



Autonomic Nervous System

Prerequisite knowledge: Before studying this Factsheet the student should know about sensory, relay and motor neurones and their structure, about myelinated and non myelinated fibres, and about cholinergic and adrenergic synapses. Details of all these can be found in Factsheet Number 20 (Nerves and Synapses, April 1998).

This Factsheet summarises:

1. The organisation of the autonomic nervous system (ANS).
2. The control functions of the ANS.
3. The roles of the ANS in controlling heart rate and flight or fight response.

Typical Exam Question

Exam questions usually require recall knowledge about the different roles of the sympathetic and parasympathetic divisions of the ANS. This could be tested by tick box, flow diagram, 'fill in the missing words', or continuous prose type questions.

The organisation of the autonomic nervous system

The ANS consists of two opposing systems, the **sympathetic** system and the **parasympathetic** system. These two systems are usually in balance with one another to regulate the **visceral** or involuntary functions of the body.

Remember – the viscera are all the organs inside the body, such as heart and blood vessels, lungs, digestive system, glands, reproductive organs.

The ANS consists of **motor** neurones which carry impulses from the central nervous system to the effector organs. The effector organs for the autonomic system are **smooth muscle** or **glands**, or, in the case of the heart, **cardiac muscle**.

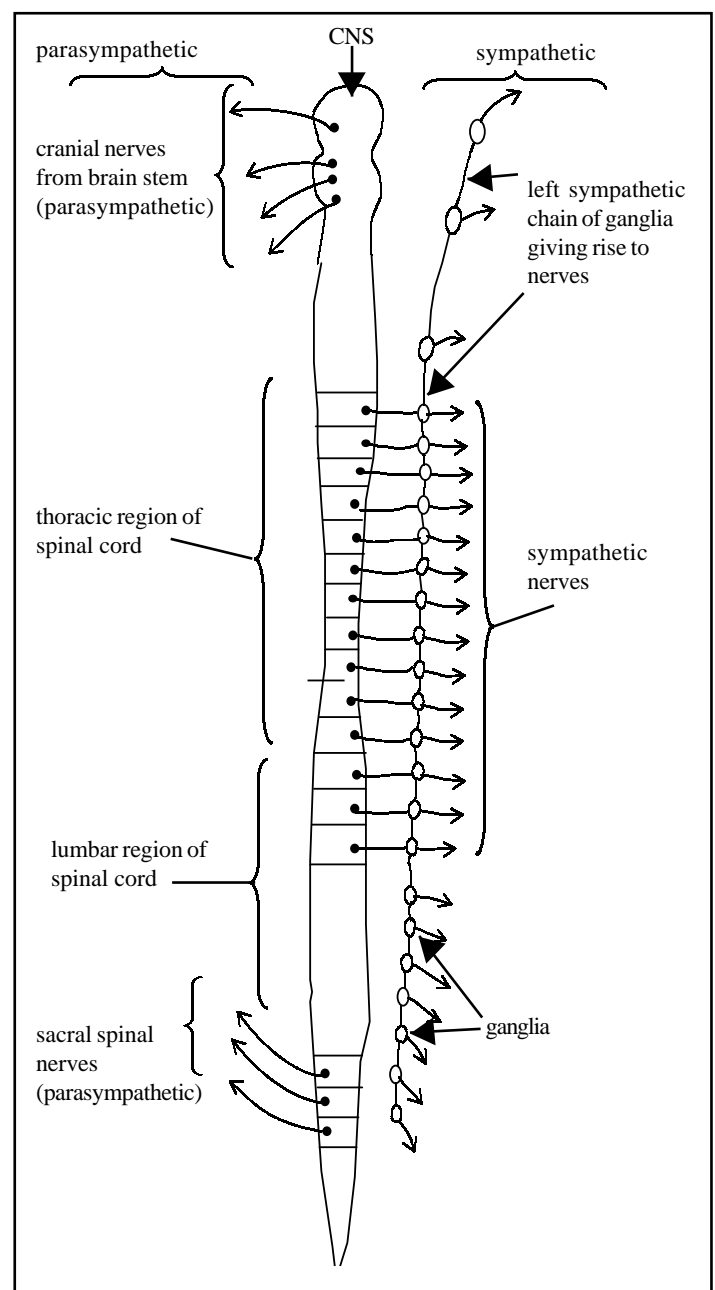
Remember – the effector organs for the voluntary nervous system are the voluntary striated skeletal muscles, rather than involuntary smooth muscle.

