CHAPTER

6 Biopsychology

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A LEVEL ONLY ZONE

SPECIFICATION CHECKLIST

AS and A Level

- The divisions of the nervous system: central and peripheral (somatic and autonomic).
- The structure and function of sensory, relay and motor neurons. The process of synaptic transmission, including reference to neurotransmitters, excitation and inhibition.
- The function of the endocrine system: glands and hormones.
- The fight-or-flight response including the role of adrenaline.

A LEVEL ONLY ZONE

A Level only

- Localisation of function in the brain and hemispheric lateralisation: motor, somatosensory, visual, auditory and language centres; Broca's and Wernicke's areas, split-brain research. Plasticity and functional recovery after trauma.
- Ways of studying the brain: scanning techniques, including functional magnetic resonance imaging (fMRI); electroencephalogram (EEGs) and event-related potentials (ERPs); post-mortem examinations.
- Biological rhythms: circadian, infradian and ultradian and the difference between these rhythms. The effect of endogenous pacemakers and exogenous zeitgebers.

Ever wondered how fast a nerve impulse travels?

A nerve impulse is an electrical signal that travels along an axon. The speed of nerve impulses varies enormously in different types of neuron, with the fastest travelling at around 250 mph – faster than a Formula 1 racing car.

TRY THIS

Okay, let's try a little experiment to measure how fast a nerve impulse travels down the length of one arm. To do this you will need a group of people, 10 people minimum, but as many as you have available. Stand one person behind the other and have them rest their right hand on the right shoulder of the person in front. At a predetermined signal from the 'experimenter' (whoever has the stopwatch), the first person squeezes the shoulder of the person in front, who, when they feel it, squeezes the shoulder of the person in front of them and so on. When the final person feels their shoulder squeezed they shout 'STOP' and the stopwatch is stopped. Given that an arm is approximately one metre in length, you should be able to work out how many metres per second the impulse travelled. For example, for 25 people, that's 25 metres, which might take about five seconds or so. That's a speed of about five metres per second. Try that a few times and then take an average speed.

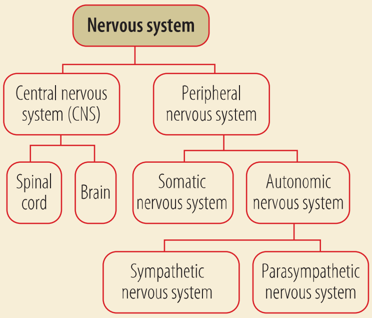
Now stand in a circle facing outwards with each person holding hands with the person standing each side of them. This time at the signal to start, the first person squeezes the hand of the person on their left, who, when they feel it, squeezes the hand of the person on their left and so on, until the starting person feels their right hand being squeezed and they shout 'STOP'. What do you predict the time will be? You should find it is a fair bit longer as the impulse must now travel through two arms, and so two metres. Again, calculate the average speed. With practice you may be able to get it up to 10–15 metres per second, which is about right for a nerve impulse of this type, or to put it another way, about 30 mph. That's quite quick, but quite a bit slower than electricity, which speeds down a wire at about 186,000 miles per second!

The nervous system

The human nervous system is a complex network of nerve cells that carry messages to and from the brain and spinal cord to different parts of the body and so helps all the parts of the body to communicate with each other. Controlling the nervous system is the brain, the powerhouse of the body, even though it only makes up about 2% of the body's weight. This organ has many billions of neural cross-connections. The brain oversees the workings of the body, while its higher functions provide us with consciousness and makes us who we are.

DIVISIONS OF THE NERVOUS SYSTEM

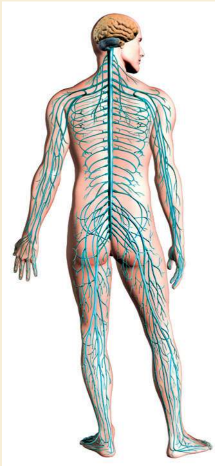
The human nervous system is divided into the **central nervous system (CNS)** and **peripheral nervous system**, with each of these further divided into different components, each with a different function but all working together. Let's begin by looking at these different divisions and their component parts (see below).



In 2014, a 24-year-old woman walked into her local emergency room in Shandong Province, China, with symptoms of vertigo (loss of balance and nausea) but ended up receiving a surprising diagnosis – her entire cerebellum was missing! However, the New Scientist *reports, the missing cerebellum had resulted in only mild to moderate motor deficiency, as other parts of her brain had filled in for it.*

THE CENTRAL NERVOUS SYSTEM

The CNS, comprising the **brain** and **spinal cord**, has two main functions: the control of behaviour and the regulation of the body's physiological processes. In order to do this, the brain must be able to receive information from the sensory receptors (eyes, ears, skin, etc.) and be able to send messages to the muscles and glands of the body. This involves the spinal cord, a collection of nerve cells that are attached to the brain and run the length of the spinal column.



▲ The central nervous system is the brain and spinal column. The peripheral nervous system comprises the nerves leading to and from the CNS.

The spinal cord

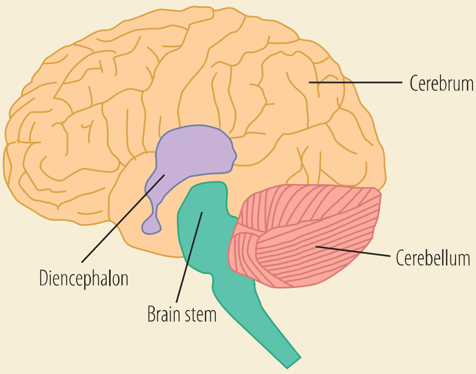
The main function of the spinal cord is to relay information between the brain and the rest of the body. This allows the brain to monitor and regulate bodily processes, such as digestion and breathing, and to coordinate voluntary movements. The spinal cord is connected to different parts of the body by pairs of spinal nerves, which connect with specific muscles and glands. For example, spinal nerves which branch off from the thoracic region of the spinal cord, carry messages to and from the chest and parts of the abdomen. The spinal cord also contains circuits of nerve cells that enable us to perform some simple reflexes without the direct involvement of the brain, for example pulling your hand away from something that is hot. If the spinal cord is damaged, areas supplied by spinal nerves below the damaged site will be cut off from the brain and will stop functioning.

