The human nervous system is made up of two parts:

- **Central nervous system (CNS)** - brain and spinal cord: role of coordination
- **Peripheral nervous system** - nerves: connect all parts of the body to the CNS.

Together, they coordinate and regulate body functions.

Sense organs are linked to the peripheral nervous system. They are groups of receptor cells responding to specific stimuli: light, sound, touch, temperature and chemicals. When exposed to a stimulus they generate an electrical impulse which passes along peripheral nerves to the CNS, triggering a response.
Peripheral nerves contain sensory and motor neurones (nerve cells).

<table>
<thead>
<tr>
<th></th>
<th>Motor neurone</th>
<th>Sensory neurone</th>
</tr>
</thead>
<tbody>
<tr>
<td>transmits nerve impulses</td>
<td>sense organs to CNS</td>
<td>CNS to effectors (muscles or glands)</td>
</tr>
</tbody>
</table>

Motor and sensory neurones are covered with a myelin sheath, which insulates the neurone to make transmission of the impulse more efficient.

The cytoplasm (mainly axon and dendron) is elongated to transmit the impulse for long distances.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Sensory neurone</th>
<th>Motor neurone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell body</td>
<td>Near end of neurone, in a ganglion (swelling) just outside the spinal cord</td>
<td>At start of neurone, inside the grey matter of the spinal cord</td>
</tr>
<tr>
<td>Dendrites</td>
<td>Present at end of neurone</td>
<td>Attached to cell body</td>
</tr>
<tr>
<td>Axon</td>
<td>Very short</td>
<td>Very long</td>
</tr>
<tr>
<td>Dendron</td>
<td>Very long</td>
<td>None</td>
</tr>
</tbody>
</table>

Fun fact: The human nervous system runs on electrical impulses that travel close to the speed of light.

Sample question and answer

**Question**  Figure above shows a type of neurone. Name this type of neurone and state a reason for your choice. [ 2 marks]

**Answer**  Name: motor neurone.  
Reason: It has a cell body, the cell body is at the end of the cell.

Video: The Human Nervous System
Video: The Spinal Cord
Video: Human Body Nervous System
A reflex action is an automatic response to a stimulus.

A reflex arc describes the pathway of an electrical impulse in response to a stimulus.

Relay neurones are found in the spinal cord, connecting sensosy neurones to motor neurones.
On the picture below, the stimulus is a drawing-pin sticking in the finger. The response is the withdrawal of the arm due to contraction of the biceps.

The sequence of events is:

- **Stimulus** (sharp pin in the finger)
- **Receptor** (pain receptor in skin)
- **Coordinator** (spinal cord)
- **Effector** (biceps muscle)
Reflex: automatically and rapidly integrating and coordinating stimuli with responses

Neurones do not connect directly with each other: there is a gap called a synapse. The impulse is 'transmitted' across the synapse by means of a chemical called acetylcholine.

**Try this**

Figure below shows a nerve cell.

![Nerve cell diagram](image_url)

a. i) Name the type of nerve cell shown in the figure [1 mark]

   ii) State two features that distinguish it from other types of nerve cell [2 mark]

   iii) Where, in the nervous system, is this cell located? [1 mark]

b. Nerve cells are specialised cells. Suggest how the following parts of the nerve cell, labelled in the figure, enable the nerve cell to function successfully:
   cytoplasm; myelin sheath. [4 mark]

c. Reflex involve a response to a stimulus.

   i) Copy and completes the flowchart by putting the following terms in the boxes to show the correct sequence in a reflex. [2 marks]
For the pupil reflex, identify each of the parts of the sequence by copying and completing the table below. The first has been done for you. [4 marks]

<table>
<thead>
<tr>
<th>Part of sequence</th>
<th>Part in pupil reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinator</td>
<td>Brain</td>
</tr>
<tr>
<td>Effector</td>
<td></td>
</tr>
<tr>
<td>Receptor</td>
<td></td>
</tr>
<tr>
<td>Response</td>
<td></td>
</tr>
<tr>
<td>Stimulus</td>
<td></td>
</tr>
</tbody>
</table>

**Answer**

a. i) Motor neurone
   ii) Two features from:
       - presence of motor end plates
       - the cell body is at the beginning of the cell
       - the cell body has dendrites on
       - there is no dendron (only on axon).
   iii) Peripheral nervous system.

b. Cytoplasm: two suggestions from:
   - is elongated
   - passes electrical signals along
   - connects different parts of the body
   - is modified to form dendrites.

