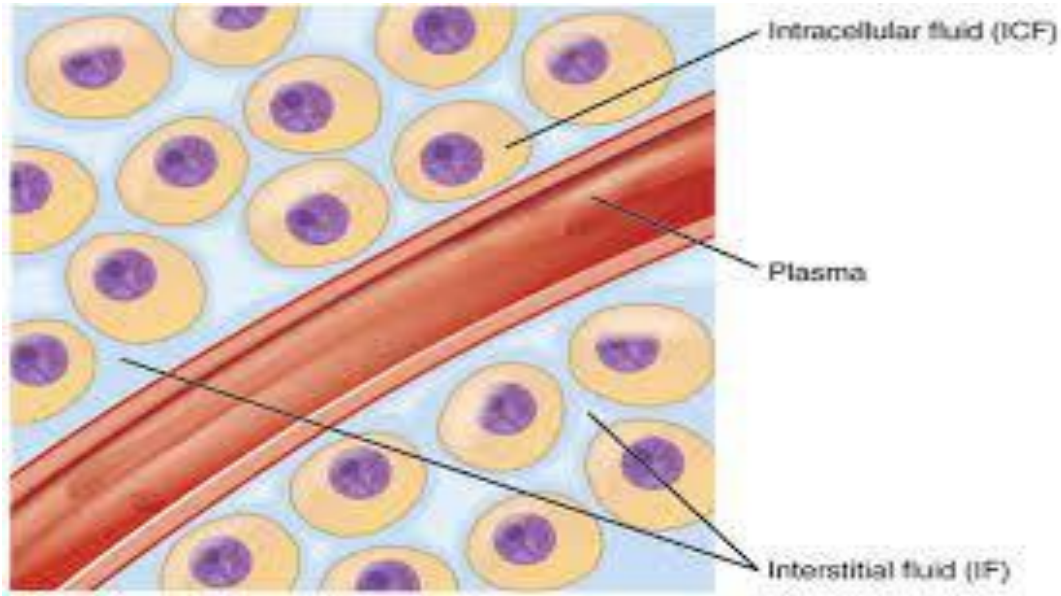
It is an aqueous solution composed of 90% water, and the remaining 10% consists of mineral components (water, ions, and dissolved gases) and organic components (plasma proteins: albumin, fibrinogen globulin, cholesterol, glucose, amino acids, hormones, urea).

Plasma composition is constant, which is a good indicator in case of pathology. However, this composition varies depending on the time of day, physical activity, and diet.



4. Interstitial fluid:

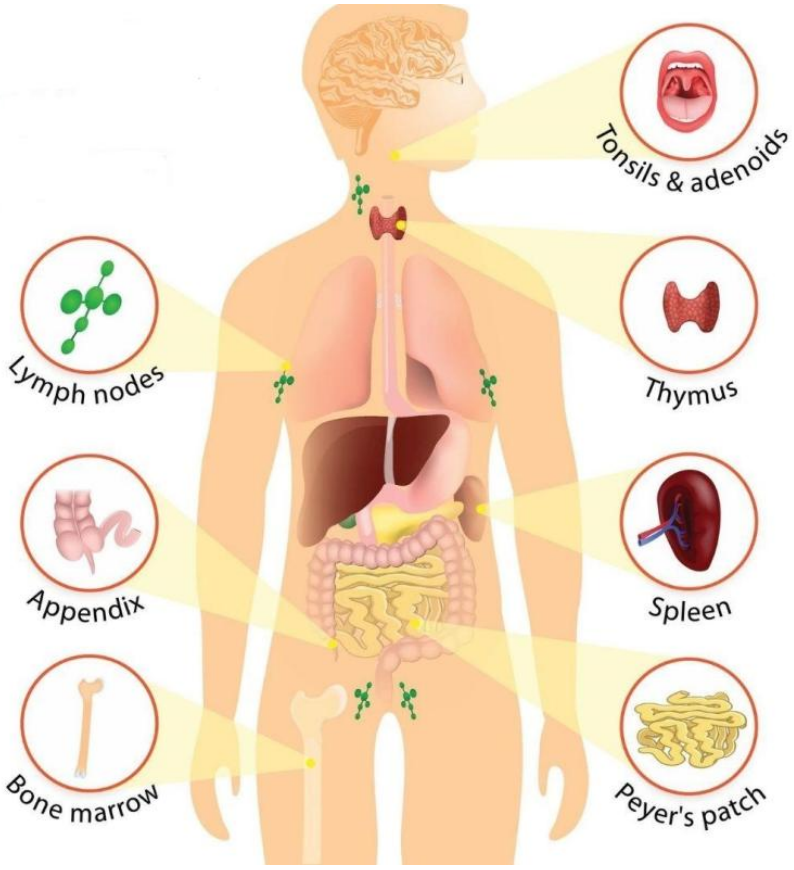
This is the fluid present in the intercellular spaces, composed of water, amino acids, sugars, fatty acids, coenzymes, hormones, neurotransmitters, salts, and cellular products. It bathes and surrounds the body's cells and provides a means of supplying materials to cells, facilitating intercellular communication, and removing metabolic waste from the extracellular space..



5. Lymph:

A colorless or amber-colored organic fluid with a composition similar to that of blood plasma.

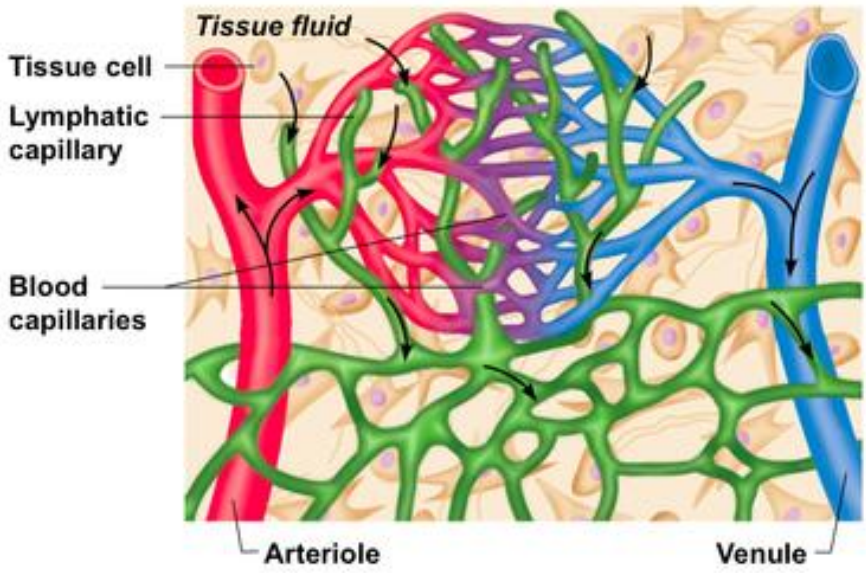
The lymphatic system consists of lymphatic vessels and lymphatic organs.



- **Role of the lymphatic system:**

Roles of the lymphatic vessels: they return excess interstitial fluid resulting from blood filtration at the capillary level to maintain homeostasis.

Role of the lymphatic organs: organs that house phagocytes and lymphocytes to eliminate foreign bodies..



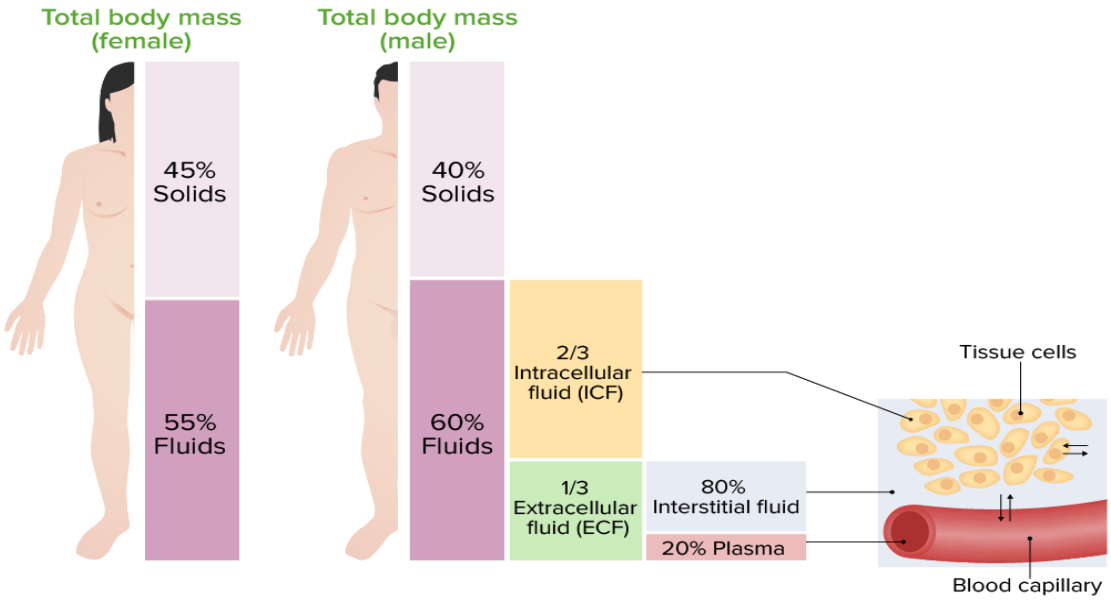
➢ **Lymph Formation:**

Water present in the capillaries, enriched with nutrients, minerals, and vitamins, leaves the capillaries and enters the interstitial fluid. Cells absorb the elements necessary for their functions from this fluid and release waste products. This fluid is partially reabsorbed in the capillaries. However, approximately 3 liters per day is reabsorbed and enters the lymphatic vessels to form lymph.

IV. Body Fluid Compartments:

The human body contains 60% fluid, 40% intracellular fluid (28L) and 20% extracellular fluid (14L).

Extracellular fluid is composed of 80% interstitial fluid and 20% plasma and lymph.



1. **Composition of fluid compartments:**

➢ **Electrolyte compounds (ionizable elements) (95%):**

- Inorganic salts: Cations; Na+, K+, Mg++, Ca++, H+ and Anions; Cl-, HCO3-, PO43-, SO42-.
- Some proteins.

➢ **Non-electrolytic substances (5%):**

- Sugar (Glucose).
- Lipid.
- Urea.
- Creatinine.

2. **Exchanges between fluid compartments:**

The fluid compartments do not represent fixed volumes; there is constant exchange between them and with the external environment; the hydroelectrolytic balance is dynamic.

➢ **Osmosis:**

Osmosis and osmotic forces facilitate the diffusion of substances across the membrane. In the internal environment, the solvent moves from the less concentrated solution to the more concentrated one. Osmosis is linked to osmotic pressure, while reverse osmosis is associated with hydrostatic pressure.

➢ **Osmotic pressure:**

The osmotic pressure of a solution represents the hydrostatic pressure required to prevent solvent from infiltrating a membrane that allows water and solutes to pass through. It is defined in mosmol/L = mmol/L multiplied by the number of particles. Osmotic pressure is primarily generated by small molecules and dissociated electrolytes. Osmotic pressure gradients promote passive water movement through the process of osmosis. Most water movement between different liquid zones is controlled by osmotic pressure gradients.

In practice, the formula allows us to obtain the value of the total osmotic pressure (TOP).

TOP = 2 × [sodium] + [urea] + [glucose] in mmol/L = 290 mosmol/L.

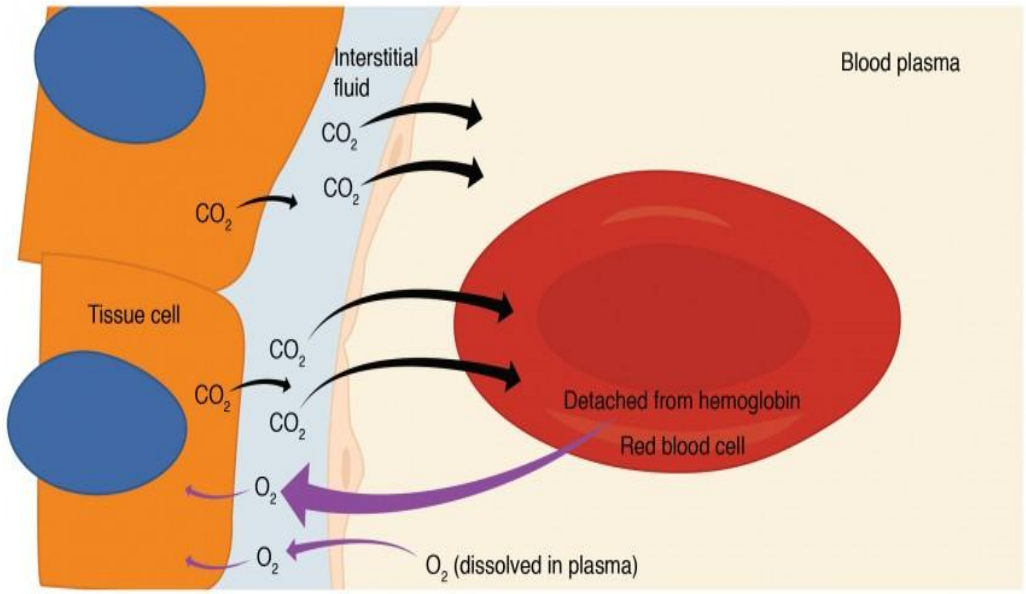
➢ **Oncotic pressure:**

This is the pressure that attracts water towards proteins; osmotic pressure attributable to proteins.

Exchanges:

Exchanges between plasma and the external environment:

Humans absorb and eliminate water, sodium, potassium, and phosphorus through the organs of exchange; ideally, the total of these exchanges should be zero (all balances would then be zero). The rapidly circulating plasma volume interacts with the external environment via the skin, the digestive system, the respiratory tract, and the kidneys. There are numerous standard water and electrolyte balances that vary depending on the individual and the situation. Urinary losses are continuously adjusted to maintain fluid and electrolyte balance.

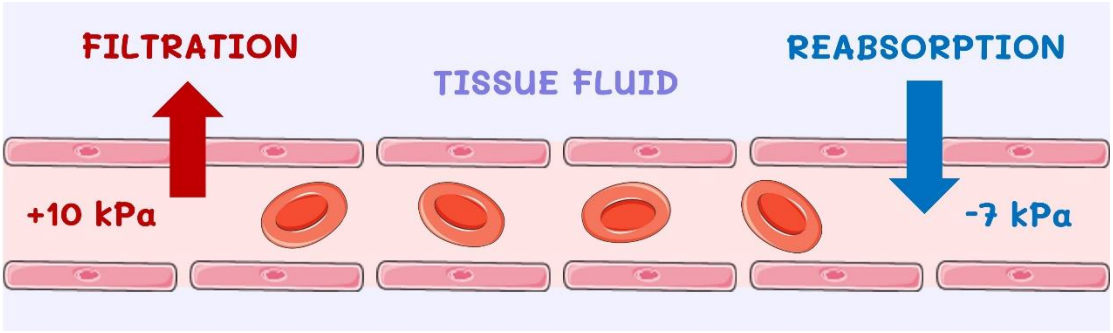


Exchanges between plasma and interstitial fluid:

There are two pathways:

Through the capillary walls: Capillaries are semi-permeable structures with a surface area varying from 300 to 1000 m² between the plasma and the interstitium. - Exchanges by diffusion: 60 L/min, bidirectional and identical for blood gases and small molecules.

Exchanges by filtration/reabsorption: these are the major exchanges, given their capacity to fluctuate and alter both volumes involved. They are governed by capillary and interstitial hydrostatic pressures, as well as by the two oncotic pressures, capillary and interstitial.

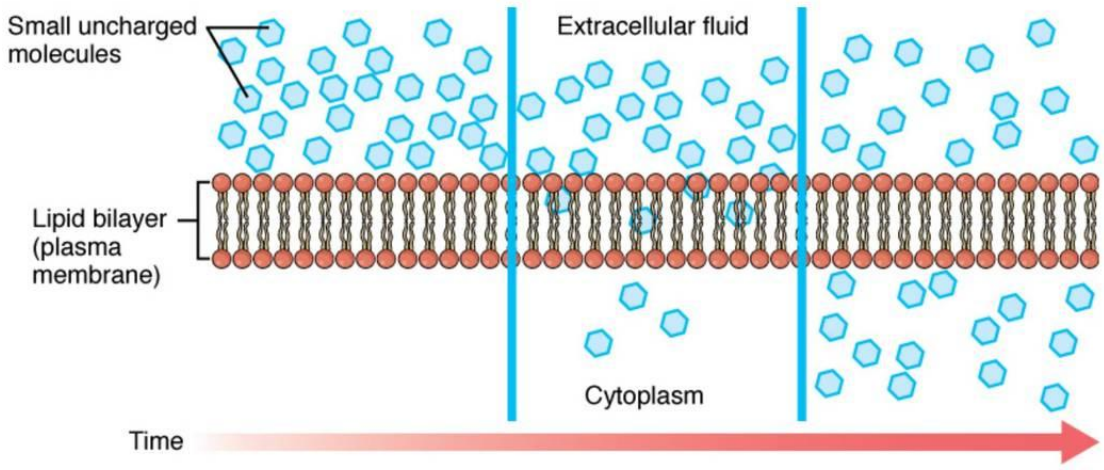


Exchanges between interstitial and intracellular fluid:

Passive diffusion: Ions move down the chemical or electrical gradient. Simple passage occurs across the plasma membrane for certain blood gases and some molecules. Ion passage occurs via selective ion channels. Facilitated transport relies on transporters present in the membranes.

Ongoing transfers: ATPase ion pumps are used to perform transfers against concentration or electrical gradients, thus maintaining distinct hydro-electrolytic concentrations between the internal and external environments. These pumps harness the energy released during ATP hydrolysis.

Passive water transfers via osmosis: These are controlled by differences in osmotic pressure between the inside and outside of the cell; water moves toward the compartment where the osmotic pressure is higher.



Physiology of the Muscular System Organs and Energy Production Systems and Sources

I. Introduction

The study of muscle physiology focuses on the functioning of muscle tissue, that is, how muscles contract, generate movement, and contribute to posture or heat production.

Muscle is a dynamic organ of movement that converts chemical energy (ATP) into mechanical energy.

II. Types of Muscles

There are three major types of muscles in the human body:

Comparison of Muscle Types

Muscle Type	Skeletal	Cardiac	Smooth
Location	Attached to bone	Heart	Walls of internal organs + in skin
Function	Movement of bone	Beating of heart	Movement of internal organs
Control Mode	Voluntary	Involuntary	Involuntary
Shape	Long + slender 	Branching 	Spindle shape 
Characteristics	Striated- light and dark bands Many nuclei	Striated One or two nuclei	Non-striated One nucleus (visceral)

III. Structure of skeletal muscle

General Organization

Skeletal muscle is composed of bundles of muscle fibers, surrounded by connective tissue sheaths:

- Endomysium: surrounds each individual muscle fiber.

- Perimysium: surrounds a bundle of fibers.
- Epimysium: surrounds the entire muscle.

Each muscle fiber (cell) contains:

Myofibrils, composed of myofilaments:

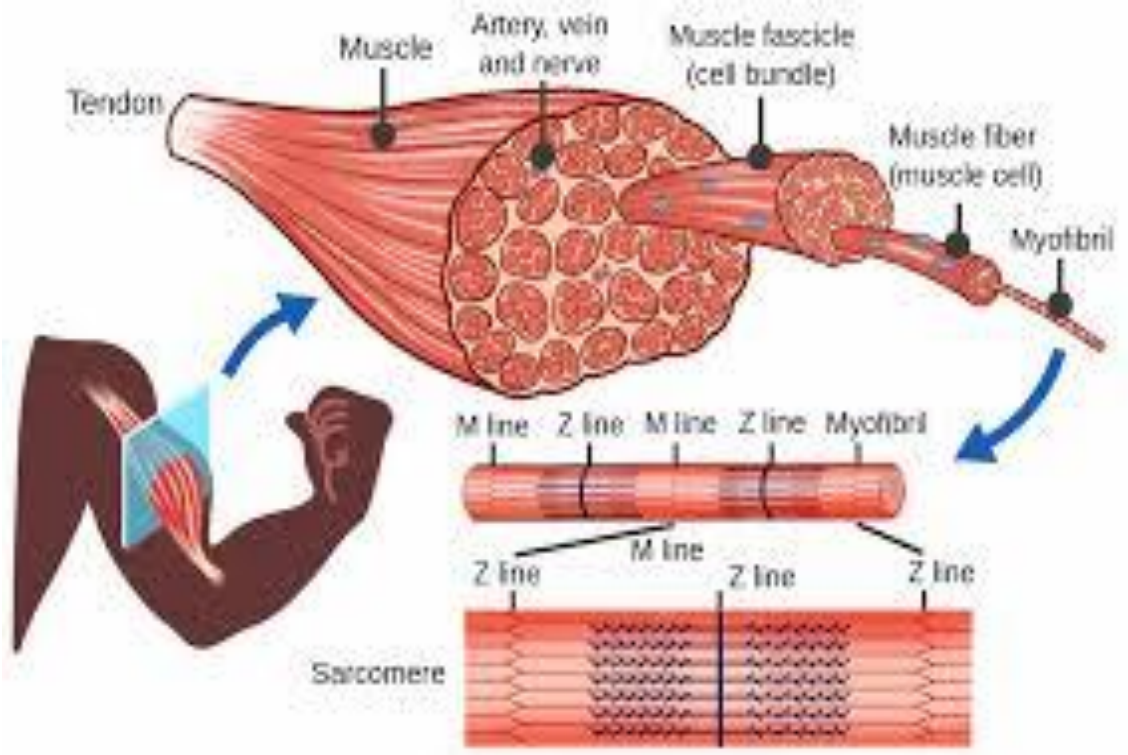
- Actin (thin filament)
- Myosin (thick filament)

Multiple nuclei

Numerous mitochondria (ATP production)

The sarcoplasmic reticulum (stores calcium)

The sarcolemma (cell membrane)



IV. The functional unit: the sarcomere

The sarcomere is the contractile unit of striated muscle.

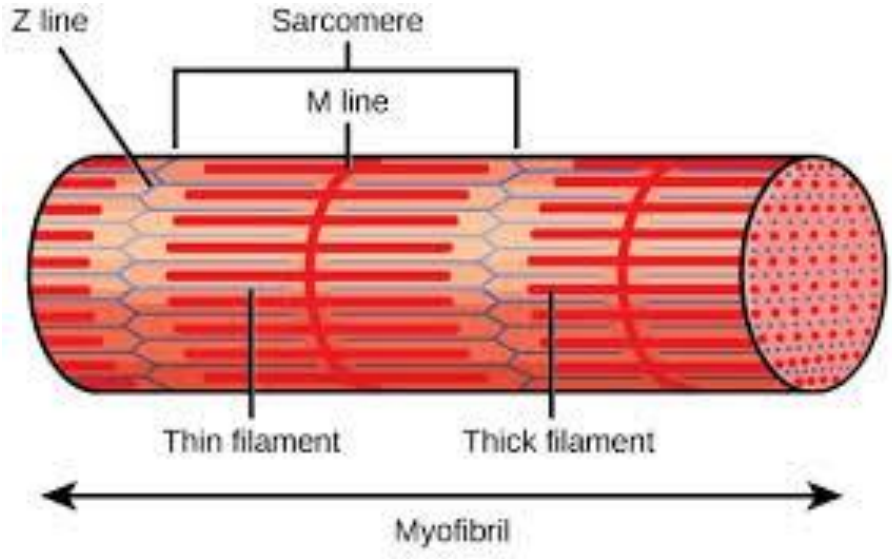
It is delimited by two Z-lines and contains:

- Actin filaments connected to the Z-lines,
- Myosin filaments located in the center.

During contraction:

The filaments slide past one another, which shortens the sarcomere without changing the length of the individual filaments.

This is the filament sliding model.



V. Muscle Contraction

Stages of Skeletal Muscle Contraction

Arrival of the Nerve Impulse

The action potential reaches the neuromuscular junction (motor endplate).

Release of acetylcholine (ACh) into the synaptic cleft.

Transmission of the Impulse to the Muscle Fiber

ACh binds to its receptors → depolarization of the sarcolemma.

The impulse propagates along the T-tubules.

Calcium Release

The sarcoplasmic reticulum releases Ca^{2+} ions into the cytoplasm.

Actin-Myosin Interaction

Ca^{2+} binds to troponin, which releases the actin binding sites.

Myosin forms cross-bridges with actin.

In the presence of ATP, the myosin heads fold back → filament sliding → contraction.

Relaxation

Ca^{2+} is pumped back into the sarcoplasmic reticulum.

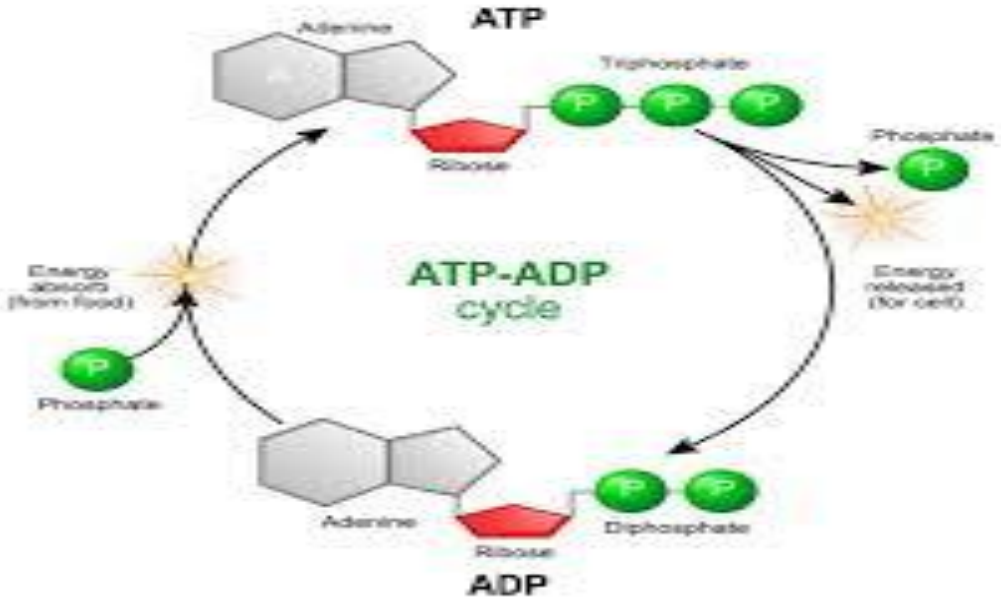
The attachment sites are masked → the muscle relaxes.

VI. The role of ATP

ATP (adenosine triphosphate) is essential for:

- The formation and breaking of actin-myosin cross-bridges,
- The functioning of the calcium pump,
- Maintaining membrane potential.

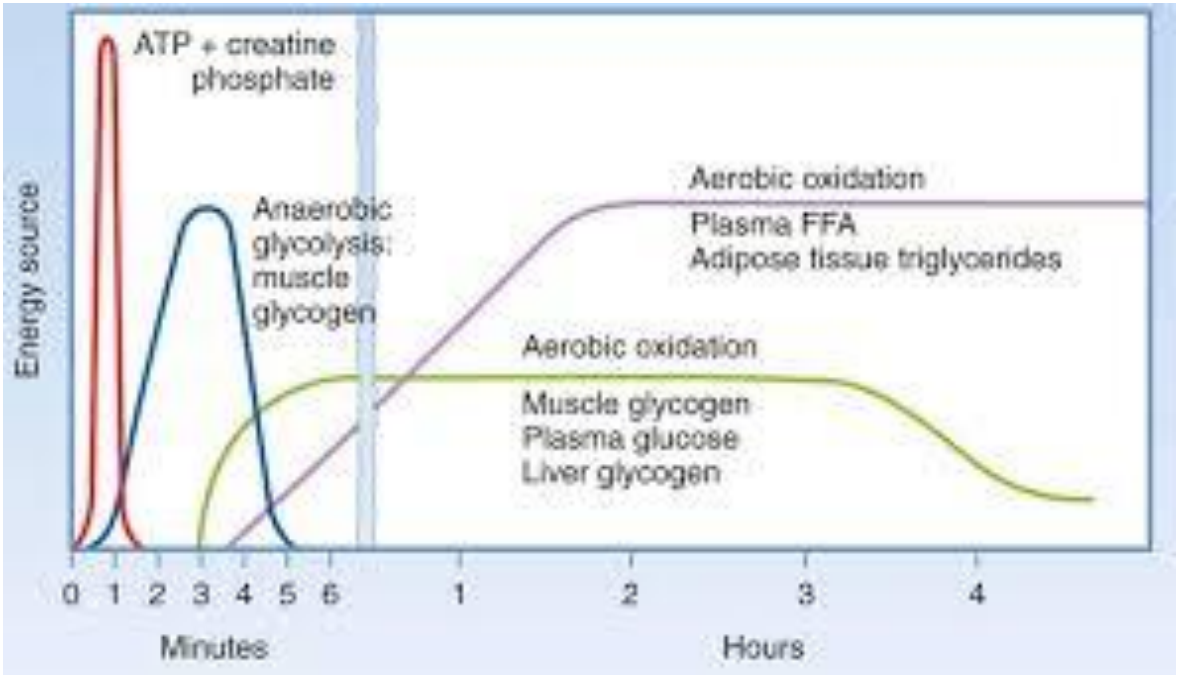
Without ATP (e.g., death), the cross-bridges remain fixed → rigor mortis (stiffness of the body).