The brain

The brain can be divided into four main areas – the cerebrum, cerebellum, diencephalon and brain stem.

The cerebrum is the largest part of the brain, and is further divided into four different lobes, each of which has a different primary function (see page 132). For example, the frontal lobe is involved in thought and the production of speech, and the occipital lobe (at the back of the cerebrum) is involved in the processing of visual images. The cerebrum is split down the middle into two halves called cerebral hemispheres. Each hemisphere is specialised for particular behaviours, and the two halves communicate with each other through the corpus callosum (see page 158).

The cerebellum sits beneath the back of the cerebrum. It is involved in controlling a person's motor skills and balance, coordinating the muscles to allow precise movements. Abnormalities of this area can result in a number of problems, including speech and motor problems and epilepsy.



The diencephalon lies beneath the cerebrum and on top of the brain stem (see diagram on the right). Within this area are two important structures, the thalamus and the hypothalamus. The thalamus acts as a relay station for nerve impulses coming from the senses, routing them to the appropriate part of the brain where they can be processed. The hypothalamus has a number of important functions, including the regulation of body temperature, hunger and thirst. It also acts as the link between the endocrine system (see page 152) and the nervous system, controlling the release of hormones from the pituitary gland.

The brain stem is responsible for regulating the automatic functions that are essential for life. These include breathing, heartbeat and swallowing. Motor and sensory neurons travel through the brain stem, allowing impulses to pass between the brain and the spinal cord.

THE PERIPHERAL NERVOUS SYSTEM

All the nerves *outside* the CNS make up the peripheral nervous system. This function of this part of the nervous system is to relay nerve impulses from the CNS (the brain and spinal cord) to the rest of the body and from the body back to the CNS. There are two main divisions of the peripheral nervous system, the **somatic nervous system** and the **autonomic nervous system (ANS)**.

The somatic nervous system

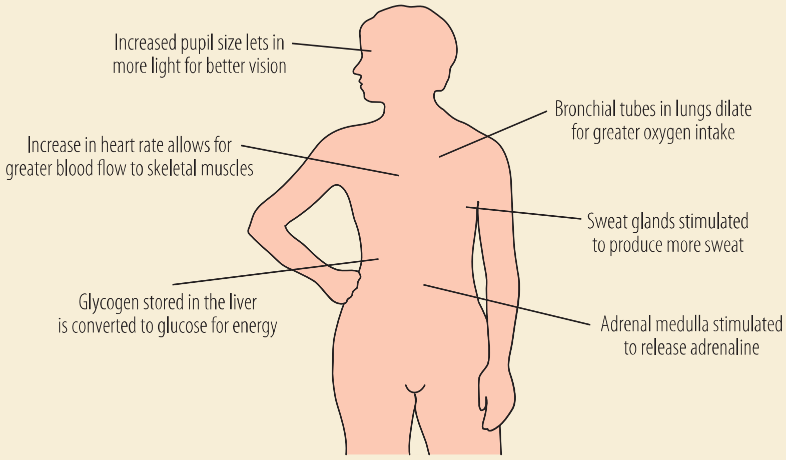
The somatic system is made up of 12 pairs of cranial nerves (nerves that emerge directly from the underside of the brain) and 31 pairs of spinal nerves (nerves that emerge from the spinal cord). These nerves have both sensory neurons and motor neurons. Sensory neurons relay messages *to* the CNS, and motor neurons relay information *from* the CNS to other areas of the body. We'll learn more about these different types of neuron on the next spread. The somatic system is also involved in reflex actions without the involvement of the CNS, which allows the reflex to occur very quickly.

The autonomic nervous system

When you type on a keyboard or take a drink you are performing voluntary actions and are conscious of what you are doing. However, the body also carries out some actions *without* your conscious awareness. For example, your heart beats and your intestines digest food without you being consciously aware of this happening. Involuntary actions such as these are regulated by the ANS. This system is necessary because vital bodily functions such as heartbeat and digestion would not work so efficiently if you had to think about them. The ANS has two parts: the sympathetic and the parasympathetic. Both of these divisions tend to regulate the same organs but have opposite effects. This is because of the neurotransmitters associated with each division. Generally, the sympathetic division uses the neurotransmitter noradrenaline, which has stimulating effects, and the parasympathetic division uses acetylcholine, which has inhibiting effects.

The sympathetic nervous system

The sympathetic nervous system (SNS) is primarily involved in responses that help us to deal with emergencies (fight or flight; see page 154), such as increasing heart rate and blood pressure and dilating blood vessels in the muscles. Neurons from the SNS travel to virtually every organ and gland within the body, preparing the body for the rapid action necessary when the individual is under threat. For example, the SNS causes the body to release stored energy, pupils to dilate and hair to stand on end. It slows bodily processes that are less important in emergencies, such as digestion and urination.



▲ Effect of SNS activation on the body.

The parasympathetic nervous system

If we think of the SNS as pushing an individual into action when faced with an emergency, then the parasympathetic nervous system (PNS) relaxes them again once the emergency has passed. Whereas the SNS causes the heart to beat faster and blood pressure to increase, the PNS slows the heartbeat down and reduces blood pressure. Another benefit is that digestion (inhibited when the SNS is aroused) begins again under PNS influence. Because the PNS is involved with energy conservation and digestion, it is sometimes referred to as the body's rest and digest system.

