Reflexes

Not just a knee-jerk response

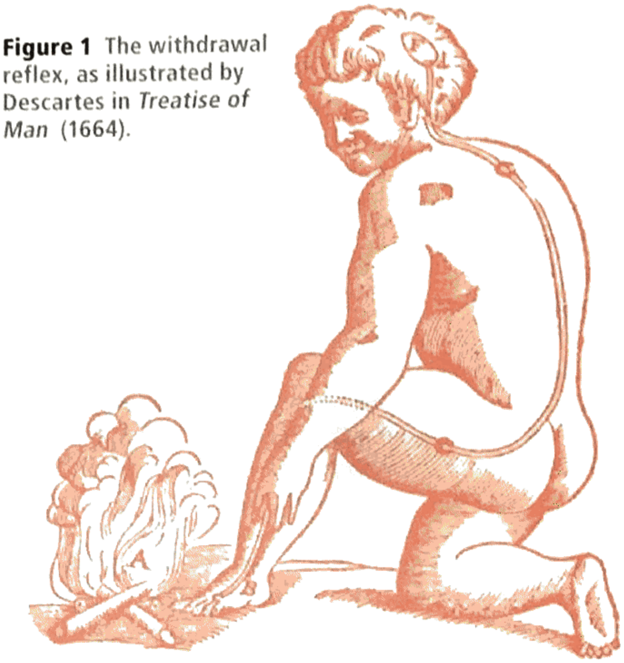

Figure 1 The withdrawal reflex, as illustrated by Descartes in *Treatise of Man* (1664).

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A reflex is an automatic response to a stimulus. Examples include blinking, gagging and withdrawing from a painful stimulus. Reflexes have specific functions. Many are there to protect the body from danger or damage — the gag reflex, for example, prevents choking. Some reflex responses involve movement of part of the body, but responses may also include changes in blood pressure, gut movement, heartbeat and breathing. Reflexes are generally considered to be **innate** and involuntary — they happen without conscious thought and we have no control over them. However, as we shall see, we can exert control over some of our reflexes, and others can be conditioned or trained.

The French philosopher René Descartes, in the mid-1600s, was the first person to try to explain the nature of reflexes. Figure 1 is a famous picture from his book *Treatise of Man*, which shows a boy withdrawing his foot from a fire. Descarte's explanation of how the reflex occurred was completely incorrect but he saw the link between sensing the heat of the fire and the response — rapid withdrawal. This was quite insightful since at that time almost nothing was known about how muscles and nerves worked.

KEY WORDS

Reflex arc
Conditioning
Spinal cord
Brain

TERMS EXPLAINED

Extensor A muscle that straightens a limb or part of the body.

Flexor A muscle that is used to bend a limb or other part of the body.

Innate Inborn, present from birth.

Interneurone, intermediate or **relay neurone** A nerve cell confined to the central nervous system (brain plus spinal cord), that provides the link between sensory and motor neurones.

Motor neurone A nerve cell with its cell body in the brain or spinal cord and an axon that connects with a muscle.

Sensory neurone A nerve cell that carries information from a sensory organ or sensory structure to the spinal cord or brain.

Synapse A junction between two nerve cells, or a nerve cell and a muscle cell, across which an action potential must pass.

The stretch reflex

Doctors use the knee-jerk reflex (see Figure 2) when looking for damage to the nervous system. The patella tendon just below the kneecap (patella) is tapped with a hammer. This briefly stretches the quadriceps muscle in the thigh. Tiny organs called muscle spindles, which are the endings of **sensory neurones** embedded in the muscle, detect the stretch. The sensory neurones transmit impulses to the spinal cord where they connect, either directly or via an **interneurone**, with **motor neurones** that control the same muscle. Impulses from the motor neurones cause the muscle to contract and this pulls the lower leg up rapidly.

The knee-jerk reflex is a postural reflex — it keeps the body in a standing posture. When you stand, gravity tends to make your knees buckle under the weight of your body. As soon as your knees start to bend, the thigh muscles are stretched and the reflex is activated to contract the thigh muscles, automatically straightening the leg and keeping you standing up. All this is done without your being aware of it happening, many times per minute. The knee-jerk reflex is extremely fast (around 50 milliseconds between stimulus and response) because it involves only two or three neurones (see Figure 2). The arrangement of neurones for the knee-jerk reflex is called a reflex arc. The pathway is confined to the spinal cord, so it is independent of the brain and occurs without conscious thought. It is often called a simple or a spinal reflex.

