Chapter 13 – The Nervous System

Subject content

Content
- Nervous System – Neurones (Reflex Action)

Learning outcomes
(a) state the relationship between receptors, the central nervous system and the effectors
(b) state that the nervous system – brain, spinal cord and nerves, serves to co-ordinate and regulate bodily functions
(c) outline the functions of sensory neurones, relay neurons and motor neurones
(d) discuss the function of the brain and spinal cord in producing a co-ordinated response as a result of a specific stimulus in a reflex action

Definition

Phrase	Definition
Reflex action	immediate response to specific stimulus without conscious control
Reflex arc	shortest pathway by which nerve impulses travel from receptor to effector in reflex action

13.1 Sensitivity

Role of nervous system in humans

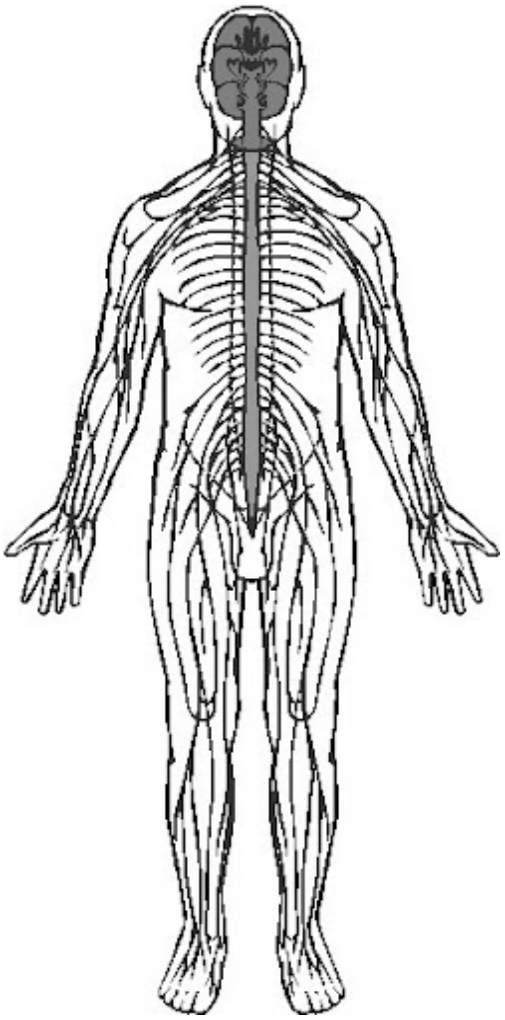
Coordinate responses in body to changes in environment
- coordinate activities of muscles & organs
- receive input from sense organs
- trigger reactions
- generate learning + understanding
- provides protection from danger

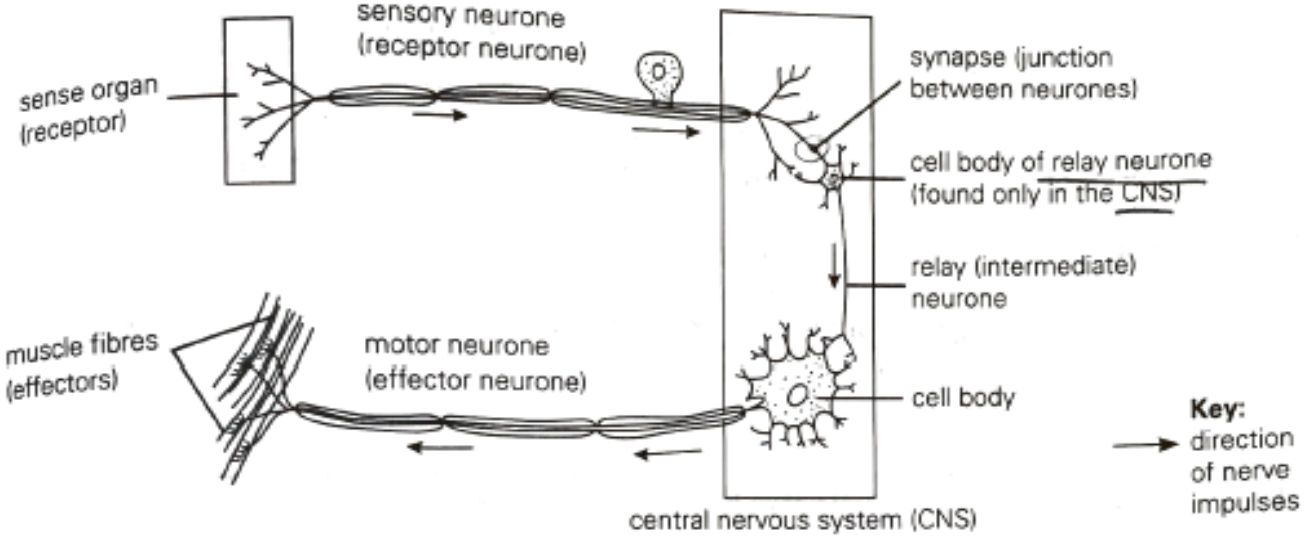
13.2 The Human Nervous System

Human nervous system

Nervous system:

