Module B1: You and your genes

B1.1 What are genes and how do they affect the way that organisms develop?

1. recall that instructions to control how an organism develops and functions are found in the nucleus of its cells and are called genes
2. recall that genes are instructions for a cell that describe how to make proteins
3. recall that proteins may be structural (e.g. collagen) or functional (e.g. enzymes such as amylase)
4. recall that genes are sections of very long DNA molecules that make up chromosomes in the nuclei of cells
5. understand that some characteristics are determined by genes (e.g. dimples), some are determined by environmental factors (e.g. scars), and some are determined by a combination of genes and the environment (e.g. weight)
6. understand that many characteristics are determined by several genes working together (e.g. eye colour).

Module B1: You and your genes

B1.2 Why can people look like their parents, brothers and sisters, but not be identical to them?

1. recall that body cells contain pairs of chromosomes and that sex cells contain only one chromosome from each pair
2. understand that chromosomes in a pair carry the same genes in the same place, but that there may be different versions of genes called alleles
3. recall that an individual usually has two alleles for each gene
4. recall that in an individual the two alleles of each gene can be the same **(homozygous)** or different **(heterozygous)**
5. understand that during sexual reproduction genes from both parents come together and produce variation in the offspring
6. understand that offspring have some similarities to their parents because of the combination of maternal and paternal alleles in the fertilised egg
7. understand that different offspring from the same parents can differ from each other because they inherit a different combination of maternal and paternal alleles
8. understand that an allele can be dominant or recessive, and that:
    a. an individual with one or both dominant alleles (in a pair of alleles) will show the associated dominant characteristic
    b. an individual with one recessive allele (in a pair of alleles) will not show the associated recessive characteristic
    c. an individual with both recessive alleles (in a pair of alleles) will show the associated recessive characteristic
9. recall that human males have XY sex chromosomes and females have XX sex chromosomes
10. **understand that the sex-determining gene on the Y chromosome triggers the development of testes, and that in the absence of a Y chromosome ovaries develop**
11. use and interpret genetic diagrams (family trees and Punnett squares) showing:
    a. the inheritance of single gene characteristics with a dominant and recessive allele
    b. the inheritance of sex chromosomes
12. **understand that the term genotype describes the genetic make-up of an organism (the combination of alleles), and the term phenotype describes the observable characteristics that the organism has.**

Module B1: You and your genes

B1.3 How can and should genetic information be used? How can we use our knowledge of genes to prevent disease?

1. understand that a small number of disorders are caused by faulty alleles of a single gene, including Huntington's disease and cystic fibrosis
2. recall that disorders may be caused by dominant alleles (e.g. Huntington's disease) or recessive alleles (e.g. cystic fibrosis)
3. recall the symptoms of Huntington's disease and cystic fibrosis, to include:
    a. Huntington's disease – late onset, tremor, clumsiness, memory loss, inability to concentrate, mood changes
    b. cystic fibrosis – thick mucus, difficulty breathing, chest infections, difficulty in digesting food
4. understand that a person with one recessive allele (in a pair of alleles) will not show the symptoms of the disorder, but is a carrier and can pass the recessive allele to their children
5. interpret through genetic diagrams (family trees and Punnett squares) the inheritance of a single gene disorder, including the risk of a child being a carrier
6. describe uses of genetic testing for screening adults, children and embryos, limited to:
    a. testing embryos for embryo selection **(pre-implantation genetic diagnosis)**
    b. predictive testing for genetic diseases
    c. testing an individual before prescribing drugs
7. understand that testing adults and fetuses for alleles that cause genetic disorders has implications that need to be considered, including:
    a. risk of miscarriage as a result of cell sampling for the genetic test
    b. using results that may not be accurate, including false positives and false negatives
    c. whether or not to have children at all
    d. whether or not a pregnancy should be terminated
    e. whether other members of the family should be informed
8. **understand the implications of testing embryos for embryo selection prior to implantation**
9. understand the implications of the use of genetic testing by others (for example, for genetic screening programmes by employers and insurance companies).

Module B1: You and your genes

B1.4 How is a clone made?

1. understand that bacteria, plants and some animals can reproduce asexually to form clones (individuals with identical genes)
2. understand that any differences between clones are likely to be due only to environmental factors
3. understand that clones of plants occur naturally when plants produce bulbs or runners
4. understand that clones of animals occur:
    a. naturally, when cells of an embryo separate (identical twins)
    b. artificially, when the nucleus from an adult body cell is transferred to an empty unfertilised egg cell
5. understand that there are different types of stem cells:
    a. adult stem cells which are unspecialised cells that can develop into many, but not all, types of cells
    b. embryonic stem cells which are unspecialised cells that can develop into any type of cell
6. understand that, as a result of being unspecialised, stem cells from embryos and adults offer the potential to treat some illnesses
7. understand that the majority of cells of multicellular organisms become specialised during the early development of the organism.

3.4.2 Module B2: Keeping healthy

Overview

Keeping healthy involves maintaining a healthy lifestyle, avoiding infection, and using medication when necessary. This module illustrates these principles through prevention of infectious diseases and heart disease.

Candidates learn about the immune system and how vaccines work to prevent infection. They also learn about the increase of 'superbugs', and how correct use of antibiotics can help to reduce their prevalence. The module explores how new drugs are developed, including the stages of testing for safety and effectiveness. Candidates also consider the causes of heart disease and how individuals can minimise this risk. They also learn about maintaining a constant internal environment, illustrated through an understanding of how our body keeps a healthy water balance.

In the contexts of vaccination policy and the study of clinical trials, candidates explore ideas of correlation and cause, and how peer review by the scientific community strengthens the confidence in scientific claims. They also consider particular ethical issues arising in modern medicine, for example the right of individual choice versus social policy, illustrated through vaccination policy.

Issues for citizens	Questions that science may help to answer
Why do I catch some diseases but not others?	How do our bodies resist infection?
Why are we encouraged to have vaccinations?	What are vaccines and antibiotics and how do they work?
Why should we always finish a course of antibiotics?	How are new drugs developed and tested?
How do drug companies make sure a new drug is as safe as possible?	What factors increase the risk of heart disease?
How can my lifestyle affect my health?	How do our bodies keep a healthy water balance?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of microorganisms
- carry out calculations using experimental data, including finding the mean and the range
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- extract information from charts, graphs and tables including data from epidemiological studies
- use ideas about correlation in the context of health risk factors
- use ideas about probability in the context of risk.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- demonstrate the rapid spread of an infection through a population using 'contaminated' hand contact
- role play discussion of the ethical questions arising from the need to have a high take-up of vaccination to establish effective herd immunity
- antibiotic action practical activity to demonstrate that different antibiotics have different activity against particular bacteria
- monitor blood pressure
- heart dissection.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- storing and displaying magnified images from microscopes
- storing and displaying data from studies of factors which may, or may not, cause disease
- modelling control systems which involve negative feedback.

