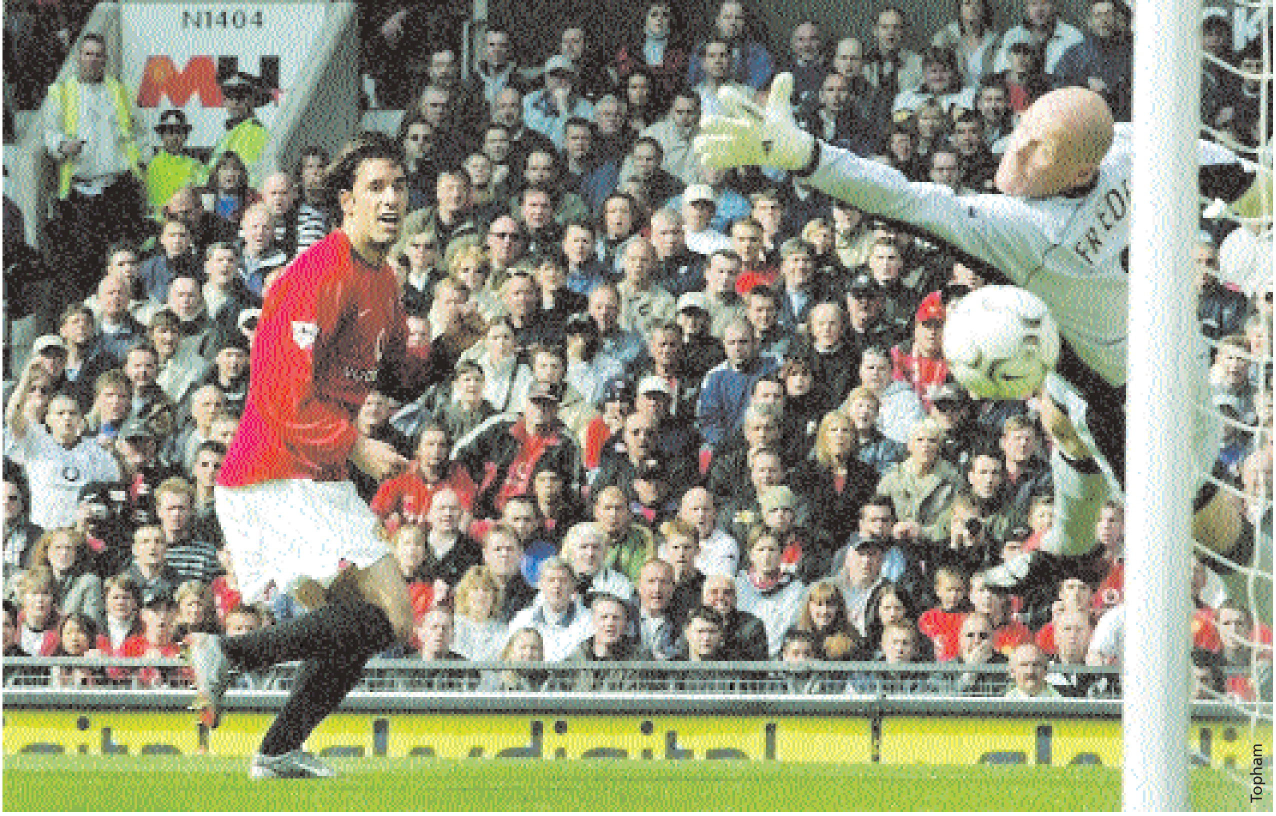
Topham

Left: **The striker's (Ruud van Nistelrooy) reactions were quicker than the goal-keeper's (Brad Friedel) in this Premiership goal**

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GCSE key words
- Neurone
- Reflex
- Synapse

Quick reactions

You take pride in your quick reactions in sports or when you are playing computer games, but how do these speedy responses happen? This article explains how the nervous system works, how nerve impulses pass around your body, and why these responses are so fast.

