An animal’s response to a stimulus is coordinated by their central nervous system (CNS).

Responding to a stimulus

A **stimulus** is a change in the environment of an organism.

Animals respond to a stimulus in order to keep themselves in favourable conditions.

Examples of this include:

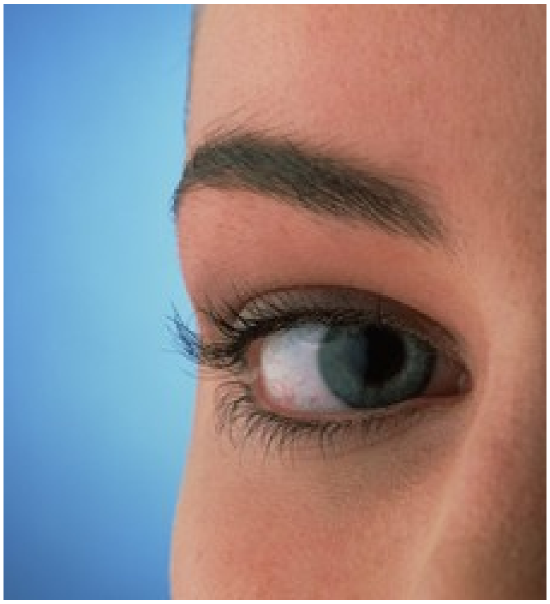
- moving to somewhere warmer if they are too cold
- moving towards food if they are hungry
- moving away from danger to protect themselves

Animals that do not respond to a stimulus do not survive for long.

An animal’s response to a stimulus is coordinated by their **central nervous system** (CNS). The CNS consists of the **brain** and the **spinal cord**. It gathers information about, and responds to, changes in the environment.

Receptors respond to a stimulus and send impulses along sensory neurons to the CNS. The CNS coordinates the information and sends impulses along motor neurons to the **effectors**, which bring about a **response**. The sequence is as follows:

1. Stimulus
2. Receptor
3. Sensory neuron
4. Central nervous system
5. Motor neuron
6. Effector
7. Response



There are light receptors in the eye

Some receptors are found in the skin. Other receptors can form part of complex organs, such as:

- light receptor cells in the retina of the eye
- hormone-secreting cells in hormone glands
- muscle cells
- position receptors in the inner ear
- sound receptors in the ear
- touch, pressure, temperature and pain receptors in skin
- chemical receptors in the nose and tongue

The peripheral nervous system

The **peripheral nervous system** (PNS) consists of **motor and sensory neurons** that carry information from the receptors to the CNS, as well as instructions from the CNS to the effectors.

Neurons carry electrical signals, and are connected by synapses.

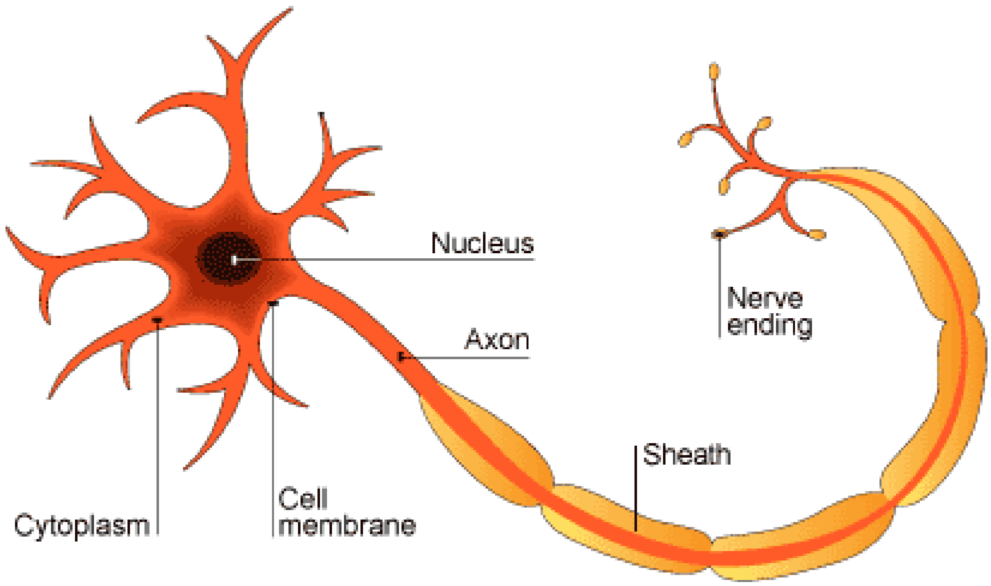
Neurons

Neurons carry signals from one place to another, around the many parts of the nervous system. They connect sense receptors to the central nervous system and also connect one part of the nervous system to another, for example in the brain and spine. They also **carry signals** from the nervous system to effector organs, such as muscles and glands.

