WJEC (England) Biology GCSE

Topic 1: Cell Biology

Notes

1.1 Prokaryotic and eukaryotic cells

Cells can be viewed using a microscope to study their structure. Plant and animal cells are known as eukaryotic cells as they contain a nucleus and membrane-bound organelles such as ribosomes and mitochondria. Bacteria are known as prokaryotes as they do not contain membrane-bound organelles. An organelle is a subcellular structure which carries out a specific function within the cell.

Subcellular structures and their functions

Eukaryotic cells contain the following sub cellular structures:

- Cytoplasm - A jelly-like material within the cell in which reactions occur. The cytoplasm contains structures such as mitochondria.
- Cell membrane - a thin membrane that surrounds the cell to control entry and exit of substances.
- Nucleus and DNA - the nucleus contains genetic material in the form of DNA which codes for proteins. DNA replication also occurs in the nucleus.
- Mitochondria - site of respiration. Provides energy for the cell to function.
- Plasmids - circular loops of DNA. These are present in prokaryotic cells and have also been found in some eukaryotic cells.

In addition to these, plant cells also contain a vacuole and chloroplasts, and are surrounded by a cell wall. The vacuole is a fluid-filled sac containing mineral salts, sugars, amino acids, waste substances and pigments which colour the cell and attract pollinating insects. Chloroplasts are the site of photosynthesis, which allows plants to convert light energy to glucose. The cell wall gives the cell structure and prevents bursting. It also controls what enters and exits the cell.

Prokaryotic cells do not contain all of these subcellular structures: they have a cell wall, cell membrane, cytoplasm and plasmids. They do not contain membrane-bound organelles, such as mitochondria and nuclei. Their genetic code is found instead in bacterial DNA and plasmids, which move freely in the cytoplasm rather than in a nucleus.

Microscopy

The development of microscopes has greatly increased the understanding of cell structure and function. As better microscopes have been invented, resolution and magnification have improved, meaning that it is now possible to produce clear, 3D images of cells and their subcellular structures. This allows more accurate explanations about the function of these subcellular structures and their roles in cellular processes, leading to a greater knowledge of the cell as a whole.

There are three main types of microscope:

- Light microscope - uses light, which passes through two or more lenses to magnify an image. Light microscopes are cheap and easy to use, although the resolution is low compared to other types of microscope.

- Electron microscopy - A beam of electrons is fired from an electron gun. Magnets are used to focus the beam on the sample and the image is recorded onto a screen. As electrons have a shorter wavelength than light, the resulting image has a higher resolution and magnification than an image from a light microscope. Electron microscopy must be carried out in a vacuum, however, as air particles would disrupt the electron beam. Consequently, live samples cannot be viewed.

- Laser scanning microscope - A laser is passed through a sample, causing photons (particles of light) to be emitted. These are recorded onto a screen to build a 3D image of the sample. Only a small part of the sample is lit up at once, resulting in a higher resolution than light microscopy, where the entire sample is illuminated.

1.2 Growth and development of cells

Mitosis and controlled cell division

Within multicellular organisms, not all cells retain the ability to divide. Eukaryotic cells which do retain the ability to divide show a cell cycle. The cell cycle is split into two main stages: interphase and mitosis. The cell spends most of the time in interphase, in which DNA is replicated, and the cell grows in preparation for the next mitosis stage, increasing the number of organelles. Mitosis is the part of the cell cycle in which a eukaryotic cell divides to produce two daughter cells, each with identical copies of DNA. This process is important as it allows the organism to grow and replace old or damaged cells.

Cells usually only replicate when growth is required or after an injury to repair damaged cells. Cancer is a result of uncontrolled growth and division of cells, which happens due to a mutation in the cell's DNA. Uncontrolled cell division leads to a large amount of unwanted cells, which is called a tumour.

Meiosis

Meiosis is another type of cell division which creates four, genetically unique daughter cells. Meiosis is used to produce gametes (reproductive cells).

During interphase, the chromosome number doubles. After this, meiosis occurs, involving two cell divisions to produce four gametes. Each gamete contains half of the chromosomes found in body cells. During fertilisation, two gametes (one from each parent) fuse to create a zygote with a full set of chromosomes. This zygote then divides via mitosis to form an embryo.

Cell differentiation

Cell differentiation is a process which produces specialised cells. These cells are adapted to carry out a specific function, leading to greater efficiency. Cells become specialised by altering genes in the cell's DNA. Once a cell differentiates, it cannot divide to make an unspecialised cell, nor a cell which has a different specialised function. For example, a cell which makes up the heart tissue cannot divide to make a skin cell, as the daughter cell will already be specialised to carry out the functions of a heart cell.

Stem cells

Stem cells are cells which retain the ability to differentiate into almost any type of cell. They are unspecialised and divide by mitosis to produce daughter cells which then specialise to have a variety of functions. They can be found in embryos and bone marrow in humans, and at the root and shoot tips of plants in areas called meristems. Embryo stem cells are able to differentiate into any type of cell, however adult stem cells can only differentiate into similar cell types, thus are more restricted in their use.

Should we use stem cell technology in medicine?

Stem cells can be used to treat a range of diseases and repair damaged tissues. Although stem cell therapy is relatively new, treatment using these cells could reduce risks and costs associated with other treatments. However, this treatment also comes with new risks, which must be weighed against potential benefits:

Benefits	**Risks**
• Can be used to treat a large variety of different diseases. • Stem cells are not rejected, unlike donor organs. • Generally, stem cell treatments have lower risks than other treatments. • Stem cells do not have to be matched to the patient, unlike organ donations which must be matched for skin type, blood type and size.	• Risk of contamination or mutation of the stem cells whilst being grown in the laboratory, which could be passed onto a patient. • Stem cell therapy is relatively new, meaning that long term risks are unknown and there is no guarantee that the treatment will work. • Stem cell treatments can have side effects, such as rashes, infections and bleeding. These side effects can be mild to severe.

