3.3 Unit 1: Biology 1

B1.1 Keeping healthy

A combination of a balanced diet and regular exercise is needed to help keep the body healthy. Our bodies provide an excellent environment for many microbes which can make us ill once they are inside us. Our bodies need to stop most microbes getting in and deal with any microbes which do get in. Vaccination can be used to prevent infection.

Candidates should use their skills, knowledge and understanding to:

- evaluate information about the effect of food on health

Additional guidance:

Candidates will be given data to work from.

- evaluate information about the effect of lifestyle on development of disease
- analyse and evaluate claims made by slimming programmes, and slimming products.

B1.1.1 Diet and exercise

Additional guidance:

Knowledge and understanding of the specific functions of nutrients and the effects of any deficiency in the diet is **not** required.

a) A healthy diet contains the right balance of the different foods you need and the right amount of energy. Carbohydrates, fats and proteins are used by the body to release energy and to build cells. Mineral ions and vitamins are needed in small amounts for healthy functioning of the body. A person is malnourished if their diet is not balanced. This may lead to a person being overweight or underweight. An unbalanced diet may also lead to deficiency diseases or conditions such as Type 2 diabetes.

b) A person loses mass when the energy content of the food taken in is less than the amount of energy expended by the body. Exercise increases the amount of energy expended by the body.

c) The rate at which all the chemical reactions in the cells of the body are carried out (the metabolic rate) varies with the amount of activity you do and the proportion of muscle to fat in your body. Metabolic rate may be affected by inherited factors.

d) Inherited factors also affect our health; for example cholesterol level.

e) People who exercise regularly are usually healthier than people who take little exercise.

Additional guidance:

The effect of exercise on breathing and heart rate is **not** required.

B1.1.2 How our bodies defend themselves against infectious diseases

Candidates should use their skills, knowledge and understanding to:

- relate the contribution of Semmelweis in controlling infection to solving modern problems with the spread of infection in hospitals

Additional guidance:

Candidates will be given data to work from.

- explain how the treatment of disease has changed as a result of increased understanding of the action of antibiotics and immunity
- evaluate the consequences of mutations of bacteria and viruses in relation to epidemics and pandemics
- evaluate the advantages and disadvantages of being vaccinated against a particular disease.

a) Microorganisms that cause infectious disease are called pathogens.

b) Bacteria and viruses may reproduce rapidly inside the body and may produce poisons (toxins) that make us feel ill. Viruses damage the cells in which they reproduce.

Additional guidance:

Knowledge of the structure of bacteria and viruses is **not** required.

c) The body has different ways of protecting itself against pathogens.

d) White blood cells help to defend against pathogens by:

- ingesting pathogens
- producing antibodies, which destroy particular bacteria or viruses
- producing antitoxins, which counteract the toxins released by the pathogens.

e) The immune system of the body produces specific antibodies to kill a particular pathogen. This leads to immunity from that pathogen. In some cases, dead or inactivated pathogens stimulate antibody production. If a large proportion of the population is immune to a pathogen, the spread of the pathogen is very much reduced.

f) Semmelweis recognised the importance of hand-washing in the prevention of spreading some infectious diseases. By insisting that doctors washed their hands before examining patients, he greatly reduced the number of deaths from infectious diseases in his hospital.

g) Some medicines, including painkillers, help to relieve the symptoms of infectious disease, but do not kill the pathogens.

h) Antibiotics, including penicillin, are medicines that help to cure bacterial disease by killing infectious bacteria inside the body. Antibiotics cannot be used to kill viral pathogens, which live and reproduce inside cells. It is important that specific bacteria should be treated by specific antibiotics. The use of antibiotics has greatly reduced deaths from infectious bacterial diseases. Overuse and inappropriate use of antibiotics has increased the rate of development of antibiotic resistant strains of bacteria.

Additional guidance:

Candidates should be aware that it is difficult to develop drugs that kill viruses without also damaging the body's tissues.

i) Many strains of bacteria, including MRSA, have developed resistance to antibiotics as a result of natural selection. To prevent further resistance arising it is important to avoid over-use of antibiotics.

Knowledge of the development of resistance in bacteria is limited to the fact that pathogens mutate, producing resistant strains.

j) Mutations of pathogens produce new strains. Antibiotics and vaccinations may no longer be effective against a new resistant strain of the pathogen. The new strain will then spread rapidly because people are not immune to it and there is no effective treatment.

Higher Tier candidates should understand that:

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- **antibiotics kill individual pathogens of the non-resistant strain**
- **individual resistant pathogens survive and reproduce, so the population of the resistant strain increases**
- **now, antibiotics are not used to treat non-serious infections, such as mild throat infections, so that the rate of development of resistant strains is slowed down.**

k) The development of antibiotic-resistant strains of bacteria necessitates the development of new antibiotics.

Additional guidance:

Details of vaccination schedules and side effects associated with specific vaccines are **not** required.

l) People can be immunised against a disease by introducing small quantities of dead or inactive forms of the pathogen into the body (vaccination). Vaccines stimulate the white blood cells to produce antibodies that destroy the pathogens. This makes the person immune to future infections by the microorganism. The body can respond by rapidly making the correct antibody, in the same way as if the person had previously had the disease.

MMR vaccine is used to protect children against measles, mumps and rubella.

m) Uncontaminated cultures of microorganisms are required for investigating the action of disinfectants and antibiotics.

For this:

- Petri dishes and culture media must be sterilised before use to kill unwanted microorganisms
- inoculating loops used to transfer microorganisms to the media must be sterilised by passing them through a flame
- the lid of the Petri dish should be secured with adhesive tape to prevent microorganisms from the air contaminating the culture.

n) In school and college laboratories, cultures should be incubated at a maximum temperature of 25 °C, which greatly reduces the likelihood of growth of pathogens that might be harmful to humans.

o) In industrial conditions higher temperatures can produce more rapid growth.

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

- investigate the effectiveness of various antibiotic discs in killing bacteria
- growing microorganisms in Petri dishes to demonstrate sterile technique and growing pure cultures
- the use of pre-inoculated agar in Petri dishes to evaluate the effect of disinfectants and antibiotics
- computer simulations to model the effect of: balanced and unbalanced diets and exercise; the growth of bacterial colonies in varying conditions; action of the immune system and the effect of antibiotics and vaccines.