Use of ICT in teaching and learning can include:

- animations to illustrate immune responses
- animations to illustrate development of antibiotic-resistant bacterial populations
- video clips to illustrate smallpox vaccination programmes
- video clips of interviews with patients who have heart disease
- video clips illustrating how epidemiological research is carried out and reported.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Cause-effect

IaS 2.3 – 2.7

The scientific community

IaS 4.1, 4.2

Risk

IaS 5.1 – 5.5, **5.6**, 5.7

Making decisions about science and technology

IaS 6.4 – 6.6

Module B2: Keeping healthy

B2.1 How do our bodies resist infection?

1. understand that symptoms of an infectious disease are caused by damage done to cells by microorganisms or the poisons (toxins) they produce
2. understand why, in suitable conditions such as those inside a human body, microorganisms (e.g. bacteria and viruses) can reproduce rapidly to produce very large numbers
3. calculate the population growth of microorganisms given appropriate data
4. understand that white blood cells are part of the body's immune system and can destroy microorganisms by engulfing and digesting them or by producing antibodies
5. understand that antibodies recognise microorganisms by the antigens that they carry on their surface, that different microorganisms have different antigens, and that a different antibody is therefore needed to recognise each different type of microorganism
6. understand that once the body has made the antibody to recognise a particular microorganism, memory cells can make that antibody again very quickly, therefore protecting against that particular microorganism in the future (immunity).

Module B2: Keeping healthy

B2.2 What are vaccines and antibiotics and how do they work?

1. understand that vaccinations provide protection from microorganisms by establishing memory cells that produce antibodies quickly on reinfection
2. understand that a vaccine usually contains a safe form of a disease-causing microorganism
3. **understand why, to prevent epidemics of infectious diseases, it is necessary to vaccinate a high percentage of a population**
4. understand that vaccines and drugs (medicines) can never be completely risk-free, since individuals have varying degrees of side effects to them
5. understand that due to genetic differences, people react differently to drugs and vaccines
6. understand that chemicals called antimicrobials can be used to kill, **or inhibit**, bacteria, fungi and viruses
7. recall that antibiotics are a type of antimicrobial that are effective against bacteria but not viruses
8. understand that over a period of time bacteria and fungi may become resistant to antimicrobials
9. **understand that random changes (mutations) in the genes of these microorganisms sometimes lead to varieties which are less affected by antimicrobials**
10. understand that to reduce antibiotic resistance we should only use antibiotics when necessary and always complete the course
11. understand that new drugs and vaccines are first tested for safety and effectiveness using animals and human cells grown in the laboratory
12. recall that human trials may then be carried out:
    a. on healthy volunteers to test for safety
    b. on people with the illness to test for safety and effectiveness
13. **describe and explain the use of 'open-label', 'blind' and 'double-blind' human trials in the testing of a new medical treatment**
14. **understand the importance of long-term human trials**
15. understand the ethical issues related to using placebos in human trials.

Module B2: Keeping healthy

B2.3 What factors increase the risk of heart disease?

1. describe the role of the heart as a double pump in the circulatory system
2. understand why heart muscle cells need their own blood supply
3. understand how the structure of arteries, veins and capillaries is related to their function
4. understand that heart rate can be measured by recording the pulse rate
5. understand that blood pressure measurements record the pressure of the blood on the walls of the artery
6. understand that a blood pressure measurement is given as two numbers, the higher value when the heart is contracting and the lower value when the heart is relaxed
7. understand that 'normal' measurements for factors such as heart rate and blood pressure are given within a range because individuals vary
8. understand how fatty deposits in the blood vessels supplying the heart muscle can produce a 'heart attack'
9. understand that heart disease is usually caused by lifestyle factors and/or genetic factors
10. understand that lifestyle factors that can increase the risk of heart disease include:
    a. poor diet
    b. stress
    c. cigarette smoking
    d. misuse of drugs
11. understand that regular moderate exercise reduces the risk of developing heart disease
12. relate differences in lifestyle factors in the UK and non-industrialised countries to the prevalence of heart disease
13. understand how factors that can increase the risk of heart disease are identified via epidemiological and large scale genetics studies
14. assess levels of heart disease risk, and actions that could be taken to reduce risk, when provided with lifestyle and genetic data
15. understand that high blood pressure increases the risk of heart disease
16. understand that the misuse of drugs (e.g. Ecstasy, cannabis, nicotine and alcohol) can have an adverse effect on health, including heart rate and blood pressure, increasing the risk of a heart attack.

Module B2: Keeping healthy

B2.4 How do our bodies keep a healthy water balance?

1. understand that nervous and hormonal communication systems are involved in maintaining a constant internal environment (homeostasis)
2. understand that automatic control systems throughout the body maintain a range of factors at steady levels and that this is required for cells to function properly
3. recall that these control systems have:
   a. receptors to detect changes in the environment
   b. processing centres to receive information and coordinate responses automatically
   c. effectors to produce the response
4. **understand the principle of negative feedback**
5. **understand that negative feedback between the effector and the receptor of a control system reverses any changes to the system's steady state**
6. understand that a balanced water level is important for maintaining the concentration of cell contents at the correct level for cell activity
7. understand that water levels are controlled by balancing gains from drinks, food and respiration and losses through sweating, breathing, faeces and the excretion of urine
8. understand that the kidneys play a vital role in balancing levels of water, waste and other chemicals in the blood

   ⓘ *Candidates are not expected to recall details of kidney structure*
9. understand that the kidneys balance water levels by producing dilute or concentrated urine as a response to concentration of blood plasma, which is affected by external temperature, exercise level and intake of fluids and salt
10. **understand that concentration of urine is controlled by a hormone called ADH, which is released into the bloodstream by the pituitary gland**
11. **understand how ADH secretion is controlled by negative feedback**
12. understand that alcohol results in the production of a greater volume of more dilute urine, **due to ADH suppression**, which can lead to dehydration and adverse effects on health
13. understand that the drug Ecstasy results in a smaller volume of less dilute urine, **due to increased ADH production**.

3.4.3 Module B3: Life on Earth

Overview

Debate about theories for the evolution of life on Earth often features in the media and popular culture. Candidates consider different explanations for evolution. These contexts illustrate how explanations arise and become accepted, and the role of the scientific community in this process. Natural selection is introduced as the mechanism for evolution.

Biodiversity is recognised as an important natural resource, which is increasingly threatened by human activity. Candidates consider how ecosystems are in balance and how living organisms are dependent on their environment and each other for survival. The extinction of species is a growing concern often featured in the media. Candidates consider causes of extinction and whether extinctions should be a global concern.

The need for sustainability is frequently referred to in the press. Candidates are introduced to what this really means and how maintaining biodiversity is one of the keys to sustainability. Specific examples are used to show how sustainability can be increased.