VII. Muscle Energy Sources

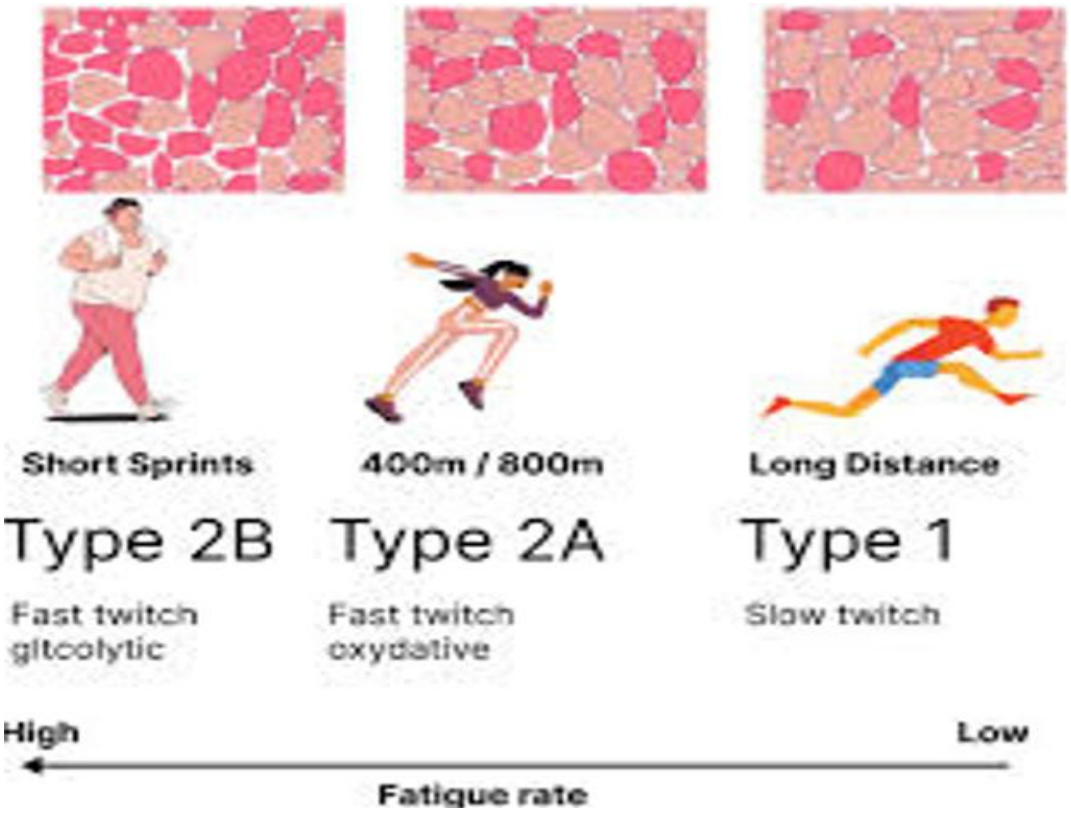
Muscle uses several energy systems depending on the duration and intensity of the effort:

Energy systems overview			
	PC System	**Lactic Acid System**	**Oxygen System**
System	Anaerobic	Anaerobic	Aerobic
Fuel source used	Stored phosphocreatine	Glucose	Glucose, free fatty acids
ATP molecule production	Low	Low	High
By/waste products	None (alactic)	Lactic acid (by-product)	Carbon dioxide and water
Duration of exercise	0-10 seconds	30s to 2 min	3-5 min plus
Intensity of exercise	Maximum (95-100% effort)	High intensity (60-95% max effort)	Low intensity (up to 60% max effort)
Level of muscle force (% of max)	Maximum	High to very high	Low to moderate
Work:rest ratio	1:6/10	1:2/3	1:5/1
Activity examples	Sprinting/Olympic weight lifting	400m sprint/500m rowing	Marathon/800m swimming



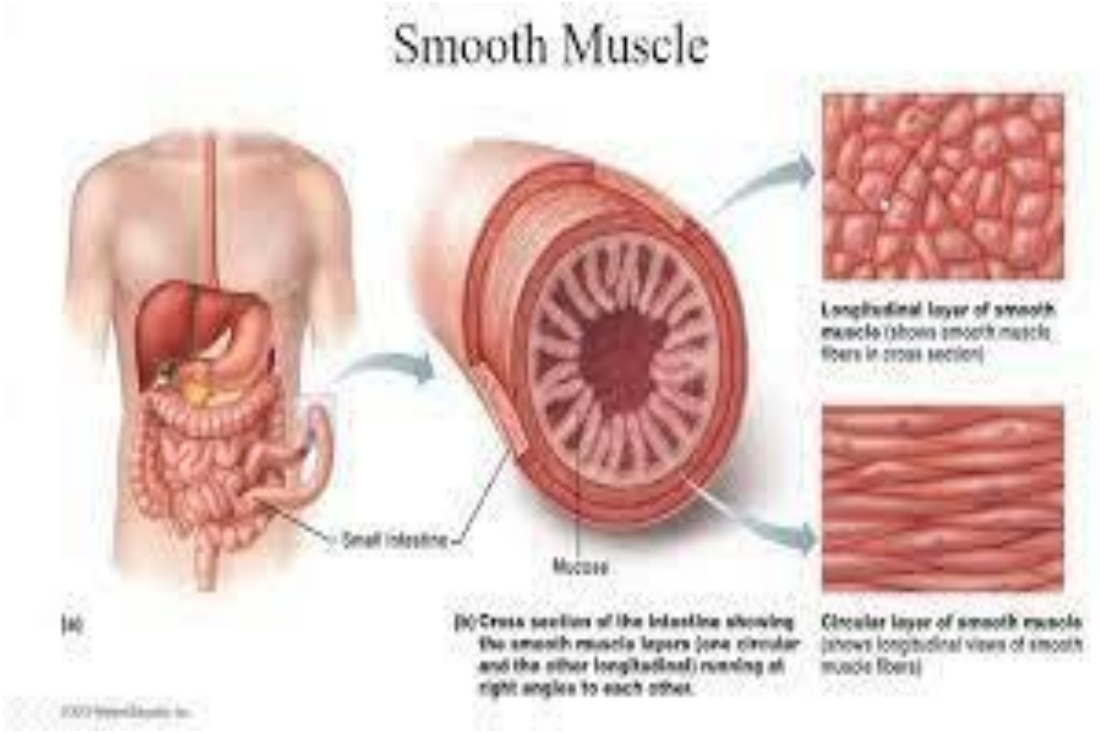
VIII. Types of muscle fibers

Fiber type	MyHC-I	MyHC-IIa	MyHC-IIx	MyHC-IIb
Activity used for	Aerobic	Long-term aerobic	Short-term anaerobic	Short-term anaerobic
Power produced	Low	Medium	High	Very high
Contraction time	Slow	Moderately fast	Fast	Very fast
Resistance to fatigue	High	Fairly high	Intermediate	Low
Maximum endurance	Hours	< 30 min	< 5 min	< 1 min
Oxidative capacity	High	High	Intermediate	Low
Glycolytic capacity	Low	High	High	High
Mitochondrial density	High	High	Intermediate	Low
Capillary density	High	Medium	Low	Low
Size of motor neuron	Small	Medium	Large	Very Large
Major storage fuel	Triglycerides	Creatine Phosphate, glycogen	Creatine phosphate, glycogen	Creatine phosphate, glycogen
Fasting tolerance	Long	Medium	Short	Short
Denervation induction atrophy sensitivity	High	Medium	Low	Low
Senescence	Slow	Very fast	Fast	Fast



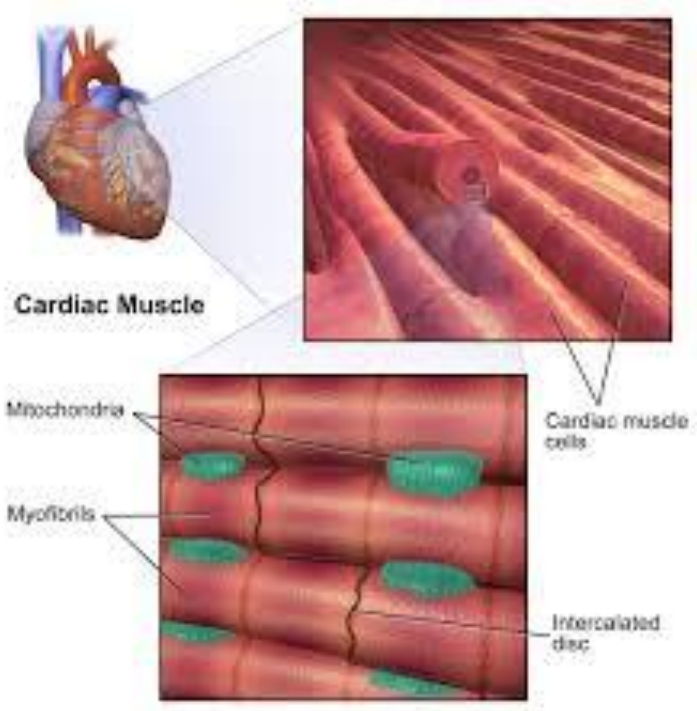
IX. Physiology of smooth muscle

- Spindle-shaped, non-striated cells.
- Slow but sustained contraction.
- Controlled by the autonomic nervous system and hormones.
- Found in: intestines, blood vessels, uterus, bronchi.
- Function: movement of the viscera (peristalsis, vasoconstriction, etc.).



X. Physiology of the Cardiac Muscle

- Striated but involuntary muscle.
- Cardiac cells (cardiomyocytes) are connected by gap junctions (intercalated discs).
- Rhythmic and automatic contraction, initiated by the sinoatrial node.
- Regulation by the autonomic nervous system and hormones (adrenaline, etc.).



XI. Muscle Fatigue and Tone

- Muscle fatigue: decreased ability to contract, due to the accumulation of waste products (lactic acid) and a lack of ATP.
- Muscle tone: a state of slight, permanent contraction, essential for maintaining posture.

XII. Conclusion

Muscle physiology demonstrates the perfect harmony between the nervous, energetic, and mechanical systems of the human body.

Thanks to its capacity for contraction and force generation, muscle plays a crucial role in movement, maintaining posture, and producing heat.

Physiology of the Cardiovascular System

I. Introduction

The **cardiovascular system** (also called the **circulatory system**) is essential for maintaining life.
It ensures the **continuous circulation of blood** throughout the body to:

- Transport **oxygen**, **nutrients**, and **hormones** to tissues,
- Remove **carbon dioxide (CO_2)** and **metabolic wastes**,
- Maintain **body temperature**, **blood pressure**, and **pH balance**.

It is composed of three main elements:

- The **heart** (the pump),
- The **blood vessels** (the transport network),
- The **blood** (the circulating fluid).

II. General Organization of Circulation

The cardiovascular system forms a **closed circuit** consisting of two main loops:

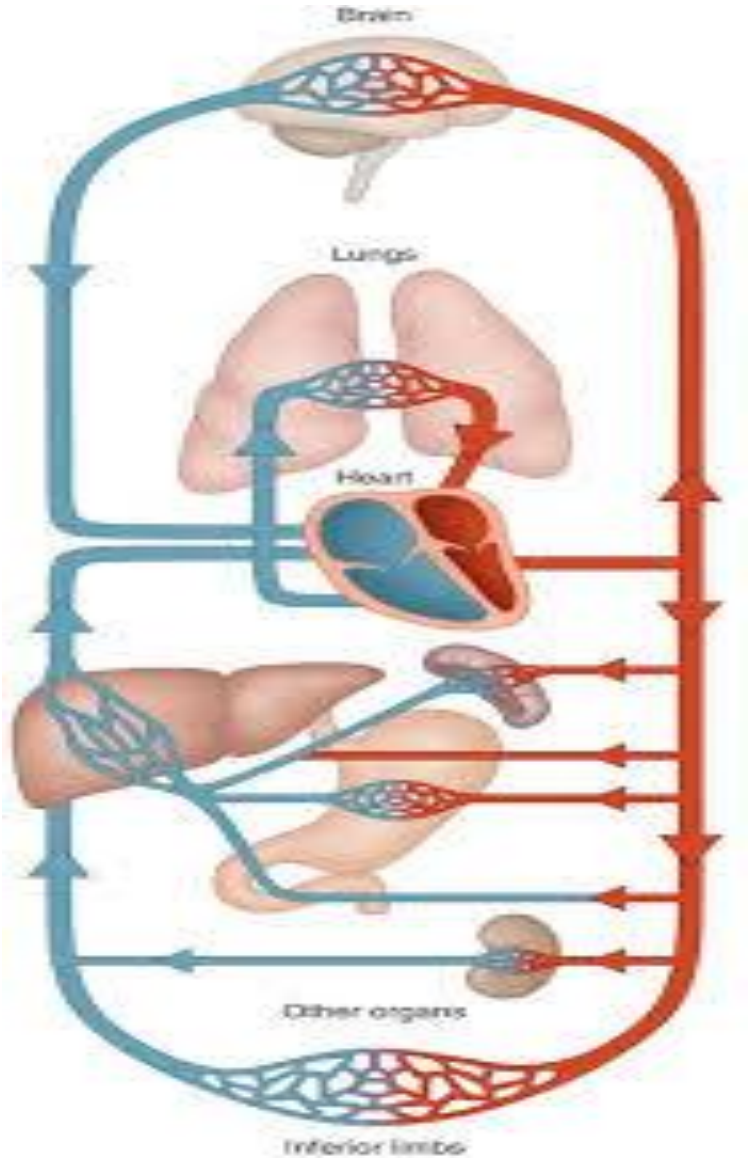
Pulmonary circulation (small circulation)

- From the **right heart** to the **lungs**, then back to the **left heart**.
- Function: **gas exchange** — deoxygenated blood becomes oxygenated.

Systemic circulation (large circulation)

- From the **left heart** to the **whole body**, then back to the **right heart**.

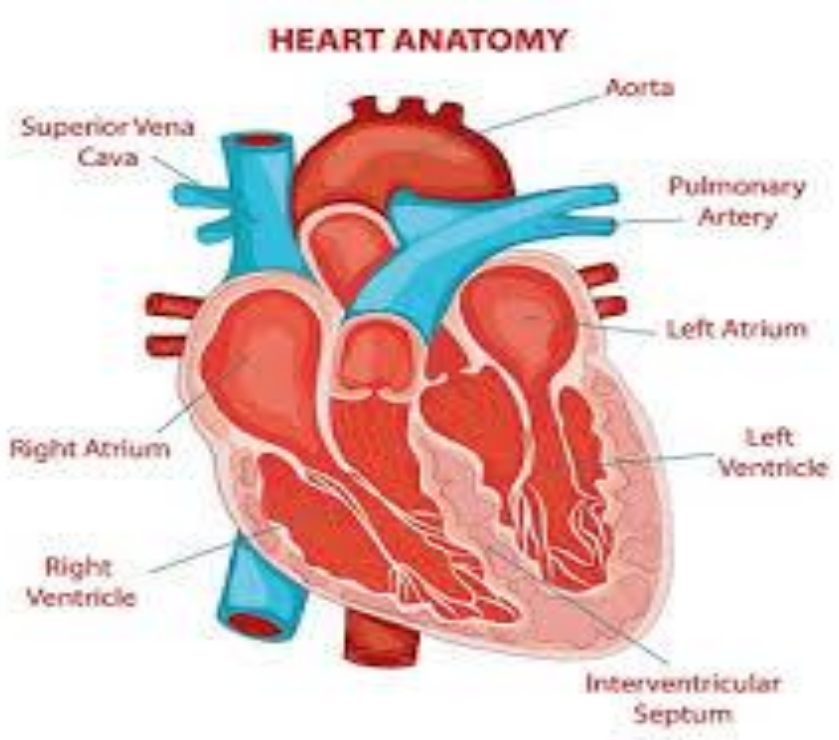
- Function: **deliver oxygen and nutrients** to all body tissues.



III. The Heart: Central Organ of Circulation

1. Structure

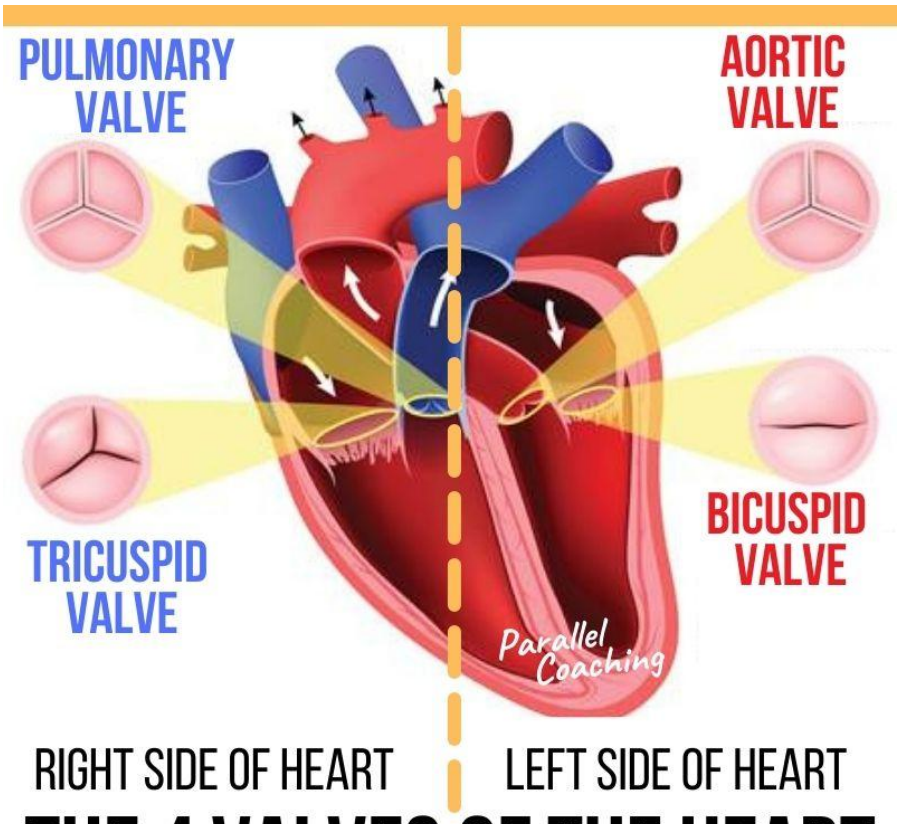
- Located in the **mediastinum**, the heart is a hollow muscular organ about the size of a fist.
- It has **four chambers**:
  - ✓ **Right atrium (RA)** → receives venous blood.
  - ✓ **Right ventricle (RV)** → pumps blood to the lungs.
  - ✓ **Left atrium (LA)** → receives oxygenated blood.
  - ✓ **Left ventricle (LV)** → pumps oxygenated blood to the whole body.

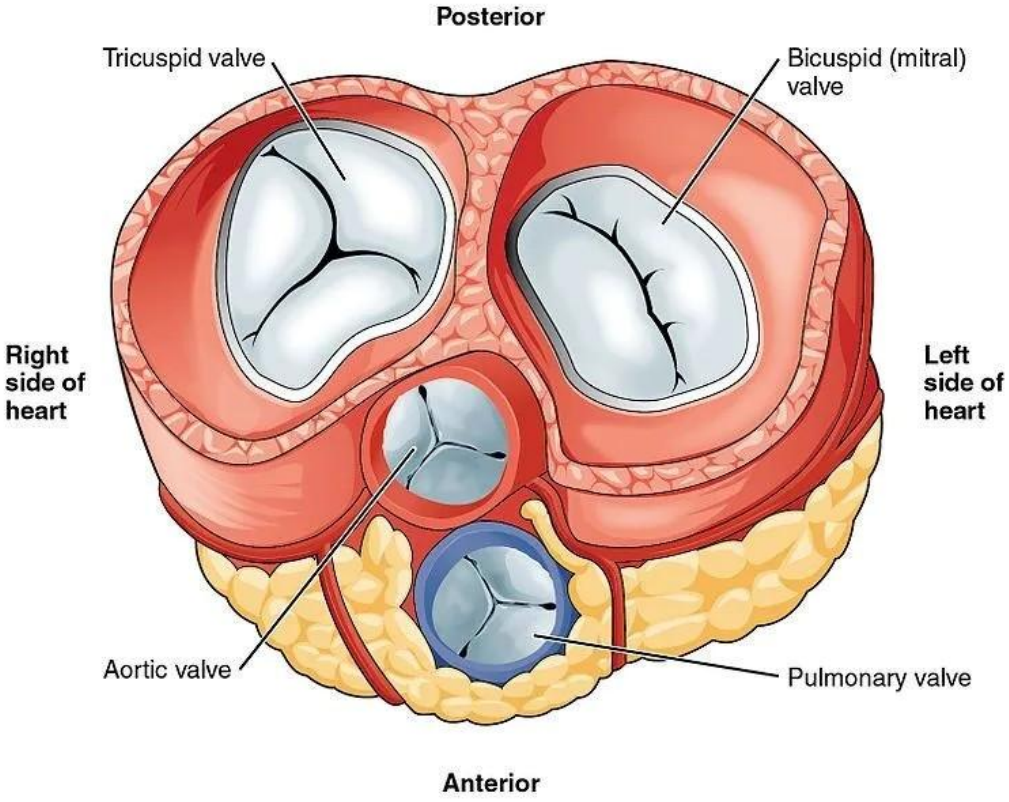


2. Cardiac Valves

Valves prevent **backflow of blood**:

- **Atrioventricular valves**: tricuspid (right) and mitral (left).
- **Semilunar valves**: pulmonary (RV) and aortic (LV).


PULMONARY VALVE
AORTIC VALVE
TRICUSPID VALVE
BICUSPID VALVE
Parallel Coaching
RIGHT SIDE OF HEART
LEFT SIDE OF HEART
THE 4 VALVES OF THE HEART


Posterior
Tricuspid valve
Bicuspid (mitral) valve
Right side of heart
Left side of heart
Aortic valve
Pulmonary valve
Anterior

IV. Physiology of Cardiac Contraction

The Cardiac Cycle

The **cardiac cycle** includes all the events that occur during a single heartbeat (≈ 0.8 seconds at rest).

1. **General diastole**:

   The heart relaxes, and the chambers fill with blood.

2. **Atrial systole**:

   The **atria contract**, pushing blood into the ventricles.

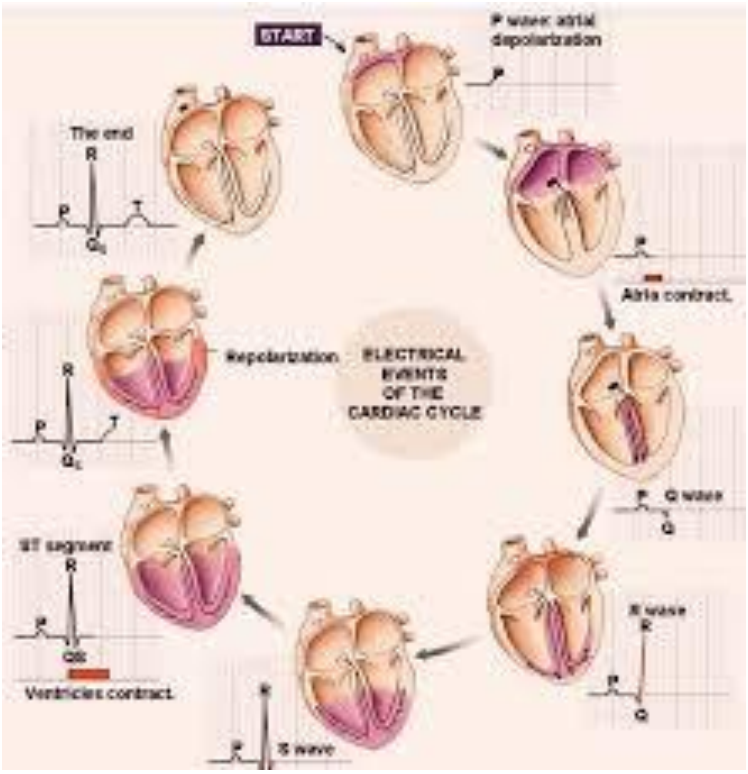
3. **Ventricular systole**:

   The **ventricles contract**, ejecting blood into the aorta and pulmonary artery.

4. **Return to diastole**:

   The heart relaxes again, and the cycle repeats.

At rest, the heart beats about **70 times per minute**.

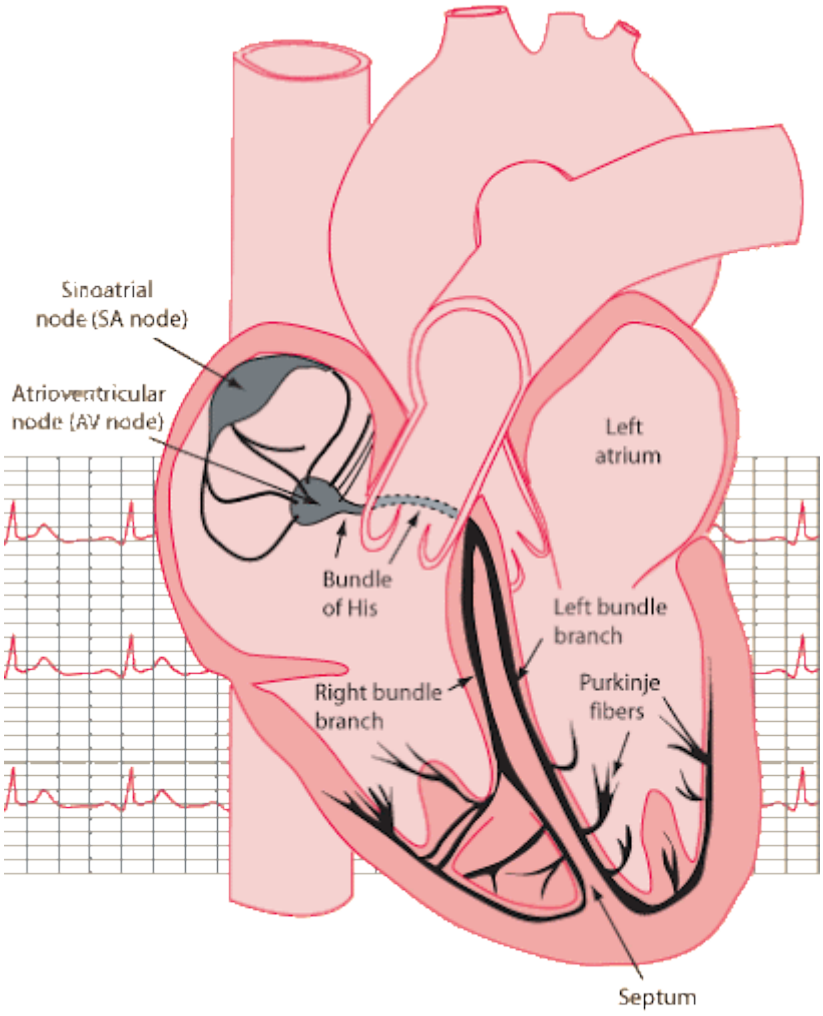


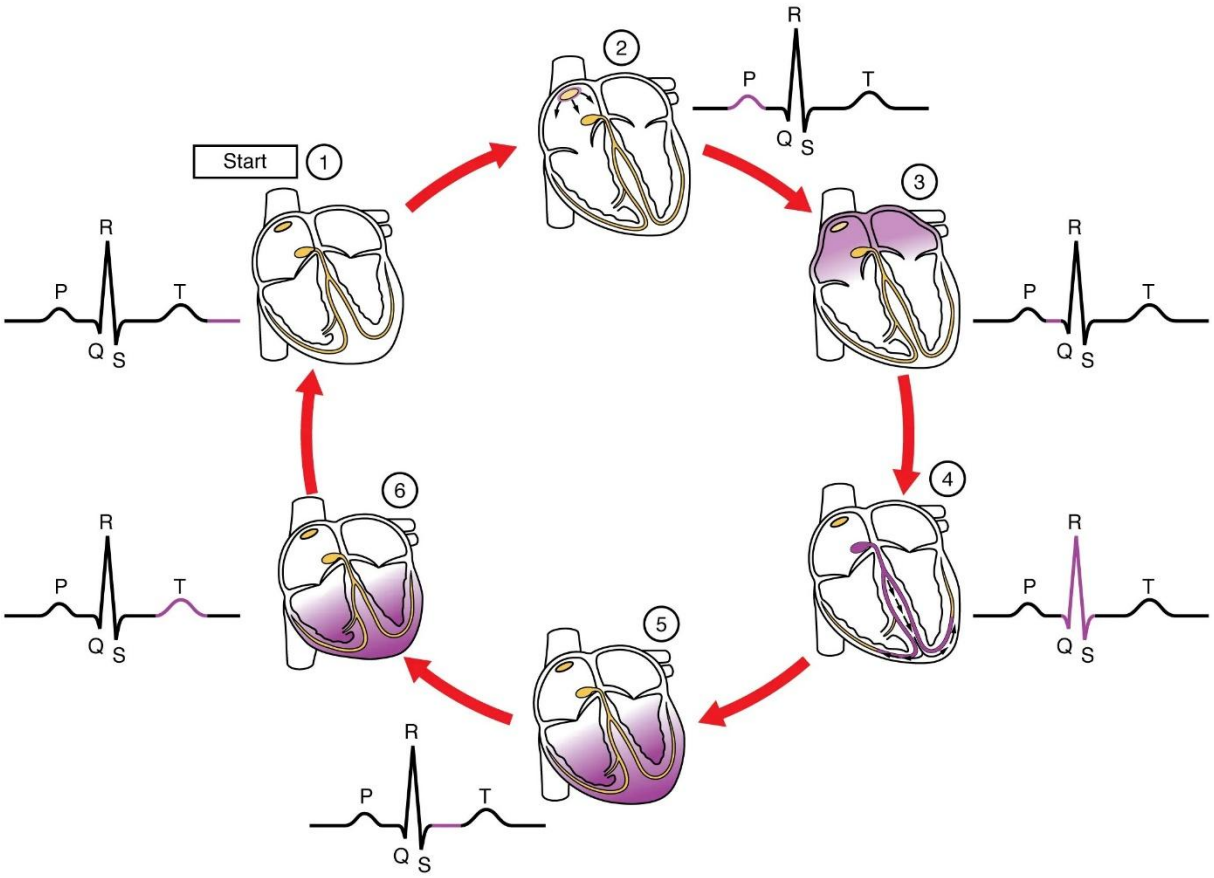
V. Cardiac Automatism

The heart has an **intrinsic rhythmic activity** due to a **specialized conduction system**:

Structure	Role	Rate (beats/min)
Sinoatrial (SA) node	Main pacemaker (initiates impulses)	70–80
Atrioventricular (AV) node	Relay, delays conduction	40–60
Bundle of His & Purkinje fibers	Conduct impulses to ventricles	20–40

The **SA node** spontaneously generates electrical impulses that spread through the heart, causing a coordinated contraction.





VI. Cardiac Output

Cardiac output (CO) is the volume of blood pumped by the heart per minute.

$$CO = HR \times SV$$

- **HR** = Heart Rate (beats/min)
- **SV** = Stroke Volume (mL/beat)

At rest:
CO ≈ 70 × 70 = ≈ **5 L/min**

During exercise:
CO can reach **20–30 L/min** in trained athletes.

VII. Regulation of Heart Activity

Neural Regulation

- **Sympathetic system** → increases heart rate and contractility.
- **Parasympathetic system (vagus nerve)** → decreases heart rate.

Hormonal Regulation

- **Adrenaline & noradrenaline** → stimulate heart activity.
- **Thyroxine** → increases heart rate over the long term.

Local Factors

- **Blood pressure**, **temperature**, and **O_2 /CO_2 levels** can affect heart rate.

VIII. Blood Vessels

Arteries

- Carry blood **away from the heart**.
- Thick, elastic, and muscular walls — withstand high pressure.

Veins

- Carry blood **back to the heart**.
- Thinner walls, contain **valves** to prevent backflow.

Capillaries

- Microscopic vessels connecting arterioles and venules.
- Site of **gas and nutrient exchange** between blood and tissues.

IX. Blood Pressure (BP)

Blood pressure is the **force exerted by blood** on arterial walls.
It's measured in **millimeters of mercury (mmHg)**:

- **Systolic pressure** (ventricular contraction): ≈ 120 mmHg
- **Diastolic pressure** (ventricular relaxation): ≈ 80 mmHg

$$BP = Cardiac\ Output \times Peripheral\ Resistance$$

Blood pressure varies with **age**, **exercise**, **stress**, and **body position**.