The withdrawal reflex

Some reflexes involve multiple responses. Figure 3 shows what happens when the hand comes into contact with a hot and/or painful object — the withdrawal reflex. The pain sensation (1) travels via sensory neurones (2) to the spinal cord where it makes contact with interneurones (3). These in turn act to excite motor neurones (4) for the **flexor** muscle (biceps) and at the same time inhibit motor neurones for the **extensor** muscle (triceps). This means that the extensor muscle relaxes at the same time as the flexor contracts (5), making the rapid movement of the arm away from the object much more efficient. Other interneurones in the cord transmit impulses to the brain. So although this is still a spinal reflex, the brain is aware of what has happened, including the feeling of pain. The brain can modify the response depending on the severity of the pain: a small amount of pain and the arm is rapidly withdrawn; more pain and the withdrawal can also involve the shoulder and upper body; a really bad burn will trigger arm and shoulder muscles, jumping away from the object, and a cry of pain.

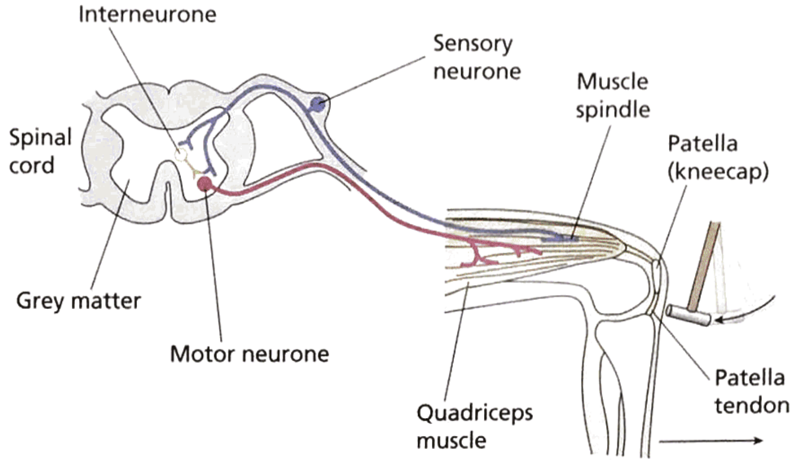

Figure 2 The knee-jerk reflex.

The blink reflex

Spinal reflexes can occur even when the spinal cord is severed from the brain, for example following an accident. However, in some reflexes the brain is involved directly. The eye-blink reflex is a fast, protective blink that happens when something touches, or appears to be heading for, the surface of the eye, or in response to a flash of light. The sensory input travels to the brain where it makes contact, both directly and indirectly, with the region of the brain containing motor neurones, which then connect via the facial nerve with muscles controlling the eyelids. All this takes about 100 milliseconds and usually leads to blinking of both eyes.

We can exert some control over the blink reflex. People who use contact lenses can consciously resist the reflex, allowing them to insert a lens. This usually takes practice. The eye-blink reflex can also be conditioned or trained. The conditioning procedure is a form of classical conditioning (see Box 1) and has been used by scientists to investigate changes that occur in the brain during learning. In untrained individuals a puff of air to the eye triggers the blink reflex; a sound does not. However, if the air puff and sound are given together a number of times, then the individual will start to respond to the sound alone with an involuntary, reflex eye-blink. He or she has learned that the sound is usually accompanied by a stimulus potentially damaging to the eye. Researchers have used this simple experiment to explore mechanisms underlying learning and memory in humans and other animals. For example, if the part of the brain called the cerebellum is damaged, then eye-blink conditioning can no longer be induced. The cerebellum is known to be involved in learning — particularly the more 'automatic' skills such as riding a bicycle and playing the piano. The reason why the blink reflex can be modified by conscious thought and learning is that the neurones involved in the reflex arc connect with many other parts of the brain, such as those involved with processing auditory information.

Primitive reflexes

An interesting class of reflex is the so-called 'primitive' or infantile reflexes. These are found only in infants and most are lost after the first few weeks or months of life. They are there to ensure that the baby can generate the movements it