When neurons are stimulated they transmit an **electrical impulse**.

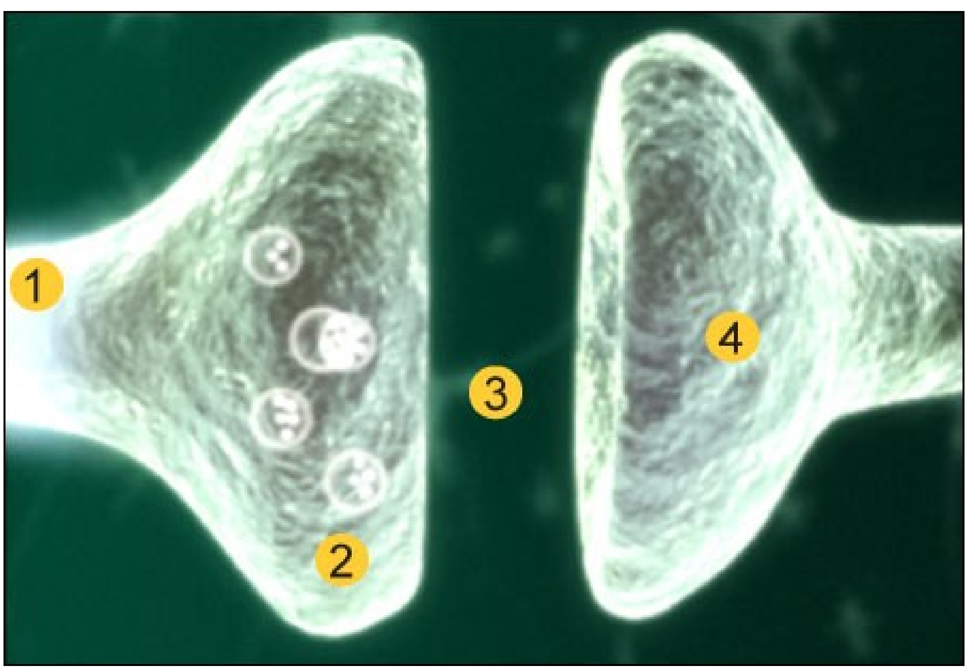
The diagram below shows a motor neuron. It has a nucleus surrounded by cytoplasm. The cytoplasm forms a long fibre that is surrounded by a cell

membrane. This is called an **axon**. The axon carries the electrical impulse and is protected by a fatty sheath - a bit like the plastic coating around an electrical wire. The fatty sheath increases the speed at which the nerve impulse is transmitted. The nerve ending is branched to make good contact with other neurons or the effector organ.



Two neurons do not make direct contact. Where they meet, there is a very small gap called a synapse. The signal needs to cross this gap to continue on its journey to, or from, the CNS. This is done by means of chemicals which **diffuse** across the gap between the two neurons.

How synapses work - Higher



1. An electrical impulse travels along an axon. (1)
2. This triggers the nerve-ending of a neuron to release **chemical messengers** called neurotransmitters. (2)
3. These chemicals **diffuse** across the synapse (the gap) (3) and bind with receptor molecules on the membrane of the next neuron. (4)
4. The receptor molecules on the second neuron bind only to the **specific chemicals** released from the first neuron. This **stimulates** the second neuron to transmit the electrical impulse.

A reflex is an automatic response to a stimulus. Humans use reflex actions in only some of their behaviour, for example controlling the eye's pupil size.

Simple reflexes

Simple reflexes produce rapid **involuntary responses** to a stimulus. This ensures that an animal responds in the way most likely to result in its survival.

Examples include:

- moving towards and finding food
- moving away and sheltering from predators
- moving towards and finding a mate

Simple animals use reflex actions for the **majority** of their behaviour. The disadvantage to using reflex actions most of the time is that these animals have difficulty responding to new situations.

More complex animals such as humans only use reflex actions in some of their behaviour. We can decide how to react to new situations and learn from our experiences.

Reflex arc

Reflex reactions in humans are controlled by the **reflex arc**.

When the safety of an organism demands a very quick response, the signals may be passed directly from a sensory neuron, via a relay neurone, to a motor neurone for instant, unthinking action. This is a **reflex action**.

A **reflex arc** is the nerve pathway which makes such a fast, automatic response possible. It does not matter how brainy you are - you will always pull your hand away from a flame without thinking about it. It is in-built, or **innate**, behaviour, and we all behave in the same way. The animation allows you to go through the stages of the reflex arc one by one:

More reflexes

Another simple reflex found in humans is the **pupil reflex**, where the pupil of the eye gets larger in dim light and smaller in bright light.

