Edexcel Biology GCSE

Topic 7: Animal Coordination, Control and Homeostasis

Notes

(Content in **bold** is for higher tier only)

CONTENTS

7.1 - Hormones

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.

7.2 - **Higher Only** Adrenaline and the Fight-or-Flight response

Adrenaline is a hormone that is produced by the adrenal glands to prepare the body for a flight or flight response. A flight-or-flight response is the body's response to a dangerous situation: historically this would have been being confronted by a dangerous animal, for example.

Aspects of the fight or flight response include:

- **Increased heart rate: this allows oxygen to reach the muscles more quickly, so we can move out of the path of danger**
- **Increased blood pressure: as above.**
- **Increased blood flow to muscles: blood vessels leading to vessels dilate (widen) to allow more blood to reach them. This allows them to contract with greater strength, and more quickly.**
- **Increased blood sugar levels: the liver is stimulated to break down glycogen (a storage molecule) into glucose, which muscles can use to contract.**

7.3 - **Higher Only** Thyroxine and Metabolic Rate

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

- **Low levels of thyroxine stimulate production of a hormone called TRH in the hypothalamus**
- **TRH causes the release of TSH from the pituitary gland**
- **TSH acts on the thyroid to produce thyroxine**
- **When thyroxine levels have reached the normal level, thyroxine inhibits the release of TRH, which stops the production of TSH.**

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 of thyroxine fall**

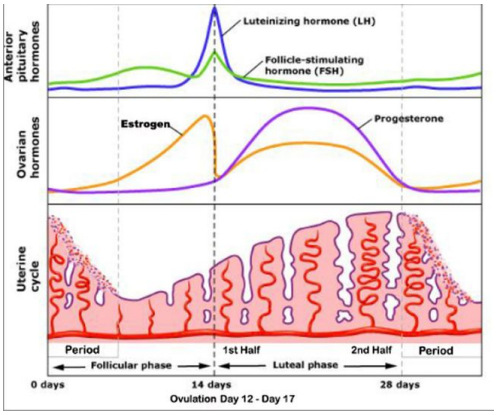
7.4 and 7.5 - The Menstrual Cycle

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.

****Higher Only****

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**



7.6 and 7.7 - Hormonal Contraception and Evaluating Methods of Contraception

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 1 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 3 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
- Lasts for 5 - 10 years

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 placed inside the vagina. They also help prevent the individual from contracting sexually transmitted diseases. A problem is that they 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. These are often permanent procedures but in some cases can be reversed.

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

7.8 - **Higher Only** IVF and Assisted Reproductive Therapy (ART)

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.
- Another drug used is called clomiphene. This increases the amount of FSH and LH released from the hypothalamus, increasing the chance that a woman will ovulate.

In Vitro Fertilisation (IVF) is another treatment.

- The mother is given FSH and LH to encourage the release and maturation of 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
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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.

7.9 and 7.10B - Homeostasis and its Importance

Homeostasis is the **maintenance of a constant internal environment.** Mechanisms are in place to keep conditions optimal and constant **despite internal and external changes**. Homeostasis is important to maintain enzyme action and all cell functions - including **growth, replication** and **controlled cell death**.

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

Biology Only

Thermoregulation is the act of **keeping internal body temperature constant**. This is important because if the temperature exceeds the optimum level of **37 degrees Celsius**, enzymes will gradually **become less effective** and eventually **denature** (irreversibly change shape)

Osmoregulation is the act of keeping the **concentration of the blood** (i.e the level of solutes in the blood) **at a constant level**. If the blood becomes too dilute, water will move into cells by **osmosis** and they will swell, eventually **bursting under the pressure**. If the blood becomes too concentrated, water will move out of cells and they will shrink.
In either case, they cannot perform their function so it is vital that the blood remains the same concentration via osmoregulation.

7.11B - **Biology Only** Thermoregulation and 7.12B - **Higher and Biology Only** Thermoregulation and Blood Vessels

The **thermoregulatory centre** which monitors and controls body temperature is found in the **hypothalamus** of 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. Note that sweat glands are located in the **dermis** layer of the skin. The sweat is released onto the surface of the **epidermis.**
- **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.

7.13 - Insulin and 7.14 - **Higher Only** Glucagon

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.

Glucagon

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.**

7.15 and 7.16 - Causes and Control of Diabetes

Diabetes is a disease where the body cannot control blood sugar levels properly.
Type 1 diabetes: the pancreas cannot produce enough insulin. This condition is **congenital (usually from birth/a young age).**

- 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

Type 2 diabetes: the body cells no longer respond to insulin. This condition is **acquired (usually occurs later in life).**

- 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

7.17 - Body Mass and Diabetes Risk

A Body Mass Index over 30 is generally considered as a definition for **obesity**. Obesity, and indeed being overweight, are considered risk factors for developing **Type 2 Diabetes.** In fact, as body mass increases the risk of developing Type 2 diabetes increases significantly.

