Bio Factsheet

Number 58

Reflex Action

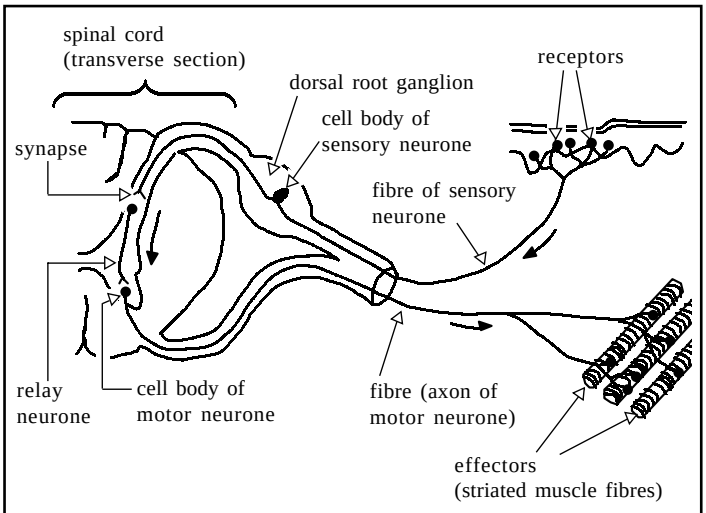
Reflex actions are simple automatic responses operated through the nervous system. They aid the survival of animals by, for example:

- **producing protective reactions such as blinking, sneezing, coughing.**
- **adjusting the activity of internal organs to the physiological needs of the body.**
- **adjusting the tone of skeletal muscles to enable balance and so maintain posture.**
- **causing reciprocal inhibition within antagonistic muscles, thus allowing one muscle to contract while the other one relaxes.**

The structure of a simple reflex arc

A reflex arc is the simplest functional unit of the nervous system, involving the complete pathway of neurones from the **receptor** which receives the stimulus to the **effector** which produces the response. The basic three neurone arc will consist of, in order, a **sensory neurone**, a **relay** or **connector neurone** and a **motor neurone**. The structure of this type of simple spinal reflex arc from the voluntary nervous system is shown in Fig 1.

Fig 1. A simple spinal reflex arc of the voluntary nervous system



NB - In a two neurone reflex arc, the sensory neurone synapses directly with the motor neurone and there is no relay neurone.

Exam Hint - *Exam questions on this topic are likely to test knowledge and understanding of the structure and operation of a three neurone spinal reflex arc, or the importances of reflex actions to the organism. Questions could be of tick box, fill in the missing words, diagram labelling, or of continual prose type.*

Many neurones together make up nerves. The fibres of sensory neurones lie in **sensory nerves** (for example, the optic nerve from the retina to the brain), the fibres of motor neurones lie in **motor nerves** (for example, the oculomotor nerve from the brain to the iris and ciliary muscles of the eye) and the relay neurones make up the **grey matter** of the spinal cord or brain. A **mixed nerve** (for example, the sciatic nerves from the spinal cord to the legs) contains both sensory and motor neurones.

In the voluntary nervous system the sensory and motor neurones are **myelinated** which enables them to conduct impulses very quickly, thus allowing fast responses.

In the autonomic nervous system the motor neurones are non-myelinated and so conduct impulses slowly. However this allows more gentle, sustained control of bodily functions. The relay neurones are non-myelinated.

Remember *– the effectors for the voluntary nervous system are the striated skeletal voluntary muscle fibres but for the autonomic system are involuntary smooth muscle cells, glands, or in the case of the heart, cardiac muscle fibres.*

The functioning of a simple spinal reflex arc

All reflex arcs must be initiated by a stimulus which is recognised by a receptor. The receptors act as **transducers**, that is, they change one form of energy into another form. Table 1 gives some examples of receptors which change various forms of energy into electrical nerve impulses in sensory neurone.

Table 1. Receptors involved in reflex actions

Receptor	Position	Sensitive to:
Rods	Retina	Dim light of any wavelength
Cones	Retina	Bright light of specific wavelengths
Paccinian corpuscles	Under the skin	Pressure changes
Stretch receptors	Alveolar walls in lungs	Tension changes
Proprio-ceptors	Muscles, tendons, joint capsules	Tension and pressure changes
Thermo-receptors	Under skin, hypothalamus	Temperature change
Taste receptors	Tongue, inside of cheeks	Various chemicals
Olfactory (smell)	Nasal mucosa	Various chemicals

The stimulus causes depolarisation of the receptor cell membrane which in turn, via the synapse from the receptor to the sensory neurone, depolarises the sensory neurone setting up nerve impulses. These are transmitted via the dorsal root ganglion (where the cell bodies of the sensory neurones are situated) into the dorsal horn of the grey matter of the spinal cord. This then sets impulses up in the relay neurone, via the synapse from the sensory neurone to the cell body of the relay neurone. This transmits the impulses to the synapse between the relay neurone and the cell body of the motor neurone in the ventral horn of the grey matter of the spinal cord.