X. Capillary Exchange

At the **capillary level**, exchange between blood and cells occurs via:

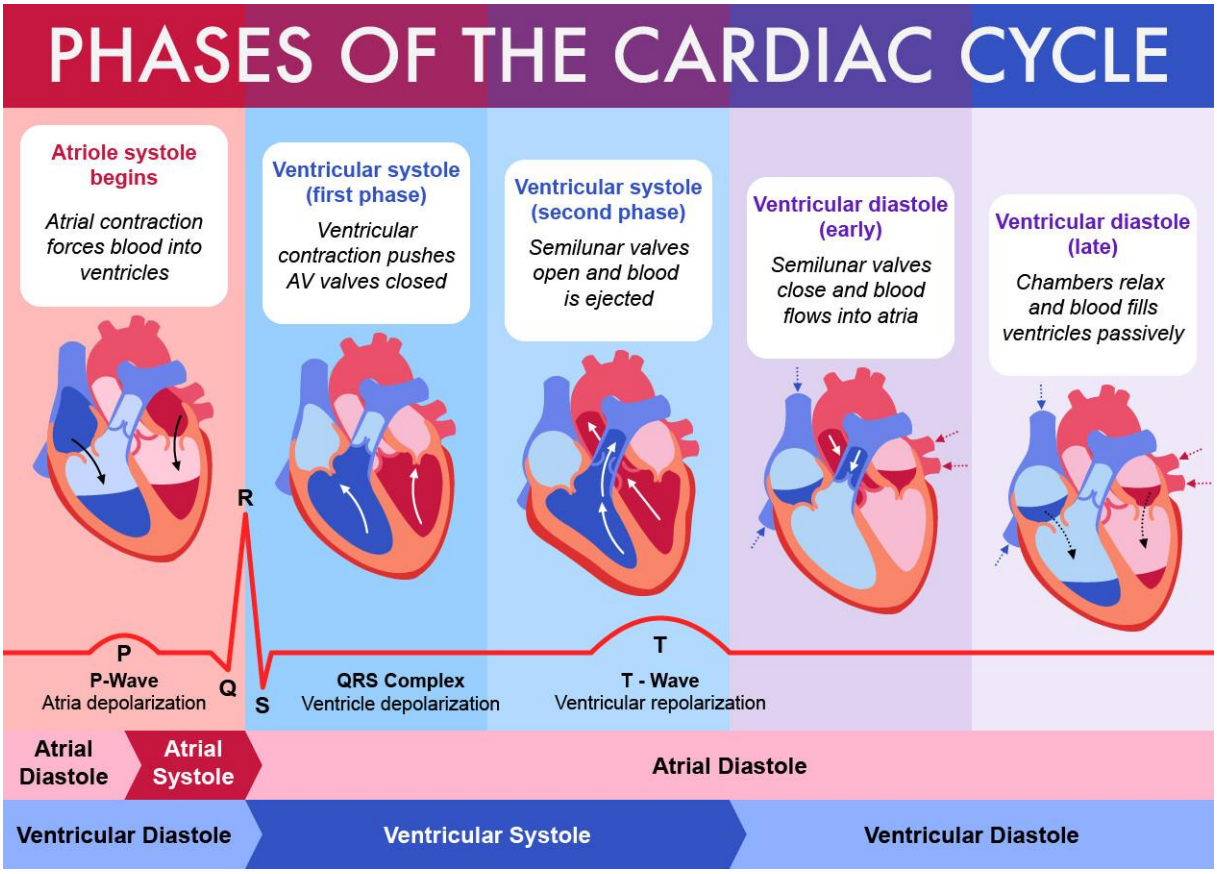
- **Diffusion** (gases, nutrients),
- **Filtration** (fluid leaving the capillary),
- **Reabsorption** (fluid returning).

These exchanges are governed by **hydrostatic** and **oncotic pressures**.

XI. The 5 Phases of the Cardiac Cycle

1 cardiac cycle = 5 phases that ensure rhythmic filling and emptying of the heart's chambers, allowing continuous blood circulation through the body

Phase	Name	Main Events	Valves Status	Type of Flow
1	Atrial systole	Atria contract, ventricles finish filling	AV open, SL closed	Atria → Ventricles
2	Isovolumetric contraction	Ventricles contract, pressure ↑	All closed	None
3	Ventricular ejection	Blood ejected into arteries	AV closed, SL open	Ventricles → Aorta/Pulmonary artery
4	Isovolumetric relaxation	Ventricles relax, pressure ↓	All closed	None
5	Ventricular filling	Blood flows passively into ventricles	AV open, SL closed	Atria → Ventricles



XII. Heart sounds

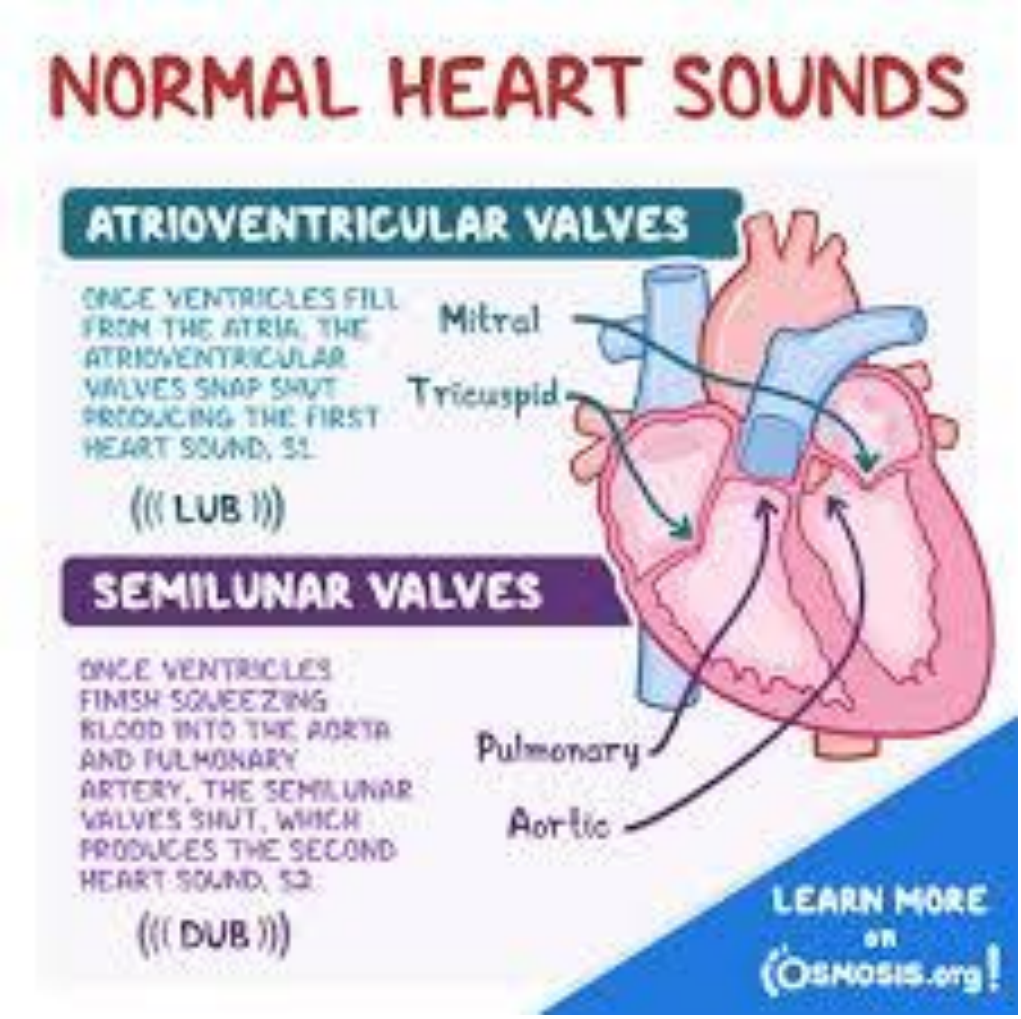
Obtained on auscultation

S1 and S2

S1 – muffled – closure of the AV valves

S2 – high-pitched – closure of the semilunar valves

S2 S1 › S1 S2



XIII. Conclusion

The circulatory system is a dynamic, interconnected network that makes sure blood is continuously transported to meet the body's metabolic requirements.

Its exact control permits adaptation to rest, stress, or exercise while preserving homeostasis.

Life, performance, and general health all depend on a functioning cardiovascular system.

Physiology of the Respiratory System

I. Introduction

The exchange of gases between the body and its surroundings is guaranteed by the respiratory system.

Its main job is to remove carbon dioxide (CO_2) created by cellular metabolism and supply oxygen (O_2) to the circulation.

These gas exchanges are essential for energy production (ATP synthesis), acid-base balance, and cellular respiration.

II. Anatomical Overview

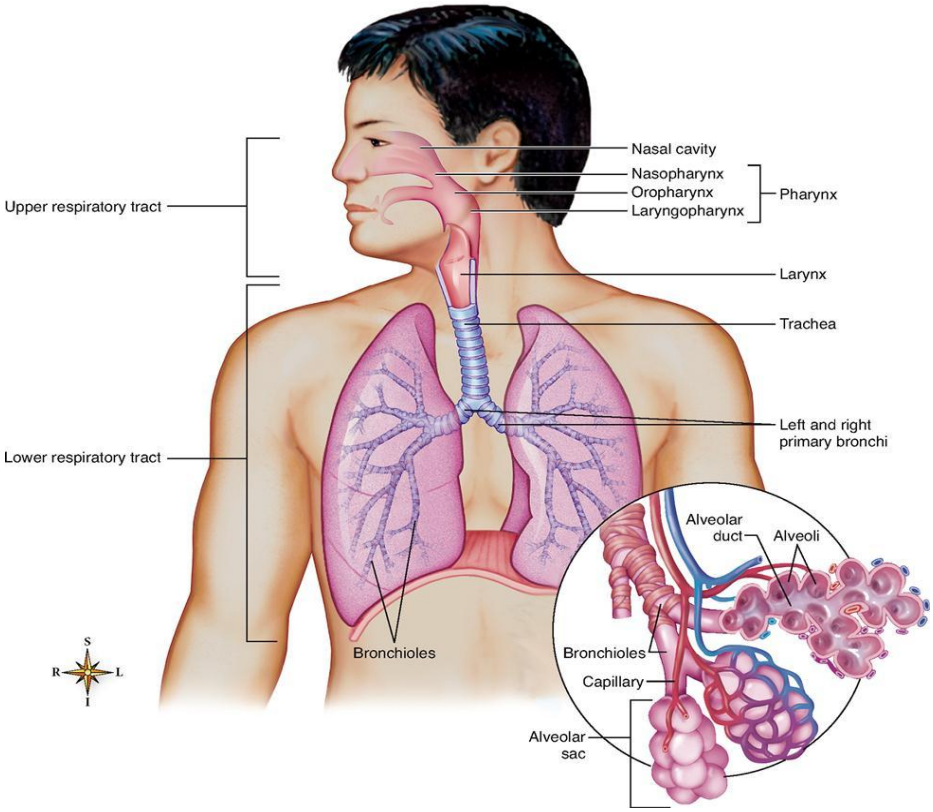
The respiratory system is divided into two parts:

1. **The Upper Respiratory Tract**
   - **Nose and nasal cavity**: filter, warm, and humidify incoming air.
   - **Pharynx**: common passage for air and food.
   - **Larynx**: contains the vocal cords and ensures air passage to the trachea.
2. **The Lower Respiratory Tract**
   - **Trachea**: main airway leading to the bronchi.
   - **Bronchi and bronchioles**: conduct air to the lungs.
   - **Alveoli**: microscopic air sacs where **gas exchange** occurs.

Each lung contains about **300–500 million alveoli**, providing a huge surface area (~70 m²) for gas exchange.

III. Functions of the Respiratory System

- **Gas exchange** (O_2 uptake, CO_2 elimination)
- **Regulation of blood pH** (via CO_2 control)
- **Voice production** (phonation)
- **Olfaction** (sense of smell)
- **Protection** (via mucus, cilia, and immune cells)



IV. The Process of Breathing (Pulmonary Ventilation)

Pulmonary ventilation = the mechanical movement of air into (**inspiration**) and out of (**expiration**) the lungs.

It depends on **pressure gradients** created by the movement of the **diaphragm** and **intercostal muscles**.

1. **AInspiration (Inhalation)**
   - **Active process**.
   - **Diaphragm contracts** → moves downward.
   - **External intercostal muscles** contract → rib cage expands.
   - Thoracic volume **increases**, intrapulmonary pressure **decreases** → air enters the lungs.

Pressure inside lungs < atmospheric pressure → air flows **in**.

2. **Expiration (Exhalation)**
   - **Passive process** at rest.
   - **Diaphragm and intercostal muscles relax** → thoracic volume decreases.
   - Lung pressure **increases** → air flows **out**.

Pressure inside lungs > atmospheric pressure → air flows **out**.

During **forced expiration** (exercise, coughing), **abdominal** and **internal intercostal muscles** contract actively.

V. Gas Exchange (External Respiration)

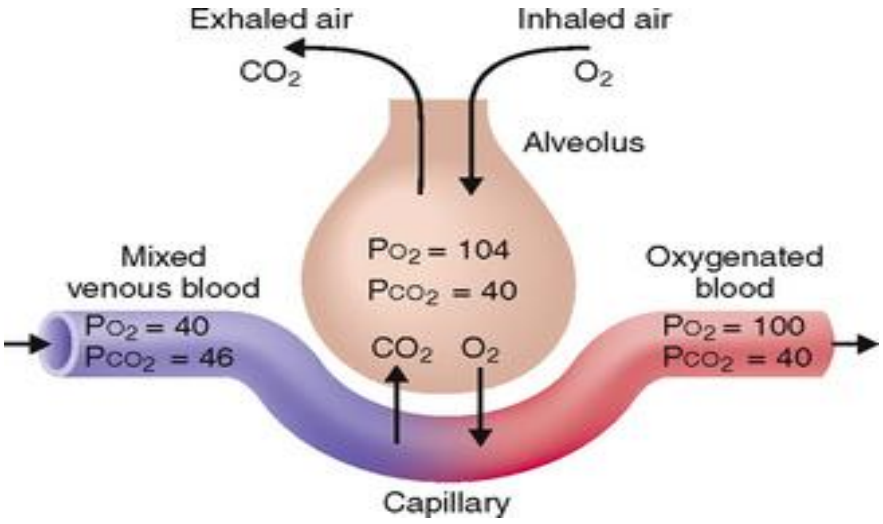
Occurs in the **alveoli** between **air** and **blood**:

- **O_2** diffuses from alveoli → pulmonary capillaries (into blood).
- **CO_2** diffuses from capillaries → alveoli (to be exhaled).

This process follows **Fick's Law of diffusion** — gases move from areas of **high partial pressure** to **low partial pressure**.

Typical partial pressures:

Location	PO_2 (mmHg)	PCO_2 (mmHg)
Alveolar air	104	40
Venous blood	40	45
Arterial blood (after exchange)	100	40



VI. Transport of Gases in the Blood

1. Oxygen Transport

- ~98% of O_2 binds to **hemoglobin (Hb)** in red blood cells:
- $Hb + O_2 \rightleftharpoons HbO_2$

- ~2% is dissolved directly in plasma.
- The **O_2 –Hb dissociation curve** shows how O_2 binding depends on PO_2 — affinity decreases with ↑ temperature, ↑ CO_2 , ↓ pH (Bohr effect).

2. Carbon Dioxide Transport

CO_2 is carried in three main forms:

Bicarbonate ions (HCO_3^-) → ~70% (via carbonic anhydrase reaction)

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

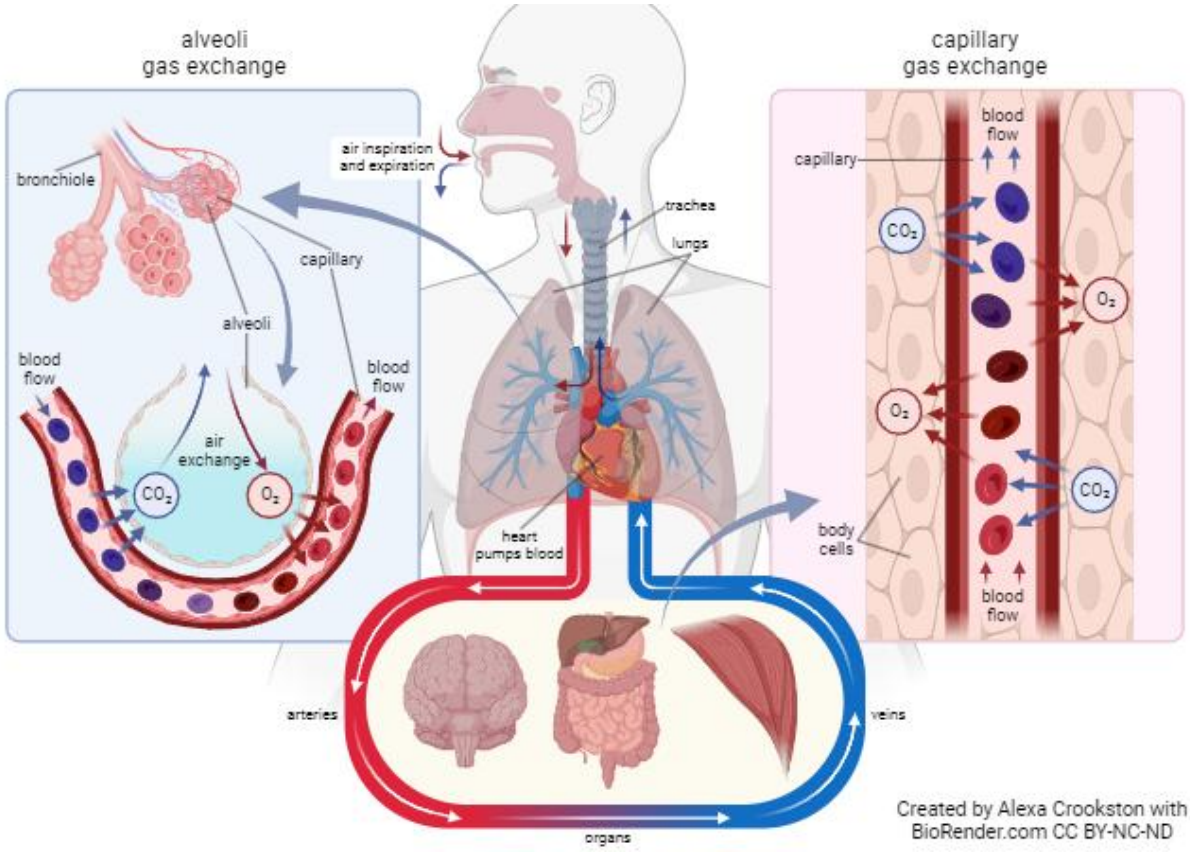
Bound to hemoglobin (carbaminohemoglobin) → ~23%

Dissolved in plasma → ~7%

VII. Internal Respiration (Tissue Gas Exchange)

At the **tissue level**:

- **O_2** diffuses from blood → cells.
- **CO_2** diffuses from cells → blood.
  This exchange ensures continuous cellular respiration and energy production.



VIII. Regulation of Respiration

Breathing is **automatic and rhythmic**, controlled by centers in the **brainstem**:

1. **Medullary Respiratory Centers**
   - **Dorsal respiratory group (DRG)** → controls inspiration.
   - **Ventral respiratory group (VRG)** → active during forced breathing.
2. **Pontine Centers (Pons)**

Apneustic and **pneumotaxic** centers → fine-tune breathing rhythm.

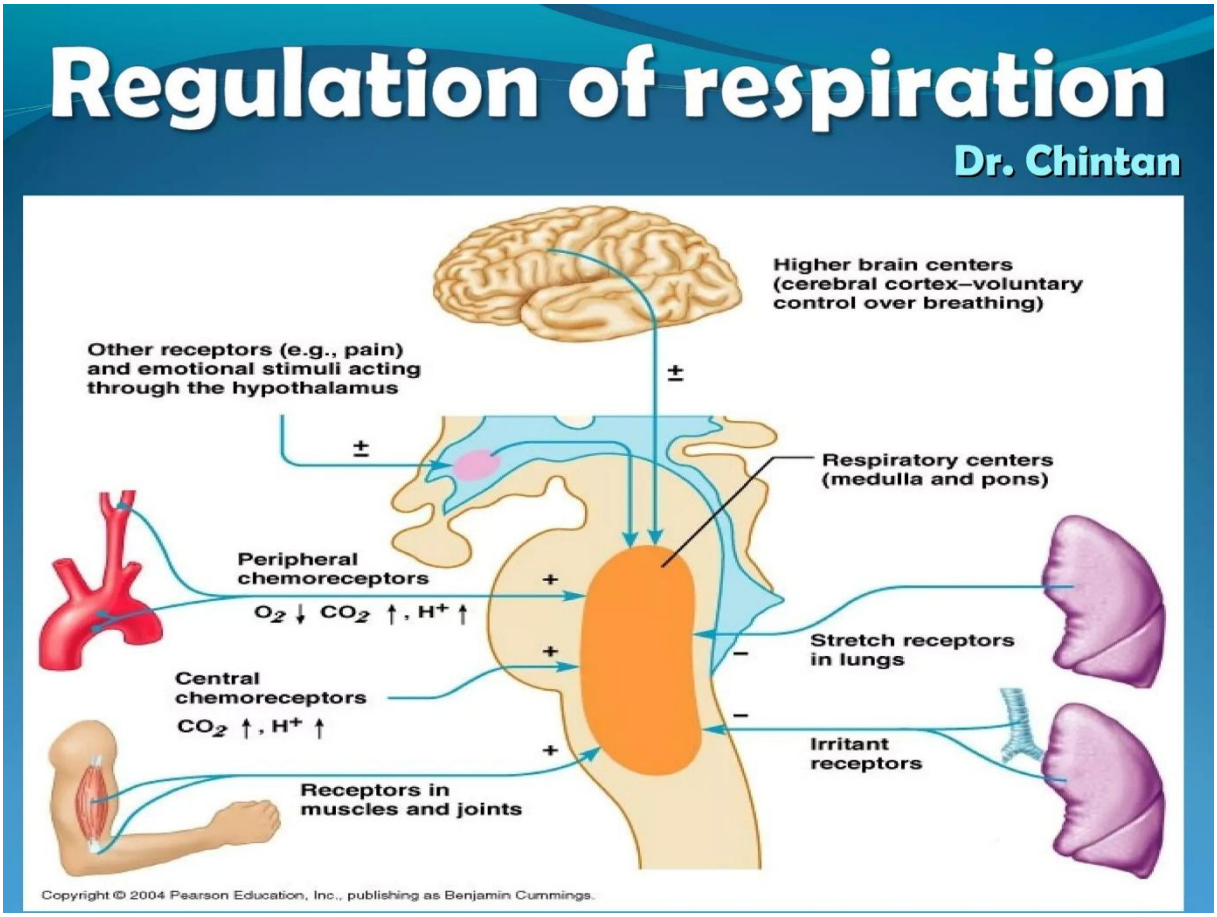
3. **Chemical Regulation**

Breathing rate is adjusted according to:

- ↑ **CO_2** → stimulates breathing (main driver)
- ↓ **O_2** → stimulates breathing (to a lesser extent)
- ↓ **pH** → increases ventilation

Chemoreceptors located in:

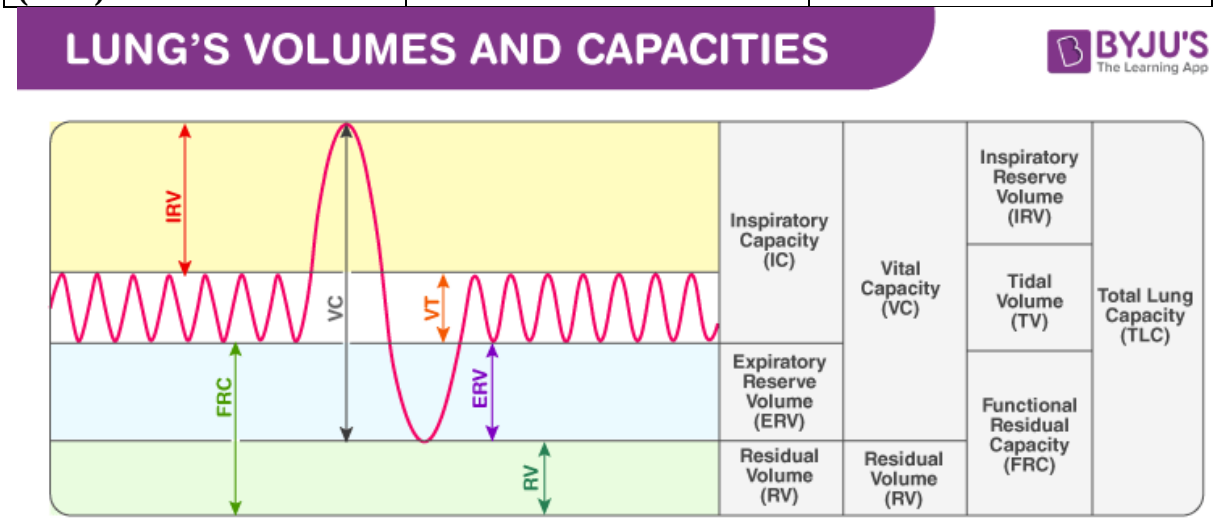
- **Central** (medulla)
- **Peripheral** (carotid and aortic bodies)



IX. Lung Volumes and Capacities

Term	Definition	Normal Value
Tidal Volume (TV)	Air inhaled/exhaled per normal breath	500 mL
Inspiratory Reserve Volume (IRV)	Max extra air inhaled after normal inspiration	3000 mL
Expiratory Reserve Volume (ERV)	Max extra air exhaled after normal expiration	1200 mL
Residual Volume (RV)	Air remaining in lungs after maximal exhalation	1200 mL
Vital Capacity (VC)	TV + IRV + ERV	4700 mL

Total Lung Capacity (TLC)	VC + RV	5900 mL



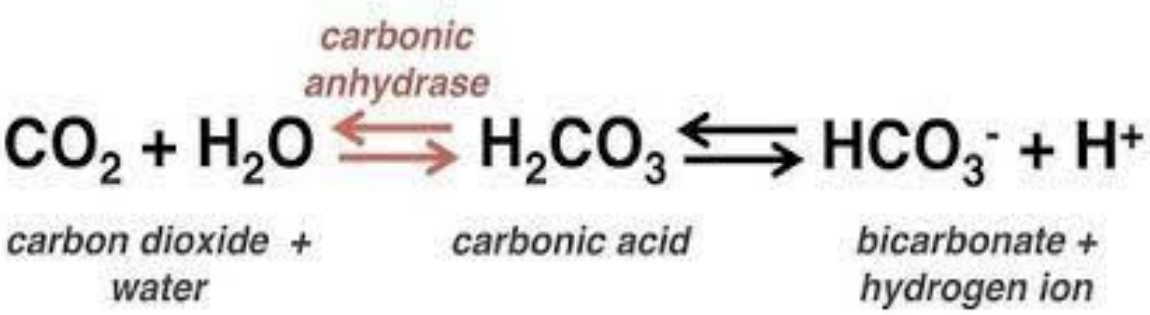
X. Respiratory Adjustments During Exercise

During physical activity:

- ↑ **Respiratory rate** and **tidal volume**
- ↑ **O_2 uptake** and **CO_2 elimination**
- Improved efficiency of **gas diffusion**
- Long-term training → ↑ **vital capacity** and **alveolar ventilation**

XI. 11. Acid–Base Balance

The respiratory system helps regulate **blood pH** by controlling CO_2 levels:

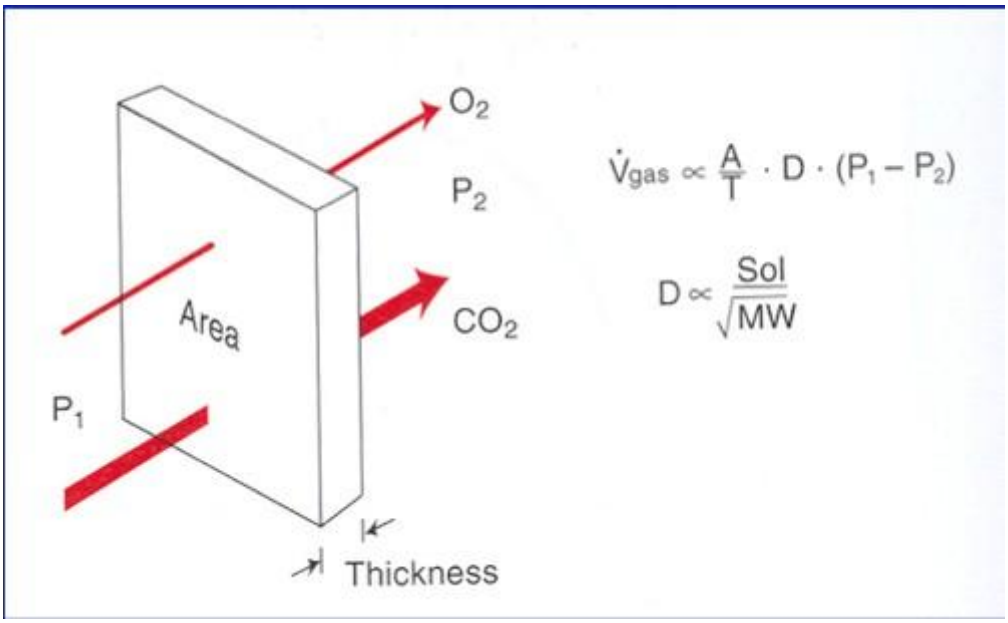


- ↑ CO_2 → ↓ pH (respiratory acidosis)
- ↓ CO_2 → ↑ pH (respiratory alkalosis)

XII. Fick's law

According to Fick's law, the rate at which a gas diffuses over a membrane is inversely proportional to the membrane's thickness and directly related to the membrane's surface area, the gas's diffusion coefficient, and the difference in partial pressure between the two sides.

This means that in the respiratory system, gases such as carbon dioxide (CO_2) and oxygen (O_2) travel across the alveolar-capillary membrane in accordance with their pressure gradients: carbon dioxide diffuses from the blood into the alveoli, while oxygen diffuses from the alveoli into the blood. Therefore, maintaining a wide surface area, a thin membrane, and significant pressure variations are essential for efficient gas exchange.



XIII. Conclusion

The respiratory system makes sure that carbon dioxide is eliminated and oxygen is continuously supplied, both of which are essential for life.

It sustains elevated metabolic demands during exercise or stress and preserves homeostasis through precise neuronal and molecular modulation.

Therefore, cellular metabolism, acid-base balance, and general health all depend on a healthy respiratory system.

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Physiology of the Nervous System

I. Introduction

The nervous system serves as the body's communication and control system.
It evaluates data, recognizes changes in the internal and external environment, and plans suitable reactions.