We are constantly monitoring the world around us. Our ancestors, like animals in the wild today, led a precarious existence, constantly on the look out for predators. The dangers in our lives may have changed, but we still depend on quick reactions.

Sensitivity — the ability to respond to stimulation — is a product of nervous system activity. The nervous system is a network of specialised nerve cells, or **neurones**, which coordinates responses to changes in our environment. Nerves are bundles of neurones that extend through the body. They are connected to the central nervous system, or CNS, which comprises the brain and spinal cord. Information about our environment passes from the sense organs to the CNS. Often, but not always, the brain coordinates and initiates any response.

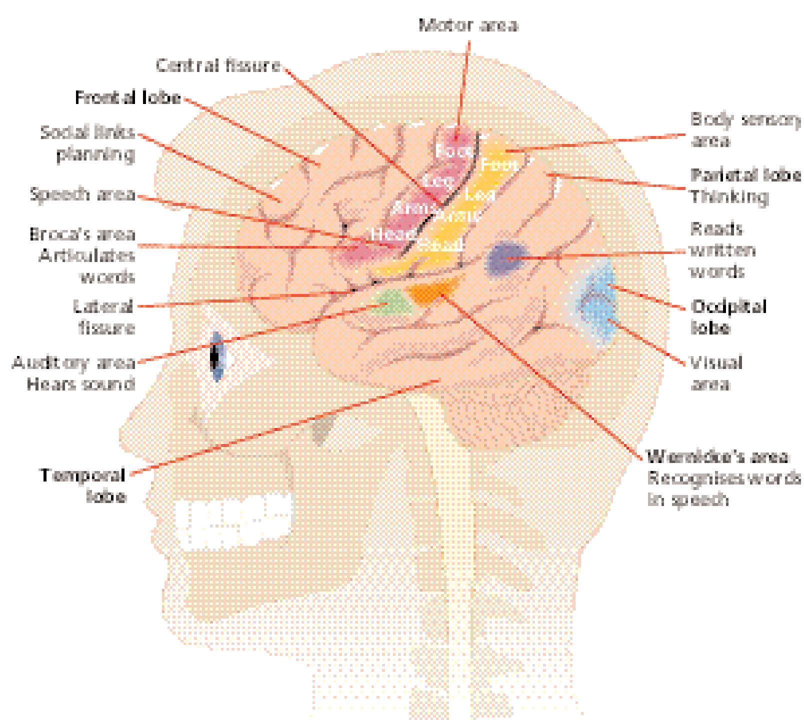

Figure 1 The cerebral cortex — the largest part of the brain — regulates thinking and feeling. This diagram shows where different functions are located

WHAT DO WE MONITOR?

We have **receptors** all over our bodies. These are sensory neurones that are specialised to respond to one particular stimulus by generating a nervous impulse which passes along the neurone.

We detect light intensity and, like other organisms that make use of fruits and flowers, we also detect colour using specialised rod and cone cells in the

A human brain contains about 10^{10} interconnecting neurones and about 10^{11} glial cells.

