CHAPTER

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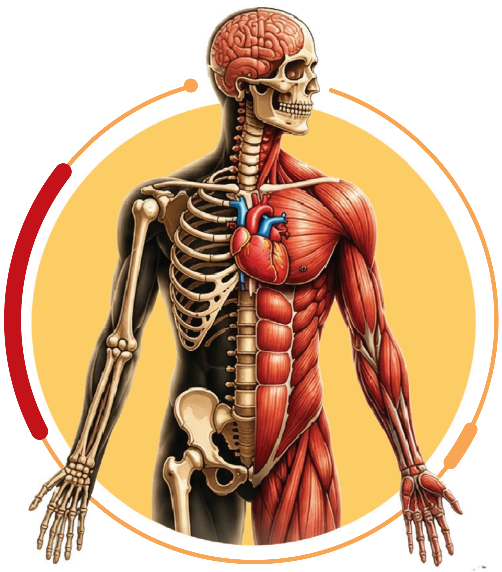

Introduction to Human Body

Learning Objectives

1.1 Cellular and Tissue level organization.

1.2 Scope of Anatomy, Physiology and Pathophysiology.

1.3 Levels of structural organization and body systems.

1.4 Major Basic Life Processes, Homeostasis, Basic Anatomical Terminologies.

1.5 Structure and Functions of Cell.

1.6 Transport across cell membrane.

1.7 Cell Division.

1.8 Cell Junction

1.9 General Principles of Cell Communication

1.10 Classification of Tissues

1.11 Study Questions

1.1 Cellular and Tissue level Organization

Introduction

The human body exhibits a highly organized structure that enables it to perform complex physiological functions efficiently. This organization occurs in a hierarchical manner, beginning with the chemical level and progressing through the cellular, tissue, organ, organ system, and organism levels. Among these, the cellular and tissue levels form the fundamental basis of life and serve as the building blocks for all higher levels of organization. Understanding these levels is essential for studying anatomy, physiology, pathology, and other biomedical sciences as shown in Figure-1.1

Cellular Level of Organization

The cellular level of organization represents the first level at which life exists. A **cell** is defined as the smallest structural and functional unit of a living organism capable of performing all vital life processes independently. The human body contains trillions of cells, each specialized to carry out particular functions. Despite differences in shape, size, and function, most human cells share a common structural organization.

A typical cell consists of three principal components: the **plasma membrane**, **cytoplasm**, and **nucleus**. The plasma membrane forms the outer boundary of the cell and regulates the movement of substances into and out of the cell. It is composed primarily of a phospholipid bilayer with embedded proteins, cholesterol, and carbohydrates, forming what is known as the fluid mosaic model. This membrane not only protects the cell but also facilitates communication with neighboring cells and the external environment.

The cytoplasm occupies the space between the plasma membrane and the nucleus. It consists of a gel-like substance known as the cytosol, within which various organelles are suspended. These organelles perform specialized functions necessary for cellular survival. The nucleus, often referred to as the control center of the cell, contains genetic material in the form of DNA. It regulates cellular activities, including growth, metabolism, protein synthesis, and reproduction.

Within the cytoplasm are several important organelles. **Mitochondria** are responsible for producing adenosine triphosphate (ATP), the primary energy currency of the cell, through cellular respiration. Because of this role, mitochondria are commonly known as the “powerhouses of the cell.” **Ribosomes** are involved in protein synthesis and may be found either freely suspended in the cytoplasm or attached to the rough endoplasmic reticulum.

The **endoplasmic reticulum (ER)** exists in two forms: rough ER and smooth ER. Rough ER contains ribosomes and plays a crucial role in protein synthesis and transport, whereas smooth ER is involved in lipid synthesis, steroid hormone production, and detoxification processes. The **Golgi apparatus** modifies, packages, and distributes proteins and lipids synthesized by the ER. It also forms secretory vesicles and lysosomes.

Lysosomes

Lysosomes contain hydrolytic enzymes responsible for digesting worn-out organelles, foreign particles, and cellular debris. **Peroxisomes** contain oxidative enzymes that detoxify harmful substances and break down fatty acids. The **cytoskeleton**, composed of microfilaments, intermediate filaments, and microtubules, provides structural support, maintains cell shape, and facilitates intracellular transport and movement.

