B1.1 What is the genome and what does it do?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
All organisms contain genetic material. Genetic material contains instructions that control how cells and organisms develop and function. Most of an organism's characteristics depend on these instructions and are modified by interaction with the environment. Genetic material in plant and animal cells is located in the nucleus, one of the main sub-cellular structures. In organisms whose cells do not have a nucleus (e.g. bacteria) the genetic material is located in the cytoplasm. All the genetic material of a cell is the organism's genome. In most organisms the genome is packaged into chromosomes. Chromosomes are long molecules of DNA. Genes are sections of this DNA. In the cells of plants and animals, chromosomes occur in pairs. The two chromosomes in a pair each carry the same genes. The two versions of each gene in the pair are called alleles, and can be the same or different. A different version of a gene is a genetic variant. The genotype of an organism is the combination of alleles it has for each gene; the phenotype is the characteristic that results from this combination and interaction with the environment. Genes tell a cell how to make proteins by joining together amino acids in a particular order.	1. a) explain how the nucleus and genetic material of eukaryotic cells (plants and animals) and the genetic material, including plasmids, of prokaryotic cells are related to cell functions b) describe how to use a light microscope to observe a variety of plant and animal cells *PAG1* 2. describe the genome as the entire genetic material of an organism 3. describe DNA as a polymer made up of nucleotides, forming two strands in a double helix 4. describe simply how the genome and its interaction with the environment influence the development of the phenotype of an organism, including the idea that most characteristics depend on instructions in the genome and are modified by interaction of the organism with its environment ⓘ *Learners are not expected to describe epigenetic effects* 5. explain the terms chromosome, gene, allele, variant, genotype and phenotype 6. explain the importance of amino acids in the synthesis of proteins, including the genome as instructions for the polymerisation of amino acids to make proteins

Linked learning opportunities

Practical work:

- use a microscope to look at a variety of plant and animal cells
- extract DNA from plant tissue

Specification links:

- principles of polymerisation, and DNA and proteins as examples of polymers (C4.2)

B1.1 What is the genome and what does it do?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
DNA is a polymer in which the monomers are nucleotides. Each nucleotide includes one of four different bases (adenine, thymine, cytosine or guanine). **The order of bases in a genome is the genetic code. The genetic code is modelled using letters (A, T, C, G) to represent the bases (IaS3). The order (sequence) of bases in a gene is the code for protein synthesis.** **Each set of three nucleotides is the code for an amino acid. The properties of the protein that is made depend on which amino acids are present and their order.**	7. describe DNA as a polymer made from four different nucleotides, each nucleotide consisting of a common sugar and phosphate group with one of four different bases attached to the sugar *(separate science only)*	**Ideas about Science:** • using letters to model the genetic code (IaS3)
	8. explain simply how the sequence of bases in DNA codes for the proteins made in protein synthesis, including the idea that each set of three nucleotides is the code for an amino acid *(separate science only)*	
	9. recall a simple description of protein synthesis, in which: • **a copy of a gene is made from messenger RNA (mRNA)** • **the mRNA travels to a ribosome in the cytoplasm** • **the ribosome joins amino acids together in an order determined by the mRNA** **ⓘ *Learners are not expected to recall details of transcription and translation*** *(separate science only)*	
The order of bases in DNA can be changed if one or more nucleotides is deleted, inserted or substituted for a different nucleotide; these are mutations, and create genetic variants. **If the sequence of bases in a gene is changed by mutation, a protein made from it may function differently or not at all, though in some cases, the mutation won't have any effect.** **Some sections of DNA do not code for a protein, but they control whether particular genes are expressed, and therefore whether particular proteins are made. Thus, mutations in these sections can also affect phenotype by altering gene expression.**	**10. recall that all genetic variants arise from mutations** *(separate science only)*	
	11. describe how genetic variants in coding DNA may influence phenotype by altering the activity of a protein *(separate science only)*	
	12. describe how genetic variants in non-coding DNA may influence phenotype by altering how genes are expressed *(separate science only)*	

B1.2 How is genetic information inherited?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
During sexual reproduction, each offspring inherits two alleles of each gene; one allele from each gamete. The two alleles can be two copies of the same genetic variant (homozygous) or different variants (heterozygous). A variant can be dominant or recessive, and the combination of alleles determines what effect the gene has. Genetic diagrams such as family trees and Punnett squares can be used to model and predict outcomes of the inheritance of characteristics that are determined by a single gene (IaS3). However, most characteristics depend on the instructions in multiple genes and other parts of the genome. Principles of inheritance of (single gene) characteristics were demonstrated in ideas developed by Gregor Mendel, using pea plants. Mendel's work illustrates how scientists develop explanations that account for data they have collected (IaS3). **Our understanding of genetics has developed greatly since Mendel did his work; we now know that most characteristics depend upon interactions between genetic variants in multiple parts of the genome. Today, scientists sequence whole genomes to investigate how genetic variants influence an organism's characteristics.**	1. explain the terms gamete, homozygous, heterozygous, dominant and recessive 2. explain single gene inheritance, including dominant and recessive alleles and use of genetic diagrams 3. predict the results of single gene crosses 4. use direct proportions and simple ratios in genetic crosses M1c 5. use the concept of probability in predicting the outcome of genetic crosses M2e 6. recall that most phenotypic features are the result of multiple genes rather than single gene inheritance ⓘ *Learners are not expected to describe epistasis and its effects* 7. describe the development of our understanding of genetics including the work of Mendel **and the modern-day use of genome sequencing** *(separate science only)*
A human individual's sex is determined by the inheritance of genes located on sex chromosomes; specifically, genes on the Y chromosome trigger the development of testes.	8. describe sex determination in humans

Linked learning opportunities

Practical work:

- microscopy of pollen tubes on agar (nuclei visible under high power)

Ideas about Science:

- use genetic diagrams (e.g. family trees and Punnett squares) to model and predict outcomes of single gene inheritance (IaS3)
- **distinguish data from explanatory ideas in an account of Mendel's work, and explain how Mendel's explanations accounted for the data he collected (IaS3)**

B1.3 How can and should gene technology be used?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Comparing the genomes of individuals with and without a disease can help to identify genetic variants associated with the disease. Once identified, we can test for these variants in adults, children, fetuses and embryos, to investigate their risk of developing certain diseases. We can also assess the risk of adults passing these variants to their offspring (including the identification of 'carriers' of recessive variants). Genetic testing can also help doctors to prescribe the correct drugs to a patient ('personalised medicine'), by testing for variants that affect how drugs will work in their body. Another application of gene technology is genetic engineering, in which the genome is modified to change an organism's characteristics. Genetic engineering has been used to introduce characteristics into organisms such as bacteria and plants that are useful to humans. Gene technology could help us provide for the needs of society by improving healthcare and producing food for the growing population. But with genetic testing we must also consider how the results will be used and by whom, and the risks of false positives/negatives and miscarriage (when sampling amniotic fluid). With genetic engineering there are concerns about the spread of inserted genes to other organisms, the need for long-term studies to check for adverse reactions, and moral concerns about modifying genomes (IaS4).	1. discuss the potential importance for medicine of our increasing understanding of the human genome, including the discovery of alleles associated with diseases and the genetic testing of individuals to inform family planning and healthcare 2. describe genetic engineering as a process which involves modifying the genome of an organism to introduce desirable characteristics **3. describe the main steps in the process of genetic engineering** **including:** • **isolating and replicating the required gene(s)** • **putting the gene(s) into a vector (e.g. a plasmid)** • **using the vector to insert the gene(s) into cells** • **selecting modified cells** 4. explain some of the possible benefits and risks, including practical and ethical considerations, of using gene technology in modern agriculture and medicine

Linked learning opportunities

Specification links:

- the involvement of genetic and other risk factors in the development of diseases such as cardiovascular disease, cancer and type 2 diabetes (B2.5)
- how can we treat disease? (B2.6)

Ideas about Science:

- genetic testing and genetic engineering as applications of science that have made a positive difference to people's lives (IaS4)
- discuss risks, benefits, ethical issues and regulation associated with gene technology (IaS4)

Chapter B2: Keeping healthy

2

Overview

Issues of risk, ethics and social responsibility related to disease prevention and treatment in humans and plants are often in the news. Understanding the science of health and disease enables us to consider the issues critically, and to explore possible answers.

