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ANATOMY AND PHYSIOLOGY 1

(HCM 112)

TABLE OF CONTENT

CHAPTER ONE

INTRODUCTION OF ANATOMY AND PHYSIOLOGY

1.1 DEFINITION

a) **Anatomy** is the study of the structure and relationship between body parts.
b) **Physiology** is the study of the function of body parts and the body as a whole. Some specializations within each of these sciences follow:
   - *Gross (macroscopic) anatomy* is the study of body parts visible to the naked eye, such as the heart or bones.
   - *Histology* is the study of tissues at the microscopic level.
   - *Cytology* is the study of cells at the microscopic level.
   - *Neurophysiology* is the study of how the nervous system functions.

1.2 ORGANIZATIONS OF LIVING SYSTEMS

Living systems can be defined from various perspectives, from the broad (looking at the entire earth) to the minute (individual atoms). Each perspective provides information about how or why a living system functions:

- At the chemical level, ***atoms***, *molecules* (combinations of atoms), and the chemical bonds between atoms provide the framework upon which all living activity is based.
- The ***cell*** is the smallest unit of life. **Organelles** within the cell are specialized bodies performing specific cellular functions. Cells themselves may be specialized. Thus, there are nerve cells, bone cells, and muscle cells.
- A *tissue* is a group of similar cells performing a common function. Muscle tissue, for example, consists of muscle cells.
- An *organ* is a group of different kinds of tissues working together to perform a particular activity. The heart is an organ composed of muscle, nervous, connective, and epithelial tissues.
- An *organ system* is two or more organs working together to accomplish a particular task. The digestive system, for example, involves the coordinated activities of many organs, including the mouth, stomach, small and large intestines, pancreas, and liver.
- An *organism* is a system possessing the characteristics of living things—the ability to obtain and process energy, the ability to respond to environmental changes, and the ability to reproduce.

1.3 HOMEOSTASIS

A characteristic of all living systems is **homeostasis**, or the maintenance of stable, internal conditions within specific limits. In many cases, stable conditions are maintained by negative feedback.

In **negative feedback**, a sensing mechanism (a receptor) detects a change in conditions beyond specific limits. A control center, or integrator (often the brain), evaluates the change and activates a second mechanism (an **effector**) to correct the condition; for example, cells that either remove or add glucose to the blood in an effort to maintain homeostasis are effectors. Conditions are constantly monitored by receptors and evaluated by the control center. When the control center determines that conditions have returned to normal, corrective action is discontinued. Thus, in negative feedback, the variant condition is canceled, or negated, so that conditions are returned to normal.

The regulation of glucose concentration in the blood illustrates how homeostasis is maintained by negative feedback. After a meal, the absorption of glucose (a sugar) from the digestive tract increases the amount of glucose in the blood. In response, specialized cells in the pancreas (alpha cells) secrete the hormone insulin, which circulates through the blood and stimulates liver and muscle cells to absorb the glucose. Once blood glucose levels return to normal, insulin secretion stops. Later, perhaps after heavy exercise, blood glucose levels may drop because muscle cells absorb glucose from the blood and use it as a source of energy for muscle contraction. In response to falling blood glucose levels, another group of specialized pancreatic cells (beta cells) secretes a second hormone, glucagon. Glucagon stimulates the liver to release its stored glucose into the blood. When blood glucose levels return to normal, glucagon secretion stops.

Compare this with **positive feedback,** in which an action intensifies a condition so that it is driven farther beyond normal limits. Such positive feedback is uncommon but does occur during blood clotting, childbirth (labor contractions), lactation (where milk production increases in response to an increase in nursing), and sexual orgasm.

1.4 ANATOMIC TERMINOLOGY

In order to accurately identify areas of the body, clearly defined anatomical terms are used. These terms refer to the body in the anatomical position—standing erect, facing forward, arms down at the side, with the palms turned forward. In this position, the following apply:

- Directional terms are used to describe the relative position of one body part to another. These terms are listed in Table 1.
- Body planes and sections are used to describe how the body or an organ is divided into two parts:
    - *Sagittal planes* divide a body or organ vertically into right and left parts. If the right and left parts are equal, the plane is a midsagittal plane; if they're unequal, the plane is a parasagittal plane.
    - A *frontal (coronal) plane* divides the body or organ vertically into front (anterior) and rear (posterior) parts.
    - A *horizontal (transverse) plane* divides the body or organ horizontally into top (superior) and bottom (inferior) parts. This is also known as a cross-section.

- Body cavities are enclosed areas that house organs. These cavities are organized into two groups:
- The *posterior/dorsal* body cavity includes the cranial cavity (which contains the brain) and the vertebral cavity (which contains the spinal cord).
- The *anterior/ventral* body cavity includes the thoracic cavity (which contains the lungs, each in its own pleural cavity, and the heart, in the pericardial cavity) and the abdominopelvic cavity (which contains the digestive organs in the abdominal cavity and the bladder and reproductive organs in the pelvic cavity).
- Regional terms identify specific areas of the body. In some cases, a descriptive word is used to identify the location. For example, the axial region refers to the main axis of the body—the head, neck, and trunk. The appendicular region refers to the appendages—the arms and legs. Other regional terms use a body part to identify a particular region of the body. For example, the nasal region refers to the nose.

Table 1. Basic Anatomy Terms

Term	Definition	Example
Superior	Above another structure.	The heart is superior to the stomach.
Inferior	Below another structure.	The stomach is inferior to the heart.
Anterior/ventral	Toward the front of the body.	The navel is anterior to the spine.
Posterior/dorsal	Toward the back of the body.	The spine is posterior to the navel.
Medial	Toward the midline of the body. (The midline divides the body into equal right and left sides.)	The nose is medial to the eyes.
Lateral	Away from the midline of the body (or toward the side of the body).	The ears are lateral to the nose.
Ipsilateral	On the same side of the body.	The spleen and descending colon are ipsilateral.
Contralateral	On opposite sides of the body.	The ascending and descending portions of the colon are contralateral.
Intermediate	Between two structures.	The knee is intermediate between the upper leg and lower leg.
Proximal	Closer to the point of attachment of a limb.	The elbow is proximal to the wrist.
Distal	Farther from the point of attachment of a limb.	The foot is distal to the knee.
Superficial	Toward the surface of the body.	The skin is superficial to the muscle.
Deep	Away from the surface of the body.	The skeleton is deep to the skin.

CHAPER TWO

THE SKELETAL SYSTEM

The skeletal system is formed of bones and cartilage, which are connected by ligaments to form a framework for the remainder of the body tissues. This article, the first in a two-part series on the structure and function of the skeletal system, reviews the anatomy and physiology of bone. Understanding the structure and purpose of the bone allows nurses to understand common pathophysiology and consider the most-appropriate steps to improve musculoskeletal health.

The skeletal system is composed of bones and cartilage connected by ligaments to form a framework for the rest of the body tissues.

There are two parts to the skeleton:

a) Axial skeleton – bones along the axis of the body, including the skull, vertebral column and ribcage;
b) Appendicular skeleton – appendages, such as the upper and lower limbs, pelvic girdle and shoulder girdle.

2.1 FUNCTION

As well as contributing to the body's overall shape, the skeletal system has several key functions, including:

- Support and movement;
- Protection;
- Mineral homeostasis;
- Blood-cell formation;
- Triglyceride storage.

1) Support and Movement

Bones are a site of attachment for ligaments and tendons, providing a skeletal framework that can produce movement through the coordinated use of levers, muscles, tendons and ligaments. The bones act as levers, while the muscles generate the forces responsible for moving the bones.

2) Protection

Bones provide protective boundaries for soft organs: the cranium around the brain, the vertebral column surrounding the spinal cord, the ribcage containing the heart and lungs, and the pelvis protecting the urogenital organs.

3) Mineral Homoeostasis

As the main reservoirs for minerals in the body, bones contain approximately 99% of the body's calcium, 85% of its phosphate and 50% of its magnesium (Bartl and Bartl, 2017). They are essential in maintaining homoeostasis of minerals in the blood with minerals stored in the bone are released in response to the body's demands, with levels maintained and regulated by hormones, such as parathyroid hormone.

4) Blood-Cell Formation (Haemopoiesis)

Blood cells are formed from haemopoietic stem cells present in red bone marrow. Babies are born with only red bone marrow; over time this is replaced by yellow marrow due to a decrease in erythropoietin, the hormone responsible for stimulating the production of erythrocytes (red blood cells) in the bone marrow. By adulthood, the amount of red marrow has halved, and this reduces further to around 30% in older age (Robson and Syndercombe Court, 2018).

5) Triglyceride Storage

Yellow bone marrow (Fig 1) acts as a potential energy reserve for the body; it consists largely of adipose cells, which store triglycerides (a type of lipid that occurs naturally in the blood) (Tortora and Derrickson, 2009).

2.2 BONE COMPOSITION

Bone matrix has three main components:

- 25% organic matrix (osteoid);
- 50% inorganic mineral content (mineral salts);
- 25% water (Robson and Syndercombe Court, 2018).

Organic matrix (osteoid) is made up of approximately 90% type-I collagen fibres and 10% other proteins, such as glycoprotein, osteocalcin, and proteoglycans (Bartl and Bartl, 2017). It forms the framework for bones, which are hardened through the deposit of the calcium and other minerals around the fibres (Robson and Syndercombe Court, 2018).

Mineral salts are first deposited between the gaps in the collagen layers with once these spaces are filled, minerals accumulate around the collagen fibres, crystallising and causing the tissue to harden; this process is called ossification (Tortora and Derrickson, 2009). The hardness of the bone depends on the type and quantity of the minerals available for the body to use; hydroxyapatite is one of the main minerals present in bones.

While bones need sufficient minerals to strengthen them, they also need to prevent being broken by maintaining sufficient flexibility to withstand the daily forces exerted on them. This flexibility and tensile strength of bone is derived from the collagen fibres. Over-mineralisation of the fibres or impaired collagen production can increase the brittleness of bones – as with the genetic disorder osteogenesis imperfecta – and increase bone fragility (Ralston and McInnes, 2014).

Bone architecture is made up of two types of bone tissue:

- Cortical bone;
- Cancellous bone.

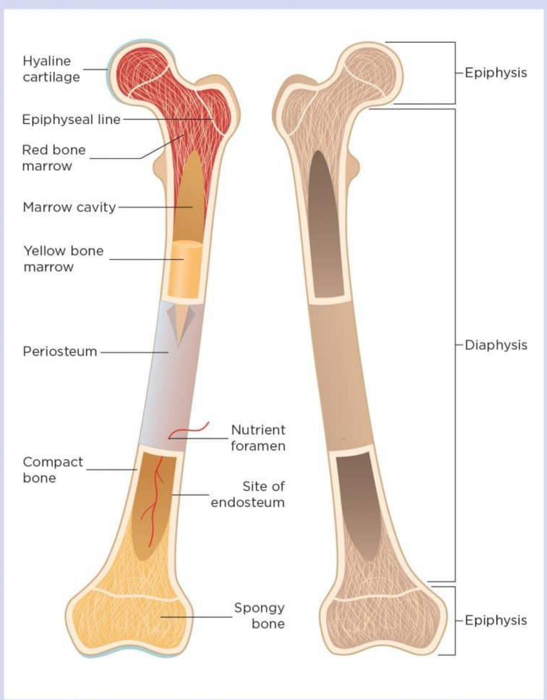
CORTICAL BONE

Also known as compact bone, this dense outer layer provides support and protection for the inner cancellous structure.

Cortical bone comprises three elements:

Periosteum (Fig 1); Intracortic

Fig 1. **Bone structure**



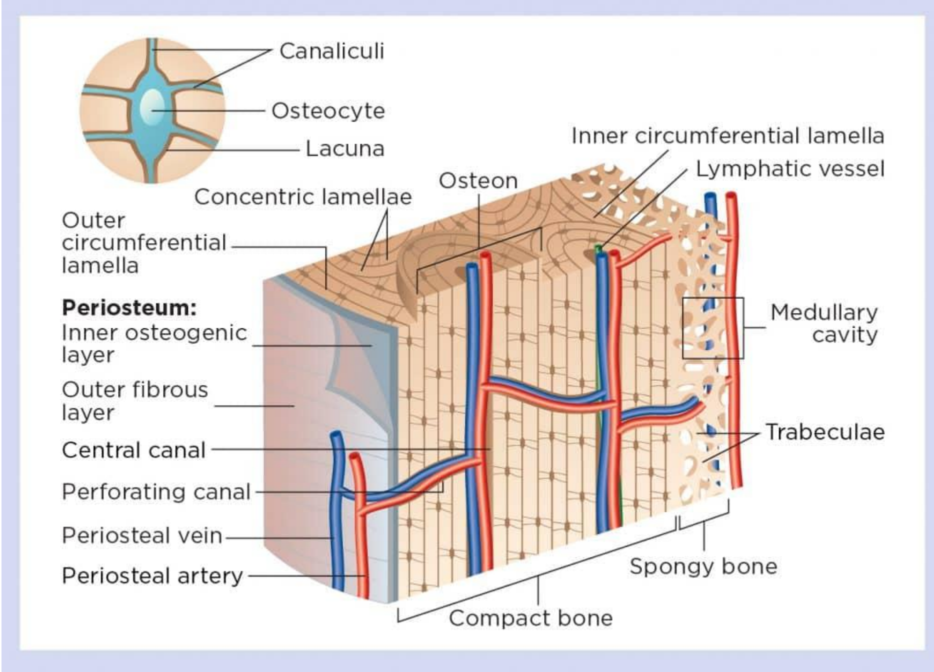


Fig 2. **Anatomy of cortical bone**

Bones are an important part of the musculoskeletal system. This article, the first in a two-part series on the skeletal system, reviews the anatomy and physiology of bone

Bones are key to providing the body with structural support and enabling movement

Most of the body's minerals are st byored in the bones

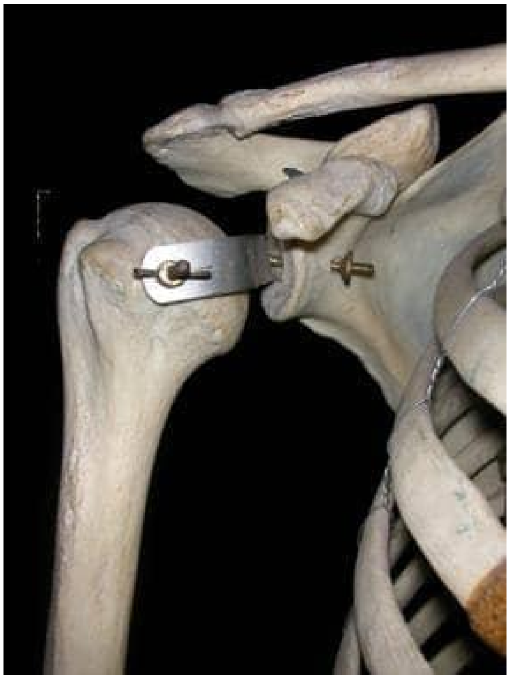
Diet and lifestyle can affect the quality of bone formation

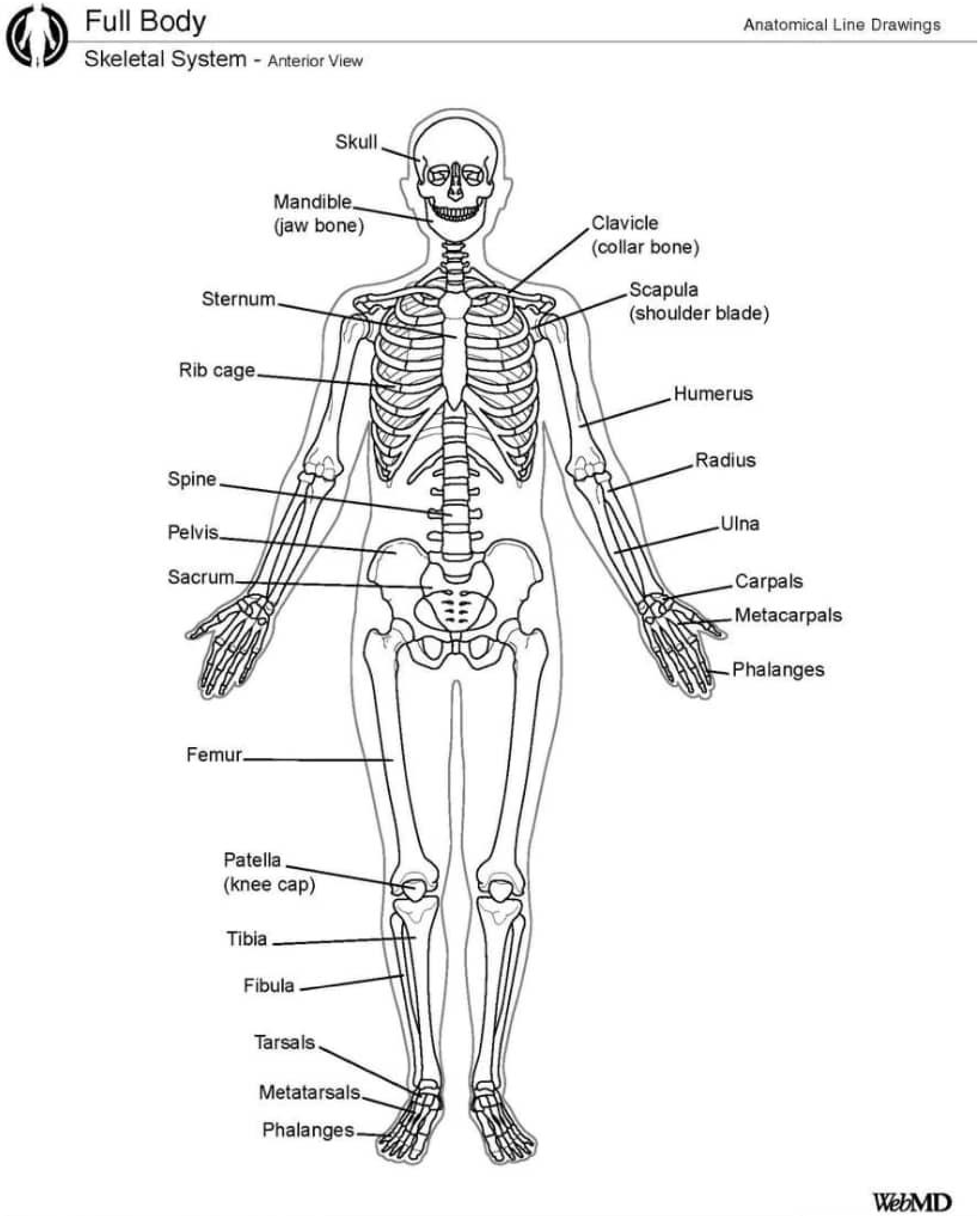
After bones have formed they undergo constant remodelling

Changes in the remodelling process can result in pathology such as Paget's disease of bone or osteoporosis

CANCELLOUS BONE is the meshwork of spongy tissue (trabeculae) of mature adult bone typically found at the core of vertebral bones in the spine and the ends of the long bones (such as the femur or thigh bone).