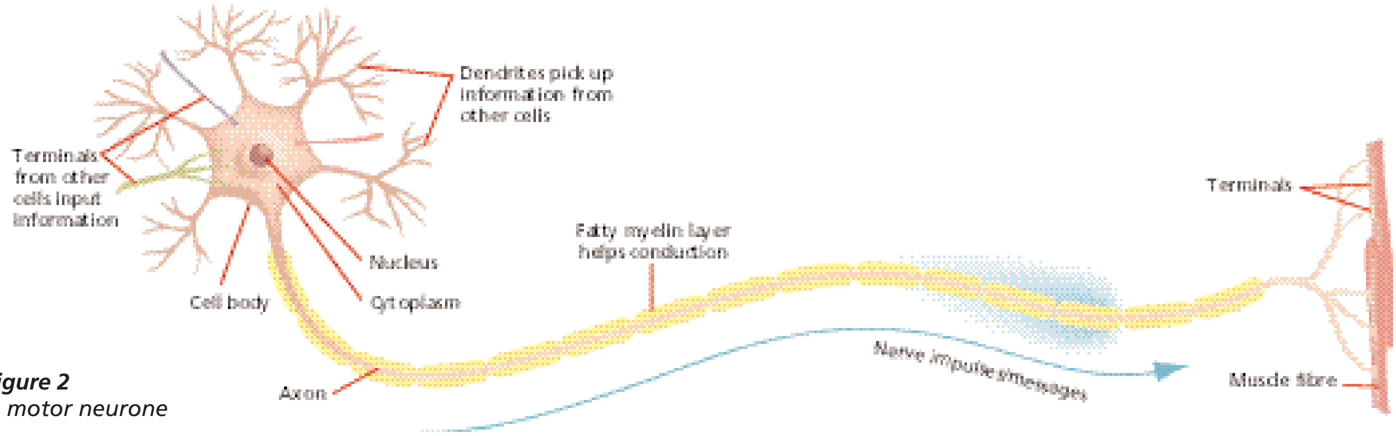

Figure 2
A motor neurone

If the myelin layer around a neurone is damaged, as in multiple sclerosis, the impulse does not pass reliably.

An impulse is not like an electrical current. It involves sodium and potassium ions changing places through the axon membrane.

retina. We detect gravity and sounds using specialised nerve endings in the inner ear. Separate areas of the brain interpret sounds as voices, noises and musical rhythms.

In the skin we have receptors that detect pressure and touch, pain, hot and cold objects, and warmth in our surroundings. These receptors are sensitive. If we touch two warm objects we can distinguish a temperature difference of a fraction of a degree. Receptors in the nose and on the tongue detect chemicals as smells and tastes. Though our sense of smell is not as sensitive as a dog's we can pick up some pungent odours at concentrations as low as one molecule in every 100 000.

As well as information about the outside world we have a constant stream of inputs about the state of our bodies — how much each muscle is contracted, feelings of hunger and thirst, and sensations of pain. Overlying these we have internally generated plans and intentions.