Cells perform numerous vital functions that are essential for maintaining life. These include metabolism, growth, reproduction, responsiveness to stimuli, movement, and homeostasis. Cellular metabolism encompasses all chemical reactions occurring within the cell and is divided into anabolism, which involves the synthesis of complex molecules, and catabolism, which involves their breakdown to release energy. Cells also possess the ability to grow, divide, and differentiate into specialized forms. This process of differentiation allows cells to acquire unique structures and functions suited to specific roles within the body.

Examples of specialized cells include neurons, which conduct nerve impulses; muscle cells, which generate movement through contraction; red blood cells, which transport oxygen; and white blood cells, which participate in immune defense. The specialization of cells contributes significantly to the complexity and efficiency of multicellular organisms.

Cell-to-cell communication and adhesion are facilitated by specialized structures known as **cell junctions**. Tight junctions create impermeable seals between adjacent cells, preventing leakage of substances. Desmosomes provide strong mechanical attachment between cells, particularly in tissues subjected to stress, such as the skin. Gap junctions permit the direct exchange of ions and small molecules between neighboring cells, allowing rapid communication, especially in cardiac and smooth muscle tissues.

Thus, the cellular level of organization forms the foundation of all biological processes and serves as the basic unit from which tissues, organs, and organ systems are constructed.

Tissue Level of Organization

The tissue level of organization is formed when groups of similar cells, along with their extracellular matrix, work together to perform specific functions. A **tissue** is therefore defined as an aggregation of structurally and functionally related cells organized to carry out a common activity. The study of tissues is known as **histology**.

The human body is composed of four primary tissue types: epithelial tissue, connective tissue, muscle tissue, and nervous tissue. Each tissue type possesses distinct structural characteristics and performs specialized functions that contribute to overall body function.

Epithelial tissue covers the external surface of the body, lines internal cavities and organs, and forms glands. It consists of closely packed cells with very little extracellular matrix. Epithelial tissues are generally avascular, meaning they lack blood vessels, and obtain nutrients through diffusion from underlying connective tissues. Their primary functions include protection, absorption, secretion, excretion, filtration, and sensory reception.

Epithelial tissue is classified according to the number of cell layers and the shape of the cells. Simple epithelium consists of a single layer of cells and is primarily involved in diffusion, filtration, absorption, and secretion. Stratified epithelium contains multiple layers of cells and provides protection against mechanical stress. Specialized forms include pseudostratified epithelium, commonly found in the respiratory tract, and transitional epithelium, which lines the urinary bladder and allows stretching.

Connective tissue is the most abundant and widely distributed tissue in the body. Its primary functions are support, binding, protection, transport, and storage. Unlike epithelial tissue, connective tissue contains relatively few cells separated by a large amount of extracellular matrix. This matrix consists of fibers and ground substance that provide structural integrity and mechanical strength.

The principal cells of connective tissue include fibroblasts, macrophages, mast cells, and adipocytes. Connective tissue fibers are classified into collagen fibers, elastic fibers, and reticular fibers. Connective tissue exists in various forms, including loose connective tissue, dense connective tissue, cartilage, bone, adipose tissue, and blood. Each type is adapted to perform specific functions. For example, tendons and ligaments provide tensile strength, cartilage offers flexible support, bone provides rigidity and protection, and blood transports gases, nutrients, hormones, and waste products throughout the body.

Muscle tissue is specialized for contraction and movement. It possesses unique properties such as excitability, contractility, extensibility, and elasticity. Muscle tissue is responsible for body movements, posture maintenance, heat production, and the movement of substances through internal organs.

There are three types of muscle tissue. Skeletal muscle is voluntary and attached to bones, enabling conscious movement. Cardiac muscle is found exclusively in the heart and contracts rhythmically to pump blood throughout the body. Smooth muscle is located in the walls of hollow organs such as the gastrointestinal tract, blood vessels, and urinary bladder, where it regulates involuntary movements.

Nervous tissue is specialized for communication, coordination, and control of body functions. It consists primarily of neurons and supporting cells called neuroglia or glial cells. Neurons are excitable cells capable of generating and transmitting electrical impulses, allowing rapid communication throughout the body. A typical neuron consists of a cell body, dendrites, and an axon. Neuroglial cells provide structural support, nourishment, insulation, and protection for neurons.