The structure of the cancellous bone can be likened to a honeycomb that consists of interconnecting spaces containing the bone marrow. The marrow of cancellous bone tissue supplies osteoprogenitor cells that help in the formation and growth of new bone. Thus, bone grafts composed of cancellous bone are sometimes used in grafting procedures to promote osteogenesis. Cancellous bone, also called trabecular bone or spongy bone, light, porous bone enclosing numerous large spaces that give a honeycombed or spongy appearance. The bone matrix, or framework, is organized into a three-dimensional latticework of bony processes, called trabeculae, arranged along lines of stress. The spaces between are often filled with marrow and blood vessels.




Full Body
Skeletal System - Anterior View
Anatomical Line Drawings
Skull
Mandible (jaw bone)
Clavicle (collar bone)
Sternum
Scapula (shoulder blade)
Rib cage
Humerus
Radius
Spine
Ulna
Pelvis
Sacrum
Carpals
Metacarpals
Phalanges
Femur
Patella (knee cap)
Tibia
Fibula
Tarsals
Metatarsals
Phalanges
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2.3 APPENDICULAR SKELETON ANATOMY

There are a total of 126 bones in the appendicular skeleton. It consists of the bones that make up the arms and legs, as well as the bones that attach them to the axial skeleton.

- **Pectoral Girdle**

The pectoral girdle is where the arms attach to the axial skeleton. It's made up of the clavicle (collarbone) and scapula (shoulder blade). There are two of each of these — one for each arm.

- **Upper Limbs**

Each arm contains 30 bones, known as the:

Humerus. The humerus is the long bone of the upper arm.

Radius. The radius is one of two long bones of the forearm, found on the thumb side.

Ulna. The ulna is the second long bone of the forearm, found on the pinky finger side.

Carpals. The carpals are a group of eight bones found in the wrist area.

Metacarpals. The metacarpals are five bones found in the middle area of the hand.

Phalanges. The phalanges are 14 bones that make up the fingers.

- **Pelvic Girdle**

The pelvic girdle, commonly known as the hips, is where the legs attach to the axial skeleton. It's made up of two hipbones — one for each leg.

Each hip bone consists of three parts, known as the:

Ilium. The ilium is the top portion of each hip bone.

Ischium. The ischium is a curved bone that makes up the base of each hip bone.

Pubis. The pubis is located in the front part of the hip bone.

- **Lower Limbs**

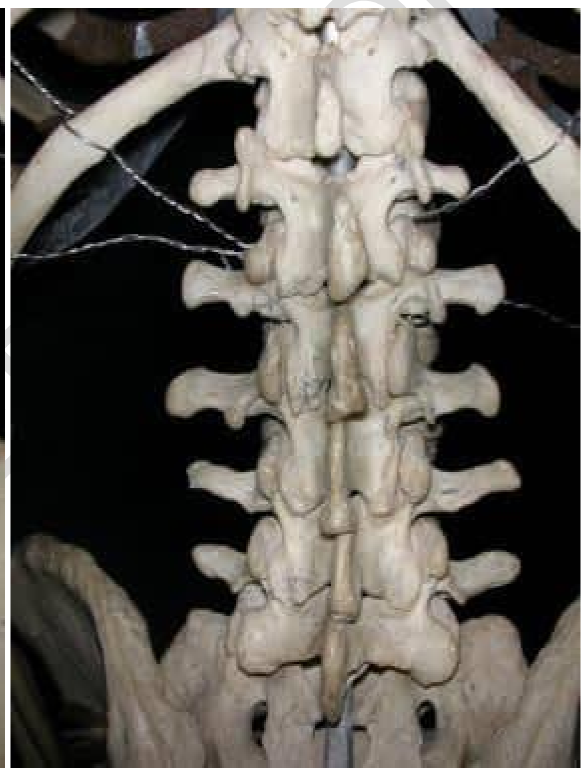
Each leg is composed of 30 bones, known as the:

a) Femur. The femur is the large bone of the upper leg.
b) Tibia. The tibia is the main bone of the lower leg. It forms the shin.
c) Fibula. The fibula is the second bone in the lower leg, found in the outer leg.
d) Patella. The patella is also called the kneecap.
e) Tarsals. The tarsals are the seven bones that make up the ankle.

f) Metatarsal. The metatarsals are the five bones that make up the middle area of the foot.
g) Phalanges. The phalanges are 14 bones that comprise the toes How is the human body similar to a well-tuned machine?

Many people have compared the human body to a machine. Think about some common machines, such as drills and washing machines. Each machine consists of many parts, and each part does a specific job, yet all the parts work together to perform an overall function. The human body is like a machine in all these ways. In fact, it may be the most fantastic machine on Earth.

The human machine is organized at different levels, starting with the cell and ending with the entire organism (see Figure below). At each higher level of organization, there is a greater degree of complexity.

CHAPTER THREE

ORGANS AND ORGAN SYSTEMS

3.1 HOW IS THE HUMAN BODY SIMILAR TO A WELL-TUNED MACHINE?

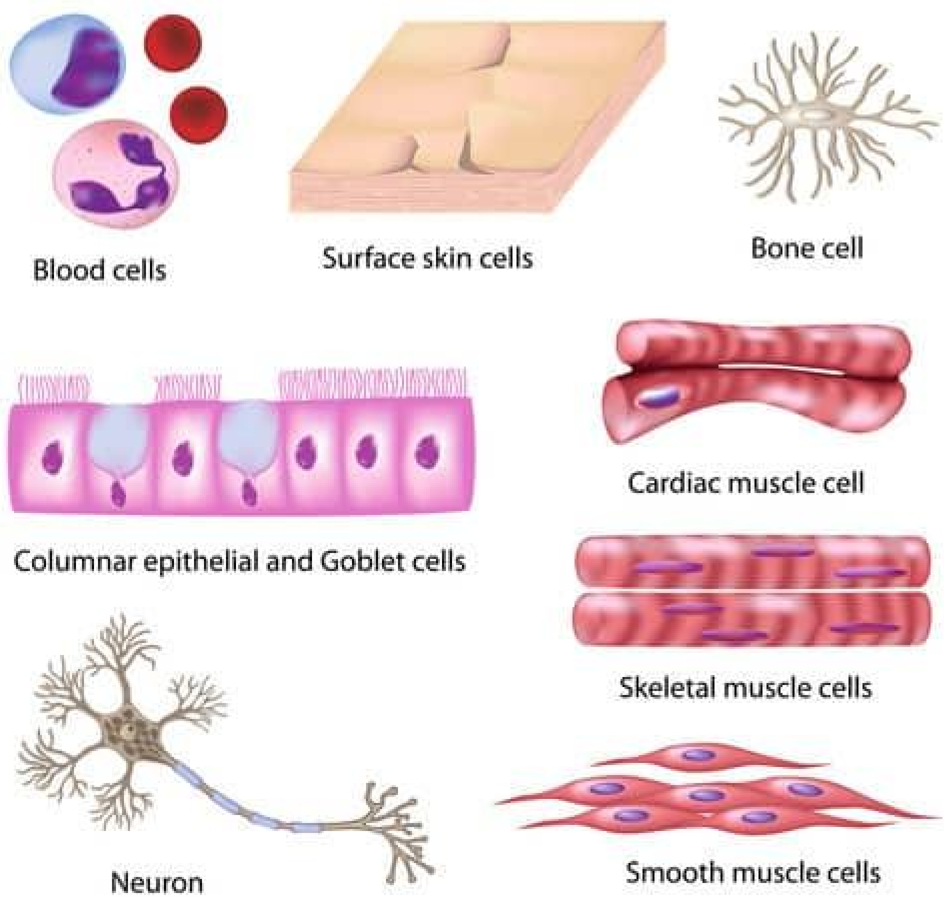
Many people have compared the human body to a machine. Think about some common machines, such as drills and washing machines. Each machine consists of many parts, and each part does a specific job, yet all the parts work together to perform an overall function. The human body is like a machine in all these ways. In fact, it may be the most fantastic machine on Earth.

The human machine is organized at different levels, starting with the cell and ending with the entire organism (see Figure below). At each higher level of organization, there is a greater degree of complexity.

3.2 THE HUMAN ORGANISM HAS SEVERAL LEVELS OF ORGANIZATION.

- **CELLS**

The most basic parts of the human machine are cells—an amazing 100 trillion of them by the time the average person reaches adulthood! Cells are the basic units of structure and function in the human body, as they are in all living things. Each cell carries out basic life processes that allow the body to survive. Many human cells are specialized in form and function, as shown in Figure below. Each type of cell in the figure plays a specific role. For example, nerve cells have long projections that help them carry electrical messages to other cells. Muscle cells have many mitochondria that provide the energy they need to move the body.

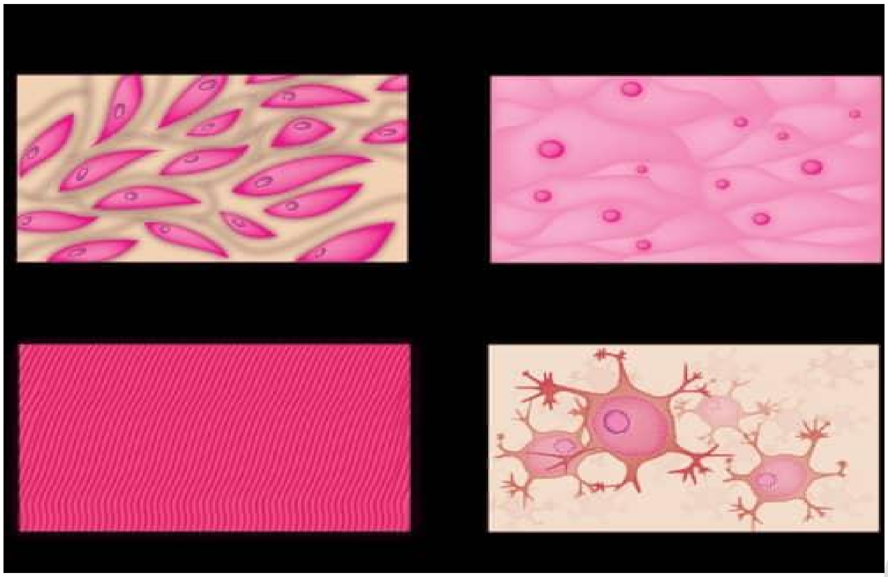


Different types of cells in the human body are specialized for specific jobs. Do you know the functions of any of the cell types shown here?

- **TISSUES**

After the cell, the tissue is the next level of organization in the human body. A tissue is a group of connected cells that have a similar function. There are four basic types of human tissues: epithelial, muscle, nervous, and connective tissues.

These four tissue types, which are shown in Figure below, make up all the organs of the human body.



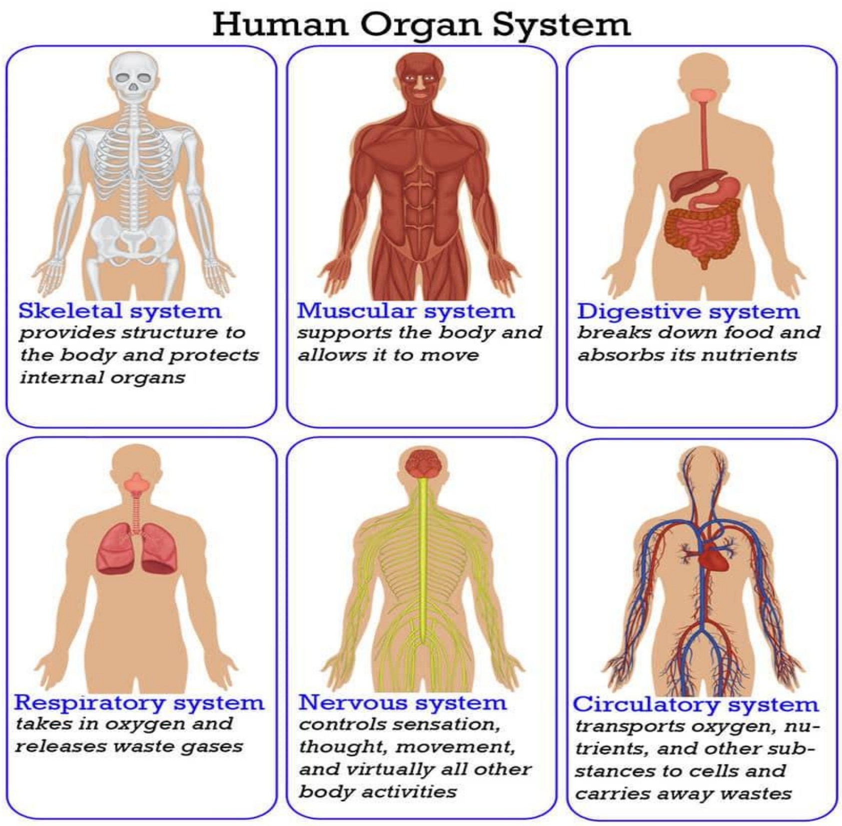
- Connective tissue.
- Epithelial tissue
- muscle tissue
- Nervous tissue

The human body consists of these four tissue types.

1) **Connective tissue** is made up of cells that form the body's structure. Examples include bone and cartilage.
2) **Epithelial tissue** is made up of cells that line inner and outer body surfaces, such as the skin and the lining of the digestive tract. Epithelial tissue protects the body and its internal organs, secretes substances such as hormones, and absorbs substances such as nutrients.
3) **Muscle tissue** is made up of cells that have the unique ability to contract, or become shorter. Muscles attached to bones enable the body to move.
4) **Nervous tissue** is made up of neurons, or nerve cells, that carry electrical messages. Nervous tissue makes up the brain and the nerves that connect the brain to all parts of the body.

3.3 HUMAN ORGAN SYSTEM

After tissues, organs are the next level of organization of the human body. An organ is a structure that consists of two or more types of tissues that work together to do the same job. Examples of human organs include the brain, heart, lungs, skin, and kidneys. Human organs are organized into organ systems, many of which are shown in Figure below. An organ system is a group of organs that work together to carry out a complex overall function. Each organ of the system does part of the larger job



Many of the organ systems that make up the human body are represented here. What is the overall function of each organ system?

Your body's 12 organ systems are shown below (Table below). Your organ systems do not work alone in your body. They must all be able to work together. For example, one of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove toxic waste products such as carbon dioxide. A number of organ systems, including the cardiovascular and respiratory systems, all work together to do this.

- **Cardiovascular**

i. Heart; blood vessels; blood
ii. Transports oxygen, hormones, and nutrients to the body cells. Moves wastes and carbon dioxide away from cells.

- **Lymphatic**

i. Lymph nodes; lymph vessels
ii. Defend against infection and disease, moves lymph between tissues and the blood stream.

- **Digestive**

i. Esophagus; stomach; small intestine; large intestine
ii. Digests foods and absorbs nutrients, minerals, vitamins, and water.

- **Endocrine**

i. Pituitary gland, hypothalamus; adrenalglands; ovaries; testes
ii. Produces hormones that communicate between cells.

- **Integumentary**

i. Skin, hair, nails

ii. Provides protection from injury and water loss, physical defense against infection by microorganisms, andtemperature control.

- **Muscular**

i. Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendons

ii. Involved in movement and heat production.

- **Nervous**

i. Brain, spinal cord; nerves

ii. Collects, transfers, and processes information.

- **Reproductive**

i. Female: uterus; vagina; fallopian tubes; ovaries

ii. Male: penis; testes; seminal vesicles

iii. Produces gametes (sex cells) and sex hormones.

- **Respiratory**

i. Trachea, larynx, pharynx, lungs

ii. Brings air to sites where gas exchange can occur between the blood and cells (around body) or blood and air (lungs)

- **Skeletal**

i. Bones, cartilage; ligaments

ii. Supports and protects soft tissues of body; produces blood cells; stores minerals.

- **Urinary**

i. Kidneys; urinary bladder

ii. Removes extra water, salts, and waste products from blood and body; controls pH; controls water and salt balance.

- **Immune**

i. Bone marrow; spleen; white blood cells

ii. Defends against diseases.

