4.1 Cell biology

Cells are the basic unit of all forms of life. In this section we explore how structural differences between types of cells enables them to perform specific functions within the organism. These differences in cells are controlled by genes in the nucleus. For an organism to grow, cells must divide by mitosis producing two new identical cells. If cells are isolated at an early stage of growth before they have become too specialised, they can retain their ability to grow into a range of different types of cells. This phenomenon has led to the development of stem cell technology. This is a new branch of medicine that allows doctors to repair damaged organs by growing new tissue from stem cells.

4.1.1 Cell structure

4.1.1.1 Eukaryotes and prokaryotes

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| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Plant and animal cells (eukaryotic cells) have a cell membrane, |  |  |
| cytoplasm and genetic material enclosed in a nucleus. |  |  |
|  |  |  |
| Bacterial cells (prokaryotic cells) are much smaller in comparison. |  |  |
| They have cytoplasm and a cell membrane surrounded by a cell |  |  |
| wall. The genetic material is not enclosed in a nucleus. It is a single |  |  |
| DNA loop and there may be one or more small rings of DNA called |  |  |
| plasmids. |  |  |
|  |  |  |
| Students should be able to demonstrate an understanding of the | MS 1b, 2a, 2h |  |
| scale and size of cells and be able to make order of magnitude | WS 4.4 |  |
| calculations, including the use of standard form. |  |
|  | Use prefixes centi, milli, |  |
|  | micro and nano. |  |
|  |  |  |

4.1.1.2 Animal and plant cells



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Content** | |  | **Key opportunities for skills** |  |
|  |  |  | **development** |  |
|  | |  |  |  |
| Students should be able to explain how the main sub-cellular | |  | WS 1.2 |  |
| structures, including the nucleus, cell membranes, mitochondria, | |  | Recognise, draw and |  |
| chloroplasts in plant cells and plasmids in bacterial cells are related | |  |  |
|  | interpret images of cells. |  |
| to their functions. | |  |  |
|  |  |  |
| Most animal cells have the following parts: | |  |  |  |
| • | a nucleus |  |  |  |
| • | cytoplasm |  |  |  |
| • | a cell membrane |  |  |  |
| • | mitochondria |  |  |  |
| • | ribosomes. |  |  |  |

In addition to the parts found in animal cells, plant cells often have:

* chloroplasts
* a permanent vacuole filled with cell sap.

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



|  |  |  |
| --- | --- | --- |
| Students should be able to use estimations and explain what they | MS 1d, 3a |  |
| should be used to judge the relative size or area of sub-cellular | AT 7 |  |
| structures. |  |
| Images of cells in videos, |  |
|  |  |
|  | bioviewers, photographs |  |
|  | and micrographs can be |  |
|  | used as comparison for |  |
|  | students own drawings. |  |

**Required practical activity 1:** use a light microscope to observe, draw and label a selection ofplant and animal cells. A magnification scale must be included.

4.1.1.3 Cell specialisation

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Students should be able to, when provided with appropriate |  |
| information, explain how the structure of different types of cell relate |  |
| to their function in a tissue, an organ or organ system, or the whole |  |
| organism. |  |
| Cells may be specialised to carry out a particular function: |  |
| • sperm cells, nerve cells and muscle cells in animals |  |
| • root hair cells, xylem and phloem cells in plants. |  |
|  |  |

4.1.1.4 Cell differentiation

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Students should be able to explain the importance of cell |  |
| differentiation. |  |
| As an organism develops, cells differentiate to form different types |  |
| of cells. |  |
| • Most types of animal cell differentiate at an early stage. |  |
| • Many types of plant cells retain the ability to differentiate |  |
| throughout life. |  |
| In mature animals, cell division is mainly restricted to repair and |  |
| replacement. As a cell differentiates it acquires different sub-cellular |  |
| structures to enable it to carry out a certain function. It has become |  |
| a specialised cell. |  |
|  |  |

4.1.1.5 Microscopy



|  |  |  |
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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |
| Students should be able to: |  | WS 1.1 |

* understand how microscopy techniques have developed over time
* explain how electron microscopy has increased understanding of sub-cellular structures.

Limited to the differences in magnification and resolution.

An electron microscope has much higher magnification and resolving power than a light microscope. This means that it can be used to study cells in much finer detail. This has enabled biologists to see and understand many more sub-cellular structures.



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| **Content** | | | **Key opportunities for skills** |  |
|  |  |  | **development** |  |
|  |  |  |  |  |
| Students should be able to carry out calculations involving | | | MS 1a, 1b, 2h, 3b |  |
| magnification, real size and image size using the formula: | | | WS 4.4 |  |
|  | size of image | |  |
| magnification = | Use prefixes centi, milli, |  |
| size of real object |  |  |
| Students should be able to express answers in standard form if | | | micro and nano. |  |
|  |  |
| appropriate. | | |  |  |
|  |  |  |  |  |