The sympathetic and parasympathetic nerves emerge from the central nervous system in different places. The sympathetic system arises from the spinal cord through the thoracic and lumbar spinal nerves. For this reason it is often referred to as the **thoraco-lumbar** system. The parasympathetic arises from the medulla (brain stem) through the cranial nerves and from the spinal cord through the sacral spinal nerves. For this reason it is often referred to as the **cranio-sacral** system. The anatomical arrangement of the ANS is shown in Fig 1.

Exam Hint - Short answer questions often ask candidates to explain:

1. Structure and function of motor and sensory neurones.
2. How the nerve impulse is generated.
3. How synaptic transmission occurs.

Fig 1. The relationship of the ANS to the central nervous system



Unlike the voluntary nervous system (VNS) the ANS has a series of interneuronal synapses outside the central nervous system. These extra synapses form structures known as **ganglia**. The sympathetic ganglia lie close to the spinal cord on either side and form the structures known as the **sympathetic chains**. These give rise to motor nerves to the organs. The parasympathetic ganglia generally lie within the effector organs.

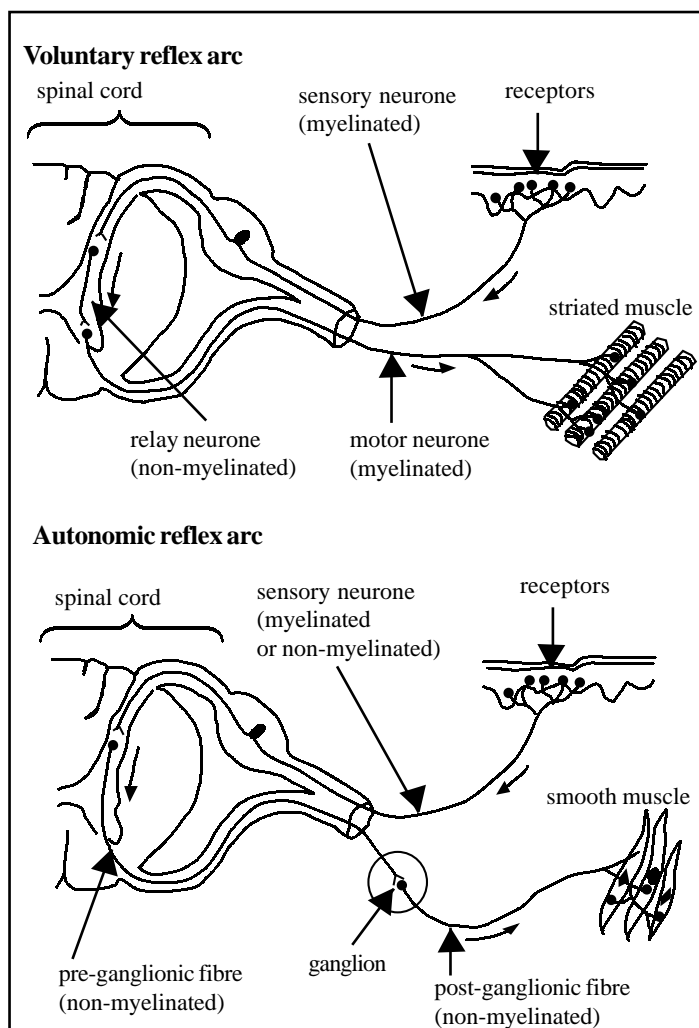
The sino-atrial and atrioventricular nodes within the heart can be considered to be ganglia of the parasympathetic vagus nerve (cranial nerve 10).

The simplest working unit of both the VNS and the ANS is the simple reflex arc. These simple neuronal circuits differ in the following respects:

- In the voluntary reflex arc there is a relay neurone between the sensory and motor neurones. In the autonomic reflex there is not.
- In the voluntary reflex arc there is a single motor neurone which runs to the effector. In the autonomic reflex there is a **pre-ganglionic** motor neurone which synapses in the ganglion to a **post-ganglionic** motor neurone which runs to the effector. The relative lengths of these neurones depends on the positions of the ganglia.
- The motor neurone of the voluntary reflex is **myelinated** and so conducts impulses very quickly. The pre- and post-ganglionic fibres are **non-myelinated** and so conduct impulses slowly.
- The voluntary reflex effectors are skeletal striated muscles. The autonomic effectors are visceral smooth muscles, glands, or the cardiac muscle in the heart.

Fig 2 illustrates the differences between spinal reflex arcs of the VNS and ANS.

Fig 2. VNS and ANS reflex arcs



The synapses of the VNS and the parasympathetic nervous system are all **cholinergic**. The synapses of the sympathetic nervous system are also cholinergic except for the synapses between the post-ganglionic neurones and the effectors. These are **adrenergic**.