The epidermis is the outer layer, resting atop the dermis. There is no direct blood supply to the epidermis and therefore, the cells of this stratified squamous tissue obtain nutrients and oxygen through diffusion. This layer also cushions underlying tissues and protects them from desiccation. In hot, dry environments, water is first lost from this layer. Similarly, extended exposure to water during baths or during swimming, crinkles the skin since water is absorbed and retained in the epidermis.

The epidermis is made of four layers – the stratum basale, stratum spinosum, stratum granulosum and stratum corneum. In each of these layers, keratinocytes undergo successive steps in differentiation beginning with the proliferative layer in the innermost stratum basale containing keratinocyte stem cells. After division, cells migrate outwards to form a layer of spiny cells called stratum spinosum. The nuclei of these cells are primarily involved in transcribing large amounts of keratin mRNA and other microfibrils that form impermeable cell junctions.

The next layer of the epidermis is called stratum granulosum and contains keratinocytes with a granular cytoplasm. This stage in keratinocyte maturation is characterized by the formation of the lipid barrier of the body. The presence of keratohyalin granules is important for crosslinking keratin filaments and dehydrating cells to form tight, interlinked layers of cells that perform the barrier function of skin. The outermost layer is called the stratum corneum and is directly exposed to the external environment. It consists of multiple layers of terminally differentiated keratinocytes that are also called corneocytes. These cells do not have a nucleus and contain copious amounts of keratin filaments. This layer of the epidermis provides mechanical strength and rigidity to the structure of skin. These anucleated cells are resistant to virus attack and are replaced every 15 days, preventing them from becoming a reservoir of infection. The parts of the skin that have no hair follicles have an extra layer of epithelium called the stratum lucidum that is sandwiched between the stratum granulosum and stratum corneum. This extra layer makes the epithelium of these regions 'thicker' than those in other parts of the body. Usually, this is the skin on the palms of the hands and soles of the feet, and in addition to stratum lucidum, is also well supplied with nerve endings.

The second major section of the integument is the dermis, and is occasionally called the 'true skin' since it is supplied with blood vessels and nerve endings. Sebaceous glands and sweat glands are also present in the dermis. The closest that the dermis gets to the external environment is at structures called dermal papillae. These are finger-like projections into the epidermis and, on the palms, form fingerprints.

Sebaceous glands produce sebum – an oily, waxy secretion containing many lipids. The cells forming a sebaceous gland have extremely short lifespans – barely over a week. The soles of the feet are free from sebaceous glands, though the sections of skin between the toes is richly supplied with these structures. Sebum also forms a part of ear wax. These lipids can provide a rich environment for the growth of bacteria, and therefore contribute towards body odor, either when the glands are clogged or when the sebum is not removed periodically.

The dermis also plays host to sweat glands. Sweat, in contrast to sebum, is a water-based secretion, containing electrolytes – sodium salts, urea, and even trace amounts of uric acid. While most water soluble waste products are removed in the urine, sweat also contributes towards clearing some of the metabolic byproducts of the body. The presence of many acids, such as lactic acid and acetic acid, makes sweat mildly acidic. A subsection of sweat glands, called apocrine glands, even release proteins, carbohydrates, lipids or steroids. Sweat from these glands, along with sebum, can encourage bacterial growth, and form the site for infection, odor or rashes.

THE SKIN

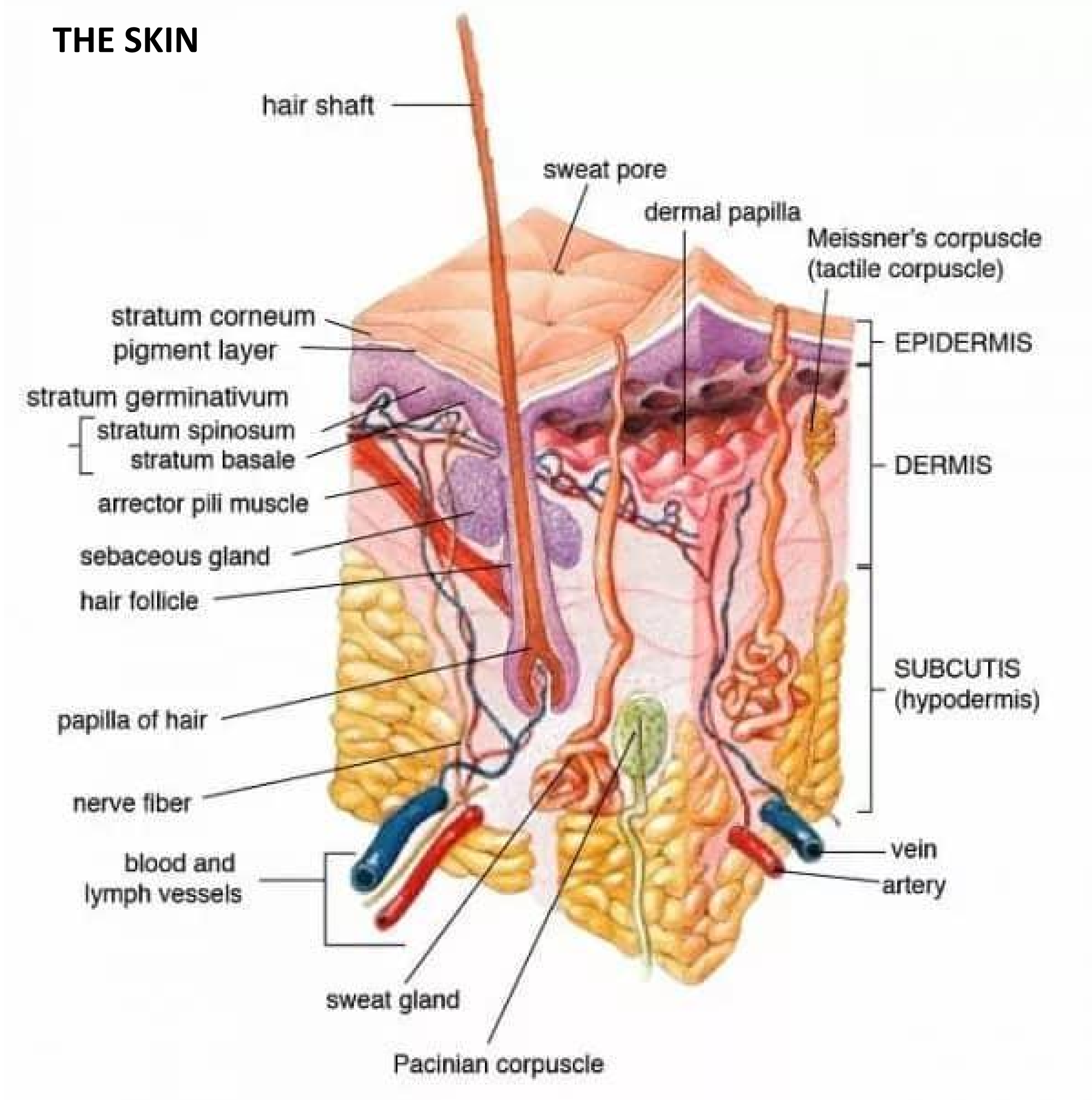


Image shows cross section of skin, with various dermal and epidermal layers, glands, nerves and blood vessels.

CHAPTER FOUR

FUNCTIONS OF THE INTEGUMENTARY SYSTEM

Each layer of the skin contributes to the overall function within the body. The most obvious role of the skin is to protect the body from external aggression.

4.1 MUSCULOSKELETAL SYSTEM

The system) is a human body system that provides our body with movement, stability, shape, and support. It is subdivided into two broad systems:

Muscular system, which includes all types of muscles in the body. Skeletal muscles, in particular, are the ones that act on the body joints to produce movements. Besides muscles, the muscular system contains the tendons which attach the muscles to the bones.

Skeletal system, whose main component is the bone. Bones articulate with each other and form the joints, providing our bodies with a hard-core, yet mobile, skeleton. The integrity and function of the bones and joints is supported by the accessory structures of the skeletal system; articular cartilage, ligaments, and bursae.

Besides its main function to provide the body with stability and mobility, the musculoskeletal system has many other functions; the skeletal part plays an important role in other homeostatic functions such as storage of minerals (e.g., calcium) and hematopoiesis, while the muscular system stores the majority of the body's carbohydrates in the form of glycogen.

This article will introduce you to the anatomy and function of the musculoskeletal system The muscular system is an organ system composed of specialized contractile tissue called the muscle tissue. There are three types of muscle tissue, based on which all the muscles are classified into three groups:

Cardiac muscle, which forms the muscular layer of the heart (myocardium)

Smooth muscle, which comprises the walls of blood vessels and hollow organs

Skeletal muscle, which attaches to the bones and provides voluntary movement.

Based on their histological appearance, these types are classified into striated and non-striated muscles; with the skeletal and cardiac muscles being grouped as striated, while the smooth muscle is non-striated. The skeletal muscles are the only ones that we can control by the power of our will, as they are innervated by the somatic part of the nervous system. In contrast to this, the cardiac and smooth muscles are innervated by the autonomic nervous system, thus being controlled involuntarily by the autonomic centers in our brain.

4.2 SKELETAL MUSCLES

The skeletal muscles are the main functional units of the muscular system. There are more than 600 muscles in the human body. They vary greatly in shape in size, with the smallest one being the stapedius muscle in the inner ear, and the largest one being the quadriceps femoris muscle in the thigh.

The skeletal muscles of the human body are organized into four groups for every region of the body:

Muscles of the head and neck, which include the muscles of the facial expression, muscles of mastication, muscles of the orbit, muscles of the tongue, muscles of the pharynx, muscles of the larynx, and muscles of the neck

Muscles of the trunk, which include the muscles of the back, anterior and lateral abdominal muscles, and muscles of the pelvic floor

Muscles of the upper limbs, which include muscles of the shoulder, muscles of the arm, muscles of the forearm and muscles of the hand

Muscles of the lower limbs, which include hip and thigh muscles, leg muscles and foot muscles

4.3 MUSCULAR SYSTEM

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Smooth muscle, which comprises the walls of blood vessels and hollow organs

Skeletal muscle, which attaches to the bones and provides voluntary movement.

Based on their histological appearance, these types are classified into striated and non-striated muscles; with the skeletal and cardiac muscles being grouped as striated, while the smooth muscle is non-striated. The skeletal muscles are the only ones that we can control by the power of our will, as they are innervated by the somatic part of the nervous system. In contrast to this, the cardiac and smooth muscles are innervated by the autonomic nervous system, thus being controlled involuntarily by the autonomic centers in our brain.

Functions of The Muscular System

The main function of the muscular system is to produce movement of the body. Depending on the axis and plane, there are several different types of movements that can be performed by the musculoskeletal system. Some of the most important ones include:

- Flexion and extension: movement of decreasing or increasing the angle between the bones involved in the movement, respectively. This motion takes place in the sagittal plane around a frontal axis. An example of flexion is bending the leg at the knee joint, whereas extension would be straightening knee from a flexed position.
- Adduction and abduction: movements of bringing the parts of the body towards or away from the midline, respectively. These movements are carried out in the frontal plane around a sagittal axis. For example, abduction of the arm at the shoulder joint involves moving the arm away from the side of the body, while adduction involves bringing it back towards the body.
- Rotation is the movement in which a part of the body rotates around its vertical (longitudinal) axis in the transverse plane. This movement is defined relative to the midline, where internal rotation involves rotating the segment towards to the midline, while external rotation involves moving it away from the midline. Examples include lateral or medial rotation of the thigh.
- Supination and pronation are special types of rotatory movements usually used to describe the movements of the forearm. Supination is essentially a lateral rotation of the forearm which turns the palms anteriorly (if the arm is anatomical position) or superiorly, when the elbow is flexed. These movements are also sometimes used to describe movements in the ankle and foot, in which supination means rolling the foot outwards, while pronation means rolling the foot inwards

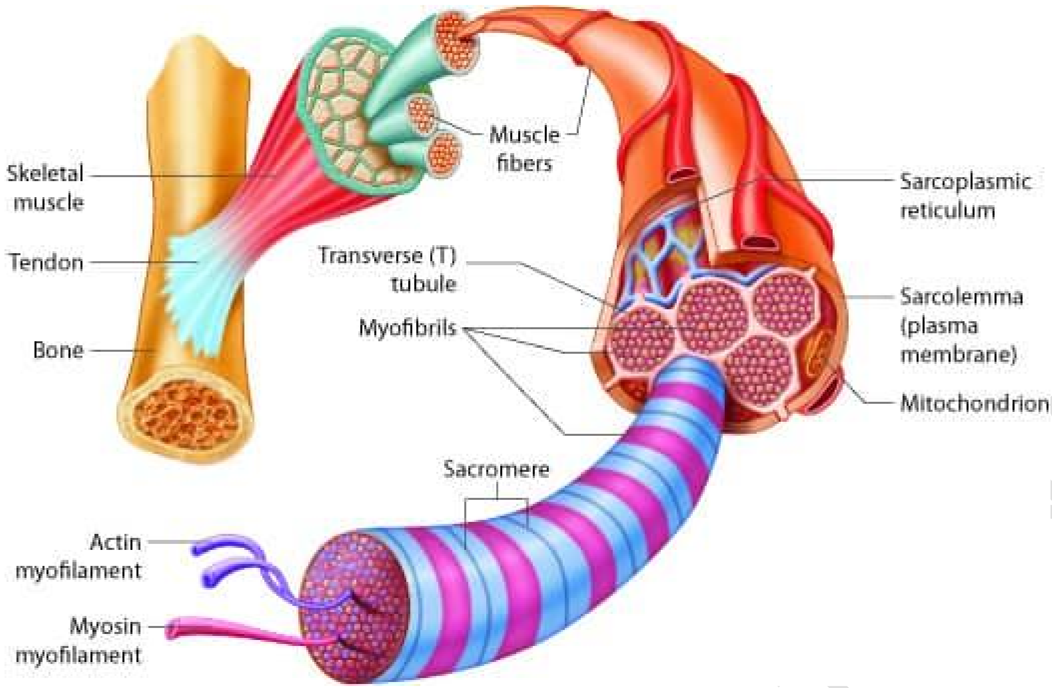
4.4 MUSCLE CONTRACTION

The most important property of skeletal muscles is its ability to contract. Muscle contraction occurs as a result of the interaction of myofibrils inside the muscle cells. This process either shortens the muscle or increases its tension, generating a force that either facilitates or slows down a movement.

There are two types of muscle contraction; isometric and isotonic. A muscle contraction is deemed as isometric if the length of the muscle does not change during the contraction, and isotonic if the tension remains unchanged while the length of the muscle changes. There are two types of isotonic contractions:

Concentric contraction, in which the muscle shortens due to generating enough force to overcome the imposed resistance. This type of contraction serves to facilitate any noticeable movement (e.g. lifting a barbell or walking on an incline).

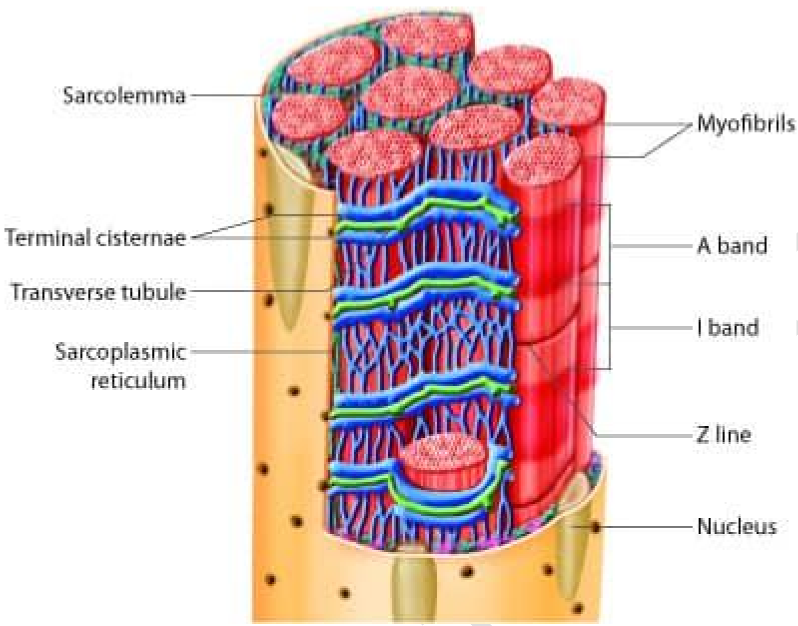
Eccentric contraction, in which the muscle stretches due to the resistance being greater than the force the muscle generates. During an eccentric contraction, the muscle maintains high tension. This type of contraction usually serves to slow down a movement (e.g. lowering a barbell or walking downhill).