   Myelin sheath: two suggestions from:
   - acts as insulating material
   - so prevents leakage of electrical signal from axon
   - allows faster transmission of impulses.

c. i) flowchart

![Flowchart](image)

ii)

<table>
<thead>
<tr>
<th>Part of sequence</th>
<th>Part in pupil reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinator</td>
<td>Brain</td>
</tr>
<tr>
<td>Effector</td>
<td>Iris (muscle)</td>
</tr>
<tr>
<td>Receptor</td>
<td>Retina or rods or cones</td>
</tr>
<tr>
<td>Response</td>
<td>Pupil changes diameter or iris muscles contract</td>
</tr>
<tr>
<td>Stimulus</td>
<td>Bright light or change in light intensity</td>
</tr>
</tbody>
</table>

**Video: Reflex Arc** https://www.youtube.com/watch?v=Y5nj3ZfeYDQ
Effectors are muscles or glands which respond when they receive impulses from motor neurones. Examples of effectors are the biceps and triceps muscles in the arm.

Structure of the human arm
When stimulated, muscles contract get shorter. The biceps and triceps are antagonistic muscles - they have opposite effects when they contract.

The biceps is attached to the scapula (shoulder blade) and the radius. Contraction of the biceps pulls on the radius, moving the lower arm toward the scapula. This results in the arm bending (flexing) at the below - the arm is raised.

The triceps is attached to the scapula, humerus and ulna. Contractions of the triceps pulls on the ulna, straightening (extending) the arm. In doing so, the triceps pulls the biceps back to its original lengths.

**Try this**

Figure below is a simplified diagram of the muscles and bones of the human leg.

![Diagram of muscles and bones](image)

a) Complete the following sentences.

Muscles are formed from cells which have special property of being able to _____. Because of this, muscles can not push, they can only _____. [2 marks]

b) Muscles operate as antagonistic pairs. With reference to figure above, explain what is mean by this statement. [2 marks]
c) i) Which muscles A, B, C or D, must contraction in order to raise the heel to stand on tiptoe? [1 mark]

   ii) Which muscles A, B, C or D, must contract to bend the leg at the knee? [1 mark]

d) When running very quickly, the muscles of the leg may not receive sufficient oxygen to supply all their energy requirements.

   i) Name the type of respiration these muscle cells carry out to release additional energy. [1 mark]

   ii) Name the waste product produced by this process. [1 mark]

**Answer**

a) Contract; pull

b) Muscles A and B; and C and D are antagonistic pairs. They have opposite effects when they contract.

c) i) C
   
   ii) B

d) i) Anaerobic respiration.
   
   ii) Lactic acid (or lactate).
#89 Structure and function of the eye, rods and cones

You need to be able to label parts of the eye on diagrams.

- The eyebrow stops sweat running down into the eye.
- Eyelashes help to stop dust blowing on to the eye.
- Eyelids can close automatically (blinking is a reflex) to prevent dust and other particles getting on to the surface of the cornea.
- Blinking also helps to keep the surface moist by moving liquid secretions (tears) over the exposed surface. Tears also contain enzymes that have an antibacterial function.

* Try this

Trace or copy both diagrams of the eyes. Practice adding the labels. [8 marks]
Distinguishing between rods and cones

Rods and cones are light-sensitive cells in the retina. When stimulated they generate electrical impulses, which pass to the brain along the optic nerve.

The normal retina has rods that see only black, white, and shades of grey and tones and three forms of color cones, red, green, and blue.

<table>
<thead>
<tr>
<th>Function</th>
<th>Distribution</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rods</td>
<td>Sensitive to low light intensity. Detect shades of grey</td>
<td>Found throughout the retina, but none in the centre of the fovea or in the blind spot</td>
</tr>
<tr>
<td>Cones</td>
<td>Sensitive only to high light intensity. Detect colour (don’t operate in poor light)</td>
<td>Concentrated in the fovea</td>
</tr>
</tbody>
</table>
Photos of rods and cones.
The amount of focusing needed by the lens depends on the distance of the object being viewed – light from near objects requires a more convex lens than light from a distant objects.

The shape of the lens needed to accommodate the image is controlled by the ciliary body - this contains a ring of muscle around the lens.

**Distance objects**

The ciliary muscles relax, giving them a larger diameter. This pulls on the suspensory ligaments which, in turn, pull on the lens. This makes the lens thinner (less convex). As the ciliary muscles are relaxed, there is no strain on the eye.