4.1.1.6 Culturing microorganisms (biology only)

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| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Bacteria multiply by simple cell division (binary fission) as often as | MS 1a, 1b, 1d, 2a, 2h |  |
| once every 20 minutes if they have enough nutrients and a suitable | Calculate the number of |  |
| temperature. |  |
| bacteria in a population |  |
|  |  |
| Bacteria can be grown in a nutrient broth solution or as colonies on | after a certain time if given |  |
| an agar gel plate. | the mean division time. |  |
| Uncontaminated cultures of microorganisms are required for | MS 5c |  |
| investigating the action of disinfectants and antibiotics. | Calculate cross-sectional |  |
|  |  |
|  | areas of colonies or clear |  |
|  | areas around colonies using |  |
|  | πr². |  |
|  |  |  |
| Students should be able to describe how to prepare an | WS 2.2, 2.4 |  |
| uncontaminated culture using aseptic technique. |  |  |
| They should be able to explain why: |  |  |
| • Petri dishes and culture media must be sterilised before use |  |  |
| • inoculating loops used to transfer microorganisms to the media |  |  |
| must be sterilised by passing them through a flame |  |  |
| • the lid of the Petri dish should be secured with adhesive tape |  |  |
| and stored upside down |  |  |
| • in school and college laboratories, cultures should be incubated |  |  |
| at a maximum temperature of 25°C. |  |  |
|  |  |  |
| Students should be able to calculate cross-sectional areas of | MS 5c |  |
| colonies or clear areas around colonies using πr². |  |  |
|  |  |  |
| Students should be able to calculate the number of bacteria in a | MS 1a, 2a, 2h |  |
| population after a certain time if given the mean division time. |  |  |
|  |  |  |
| (HT only) Students should be able to express the answer in | MS 1b |  |
| standard form. |  |  |

4.1.2 Cell division

4.1.2.1 Chromosomes

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| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| The nucleus of a cell contains chromosomes made of DNA | WS 1.2 |  |
| molecules. Each chromosome carries a large number of genes. | Use models and analogies |  |
|  |  |
| In body cells the chromosomes are normally found in pairs. | to develop explanations of |  |
|  | how cells divide. |  |
|  |  |  |

4.1.2.2 Mitosis and the cell cycle

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Cells divide in a series of stages called the cell cycle. Students |  |
| should be able to describe the stages of the cell cycle, including |  |
| mitosis. |  |
| During the cell cycle the genetic material is doubled and then |  |
| divided into two identical cells. |  |
| Before a cell can divide it needs to grow and increase the number |  |
| of sub-cellular structures such as ribosomes and mitochondria. The |  |
| DNA replicates to form two copies of each chromosome. |  |
| In mitosis one set of chromosomes is pulled to each end of the cell |  |
| and the nucleus divides. |  |
| Finally the cytoplasm and cell membranes divide to form two |  |
| identical cells. |  |
| Students need to understand the three overall stages of the cell |  |
| cycle but do not need to know the different phases of the mitosis |  |
| stage. |  |
| Cell division by mitosis is important in the growth and development |  |
| of multicellular organisms. |  |
| Students should be able to recognise and describe situations in |  |
| given contexts where mitosis is occurring. |  |
|  |  |

4.1.2.3 Stem cells

|  |  |  |
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| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| A stem cell is an undifferentiated cell of an organism which is |  |  |
| capable of giving rise to many more cells of the same type, and |  |  |
| from which certain other cells can arise from differentiation. |  |  |
| Students should be able to describe the function of stem cells in |  |  |
| embryos, in adult animals and in the meristems in plants. |  |  |
| Stem cells from human embryos can be cloned and made to |  |  |
| differentiate into most different types of human cells. |  |  |
| Stem cells from adult bone marrow can form many types of cells |  |  |
| including blood cells. |  |  |
| Meristem tissue in plants can differentiate into any type of plant cell, |  |  |
| throughout the life of the plant. |  |  |
| Knowledge and understanding of stem cell techniques are not |  |  |
| required. |  |  |
| Treatment with stem cells may be able to help conditions such as |  |  |
| diabetes and paralysis. |  |  |
|  |  |  |
| In therapeutic cloning an embryo is produced with the same genes | WS 1.3 |  |
| as the patient. Stem cells from the embryo are not rejected by the | Evaluate the practical risks |  |
| patient’s body so they may be used for medical treatment. |  |
| and benefits, as well as |  |
|  |  |
| The use of stem cells has potential risks such as transfer of viral | social and ethical issues, of |  |
| infection, and some people have ethical or religious objections. | the use of stem cells in |  |
| Stem cells from meristems in plants can be used to produce clones | medical research and |  |
| treatments. |  |
| of plants quickly and economically. |  |
|  |  |
| • Rare species can be cloned to protect from extinction. |  |  |
| • Crop plants with special features such as disease resistance can |  |  |
| be cloned to produce large numbers of identical plants for |  |  |
| farmers. |  |  |