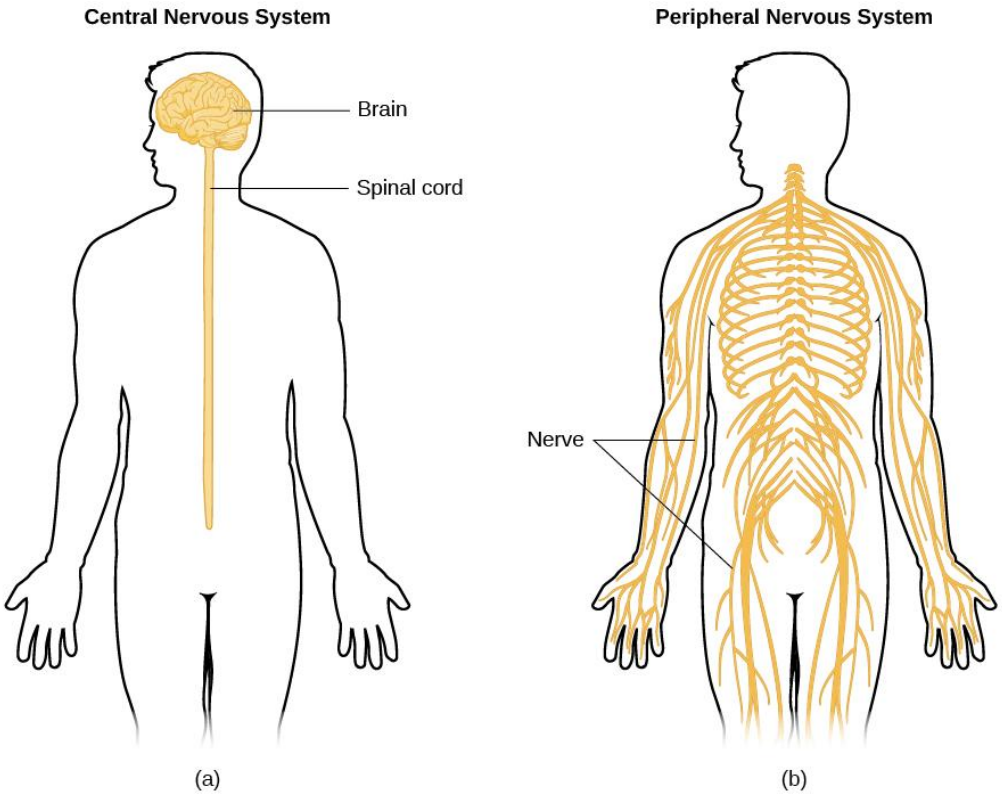
Its main functions are:

- **Sensory input** → detection of stimuli,
- **Integration** → interpretation and decision-making,
- **Motor output** → activation of muscles or glands.

II. Divisions of the Nervous System

The nervous system is organized into two major parts:

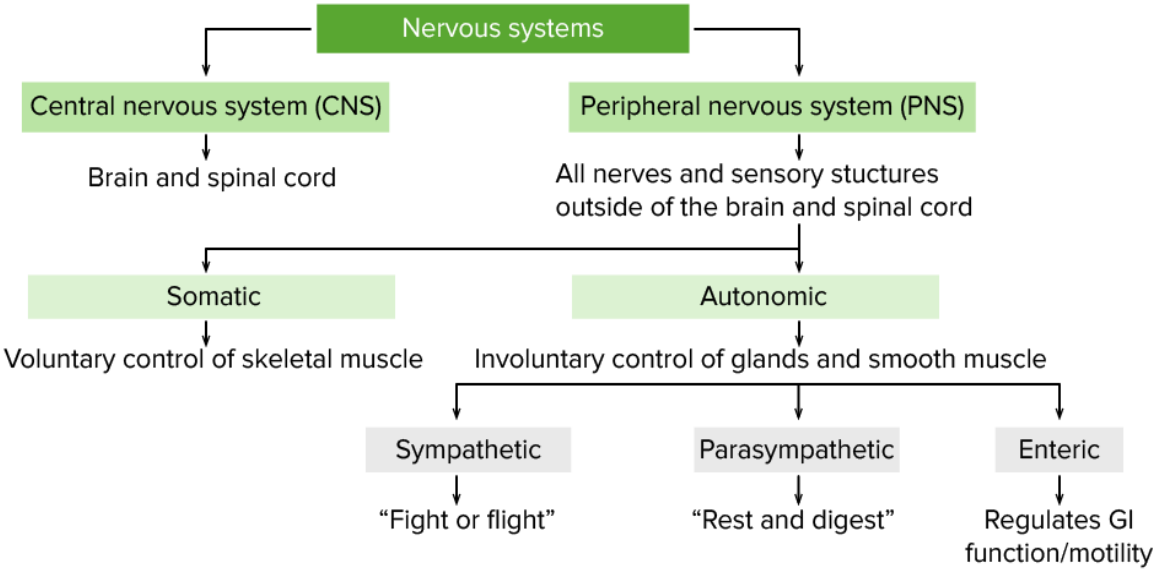
1. **Central Nervous System (CNS)**
   - **Components:** Brain and spinal cord.
   - **Functions:** Integration and control center — it interprets sensory input and dictates motor responses.
2. **Peripheral Nervous System (PNS)**
   - **Components:** All nerves outside the CNS (cranial and spinal nerves).
   - **Functions:** Connects the CNS to the body’s organs, muscles, and sensory receptors.



The PNS is further divided into:

- **Somatic Nervous System** – controls **voluntary** movements (skeletal muscles).
- **Autonomic Nervous System (ANS)** – controls **involuntary** activities (heart, glands, smooth muscles).
  - **Sympathetic division** → "fight or flight."

  Parasympathetic division → "rest and digest."



III. The Neuron: The Functional Unit

A **neuron** is a specialized cell that conducts electrical impulses.

Main parts:

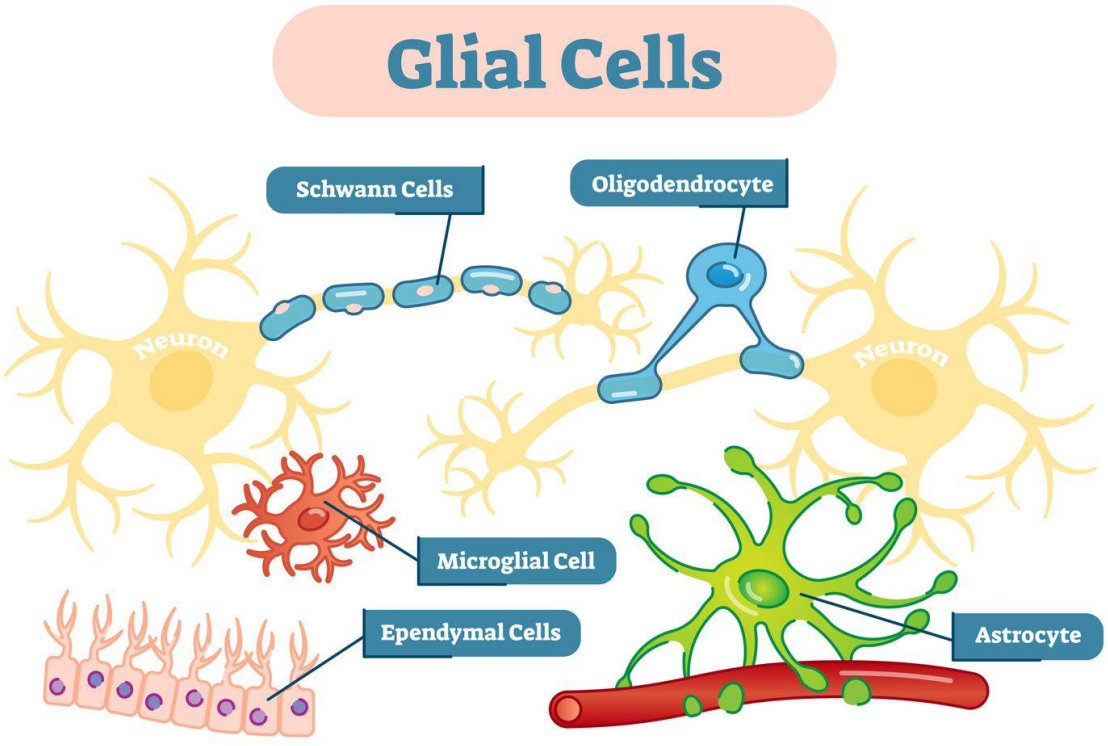
- **Dendrites:** Receive signals from other neurons.
- **Cell body (soma):** Contains the nucleus and metabolic machinery.
- **Axon:** Conducts impulses away from the cell body.
- **Myelin sheath:** Insulates the axon and speeds up impulse conduction.
- **Axon terminals:** Release neurotransmitters into synapses.

IV. Neuroglia (Supporting Cells)

Neurons are supported by neuroglial cells, which protect, nourish, and assist neural function.

Examples:

- **Astrocytes** → support and maintain the blood–brain barrier.
- **Oligodendrocytes (CNS)** and **Schwann cells (PNS)** → form myelin.
- **Microglia** → act as immune defense cells.
- **Ependymal cells** → produce and circulate cerebrospinal fluid (CSF).



V. The Nerve Impulse (Action Potential)

1. Resting Membrane Potential

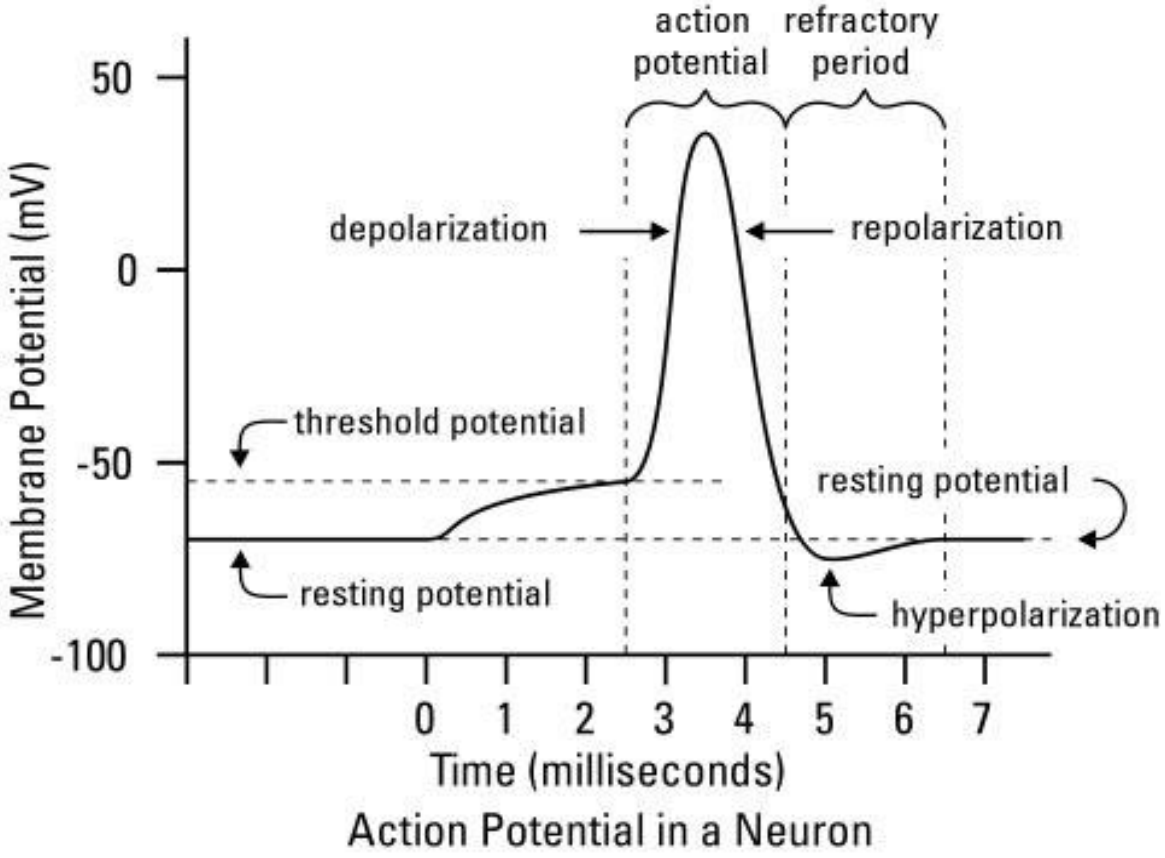
- The neuron's resting state shows a **negative electrical charge inside** (≈ –70 mV).
- Caused by **unequal ion distribution**:
  - High **Na^+** outside, high **K^+** inside.
  - Maintained by the **sodium–potassium pump (Na^+ /K^+ ATPase)**.

2. Generation of an Action Potential

When a stimulus reaches a neuron:

- **Depolarization** → Na^+ channels open, Na^+ enters the cell, inside becomes positive.
- **Repolarization** → K^+ channels open, K^+ leaves the cell, restoring negative charge.
- **Hyperpolarization** → brief period where the membrane potential becomes more negative than at rest.
- **Refractory period** → neuron cannot fire another impulse immediately.

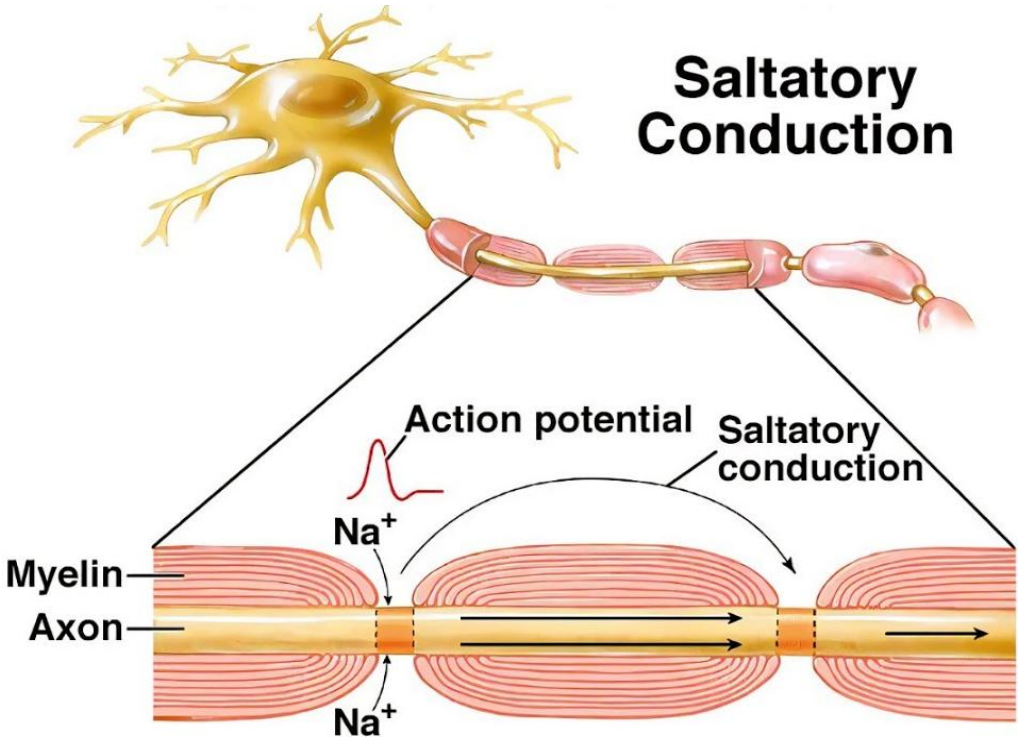
The action potential travels **unidirectionally** along the axon.



Action Potential in a Neuron

3. Saltatory Conduction

In **myelinated neurons**, impulses jump from one **node of Ranvier** to the next, making conduction **much faster** than in unmyelinated fibers.

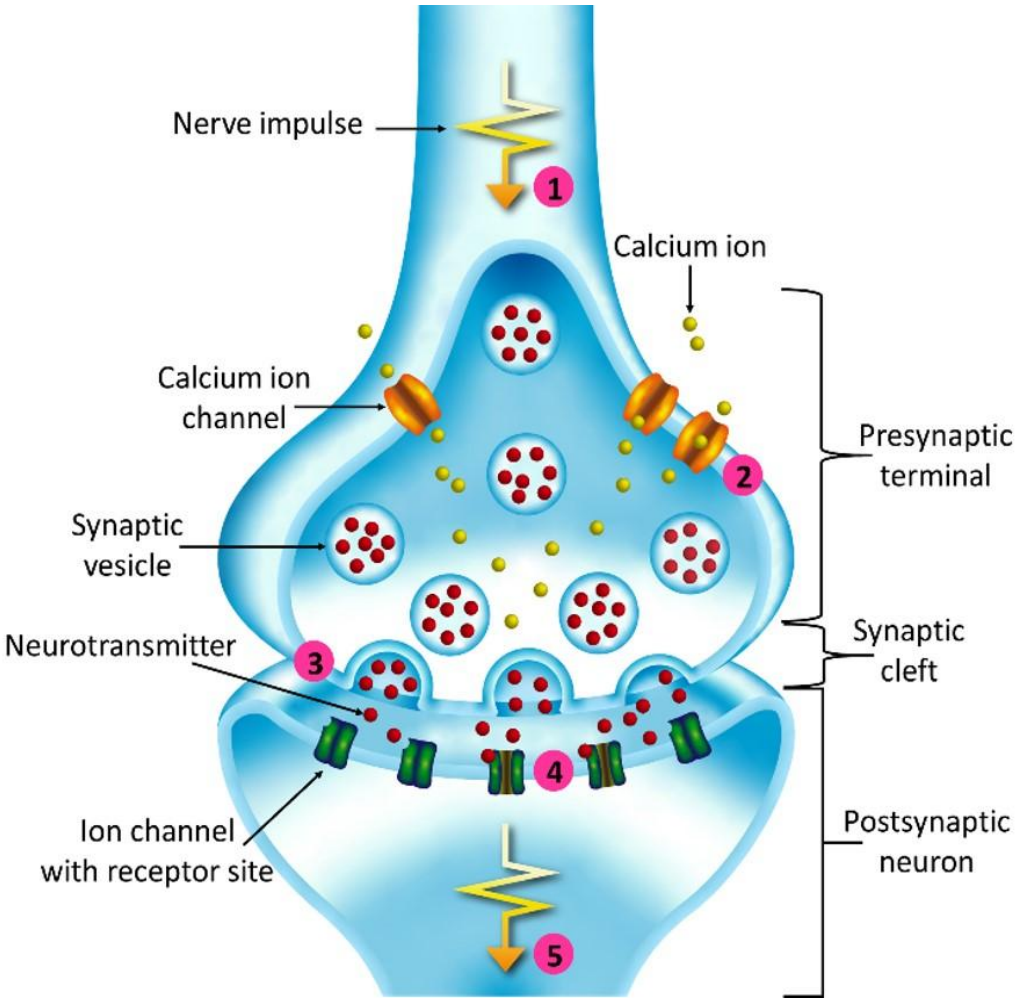


VI. The Synapse

A synapse is the junction between two neurons (or between a neuron and a muscle cell).

Steps of Synaptic Transmission:

- Action potential arrives at the axon terminal.
- **Calcium (Ca^{2+})** enters the terminal.
- **Vesicles release neurotransmitters** (e.g., acetylcholine, dopamine, serotonin).
- Neurotransmitters cross the **synaptic cleft**.
- They bind to **receptors** on the postsynaptic membrane → new electrical signal.
- Neurotransmitters are then **degraded**, **reabsorbed**, or **diffused** away.



VII. Neurotransmitters

Neurotransmitter	Function	Example
Acetylcholine (ACh)	Muscle contraction, memory	Neuromuscular junction
Dopamine	Motivation, pleasure, motor control	Parkinson's disease (deficiency)
Serotonin	Mood regulation, sleep	Low in depression
Noradrenaline	Alertness, stress response	Sympathetic system
GABA	Inhibitory neurotransmitter	Reduces neural excitability
Glutamate	Main excitatory transmitter	Learning and memory

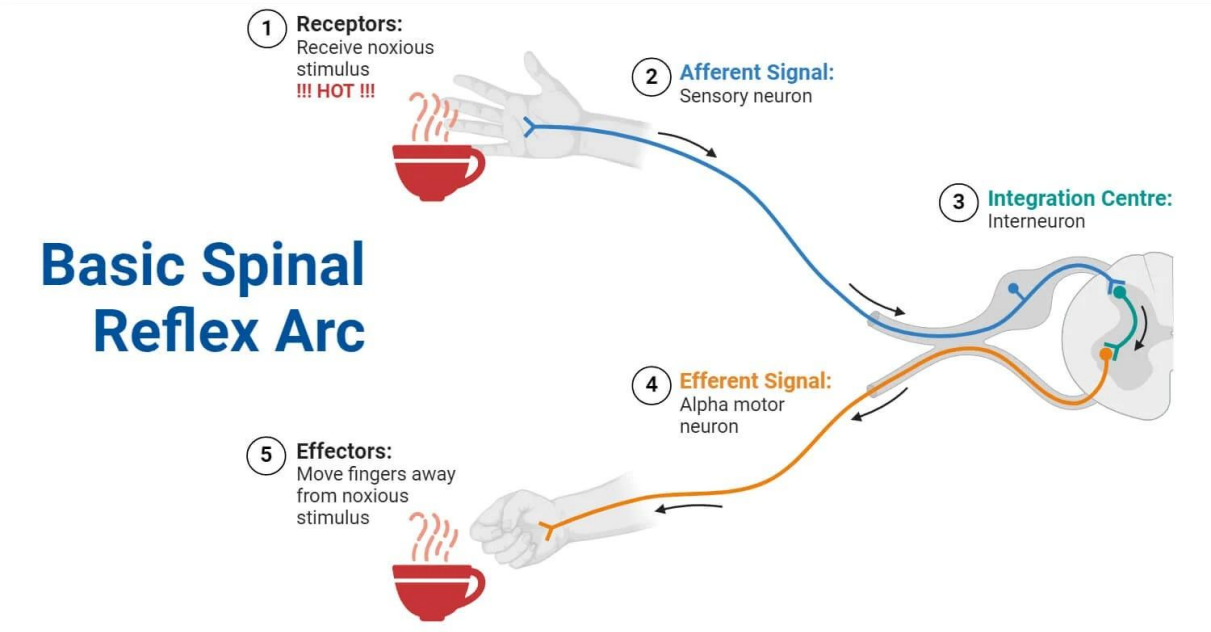
VIII. Reflexes and Reflex Arc

A reflex is a rapid, automatic response to a stimulus (e.g., knee jerk).
It protects the body by allowing quick reactions without conscious thought.

Reflex arc components:

- **Receptor** – detects the stimulus.
- **Sensory neuron** – carries impulse to CNS.
- **Integration center** – spinal cord or brain.
- **Motor neuron** – carries impulse to effector.

- **Effector** – muscle or gland responds.



IX. Autonomic Nervous System (ANS) Physiology

1. Sympathetic Division ("Fight or Flight")

- ↑ Heart rate and blood pressure
- ↑ Breathing rate
- Dilates pupils and bronchioles
- Inhibits digestion

2. Parasympathetic Division ("Rest and Digest")

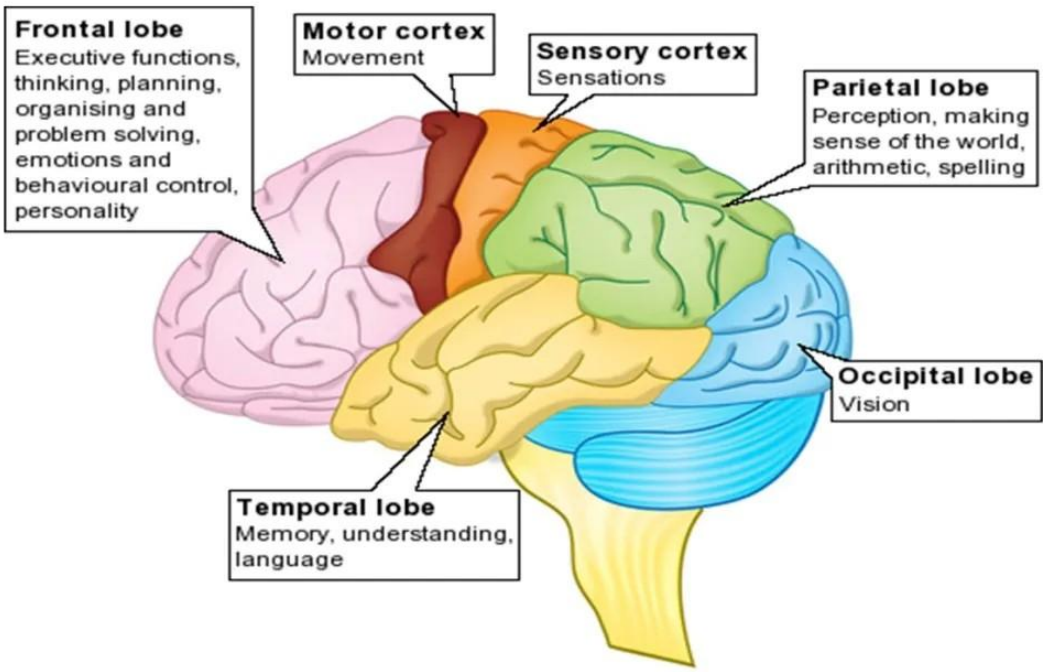
- ↓ Heart rate and blood pressure
- Stimulates digestion and salivation
- Constricts pupils and bronchioles
- Promotes energy storage

X. Higher Brain Functions

The **cerebral cortex** controls higher processes:

- Sensory perception
- Motor control
- Language and speech
- Memory and learning
- Emotions and reasoning

The **limbic system** regulates emotions, while the **hypothalamus** coordinates the autonomic system and endocrine functions.



XI. Integration and Homeostasis

The nervous system works with the **endocrine system** to maintain **homeostasis**.
For example:

- Detecting changes in body temperature.
- Regulating heart rate and respiration.
- Controlling hormone secretion (via hypothalamic–pituitary axis).

XII. Conclusion

All bodily functions are coordinated by the nervous system, a highly structured and effective communication network.

It maintains the body's homeostasis and permits thought, emotion, and movement by ensuring quick detection, integration, and reaction to inputs through chemical messengers and electrical impulses.

Physiology of the Skeletal System and the Postural Balance System of the Human Body

I. Introduction

The skeletal system gives the human body its basic foundation, supports and shields important organs, permits mobility, stores minerals, and generates blood cells.

It also plays a crucial part in postural balance, which enables the body to maintain stability and an upright posture when moving, in conjunction with the neurological and muscular systems.

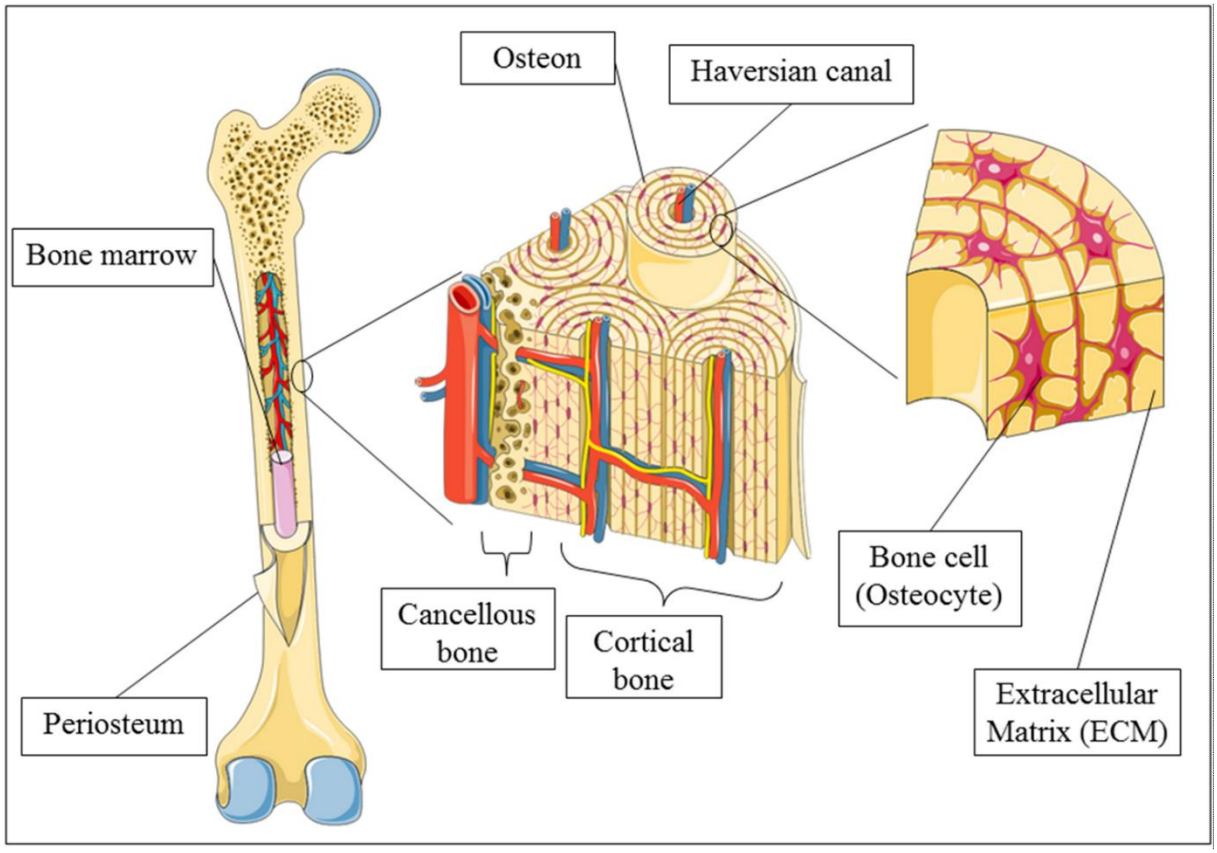
II. Functions of the Skeletal System

- **Support** – Provides a rigid framework for the attachment of muscles and soft tissues.
- **Protection** – Shields vital organs (e.g., skull protects the brain, ribs protect the lungs and heart).
- **Movement** – Bones act as levers; joints and muscles generate motion.
- **Mineral Storage** – Reservoir for calcium and phosphorus, essential for muscle and nerve function.
- **Blood Cell Formation (Hematopoiesis)** – Occurs in red bone marrow.
- **Energy Storage** – Yellow marrow stores lipids as an energy reserve.

III. Composition of Bone Tissue

Bone is a **living dynamic tissue**, constantly being remodeled and renewed.
It consists of:

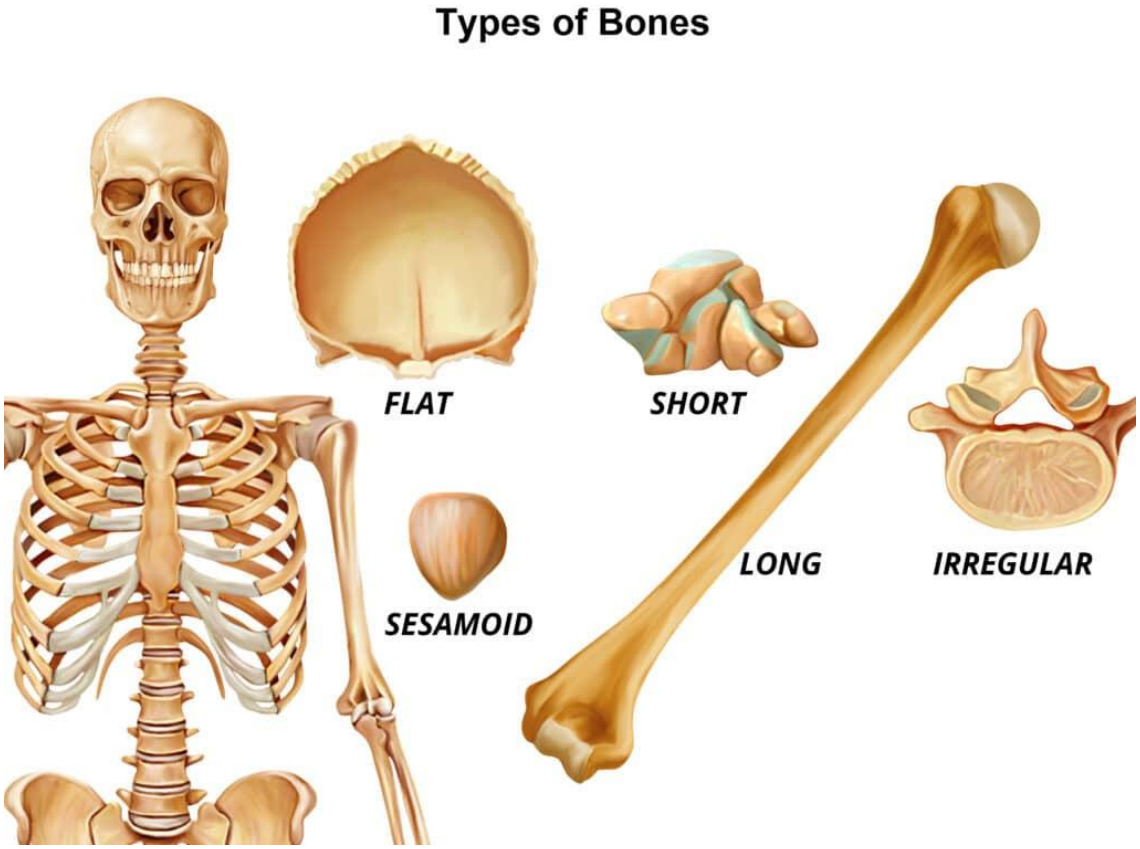
1. **Cellular Components**
   - **Osteoblasts** – Build bone matrix (bone formation).
   - **Osteocytes** – Mature bone cells that maintain bone tissue.
   - **Osteoclasts** – Break down bone matrix (resorption).
2. **Extracellular Matrix**
   - **Organic component (≈ 35%)** → collagen fibers (provide flexibility).
   - **Inorganic component (≈ 65%)** → calcium phosphate crystals (provide hardness).