B1.2 Nerves and hormones

The nervous system and hormones enable us to respond to external changes. They also help us to control conditions inside our bodies. Hormones are used in some forms of contraception and in fertility treatments. Plants also produce hormones and respond to external stimuli.

Candidates should use their skills, knowledge and understanding to:

- evaluate the benefits of, and the problems that may arise from, the use of hormones to control fertility, including In Vitro Fertilisation (IVF)

Additional guidance:

Candidates will be given data to work from.

- evaluate the use of plant hormones in horticulture as weedkillers and to encourage the rooting of plant cuttings.

B1.2.1 The nervous system

a) The nervous system enables humans to react to their surroundings and coordinate their behaviour.

Additional guidance:

Knowledge and understanding of the structure and functions of sense organs such as the eye and the ear are **not** required.

b) Cells called receptors detect stimuli (changes in the environment).

Receptors and the stimuli they detect include:

- receptors in the eyes that are sensitive to light
- receptors in the ears that are sensitive to sound
- receptors in the ears that are sensitive to changes in position and enable us to keep our balance
- receptors on the tongue and in the nose that are sensitive to chemicals and enable us to taste and to smell
- receptors in the skin that are sensitive to touch, pressure, pain and to temperature changes.

Additional guidance:

A knowledge of the functions of the cell components is **not** required.

c) Light receptor cells, like most animal cells, have a nucleus, cytoplasm and cell membrane.

d) Information from receptors passes along cells (neurones) in nerves to the brain. The brain coordinates the response. Reflex actions are automatic and rapid. They often involve sensory, relay and motor neurones.

e) Candidates should understand the role of receptors, sensory neurones, motor neurones, relay neurones, synapses and effectors in simple reflex actions.

In a simple reflex action:

- impulses from a receptor pass along a sensory neurone to the central nervous system
- at a junction (synapse) between a sensory neurone and a relay neurone in the central nervous system, a chemical is released that causes an impulse to be sent along a relay neurone
- a chemical is then released at the synapse between a relay neurone and motor neurone in the central nervous system, causing impulses to be sent along a motor neurone to the organ (the effector) that brings about the response
- the effector is either a muscle or a gland, a muscle responds by contracting and a gland responds by releasing (secreting) chemical substances.

B1.2.2 Control in the human body

Additional guidance:

Details of the action of the skin and kidneys and the control of blood sugar are **not** required.

a) Internal conditions that are controlled include:

- the water content of the body – water leaves the body via the lungs when we breathe out and via the skin when we sweat to cool us down, and excess water is lost via the kidneys in the urine
- the ion content of the body – ions are lost via the skin when we sweat and excess ions are lost via the kidneys in the urine
- temperature – to maintain the temperature at which enzymes work best
- blood sugar levels – to provide the cells with a constant supply of energy.

b) Many processes within the body are coordinated by chemical substances called hormones. Hormones are secreted by glands and are usually transported to their target organs by the bloodstream.

c) Hormones regulate the functions of many organs and cells. For example, the monthly release of an egg from a woman's ovaries and the changes in the thickness of the lining of her womb are controlled by hormones secreted by the pituitary gland and by the ovaries.

d) Several hormones are involved in the menstrual cycle of a woman. Hormones are involved in promoting the release of an egg:

- follicle stimulating hormone (FSH) is secreted by the pituitary gland and causes eggs to mature in the ovaries. It also stimulates the ovaries to produce hormones including oestrogen
- luteinising hormone (LH) stimulates the release of eggs from the ovary
- oestrogen is secreted by the ovaries and inhibits the further production of FSH.

e) The uses of hormones in controlling fertility include:

- giving oral contraceptives that contain hormones to inhibit FSH production so that no eggs mature
  - oral contraceptives may contain oestrogen and progesterone to inhibit egg maturation
  - the first birth-control pills contained large amounts of oestrogen. These resulted in women suffering significant side effects
  - birth-control pills now contain a much lower dose of oestrogen, or are progesterone only
  - progesterone-only pills lead to fewer side effects
- giving FSH and LH in a 'fertility drug' to a woman whose own level of FSH is too low to stimulate eggs to mature, for example in In Vitro Fertilisation (IVF) treatment
  - IVF involves giving a mother FSH and LH to stimulate the maturation of several eggs. The eggs are collected from the mother and fertilised by sperm from the father. The fertilised eggs develop into embryos. At the stage when they are tiny balls of cells, one or two embryos are inserted into the mother's uterus (womb).

Additional guidance:

Knowledge of the role of progesterone in the natural menstrual cycle, including details of negative feedback, is **not** required

B1.2.3 Control in plants

a) Plants are sensitive to light, moisture and gravity:

- their shoots grow towards light and against the force of gravity
- their roots grow towards moisture and in the direction of the force of gravity.

b) Plants produce hormones to coordinate and control growth. Auxin controls phototropism and gravitropism (geotropism).

Additional guidance:

Candidates should understand the role of auxin in phototropism and gravitropism.

c) The responses of plant roots and shoots to light, gravity and moisture are the result of unequal distribution of hormones, causing unequal growth rates.

d) Plant growth hormones are used in agriculture and horticulture as weed killers and as rooting hormones.

Additional guidance:

Names of specific weed killers and rooting hormones are **not** required.

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

- investigation into candidates' reaction times – measuring reaction times using metre rules, stop clocks or ICT
- using forehead thermometers before and after exercise
- demonstrating the speed of transmission along nerves by candidates standing in a semi-circle and holding hands and squeezing with eyes closed
- design an investigation to measure the sensitivity of the skin
- demonstrating the knee jerk reaction
- investigation to measure the amount of sweat produced during exercise
- investigate:
  - the effect of light on the growth of seedlings
  - the effect of gravity on growth in germinating seedlings
  - the effect of water on the growth of seedlings
  - using a motion sensor to measure the growth of plants and seedlings
  - the effect of rooting compounds and weed killers on the growth of plants.

B1.3 The use and abuse of drugs

Drugs affect our body chemistry. Medical drugs are developed and tested before being used to relieve illness or disease. Drugs may also be used recreationally as people like the effect on the body. Some drugs are addictive. Some athletes take drugs to improve performance. People cannot make sensible decisions about drugs unless they know their full effects.

