

## Human Biology 3A/3B Revision.

By Rhiannon Sander-David

**homeostasis**; the maintenance of a constant internal environment.

this means that there is a steady state for factors that are vital for the cells to maintain their optimal function.

controlled characteristics

- concentration of nutrients
- pH
- hydration
- temperature
- pressure
- oxygen levels
- fluid retention

the steady state is maintained by a dynamic equilibrium, meaning that the inputs and outputs are balanced so that there is no overall change in the levels.

the endocrine system and the nervous system work together to be able to sense changed and regulate them. this is usually achieved through a negative feedback system.

the endocrine system involves the release of hormones, the nervous system involves electrical messages.

### **feedback systems**

a negative feedback system leads to a response that opposes the original stimulus.

a positive feedback system leads to a response that enhances the original stimulus.

1. a receptor detects the stimulus and sends a message to the modulator.
2. the modulator determines the appropriate response and sends a message to the effector.
3. the effector carries out the response which changes the stimulus.

### **the nervous system**

the central nervous system is composed of the brain and spinal cord. the CNS is where incoming messages are processed and where outgoing messages are initiated.

*nerve cells and structure*

outside the CNS, the nerve fibres are arranged into bundles called nerves in which the fibres are held together by connective tissue.

nerves vary in size and shape but all consist of two types of extension, dendrites and the axon.

the cell body contains the nucleus, cytoplasm and organelles.

dendrites are short extensions of the cytoplasm and are highly branched.

the axon is a long extension of the cytoplasm and vary in length enormously.

nerve cells (neurons) are composed of a cell body with long extensions that carry messages to or from the cell body.

- dendrites carry messages to the cell
- axons carry messages away from the cell
- axons may be myelinated or unmyelinated.
- outside the brain, the myelin is formed by schwan cells, however in the CNS the oligodendrocytes form the myelin.

Myelin wraps around the axon, layering which increases the speed of a nerve impulse. it also insulates and protects.

at intervals there are gaps in the myelin sheath called nodes of Ranvier.

the outermost coil is called the neurilemma which helps repair injured fibres.

#### *types of neurons*

SENSORY    carry messages to the CNS

MOTOR            carry messages from the CNS to muscles or glands

INTERNEURONS    Are within the CNS and act as the connection between sensory and motor neurons.

MULTIPOLAR        Have one axon and multiple dendrites.

Are most of the interneurons in the CNS and motor neurons that carry messages to the skeletal muscles.

BIPOLAR            have one axon and one dendrite

Are found in the eye, ear and nose where they carry impulses from receptor cells.

UNIPOLAR        have just one axon.

make up most of the sensory neurons that carry messages to the spinal cord.

*the transmission of nerve impulses.*

opposite charges attract each other and like charges repel. opposite charges have the potential to release energy.

this potential to release energy is called the potential difference. this is measured in volts.

an ion is an atom with a charge.

- sodium has a positive charge  $\text{Na}^+$
- potassium has a positive charge  $\text{K}^+$
- chloride has a negative charge  $\text{Cl}^-$
- organic ions have a negative charge.

A separated difference in charges due to ions separated by a membrane will produce a potential difference called the membrane potential.

in an active nerve cell, there is a potential difference of 70 millivolts. this means that the potential inside the cell is 70 millivolts less than outside the cell.

this is called the resting membrane potential, when the membrane is in this state it is said to be polarized.

- sodium is semi permeable.
- chloride is permeable
- potassium is permeable
- organic ions are impermeable.

the difference in charge is maintained by the sodium potassium pump which actively transports sodium ions out the cell and potassium ions into the cell.

the large numbers of organic ions trapped inside the cell help to ensure the inside of the cell remains negatively charged as the cell membrane is impermeable to them. there are not enough positive ions to balance out this negative charge.