An important component associated with many tissues is the **extracellular matrix (ECM)**. The ECM is a complex network of proteins and carbohydrates secreted by cells. It provides structural support, facilitates cell adhesion, regulates cellular behavior, and plays a vital role in tissue repair and regeneration. Major components of the ECM include collagen fibers, elastic fibers, proteoglycans, and glycoproteins.

Relationship Between Cellular and Tissue Levels

The cellular and tissue levels of organization are closely interconnected. Cells serve as the fundamental building blocks of tissues, while tissues represent organized groups of cells working together to

achieve specific functions. Cellular specialization enables tissues to perform complex tasks more efficiently than individual cells acting alone. For example, individual muscle cells contract, but collectively they form muscle tissue capable of generating coordinated body movements. Similarly, neurons function individually to transmit impulses, but together they form nervous tissue that coordinates the activities of the entire organism. **(Fig. 1.1)**

1.2 Scope of Anatomy, Physiology and Pathophysiology

1. Scope of Anatomy

Anatomy is the branch of science that studies the structure of the human body and the relationship among body parts. It provides the foundation for medical and pharmaceutical sciences as shown in Table-1.1.

Areas Included in Anatomy

- **Gross Anatomy:** Study of organs and body structures visible to the naked eye.
- **Microscopic Anatomy (Histology):** Study of tissues and cells using microscopes.
- **Developmental Anatomy (Embryology):** Study of development of the body from fertilization to birth.
- **Regional Anatomy:** Study of structures in specific body regions.
- **Systemic Anatomy:** Study of body systems such as skeletal, muscular, nervous, and cardiovascular systems.
- **Radiological Anatomy:** Study of body structures using imaging techniques like X-ray, CT scan, and MRI.

Importance and Applications

- Helps understand body organization and structural relationships.