IV. Bone Types and Structure

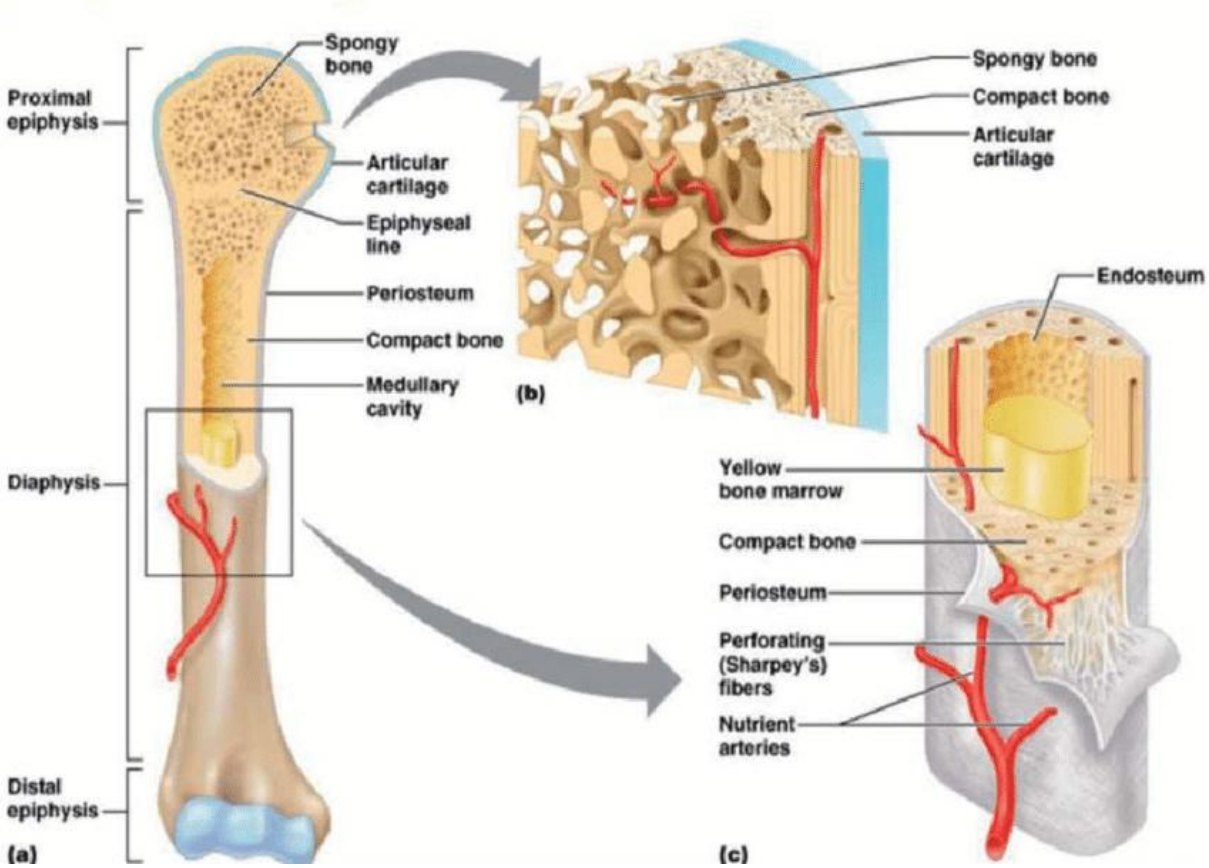
1. Types of Bones (by shape):

- Long (femur, humerus)
- Short (carpals, tarsals)
- Flat (skull, ribs)
- Irregular (vertebrae)
- Sesamoid (patella)



2. Structure of a Long Bone:

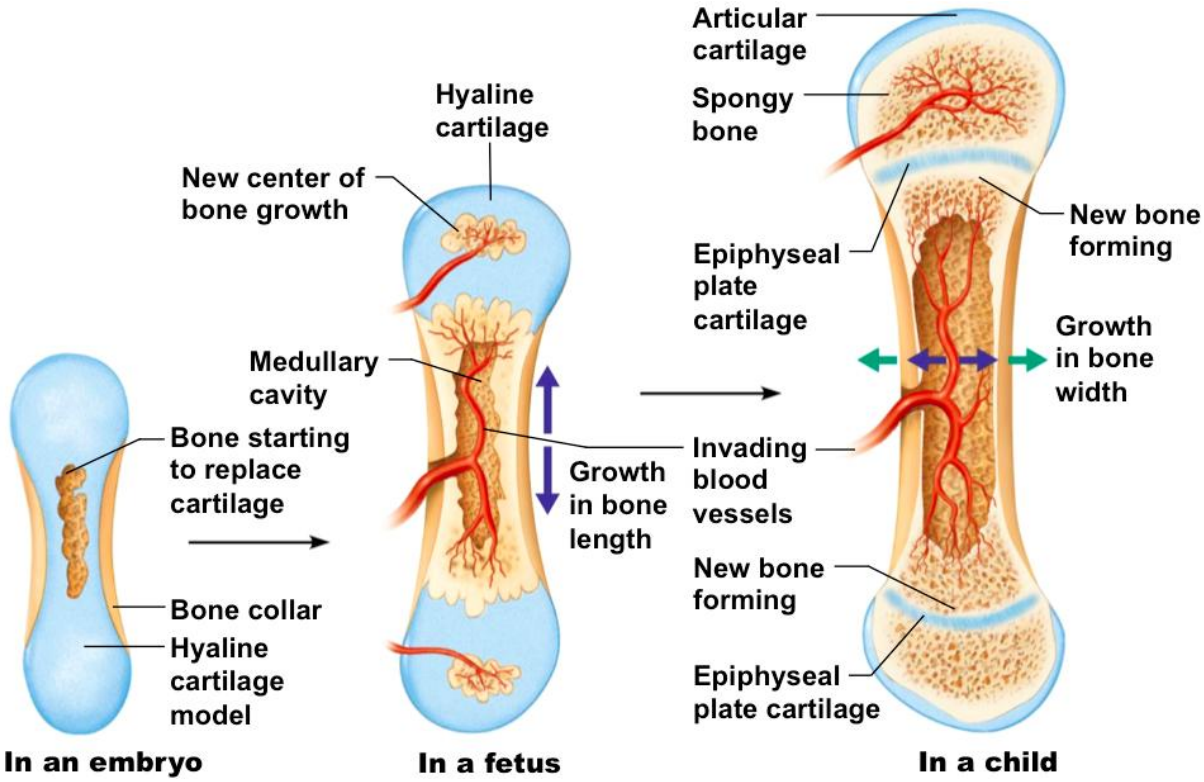
- **Diaphysis:** shaft containing the medullary cavity (yellow marrow).
- **Epiphyses:** ends of bone, containing red marrow.
- **Periosteum:** outer connective tissue layer rich in nerves and blood vessels.
- **Endosteum:** inner lining of bone cavities.
- **Articular cartilage:** covers joint surfaces to reduce friction.



V. Bone Physiology: Growth and Remodeling

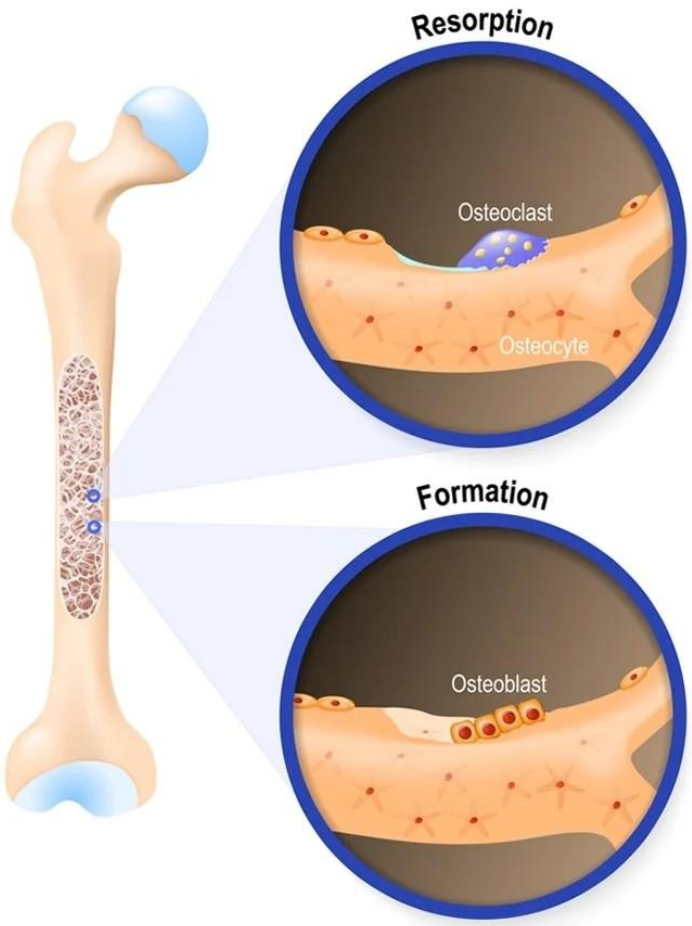
1. Bone Growth

- Occurs by **endochondral ossification** (in long bones) or **intramembranous ossification** (in flat bones).
- Regulated by **growth hormone**, **thyroid hormone**, and **sex hormones** (estrogen/testosterone).



2. Bone Remodeling

- Continuous process of bone **formation** (by osteoblasts) and **resorption** (by osteoclasts).
- Regulated by:
  - **Mechanical stress** (Wolff's law: bone adapts to the forces placed on it)
  - **Hormones:**
    - **Parathyroid hormone (PTH):** ↑ calcium in blood (stimulates bone resorption)
    - **Calcitonin:** ↓ calcium in blood (inhibits osteoclasts)
    - **Vitamin D:** enhances calcium absorption and bone mineralization

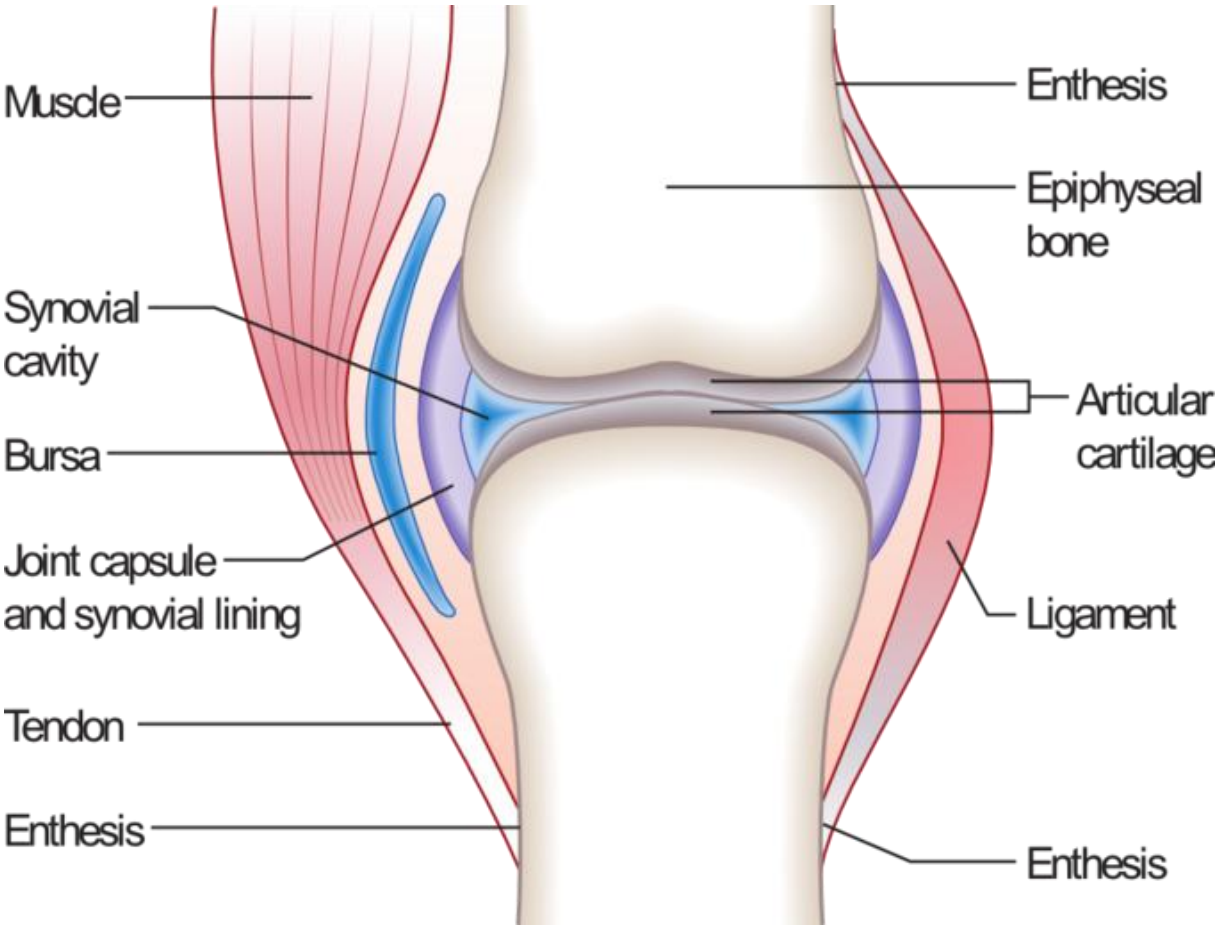


VI. Joints and Movement

Bones are connected by **joints (articulations)** that allow varying degrees of movement:

Type of Joint	Example	Function
Fibrous	Skull sutures	Immovable
Cartilaginous	Intervertebral discs	Slightly movable
Synovial	Shoulder, knee	Freely movable

Synovial joints contain **synovial fluid** that lubricates and nourishes the articular cartilage, reducing friction during motion.



VII. Interaction with the Muscular System

Movement and posture depend on the **skeletal–muscular interaction**:

- **Bones** act as levers.
- **Joints** act as fulcrums.
- **Muscles** provide the force of movement through **tendons**.

This cooperation allows **voluntary movements** and **stability**, under the control of the **nervous system**.

The Postural Balance System

I. Definition

The capacity to keep the body's center of gravity (COG) above its base of support (BOS) both at rest (static balance) and during movement (dynamic balance) is known as postural balance, or postural control.

It relies on the nervous system's coordination of motor responses and the assimilation of sensory data.

II. Components of the Postural Balance System

Postural control involves **three main systems** working together:

1. Sensory Systems

Provide information about body position and motion:

- **Visual system:** detects orientation and motion relative to surroundings.
- **Vestibular system (inner ear):** detects head position, gravity, and acceleration.
- **Somatosensory (proprioceptive) system:** provides feedback from muscles, joints, and skin.

2. Central Nervous System (CNS)

- Integrates sensory input in the **cerebellum**, **brainstem**, and **cerebral cortex**.
- The **cerebellum** fine-tunes motor commands for equilibrium.
- The **vestibular nuclei** coordinate eye and head movements (vestibulo-ocular reflex).

3. Musculoskeletal System

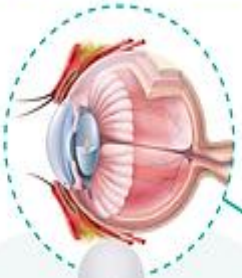
- Provides the **mechanical support** and **motor execution** to maintain posture.
- Involves coordinated action of **antigravity muscles** (erector spinae, gluteals, quadriceps, calves).

Balance

MECHANISMS

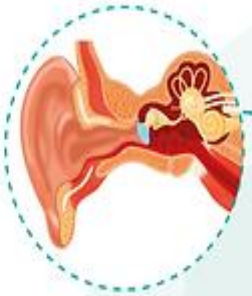
visual

Spatial, motion and depth perception
Eye coordination
Stable Gaze
Clear Vision



brain

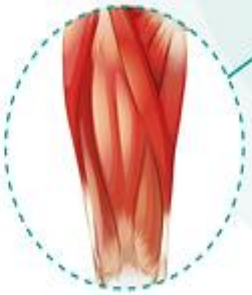
The brain receives the information processes it, sorts it, and integrates it.



vestibular

Rotational movement
Linear movement
Equilibrium
Gravity

Brain sends impulses to the muscles that control movement, to coordinate posture and balance.



proprioception

Sense of body positioning
Joints
Muscles
Skin

balance

Balance is maintained by the complex system of sensory inputs and motor control.

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www.physiosensing.net
info@sensingfuture.pt

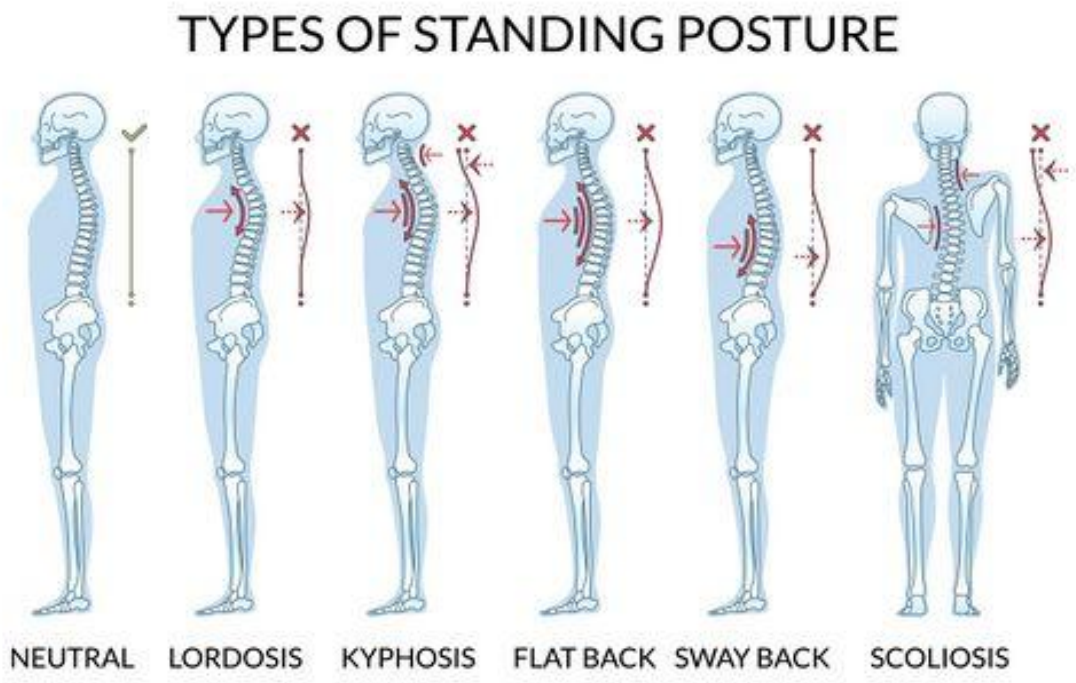
III. Mechanisms of Postural Control

The body maintains balance through **continuous feedback and correction**:

- **Sensory detection** of position or motion (visual, vestibular, proprioceptive).
- **Integration** of sensory input in the CNS.
- **Motor output** to muscles to correct imbalance.

➢ **Types of postural adjustments:**

- **Anticipatory (feedforward):** prepared before movement (e.g., tightening core muscles before lifting).
- **Compensatory (feedback):** activated after a disturbance (e.g., catching your balance after slipping).



IV. Factors Affecting Postural Balance

- **Age:** reduced proprioception and muscle strength with aging.
- **Fatigue:** decreases neuromuscular control.
- **Injury:** particularly to ankle or knee joints.
- **Vision impairment:** reduces stability.
- **Neurological disorders:** Parkinson's, cerebellar lesions, vestibular dysfunction.

Conclusion

The postural balance system integrates sensory, neurological, and muscular components to maintain the body's equilibrium, while the skeletal system provides the mechanical framework and protection required for movement and stability.

Together, they preserve posture, coordination, and effective mobility, enabling people to engage with their surroundings in a safe and productive manner.

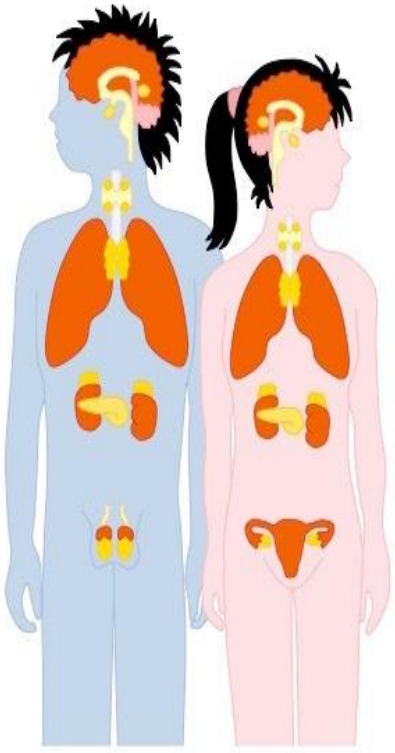
Physiology of the Endocrine System

I. Introduction

A group of glands known as the endocrine system create and release hormones, which are chemical messengers that control a variety of physiological functions.

The endocrine system coordinates long-term processes including growth, metabolism, reproduction, and homeostasis by using hormones that flow through the bloodstream to target distant organs, in contrast to the nervous system, which employs electrical impulses.

II. Major Endocrine Glands and Their Hormones



Gland	Hormone	Target Organ	Function
Pineal gland	melatonin	many	biological clock
Pituitary gland	FSH / LH ADH growth hormone oxytocin prolactin	ovaries kidneys many uterus breast tissue	menstrual cycle osmoregulation growth & division birth contractions milk production
Thyroid gland	thyroxin	liver	metabolic rate
Adrenal glands	adrenaline cortisol	many many	fight or flight anti-stress
Pancreas	insulin / glucagon	liver	blood sugar levels
Ovaries	estrogen / progesterone	uterus	menstrual cycle
Testes	testosterone	many	male characteristics

III. Hormone Types and Mechanisms of Action

I. Hormone Types:

- **Peptide/Protein hormones** (e.g., insulin, growth hormone): water-soluble, bind to surface receptors.
- **Steroid hormones** (e.g., cortisol, sex hormones): lipid-soluble, pass through cell membranes, bind to intracellular receptors.
- **Amine hormones** (e.g., thyroid hormones, catecholamines): derived from amino acids, act via various mechanisms.

II. Mechanisms of Action:

- **Peptide hormones** bind to cell surface receptors → activate second messengers (e.g., cAMP) → alter cellular activity.

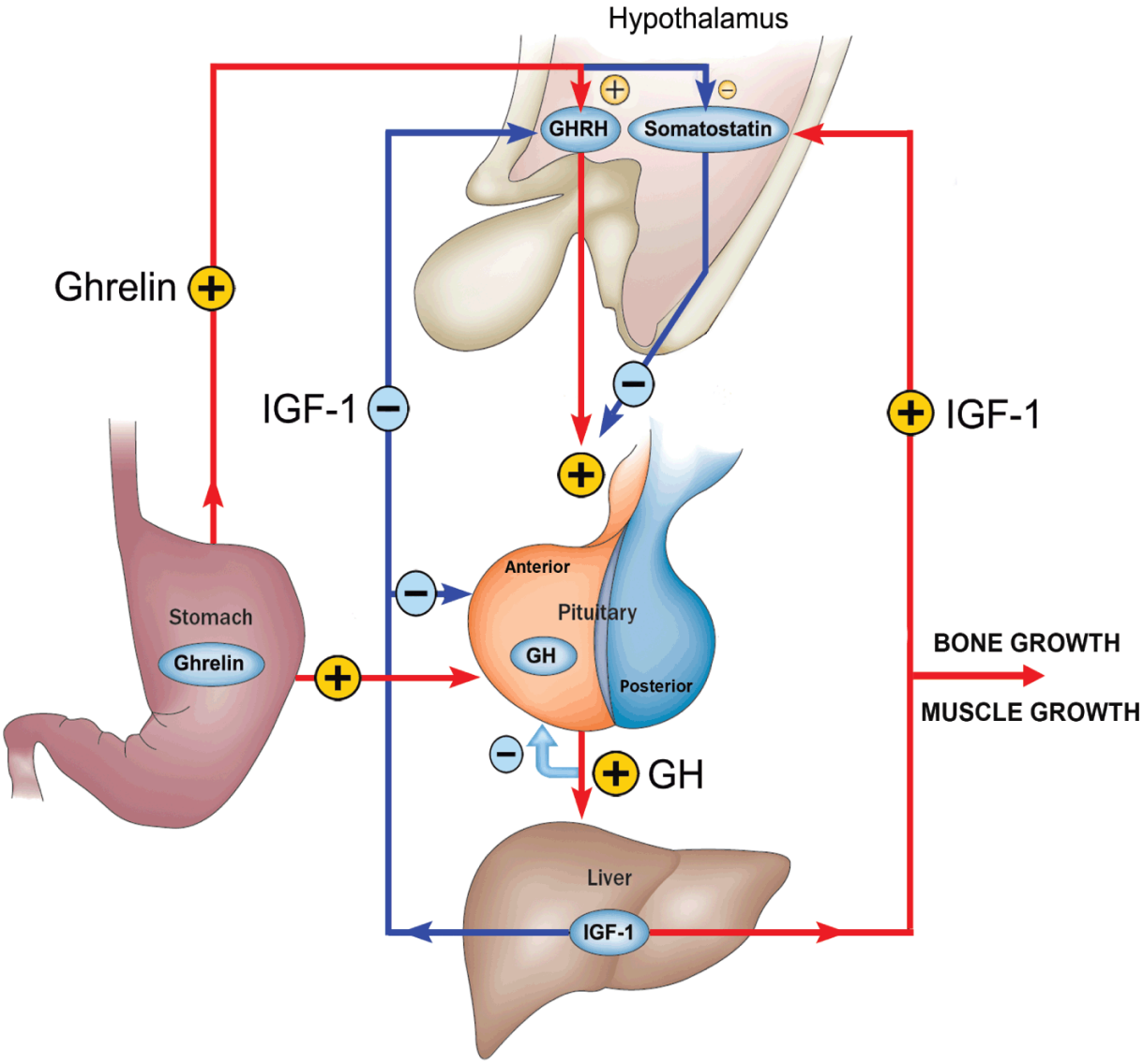
- **Steroid hormones** enter the cell → bind to nuclear receptors → modulate gene transcription → protein synthesis changes.

III. Regulation of Hormone Secretion

Hormone secretion is tightly regulated by **feedback loops**, mainly **negative feedback**, to maintain homeostasis.

Examples:

- **Hypothalamic-pituitary axis**: hypothalamus releases releasing hormones → pituitary secretes stimulating hormones → target gland produces hormone → high levels inhibit hypothalamus and pituitary.
- **Blood glucose regulation**: high blood glucose stimulates insulin release; low glucose stimulates glucagon release.



IV. Key Endocrine Axes

1. Hypothalamic-Pituitary-Adrenal (HPA) Axis

Stress stimulates hypothalamus → CRH release → pituitary → ACTH release → adrenal cortex → cortisol release.

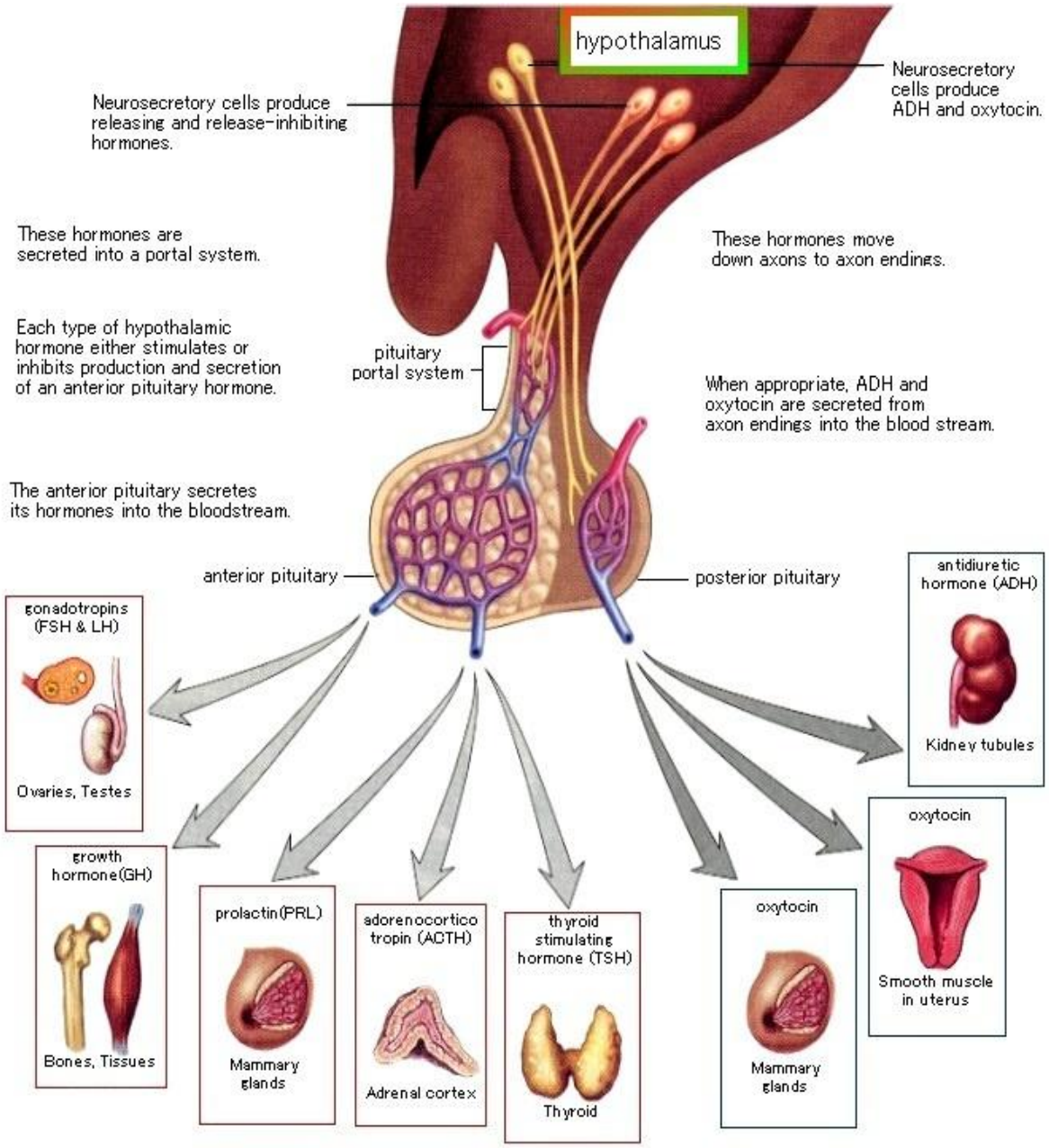
Cortisol regulates metabolism and immune response.