In Topic B2.1, learners explore how different pathogens are spread and cause disease, with reference to some common communicable diseases of humans and plants, then in Topic B2.2 they consider how the immune system in humans and plants protects against infection.

Topic B2.3 looks at ways in which individuals and society can reduce the spread of diseases, linked to issues of risk and decision making, for example with regard to vaccination.

Topic B2.4 develops understanding of ways in which diseases can be identified in the lab and in the field, and how new technologies offer the potential to improve lives.

In Topics B2.4 and B2.5, the way that lifestyle, environmental and genetic factors affect the risk of developing non-communicable diseases is explored, with reference to ideas about health studies, sampling, correlation and cause. Finally, learners learn about ways of treating diseases in Topics B2.5 and B2.6 and explore issues related to the development and testing of new medicines.

Learning about health and disease before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- appreciate that good hygiene helps humans keep healthy
- be able to identify and name the main parts of the human circulatory system, and describe the functions of the heart, blood vessels and blood
- appreciate the importance of bacteria in the human digestive system
- know that animals, including humans, need the right types and amount of nutrition, and that a healthy human diet includes carbohydrates, lipids (fats and oils), proteins, vitamins, minerals, dietary fibre and water
- recall some of the consequences of imbalances in the diet, including obesity, starvation and deficiency diseases
- recognise the impact of diet, exercise, drugs and lifestyle on the way their bodies function
- recall some of the effects of recreational drugs (including substance misuse) on behaviour, health and life processes.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.

All other statements will be assessed in both Foundation and Higher Tier papers.

B2.1 What are the causes of disease?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
The health of most organisms will be compromised by disease during their lifetime. Physical and mental health can be compromised by disease caused by infection by a pathogen, an organism's genes, environment or lifestyle, or trauma. Disease damages host cells and impairs functions, causing symptoms. However, an unhealthy organism may not always show symptoms of disease, particularly during the 'incubation period' after infection with a pathogen. Some diseases are communicable: they are caused by infection with pathogenic bacteria, viruses, protists and fungi, and can be spread from organism to organism in bodily fluids, on surfaces, and in food and water. Other diseases are non-communicable: they are not caused by infection but are associated with genetic, environmental and lifestyle factors. Some common diseases illustrate different types of pathogen and common routes of spread and infection, including: In humans: influenza (viral), *Salmonella* food poisoning (bacterial), Athlete's foot (fungal), malaria (protist) and HIV (viral STI). In plants: tobacco mosaic virus (viral), ash dieback (fungal) and crown gall disease (bacterial).	1. describe the relationship between health and disease 2. describe different types of diseases (including communicable and non-communicable diseases) 3. explain how communicable diseases (caused by viruses, bacteria, protists and fungi) are spread in animals and plants 4. describe common human infections including influenza (viral), Salmonella (bacterial), Athlete's foot (fungal) and malaria (protist) and sexually transmitted infections in humans including HIV/AIDS (viral) 5. describe plant diseases including tobacco mosaic virus (viral), ash dieback (fungal) and crown gall disease (bacterial)

Linked learning opportunities

Practical work:

- model the spread of infection using liquids (where one is 'infected' with an invisible chemical that can be detected experimentally)
- culture and microscopy of swabs from different surfaces

B2.2 How do organisms protect themselves against pathogens?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Humans have physical, chemical and bacterial defences that make it difficult for pathogens to enter the blood. These include the skin and mucus, stomach acid, saliva, tears, and bacteria in the gut. Platelets help to seal wounds to reduce the chance of pathogens entering the blood. These defences are always present, and are not produced in response to a specific pathogen. Plants have physical defences against pathogens, including the leaf cuticle and cell wall.	1. describe non-specific defence systems of the human body against pathogens, including examples of physical, chemical and microbial defences	
	2. explain how platelets are adapted to their function in the blood	
	3. describe physical plant defences, including leaf cuticle and cell wall *(separate science only)*	
The immune system of the human body works to protect us against disease caused by pathogens. White blood cells destroy pathogens. White blood cells have receptors that recognise antigens on pathogens, to distinguish between non-self and self. Different types of white blood cell are adapted to either ingest and digest pathogens, or produce antibodies to disable them or tag them for attack by other white blood cells. An antibody is specific for (only recognises) a particular antigen. Once the body has made antibodies against a pathogen, memory cells stay in the body to make antibodies quickly upon re-infection (immunity).	4. explain the role of the immune system of the human body in defence against disease	
	5. explain how white blood cells are adapted to their functions in the blood, including what they do and how it helps protect against disease	
Plants do not have circulating immune cells or produce antibodies, but they have a simple immune system that protects them against pathogens. For example, plants can make antimicrobial substances in response to pathogens. The ability of plants to protect themselves against pathogens is important in human food security.	6. describe chemical plant defence responses, including antimicrobial substances *(separate science only)*	

B2.3 How can we prevent the spread of infections?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Reducing and preventing the spread of communicable diseases in animals and plants helps prevent loss of life, destruction of habitats and loss of food sources. For plants, strategies include regulating the movement of plant material, sourcing healthy plants and seeds, destroying infected plants, polyculture, crop rotation, and chemical and biological control. For animals, including humans, strategies include vaccination (to establish immunity), contraception, hygiene, sanitation, sterilising wounds, restricting travel, and destruction of infected animals. The likely effectiveness, benefits, risks and cost of each strategy must be considered, and an individual's right to decide balanced with what is best for society (IaS4).	1. explain how the spread of communicable diseases may be reduced or prevented in animals and plants, to include a minimum of one common human infection, one plant disease and sexually transmitted infections in humans including HIV/AIDS 2. explain the use of vaccines in the prevention of disease, including the use of safe forms of pathogens and the need to vaccinate a large proportion of the population

Linked learning opportunities

Practical work:

- investigate microbial growth on different foods and surfaces in different conditions.

Ideas about Science:

- discuss risk and decision making in the context of disease prevention (IaS4)

B2.4 How can we identify the cause of an infection? *(separate science only)*

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
In order to decide upon a course of treatment for a communicable disease, it is important to identify the disease and the pathogen causing it. There are standard ways to do this, including observing symptoms and taking samples of tissue or body fluid for cell counting, culture, microscopy, staining, testing with antimicrobials, and genome analysis. In addition, isolation and reinfection can be used to identify plant pathogens. Correct identification relies on use of aseptic techniques to avoid contamination of samples.	1. a) describe ways in which diseases, including plant diseases, can be detected and identified, in the lab and in the field b) describe how to use a light microscope to observe microorganisms *PAG1*	**Practical work:** • investigate the effect of antibiotic discs on growth of microorganisms on agar plates • practice aseptic techniques
	2. describe and explain the aseptic techniques used in culturing organisms *PAG7*	
	3. calculate cross-sectional areas of bacterial cultures and of clear zones around antibiotic discs on agar jelly using πr^2 M5c *PAG7*	
Monoclonal antibodies can be produced in the laboratory, using cultured clones of a white blood cell to produce antibodies against a particular antigen. All the antibodies produced by the clones recognise the same antigen. **New technologies using monoclonal antibodies are providing diagnostic tests (e.g. for diseases) with greater sensitivity and specificity. These tests give faster and more accurate results, which enables decisions (e.g. about treatment) to be made more quickly and based on more accurate information (IaS4).**	**4. describe how monoclonal antibodies are produced** **including the following steps:** • **antigen injected into an animal** • **antibody-producing cells taken from animal** • **cells producing the correct antibody selected then cultured**	**Ideas about Science:** • **use of monoclonal antibodies as a technological application of science that could make a significant differences to people's lives (IaS4)**
	5. describe some of the ways in which monoclonal antibodies can be used in diagnostic tests	