1. when a nerve fibre receives a strong enough stimulus it causes the sodium channels to open.
2. sodium ions are able to move along the concentration gradient into the cell.
3. the outward movement of potassium ions isn't enough to balance out the number of sodium ions moving into the cell.
4. the inside becomes positively charged and the cell is said to be depolarised.

for depolarisation to occur the stimulus has to be over 15 millivolts. this is known as the threshold and a stimulus below this level will not trigger an impulse. this is known as an all or nothing response.

the membrane quickly returns to its original potential as the gated channels close. this is repolarisation.

each action potential generates another potential adjacent to it due to the flow of the current.

this causes the progression of action potential along the nerve which is called a nerve impulse.

during the action potential and for a brief period afterwards that part of the nerve fibre cannot be stimulated again. this is called the refractory period, there is both an absolute and partial refractory period.

the absolute refractory period is straight after the impulse, while the partial refractory period is the brief period where the cell membrane recovers.

in an unmyelinated neuron the impulse travels in a domino effect kind of way.

in a myelinated neuron the impulse jumps along the nodes of Ranvier, being a quicker impulse.

### *synapse*

nerve impulses have to be passed from neurons to neuron, the junctions between adjacent neurons is the synapse.

most synapses occur between the terminal branches of an axon and dendrites or the cell body of another neuron.

neurotransmitters are released across the gap to trigger the adjacent neuron.

a similar synapse exists where an axon meets a skeletal muscle cell, this is called the neuromuscular junction.

### *peripheral nervous system*

the peripheral nervous system is made up of nerve fibres that pass impulses from the CNS and groups of nerve cell bodies, ganglia which lie outside the brain and spinal cord.

- there are 12 pairs of nerves that arise from the brain- cranial nerves
- 31 pairs of spinal nerves arise from the spinal cord
- each spinal nerve is joined to the spinal cord by two roots.
- the ventral root contains the axons of motor neurons that have their cell bodies in the gray matter of the spinal cord.
- the dorsal root contains the axons of sensory neurons that have their cell bodies in a small swelling on the dorsal root known as the dorsal root ganglion.

the nerves in the PNS connect to the CNS to receptors, muscles and glands.

### *afferent/sensory division*

carried impulses into the CNS via fibres.

it involves 1 motor neuron.

### *somatic division*

- impulses are carried by sensory nerve cells from receptors in the skin, muscles and joints.

### *visceral division*

- impulses are also carried by sensory nerve cells from internal organs.

*efferent/motor division*

carries impulses away from the CNS.

it involves two motor neurons.

*somatic division*

- takes impulses away from the CNS to the skeletal muscles.
- uses acetylcholine as a neurotransmitter.

*autonomic division*

- carries impulses from the central nervous system to the heart muscle, involuntary muscle and glands.
- controls the bodies of internal movement
- is regulated by the medulla oblongata, the hypothalamus and the cerebral cortex.
- nerve fibres of the autonomic nervous system make up parts of the cranial and spinal nerves.
- most organs under the control of the autonomic nervous system receive fibres from both the parasympathetic and the sympathetic divisions.

*sympathetic division*

- prepares the body for strenuous activity or the fight or flight response.
- increases heart rate, breathing rate and diverts blood flow to the muscles.
- the neurotransmitter is noradrenaline.

*parasympathetic*

- responsible for maintaining the body during quiet activity.
- the neurotransmitter is acetylcholine.

*protection of the central nervous system.*

the CNS is heavily protected by three structures.

bone – the cranium protects the skull and vertebrae protect the spinal cord.

membranes – the meninges consist of three layers

1. a very fibrous layer which sticks to the bone.
2. a loose mesh of fibres.
3. a delicate layer consisting of blood vessels.

cerebrospinal fluid- found between the inner and middle meninges, in cavities in the brain and in the canal in the middle of the spinal cord. it acts as a shock absorber, protection and support as well as transporting nutrients. it is formed from blood and is clear and watery.

## the brain

### the cerebellum

- is located in the cerebrum and at the back of the brain.
- it has a folded surface.
- the outer part is gray matter and the inner white matter which branches out to all parts of the cerebellum.
- it receives sensory information from the inner ear and from stretch receptors in skeletal muscles.
- all functions take place below a conscious level, impulses do not originate in the cerebellum.
- it's function is to exercise control over posture and balance as well as co-ordination of voluntary muscle movement.

### the hypothalamus.

- is found in the middle of the brain.
- it controls many bodily functions and is primarily concerned with homeostasis.
- it regulates heart rate, blood pressure, secretion of digestive juices, movement of the alimentary canal, diameter of pupils and other functions.
- secretion of hormones and coordinates parts of the pituitary gland.
- it also effect food and water intake, temperature, patterns of sleeping and waking, contraction of urinary bladder and emotional responses.