APPLY YOUR KNOWLEDGE

On your way home from a day relaxing with friends you are chased by a neighbour's dog. You are forced to run to escape the dog.

When you get home you slump down on the sofa and switch on *Shaun the Sheep* on the TV. Gradually you feel yourself relaxing as your body returns to normal. Maybe tomorrow you'll take the bus home!

Try to explain this sequence of events using your knowledge of the sympathetic and parasympathetic nervous systems.

KEY TERMS

Autonomic nervous system (ANS) Governs the brain's involuntary activities (e.g. stress, heartbeat) and is self-regulating (i.e. autonomous). It is divided into the sympathetic branch (fight or flight) and the parasympathetic branch (rest and digest).

Brain That part of the central nervous system that is responsible for coordinating sensation, intellectual and nervous activity.

Central nervous system (CNS) Comprises the brain and spinal cord. It receives information from the senses and controls the body's responses.

Peripheral nervous system The part of the nervous system that is outside the brain and spinal cord.

Somatic nervous system The part of the peripheral nervous system responsible for carrying sensory and motor information to and from the central nervous system.

Spinal cord A bundle of nerve fibres enclosed within the spinal column and which connects nearly all parts of the body with the brain.

CAN YOU? No. 6.1

1. Outline the role of the central nervous system. (4 marks)
2. Identify the **two** divisions of the autonomic nervous system. (2 marks)
3. Identify the **two** components of the central nervous system. (2 marks)
4. Outline the role of the somatic nervous system. (4 marks)
5. Outline the role of the autonomic nervous system. (4 marks)

Neurons and synaptic transmission

What we think of as our mental life involves the activities of the nervous system, especially the brain. Most of the brain is made up of cells called glial cells and astrocytes. Among these cells are neurons – specialised cells whose function is to move electrical impulses to and from the central nervous system. The average human brain contains somewhere in the region of 100 billion neurons and, on average, each neuron is connected to 1,000 other neurons. This creates highly complex neural networks that give the brain its impressive processing capabilities.

The action potential

Neurons must transmit information both within the neuron and from one neuron to the next. The dendrites of neurons receive information from sensory receptors or other neurons. This information is then passed down to the cell body and on to the axon. Once the information has arrived at the axon, it travels down its length in the form of an electrical signal known as an action potential.

Research methods

Here are some facts and questions about neurons.

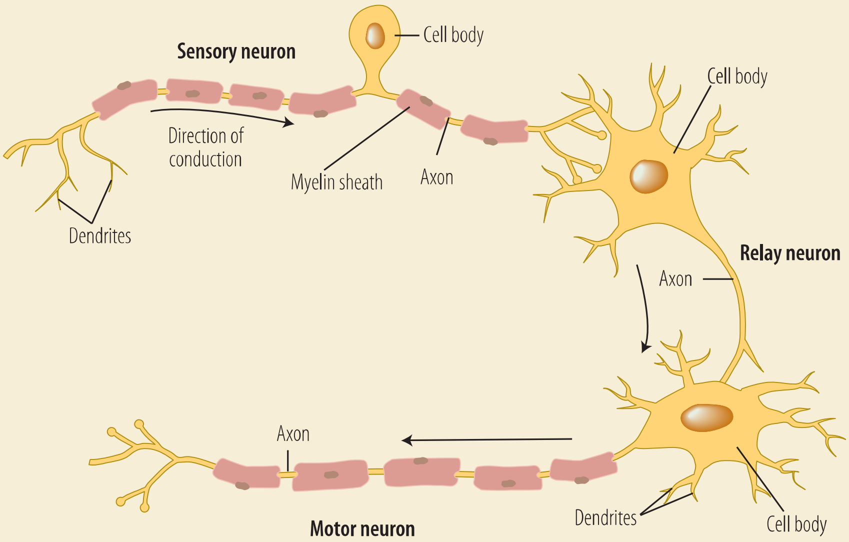
1. One neuron may be as narrow as 0.004 centimetres in diameter. Express this in standard form. (2 marks)
2. The mean number of neurons in the human brain is 100,000,000,000 (100 billion). Express this in standard form. (2 marks)
3. The longest neuron in the body is about 1 metre in length. What fraction is this of the body length of a person who is 2 metres tall? (2 marks)
4. The rate of neuron growth during foetal development in utero is 250,000 neurons per minute. Estimate how many neurons grow every hour. (2 marks)
5. Your brain makes up only about 2% of body mass, but uses 10 times as much of the oxygen. What fraction of your body's requirements of oxygen are used by the brain? (2 marks)
6. What percentage of your body's oxygen is used by the brain? (2 marks)

LINK TO RESEARCH METHODS

Mathematical skills on page 210

THE STRUCTURE AND FUNCTION OF NEURONS

Neurons are cells that are specialised to carry neural information throughout the body. Neurons can be one of three types: sensory neurons, relay neurons or motor neurons. Neurons typically consist of a cell body, dendrites and an axon. Dendrites at one end of the neuron receive signals from other neurons or from sensory receptors. Dendrites are connected to the cell body, the control centre of the neuron. From the cell body, the impulse is carried along the axon, where it terminates at the axon terminal. In many nerves, including those in the brain and spinal cord, there is an insulating layer that forms around the axon – the myelin sheath. This allows nerve impulses to transmit more rapidly along the axon. If the myelin sheath is damaged, impulses slow down. The length of a neuron can vary from a few millimetres up to one metre.



▲ Three types of neuron.

