Topic 3: Peripheral Nervous System

The peripheral nervous system is divided into two parts:

- Autonomic Nervous System (ANS): Involuntary branch of the PNS, innervates cardiac and smooth muscle, glands, organs and adipose tissue (fat). This subdivides further into the sympathetic and parasympathetic nervous system.
- Somatic Nervous System (SNS): Subject to voluntary control, innervates skeletal muscle.

Autonomic Nervous System

Consists of two subdivisions: Sympathetic and Parasympathetic. Each autonomic nerve pathway consists of a two neuron chain.

- Sympathetic system: Dominates in emergency or stressful ('fight-or-flight') situations. Promotes responses that prepare the body for strenuous physical activity.
- Parasympathetic system: Dominates in quiet, relaxed ('rest-and-digest') situations. Promotes body-maintenance activities such as digestion.

Parasympathetic Anatomy

Both preganglionic and postganglionic parasympathetic nerve fibres release Acetylcholine (Ach) as their neurotransmitter. Typically have a very long preganglionic fibre and a very short post ganglionic fibre, which is close to the effector organ.

Fibres come from the cranial and sacral region of the CNS.

Sympathetic Anatomy

Preganglionic sympathetic fibres release Ach whilst post ganglionic sympathetic nerve fibres release norepinephrine (NE) as their neurotransmitter. Have a very short preganglionic fibre and a longer postganglionic fibre.

Fibres comes from the thoracic and abdominal region of the CAN.

Adrenal Medulla

A modified sympathetic ganglion with only a preganglionic neuron, no postganglionic neuron. Preganglionic neuron innervates it and it releases neurotransmitter into the bloodstream- exception to the 2 neuron sequence rule. 2 adrenal glands lie above the kidneys: Endocrine glands, each with an outer portion (cortex) and inner portion (medulla). The adrenal medulla secretes the hormones adrenaline (80%) and noradrenaline (20%) into the bloodstream in response to stimulation by the sympathetic nervous system. These hormones reinforce sympathetic activity.

Functions as an endocrine gland, releasing noradrenaline, adrenaline and dopamine (DA) peptides into the bloodstream.

Sympathetic and Parasympathetic Nervous System

Sympathetic: Originates in the thoracic (chest) and lumbar (abdominal) regions of the spinal cord. It has short cholinergic (ACh releasing) preganglionic fibres and long adrenergic (NE releasing) postganglionic fibres. Ganglia (sympathetic trunk) lie alongside the spinal cord.

Parasympathetic: Arise from cranial (brain) and sacral (lower spine) areas of the spinal cord. Long cholinergic (ACh releasing) preganglionic fibres and short cholinergic (ACh releasing) postganglionic fibres. Ganglia (terminal ganglia) lie near the effector organ.

ANS Neurotransmitters

All preganglionic fibres and parasympathetic postganglionic fibres release acetylcholine (ACh) Sympathetic postganglionic fibres release noradrenaline (NA). Cells that release ACh are cholinergic and cells that release NA (or NE) are adrenergic.

ANS Receptors

The neurotransmitter released must bind to a receptor on the effector organ. Binding of the neurotransmitter induces a tissue specific response. Cholinergic receptors include nicotinic and muscarinic receptors. Adrenergic receptors include α_1, α_2, β_1, β_2 and β_3 receptors.

Cholinergic Receptors

1. **Nicotinic:** Found on all autonomic postganglionic neurons. Respond to ACh release from both sympathetic and parasympathetic preganglionic fibres.
2. **Muscarinic:** Found on all target cells stimulated by postganglionic neurons releasing ACh (parasympathetic).

The first target is always nicotinic. ACh is released from preganglionic fibres binds to the nicotinic receptor on the postganglionic fibre. Opening of non-specific cation receptor channels in the postganglionic cell membrane permits passage of both Na^+ and K^+ along electrochemical gradients. The Na^+ influx occurs very rapidly due to very high electrical and chemical potentials. Rapid and extensive depolarisation of the cell membrane results in an action potential produced in the postganglionic cell. This always produces an excitatory response on the effector.

Adrenergic Receptors

Adrenergic receptors are variably distributed among sympathetically controlled organs. Adrenoceptor subclasses also have different affinities for adrenaline and noradrenaline:

- α_1 – present on most sympathetic target tissues. Greater affinity for noradrenaline. Usually an excitatory response (constriction of blood vessels)
- α_2 – present on digestive organs. Greater affinity for noradrenaline. Inhibitory response (decreased smooth muscle contraction in digestive tract).
- β_1 – present on the heart. Equal affinity for noradrenaline and adrenaline. Excitatory response (increased heart rate and force of contraction).
- β_2 – present on smooth muscle of arterioles and bronchioles (smaller blood vessels and airways). Binds primarily adrenaline. Generally inhibitory (arteriolar or bronchiolar dilation by relaxation of smooth muscle in those tubes).
- β_3 – present in adipose tissue

Dual Innervation

Most organs are innervated by both parasympathetic and sympathetic divisions of the autonomic nervous system. They usually produce opposite effects on an organ and allows precise control over an organ's activity. Usually both systems are partially active (ie some level of action potential activity exists in both sympathetic and parasympathetic fibres supplying an organ) = sympathetic or parasympathetic tone.

Exceptions to Dual Innervation

Most arterioles and veins receive only sympathetic nerve fibres. Regulation is achieved via increased or decreased firing rate above or below tone level. Most sweat glands are innervated only by sympathetic nerves. Salivary glands are stimulated by both divisions, but not antagonistic- each stimulates different volumes and composition of saliva.

Sympathetic Dominance

'Fight or flight'- rapid response. Increase in heart rate and force of contraction, increase in blood pressure due to blood vessel constriction, increase in airflow in respiratory system (airway dilation) and increase blood flow to muscle. Pupils dilate to adjust for far vision, sweating increases in prep for increased heat production. Digestion and urinary activity decrease.

Parasympathetic Dominance

Generally related to the body's own general housekeeping or maintenance activities ('rest and digest'). Also slows down those activities that are enhance by the sympathetic system.

Clinical Relevance

Drugs are available to selectively alter autonomic nervous system activity.

- *Agonist:* Upon binding to a receptor causes the same response as the neurotransmitter would have (mimics response). β_1 agonists increase cardiac contractility. β_2 agonists are used in asthma to dilate airways.
- *Antagonist:* Upon binding to the receptor prevents the neurotransmitter from eliciting a response (blocks a response). α_1 antagonists reduce blood pressure by dilating blood vessels. β_1 antagonists decrease cardiac output. Atropine is an antagonist for muscarinic receptors (blocks PNS ACh signalling).

Autonomic vs Somatic Nerve Pathways

Autonomic is a 'two neuron' model. It innervates smooth and cardiac muscle, glands, and GI neurons. Can lead to excitation or inhibition of the effector glands.

Somatic consists of a single neuron (motor neuron) between the CNS and effector organ. It innervates skeletal muscle and leads to muscle excitation.