## **4.1a Cells and Simple Transport**

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 Cell Structure**

**4.1.1.1 Eukaryotes and prokaryotes**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.

Demonstrate an understanding of the scale and size of cells and be able to make order of magnitude calculations, including the use of standard form.

**4.1.1.2 Animal and plant cells**

Explain how the main sub-cellular structures, including the nucleus, cell membranes, mitochondria, chloroplasts in plant cells and plasmids in bacterial cells are related to their functions.

Most animal cells have the following parts: A nucleus, cytoplasm, 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 and a cell wall made of cellulose, which strengthens the cell.

**Required practical activity 1**: use a light microscope to observe, draw and label a selection of plant

and animal cells. A magnification scale must be included.

**4.1.1.3 Cell specialisation**

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**

Students should be able to:

• understand how microscopy techniques have developed over time

• explain how electron microscopy has increased understanding of sub-cellular structures.

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.

Carry out calculations involving magnification, real size and image size using the formula:   
*Magnification = size of image/size of real object.*

Express answers in standard form if appropriate.

**4.1.3 Transport in cells   
4.1.3.1 Diffusion**

Substances may move into and out of cells across the cell membranes via diffusion.

Diffusion is the spreading out of the particles of any substance in solution, or particles of a gas, resulting in a net movement from an area of higher concentration to an area of lower concentration.

Some of the substances transported in and out of cells by diffusion are oxygen and carbon dioxide in gas exchange, and of the waste product urea from cells into the blood plasma for excretion in the kidney.

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.

Calculate and compare surface area to volume ratios.

Explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area to volume ratio.

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. 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**Water may move across cell membranes via osmosis. Osmosis is the diffusion of water from a dilute solution to a concentrated solution through a partially permeable membrane.

Students should be able to:

* Use simple compound measures of rate of water uptake.
* Use percentages.
* Calculate percentage gain and loss of mass of plant tissue.

Students should be able to plot, draw and interpret appropriate graphs.

**Required practical activity 2:** investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue.

**4.1.3.3 Active transport**Active transport moves substances from a more dilute solution to a more concentrated solution (against a concentration gradient). This requires energy from respiration.

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.

Describe how substances are transported into and out of cells by diffusion, osmosis and active transport

Explain the differences between the three processes.

**4.1b Cell Division and Stem Cells**

**4.1.2 Cell division**

**4.1.2.1 Chromosomes**

The nucleus of a cell contains chromosomes made of DNA molecules. Each chromosome carries a large number of genes.

In body cells the chromosomes are normally found in pairs.

**4.1.2.2 Mitosis and the cell cycle**

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.

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.

Recognise and describe situations in given contexts where mitosis is occurring.

**4.1.2.3 Stem cells**

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.

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.

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 as the patient. Stem cells from the embryo are not rejected by the patient’s body so they may be used for medical treatment.

The use of stem cells has potential risks such as transfer of viral infection, and some people have ethical or religious objections.

Stem cells from meristems in plants can be used to produce clones 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.

## **4.2 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.

### **4.2.1 Principles of organisation** Cells are the basic building blocks of all living organisms.

### A tissue is a group of cells with a similar structure and function.

### Organs are aggregations of tissues performing specific functions.

### Organs are organised into organ systems, which work together to form organisms.

#### **4.2.2 Animal tissues, organs and organ systems 4.2.2.1 The human digestive system**

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.

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 reactions.

Enzymes catalyse specific reactions in living organisms due to the shape of their active site.

Students should be able to use the ‘lock and key theory’ as a simplified model to explain enzyme action.

Students should be able to recall the sites of production and the action of amylase, proteases and lipases.

Students should be able to understand simple word equations (no chemical symbol equations 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, lipids and proteins. To include: Benedict’s test for sugars; iodine test for starch; and Biuret reagent for protein.

**Required practical activity 5:** investigate the effect of pH on the rate of reaction of amylase enzyme.

## **4.2 Organisation II – The Circulatory System and Heart Disease**

**4.2.2.2 The Heart and Blood Vessels**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 as rate and carry out rate calculations for blood flow.