**Near objects**

The ciliary muscles contract, giving them a smaller diameter. This removes the tension on the suspensory ligaments which, in turn, stop pulling on the lens. The lens becomes thicker (more convex). As the ciliary muscles are contracted, there is strain on the eye, which can cause a headache if a near object (book, microscope, computer screen etc.) is viewed for too long.
**Pupil reflex**

The reflex changes the size of the pupil to control the amount of light entering the eye. In bright light, pupil size is reduced as too much light falling on the retina could damage it. In dim light, pupil size is increased to allow as much light as possible to enter the eye.

The retina detects the brightness of light entering the eye. An impulse passes to the brain along sensory neurones and travels back to the muscles of the iris along motor neurones, triggering a response - the change in size of the pupil due to contraction of radial or circular muscles.
Video: BBC Eye pupil reflex

**Common misconceptions**

Students often confuse circular muscles and ciliary muscles. Remember that **circular** muscles affect the size of the **iris**, **ciliary** muscles affect the shape of the **lens**.

**Try this**

Describe and explain how the eye changes its focus from a distant object to a near object.

**Answer**

- ciliary muscle contract
- the suspensory ligaments become relaxed
- so tension is removed from the lens
- the lens becomes more convex
- so light is focused more strongly.

Video: Human eye structure, accommodation
**Hormone** is a chemical substance, secreted by endocrine gland, carried by the blood, which alters the activity of one or more specific target organs and is then destroyed by the liver.

1. **Chemical control of metabolic activity by adrenaline**

**Adrenaline** is a hormone secreted by adrenal glands. When you are frightened, excited, your brain sends impulses along a nerve to your adrenal glands. This makes them secrete adrenaline into the blood.
Adrenaline helps you to cope with danger:

1. **↑ heart rate** → supply $O_2$ to brain and muscle more **quickly** →↑ energy for action (fighting, running...).

   Contract blood vessels in skin and digestive system → they carry very little blood → supplies blood back to vital organs (brain and muscles).

2. Stimulate **liver** to convert glycogen to glucose, **↑ glucose** release into the blood by liver → extra glucose for muscle → help muscle to contract.

**Examples of situations in which adrenaline secretion increases**

Adrenaline is needed and secreted in a “fright, fight or flight” situation.

*E.g.: When you are facing danger, for example, a masked man with a gun is approaching you.*

- Your brain sends a signal to the adrenal glands, to start secreting and pumping adrenaline into the bloodstream.

- the actions of the adrenaline is listed above

- this gets you ready to either stand and fight or run away from the man.

### Comparison of nervous and hormonal control systems

<table>
<thead>
<tr>
<th>Feature</th>
<th>Nervous</th>
<th>Hormonal (endocrine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made up of</td>
<td>Neurones</td>
<td>Secretory cells</td>
</tr>
<tr>
<td>Form of transmission</td>
<td>Electrical impulses</td>
<td>Chemical (hormones)</td>
</tr>
<tr>
<td>Transmission pathway</td>
<td>Nerves fibres (axons and dendrons)</td>
<td>Blood plasma</td>
</tr>
<tr>
<td>Speed of transmission</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Duration of effect</td>
<td>Short term</td>
<td>Long term</td>
</tr>
<tr>
<td>Response</td>
<td>Localised</td>
<td>Widespread (although there may be a specific target organ)</td>
</tr>
</tbody>
</table>
Farmer sometimes use hormones to make their animals grow faster, or to produce more of a particular product. One hormone used in this way is called bovine somatotropin, or BST.

BST is a hormone which is naturally produced by cattle. However, if cows are given extra BS, they make more milk. Some people think it would be a good idea to give cow BST, to get higher milk yields. You would need fewer cows to get the same amount of milk.

Here are arguments against it.

- Some people are worried about drinking milk form cows treated with BST. They think BST might damage their health. This is very unlikely, because the hormone does not get into the milk in any significant quantity.

- It is difficult to see why we need BST. For example, the European Union already produces more milk than it needs, so milk quotas have to be imposed, to stop farmer from producing too much milk.

- There are concerns that the BST might harm the cows. Cows treated with BST make very large amounts of milk, far beyond the ‘natural’ levels which they produce. This make them more likely to get infections of their udders (breast), and may make them feel less comfortable.

Mammary infections in BST treated cows require treatment with antibiotics.

Read more on this topic:
Recombinant bovine somatotropin
#93 Voluntary and involuntary actions

Knee jerk is an involuntary reflex

Two types of action controlled by the human nervous system are: voluntary and involuntary actions. The peripheral nerves transmit both of them.

