Peripheral Nervous System (PNS)

The peripheral nervous system consists of sensory receptors, nerves that branch out from the CNS and connect to other parts of the body, their associated ganglia, and motor endings.

Sensory receptors are specialized to respond to stimuli (internal and external changes). Most sense receptors consist of modified dendrites of sensory neurons. Sense organs are a complex structure consisting of sensory receptors and other cells that serve a specific response. Sensory receptors include those for pain, touch, pressure, and temperature in the skin, those in the skeletal muscles and tendons, and those in the visceral organs. Complex receptors (sense organs) serve the special senses (vision, hearing, equilibrium, smell, and taste).

Receptors are classified according to location, the stimulus type detected, and structural complexity.

Location

a. exteroreceptors - respond to stimuli outside of the body (touch, temperature, pressure, sight, smell, taste, hearing).

b. interoceptors or visceoroceptors - respond to stimuli within the body (digestion, respiration, cardiovascular, urinary, reproductive).

c. proprioceptors - respond to internal stimuli like interoceptors but are found in the musculoskeletal system (skeletal muscles, tendons, joints, ligaments, and connective tissue covering the bones and muscles).

Stimulus type detected

a. mechanoreceptors - generate nerve impulses when they, or adjacent tissues, are deformed by mechanical forces such a touch, pressure, vibrations, and stretch.

b. thermoreceptors - sensitive to changes in temperature.

c. photoreceptors - respond to light.

d. chemoreceptors - respond to chemicals in solution, molecules smelled or tasted, or changes in blood chemistry.

e. nocioceptors - respond to potentially damaging stimuli that result in pain.
Structural Complexity

a. **Simple receptors** - modified dendritic endings of sensory nerves (skin, mucous membranes, muscle, and connective tissues, and monitor most types of general sensory information).

b. **Complex receptors** (sense organs) - localized collections of cells working together to accomplish a specific receptive process. Complex receptors are associated with the special senses (vision, hearing, equilibrium, smell, and taste).

The peripheral nervous system includes the cranial nerves and the spinal nerves and can be subdivided into the somatic system and the autonomic system.

1. **Somatic system** - consists of the cranial and spinal nerve fibers that connect the skin and skeletal muscles and is involved in conscious activities.

2. **Autonomic system** - includes those fibers that connect the CNS to the visceral organs (heart, stomach, intestines), and various glands and is concerned with unconscious activities.

A nerve is a bundle of neuron fibers in the PNS. Each fiber is enclosed by an endoneurium, fascicles of fibers are wrapped by a perineurium, and the whole nerve is bundled in by the epineurium.

Nerves are classified according to the direction in which they transmit impulses:

1. **Sensory (afferent) nerves** - carry impulses toward the CNS.

2. **Motor (efferent) nerves** - carry impulses away from the CNS.

3. **Mixed nerves** - containing both sensory and motor fibers and transmitting impulses both to and from the CNS. Most nerves are mixed and often carry both somatic and autonomic (visceral) nervous system fibers. The fibers within them may be classified further according to the region they innervate as somatic afferent, somatic efferent, visceral afferent, and visceral efferent.

Ganglia are collections of neuron cell bodies associated with nerves in the PNS. Ganglia associated with afferent nerve fibers contain only cell bodies of sensory neurons (dorsal root ganglia). Ganglia associated with efferent nerve fibers contain cell
bodies of autonomic motor neurons (ventral root ganglia), as well as a special variety of integrative neurons.

Cranial nerves

Twelve pairs of cranial nerves arise from various locations on the underside of the brain. With the exception of the first pair, which begins within the cerebrum, these nerves originate from the brain stem. They pass from their sites of origin through various foramina of the skull and lead to parts of the head, neck, and trunk.

The cranial nerves are designated by names or numbers. The numbers indicate the order in which they arise from the front to the back of the brain, and the names describe their primary functions or the general distribution of their fibers.

I. olfactory nerves (sensory) - associated with the sense of smell.

II. optic nerves (sensory) - associated with the sense of vision and transmit visual impulses from the retina to the thalamus.