Candidates should use their skills, knowledge and understanding to:

- evaluate the effect of statins in cardiovascular disease

Additional guidance:

Candidates will be given data to work from.

- evaluate different types of drugs and why some people use illegal drugs for recreation

Classification of drug types is **not** required.

- evaluate claims made about the effect of prescribed and non-prescribed drugs on health
- consider the possible progression from recreational drugs to hard drugs
- evaluate the use of drugs to enhance performance in sport and to consider the ethical implications of their use.

B1.3.1 Drugs

a) Scientists are continually developing new drugs.

Additional guidance:

Candidates should understand that tissues and animals are used as models to predict how the drugs may behave in humans.

b) When new medical drugs are devised, they have to be extensively tested and trialled before being used. Drugs are tested in a series of stages to find out if they are safe and effective.

New drugs are extensively tested for toxicity, efficacy and dose:

- in the laboratory, using cells, tissues and live animals
- in clinical trials involving healthy volunteers and patients. Very low doses of the drug are given at the start of the clinical trial. If the drug is found to be safe, further clinical trials are carried out to find the optimum dose for the drug. In some double blind trials, some patients are given a placebo, which does not contain the drug. Neither the doctors nor the patients know who has received a placebo and who has received the drug until the trial is complete.

c) Candidates should be aware of the use of statins in lowering the risk of heart and circulatory diseases.

d) Thalidomide is a drug that was developed as a sleeping pill. It was also found to be effective in relieving morning sickness in pregnant women.

Thalidomide had not been tested for use in pregnant women. Unfortunately, many babies born to mothers who took the drug were born with severe limb abnormalities. The drug was then banned. As a result, drug testing has become much more rigorous. More recently, thalidomide has been used successfully in the treatment of leprosy and other diseases.

e) Candidates should be aware of the effects of misuse of the legal recreational drugs, alcohol and nicotine. Candidates should understand that the misuse of the illegal recreational drugs ecstasy, cannabis and heroin may have adverse effects on the heart and circulatory system.

Additional guidance:

Knowledge and understanding of the specific effects of recreational drugs on the body, except for cannabis are **not** required. The legal classification of specific drugs is **not** required.

f) Cannabis is an illegal drug. Cannabis smoke contains chemicals which may cause mental illness in some people.

g) The overall impact of legal drugs (prescribed and non-prescribed) on health is much greater than the impact of illegal drugs because far more people use them.

Additional guidance:

Awareness of the benefits of medical drugs, the impact of non-medical drugs such as alcohol and the possible misuse of legal drugs should be considered.

h) Drugs change the chemical processes in peoples' bodies so that they may become dependent or addicted to the drug and suffer withdrawal symptoms without them. Heroin and cocaine are very addictive.

i) There are several types of drug that an athlete can use to enhance performance. Some of these drugs are banned by law and some are legally available on prescription, but all are prohibited by sporting regulations. Examples include stimulants that boost bodily functions such as heart rate; and anabolic steroids which stimulate muscle growth.

Additional guidance:

Knowledge of the mode of action of steroids and other performance-enhancing drugs is **not** required.

B1.4 Interdependence and adaptation

Organisms are well adapted to survive in their normal environment. Population size depends on a variety of factors including competition, predation, disease and human influences. Changes in the environment may affect the distribution and behaviour of organisms.

Candidates should use their skills, knowledge and understanding to:

- suggest how organisms are adapted to the conditions in which they live

Additional guidance:

Examination questions will use examples that are unfamiliar to candidates.

- observe the adaptations, eg body shape, of a range of organisms from different habitats
- develop an understanding of the ways in which adaptations enable organisms to survive
- suggest the factors for which organisms are competing in a given habitat

Additional guidance:

Factors are limited to light, water, space and nutrients in plants; food, mates and territory in animals.

- evaluate data concerned with the effect of environmental changes on the distribution and behaviour of living organisms.

B1.4.1 Adaptations

a) To survive and reproduce, organisms require a supply of materials from their surroundings and from the other living organisms there.

b) Plants often compete with each other for light and space, and for water and nutrients from the soil.

c) Animals often compete with each other for food, mates and territory.

d) Organisms, including microorganisms have features (adaptations) that enable them to survive in the conditions in which they normally live.

e) Some organisms live in environments that are very extreme. Extremophiles may be tolerant to high levels of salt, high temperatures or high pressures.

f) Animals and plants may be adapted for survival in the conditions where they normally live, eg deserts, the Arctic.

Animals may be adapted for survival in dry and arctic environments by means of:

- changes to surface area
- thickness of insulating coat
- amount of body fat
- camouflage.

Plants may be adapted to survive in dry environments by means of:

- changes to surface area, particularly of the leaves
- water-storage tissues
- extensive root systems.

g) Animals and plants may be adapted to cope with specific features of their environment, eg thorns, poisons and warning colours to deter predators.

B1.4.2 Environmental change

a) Changes in the environment affect the distribution of living organisms.

Additional guidance:

Examples might include, but not limited to, the changing distribution of some bird species and the disappearance of pollinating insects, including bees.

b) Animals and plants are subjected to environmental changes. Such changes may be caused by living or non-living factors such as a change in a competitor, or in the average temperature or rainfall.

c) Living organisms can be used as indicators of pollution:

- lichens can be used as air pollution indicators, particularly of the concentration of sulfur dioxide in the atmosphere
- invertebrate animals can be used as water pollution indicators and are used as indicators of the concentration of dissolved oxygen in water.

Additional guidance:

Knowledge and understanding of the process of eutrophication is **not** required.

d) Environmental changes can be measured using non-living indicators such as oxygen levels, temperature and rainfall.

Candidates should understand the use of equipment to measure oxygen levels, temperature and rainfall.

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

- investigations of environmental conditions and organisms in a habitat such as a pond
- 'hunt the cocktail stick' using red and green cocktail sticks on a green background
- investigate the distribution of European banded snails
- investigate the behaviour of woodlice using choice chambers
- investigate the effect on plant growth of varying their environmental conditions, eg degrees of shade, density of sowing, supply of nutrients
- investigating particulate levels, eg with the use of sensors to measure environmental conditions
- the use of maximum–minimum thermometers, rainfall gauges and oxygen meters
- investigating the effect of phosphate on oxygen levels in water using jars with algae, water and varying numbers of drops of phosphate, then monitor oxygen using a meter
- computer simulations to model the effect on organisms of changes to the environment.