Nervous system	Components
1. **Central nervous system (CNS)**	• brain • spinal cord
2. **Peripheral nervous system (PNS)**	• cranial nerves • spinal nerves • sense organs

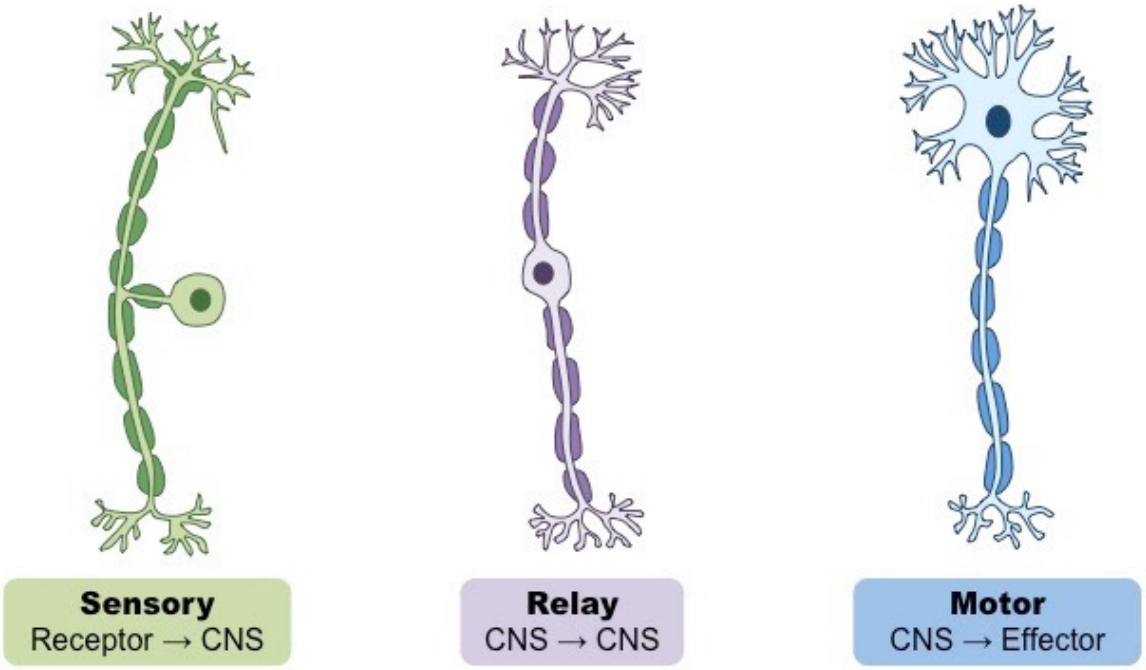



sense organ (receptor)
sensory neurone (receptor neurone)
synapse (junction between neurones)
cell body of relay neurone (found only in the CNS)
relay (intermediate) neurone
muscle fibres (effectors)
motor neurone (effector neurone)
cell body
central nervous system (CNS)
Key:
direction of nerve impulses

Nervous tissue

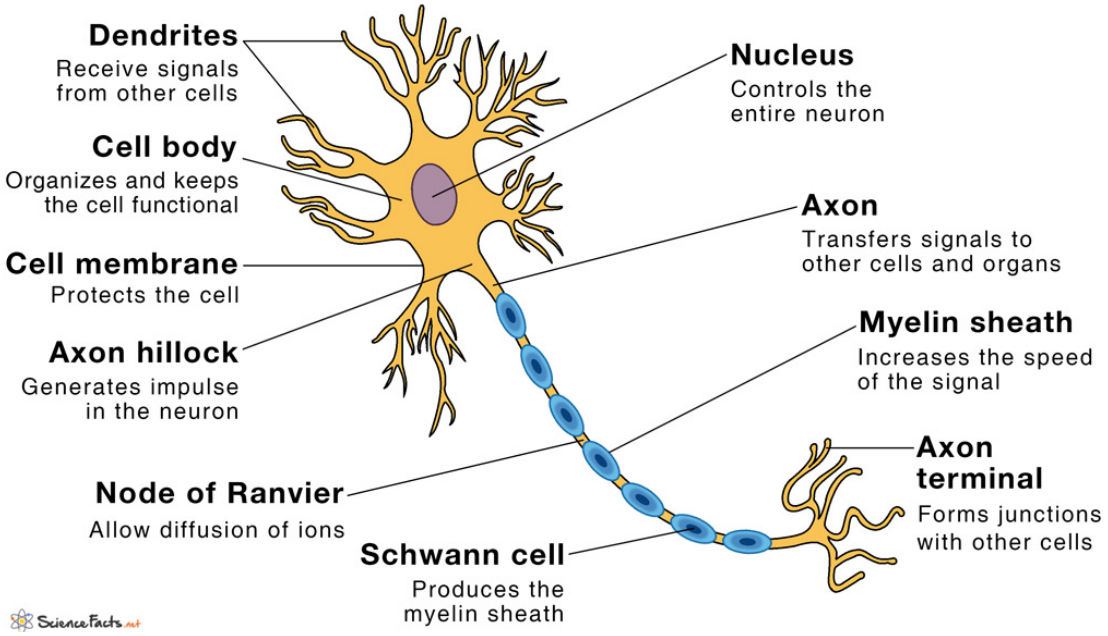
Types of neurones:

Neurone	Explanation
1. **Sensory neurone** (receptor neurone)	• Transmit nerve impulses: receptors → CNS
2. **Relay neurone** (intermediate neurone)	• Interconnect with other neurones (found only in CNS) • Transmit nerve impulse: sensory → motor neurone
3. **Motor neurone** (effector neurone)	• Transmit nerve impulses: CNS → effector (muscle / gland) which prompt response



Differences between sensory & motor neurone:

Neurone	**Sensory**	**Motor**
Structural	long dendron & short axon	short dendrons & long axon
	cell body → irregularly shaped	cell body → round
Functional	transmit nerve impulses: receptor → CNS	transmit nerve impulses: CNS → effector



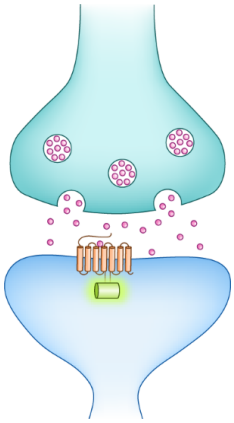
Structure of motor neurone:

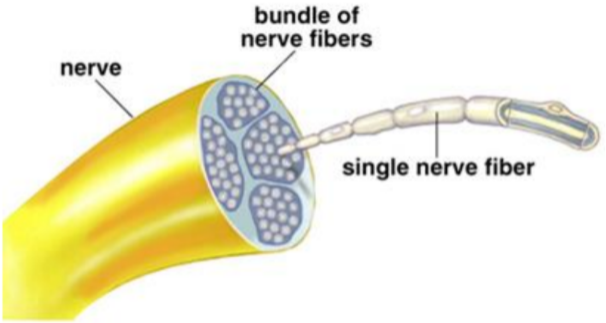
Parts	Explanation	Function
1. **cell body**	contains nucleus, cytoplasm, CNS, organelles	control centre
2. **dendron**		transmit nerve impulses: towards cell body
3. **dendrite**	end branches of dendron	receive nerve impulses from other neurones / receptor
4. **axon**		transmit nerve impulses: away from cell body
5. **myelin sheath**	layer of lipid substance enclosing nerve fibre (axon)	insulate axon → faster nerve impulse transmission
6. **neurilemma**	tough, inelastic membrane	outermost layer of nerve fibre
7. **node of Ranvier**	region where myelin sheath is absent	nerve impulses 'jumps' from node to node → speed up transmission of impulses along nerve fibre
8. **axon terminal**		
9. **motor end plate**	formed when end branch of axon comes into contact with muscle fibre	transmit nerve impulses: dendrite → muscle fibre