Skeletal muscle
Tendon
Bone
Muscle fibers
Sarcoplasmic reticulum
Transverse (T) tubule
Myofibrils
Sarcolemma (plasma membrane)
Mitochondrion
Sacromere
Actin myofilament
Myosin myofilament

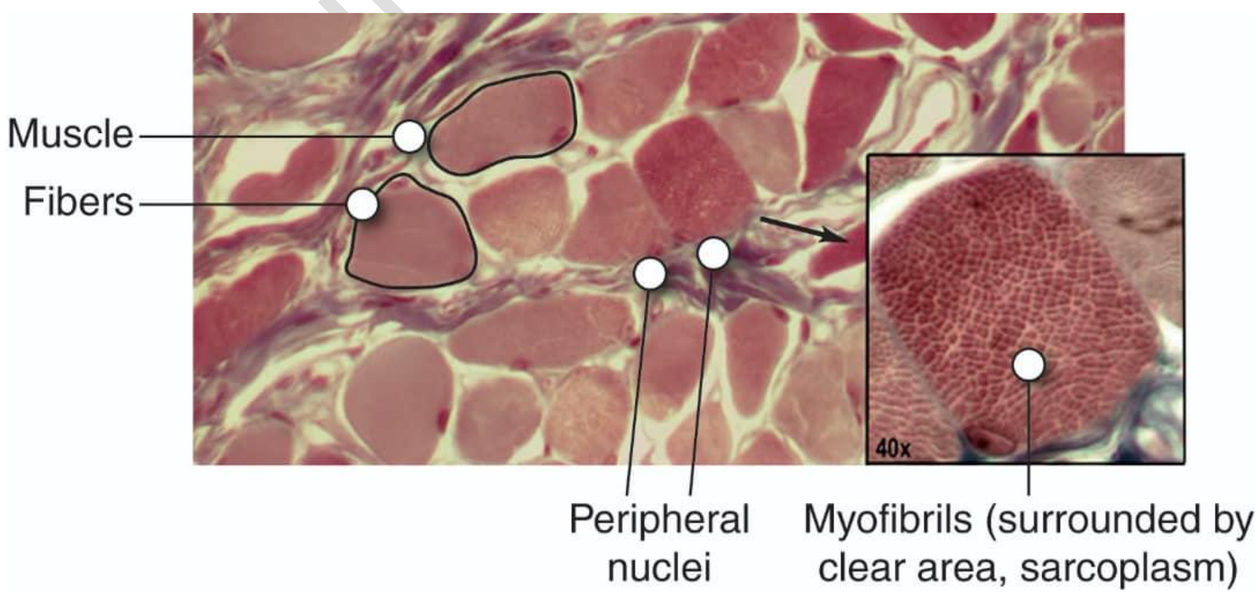
CHAPTER FIVE

CELLULAR ORGANELLES AND STRUCTURES

Muscle cells contain organelles found in all cells, including nuclei, the endoplasmic reticulum, mitochondria and the Golgi apparatus. The amount and organization of organelles and structures is slightly different in muscle cells. Actin is found inside every cell in the body, but actin is specially organized within the sarcomeres of muscle cells. Muscle cells also have extremely high numbers of mitochondria to produce ATP for force generation. Recall that an ATP molecule is required for one myosin to perform one power stroke.



Organelles and Structures Specific to Muscle Cells



5.1 GROSS-SECTION OF THE MUSCLE CELLS

The image is a light microscopic image of skeletal muscle in cross section showing a group muscle cells, each surrounded by epimysium and the group surrounded by perimysium. Blood vessels are seen passing through the image and in cross section on the right. The magnified image shows cross section of a single cell (fiber) at higher magnification with many myofibrils visible (small dark circles).

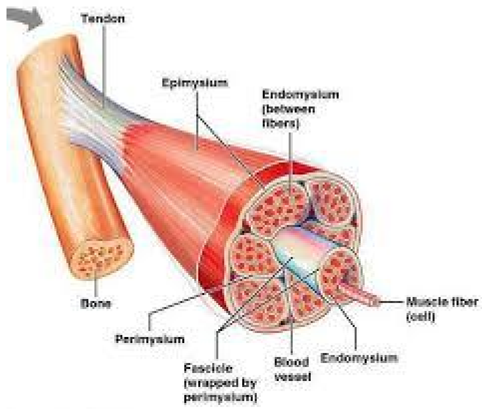
Each skeletal muscle fiber is a single cell produced from the fusion of many precursor cells. These fused cells are therefore functionally quite large, with diameters of up to 100 micrometers and lengths of up to 30 centimeters. Compare this with a cell of the skin which is a cube of 20 micrometers in nearly every diameter. In muscle fibers, sarcomeres arrange into parallel structures called myofibrils, so both the Z disc and the M line hold myofilaments in place to maintain the structural arrangement and layering. Myofibrils are connected to each other by intermediate, or desmin, filaments that attach to the Z disc.

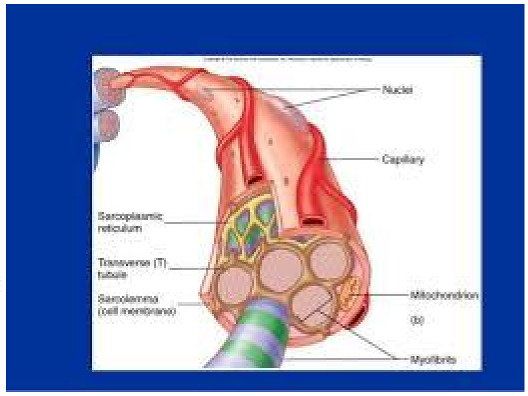
There is some special nomenclature associated with these fused cells. Each skeletal muscle fiber cell has more than one nucleus, which is called multinucleate. The plasma membrane of this fused skeletal muscle cell is called the sarcolemma. The muscle interacts with the nerves that stimulate the muscle at the sarcolemma, and we will describe this interaction later. Within the sarcolemma is the sarcoplasm, which is the cytoplasm of the fused muscle fiber. The sarcoplasm has most of the same components as standard cytoplasm in addition to high levels of the protein myoglobin, which stores oxygen.

Also, the sarcolemma contains many structures similar to the plasma membrane of other cells, but it also possesses structures unique to muscle cells. The sarcolemma has transverse tubules, or T tubules, which are indentations of the sarcolemma into the interior of the cell along the length of the muscle cell. The T tubules are filled with extracellular fluid, and they conduct the action potential from the nerve deep into the interior of the muscle cells, which can be very large. With T-tubules, nerves can stimulate entire muscles and muscle groups quickly and effectively. Without T tubules, action potential conduction into the interior of the cell would happen much more slowly, causing delays between neural stimulation and muscle contraction, resulting in slower, weaker contractions.

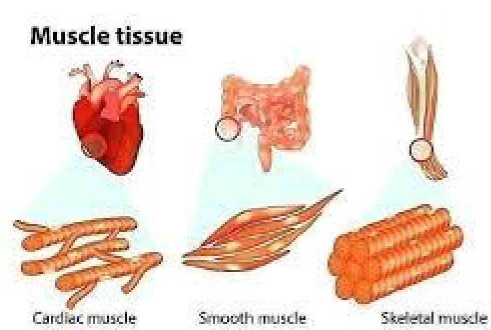
Inside skeletal muscle fibers is a network of membranous tubules called the sarcoplasmic reticulum (SR), which is similar to the smooth endoplasmic reticulum found in other cells. SR tubules are filled with high-calcium fluid, and they surround each myofibril. Terminal cisternae are dilated regions of the SR that form on either side of each T tubule extending into the cell. A grouping consisting of a T tubule, from the outside of the muscle fiber, and two terminal cisternae, from the inside of the muscle fiber, is called a triad.

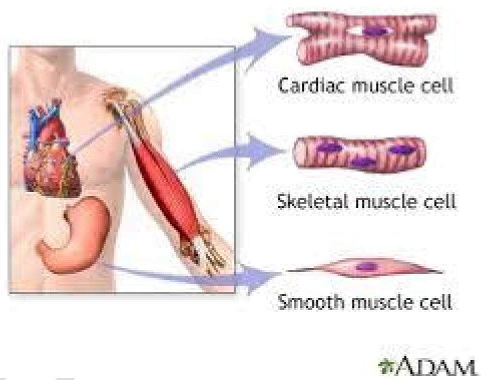
T tubules conduct an action potential along the surface of the muscle fiber into triads that trigger the release of Ca2+ ions from the nearby terminal cisternae. This, in turn, triggers muscle contraction when the calcium ions in the sarcoplasm can bind to the troponin of the sarcomeres.



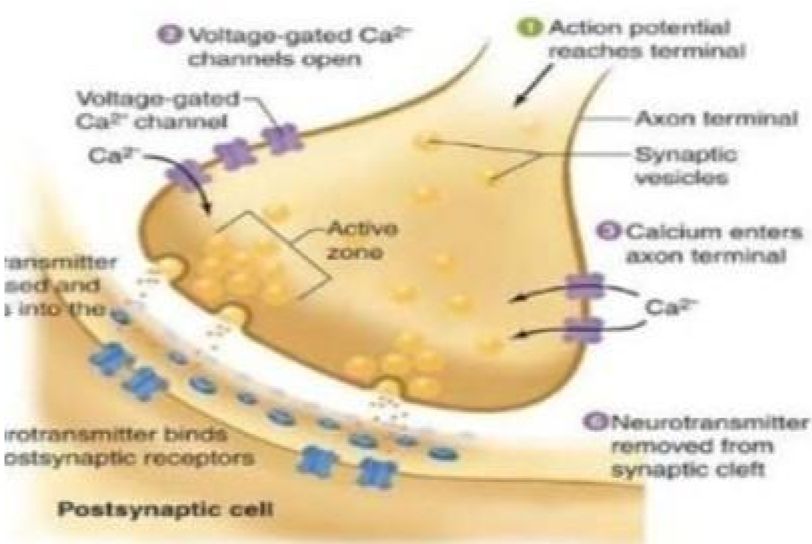


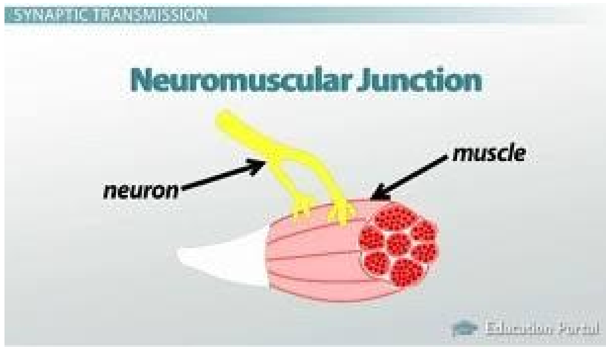
Microscopic structure of the musculoskeletal system Macroscopic and microscopic structure of the muscles





TYPES OF MUSCLES





5.2 SENSE ORGAN

Senses provide information about the body and its environment. Humans have five special senses: olfaction (smell), gustation (taste), equilibrium (balance and body position), vision, and hearing. Additionally, we possess general senses, also called somatosensation, which respond to stimuli like temperature, pain, pressure, and vibration. Vestibular sensation, which is an organism's sense of spatial orientation and balance, proprioception (position of bones, joints, and muscles), and the sense of limb position that is used to track kinesthesia (limb movement) are part of somatosensation. Although the sensory systems associated with these senses are very different, all share a common function: to convert a stimulus (such as light, or sound, or the position of the body) into an electrical signal in the nervous system. This process is called sensory transduction.

There are two broad types of cellular systems that perform sensory transduction. In one, a neuron works with a sensory receptor, a cell, or cell process that is specialized to engage with and detect a specific stimulus. Stimulation of the sensory receptor activates the associated afferent neuron, which carries information about the stimulus to the central nervous system. In the second type of sensory transduction, a sensory nerve ending responds to a stimulus in the internal or external environment: this neuron constitutes the sensory receptor. Free nerve endings can be stimulated by several different stimuli, thus showing little receptor specificity. For example, pain receptors in your gums and teeth may be stimulated by temperature changes, chemical stimulation, or pressure

- **TASTE AND SMELL**

Taste, also called gustation, and smell, also called olfaction, are the most interconnected senses in that both involve molecules of the stimulus entering the body and bonding to receptors. Smell lets an animal sense the presence of food or other animals—whether potential mates, predators, or prey—or other chemicals in the environment that can impact their survival. Similarly, the sense of taste allows animals to discriminate between types of foods. While the value of a sense of smell is obvious, what is the value of a sense of taste? Different tasting foods have different attributes, both helpful and harmful. For example, sweet-tasting substances tend to be highly caloric, which could be necessary for survival in lean times. Bitterness is associated with toxicity, and sourness is associated with spoiled food. Salty foods are valuable in maintaining homeostasis by helping the body retain water and by providing ions necessary for cells to function.

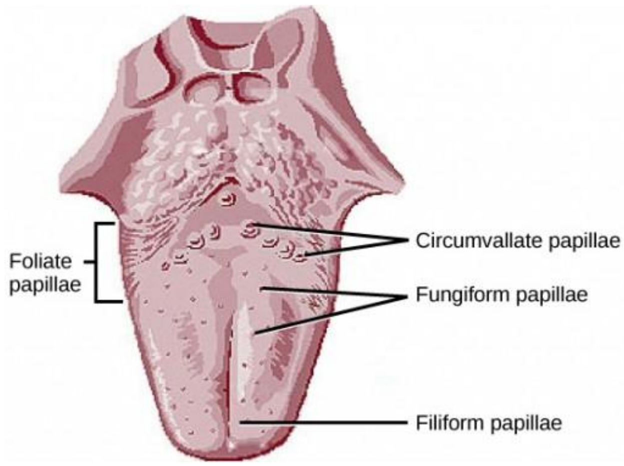
- **TASTES AND ODORS**

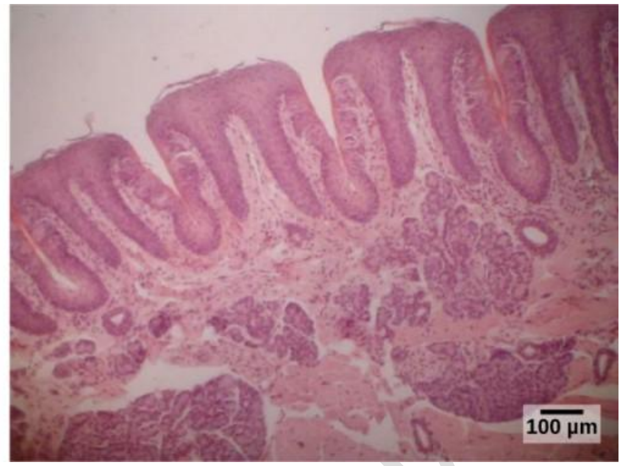
Both taste and odor stimuli are molecules taken in from the environment. The primary tastes detected by humans are sweet, sour, bitter, salty and umami. The first four tastes need little explanation. The identification of umami as a fundamental taste occurred fairly recently—it was identified in 1908 by Japanese scientist Kikunae Ikeda while he worked with seaweed broth, but it was not widely accepted as a taste that could be physiologically distinguished until many years later. The taste of umami, also known as savoriness, is attributable to the taste of the amino acid L-glutamate. In fact, monosodium glutamate, or MSG, is often used in cooking to enhance the savory taste of certain foods. What is the adaptive value of being able to distinguish umami? Savory substances tend to be high in protein.

All odors that we perceive are molecules in the air we breathe. If a substance does not release molecules into the air from its surface, it has no smell. And if a human or other animal does not have a receptor that recognizes a specific molecule, then that molecule has no smell. Humans have about 350 olfactory receptor subtypes that work in various combinations to allow us to sense about 10,000 different odors. Compare that to mice, for example, which have about 1,300 olfactory receptor types, and therefore probably sense more odors. Both odors and tastes involve molecules that stimulate specific chemoreceptors. Although humans commonly distinguish taste as one sense and smell as another, they work together to create the perception of flavor. A person's perception of flavor is reduced if he or she has congested nasal passages.

- **TASTE**

Detecting a taste (gustation) is fairly similar to detecting an odor (olfaction), given that both taste and smell rely on chemical receptors being stimulated by certain molecules. The primary organ of taste is the taste bud. A taste bud is a cluster of gustatory receptors (taste cells) that are located within the bumps on the tongue called papillae (singular: papilla) (illustrated in Figure 8.16). There are several structurally distinct papillae. Filiform papillae, which are located across the tongue, are tactile, providing friction that helps the tongue move substances, and contain no taste cells. In contrast, fungiform papillae, which are located mainly on the anterior two-thirds of the tongue, each contain one to eight taste buds and also have receptors for pressure and temperature. The large circumvallate papillae contain up to 100 taste buds and form a V near the posterior margin of the tongue





