THE AUTONOMIC NERVOUS SYSTEM

The nervous system is considered the biological machinery for the integration and cooperation of body functions. Even in some body functions which are regulated by hormonal control, the nervous system is responsible for the release of hormone in he first instance. The nervous system is responsible for the regulation of the internal environment of the organism as well as the regulation of its behavior within the external environment. From the anatomical point of view, the nervous system can be classified into the following three main classes:

I-The central nervous system (CNS): the brain and spinal N.

II- The peripheral nervous system (PNS): the cranial and spinal nerves.

III- The autonomic nervous system (ANS): the sympathetic and parasympathetic nervous systems.

The autonomic nervous system is that part of the nervous system which innervates the viscera and glands (or in other words all structures other than striated muscles). The regulation of the internal environment of the body is achieved by the autonomic nervous system.

The autonomic nervous system is composed of two divisions; the sympathetic and parasympathetic; acting in an alternating manner and thus counter act any deviation in the function of any organ. In general the most parasympathetic fibers release acetycholine and are called cholinergic fibers, whereas, the most sympathetic fibers release nor epinephrine (nor adrenaline or sympathin) and thus they are termed adrenergic fibers.

Gross anatomy of the brain:

The brain consists of three parts, cerebellum, cerebrum and brain stem. The cerebrum is composed of two hemispheres separated by a longitudinal fissure. Each hemisphere is composed of four lobes (frontal, parietal, temporal and occipital). The cerebellum is formed of two hemispheres connected with a median ridge termed the Vermis. The brain stem consists of the mid brain and basal ganglia which are parts of the cerebrum as well as the pons and medulla oblongata. The brain has four continued ventricles containing four blood plexuses (choroid plexuses). These plexuses aid in the formation of the so called cerebrospinal fluid.

Reflex action:

It is the response of the tissue toward a stimulus for the welfare of the body. It is divided into two types according to the responding tissue:

1- Somatic reflex action: for skeletal muscle

2- Autonomic reflex action: for internal organs e.g. heart, viscera, gland, blood vessels,...etc.

The pathway carry the reflex action is called Reflex arc.

Composition of reflex arc:

1- Receptor: for reception of stimulus.

2- Afferent nerve: carry nerve impulse to the center.

3- Center: for analysis of afferent nerve impulse

N.B.: center for somatic reflex action is the anterior horn cells in the spinal cord or cranial nuclei. While, center for autonomic reflex action is the lateral horn cells in the spinal cord or cranial nuclei

4- Efferent nerve: carry nerve impulses from the center to the effector organ. It have of two types:

1- Somatic efferent: composed of single neuron which supply the skeletal muscle.

2- Autonomic efferent: composed of two neurons in between a ganglia called autonomic ganglia. The first neuron arise from L.H.C or cranial nuclei and called preganglionic fiber. The second neuron (postganglionic fiber) arise from autonomic ganglia and terminate in the organ.

5- Effector organ: gives the response.

Origin of the autonomic nervous system:

1) Brain stem (cranial origin):

a- Mid brain: 3rd cranial nerve (oculomotor)

b- Medulla oblongata:

7^{th} cranial nerve (facial)

9^{th} cranial nerve (glossopharyngeal).

10^{th} cranial nerve (vagus).

2) Thoracico-lumbar segments of the spinal cord:

From the L.H.C. of all thoracic and upper two lumbar segments.

3) Sacral segment of the spinal cord:

From the L.H.C of the 2^{nd}, 3^{rd} and 4^{th} sacral segments.

Divisions of the ANS

1- Sympathetic division: arise from thoracico-lumbar segments of the spinal cord.

2- Parasympathetic division: it is a cranio-sacral in origin.

Some characteristics of the sympathetic and parasympathetic nervous system:

1- They are antagonistic in function:

Parasympathetic: anabolic (store energy).

Sympathetic: catabolic (release energy).

2- Reciprocal in function: if one system is active, the other is inhibited.

3- The sympathetic has a wider distribution and acts as one unit. While, the parasympathetic has a limited distribution and has isolated activity.

4- The sympathetic ganglia are nearer to the CNS and away from the tissues. While, the parasympathetic ganglia are away from the CNS and nearer to the tissues.

Autonomic ganglion

It is a collection of nerve cells outside the C.N.S.

Types:

1- Lateral (paravertebral) ganglia:

- Lie on both sides of the vertebral column forming sympathetic trunk.
- This type of autonomic ganglia is for sympathetic relay only.
- The number of which is 22-24 ganglia; 3 cervical, 10-12 thoracic, 4 lumbar, 4 sacral and 1 coccygeal.

