Introduction to the Nervous System

The nervous system is divided into two anatomical divisions: 1) the central nervous system (CNS), which is composed of the brain, and spinal cord, and 2) the peripheral nervous system, which includes neurons located outside the brain and spinal cord that is, any nerves that enter or leave the CNS. The peripheral nervous system is subdivided into the efferent division, the neurons of which carry signals away from the brain and spinal cord to the peripheral tissues, and the afferent division, the neurons of which bring information from the periphery to the CNS.

The autonomic system regulates the everyday requirements of vital bodily functions without the conscious participation of the mind. It is composed of efferent neurons that innervate smooth muscle of the viscera, cardiac muscle, vasculature, and the exocrine glands, thereby controlling digestion, cardiac output, blood flow, and glandular secretions.

- **Efferent neurons**: The autonomic nervous system carries nerve impulses from the CNS to the effector organs by way of two types of efferent neurons. The first nerve cell is called a preganglionic neuron, and its cell body is located within the CNS. Preganglionic neurons emerge from the brainstem or spinal cord and make a synaptic connection in ganglia (an aggregation of nerve cell bodies located in the peripheral nervous system). These ganglia function as relay points for nerve impulses.
stations between a preganglionic neuron and a second nerve cell, the postganglionic neuron. The latter neuron has a cell body originating in the ganglion. It is generally nonmyelinated and terminates on effector organs, such as smooth muscles of the viscera, cardiac muscle, and the exocrine glands.

**Note:**

- **Afferent neurons**: The afferent neurons (fibers) of the autonomic nervous system are important in the reflex regulation of this system (see below). The efferent autonomic nervous system is divided into the sympathetic and the parasympathetic nervous systems.

**Functions of the sympathetic nervous system**

- Although continually active to some degree (for example, in maintaining the tone of vascular beds), the sympathetic division has the property of adjusting in response to stressful situations, such as trauma, fear, hypoglycemia, cold, or exercise.
- Effects of stimulation of the sympathetic division: The effect of sympathetic output is to:

  - Increase heart rate and blood pressure.
  - To mobilize energy stores of the body.
  - Increase blood flow to skeletal muscles and the heart while diverting flow from the skin and internal organs.
  - Dilation of the pupils and the bronchioles.
  - Affects gastrointestinal motility and the function of the bladder and sexual organs.
**Fight or flight response**: The changes experienced by the body during emergencies have been referred to as the **fight or flight** response. These reactions are triggered both by direct sympathetic activation of the effector organs and by stimulation of the adrenal medulla to release epinephrine and lesser amounts of norepinephrine (*epinephrine is the American name of adrenaline, nor adrenaline also mimics norepinephrine*). These hormones enter the bloodstream and promote responses in effector organs that contain adrenergic receptors.

**Functions of the parasympathetic nervous system**

The parasympathetic division maintains essential bodily functions, such as digestive processes and elimination of wastes, and is required for life. It usually acts to oppose or balance the actions of the sympathetic division and is generally dominant over the sympathetic system in rest and digest situations.

**Organs receiving only sympathetic innervations**: Although most tissues receive dual innervations, some effector organs, such as the *adrenal medulla, kidney, pilomotor muscles, and sweat glands*, receive innervations only from the sympathetic system. The control of blood pressure is also mainly a sympathetic activity, with essentially no participation by the parasympathetic system.

**Neurotransmitters**

All neurons are distinct anatomic units, and no structural continuity exists between most neurons. Communication between nerve cells and between nerve cells and effector organs occurs through the release of specific chemical signals, called neurotransmitters, from the nerve terminals. This release is triggered by the arrival of the **action potential** at the nerve ending, leading to depolarization. Uptake of Ca2+ initiates fusion of the synaptic vesicles with the presynaptic membrane and release of their contents. The neurotransmitters rapidly diffuse across the synaptic cleft or space (synapse)
between neurons and combine with specific receptors on the postsynaptic (target) cell.