B2.5 How can lifestyle, genes and the environment affect health?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Whether or not a person develops a non-communicable disease depends on many factors, including the genetic variants they inherited, their environment and aspects of their lifestyle. The interaction of genetic and lifestyle factors can increase or decrease the risk.	1. a) describe how the interaction of genetic and lifestyle factors can increase or decrease the risk of developing non-communicable human diseases, including cardiovascular diseases, many forms of cancer, some lung and liver diseases and diseases influenced by nutrition, including type 2 diabetes b) describe how to practically investigate the effect of exercise on pulse rate and recovery rate *PAG6*
	2. use given data to explain the incidence of non-communicable diseases at local, national and global levels with reference to lifestyle factors, including exercise, diet, alcohol and smoking
	3. in the context of data related to the causes, spread, effects and treatment of disease: a) translate information between graphical and numerical forms M4a b) construct and interpret frequency tables and diagrams, bar charts and histograms M4a, M4c c) understand the principles of sampling as applied to scientific data M2d d) use a scatter diagram to identify a correlation between two variables M2g
Different types of disease can interact, such as when having a disease increases or decreases the risk of developing or contracting another.	4. describe interactions between different types of disease

Linked learning opportunities

Specification links:

- what causes cancer (B4.3)
- diseases caused by genes (B1.3)

Practical work:

- investigate the amounts of fat and sugar in foods/drinks
- measure blood pressure, recovery rate

Ideas about Science:

- discuss correlation, cause and risk in the context of non-communicable diseases (IaS3, IaS4)

B2.6 How can we treat disease?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Humans have developed medicines that can control or eliminate the cause of some diseases and/or reduce the length or severity of symptoms. Antibiotics are becoming less effective due to the appearance of antibiotic-resistant bacteria. For non-communicable diseases such as cardiovascular diseases, strategies that lower the risk of developing the disease have benefits compared to treatments administered later. Many factors need to be considered when prescribing treatments, including the likely effectiveness, risk of adverse reactions and the costs and benefits to the patient and others (IaS4).	1. explain the use of medicines, including antibiotics, in the treatment of disease 2. calculate cross-sectional areas of bacterial cultures and of clear zones around antibiotic discs on agar jelly using πr^2 M5c *PAG7* 3. evaluate some different treatments for cardiovascular disease, including lifestyle changes, medicines and surgery	**Specification links:** • 'personalised medicine' (B1.3) • antibiotic resistance in microorganisms (B6.1) **Ideas about Science:** • risk and decision making in the context of medicines and treatment (IaS4)
Studying the genomes and proteins of pathogens and host cells can suggest targets for new medicines. Large libraries of substances are screened for their ability to affect a target. It is unlikely that a perfect medicine will be found during screening, but substances are selected for modification and further tests. All new medicines have to be tested before they are made widely available. Preclinical testing, for safety and effectiveness, uses cultured human cells and animals. Clinical testing uses healthy human volunteers to test for safety, and humans with the disease to test for safety and effectiveness. 'Open-label', 'blind' and 'double-blind' trials can be used. There are ethical questions around using placebos in tests on people with a disease (IaS4).	4. describe the process of discovery and development of potential new medicines including preclinical and clinical testing	**Ideas about Science:** • ethics in the context of using placebos in clinical testing of new medicines (IaS4)

B2.6 How can we treat disease?

Some traditional treatments (e.g. radiotherapy and chemotherapy for cancer) cause adverse reactions. New technologies are enabling us to develop treatments that are more effective and have a lower risk of adverse reactions. For example, the specificity of monoclonal antibodies can be used to target cancer cells without damaging normal host cells.	**5.**	**describe how monoclonal antibodies can be used to treat cancer** **including:** • **produce monoclonal antibodies specific to a cancer cell antigen** • **inject the antibodies into the blood** • **the antibodies bind to cancer cells, tagging them for attack by white blood cells** • **the antibodies can also be attached to a radioactive or toxic substance to deliver it to cancer cells** *(separate science only)*

Ideas about Science:
- use of monoclonal antibodies as a technological application of science that could make a difference to people's lives (IaS4)

2

Chapter B3: Living together – food and ecosystems

2

Overview

All living organisms depend on the ability of photosynthetic organisms to synthesise glucose from carbon dioxide and water in the presence of light, and on feeding relationships to transfer biomass through communities.

From study at earlier Key Stages, learners will be familiar with the reactants and products of photosynthesis, and the need for light in the process. In Topics B3.1 and B3.2 the context of photosynthesis is used to explore several fundamental concepts in biology, including enzyme action and the movement of substances by diffusion, osmosis and active transport.

Learners expand their knowledge of the interdependencies between organisms within ecosystems in Topic B3.3, through understanding of food webs, competition for resources, and the cycling of substances.

Finally, Topic B3.4 considers the effects that environmental changes and human activities can have on interacting populations within ecosystems.

Learning about food and ecosystems before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- understand the similarities and differences between plant and animal cells
- know that some organisms make their own food using photosynthesis
- know that photosynthesis in plant cells occurs in the chloroplasts
- know the reactants in, and products of, photosynthesis, and be able to write a word summary
- know that photosynthesis requires light
- be familiar with the adaptations of leaves for photosynthesis, and the role of stomata in gas exchange
- know that water and minerals enter a plant through the roots
- know that molecules of a solute move through solvent, and through cell membranes, by diffusion
- know that animals obtain their food from plants (and other animals that ate plants)
- understand the difference between carnivores, herbivores and omnivores, and between producers and consumers
- know that individuals of the same type living in the same place make up a population, and that all the interacting populations in an ecosystem make up the community
- understand the use of food chains and food webs as models of the feeding relationships within a community
- appreciate the interdependence of organisms in a community, including food webs, the breakdown and cycling of substances, and animals as pollinators
- know that changes in an ecosystem can affect the survival of individuals and populations.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

B3.1 What happens during photosynthesis?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Producers make glucose using photosynthesis. Some of the glucose is used as the fuel for cellular respiration, some is converted into starch and then stored, and the rest is used to make lipids, proteins and other carbohydrates for growth. Photosynthesis involves many chemical reactions, but can be summarised in two main stages. The first stage requires light and chlorophyll (located in chloroplasts in plant cells) to split water molecules into hydrogen and oxygen. The hydrogen is transferred to the second stage, but the oxygen is released into the atmosphere as a waste product. The second stage combines carbon dioxide with hydrogen to make glucose.	1. a) describe the process of photosynthesis, including the inputs and outputs of the two mains stages and the requirement of light in the first stage, and describe photosynthesis as an endothermic process b) describe practical investigations into the requirements and products of photosynthesis *PAG5*	**Practical work:** • on a whole plant, wrap one leaf in foil, and enclose another leaf in a conical flask with a small amount of KOH (to remove CO_2); after 24h, test leaves for starch
	2. explain how chloroplasts in plant cells are related to photosynthesis	
The reactions in photosynthesis and many other biological processes are catalysed by enzymes. The lock and key model can be used to explain enzyme action. It can also be used to make predictions about the effect on the rate of enzyme-catalysed reactions when the substrate concentration, temperature and pH are changed (IaS3).	3. a) explain the mechanism of enzyme action including the active site, enzyme specificity and factors affecting the rate of enzyme-catalysed reactions, including substrate concentration, temperature and pH b) describe practical investigations into the effect of substrate concentration, temperature and pH on the rate of enzyme controlled reactions M2b, M2f, M4a, M4b, M4c *PAG4*	**Practical work:** • investigate effects of substrate concentration, temperature and pH on enzyme activity **Ideas about Science:** • lock and key model to explain and make predictions about enzyme activity (IaS3)