2. Hypothalamic-Pituitary-Thyroid (HPT) Axis

TRH from hypothalamus → TSH from pituitary → thyroid gland → T3 and T4 secretion → regulate basal metabolic rate.

3. Hypothalamic-Pituitary-Gonadal (HPG) Axis

GnRH → LH and FSH → gonads → sex hormone production → regulate reproduction.



V. Physiological Roles of Hormones

Hormone	Main Effects
Growth Hormone (GH)	Stimulates growth, protein synthesis, fat metabolism
Thyroid Hormones (T3, T4)	Increase metabolic rate, regulate development
Insulin	Lowers blood glucose by promoting uptake into cells
Glucagon	Raises blood glucose by stimulating glycogen breakdown
Cortisol	Increases blood glucose, suppresses inflammation
Aldosterone	Increases sodium retention, regulates blood pressure
Antidiuretic Hormone (ADH)	Promotes water reabsorption in kidneys
Estrogen and Testosterone	Regulate sexual development and reproduction

VI. Integration with Other Systems

The endocrine system works closely with:

- **Nervous system**: hypothalamus acts as a link, rapid and slow responses.
- **Immune system**: hormones modulate immune activity.
- **Cardiovascular system**: hormones regulate blood pressure and volume.

VII. Conclusion

Maintaining homeostasis, controlling metabolism, development, reproduction, and stress adaptation all depend on the endocrine system.

Its hormones serve as potent transmitters that coordinate intricate body processes over both brief and extended periods of time.

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Physiology of the membrane system

I. Introduction

All of the cellular membranes that encircle a cell and its internal compartments make up the membrane system, also known as the biological membrane system.
It is essential to:

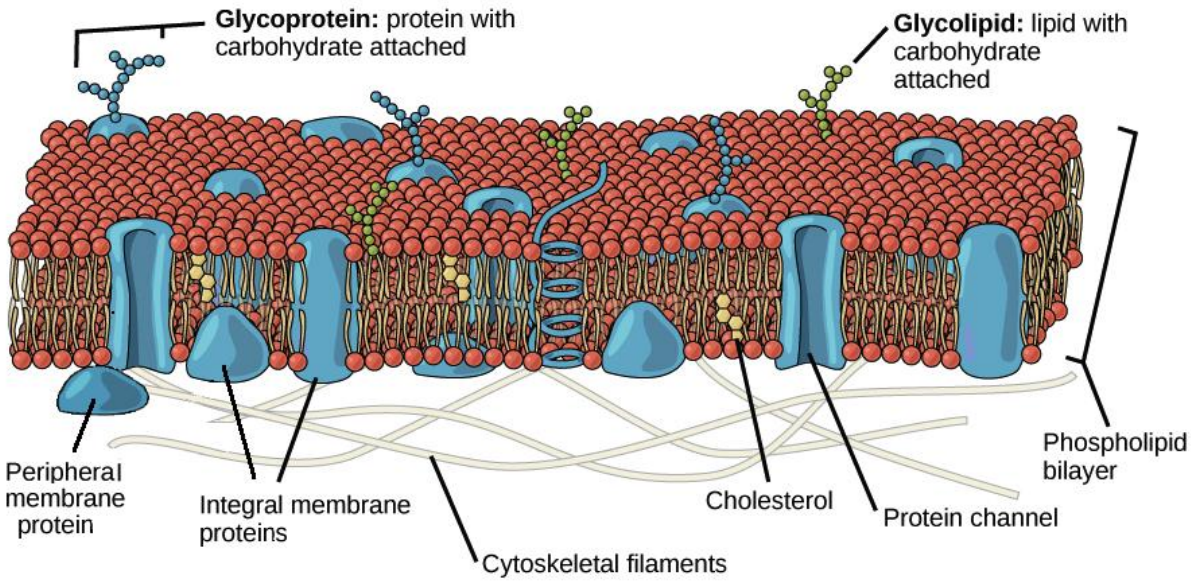
- Protecting the cell,
- Controlling exchanges between the intracellular and extracellular environments,
- Cell communication,
- Transport of substances, and
- Signal transmission.

Membrane physiology examines how the structure, content, and bioelectrical characteristics of these membranes enable them to carry out their vital duties.

II. Structure of the Plasma Membrane

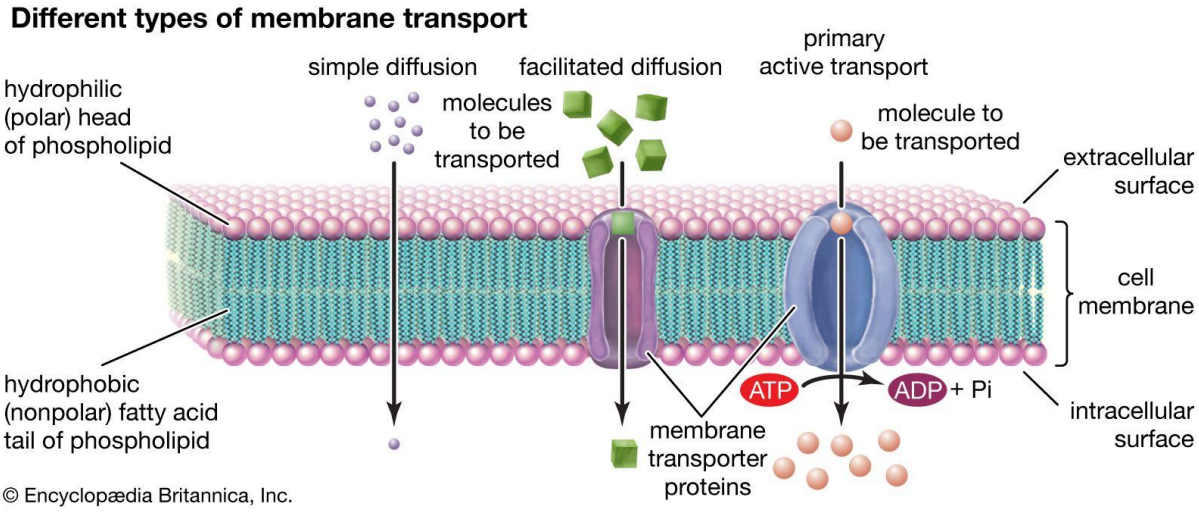
The plasma membrane is a flexible lipid bilayer about 7–10 nm thick, composed of:

1. **Lipids**
   - Phospholipids: form the amphipathic bilayer (hydrophilic heads and hydrophobic tails).
   - Cholesterol: stabilizes and regulates membrane fluidity.
   - Glycolipids: involved in cell recognition.
2. **Proteins**
   - Peripheral proteins: located on the membrane surface; involved in signaling and anchoring.
   - Integral (transmembrane) proteins: span the lipid bilayer and act as channels, carriers, or receptors.
3. **Carbohydrates**
   - Attached to lipids (glycolipids) or proteins (glycoproteins).
   - Form the glycocalyx, which protects the cell and allows for recognition and adhesion.



III. General Functions of the Membrane

1. **Selective barrier:** controls movement of molecules into and out of the cell.
2. **Communication:** via membrane receptors and signaling molecules.
3. **Transport:** regulates exchange of ions, nutrients, and waste.
4. **Immune recognition:** through membrane antigens.
5. **Structural support:** anchors cytoskeletal elements and maintains cell shape.



IV. Types of Transport Across the Membrane

A. Passive Transport (no energy required)

Movement occurs **down the concentration gradient** (from high to low concentration).

1. Simple Diffusion

- Movement of small, nonpolar molecules (O_2 , CO_2 , steroid hormones) directly through the lipid bilayer.
- Governed by Fick's law, which states that:

The rate of diffusion is proportional to surface area, concentration gradient, and permeability, and inversely proportional to membrane thickness.

2. Facilitated Diffusion

- Movement of polar molecules (glucose, ions) through protein channels or carriers.
- Examples:
  - Sodium (Na^+) and potassium (K^+) channels.
  - Glucose transporter (GLUT).

3. Osmosis

- Movement of water across a semipermeable membrane.
- Water moves from a region of low solute concentration to high solute concentration.
- Important for maintaining cell volume and osmotic balance.

B. Active Transport (requires energy, usually ATP)

→ Moves substances **against** their concentration gradient.

1. Primary Active Transport

- Uses ATP directly.
- Example: Na^+ /K^+ -ATPase pump
  - Pumps 3 Na^+ ions out and 2 K^+ ions in.
  - Maintains the resting membrane potential and osmotic balance.

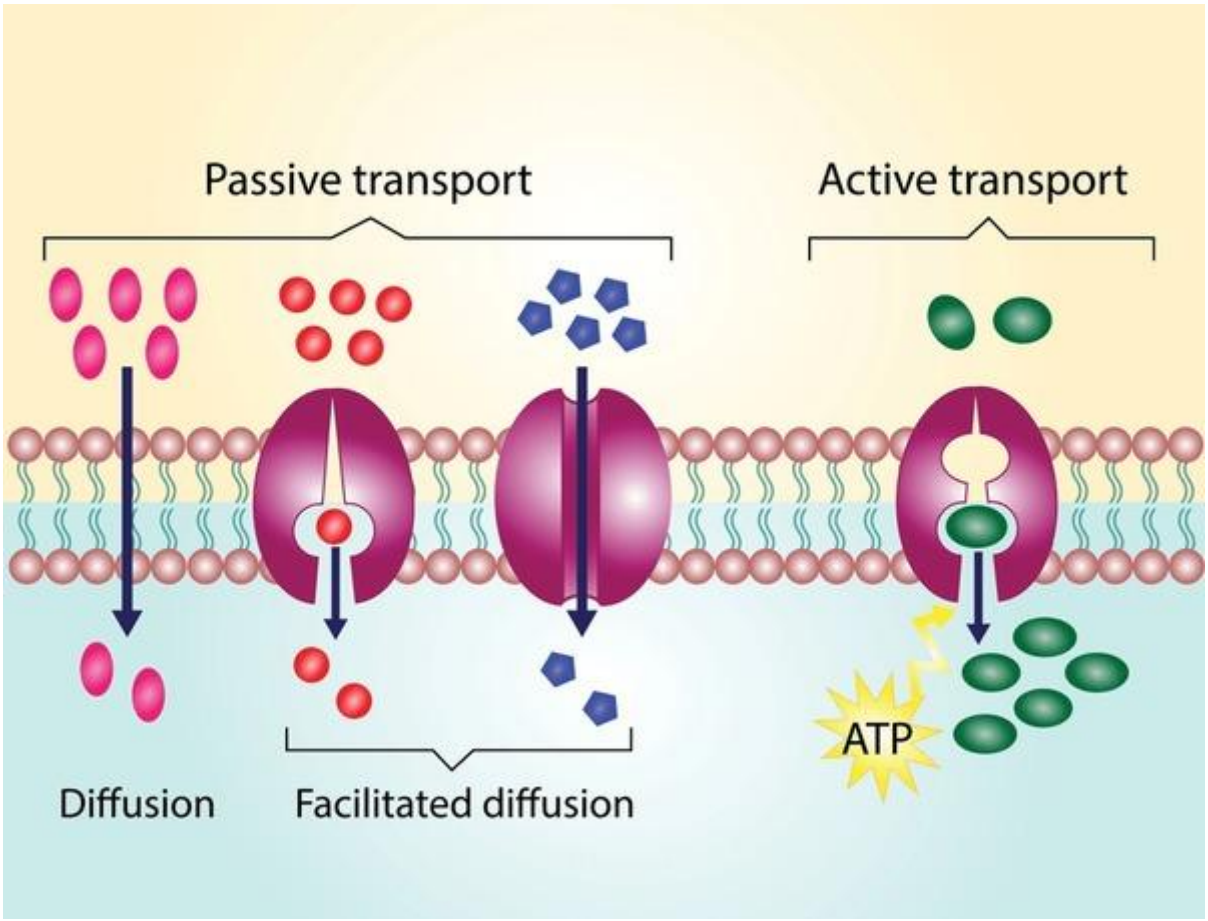
2. Secondary Active Transport

- Uses energy from ion gradients (often Na^+) created by primary transport.
  - Cotransport (symport): two molecules move in the same direction (e.g., Na^+ /glucose).
  - Countertransport (antiport): molecules move in opposite directions (e.g., Na^+ /Ca^{2+} exchanger).

C. Vesicular Transport

Involves movement of large particles via **membrane deformation**.

Type	Description	Example
Endocytosis	Intake of materials via vesicles formed from the plasma membrane	Phagocytosis (cell eating), pinocytosis (cell drinking)
Exocytosis	Release of substances from vesicles to the outside	Hormone or neurotransmitter secretion
Transcytosis	Transport of substances across a cell	Passage of antibodies through epithelial cells



V. Membrane Potential

The plasma membrane is **electrically polarized**:

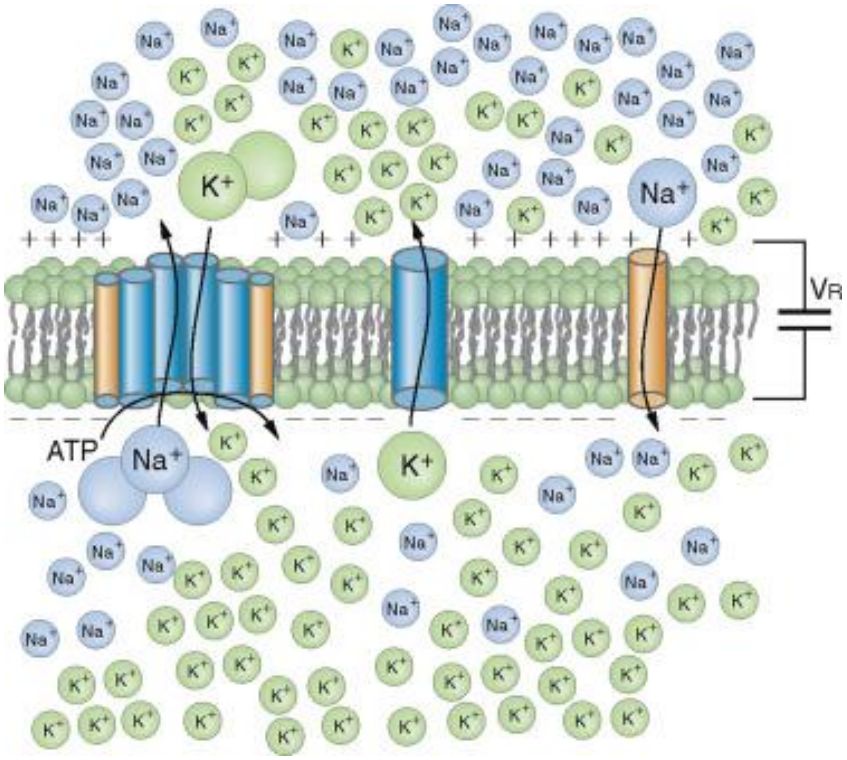
- Inside: negatively charged (≈ –70 mV)
- Outside: positively charged

Mechanisms:

- Unequal distribution of ions (Na^+ , K^+ , Cl^-).
- Na^+ /K^+ -ATPase pump activity.
- Selective permeability of K^+ channels.

Types of Potentials:

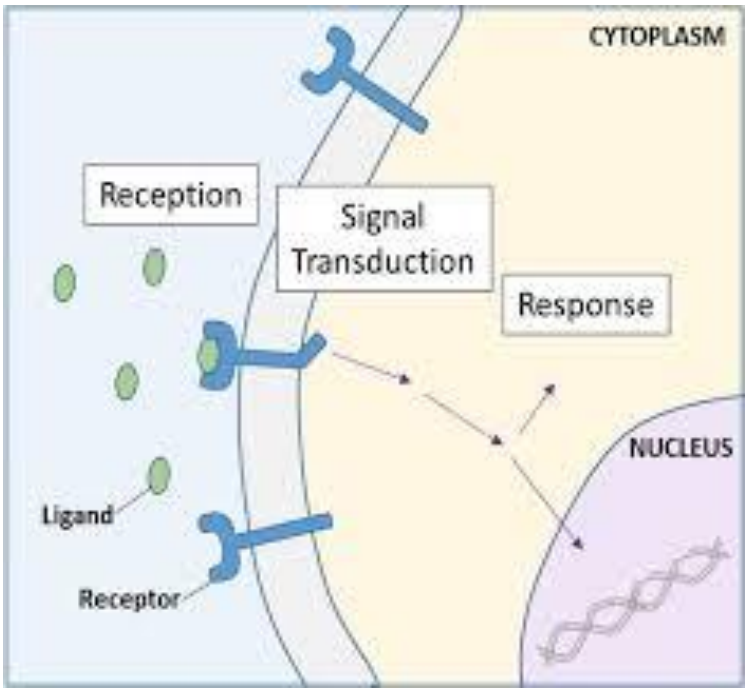
- Resting membrane potential: stable electrical state of a non-excited cell.
- Action potential: rapid change in potential during stimulation (in neurons, muscles).
    - **Depolarization:** Na^+ influx.
    - **Repolarization:** K^+ efflux.
    - **Return to rest:** restoration by ion pumps.



VI. Cell Communication and Membrane Receptors

Cells communicate through **chemical signals** (ligands) that bind to **specific membrane receptors**:

Receptor Type	Example	Mechanism
Ligand-gated ion channel	Nicotinic acetylcholine receptor	Opens ion channels when ligand binds
G-protein-coupled receptor (GPCR)	Adrenergic receptor	Activates intracellular messengers (cAMP, IP_3)
Enzyme-linked receptor	Insulin receptor	Activates intracellular phosphorylation cascades



VII. Membrane Physiology and Pathophysiology

Abnormalities in membrane function can cause diseases:

Disease	Mechanism
Cystic Fibrosis	Mutation in CFTR chloride channel → thick mucus secretion
Bartter Syndrome	Defective renal ion transporters
Myasthenia Gravis	Autoantibodies block acetylcholine receptors → muscle weakness
Cyanide Poisoning	Inhibits electron transport → blocks ATP-dependent membrane pumps

VIII. Conclusion

The membrane system is fundamental to cell life. It ensures:

- Selective control of molecular exchanges,
- Transmission of electrical and chemical signals,
- Maintenance of ionic balance, and
- Coordination of metabolic processes across compartments.

Any disturbance in membrane structure or function can severely disrupt **cell homeostasis** and lead to disease

Physiology of the organs of the digestive system

I. Introduction

The digestive system is in charge of converting food into nutrients, absorbing those nutrients into the blood, and getting rid of waste.

To perform digestion, absorption, and excretion, a number of specialized organs collaborate..

II. Main Organs and Their Functions

1. Mouth (Oral Cavity)

- Function: Mechanical digestion (chewing) and chemical digestion (saliva).
- Saliva contains:
  - Amylase: begins starch digestion.
  - Mucus: lubricates food for easier swallowing.
- Taste buds also help in the sensory evaluation of food.

2. Pharynx and Esophagus

- **Pharynx:** connects mouth to esophagus; initiates swallowing.
- **Esophagus:** muscular tube that transports food to the stomach by **peristalsis** (wave-like muscle contractions).

3. Stomach

- **Function:** Temporary food storage, mechanical mixing, and chemical digestion.
- **Secretion:**
  - Gastric juice contains hydrochloric acid (HCl) which kills bacteria and activates pepsinogen → pepsin (protease).
  - Mucus protects the stomach lining from acid.
  - Intrinsic factor aids vitamin B12 absorption.
- Food is converted into chyme (semi-liquid).

4. Small Intestine

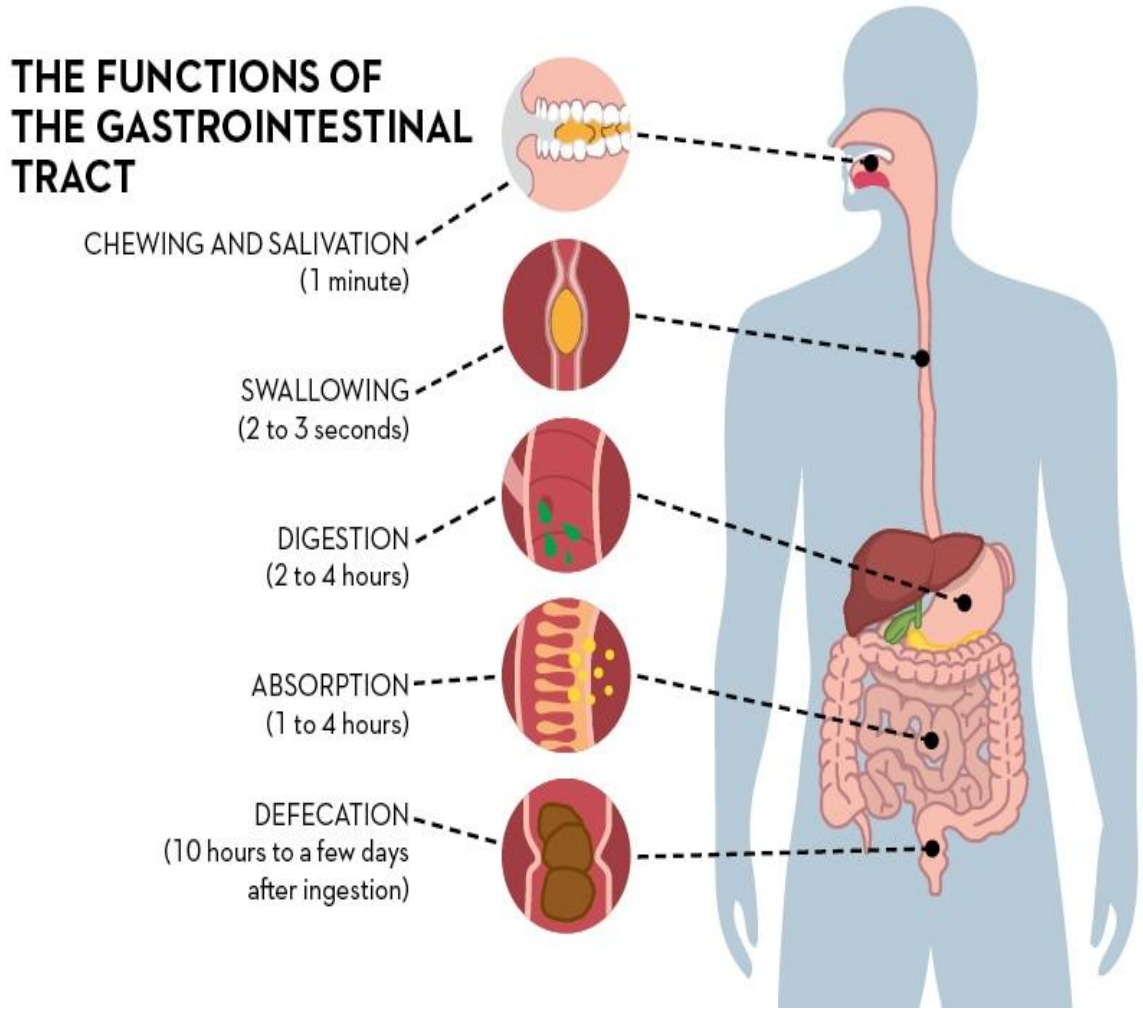
- Segments: Duodenum, jejunum, ileum.
- Function: Main site for digestion and nutrient absorption.
- Digestive enzymes come from the pancreas and intestinal lining.
- Bile (from liver/gallbladder) emulsifies fats for lipase action.
- Villi and microvilli increase surface area for absorption into blood and lymph.

5. Pancreas

- **Exocrine function:** Secretes digestive enzymes (amylase, lipase, proteases) into the duodenum.

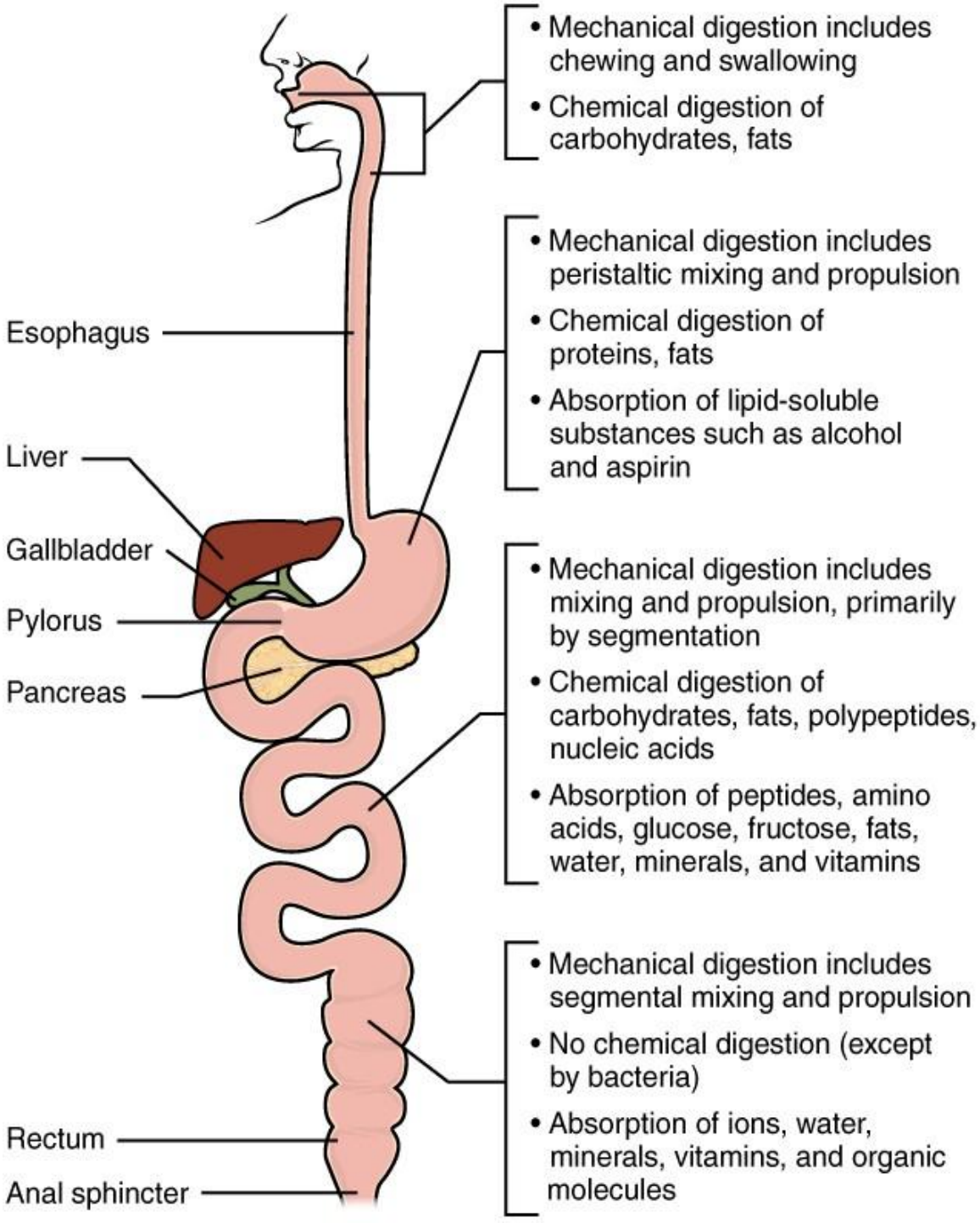
- **Endocrine function:** Produces insulin and glucagon to regulate blood glucose.

6. **Liver**
   - Produces bile to emulsify fats.
   - Metabolizes nutrients absorbed from the small intestine.
   - Detoxifies harmful substances.
   - Stores glycogen, vitamins, and minerals.
   - Synthesizes plasma proteins (e.g., albumin, clotting factors).
7. **Gallbladder**
   - Stores and concentrates bile from the liver.
   - Releases bile into the duodenum during digestion.
8. **Large Intestine (Colon)**
   - Function: Absorbs water and electrolytes, forms and stores feces.
   - Houses gut bacteria that ferment undigested carbohydrates producing vitamins (e.g., vitamin K).
   - Propels feces towards rectum by peristalsis.
9. **Rectum and Anus**
   - Rectum: stores feces before elimination.
   - Anus: controls defecation through internal and external sphincters.



III. Processes of Digestion

- **Ingestion:** Taking in food (mouth).
- **Propulsion:** Swallowing and peristalsis (esophagus to anus).
- **Mechanical digestion:** Chewing, churning (stomach), segmentation (intestine).
- **Chemical digestion:** Enzymatic breakdown of macromolecules.
- **Absorption:** Nutrients move into blood or lymph.
- **Defecation:** Elimination of indigestible substances as feces.



IV. Control of Digestive Function

1. Neural Control

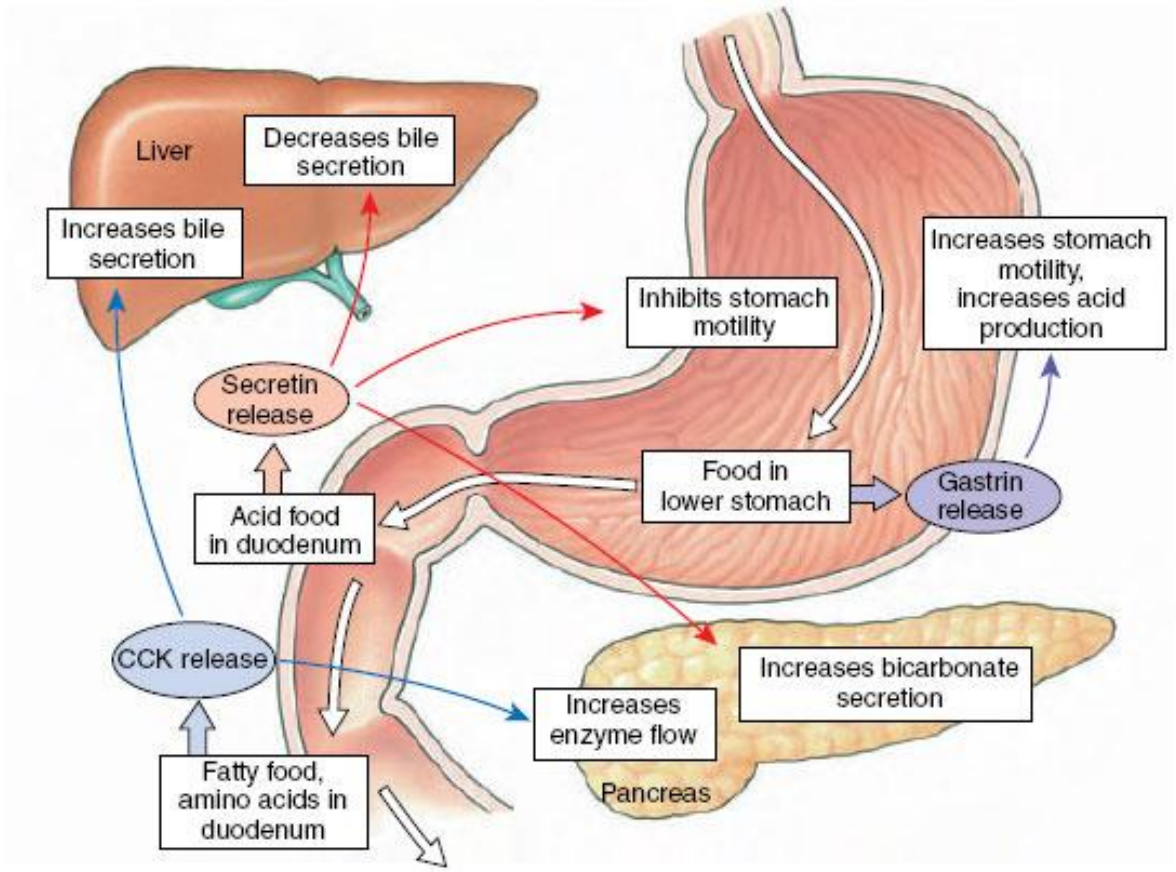
- **Enteric nervous system (ENS):** "Brain of the gut," regulates motility and secretion locally.
- **Autonomic nervous system:**
  - **Parasympathetic** stimulates digestion (rest and digest).