The eye needs to control the amount of light entering it in different light conditions. In dim conditions, **more light** is allowed to enter so that a clear image can be formed on the retina. In bright conditions, **less light** is allowed to enter so that the retina is not damaged.

Baby reflexes

Newborn babies also have simple reflexes. These include:

- **the grasping reflex**, where babies grip a finger tightly
- **the breathing reflex**, where babies do not breathe when they go under water

Conditioned reflexes - Higher

A reflex response to a new stimulus can be **learned**.

A Russian scientist called **Pavlov** trained dogs to expect food whenever he rang a bell. The dogs eventually produced saliva when they heard the bell ring.

1. The dog salivates naturally when given food.
2. Pavlov rings a bell every time the dog eats.
3. After much repetition the dog salivates when the bell rings, even when there is no food.

This is an example of a **conditioned reflex**. The dogs were conditioned to salivate when the bell rang.

- The food is called a **primary stimulus**.
- The ringing bell is called a **secondary stimulus**.

A ringing bell does not normally cause salivation in dogs. However, when the ringing bell becomes a secondary stimulus, it does cause salivation, even though the dog will not be able to eat the bell as food.

This is now called a conditioned reflex. In a conditioned reflex the final response (salivation) has no direct connection with the stimulus (ringing bell).

Why are conditioned reflexes useful?

Predators mistake the hoverfly for a wasp due to similar markings

Conditioned reflexes are useful because they **increase** an animal's chances of survival.

For example, birds will not eat caterpillars with bright colouring because they are conditioned to think of bright colours as poisonous. Some caterpillars use this to their advantage. Their bright colours protect them, even though they are not poisonous.

How often have you run away from a harmless hoverfly because it has the same markings as a wasp?

Modifying a reflex response

In some circumstances the brain can **modify** a reflex response. It does this by sending an impulse along a motor neuron of the reflex arc. This enables us, for example, to hold onto a hot dinner plate when normally we would drop it.

When we experience something new, our brain develops a new pathway of neurons and this is how we learn. If we repeat the experience, the pathway becomes stronger which is why humans can develop very complex behaviour and skills.

The learning process

Gymnasts have repeated the complex movements so many times that their brain and body have learnt a new set of skills

The human brain consists of billions of neurons. These neurons are connected together to form even more billions of different pathways. Whenever we have a new experience, a new pathway in the brain is used. Each new experience changes our behaviour - this is called **learning**.

If the experience is repeated, or the **stimulus** is very strong, more nerve impulses are sent along the new pathway. This reinforces the learning process and explains why **repetition** helps us to learn new things. Repetition strengthens the connections between neurons and makes it easier for impulses to travel along the pathway.

Skills can also be learnt through repetition. For example learning to ride a bike requires practice and repetition to learn a new set of skills.

A gymnast has exactly the same sets of muscles as the rest of us. The difference is that they have repeated and practised the complex movements so many times that their brain and body have learnt a new set of skills.

Why humans learn

Learning is important to an animal’s survival. It enables the animal to adapt and survive in new situations. Human babies learn not to touch hot objects, for instance. This helps the baby to survive.

Learning language - Higher

Some skills can only be learnt at a certain age. For example the ability to use spoken language only occurs in young children.

In France, back in 1799, a young **feral child** was found living in a forest. He had been living wild without contact with his parents or other human beings. The people called him Victor and guessed that he was about 12 years old. Victor had never communicated using a structured language. During the rest of his life, he only ever learnt to say a couple of words.