B1.5 Energy and biomass in food chains

By observing the numbers and sizes of the organisms in food chains we can find out what happens to energy and biomass as it passes along the food chain.

Candidates should use their skills, knowledge and understanding to:

- interpret pyramids of biomass and construct them from appropriate information.

Additional guidance:

An understanding of pyramids of number is **not** required.

B1.5.1 Energy in biomass

a) Radiation from the Sun is the source of energy for most communities of living organisms. Green plants and algae absorb a small amount of the light that reaches them. The transfer from light energy to chemical energy occurs during photosynthesis. This energy is stored in the substances that make up the cells of the plants.

b) The mass of living material (biomass) at each stage in a food chain is less than it was at the previous stage. The biomass at each stage can be drawn to scale and shown as a pyramid of biomass.

Additional guidance:

Construction of food webs and chains, and of pyramids of numbers, is **not** required.

c) The amounts of material and energy contained in the biomass of organisms is reduced at each successive stage in a food chain because:

- some materials and energy are always lost in the organisms' waste materials
- respiration supplies all the energy needs for living processes, including movement. Much of this energy is eventually transferred to the surroundings.

B1.6 Waste materials from plants and animals

Many trees shed their leaves each year and most animals produce droppings at least once a day. All plants and animals eventually die. Microorganisms play an important part in decomposing this material so that it can be used again by plants. The same material is recycled over and over again and can lead to stable communities.

Candidates should use their skills, knowledge and understanding to:

- evaluate the necessity and effectiveness of schemes for recycling organic kitchen or garden waste.

B1.6.1 Decay processes

a) Living things remove materials from the environment for growth and other processes. These materials are returned to the environment either in waste materials or when living things die and decay.

b) Materials decay because they are broken down (digested) by microorganisms. Microorganisms are more active and digest materials faster in warm, moist, aerobic conditions.

c) The decay process releases substances that plants need to grow.

d) In a stable community, the processes that remove materials are balanced by processes that return materials. The materials are constantly cycled.

B1.6.2 The carbon cycle

a) The constant cycling of carbon is called the carbon cycle.

In the carbon cycle:

- carbon dioxide is removed from the environment by green plants and algae for photosynthesis
- the carbon from the carbon dioxide is used to make carbohydrates, fats and proteins, which make up the body of plants and algae
- when green plants and algae respire, some of this carbon becomes carbon dioxide and is released into the atmosphere
- when green plants and algae are eaten by animals and these animals are eaten by other animals, some of the carbon becomes part of the fats and proteins that make up their bodies
- when animals respire some of this carbon becomes carbon dioxide and is released into the atmosphere
- when plants, algae and animals die, some animals and microorganisms feed on their bodies
- carbon is released into the atmosphere as carbon dioxide when these organisms respire
- by the time the microorganisms and detritus feeders have broken down the waste products and dead bodies of organisms in ecosystems and cycled the materials as plant nutrients, all the energy originally absorbed by green plants and algae has been transferred
- combustion of wood and fossil fuels releases carbon dioxide into the atmosphere.

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

- design and carry out an investigation to measure the rate of decay of bread by, for example, exposing cubes of bread to air before placing them in sealed Petri dishes at different temperatures and/or different moisture levels
- investigate the rates of decay using containers (eg thermos flasks) full of grass clippings, one with disinfectant, one with dry grass, one with wet grass and one with a composting agent. If the container is sealed, a thermometer or temperature probe can be placed through a cotton wool plug to monitor the temperature
- potato decay competition, using fresh potatoes. Candidates decide on the environmental conditions and the rate of decay is measured over a 2 week period
- role play exercise – A4 sheets labelled with different stages of the carbon cycle. Candidates arrange themselves in the correct order to pass a ball along labelled as carbon
- using a sensor and data logger to investigate carbon dioxide levels during the decay process.

B1.7 Genetic variation and its control

There are not only differences between different species of plants and animals but also between individuals of the same species. These differences are due partly to the information in the cells they have inherited from their parents and partly to the different environments in which the individuals live and grow. Asexual reproduction can be used to produce individuals that are genetically identical to their parent. Scientists can now add, remove or change genes to produce the plants and animals they want.

Candidates should use their skills, knowledge and understanding to:

- interpret information about cloning techniques and genetic engineering techniques

Additional guidance:

Candidates will be given data to work from.

- make informed judgements about the economic, social and ethical issues concerning cloning and genetic engineering, including genetically modified (GM) crops.

B1.7.1 Why organisms are different

Additional guidance:

Candidates should understand that genes operate at a molecular level to develop characteristics that can be seen.

a) The information that results in plants and animals having similar characteristics to their parents is carried by genes, which are passed on in the sex cells (gametes) from which the offspring develop.

b) The nucleus of a cell contains chromosomes. Chromosomes carry genes that control the characteristics of the body.

c) Different genes control the development of different characteristics of an organism.

d) Differences in the characteristics of different individuals of the same kind may be due to differences in:

- the genes they have inherited (genetic causes)
- the conditions in which they have developed (environmental causes)
- or a combination of both.

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

- look at variation in leaf length or width, pod length, height. Compare plants growing in different conditions – sun/shade.

B1.7.2 Reproduction

a) There are two forms of reproduction:

- sexual reproduction – the joining (fusion) of male and female gametes. The mixture of the genetic information from two parents leads to variety in the offspring
- asexual reproduction – no fusion of gametes and only one individual is needed as the parent. There is no mixing of genetic information and so no genetic variation in the offspring. These genetically identical individuals are known as clones.

b) New plants can be produced quickly and cheaply by taking cuttings from older plants. These new plants are genetically identical to the parent plant.

c) Modern cloning techniques include:

- tissue culture – using small groups of cells from part of a plant
- embryo transplants – splitting apart cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers
- adult cell cloning – the nucleus is removed from an unfertilised egg cell. The nucleus from an adult body cell, eg a skin cell, is then inserted into the egg cell. An electric shock then causes the egg cell to begin to divide to form embryo cells. These embryo cells contain the same genetic information as the adult skin cell. When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development.

d) In genetic engineering, genes from the chromosomes of humans and other organisms can be 'cut out' using enzymes and transferred to cells of other organisms.

e) Genes can also be transferred to the cells of animals, plants or microorganisms at an early stage in their development so that they develop with desired characteristics.