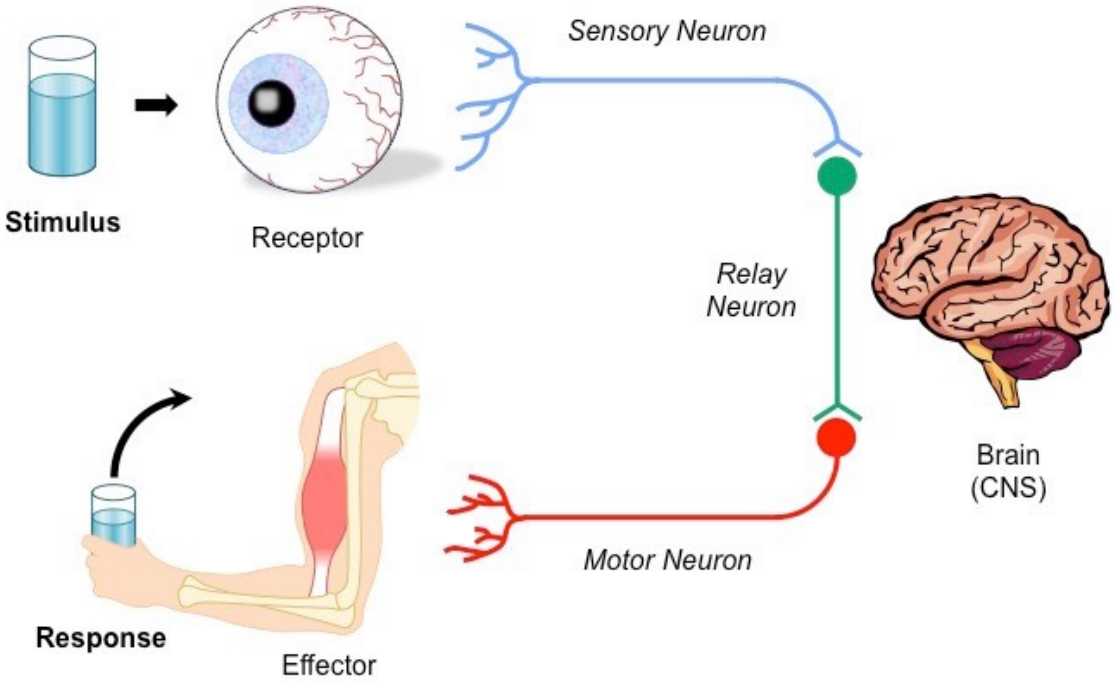
Synapse: junction between 2 neurones / 1 neurone & effector
Neurotransmitters: chemicals transmit nerve impulses across synapse

Nerve: made up of bundle of nerve fibres enclosed by connective tissue and blood vessels.
Nerve fibre: strand of cytoplasm extending from cell body of neurone

- axon of sensory / motor neurone
- dendron of sensory neurone (dendrons are elongated in sensory neurone)



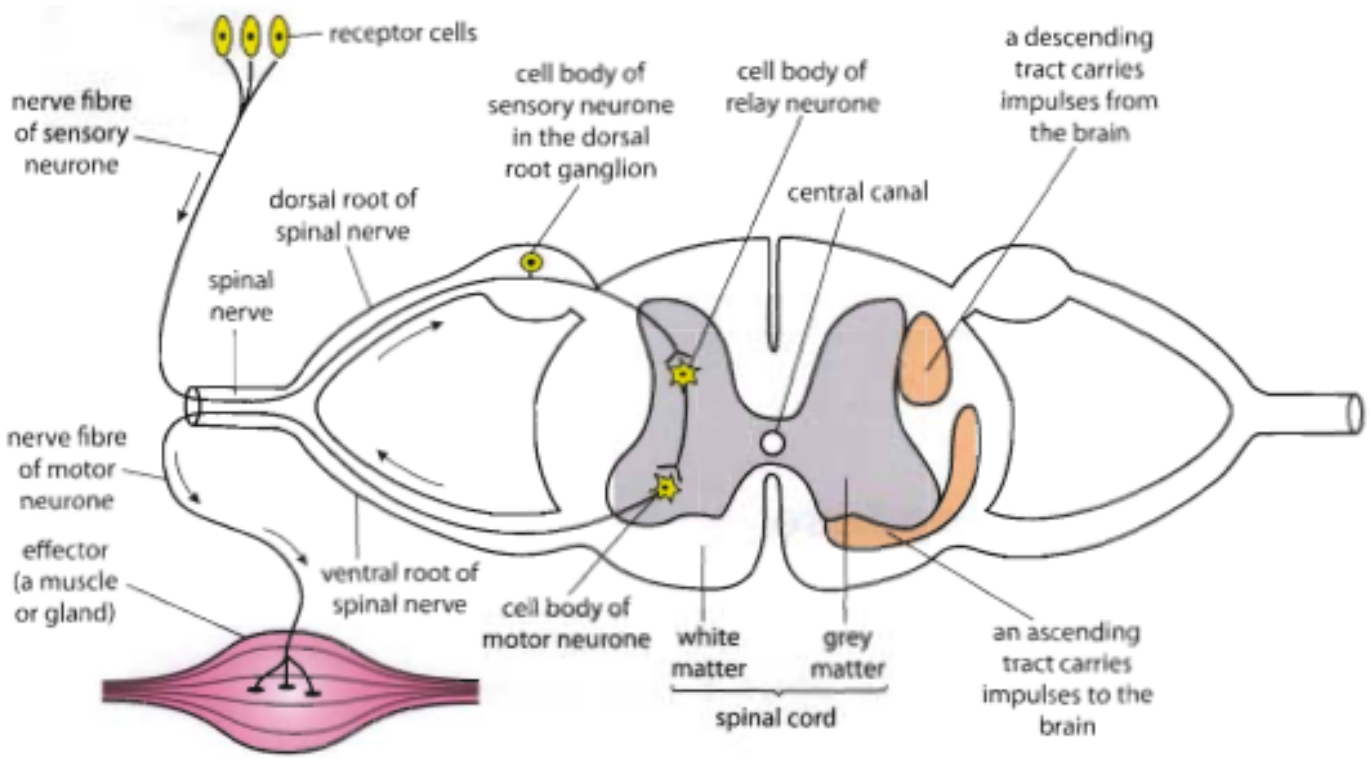




Different types of receptors:

1. **thermoreceptor** → temperature
2. **photoreceptor** → light
3. **pressure receptor** (baroreceptor) → pressure

Brain, spinal cord and spinal nerves



Structure

Structure	Description
1. **Grey matter**	consists mainly of cell bodies, dendrites, and synapses
2. **White matter**	consists of mainly nerve fibres with their insulating sheaths
3. **Central canal**	contains cerebrospinal fluid → nutrients to spinal cord
4. **Dorsal root**	contains only the axons of sensory neurones (towards the back)
5. **Dorsal root ganglion**	contains cell bodies of sensory neurones
6. **Ventral root**	contains only axons of motor neurones (towards the front) cell bodies and dendrons of motor neurones lie in the grey matter of the spinal cord
7. **Spinal nerve**	contains nerve fibres from both dorsal and ventral root

Brain

Parts	Description	Function

1. **Forebrain**	consist of cerebrum, hypothalamus, pituitary gland	• Intelligence, memory, learning, sensations
		• Overall control of all voluntary actions
		• Regulation of:
		  ○ body temperature
		  ○ blood water potential
		  ○ appetite
		  ○ sleep
		  ○ emotions
		• Produce + release important hormones (e.g. ADH)

2. **Midbrain**		• Auditory (hearing) • Sight • Visual reflexes ○ movement of eyeballs

3. **Hindbrain**	consist of cerebellum and medulla oblongata	• Control muscular coordination → maintain balance
		• Control involuntary actions:
		  ○ heartbeat
		  ○ peristalsis
		  ○ rate of respiratory movements
		  ○ contraction & dilation of blood vessels

