3.5 Unit 3: Biology 3

We need to understand how biological and environmental systems operate when they are working well in order to be able to intervene when things go wrong. Modern developments in biomedical and technological research allow us to do so.

B3.1 Movement of molecules in and out of cells

The cells, tissues and organs in plants and animals are adapted to take up and get rid of dissolved substances. Different conditions can affect the rate of transfer. Sometimes energy is needed for transfer to take place.

Candidates should use their skills, knowledge and understanding to:

- evaluate the development and use of artificial aids to breathing, including the use of artificial ventilators
- evaluate the claims of manufacturers about sports drinks
- analyse and evaluate the conditions that affect water loss in plants.

B3.1.1 Dissolved substances

a) Dissolved substances move by diffusion and by active transport.

b) Water often moves across boundaries by osmosis. Osmosis is the diffusion of water from a dilute to a more concentrated solution through a partially permeable membrane that allows the passage of water molecules.

Additional guidance:

Use of the terms turgor and plasmolysis is **not** required.

c) Differences in the concentrations of the solutions inside and outside a cell cause water to move into or out of the cell by osmosis.

d) Most soft drinks contain water, sugar and ions.

e) Sports drinks contain sugars to replace the sugar used in energy release during the activity. They also contain water and ions to replace the water and ions lost during sweating.

f) If water and ions are not replaced, the ion / water balance of the body is disturbed and the cells do not work as efficiently.

g) Substances are sometimes absorbed against a concentration gradient. This requires the use of energy from respiration. The process is called active transport. Active transport enables cells to absorb ions from very dilute solutions.

h) Many organ systems are specialised for exchanging materials. The effectiveness of an exchange surface is increased by:

- having a large surface area
- being thin, to provide a short diffusion path
- (in animals) having an efficient blood supply
- (in animals, for gaseous exchange) being ventilated.

i) Gas and solute exchange surfaces in humans and other organisms are adapted to maximise effectiveness.

j) The size and complexity of an organism increases the difficulty of exchanging materials.

k) In humans:

- the surface area of the lungs is increased by the alveoli
- the surface area of the small intestine is increased by villi.

l) The villi provide a large surface area with an extensive network of capillaries to absorb the products of digestion by diffusion and active transport.

B3.1.2 Gaseous exchange

a) The lungs are in the upper part of the body (thorax), protected by the ribcage and separated from the lower part of the body (abdomen) by the diaphragm.

Additional guidance:

Candidates should be able to recognise these structures on a diagram.

b) The breathing system takes air into and out of the body so that oxygen from the air can diffuse into the bloodstream and carbon dioxide can diffuse out of the bloodstream into the air.

c) To make air move into the lungs the ribcage moves out and up and the diaphragm becomes flatter. These changes are reversed to make air move out of the lungs. The movement of air into and out of the lungs is known as ventilation.

Additional guidance:

Candidates should be able to describe the mechanism by which ventilation takes place, including the relaxation and contraction of muscles leading to changes in pressure in the thorax.

B3.1.3 Exchange systems in plants

a) In plants:

- carbon dioxide enters leaves by diffusion
- most of the water and mineral ions are absorbed by roots.

b) The surface area of the roots is increased by root hairs and the surface area of leaves is increased by the flattened shape and internal air spaces.

c) Plants have stomata to obtain carbon dioxide from the atmosphere and to remove oxygen produced in photosynthesis.

d) Plants mainly lose water vapour from their leaves. Most of the loss of water vapour takes place through the stomata.

- Evaporation is more rapid in hot, dry and windy conditions.
- If plants lose water faster than it is replaced by the roots, the stomata can close to prevent wilting.

e) The size of stomata is controlled by guard cells, which surround them.

Suggested ideas for practical work to develop skills and understanding include the following:

- use sensors, eg spirometers, to measure air flow and lung volume
- investigating potato slices in different concentrations of liquid in terms of mass gain and mass loss
- design an investigation to measure the mass change of potato when placed in a series of molarities of sucrose solution
- investigating the relationship between concentrations of sugar solution and change in length of potato strips
- placing shelled eggs in different concentrations of liquid to observe the effect
- placing slices of fresh beetroot in different concentrations of liquid to observe the effect, and then taking thin slices to observe the cells
- observing guard cells and stomata using nail varnish
- observing water loss from plants by placing in a plastic bag with cobalt chloride paper.