**Membrane receptors:** All neurotransmitters and most hormones and local mediators are too hydrophilic to penetrate the lipid bilayer of target-cell plasma membranes. Instead, their signal is mediated by binding to specific receptors on the cell surface of target organs. [Note: A receptor has a binding specificity. Most receptors are proteins.]

**Types of neurotransmitters:** Although over fifty signal molecules in the nervous system have tentatively been identified, six signal compounds norepinephrine (and the closely related epinephrine), acetylcholine, dopamine, serotonin, histamine, and amino butyric acid are most commonly involved in the actions of therapeutically useful drugs. Each of these chemical signals binds to a specific family of receptors. Acetylcholine and norepinephrine are the primary chemical signals in the autonomic nervous system, whereas a wide variety of neurotransmitters function in the CNS.

**Acetylcholine:** The autonomic nerve fibers can be divided into two groups based on the chemical nature of the neurotransmitter released. If transmission is mediated by acetylcholine, the neuron is termed cholinergic. Acetylcholine mediates the transmission of nerve impulses across autonomic ganglia in both the sympathetic and parasympathetic nervous systems. It is the neurotransmitter at the adrenal medulla. Transmission from the autonomic postganglionic nerves to the effector organs in the parasympathetic system and a few sympathetic system organs also involves the release of acetylcholine.

**Norepinephrine and epinephrine:** When norepinephrine or epinephrine is the transmitter, the fiber is termed adrenergic (adrenaline being another name (British) for epinephrine (American)). In the sympathetic system, norepinephrine mediates the transmission of nerve impulses from autonomic postganglionic nerves to effector organs.
**Adrenergic Drugs**

The adrenergic drugs affect receptors that are stimulated by norepinephrine or epinephrine. 1) Some adrenergic drugs act directly on the adrenergic receptor (adrenoceptor) by activating it and are said to be **sympathomimetic** *(mimic= similar to)*. 2) Others block the action of the neurotransmitters at the receptors *(sympatholytics)*, 3) whereas still other drugs affect adrenergic function by interrupting the **release of norepinephrine** from adrenergic neurons.

**The Adrenergic Neuron**

Adrenergic neurons release norepinephrine as the primary neurotransmitter. These neurons are found in the central nervous system (CNS) and also in the sympathetic nervous system, where they serve as links between ganglia and the effector organs. The adrenergic neurons and receptors located either presynaptically on the neuron or postsynaptically on the effector organ, are the sites of action of the adrenergic drugs.

**Neurotransmission at adrenergic neurons**

Neurotransmission in adrenergic neurons is a process involves five steps: **synthesis, storage, release, and receptor binding of norepinephrine**, followed by **removal** of the neurotransmitter from the synaptic gap.

- **Synthesis of norepinephrine**: Tyrosine is transported by a Na+-linked carrier into the axoplasm of the adrenergic neuron, where it is hydroxylated to dihydroxyphenylalanine (DOPA) by tyrosine hydroxylase. This is the rate-limiting step in the formation of norepinephrine. DOPA is then decarboxylated by the enzyme dopa...
decarboxylase (aromatic l-amino acid decarboxylase) to form dopamine in the cytoplasm of the presynaptic neuron.

- **Storage of norepinephrine in vesicles**: Dopamine is then transported into synaptic vesicles by an amine transporter system. Dopamine is hydroxylated to form norepinephrine by the enzyme, dopamine hydroxylase. [Note: Synaptic vesicles contain dopamine or norepinephrine plus adenosine triphosphate (ATP), and hydroxylase, etc.] In the adrenal medulla, norepinephrine is methylated to yield epinephrine, both of which are stored in chromaffin cells. On stimulation, the adrenal medulla releases about 80 percent epinephrine and 20 percent norepinephrine directly into the circulation.

**Note:**

The structures of epinephrine and nor-epinephrine are the same, except epinephrine has -NH-CH3, and norepinephrine has -NH2. So the first considered as a hormone because it acts directly after release from adrenal medulla while the latter is a neurotransmitter because it acts after release from the nerve terminals.