### the medulla oblongata

- is a 3 cm continuation of the spinal cord.
- all centres in the medulla oblongata are influenced and controlled by higher centres in the brain, particularly the hypothalamus.
- the cardiac centre regulates the rate and force of heart beats.
- the respiratory centre which control the rate and depth of breath.
- the vasomotor centre regulated the diameter of blood vessels.
- it also regulates sneezing, swallowing, coughing and vomiting.

### the cerebrum

- consists of an outer layer of gray matter about 2-4mm thick known as the cerebral cortex.
- below the cortex is the white matter, then an additional gray matter section is found deep inside called the basal ganglia.
- the cerebrum is heavily folded to increase its surface area.
- within the cortex are 70% of all the neurons in the central nervous system.
- the folding creates rounded ridges called convolutions.
- convolutions are separated by downfalls called fissures (deep) and sulci (shallow)
- the deepest fissure separates the right and left hemispheres of the brain and is called the longitudinal fissure.

- functions of the cerebrum include thinking, reasoning, learning, memory, intelligence and a sense of responsibility, perception of senses and initiation and control of voluntary muscle contraction.
- sensory areas interpret impulses from receptors.
- motor areas which control muscle movement.
- there are also associated areas which are concerned with intellectual and emotional responses/ processes.

the spinal cord

- contains both gray and white matter.
- ascending tracks are sensory axons and they carry impulses upwards to the brain.
- descending tracks contain motor axons which conduct impulses down and away from the brain.
- it aids in certain reflexes.

the control of movement

1. the intent to contract muscles begins in the cerebral cortex's motor association area.
2. neurons there make up the program for the sequence and intensity of muscle contractions.
3. the program is sent to the primary motor association area.
4. from there impulses are sent to the lower centres in the brain and spinal cord.

the motor association area is a large area in the front of the cortex where behaviour is planned.

the primary motor association area is like a map of the body as it contains neurons that control contractions of muscles in different parts of the body. adjacent muscles are controlled by adjacent neurons.

parts of the body that involve more muscles also have more neurons thusly.

upper motor neurons carry impulses away from the motor area. these neurons connect the brain to the appropriate level in the spinal cord.

the messages are then passed to lower motor neurons that carry the messages to the muscles.

in the medulla oblongata the fibres of most upper motor neurons cross over one another as the right side of the brain controls the left side of the body and vice versa.

the cerebellum receives impulses through the upper motor neurons. it assesses the conscious desired movement.

all input is then integrated so the muscles can move in a smooth and coordinated way.

*the spinal arch reflex*

a reflex is a rapid automatic response to a change in the external or internal environment.

1. a receptor either the ending of a sensory neuron or associated cell, reacts to a change by initiating an impulse to the sensory neuron.
2. a sensory neuron carries the impulse to the CNS.
3. the impulse is passed to a motor neuron, either directly or through an interneuron.
4. the motor neuron carries the nerve impulse to an effector.
5. an effector receives the impulse and carries out the appropriate response.

some reflexes involve the brain, however most involve the spinal cord.

the pathways an impulse follows travelling from the receptor to effector are known as the spinal arc reflex.

this does not involve the brain, thus it is involuntary. impulses may be sent to the brain so as to become aware of what is happening.

### **The endocrine system**

there are two types of glands in the body, endocrine and exocrine.

exocrine secrete into a duct that transports the secretions to the surface or a body cavity.

endocrine glands secrete hormones into extracellular fluid from which it then passes into the blood. they are also known as ductless glands.

hormones may affect all cells of the body or just target cells or organs.

cells can communicate with each other by secreting chemicals that diffuse into adjacent cells, these are known as local hormones.

hormones are only able to influence cells with the corresponding receptors.

saturation can also occur when all receptor molecules are occupied by hormone molecules therefore the addition of more hormone molecules does not achieve a greater effect.

protein and amine hormones work by attaching to receptor molecules on the target cells membrane. the combination of the hormone and receptor cause a secondary message substance to diffuse through the cell and activate similar enzymes.

steroid hormones enter the cell and combine with a receptor on an organelle, or the nucleus. the hormone receptor complex activates the genes controlling the formation of particular proteins. that being how hormones change the function of a cell, through the type or quantity of the protein they produce.

hormones extend their influence to changing the activity of enzymes or by changing the concentration.

enzyme amplification is when one hormone molecule can cause the production or activation of thousands of enzyme molecules.

once a hormone has produced its desired effect it is either broken down by the target cell or the liver and kidneys. they are then secreted in bile or urine.