4.1.3 Transport in cells

4.1.3.1 Diffusion

|  |  |  |
| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Substances may move into and out of cells across the cell | WS 1.2 |  |
| membranes via diffusion. | Recognise, draw and |  |
|  |  |
| Diffusion is the spreading out of the particles of any substance in | interpret diagrams that |  |
| solution, or particles of a gas, resulting in a net movement from an | model diffusion. |  |
| area of higher concentration to an area of lower concentration. | WS 1.5 |  |
| Some of the substances transported in and out of cells by diffusion |  |
| Use of isotonic drinks and |  |
| are oxygen and carbon dioxide in gas exchange, and of the waste |  |
| high energy drinks in sport. |  |
| product urea from cells into the blood plasma for excretion in the |  |
|  |  |
| kidney. |  |  |
| Students should be able to explain how different factors affect the |  |  |
| rate of diffusion. |  |  |
| Factors which affect the rate of diffusion are: |  |  |
| • the difference in concentrations (concentration gradient) |  |  |
| • the temperature |  |  |
| • the surface area of the membrane. |  |  |
| A single-celled organism has a relatively large surface area to |  |  |
| volume ratio. This allows sufficient transport of molecules into and |  |  |
| out of the cell to meet the needs of the organism. |  |  |
|  |  |  |
| Students should be able to calculate and compare surface area to | MS 1c, 5c |  |
| volume ratios. |  |  |
| Students should be able to explain the need for exchange surfaces |  |  |
| and a transport system in multicellular organisms in terms of |  |  |
| surface area to volume ratio. |  |  |
| Students should be able to explain how the small intestine and |  |  |
| lungs in mammals, gills in fish, and the roots and leaves in plants, |  |  |
| are adapted for exchanging materials. |  |  |
| In multicellular organisms, surfaces and organ systems are |  |  |
| specialised for exchanging materials. This is to allow sufficient |  |  |
| molecules to be transported into and out of cells for the organism’s |  |  |
| needs. The effectiveness of an exchange surface is increased by: |  |  |
| • having a large surface area |  |  |
| • a membrane that is thin, to provide a short diffusion path |  |  |
| • (in animals) having an efficient blood supply |  |  |
| • (in animals, for gaseous exchange) being ventilated. |  |  |
|  |  |  |

4.1.3.2 Osmosis

|  |  |  |
| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Water may move across cell membranes via osmosis. Osmosis is | WS 1.2 |  |
| the diffusion of water from a dilute solution to a concentrated | Recognise, draw and |  |
| solution through a partially permeable membrane. |  |
| interpret diagrams that |  |
|  |  |
|  | model osmosis. |  |
|  |  |  |
| Students should be able to: | MS 1a, 1c |  |
| • use simple compound measures of rate of water uptake |  |  |
| • use percentiles |  |  |
| • calculate percentage gain and loss of mass of plant tissue. |  |  |
|  |  |  |
| Students should be able to plot, draw and interpret appropriate | MS 4a, 4b, 4c, 4d |  |
| graphs. |  |  |
|  |  |  |

**Required practical activity 3:** investigate the effect of a range of concentrations of salt or sugarsolutions on the mass of plant tissue.

4.1.3.3 Active transport



|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Content** |  | **Key opportunities for skills** | | | |  |
|  |  | **development** | | | |  |
|  |  |  |  |  |  |  |
| Active transport moves substances from a more dilute solution to a |  | There are links with this | | | |  |
| more concentrated solution (against a concentration gradient). This |  | content to [Cell](#page20) | | | |  |
| requires energy from respiration. |  |  |  |  |  |  |
|  | [specialisation](#page20) (page 20). | | | |  |
| Active transport allows mineral ions to be absorbed into plant root |  |  |  |  |  |  |
| hairs from very dilute solutions in the soil. Plants require ions for |  |  |  |  |  |  |
| healthy growth. |  |  |  |  |  |  |
| It also allows sugar molecules to be absorbed from lower |  |  |  |  |  |  |
| concentrations in the gut into the blood which has a higher sugar |  |  |  |  |  |  |
| concentration. Sugar molecules are used for cell respiration. |  |  |  |  |  |  |
| Students should be able to: |  |  |  |  |  |  |

* describe how substances are transported into and out of cells by diffusion, osmosis and active transport
* explain the differences between the three processes.

4.2 Organisation

In this section we will learn about the human digestive system which provides the body with nutrients and the respiratory system that provides it with oxygen and removes carbon dioxide. In each case they provide dissolved materials that need to be moved quickly around the body in the blood by the circulatory system. Damage to any of these systems can be debilitating if not fatal. Although there has been huge progress in surgical techniques, especially with regard to coronary heart disease, many interventions would not be necessary if individuals reduced their risks through improved diet and lifestyle. We will also learn how the plant’s transport system is dependent on environmental conditions to ensure that leaf cells are provided with the water and carbon dioxide that they need for photosynthesis.