- new genes can be transferred to crop plants
- crops that have had their genes modified in this way are called genetically modified crops (GM crops)
- examples of genetically modified crops include ones that are resistant to insect attack or to herbicides
- genetically modified crops generally show increased yields.

f) Concerns about GM crops include the effect on populations of wild flowers and insects, and uncertainty about the effects of eating GM crops on human health.

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

- investigate the optimum conditions for the growth of cuttings, of, eg Mexican hat plants, spider plants, African violets
- investigate the best technique for growing new plants from tissue cultures (eg cauliflower).

B1.8 Evolution

Particular genes or accidental changes in the genes of plants or animals may give them characteristics which enable them to survive better. Over time this may result in entirely new species. There are different theories of evolution. Darwin's theory is the most widely accepted.

Candidates should use their skills, knowledge and understanding to:

- interpret evidence relating to evolutionary theory

Additional guidance:

Candidates will be given data to work from.

- suggest reasons why Darwin's theory of natural selection was only gradually accepted
- identify the differences between Darwin's theory of evolution and conflicting theories, such as that of Lamarck
- suggest reasons for the different theories.

Additional guidance:

Scientists may produce different hypotheses to explain similar observations. It is only when these hypotheses are investigated that data will support or refute hypotheses.

B1.8.1 Evolution

a) Darwin's theory of evolution by natural selection states that all species of living things have evolved from simple life forms that first developed more than three billion years ago.

Additional guidance:

A study of creationism is **not** required.

b) The theory of evolution by natural selection was only gradually accepted because:

- the theory challenged the idea that God made all the animals and plants that live on Earth
- there was insufficient evidence at the time the theory was published to convince many scientists
- the mechanism of inheritance and variation was not known until 50 years after the theory was published.

c) Other theories, including that of Lamarck, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur.

d) Studying the similarities and differences between organisms allows us to classify living organisms into animals, plants and microorganisms, and helps us to understand evolutionary and ecological relationships. Models allow us to suggest relationships between organisms.

Additional guidance:

Candidates should understand how evolutionary trees (models) are used to represent the relationships between organisms.

e) Evolution occurs via natural selection:

- individual organisms within a particular species may show a wide range of variation because of differences in their genes
- individuals with characteristics most suited to the environment are more likely to survive to breed successfully
- the genes that have enabled these individuals to survive are then passed on to the next generation.

Candidates should develop an understanding of the timescales involved in evolution.

f) Where new forms of a gene result from mutation there may be relatively rapid change in a species if the environment changes.

3.4 Unit 2: Biology 2

B2.1 Cells and simple cell transport

All living things are made up of cells. The structures of different types of cells are related to their functions. To get into or out of cells, dissolved substances have to cross the cell membranes.

Candidates should use their skills, knowledge and understanding to:

- relate the structure of different types of cells to their function.

B2.1.1 Cells and cell structure

a) Most human and animal cells have the following parts:

- a nucleus, which controls the activities of the cell
- cytoplasm, in which most of the chemical reactions take place
- a cell membrane, which controls the passage of substances into and out of the cell
- mitochondria, which is where most energy is released in respiration
- ribosomes, which is where protein synthesis occurs.

b) Plant and algal cells also have a cell wall made of cellulose, which strengthens the cell. Plant cells often have:

- chloroplasts, which absorb light energy to make food
- a permanent vacuole filled with cell sap.

c) A bacterial cell consists of cytoplasm and a membrane surrounded by a cell wall; the genes are not in a distinct nucleus.

d) Yeast is a single-celled organism. Yeast cells have a nucleus, cytoplasm and a membrane surrounded by a cell wall.

e) Cells may be specialised to carry out a particular function.

B2.1.2 Dissolved substances

a) Dissolved substances can move into and out of cells by diffusion.

b) Diffusion is the spreading of the particles of a gas, or of any substance in solution, resulting in a net movement from a region where they are of a higher concentration to a region with a lower concentration. The greater the difference in concentration, the faster the rate of diffusion.

c) Oxygen required for respiration passes through cell membranes by diffusion.

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

- observation of cells under a microscope, eg sprouting mung beans to show root hair cells
- computer simulations to model the relative size of different cells, organelles and molecules
- computer simulations to model the process of diffusion
- making model cells
- diffusion of ammonium hydroxide in a glass tube using litmus as the indicator
- investigate how temperature affects the rate of diffusion of glucose through Visking tubing.

B2.2 Tissues, organs and organ systems

The cells of multicellular organisms may differentiate and become adapted for specific functions. Tissues are aggregations of similar cells; organs are aggregations of tissues performing specific physiological functions. Organs are organised into organ systems, which work together to form organisms.

B2.2.1 Animal organs

a) Large multicellular organisms develop systems for exchanging materials. During the development of a multicellular organism, cells differentiate so that they can perform different functions.

Additional guidance:

Candidates should develop an understanding of size and scale in relation to cells, tissues, organs and organ systems.

b) A tissue is a group of cells with similar structure and function. Examples of tissues include:

- muscular tissue, which can contract to bring about movement
- glandular tissue, which can produce substances such as enzymes and hormones
- epithelial tissue, which covers some parts of the body.

c) Organs are made of tissues. One organ may contain several tissues. The stomach is an organ that contains:

- muscular tissue, to churn the contents
- glandular tissue, to produce digestive juices
- epithelial tissue, to cover the outside and the inside of the stomach.

d) Organ systems are groups of organs that perform a particular function. The digestive system is one example of a system in which humans and other mammals exchange substances with the environment.

The digestive system includes:

- glands, such as the pancreas and salivary glands, which produce digestive juices
- the stomach and small intestine, where digestion occurs
- the liver, which produces bile
- the small intestine, where the absorption of soluble food occurs
- the large intestine, where water is absorbed from the undigested food, producing faeces.

Additional guidance:

Candidates should be able to recognise the organs of the digestive system on a diagram.

B2.2.2 Plant organs

a) Plant organs include stems, roots and leaves.

Additional guidance:

Details of the internal structure of these organs are limited to the leaf.

b) Examples of plant tissues include:

- epidermal tissues, which cover the plant
- mesophyll, which carries out photosynthesis
- xylem and phloem, which transport substances around the plant.