Sensory neurons

Sensory neurons carry nerve impulses *from* sensory receptors (e.g. receptors for vision, taste, touch) *to* the spinal cord and the brain. Sensory receptors are found in various locations in the body, for example in the eyes, ears, tongue and skin. Sensory neurons convert information from these sensory receptors into neural impulses. When these impulses reach the brain, they are translated into sensations of, for example, visual input, heat, pain, etc., so that the organism can react appropriately.

Not all sensory information travels as far as the brain, with some neurons terminating in the spinal cord. This allows reflex actions to occur quickly without the delay of sending impulses to the brain.

Relay neurons

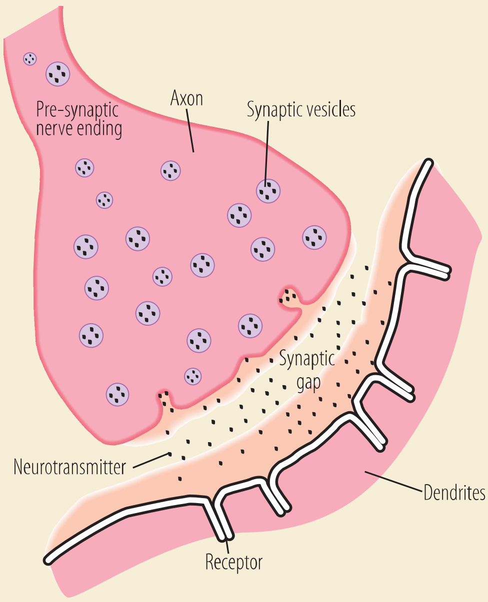
Most neurons are neither sensory nor motor, but lie somewhere between the sensory input and the motor output. Relay neurons allow sensory and motor neurons to communicate with each other. These **relay neurons** (or interneurons) lie wholly within the brain and spinal cord.

Motor neurons

The term **motor neuron** refers to neurons located in the PNS that project their axons outside the PNS and directly or indirectly control muscles. Motor neurons form **synapses** with muscles and control their contractions. When stimuated, the motor neuron releases **neurotransmitters** that bind to receptors on the muscle and triggers a response which leads to muscle movement. When the axon of a motor neuron fires, the muscle with which it has formed synapses with contracts. The strength of the muscle contraction depends on the rate of firing of the axons of motor neurons that control it. Muscle relaxation is caused by inhibition of the motor neuron.

SYNAPTIC TRANSMISSION

Once an action potential has arrived at the terminal button at the end of the axon, it needs to be transferred to another neuron or to tissue. To achieve this, it must cross a gap between the presynaptic neuron and the postsynaptic neuron. This area is known as the synapse – which includes the end of the presynaptic neuron, the membrane of the postsynaptic neuron and the gap in between. The physical gap between the pre- and postsynaptic cell membranes is known as the synaptic gap. At the end of the axon of the nerve cell are a number of sacs known as synaptic vesicles. These vesicles contain the chemical messengers that assist in the transfer of the impulse, the neurotransmitters. As the action potential reaches the synaptic vesicles, it causes them to release their contents through a process called exocytosis.



▲ The synapse.

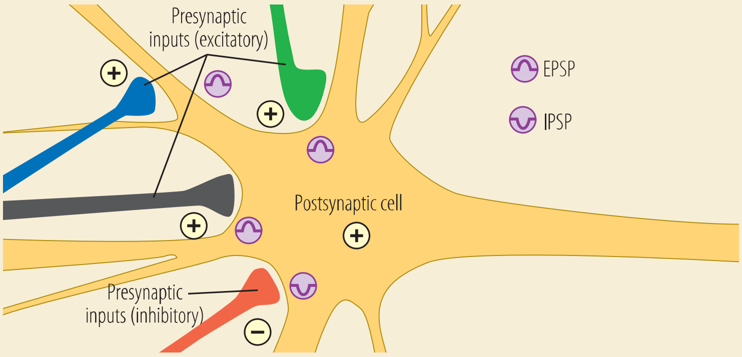
The released neurotransmitter diffuses across the gap between the pre- and the postsynaptic cell, where it binds to specialised receptors on the surface of the cell that recognise it and are activated by that particular neurotransmitter. Once they have been activated, the receptor molecules produce either excitatory or inhibitory effects (see right) on the postsynaptic neuron.

This whole process of **synaptic transmission** takes only a fraction of a second, with the effects terminated at most synapses by a process called 're-uptake'. The neurotransmitter is taken up again by the presynaptic neuron, where it is stored and made available for later release (a sort of recycling programme). How quickly the presynaptic neuron takes back the neurotransmitter from the synaptic cleft determines how prolonged its effects will be. The quicker it is taken back, the shorter the effects on the postsynaptic neuron. Some antidepressant drugs prolong the action of the neurotransmitter by inhibiting this re-uptake process, leaving the neurotransmitter in the synapse for longer. Neurotransmitters can also be 'turned off' after they have stimulated the postsynaptic neuron. This takes place through the action of enzymes produced by the body, which make the neurotransmitters ineffective.

EXCITATORY AND INHIBITORY NEUROTRANSMITTERS

Neurotransmitters are the chemical messengers that carry signals across the synaptic gap to the receptor site on the postsynaptic cell. Neurotransmitters can be classified as either excitatory or inhibitory in their action. Excitatory neurotransmitters such as acetylcholine and noradrenaline are the nervous system's 'on switches'. These increase the likelihood that an excitatory signal is sent to the postsynaptic cell, which is then more likely to fire. Inhibitory neurotransmitters, such as serotonin and GABA, are the nervous system's 'off switches', in that they decrease the likelihood of that neuron firing. Inhibitory neurotransmitters are generally responsible for calming the mind and body, inducing sleep, and filtering out unnecessary excitatory signals.