B3.1 What happens during photosynthesis?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Understanding of how factors affect enzyme activity helps to explain the effects of temperature and carbon dioxide concentration on the rate of photosynthesis. The effect of light intensity is explained by the need for light to bring about reactions in photosynthesis. **Light intensity is inversely proportional to the square of the distance from the light source (the inverse square law); this helps us explain why the rate of photosynthesis changes in the way that it does with distance from a point light source.**	4. a) explain the effect of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis b) describe practical investigations into the effect of environmental factors on the rate of photosynthesis *PAG5*
	5. use the inverse square law to explain changes in the rate of photosynthesis with distance from a light source
	6. explain the interaction of temperature, light intensity and carbon dioxide concentration in limiting the rate of photosynthesis, and use graphs depicting the effects
	7. in the context of the rate of photosynthesis: a) understand and use simple compound measures such as the rate of a reaction M1a, M1c b) translate information between graphical and numerical form M4a c) plot and draw appropriate graphs selecting appropriate scales for axes M4a, M4c d) extract and interpret information from graphs, charts and tables M2c

Linked learning opportunities

Practical work:

- investigate rate of photosynthesis by collecting gas or counting bubbles from pondweed
- use a datalogger to measure oxygen concentration, pH, temperature and light intensity over 24h for pondweed

B3.2 How do producers get the substances they need?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
The ways in which photosynthetic organisms take in carbon dioxide and water for photosynthesis, and release the waste product oxygen, illustrate the principles of diffusion and osmosis. Generally, molecules move from a region of their higher concentration to a region of their lower concentration; the difference in concentration drives a change towards equal concentration. Carbon dioxide and oxygen molecules move by diffusion, through cell membranes in single-cellular (prokaryotic) producers, and through stomata and cell membranes in plants. Water molecules move by osmosis through cell membranes; projections from root cells ("root hairs") of plants increase the surface area for osmosis. The way in which photosynthetic organisms take in nitrogen (to make proteins) illustrates the process of active transport. Producers get nitrogen from nitrate ions (NO_3^-). Molecules of water and gases can diffuse through partially-permeable cell membranes but nitrate ions cannot; producers use energy from molecules of ATP to transport nitrate ions through the cell membrane by active transport.	1. describe some of the substances transported into and out of photosynthetic organisms in terms of the requirements of those organisms, including oxygen, carbon dioxide, water and mineral ions 2. a) explain how substances are transported into and out of cells through diffusion, osmosis and active transport b) describe practical investigations into the processes of diffusion and osmosis *PAG8* ⓘ *Learners are not expected to explain osmosis in terms of water potential* 3. explain how the partially-permeable cell membranes of plant cells and prokaryotic cells are related to diffusion, osmosis and active transport 4. explain how water and mineral ions are taken up by plants, relating the structure of the root hair cells to their function

Linked learning opportunities

Practical work:

- investigate diffusion using drops of ink in water and in agar in Petri dishes on graph paper
- investigate diffusion across a partially permeable membrane using starch suspension in dialysis tubing in a beaker of water; compare adding idione solution inside versus outside the tubing
- investigate the effect of solute concentration on osmosis using potato cylinders in sugar solution

B3.2 How do producers get the substances they need?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Plants do not have blood to transport substances around the organism; they have transport vessels formed from xylem and phloem. Water and ions (e.g. nitrate) in aqueous solution are moved through xylem from the roots and up the stem/trunk by transpiration, to replace water that evaporates from the plant surface and diffuses out of open stomata. Sugars are moved through phloem from photosynthetic to non-photosynthetic tissues by translocation. Sugars are loaded into phloem by active transport, then water moves into the concentrated solution by osmosis and pushes the substances along the tube. The rate of water uptake by a plant can be affected by environmental factors. Light intensity and temperature affect the rate of photosynthesis (and therefore the demand for water), while air movement and temperature affect the rate of water loss from aerial parts of the plant.	5. a) explain how the structure of the xylem and phloem are adapted to their functions in the plant b) describe how to use a light microscope to observe the structure of the xylem and phloem *PAG1* 6. a) describe the processes of transpiration and translocation, including the structure and function of the stomata b) describe how to use a light microscope to observe the structure of stomata *PAG1* c) describe how to use a simple potometer *PAG6* ⓘ *Learners are not expected to describe transpiration in terms of tension or pressure, and are not expected to describe translocation in terms of water potential or hydrostatic pressure* 7. a) explain the effect of a variety of environmental factors on the rate of water uptake by a plant, to include light intensity, air movement, and temperature b) describe practical investigations into the effect of environmental factors on the rate of water uptake by a plant *PAG6* 8. in the context of water uptake by plants: a) use simple compound measures such as rate M1a, M1c b) carry out rate calculations M1a, M1c c) plot, draw and interpret appropriate graphs M4a, M4b, M4c, M4d d) calculate percentage gain and loss of mass M1c

Linked learning opportunities

Practical work:

- use eosin stain to observe xylem in broad bean plant stem under hand lens and microscope
- observe stomata (paint two thin layers of nail varnish onto a leaf, put clear tape over then peel off, stick to microscope slide)

B3.3 How are organisms in an ecosystem interdependent?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Producers take in carbon and nitrogen compounds from their environment and use them (along with oxygen, hydrogen and other elements) to make small organic molecules including sugars, fatty acids, glycerol and amino acids. These small molecules are used to make larger organic molecules, such as long-chain carbohydrates, lipids and proteins. The larger molecules are used to build new structures (e.g. membranes, organelles). Consumers can only get their supply of carbon and nitrogen compounds by eating producers (or other consumers that ate producers) and digesting the biomass. This releases the small molecules so they can be absorbed and then used to build biomass in the consumer. The transfer of biomass between organisms is one way in which the populations in a community are interdependent, and can be modelled using a food web (IaS3). The amount of biomass present at each trophic level is not shown by a food web, but can be modelled using a pyramid of biomass (IaS3). The size of each population in a community is limited by predation and competition for food and other resources including space, water, light, shelter, mates, pollinators and seed dispersers.	1. a) explain the importance of sugars, fatty acids and glycerol, and amino acids in the synthesis and breakdown of carbohydrates, lipids and proteins b) describe the use of qualitative tests for biological molecules *PAG2* 2. describe photosynthetic organisms as the main producers of food and therefore biomass for life on Earth 3. describe some of the substances transported into organisms in terms of the requirements of those organisms, including dissolved food molecules 4. describe different levels of organisation in an ecosystem from individual organisms to the whole ecosystem 5. explain the importance of interdependence and competition in a community 6. describe the differences between the trophic levels of organisms within an ecosystem *(separate science only)* 7. describe pyramids of biomass and explain, with examples, how biomass is lost between the different trophic levels *(separate science only)* 8. calculate the efficiency of biomass transfers between trophic levels and explain how this affects the number of organisms at each trophic level *(separate science only)* M1c

Linked learning opportunities

Practical work:

- investigate the breakdown of starch into sugars using amylase and test strips

Ideas about Science:

- use a food web as a model to explain interdependence in a community, identify limitations of the model, and use it to make predictions about the effects that a change in the ecosystem could have on the interacting populations (IaS3)
- pyramids of biomass as models of biomass transfer in a food chain (IaS3)