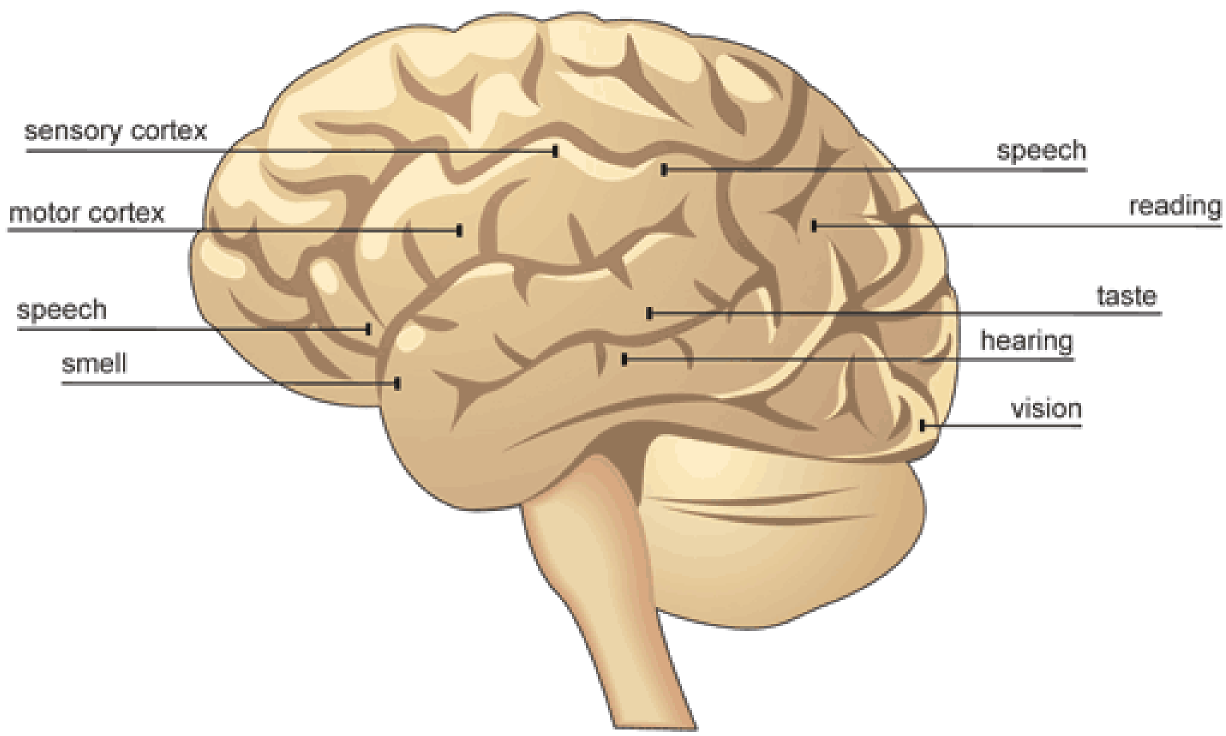
At 12 years old, he was no longer able to learn a language.

The brain and memory

The brain contains the cerebral cortex, which is responsible for high-level brain functions such as language and verbal memory.

The cerebral cortex

The **cerebral cortex** is the part of the brain responsible for **intelligence**, **language**, **memory** and **consciousness**.



Cerebral cortex

Scientists have used different methods to find out which parts of the cerebral cortex do different jobs. These include:

- **Brain damage**

  By studying patients with brain damage, scientists can learn which parts of the brain are responsible for doing different jobs.

- **Electrical stimulation**

  Scientists have stimulated different parts of the brain with a weak electrical current and then asked patients to describe what they experienced. If the motor area is stimulated, the patient makes an involuntary movement. If the visual area is stimulated, they may see a flash of colour.

- **MRI brain scans**

  Modern imaging methods such as **MRI (Magnetic Resonance Imaging)** scans can show details of brain structure and function. Patients are asked to perform various tasks and, by looking at the scan, scientists can see which parts of the brain are active when the task is carried out.

Understanding memory

Two types of memory

Memory is the ability to store and retrieve information. **Verbal memory** can be divided into long-term memory and short-term memory.

Short-term memory lasts for about **30 seconds**. This is why, when you look up a new telephone number, by the time the call has ended you have forgotten the number.

Long-term memory may last for the whole of your life. When you sing the words of a favourite song, you are using your long-term memory. Although we often complain about how hard it is to learn new things, there is **no limit** to how much information you can store in your long-term memory.