III. oculomotor nerves (motor) - arise in the midbrain and pass into the orbits of the eyes and connects to the voluntary muscles that raise the eyelid and muscles that move the eye, and supplies involuntary muscles within the eyes that adjust the amount of light entering the eyes and focus the lens of the eyes.

IV. trochlear nerves (motor) - the smallest of the cranial nerves. They arise from the midbrain and carry motor impulses to certain voluntary muscles that move the eyes but are not supplied by the oculomotor nerve.

V. trigeminal nerves (mixed) - the largest of the cranial nerves. They are the major sensory nerves of the face. They contain three sensory divisions - ophthalmic (eye), maxillary, and mandibular.

VI. abducens nerves (motor) - small and they enter the orbits of the eyes and supply motor impulses to a pair of muscles that move the eye.

VII. facial nerves (mixed) - Their sensory branches are two-thirds of the tongue, and some of their motor fibers transmit impulses to the muscles of facial expression.
VIII. **vestibulocochlear nerves** (sensory) - Each has two distinct parts - a vestibular branch (equilibrium) and a cochlear branch (hearing).

IX. **glossopharyngeal nerves** (mixed) - associated with the tongue and pharynx. The sensory fibers carry impulses from the linings of the pharynx, tonsils, and posterior third of the tongue to the brain. Fibers of the motor component innervate muscles of the pharynx that function in swallowing.

X. **vagus nerves** (mixed) - longest nerve and it extends downward through the neck into the chest and abdomen. Some somatic motor fibers carry impulses to muscles of the larynx that are associated with speech and swallowing. Autonomic motor fibers supply the heart and a variety of smooth muscles and glands in the thorax and abdomen.

XI. **accessory nerves** (motor) - originate in the brain (medulla oblongata) and the spinal cord and have both cranial and spinal branches. Each cranial branch joins a vagus nerve and carries impulses to muscles of the soft palate, pharynx, and larynx. The spinal branch descends into the neck and supplies motor fibers to the trapezius and sternocleidomastoid muscles.

XII. **hypoglossal nerves** (motor) - They pass into the tongue and carry impulses to muscles that move the tongue in speaking, chewing, and swallowing.

**Spinal Nerves**

Thirty-one pairs of spinal nerves originate from the spinal cord and supply all parts of the body except the head and some areas of the neck. They are mixed nerves and they provide two-way communication between the spinal cord and parts of the arms, legs, neck, and trunk.

The spinal nerves are not named individually, but grouped according to the level from which they arise. The spinal column and each nerve is numbered in sequence. There are eight pairs of **cervical nerves** (C₁ - C₈), twelve pairs of **thoracic nerves** (T₁ - T₁₂), five pairs of **lumbar nerves** (L₁ - L₅), five pairs of **sacral nerves** (S₁ - S₅), and one pair of **coccygeal nerves** (C₈). There are seven cervical vertebrae, but eight nerves because seven leave the vertebral column superior to the vertebrae for which they are named. C₈ emerges inferior to the seventh cervical vertebra (between C₇ and T₁). Below the cervical level, the nerves leave the vertebral column inferior to the same numbered vertebra.

The spinal cord ends at the level between the first and second
lumbar vertebrae, so the lumbar, sacral, and coccygeal nerves descend to their exits beyond the end of the cord. These descending nerves form the cauda equina (horse’s tail).

Each spinal nerve emerges from the cord by two short branches, or roots, which lie within the vertebral column. The dorsal root (sensory root) contains an enlargement (dorsal root ganglion) which contains cell bodies of the sensory neurons whose dendrites conduct impulses inward from the peripheral body parts. The axons of these neurons extend through the dorsal root and into the spinal cord, where they form synapses with the dendrites of other neurons. The fibers are afferent.

The ventral root (motor root) of each spinal nerve consists of axons from the motor neurons, whose cell bodies are located within the gray matter of the cord. The fibers are efferent and extend to and innervate the skeletal muscles (somatic), and visceral effectors.