Issues for citizens	Questions that science may help to answer
Why do some species survive whereas others do not survive?	How do different species depend on their environment and each other?
Is evolution 'just a theory'?	How have scientists developed explanations of evolution?
Where do new species come from?	How does evolution work?
Why do some species become extinct, and does it matter?	What is the importance of biodiversity?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations using fractions and percentages for energy transfer
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- extract information from charts, graphs and tables
- use ideas about correlation in the context of climate change.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- investigate adaptation in plants and animals
- eco-column practical investigation of food webs
- fieldwork to investigate biodiversity and environmental change in local habitats
- investigate the changes in nitrogen in an establishing aquarium over three weeks
- calculate an ecological 'footprint' that measures how great an impact an individual's lifestyle has on the environment.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- recording and displaying the results of DNA analysis
- monitoring and recording human and animal behaviour.

Use of ICT in teaching and learning can include:

- video clips to illustrate varied ecosystems
- use of the internet to research endangered plants or animals
- presentation to show how understanding of evolution develops as new evidence is discovered.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Developing scientific explanations

IaS 3.1 – 3.4

The scientific community

IaS 4.3, 4.4

Making decisions about science and technology

IaS 6.1, 6.2

Module B3: Life on Earth

B3.1 Systems in balance – how do different species depend on each other?

1. understand that a species is a group of organisms that can breed together to produce fertile offspring
2. understand that adaptation of living organisms to their environment increases the species' chance of survival by making it more likely that individuals will survive to reproduce
3. recall, and recognise when given relevant data, examples of how different organisms are adapted to their environment, and explain how the adaptations increase the organism's chance of surviving to successfully reproduce
4. understand that living organisms are dependent on the environment and other species for their survival
5. understand that there is competition for resources between different species of animals or plants in the same habitat
6. relate changes affecting one species in a food web to the impact on other species that are part of the same food web
7. **explain the interdependence of living organisms by using food webs**
8. understand that a change in the environment may cause a species to become extinct, for example, if:
    a. the environmental conditions change beyond its ability to adapt
    b. a new species that is a competitor, predator or disease organism of that species is introduced
    c. another species (animal, plant or microorganism) in its food web becomes extinct
9. understand that nearly all organisms are ultimately dependent on energy from the Sun
10. recall that plants absorb a small percentage of the Sun's energy for the process of photosynthesis
11. recall that this absorbed energy is stored in the chemicals which make up the plants' cells
12. understand that energy is transferred between organisms in an ecosystem:
    a. when organisms are eaten
    b. when dead organisms and waste materials are fed on by decay organisms (decomposers **and detritivores**)
13. explain how energy passes out of a food chain at each stage via heat, waste products and uneaten parts, limiting the length of food chains
14. calculate from given data the percentage efficiency of energy transfer at different stages of a food chain
15. understand how carbon is recycled through the environment to include the processes of combustion, respiration, photosynthesis and decomposition
16. understand the importance of the role of microorganisms in the carbon cycle

B3.1 Systems in balance – how do different species depend on each other?

17. understand how nitrogen is recycled through the environment in the processes of:

    a. nitrogen fixation to form nitrogen compounds including nitrates

    b. conversion of nitrogen compounds to protein in plants and animals

    c. transfer of nitrogen compounds through food chains

    d. excretion, death and decay of plants and animals resulting in release of nitrates into the soil

    e. uptake of nitrates by plants

    f. denitrification

    ⓘ *Foundation tier candidates are not expected to recall details of conversion of atmospheric nitrogen to nitrates, or nitrates to atmospheric nitrogen*

18. understand the importance of the role of microorganisms in the nitrogen cycle, including decomposition, **nitrogen fixation and denitrification**

19. interpret simple diagrams of the carbon cycle and nitrogen cycle

    ⓘ *Foundation tier candidates are not expected to recall nitrogen fixation or denitrification*

20. understand how environmental change can be measured using non-living indicators, including nitrate levels, temperature and carbon dioxide levels

21. understand how climate and environmental change can be measured using living indicators, including phytoplankton, lichens and aquatic river organisms such as mayfly nymphs

22. interpret data obtained from living and non-living indicators to investigate environmental change.

Module B3: Life on Earth

B3.2 How has life on Earth evolved?

1. recall that life on Earth began approximately 3500 million years ago
2. understand that life on Earth (including species that are now extinct) evolved from very simple living things
3. understand that there is variation between individuals of the same species and that some of this variation is genetic so can be passed on to offspring
4. understand that genetic variation is the result of changes that occur in genes (mutations)
5. understand that mutated genes in sex cells can be passed on to offspring and may occasionally produce new characteristics
6. understand the process of natural selection in terms of the effects of genetic variation and competition on survival and reproduction, leading to an increase in the number of individuals displaying beneficial characteristics in later generations
7. describe the similarities and differences between natural selection and selective breeding
8. interpret data on changes in a species in terms of natural selection
9. understand how the combined effect of mutations, environmental changes, natural selection and isolation can produce new species in the process of evolution
10. understand that evidence for evolution is provided by the fossil record and from analysis of similarities and differences in the DNA of organisms
11. understand that Darwin's theory of evolution by natural selection was the result of many observations and creative thought and why it is a better scientific explanation than Lamarck's (e.g. fits with advances in understanding of genetics, no evidence or mechanism for inheritance of acquired characteristics).

Module B3: Life on Earth

B3.3 What is the importance of biodiversity?

1. understand that organisms are classified into groups according to similarities and differences in characteristics including:
   a. physical features (e.g. flowers in flowering plants and the skeleton in vertebrates)
   b. DNA
   ⓘ *Candidates will not be expected to give examples of characteristics of particular taxonomic groups*
2. understand that organisms are classified at different levels, and that these levels can be arranged in an order progressing from large groups containing many organisms with a small number of characteristics in common (e.g. kingdom) to smaller groups containing fewer organisms with more characteristics in common (e.g. species)
   ⓘ *Candidates will not be expected to recall the names of taxa other than kingdom and species*
3. understand that the classification of living and fossil organisms can help to:
   a. make sense of the enormous diversity of organisms on Earth
   b. show the evolutionary relationships between organisms
4. understand that biodiversity refers to the variety of life on Earth including:
   a. the number of different species
   b. the range of different types of organisms, e.g. plants, animals and microorganisms
   c. the genetic variation within species
5. understand why biodiversity is important for the future development of food crops and medicines
6. understand that the rate of extinction of species is increasing and why this is likely to be due to human activity
7. understand that maintaining biodiversity to ensure the conservation of different species is one of the keys to sustainability
8. understand that sustainability means meeting the needs of people today without damaging the Earth for future generations
9. understand that large-scale monoculture crop production is not sustainable because it does not maintain biodiversity
10. describe and explain how sustainability can be improved, for example in the use of packaging materials, by considering the materials used, energy used and pollution created
11. understand why it is preferable to decrease the use of some materials, including packaging materials, even when they are biodegradable, because of:
    a. use of energy in their production and transport
    b. slow decomposition in oxygen deficient landfill sites.

3.5 Summary of Unit A162: *Biology A Modules B4, B5, B6*

Unit A162 assesses the content of *Modules B4, B5 and B6* together with the Ideas about Science.