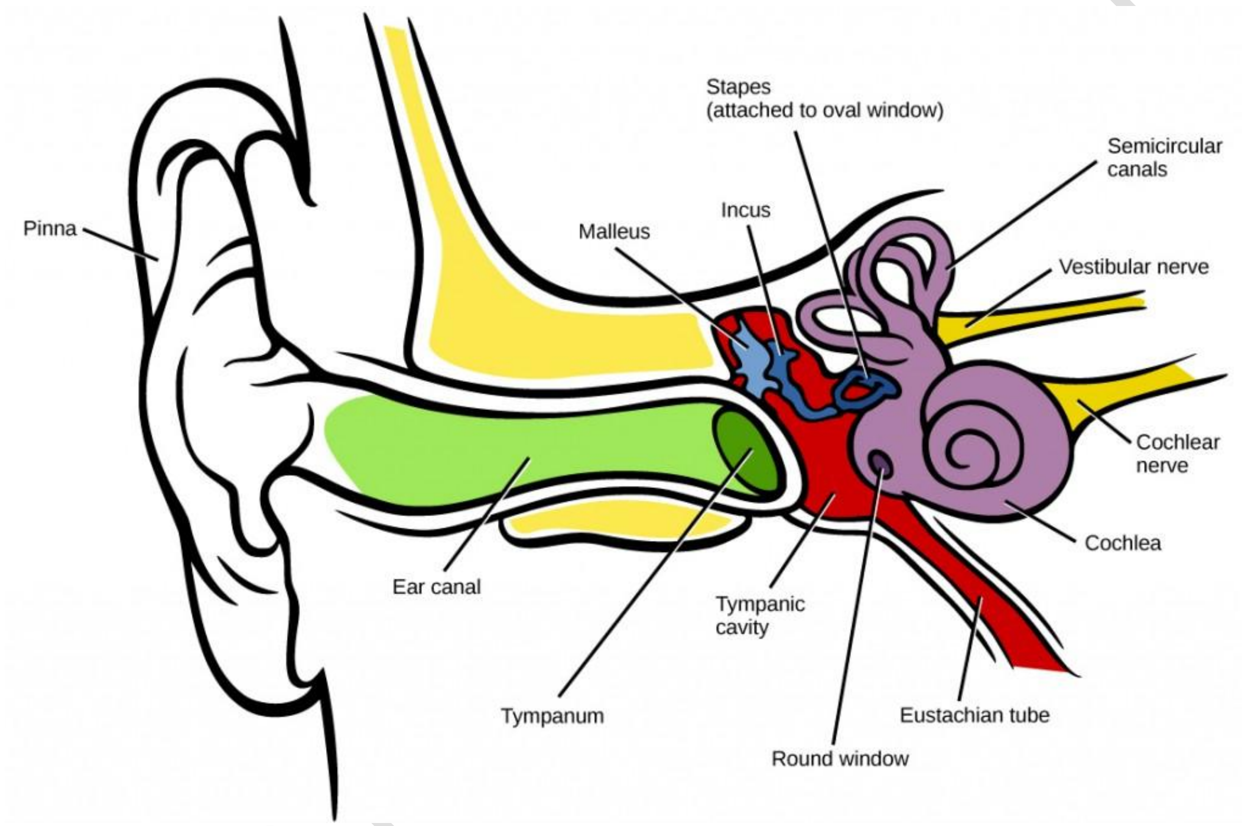
➢ SMELL AND TASTE IN THE BRAIN

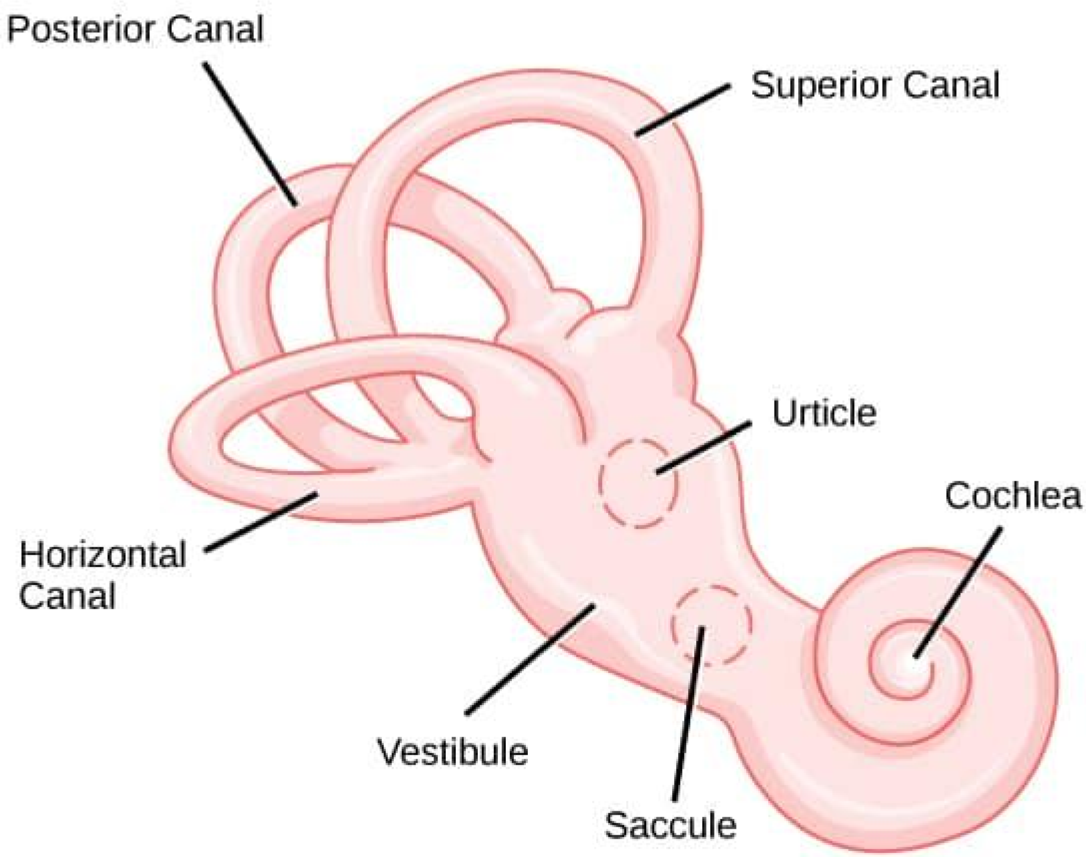
Olfactory neurons project from the olfactory epithelium to the olfactory bulb as thin, unmyelinated axons. The olfactory bulb is composed of neural clusters called glomeruli, and each glomerulus receives signals from one type of olfactory receptor, so each glomerulus is specific to one odorant. From glomeruli, olfactory signals travel directly to the olfactory cortex and then to the frontal cortex and the thalamus. Recall that this is a different path from most other sensory information, which is sent directly to the thalamus before ending up in the cortex. Olfactory signals also travel directly to the amygdala, thereafter reaching the hypothalamus, thalamus, and frontal cortex. The last structure that olfactory signals directly travel to is a cortical center in the temporal lobe structure important in spatial, autobiographical, declarative, and episodic memories. Olfaction is finally processed by areas of the brain that deal with memory, emotions, reproduction, and thought.

Taste neurons project from taste cells in the tongue, esophagus, and palate to the medulla, in the brainstem. From the medulla, taste signals travel to the thalamus and then to the primary gustatory cortex. Information from different regions of the tongue is segregated in the medulla, thalamus, and cortex

5.3 RECEPTION OF SOUND

In mammals, sound waves are collected by the external, cartilaginous part of the ear called the pinna, then travel through the auditory canal and cause vibration of the thin diaphragm called the tympanum or ear drum, the innermost part of the outer ear (illustrated in Figure 8.19). Interior to the tympanum is the middle ear. The middle ear holds three small bones called the ossicles, which transfer energy from the moving tympanum to the inner ear. The three ossicles are the malleus(also known as the hammer), the incus (the anvil), and stapes (the stirrup). The aptly named stapes looks very much like a stirrup. The three ossicles are unique to mammals, and each plays a role in hearing. The malleus attaches at three points to the interior surface of the tympanic membrane. The incus attaches the malleus to the stapes. In humans, the stapes is not long enough to reach the tympanum. If we did not have the malleus and the incus, then the vibrations of the tympanum would never reach the inner ear. These bones also function to collect force and amplify sounds. The ear ossicles are homologous to bones in a fish mouth: the bones that support gills in fish are thought to be adapted for use in the vertebrate ear over evolutionary time. Many animals (frogs, reptiles, and birds, for example) use the stapes of the middle ear to transmit vibrations to the middle ear.





Vision is the ability to detect light patterns from the outside environment and interpret them into images. Animals are bombarded with sensory information, and the sheer volume of visual information can be problematic. Fortunately, the visual systems of species have evolved to attend to the most-important stimuli. The importance of vision to humans is further substantiated by the fact that about one-third of the human cerebral cortex is dedicated to analyzing and perceiving visual information.

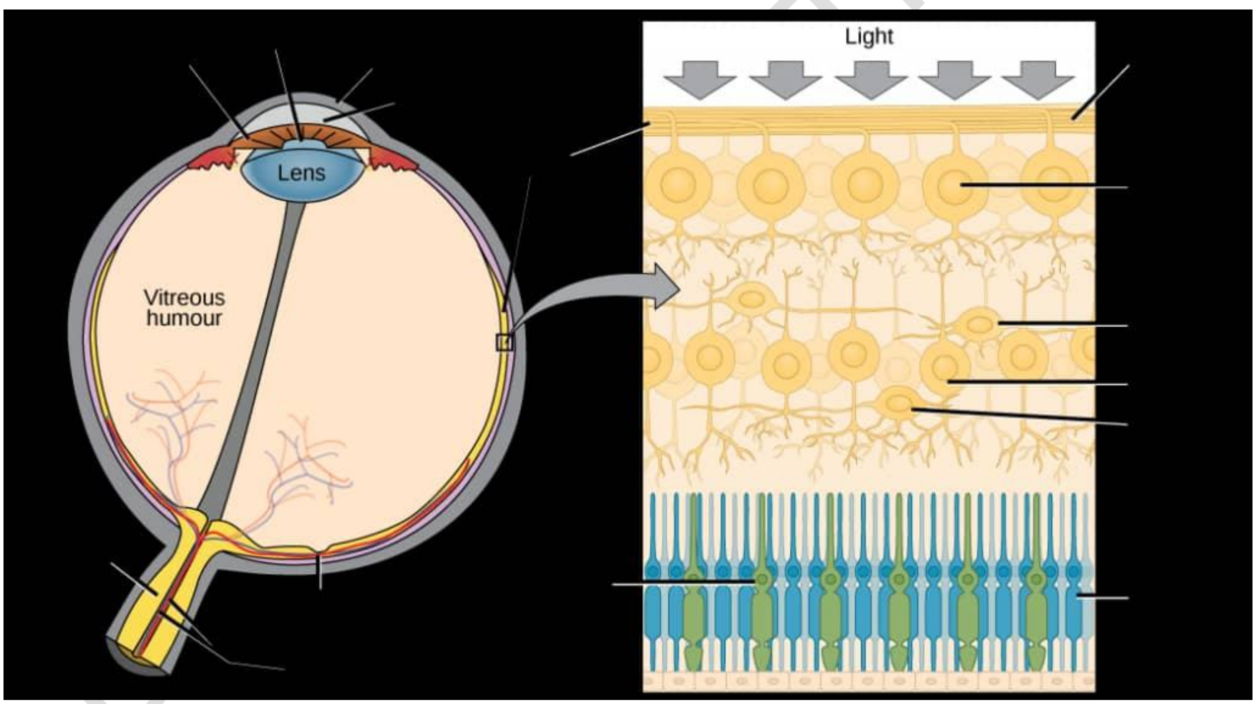
5.4 LIGHT

As with auditory stimuli, light travels in waves. The compression waves that compose sound must travel in a medium—a gas, a liquid, or a solid. In contrast, light is composed of electromagnetic waves and needs no medium; light can travel in a vacuum (Figure 8.22). The behavior of light can be discussed in terms of the behavior of waves and also in terms of the behavior of the fundamental unit of light—a packet of electromagnetic radiation called a photon. A glance at the electromagnetic spectrum shows that visible light for humans is just a small slice of the entire spectrum, which includes radiation that we cannot see as light because it is below the frequency of visible red light and above the frequency of visible violet light.

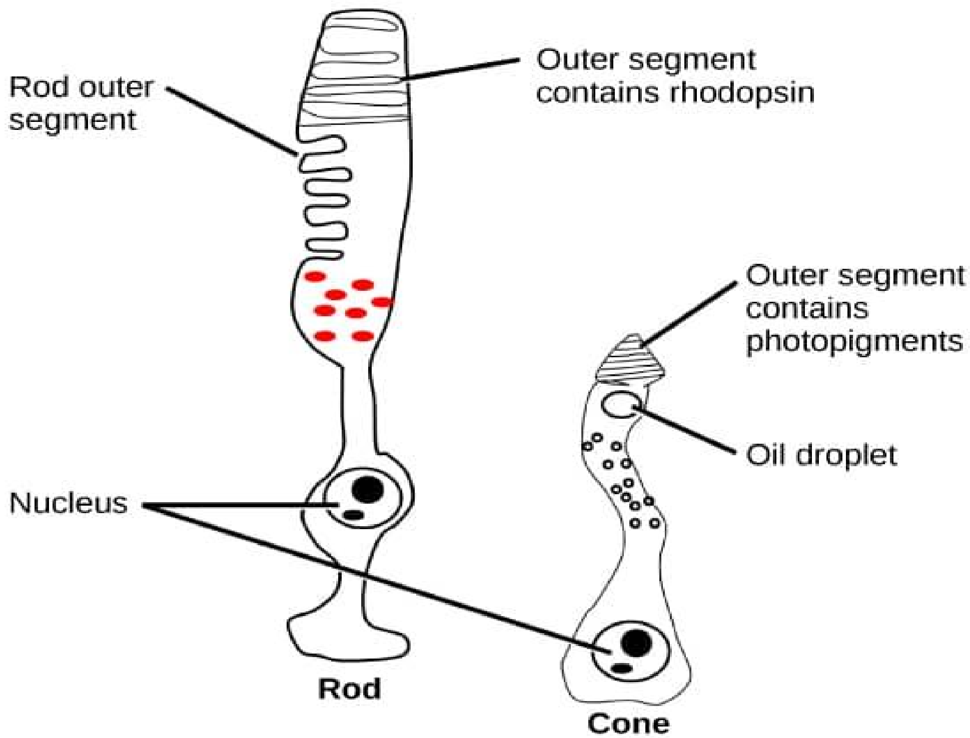
Certain variables are important when discussing perception of light. Wavelength (which varies inversely with frequency) manifests itself as hue. Light at the red end of the visible spectrum has longer wavelengths (and is lower frequency), while light at the violet end has shorter wavelengths (and is higher frequency). The wavelength of light is expressed in nanometers (nm); one nanometer is one billionth of a meter. Humans perceive light that ranges between approximately 380 nm and 740 nm. Some other animals, though, can detect wavelengths outside of the human range. For example, bees

5.5 ANATOMY OF THE EYE

The photoreceptive cells of the eye, where transduction of light to nervous impulses occurs, are located in the retina (Figure 8.23) on the inner surface of the back of the eye. But light does not impinge on the retina unaltered. It passes through other layers that process it so that it can be interpreted by the retina (Figure 8.23b). The cornea, the front transparent layer of the eye, and the crystalline lens, a transparent convex structure behind the cornea, both refract (bend) light to focus the image on the retina. The iris, which is conspicuous as the colored part of the eye, is a circular muscular ring lying between the lens and cornea that regulates the amount of light entering the eye. In conditions of high ambient light, the iris contracts, reducing the size of the pupil at its center. In conditions of low light, the iris relaxes and the pupil enlarges.

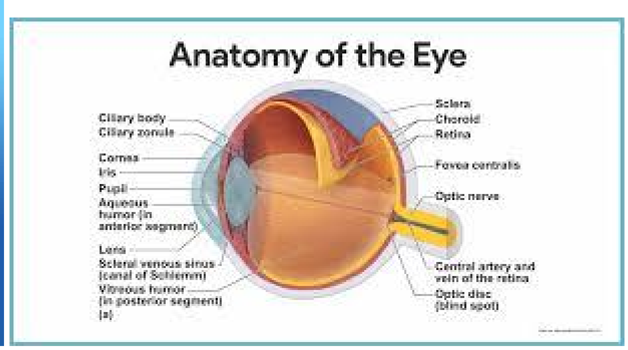


There are two types of photoreceptors in the retina: rods and cones, named for their general appearance as illustrated in Figure 8.24. Rods are strongly photosensitive and are located in the outer edges of the retina. They detect dim light and are used primarily for peripheral and nighttime vision. Cones are TCT weakly photosensitive and are located near the center of the retina. They respond to bright light, and their primary role is in daytime, color vision.



Rods and cones are photoreceptors in the retina. Rods respond in low light and can detect only shades of gray. Cones respond in intense light and are responsible for color vision.

The fovea is the region in the center back of the eye that is responsible for acute vision. The fovea has a high density of cones. When you bring your gaze to an object to examine it intently in bright light, the eyes orient so that the object's image falls on the fovea. However, when looking at a star in the night sky or other object in dim light, the object can be better viewed by the peripheral vision because it is the rods at the edges of the retina, rather than the cones at the center, that operate better in low light. In humans, cones far outnumber rods in the fovea.



CHAPTER SIX

NERVOUS SYSTEM ANATOMY AND PHYSIOLOGY

The nervous system transmits signals between the brain and the rest of the body, including internal organs. In this way, the nervous system's activity controls the ability to move, breathe, see, think, and more.

The basic unit of the nervous system is a nerve cell, or neuron. The human brain contains about 100 billion neurons. A neuron has a cell body, which includes the cell nucleus, and special extensions called axons (pronounced AK-sonz) and dendrites (pronounced DEN-drahytz). Bundles of axons, called nerves, are found throughout the body. Axons and dendrites allow neurons to communicate, even across long distances.

Different types of neurons control or perform different activities. For instance, motor neurons transmit messages from the brain to the muscles to generate movement. Sensory neurons detect light, sound, odor, taste, pressure, and heat and send messages about those things to the brain. Other parts of the nervous system control involuntary processes. These include keeping a regular heartbeat, releasing hormones like adrenaline, opening the pupil in response to light, and regulating the digestive system.

When a neuron sends a message to another neuron, it sends an electrical signal down the length of its axon. At the end of the axon, the electrical signal changes to a chemical signal. The axon then releases the chemical signal with chemical messengers called neurotransmitters (pronounced noor-oh-TRANS-mit-erz) into the synapse (pronounced SIN-aps)—the space between the end of an axon and the tip of a dendrite from another neuron. The neurotransmitters move the signal through the synapse to the neighboring dendrite, which converts the chemical signal back into an electrical signal. The electrical signal then travels through the neuron and goes through the same conversion processes as it moves to neighboring neurons.

The nervous system also includes non-neuron cells, called glia (pronounced GLEE-uh). Glia perform many important functions that keep the nervous system working properly. For example,

- glia:
- Help support and hold neurons in place
- Protect neurons
- Create insulation called myelin, which helps move nerve impulses
- Repair neurons and help restore neuron function
- Trim out dead neurons
- Regulate neurotransmitters

The brain is made up of many networks of communicating neurons and glia. These networks allow different parts of the brain to "talk" to each other and work together to control body functions, emotions, thinking, behavior, and other activities

The nervous system is the master controlling and communicating system of the body. Every thought, action, and emotion reflects its activity. Its signaling device, or means of communicating with body cells, is electrical impulses, which are rapid and specific and cause almost immediate responses.