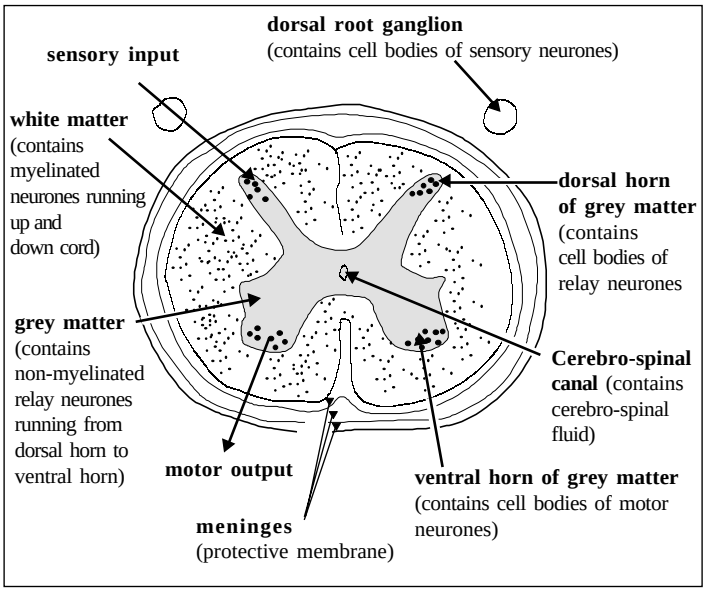
Impulses are then set up in the motor neurone which are then transmitted through the ventral root of the spinal cord to the effector. The motor neurone will induce a response in the effector, (via the neuromuscular junction in the case of a muscle.

Dependent on which reflex action is involved, the higher conscious centres of the brain may or may not be involved. For example, reflex actions that control physiological functions such as gastro-intestinal movements, heart beat changes, blood pressure changes and breathing changes are generally carried out at a subconscious level. Reflex actions such as coughing, sneezing and responses to pain are generally given conscious attention. To enable this to happen the sensory and relay neurones in the reflex arc can synapse with myelinated relay neurones which run up and down the length of the spinal cord, to and from the brain. These myelinated fibres are fast conducting and make up the white matter of the spinal cord. The arrangement of the white and grey matter in the spinal cord is shown in Fig 2.

Remember *- synapses between the grey and white matter neurones occur in both the dorsal and ventral horns of the grey matter enabling impulses to be transmitted between the reflex arc and the brain and vice versa, if necessary.*

Other examples of reflex actions are shown in Table 2.

Fig 2. Transverse section of spinal cord



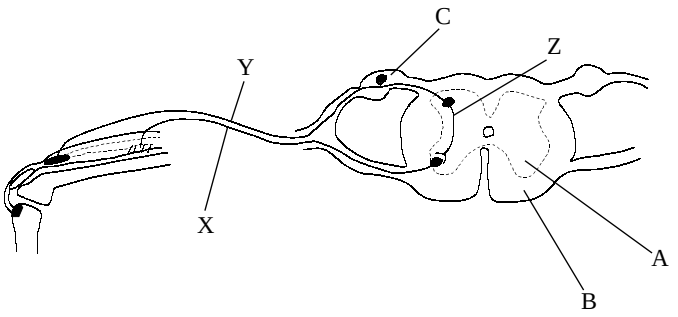
Exam Hint *- A common error made by candidates in examinations is to confuse white and grey matter. Remember- white matter contains myelinated fibres and grey matter contains non-myelinated fibres. (Myelin is white in colour)*