An excitatory neurotransmitter binding with a postsynaptic receptor causes an electrical change in the membrane of that cell, resulting in an excitatory post-synaptic potential (EPSP), meaning that the postsynaptic cell is more likely to fire. An inhibitory neurotransmitter binding with a postsynaptic receptor results in an inhibitory postsynaptic potential (IPSP), making it less likely that the cell will fire.



▲ The likelihood of a cell firing is determined by the summation of EPSPs and IPSPs.

A nerve cell can receive both EPSPs *and* IPSPs at the same time. The likelihood of the cell firing is therefore determined by adding up the excitatory and the inhibitory synaptic input. The net result of this calculation (known as summation) determines whether or not the cell fires. The strength of an EPSP can be increased in two ways. In *spatial* summation, a large number of EPSPs are generated at many different synapses on the same postsynaptic neuron at the same time. In *temporal* summation, a large number of EPSPs are generated at the same synapse by a series of high-frequency action potentials on the presynaptic neuron. The rate at which a particular cell fires is determined by what goes on in the synapses. If excitatory synapses are more active, the cell fires at a high rate. If inhibitory synapses are more active, the cell fires at a much lower rate, if at all.

KEY TERMS

Motor neurons form synapses with muscles and control their contractions.
Neurotransmitter Chemical substances that play an important part in the workings of the nervous system by transmitting nerve impulses across a synapse.
Relay neurons These neurons are the most common type of neuron in the CNS. They allow sensory and motor neurons to communicate with each other.
Sensory neurons carry nerve impulses from sensory receptors to the spinal cord and the brain.
Synapse The conjunction of the end of the axon of one neuron and the dendrite or cell body of another.
Synaptic transmission refers to the process by which a nerve impulse passes across the synaptic cleft from one neuron (the presynaptic neuron) to another (the postsynaptic neuron).

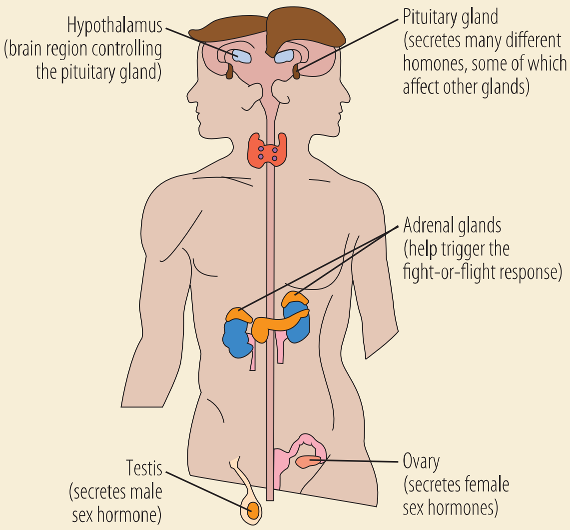
CAN YOU? No. 6.2

1. Briefly explain what is meant by 'sensory', 'relay' and 'motor neurons'. (2 marks each)
2. Explain the nature of synaptic transmission. (5 marks)
3. Briefly explain what is meant by 'excitation' and 'inhibition' in synaptic transmission. (2 marks each)
4. Explain the role of excitatory and inhibitory neurotransmitters. (3 marks each)

The endocrine system

The work of the nervous system is supplemented by a second system in the body, the **endocrine system**. This is a network of glands throughout the body that manufacture and secrete chemical messengers known as hormones. The endocrine and nervous systems work very closely together to regulate the physiological processes of the human body. However, instead of using nerves to transmit information, the endocrine system uses blood vessels to deliver hormones to their target sites in the body.

GLANDS AND HORMONES



▲ The endocrine system.

Endocrine glands

Endocrine glands produce and secrete hormones, chemical substances that regulate the activity of cells or organs in the body. The major glands of the endocrine system include the pituitary gland, adrenal glands and the reproductive organs (ovaries and testes). Each gland in the endocrine system produces different hormones, which regulate the activity of organs and tissues in the body.

The endocrine system is regulated by feedback similar to how a thermostat regulates temperature in a room. For example, a signal is sent from the hypothalamus to the pituitary gland in the form of a 'releasing hormone'. This causes the pituitary to secrete a 'stimulating hormone' into the bloodstream. This hormone then signals the target gland (e.g. the adrenal glands) to secrete *its* hormone. As levels of this hormone rises in the bloodstream, the hypothalamus shuts down secretion of the releasing hormone and the pituitary gland shuts down secretion of the stimulating hormone. This slows down secretion of the target gland's hormone, resulting in stable concentrations of hormones circulating in the bloodstream.

Hormones

Hormones are chemicals that circulate in the bloodstream and are carried to target sites throughout the body. The word 'hormone' comes from the Greek word *hormao* meaning 'I excite', which refers to the fact that each hormone 'excites' or stimulates a particular part of the body.

Although hormones come into contact with most cells in the body, a given hormone usually affects only a limited number of cells, known as target cells. Target cells respond to a particular hormone because they have receptors for that hormone. Cells that do not have such a receptor cannot be influenced directly by that hormone. When enough receptor sites are stimulated by hormones, this results in a physiological reaction in the target cell. Timing of hormone release is critical for normal functioning, as are the levels of hormones released. Too much or too little at the wrong time can result in dysfunction of bodily systems. For example, too high a level of cortisol can lead to Cushing's syndrome, characterised by high blood pressure and depression. The most common cause of excess cortisol is a tumour in the pituitary gland which makes too much of a hormone called adrenocorticotrophic hormone (ACTH) which stimulates the adrenal glands to make too much cortisol.