B2.3 Photosynthesis

Green plants and algae use light energy to make their own food. They obtain the raw materials they need to make this food from the air and the soil. The conditions in which plants are grown can be changed to promote growth.

Candidates should use their skills, knowledge and understanding to:

- interpret data showing how factors affect the rate of photosynthesis
- evaluate the benefits of artificially manipulating the environment in which plants are grown.

B2.3.1 Photosynthesis

a) Photosynthesis is summarised by the equation:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light energy}} \text{glucose} + \text{oxygen}$$

b) During photosynthesis:

- light energy is absorbed by a green substance called chlorophyll, which is found in chloroplasts in some plant cells and algae
- this energy is used by converting carbon dioxide (from the air) and water (from the soil) into sugar (glucose)
- oxygen is released as a by-product.

c) The rate of photosynthesis may be limited by:

- shortage of light
- low temperature
- shortage of carbon dioxide.

d) Light, temperature and the availability of carbon dioxide interact and in practice any one of them may be the factor that limits photosynthesis.

Additional guidance:

Candidates should be able to relate the principle of limiting factors to the economics of enhancing the following conditions in greenhouses:

- light intensity
- temperature
- carbon dioxide concentration.

e) The glucose produced in photosynthesis may be converted into insoluble starch for storage. Plant cells use some of the glucose produced during photosynthesis for respiration.

f) Some glucose in plants and algae is used:

- to produce fat or oil for storage
- to produce cellulose, which strengthens the cell wall
- to produce proteins.

g) To produce proteins, plants also use nitrate ions that are absorbed from the soil.

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

- investigating the need for chlorophyll for photosynthesis with variegated leaves
- taking thin slices of potato and apple and adding iodine to observe under the microscope
- investigate the effects of light, temperature and carbon dioxide levels (using Cabomba, algal balls or leaf discs from brassicas) on the rate of photosynthesis
- computer simulations to model the rate of photosynthesis in different conditions
- the use of sensors to investigate the effect of carbon dioxide and light levels on the rate of photosynthesis and the release of oxygen.

B2.4 Organisms and their environment

Living organisms form communities, and we need to understand the relationships within and between these communities. These relationships are affected by external influences.

Candidates should use their skills, knowledge and understanding to:

- suggest reasons for the distribution of living organisms in a particular habitat
- evaluate methods used to collect environmental data, and consider the validity of the method and the reproducibility of the data as evidence for environmental change.

Additional guidance:

Candidates should understand:

- the terms mean, median and mode
- that sample size is related to both validity and reproducibility.

B2.4.1 Distribution of organisms

a) Physical factors that may affect organisms are:

- temperature
- availability of nutrients
- amount of light
- availability of water
- availability of oxygen and carbon dioxide.

b) Quantitative data on the distribution of organisms can be obtained by:

- random sampling with quadrats
- sampling along a transect.

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

- investigative fieldwork involving sampling techniques and the use of quadrats and transects; which might include, on a local scale, the:
  - patterns of grass growth under trees
  - distribution of daisy and dandelion plants in a field
  - distribution of lichens or moss on trees, walls and other surfaces
  - distribution of the alga *Pleurococcus* on trees, walls and other surfaces
  - leaf size in plants growing on or climbing against walls, including height and effect of aspect
- analysing the measurement of specific abiotic factors in relation to the distribution of organisms
- the study of hay infusions
- the use of sensors to measure environmental conditions in a fieldwork context.

B2.5 Proteins – their functions and uses

Proteins have many functions, both inside and outside the cells of living organisms. Proteins, as enzymes, are now used widely in the home and in industry.

Candidates should use their skills, knowledge and understanding to:

- evaluate the advantages and disadvantages of using enzymes in the home and in industry.

B2.5.1 Proteins

a) Protein molecules are made up of long chains of amino acids. These long chains are folded to produce a specific shape that enables other molecules to fit into the protein. Proteins act as:

- structural components of tissues such as muscles
- hormones
- antibodies
- catalysts.

b) Catalysts increase the rate of chemical reactions. Biological catalysts are called enzymes. Enzymes are proteins.

B2.5.2 Enzymes

a) The shape of an enzyme is vital for the enzyme's function. High temperatures change the shape.

b) Different enzymes work best at different pH values.

c) Some enzymes work outside the body cells. The digestive enzymes are produced by specialised cells in glands and in the lining of the gut. The enzymes then pass out of the cells into the gut where they come into contact with food molecules. They catalyse the breakdown of large molecules into smaller molecules.

d) The enzyme amylase is produced in the salivary glands, the pancreas and the small intestine. This enzyme catalyses the breakdown of starch into sugars in the mouth and small intestine.

e) Protease enzymes are produced by the stomach, the pancreas and the small intestine. These enzymes catalyse the breakdown of proteins into amino acids in the stomach and the small intestine.

f) Lipase enzymes are produced by the pancreas and small intestine. These enzymes catalyse the breakdown of lipids (fats and oils) into fatty acids and glycerol in the small intestine.

g) The stomach also produces hydrochloric acid. The enzymes in the stomach work most effectively in these acid conditions.

h) The liver produces bile, which is stored in the gall bladder before being released into the small intestine. Bile neutralises the acid that was added to food in the stomach. This provides alkaline conditions in which enzymes in the small intestine work most effectively.

i) Some microorganisms produce enzymes that pass out of the cells. These enzymes have many uses in the home and in industry.