B3.3 How are organisms in an ecosystem interdependent?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Substances essential to life, including water and carbon, cycle through the biotic and abiotic components of ecosystems so that they can be used and reused by organisms. Water cycles through precipitation, food chains, transpiration, excretion, runoff, flow through streams/ rivers/oceans, and evaporation. Carbon cycles through photosynthesis, food chains, cellular respiration, decomposition and combustion. Decomposition is catalysed by enzymes released by microorganisms. Rate of decomposition is affected by environmental factors: temperature affects enzymes and the rate of reactions; microorganisms need water to survive and many need oxygen for aerobic respiration. Landfill sites are often oxygen deficient, leading to an increase in anaerobic decomposition which produces methane – a gas with a much greater greenhouse effect than the carbon dioxide produced by aerobic decomposition.	9. recall that many different substances cycle through the abiotic and biotic components of an ecosystem, including carbon and water
	10. explain the importance of the carbon cycle and the water cycle to living organisms
	11. explain the role of microorganisms in the cycling of substances through an ecosystem
	12. calculate the percentage of mass, in the context of the use and cycling of substances in ecosystems M1c
	13. explain the effect of factors such as temperature and water content on rate of decomposition in aerobic and anaerobic environments *(separate science only)*
	14. calculate rate changes in the decay of biological material *(separate science only)* M1c

Linked learning opportunities

Practical work:

- culture microorganisms on starch agar, stain with iodine solution; clear areas beyond cultures show digestion by extracellular amylase

B3.4 How are populations affected by conditions in an ecosystem?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
The distribution and abundance of organisms in an ecosystem depends on abiotic and biotic factors. The size of one or more populations in a community may be affected if the environmental conditions change, or if a new substance, competitor, predator or pathogen is introduced. A substance can bioaccumulate in a food chain to toxic concentration, and some can cause eutrophication (IaS4). A change in the size of a population will affect other populations in the same community. The distribution and abundance of organisms, and changing conditions, within an ecosystem can be investigated using techniques including: identification keys; transects and quadrats; capture, mark, release and recapture; sampling indicator species; and using instruments to measure abiotic factors such as temperature, light intensity, soil moisture and pH.	1. explain how some abiotic and biotic factors affect communities, including environmental conditions, toxic chemicals, availability of food and other resources, and the presence of predators and pathogens 2. describe how to carry out a field investigation into the distribution and abundance of organisms in an ecosystem and explain how to determine their numbers in a given area M2d *PAG3* 3. in the context of data related to organisms within a population: a) calculate arithmetic means M2b, M2f b) use fractions and percentages M1c c) plot and draw appropriate graphs selecting appropriate scales for the axes M4a, M4c d) extract and interpret information from charts, graphs and tables M2c

Linked learning opportunities

Practical work:

- investigate the distribution and abundance of organisms in an ecosystem

Ideas about Science:

- bioaccumulation and eutrophication as unintended impacts of human activity on the environment (IaS4)

Chapter B4: Using food and controlling growth

Overview

All living organisms depend on molecules of glucose obtained from photosynthesis (or from biomass obtained through food chains that start with photosynthetic organisms). The glucose is used for cellular respiration and in the synthesis of larger organic molecules used for growth.

From study at earlier Key Stages, learners will be familiar with the reactants and products of cellular respiration. In Topic B4.1 they explore how cellular respiration increases the amount of energy associated with cellular energy stores, in particular molecules of ATP that are essential for many life processes. In Topic B4.2 they consider briefly how we came to know what we do about organelles such as mitochondria, using the context of electron microscopy to illustrate the idea that some scientific explanations were only developed once a technological development made certain observations possible. Topic B4.3 links growth in multicellular organisms to the division of cells during the cell cycle, and explores the nature of stem cells and the role of cell differentiation. As a development of ideas, learners consider how cancer results from changes in DNA that cause a loss of control of cell division.

The role of plant hormones in controlling plant growth and environmental responses is explored in Topic B4.4, and these ideas applied to use of these hormones by humans to control plant growth to our advantage.

Finally, Topics B4.4 and B4.5 explore the question of whether stem cells should be used to regenerate tissue and treat disease.

Learning about cellular respiration and growth before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- be familiar with the processes of aerobic and anaerobic respiration in living organisms, and fermentation in microorganisms, including word summaries of the reactions
- be able to recall the differences between aerobic and anaerobic respiration in terms of the reactants, products and implications for the organism
- be familiar with the tissues and organs of the human digestive system, including adaptations to function
- understand in simple terms that the human digestive system uses chemicals (including enzymes) to digest food
- appreciate the importance of bacteria in the human digestive system
- know how nutrients and water are transported within animals, including humans.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.

All other statements will be assessed in both Foundation and Higher Tier papers.

B4.1 What happens during cellular respiration?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Consumers gain biomass from other organisms when they eat them. Some of this biomass is converted into molecules of glucose, the fuel for cellular respiration. Cellular respiration involves many chemical reactions and makes molecules of ATP. It occurs in the cytoplasm and mitochondria of animal and plant cells, and in the cytoplasm of microorganisms. ATP is required for processes that are essential for life, including breakdown and synthesis of molecules, active transport and muscle contraction. Aerobic respiration breaks down glucose and combines the breakdown products with oxygen, making water and carbon dioxide (a waste product). In conditions of low or no oxygen (such as in human cells during vigorous exercise, plant root cells in waterlogged soil and bacteria in puncture wounds) anaerobic respiration occurs. There is a partial breakdown of glucose, producing fewer molecules of ATP. In animal cells and some bacteria, this produces lactic acid (a waste product). In plants and some microorganisms, including yeast, it produces ethanol and carbon dioxide.	1. compare the processes of aerobic and anaerobic respiration, including conditions under which they occur, the inputs and outputs, and comparative yields of ATP 2. explain why cellular respiration occurs continuously in all living cells 3. explain how mitochondria in eukaryotic cells (plants and animals) are related to cellular respiration 4. describe cellular respiration as an exothermic process 5. a) describe practical investigations into the effect of different substrates on the rate of respiration in yeast *PAG5* b) carry out rate calculations for chemical reactions in the context of cellular respiration M1a, M1c

Linked learning opportunities

Practical work:

- investigate the amount of energy released from different foods, by burning them under a boiling tube of water where:
  energy (kJ) = mass of water (kg) x change in temperature (deg C) x 4.2 kJ/kg/deg C)
- investigate respiration in microorganisms by collecting CO_2 given off; which substrate works best?

B4.2 How do we know about mitochondria and other cell structures?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Scientific progress often relies on technological developments which enable new observations to be made. The invention of the electron microscope enabled us to observe cell organelles such as mitochondria and chloroplasts at much higher magnification than had previously been possible with light microscopes, and thus to develop explanations about how their structures relate to their roles in cellular processes (IaS3).	1. explain how electron microscopy has increased our understanding of sub-cellular structures
	2. in the context of cells and sub-cellular structures: a) demonstrate an understanding of number, size and scale and the quantitative relationship between units M2a, M2h b) use estimations and explain when they should be used M1d **c) calculate with numbers written in standard form M1b**

Linked learning opportunities

Ideas about Science:

- explanations about the roles of cell organelles were developed from observations that could only be made using electron microscopy (IaS3)