6.1 FUNCTIONS OF THE NERVOUS SYSTEM

To carry out its normal role, the nervous system has three overlapping functions.

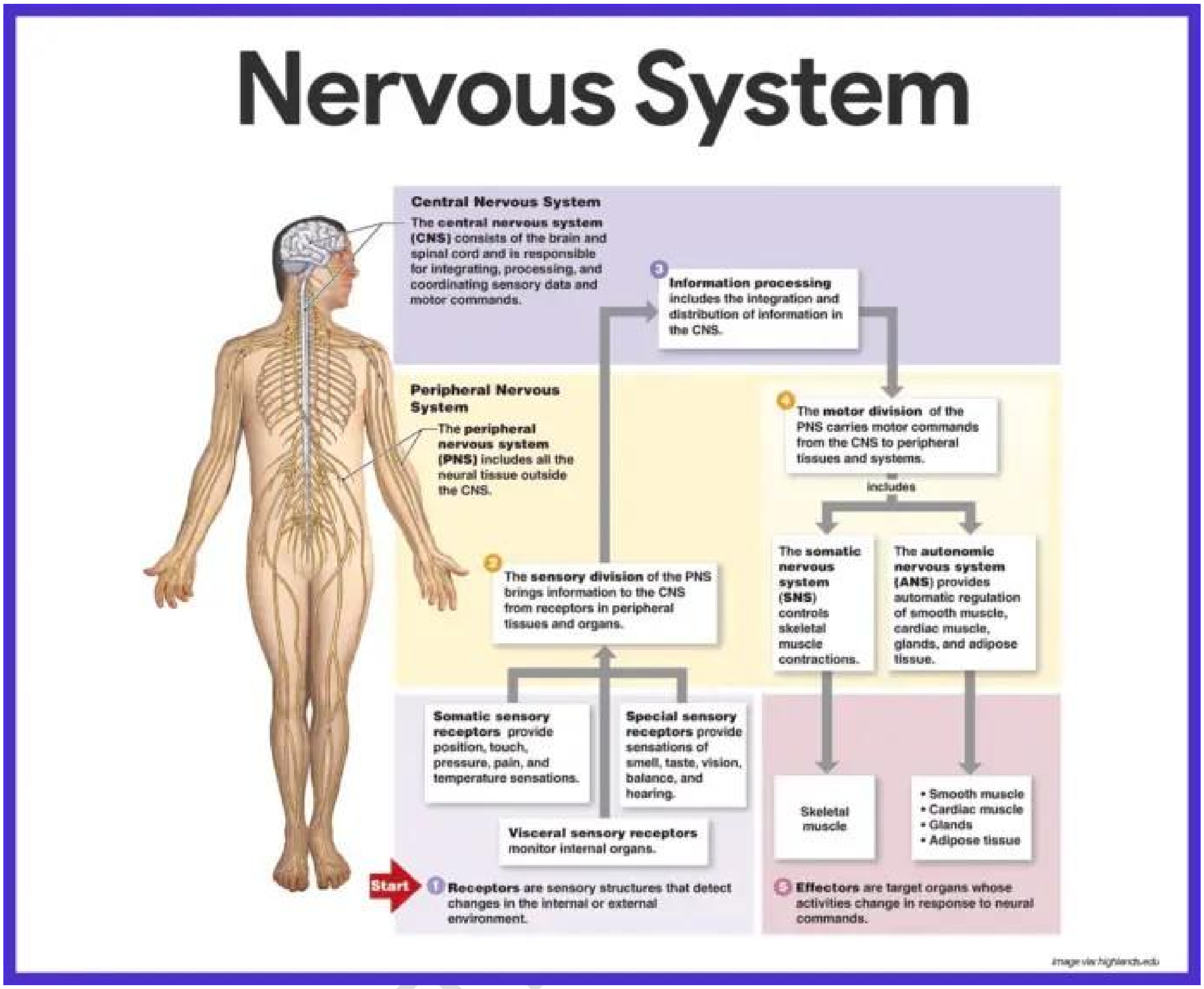
Monitoring changes. Much like a sentry, it uses its millions of sensory receptors to monitor changes occurring both inside and outside the body; these changes are called stimuli, and the gathered information is called sensory input.

Interpretation of sensory input. It processes and interprets the sensory input and decides what should be done at each moment, a process called integration.

Effects responses. It then effects a response by activating muscles or glands (effectors) via motor output.

Mental activity. The brain is the center of mental activity, including consciousness, thinking, and memory.

Homeostasis. This function depends on the ability of the nervous system to detect, interpret, and respond to changes in the internal and external conditions. It can help stimulate or inhibit the activities of other systems to help maintain a constant internal environment.



6.2 ANATOMY OF THE NERVOUS SYSTEM

The nervous system does not work alone to regulate and maintain body homeostasis; the endocrine system is a second important regulating system.

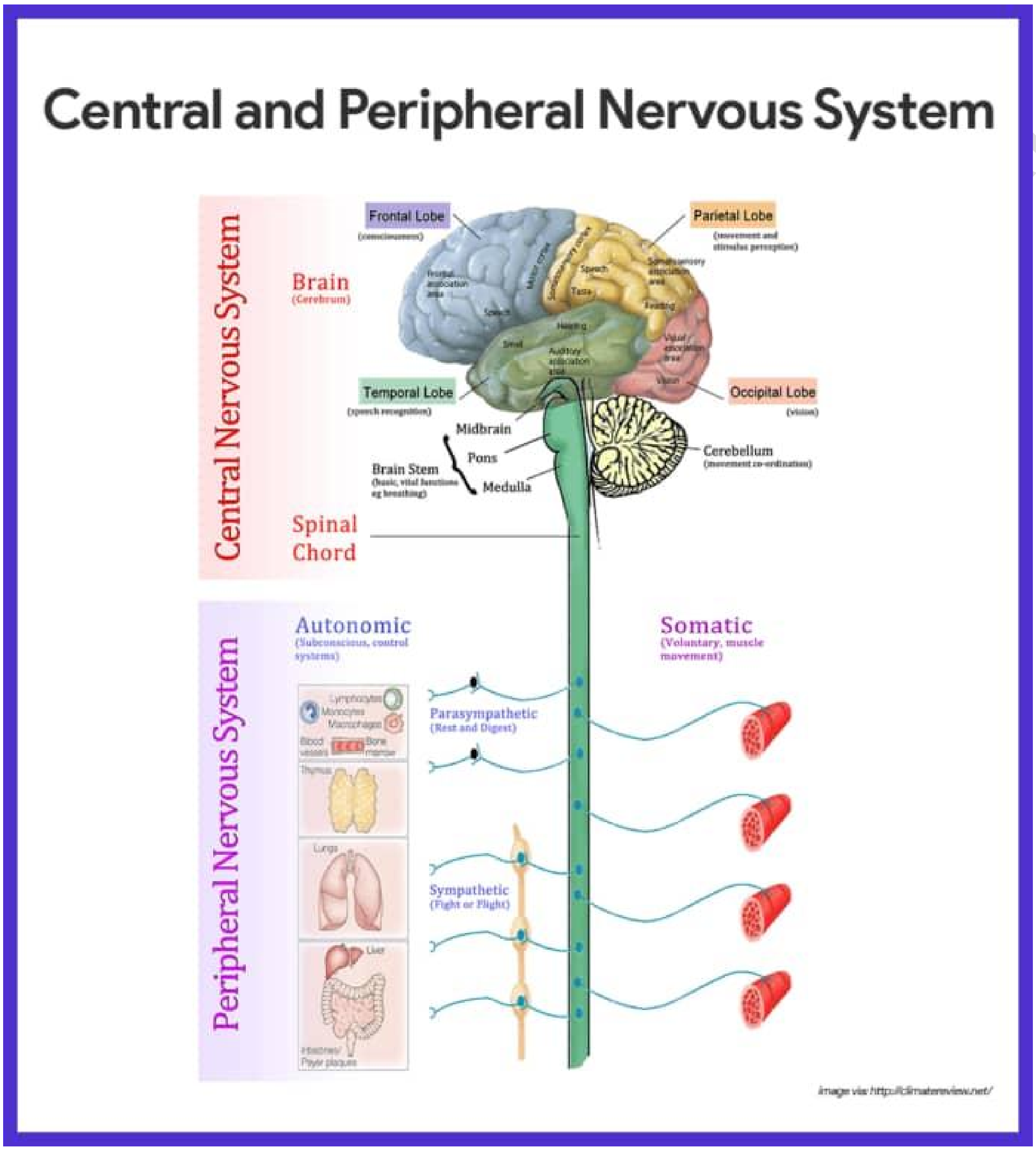
6.3 ORGANIZATION OF THE NERVOUS SYSTEM

We only have one nervous system, but, because of its complexity, it is difficult to consider all of its parts at the same time; so, to simplify its study, we divide it in terms of its structures (structural classification) or in terms of its activities (functional classification).

6.4 STRUCTURAL CLASSIFICATION

The structural classification, which includes all of the nervous system organs, has two subdivisions- the central nervous system and the peripheral nervous system.

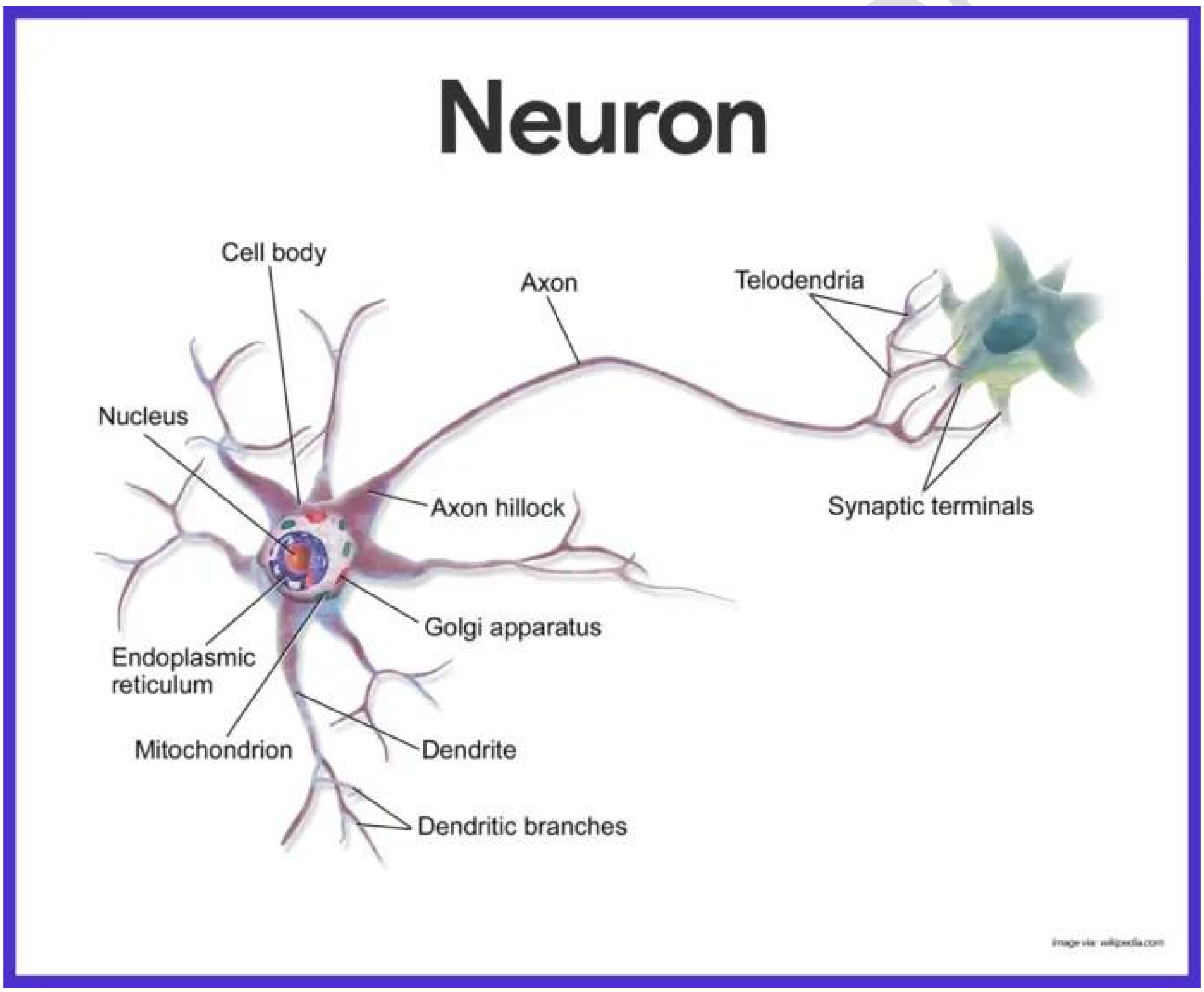
- Central nervous system (CNS). The CNS consists of the brain and spinal cord, which occupy the dorsal body cavity and act as the integrating and command centers of the nervous system
- Peripheral nervous system (PNS). The PNS, the part of the nervous system outside the CNS, consists mainly of the nerves that extend from the brain and spinal cord.



6.5 FUNCTIONAL CLASSIFICATION

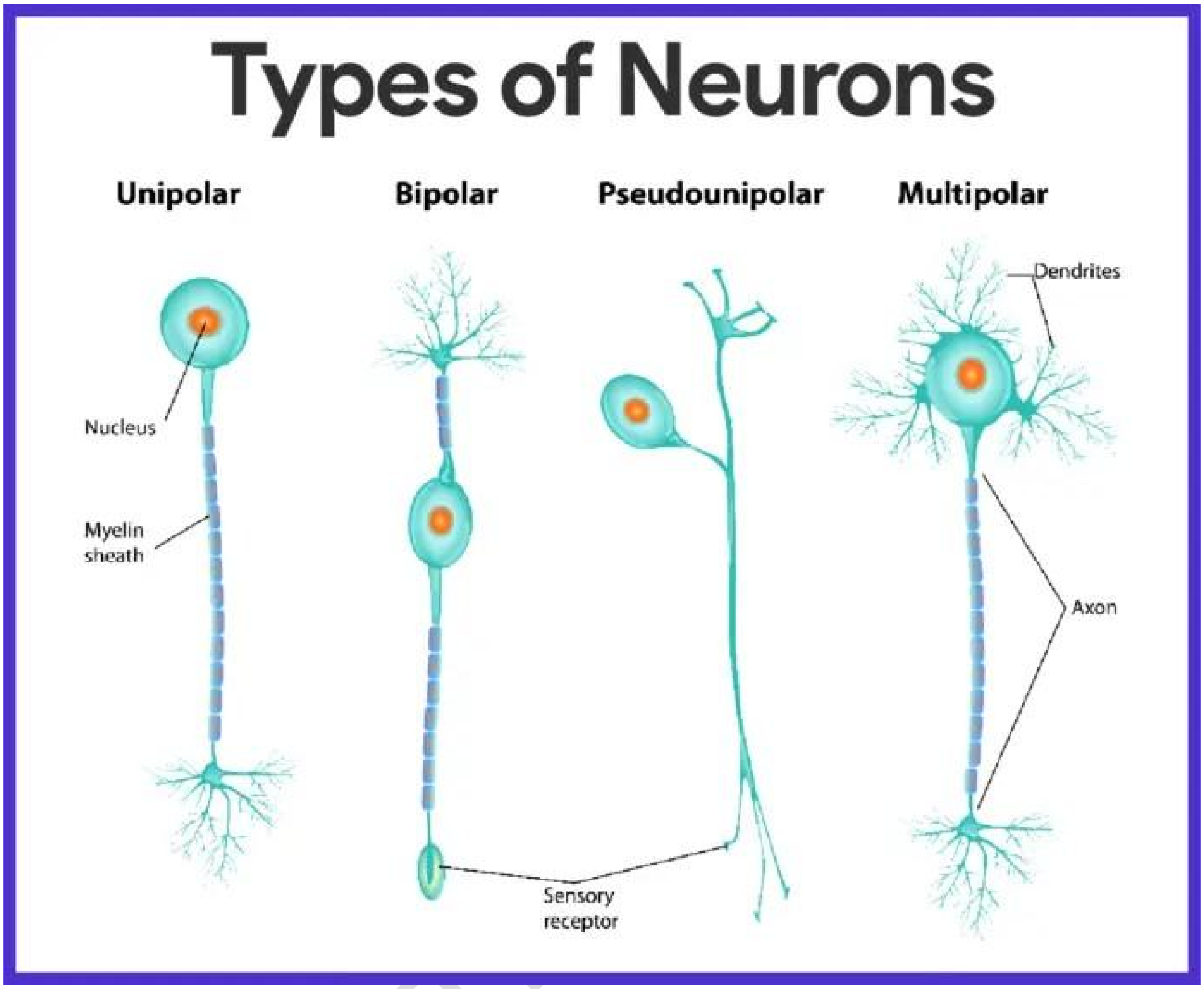
The functional classification scheme is concerned only with PNS structures.

- Sensory division. The sensory, or afferent division, consists of nerves (composed of nerve fibers) that convey impulses to the central nervous system from sensory receptors located in various parts of the body.
- Somatic sensory fibers. Sensory fibers delivering impulses from the skin, skeletal muscles, and joints are called somatic sensory fibers.
- Visceral sensory fibers. Those that transmit impulses from the visceral organs are called visceral sensory fibers.