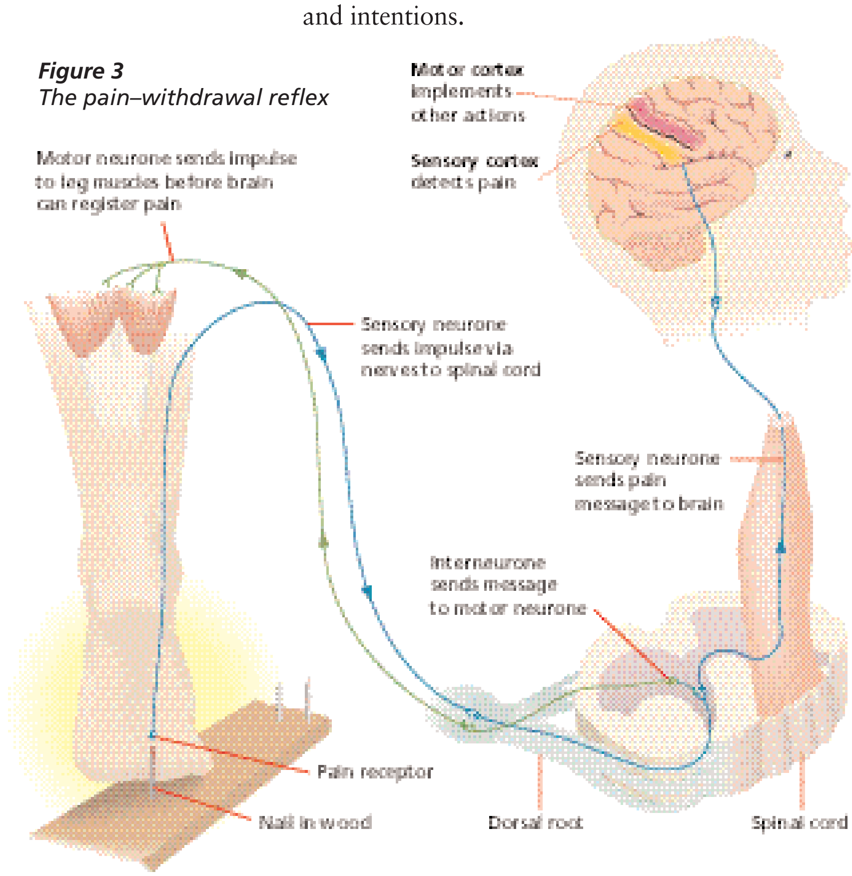

Figure 3
The pain–withdrawal reflex

The brain's function is to receive all these inputs, interpret them and integrate them into a mental image of the state of our body and the world around us. Different areas within the brain process this information and initiate a response (Figure 1).

NEURONES

There are several kinds of neurone. **Sensory neurones** detect stimuli and pass an impulse to the central nervous system. **Motor neurones** extend from the CNS to our muscles. An impulse along these makes a muscle contract. Figure 2 shows the structure of a motor neurone. Many glands are controlled in the same way.

In the brain millions of **interneurones** make connections with each other. These carry out our thinking and planning as well as housing our memory and ability to gossip and ride a bike. The nervous system also has **glial cells** that help to support and maintain the highly specialised neurones.

Information passes along our personal information superhighway in the sequence

stimulus ⟶ receptor ⟶ sensory neurone ⟶ coordination ⟶ motor neurone ⟶ effector ⟶ response

e.g. bright light ⟶ retina ⟶ neurones in optic nerve ⟶ brain ⟶ motor nerve ⟶ circular iris muscle ⟶ contracts and narrows pupil

REFLEXES

Nerve impulses speed along neurones at up to 120 m/s so it takes only a fraction of a second for an

BOX 1 FRANÇOIS MAGENDIE

François Magendie, a nineteenth-century French physiologist, discovered the role of the two roots of the spinal cord, shown in Figure 3. He made important discoveries about strychnine that led to its use in medicine as well as poisoning. Magendie is also known for his efforts to find out about the nutrients we need in our diet.

Prozac is an anti-depressant that inhibits uptake of serotonin, a neuro-transmitter, and keeps it in synapses for longer

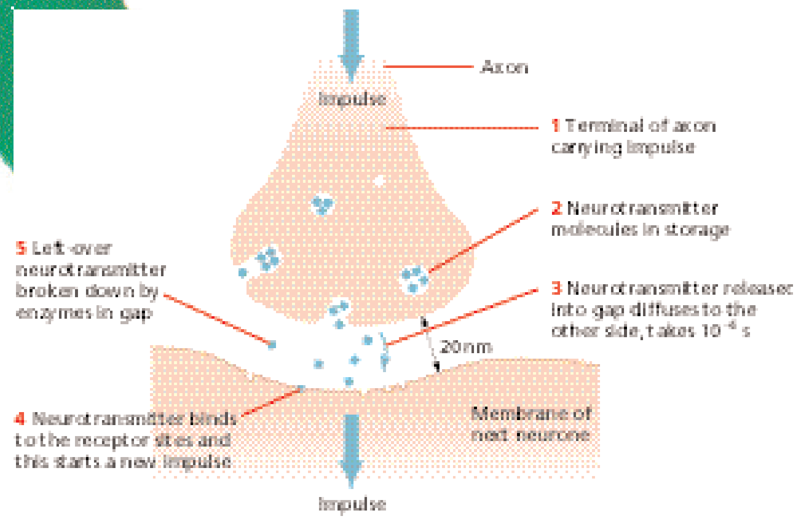

Figure 4 *A synapse. Each neurone makes neurotransmitter molecules. These are stored in small sacs at the end of the neurone. When an impulse reaches the end of the neurone the neurotransmitter molecules are emptied into the synapse. They diffuse across the gap and bind to receptors on the next neurone where they start an impulse. The neurotransmitter molecules are then either broken down or reabsorbed to clear the gap ready for the next impulse. Some painkillers bind to receptors in the postsynaptic membrane and so block the passage of pain impulses*

impulse to complete the circuit through the brain. Even so there are occasions when this is too slow. We have some fast protective **reflexes** that do not involve the thinking part of the brain directly. These are routed through the spine or other parts of the brain. They let us act first and think later.