As a reminder, body mass is calculated using the following formula:

$$\text{BMI} = \frac{\text{mass (kg)}}{(\text{height (m)})^2}$$

Waist-hip measurements can also be used to evaluate body mass, and therefore a person's risk for developing type 2 diabetes. A **doctor** might advise somebody who is at risk of Type 2 diabetes to take a **glucose tolerance test** to examine how well their body can produce **insulin** when it is needed.

7.18B - **Biology Only** Structure of the Urinary System

The urinary system is the bodily system that removes impurities and waste products from our blood. These impurities are **excreted in urine.** Its main organ is the **kidney.** We have two kidneys, one on the left and one on the right - they are located in the **lower back (lumbar) region**.

The route that blood takes to be purified is as follows:

1. Blood containing impurities travels in the **renal artery** to the kidneys.
2. The kidneys regulate the levels of salt, ions and **urea** in the blood. Any excess is sent to the **ureter** for excretion, and eventually the **bladder**.
3. The purified blood returns to the circulation by way of the **renal vein.**

Structure of the kidney

- The inner part of the kidney is called the **medulla** and the outer part is called the **cortex**.
- The **ureter** carries from kidneys to the bladder to be excreted out the body.
- The kidney is supplied by the **renal artery** and a **renal vein** takes blood away.
- Each kidney contains millions of kidney tubules or nephrons and these are made up of a **glomerulus** (ball of capillaries), a region for selective reabsorption of substances to occur and a kidney tubule where water and salt is regulated.

7.19B - **Biology Only** Structure and Function of the Nephron

The kidney contains over a million small units called nephrons. The structure of the **nephrons** of the kidney are closely related to their function:

1. Filtration - filtration, or **ultrafiltration,** occurs in the **glomerulus**, a collection of capillaries (small blood vessels) at the start of the nephron. Urea, water, ions and glucose are small enough to pass out of the capillaries into the **Bowman's capsule -** however proteins and cells are too large, and remain in the blood).

2. Selective reabsorption of glucose and ions - The substances in the Bowman's capsule move into the tubule. At a point called the **proximal convoluted tubule** (the first 'bend' in the tubule), as much glucose as was lost during ultrafiltration is **selectively** reabsorbed into the blood.
    - This is important, as glucose is valuable to the body for energy (from respiration) and we do not want it to be excreted.
3. Reabsorption of water and ions - water and ions are reabsorbed at the **Loop of Henle** and **collecting duct** areas of the tubule. This process is tightly controlled according to the osmotic pressure of the blood (see next section.)

7.20B - **Higher and Biology Only** ADH and the Collecting Duct

ADH (antidiuretic hormone) is a hormone that is produced by, and released from, the pituitary gland in the brain. It is released into the bloodstream and travels from the brain to the kidney. It has special effects on the collecting duct of the nephron that relate to the water potential of the blood:

- **If water potential of the blood is too high, less ADH is released from the pituitary gland and the collecting duct becomes less permeable to water. This leads to more water being released in urination (as more remains in the tubule, ending up in the ureter).**
- **If water potential of the blood is too low, more ADH is released from the pituitary gland and the collecting duct becomes more permeable to water. This leads to less water remaining in the tubule, and more entering blood vessels surrounding the tubule. Less water is released in urination.**

A helpful way to think about the above is by remembering that ADH stands for antidiuretic hormone:

Anti- means the opposite of
Diuretic is a substance that causes increased urination
Hence ADH is a hormone which 'prevents you urinating'!

7.21B - **Biology Only** Treatments for Kidney Failure and 7.22B - **Biology Only** Urea

Kidney failure, also known as chronic kidney disease (CKD) is a serious condition where the kidneys are unable to perform the processes listed in section 7.20B. Kidney failure is normally treated using either **transplantation** or **dialysis:**

Dialysis

- Dialysis is a type of therapy where a **machine outside the body** performs the action of the kidneys (filtering out urea and other waste substances and reabsorbing sugar, water etc).
- Blood is taken from a vessel in the arm and is mixed with an **anticoagulant** to prevent the blood clotting and 'clogging up' the machine.
- The machine contains **dialysis fluid**, which is separated from blood via a **partially-permeable membrane** (allows some things to travel across it, but not others).
- Dialysis fluid contains a **similar level of glucose and ions as is found in the blood,** which means these substances remain in the blood and return to the body.

- Dialysis fluid contains **no urea,** therefore urea diffuses out of the blood into the dialysis fluid down a concentration gradient.

Transplantation

- Transplantation is an alternative to dialysis, where the kidney is replaced altogether. This is a lot less restrictive than a dialysis machine, as regular, time-consuming visits are not required
- There is a significant risk of **rejection** of the donor kidney, which occurs if specific **antigens** on the kidney cells do not match those of the host. Rejection means that an immune reaction will occur, which can lead to severe illness or death. There is a risk of this occurring in **almost every case of organ transplantation.**
- **Immunosuppressive drugs** can also be useful - these suppress the immune system and must be taken for the rest of the patient's life. They prevent an immune rejection from occurring, but they also cause the immune system to be weak against **pathogens**.
- **Tissue typing** allows us to check if an organ is compatible with the recipient before transplantation - this often leads to long waits for an organ, but can prevent organ rejection.

Urea is produced from the breakdown of excess amino acids in the liver.