PITUITARY GLAND

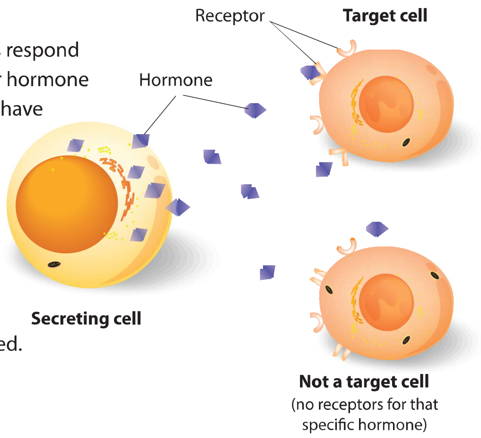
The **pituitary gland** produces **hormones** whose primary function is to influence the release of hormones from other glands, and in so doing regulate many of the body's functions. The pituitary is controlled by the hypothalamus, a region of the brain just above the pituitary gland. The hypothalamus receives information from many sources about the basic functions of the body, then uses this information to help regulate these functions. One of the ways it does this involves controlling the pituitary gland.

As the 'master gland', the pituitary produces hormones that travel in the bloodstream to their specific target. These hormones either directly cause changes in physiological processes in the body or stimulate other glands to produce other hormones. High levels of hormones produced in other endocrine glands can stop the hypothalamus and pituitary releasing more of their own hormones. This is called negative feedback, and prevents hormone levels from rising too high.

Hormones produced by the pituitary gland

The pituitary gland has two main parts: the anterior (front) pituitary and the posterior (back) pituitary. These two parts release different hormones, which target different parts of the body. The two sections of the pituitary gland produce a number of different hormones, which act on different target glands or cells. For example, the *anterior* pituitary releases ACTH as a response to stress. ACTH stimulates the adrenal glands to produce cortisol. The anterior pituitary also produces two hormones important in the control of reproductive functioning and sexual characteristics – luteinising hormone (LH) and follicle-stimulating hormone (FSH). In females these hormones stimulate the ovaries to produce oestrogen and progesterone, and in males they stimulate the testes to produce testosterone and sperm. The *posterior* pituitary releases oxytocin, which stimulates contraction of the uterus during childbirth, and is important for mother–infant bonding. Recent research using mice has found that oxytocin is indispensable for healthy maintenance and repair, and that it declines with age (Elabd *et al*., 2014).

▶ Target cells respond to a particular hormone because they have receptor cells for that hormone, whereas cells without these specific receptor cells are not affected.



THE ADRENAL GLANDS

The two adrenal glands sit on top of the kidneys. The name 'adrenal' relates to their location (*ad* – near or at; *renes* – kidneys). Each adrenal gland is made up of two distinct parts. The outer part of each gland is called the adrenal cortex and the inner region is known as the adrenal medulla. The adrenal cortex and the adrenal medulla have very different functions. One of the main distinctions between them is that the hormones released by the adrenal cortex are necessary for life; those released by the adrenal medulla are not.

Hormones produced by the adrenal glands

The adrenal cortex (the outer part of the adrenal gland) produces cortisol, which regulates or supports a variety of important bodily functions including cardiovascular and anti-inflammatory functions. Cortisol production is increased in response to stress. If the cortisol level is low, the individual has low blood pressure, poor immune function and an inability to deal with stress. The adrenal cortex also produces aldosterone, which is responsible for maintaining blood volume and blood pressure. The adrenal medulla (the inner part of the adrenal gland) releases adrenaline and noradrenaline, hormones that prepare the body for fight or flight (see page 154). Adrenaline helps the body respond to a stressful situation, for example by increasing heart rate and blood flow to the muscles and brain and helping with the conversion of glycogen to glucose to provide energy. Noradrenaline constricts the blood vessels, causing blood pressure to increase.

UPGRADE

When answering exam questions it is important to learn the skill of précis – to give a summary or the main points of something. We have emphasised the need for elaboration with AO3 but you also need to be able to reduce material to fit a specific question, giving your answer more focus. This is something students can struggle to do for AO1 material.

Let's take Q1 in the 'Can you?' box on the right as an example:

'Outline **one or more** functions of the endocrine system.' (6 marks)

- Begin by outlining the overall function of the endocrine system (to regulate the activity of cells or organs within the body).
- Then move on to illustrate this by looking at the specific functions of perhaps two of the glands that make up the system. For example, the pituitary gland's primary function is to influence the release of hormones from other glands.
- You might link this to other functions such as that the anterior pituitary releases growth hormones to stimulate growth and ACTH in response to stress, which in turn stimulates the adrenal glands to produce cortisol.

You need to practise choosing the right material so you can answer questions accurately in the time you have. For Q3 on the right; you would only need 2 marks worth of information for each part of the question, so you wouldn't need to start with any 'general' information about the system. The lesson from all this is to go straight into answering the question and to practise your précis!

There is a lot of information on these two pages. This gives you a good overview of the endocrine system and hormones. This is more than you need when answering questions such as those in the 'Can you?' box on the right, so you need to be selective when choosing content to answer these questions.

Ovaries

The two ovaries are part of the female reproductive system. Ovaries are responsible for the production of eggs and for the hormones oestrogen and progesterone. Progesterone, which is more important in the post-ovulation phase of the menstrual cycle, has also been found to be associated with heightened sensitivity to social cues that indicate the presence of social opportunity (e.g. recruiting allies) or threat (e.g. from outsiders) that would be significant in the case of pregnancy (Maner and Miller, 2014).

Testes

The testes are the male reproductive glands that produce the hormone testosterone. Testosterone causes the development of male characteristics such as growth of facial hair, deepening of the voice and the growth spurt that takes place during puberty. Testosterone production is controlled by the hypothalamus and pituitary gland. The hypothalamus instructs the pituitary gland on how much testosterone to produce, and the pituitary gland passes this message on to the testes. Testosterone also plays a role in sex drive, sperm production and maintenance of muscle strength, and is associated with overall health and well-being in men. Testosterone is not exclusively a male hormone. Women also have testosterone, but in smaller amounts.