- **Sympathetic** inhibits digestion (fight or flight).

2. Hormonal Control

Important hormones include:

- **Gastrin:** stimulates acid secretion and motility.
- **Secretin:** stimulates pancreatic bicarbonate secretion to neutralize acid.
- **Cholecystokinin (CCK):** stimulates bile and pancreatic enzyme release.
- **Ghrelin:** stimulates hunger.
- **Peptide YY:** signals satiety.



V. Summary Table of Digestive Enzymes and Their Actions

Enzyme		Source	Substrate	Product
Salivary amylase		Salivary glands	Starch	Maltose
Pepsin		Stomach	Proteins	Peptides
Pancreatic amylase		Pancreas	Starch	Maltose

Trypsin & chymotrypsin		Pancreas	Proteins	Peptides & amino acids
Lipase		Pancreas	Triglycerides	Fatty acids & glycerol
Lactase		Intestinal lining	Lactose	Glucose & galactose

VI. Conclusion

The digestive system is a sophisticated, well-coordinated system that converts food into nutrients that can be absorbed, giving life-giving energy and building blocks.

In order to ensure effective digestion, absorption, and waste removal, its organs cooperate mechanically and chemically under the direction of complex neurological and hormonal processes.

Physiology of the organs of the urinary system

I. Introduction

The main organs of this system include the **kidneys**, **ureters**, **urinary bladder**, and **urethra**.

By controlling blood volume and composition, the urine system (also referred to as the renal system) is essential to preserving the body's equilibrium.

It eliminates waste products from metabolism, manages electrolyte and water balance, controls blood pressure, and preserves acid-base equilibrium.

The kidneys, ureters, bladder, and urethra are the primary organs of this system.

II. Main Organs of the Urinary System

1. Kidneys

- Location: Retroperitoneal (behind the peritoneum), on either side of the spine.
- Function:
    - Filter blood to remove wastes (urea, creatinine, uric acid).
    - Regulate water, salt, and pH balance.
    - Produce hormones such as:
        - Erythropoietin (EPO): stimulates red blood cell production.
        - Renin: helps control blood pressure.
        - Calcitriol: active form of vitamin D, regulates calcium levels.

2. Ureters

- Function: Muscular tubes that transport urine from the kidneys to the bladder by peristaltic contractions.
- Valves at the bladder entrance prevent backflow of urine.

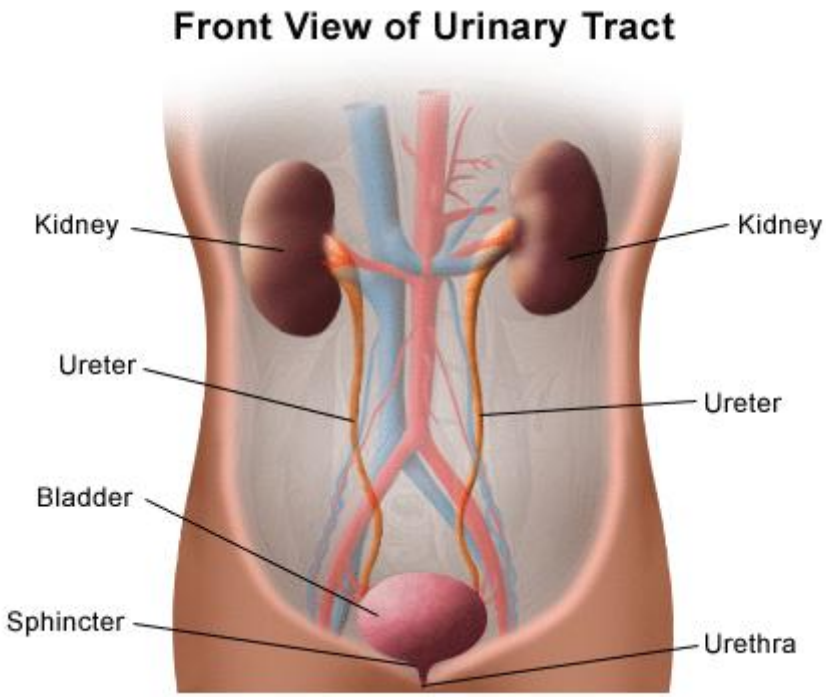
3. Urinary Bladder

- Function: Hollow muscular organ that stores urine until excretion.
- The detrusor muscle in the bladder wall contracts during urination.
- Stretch receptors in the bladder wall signal the need to urinate when the bladder fills (about 300–400 mL).

4. Urethra

- **Function:** Tube that carries urine from the bladder to the outside of the body.

- Sphincters (internal and external) control the release of urine.
- Differences:
  - In males: longer and passes through the prostate and penis.
  - In females: shorter and opens above the vaginal opening.

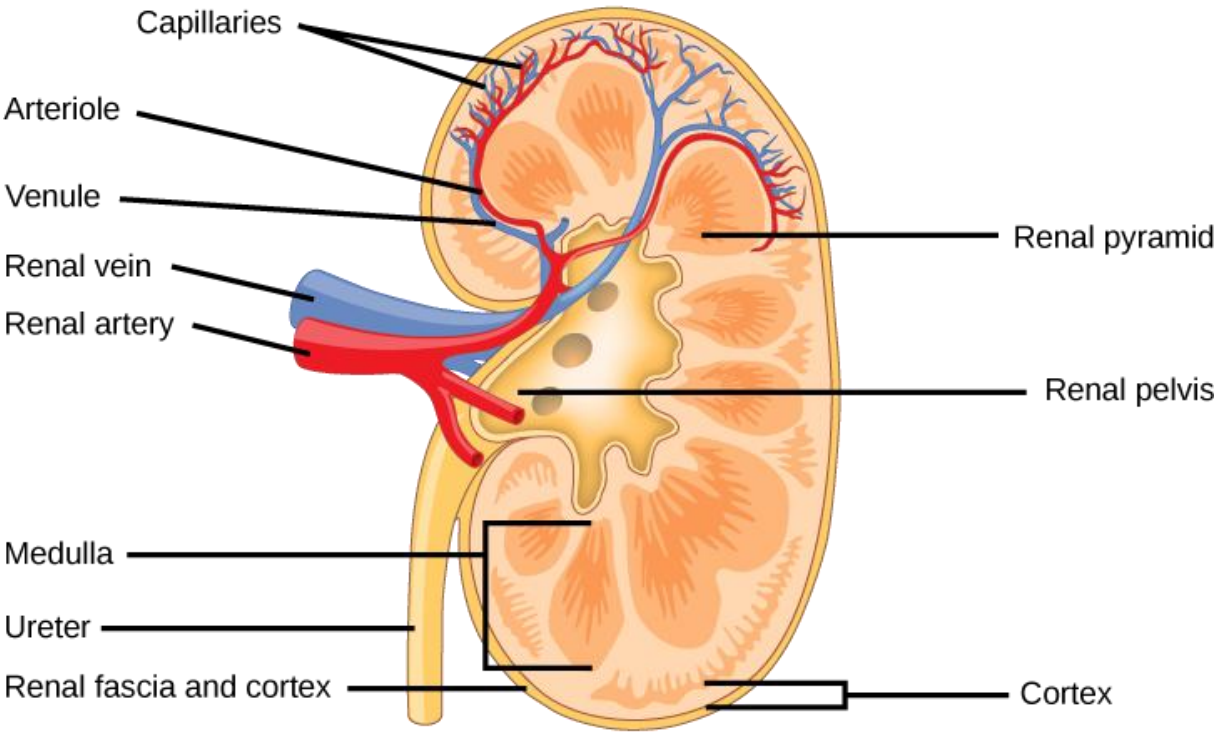


3. Structure of the Kidney

Each kidney has three main regions:

- **Renal Cortex** – outer region containing glomeruli and convoluted tubules.
- **Renal Medulla** – inner region containing renal pyramids and loops of Henle.
- **Renal Pelvis** – funnel-shaped cavity collecting urine before it passes into the ureter.

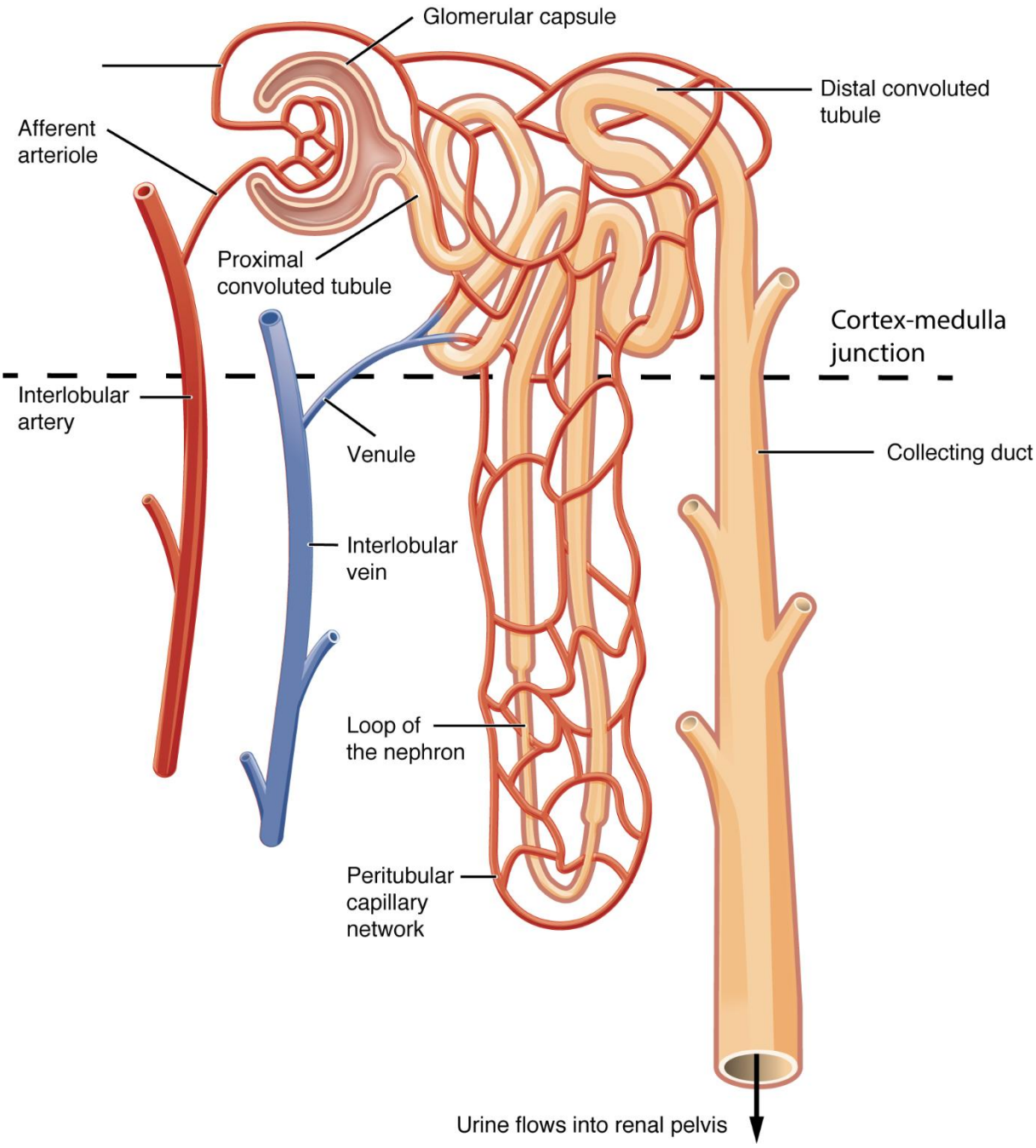
The functional unit of the kidney is the nephron. Each kidney contains about 1–1.5 million nephrons.



III. Structure and Function of the Nephron

Each nephron consists of:

Structure	Description	Function
Glomerulus	Capillary network inside Bowman's capsule	Filtration of blood plasma
Bowman's capsule	Surrounds glomerulus	Collects filtrate
Proximal convoluted tubule (PCT)	Highly coiled segment after Bowman's capsule	Reabsorption of water, glucose, amino acids, ions
Loop of Henle	Descending and ascending limbs	Concentrates urine by water and salt exchange
Distal convoluted tubule (DCT)	Further reabsorption and secretion	Regulated by hormones (aldosterone, ADH)
Collecting duct	Receives urine from several nephrons	Final urine concentration and transport to renal pelvis



IV. Urine Formation

Urine formation occurs through **three major processes**:

1. **Glomerular Filtration**

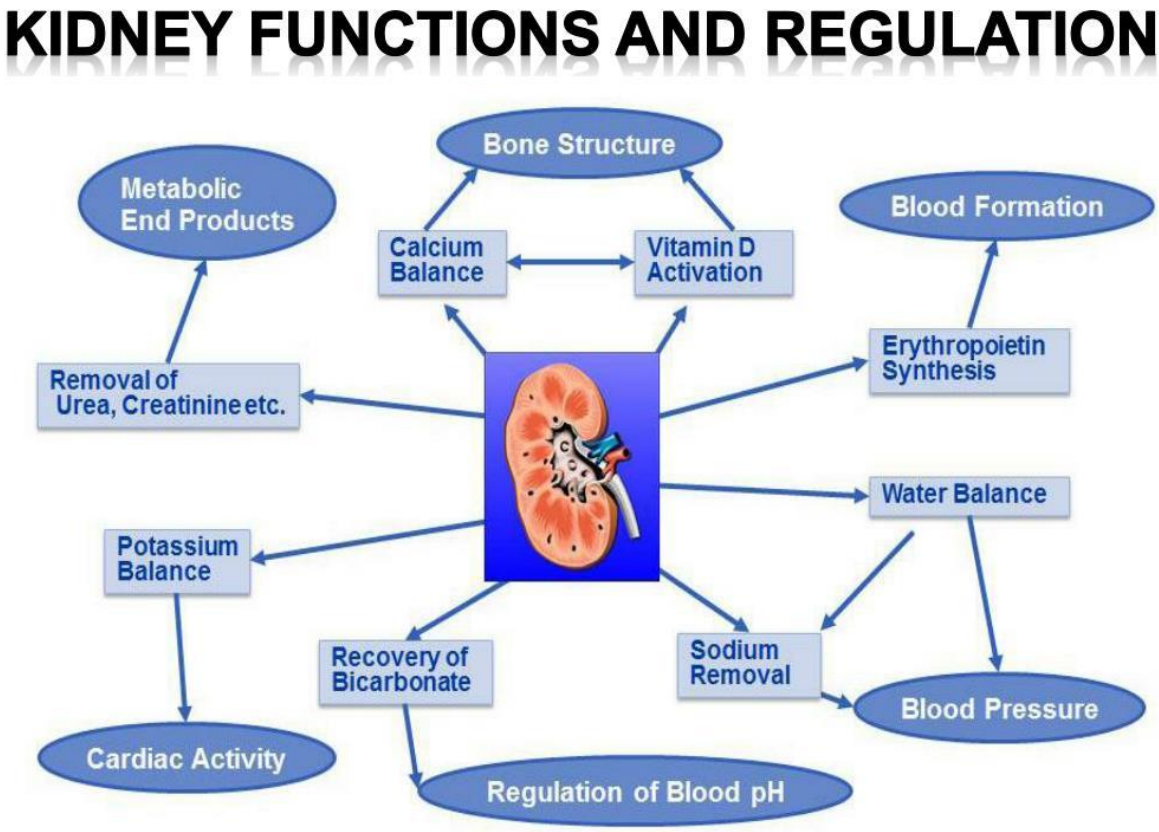
- Occurs in the glomerulus.
- Blood pressure forces water and small solutes (glucose, salts, urea) out of the capillaries into Bowman's capsule.
- Large proteins and blood cells remain in the bloodstream.
- The rate of filtration is called the glomerular filtration rate (GFR) (~125 mL/min in adults).

2. **Tubular Reabsorption**

- Occurs mainly in the proximal convoluted tubule.
- The body reabsorbs useful substances such as:
    - Water
    - Glucose
    - Amino acids
    - Ions (Na^+ , K^+ , Cl^- , HCO_3^-)
- These materials return to the blood through capillaries surrounding the tubules.

3. Tubular Secretion

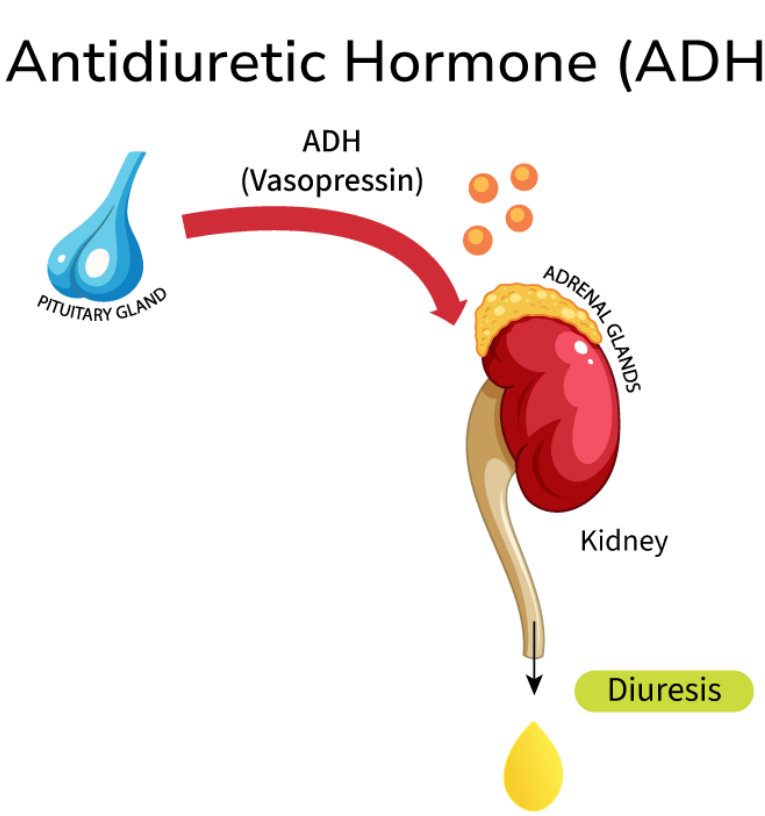
- Occurs in the distal convoluted tubule and collecting duct.
- Substances such as hydrogen ions (H^+), potassium (K^+), ammonia (NH_3), and drugs are secreted into the filtrate.
- This helps maintain acid-base and electrolyte balance.



V. Hormonal Regulation of Kidney Function

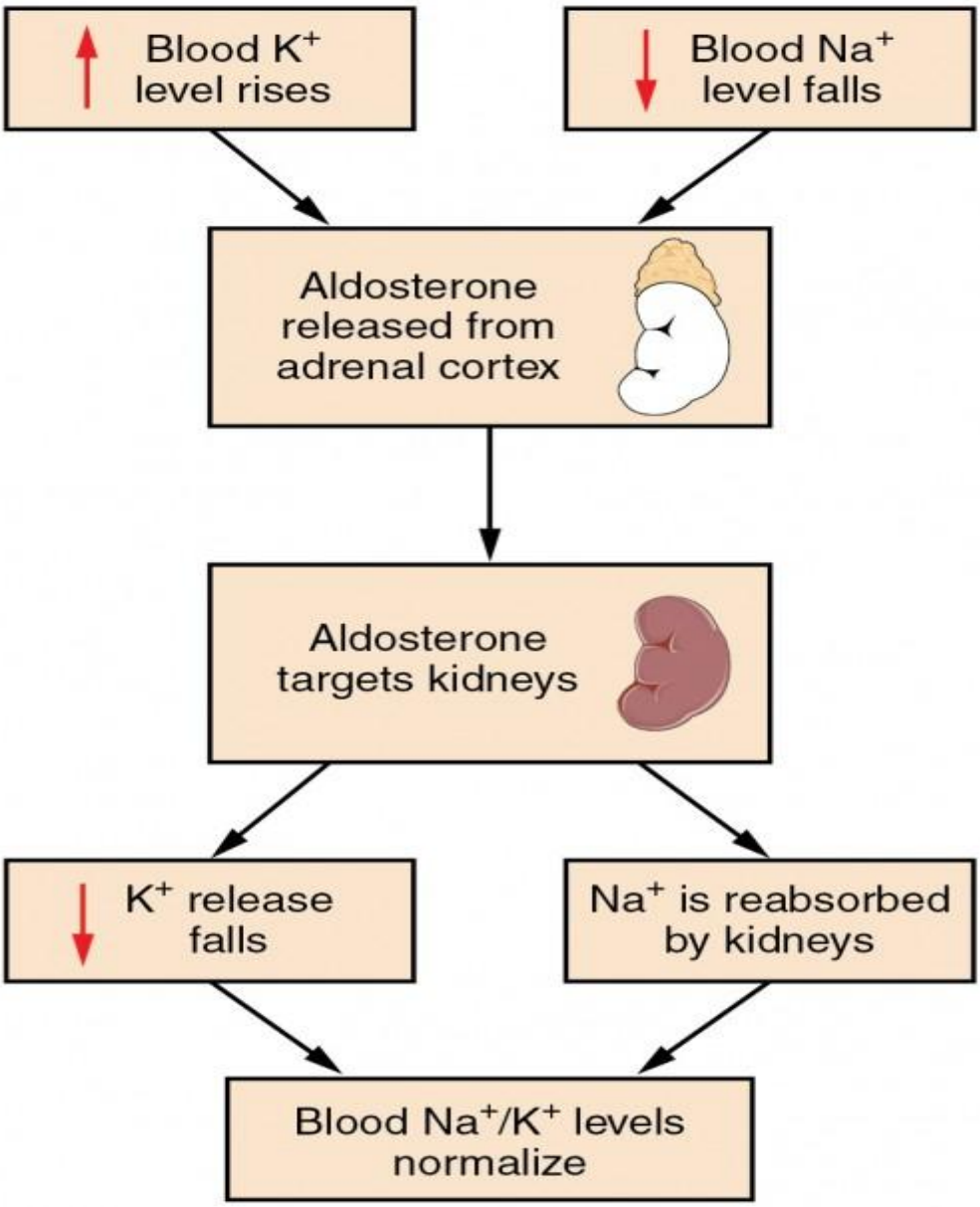
I. Antidiuretic Hormone (ADH)

- Secreted by the posterior pituitary.
- Increases water reabsorption in the collecting ducts.
- Results in concentrated urine and reduced urine volume.
- Low ADH → dilute urine (as in diabetes insipidus).



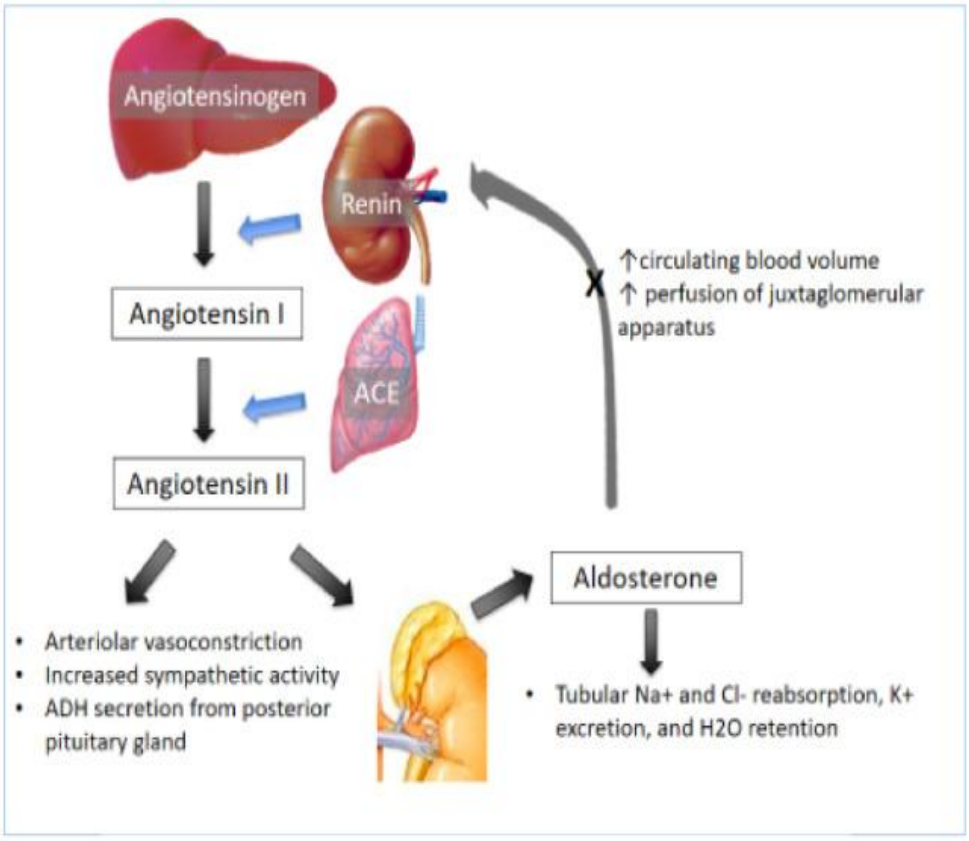
II. Aldosterone

- Secreted by the adrenal cortex.
- Increases sodium reabsorption and potassium secretion in the distal tubule.
- Helps regulate blood pressure and blood volume.



III. Renin-Angiotensin-Aldosterone System (RAAS)

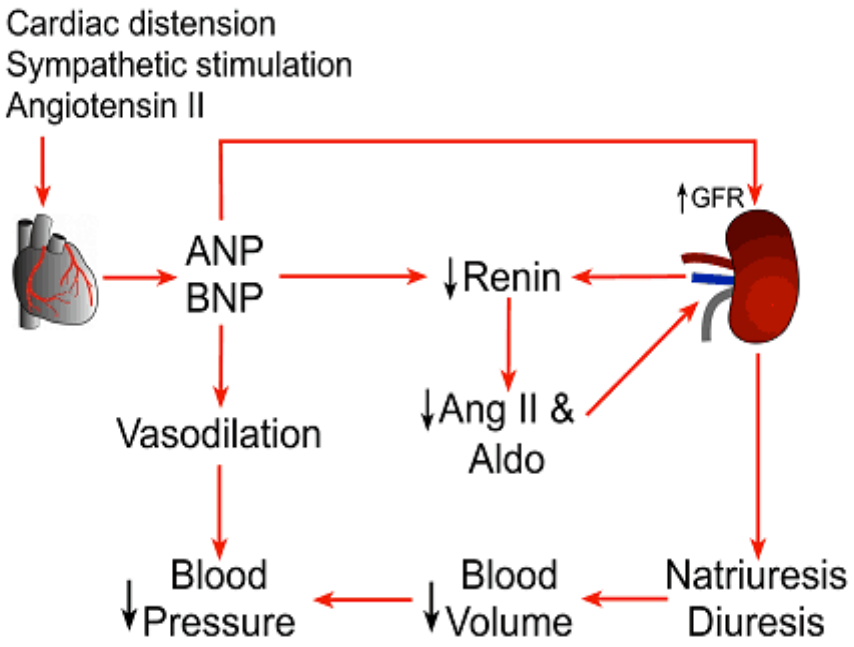
- Activated when blood pressure drops.
- Renin converts angiotensinogen → angiotensin I → (via ACE) → angiotensin II, which:
    - Constricts blood vessels (↑ blood pressure).
    - Stimulates **aldosterone** release.



Renin-Angiotensin-Aldosterone System (RAAS)

IV. Atrial Natriuretic Peptide (ANP)

- Secreted by the heart's atria in response to high blood pressure.
- Inhibits aldosterone and ADH, increasing sodium and water excretion → lowers blood pressure.



V. Composition of Normal Urine

Composition of Normal Urine

Constituents	Amount present
Water	95%
Urea	9.3 to 23.3 gram/liter
Chloride	1.87 to 8.4 gram/liter
Sodium	1.17 to 4.39 gram/liter
Potassium	0.750 to 2.61 gram/liter
Creatinine	0.670 to 2.15 gram/liter
Sulfur	0.163 to 1.80 gram/liter

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Abnormal findings (e.g., glucose, protein, blood, ketones) may indicate disease (e.g., diabetes, infection, kidney failure).

VI. Functions of the Urinary System

- Excretion of metabolic wastes (urea, uric acid, creatinine).
- Regulation of water balance and osmotic pressure.
- Regulation of electrolyte levels (Na^+ , K^+ , Ca^{2+} , Cl^-).
- Regulation of acid-base balance (pH).
- Regulation of blood pressure and volume.
- Secretion of hormones (EPO, renin, calcitriol).

VII. Conclusion

The body's internal chemical stability depends on the urinary system.

It guarantees that the proper balance of water, salts, and acids is maintained while metabolic wastes are effectively eliminated through the intricate functions of the kidneys and related structures.

Homeostasis, which is essential for regular cellular activity and general health, is continuously maintained by this system.