4.2.2 Animal tissues, organs and organ systems

4.2.2.1 The human digestive system

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Content** | | **Key opportunities for skills** |
|  |  |  | **development** |
|  |  |  |  |
|  | This section assumes knowledge of the digestive system studied in | |  |
|  | Key Stage 3 science. | |  |
|  | The digestive system is an example of an organ system in which | |  |
|  | several organs work together to digest and absorb food. | |  |
|  | Students should be able to relate knowledge of enzymes to | |  |
|  | [Metabolism](#page44) (page 44). | |  |
|  |  |  |  |
|  | Students should be able to describe the nature of enzyme | |  |
|  | molecules and relate their activity to temperature and pH changes. | |  |
|  |  | |  |
|  | Students should be able to carry out rate calculations for chemical | | MS 1a, 1c |
|  | reactions. | |  |
|  | Enzymes catalyse specific reactions in living organisms due to the | |  |
|  | shape of their active site. | |  |
|  |  |  |  |

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| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Students should be able to use the ‘lock and key theory’ as a | WS 1.2 |  |
| simplified model to explain enzyme action. | Students should be able to |  |
|  |  |
| Students should be able to recall the sites of production and the | use other models to explain |  |
| action of amylase, proteases and lipases. | enzyme action. |  |
| Students should be able to understand simple word equations but |  |  |
| no chemical symbol equations are required. |  |  |
| Digestive enzymes convert food into small soluble molecules that |  |  |
| can be absorbed into the bloodstream. |  |  |
| Carbohydrases break down carbohydrates to simple sugars. |  |  |
| Amylase is a carbohydrase which breaks down starch. |  |  |
| Proteases break down proteins to amino acids. |  |  |
| Lipases break down lipids (fats) to glycerol and fatty acids. |  |  |
| The products of digestion are used to build new carbohydrates, |  |  |
| lipids and proteins. Some glucose is used in respiration. |  |  |
| Bile is made in the liver and stored in the gall bladder. It is alkaline |  |  |
| to neutralise hydrochloric acid from the stomach. It also emulsifies |  |  |
| fat to form small droplets which increases the surface area. The |  |  |
| alkaline conditions and large surface area increase the rate of fat |  |  |
| breakdown by lipase. |  |  |
|  |  |  |

**Required practical activity 4:** use qualitative reagents to test for a range of carbohydrates, lipidsand proteins.

To include: Benedict’s test for sugars; iodine test for starch; and Biuret reagent

for protein.

4.2.2.2 The heart and blood vessels



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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
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Students should know the structure and functioning of the human heart and lungs, including how lungs are adapted for gaseous exchange.

The heart is an organ that pumps blood around the body in a double circulatory system. The right ventricle pumps blood to the lungs where gas exchange takes place. The left ventricle pumps blood around the rest of the body.

Knowledge of the blood vessels associated with the heart is limited to the aorta, vena cava, pulmonary artery, pulmonary vein and coronary arteries. Knowledge of the names of the heart valves is not required.

Knowledge of the lungs is restricted to the trachea, bronchi, alveoli and the capillary network surrounding the alveoli.

The natural resting heart rate is controlled by a group of cells located in the right atrium that act as a pacemaker. Artificial pacemakers are electrical devices used to correct irregularities in the heart rate.

The body contains three different types of blood vessel:

|  |  |  |
| --- | --- | --- |
| • | arteries |  |
| • | veins |  |
| • | capillaries. |  |
| Students should be able to explain how the structure of these | |  |
| vessels relates to their functions. | |  |
|  | |  |
| Students should be able to use simple compound measures such | | MS 1a, 1c |
| as rate and carry out rate calculations for blood flow. | |  |

4.2.2.4 Coronary heart disease: a non-communicable disease

|  |  |  |
| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Students should be able to evaluate the advantages and | WS 1.4 |  |
| disadvantages of treating cardiovascular diseases by drugs, | WS 1.3 |  |
| mechanical devices or transplant. |  |
| Evaluate methods of |  |
| In coronary heart disease layers of fatty material build up inside the |  |
| treatment bearing in mind |  |
| coronary arteries, narrowing them. This reduces the flow of blood |  |
| the benefits and risks |  |
| through the coronary arteries, resulting in a lack of oxygen for the |  |
| associated with the |  |
| heart muscle. Stents are used to keep the coronary arteries open. |  |
| treatment. |  |
| Statins are widely used to reduce blood cholesterol levels which |  |
|  |  |
| slows down the rate of fatty material deposit. |  |  |
| In some people heart valves may become faulty, preventing the |  |  |
| valve from opening fully, or the heart valve might develop a leak. |  |  |
| Students should understand the consequences of faulty valves. |  |  |
| Faulty heart valves can be replaced using biological or mechanical |  |  |
| valves. |  |  |
| In the case of heart failure a donor heart, or heart and lungs can be |  |  |
| transplanted. Artificial hearts are occasionally used to keep patients |  |  |
| alive whilst waiting for a heart transplant, or to allow the heart to |  |  |
| rest as an aid to recovery. |  |  |
|  |  |  |



4.2.2.5 Health issues



|  |  |  |
| --- | --- | --- |
| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |

Students should be able to describe the relationship between health and disease and the interactions between different types of disease.

Health is the state of physical and mental well-being.

Diseases, both communicable [Communicable diseases](#page34) (page 34) and non-communicable, are major causes of ill health. Other factors including diet, stress and life situations may have a profound effect on both physical and mental health.

Different types of disease may interact.

* Defects in the immune system mean that an individual is more likely to suffer from infectious diseases.
* Viruses living in cells can be the trigger for cancers.
* Immune reactions initially caused by a pathogen can trigger allergies such as skin rashes and asthma.
* Severe physical ill health can lead to depression and other mental illness.