There are also ethical issues with using stem cells. This is mainly because the most useful stem cells must be harvested from embryos, which are destroyed in the process. This is contentious as there is the question of at which point the embryo should be considered a person. Harvesting the cells is also difficult as they must be taken before birth, although unused embryos from IVF treatments can be used.

1.3 Cell Metabolism

Enzymes

Enzymes are proteins that are used to control chemical reactions within cells by acting as biological catalysts. A catalyst is a substance which speeds up the rate of a chemical reaction. The enzyme is not changed by the reaction and can be used repeatedly. Enzymes are crucial to living organisms as they speed up metabolic reactions which would take too long to occur without them.

Enzymes are made within cells out of chains of amino acids, which bind together and fold to form a protein molecule. All enzymes contain an active site, which is a sequence of amino acids with a specific shape. This shape is complementary to the substrate molecule. When the enzyme breaks the substrate down, the substrate enters the active site to form an enzyme-substrate complex. The substrate is broken down and the product is released. The enzyme can then bind to another substrate molecule and repeat this process. Each enzyme is complementary to only one type of substrate, hence cannot break down other substrates. For example, proteases break down proteins so that amino acids can be absorbed into the blood. Proteases cannot, however, break down other molecules such as carbohydrates, which can only be broken down by carbohydrase enzymes. This is called the 'lock and key' hypothesis, since only one key can fit in each lock, as only one substrate molecule can fit in each enzyme.

Factors affecting enzyme action:

- pH - Enzymes have an optimum pH that they work best at. As the pH moves away from this, the shape of the active site begins to change, known as denaturing. This means that the substrate cannot fit into the active site, hence no enzyme-substrate complexes can form. Consequently, the rate of reaction decreases.

- Temperature - As the temperature increases up to the enzyme's optimum, the rate of reaction increases. This is because the molecules have more kinetic energy, thus move faster. Consequently, more successful collisions occur and more enzyme-substrate complexes can form. At very high temperatures above the optimum, the enzymes become denatured and the active site changes shape. This decreases the rate of reaction as enzyme-substrate complexes cannot form.

Cellular respiration

Respiration is a continuous process which takes place in almost all cells to produce energy from nutrient molecules. It involves a series of exothermic chemical reactions occurring in the mitochondria and cytoplasm of cells, which convert glucose into ATP. ATP is a small molecule which can instantly release a small, manageable amount of energy in a single reaction. This energy can be used in a variety of processes such as muscle contraction, nerve impulses and growth.

There are two types of respiration: aerobic respiration and anaerobic respiration. Aerobic respiration occurs when oxygen is present, whereas anaerobic respiration takes place when no oxygen is available. Both types of respiration are catalysed by enzymes. This means that the rate of respiration can be influenced by factors such as temperature and pH.

During aerobic respiration, glucose is broken down and the products are combined with oxygen to produce carbon dioxide (waste) and water, as well as energy in the form of ATP. The word equation for aerobic respiration is:

glucose + oxygen → carbon dioxide + water + ATP

Animal cells usually undergo anaerobic respiration during vigorous exercise, when not enough oxygen is delivered to muscles. In this reaction, glucose is partially broken down to produce lactic acid and ATP. This reaction is much less efficient, producing less ATP per glucose molecule. The word equation for anaerobic respiration in animal cells is:

glucose → lactic acid + ATP

Anaerobic respiration also produces an ‘oxygen debt’, due to lactic acid building up in muscles which causes fatigue. To ‘repay’ this, the lactic acid must be transported to the liver where it is broken down into carbon dioxide and water using oxygen. This is the reason why breathing and heart rates remain high after exercise.

Microorganisms, such as yeast, also undergo anaerobic respiration during fermentation. Yeast breaks down anaerobically to form alcohol and carbon dioxide instead of lactic acid. This can be used to make bread or alcoholic drinks. The word equation for this is:

glucose → alcohol + carbon dioxide + ATP

Comparing aerobic and anaerobic respiration:

Aerobic respiration	**Anaerobic respiration**
Uses oxygen	Does not use oxygen
Produces around 38 ATP per glucose	Produces around 2 ATP per glucose
Occurs in the mitochondria and cytoplasm	Occurs only in the cytoplasm
Produces carbon dioxide, water and ATP	Produces lactic acid and ATP (animal cells)

Biological molecules and digestion

Biological molecules are important in organisms to build structures and for use in metabolic reactions. Large molecules are made when many smaller molecules bind together. The main biological molecules are:

- Fats - Fats are made up of glycerol and fatty acids. Fats have a variety of roles in organisms including insulation, energy, waterproofing, structure and protection around delicate organs.

- Carbohydrates - Carbohydrates are made up of many sugar molecules. Starch is an example of a carbohydrate and is made from glucose molecules. Starch is insoluble, and can therefore be stored in plants as an energy source.

- Proteins - Proteins are made up of amino acids, which bind together in a chain. Different arrangements of amino acids make up different proteins and form different shapes.

Digestion is the process of breaking down biological molecules from food so that they can be absorbed into the body. Fat, carbohydrate and protein molecules are insoluble. To be absorbed, they must first be broken down into their smaller, soluble components: fats are broken down into fatty acids and glycerol, carbohydrates break down into glucose, and proteins are broken down into amino acids. These are then absorbed in the small intestine and travel in the blood to cells, where they are resynthesized into new molecules or used in reactions. For example, glucose from carbohydrates is used in respiration to provide energy, and amino acids can be used to resynthesise new proteins.