Remember - A cholinergic synapse uses acetylcholine as neurotransmitter and acetylcholine esterase enzyme to break it down after transmission. An adrenergic synapse uses noradrenaline as neurotransmitter and mono-amine oxidase enzyme to break it down.

Control of physiological functions by the ANS

Generally the sympathetic system tends to increase or accelerate activity to meet increased demands by the body. The parasympathetic system tends to reduce or slow up activity, allowing organs to rest when the body's needs are reduced. The two systems act in harmony to keep the body systems working at the level needed.

Remember - although most organs are regulated by both sympathetic and parasympathetic systems, some organs are controlled by only one of them. In these cases it is increased stimulation or decreased stimulation by the one system which alters the level of activity.

The ANS operates through **negative** and **positive feedback control systems** in which a variation in a physiological function is sensed by receptors. These send impulses to the appropriate brain centres which then send impulses to the appropriate effectors through the ANS to cause an appropriate response.

Remember - in negative feedback control a varying physiological value is returned to its mean value by the controlling mechanism. In positive feedback control a physiological value is increased to meet any increased immediate needs of the body.

The overall functions of the ANS are shown in Table 1 (page 3).

Specific roles of the ANS

1. Control of cardiac output

The cardiac branch of the **vagus** nerve (cranial nerve 10) is the parasympathetic nerve to the heart. It synapses with the sinoatrial node (SAN) and atrioventricular node (AVN). It reduces cardiac output by reducing the signal frequency from the SAN, and by increasing the delay time for the cardiac impulses to pass through the AVN. Thus the frequency and force of the heart beat are reduced. The sympathetic nerves to the heart arise from the sympathetic chains and synapse with the SAN, the AVN and the ventricular cardiac muscle fibres. They increase the cardiac output by increasing the signal frequency of the SAN, by reducing the delay at the AVN and by increasing the force of contraction of the ventricular muscles.

The cardiac needs of the body are monitored by **baroreceptors** (blood pressure receptors) in the aortic and carotid bodies and walls of the great veins, and also by **chemoreceptors** (sensitive to the CO₂ or hydrogen carbonate ion tension of the blood). These are also situated in the aortic and carotid bodies, and also in the blood vessels of the medulla. These receptors send sensory impulses to the **vasomotor** centre in the medulla which sends motor impulses to the heart via the ANS to adjust the heartbeat as necessary.

Remember - decreased blood pressure or raised blood CO₂ tension will cause an increase in cardiac output. Raised blood pressure (unless abnormal) or decreased blood CO₂ tension will cause a reduction in cardiac output.

Table 1. Overall functions of the ANS

Visceral effector	Effects of Sympathetic stimulation	Effects of Parasympathetic stimulation
EYE: Radial iris muscle* Circular iris muscle* Ciliary muscles *	Contraction, dilating pupil. None. Relaxation for distant vision.	None. Contraction, constricting pupil. Contraction for near vision.
LUNGS: Bronchial muscle *	Relaxation/bronchodilation.	Contraction/bronchoconstriction.
HEART: Cardiac muscle * Coronary vessels *	Increases rate/force of contraction. Dilation to increase blood flow.	Decreases rate/force of contraction. Constriction to reduce blood flow.
ARTERIOLES: Skin and nasal mucosa Skeletal muscle Abdominal viscera	Constriction. Constriction or dilation. Constriction.	None. None. None.
GLANDS: Sweat Lachrymal(tear) * Salivary * Gastric(stomach) * Intestinal (crypts) * Pancreas(digestive) Pancreas(islets) Adrenal medulla Liver	Stimulates local secretion. None. Decreases secretion. Inhibits secretion. Inhibits secretion. Inhibits enzyme secretion. Inhibits insulin secretion, promotes glucagon secretion. Promotes secretion of adrenaline and noradrenaline. Inhibits bile secretion, promotes glycogen breakdown to glucose.	Stimulates overall/general secretion. Stimulates secretion. Increases secretion. Stimulates secretion. Stimulates secretion. Stimulates enzyme secretion. Promotes insulin secretion, effect on glucagon unknown. None. Stimulates bile secretion, promotes glycogen storage.
SMOOTH MUSCLE: Stomach Intestines Gallbladder and ducts Spleen Arrector pili(hair) muscles Urinary bladder * Uterus	Decreases motility/relaxes tone but contracts sphincters. Decreases motility/relaxes tone but contracts sphincters. Relaxation. Contraction, pushing stored blood into circulation. Contraction/hair erection. Relaxation of wall muscle, contraction of sphincter muscle. Inhibits contraction unless pregnant when it stimulates birth contractions.	Increases motility and tone but relaxes sphincters, causing emptying. Increases motility and tone but relaxes sphincters/ileocolic sphincter. Contraction. None. None. Contraction of wall muscle, relaxation of sphincter muscle. None.