Students should be able to translate disease incidence information between graphical and numerical forms, construct and interpret

frequency tables and diagrams, bar charts and histograms, and use a scatter diagram to identify a correlation between two variables.



Students should understand the principles of sampling as applied to scientific data, including epidemiological data

4.2.2.6 The effect of lifestyle on some non-communicable diseases



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| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |
| Students should be able to: |  | WS 1.4 |

* discuss the human and financial cost of these non-communicable diseases to an individual, a local community, a nation or globally
* explain the effect of lifestyle factors including diet, alcohol and smoking on the incidence of non-communicable diseases at local, national and global levels.



|  |  |  |
| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Risk factors are linked to an increased rate of a disease. | WS 1.5 |  |
| They can be: | Interpret data about risk |  |
| • aspects of a person’s lifestyle | factors for specified |  |
| diseases. |  |
| • substances in the person’s body or environment. |  |
|  |  |
| A causal mechanism has been proven for some risk factors, but not |  |  |
| in others. |  |  |
| • The effects of diet, smoking and exercise on cardiovascular |  |  |
| disease. |  |  |
| • Obesity as a risk factor for Type 2 diabetes. |  |  |
| • The effect of alcohol on the liver and brain function. |  |  |
| • The effect of smoking on lung disease and lung cancer. |  |  |
| • The effects of smoking and alcohol on unborn babies. |  |  |
| • Carcinogens, including ionising radiation, as risk factors in |  |  |
| cancer. |  |  |
| Many diseases are caused by the interaction of a number of factors. |  |  |
|  |  |  |
| Students should be able to understand the principles of sampling as | MS 2d |  |
| applied to scientific data in terms of risk factors. |  |  |
|  |  |  |
| Students should be able to translate information between graphical | MS 2c, 4a |  |
| and numerical forms; and extract and interpret information from |  |  |
| charts, graphs and tables in terms of risk factors. |  |  |
|  |  |  |
| Students should be able to use a scatter diagram to identify a | MS 2g |  |
| correlation between two variables in terms of risk factors. |  |  |
|  |  |  |

4.2.3 Plant tissues, organs and systems

4.2.3.1 Plant tissues



|  |  |  |  |
| --- | --- | --- | --- |
| **Content** |  | **Key opportunities for skills** |  |
|  |  | **development** |  |
|  |  |  |  |
| Students should be able to explain how the structures of plant |  | AT 7 |  |
| tissues are related to their functions. |  | Observation and drawing of |  |
|  |  |  |
| Plant tissues include: |  | a transverse section of leaf. |  |

* epidermal tissues
* palisade mesophyll
* spongy mesophyll
* xylem and phloem
* meristem tissue found at the growing tips of shoots and roots.

The leaf is a plant organ. Knowledge limited to epidermis, palisade and spongy mesophyll, xylem and phloem, and guard cells surrounding stomata.

4.2.3.2 Plant organ system

|  |  |  |
| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Students should be able to explain how the structure of root hair | AT 3, 4, 5 |  |
| cells, xylem and phloem are adapted to their functions. | Measure the rate of |  |
|  |  |
| Students should be able to explain the effect of changing | transpiration by the uptake |  |
| temperature, humidity, air movement and light intensity on the rate | of water. |  |
| of transpiration. | AT 6, 7 |  |
|  |  |
|  | Investigate the distribution |  |
|  | of stomata and guard cells. |  |
|  | MS 2a, 2d, 5c |  |
|  | Process data from |  |
|  | investigations involving |  |
|  | stomata and transpiration |  |
|  | rates to find arithmetic |  |
|  | means, understand the |  |
|  | principles of sampling and |  |
|  | calculate surface areas and |  |
|  | volumes. |  |
|  |  |  |
| Students should be able to understand and use simple compound | MS 1a, 1c |  |
| measures such as the rate of transpiration. |  |  |
|  |  |  |

|  |  |  |
| --- | --- | --- |
| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |
| Students should be able to: |  | MS 2c, 4a, 4c |

* translate information between graphical and numerical form
* plot and draw appropriate graphs, selecting appropriate scales for axes
* extract and interpret information from graphs, charts and tables.



The roots, stem and leaves form a plant organ system for transport of substances around the plant.

Students should be able to describe the process of transpiration and translocation, including the structure and function of the stomata.

Root hair cells are adapted for the efficient uptake of water by osmosis, and mineral ions by active transport.

Xylem tissue transports water and mineral ions from the roots to the stems and leaves. It is composed of hollow tubes strengthened by lignin adapted for the transport of water in the transpiration stream.

The role of stomata and guard cells are to control gas exchange and water loss.

Phloem tissue transports dissolved sugars from the leaves to the rest of the plant for immediate use or storage. The movement of food molecules through phloem tissue is called translocation.

Phloem is composed of tubes of elongated cells. Cell sap can move from one phloem cell to the next through pores in the end walls.

Detailed structure of phloem tissue or the mechanism of transport is not required.

