AQA Biology GCSE

Topic 5: Homeostasis and Response

Notes

(Content in bold is for higher tier only)

Homeostasis (5.1)

Homeostasis is the maintenance of a constant internal environment. Mechanisms are in place to keep optimum conditions despite internal and external changes. This is needed for enzyme action and all cell functions.

In the human body, homeostasis controls:

- Blood glucose concentration
- Body temperature
- Water levels

Nervous and hormonal communication is involved in the automatic control systems, which detect changes and respond to them.
All control systems have:

- Receptors - cells that detect stimuli (changes in the environment)
- Coordination centres - process the information received from the receptors, e.g. brain, spinal cord and pancreas
- Effectors - bring about responses to bring the conditions in the body back to optimum levels, e.g. muscles or glands

The Human Nervous System

Structure and Function (5.2.1)

The nervous system allows us to react to our surroundings, and coordinate actions in response to stimuli.

1. Receptor cells convert a stimulus into an electrical impulse.
2. This electrical impulse travels along cells called sensory neurons to the central nervous system (CNS).
3. Here, the information is processed and the appropriate response is coordinated, resulting in an electrical impulse being sent along motor neurones to effectors.
4. The effectors carry out the response (this may be muscles contracting or glands secreting hormones).

Automatic responses which take place before you have time to think are called reflexes. They are important as they prevent the individual from getting hurt. This because the information travels down a pathway called a reflex arc, allowing vital responses to take place quickly. This pathway is different from the usual response to stimuli because the impulse does not pass through the conscious areas of your brain.

1. A stimulus is detected by receptors.
2. Impulses are sent along a sensory neuron.
3. In the CNS the impulse passes to a relay neuron.
4. Impulses are sent along a motor neuron.
5. The impulse reaches an effector resulting in the appropriate response.

Examples of reflex arcs are: pupils getting smaller to avoid damage from bright lights, moving your hand from a hot surface to prevent damage.

Synapses are the gaps between two neurons.

- When the impulse reaches the end of the first neuron, a chemical is released into the synapse.
- This chemical diffuses across the synapse.
- When the chemical reaches the second neuron, it triggers the impulse to begin again in the next neuron.

Your reaction time is how long it takes you to respond to a stimulus. It can be measured with the ruler drop test.

The Brain (Biology Only) (5.2.2)

The brain is made up of many connected neurons and controls complex behaviour. It is a part of the central nervous system, along with the spinal cord. Different regions control different functions.

Components of the brain:

1. Cerebral cortex: controls consciousness, intelligence, memory and language; it is the outer part of the brain
2. Cerebellum: controls fine movement of muscles; rounded structure towards the bottom/back of brain
3. Medulla: controls unconscious actions such as breathing and heart rate,; found in the brain stem in front of the cerebellum

Investigating brain function and treating brain damage and disease is difficult because:

- **It is complex and delicate**
- **It is easily damaged**
- **Drugs given to treat diseases cannot always reach the brain because of the membranes that surround it**
- **It is not fully understood which part of the brain does what**

Neuroscientists (those that study the nervous system) can map out the regions of the brain using a number of methods:

1. **Studying patients with brain damage**
   Observing the changes in an individual following damage on a certain area of the brain can provide information on the role this area has.
2. **Electrically stimulating different parts of the brain**
   This can be done by pushing an electrode into the brain. The stimulation may result in a mental or physical change in the individual, providing information on the role this area of the brain has.
3. **Using MRI scanning techniques**
   A magnetic resonance imaging scanner can be used to create an image of the brain. This can be used to show which part of the brain is affected by a tumour, or which part is active during a specific task.

The Eye (5.2.3)
(Biology Only)

The eye is a sense organ containing receptors sensitive to light intensity and colour. It has many different structures within it. They are adapted to allow the eye to change its shape in order to focus on near or distant objects (a process called accommodation), and to dim light.