*feedback loops involving hormones.*

1. a stimulus, the change in the environment
2. the stimulus is detected by sensory cells
3. the sensory cells generate a message in the form of a hormone or a nerve impulse.
4. a control centre processes the message received from the receptor
5. a new message is sent out by the modulator
6. muscles or glands receive the message from the modulator
7. the effector organs bring about an appropriate reaction
8. the response changes the original stimulus.

childbirth is an example of a positive feedback system in the endocrine system. labour is initiated by the secretion of oxytocin from the posterior pituitary which causes the contractions of the uterus.

the contractions push the baby's head against the cervix, which causes the cervix to send a nerve impulse to the brain which responds by instructing the pituitary to secrete more oxytocin.

another example is the clotting of blood.

a negative feedback loop involving hormones is the regulation of blood glucose levels in which the receptors detect an increase and insulin is then released to decrease the original stimulus of glucose by converting it to glycogen.

*the hypothalamus and the pituitary gland*

the pituitary gland is joined to the hypothalamus by a small stalk called the infundibulum.

the pituitary consists of an anterior and posterior lobe. the anterior lobe has no nerves connecting it to the hypothalamus, but is connected by a complex network of blood vessels.

the anterior lobe produces and releases hormones such as follicle stimulating hormone, luteinising hormone, growth hormone, prolactin, thyroid stimulating hormone and adrenocorticotrophic hormone.

the hypothalamus produces many hormones, some are carried by the blood to the anterior lobe where they stimulate or inhibit the release of hormones made in the anterior lobe. these are releasing and inhibiting factors, which are in fact hormones themselves.

other hormones pass along the nerve fibres from the hypothalamus to the posterior pituitary where they are secreted.

the posterior lobe releases the hormones oxytocin and antidiuretic hormone, both are manufactured in special nerve cells in the hypothalamus. these cells have long extensions that pass through the infundibulum to the posterior lobe.

the release of the hormones is triggered by nerve impulses initiated in the hypothalamus and conducted along the cell extensions.

*The thyroid gland*

the thyroid is located in the neck just below the larynx. it consists of a left and right lobe. it also has four parathyroid glands which secrete parathyroid hormone to maintain calcium and phosphate levels in the blood.

the main hormone secreted is thyroxine, which controls body metabolism by regulating cellular respiration, the process of breaking down molecules in the cells to produce energy.

the overall effect of thyroxine is to bring about the release of energy, and as a large amount of energy is released as heat, to maintain body temperature.

it is secreted in response to the thyroid stimulating hormone released from the anterior pituitary.

#### *the adrenal glands*

the two adrenal glands are attached just above each kidney, each composed of an inner medulla and outer cortex.

the adrenal medulla produces adrenaline and noradrenaline. adrenaline helps prepare the body for the fight or flight response by diverting blood flow to muscles, and increasing the heart rate. noradrenaline has similar effects but in particular increases the rate and force of the heart beat.

the hormones released from the adrenal cortex are collectively known as corticosteroids, the two main ones being aldosterone (which reduces the amount of sodium and increases the amount of potassium in the urine) and cortisol (which promotes a normal metabolism and helps the body withstand stress).

#### *hyperthyroidism and hypothyroidism*

Thyroxine, released from the thyroid gland, is secreted in response to thyroid stimulating hormone.

the thyroid secretes both T4 (thyroxine) and T3 (tri-iodothyronine) and both have the same effect.

Thyroxine affects nearly every tissue in the body by stimulating carbohydrate, protein and fat metabolism, this the secretion of thyroxine from the thyroid regulates basal metabolic rate.

An excess or deficiency in thyroxine can cause a disorder. in some cases the imbalance of thyroxine can be due to an imbalance in TSH.