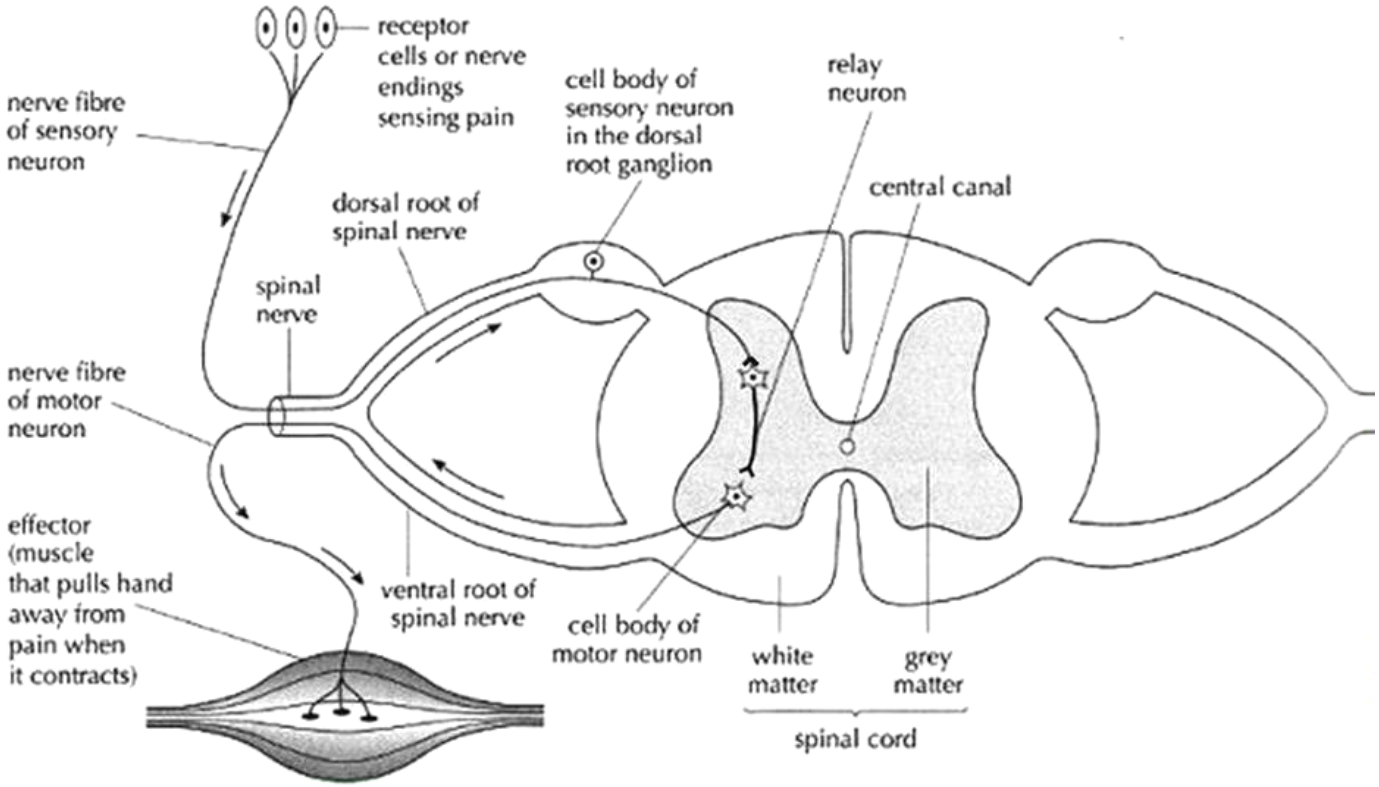
Processing of information

General process:

1. **Receptors** (photoreceptors, thermoreceptor) gather information → nerve impulses
2. Nerve impulses: sensory neurone → **CNS**
3. Nerve impulses: relay neurons in CNS → brain
4. Brain interprets nerve impulses → decide on course of action
5. CNS initiates + transmits nerve impulses → motor neurone → effectors
6. Effectors carry out intended actions

Actions	Pathway of impulses
1. **Sensation**	receptor → sensory neurone → relay neurone → forebrain
2. **Voluntary action**	forebrain → relay neurone → motor neurone → effector
3. **Reflex action**	receptor → sensory neurone → relay neurone → motor neurone → effector

13.3 Reflex Action



Reflex action

- immediate response to specific stimulus without conscious control
- enable quick action → protect body from serious danger / avoid injuries

Reflex arc → shortest pathway

1. Receptor / sense organ
2. Sensory neurone
3. Relay neurone in reflex centre (brain / spinal cord)
4. Motor neurone
5. Effector (muscle / gland)

Examples of reflex actions:

Example	Action	Protect body
1. **withdraw reflex**	When touch hot / sharp objects, withdraw arm / leg	prevent damage to body
2. **choke reflex**	When food / water enters trachea, muscles constrict → cough or choke to repel food	keep airway open for breathing
3. **blink reflex**	When something approaches the eye suddenly, eyelids close	prevent foreign objects from damaging eye surface

Differences between voluntary action & reflex action:

Voluntary action	**Reflex action**
variety of functions	protect body from harm
can be controlled by the will	not controlled by the will
variable responses (not same response to same stimulus)	same response to specific stimulus (same response to same stimulus)
not immediate, may not even respond	immediate
involves parts of brain responsible for conscious thought and decision making	bypass parts of brain responsible for conscious thought and decision making
brain interprets nerve impulses and decides on response	brain is only stimulated after nerve impulses have been transmitted to effector and response has been initiated
receptor is not necessary as nerve impulses can be initiated in brain	receptor is necessary to generate nerve impulses
nerve impulses initiated by brain	nerve impulses not initiated by brain
may or may not involve sensory neurone	always involve sensory neurone

