General Organization of Nervous System

Objectives

After going through this lesson, the learners will be able to understand the following:

- Develop a clear concept about the location and organization of the neural system.
- Develop understanding about the functioning of the neural system.
- Classify different types of nerve fibers depending on the functioning.

Content Outline

- Introduction
- Human Neural System
  - Functional steps
  - Divisions - Central nervous system and Peripheral nervous system
  - Divisions of PNS depending on functions
  - Types of PNS depending on the type of effectors
  - Autonomic Nervous System
  - Divisions of ANS motor part
  - Anatomy of autonomic pathway
  - Neurotransmitters
  - Action of drugs on neurotransmitter receptors
  - Physiology of Peripheral Nervous System
  - Functions of Neural system
  - Concept map of neural system
- Summary

Introduction

Nervous system is the master controller and communicating system of the body. Reflection of thought and emotions by outward expression is due to the activity of the neural system. Responses shown due to external stimuli, for e.g Shivering on a cold winter night, Perspiration on a hot humid day or an increase in heart beat after watching a horror movie are all due to the functioning of the nervous system.

Neural system acts through neurons, which are long, fibrillar, electrically stimulated cells. These cells communicate through electrical signals and act rapidly and specifically almost with immediate responses.

Human Neural (Nervous) System

a) Functional Steps of Action

Besides helping in maintenance of homeostasis, neural system is also responsible for receiving perceptions, behaviour, retaining memory and initiation of all voluntary actions. Basically all these activities are performed broadly in three different steps:

(i) **Sensory Input:** The information about various changes occurring both outside and inside the body perceived by sense or receptor organs is called sensory inputs.

(ii) **Integration:** During this period, processing and interpretation of the perceived information are done.

(iii) **Motor Output:** The interpreted information is conveyed to an effector organ for a response is called motor output.

b) Divisions (in Human Neural System) - CNS and PNS

There is a single, specialized and integrated nervous system in the human body. For the convenience of studying, it is broadly divided into **(i) Central Nervous System (CNS)** and **(ii) Peripheral Nervous System (PNS).**

i) **Central Nervous System:** It occupies the central, axial position in the body and includes the brain and spinal cord. It is the main integrating and commanding center of the nervous system. It receives sensory input, integrates them depending on past experience, reflexes, current situation and then commands motor responses. Central nervous system develops from neural tubes present in embryos.

ii) **Peripheral Nervous System:** This is the part of the nervous system which lies outside CNS. It mainly consists of bundles of axons which extend from and end in the brain or spinal cord. These peripheral nerves help to maintain communication links from all parts of the body with CNS. According to the origin and where they are ending, peripheral nerves are divided into **cranial nerves** (originating and ending from and into

brain respectively) and **spinal nerves** (originating and ending from and into brain respectively). Peripheral nervous system arises from neural crest cells.

The PNS consists of the nerves and ganglia (a group of cell bodies of neurons located inside the sensory system and autonomic nervous system) outside the brain and spinal cord. The main function of the PNS is to connect the CNS to the limbs and organs, essentially serving as a relay between the brain and spinal cord and the rest of the body.

c) Divisions of Peripheral Nervous System Depending on Functions

Functionally PNS has two divisions:

(i) Sensory or Afferent Fibers

(ii) Motor or Efferent Fibers

(i) **Sensory or afferent Nerve Fibres** consist of nerve fibres which carry impulses from both external and internal sensory receptors (located throughout the body) to CNS. They keep CNS informed about the external and internal environment of the body. Afferent fibres are again divided into two different types –

- **Somatic Sensory Fibres** - These nerve fibers carry impulses from skin, muscles and joints to CNS.
- **Visceral Sensory Fibers** - These nerve fibers carry impulses from visceral organs located in the ventral body cavity.