#### hyperthyroidism

- is caused by too much thyroxine.
- it is also known as Graves disease.
- the enlargement of the gland is caused by an immune system reaction.
- whilst not inherited, there seems to be a genetic predisposition.
- symptoms include weightloss, increased heart rate, increased appetite, fatigue, sweating, anxiety, protruding eyeballs, hair loss, hypoglycaemia, insomnia/hyperactivity and muscles spasm/tremours.

- a diagnosis can be found with a blood test to determine the levels of TSH in the blood, a decrease is often a sign that hyperthyroidism is present as the hypothalamus would attempt to regulate the release of thyroxine.
- another test involves the patient being given a dosage of radioactive iodine, the urine is then tested for the levels of iodine that are excreted.
- furthermore a thyroid scan can be performed to see if the thyroid is enlarged.
- treatment in the short term generally takes form of anti-thyroid drugs known as thyrostatics.
- beta blockers are used to treat the symptoms involving the heart such as palpitations, tremors and anxiety as it reduces the pulse rate.
- long term treatment is more drastic involving surgery to remove all or some of the thyroid however is no longer commonly practised.
- radioiodine treatment is when radioactive iodine is given to the patient orally. it works to restrict or destroy functions of an overactive gland and has a high success rate.
- a negative consequence of this treatment is hypothyroidism.

#### hypothyroidism

- is caused by too little thyroxine and is more common than hyperthyroidism.
- it occurs either through problems with the gland or due to problems with the pituitary gland or hypothalamus.
- a deficiency of iodine in a diet can prevent the thyroid from making enough hormone.
- a common form is Hashimoto's disease where the lack of iodine causes an attack on the thyroid by the immune system.
- the removal of the thyroid can also cause hypothyroidism.
- symptoms include the enlargement of the gland, slowing heart rate, weight gain, amenorrhoea, muscle hypotonia, cold intolerance, colour sensitivity, depression, brittle nails, thin hair, decreased sweating, joint pain, muscle cramps, dry puffy skin and coarseness of voice.
- hypothyroidism is diagnosed by measuring TSH levels in the blood, an increase is usually a sign.
- it is often found when testing for anemia and if using anti-depressants it is often determined that they have hypothyroidism.
- the only form of treatment is thyroid tablets of thyroxine and tri-iodothyronine that can be taken daily.
- supplementary diet vitamins can assist with the slowed metabolism and immune system.

#### diabetes

- a diabetic either does not produce enough insulin or their cells have become abnormally resistant to the effects of the hormone.
- if a person produces insufficient insulin or their cells are resistant to the effect, the amount of glucose in the blood remains high and they excrete large quantities in the urine.
- type one occurs because of a fault in the patient's immune system which causes the destruction of Beta cells in the islets of Langerhan

- the Beta cells can no longer produce insulin, however their cells still respond to insulin, thus the disease can be managed by giving the patient insulin.
- long term effects are likely to be kidney failure, heart attack, stroke, amputations, blindness or nerve damage.
- type two patients are able to produce insulin however their cells are not responsive to it, this is known as a lifestyle disease.
- lifestyle factors causing diabetes include obesity, lack of physical activity, high blood pressure, high cholesterol and smoking.

*risks, ethical concerns and benefits of treatments*

all treatments come with a weighted risk factor, these risks may be minor or serious, long term or short term and may result from the treatment itself or the way it is administered.

treatments may also cause moral or ethical dilemma for patients, for example hormonal contraceptives may cause problems for women who hold certain religious beliefs.

the medical provider must disclose all significant risks of a proposed medical procedure as well as any risks that would be of concern to a patient, this is a legal requirement and an ethical obligation.

furthermore the side effects of a treatment may seriously impact upon a patient's enjoyment of life, such as an infertile couple receiving IVF and then being unable to deal with triplets as a result, causing both parents to become stressed and placing them in a situation they are incapable of handling.

**the nervous system vs. the endocrine system.**

while the nervous system is a quicker system to respond to a stimulus, the endocrine system has a longer lasting effect than the nervous system.

the nervous system uses nerves and nerve impulses to detect and then respond to a change whereas the endocrine system can use either a nerve impulse or a hormone to detect a change and then release a hormone as a response.

the nervous system is able to produce a more specific response as it can influence each specific neuron, for example in conscious movement each neuron in the brain is able to influence a specific muscle. the endocrine system may have a target organ or structure however this is broader, furthermore some hormones can influence almost all cells while a nerve impulse has a set path.