1. Retina: Layer of light sensitive cells found at the back of the eye.
   When light hits this, the cells are stimulated. Impulses are sent to the brain, which interprets the information to create an image.
2. Optic nerve: A nerve that leaves the eye and leads to the brain.
   It carries the impulses from the retina to the brain to create an image.
3. Sclera: White outer layer which supports the structures inside the eye.
   It is strong to prevent some damage to the eye.
4. Cornea: The see-through layer at the front of the eye.
   It allows light through and the curved surface bends and focuses light onto the retina.
5. Iris: Muscles that surround the pupil
   They contract or relax to alter the size of the pupil.
   In bright light, the circular muscles contract and radial muscles relax to make the pupil smaller- avoiding damage to the retina.
   In dim light, the circular muscles relax and the radial muscles contract to make the pupil larger- so more light can enter to create a better image.
6. Ciliary muscles and suspensory ligaments: Hold the lens in place
   They control its shape.

The process of accommodation:

To focus on a near object:
- The ciliary muscles contract
- The suspensory ligaments loosen
- The lens is then thicker and more curved- this refracts the light more

To focus on a distant object
- The ciliary muscles relax
- The suspensory ligaments tighten
- The lens then becomes thinner- light is refracted less

Eye defects occur when light cannot focus on the retina.

1. Short sightedness is called myopia.
   - The lens is too curved, so distant objects appear blurry.
2. Long sightedness is called hyperopia.
   - The lens is too flat, so it cannot refract light enough.

There are a number of treatment methods:
- They can be treated with spectacle lenses- concave lenses to spread out the light to treat myopia and convex lenses to bring the rays together to treat hyperopia
- Contact lenses- work in the same way as glasses but allow activities such as sport to be carried out, hard or soft contact lenses last for different lengths of time

- Laser eye surgery- lasers can be used to either reduce the thickness of the cornea (so it refracts light less) to treat myopia or change its curvature (so it refracts light more strongly) to treat hyperopia
- Replacement lens- Hyperopia can be treated by replacing the lens with an artificial one made of clear plastic (or adding the plastic on top of the natural lens). The risks include damage to retina or cataracts developing.

Control of Body Temperature (5.2.4)
(Biology Only)

The thermoregulatory centre which monitors and controls body temperature is found in the brain.

- Has receptors that monitor the temperature of the blood
- Has receptors in the skin that send impulses to the thermoregulatory centre

Human body temperature is 37.5 degrees celsius.
If it becomes too high:

- Sweat (evaporates from skin surface resulting in increased energy transfer away from body) is produced from sweat glands
- Vasodilation means more blood flows closer to the surface of the skin, resulting in increased energy transfer from the body

If it decreases too much:

- Sweating stops
- Skeletal muscles contract rapidly (shivering) to generate heat from respiration
- Hairs stand on end to create an insulating layer, trapping warm air
- Vasoconstriction means blood does not flow so close to the surface, resulting in less heat lost

You need to be able to explain how these mechanisms work in a given context/situation.

Hormonal Coordination in Humans

Human endocrine system (5.3.1)

The human body has two communication system- the nervous system and the endocrine system. The endocrine system sends hormones (chemical messengers) around the body. When they reach a target tissue they produce a response.

It is made up of glands which secrete hormones directly into the bloodstream.

- Pituitary gland
  - The master gland
  - Secretes hormones into the blood to either have an effect on the body or act on other glands to stimulate them to produce different hormones
- Pancreas
  - Secretes insulin
  - Controls blood glucose levels
- Thyroid
  - Secretes thyroxine

    - Controls metabolic rate, heart rate and temperature
- Adrenal gland
    - Secretes adrenaline
    - Involved in the 'fight or flight' response (the body's response to stressful situations)
- Ovary
    - Secretes oestrogen
    - Is involved in the menstrual cycle and the development of female secondary sexual characteristics (different features that develop during puberty that distinguish a female from a male)
- Testes
    - Secretes testosterone
    - Is involved in the production of sperm and the development of male secondary sexual characteristics

The blood transports the hormone to a target organ or tissue where it has an effect.