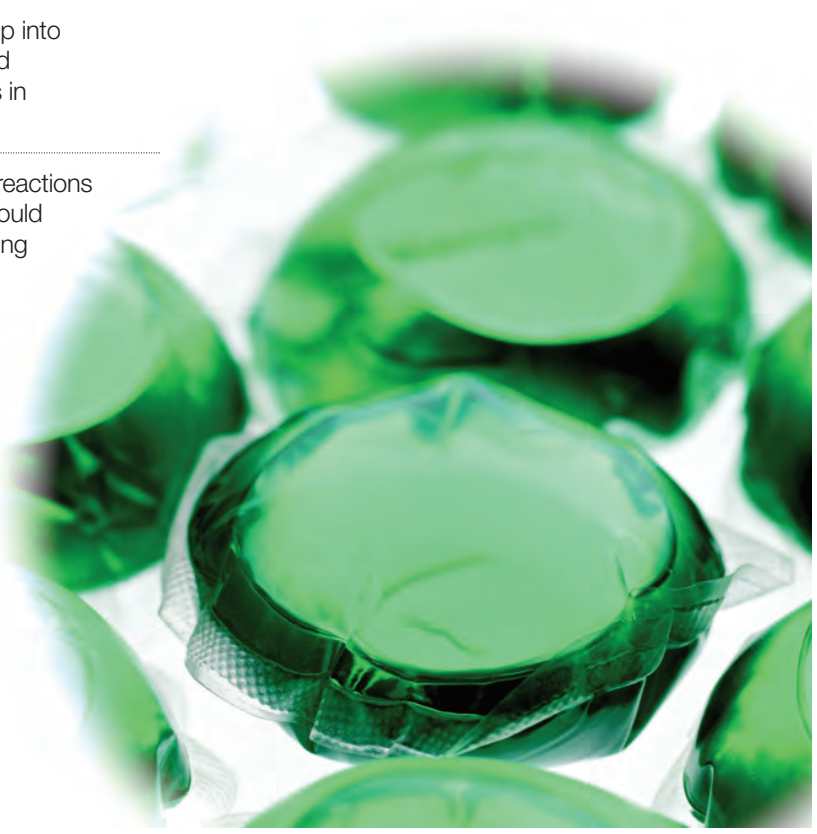
In the home:

- biological detergents may contain protein-digesting and fat-digesting enzymes (proteases and lipases)
- biological detergents are more effective at low temperatures than other types of detergents.

In industry:

- proteases are used to 'pre-digest' the protein in some baby foods
- carbohydrases are used to convert starch into sugar syrup
- isomerase is used to convert glucose syrup into fructose syrup, which is much sweeter and therefore can be used in smaller quantities in slimming foods.

j) In industry, enzymes are used to bring about reactions at normal temperatures and pressures that would otherwise require expensive, energy-demanding equipment. However, most enzymes are denatured at high temperatures and many are costly to produce.



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

- design an investigation to find the optimum temperature for biological and non-biological washing powders to remove stains from cotton and other materials
- investigate the action of enzymes using catalase at different concentrations and measuring the rate at which oxygen is given off from different foods, eg liver, potato, celery and apple
- plan and carry out an investigation into enzyme action using the reaction between starch and amylase at different temperatures, pH and concentrations
- using small pieces of cooked sausage, use 2% pepsin and 0.01M HCl in water baths at different temperatures to estimate the rate of digestion. This can also be carried out with 2% trypsin and 0.1M NaOH. The concentration of both enzymes can be varied
- using computer simulations of enzymes to model their action in varying conditions of pH, temperature and concentration.

B2.6 Aerobic and anaerobic respiration

Respiration in cells can take place aerobically or anaerobically. The energy released is used in a variety of ways. The human body needs to react to the increased demand for energy during exercise.

Candidates should use their skills, knowledge and understanding to:

- interpret the data relating to the effects of exercise on the human body.

B2.6.1 Aerobic respiration

a) The chemical reactions inside cells are controlled by enzymes.

b) During aerobic respiration (respiration that uses oxygen) chemical reactions occur that:

- use glucose (a sugar) and oxygen
- release energy.

c) Aerobic respiration takes place continuously in both plants and animals.

d) Most of the reactions in aerobic respiration take place inside mitochondria.

e) Aerobic respiration is summarised by the equation:

glucose + oxygen → carbon dioxide + water (+ energy)

f) Energy that is released during respiration is used by the organism. The energy may be used:

- to build larger molecules from smaller ones
- in animals, to enable muscles to contract
- in mammals and birds, to maintain a steady body temperature in colder surroundings
- in plants, to build up sugars, nitrates and other nutrients into amino acids which are then built up into proteins.

g) During exercise a number of changes take place:

- the heart rate increases
- the rate and depth of breathing increases.

h) These changes increase the blood flow to the muscles and so increase the supply of sugar and oxygen and increase the rate of removal of carbon dioxide.

i) Muscles store glucose as glycogen, which can then be converted back to glucose for use during exercise.

B2.6.2 Anaerobic respiration

a) During exercise, if insufficient oxygen is reaching the muscles they use anaerobic respiration to obtain energy.

b) Anaerobic respiration is the incomplete breakdown of glucose and produces lactic acid.

c) **As the breakdown of glucose is incomplete, much less energy is released than during aerobic respiration. Anaerobic respiration results in an oxygen debt that has to be repaid in order to oxidise lactic acid to carbon dioxide and water.**

Additional guidance:

HT only

d) If muscles are subjected to long periods of vigorous activity they become fatigued, ie they stop contracting efficiently. One cause of muscle fatigue is the build-up of lactic acid in the muscles. Blood flowing through the muscles removes the lactic acid.

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

- investigating the rate of respiration in yeast using carbon dioxide sensors and dataloggers
- investigating the effect of exercise on pulse rate, either physically or using pulse sensors and dataloggers
- investigating the link between exercise and breathing rate with a breathing sensor
- investigating holding masses at arm's length and timing how long it takes the muscles to fatigue
- designing an investigation using force meters and dataloggers to find the relationship between the amount of force exerted by a muscle and muscle fatigue.

B2.7 Cell division and inheritance

Characteristics are passed on from one generation to the next in both plants and animals. Simple genetic diagrams can be used to show this. There are ethical considerations in treating genetic disorders.

Candidates should use their skills, knowledge and understanding to:

- explain why Mendel proposed the idea of separately inherited factors and why the importance of this discovery was not recognised until after his death

Additional guidance:

Candidates should be familiar with principles used by Mendel in investigating monohybrid inheritance in peas. They should understand that Mendel's work preceded the work by other scientists which linked Mendel's 'inherited factors' with chromosomes.

- interpret genetic diagrams, including family trees
- **construct genetic diagrams of monohybrid crosses and predict the outcomes of monohybrid crosses and be able to use the terms homozygous, heterozygous, phenotype and genotype**

Additional guidance:

HT only

Foundation Tier candidates should be able to interpret genetic diagrams of monohybrid inheritance and sex inheritance but will **not** be expected to construct genetic diagrams or use the terms homozygous, heterozygous, phenotype or genotype.