4.3.1 Communicable diseases

4.3.1.1 Communicable (infectious) diseases

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| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Students should be able to explain how diseases caused by | WS 1.4 |
| viruses, bacteria, protists and fungi are spread in animals and |  |
| plants. |  |
| Students should be able to explain how the spread of diseases can |  |
| be reduced or prevented. |  |
| Pathogens are microorganisms that cause infectious disease. |  |
| Pathogens may be viruses, bacteria, protists or fungi. They may |  |
| infect plants or animals and can be spread by direct contact, by |  |
| water or by air. |  |
| Bacteria and viruses may reproduce rapidly inside the body. |  |
| Bacteria may produce poisons (toxins) that damage tissues and |  |
| make us feel ill. |  |
| Viruses live and reproduce inside cells, causing cell damage. |  |
|  |  |

4.3.1.2 Viral diseases

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| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Measles is a viral disease showing symptoms of fever and a red |  |
| skin rash. Measles is a serious illness that can be fatal if |  |
| complications arise. For this reason most young children are |  |
| vaccinated against measles. The measles virus is spread by |  |
| inhalation of droplets from sneezes and coughs. |  |
| HIV initially causes a flu-like illness. Unless successfully controlled |  |
| with antiretroviral drugs the virus attacks the body’s immune cells. |  |
| Late stage HIV infection, or AIDS, occurs when the body's immune |  |
| system becomes so badly damaged it can no longer deal with other |  |
| infections or cancers. HIV is spread by sexual contact or exchange |  |
| of body fluids such as blood which occurs when drug users share |  |
| needles. |  |
| Tobacco mosaic virus (TMV) is a widespread plant pathogen |  |
| affecting many species of plants including tomatoes. It gives a |  |
| distinctive ‘mosaic’ pattern of discolouration on the leaves which |  |
| affects the growth of the plant due to lack of photosynthesis. |  |
|  |  |

4.3.1.3 Bacterial diseases

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| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| *Salmonella* food poisoning is spread by bacteria ingested in food, or |  |
| on food prepared in unhygienic conditions. In the UK, poultry are |  |
| vaccinated against *Salmonella* to control the spread. Fever, |  |
| abdominal cramps, vomiting and diarrhoea are caused by the |  |
| bacteria and the toxins they secrete. |  |
| Gonorrhoea is a sexually transmitted disease (STD) with symptoms |  |
| of a thick yellow or green discharge from the vagina or penis and |  |
| pain on urinating. It is caused by a bacterium and was easily treated |  |
| with the antibiotic penicillin until many resistant strains appeared. |  |
| Gonorrhoea is spread by sexual contact. The spread can be |  |
| controlled by treatment with antibiotics or the use of a barrier |  |
| method of contraception such as a condom. |  |
|  |  |

4.3.1.4 Fungal diseases

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Rose black spot is a fungal disease where purple or black spots |  |
| develop on leaves, which often turn yellow and drop early. It affects |  |
| the growth of the plant as photosynthesis is reduced. It is spread in |  |
| the environment by water or wind. Rose black spot can be treated |  |
| by using fungicides and/or removing and destroying the affected |  |
| leaves. |  |
|  |  |

4.3.1.5 Protist diseases

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| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| The pathogens that cause malaria are protists. |  |
| The malarial protist has a life cycle that includes the mosquito. |  |
| Malaria causes recurrent episodes of fever and can be fatal. The |  |
| spread of malaria is controlled by preventing the vectors, |  |
| mosquitos, from breeding and by using mosquito nets to avoid |  |
| being bitten. |  |
|  |  |

4.3.1.6 Human defence systems



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| --- | --- | --- |
| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |

Students should be able to describe the non-specific defence systems of the human body against pathogens, including the:

* skin
* nose
* trachea and bronchi
* stomach.

Students should be able to explain the role of the immune system in the defence against disease.

If a pathogen enters the body the immune system tries to destroy the pathogen.

White blood cells help to defend against pathogens by:

• phagocytosis

• antibody production

• antitoxin production.

4.3.1.7 Vaccination

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| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
| **development** |  |
|  |  |
|  |  |  |
| Students should be able to explain how vaccination will prevent | WS 1.4 |  |
| illness in an individual, and how the spread of pathogens can be | Evaluate the global use of |  |
| reduced by immunising a large proportion of the population. |  |
| vaccination in the |  |
|  |  |
| Vaccination involves introducing small quantities of dead or inactive | prevention of disease. |  |
| forms of a pathogen into the body to stimulate the white blood cells |  |  |
| to produce antibodies. If the same pathogen re-enters the body the |  |  |
| white blood cells respond quickly to produce the correct antibodies, |  |  |
| preventing infection. |  |  |
| Students do not need to know details of vaccination schedules and |  |  |
| side effects associated with specific vaccines. |  |  |
|  |  |  |