- Cell body. The cell body is the metabolic center of the neuron; it has a transparent nucleus with a conspicuous nucleolus; the rough ER, called Nissl substance, and neurofibrils are particularly abundant in the cell body.
- Processes. The armlike processes, or fibers, vary in length from microscopic to 3 to 4 feet; dendrons convey incoming messages toward the cell body, while axons generate nerve impulses and typically conduct them away from the cell body.
- Axon hillock. Neurons may have hundreds of the branching dendrites, depending on the neuron type, but each neuron has only one axon, which arises from a conelike region of the cell body called the axon hillock.
- Axon terminals. These terminals contain hundreds of tiny vesicles, or membranous sacs that contain neurotransmitters.
- Synaptic cleft. Each axon terminal is separated from the next neuron by a tiny gap called synaptic cleft.
- Myelin sheaths. Most long nerve fibers are covered with a whitish, fatty material called myelin, which has a waxy appearance; myelin protects and insulates the fibers and increases the transmission rate of nerve impulses.
- Nodes of Ranvier. Because the myelin sheath is formed by many individual Schwann cells, it has gaps, or indentations, called nodes of Ranvier.

Neurons may be classified either according to how they function or according to their structure.



Functional classification groups neurons according to the direction the nerve impulse is traveling relative to the CNS; on this basis, there are sensory, motor, and association neurons.

- **Sensory neurons.** Neurons carrying impulses from sensory receptors to the CNS are sensory, or afferent, neurons; sensory neurons keep us informed about what is happening both inside and outside the body.
- **Motor neurons.** Neurons carrying impulses from the CNS to the viscera and/or muscles and glands are motor, or efferent, neurons.
- **Interneurons.** The third category of neurons is known as the interneurons, or association neurons; they connect the motor and sensory neurons in neural pathways.

Structural classification. Structural classification is based on the number of processes extending from the cell body.

- **Multipolar neuron.** If there are several processes, the neuron is a multipolar neuron; because all motor and association neurons are multipolar, this is the most common structural type.

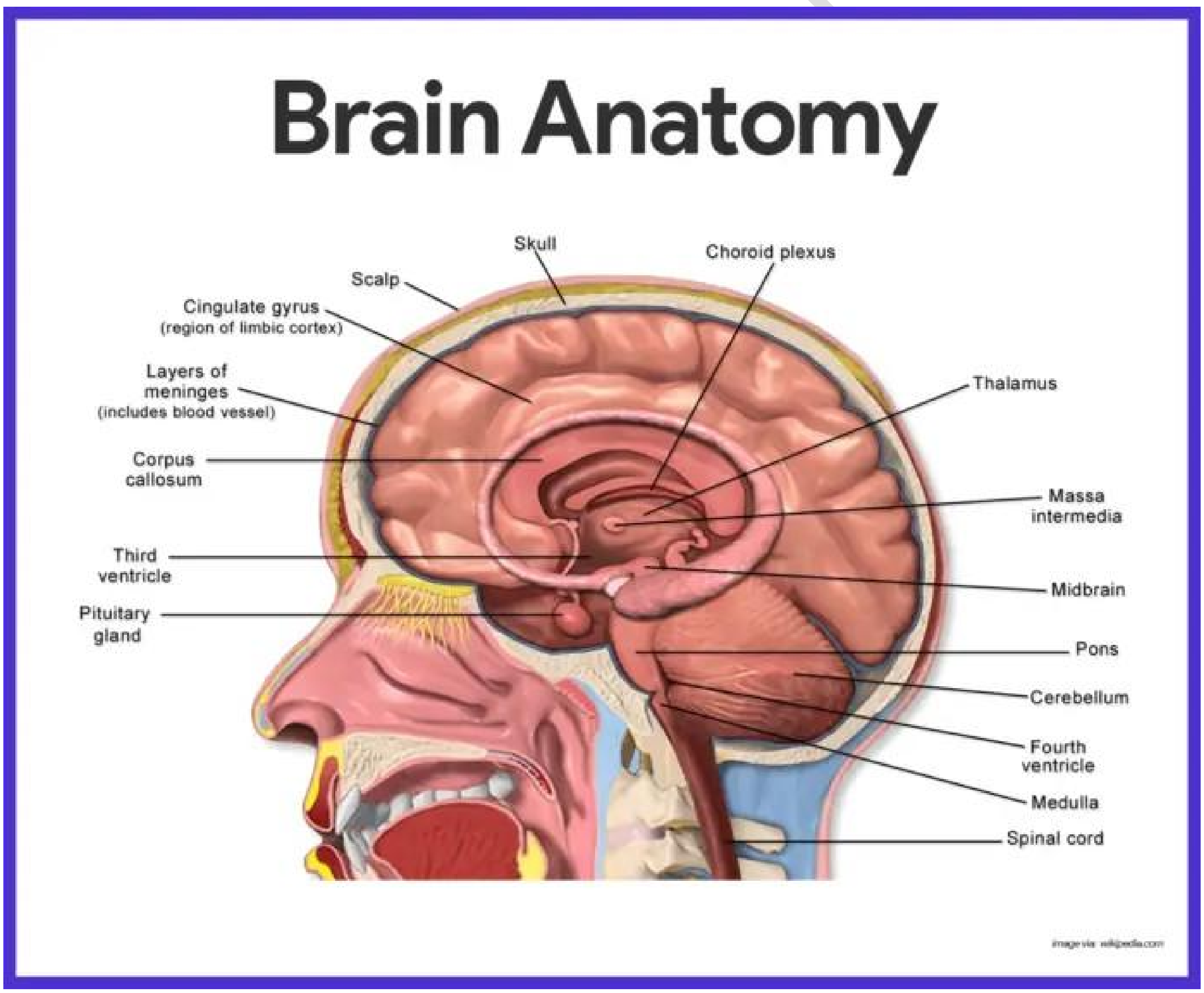
- **Bipolar neurons**. Neurons with two processes- an axon and a dendrite- are called bipolar neurons; these are rare in adults, found only in some special sense organs, where they act in sensory processing as receptor cells.
- **Unipolar neurons.** Unipolar neurons have a single process emerging from the cell's body, however, it is very short and divides almost immediately into proximal (central) and distal (peripheral) processes.

➢ **Central Nervous System**

During embryonic development, the CNS first appears as a simple tube, the neural tube, which extends down the dorsal median plan of the developing embryo's body.

➢ **Brain**

Because the brain is the largest and most complex mass of nervous tissue in the body, it is commonly discussed in terms of its four major regions – cerebral hemispheres, diencephalon, brain stem, and cerebellum.



- **Cerebral Hemispheres**

The paired cerebral hemispheres, collectively called cerebrum, are the most superior part of the brain, and together are a good deal larger than the other three brain regions combined.

- Gyri. The entire surface of the cerebral hemispheres exhibits elevated ridges of tissue called gyri, separated by shallow grooves called sulci.
- Fissures. Less numerous are the deeper grooves of tissue called fissures, which separate large regions of the brain; the cerebral hemispheres are separated by a single deep fissure, the longitudinal fissure.
- Lobes. Other fissures or sulci divide each hemisphere into a number of lobes, named for the cranial bones that lie over them.
- Regions of cerebral hemisphere. Each cerebral hemisphere has three basic regions: a superficial cortex of gray matter, an internal white matter, and the basal nuclei.
- Cerebral cortex. Speech, memory, logical and emotional response, as well as consciousness, interpretation of sensation, and voluntary movement are all functions of neurons of the cerebral cortex.
- Parietal lobe. The primary somatic sensory area is located in the parietal lobe posterior to the central sulcus; impulses traveling from the body's sensory receptors are localized and interpreted in this area.
- Occipital lobe. The visual area is located in the posterior part of the occipital lobe.
- Temporal lobe. The auditory area is in the temporal lobe bordering the lateral sulcus, and the olfactory area is found deep inside the temporal lobe.
- Frontal lobe. The primary motor area, which allows us to consciously move our skeletal muscles, is anterior to the central sulcus in the front lobe.
- Pyramidal tract. The axons of these motor neurons form the major voluntary motor tract- the corticospinal or pyramidal tract, which descends to the cord.
- Broca's area. A specialized cortical area that is very involved in our ability to speak, Broca's area, is found at the base of the precentral gyrus (the gyrus anterior to the central sulcus).
- Speech area. The speech area is located at the junction of the temporal, parietal, and occipital lobes; the speech area allows one to sound out words.
- Cerebral white matter. The deeper cerebral white matter is compose of fiber tracts carrying impulses to, from, and within the cortex.
- Corpus callosum. One very large fiber tract, the corpus callosum, connect the cerbral hemispheres; such fiber tracts are called commisures.
- Fiber tracts. Association fiber tracts connect areas within a hemisphere, and projection fiber tracts connect the cerebrum with lower CNS centers.
- Basal nuclei. There are several islands of gray matter, called the basal nuclei, or basal ganglia, buried deep within the white matter of the cerebral hemispheres; it helps regulate the voluntary motor activities by modifying instructions sent to the skeletal muscles by

the primary motor cortex.

- **Diencephalon**

The diencephalon, or interbrain, sits atop the brain stem and is enclosed by the cerebral hemispheres.

- Thalamus. The thalamus, which encloses the shallow third ventricle of the brain, is a relay station for sensory impulses passing upward to the sensory cortex.
- Hypothalamus. The hypothalamus makes up the floor of the diencephalon; it is an important autonomic nervous system center because it plays a role in the regulation of body temperature, water balance, and metabolism; it is also the center for many drives and emotions, and as such, it is an important part of the so-called limbic system or "emotional-visceral brain"; the hypothalamus also regulates the pituitary gland and produces two hormones of its own.
- Mammillary bodies. The mammillary bodies, reflex centers involved in olfaction (the sense of smell), bulge from the floor of the hypothalamus posterior to the pituitary gland.
- Epithalamus. The epithalamus forms the roof of the third ventricle; important parts of the epithalamus are the pineal body (part of the endocrine system) and the choroid plexus of the third ventricle, which forms the cerebrospinal fluid.

- **Brain Stem**

The brain stem is about the size of a thumb in diameter and approximately 3 inches long.

- Structures. Its structures are the midbrain, pons, and the medulla oblongata.
- Midbrain. The midbrain extends from the mammillary bodies to the pons inferiorly; it is composed of two bulging fiber tracts, the cerebral peduncles, which convey descending and ascending impulses.
- Corpora quadrigemina. Dorsally located are four rounded protrusions called the corpora quadrigemina because they remind some anatomist of two pairs of twins; these bulging nuclei are reflex centers involved in vision and hearing.
- Pons. The pons is a rounded structure that protrudes just below the midbrain, and this area of the brain stem is mostly fiber tracts; however, it does have important nuclei involved in the control of breathing.
- Medulla oblongata. The medulla oblongata is the most inferior part of the brain stem; it contains nuclei that regulate vital visceral activities; it contains centers that control heart rate, blood pressure, breathing, swallowing, and vomiting among others.
- Reticular formation. Extending the entire length of the brain stem is a diffuse mass of gray matter, the reticular formation; the neurons of the reticular formation are involved in motor control of the visceral organs; a special group of reticular formation neurons, the

reticular activating system (RAS), plays a role in consciousness and the awake/sleep cycles.

- **Cerebellum**

The large, cauliflower-like cerebellum projects dorsally from under the occipital lobe of the cerebrum.

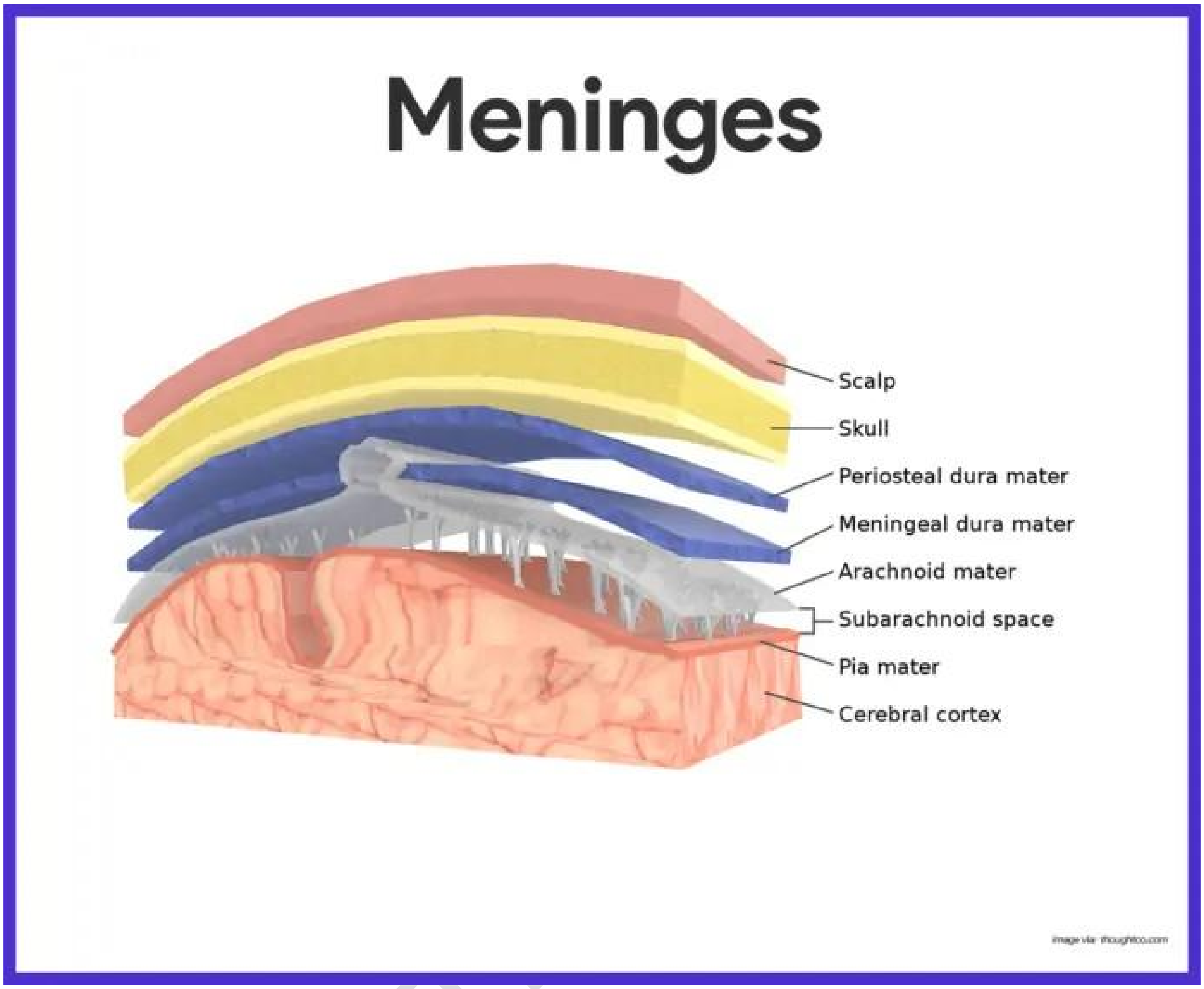
- Structure. Like the cerebrum. the cerebellum has two hemispheres and a convoluted surface; it also has an outer cortex made up of gray matter and an inner region of white matter.
- Function. The cerebellum provides precise timing for skeletal muscle activity and controls our balance and equilibrium.
- Coverage. Fibers reach the cerebellum from the equilibrium apparatus of the inner ear, the eye, the proprioceptors of the skeletal muscles and tendons, and many other areas.

6.6 PROTECTION OF THE CENTRAL NERVOUS SYSTEM

Nervous tissue is very soft and delicate, and the irreplaceable neurons are injured by even the slightest pressure, so nature has tried to protect the brain and the spinal cord by enclosing them within bone (the skull and vertebral column), membranes (the meninges), and a watery cushion (cerebrospinal fluid).

- **Meninges**

The three connective tissue membranes covering and protecting the CNS structures are the meninges



- Dura mater. The outermost layer, the leathery dura mater, is a double layered membrane where it surrounds the brain; one of its layer is attached to the inner surface of the skull, forming the periosteum (periosteal layer); the other, called the meningeal layer, forms the outermost covering of the brain and continues as the dura mater of the spinal cord.
- Falx cerebri. In several places, the inner dural membrane extends inward to form a fold that attaches the brain to the cranial cavity, and one of these folds is the falx cerebri.
- Tentorium cerebelli. The tentorium cereberi separates the cerebellum from the cerebrum.
- Arachnoid mater. The middle layer is the weblike arachnoid mater; its threadlike extensions span the subarachnoid space to attach it to the innermost membrane.
- Pia mater. The delicate pia mater, the innermost meningeal layer, clings tightly to the surface of the brain and spinal cord, following every fold.

Cerebrospinal Fluid

Cerebrospinal fluid (CSF) is a watery “broth” similar in its makeup to blood plasma, from which it forms.

- Contents. The CSF contains less protein and more vitamin C, and glucose.
- Choroid plexus. CSF is continually formed from blood by the choroid plexuses; choroid plexuses are clusters of capillaries hanging from the “roof” in each of the brain’s ventricles.
- Function. The CSF in and around the brain and cord forms a watery cushion that protects the fragile nervous tissue from blows and other trauma.
- Normal volume. CSF forms and drains at a constant rate so that its normal pressure and volume (150 ml-about half a cup) are maintained.
- Lumbar tap. The CSF sample for testing is obtained by a procedure called lumbar or spinal tap;because the withdrawal of fluid for testing decreases CSF fluid pressure, the patient must remain in a horizontal position (lying down) for 6 to 12 hours after the procedure to prevent an agonizingly painful “spinal headache”.