(ii) **Motor or Efferent Nerve Fibres**

The motor or efferent nerve fibres carry impulses from CNS to effector organs. The latter may be muscles or glands. The effector organs are called such because after getting an impulse from motor nerves they bring out an effect by contracting muscles or secreting hormones or other chemical substances by glands.

d) Division of PNS Depending on the Types of Effectors

Like sensory fibres, motor fibres also constitutes two divisions –

(i) Somatic Nervous System –

It consists of somatic nerve fibres that conduct impulses from CNS to skeletal muscles. As skeletal muscles are voluntary muscles, this system is also known as the voluntary **nervous system**.

Sensory neurons convey input from receptors for somatic senses (touch, thermal and pain sensation) and receptors for special senses (vision, hearing, taste, smell and equilibrium). All of these sensations are perceived consciously in the presence of specific stimulus. After receiving stimulus it is interpreted in CNS and somatic motor neurons are stimulated which in turn activated skeletal muscles, the effectors of the somatic nervous system and produce voluntary movements. When a somatic motor neuron stimulates muscle it contracts, due to excitation. If somatic motor neurons fail to stimulate muscles then the muscle remains limp and it is paralysed. Although in normal conditions we are not aware of breathing, several skeletal muscles are involved in the process of breathing. When these associated skeletal muscles stop acting, breathing fails. A few skeletal muscles present in the middle ear cannot be activated voluntarily.

(ii) Autonomic Nervous System (ANS) –

It comprises visceral motor nerve fibers that regulate the activities of smooth muscles, cardiac muscle and glands. ANS helps to regulate those activities (for example: beating of heart, movement of food through alimentary canal) which cannot be controlled voluntarily, so it is also referred to as **involuntary nervous system.**

The ANS usually operates without conscious control. Autonomic nervous system was named such because it was thought that it acts in a self-governing manner without the involvement of CNS. However, the hypothalamic centre and brain stem do regulate the ANS reflexes.