B3.2 Transport systems in plants and animals

Substances are transported around the body by the circulatory system (the heart, the blood vessels and the blood). They are transported from where they are taken into the body to the cells, or from the cells to where they are removed from the body. Modern developments in biomedical and technological research enable us to help when the circulatory system is not working well. Plants have separate transport systems for water and nutrients.

Candidates should use their skills, knowledge and understanding to:

- evaluate data on the production and use of artificial blood products
- evaluate the use of artificial hearts and heart valves
- evaluate the use of stents.

B3.2.1 The blood system

a) The circulatory system transports substances around the body.

b) The heart is an organ and pumps blood around the body. Much of the wall of the heart is made from muscle tissue.

Additional guidance:

Knowledge of the cardiac cycle is **not** required.

c) There are four main chambers (left and right atria and ventricles) of the heart.

d) Blood enters the atria of the heart. The atria contract and force blood into the ventricles. The ventricles contract and force blood out of the heart. Valves in the heart ensure that blood flows in the correct direction. Blood flows from the heart to the organs through arteries and returns through veins. There are two separate circulation systems, one for the lungs and one for all other organs of the body.

Additional guidance:

Knowledge of the names of the heart valves is **not** required.

Knowledge of the names of the blood vessels associated with the heart is limited to aorta, vena cava, pulmonary artery and pulmonary vein.

e) Arteries have thick walls containing muscle and elastic fibres. Veins have thinner walls and often have valves to prevent back-flow of blood.

f) If arteries begin to narrow and restrict blood flow stents are used to keep them open.

Additional guidance:

Candidates should understand the importance of stents, particularly with reference to the coronary arteries.

g) In the organs, blood flows through very narrow, thin-walled blood vessels called capillaries. Substances needed by the cells in body tissues pass out of the blood, and substances produced by the cells pass into the blood, through the walls of the capillaries.

B3.2.2 The blood

a) Blood is a tissue and consists of a fluid called plasma in which red blood cells, white blood cells, and platelets are suspended.

b) Blood plasma transports:

- carbon dioxide from the organs to the lungs
- soluble products of digestion from the small intestine to other organs
- urea from the liver to the kidneys.

c) Red blood cells transport oxygen from the lungs to the organs. Red blood cells have no nucleus. They are packed with a red pigment called haemoglobin. In the lungs haemoglobin combines with oxygen to form oxyhaemoglobin. In other organs oxyhaemoglobin splits up into haemoglobin and oxygen.

d) White blood cells have a nucleus. They form part of the body's defence system against microorganisms.

e) Platelets are small fragments of cells. They have no nucleus. Platelets help blood to clot at the site of a wound.

B3.2.3 Transport systems in plants

a) Flowering plants have separate transport systems:

- xylem tissue transports water and mineral ions from the roots to the stem and leaves
- the movement of water from the roots through the xylem and out of the leaves is called the transpiration stream
- phloem tissue carries dissolved sugars from the leaves to the rest of the plant, including the growing regions and the storage organs.

Suggested ideas for practical work to develop skills and understanding include the following:

- dissection of the heart
- use software simulations of the work of the heart and blood vessels
- observation of arteries and veins from slides
- observation of blood smears
- observation of valves in veins preventing backflow of blood using the 'athletic' arm / prominent vein
- use sensors to measure blood pressure before, during and after exercise
- investigate flow rate in xylem using celery, which can include calculation of flow rate
- investigate the content of artificial phloem and xylem given knowledge of the appropriate tests
- plan an investigation using a potometer to measure the effect of temperature or wind speed on the transpiration rate.

B3.3 Homeostasis

Humans need to remove waste products from their bodies to keep their internal environment relatively constant. People whose kidneys do not function properly may die because toxic substances accumulate in their blood. Their lives can be saved by using dialysis machines or having a healthy kidney transplanted. Water and ion content, body temperature and blood glucose levels must be kept within very narrow ranges.