Physiology of the genital system system

I. Introduction

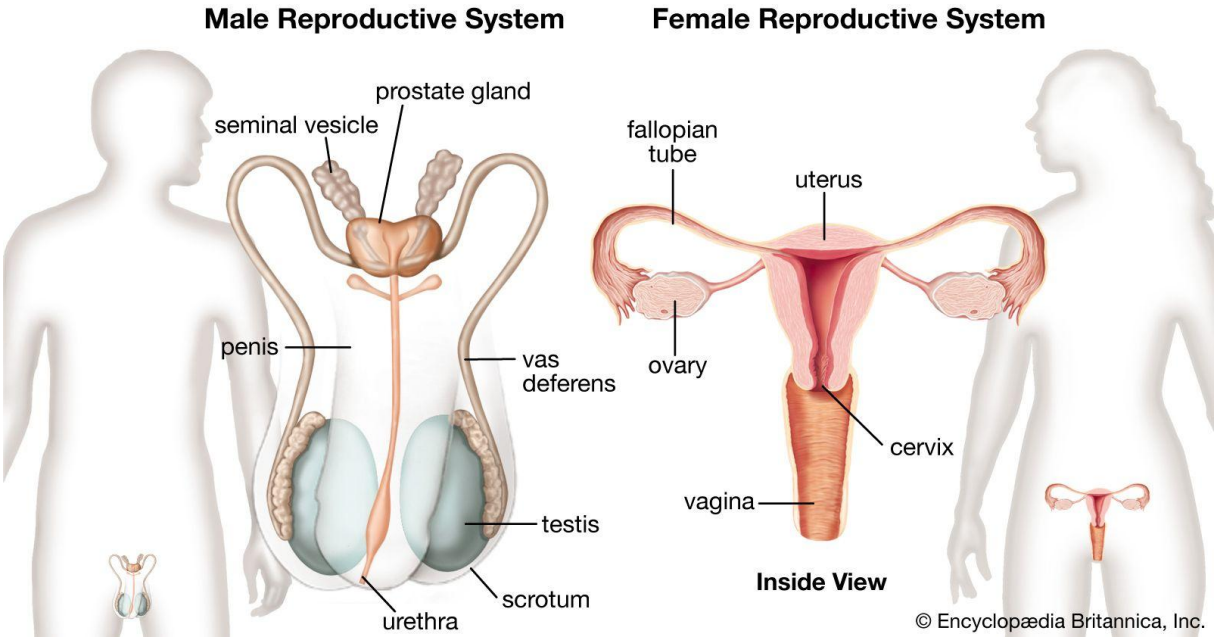
The genital system, also known as the reproductive system, is in charge of producing gametes (sperm and eggs), secreting sex hormones, and ensuring that the species continues to exist through reproduction.

Although it varies across males and females, it cooperates to facilitate conception and the growth of progeny.

Additionally, puberty, sexual function, and secondary sexual traits are all significantly influenced by the reproductive system.

II. General Functions of the Reproductive System

1. **Production of gametes** — sperm in males, ova (eggs) in females.
2. **Secretion of sex hormones** — testosterone, estrogen, progesterone.
3. **Facilitation of fertilization** — bringing sperm and ovum together.
4. **Development of offspring** — gestation and lactation in females.
5. **Transmission of genetic material** to the next generation.



Physiology of the male Reproductive System

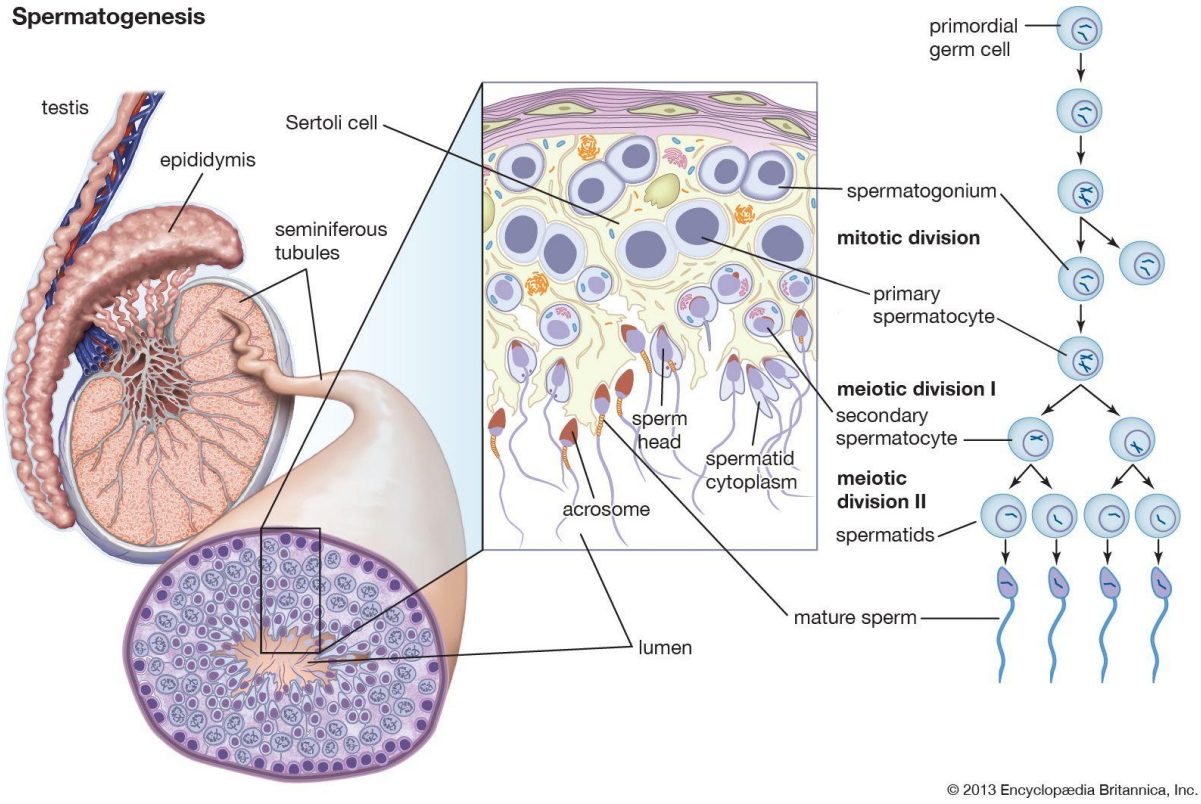
I. Anatomy and Main Organs

Organ	Function
Testes	Produce sperm (spermatogenesis) and secrete testosterone.
Epididymis	Site of sperm maturation and storage.
Vas deferens	Transports sperm from epididymis to urethra.
Seminal vesicles	Secrete fructose-rich fluid to nourish sperm.
Prostate gland	Produces alkaline fluid to protect sperm in acidic vaginal environment.
Bulbourethral glands (Cowper's glands)	Secrete mucus that lubricates the urethra.
Penis and urethra	Deliver semen to the female reproductive tract.

II. Spermatogenesis

- The process of sperm production occurs in the seminiferous tubules of the testes.
- Begins at puberty under the influence of FSH (follicle-stimulating hormone) and testosterone.
- Each sperm cell (spermatozoon) has:
  - Head: contains genetic material and acrosome (enzymes for fertilization).
  - Midpiece: contains mitochondria for energy.
  - Tail (flagellum): enables motility.

The entire process takes approximately 64–72 days.

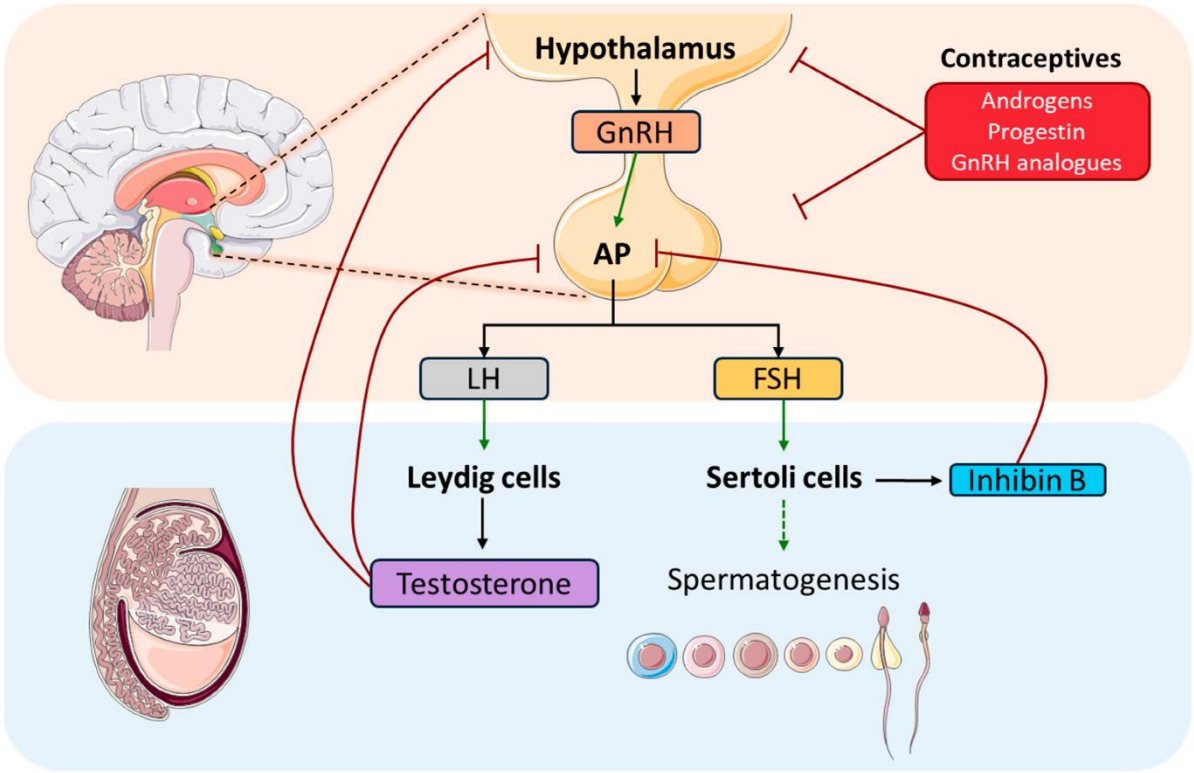


III. Hormonal Regulation in Males

The **hypothalamic-pituitary-gonadal (HPG) axis** controls male reproductive physiology:

1. **Hypothalamus** → releases **GnRH (gonadotropin-releasing hormone)**.
2. **Pituitary gland** → secretes:
    - **FSH** → stimulates spermatogenesis in seminiferous tubules.
    - **LH** → stimulates **Leydig cells** to produce **testosterone**.
3. **Testosterone** → promotes:
    - Sperm production.
    - Growth of reproductive organs.
    - Development of **secondary sexual characteristics** (muscle mass, deep voice, body hair).
    - Libido and sexual function.

Negative feedback: High testosterone inhibits GnRH and LH secretion.


Hypothalamus
GnRH
AP
Contraceptives
Androgens
Progestin
GnRH analogues
LH
FSH
Leydig cells
Sertoli cells
Inhibin B
Testosterone
Spermatogenesis

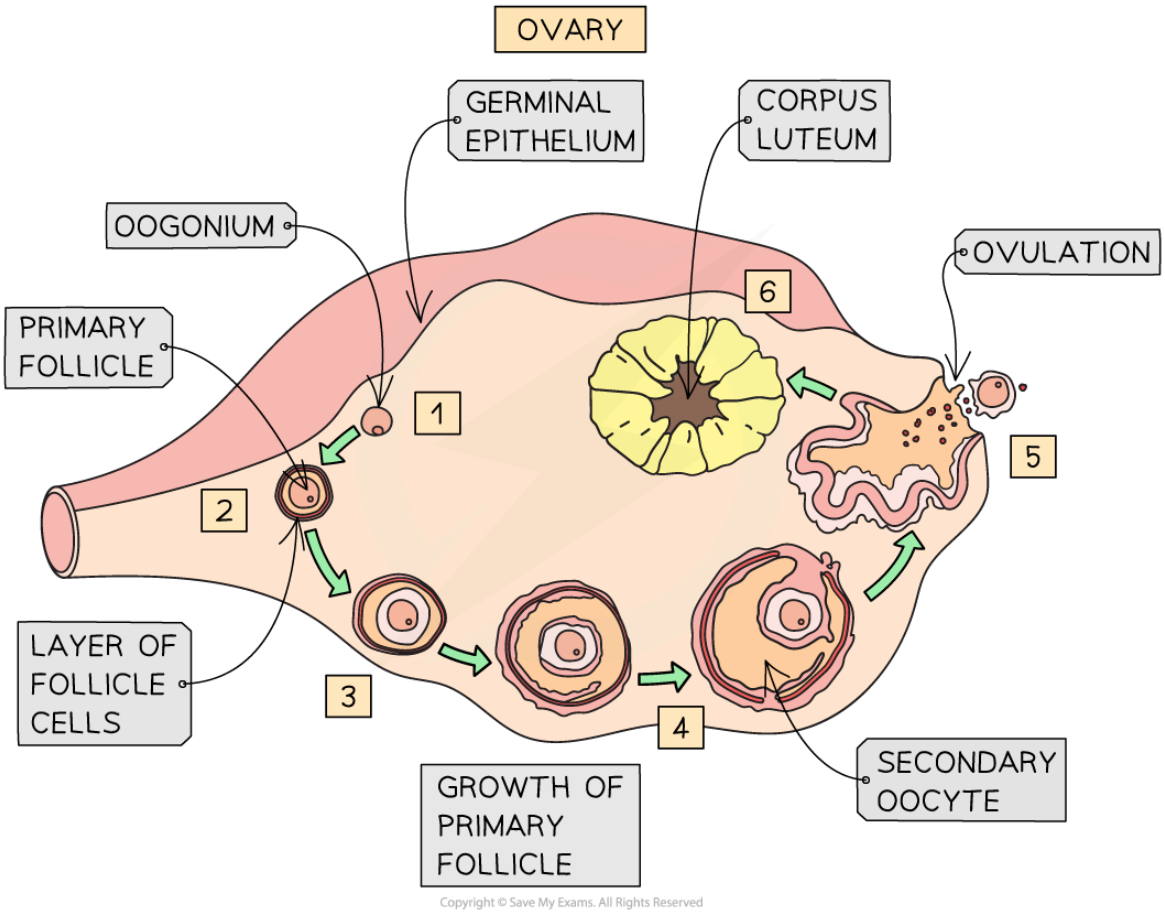
Physiology of the Female Reproductive System

I. Anatomy and Main Organs

Organ	Function
Ovaries	Produce ova (oogenesis) and secrete estrogen and progesterone.
Fallopian tubes (oviducts)	Transport ova; site of fertilization.
Uterus	Site of implantation and fetal development.
Cervix	Connects uterus to vagina; secretes mucus.
Vagina	Receives sperm during intercourse and serves as birth canal.
External genitalia (vulva)	Protect internal reproductive organs.
Mammary glands	Produce milk after childbirth (lactation).

II. Oogenesis

- The process of **egg (ovum) formation** begins before birth but completes after **puberty**.
- Each month, one **primary oocyte** matures into a **secondary oocyte** that is released during **ovulation**.
- If fertilized by sperm, it completes meiosis to form a **zygote**.



III. Menstrual (Ovarian) Cycle

The menstrual cycle lasts about **28 days** and involves cyclical changes in the ovaries and uterus, regulated by hormones.

Phases of the Ovarian Cycle:

1. **Follicular Phase (Days 1–14):**
    - FSH stimulates growth of ovarian follicles.
    - Follicles produce **estrogen**, which thickens the uterine lining (endometrium).
2. **Ovulation (Day 14):**
    - Triggered by a surge in LH.
    - The mature follicle releases an ovum into the fallopian tube.
3. **Luteal Phase (Days 15–28):**
    - Remaining follicle becomes the corpus luteum, which secretes progesterone.
    - Progesterone maintains the uterine lining for potential implantation.
    - If no fertilization occurs → corpus luteum degenerates → menstruation begins.

IV. Hormonal Regulation in Females

The **HPG axis** also controls the female reproductive system:

1. **Hypothalamus:** releases **GnRH**.
2. **Pituitary gland:** releases **FSH** and **LH**.
3. **Ovaries:** produce **estrogen** and **progesterone**, which regulate:
    - Ovulation.
    - Uterine lining development.
    - Secondary sexual characteristics (breast development, fat distribution, etc.).
4. **Negative and positive feedback:**
    - Low estrogen → inhibits GnRH (negative feedback).
    - High estrogen mid-cycle → stimulates LH surge (positive feedback → ovulation).

IV. Fertilization and Pregnancy

- Fertilization usually occurs in the ampulla of the fallopian tube.
- The sperm penetrates the ovum to form a zygote, which travels to the uterus.
- The zygote implants in the uterine wall, forming the embryo.
- The placenta develops, serving as a site of nutrient and gas exchange.
- hCG (human chorionic gonadotropin), secreted by the embryo, maintains the corpus luteum and progesterone production early in pregnancy.

V. Lactation

- After childbirth, prolactin (from the anterior pituitary) stimulates milk production in the mammary glands.
- Oxytocin (from the posterior pituitary) triggers milk ejection during nursing by contracting smooth muscle around alveoli.

VI. Puberty and Secondary Sexual Characteristics

- Puberty marks the onset of reproductive capability.
- Triggered by increased secretion of GnRH → stimulation of sex hormone production.
- Males: deep voice, facial/body hair, muscle growth.
- Females: breast development, widening of hips, menstrual cycle initiation.

VII. Menopause

- Natural cessation of menstruation (around age 45–55).
- Ovarian function declines → decreased estrogen and progesterone levels.
- Symptoms: hot flashes, mood changes, decreased bone density (osteoporosis risk).

VIII. Summary of Major Hormones

Hormone	Origin	Main Function
FSH	Pituitary	Stimulates follicle (female) and sperm (male) production
LH	Pituitary	Triggers ovulation (female), stimulates testosterone (male)
Estrogen	Ovaries	Promotes female secondary sex traits, uterine growth
Progesterone	Corpus luteum	Prepares uterus for implantation
Testosterone	Testes	Promotes male secondary sex traits and spermatogenesis
Prolactin	Pituitary	Stimulates milk production
Oxytocin	Hypothalamus/posterior pituitary	Triggers uterine contractions and milk ejection
Hormone	**Origin**	**Main Function**

IX. Conclusion

Through gamete creation, fertilization, pregnancy, and delivery, the genital (reproductive) system guarantees the continuance of life.

Hormonal feedback loops including the brain, pituitary gland, and gonads carefully regulate it.

The system is essential for sexual development, endocrine regulation, and the preservation of species survival in addition to reproduction.

References

References

1. Agnès Castan. Inhibition de l'angiogenèse tumorale : criblage d'une chimiothèque et caractérisation d'un nouveau composé agissant sur la voie de signalisation Ras-ERK. Thèse de doctorat en Médecine humaine et pathologie.Université de Grenoble, 2014. Français. NNT : 2014GRENV017.
2. ANTOINE Emilie. BARTH, Marie. HECKY, Géraldine. REMY, Frédéric. ROBERT, Nathalie. SONGY, Harmonie. Du processus physiologique à la cible thérapeutique. Formation SFC, Angiogenèse tumorale, Bulletin du Cancer, N° HS, Avril 2006, Vol 93, p.154-64
3. Badenoch AW. (1945). Descent of Testis in Relation to Temperature. Br Med J. 1945 Nov 3;2(4426):601-3. doi: 10.1136/bmj.2.4426.601. PMID: 20786376; PMCID: PMC2060148.
4. Bio Nigan Issiako, Polycarpe Gouthon, Mansourou Arèmou, Jean-Marie Falola, Houndjovi Pierre Dansou, Jean Koudouvo Houngbélagnon, Basile Kocou Nouatin, Brigitte Affidéhomè Tonon, Raïmath Yon-Taro Bio Nigan. (2013). Modifications de certains paramètres hématologiques dans une équipe féminine lors de la 25e Coupe d'Afrique des vainqueurs de handball disputée à Cotonou (Bénin). Advances in Physical Education. Vol.3 No.1 : 43-49 Published Online February 2013 in SciRes (http://www.scirp.org/journal/ape)
5. Brindley G.S. (1982). Deep scrotal temperature and the effect on it of clothing, air temperature, activity, posture and paraplegia. Br J Urol. 1982 Feb;54(1):49-55. doi: 10.1111/j.1464-410x.1982.tb13510.x. PMID: 7059758.
6. Clement, D.B. Sawchuk, L.L. (1984). Iron status and sports performance. Sports Med. 1: 65-74.
7. Cometti, Gilles. Cometti, Dominique. (2012), La pliométrie : méthode de restitution d'énergie au service de la performance sportive, Chiron, Vincennes, France.
8. Costanzo, Linda S. (2018). Physiology. 6th edition. Elsevier.
9. Dahl, E.V. Herrick J.F. (1959). A vascular mechanism for maintaining testicular temperature by counter-current exchange. Surg Gynecol Obstet. 1959 Jun;108(6):697-705. PMID: 13659355.

10. Dahmani, Dahbia Ines. (2020). L'angiogènèse, Cours de biologie cellulaire et moléculaire. Faculté de Biologie, Université de Constantine-1. https://fac.umc.edu.dz/snv/faculte/BCM/2020/angiogen%C3%A8se%20ppt%20(1).pdf
11. Desvaux, Xavier. (2022). Comprendre la cryptorchidie ou testicule non descendu, https://www.ameli.fr/assure/sante/themes/cryptorchidie-testicule-non-descendu-ectopie-testiculaire/comprendre-cryptorchidie, 09 avril 2020 consulté 04 aout 2022

12. Didier Reiss, La bible de la préparation physique, 2017, Amphora, Paris, France.
13. Douglas, P.PD. (1989). Effect of a season of competition and training on heamatological status of women field hockey and soccer players. J. Spoerts Med. Phys. Fit. 29: 179-183.

14. Douterloux, Jean-Paul. (2015). Physiologie et biologie du sport. 3ème édition. Vigot. Paris. France.
15. Douterloux, Jean-Paul. (2015). Physiologie et biologie du sport. 3ème édition. Vigot. Paris. France.

16. Faix, Or. Varicocèle testiculaire : symptômes, échographie, traitement, opération. (2022) https://sante.journaldesfemmes.fr/fiches-sexo-gyneco/2659693-varicocele-testiculaire-symptomes-gauche-droite-echographie-traitements-operation-resultats/. 14/09/20 consulté le 04 aout 2022.

17. Feron, J.-G. Roumieux, M. Pocard, M. Plouet, J. Angiogenèse normale et tumorale. Antiangiogéniques et chirurgie Vol 144 - N° HS3 - novembre 2007, Page :3-6
18. Gayrard, V. (2000). Physiologie de la reproduction des mammifères domestiques. http://physiologie.envt.fr/wp-content/uploads/Gayrard/Enseignement/polyreprod2018.pdf

19. Gothié, Emmanuel. Pouysségur, Jacques. (2002). HIF-1 : régulateur central de l'hypoxie. Med Sci (Paris). Volume 18(1). 70–78. https://doi.org/10.1051/medsci/200218170.
20. Gouthon, P., Akplogan, B., Anani, L., Quenum, C., Dansou, P., Arèmou, M., & Agboton, H. (2007).Valeurs érythrocytaires de jeunes footballeurs en périodes de compétition et de tréve au Bénin. Journal de la Société de Biologie Clinique Bénin, 11, 5-11.

21. Gregg L. Semenza. (2012). Hypoxia-Inducible Factors in Physiology and Medicine. A Cell Press journal. VOLUME 148 (3). P399-408, FEBRUARY 03, 2012. DOI:https://doi.org/10.1016/j.cell.2012.01.021
22. Hoier B, Passos M, Bangsbo J, Hellsten Y. Intense intermittent exercise provides weak stimulus for vascular endothelial growth factor secretion and capillary growth in skeletal muscle. Exp Physiol. 2013 Feb;98(2):585-97. doi: 10.1113/expphysiol.2012.067967. Epub 2012 Sep 7. PMID: 22962287.
23. Hsiung, R. Bothorel, B., Dewasmes, G. Candas, V. Clavert, A. (1991a). Effect of local heating on scrotal temperature. In Temperature and Environmental Effects on the Testis. p.l73-177. A. W. Zorgniotti ed., Plenum Press, New York. https://www.urofrance.org/fileadmin/documents2/data/PU/1992/PU-1992-00020031/TEXF-PU-1992-00020031.PDF
24. Hsiung, R. Nieva, H. Clavert, A. (1991b). Scrotal hyper ther mia a nd va ric ocel e. In Te mper atur e a nd Environmental Effects on the Testis. p.241-244. A. W. Zorgniotti, ed., Plenum Press, New York.
25. http://hypercussive.free.fr/atesto.html
26. http://www.vetopsy.fr/anatomie/systeme-genital/canal-deferent-utricule-prostatique.php
27. http://www.vetopsy.fr/anatomie/systeme-genital/testicules-enveloppes.php
28. https://sante.journaldesfemmes.fr/fiches-anatomie-et-examens/2820275-muscle-dartos-definition-schema/
29. https://www.academie-medecine.fr/le-dictionnaire/index.php?q=plexus%20veineux%20pampiniforme#:~:text=Plexus%20form%C3%A9%20par%20les%20anastomoses,dans%20la%20veine%20r%C3%A9nale%20gauche.
30. https://www.broussal-derval.com/2019/07/06/masse-force-puissance-musculaire/#:~:text=Les%20adaptations%20musculaires%20reposent%20sur,de%20signalisations%20anaboliques%20et%20cataboliques.
31. https://www.doctissimo.fr/sante/dictionnaire-medical/angiogenese

32. https://www.invitra.fr/fertilite-de-lhomme/systeme-reproducteur-masculin/

33. https://www.ipubli.inserm.fr/bitstream/handle/10608/1593/MS_2000_12_1378.pdf?sequence=5&isAllowed=y
34. https://www.larousse.fr/dictionnaires/francais/angiogen%C3%A8se/3473

35. https://www.neonmag.fr/pourquoi-le-penis-retrecit-il-quand-on-a-froid-527004.html

36. https://www.powerliftingmag.fr/qu-est-ce-que-la-force/
37. https://www.salomon.com/fr-fr/outdoor/outdoor-advice/hiking-gear-what-bring , consulté le 17 décembre 2022.
38. https://www.sportsdenature.gouv.fr/randonnee-pedestre/reglementation/definition. Publié le 12 mars 2019

39. https://www.universalis.fr/encyclopedie/vaisseaux-sanguins-et-lymphatiques/2-les-capillaires/#:~:text=Structure,enduit%20d'absorption%2C%20interne.
40. https://www.who.int/fr/news-room/fact-sheets/detail/obesity-and-overweight#:~:text=D'apr%C3%A8s%20les%20estimations%20mondiales,femmes)%20%C3%A9taient%20ob%C3%A8ses%20en%202016. Publié le 20 août 2020, consulté le 19 décembre 2022.
41. https://www.who.int/fr/news-room/fact-sheets/detail/physical-activity#:~:text=Les%20recommandations%20mondiales%20pr%C3%A9conisent%20au,d'intensit%C3%A9%20soutenue%20par%20semaine. Publié le 5 octobre 2022, consulté le 17 décembre 2022.

42. https://www.who.int/fr/news-room/fact-sheets/detail/physical-activity, 26 novembre 2020, 04 aout 2022.

43. Jack H, Wilmore, David L, Costil, (2006), Physiologie du sport et de l'exercice, 3e édition, Edition de Boeck, Bruxelles, Belgique.
44. Jack H.Wilmore et David L.Costill, (2006), Physiologie du sport et de l'exercice, 3ème édition, édition de boeck, Bruxelles.
45. Jakicic JM & Otto AD (2005) Physical activity considerations for the treatment and prevention of obesity. Am J Clin Nutr 82, 226S-229.

46. Jensen L, Bangsbo J, Hellsten Y. Effect of high intensity training on capillarization and presence of angiogenic factors in human skeletal muscle. J Physiol. 2004 Jun 1;557(Pt 2):571-82. doi:

10.1113/jphysiol.2003.057711. Epub 2004 Mar 12. PMID: 15020701; PMCID: PMC1665084
47. Jesus Cardenas. (2015). https://www.doctissimo.fr/html/sante/atlas/fiches-corps-humain/artere-en-coupe.htm
48. Kamina, Pierre. (2002). Atlas d'anatomie. 2ème edition. Masson. France.
49. Lioret, S., Maire, B., Volatier, J. L. and M.A. Charles, Child overweight in France and its relationship with physical activity, sedentary behaviour and socioeconomic status. Eur J Clin Nutr, 2007. 61(4): p. 509-516.
50. Malcovati, L. Pascutto, C. Cazzola, M. (2003). Hematologic passport for athletes competing in endurance sports: a feasibility study. Haematologica. 88: 570-581.
51. Michael S. Pepper. (2000). Angiogenèse et morphogenèse de l'arbre vasculaire: de la biologie cellulaire à la clinique. médecine/sciences: 16 : 1378-1386
52. Mieusset R, Bujan L, Mondinat C, Mansat A, Pontonnier F, Grandjean H. (1987). Association of scrotal hyperthermia with impaired spermatogenesis in infertile men. Fertil Steril. Dec;48(6):1006-11. doi: 10.1016/s0015-0282(16)59600-9. PMID: 3678498.
53. Mieusset, R. (1989a) Régulation thermique de la fonction testiculaire. Rech. Gynecol. 3:163-171
54. Mieusset, R. Bujan, L. Mansat, A. Pontonnier, F. (1992). Hyperthermie scrotale et infécondité masculine. Progrès en Urologie, 2.31-36. https://www.urofrance.org/fileadmin/documents2/data/PU/1992/PU-1992-00020031/TEXF-PU-1992-00020031.PDF
55. O'Malley G, Fillon A, Masurier J, Thivel D (2017). Jeux actifs, activité physique et obésité pédiatrique. Dans M.L. Frelut (Ed.), Le livre électronique (eBook) de l'ECOG sur l'obésité des enfants et des adolescents. Téléchargé sur ebook.ecog-obesity.eu.https://ebook.ecog-obesity.eu/fr/depense-energetique-activite-physique/jeux-actifs-activite-physique-et-obesite-pediatrique/
56. OMS.2020 Nouveau coronavirus (2019-nCoV) Consulté :16/8/2020. https://www.who.int/fr/emergencies/diseases/novel-coronavirus-2019
57. Poortmans, Jacques R. Boisseau, Nathalie. (2003). Biochimie des activités physiques. 2ème édition. De Boeck. Bruxelles.

58. Ramé, Alain. Thérond, Sylvie. (2007). Anatomie et physiologie. Elsevier-Masson. France.

59. Robinson, S. (1938). Experimental studies of physical fitness in relation to age. Arbeitsphysiologie. 10 :318-323.

60. Salmon J, Ball K, Hume C, Booth M, Crawford D, Centre for Physical A, et al, Outcomes of a group-randomized trial to prevent excess weight gain, reduce screen behaviours and promote physical activity in 10-year-old children : SwitchPlay. Int J Obes. 2008;32:601-12.

61. Sandrine LAUNOIS-ROLLINAT. Cours de Physiologie Respiratoire. Ventilation pulmonaire et Le cycle respiratoire. Université Joseph Fourier de Grenoble. Année universitaire 2011/2012.

62. Shaskey, D.J. Green G.A. (2000). Sports haematology.Sports Med. 29: 27-38.

63. Szygula, D.J. (1990). Erythrocytic system under the influence of physical exercice and training. Sports Med. 10: 181-197.

64. Talagas, (2014). L'angiogenese. Cours UE 1B - DFGSM2. Université Sorbone. France. jeudi 30 octobre 2014

65. Thibault Hélène, Activités physiques adaptées et prise en charge des jeunes en surpoids et obèses. Document annexe à la synthèse du PNNS. 2008.

66. Watts K, Jones TW, Davis EA, Green D. Exercise training in obese children and adolescents: current concepts. Sports Med. 2005; 35: 375-92.

67. Weineck, Jürgen. (1992). Biologie du sport. Vigot. Pais. France.

68. Weineck, Jürgen. (1992). Biologie du sport. Vigot. Paris. France.

69. Zorgniotti AW, Sealfon AI. Measurement of intrascrotal temperature in normal and subfertile men. J Reprod Fertil. 1988 Mar;82(2):563-6. doi: 10.1530/jrf.0.0820563. PMID: 3361490.