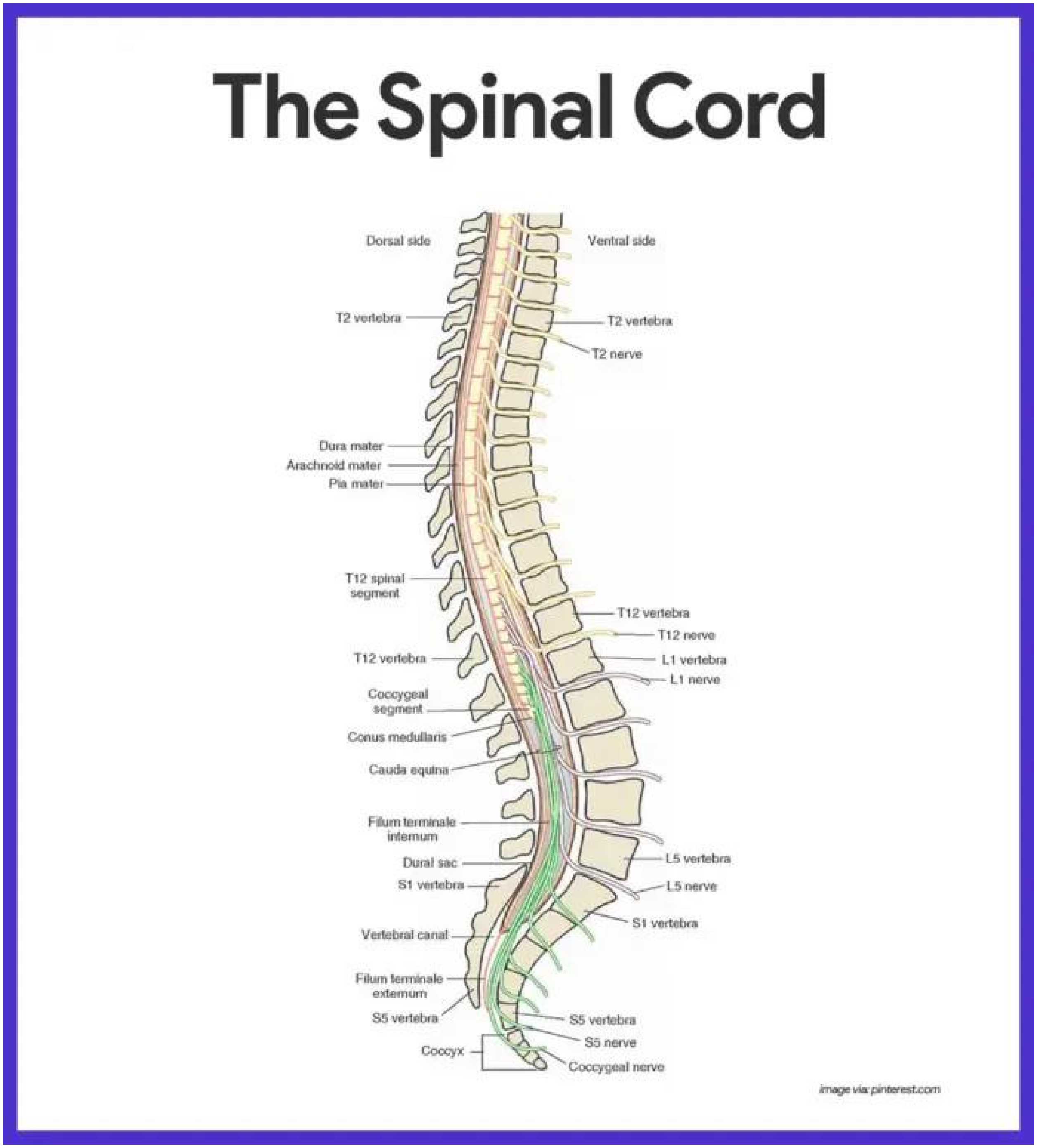
The Blood-Brain Barrier

No other body organ is so absolutely dependent on a constant internal environment as is the brain, and so the blood-brain barrier is there to protect it.

- Function. The neurons are kept separated from bloodborne substances by the so-called blood-brain barrier, composed of the least permeable capillaries in the whole body.
- Substances allowed. Of water-soluble substances, only water, glucose, and essential amino acids pass easily through the walls of these capillaries.
- Prohibited substances. Metabolic wastes, such as toxins, urea, proteins, and most drugs are prevented from entering the brain tissue.
- Fat-soluble substances. The blood-brain barrier is virtually useless against fats, respiratory gases, and other fat-soluble molecules that diffuse easily through all plasma membranes.

- **Spinal Cord**

The cylindrical spinal cord is a glistening white continuation of the brain stem.



Length. The spinal cord is approximately 17 inches (42 cm) long.

- Major function. The spinal cord provides a two-way conduction pathway to and from the brain, and it is a major reflex center (spinal reflexes are completed at this level).

- Location. Enclosed within the vertebral column, the spinal cord extends from the foramen magnum of the skull to the first or second lumbar vertebra, where it ends just below the ribs.
- Meninges. Like the brain, the spinal cord is cushioned and protected by the meninges; meningeal coverings do not end at the second lumbar vertebra but instead extend well beyond the end of the spinal cord in the vertebral canal.
- Spinal nerves. In humans, 31 pairs of spinal nerves arise from the cord and exit from the vertebral column to serve the body area close by.
- Cauda equina. The collection of spinal nerves at the inferior end of the vertebral canal is called cauda equina because it looks so much like a horse's tail.
- Gray Matter of the Spinal Cord and Spinal Roots
- The gray matter of the spinal cord looks like a butterfly or a letter H in cross section.
- Projections. The two posterior projections are the dorsal, or posterior, horns; the two anterior projections are the ventral, or anterior, horns.
- Central canal. The gray matter surrounds the central canal of the cord, which contains CSF.
- Dorsal root ganglion. The cell bodies of sensory neurons, whose fibers enter the cord by the dorsal root, are found in an enlarged area called dorsal root ganglion; if the dorsal root or its ganglion is damaged, sensation from the body area served will be lost.
- Dorsal horns. The dorsal horns contain interneurons.
- Ventral horns. The ventral horns of gray matter contain cell bodies of motor neurons of the somatic nervous system, which send their axons out the ventral root of the cord.
- Spinal nerves. The dorsal and ventral roots fuse to form the spinal nerves.

➢ **White Matter of the Spinal Cord**

White matter of the spinal cord is composed of myelinated fiber tracts- some running to higher centers, some traveling from the brain to the cord, and some conducting impulses from one side of the spinal cord to the other.

- Regions. Because of the irregular shape of the gray matter, the white matter on each side of the cord is divided into three regions- the dorsal, lateral, and ventral columns; each of the columns contains a number of fiber tracts made up of axon with the same destination and function.
- Sensory tracts. Tracts conducting sensory impulses to the brain are sensory, or afferent, tracts.
- Motor tracts. Those carrying impulses from the brain to skeletal muscles are motor, or efferent, tracts.

➢ **Peripheral Nervous System**

The peripheral nervous system consists of nerves and scattered groups of neuronal cell bodies (ganglia) found outside the CNS.

CHAPTER SEVEN

STRUCTURE OF A NERVE

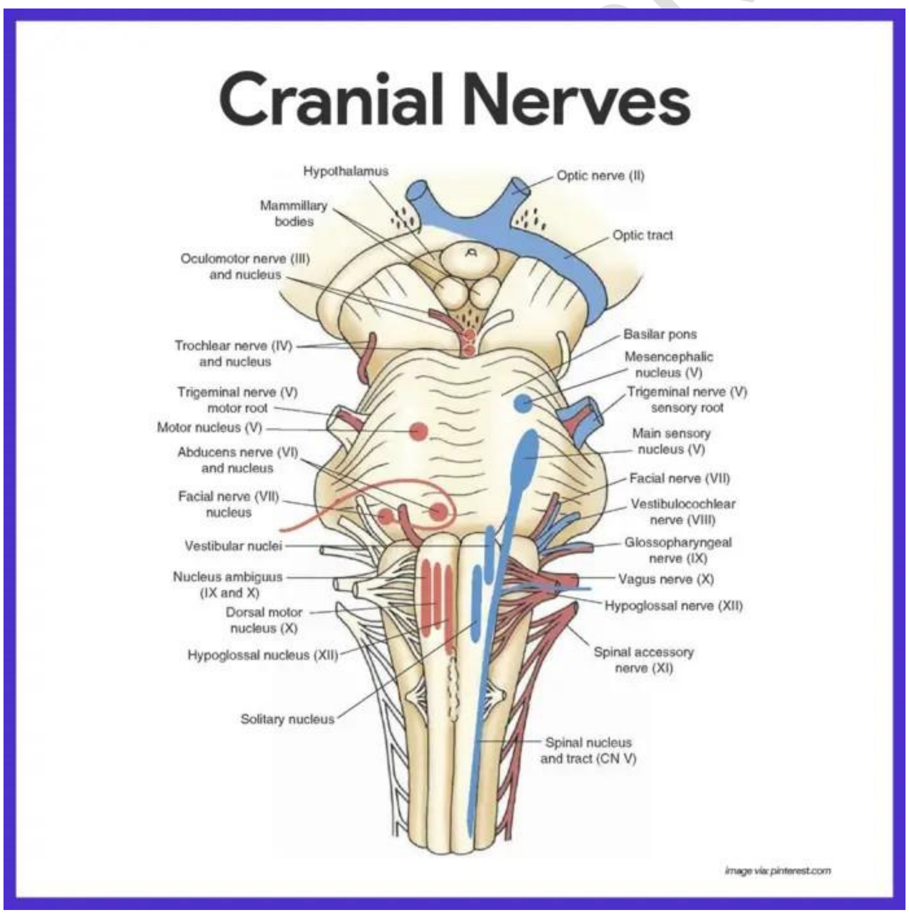
A nerve is a bundle of neuron fibers found outside the CNS.

- Endoneurium. Each fiber is surrounded by a delicate connective tissue sheath, an endoneurium.
- Perimeurium. Groups of fibers are bound by a coarser connective tissue wrapping, the perineurium, to form fiber bundles, or fascicles.
- Epineurium. Finally, all the fascicles are bound together by a tough fibrous sheath, the epineurium, to form the cordlike nerve.

- Mixed nerves. Nerves carrying both sensory and motor fibers are called mixed nerves.
- Sensory nerves. Nerves that carry impulses toward the CNS only are called sensory, or afferent, nerves.
- Motor nerves. Those that carry only motor fibers are motor, or efferent, nerves.

7.1 CRANIAL NERVES

The 12 pairs of cranial nerves primarily serve the head and the neck.



- Olfactory. Fibers arise from the olfactory receptors in the nasal mucosa and synapse with the olfactory bulbs; its function is purely sensory, and it carries impulses for the sense of smell.
- Optic. Fibers arise from the retina of the eye and form the optic nerve; its function is purely sensory, and carries impulses for vision.
- Oculomotor. Fibers run from the midbrain to the eye; it supplies motor fibers to four of the six muscles (superior, inferior, and medial rectus, and inferior oblique) that direct the eyeball; to the eyelid; and to the internal eye muscles controlling lens shape and pupil size.
- Trochlear. Fibers run from the midbrain to the eye; it supplies motor fibers for one external eye muscle (superior oblique).
- Trigeminal. Fibers emerge from the pons and form three divisions that run to the face; it conducts sensory impulses from the skin of the face and mucosa of the nose and mouth; also contains motor fibers that activate the chewing muscles.
- Abducens. Fibers leave the pons and run to the eye; it supplies motor fibers to the lateral rectus muscle, which rolls the eye laterally.
- Facial. Fibers leave the pons and run to the face; it activates the muscles of facial expression and the lacrimal and salivary glands; carries sensory impulses from the taste buds of the anterior tongue.
- Vestibulocochlear. fibers run from the equilibrium and hearing receptors of the inner ear to the brain stem; its function is purely sensory; vestibular branch transmits impulses for the sense of balance, and cochlear branch transmits impulses for the sense of hearing.
- Glossopharyngeal. Fibers emerge from the medulla and run to the throat; it supplies motor fibers to the pharynx (throat) that promote swallowing and saliva production; it carries sensory impulses from the taste buds of the posterior tongue and from pressure receptors of the carotid artery.
- Vagus. Fibers emerge from the medulla and descend into the thorax and abdominal cavity; the fibers carry sensory impulses from and motor impulses to the pharynx, larynx, and the abdominal and thoracic viscera; most motor fibers are parasympathetic fibers that promote digestive activity and help regulate heart activity.
- Accessory. Fiber arise from the medulla and superior spinal cord and travel to muscles of the neck and back; mostly motor fiber that activate the sternocleidomastoid and trapezius muscles.
- Hypoglossal. Fibers run from the medulla to the tongue; motor fibers control tongue movements;; sensory fibers carry impulses from the tongue.

7.2 SPINAL NERVES AND NERVE PLEXUSES

The 31 pairs of human spinal nerves are formed by the combination of the ventral and dorsal roots of the spinal cord.

- Rami. Almost immediately after being formed, each spinal nerve divides into dorsal and ventral rami, making each spinal nerve only about 1/2 inch long; the rami contains both sensory and motor fibers.
- Dorsal rami. The smaller dorsal rami serve the skin and muscles of the posterior body trunk.
- Ventral rami. The ventral rami of spinal nerves T1 through T12 form the intercostal nerves, which supply the muscles between the ribs and the skin and muscles of the anterior and lateral trunk.
- Cervical plexus. The cervical plexus originates from the C1-C5, and phrenic nerve is an important nerve; it serves the diaphragm, and skin and muscles of the shoulder and neck.
- Brachial plexus. The axillary nerve serve the deltoid muscles and skin of the shoulder, muscles, and skin of superior thorax; the radial nerve serves the triceps and extensor muscles of the forearm, and the skin of the posterior upper limb; the median nerve serves the flexor muscles and skin of the forearm and some muscles of the hand; the musculocutaneous nerve serves the flexor muscles of arm and the skin of the lateral forearm; and the ulnar nerve serves some flexor muscles of forearm; wrist and many hand muscles, and the skin of the hand.
- Lumbar plexus. The femoral nerve serves the lower abdomen, anterior and medial thigh muscles, and the skin of the anteromedial leg and thigh; the obturator nerve serves the adductor muscles of the medial

7.3 NERVE IMPULSE

Neurons have two major functional properties: irritability, the ability to respond to a stimulus and convert it into a nerve impulse, and conductivity, the ability to transmit the impulse to other neurons, muscles, or glands.

- Electrical conditions of a resting neuron’s membrane. The plasma membrane of a resting, or inactive, neuron is polarized, which means that there are fewer positive ions sitting on the inner face of the neuron’s plasma membrane than there are on its outer surface; as long as the inside remains more negative than the outside, the neuron will stay inactive.
- Action potential initiation and generation. Most neuron in the body are excited by neurotransmitters released by other neurons; regardless what the stimulus is, the result is always the same- the permeability properties of the cell’s plasma membrane change for a very brief period.
- Depolarization. The inward rush of sodium ions changes the polarity of the neuron’s membrane at that site, an event called depolarization.

- Graded potential. Locally, the inside is now more positive, and the outside is less positive, a situation called graded potential.
- Nerve impulse. If the stimulus is strong enough, the local depolarization activates the neuron to initiate and transmit a long-distance signal called action potential, also called a nerve impulse; the nerve impulse is an all-or-none response; it is either propagated over the entire axon, or it doesn't happen at all;it never goes partway along an axon's length, nor does it die out with distance as do graded potential.
- Repolarization. The outflow of positive ions from the cell restores the electrical conditions at the membrane to the polarized or resting, state, an event called repolarization; until a repolarization occurs, a neuron cannot conduct another impulse.
- Saltatory conduction. Fibers that have myelin sheaths conduct impulses much faster because the nerve impulse literally jumps, or leaps, from node to node along the length of the fiber; this occurs because no electrical current can flow across the axon membrane where there is fatty myelin insulation.

7.4 THE NERVE IMPULSE PATHWAY

How the nerve impulse actually works is detailed below.

- Resting membrane electrical conditions. The external face of the membrane is slightly positive; its internal face is slightly negative; the chief extracellular ion is sodium, whereas the chief intracellular ion is potassium; the membrane is relatively permeable to both ions.
- Stimulus initiates local depolarization. A stimulus changes the permeability of a "patch" of the membrane, and sodium ions diffuse rapidly into the cell; this changes the polarity of the membrane (the inside becomes more positive; the outside becomes more negative) at that site.
- Depolarization and generation of an action potential. If the stimulus is strong enough, depolarization causes membrane polarity to be completely reversed and an action potential is initiated.
- Propagation of the action potential. Depolarization of the first membrane patch causes permeability changes in the adjacent membrane, and the events described in (b) are repeated; thus, the action potential propagates rapidly along the entire length of the membrane.
- Repolarization. Potassium ions diffuse out of the cell as the membrane permeability changes again, restoring the negative charge on the inside of the membrane and the positive charge on the outside surface; repolarization occurs in the same direction as depolarization.

Communication of Neurons at Synapses

The events occurring at the synapse are arranged below.

- Arrival. The action potential arrives at the axon terminal.
- Fusion. The vesicle fuses with plasma membrane.
- Release. Neurotransmitter is released into synaptic cleft.
- Binding. Neurotransmitter binds to receptor on receiving neuron's end.
- Opening. The ion channel opens.
- Closing. Once the neurotransmitter is broken down and released, the ion channel close.

Autonomic Functioning

Body organs served by the autonomic nervous system receive fibers from both divisions.