Candidates should use their skills, knowledge and understanding to:

- evaluate the advantages and disadvantages of treating kidney failure by dialysis or kidney transplant
- evaluate modern methods of treating diabetes.

B3.3.1 Removal of waste and water control

a) Waste products that have to be removed from the body include:

- carbon dioxide, produced by respiration and removed via the lungs when we breathe out
- urea, produced in the liver by the breakdown of amino acids and removed by the kidneys in the urine, which is temporarily stored in the bladder.

b) If the water or ion content of the body is wrong, too much water may move into or out of the cells and damage them. Water and ions enter the body when we eat and drink.

Additional guidance:

Knowledge of other parts of the urinary system, the structure of the kidney and the structure of a nephron is **not** required.

c) A healthy kidney produces urine by:

- first filtering the blood
- reabsorbing all the sugar
- reabsorbing the dissolved ions needed by the body
- reabsorbing as much water as the body needs
- releasing urea, excess ions and water as urine.

d) People who suffer from kidney failure may be treated either by using a kidney dialysis machine or by having a healthy kidney transplanted.

e) Treatment by dialysis restores the concentrations of dissolved substances in the blood to normal levels and has to be carried out at regular intervals.

f) In a dialysis machine a person's blood flows between partially permeable membranes. The dialysis fluid contains the same concentration of useful substances as the blood. This ensures that glucose and useful mineral ions are not lost. Urea passes out from the blood into the dialysis fluid.

g) In kidney transplants a diseased kidney is replaced with a healthy one from a donor. However, the donor kidney may be rejected by the immune system unless precautions are taken.

h) Antigens are proteins on the surface of cells. The recipient's antibodies may attack the antigens on the donor organ as they do not recognise them as part of the recipient's body.

Additional guidance:

Knowledge of the ABO blood grouping and compatibility tables is **not** required.

i) To prevent rejection of the transplanted kidney:

- a donor kidney with a 'tissue-type' similar to that of the recipient is used
- the recipient is treated with drugs that suppress the immune system.

B3.3.2 Temperature control

a) Sweating helps to cool the body. More water is lost when it is hot, and more water has to be taken as drink or in food to balance this loss.

b) Body temperature is monitored and controlled by the thermoregulatory centre in the brain. This centre has receptors sensitive to the temperature of the blood flowing through the brain.

Additional guidance:

The name of the centre in the brain (hypothalamus) is **not** required.

c) Also temperature receptors in the skin send impulses to the thermoregulatory centre, giving information about skin temperature.

d) **If the core body temperature is too high:**

- **blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more heat is lost**
- **sweat glands release more sweat which cools the body as it evaporates.**

Additional guidance:

HT only

FT candidates are **not** expected to describe details of changes in the blood vessels when the core body temperature is too high or too low but should understand that the skin looks red when we are hot due to increased blood flow.

e) **If the core body temperature is too low:**

- **blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries**
- **muscles may 'shiver' – their contraction needs respiration, which releases some energy to warm the body.**

HT only

B3.3.3 Sugar control

a) The blood glucose concentration of the body is monitored and controlled by the pancreas. The pancreas produces the hormone insulin, which allows the glucose to move from the blood into the cells.

b) **A second hormone, glucagon, is produced in the pancreas when blood glucose levels fall. This causes glycogen to be converted into glucose and be released into the blood.**

Additional guidance:

HT only

c) Type 1 diabetes is a disease in which a person's blood glucose concentration may rise to a high level because the pancreas does not produce enough of the hormone insulin.

d) Type 1 diabetes may be controlled by careful attention to diet, exercise, and by injecting insulin.

Suggested ideas for practical work to develop skills and understanding include the following:

- use surface temperature sensors to monitor skin temperature in different conditions
- plan an investigation to measure the cooling effect of sweating
- demonstrate blood testing (using meters)
- dissect and make observations of a kidney
- design a model kidney dialysis machine using Visking tubing as the filter
- test urine from diabetic and non-diabetic people using Clinistix.