4.3.2 Monoclonal antibodies (biology only) (HT only)

4.3.2.1 Producing monoclonal antibodies

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Students should be able to describe how monoclonal antibodies are |  |
| produced. |  |
| Monoclonal antibodies are produced from a single clone of cells. |  |
| The antibodies are specific to one binding site on one protein |  |
| antigen and so are able to target a specific chemical or specific |  |
| cells in the body. |  |
| They are produced by stimulating mouse lymphocytes to make a |  |
| particular antibody. The lymphocytes are combined with a particular |  |
| kind of tumour cell to make a cell called a hybridoma cell. The |  |
| hybridoma cell can both divide and make the antibody. Single |  |
| hybridoma cells are cloned to produce many identical cells that all |  |
| produce the same antibody. A large amount of the antibody can be |  |
| collected and purified. |  |
|  |  |

4.3.2.2 Uses of monoclonal antibodies

|  |  |  |
| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Students should be able to describe some of the ways in which | WS 1.3 |  |
| monoclonal antibodies can be used. | Appreciate the power of |  |
|  |  |
| Some examples include: | monoclonal antibodies and |  |
| • For diagnosis such as in pregnancy tests. | consider any ethical issues. |  |
|  |  |
| • In laboratories to measure the levels of hormones and other |  |  |
| chemicals in blood, or to detect pathogens. |  |  |
| • In research to locate or identify specific molecules in a cell or |  |  |
| tissue by binding to them with a fluorescent dye. |  |  |
| • To treat some diseases: for cancer the monoclonal antibody can |  |  |
| be bound to a radioactive substance, a toxic drug or a chemical |  |  |
| which stops cells growing and dividing. It delivers the substance |  |  |
| to the cancer cells without harming other cells in the body. |  |  |
| Students are not expected to recall any specific tests or treatments |  |  |
| but given appropriate information they should be able to explain |  |  |
| how they work. |  |  |
|  |  |  |
| Monoclonal antibodies create more side effects than expected. | WS 1.5 |  |
| They are not yet as widely used as everyone hoped when they | Evaluate the advantages |  |
| were first developed. |  |
| and disadvantages of |  |
|  |  |
|  | monoclonal antibodies. |  |
|  |  |  |

4.3.3 Plant disease (biology only)

4.3.3.1 Detection and identification of plant diseases



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Content** | |  | **Key opportunities for skills** |  |
|  |  |  | **development** |  |
|  | |  |  |  |
| (HT only) Plant diseases can be detected by: | |  | WS 1.4 |  |
| • | stunted growth |  | The everyday application of |  |
| • | spots on leaves |  | scientific knowledge to |  |
| • areas of decay (rot) | |  | detect and identify plant |  |
| • | growths |  | disease. |  |
|  |  |  |

* malformed stems or leaves
* discolouration
* the presence of pests.

|  |  |  |
| --- | --- | --- |
| (HT only) Identification can be made by: |  |  |
| • reference to a gardening manual or website |  |  |
| • taking infected plants to a laboratory to identify the pathogen |  |  |
| • using testing kits that contain monoclonal antibodies. |  |  |
|  |  |  |
| Plants can be infected by a range of viral, bacterial and fungal | WS 1.4 |  |
| pathogens as well as by insects. | The understanding of ion |  |
|  |  |
| Knowledge of plant diseases is restricted to tobacco mosaic virus | deficiencies allows |  |
| as a viral disease, black spot as a fungal disease and aphids as | horticulturists to provide |  |
| insects. | optimum conditions for |  |
| Plants can be damaged by a range of ion deficiency conditions: | plants. |  |
|  |  |
| • stunted growth caused by nitrate deficiency |  |  |
| • chlorosis caused by magnesium deficiency. |  |  |
| Knowledge of ions is limited to nitrate ions needed for protein |  |  |
| synthesis and therefore growth, and magnesium ions needed to |  |  |
| make chlorophyll. |  |  |



4.3.3.2 Plant defence responses



|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Content** |  | **Key opportunities for skills** | | |  |
|  |  | **development** | | |  |
|  |  |  |  |  |  |
| Students should be able to describe physical and chemical plant |  | There are links with this | | |  |
| defence responses. |  | content to [Adaptations](#page73) | | |  |
| Physical defence responses to resist invasion of microorganisms. |  | (page 73). |  |  |  |
|  |  |  |  |  |

* Cellulose cell walls.
* Tough waxy cuticle on leaves.
* Layers of dead cells around stems (bark on trees) which fall off.

Chemical plant defence responses.

* Antibacterial chemicals.
* Poisons to deter herbivores.

Mechanical adaptations.

* Thorns and hairs deter animals.
* Leaves which droop or curl when touched.
* Mimicry to trick animals.

4.4 Bioenergetics

In this section we will explore how plants harness the Sun’s energy in photosynthesis in order to make food. This process liberates oxygen which has built up over millions of years in the Earth’s atmosphere. Both animals and plants use this oxygen to oxidise food in a process called aerobic respiration which transfers the energy that the organism needs to perform its functions.

Conversely, anaerobic respiration does not require oxygen to transfer energy. During vigorous exercise the human body is unable to supply the cells with sufficient oxygen and it switches to anaerobic respiration. This process will supply energy but also causes the build-up of lactic acid in muscles which causes fatigue.