## Comparison of voluntary and involuntary actions

<table>
<thead>
<tr>
<th>Feature</th>
<th>Voluntary action</th>
<th>Involuntary action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nature</strong></td>
<td>- Conscious thought (make decision about making action).</td>
<td>- Does not involve thought</td>
</tr>
<tr>
<td></td>
<td>- Free will</td>
<td>- Not under the control of the will</td>
</tr>
<tr>
<td></td>
<td>- Consciously control skeletal muscles</td>
<td>- Cannot control the activities.</td>
</tr>
<tr>
<td><strong>Examples</strong></td>
<td>If we want to ask question, we raise our hands</td>
<td>Involving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- skeletal muscle (e.g. knee jerk)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- smooth muscles (e.g. peristalsis)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- cardiac muscles (e.g. pumping of the heart)</td>
</tr>
<tr>
<td><strong>Role</strong></td>
<td>Respond with the benefit of experience</td>
<td>Respond quickly to avoid danger</td>
</tr>
<tr>
<td><strong>Controlled by</strong></td>
<td>Forebrain (Cerebrum): - coordinates incoming information, initiates impulses sent to the effectors.</td>
<td>- Hind-brain (cranial reflex action)</td>
</tr>
<tr>
<td></td>
<td>- may spontaneously initiates actions without any sensory stimulation.</td>
<td>- Spinal cord (spinal reflex action), e.g. blinking of the eyes</td>
</tr>
<tr>
<td>Speed of action</td>
<td>Slow response, as the cerebrum needs time to “think” before an action is carried out.</td>
<td>Rapid response, as the cerebrum is not involved.</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Response to the same stimulus</td>
<td>The same stimulus may produce various responses. E.g. when you are hungry, you may decide to eat or not to eat, or just need to drink water.</td>
<td>The same stimulus always results in the same response (stereotyped response), e.g. the knee jerk reflex.</td>
</tr>
</tbody>
</table>

*Forebrain is responsible for voluntary actions, hindbrain is responsible for involuntary actions*

Source: [Voluntary and Involuntary Actions](#)
Coordination in plants – tropism

Tropism are responses by part of a plant toward or away from a stimulus coming from one direction.

The movement is always a growth movement.

Like animals, plants are able to respond to their environment, although usually with much slower responses than those of animals.

Tropic responses can be:

Positive – if growth is towards the stimulus

Negative – if growth is away from the stimulus

In general, plants respond to stimuli by changing their rate or direction of growth. They may grow either towards or away from a stimulus. These responses are called tropisms.

Two important stimuli for plants are light and gravity.

Phototropism

Geotropism
Shoots normally grow towards light. Roots do not usually respond to light, but a few grow away from it.

Shoots tend to grow away from the pull of gravity, while roots normally grow towards it.

**Plant tropism**

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Light</th>
<th>Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot</td>
<td>(+)</td>
<td>(-)</td>
</tr>
<tr>
<td>Root</td>
<td>(-)</td>
<td>(+)</td>
</tr>
</tbody>
</table>

(+) Grow towards the stimulus  
(-) Grow away from the stimulus

---

**A shoot is:**

- NEGATIVELY GEOTROPIC
- POSITIVELY PHOTOTROPIC

**A root is:**

- POSITIVELY GEOTROPIC
- NEGATIVELY PHOTOTROPIC

Pictures are taken from: **Tropism slideshow**
Auxins are plant growth substances, produced by the shoot and root tips of growing plants.

- Auxins in the shoot → stimulate cell growth, by the absorption of water.
- Auxins in the root → slow down the cell growth.

**Auxin in phototropism**

1. If a shoot is exposed to light from one side

   - More auxins are moving in the shaded side (from the tip of the shoot)
   - On this side, cells are stimulated to absorb more water, plant grows more
   - Shoot bends toward the light.
   - This is called positive phototropism.
2. If a root is exposed to light in the absence of gravity

- More auxins are moving in the shaded side (from the tip of the root) →
- On this side, cells are stimulated to absorb less water, plant grows less
- Root bends away from the light.
- This is called negative phototropism.

When exposed to light from one side

<table>
<thead>
<tr>
<th>Features</th>
<th>Shoot</th>
<th>Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>More auxins are moving in the shaded side</td>
<td>(+)</td>
<td>(+)</td>
</tr>
<tr>
<td>Cell are stimulated to absorb (on the shaded side)</td>
<td>more water</td>
<td>less water</td>
</tr>
<tr>
<td>Stem bends</td>
<td>toward the light</td>
<td>away from the light</td>
</tr>
<tr>
<td>Process</td>
<td>Positive phototropism</td>
<td>Negative phototropism</td>
</tr>
</tbody>
</table>

Auxin in geotropism

1. If a shoot is placed horizontally in the absence of light:

- Auxins accumulate on the lower side of the shoot, due to gravity.
- Cells on the lower side grow more quickly
- The shoot bends upwards.
- This is called negative geotropism.