2- Collateral (pre vertebral) ganglia:

- Lie in the mid way between the spinal cord and the organ.
- This group is mainly for parasympathetic relay.
- Examples: superior and inferior mesenteric ganglia are considered as sympathetic ganglia. While, Ciliary ganglion (for occulomotor nerve) is parasympathetic.

3- Terminal ganglia:

- Lie on the surface or embedded in the visceral organ.
- They are for parasympathetic relay.

Functions of sympathetic ganglia:

1- They represent the points of synaptic junctions. The cell bodies of preganglionic fibers lie in the centrolateral horn of the spinal cord, while the cell bodies of postganglionic fibers are located within the synaptic ganglia.

2- The nerve impulses coming from C.N.S to the sympathetic ganglia are of variable frequencies but they leave the ganglia at a relatively fixed frequency which is optimal to the target tissue.

3- Some ganglia e.g. the cervical ganglia in cats, can act as centers for reflexes.

4- At the site of synaptic junction within the sympathetic ganglia acetylcholine is liberated to act as a chemical transmitter of nerve impulse from the preganglionic terminals to the cell bodies of postganglionic fibers.

Sympathetic division of the autonomic nervous system:

It is also termed the thoracolumber division because spinal nerves in the regions of the thorax and lumber vertebrae contain sympathetic fibers.

I- Cervical division to head and neck:

The preganglionic neurons originate from the lateral horn cells of the upper two thoracic segments and relay in the superior cervical ganglia. The postganglionic fibers run in the outer coat of the blood vessels to supply the various structures in the head and neck (eye, salivary and lacrimal glands, skin, meningeal blood vessels)

Functions:

1- Eye:

- Dilatation of eye pupil.
- Widening of the palpebral fissure.
- Exophthalmos (motor to Mullers muscle)

2- Glands:

a) Salivary gland:

- Stimulates their secretion (concentrated, very little in amount and rich in organic matter).
- Vasoconstriction of blood vessels.
- Evacuation of the acini (motor to myoepithelial cells around acini)

b) Lacrimal gland:

- Decrease the secretion of lacrimal glands.

3- Skin:

- Stimulates sweet gland secretion.
- Vasoconstriction of the cutaneous blood vessels.
- Erection of hairs (motor to pilomotor muscle).

4- Vasoconstriction of meningeal blood vessels.

II- Cardio-pulmonary division to thoracic viscera:

The preganglionic neurons originate from the lateral horn cells of the upper five thoracic segments and relay in the superior, inferior, middle cervical and the upper 5 thoracic ganglia. The postganglionic fibers pass to supply the various organs.

Functions:

1- Heart:

- Increase all properties of the cardiac muscle.
- Vasodilatation of the coronary blood vessels.

2- Lungs:

- Bronchodilatation (inhibitory to smooth muscle fibers of bronchi).
- Slight vasoconstriction of pulmonary blood vessels.

III- To limb and trunk (skin and muscles):

a) Fore limb: The preganglionic neurons originate from the lateral horn cells of the 5-9 thoracic segments and relay in the inferior and middle cervical as well as the upper two thoracic sympathetic ganglia.

b) Hind limb: The preganglionic neurons originate from the lateral horn cells of the thoracic (10) and lumbar (2) segments of the spinal cord, and relay in the lumbar and sacral sympathetic ganglia.

c) Thoracic and abdominal parities: The preganglionic neurons originate from the lateral horn cells of all thoracic and lumbar segments. Then, pass to relay in the corresponding ganglia in the sympathetic chain .

Functions:

1- Better contraction.

2- Delayed fatigue.

3- Early recovery after fatigue.

4- Vasodilatation of blood vessels.

IV- To abdominal and pelvic viscera:

a) Abdominal viscera: The preganglionic neurons which supply the abdominal viscera originate from the lateral horn cells of 6-12 thoracic segments. Then, pass to relay in the collateral ganglia (celiac, superior, mesenteric and renal).

Functions:

1- Inhibition of the movement of the wall of the stomach, small intestine, proximal part of the large intestine and gall bladder, but it is excitatory to their corresponding sphincters.

2- Motor to splenic capsule leading to pumping the stored RBCs into the circulation.

3- Increase glycogenolysis in liver

4- Vasoconstriction to splanchnic blood vessels.

5- Secretion of adrenaline and nor adrenaline from the adrenal medulla.

6- Vasodilatation of some splanchnic blood vessels.