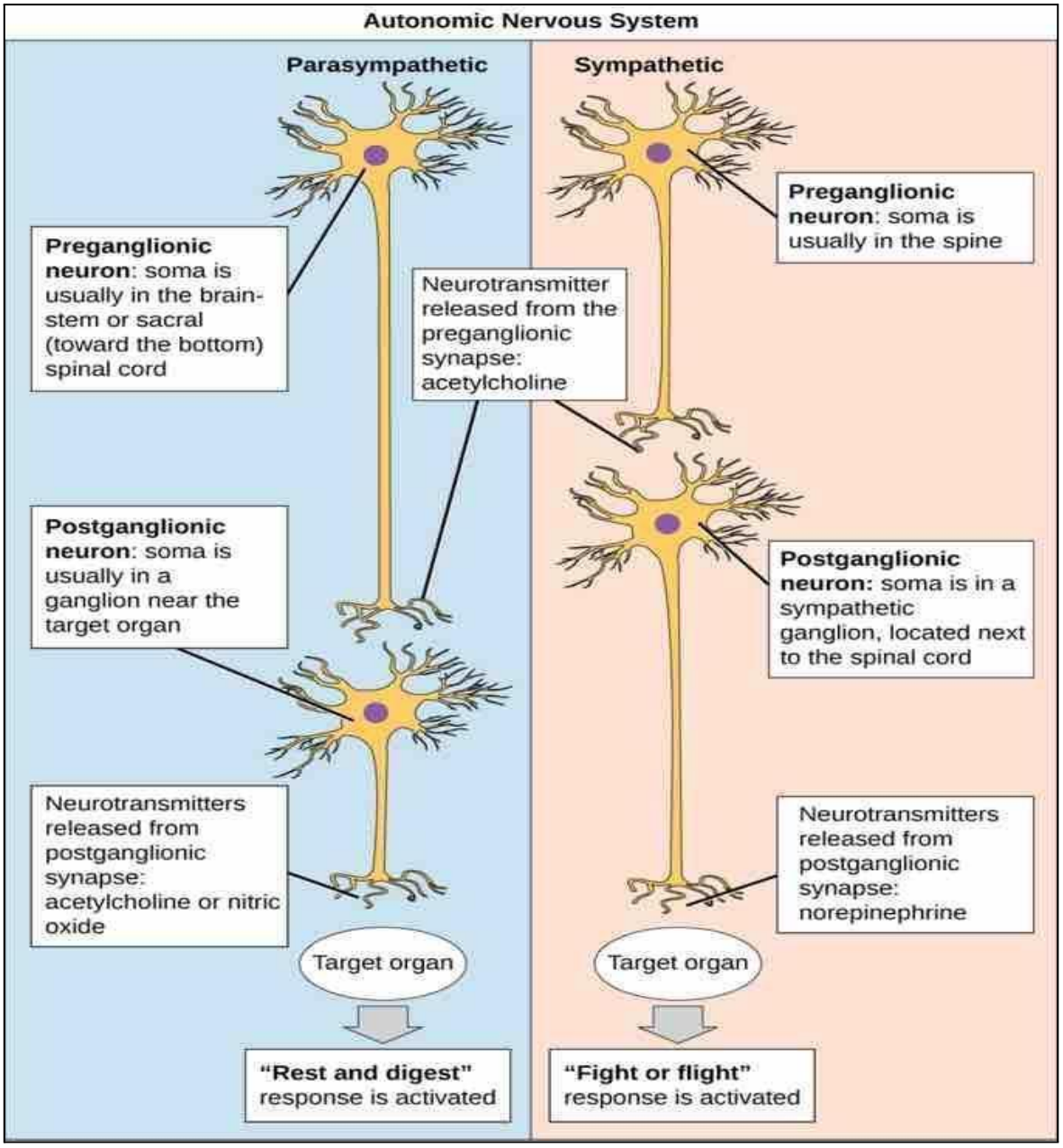
e) Autonomic Nervous System

Like other nervous systems, the Autonomic nervous system acts through neurons. Depending on the functions, these neurons are divided into Autonomic sensory neurons and Autonomic motor neurons.

ANS receives input from **Autonomic Sensory Neurons**. These neurons are mostly associated with interoceptors, located in muscles, blood vessels, visceral organs and nervous systems responsible for maintenance of the inner environment. Interoceptors are basically chemoreceptors which measure CO_2 concentration level of blood or mechanoreceptors which measure the stretching of walls of blood vessels. Although interoceptors perform their functions without our knowledge, intense activation of interoceptors may cause conscious sensation. For example, poor supply of blood to the heart results in a feeling of chest pain (Angina pectoris). Exteroreceptors receive stimuli directly from external objects, like watching a beautiful painting and smiling or looking at or getting the smell of delicious food and salivating. In first example, impulses received from the image of painting (formed on retina) is perceived by optic nerves (located on the posterior side of retina) and the image is interpreted by brain and command is transmitted through motor fibres to facial muscles (effectors) to get activated in such a way that it looks like smile. In the second example, the pathway of the activity is the same only the effector organ is here salivary glands.

Autonomic Motor Neurons regulate visceral activities by increasing or decreasing on-going activities in their effector tissues (smooth muscle, cardiac muscles, and glands). In previous examples, activity of salivary glands is increased looking at favourite food which causes profuse salivation but on the contrary the activity of salivary glands is decreased when someone is frightened causing dryness of mouth. Changes in the diameter of pupils, dilation and constriction of blood vessels and adjustments of rate of heart beat are some examples of autonomic motor neuron activities. Tissues controlled by ANS remain active up to some extent even if the nerves attached to them are removed. Heart removed from the body for heart transplant continues to beat for some time. Tissues of gastrointestinal tract contract rhythmically by themselves.

Normally the activity of ANS cannot be controlled by will that is why ‘Lie detector’ is used to find the truth from a person. Although ANS is involuntary in its functioning, but it has been proven that by prolonged practice of Yoga and meditation one can have control over heart beat to some extent. Responses of ANS can be altered in certain conditions by general somatic senses to some extent. For example, Hearing sudden, unexpected, loud noises or looking at a poisonous snake approaching heart beat increases.