#### **4.2.2.3 Blood**

Blood is a tissue consisting of plasma, in which the red blood cells, white blood cells and platelets are suspended.

Students should know the functions of each of these blood components.

Students should be able to recognise different types of blood cells in a photograph or diagram, and explain how they are adapted to their functions.

#### **4.2.2.4 Coronary heart disease: a non-communicable disease**

Students should be able to evaluate the advantages and disadvantages of treating cardiovascular diseases by drugs, mechanical devices or transplant.

In coronary heart disease layers of fatty material build up inside the coronary arteries, narrowing them. This reduces the flow of blood through the coronary arteries, resulting in a lack of oxygen for the heart muscle. Stents are used to keep the coronary arteries open. 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.

### **4.2.3 Plant tissues, organs and systems**

#### **4.2.3.1 Plant tissues**

Students should be able to explain how the structures of plant tissues are related to their functions.

Plant tissues include:

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

Students should be able to explain how the structure of root hair cells, xylem and phloem are adapted to their functions.

The leaf is a plant organ. Knowledge limited to epidermis, palisade and spongy mesophyll, xylem and phloem, and guard cells surrounding stomata.  
  
Students should be able to explain the effect of changing temperature, humidity, air movement and light intensity on the rate of transpiration.

Students should be able to:

* 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

**4.2.3.2 Plant organ system**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 Infection and response**

Pathogens are microorganisms such as viruses and bacteria that cause infectious diseases in animals and plants. They depend on their host to provide the conditions and nutrients that they need to grow and reproduce. They frequently produce toxins that damage tissues and make us feel ill.

This section will explore how we can avoid diseases by reducing contact with them, as well as how the body uses barriers against pathogens. Once inside the body our immune system is triggered which is usually strong enough to destroy the pathogen and prevent disease.

When at risk from unusual or dangerous diseases our body’s natural system can be enhanced by the use of vaccination. Since the 1940s a range of antibiotics have been developed which have proved successful against a number of lethal diseases caused by bacteria. Unfortunately many groups of bacteria have now become resistant to these antibiotics. The race is now on to develop a new set of antibiotics.

#### **4.3.1.1 Communicable (infectious) diseases**

Students should be able to explain how diseases caused by 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**

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**

*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**

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**

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 Infection and Response II**

#### **4.3.1.6 Human defence systems**

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**

Students should be able to explain how vaccination will prevent illness in an individual, and how the spread of pathogens can be reduced by immunising a large proportion of the population.

Vaccination involves introducing small quantities of dead or inactive 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.

#### **4.3.1.8 Antibiotics and painkillers**

Students should be able to explain the use of antibiotics and other medicines in treating disease.

Antibiotics, such as penicillin, are medicines that help to cure bacterial disease by killing infective bacteria inside the body. It is important that specific bacteria should be treated by specific antibiotics.

The use of antibiotics has greatly reduced deaths from infectious bacterial diseases. However, the emergence of strains resistant to antibiotics is of great concern.

Antibiotics cannot kill viral pathogens.

Painkillers and other medicines are used to treat the symptoms of disease but do not kill pathogens.

It is difficult to develop drugs that kill viruses without also damaging the body’s tissues.

**4.1.1.6 Culturing microorganisms (biology only)**

Bacteria multiply by simple cell division (binary fission) as often as once every 20 minutes if they have enough nutrients and a suitable temperature.

Bacteria can be grown in a nutrient broth solution or as colonies on an agar gel plate.

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

Describe how to prepare an 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 laboratories, cultures should generally be incubated at 25°C.

Calculate cross-sectional areas of colonies or clear areas around colonies using πr².

Calculate the number of bacteria in a population after a certain time if given the mean division time.

(HT only) Students should be able to express the answer in standard form.

**Required practical activity 2**: investigate the effect of antiseptics or antibiotics on bacterial growth

using agar plates and measuring zones of inhibition.

#### **4.3.1.9 Discovery and development of drugs**

Students should be able to describe the process of discovery and development of potential new medicines, including preclinical and clinical testing.

Traditionally drugs were extracted from plants and microorganisms.