As well as playing an important reproductive role in preparing the womb for pregnancy, there is also evidence that oestrogen, administered in the form of hormone replacement therapy, might lead to a reduction in the long-term risk of Alzheimer's disease (Maki and Henderson, 2012).

KEY TERMS

Endocrine glands Special groups of cells within the endocrine system, whose function is to produce and secrete hormones.

Endocrine system A network of glands throughout the body that manufacture and secrete chemical messengers known as hormones.

Hormones The body's chemical messengers. They travel through the bloodstream, influencing many different processes including mood, the stress response and bonding between mother and newborn baby.

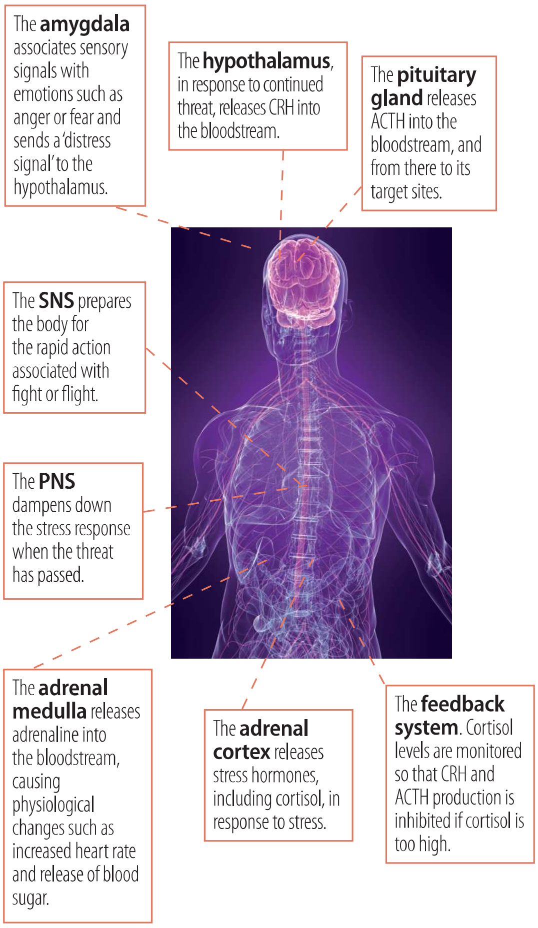
Pituitary gland The 'master gland', whose primary function is to influence the release of hormones from other glands.

CAN YOU? No. 6.3

1. Outline **one or more** functions of the endocrine system. (6 marks)
2. Explain the relationship between endocrine glands and hormones. (4 marks)
3. Outline the role of **one** endocrine gland and of **one** hormone that it produces. (4 marks)

The fight-or-flight response

When a person experiences a threatening or stressful situation, their body reacts in specific ways. The heart beats faster, their breathing becomes more rapid and their muscles tense. These reactions to stressful situations are known collectively as the **fight-or-flight response**. This response evolved as a survival mechanism, enabling animals and humans to react quickly to life-threatening situations. The bodily changes associated with 'fight or flight' allow an individual to fight off the threat or flee to safety. Unfortunately, the fight-or-flight response is also activated in conditions that are not life-threatening, and where fighting or running away is not particularly helpful.



▲ The fight-or-flight response

These changes happen so quickly that people usually aren't aware of them. In fact, this response is so efficient that the amygdala and hypothalamus start responding even before the brain has a chance to fully process what is happening. This is why people are able to jump out of the path of an oncoming car before they have the chance to think about what they are doing.

THE FIGHT-OR-FLIGHT RESPONSE TO STRESS

The amygdala and hypothalamus

When an individual is faced with a threat, an area of the brain called the amygdala is mobilised. The amygdala associates sensory signals (what we see, hear or smell) with emotions associated with fight or flight, such as fear or anger. The amygdala then sends a distress signal to the hypothalamus, which functions like a command centre in the brain, communicating with the rest of the body through the sympathetic nervous system. The body's response to stressors involves two major systems, one for *acute* (i.e. sudden) stressors such as personal attack, and the second for *chronic* (i.e. ongoing) stressors such as a stressful job.

Response to acute (sudden) stressors

The sympathetic nervous system

When the sympathetic nervous system (SNS) is triggered, it begins the process of preparing the body for the rapid action necessary for fight or flight. The SNS sends a signal through to the adrenal medulla, which responds by releasing the hormone adrenaline into the bloodstream.

Adrenaline

As adrenaline circulates through the body, it causes a number of physiological changes. The heart beats faster, pushing blood to the muscles, heart and other vital organs, and blood pressure increases. Breathing becomes more rapid in order to take in as much oxygen as possible with each breath. Adrenaline also triggers the release of blood sugar (glucose) and fats, which flood into the bloodstream, supplying energy to parts of the body associated with the fight-or-flight response.

The parasympathetic nervous system

When the threat has passed, the parasympathetic branch of the autonomic nervous system (ANS) dampens down the stress response. Whereas the sympathetic branch causes the heart to beat faster and blood pressure to increase, the parasympathetic branch slows down the heartbeat again and reduces blood pressure. Another benefit of parasympathetic action is that digestion (inhibited when the SNS is aroused) begins again.

Response to chronic (ongoing) stressors

If the brain continues to perceive something as threatening, the second system kicks in. As the initial surge of adrenaline subsides, the hypothalamus activates a stress response system called the **HPA axis**. This consists of the hypothalamus, the pituitary gland and the adrenal glands.

'H' – The hypothalamus

The HPA axis relies on a series of hormonal signals to keep the SNS working. In response to continued threat, the hypothalamus releases a chemical messenger, *corticotrophin-releasing hormone* (CRH), which is released into the bloodstream in response to the stressor.