2. If a root is placed horizontally in the absence of light:

- Auxins accumulate on the lower side of the shoot, due to gravity.
- Cells on the lower side grow more slowly
- The shoot bends downwards.
- This is called positive geotropism.

When is placed horizontally in the absence of light

<table>
<thead>
<tr>
<th>Features</th>
<th>Shoot</th>
<th>Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>More auxins are moving in the lower side</td>
<td>(+)</td>
<td>(+)</td>
</tr>
<tr>
<td>Cell growth (on the lower side)</td>
<td>more quickly</td>
<td>more slowly</td>
</tr>
<tr>
<td>Bending</td>
<td>upwards</td>
<td>downwards</td>
</tr>
<tr>
<td>Process</td>
<td>Negative geotropism</td>
<td>Positive phototropism</td>
</tr>
</tbody>
</table>
Darwin did the first experiments to study the effects of Auxin

- Shoots and roots that have their tips removed will not respond to light or gravity because the part that produces auxins has been cut off.

- Shoots that have their tips covered with opaque material grow straight upwards when exposed to one-sided light, because the auxin distribution is not influenced by the light.

**Effects of weedkillers**

Weedkillers (herbicide) are synthetic plant hormones, similar to auxins. If these chemicals are sprayed on to plants they can cause rapid, uncontrolled growth and respiration, resulting in the death of the plant.
Some plant species are more sensitive than others to synthetic plant hormones, so weedkillers can be selective.

Many weedkillers kill only broad-leaved plants (dicotyledons), leaving grasses (monocotyledons) unharmed.

**Try this**

In figure above, the left-hand side shows an experiment in which the coleoptiles (shoots) of similar seedlings have been treated in different ways, and the right-hand side shows the result in shoot D 24 hours later.

a) i) Name the response shown by shoot D. [2 marks]
   ii) Explain what has caused this response. [3 marks]

b) Copy and complete the right-hand side figure to show the likely results for shoots A, B and C. [3 marks]

**Answer**

a) i) Positive phototropism
   ii) Three points from:
   - the coleoptiles have been exposed to one-sided light
   - auxins have been produced by the tip
   - and have passed into the block
   - auxins have passed from the block to the cut coleoptile
   - more auxins accumulates on the shaded side of the coleoptile
   - causing more growth on the shaded side.

b) A, taller and growing vertically upwards;
   B, taller and bending towards the light;
   C, taller and growing vertically upwards.
#96 Summary of coordination and response

- All organisms are able to sense changes in their environment, called **stimuli**, and respond to them. The part of the body that senses the stimulus is a **receptor**, and the part that responds is an **effector**.

- The **human nervous system** contains specialized cells called neurons. The brain and spinal cord make up the central nervous system (CNS), which coordinates responses to stimuli.

- **Reflex actions** are fast, automatic responses to a stimulus. They involve a series of neurons making up a reflex arc. A sensory neurone takes the impulse to the CNS and a motor neurone takes it from the CNS to an effector.

- Receptors are generally found within **sense organs**.

- The receptors in the eye are **rod** and **cone cells**, found in the retina. Rods respond to dim light and cones to bright light. Cones give colour vision.

- The cornea and lens focus light rays onto the **fovea**, the part of the eye where cone cells are most densely packed.

- The shape of the lens is changed by the contraction or relaxation of the **ciliary muscle**. When focusing on a distance subject, the muscle relaxes so that the suspensory ligament are pulled taut and the lens is pulled into a thin shape. When focusing on a near object, the muscle contracts and the lens falls into its natural, more rounded shape.

- Muscles can pull when they contracts, but they cannot push. A pair of muscles is therefore needed to pull in different directions, e.g. at the elbow joint. They are **antagonistic muscles**.

- **Hormones** are chemicals made in endocrine glands and carried in the blood plasma. **Adrenaline** is secreted by the adrenal glands, and bring about changes that supply the muscles with extra glucose. This gives the energy for contraction for ‘fight or flight’.

- Plant response to some stimuli by growing towards or away from them. These responses are **tropism**.

- **Auxins** are mostly made in the tips of the shoots and roots, and can diffuse to other parts of the shoots or roots. It collects in the shady side of the shoot, making the side grow faster so the shoot bends towards the light. Auxins are used as selective weedkillers.