*feedback systems (for example, the hormonal control of water regulation)*

<b>STIMULUS</b> →	<b>RESPONSE</b> ↓
the water concentration of blood plasma decreases	the change is detected by osmoreceptors in the hypothalamus.
<b>EFFECTOR</b> ↑	<b>MODULATOR</b> ←
more water is retained thus the blood fluid levels are increased.	the posterior pituitary is stimulated to release antidiuretic hormone which stimulates water release from the kidneys by increasing the

	permeability of the tubules to increase.
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### *thermoregulation*

thermoregulation is maintaining the balance between heat production and heat loss.

the normal body temperature of 37 degrees is required for cellular reactions to occur at an optimum level.

most of the energy from cellular respiration is released in the form of heat.

- many factors such as exercise, stress and body temperature effect the metabolic rate. the metabolic rate increases in times of stress because of the activities of the autonomic division of the nervous system. when an individual is suffering from fever their metabolic rate may be double that of normal.

the stimulation of sympathetic nerves releases noradrenaline from the nerve endings, noradrenaline increases metabolic activity of cells.

the body has temperature receptors called thermoreceptors. those in the skin and some in mucous membranes are called peripheral thermoreceptors. others are located in the hypothalamus and are called central thermoreceptors.

peripheral thermoreceptors

- provide the hypothalamus with information about the external environment.
- there are cold and heat receptors.
- when either are stimulated the hypothalamus receives information and initiates either heat conservation and production mechanisms or mechanisms to reduce heat production and increase heat loss.

central thermoreceptors.

- are located in the hypothalamus and other internal locations such as the spinal cord and abdominal organs.
- all are connected by the hypothalamus.
- nerve impulses sent out by the hypothalamus control activities that help to either increase or decrease body temperature.

the skin

- blood vessels carry heat to the skin from the core of the body, heat can then be lost from the skin by conduction, convection, radiation and evaporation.
- the diameter of blood vessels rising to the skin is controlled by autonomic nerves which can act to increase or decrease the flow of blood to the surface.
- through this influence the autonomic nerves can either increase or decrease the rate of heat loss.
- when large amounts of body heat must be lost and blood vessels are already dilated to their maximum capacity, sweating must occur.

- sweating can be defined as the active secretion of fluid by the sweat glands and the periodic contraction of cells surrounding the ducts to pump the sweat to the skin surface.
- the evaporation of sweat from the skin has a cooling effect; heat is removed when liquid sweat changes to vapour.
- the cooling of the skin results in a cooling of the blood.
- even in the absence of sweating, there is a continued loss of water by evaporation from external body surfaces.
- this evaporation, along with the water that is evaporated from the respiratory passages and lungs accounts for a considerable proportion of the daily heat loss from the body.

to prevent the body temperature from falling, the body has several mechanisms it employs.

1. vasoconstriction which is stimulated by impulses from the hypothalamus to the sympathetic nerves.
2. the adrenal medulla is stimulated by the hypothalamus to release more adrenaline and noradrenaline which speeds up the metabolic rate.
3. shivering is stimulated by the hypothalamus sending stimuli to parts of the brain that increase skeletal muscle tone, this leads to the rhythmic muscle tremors which increase metabolic rate.
4. thyroxine production is increased to increase the metabolic rate through the stimulation of the anterior pituitary gland which secretes more thyroid stimulating hormone.
5. behavioural responses can occur, such as putting on a jumper or moving to a warmer area.

the body also has many ways to prevent the core temperature from rising.

1. vasodilation due to impulses from the hypothalamus to the parasympathetic nerves and heat is lost through radiation and convection.
2. sweating can occur however it requires a low humidity to be effective.
3. a reduction in thyroxine production caused by a lowering of the production of thyroid stimulating hormone slows the metabolic rate decreasing heat production.
4. behavioural responses such as removing clothing and moving to a cooler area.

in either situation, the body will employ two kinds of mechanisms; a mechanism to reduce the stimulus such as decreasing heat loss when cold, and mechanisms to increase the opposite temperature such as increasing heat production when cold.