'P' – The pituitary gland

On arrival at the pituitary gland, CRH causes the pituitary to produce and release *adrenocorticotrophic hormone* (ACTH). From the pituitary, ACTH is transported in the bloodstream to its target site in the adrenal glands.

'A' – The adrenal glands

ACTH stimulates the adrenal cortex to release various stress-related hormones, including cortisol. Cortisol is responsible for several effects in the body that are important in the fight-or-flight response. Some of these are positive (e.g. a quick burst of energy and a lower sensitivity to pain) whereas others are negative (e.g. impaired cognitive performance and a lowered immune response).

Feedback

This system is also very efficient at regulating itself. Both the hypothalamus and pituitary gland have special receptors that monitor circulating cortisol levels. If these rise above normal, they initiate a reduction in CRH and ACTH levels, thus bringing cortisol levels back to normal.

EVALUATION: FIGHT OR FLIGHT

The 'tend and befriend' response

Taylor *et al.* (2000) suggest that, for females, behavioural responses to stress are more characterised by a pattern of tend and befriend than fight or flight.

This involves protecting themselves and their young through nurturing behaviours (tending) and forming protective alliances with other women (befriending). Women may have a different system for coping with stress because their responses evolved in the context of being the primary caregiver of their children. Fleeing at any sign of danger would put a female's offspring at risk.

This finding, explained in terms of the higher levels of the hormone oxytocin in females, suggests that previous research, which has mainly focused on males, has obscured patterns of stress response in females.

Negative consequences of the fight-or-flight response

The physiological responses associated with fight or flight may be adaptive for a stress response that requires energetic behavioural responses. However, the stressors of modern life rarely require such levels of physical activity.

The problem for modern humans arises when the stress response is repeatedly activated. For example, the increased blood pressure that is characteristic of SNS activation can lead to physical damage in blood vessels and eventually to heart disease.

As a consequence, although cortisol may assist the body in fighting a viral infection, too much cortisol suppresses the immune response, shutting down the very process that fights infection and increasing the likelihood of stress-related illness.

'Fight or flight' does not tell the whole story

Gray (1988) argues that the first phase of reaction to a threat is not to fight or flee, but to avoid confrontation.

He suggests that, prior to responding with attacking or running away, most animals (including humans) typically display the 'freeze response'. This initial freeze response is essentially a 'stop, look and listen' response, where the animal is hyper-vigilant, alert to the slightest sign of danger.

The adaptive advantages of this response for humans are that 'freezing' focuses attention and makes them look for new information in order to make the best response for that particular threat.

A03 plus Positive rather than 'fight or flight' behaviours

Von Dawans *et al.* (2012) challenge the classic view that, under stress, men respond only with 'fight or flight', whereas women are more prone to 'tend and befriend'.

Von Dawans *et al.*'s study found that acute stress can actually lead to greater cooperative and friendly behaviour, in both men and women. This could explain the human connection that happens during times of crises such as the 9/11 terrorist attacks in New York.

One reason why stress may lead to greater cooperative behaviour is because human beings are fundamentally social animals and it is the protective nature of human social relationships that has allowed our species to thrive.

▲ Acute stress, such as that experienced in the terrorist attacks on New York in 2001, can lead to greater cooperative and friendly behaviour.

A03 plus A genetic basis to sex differences in the fight-or-flight response

Lee and Harley (2012) have found evidence of a genetic basis for gender differences in the fight-or-flight response.

The *SRY* gene, found exclusively on the male Y chromosome, directs male development, promoting aggression and resulting in the fight-or-flight response to stress. The *SRY* gene may prime males to respond to stress in this way by the release of stress hormones such as adrenaline and through increased blood flow to organs involved in the fight-or-flight response.

In contrast, the absence of the SRY *gene in females (who do not have a Y chromosome) may prevent this response to stress, leading instead to 'tend and befriend' behaviours.*

KEY TERMS

Fight-or-flight response A sequence of activity within the body that is triggered when the body prepares itself for defending or attacking (fight) or running away to safety (flight). This activity involves changes in the nervous system and the secretion of hormones that are necessary to sustain arousal.

HPA axis describes the sequence of bodily activity in response to stress that involves the hypothalamus, pituitary and adrenal cortex.

APPLY YOUR KNOWLEDGE

Consider these two stressful situations:

1. In an episode of the BBC series *The Apprentice*, one of the contestants publicly criticises one of his teammates, blaming him personally for the team's failure to successfully complete a task. As everyone's eyes turn on him, the accused contestant feels his face going red, his muscles tensing and his anger rising. He turns on his accuser, trying to contain the almost overwhelming urge to hit him.
2. Another contestant has to pitch a sales presentation to executives from a major department store. She starts hesitantly, then, as she sees the faces of the executives looking back at her, she stops mid-sentence. Her mouth goes dry and she just stands there, shaking uncontrollably and staring at her audience, wishing she could just get out of there.

Using your knowledge of the fight-or-flight response, explain what is going on in each of these examples and why the two contestants are behaving in the way that they are.

Insider tip…

Question 3 in the 'Can you?' box below asks you to 'Outline the role of adrenaline in the fight-or-flight response'. Your material for this question should be restricted to the role of the SNS on the opposite page. Although adrenaline does have a role in the regulation of the HPA axis, it is not considered a core component of this response to stress.

CAN YOU? No. 6.4

1. Explain what is meant by the term 'fight-or-flight response'. (3 marks)
2. Outline the fight-or-flight response. (6 marks)
3. Outline the role of adrenaline in the fight-or-flight response. (3 marks)
4. Discuss the fight-or-flight response. (12 marks AS, 16 marks A)