B4.3 How do organisms grow and develop?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Growth of multicellular organisms involves an increase in the number of body cells. All new cells are created from existing cells when they divide. New body cells are created as part of the cell cycle. During interphase the cell grows larger, the numbers of organelles increase, and each chromosome is copied; then during mitosis the chromosome copies separate, the nucleus divides, and the cell divides to produce two new cells that are genetically identical to one another. Cancer is a non-communicable disease in humans caused by changes in a person's DNA. The changes cause a cell to divide many times by mitosis, which can create a tumour.	1. a) describe the role of the cell cycle in growth, including interphase and mitosis b) describe how to use a light microscope to observe stages of mitosis *PAG1* ⓘ *Learners are not expected to recall intermediate phases*	**Practical work:** • investigate mitosis using a microscope to look at stained cells from onion root tip
	2. describe cancer as the result of changes in cells that lead to uncontrolled growth and division	
Gametes are produced by meiosis, a different type of cell division. After interphase (during which the chromosome number has doubled), two meiotic divisions occur. Gametes contain half the number of chromosomes found in body cells (one chromosome from each pair). At fertilisation, maternal and paternal chromosomes pair up, so the zygote has the normal chromosome number.	3. explain the role of meiotic cell division in halving the chromosome number to form gametes, including the stages of interphase and two meiotic divisions ⓘ *Learners are not expected to recall intermediate phases*	**Specification links:** • factors that increase the risk of developing cancer (B2.5)
A zygote divides by mitosis to form an embryo. All of the cells in an embryo are initially identical and unspecialised; these are embryonic stem cells, and can become specialised to form any type of cell (differentiation) by switching genes off and on. Most cells in a human embryo become specialised after the eight cell stage. However, some (adult stem cells) remain unspecialised and can become specialised later to become many, but not all, types of cells. In plants, only cells in meristems undergo mitosis, producing unspecialised cells that can develop into any kind of plant cell.	4. describe the function of stem cells in embryonic and adult animals and meristems in plants	
	5. explain the importance of cell differentiation, in which cells become specialised by switching genes off and on to form tissues with particular functions	

B4.4 How is plant growth controlled? *(separate science only)*

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Plants are able to respond to their environment in different ways, e.g. phototropism in shoots and gravitropism in roots. These responses are controlled and coordinated by a group of plant hormones called auxins, and increase a plant's chances of survival. **Plants can also respond to environmental factors using other hormones. Gibberellins are involved in breaking seed dormancy (germination) in response to water, and bolting (production of flowers in an attempt to reproduce before death) in response to cold or lack of water. Ethene is involved in the ripening of fruit and dropping of leaves. Humans can exploit these responses and others such as triggering rooting in cuttings, by using plant hormones to trigger responses that are advantageous to us.**	1. a) explain how plant hormones are important in the control and coordination of plant growth and development, with reference to the role of auxins in phototropisms and gravitropisms b) describe practical investigations into the role of auxin in phototropism *PAG6* **2. describe some of the variety of effects of plant hormones, relating to gibberellins and ethene** **3. describe some of the different ways in which people use plant hormones to control plant growth**

Linked learning opportunities

Practical work:

- investigate phototropism and the role of auxins in seedlings, using directional light sources and foil caps and rings

B4.5 Should we use stem cells to treat damage and disease?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Stem cells offer the potential to treat patients by replacing damaged tissues or cells. But the benefits must be weighed against risks and ethical concerns about the use and destruction of human embryos to collect embryonic stem cells. For these reasons, use of stem cells in research and medicine is subject to government regulation in many countries (IaS4).	1. discuss potential benefits, risks and ethical issues associated with the use of stem cells in medicine

Linked learning opportunities

Specification links:

- **stem cell therapy for neuron damage (B5.6)**

Ideas about Science:

- stem cell therapy as an application of science that could change lives (IaS4)
- risks, benefits and ethical issues associated with use of stem cells in medicine (IaS4)

Chapter B5: The human body – staying alive

2

Overview

From previous study, learners should appreciate that cells work together in multi-cellular organisms – in a hierarchy of cells, tissues, organs and systems – to support the functioning of each cell and of the organism as a whole. This chapter develops understanding of how cells and systems work together to support life in the human body.

In Topic B5.1, learners consider how the substances essential for chemical reactions are transported into, out of and around the human body, and why exchange surfaces are necessary. In Topics B5.2 and B5.3 they explore how the nervous and endocrine systems help the body to detect and respond to external and internal changes. Topic B5.4 illustrates the importance of maintaining a constant internal environment.

The essential role of hormones in human reproduction is explored in Topic B5.5, followed in Topic B5.6 by consideration of what can happen when certain structures and systems – including the regulation of blood sugar, structures in the eye and neurons in the nervous system – go wrong.

Learning about the human body before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- appreciate the hierarchical organisation of multicellular organisms: from cells to tissues to organs to systems to organisms
- be able to identify, name, draw and label the basic parts of the human body
- have a basic understanding of the function of muscles
- be familiar with the tissues and organs of the human digestive system, including adaptations to function
- understand the basic structures and functions of the gas exchange system in humans, including adaptations to function
- understand the mechanism of breathing to move air in and out of the lungs, and be able to use a pressure model to explain the movement of gases
- understand, in outline, how nutrients and water are transported within animals, including humans
- be able to identify and name the main parts of the human circulatory system
- be familiar with the functions of the heart, blood vessels and blood
- know which part of the body is associated with each sense.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.

All other statements will be assessed in both Foundation and Higher Tier papers.

B5.1 How do substances get into, out of and around our bodies?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Oxygen, water and molecules from food are essential for chemical reactions in cells in the human body, including cellular respiration and synthesis of biomass. Carbon dioxide and urea are waste products that need to be removed from cells before they reach toxic levels. Moving these substances into, around and out of the body depends upon interactions between the circulatory, gaseous exchange, digestive and excretory systems. Oxygen and carbon dioxide diffuse between blood in capillaries and air in alveoli. Water and dissolved food molecules are absorbed from the digestive system into blood in capillaries. Waste products including carbon dioxide and urea diffuse out of cells into the blood. Urea is filtered out of the blood by the kidneys into urine. Partially-permeable cell membranes regulate the movement of these substances; gases move across the membranes by diffusion, water by osmosis and other substances by active transport. The heart, blood vessels, red blood cells and plasma are adapted to transport substances around the body.	1. describe some of the substances transported into and out of the human body in terms of the requirements of cells, including oxygen, carbon dioxide, water, dissolved food molecules and urea 2. explain how the partially-permeable cell membranes of animal cells are related to diffusion, osmosis and active transport 3. describe the human circulatory system, including its relationships with the gaseous exchange system, the digestive system and the excretory system 4. explain how the structure of the heart is adapted to its function, including cardiac muscle, chambers and valves 5. explain how the structures of arteries, veins and capillaries are adapted to their functions, including differences in the vessel walls and the presence of valves 6. explain how red blood cells and plasma are adapted to their functions in the blood	**Practical work:** • dissect lamb's heart to observe atria, ventricles and valves • investigate valves in an arm vein (tourniquet around bicep; when veins become prominent, gently try to push blood in each direction)
To sustain all the living cells inside humans and other multi-cellular organisms, exchange surfaces increase the surface area:volume ratio, and the circulatory system moves substances around the body to decrease the distance they have to diffuse to and from cells.	7. explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area:volume ratio 8. calculate surface area:volume ratios M1c, M5c	**Practical work:** • investigate the effect of surface area:volume ratio on diffusion of dye into agar cubes

B5.2 How does the nervous system help us respond to changes?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
In order to survive, organisms need to detect and respond to changes in their external and internal environments. The highly adapted structures of the nervous system facilitate fast, short-lasting responses to stimuli.	1. explain how the components of the nervous system work together to enable it to function, including sensory receptors, sensory neurons, the CNS, motor neurons and effectors	
In a stimulated neuron, an electrical impulse passes along the axon. Most axons have a fatty sheath to increase impulse transmission speed. An impulse is transmitted from one neuron to another across a synapse by the release of transmitter substances, which diffuse across the gap and bind to receptors on the next neuron, stimulating it.	2. explain how the structures of nerve cells and synapses relate to their functions ⓘ Learners are not expected to explain nerve impulse transmission in terms of membrane potentials	
Reflexes provide rapid, involuntary responses without involving a processing centre, and are essential to the survival of many organisms. In some circumstances the brain can modify a reflex response via a neuron to the motor neuron of the reflex arc (e.g. to stop us dropping a hot object).	3. a) explain how the structure of a reflex arc, including the relay neuron, is related to its function b) describe practical investigations into reflex actions *PAG6*	
Research into the structure and function of the brain has huge potential impact for the ageing population. We know the brain is made of billions of neurons. We also know that different areas of the brain are important in different functions. **However, our ability to investigate and develop explanations about brain function remains limited. Most areas of the brain are concerned with many functions, but some functions can be mapped to particular areas using functional magnetic resonance imaging (fMRI), studies of patients with brain damage, and electrical stimulation (IaS3). There are ethical issues associated with studying brain damaged patients, including informed consent (IaS4).**	4. describe the structure and function of the brain and roles of the cerebral cortex (intelligence, memory, language and consciousness), cerebellum (conscious movement) and brain stem (regulation of heart and breathing rate) *(separate science only)* **5. explain some of the difficulties of investigating brain function** ***(separate science only)***	**Ideas about Science:** • **fMRI as a technological development that enabled observations that led to new scientific explanations (IaS3)** • **ethical issues around studying brain damaged patients (IaS4)**