Source:

http://oer2go.org/mods/en-boundless/www.boundless.com/biology/textbooks/boundless-biology-textbook/the-nervous-system-35/the-peripheral-nervous-system-203/autonomic-nervous-system-770-12003/index.html

f) Divisions of ANS Motor Neurons

The motor part of the ANS has two divisions:

i) **Sympathetic Division**

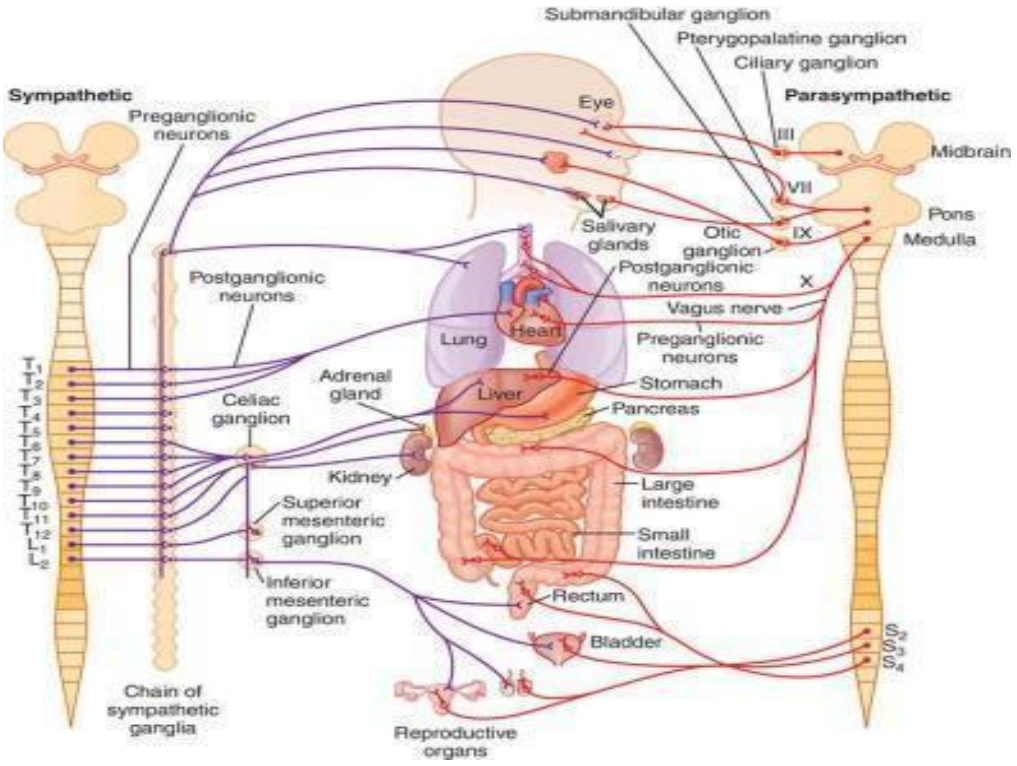
ii) **Parasympathetic Division**

These two divisions act oppositely. Most of the organs receive both sympathetic and parasympathetic impulses. In general nerves from one division excite or increase the activity of the organ and the other inhibits or decreases the activity of the same organ. For example, increased rate of nerve impulses from sympathetic division increases heart rate whereas increased rate of nerve impulses from parasympathetic nerves decreases heart rate. Sympathetic activities increase alertness towards the environment and increase metabolic rate to prepare the body to meet emergency situations.

g) Anatomy of Autonomic Pathways

Anatomical components

Anatomically ANS has a ganglion (**autonomic ganglion**) and two motor neurons for each division. The cell body of the first motor neuron is located in the brain or spinal cord and its axon comes out in the form of cranial or spinal nerve. This first motor nerve is called a **Preganglionic neuron**. The axon of preganglionic neuron is of small diameter and it possesses myelinated nerve fibre. The cell body of the second motor neuron is located in the ganglion. Its dendron receives impulses from preganglionic neuron(s) and axons transmit impulses to visceral effectors. This second set of motor nerves is called **Post ganglionic neurons**. This neuron is located outside CNS or PNS. Axon of the post ganglionic neuron has small diameter and is made up of unmyelinated nerve fibre.



