## i. Fundamentals of human physiology and cellular function

# **Introduction to Human Physiology**

#### 1. Definition and Scope

- Physiology studies the mechanical, physical, and biochemical functions of living organisms.
- Human physiology focuses on how cells, tissues, and organs coordinate to maintain health and respond to internal and external challenges.

#### 2. Homeostasis

- Coined by Walter Cannon, homeostasis refers to the body's ability to maintain stable internal conditions (e.g., temperature, pH, ion concentrations) despite external fluctuations.
- Involves **feedback loops**—negative feedback (common; opposes change) and positive feedback (less common; amplifies an initial stimulus, e.g., in blood clotting or labor contractions).

### 3. Levels of Organization

- Cellular → Tissues → Organs → Organ Systems
- Specialized cell types form tissues with distinct structures and functions, which integrate into larger organ systems (e.g., nervous, cardiovascular, respiratory).

## **Cellular Architecture and Function**

#### 1. Cell Membrane and Fluid Compartments

- Phospholipid Bilayer: Embedded with proteins (channels, transporters, receptors) and cholesterol (stabilizes fluidity).
- Intracellular Fluid (ICF): High K^+, low Na^+, abundant proteins and organelles.
- Extracellular Fluid (ECF): Composed of interstitial fluid and plasma, higher Na^+, lower K^+, crucial for nutrient delivery and waste removal.

## 2. Organelles

- $\circ~$  Nucleus: Houses genetic material (DNA), site of transcription, cell cycle control.
- **Mitochondria**: Powerhouse for ATP production via oxidative phosphorylation, also key in apoptosis and calcium buffering.
- Endoplasmic Reticulum (ER):
  - Rough ER: Synthesizes membrane-bound and secretory proteins.
  - Smooth ER: Lipid metabolism, detoxification, calcium storage.
- o **Golgi Apparatus**: Modifies, sorts, and packages proteins/lipids for secretion or organelle targeting.
- **Lysosomes/Peroxisomes**: Degradation and recycling of cellular waste; detoxification of reactive oxygen species.

#### 3. Cytoskeleton

- Microfilaments (Actin): Cell shape, motility, muscle contraction (in concert with myosin).
- Intermediate Filaments: Structural integrity (e.g., keratins, neurofilaments).
- o Microtubules: Intracellular transport, mitotic spindle, ciliary/flagellar motility (with dynein, kinesin).

# **Membrane Transport and Electrochemical Gradients**

### 1. Passive Transport

- o Simple Diffusion: Movement of small or lipid-soluble molecules down their concentration gradient.
- **Facilitated Diffusion**: Movement down a gradient via carrier proteins or ion channels (e.g., glucose transporter, ion-specific channels).

### 2. Active Transport

- **Primary Active Transport**: Directly uses ATP (e.g., Na^+/K^+ ATPase pumping Na^+ out, K^+ in).
- **Secondary Active Transport**: Coupled transport (e.g., Na^+-glucose symport) uses the gradient established by a primary pump.

#### 3. Vesicular Transport

• **Endocytosis** (phagocytosis, pinocytosis, receptor-mediated) and **Exocytosis** (secretion of hormones, neurotransmitters) require membrane remodeling and ATP.

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#### WHERE CLASSICAL WISDOM MEETS INTELLIGENT LEARNING

#### 4. Membrane Potential

- Resting Membrane Potential (RMP): Cells maintain an electrical potential difference (usually -70 mV in neurons) due to ion gradients and selective permeability.
- **Excitable Cells**: Neurons and muscle cells can rapidly alter membrane potential (action potentials, signaling).

## **Intercellular Communication**

#### 1. Chemical Messengers

- Hormones (Endocrine Signaling): Released into the bloodstream by glands, act on distant targets (e.g., insulin, cortisol).
- Paracrine Factors: Local signaling molecules (e.g., nitric oxide, growth factors).
- **Neurotransmitters**: Released by neurons into synaptic clefts for rapid, localized signaling (e.g., acetylcholine, dopamine).

#### 2. Receptors

- Cell-Surface Receptors: G protein-coupled receptors (GPCRs), ion channels, enzyme-linked receptors.
- Intracellular Receptors: For lipophilic molecules (e.g., steroid hormones); alter gene transcription directly in the nucleus.

#### 3. Signal Transduction Cascades

- **Second Messengers** (cAMP, Ca^2+, IP 3, DAG) amplify signals.
- Protein Kinase Cascades (e.g., MAPK, PKA, PKC) modulate cellular processes—gene expression, metabolism, cell division.

## Tissue Organization and Function

## 1. Epithelial Tissue

- o Covers body surfaces and lines cavities (e.g., intestines, kidney tubules).
- o Functions in protection, absorption, secretion.
- o Tight junctions form selectively permeable barriers.

### 2. Connective Tissue

- Provides structural support (extracellular matrix, collagen, elastin).
- o Includes bone, cartilage, blood, adipose tissues.
- Fibroblasts, osteoblasts, chondrocytes produce and maintain ECM.

## 3. Muscle Tissue

- **Skeletal Muscle**: Voluntary control, striated fibers, multinucleated.
- Cardiac Muscle: Involuntary, striated, intercalated discs for synchronized contraction.
- Smooth Muscle: Involuntary, non-striated, present in walls of hollow organs (e.g., intestines, blood vessels).

### 4. Nervous Tissue

- Neurons: Excitable cells that transmit electrical impulses.
- o **Glial Cells**: Support and protect neurons (astrocytes, oligodendrocytes/Schwann cells for myelin formation).

# **Integration into Organ Systems**

## 1. Neural Control

- o Central (brain and spinal cord) and peripheral nervous systems coordinate rapid communication.
- Reflex arcs integrate sensory inputs with motor outputs for immediate responses.

#### 2. Endocrine Regulation

• Hormone-secreting glands (pituitary, thyroid, adrenals, pancreas) orchestrate slower, long-term regulation (e.g., growth, metabolism, reproduction).

#### 3. Cardiovascular and Respiratory Systems

- Work together to supply oxygen, remove CO<sub>2</sub>, circulate nutrients, and maintain tissue perfusion.
- **Homeostatic Mechanisms**: Blood pressure control (baroreceptor reflex), regulation of blood gases (chemoreceptors).

#### 4. Renal and Digestive Systems

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- **Kidneys** filter blood, maintain electrolyte balance and pH, excrete waste (urea).
- **Gastrointestinal Tract** breaks down nutrients, absorbs them into circulation, eliminates undigested residues.

#### 5. Immune and Lymphatic Systems

 Defend against pathogens, clear damaged cells, involve both innate (macrophages, neutrophils) and adaptive immunity (T/B lymphocytes).

# **Concluding Perspectives**

**Human physiology** is fundamentally anchored in **cellular function**—how cells harness chemical gradients, respond to signals, generate electrical impulses, and coordinate their activities to sustain life. The human body relies on a delicate **equilibrium** maintained by feedback mechanisms across organ systems. Advances in molecular and cellular biology continue to deepen our knowledge, informing disciplines from **medicine** and **pharmacology** to **bioengineering** and **systems biology**. Understanding these foundational principles is essential for exploring disease pathology (when regulation fails) and designing novel therapeutic interventions.

## **Key Takeaways**

- Cellular organization underpins tissue and organ function.
- Membrane physiology (transport, potentials) drives excitability, communication, and metabolism.
- Tissue specialization (epithelial, connective, muscle, nervous) enables the diverse roles of organ systems.

**Homeostatic feedback loops** and **signal transduction** unify processes across systems, ensuring adaptability and stability in a changing environment.

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