A ventral root and a dorsal root unite to form a spinal nerve, which extends outward from the vertebral canal through an intervertebral foramen. Just beyond its foramen, each spinal nerve divides into a large ventral ramus, a smaller dorsal ramus, and a tiny meningeal branch that reenters the vertebral canal to innervate the meninges and blood vessels within. Each ramus is mixed. Joined to the base of ventral rami of spinal nerves in the thoracic region, there are the rami communicantes (communicating branches), which contain autonomic (visceral) nerve fibers. Dorsal rami serve the muscles and skin of the posterior body trunk. Ventral rami T₁ and T₁₂, form plexuses that serve the limbs. T₁ - T₁₁ ventral rami give rise to intercostal nerves that serve the thorax wall and abdominal surface. T₁ fibers enter the brachial plexus and T₁₂ lies internal to the twelfth rib and is a subcostal nerve.

Except in the thoracic region, the ventral rami combine to form complex networks, called plexuses, instead of continuing directly to the peripheral body parts. In a plexus, the fibers of various spinal nerves are sorted and recombined, so that the fibers associated with a particular peripheral part reach it in the same nerve, even though the fibers originate from different spinal nerves.

**Plexuses**

The principal plexuses are the cervical, brachial, lumbar, and sacral.

1. **cervical plexuses** - found deep on either side of the neck and are formed by branches of the first four cervical nerves (C₁ - C₄). Fibers from these plexuses supply the muscles and skin of the neck. Fibers from the third, fourth, and fifth cervical nerves pass into the phrenic nerves, which conduct motor impulses to the muscle fibers of the diaphragm.
2. **brachial plexuses** - formed from branches of the lower four cervical nerves and the first thoracic nerve C5 - T1. These networks of fibers are located deep within the shoulder between the neck and axillae (arm pits). The major branches emerging from the brachial plexuses supply the muscles of skin and part of the thorax, the shoulder, arm, forearm, and hand.

3. **lumbosacral plexuses** - The sacral and lumbar plexuses overlap and many fibers of the lumbar plexus contribute to the sacral plexuses, so the two plexuses are referred to as the lumbosacral plexuses.
   - a. **lumbar plexus** (L1 - L4) - provides the motor supply to the anterior and median thigh muscles and the cutaneous supply to the anterior thigh and part of the leg.
   - b. **sacral plexus** (L4 - S4) - supplies the posterior muscles and skin of the lower limbs. A major branch is the sciatic nerve.

**Reflex Activity**

A reflex is a nerve pathway in which there is a rapid, involuntary (unconscious) motor response to a stimulus. Reflexes help to maintain homeostasis by controlling many involuntary processes such as heart rate, breathing rate, blood pressure, and digestive activities, and the withdrawal reflex for painful stimuli. Reflexes are also involved in the automatic acts of swallowing, sneezing, coughing, and vomiting.

The reflex arc has five elements - receptor, sensory neuron, CNS integration center or interneuron, motor neuron, and effector.

1. **receptor** - receptor end of a dendrite or a specialized receptor cell in a sensory organ which is sensitive to a specific type of internal or external change.

2. **sensory neuron** - dendrite, cell body, and axon of a sensory neuron which transmits a nerve impulse from the receptor into the brain or spinal cord.

3. **interneuron** - dendrite, cell body, and axon of a neuron within the brain and spinal cord which analyses and interprets the information and conducts a nerve impulse from the sensory neuron to a motor neuron.

4. **motor neuron** - dendrite, cell body, and axon of a motor neuron which transmits a nerve impulse from the brain or spinal cord to an effector.
5. **effector** - muscle or gland outside the nervous system which responds to stimulation by the motor neuron and produces the reflex or behavioral action.

A reflex arc begins with a receptor at the end of a sensory nerve fiber. The fiber usually leads to several interneurons within the CNS, which serves as a processing center, or *reflex center*. Fibers from the interneurons may connect with interneurons in other parts of the nervous system. They also communicate with motor neurons, where fibers pass outward to effectors. Such a reflex arc represents the behavioral unit of the nervous system.