Compared to the nervous system, the hormonal system is much slower but it acts for longer.

Control of Blood Glucose Concentration (5.3.2)

The concentration of glucose in your blood needs to be kept within a certain limit because glucose is needed by cells for respiration. It is controlled by the pancreas.

Eating foods that contain carbohydrates increases the glucose levels in the blood.

- If the glucose levels are too high, the pancreas produces the hormone insulin
- Insulin binds to cell in target organs (muscles and liver) causing:
    - 1) Glucose to move from the blood into muscle cells for respiration
    - 2) Excess glucose to be converted into glycogen which is stored in the liver
- The blood glucose concentration is reduced

Rigorous activity, e.g. exercise, uses glucose for respiration and therefore there is less in the blood.

- **If glucose levels decrease, the pancreas produces the hormone glucagon**
- **Glucagon binds to to the liver cells causing glycogen to be broken down into glucose**
- **Glucose is released into the blood, increasing the blood glucose concentration**

Your blood glucose concentration is kept constant through using these two hormones. They work in a negative feedback loop.

- **When blood glucose levels increase/decrease, a hormone is secreted to oppose the change.**
- **The action of this hormone cannot occur continually because when the blood arrives at a certain glucose concentration the other hormone is produced, resulting in the opposite effect.**

When you have diabetes you cannot control your blood glucose level.

1. Type 1 diabetes: the pancreas cannot produce enough insulin
    - Blood glucose level can rise to a fatal amount
    - Glucose is excreted with urine and lots of urine is produced leaving the individual very thirsty
    - It is treated with insulin injections at meal times, which results in glucose being taken up from the bloodstream
    - It is also advised to limit the intake of simple carbohydrates which contain lots of glucose
    - Doctors are attempting to cure diabetes with pancreas and pancreatic cell transplants, and genetically engineering pancreatic cells from mice to make insulin
2. Type 2 diabetes: the body cells no longer respond to insulin
    - Blood glucose levels can rise to a fatal amount
    - Obesity is a risk factor for this disease
    - Treatments include reducing the number of simple carbohydrates in diet, losing weight and increasing exercise
    - There are also drugs to make insulin more effective on body cells, help the pancreas make more insulin or reduce the amount of glucose absorbed from the gut

Maintaining Water and Nitrogen Balance in the Body (5.3.3) (Biology only)

Osmosis is the process by which water molecules move from a place where they are in high concentration to a place where they are in low concentration.

- If the water concentration of the blood increases then cells in the body take up water.
- This is because the concentration of water in the bloodstream is higher than the concentration of water in the cells, so water moves into the cells by osmosis.
- Cells then expand as they take up more water, and may eventually burst.

- If the water concentration of the blood decreases then cells in the body lose water.
- This is because the concentration of water in the bloodstream is lower than the concentration of water in the cells, so water moves out of the cells by osmosis.
- Cells shrink as they lose water.

If body cells lose or gain too much water by osmosis, they do not function properly.

The Kidneys

The kidneys are very important in maintaining the balance of water and other substances in the body. As blood moves through the body, it makes urine by:

- Filtering out the waste products
- Selectively reabsorbing useful substances such as glucose, ions and water

Examples of waste products that are processed at the kidney include water, ions and urea.