Source:

https://medical-dictionary.thefreedictionary.com/_/viewer.aspx?path=davisTab&name=a49.jpg&url=https%3A%2F%2Fmedical-dictionary.thefreedictionary.com%2Fautonomic%2Bnervous%2Bsystem

h) Neurotransmitters

Neurons of the Autonomic Nervous System produce and release either acetylcholine or norepinephrine (noradrenaline). Based on the type of neurotransmitter released the ANS neurons are divided into two types- (i) **Cholinergic Neurons** and (ii) **Adrenergic Neurons**.

The **cholinergic neurons** of ANS include (a) all sympathetic and parasympathetic preganglionic neurons (b) all parasympathetic postganglionic neurons and (c) sympathetic postganglionic neurons.

Adrenergic neurons are called such because they release noradrenaline (also called as norepinephrine). Most of the sympathetic postganglionic neurons are of the adrenergic type. Norepinephrine either excites or inhibits the effectors they stimulate.Both of these neurotransmitters, i.e., acetylcholine and norepinephrine are stored in the synaptic vesicles and released at the axon endings by exocytosis. They diffuse through the synaptic cleft and

are received by respective receptors. These receptors are membrane proteins located on the plasma membrane. Depending on the type of neurotransmitters received by them they are divided into (i) **Cholinergic Receptors** and (ii) **Adrenergic Receptors**.

Difference between Somatic Nervous System and Autonomic Nervous System

Serial No.	Somatic Nervous System	Autonomic Nervous System
1.	It is the part of the nervous system which controls voluntary muscular movements.	It is the part of the nervous system which controls involuntary movements of the body.
2.	Innervates voluntary muscles.	Innervates involuntary (smooth and cardiac) muscles and glands.
3.	This system receives sensory stimuli from exterior receptors	ANS receives stimuli like blood pressure, salinity etc.
4.	Always excites an effector.	ANS may excite or inhibit the activities of effectors.
5.	Released neurotransmitter is acetylcholine.	Released neurotransmitter is norepinephrine or acetylcholine.
6.	Consists of cranial and spinal nerves.	Consists of sympathetic and parasympathetic nerves.

i) Action of Drugs on Cholinergic or Adrenergic Receptors

Like other cell receptors, neurotransmitter receptors are membrane proteins. They bind with specific chemical substances (for eg. neurotransmitters). A large variety of chemicals (drugs and some natural products) which are similar in structure like neurotransmitters can bind with the receptors and may activate or inhibit the effect in the effector cells. There are two types of such chemicals: (a) **Agonists** is a chemical substance which binds with and activates the receptors; (b) **Antagonist** is a substance which binds with the receptors and makes it unavailable for neurotransmitter to bind with it thus inhibiting the activity of effector cells.

j) Physiology of Autonomic Nervous System

Most of the body organs receive innervations both from sympathetic and parasympathetic nervous systems. These two systems act in opposite ways. It is necessary to maintain balance

between these two systems. The balance maintained between these two systems is called **autonomic tone**. Hypothalamus regulates autonomic tone and helps the organs to function normally. Hypothalamus balances the systems by switching on one system and at the same time switching off another. These two systems act oppositely on the organs and this is possible because their postganglionic neurons release different neurotransmitters. The effector organs too possess different cholinergic and adrenergic receptors. Certain organs or parts of the body like sweat glands, kidneys, spleen etc., possess only sympathetic neurons but not innervated by parasympathetic neurons.