The modules in Unit A162 give emphasis and space to fundamental ideas in the sciences, ensure that appropriate skills are developed in preparation for further study, and provide a stimulating bridge to advanced level studies in science. The emphasis of the unit is on 'science for the scientist' and those aspects of 'How Science Works' that relate to the process of science.

3.5.1 Module B4: The processes of life

Overview

Biological processes that take place in cells involve chemical reactions catalysed by enzymes. Photosynthesis and respiration are examples of these processes, and these reactions take place in specialised structures within cells. The conditions for optimum enzyme action require temperature and pH to be controlled. Anaerobic respiration of microorganisms and yeast provides humans with useful products, including biogas, bread and alcohol.

The first topic considers some of the most fundamental chemical reactions that occur within cells and highlights the crucial role that enzymes play in these processes. The highly specific nature of enzymes is explored, along with sensitivity of enzymes to their environment. The lock and key model provides an accessible example of how models and analogy can enhance understanding of scientific processes.

The second topic focuses in more detail on photosynthesis and the processes plants utilise to take in and transport water and nutrients, necessary to produce the complex molecules required for plant growth.

The processes of plant growth are also fundamental to providing the glucose and complex sugars that many animal and microbial life forms depend upon for respiration. Respiration is explored in more detail in the third topic.

Topics
B4.1 How do chemical reactions take place in living things?
Reactions in cells; role of enzymes
B4.2 How do plants make food?
Photosynthesis; cell structures for photosynthesis; limiting factors
B4.3 How do living organisms obtain energy?
Aerobic respiration; anaerobic respiration; cell structures for respiration

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations using fractions and percentages
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use ideas about correlation.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- investigate how seed beetles are able to sense their surroundings
- investigate the effects of an enzyme on biological processes
- investigate the factors affecting photosynthesis
- use microscopes to look carefully at the structure of leaves
- investigate rates of diffusion in different media
- investigate the effect of solute concentration on potato cell water balance
- use soil tests to compare soils and composts
- use field work to investigate factors affecting the species of plants in different environmental conditions
- investigate the energy content of different foods
- use data logging to track temperature changes during respiration in peas
- investigate anaerobic respiration in yeast.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- molecular modelling to develop explanations of enzyme action.

Use of ICT in teaching and learning can include:

- animations to explain enzyme action and the effect of temperature on enzyme activity
- animations of diffusion, osmosis and active transport.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

IaS 1.1 – 1.6

Cause-effect explanations

IaS 2.1, 2.2

Module B4: The processes of life

B4.1 How do chemical reactions take place in living things?

1. understand that the basic processes of life carried out by all living things depend on chemical reactions within cells that require energy released by respiration
2. understand the role of photosynthesis in making food molecules and energy available to living organisms through food chains
3. describe photosynthesis as a series of chemical reactions that use energy from sunlight to build large food molecules in plant cells and some microorganisms (e.g. phytoplankton)
4. describe respiration as a series of chemical reactions that release energy by breaking down large food molecules in all living cells
5. recall that enzymes are proteins that speed up chemical reactions
6. recall that cells make enzymes according to the instructions carried in genes
7. understand that molecules have to be the correct shape to fit into the active site of the enzyme (the lock and key model)
8. understand that enzymes need a specific constant temperature to work at their optimum, and that they permanently stop working (**denature**) if the temperature is too high
9. **explain that enzyme activity at different temperatures is a balance between:**
   - a. **increased rates of reaction as temperature increases**
   - b. **changes to the active site at higher temperatures, including denaturing**
   - ⓘ *Candidates are not expected to explain why rates of reaction increase with temperature*
10. recall that an enzyme works at its optimum at a specific pH
11. **explain the effect of pH on enzyme activity in terms of changes to the shape of the active site.**

Module B4: The processes of life

4.2 How do plants make food?

1. recall the names of the reactants and products of photosynthesis, and use the word equation:

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

2. recall the formulae of the reactants and products of photosynthesis, and use the symbol equation:

$$\mathbf{6CO_2 + 6H_2O \xrightarrow{\text{light energy}} C_6H_{12}O_6 + 6O_2}$$

3. recall the main stages of photosynthesis:
   a. light energy absorbed by the green chemical chlorophyll
   b. energy used to bring about the reaction between carbon dioxide and water to produce glucose (a sugar)
   c. oxygen produced as a waste product
4. recall that glucose may be:
   a. converted into chemicals needed for growth of plant cells, for example cellulose, protein and chlorophyll
   b. converted into starch for storage
   c. used in respiration to release energy
5. recall the structure of a typical plant cell, limited to chloroplasts, cell membrane, nucleus, cytoplasm, mitochondria, vacuole and cell wall
6. understand the functions of the structures in a typical plant cell that have a role in photosynthesis, including:
   a. chloroplasts contain chlorophyll and the enzymes for the reactions in photosynthesis
   b. cell membrane allows gases and water to pass in and out of the cell freely while presenting a barrier to other chemicals
   c. nucleus contains DNA which carries the genetic code for making enzymes and other proteins used in the chemical reactions of photosynthesis
   d. cytoplasm where the enzymes and other proteins are made
7. recall that minerals taken up by plant roots are used to make some chemicals needed by cells, including nitrogen from nitrates to make proteins
8. understand that diffusion is the passive overall movement of molecules from a region of their higher concentration to a region of their lower concentration
9. recall that the movement of oxygen and carbon dioxide in and out of leaves during photosynthesis occurs by diffusion

4.2 How do plants make food?

10. understand that osmosis (a specific case of diffusion) is the overall movement of water from a dilute to a more concentrated solution through a partially permeable membrane

11. recall that the movement of water into plant roots occurs by osmosis

12. understand that active transport is the overall movement of chemicals across a cell membrane requiring energy from respiration

13. recall that active transport is used in the absorption of nitrates by plant roots

14. understand that the rate of photosynthesis may be limited by:

    a. temperature

    b. carbon dioxide

    c. light intensity

15. interpret data on factors limiting the rate of photosynthesis

16. describe and explain techniques used in fieldwork to investigate the effect of light on plants, including:

    a. using a light meter

    b. using a quadrat

    c. using an identification key

17. understand how to take a transect.

Module B4: The processes of life

B4.3 How do living organisms obtain energy?