1. Water
    - Can also leave the body at the lungs as a result of exhalation, or from the skin in sweat (there is no control over the amount lost)
    - Depending on the concentration of water in the blood, a certain amount of water is lost as urine
2. Ions
    - They are taken into the body via food
    - If the ion concentration is incorrect, then too little or too much water may enter body cells. This is because the water potential of the blood would be altered
    - They are lost in sweat (there is no control over the amount lost)
    - In the kidneys, certain amounts of ions are reabsorbed into the blood after it has been filtered to ensure the concentration in the blood is maintained
3. Urea
    - Amino acids are the products of the digestion of proteins. Amino acids are deaminated in the liver to form ammonia. As ammonia is toxic it is converted to urea.
    - It is lost in sweat (there is no control over the amount lost)
    - In the kidneys, it is filtered out of the blood

Anti-diuretic hormone (ADH) is a hormone involved in the control of the loss of water as urine.
It is released into the pancreas by the pituitary gland when a receptor in the brain detects that the blood is too concentrated.

- **It travels in the bloodstream to the kidney tubules**
- **An increased amount of ADH reaching the tubules increases their permeability to water, so more moves out of the tubule and back into the bloodstream**
- **This results in a smaller volume of more concentrated (yellow) urine and the blood becoming less concentrated as more water moves into it.**

This is an example of a negative feedback loop, because if the concentration of the blood increases/decreases, more/less ADH is secreted to reverse this change.

Kidney failure is when your kidneys stop working.
This means waste products build up which can be harmful to the body, and eventually results in death.
There are two ways to treat people with kidney failure.

1. Dialysis: the function of the kidneys is carried out using an artificial membrane
    - Blood moves between partially permeable membranes surrounded by dialysis fluid (has the same concentrations of ions and glucose as healthy blood).
    - Useful ions and glucose are not lost from the blood but urea, excess ions and water diffuse across the membrane.
    - It has to be done three times a week, with the process itself taking three to four hours.
    - It acts as an artificial kidney and keeps people alive while they wait for a transplant.
    - The problems of dialysis are the possibility of blood clots forming, the amount of time it takes and the fact you have to follow a strict diet. It is also an unpleasant

experience, and the build up of waste products between sessions can leave you feeling ill.

2. Kidney transplants: providing the individual with a healthy kidney
    - This is currently the only cure.
    - They are transplanted from people who have died suddenly, or from people still alive (as we have two and only need one to survive).
    - They mean that the person does not need to visit the hospital as regularly as they did when undergoing dialysis, and it is cheaper than the overall cost of dialysis.
    - The main problem is that they could be rejected from the body as a result of the immune system recognising the antigens on the donor organ as foreign. The chance of this happening can be reduced by using immunosuppressant drugs.
    - However, this means that the person can be left vulnerable to other diseases. In addition, transplanted kidneys do not last forever.

Hormones in Human Reproduction (5.3.4)

During puberty, reproductive hormones begin to be released. These causes secondary sexual characteristics to develop in men and women and eggs to mature in women.

The main male reproductive hormone is testosterone.

- Produced by the testes
- Stimulates sperm production

The main female reproductive hormone is oestrogen.

- Produced in the ovary
- Produces physical changes and is involved in the menstrual cycle

The menstrual cycle is the process the body undergoes each month to prepare for a potential pregnancy.
It begins with the lining of the uterus breaking down, and the woman has her period.
The layer then builds up again, until ovulation (day 14) occurs- an egg is released from the ovary and moves to the uterus via the fallopian tube.
If a fertilised egg has not been embedded in the lining after 28 days, it begins to break down and the cycle continues.

The events of the cycle are controlled by four hormones.

1. Follicle stimulating hormone (FSH) causes the maturation of an egg in the ovary, within a structure called a follicle
    - Produced in the pituitary gland
    - **Stimulates the ovaries to produce oestrogen**
2. Oestrogen causes the lining of the uterus to grow again
    - Produced in the ovaries
    - **Secreted as a result of FSH**
    - **Stimulates the production of LH and inhibits the secretion of more FSH**
3. Luteinising hormone (LH)
    - Produced in the pituitary gland

- **Produced as a result of the hormone oestrogen**
- Its release results in ovulation

4. Progesterone
    - Produced in the ovaries and secreted from the egg follicle.
    - Maintains the lining of the uterus, and supports a pregnancy if the egg is fertilised
    - **Inhibits the release of both FSH and LH**

Contraception (5.3.5)

Hormonal methods of contraception

The contraceptive pill must be taken regularly or the bodies own hormones will be released, leading to an egg maturing.