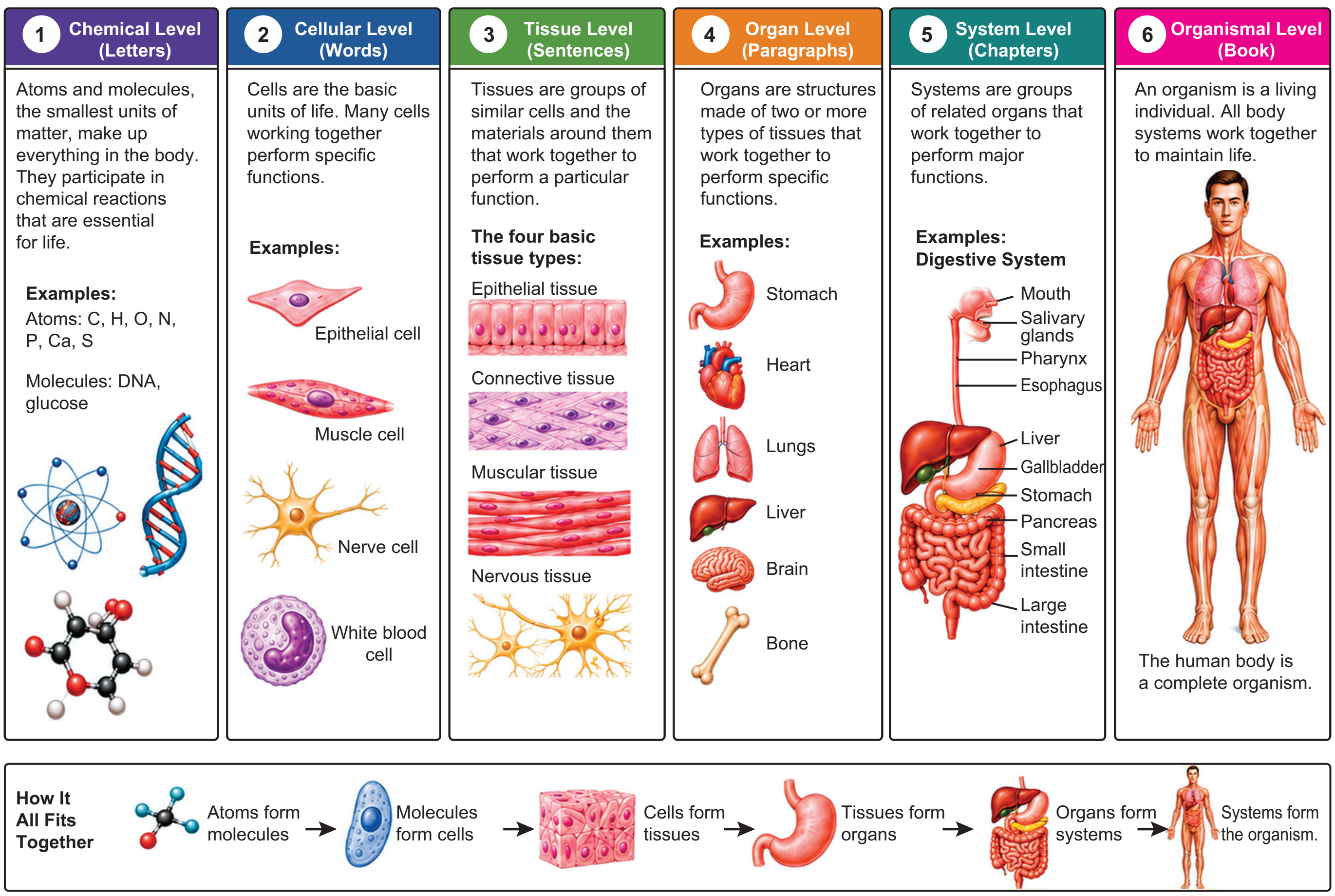

Fig. 1.1 : Level of Organization in the Human Body

- Essential for surgery, medicine, pharmacy, nursing, and physiotherapy.
- Assists in diagnosis through imaging and clinical examination.
- Forms the basis for understanding physiology and pathology.

2. Scope of Physiology

Physiology is the study of the normal functions of the human body and how different organs and systems work together to maintain life as shown in Table-1.1.

Areas Included in Physiology

- **Cell Physiology:** Functions of cells and cellular processes.
- **Systemic Physiology:** Study of functions of organ systems such as:
  - Cardiovascular physiology
  - Respiratory physiology
  - Renal physiology
  - Nervous system physiology
  - Endocrine physiology
- **Exercise Physiology:** Body responses during physical activity.
- **Clinical Physiology:** Application of physiological principles in disease diagnosis and treatment.

Importance and Applications

- Explains mechanisms of normal body functioning.
- Helps understand maintenance of homeostasis.
- Provides the basis for pharmacology and therapeutics.
- Important in diagnosis and treatment of diseases.
- Useful in sports science, nutrition, and biomedical research.

3. Scope of Pathophysiology

Pathophysiology is the study of functional and structural changes in the body caused by diseases or abnormal conditions. It connects pathology with physiology as shown in Table-1.1.

Areas Included in Pathophysiology

- Cellular Pathophysiology: Cellular injury, inflammation, and adaptation.
- Systemic Pathophysiology: Disease mechanisms affecting body systems such as:
- Cardiovascular disorders
- Respiratory disorders
- Endocrine disorders
- Neurological disorders
- Genetic and Molecular Pathophysiology: Study of hereditary and molecular causes of disease.
- Immunopathophysiology: Disorders related to the immune system.

Importance and Applications

- Helps understand disease development and progression.
- Assists in identifying signs, symptoms, and complications of diseases.
- Provides the scientific basis for diagnosis and treatment.
- Important for pharmacists in understanding drug action and adverse effects.
- Supports research in disease prevention and therapy development. **(Table-1.1)**

Table - 1.1 : Interrelationship Among Anatomy, Physiology, and Pathophysiology

Subject	Focus	Example
Anatomy	Structure of the body	Structure of the heart
Physiology	Normal function	Pumping action of the heart
Pathophysiology	Abnormal function during disease	Heart failure or hypertension

Together, these subjects provide complete knowledge of the human body in health and disease and form the core foundation of medical, pharmaceutical, and allied health sciences.

Basic life processes are the essential functions performed by living organisms to maintain life and survival. In human beings, these processes help maintain normal body function and homeostasis.

1.3 Levels of structural organization and body systems

The human body is organized into different structural levels, from the simplest to the most complex.

1. **Chemical Level**
   - This is the simplest level of body organization.
   - It includes atoms (smallest units of matter) such as carbon, hydrogen, oxygen, nitrogen, calcium, and phosphorus.
   - Atoms combine to form molecules like water, glucose, proteins, lipids, and DNA.
   - These chemical substances are essential for body functions. Example: Water (H_2O), glucose, proteins.
2. **Cellular Level**
   - Cells are the basic structural and functional units of life.
   - Molecules combine to form cells.
   - Each cell performs specific functions necessary for survival.
   - The human body contains trillions of cells.