B3.4 Humans and their environment

Humans often upset the balance of different populations in natural ecosystems, or change the environment so that some species find it difficult to survive. With so many people in the world, there is a serious danger of causing permanent damage not just to the local environments but also to the global environment unless our overall effect is managed carefully. Humans rely on ecosystems for food, water and shelter.

Candidates should use their skills, knowledge and understanding to:

- analyse and interpret scientific data concerning environmental issues

Additional guidance:

Candidates will be given data to work from.

- evaluate methods used to collect environmental data and consider their validity and reliability as evidence for environmental change
- evaluate the methods being used to feed and provide water to an increasing human population, both in terms of short term and long term effects
- evaluate the use of biogas generators

Additional guidance:

Candidates should have considered a number of biogas generator designs ranging from third-world generators supplying a single family to commercial generators. They should understand how the output from a biogas generator might be affected by climatic conditions.

- evaluate the positive and negative effects of managing food production and distribution, and be able to recognise that practical solutions for human needs may require compromise between competing priorities.

Candidates should consider:

- the differences in efficiency between producing food from animals and plants
- the pros and cons of factory farming of animals
- the implications of 'food miles'.

B3.4.1 Waste from human activity

a) Rapid growth in the human population and an increase in the standard of living means that increasingly more waste is produced. Unless waste is properly handled, more pollution will be caused.

b) Waste may pollute:

- water, with sewage, fertiliser or toxic chemicals
- air, with smoke and gases such as sulfur dioxide, which contributes to acid rain
- land, with toxic chemicals such as pesticides and herbicides, which may be washed from the land into waterways.

c) Humans reduce the amount of land available for other animals and plants by building, quarrying, farming and dumping waste.

B3.4.2 Deforestation and the destruction of areas of peat

a) Large-scale deforestation in tropical areas, for timber and to provide land for agriculture, has:

- increased the release of carbon dioxide into the atmosphere (because of burning and the activities of microorganisms)
- reduced the rate at which carbon dioxide is removed from the atmosphere and 'locked up' for many years as wood.

b) Deforestation leads to reduction in biodiversity.

c) Deforestation has occurred so that:

- crops can be grown from which biofuels, based on ethanol, can be produced
- there can be increases in cattle and in rice fields to provide more food. These organisms produce methane and this has led to increases in methane in the atmosphere.

d) The destruction of peat bogs and other areas of peat releases carbon dioxide into the atmosphere.

Additional guidance:

Candidates should understand why 'peat free' composts are of increasing importance.

B3.4.3 Biofuels

a) Levels of carbon dioxide and methane in the atmosphere are increasing and contribute to 'global warming'. An increase in the Earth's temperature of only a few degrees Celsius:

- may cause big changes in the Earth's climate
- may cause a rise in sea level
- may reduce biodiversity
- may cause changes in migration patterns, eg in birds
- may result in changes in the distribution of species.

b) Carbon dioxide can be sequestered in oceans, lakes and ponds and this is an important factor in removing carbon dioxide from the atmosphere.

c) Biofuels can be made from natural products by fermentation. Biogas, mainly methane, can be produced by anaerobic fermentation of a wide range of plant products or waste material containing carbohydrates.

B3.4.4 Food production

a) At each stage in a food chain, less material and less energy are contained in the biomass of the organisms. This means that the efficiency of food production can be improved by reducing the number of stages in food chains.

b) The efficiency of food production can also be improved by restricting energy loss from food animals by limiting their movement and by controlling the temperature of their surroundings.

c) Fish stocks in the oceans are declining. It is important to maintain fish stocks at a level where breeding continues or certain species may disappear altogether in some areas. Net size and fishing quotas play an important role in conservation of fish stocks.

Additional guidance:

This is an example of sustainable food production.

d) The fungus *Fusarium* is useful for producing mycoprotein, a protein-rich food suitable for vegetarians. The fungus is grown on glucose syrup, in aerobic conditions, and the biomass is harvested and purified.

Suggested ideas for practical work to develop skills and understanding include the following:

- build a simple biogas generator to collect methane and demonstrate how the methane can be burned as a fuel
- investigate and design a way of measuring the gas output of a biogas generator and compare the amount of gas produced by different materials.