- The mixed pill contains oestrogen and progesterone
    - This means the oestrogen levels are constantly high, inhibiting FSH so no eggs mature.
    - The lining also stops developing and the mucus in the cervix becomes thick so sperm cannot move through
    - Some possible side effects include changes in mood, mood swings, depression, breast pain or tenderness, breast enlargement, increased blood pressure.
- The progesterone only pill
    - This has less side effects in comparison to the mixed pill.

The contraceptive patch contains oestrogen and progesterone.

- It is small and is stuck on the skin
- Lasts for one week

The contraceptive implant releases a continuous amount of progesterone.

- This prevents the ovaries from releasing the egg, thickens the mucus in cervix so sperm cannot swim and stops fertilised eggs from embedding in the uterus
- Lasts for three years

The contraceptive injection is made up of progesterone.

- Same effect as the implant
- Lasts for 2 to 3 months

The plastic intrauterine device (IUD) releases progesterone.

- Same effect as the implant
- T shaped, inserted into the uterus

Non-hormonal methods of contraception

These stop sperm fertilising the egg.

- Chemical methods involve spermicides. These kill or disable sperm, but are only 70% to 80% effective.
- Barrier methods include condoms and diaphragms:
    - Condoms are either worn over the penis or are inside the vagina. They also prevent the individual from contracting sexually transmitted diseases. A problem is that it can tear and therefore let sperm through.
    - A diaphragm is a plastic cup which is positioned over the cervix. It is used with spermicide.

The copper intrauterine device works by killing sperm in the uterus and stopping any fertilised embryos from implanting in the uterus lining.

Surgical methods of male and female sterilisation involve cutting and tying the fallopian tubes or sperm duct. This lasts forever.

Abstaining from intercourse ensures that an egg is not fertilised. Others may only abstain during ovulation.

The Use of Hormones to Treat Infertility (5.3.6)

Fertility drugs are used to increase the chance of pregnancy.

- **The main hormones used are FSH and LH because they stimulate the maturation and release of the egg.**
- **The woman can then become pregnant normally.**

In Vitro Fertilisation (IVF) is another treatment.

- **The mother is given FSH and LH to encourage the maturation eggs**
- **These are extracted from the mother and fertilised in the lab using sperm**
- **The fertilised eggs develop into embryos and then one or two are inserted in the uterus**

Benefits	**Cons**
Provides a way for an infertile couple to have a child.	**It is physically stressful as women may have reactions to the hormones, such as feeling sick.**
	It is emotionally stressful because it may not work- success rate for IVF is 26%.
	It can lead to multiple births- unexpected and may be a risk to the babies and the mother.
	Can be expensive if the process needs to be repeated.

Negative Feedback (5.3.7)

As discussed earlier, negative feedback is when the body responds to an increase or decrease in a factor by returning it back to its original level.

Thyroxine regulates metabolic rate (how quickly reactions occur). It is also important in growth and development.

- **Released by the thyroid gland**
- **Its release is stimulated by the thyroid stimulating hormone**

The levels of thyroxine are controlled by negative feedback.

- **When the levels increase, it is detected by receptors in the brain**
- **This inhibits the release of TSH**
- **This inhibits the release of thyroxine, so levels fall**

Adrenaline is produced in times of stress, and stimulates the 'fight or flight' response

- **Released by the adrenal glands (on top of the kidneys)**
- **This is stimulated by fear or stress, detected in the brain**
- **The effects of adrenaline include:**
  - **Increased heart rate and breathing rate to deliver more oxygen and glucose to the brain and muscles for respiration**
  - **Glycogen stored in liver is converted to glucose for respiration**
  - **Pupils dilate to let in more light**
  - **Blood flow to muscles is increased**
  - **Blood flow to digestive system is decreased**

Plant Hormones (Biology Only)

Control and Coordination (5.4.1)

Plants need hormones to coordinate and control growth. They are needed for tropisms. Examples of these include phototropism, the response to light, and gravitropism or geotropism, the response to gravity. Hormones move from the place they are made to where they are needed in order to produce the appropriate response.