4.4.1 Photosynthesis

4.4.1.1 Photosynthetic reaction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Content** | **Key opportunities for skills** | | |  |
|  | **development** | | |  |
|  |  |  |  |  |
| Photosynthesis is represented by the equation: |  |  |  |  |
| carbon dioxide + water light glucose + oxygen |  |  |  |  |
| Students should recognise the chemical symbols: CO2, H2O, O2 |  |  |  |  |
| and C6H12O6. |  |  |  |  |
| Students should be able to describe photosynthesis as an | There are links with this | | |  |
| endothermic reaction in which energy is transferred from the | content to | [Plant tissues](#page32) |  |  |
|  |  |
| environment to the chloroplasts by light. | (page 32), the leaf. | | |  |
|  |  |  |  |  |

#

4.4.1.2 Rate of photosynthesis

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| --- | --- | --- |
| **Content** | **Key opportunities for skills** |  |
|  | **development** |  |
|  |  |  |
| Students should be able to explain the effects of temperature, light |  |  |
| intensity, carbon dioxide concentration, and the amount of |  |  |
| chlorophyll on the rate of photosynthesis. |  |  |
|  |  |  |
| Students should be able to: | MS 3d |  |
| • measure and calculate rates of photosynthesis | Solve simple algebraic |  |
| • extract and interpret graphs of photosynthesis rate involving one | equations. |  |
| limiting factor | MS 1a, 1c, 2c, 4a, 4c |  |
| • plot and draw appropriate graphs selecting appropriate scale for |  |
|  |  |
| axes |  |  |
| • translate information between graphical and numeric form. |  |  |
|  |  |  |
| (HT only) These factors interact and any one of them may be the |  |  |
| factor that limits photosynthesis. |  |  |
| (HT only) Students should be able to explain graphs of |  |  |
| photosynthesis rate involving two or three factors and decide which |  |  |
| is the limiting factor. |  |  |
|  |  |  |
| (HT only) Students should understand and use inverse proportion – | MS 3a, 3d |  |
| the inverse square law and light intensity in the context of | (HT only) WS 1.4 |  |
| photosynthesis. |  |
| Use data to relate limiting |  |
| (HT only) Limiting factors are important in the economics of |  |
| factors to the cost |  |
| enhancing the conditions in greenhouses to gain the maximum rate |  |
| effectiveness of adding |  |
| of photosynthesis while still maintaining profit. |  |
| heat, light or carbon dioxide |  |
|  |  |
|  | to greenhouses. |  |
|  |  |  |

4.4.1.3 Uses of glucose from photosynthesis



|  |  |  |
| --- | --- | --- |
| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |
| The glucose produced in photosynthesis may be: |  | AT 8 |
| • used for respiration |  | Tests to identify starch, |
| • converted into insoluble starch for storage |  | glucose and proteins using |
| • used to produce fat or oil for storage |  | simple qualitative reagents. |

* used to produce cellulose, which strengthens the cell wall
* used to produce amino acids for protein synthesis.

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

4.4.2 Respiration

4.4.2.1 Aerobic and anaerobic respiration



|  |  |  |
| --- | --- | --- |
| **Content** |  | **Key opportunities for skills** |
|  |  | **development** |
|  |  |  |

Students should be able to describe cellular respiration as an exothermic reaction which is continuously occurring in living cells.

The energy transferred supplies all the energy needed for living processes.

Respiration in cells can take place aerobically (using oxygen) or anaerobically (without oxygen), to transfer energy.

Students should be able to compare the processes of aerobic and anaerobic respiration with regard to the need for oxygen, the differing products and the relative amounts of energy transferred.

Organisms need energy for:

* chemical reactions to build larger molecules
* movement
* keeping warm.

Aerobic respiration is represented by the equation:

glucose + oxygen  carbon dioxide + water

Students should recognise the chemical symbols: C6H12O6, O2, CO2 and H2O.

Anaerobic respiration in muscles is represented by the equation:

glucose  lactic acid

As the oxidation of glucose is incomplete in anaerobic respiration much less energy is transferred than in aerobic respiration.

Anaerobic respiration in plant and yeast cells is represented by the equation:

glucose  ethanol + carbon dioxide

Anaerobic respiration in yeast cells is called fermentation and has economic importance in the manufacture of bread and alcoholic drinks.

4.4.2.3 Metabolism

|  |  |
| --- | --- |
| **Content** | **Key opportunities for skills** |
|  | **development** |
|  |  |
| Students should be able to explain the importance of sugars, amino |  |
| acids, fatty acids and glycerol in the synthesis and breakdown of |  |
| carbohydrates, proteins and lipids. |  |
| Metabolism is the sum of all the reactions in a cell or the body. |  |
| The energy transferred by respiration in cells is used by the |  |
| organism for the continual enzyme controlled processes of |  |
| metabolism that synthesise new molecules. |  |
| Metabolism includes: |  |
| • conversion of glucose to starch, glycogen and cellulose |  |
| • the formation of lipid molecules from a molecule of glycerol and |  |
| three molecules of fatty acids |  |
| • the use of glucose and nitrate ions to form amino acids which in |  |
| turn are used to synthesise proteins |  |
| • respiration |  |
| • breakdown of excess proteins to form urea for excretion. |  |
| All of these aspects are covered in more detail in the relevant |  |
| specification section but are linked together here. |  |