Table 2. Examples of reflex actions in mammals

Reflex action	Stimulus	Receptors	Effects
Salivation	Smell or taste of food	Olfactory and taste	Secretion of saliva into buccal cavity.
Pupil reflex	Light intensity	Rods and cones	Iris muscles adjust pupil diameter, wide in dim light, narrow in bright light.
Accommodation	Lack of clarity of of image on retina	Rods and cones	Ciliary muscles adjust lens curvature, more convex for near vision, less convex for distant vision.
Flexion reflex	Pain	Pain receptors	Limb muscles flex, drawing limb away from pain, (pin, hotplate).
Stretch reflex	Stretching of muscles	Proprioceptors (muscle spindles)	Contraction of muscles to maintain constant tone, thus enabling balance, maintaining posture.
Knee jerk	Tapping patellar tendon	Proprioceptors/ stretch receptors	Lower leg kicks forwards due to sudden contraction of front thigh muscles.
Sweating	Increased body temperature	Thermoreceptors	Increased sweat release to cool body surface down.
Vaso-constriction	Decreased body temperature	Thermoreceptors	Constriction of skin arterioles so less heat loss from blood via skin.
Vasodilation	Increased body temperature	Thermoreceptors	Dilation of skin arterioles so more heat loss from blood via skin.
Shivering	Decreased body temperature	Thermoreceptors	Skeletal muscles have continual spasms to generate metabolic heat.
Coughing and sneezing	Irritant material on mucosa of airways	Chemoreceptors	Sudden contraction of diaphragm and internal intercostal muscles causing a violent expiration to blow irritant material out.
Increased cardiac activity	Lowered blood pressure, raised blood hydrogen carbonate level	Baroreceptors (for blood pressure) Chemoreceptors	Increased frequency and force of cardiac muscle contractions, so blood pressure raised and more blood carried to lungs for CO_2 removal.
Increased ventilation	Raised blood hydrogen carbonate level	Chemoreceptors	Increased frequency and depth of breathing to remove extra CO_2.

Practice questions

1. The diagram below shows the spinal cord of a mammal in transverse section and the neurones involved in a knee jerk reflex action.

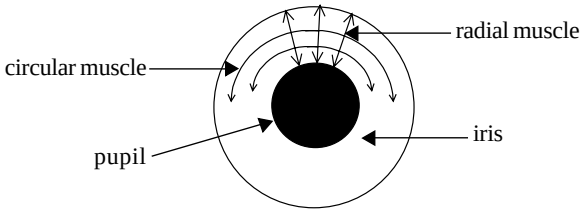


(a) (i) Name the parts labelled A, B and C. (3 marks)
(ii) Distinguish between parts A and B. (2 marks)

(b) (i) Name neurones X, Y and Z and state their functions in this reflex arc. (6 marks)
(ii) What stimulus would cause a knee jerk reflex to operate? (1 mark)

(c) The knee jerk reflex is a spinal reflex but some reflexes are cranial since they operate through the brain stem. Suggest <u>three</u> examples of cranial reflexes. (3 marks)

2. The diagram of the pupil and iris shows the directions in which the muscles of the iris run.



(a) (i) What is the main function of the iris? (1 mark)
(ii) What type of muscle is found in the iris? (1 mark)
(iii) What type of nervous control regulates the iris muscles? (1 mark)

(b) Describe how the size of the pupil would be adjusted when moving from dim light to bright light. (6 mark)

3. The table below refers to features of three reflex actions. If a feature is correct put a tick in the appropriate box and if it is incorrect, a cross.

Feature	Salivation	Blinking	Elbow jerk
Spinal reflex			
Cranial reflex			
Autonomic			

(3 marks)

Answers

1. (a) (i) A = grey matter;
B = white matter;
C = dorsal root ganglion;

(ii) A contains non-myelinated fibres <u>and</u> B contains myelinated fibres;
A contains relay fibres running across the cord <u>and</u> **B** contains relay fibres running up and down the cord;

(b) (i) X = motor neurone;
Y = sensory neurone;
Z = relay neurone;

Y transfers impulses from the receptor to the dorsal horn of the grey matter (or equivalent);
Z transfers impulses from the sensory neurone to the motor neurone/dorsal horn of grey matter to ventral horn;
X transfers impulses from the relay neurone/ventral horn to the effector;

(ii) tension/tapping on the patellar tendon;

(c) Any three of: blinking/pupil reflex/focussing/salivation/tear release/ any correct example;;;

2. (a) (i) To regulate the intensity of light reaching the retina (thus protecting the retina from damage);

(ii) smooth/involuntary;

(iii) reflex action;

(b) bright light causes cones/rods to be depolarised;
this sets up impulses in optic nerve to brain;
impulses sent in motor/oculomotor nerves to iris muscles;
circular muscles contract and radial muscles relax;
thus pupil size reduced;
this is an autonomic reflex;

3.

Feature	Salivation	Blinking	Elbow jerk
Spinal reflex	✗	✗	✓ ;
Cranial reflex	✓	✓	✗ ;
Autonomic	✓	✓	✗ ;

Acknowledgements;
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