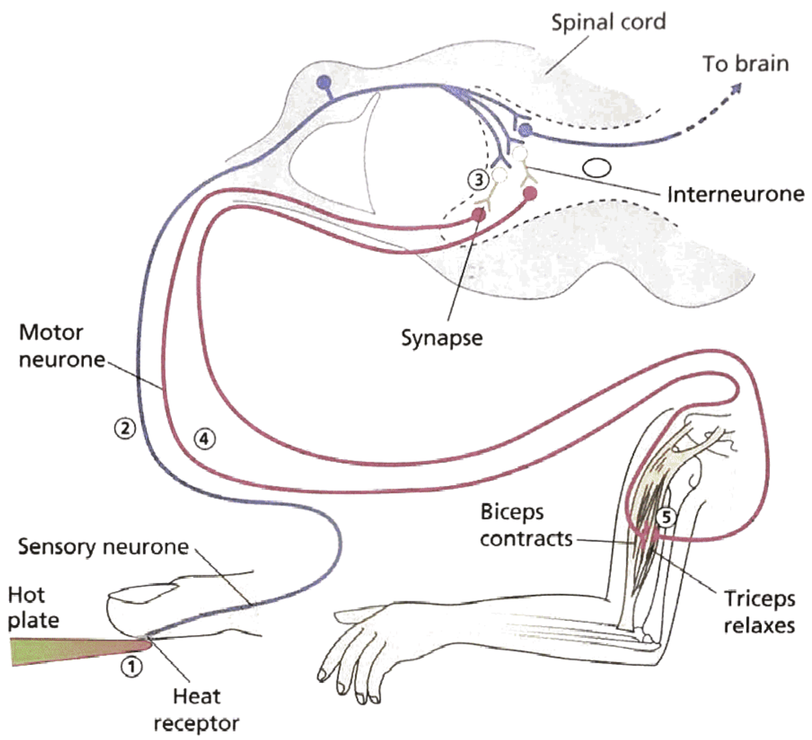

Figure 3 The withdrawal reflex. The hand and arm withdraw rapidly in response to touching a hot plate.

BOX 1

Classical conditioning

Classical conditioning is a form of associative learning, first described by the Russian physiologist Ivan Pavlov in the early 1900s. He studied the salivation reflex in dogs. When presented with food, the dog would produce saliva, which could be collected and measured. Then Pavlov noticed that the dog started to salivate when it saw its trainer enter the room, even before it saw or smelt the food. In his learning experiments Pavlov paired ringing a bell (the conditioned stimulus) with presentation of food (unconditioned stimulus). After a number of such pairings, he tested the dog by ringing the bell on its own. The trained dog now salivated in response to the bell alone (conditioned response). It had learned an association between the bell and the arrival of food. Animals and humans learn such associations continuously throughout their lives, helping them make sense of the world.

Figure 4 Infantile reflexes. (A) The startle or Moro reflex; (B) the stepping reflex.

needs for survival before it has had a chance to learn about the world around it. The grasping, rooting and sucking reflexes are all directed towards making contact with the mother and obtaining milk. These persist for a few months. The Moro (or startle) reflex is shown at birth and disappears after a couple of months. It occurs in response to a sudden movement — especially a falling sensation — or noise. The arms are flung out sideways and the face changes expression (Figure 4A). After this, the arms clutch forwards, seeking the mother, and the baby may start to cry.

The walking reflex is seen from birth but lost after only about 6 weeks. If the baby is held with its feet touching the floor it will make alternate stepping movements (Figure 4B). Similarly, when placed with its face in water (don't try this!), a baby will show paddling/kicking (swimming) actions. The purpose of the stepping and swimming reflexes is unknown. What they do show is that the control circuits for stepping and swimming movements are present in the nervous system from birth, even though we have to learn to express these behaviours later, when we grow up.

When reflexes go wrong

Testing different reflexes can tell us a huge amount about sites of damage or disease of the nervous system. A full neurological examination will include testing a number of reflexes. Spinal cord injury leads to changes in spinal reflexes. Stretch reflexes, for example, such as the knee jerk, become stronger, sometimes to the point where the muscle is permanently shortened. This is thought to be because the brain normally suppresses these reflexes to some extent.

Some infantile reflexes reappear in adults with neurological damage. A good example is the plantar reflex. The sole of the foot is firmly stroked with a probe. The normal response in adults is a downward, curling movement of the toes. The response in infants is the opposite — the toes splay and bend upwards. The infant response is called Babinski's response. If seen in adults, Babinski's response is a sign of disease or damage in the region of the brain responsible for controlling movement, or of the pathways between this area of the brain and the spinal cord. This simple test alerts the doctor to the need for further investigation, such as a brain scan. Adults with permanent brain damage, such as cerebral palsy, may exhibit the Moro reflex in response to sudden changes in their environment. This can be disabling but it is possible in some cases to learn to suppress it.

In patients with serious head injury, for example those in a coma, reflexes provide information about possible brain damage. Loss of the blink reflex suggests damage to the facial nerve. The pupillary light reflex is the rapid contraction of pupil size when a light is shone into the eye. Normally both eyes respond even when only one is stimulated. If only one pupil contracts, this suggests damage on one side of the brain. Complete absence of the reflex may indicate damage to the brain stem — an important region for controlling the heart and breathing.

Although reflexes appear fixed and innate, they play a huge role in shaping our response to the world around us, providing us with the basic tools to avoid danger. They also provide doctors with quick and simple ways of assessing how well our brain is working. We still have a lot to learn about these apparently simple responses, especially how it is that they can be modified by conscious thought and learning.

Things to do

- The Neuroscience for Kids website has some simple tests that you can try:
  http://tinyurl.com/3vckevo
- Try testing whether a subject can exert voluntary control over the knee-jerk or eye-blink reflex. Do these reflexes change when the subject is concentrating on another task, for example simple mental arithmetic?

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