Memory problems

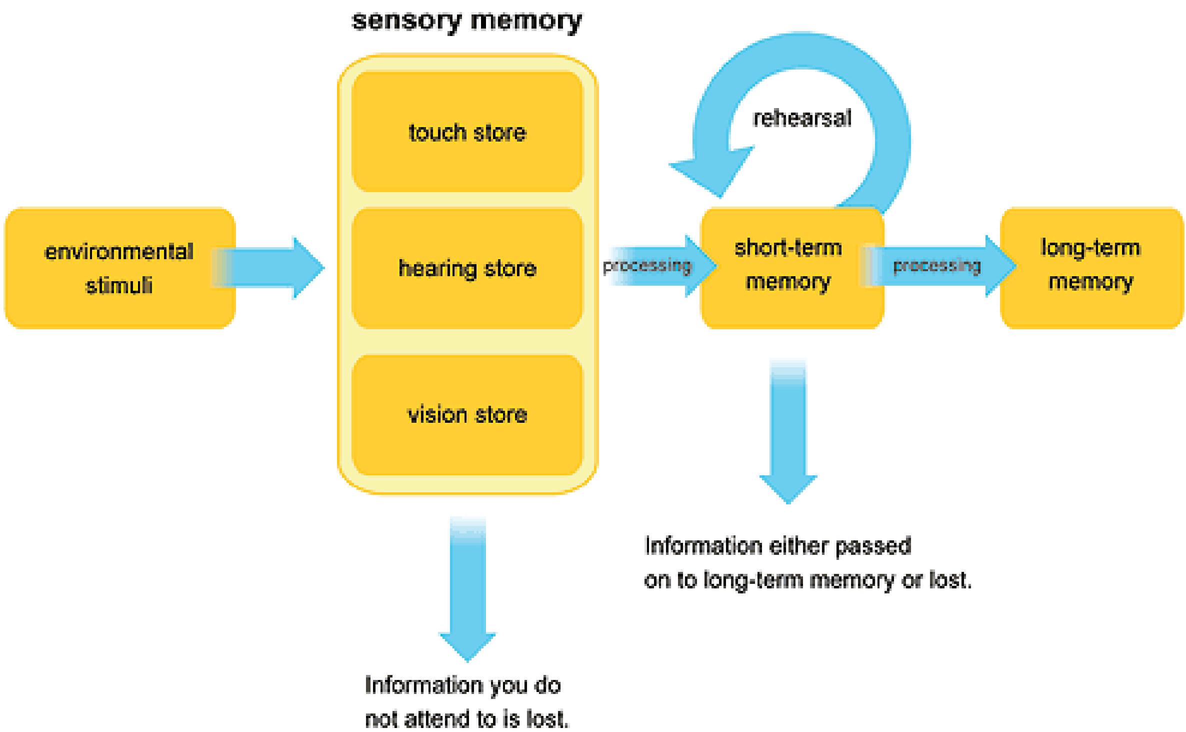
People with Alzheimer’s disease suffer a loss of short-term memory. They may not remember what day of the week it is, but they can remember details of their childhood.

Individuals with brain damage may lose their long-term memory and even forget who they are, but their short-term memory still works fine. This shows that the two types of memory must work in **different ways**.

A scientific model for memory

Scientists have produced models to help explain how memory works. But so far none of these models have provided an exact explanation.

The multistore memory model can be used to help explain some steps involved in long-term and short-term memory.



Multistore memory model explaining some steps involved in long-term and short-term memory

Understanding memory - Higher

Repetition

Memory is improved through repetition. If we repeat things, especially over a long period of time, we are much more likely to remember them using our long-term memory.

Strong stimulus

A strong stimulus - including colour, light, smell or sound - also helps us to remember things.

For example, which of these are you more likely to remember?

- Incident 1: The sound of a car, braking suddenly, to avoid a cat crossing the road.

- Incident 2: Your mother asking you to pick up a loaf of bread on your way home.

You are more likely to remember Incident 1, as the stimulus is stronger.

Patterns

We are more likely to remember information if we can either see or make a pattern out of it.

Look at this list of words:

- yellow
- pieces
- dog
- wool
- window
- table
- quickly
- lamp

They are much easier to remember if we impose a pattern on them:

A **dog** looked through a **window** and saw a **yellow** car drive **quickly** down the road. The dog barked and knocked a **lamp** off the **table**, which broke into **pieces** on the **wool** carpet.

How drugs affect our nervous system

Some drugs and toxins affect how impulses pass from one neuron to the next across a synapse.

Drugs and synapses

Strychnine is used by Australian aborigines to paralyze fish

Some drugs stop the impulse from passing across the **synapse**. Drugs such as **curare** (the South American plant toxin used in arrow poison) do this. They cause complete paralysis, and even stop the person from breathing.

Other drugs stimulate the synapse so that once an impulse crosses the gap the impulse is repeated over and over again. Drugs such as **strychnine** do this. They cause all the muscles in the body to go into a continuous spasm of constriction. This also stops the person from breathing.

How drugs affect our nervous system

Drugs and synapses - Higher

Serotonin is a chemical that is released into synapses in the brain. An increase in serotonin levels in the synapses makes us feel happier.

However, serotonin is normally absorbed by **receptor molecules** on the other side of the synapse. This prevents the levels of serotonin from increasing.

Ecstasy (also called MDMA) is a drug that **blocks** the serotonin receptor sites in the synapses in the brain. This prevents the serotonin from being absorbed by the receptor molecules. As a result, the level of serotonin in the synapse increases. This produces a feeling of wellbeing.

However, there is evidence to suggest that the use of Ecstasy reduces memory. Ecstasy can also cause severe dehydration which can result in death.