* The heart drug digitalis originates from foxgloves.
* The painkiller aspirin originates from willow.
* Penicillin was discovered by Alexander Fleming from the *Penicillium* mould.

Most new drugs are synthesised by chemists in the pharmaceutical industry. However, the starting point may still be a chemical extracted from a plant.

New medical drugs have to be tested and trialled before being used to check that they are safe and effective.

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

Preclinical testing is done in a laboratory using cells, tissues and live animals.

Clinical trials use healthy volunteers and patients.

* Very low doses of the drug are given at the start of the clinical trial.
* If the drug is found to be safe, further clinical trials are carried out to find the optimum dose for the drug.

In double blind trials, some patients are given a placebo.

### **4.3.2 Monoclonal antibodies (biology only) (HT only)**

#### **4.3.2.1 Producing monoclonal antibodies**

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**

Students should be able to describe some of the ways in which monoclonal antibodies can be used.

Some examples include:

* for diagnosis such as in pregnancy tests
* 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. They are not yet as widely used as everyone hoped when they were first developed.

#### **4.2.2(cont) Health**

#### **4.2.2.5 Health issues**

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 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**

Students should be able to:

* 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.

Risk factors are linked to an increased rate of a disease.

They can be:

* aspects of a person’s lifestyle
* 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 applied to scientific data in terms of risk factors

Students should be able to translate information between graphical 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 correlation between two variables in terms of risk factors.

#### **4.2.2.7 Cancer**

Students should be able to describe cancer as the result of changes in cells that lead to uncontrolled growth and division.

Benign tumours are growths of abnormal cells which are contained in one area, usually within a membrane. They do not invade other parts of the body.

Malignant tumour cells are cancers. They invade neighbouring tissues and spread to different parts of the body in the blood where they form secondary tumours.

Scientists have identified lifestyle risk factors for various types of cancer.

There are also genetic risk factors for some cancers.

#### **4.3.3 Plant Disease**

**Detection and identification of plant diseases** (HT only)

Plant diseases can be detected by:

* stunted growth
* spots on leaves
* areas of decay (rot)
* growths
* malformed stems or leaves
* discolouration
* the presence of pests.

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 pathogens as well as by insects.

Knowledge of plant diseases is restricted to tobacco mosaic virus as a viral disease, black spot as a fungal disease and aphids as insects.

Plants can be damaged by a range of ion deficiency conditions:

• 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**

Students should be able to describe physical and chemical plant defence responses.

Physical defence responses to resist invasion of microorganisms.

* 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 I**

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**

Photosynthesis is represented by the equation:

light

carbon dioxide + water glucose + oxygen   
Students should recognise the chemical symbols: CO2, H2O, O2 and C6H12O6.

#### **4.4.1.2 Rate of photosynthesis** 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:

* measure and calculate rates of photosynthesis
* extract and interpret graphs of photosynthesis rate involving one limiting factor
* 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 – the inverse square law and light intensity in the context of photosynthesis.

(HT only) Limiting factors are important in the economics of enhancing the conditions in greenhouses to gain the maximum rate of photosynthesis while still maintaining profit.

**Required practical activity 6:** investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed. [Click here for a video.](https://www.youtube.com/watch?v=yDbMae2gYXo)

#### **4.4.1.3 Uses of glucose from photosynthesis**

The glucose produced in photosynthesis may be:

* used for respiration
* converted into insoluble starch for storage
* used to produce fat or oil for storage
* 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**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.

**4.4.2.2 Response to exercise**During exercise the human body reacts to the increased demand for energy.

The heart rate, breathing rate and breath volume increase during exercise to supply the muscles with more oxygenated blood.

If insufficient oxygen is supplied anaerobic respiration takes place in muscles.   
  
The incomplete oxidation of glucose causes a build up of lactic acid and creates an oxygen debt.  
  
During long periods of vigorous activity muscles become fatigued and stop contracting efficiently.  
  
(HT only) Blood flowing through the muscles transports the lactic acid to the liver where it is converted back into glucose.   
  
Oxygen debt is the amount of extra oxygen the body needs after exercise to react with the accumulated lactic acid and remove it from the cells.

#### **4.4.2.3 Metabolism**

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.