1. understand that all living organisms require energy released by respiration for some chemical reactions in cells, including chemical reactions involved in:
   a. movement
   b. synthesis of large molecules
   c. active transport
2. understand that synthesis of large molecules includes:
   a. synthesis of polymers required by plant cells such as starch and cellulose from glucose in plant cells
   b. synthesis of amino acids from glucose and nitrates, and then proteins from amino acids in plant, animal and microbial cells
3. recall that aerobic respiration takes place in animal and plant cells and some microorganisms, and requires oxygen
4. recall the names of the reactants and products of aerobic respiration and use the word equation:

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

5. recall the formulae of the reactants and products of aerobic respiration and use the symbol equation:

$$\mathbf{C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O}$$

6. recall that anaerobic respiration takes place in animal, plant and some microbial cells in conditions of low oxygen or absence of oxygen, to include:
   a. plant roots in waterlogged soil
   b. bacteria in puncture wounds
   c. human cells during vigorous exercise
7. recall the names of the reactants and products of anaerobic respiration in animal cells and some bacteria, and use the word equation:

   glucose → lactic acid (+ energy released)

8. recall the names of the reactants and products of anaerobic respiration in plant cells and some microorganisms including yeast, and use the word equation:

   glucose → ethanol + carbon dioxide (+ energy released)

9. understand that aerobic respiration releases more energy per glucose molecule than anaerobic respiration

B4.3 How do living organisms obtain energy?

10. recall the structure of typical animal and microbial cells (bacteria and yeast) limited to:
    a. nucleus
    b. cytoplasm
    c. cell membrane
    d. mitochondria (for animal and yeast cells)
    e. cell wall (for yeast and bacterial cells)
    f. circular DNA molecule (for bacterial cells)
11. understand the functions of the structures in animal, plant, bacteria and yeast cells that have a role in respiration, including:
    a. mitochondria contain enzymes for the reactions in aerobic respiration (in animals, plants and yeast)
    b. cell membrane allows gases and water to pass in and out of the cell freely while presenting a barrier to other chemicals
    c. nucleus or circular DNA in bacteria contains DNA which carries the genetic code for making enzymes used in the chemical reactions of respiration
    d. cytoplasm where enzymes are made and which contains the enzymes used in anaerobic respiration
12. describe examples of the applications of the anaerobic respiration of microorganisms, including the production of biogas and fermentation in bread making and alcohol production.

3.5.2 Module B5: Growth and development

Overview

Genetic technologies are at the cutting edge of contemporary science. Research into proteomics, stem cell technology and cellular growth control is at the forefront of modern medical science. Knowledge and understanding of these areas promise powerful applications to benefit both present and future generations.

The first topic explains plant and animal development, comparing and contrasting the development of unspecialised cells. The ability of plant meristems to regenerate whole plants is considered, including the effect of plant hormones on their development.

The second topic looks at how the structure of DNA allows cells to be accurately copied. Key stages in the cell cycle are identified, and cell division by mitosis and meiosis compared.

The final topic describes the process of protein synthesis, following the one-gene-one-protein hypothesis.

Topics
B5.1 How do organisms develop?
Embryo development; cell specialisation in plants and animals; plant growth responses
B5.2 How does an organism produce new cells?
Main processes of the cell cycle; comparisons of mitosis and meiosis
B5.3 How do genes control growth and development within the cell?
Structure of genetic code and mechanism for protein synthesis

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of DNA, cells and plants
- carry out calculations using fractions and percentages
- plot, draw and interpret graphs and charts from candidates' own and secondary data.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- use microscopes to look at a variety of plant and animal cells
- dissect and draw a broad bean
- take plant cuttings and investigate the effects of using hormone rooting powder
- investigate the effects of phototropism
- view germinating pollen
- extract DNA from plants.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- imaging cells and observing their growth and development.

Use of ICT in teaching and learning can include:

- animations to illustrate DNA structure, replication, and protein synthesis
- animations to illustrate cell division
- video clips to show stages in human development.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Developing scientific explanations

IaS 3.1 – 3.4

Module B5: Growth and development

B5.1 How do organisms develop?

1. recall that cells in multicellular organisms can be specialised to do particular jobs
2. recall that groups of specialised cells are called tissues, and groups of tissues form organs
3. recall that a fertilised egg cell (zygote) divides by mitosis to form an embryo
4. recall that in a human embryo up to (and including) the eight cell stage, all the cells are identical (embryonic stem cells) and could produce any type of cell required by the organism
5. understand that after the eight cell stage, most of the embryo cells become specialised and form different types of tissue
6. understand that some cells (adult stem cells) remain unspecialised and can become specialised at a later stage to become many, but not all, types of cell required by the organism
7. understand that in plants, only cells within special regions called meristems are mitotically active
8. understand that the new cells produced from plant meristems are unspecialised and can develop into any kind of plant cell
9. understand that unspecialised plant cells can become specialised to form different types of tissue (including xylem and phloem) within organs (including flowers, leaves, stems and roots)
10. understand that the presence of meristems (as sources of unspecialised cells) allows the production of clones of a plant from cuttings, and that this may be done to reproduce a plant with desirable features
11. understand that a cut stem from a plant can develop roots and then grow into a complete plant which is a clone of the parent, and that rooting can be promoted by the presence of plant hormones (**auxins**)
12. understand that the growth and development of plants is also affected by the environment, e.g. phototropism
13. understand how phototropism increases the plant's chance of survival
14. **explain phototropism in terms of the effect of light on the distribution of auxin in a shoot tip.**

Module B5: Growth and development

B5.2 How does an organism produce new cells?

1. recall that cell division by mitosis produces two new cells that are genetically identical to each other and to the parent cell
2. describe the main processes of the cell cycle:
   a. cell growth during which:
      - numbers of organelles increase
      - the chromosomes are copied when the two strands of each DNA molecule separate and new strands form alongside them
   b. mitosis during which:
      - copies of the chromosomes separate
      - the nucleus divides

   ⓘ *Candidates are not expected to recall intermediate stages of mitosis*
3. recall that meiosis is a type of cell division that produces gametes
4. understand why, in meiosis, it is important that the cells produced only contain half the chromosome number of the parent cell

   ⓘ *Candidates are not expected to recall intermediate stages of meiosis*
5. understand that a zygote contains a set of chromosomes from each parent.

Module B5: Growth and development

B5.3 How do genes control growth and development within the cell?

1. recall that DNA has a double helix structure
2. recall that both strands of the DNA molecule are made up of four different bases which always pair up in the same way: A with T, and C with G
3. understand that the order of bases in a gene is the genetic code for the production of a protein
4. **explain how the order of bases in a gene is the code for building up amino acids in the correct order to make a particular protein**

   ⓘ *Candidates are not expected to recall details of nucleotide structure, transcription or translation*

5. recall that the genetic code is in the cell nucleus of animal and plant cells but proteins are produced in the cell cytoplasm
6. understand that genes do not leave the nucleus but a copy of the gene (**messenger RNA**) is produced to carry the genetic code to the cytoplasm
7. understand that although all body cells in an organism contain the same genes, many genes in a particular cell are not active (switched off) because the cell only produces the specific proteins it needs
8. understand that in specialised cells only the genes needed for the cell can be switched on, but in embryonic stem cells any gene can be switched on during development to produce any type of specialised cell
9. understand that adult stem cells and embryonic stem cells have the potential to produce cells needed to replace damaged tissues
10. understand that ethical decisions need to be taken when using embryonic stem cells and that this work is subject to Government regulation
11. **understand that, in carefully controlled conditions of mammalian cloning, it is possible to reactivate (switch on) inactive genes in the nucleus of a body cell to form cells of all tissue types.**

3.5.3 Module B6: Brain and mind

Overview

How the human brain functions remains largely unknown. Neuroscience is an area at the frontier of medical research, and has huge potential impact for an ageing population.