You do not need to learn all the information in this table, but some of it may be useful when answering certain questions, for instance, about the 'flight or fight' response. You should learn the effectors marked with a star, (*), since these are stated on some syllabuses and so can be specifically tested. Check your particular syllabus if in doubt.

2. The flight or fight response

The parasympathetic system is mainly concerned with activities that conserve and restore body energy, particularly during times of rest. For this reason it is often referred to as an **energy conservation-restorative system**. In contrast, the sympathetic system is mainly concerned with activities which cause the use of energy, especially in times of stress. Fear may induce the 'flight or fight' response. This produces the following effects:

- the pupils of the eyes dilate.
- cardiac output and blood pressure increase.
- arterioles to the skin and viscera constrict.
- arterioles to skeletal muscle, cardiac muscle and lungs dilate.
- bronchioles dilate, breathing becomes deeper and faster.
- more liver glycogen converted to glucose raising blood glucose level.
- muscular movements of gut are inhibited and digestive secretions reduced, thus less energy used in immediate non-essential processes.
- adrenal medulla stimulated to release more adrenaline and noradrenaline. These enhance the effects of sympathetic stimulation.

Practice Questions

1. Read through the following passage about the regulation of the heart beat and then complete it by filling in the spaces with the most appropriate word or words.

When _____ in the carotid bodies sense a fall in blood pressure impulses are sent to the _____ centre in the medulla. This sends impulses to the heart via the _____ system. The effects of this are to _____ the signal frequency of the _____ node, to _____ the delay at the _____ node, and to _____ the force of contraction of the _____ cardiac muscle fibres. Thus the _____ is _____ returning the blood pressure to its 'norm' value.

(11 marks)

2. The table below refers to certain effects of sympathetic or parasympathetic stimulation. If an effect is correct place a tick in the appropriate box and if it is incorrect, place a cross in the box.

Effect	Sympathetic stimulation	Parasympathetic stimulation
Dilates pupil		
Broncho-constriction		
Tear production		
Increased cardiac output		
Saliva released		
Urination		
Coronary supply reduced		
Lens fatter		

(8 marks)

3.(a) List **five** ways in which the parasympathetic system is an energy conservation-restorative system.

(5 marks)

(b) Describe the 'flight or fight' response.

(5 marks)

4. State **four** differences (other than functional differences) between the sympathetic and parasympathetic nervous systems.

(4 marks)

Acknowledgements;

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Answers

Semicolons indicate marking points

1. baroreceptors; vasomotor; sympathetic; increase; sinoatrial; decrease/reduce; atrioventricular; increase; ventricular; cardiac output; increased;

2.

Effect	Sympathetic stimulation	Parasympathetic stimulation
Dilates pupil	✓	✗
Broncho-constriction	✗	✓
Tear production	✗	✓
Increased cardiac output	✓	✗
Saliva released	✗	✓
Urination	✗	✓
Coronary supply reduced	✗	✓
Lens fatter	✗	✓

3.(a) decreases cardiac output/reduces frequency of heartbeat/reduces force of contraction of cardiac muscle thus allowing heart to rest;
stimulates gastric secretion so that (energy containing) food can be digested;
stimulates pancreatic/intestinal secretion so that food can be digested;
promotes glycogen synthesis in liver/insulin release by islets of Langerhans/ β -cells;
increases motility of stomach/intestines causing better mixing/absorption of food;
stimulates bile release/contraction of gall bladder to enhance digestion;
(max 5)

(b) pupils dilate;

cardiac output raised/heart rate increases/force of beat increases;
arterioles to skin and viscera contract diverting blood to muscles/lungs/heart muscle;
arterioles to heart muscle/lungs/skeletal muscles dilate to enable faster flow of blood;
breathing becomes faster and deeper/bronchioles dilate, improving O_2 uptake;
more liver glycogen converted to glucose to supply more energy;
adrenalin release promoted to enhance sympathetic effects;
energy using non-essential muscular movements/secretions of gut are suppressed;

(max 5)

4. sympathetic outflow from CNS is via thoracic and lumbar spinal nerves, parasympathetic outflow is through cranial and sacral nerves; ganglia in sympathetic system are in sympathetic chains on either side of spinal cord, ganglia in parasympathetic system are in the effectors;
preganglionic fibres of sympathetic system are short, in parasympathetic system are long;
postganglionic fibres of sympathetic system are long, in parasympathetic system are short;
all parasympathetic synapses are cholinergic, some sympathetic synapses are adrenergic;

(max 4)