The pathway in the example above involving the eye is really a reflex. It does not need thought to work. The withdrawal reflex shown in Figure 3 is a protective reaction that operates through the spinal cord. If you encounter a painful stimulus in, say, the skin of a finger, you quickly pull your hand away from the stimulus — and from danger. However, you know you have been hurt because information is also passed up the spinal cord to the brain. The brain coordinates other actions — pulling the shoulders back, bringing your head round towards the stimulus, focusing your eyes on the stimulus and making you yell 'ouch' while you consider the bigger picture of what has caused the pain.

SYNAPSES

At the junction between two neurones there is a small gap called a **synapse**. A chemical called a **neurotransmitter** diffuses across the gap and triggers an impulse in the next neurone. You can see how this works in Figure 4.

Different pathways through the nervous system use different neurotransmitter molecules. The nerves serving the muscles we use to move around and those which slow our heart rate use acetylcholine. The nerves that calm us down after adrenalin has wound us up use noradrenalin. The neurones that smooth out the actions of our arm and leg muscles use dopamine. People with Parkinson's Disease lack dopamine. They cannot control the fine movements of their muscles, which may tremble and make it hard to balance, speak fluently or hold a cup of tea.

The nerve pathways in the brain that are linked to our moods use serotonin as a neurotransmitter. We know that one of the commonest mental disorders, depression, is linked to low levels of serotonin in the brain. Medicines that keep serotonin molecules in synapses for longer help to lift a low mood. Ecstasy makes neurones in the brain release large amounts of this neurotransmitter. This accounts for the warm emotional feelings it creates. However it depletes the stores of serotonin and, because it takes a while for normal stores to build up again, users feel low afterwards. Research is being done to see if the repeated depletion of this important neurotransmitter may have permanent effects — perhaps the prospect of longer-term depression for Ecstasy users.

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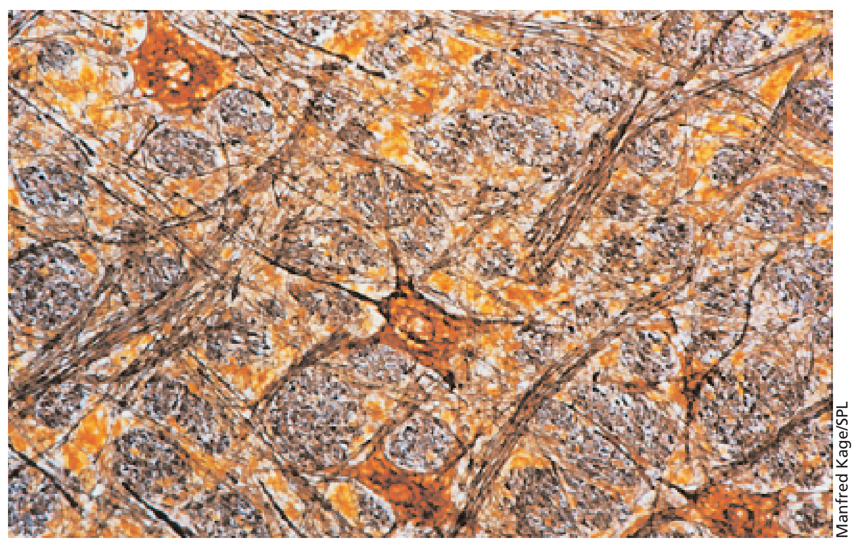

Above: *Neurones in the brain*

You will learn about other effects of drugs such as Ecstasy in PSHE.

In Alzheimer's syndrome the normal mechanism involved in releasing neurotransmitter stays open, flooding the neurone with calcium ions and killing it.