This module begins by looking at how, in order to survive, simple organisms respond to changes in their environment. The nervous system of multicellular animals is also considered.

The second topic considers how information is transmitted from receptor cells to effector cells, including a simple description of chemical transmission across synapses. The effects of drugs on synapses in the brain are explored (for example, Ecstasy).

Simple, conditioned and modified reflexes are introduced in the third topic, with reference to survival and adaptation.

The fourth topic takes a closer look at the brain, and how some neuron pathways become 'preferred' while other potential pathways remain available to allow for adaptation to new situations. This topic illustrates specialised areas of the brain, identifies methods scientists have used to map the cerebral cortex and introduces a basic understanding of memory.

Topics
B6.1 How do animals respond to changes in their environment?
Co-ordination of responses to stimuli via the central nervous system
B6.2 How is information passed through the nervous system?
Structure of neurons; transmission of electrical impulses, including synapses; effects of Ecstasy on synapse action
B6.3 What can we learn through conditioning?
Simple reflex actions for survival; mechanism of a reflex arc; conditioned reflexes
B6.4 How do humans develop more complex behaviour?
Formation of neuron pathways and learning through repetition; mapping brain function; models for understanding memory

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- plot, draw and interpret graphs and charts from candidates' own and secondary data.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- investigate reflex behaviour of woodlice
- look at microscope slides of neurons
- research reflex behaviour in newborn babies and in other animals
- investigate receptor cells on the tongue
- measure the speed at which a nerve impulse travels
- investigate factors that affect reaction times
- measure the touch sensitivity of different areas of the body
- make a presentation about Pavlov and his work on conditioned reflexes
- investigate how practice of a skill improves performance
- investigate pupils' own learning
- investigate whether woodlice have a memory.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- observe and digitally record human and animal behaviour
- log, record and display physiological data.

Use of ICT in teaching and learning can include:

- video clips to illustrate patterns in the behaviour of living things
- animations to explain synapse function and the effects of drugs on synapses
- interactive animations on brain function
- using the internet to research behaviour and memory.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Making decisions about science and technology

IaS 6.5, 6.6

Module B6: Brain and mind

B6.1 How do animals respond to changes in their environment?

1. recall that a stimulus is a change in the environment of an organism
2. understand that simple reflexes produce rapid involuntary responses to stimuli
3. understand that the simplest animals rely on reflex actions for the majority of their behaviour
4. understand that these reflex actions help to ensure that the simplest animals respond to a stimulus in a way that is most likely to result in their survival, to include finding food and sheltering from predators
5. recall examples of simple reflexes in humans, to include newborn reflexes (e.g. stepping, grasping, sucking), pupil reflex, knee jerk and dropping a hot object
6. understand that nervous co-ordination, including simple reflexes, requires:
    a. receptors to detect stimuli
    b. processing centres to receive information and coordinate responses
    c. effectors to produce the response
7. understand that receptors and effectors can form part of complex organs, for example:
    a. light receptor cells in the retina of the eye
    b. hormone secreting cells in a gland
    c. muscle cells in a muscle
8. understand that nervous systems use electrical impulses for fast, short-lived responses including simple reflexes
9. recall that hormones are chemicals that are produced in glands, travel in the blood and bring about slower, longer-lasting responses, e.g. insulin and oestrogen
10. recall that the development of nervous and hormonal communication systems depended on the evolution of multicellular organisms.

Module B6: Brain and mind

B6.2 How is information passed through the nervous system?

1. recall that nervous systems are made up of neurons (nerve cells) linking receptor cells (e.g. in eyes, ears and skin) to effector cells (in muscles/glands)
2. recall that neurons transmit electrical impulses when stimulated
3. recall that an axon is a long extension of the cytoplasm in a neuron and is surrounded by cell membrane
4. understand that some axons are surrounded by a fatty sheath, which insulates the neuron from neighbouring cells and increases the speed of transmission of a nerve impulse
5. recall that in humans and other vertebrates the central nervous system (CNS) is made up of the spinal cord and brain
6. recall that in the mammalian nervous system the CNS (brain and spinal cord) is connected to the body via the peripheral nervous system (PNS) (sensory and motor neurons)
7. understand that the CNS coordinates an animal's responses via:
    a. sensory neurons carrying impulses from receptors to the CNS
    b. motor neurons carrying impulses from the CNS to effectors
8. understand that within the CNS, impulses are passed from sensory neurons to motor neurons through relay neurons
9. describe the nervous pathway of a spinal reflex arc to include receptor, sensory neuron, relay neuron, spinal cord, motor neuron and effector
10. **understand that this arrangement of neurons into a fixed pathway allows reflex responses to be automatic and so very rapid, since no processing of information is required**
11. recall that there are gaps between adjacent neurons called synapses and that impulses are transmitted across them
12. **understand that at a synapse an impulse triggers the release of chemicals (transmitter substances) from the first neuron into the synapse, which diffuse across and bind to receptor molecules on the membrane of the next neuron**
13. **understand that only specific chemicals bind to the receptor molecules, initiating a nerve impulse in the next neuron**
14. recall that some toxins and drugs, including Ecstasy, beta blockers and Prozac, affect the transmission of impulses across synapses
15. **understand that Ecstasy (MDMA) blocks the sites in the brain's synapses where the transmitter substance, serotonin, is removed**
16. **understand that the effects of Ecstasy on the nervous system are due to the subsequent increase in serotonin concentration**
17. recall that the cerebral cortex is the part of our brain most concerned with intelligence, memory, language and consciousness
18. understand that scientists can map the regions of the brain to particular functions (including studies of patients with brain damage, studies in which different parts of the brain are stimulated electrically, and brain scans such as MRI, showing brain structure and activity).

Module B6: Brain and mind

B6.3 Can reflex responses be learned?

1. understand that a reflex response to a new stimulus can be learned by introducing the secondary (new) stimulus in association with the primary stimulus, and that this is called conditioning
2. describe and explain two examples of conditioning, including Pavlov's dogs
3. **understand that in a conditioned reflex the final response (e.g. salivation) has no direct connection to the secondary stimulus (e.g. ringing of a bell)**
4. **understand that conditioned reflexes are a form of simple learning that can increase an animal's chance of survival**
5. **recall that in some circumstances the brain can modify a reflex response via a neuron to the motor neuron of the reflex arc, for example keeping hold of a hot object.**

Module B6: Brain and mind

B6.4 How do humans develop more complex behaviour?