   Examples: Nerve cell (neuron), muscle cell, red blood cell.
3. **Tissue Level**
   - A tissue is a group of similar cells working together to perform a specific function.
   - There are four main types of tissues in the body:

   a) **Epithelial Tissue**
      - Covers body surfaces and lines organs/cavities.
      - Protection, absorption, secretion.

   b) **Connective Tissue**
      - Supports and binds body parts.
      - Includes bone, blood, cartilage, fat.

   c) **Muscle Tissue**
      - Responsible for movement.
      - Types: skeletal, smooth, cardiac.

   d) **Nervous Tissue**
      - Conducts electrical impulses.
      - Found in brain, spinal cord, nerves.
4. **Organ Level**
   - Different tissues combine to form an organ.
   - Each organ has a specific shape and function. Examples:
   - Heart → pumps blood
   - Lungs → respiration
   - Stomach → digestion
   - Kidney → filtration
5. Organ System Level
   - A group of organs working together to perform a common function forms an organ system. Examples:
   - Digestive system
   - Respiratory system
   - Nervous system
6. Organism Level

   This is the highest level of organization.

   All organ systems work together to form a complete living organism

   Example: Human body.

Body Systems of Human Body

There are 11 major organ systems in the human body as shown in Figure-1.2

1. **Integumentary System**

   Organs: Skin, hair, nails, sweat glands Functions:
   - Protection from injury and infection
   - Regulation of body temperature
   - Sensation
   - Vitamin D synthesis
2. **Skeletal System**

   Organs: Bones, cartilage, ligaments, joints Functions:
   - Support and shape
   - Protection of organs
   - Blood cell formation
   - Mineral storage
3. **Muscular System**

   Organs: Skeletal muscles, tendons Functions:
   - Movement
   - Posture maintenance
   - Heat production
4. **Nervous System**

   Organs: Brain, spinal cord, nerves Functions:
   - Control and coordination
   - Response to stimuli
   - Transmission of nerve impulses
5. **Endocrine System**

   Organs: Pituitary, thyroid, adrenal glands, pancreas Functions:
   - Hormone secretion

- Growth regulation
- Metabolism control

6. **Cardiovascular (Circulatory) System**

   Organs: Heart, blood vessels, blood Functions:

   - Transport oxygen, nutrients, hormones
   - Remove wastes

7. **Lymphatic/Immune System**

   Organs: Lymph nodes, spleen, thymus, lymph vessels Functions:

   - Defense against infection
   - Fluid balance

8. **Respiratory System Organs: Nose, trachea, lungs Functions:**

   - Gas exchange
   - Oxygen supply
   - Carbon dioxide removal

9. **Digestive System**

   Organs: Mouth, esophagus, stomach, intestines, liver, pancreas Functions:

   - Digestion of food
   - Nutrient absorption
   - Waste elimination

10. **Urinary System**

    Organs: Kidneys, ureters, bladder, urethra Functions:

    - Excretion of waste
    - Water and electrolyte balance

11. **Reproductive System**

    Male Organs: Testes, penis, vas deferens Female Organs: Ovaries, uterus, vagina Functions:

    - Reproduction
    - Production of sex hormones. **(Fig. 1.2)**

1.4 Major Basic Life Processes, Homeostasis, Basic Anatomical Terminologies.

Major Basic Life Processes

1. **Metabolism**

   Metabolism refers to all the chemical reactions occurring inside the body cells. It is divided into two types:

   (a) Catabolism

   - Breakdown of complex substances into simpler substances.
   - Releases energy.
   - Example: Breakdown of glucose during cellular respiration.

   (b) Anabolism

   - Formation of complex substances from simpler substances.
   - Requires energy.
   - Example: Protein synthesis from amino acids.

2. **Responsiveness (Irritability)**

   Responsiveness is the ability of the body to detect and respond to internal or external changes (stimuli).

   Examples

   - Sweating in response to heat.
   - Withdrawal of hand from a hot object.
   - Increase in heart rate during exercise.

   The nervous and endocrine systems mainly control responsiveness.

3. **Movement**

   Movement includes motion of the whole body, organs, cells, and substances within the body.

   Types of Movement

   - Walking and running.
   - Movement of food through the digestive tract.
   - Blood circulation.
   - Contraction of muscles.