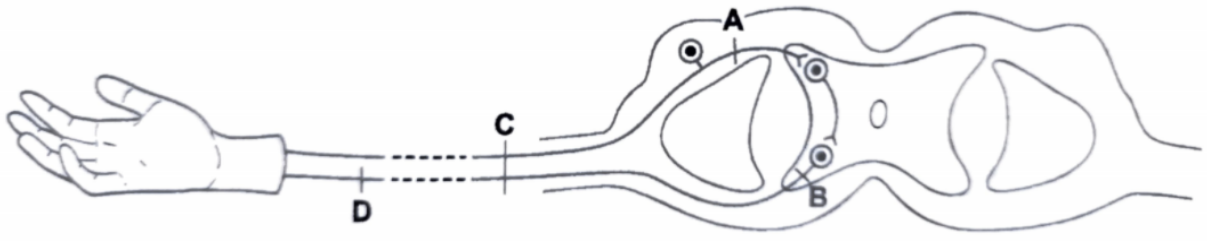
Typical questions

Multiple choice questions

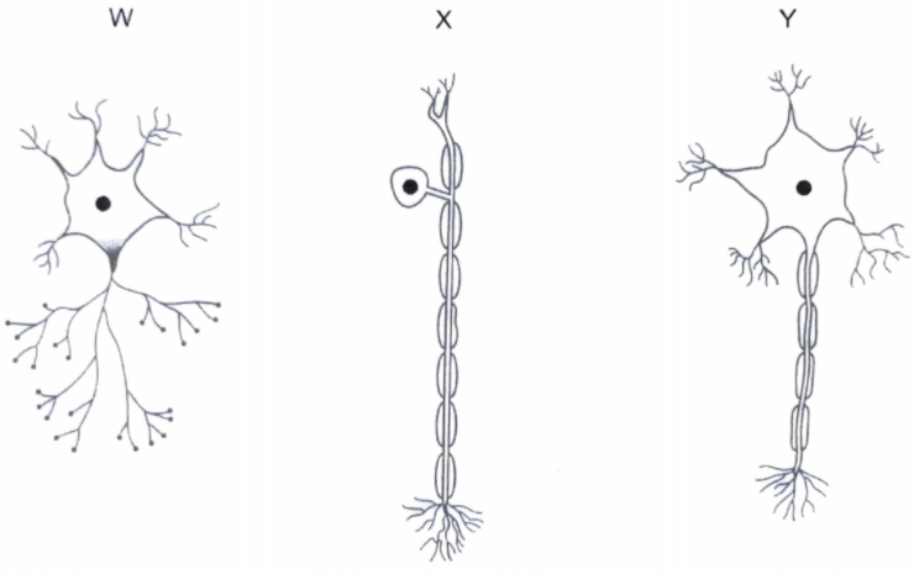
1. When a person steps on a drawing pin, the leg muscles contract to pull the foot away and pain is felt.
   Which part of the nervous system coordinates leg movement and which part perceives pain?
   (N2012/P1/Q24 / N2016/P1/Q24)

	coordinator of leg movement	perception of pain
A	brain	sensory neurone
B	motor neurone	leg muscles
C	sensory neurone	spinal cord
D	spinal cord	brain

2. The diagram shows a section through the spinal cord and the neurones involved in a reflex action of a hand.
   A student has been injured in an accident. When a sharp point is stuck into one of his fingers, no reflex occurs. However, he can move his fingers when asked to do so.
   Where has his nervous system been damaged? (N2015/P1/Q26)



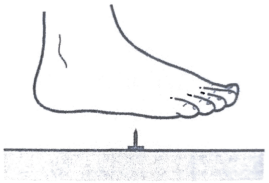
3. The diagrams show three types of neurones.



Which sequence shows the direction in which impulses travel during a reflex action?
(N2017/P1/Q24)

A W → X → Y
B W → Y → X
C X → W → Y
D Y → W → X

4. A person steps on a pin then rapidly lifts up the foot.



What is the order in which the impulse passes to these structures? (N2019/P1/Q24)

A relay neurone → leg muscles → sensory neurone → motor neurone
B motor neurone → sensory neurone → leg muscles → relay neurone
C sensory neurone → motor neurone → relay neurone → leg muscles
D sensory neurone → relay neurone → motor neurone → leg muscles

5. Which of the following comparisons between the nervous system and the endocrine system is NOT correct?

	nervous system	endocrine system
A	impulses transmitted along nerves	hormones transmitted by blood
B	impulses only electrical in nature	hormones only chemical in nature
C	faster in response	slower in response
D	shorter duration of response	longer duration of response

Structured questions

1 Describe two ways in which the pathway of a reflex action is different from that of a voluntary action. [2]

- Stimuli is necessary in a reflex action, whereas a voluntary action may be initiated in the absence of stimuli.
- In a reflex action, the brain is only stimulated after nerve impulses have been transmitted to the effector and the response has been initiated. On the other hand, in a voluntary action, the brain interprets nerve impulses and decides on a response.

2 By what means does a motor neurone receive nerve impulses? [3]

When the receptor receives a stimulus, it is stimulated and generates nerve impulses. Nerve impulses are transmitted along sensory neurones to the central nervous system. Nerve impulses are transmitted across two synapses through the diffusion of neurotransmitters from sensory neurones to relay neurone, then from relay neurone to motor neurone. Thus, the motor neurone receives nerve impulses.

3 Multiple sclerosis (MS) is a medical condition in which there is a loss of the myelin sheath from (demyelination of) the patient's neurones in the brain and spinal cord.

(a) Describe the function of the myelin sheath. [1]

Myelin sheath is a layer of lipids which wraps around the axon and insulates the axon for faster nerve impulse transmission.

(b) Suggest **two** symptoms of a person with MS. [2]

- Visual disturbance
- Difficulty in moving / coordination and balance
- Thinking and memory problems
- Muscle weakness

4 Spinal cord injuries can be quite devastating, possibly leading to a total loss of sensory feelings and even paralysis.