Most plants show positive phototropism because they grow towards the light source.

- The plant is exposed to light on one side.
- Auxin, a hormone, moves to the shaded side of the shoot.
- Auxin stimulates cells to grow more here.
- This means the shoot bends towards the light.
- The plant receives more light, meaning photosynthesis can occur at a faster rate.

Most shoots show negative gravitropism as they grow away from gravity. If a shoot is horizontal:

- Auxin moves to the lower side.
- The cells of the shoot grow more on the side with most auxin, so it stimulates cells to grow more here.
- This makes the shoot bend and grow away from the ground.
- This is beneficial as light levels are likely to be higher further away from the ground.

Most roots show positive gravitropism as they grow towards gravity. If a root is horizontal:

- Auxin moves to the lower side.
- The cells of the root grow more on the side with less auxin, so it stimulates cells to grow on the upper side.
- This makes the root bend and grow downwards.
- This is beneficial as there are more likely to be increased levels of water and nutrients lower down, and it provides stability for the plant.

When the auxin distribution becomes equal on both sides it grows straight in that directions.

You can investigate the effect of light or gravity on newly germinated seedlings by varying conditions.

- Placing in cardboard box and shining light from one side
- Attaching a petri dish containing the seedlings to a wall (effects of gravity)

Two other plant hormones are gibberellins and ethene.

- **Gibberellins are important to stimulate seed germination.**
- **Ethene is involved in cell division and the ripening of fruits.**

Use of Plant Hormones (5.4.2)

Humans can use plant hormones to alter plant growth. They are used in areas such as agriculture and horticulture for many reasons: to increase yield, obtain desirable features and to lower costs.

<u>Auxin</u>

1. **As weed killers**
    - **Many weeds are broad-leaved**
    - **Weedkillers, containing auxin, have been synthesised so they only affect broad-leaved plants**
    - **The increased amount of auxin causes the cells to grow too rapidly**
    - **This results in the weed dying**
2. **As rooting powders**
    - **Plants with desirable features are cloned to make more plants with the same feature**
    - **One way to clone a plant is to take a cutting from the original plant**
    - **Rooting powder containing auxin is applied to it and it is placed in the ground**
    - **Roots grow and the new plant begins to grow very quickly**

3. **To promote growth in tissue culture**
    - **Another way to clone a plant is to use tissue culture**
    - **Cells from the plant are taken are placed in a growth medium containing lots of nutrients**
    - **Hormones such as auxins are added**
    - **The cells begin to form roots and shoots**

As ethene controls ripening, it is used in the food industry.

- **Fruit is picked when it is not ripe**
- **It is firm which means that during transport it gets less bruised and damaged**
- **When it is needed to be sold, it is exposed to ethene and warmer temperatures**
- **Ethene is involved in controlling cell division and stimulates enzymes that result in fruit ripening.**
- **This reduces wastage as more fruit is suitable to be sold and it does not ripen too early**

Gibberellins are used for:

1. **Ending seed dormancy**
    - **In the brewing industry, the germination rate of barley seeds is increased to make malt.**
2. **Promoting flowering**
    - **Instead of requiring certain conditions such as longer days and low temperatures to flower, applying this hormone allows it to flower in any conditions and with bigger flowers.**
3. **Increasing fruit size**
    - **The seeds in fruit produce gibberellins to increase fruit size.**
    - **This means that seedless fruit is generally smaller.**
    - **Seedless fruit can be sprayed with gibberellins to increase their size.**