Physiological Role of Sympathetic Nervous System

Sympathetic nervous system is also called the "fight or flight system". During intense exercise, physical stress or emotions the sympathetic division dominates the activity of parasympathetic division. This results in activation of adrenal medulla and release of hormones adrenaline and noradrenaline. These hormones trigger a series of changes which help to confront 'E' situations (exercise, emergency, excitement and embarrassment). For example, when suddenly we are frightened our heartbeat increases, skin becomes sweaty and cold, pupil becomes dilated and mouth dries up. Some of these activities are as follows:

- The diameter of the respiratory tract enlarges to allow more air (containing oxygen) to rush into and out of the lungs.
- Blood vessels supplying blood to the gastrointestinal tract and kidneys constrict as in such a situation these organs need not do excess functions.
- In liver cells, breakdown of glycogen to glucose (glycogenolysis) and in adipose tissues, breakdown of triglycerides to fatty acids and glycerol (lipolysis) take place.
- Blood glucose level increases as glucose is released in the blood vessels from the liver.
- The organs whose functions do not directly help to meet the 'E' situations show slow functioning. For example, movement of food through the gastrointestinal tract either slows down or stops.

The effects of sympathetic stimulation are long lasting and widespread because the postganglionic axons of the sympathetic system are very extensively distributed and it innervates many cells simultaneously.

Physiological role of parasympathetic nervous system

Parasympathetic nervous system is also called the "resting and digesting system". This system slows down the vital processes and helps in storage of energy. Although it counteracts the activities of the sympathetic system by withdrawing extra blood flow through the blood vessels to skeletal muscles, it maintains "housekeeping" activities like digestion of food and its movement through the alimentary tract. For this purpose, it maintains constant blood flow to the gastrointestinal tract. It regulates heart rate, blood pressure and respiratory rate low to moderate level. It is always advisable to take rest after taking food which ensures better digestion and absorption. Under the effect of the parasympathetic nervous system, skin gets ample blood supply and it feels warm. The pupil of the eye is constricted to protect the retina from getting damaged due to excessive sunlight. Sympathetic division can also be remembered as 'E' (emergency, excitement, embarrassment) division. Likewise, parasympathetic division can be called 'D' (digestion, defecation, and diuresis) division.

k) Functions of Nervous System

Nervous system performs multiple, complex tasks. These tasks include sensing smell, touch, feeling of cold and heat, taste and viewing. These senses are received from the environment. It helps to receive senses from the surroundings, to act according to the need and also to retain this experience as memory. Nervous system innervates skeletal muscles and enables us to do work, move from one place to another, movement of body parts keeping body fixed at one place, speaking, making facial expressions etc. It allows us to think, analyse and make decisions. Nervous system is responsible for emotions, feelings, maintenance of homeostasis etc. It controls body movements and regulates the activities of internal organs. All these diverse types of activities can be divided into three basic functions-

Sensory Functions - Sensory receptors receive stimuli from external and internal environment and pass it to CNS through cranial and spinal nerves.

Integrative Functions - CNS (brain and spinal cord) receive the information, analyses and sends instructions to the effector organs so that they act appropriately. Some part of this information is stored in fore brain as memory.

Motor Functions - once the sensory information is analysed the effector organs are innervated by cranial and spinal motor nerves. The effector organs accordingly function which are called as responses.

Summary

In multicellular organisms, coordination of physiological functions must be in unison to maintain homeostasis. Apart from that, animals exhibit movements; they perform many activities with their limbs. Higher organisms like human beings think, analyse, take decisions and speak to communicate. Our heart beats increase when frightened, our respiratory rate increases while running. All these activities take place in a coordinated manner. This coordination is regulated by two systems; neural system and endocrine system. Neural system coordinates the activities at a faster rate than the endocrine system.

Neural system consists of two divisions: the central nervous system and peripheral nervous system. Central nervous system consists of the brain and spinal cord. Peripheral nervous system consists of cranial nerves and spinal nerves. Motor part of the peripheral nervous system constitutes two divisions; somatic sensory system and autonomic nervous system. Autonomic nervous systems possess sympathetic and parasympathetic nervous systems. These two systems are antagonistic in their functions.