1. understand that the evolution of a larger brain gave early humans a better chance of survival
2. recall that mammals have a complex brain of billions of neurons that allows learning by experience, including social behaviour
3. understand that during development the interaction between mammals and their environment results in neuron pathways forming in the brain
4. understand that learning is the result of experience where:
    a. certain pathways in the brain become more likely to transmit impulses than others
    b. new neuron pathways form and other neuron pathways are lost
5. understand that this is why some skills may be learnt through repetition
6. **understand that the variety of potential pathways in the brain makes it possible for the animal to adapt to new situations**
7. **understand the implications of evidence suggesting that children may only acquire some skills at a particular age, to include language development in feral children**
8. describe memory as the storage and retrieval of information
9. recall that memory can be divided into short-term memory and long-term memory
10. understand that humans are more likely to remember information if:
    a. they can see a pattern in it (or impose a pattern on it)
    b. there is repetition of the information, especially over an extended period of time
    c. there is a strong stimulus associated with it, including colour, light, smell, or sound
11. understand how models can be used to describe memory (including the multi-store model) to include short-term memory, long-term memory, repetition, storage, retrieval and forgetting
12. understand that models are limited in explaining how memory works.

3.6 Summary of Unit A163: *Biology A Module B7*

Unit A163 assesses the content of *Module B7* together with the Ideas about Science.

Unit A163 includes additional content to enhance progression and to give a greater understanding of the subjects concerned. This unit continues the emphasis on 'science for the scientist' in preparation for further study, and provides a stimulating bridge to advanced level studies in science.

3.6.1 Module B7: Further Biology

Overview

More than ever before, Biology in the Twenty First Century is at the forefront of science. In this module, candidates draw together and develop their understanding of some of the major science explanations they have studied during Modules B1 – B3 (Unit A161) and Modules B4 – B6 (Unit A162). Throughout *Module B7* candidates have opportunities to employ Ideas about Science from IaS1 (Data: their importance and limitations), IaS5 (Risk), and IaS6 (Making decisions about science and technology).

Medicine and health, and production of food and other resources such as fuels are important areas involving biological sciences. In 'Peak performance' pupils learn more about how human bodies work and how to keep fit and healthy.

Humans cannot live without consideration of their place in the natural world. We are part of the natural world and dependent on it for our survival. In 'What can we learn from natural ecosystems?' pupils find out how the natural world provides humans with a model for sustainable systems.

In 'New technologies' pupils discover more about the fast-moving world of modern biological techniques. Many of these have implications for human food production and production of medicines and other useful products.

Topics
B7.1 Peak performance – movement and exercise
Skeletal system; health and fitness
B7.2 Peak performance – circulation
Components of blood; the circulatory system
B7.3 Peak performance – energy balance
Maintaining constant body temperature and blood sugar; diabetes
B7.4 What can we learn from natural ecosystems?
Closed loop systems; sustainability
B7.5 New technologies
DNA technology; genetic modification; nanotechnology; stem cells

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of DNA, cells, organs, organisms and ecosystems
- develop a sense of scale in the context of nanotechnology
- carry out calculations using experimental data on heart rate and recovery period after exercise
- carry out calculations to find the percentage increase in measured values including muscle length and heart rate
- use ideas of proportion in the context of gel electrophoresis of DNA fragments
- plot, draw, and interpret graphs and charts from candidates' own and secondary data in the context of seed germination, injury recovery times, body mass index, and enzyme activity
- use ideas about correlation in the context of blood sugar and insulin levels
- use ideas about uncertainty and probability in the context of the risks and benefits of genetically modified organisms
- use the equation for calculating BMI including appropriate units for physical quantities.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- find out how muscles and bones enable humans and other animals to move, both by self-observation and by dissecting a chicken wing
- investigate the physiology of fitness
- investigate the energy content of oil from different seeds
- investigate the role of microorganisms in recycling
- investigate the effect of temperature on enzyme activity
- investigate the conditions required for seed germination
- heart dissection
- model an ecosystem on a small scale
- use a model to investigate the role of blood in maintaining a constant body temperature.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- log, store and display data for analysis and evaluation
- the integral role of ICT in DNA technologies
- animations of movement at a joint
- animations of the heart
- animations of valves in veins
- investigate the structures in a chicken leg

Use of ICT in teaching and learning can include:

- video clips of physiotherapy
- video clips showing behaviour of living things in response to extreme temperatures
- a data logger to monitor body temperature over 12 or 24 hours
- video clips of Easter Island
- video clips of Masai people
- video clips of biodigester in use
- video clips of desert
- animations of genetic modification
- animations to illustrate the change in surface area as material is divided up
- using the internet to research new technologies.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

IaS 1.1 – 1.6

Cause-effect explanations

IaS 2.3 – 2.5

Developing scientific explanations

IaS 3.4

Risk

IaS 5.1 – 5.3

Making decisions about science and technology

IaS 6.1 – 6.6

Module B7: Further Biology

B7.1 Peak performance – movement and exercise

1. understand that the internal skeleton of vertebrates is needed for support and movement
2. understand that muscles can only move bones at a joint by contraction, and thus operate in antagonistic pairs
3. recall the structure and function of the components of a joint, to include:
   a. smooth layer of cartilage and synovial fluid to reduce friction between bones
   b. elastic ligaments to stabilise joints while allowing movement
   c. tendons to transmit the forces between muscle and bones
4. understand how the specific properties of ligaments, cartilage and tendons enable them to function effectively
5. explain why certain factors in a person's medical or lifestyle history need to be disclosed before an exercise regime is started (for example: symptoms, current medication, alcohol and tobacco consumption, level of physical activity, family medical history and previous treatments)
6. interpret data obtained when monitoring a person during and after exercise, including change in heart rate, change in blood pressure and the recovery period
7. use proportion of body fat and body mass index (BMI) as measurements of fitness
8. use the equation:

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

9. **understand that any assessment of progress needs to take into account the accuracy of the monitoring technique and the repeatability of the data obtained**
10. recall common injuries that can be caused by excessive exercise, to include sprains, dislocations, and torn ligaments or tendons
11. recall symptoms and basic treatments for a sprain
12. describe the role of the physiotherapist in treatment of skeletal-muscular injury.

Module B7: Further Biology

B7.2 Peak performance – circulation

1. explain what is meant by a double circulatory system
2. understand that the blood carries glucose molecules and oxygen to the muscles, and waste products such as carbon dioxide away from muscles
3. relate the components of the blood to their functions, including:
    a. red blood cells – transport oxygen
    b. white blood cells – fighting infections
    c. platelets – blood clotting at injury sites
    d. plasma – transporting nutrients (e.g. glucose and amino acids), antibodies, hormones and waste (carbon dioxide and urea)
4. understand how red blood cells are adapted to their function, limited to:
    a. packed with haemoglobin (to bind oxygen)
    b. no nucleus (more space for haemoglobin)
    c. biconcave shape (increased surface area for oxygen exchange)
5. describe and name the main structures and blood vessels of the heart including the left and right atria and ventricles, vena cava, aorta, pulmonary vein, pulmonary artery, coronary arteries and valves
6. describe the function of valves in the heart and veins
7. **understand how tissue fluid is formed in capillary beds and that it assists the exchange of chemicals by diffusion between capillaries and tissues, to include oxygen, carbon dioxide, glucose and urea.**