B5.3 How do hormones control responses in the human body?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
The endocrine system of humans and other animals uses hormones, secreted by glands and transported by the blood, to enable the body to respond to external and internal stimuli. Hormones bind to receptors on effectors, stimulating a response. The endocrine system provides slower, longer-lasting responses than the nervous system. **The production of hormones is regulated by negative feedback.**	1. describe the principles of hormonal coordination and control by the human endocrine system	
	2. explain the roles of thyroxine and adrenaline in the body, including thyroxine as an example of a negative feedback system	

B5.4 Why do we need to maintain a constant internal environment?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Cells, enzymes and life processes function only in certain conditions, and optimally when conditions are within a narrow range. The maintenance of a constant internal environment is homeostasis, and depends on receptors, nerves, hormones and (often antagonistic) effectors to counteract changes. The skin and muscles (including muscles in artery walls and hair follicles) work to control internal body temperature. **Maintenance of an ideal internal temperature depends on temperature receptors in the skin and hypothalamus, processing in the hypothalamus, responses such as sweating, hair erection, shivering, vasoconstriction and vasodilation, and negative feedback.** The kidneys filter water and urea from the blood into kidney tubules then reabsorb as much water as required, to maintain the water balance of the body. This helps to ensure the blood plasma is at the correct concentration to prevent the shrinking or bursting of cells due to osmosis. **Maintenance of an ideal water balance depends on receptors and processing in the hypothalamus, response by the pituitary gland (increased/decreased ADH production), and negative feedback.**	1. explain the importance of maintaining a constant internal environment in response to internal and external change 2. a) describe the function of the skin in the control of body temperature, including changes to sweating, hair erection and blood flow b) describe practical investigations into temperature control of the body *PAG6* *(separate science only)* **3. explain the response of the body to different temperature challenges, including receptors, processing, responses and negative feedback *(separate science only)*** 4. explain the effect on cells of osmotic changes in body fluids ⓘ *Learners are not expected to discuss water potential* *(separate science only)* 5. describe the function of the kidneys in maintaining the water balance of the body, including filtering water and urea from the blood into kidney tubules then reabsorbing as much water as required *(separate science only)* **6. describe the effect of ADH on the permeability of the kidney tubules *(separate science only)*** **7. explain the response of the body to different osmotic challenges, including receptors, processing, response, and negative feedback *(separate science only)*** 8. in the context of maintaining a constant internal environment: a) extract and interpret data from graphs, charts and tables M2c b) translate information between numerical and graphical forms M4a

Linked learning opportunities

Specification links:

- the effects of temperature on enzyme activity (B3.1)

Practical work:

- compare skin temperature and core body temperature under different conditions
- model the control of temperature by trying to keep a beaker of water at 40°C using just a Bunsen burner (single effector) compared to a Bunsen burner and ice (antagonistic effectors)

B5.5 What role do hormones play in human reproduction?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Hormones play a vital role in enabling sexual reproduction in humans: they regulate the menstrual cycle, including ovulation, in adult females. Without this process, sexual reproduction would not be possible.	1. describe the role of hormones in human reproduction, including the control of the menstrual cycle	
A number of hormones interact to control the menstrual cycle: • **FSH causes the ovaries to develop a follicle containing an egg, and produce oestrogen** • **oestrogen causes the uterus wall to thicken** • **LH causes the follicle to release the egg (ovulation)** • **the remains of the follicle secretes progesterone** • **progesterone prepares the lining of the uterus for implantation of a fertilised egg** • **oestrogen and progesterone stop the production of LH and FSH** • **as progesterone levels fall, the thickened uterus wall breaks down and is discharged (menstruation).**	**2. explain the interactions of FSH, LH, oestrogen and progesterone in the control of the menstrual cycle**	
The menstrual cycle can be controlled artificially by the administration of hormones, often as an oral pill. The hormones prevent ovulation, so can be used as a contraceptive, but they do not decrease the risk of sexual transmission of communicable diseases (IaS4).	3. explain the use of hormones in contraception and evaluate hormonal and non-hormonal methods of contraception	**Specification links:** • sexually transmitted disease (B2.1) **Ideas about Science:** • risk in the context of sex and contraception (IaS4)
Hormones can also be used to artificially manipulate the menstrual cycle as a treatment in certain cases of female infertility in which follicle development and ovulation do not occur successfully. The use of hormones to treat infertility is an example of an application of science that has made a significant positive difference to people's lives (IaS4).	**4. explain the use of hormones in modern reproductive technologies to treat infertility**	**Ideas about Science:** • **infertility treatment as an application of science that makes a positive difference to lives (IaS4)**

B5.6 What can happen when organs and control systems stop working?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
Blood sugar level is controlled by insulin **and glucagon acting antagonistically**. Type 1 diabetes arises when the pancreas stops making insulin; blood sugar can be regulated using insulin injections. Type 2 diabetes develops when the body no longer responds to its own insulin or does not make enough insulin; blood sugar can be regulated using diet (high in complex carbohydrates), exercise and insulin injections.	1. explain how insulin controls the blood sugar level in the body	
	2. explain how glucagon and insulin work together to control the blood sugar level in the body	
	3. compare type 1 and type 2 diabetes and explain how they can be treated	
The human eye is an important sense organ. Tissues in the eye are adapted to enable it to function. Damage or degradation of tissues and cells in the eye can impair sight. Ray diagrams can be used to model some of these problems and how they can be overcome (IaS3).	4. a) explain how the main structures of the eye are related to their functions, including the cornea, iris, lens, ciliary muscle and retina and to include the use of ray diagrams b) describe practical investigations into the response of the pupil in different light conditions *PAG6* *(separate science only)*	**Specification links**: • lenses and ray diagrams (P1.4) **Practical work**: • investigate the diameter of the pupil in different light conditions • investigate the focusing of light using lenses
	5. describe common defects of the eye, including short-sightedness, long-sightedness and cataracts, and explain how these problems may be overcome, including using ray diagrams to illustrate the effect of lenses *(separate science only)*	
Damage to neurons can lead to debilitating illness. Neurons, once differentiated, do not undergo mitosis, so cannot divide to replace lost neurons; this means damage to the nervous system can be difficult or impossible to treat. **Research into the use of stem cells to replace damaged cells of the nervous system offers the potential to improve the lives of people with nervous system injury and disease, but the ethics of stem cells use must also be considered (IaS4).**	**6. explain some of the limitations in treating damage and disease in the brain and other parts of the nervous system *(separate science only)***	**Specification links:** • Is it right to use stem cells in medicine? (B4.5) **Ideas about Science:** • stem cell therapy as an application of science that could change lives (IaS4)

Chapter B6: Life on Earth – past, present and future

Overview

The modern explanation of evolution by natural selection is one of the central ideas in biology. The historical development of the explanation and its journey to widespread acceptance in the science community illustrate key *Ideas about Science*.