- predict and/or explain the outcome of crosses between individuals for each possible combination of dominant and recessive alleles of the same gene
- make informed judgements about the social and ethical issues concerning the use of stem cells from embryos in medical research and treatments
- make informed judgements about the economic, social and ethical issues concerning embryo screening.

Additional guidance:

Data may be given for unfamiliar contexts.

B2.7.1 Cell division

a) In body cells the chromosomes are normally found in pairs. Body cells divide by mitosis.

Additional guidance:

Knowledge and understanding of the stages in mitosis and meiosis is **not** required.

b) The chromosomes contain the genetic information.

c) When a body cell divides by mitosis:

- copies of the genetic material are made
- then the cell divides once to form two genetically identical body cells.

Additional guidance:

Throughout section 2.7 candidates should develop an understanding of the relationship from the molecular level upwards between genes, chromosomes, nuclei and cells and to relate these to tissues, organs and systems (2.2 and 2.3).

d) Mitosis occurs during growth or to produce replacement cells.

e) Body cells have two sets of chromosomes; sex cells (gametes) have only one set.

f) Cells in reproductive organs – testes and ovaries in humans – divide to form gametes.

Additional guidance:

For Foundation Tier, knowledge of meiosis is restricted to where the process occurs and that gametes are produced by meiosis.

g) The type of cell division in which a cell divides to form gametes is called meiosis.

h) **When a cell divides to form gametes:**

- **copies of the genetic information are made**
- **then the cell divides twice to form four gametes, each with a single set of chromosomes.**

Additional guidance:

HT only

i) When gametes join at fertilisation, a single body cell with new pairs of chromosomes is formed. A new individual then develops by this cell repeatedly dividing by mitosis.

Additional guidance:

Candidates should understand that genetic diagrams are biological models which can be used to predict the outcomes of crosses.

j) Most types of animal cells differentiate at an early stage whereas many plant cells retain the ability to differentiate throughout life. In mature animals, cell division is mainly restricted to repair and replacement.

k) Cells from human embryos and adult bone marrow, called stem cells, can be made to differentiate into many different types of cells, eg nerve cells.

Additional guidance:

Knowledge and understanding of stem cell techniques is **not** required.

l) Human stem cells have the ability to develop into any kind of human cell.

m) Treatment with stem cells may be able to help conditions such as paralysis.

n) The cells of the offspring produced by asexual reproduction are produced by mitosis from the parental cells. They contain the same alleles as the parents.

B2.7.2 Genetic variation

a) Sexual reproduction gives rise to variation because, when gametes fuse, one of each pair of alleles comes from each parent.

b) In human body cells, one of the 23 pairs of chromosomes carries the genes that determine sex. In females the sex chromosomes are the same (XX); in males the sex chromosomes are different (XY).

c) Some characteristics are controlled by a single gene. Each gene may have different forms called alleles.

d) An allele that controls the development of a characteristic when it is present on only one of the chromosomes is a dominant allele.

e) An allele that controls the development of characteristics only if the dominant allele is not present is a recessive allele.

f) Chromosomes are made up of large molecules of DNA (deoxyribo nucleic acid) which has a double helix structure.

Additional guidance:

Candidates are **not** expected to know the names of the four bases or how complementary pairs of bases enable DNA replication to take place.

g) A gene is a small section of DNA.

h) **Each gene codes for a particular combination of amino acids which make a specific protein.**

Additional guidance:

HT only

i) Each person (apart from identical twins) has unique DNA. This can be used to identify individuals in a process known as DNA fingerprinting.

Additional guidance:

Knowledge and understanding of genetic fingerprinting techniques is **not** required.

B2.7.3 Genetic disorders

a) Some disorders are inherited.

b) Polydactyly – having extra fingers or toes – is caused by a dominant allele of a gene and can therefore be passed on by only one parent who has the disorder.

Additional guidance:

Attention is drawn to the potential sensitivity needed in teaching about inherited disorders.

c) Cystic fibrosis (a disorder of cell membranes) must be inherited from both parents. The parents may be carriers of the disorder without actually having the disorder themselves. It is caused by a recessive allele of a gene and can therefore be passed on by parents, neither of whom has the disorder.

d) Embryos can be screened for the alleles that cause these and other genetic disorders.

Additional guidance:

Knowledge and understanding of embryo screening techniques is **not** required.

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

- observation or preparation and observation of root tip squashes to illustrate chromosomes and mitosis
- using genetic beads to model mitosis and meiosis and genetic crosses
- making models of DNA
- extracting DNA from kiwi fruit.

B2.8 Speciation

Changes in the environment of plants and animals may cause them to die out. The fossil record shows that new organisms arise, flourish, and after a time become extinct. The record also shows changes that lead to the formation of new species.

Candidates should use their skills, knowledge and understanding to:

- suggest reasons why scientists cannot be certain about how life began on Earth.

Additional guidance:

The uncertainty arises from the lack of enough valid and reliable evidence.

B2.8.1 Old and new species

a) Evidence for early forms of life comes from fossils.

b) Fossils are the 'remains' of organisms from many years ago, which are found in rocks. Fossils may be formed in various ways:

- from the hard parts of animals that do not decay easily
- from parts of organisms that have not decayed because one or more of the conditions needed for decay are absent
- when parts of the organism are replaced by other materials as they decay
- as preserved traces of organisms, eg footprints, burrows and rootlet traces.

c) Many early forms of life were soft-bodied, which means that they have left few traces behind. What traces there were have been mainly destroyed by geological activity.

d) We can learn from fossils how much or how little different organisms have changed as life developed on Earth.

e) Extinction may be caused by:

- changes to the environment over geological time
- new predators
- new diseases
- new, more successful, competitors
- a single catastrophic event, eg massive volcanic eruptions or collisions with asteroids
- through the cyclical nature of speciation.

f) New species arise as a result of:

- isolation – two populations of a species become separated, eg geographically
- **genetic variation – each population has a wide range of alleles that control their characteristics**
- **natural selection – in each population, the alleles that control the characteristics which help the organism to survive are selected**
- **speciation – the populations become so different that successful interbreeding is no longer possible.**

Additional guidance:

HT only

For Foundation Tier, ideas are restricted to knowledge and understanding of isolation.

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.