Module B7: Further Biology

B7.3 Peak performance – energy balance

1. understand that to maintain a constant body temperature, heat gained (including heat released during respiration) is balanced by heat lost
2. recall that temperature receptors in the skin detect external temperature
3. recall that temperature receptors in the brain (**hypothalamus**) detect the temperature of the blood
4. understand that the brain (**hypothalamus**) acts as a processing centre, receiving information from the temperature receptors, and sending instructions to trigger the effectors automatically
5. recall that effectors include sweat glands and muscles
6. understand that at high body temperatures:
   a. more sweat is produced by sweat glands which cools the body when it evaporates
   b. blood vessels supplying the capillaries of the skin dilate (vasodilation) allowing more blood to flow through skin capillaries which increases heat loss
7. explain how exercise produces increased sweating, and can produce dehydration, which may lead to reduced sweating and further increase of core body temperature
8. understand that at low body temperatures:
   a. the increased rate of respiration stimulated when muscles contract rapidly (shivering) results in some of the energy transferred in respiration warming the surrounding tissues
   b. blood vessels supplying the capillaries of the skin constrict (vasoconstriction) restricting blood flow through skin capillaries which reduces heat loss
9. **understand that some effectors work antagonistically, which allows a more sensitive and controlled response**
10. understand that high levels of sugar, common in some processed foods, are quickly absorbed into the blood stream, causing a rapid rise in the blood sugar level
11. recall that there are two types of diabetes (type 1 and type 2), and that it is particularly late-onset diabetes (type 2) which is more likely to arise because of poor diet or obesity
12. understand that type 1 diabetes arises when the pancreas stops producing enough of the hormone, insulin, but that type 2 diabetes develops when the body no longer responds to its own insulin or does not make enough insulin
13. recall that type 1 diabetes is controlled by insulin injections and that type 2 diabetes can be controlled by diet and exercise
14. explain how a diet high in fibre and complex carbohydrates can help to maintain a constant blood sugar level
15. interpret data on risks associated with an unhealthy lifestyle (limited to poor diet and lack of exercise), including obesity, heart disease, diabetes and some cancers.

Module B7: Further Biology

B7.4 What can we learn from natural ecosystems?

1. recall that a perfect closed loop system is a system that has no waste because the output from one part of the system becomes the input to another part
2. understand that an ecosystem is a type of closed loop system since most waste materials are not lost but are used as food or reactants
3. name examples of waste products in natural ecosystems, to include oxygen (from photosynthesis), carbon dioxide (from respiration), and dead organic matter such as fallen petals, leaves and fruits, and faeces
4. understand how these waste products may become food or reactants for animals, plants and microorganisms in the ecosystem, including the role of the digestive enzymes of microorganisms
5. interpret closed loop system diagrams and data on the storage and movement of chemicals through an ecosystem, including water, carbon, nitrogen and oxygen

   ⓘ *Candidates will not be expected to recall details of the nutrient cycles*
6. understand that no ecosystem is a perfect closed loop system since some output is always lost, e.g. migration of organisms and loss of nutrients transferred by air or water
7. understand that in stable ecosystems, including rainforests, the output (losses) is balanced by gains
8. understand why the production of large quantities of reproductive structures, including eggs, sperm, pollen, flowers and fruit, is a necessary strategy for successful reproduction
9. understand that, in stable ecosystems, the production of large quantities of these reproductive structures is not wasteful, since the surplus is recycled in the ecosystem
10. recall that vegetation in stable ecosystems, such as rain forests, prevents soil erosion and extremes of temperature, and promotes cloud formation
11. understand that vegetation reduces soil erosion since foliage protects the soil from direct rainfall and roots help to bind the soil together
12. understand that humans depend on natural ecosystems to provide 'ecosystem services', for example providing clean air, water, soil, mineral nutrients, pollination, fish and game
13. understand that human systems are not closed loop systems because some waste leaves the system, including non-recycled waste from households, agriculture and industry, and emissions from burning fossil fuels
14. understand that some non-recycled waste can build up to harmful levels, **including bioaccumulation in food chains**
15. understand that human activity can unbalance natural ecosystems by altering the inputs and outputs, and that this leads to change
16. **describe and explain the process of eutrophication**
17. describe the environmental impact of removing biomass from natural closed loop systems for human use, to include unsustainable timber harvesting and fishing

B7.4 What can we learn from natural ecosystems?

18. explain the impact of replacing vegetation in natural ecosystems with agricultural crops and livestock, to include the loss of biodiversity, silting of rivers and desertification

19. understand that the use of natural resources by humans can only be sustainable if used at a rate at which they can be replaced

20. understand why the use of crude oil does not fulfil the requirements of a closed loop system, including:

    a. crude oil takes millions of years to form from the decay of dead organisms

    b. energy released from burning crude oil originated from the Sun when these organisms were alive ('fossil sunlight energy')

21. recall and understand solutions to allow sustainable harvesting of natural resources such as timber and fish, including the use of quotas and restocking/replanting

22. describe the role of sunlight as a sustainable source of energy for natural ecosystems and sustainable agriculture

23. understand the tensions between conserving natural ecosystems and the needs of local human communities.

Module B7: Further Biology

B7.5 New technologies

1. recall the features of bacteria that make them ideal for industrial and genetic processes to include:
   a. rapid reproduction
   b. presence of plasmids
   c. simple biochemistry
   d. ability to make complex molecules
   e. lack of ethical concerns in their culture
2. understand that bacteria and fungi can be grown on a large scale (fermentation) to include production of:
   a. antibiotics and other medicines
   b. single-cell protein
   c. enzymes for food processing, for example chymosin as a vegetarian substitute for rennet
   d. enzymes for commercial products, such as washing powders and to make biofuels
3. recall that genetic modification is where a gene from one organism is transferred to another and continues to work
4. recall the main steps in genetic modification as:
   a. isolating and replicating the required gene
   b. putting the gene into a suitable vector (virus or plasmid)
   c. using the vector to insert the gene into a new cell
   d. selecting the modified individuals
5. recall examples of the application of genetic modification, to include:
   a. bacterial synthesis of medicines, for example insulin
   b. herbicide resistance in crop plants
6. **understand and explain the use of DNA technology in genetic testing, to include:**
   a. isolation of a DNA sample from white blood cells
   b. production of a gene probe labelled with a fluorescent chemical
   c. addition of the labelled gene probe (marker) to the DNA sample
   d. use of UV to detect the marker and therefore indicate the position of the gene or the presence of a specific allele in the DNA sample
7. recall that nanotechnology involves structures that are about the same size as some molecules
8. describe the application of nanotechnology in the food industry, including food packaging which can increase shelf life and detect contaminants
9. describe applications of stem cell technology in tissue and organ culture, including the treatment of leukaemia and the potential to treat spinal cord injuries
10. describe the role of biomedical engineering in pacemakers and the replacement of faulty heart valves.