(a) If the pathway for nerve impulse transmission along the spinal cord is impeded by an injury, generally, what are the likely consequences? [3]

- The reflex arc is disrupted since nerve impulses cannot be transmitted from sensory neurone to relay neurone in the spinal cord. Thus, he may not be able to enable a quick reaction to protect himself from immediate danger in time.
- Since relay neurones in the spinal cord cannot transmit nerve impulses from the brain to sensory neurone, he may not be able to respond to the sensory impulses received.
- Since sensory neurone cannot transmit nerve impulses from receptor along sensory neurone to relay neurones in spinal cord and up to the brain, he may also not be aware of what sense organs detected.

(b) After a traffic accident, the victim was discovered to have lost his ability to move some fingers of his left hand. Would the area where doctors found his injury, be a dorsal or ventral root? Why? [2]

His ventral root is injured.
During voluntary movements, nerve impulses initiated by the brain are transmitted along relay neurones down the spinal cord. The ventral root contains motor neurones only, whereas the dorsal root contains sensory neurones only. When the ventral root is injured, motor neurones receiving nerve impulses transmitted from relay neurones across a synapse cannot transmit nerve impulses to the effector, i.e. muscles in fingers, thus he cannot move some of his fingers.

5 When the finger touches the hot pan, a reflex action will occur. The reflex arc happens between receptors in a finger and muscles in the arm.

(a) State the importance of a reflex arc to the reflex action. [1]

The reflex arc is the shortest pathway from the receptor to the effector in a reflex action. This allows one to make a faster response to protect the body from serious harm or danger quickly.

(b) In the reflex action above, the hand was first moved away from the hot pan before pain was felt at the finger. Explain this observation. [3]

The distance between relay neurone in the spinal cord and the brain is longer than that between the relay neurone in the spinal cord and motor neurone. Thus, nerve impulses reach the effector, i.e. hand muscles earlier than it reaches the brain.

6 (N2012/P2/B10 EITHER)

(a) Describe the similarities and differences between a voluntary action and a reflex action. [4]

SIMILARITIES:

Both a voluntary action and a reflex action send messages in the form of nerve impulses through the neurones.

DIFFERENCES:

A voluntary action is consciously controlled by the brain while a reflex action is an instant response to a specific stimulus without conscious control. A voluntary action may not require a sensory neurone while a reflex action requires a sensory neurone.

(b) Describe the pathway of nerve impulses in a named reflex action. [6]

The pupil reflex is a cranial reflex action.

The reflex arc for the pupil reflex is retina (receptor) → sensory neurone in the optic nerve → relay neurone in brain → motor neurone → iris (effector).

During this reflex action, the pupil changes in size according to the changes in light intensity. When the light intensity changes from low to high, too much light enters the eye through the pupil and stimulates the photoreceptors in the retina. Nerve impulses are generated and travel along the sensory neurone in the optic nerve to the relay neurone in the brain. Then, the nerve impulses travel along the motor neurone to the muscles of the iris. The circular muscles of the iris contract while the radial muscles of the iris relax to make the pupil smaller. Thus, the eye constricts and less light enters the eye.

When light intensity changes from high to low, too little light enters the eye through the pupil and stimulates the photoreceptors in the retina. Nerve impulses are generated and travel along the sensory neurone in the optic nerve to the relay neurone in the brain. Then, the nerve impulses travel along the motor neurone to the muscles of the iris. The circular muscles of the iris relax while the radial muscles of the iris contract to make the pupil larger. Thus, the eye dilates and more light enters the eye.

OR

15

A named reflex action is the withdrawal of the hand upon contact with a hot pot.

- High temperature of the pot stimulates thermoreceptors in the skin. Nerve impulses are generated by the thermoreceptors.
- Nerve impulses transmitted to the spinal cord via the sensory neurone.
- In the spinal cord, nerve impulses are transmitted first across a synapse to the relay neurone, and then across another synapse to the motor neurone (must mention two synapses or have neurotransmitters moving from sensory neurone to relay neurone).
- Motor neurone transmits nerve impulses from spinal cord to effector (bicep muscle).
- Bicep muscle in the arm contracts to cause the hand to withdraw suddenly.

OR

A named reflex action is the knee-jerk reflex. In this reflex action, the leg kicks upwards when the knee is hit with much force.

- When an external force is applied on the leg below the kneecap, the pressure applied onto it stretches the upper thigh muscle.
- The sudden increase in the stretching at the leg is detected by stretch receptors at the thigh muscles, which are stimulated and generate nerve impulses.
- Nerve impulses are transmitted along sensory neurones to the relay neurones located in the spinal cord.
- In the spinal cord, nerve impulses are transmitted first across a synapse to the relay neurone, and then across another synapse to the motor neurone through the diffusion of neurotransmitters.
- Nerve impulses are then transmitted along motor neurones from the spinal cord to the effector, i.e. the upper thigh muscles in the leg.
- The upper thigh muscles receive nerve impulses and contract, thus kicking the leg upwards.