4. **Growth**

   Growth is an increase in body size due to increase in number of cells, Size of cells, Intercellular substances

   Example

   Growth of bones and muscles during childhood, Growth requires nutrients and proper metabolism.

5. **Differentiation**

   Differentiation is the process by which unspecialized cells become specialized in structure and function.

   Example

   Stem cells developing into nerve cells, muscle cells, or blood cells. This process is important for development and tissue repair

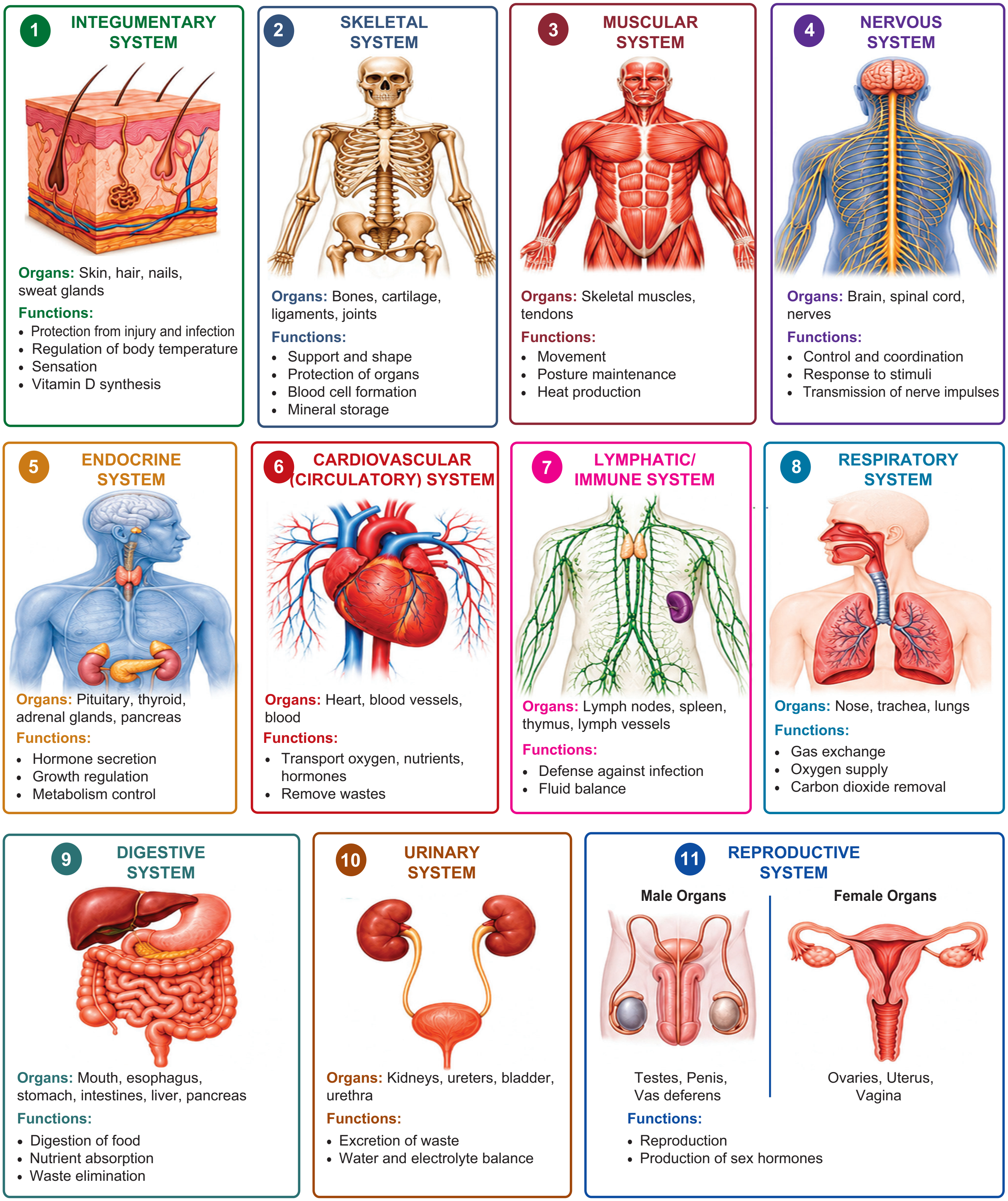

Fig. 1.2 : Major Organ systems of Human Body