7- Increase the metabolic rate.

b) Pelvic viscera: The preganglionic neurons which supply the pelvic viscera originate from the lateral horn cells of the upper two lumbar segments. Then, pass to relay in the collateral ganglia (inferior and mesenteric).

Functions:

1- Inhibition of the wall of the urinary bladder and excitation of the internal uretheral sphincter leading to retention of urine.

2- Inhibition of the wall of the large intestine and excitation of the internal anal sphincter leading to retention of feces.

3- Vasoconstriction of blood vessels of the penis and clitoris leading to shrinkage of the penis and clitoris.

4- Motor to plain muscles of vas deferens, seminal vesicle and ejaculatory duct leading to ejaculation of semen, in man.

5- Induce uterine antiperstalisis during sexual intercourse, in women.

Parasympathetic or craniosacral division of the autonomic nervous system:

(I) The cranial portion: Parasympathetic fibers are contained in the following cranial nerves:

1- Occulomotor nerve (3rd cranial nerve): The preganglionic nerve fibers of this part originate from Edinger-Westphal nucleus in the mid brain and run in the

occulomotor nerve (3rd cranial nerve) to the ciliary ganglion which give the postganglionic nerve fibers to the eye.

Functions:

1- Constriction of eye pupil (motor to the pupillary constricting muscle).

2- Motor to ciliary muscle leading to accommodation of the eyes for near vision (increase the convexity of the eye lens).

2- Facial nerve (7th cranial nerve): The preganglionic nerve fibers originate from the nerve cells of the superior salivary nucleus. Then, pass in two groups; one group runs in the Chorda tympani nerve to relay in the submandibular ganglion which gives the postganglionic nerve fibers to submandibular and sublingual salivary glands and their blood vessels, the other group runs in the greater superficial petrosal nerve to reach the spheno-palatine ganglion which supplies the lacrimal gland and the mucosa of pharynx.

Functions:

1- Secretory and vasodilator to sublingual and submandibular salivary glands as well as lacrimal gland (the secretion is large in volume, rich in electrolytes and poor in organic matter.

2- Secretory and vasodilator to the mucosa of soft palate, nasopharynx and pharynx.

3- Vasodilatation of blood vessels of the anterior two third of the tongue.

3- Glossopharyngeal nerve (9th cranial nerve): The preganglionic nerve fibers arise from the nerve cells of the inferior salivary nucleus (present in the medulla oblongata) and pass to the otic ganglion which supplies postganglionic fibers to the parotid salivary gland.

Function:

1- Vasodilator and secretory to parotid salivary gland (copious secretion rich in enzymes).

2- Vasodilator to the blood vessels posterior third of the tongue.

4- Vagus nerve (10th cranial nerve): The preganglionic nerve fibers arise from the dorsal nucleus of the vagus in the medulla oblongata. Then, emerge as vagus nerve for long way to relay in terminal ganglion found in the target organs (thoracic and abdominal viscera).

Functions:

1- Inhibit all properties of the cardiac muscle (rhythmicity, conductivity, contractility and excitability).

2- Constriction of coronary blood vessels.

3- Motor to the plain muscle of the bronchi and bronchioles and secretory to their mucus gland.

4- Slight vasodilatation of blood vessels of bronchi and bronchioles.

5- Motor to the plain muscles of oesophagus, stomach, small intestine, proximal part of large intestine and gall bladder, but inhibitory to their corresponding sphincters.

6- Secretory to glands of stomach and pancreas.

7- Stimulate insulin secretion.

(II) The sacral segment: The preganglionic fibers of this segment leave the spinal cord in the ventral roots of the sacral nerves. The sacral nerves differ in number from species to another e.g. 5 in horse and cattle, 4 in sheep and swines and 2-3 in dog. The preganglionic fibers leave the sacral nerves and join the hypo gastric nerve to form the pelvic plexus. They have no certain ganglia, but they make synaptic junction with ganglionic cells found in the innervated organs.

Functions:

1- Motor to the wall of urinary bladder and inhibitory to internal uretheral sphincter → nerve of micturition

2- Motor to the muscles of colon and rectum but inhibitory to internal anal sphincter → nerve of defecation .

3- Vasodilator to the blood vessels of penis and clitoris → nerve of erection.

4- Secretory to seminal vesicle and prostate gland.

Centers controlling autonomic activity

(I) Lower centers (spinal cord and brain stem)

1- L.H.C. of spinal cord:

2- Medulla oblongata and pons: contain centers controlling autonomic activities e.g. cardiac centers, vasomotor centers, deglutition center and respiratory center.