Learners explore ideas about evolution in Key Stages 2 and 3, so by GCSE (9–1) they should be familiar with the concepts of variation (at phenotype level), adaptation, advantage, competition and natural selection. In Topic B6.1, learners begin to expand their understanding by linking variation to genetics, and the concept of evolution by natural selection is explored within the story of how the theory was developed, evaluated and modified by the scientific community. The topic considers the importance of evidence as the basis for widespread scientific acceptance of the theory, and probes reasons why some people may still not accept it.

The effects that sexual and asexual reproduction have on evolution are considered in Topic B6.2, followed by a brief examination in Topic B6.3 of the impact that developments in scientific understanding have had on the way we classify the diversity of life on Earth today.

Finally, in Topic B6.4 learners examine the impacts of human activities on the Earth's biodiversity, the tremendous importance of protecting it, issues that affect decision making, and ways in which our understanding of science can help us to interact positively with ecosystems so that biodiversity and ecosystem resources are conserved for the future.

Learning about evolution and biodiversity before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- know that there are many different types of organisms living in many different environments, and that there are similarities and differences between all organisms
- recognise that living organisms can be grouped and classified in a variety of ways based on commonalities and differences
- be able to use classification keys
- recognise that living organisms have changed over time and that fossils provide information about organisms that lived millions of years ago
- appreciate that organisms live in habitats to which they are adapted
- recognise that organisms produce offspring of the same kind, but normally offspring vary and are not identical to their parents
- know that there is variation between individuals within a species, and that variation can be described as continuous or discontinuous
- understand that the variation means some organisms compete more successfully, resulting in natural selection
- appreciate that variation, adaptation, competition and natural selection result in the evolution of species
- understand that changes in the environment may leave organisms less well adapted to compete successfully and reproduce, which can lead to extinction
- be familiar with some of the reasons why it's important to protect and conserve biodiversity, and some ways of doing so.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.

All other statements will be assessed in both Foundation and Higher Tier papers.

B6.1 How was the theory of evolution developed?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
The modern theory of evolution by natural selection combines ideas about genes, variation, advantage and competition to explain how the inherited characteristics of a population can change over a number of generations. It includes the ideas that: Mutations in DNA create genetic variants, which may be inherited. Most genetic variants do not affect phenotype, but those that do may increase an organism's ability to survive in its environments and compete for resources (i.e. confer an advantage). Individuals with an advantage are more likely to reproduce; thus, by natural selection, the proportion of individuals possessing beneficial genetic variants increases in subsequent generations. A new species can arise if the organisms in a population evolve to be so different from their ancestors that they could no longer mate with them to produce fertile offspring. Speciation is more likely to occur when two populations of an organism are isolated.	1. state that there is usually extensive genetic variation within a population of a species 2. recall that genetic variants arise from mutations, and that most have no effect on the phenotype, some influence phenotype and a very few determine phenotype 3. explain how evolution occurs through natural selection of variants that give rise to phenotypes better suited to their environment 4. explain the importance of competition in a community, with regard to natural selection 5. describe evolution as a change in the inherited characteristics of a population over a number of generations through a process of natural selection which may result in the formation of new species	
Charles Darwin noticed that the selective breeding of plants and animals had produced new varieties with many beneficial characteristics, quite different to their wild ancestors. Most of what we eat, and our ability to feed the growing human population depends on selectively bred plants and animals. Darwin wondered whether a similar process of selection in nature could have created new species.	6. explain the impact of the selective breeding of food plants and domesticated animals	

B6.1 How was the theory of evolution developed?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
The theory of evolution by natural selection was developed to explain observations made by Darwin, Wallace and other scientists, including: • the production of new varieties of plants and animals by selective breeding • fossils with similarities and differences to living species • the different characteristics shown by isolated populations of the same species living in different ecosystems. The development of the theory is an example of how scientists develop explanations. Darwin: made observations of the natural world; suggested natural selection to explain differences between fossils and living organisms, and between isolated populations; used ideas from Wallace and other scientists to improve his explanation; and shared his explanation with the scientific community (IaS3).	7. describe how fossils provide evidence for evolution 8. describe the work of Darwin and Wallace in the development of the theory of evolution by natural selection *(separate science only)*	**Ideas about Science:** • the theory of evolution by natural selection as an example of how scientific explanations are developed (IaS3)
The theory of evolution by natural selection illustrates how scientists continue to test a proposed explanation by making new observations and collecting new evidence, and how if the explanation is able to explain these it can become widely accepted by the scientific community (IaS3). For example, the spread of antibiotic resistance in bacteria can be explained by mutation, advantage and natural selection.	9. describe modern examples of evidence for evolution including antibiotic resistance in bacteria	**Ideas about Science:** • the theory of evolution by natural selection as a scientific explanation modified in light of new observations and ideas (IaS3)
Most scientists accept the modern theory of evolution because it is the best explanation for many of our observations of the natural world. However, some people do not accept it either because they are unaware of (or do not understand) the evidence, or because it does not fit with their beliefs (IaS4).	10. explain the impact of these ideas on modern biology and society *(separate science only)*	**Ideas about Science**: • reasons why different people do or do not accept an explanation (IaS4)

B6.2 How do sexual and asexual reproduction affect evolution? *(separate science only)*

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
The evolution of a population or species is affected by whether the individual organisms reproduce sexually or asexually. Sexual reproduction occurs at a slower rate than asexual reproduction, but provides genetic variation in the offspring.	1. explain some of the advantages and disadvantages of asexual and sexual reproduction in a range of organisms	

B6.3 How does our understanding of biology help us classify the diversity of organisms on Earth?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*	*Linked learning opportunities*
The enormous diversity of organisms on Earth can be classified into groups on the basis of observed similarities and differences in their physical characteristics and, more recently, their DNA. We are more likely to classify species into the same group if there are lots of similarities in their genomes (i.e. if they have many genes, and genetic variants, in common). Genome analysis can also suggest whether different groups have a common ancestor, and how recently speciation occurred.	1. describe the impact of developments in biology on classification systems, including the use of DNA analysis to classify organisms	

B6.4 How is biodiversity threatened and how can we protect it?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
The biodiversity of the Earth, or of a particular area, is the combination of the diversity of living organisms, the diversity of genes these organisms have, and the diversity of ecosystems. The biodiversity of many areas is being reduced by activities related to increasing human population size, industrialisation and globalisation. Such interactions can result in ecosystems being damaged or destroyed, populations dying out, and species becoming extinct when conditions change more quickly than they can adapt. Humans can interact with ecosystems positively by using ecosystem resources in a sustainable way (at the same rate as they can be replaced), and by protecting and conserving biodiversity. All organisms, including humans, depend on other organisms and the environment for their survival. Protecting and conserving biodiversity will help ensure we can continue to provide the human population with food, materials and medicines. Biodiversity can be protected at different levels, including protection of individual species, protection of ecosystems, and control of activities that contribute to global climate change. Decisions about protecting and conserving biodiversity are affected by ecological, economic, moral and political issues (IaS4).	1. describe both positive and negative human interactions within ecosystems and explain their impact on biodiversity **2. evaluate evidence for the impact of environmental changes on the distribution of organisms, with reference to water and atmospheric gases *(separate science only)*** 3. describe some of the biological factors affecting levels of food security including increasing human population, changing diets in wealthier populations, new pests and pathogens, environmental change, sustainability and cost of agricultural inputs *(separate science only)* 4. explain some of the benefits and challenges of maintaining local and global biodiversity 5. extract and interpret information related to biodiversity from charts, graphs and tables M2c, M4a 6. describe and explain some possible biotechnological and agricultural solutions, including genetic modification, to the demands of the growing human population *(separate science only)*

Linked learning opportunities

Specification links:
- greenhouse gases and global warming (P1.3, C1.1)

Ideas about Science:
- the impacts of science on biodiversity, including negative impacts and potential solutions (IaS4)
- decision making in the context of the protection and conservation of biodiversity (IaS4)

Practical work:
- measure living and non-living indicators to assess the effect of pollution on organisms