3- Mid brain: contains centers controlling pupillary reflexes

N.B. The lower centers still functioning even after separation from higher centers.

(II) Higher centers (controlling activities of lower centers):

1- Cerebral cortex: control autonomic activity either directly or indirectly.

2- Hypothalamus: it is considered the main higher centers controlling the activity of both sympathetic and parasympathetic function through:

a) Posterior nuclei: controlling sympathetic function

b) Anterior nuclei: controlling parasympathetic function.

CHEMICAL TRANSMITTER

They are chemical substances released at the nerve endings to transmit the nerve impulse across the synapse, neuromuscular junction or neuroeffector junction. There are two types of chemical transmitter in the autonomic nervous system:
A- Acetyl choline B- Catecholamines (adrenaline and nor adrenaline).

A) Acetylcholine: It is the chemical transmitter released by the cholinergic fibers which include:

1- All preganglionic sympathetic and parasympathetic fibers.

2- All postganglionic parasympathetic fibers.

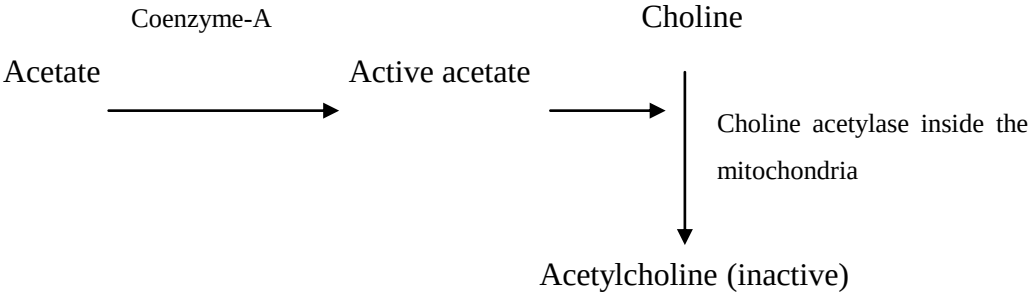
3- Postganglionic sympathetic to sweet gland.

4- Preganglionic fibers to adrenal medulla.

5- Motor end plate to skeletal muscle.

6- Many neurons in C.N.S.

Synthesis of acetyl choline:



N.B.: The biosynthesis of acetyl choline requires energy derived from ATP within the mitochondria (present mainly in the nerve cell body). Then the mitochondria migrate via the axon of the nerve cell to the pre synaptic knob. Acetyl choline is then transported to be stored in clear vesicles (synaptic vesicle or cholinergic vesicles) till release.

Inactivation of acetyl choline:

After acetyl choline produces its physiologic effects, it becomes inactivated through:

1- Reuptake by the nerve endings.

2- Inactivation by cholinesterase enzyme.

Acetyl choline $\xrightarrow{\text{Choline esterase}}$ Choline + acetic acid.

Nicotine-like action of acetyl choline:

Acetyl choline has the same effect of nicotine at the following sites:

1- Autonomic ganglia. 2- Motor end plate. 3- Adrenal medulla.

Muscarine-like action of acetyl choline:

Acetyl choline has the same effects as muscarine at the postganglionic parasympathetic nerve endings.

* Parasympathomimetics: Drugs which produce the same effects as parasympathetic stimulants e.g. Acetyl choline, Physostigmine (eserine), prostigmine (neostigmine).

* Parasympatholytics: Drugs which antagonize acetyl choline action e.g. Atropine

B) Catecholamines (adrenaline and nor adrenaline):

It is the chemical transmitter released by the adrenergic fibers which include, all postganglionic sympathetic fibers except those of sweet glands.

Adrenergic receptors:

The receptors respond to adrenaline and nor adrenaline are called adrenergic receptors. It is of two types:

1- Alpha adrenergic receptors: mainly excitatory e.g. vasoconstriction.

2- Beta adrenergic receptors: mainly inhibitory e.g. vasodilatation.

N.B.: Adrenaline stimulates both alpha and beta receptors. While, nor adrenaline stimulates alpha receptors only.

Inactivation of catecholamines:

1- Reuptake.

2- Destruction by enzymes:

a) Catechol-ortho-methyl-transferase (C.O.M.T).

b) Monoamino oxidase (M.A.O)

* Sympathomimetics: Drugs which produce the same effects as sympathetic stimulants e.g. adrenaline and nor adrenaline.

* Sympatholytics: Drugs which antagonize catecholamines action e.g. reserpine