Cambridge Advanced Subsidiary Level Notes
9700 Biology

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Contents

1 Cell structure

1.1 The microscope in cell studies

Make temporary preparations of cellular material suitable for viewing with a light microscope

Part of Paper 3.

Draw cells from microscope slides and photomicrographs

The drawings made must have *continuous* outlines. Any structures clearly visible in the photomicrograph must also be drawn on the drawing.

Calculate magnifications of images and actual sizes of specimens from drawings, photomicrographs and electron micrographs (scanning and transmission)

The definition of magnification is as follows

$$\text{magnification} = \frac{\text{image size}}{\text{object size}}$$

which we can use as a formula to find any unknown variable when two other variables are given.

Use an eyepiece graticule and stage micrometer scale to make measurements and use the appropriate units, millimetre (mm), micrometre (µm) and nanometre (nm)

The *eyepiece graticule* is a transparent piece of glass, with a hundred divisions that can be added to the end of a microscope lens, such that the hundred markings of length can be overlain on top of the slide being observed. We can use these markings to determine the length of a cell being observed, in terms of *eyepiece graticule units*, the equivalent of which we are to deduce after calibrating it.

To calibrate the eyepiece graticule, we bring into focus a piece similar to the eyepiece graticule, called a *stage micrometer*, on which there are markings with real world units. We align those markings with those of the graticule, hence finding the equivalent of one graticule unit.

Because the objects viewed with microscopes are very small, measuring them in terms of millimetres (mm) is not convenient enough, we must use smaller units, namely micrometres (µm) and nanometres (nm). The conversions are as follows

$$1\,\text{mm} = 1 \times 10^{-3}\,\text{µm}$$

$$1\,\text{mm} = 1 \times 10^{-6}\,\text{nm}$$

Define resolution and magnification and explain the differences between these terms, with reference to light microscopy and electron microscopy

The *resolution* of an image is the ability to distinguish between to very closely located objects; the higher the resolution of an image, the greater the detail that can be observed. Electron micrographs tend to have a higher resolution than light micrographs at the same magnification. *The light microscope has a maximum resolution of 200 nm.*

The reason behind this is the fact that visible light has a minimum wavelength of 400 nm, and half of a light wave can collide and reflect off of an object.

Electron microscopes can give a resolution of 0.5 nm. Electrons are shot at the specimen to be observed, through which the electrons pass and hit a fluorescent screen, which gives an overall black and white image. However, if the subject being observed is stained beforehand, a greater clarity can be achieved.

1.2 Cells as the basic units of living organisms

Recognise organelles and other cell structures found in eukaryotic cells and outline their structures and functions, limited to:

- *cell surface membrane*
- *nucleus, nuclear envelope and nucleolus*
- *rough endoplasmic reticulum*
- *smooth endoplasmic reticulum*
- *Golgi body (Golgi apparatus or Golgi complex)*

- *mitochondria (including the presence of small circular DNA)*
- *ribosomes (80S in the cytoplasm and 70S in chloroplasts and mitochondria)*
- *lysosomes*
- *centrioles and microtubules*
- *cilia*
- *microvilli*
- *chloroplasts (including the presence of small circular DNA)*
- *cell wall*
- *plasmodesmata*
- *large permanent vacuole and tonoplast of plant cells*

The *cell surface membrane* is present in both plant and animal cells. It is about 7 nm thick and has three layers which are visible at high magnification. The membrane is *partially permeable* and controls exchange between the cells and its environment.

The *nucleus* consists of the *nuclear envelope* and the *nucleolus*. The nuclear envelope is made up of two membranes, the outer of which is continuous with the endoplasmic reticulum. This envelope has many small pores called *nuclear pores* which allow and control exchange of substances between the nucleus and the cytoplasm. Substances such as messenger RNA (mRNA), transfer RNA (tRNA) and ribosomes are substances that leave the nucleus. Proteins, nucleotides, ATP and some hormones are examples of substances that enter the nucleus. The nucleus contains the chromosomes, which contain DNA, the genetic material that encodes genetic information. The average cell contains almost two metres of DNA, which is folded up into a very compact shape. This is done with the help of histone proteins. This combination of DNA and proteins is called *chromatin*, which also contains some RNA. The cell may also contain one or more structures called *nucleoli* (singlar: nucleolus). It has its own DNA, the instructions of which it uses to synthesise ribosomes. This DNA is one or two chromosomes which contain the genetic code for ribosomal RNA (rRNA), which is the form of RNA used in the manufacture of ribosomes. It also contains the genes for making tRNA. Around the core of the nucleolus are less dense units where the ribosomal subunits are assembled, combining rRNA and ribosomal proteins. The size of a cell is related to the amount of ribosomes it makes. The structures making up the nucleolus are only together when ribosomes need to be synthesised, during nuclear division, ribosomes need not be synthesised, as a result the nucleolus does not exist during cell division.

The *endoplasmic reticulum (ER)* is of two types: *smooth endoplasmic reticulum (SER)* and *rough endoplasmic reticulum (RER)*. Both of these structures are continuous with the outer layer of the nuclear membrane. The membranes of the ER form flattened compartments called *sacs/cisternae*. Processes take place inside these cisternae separate from the cytoplasm. Transport of molecules can also occur through the ER separate from the rest of the cytoplasm. The RER is so called because it is covered with numerous ribosomes, which are the sites of protein synthesis. They are found free in the cytoplasm as well as part of the RER. The SER lacks ribosomes, thus appearing smooth. Its function is to produce lipids, steroids, such as cholesterol and hormones such as testosterone and oestrogen. The SER stores calcium ions which are involved in muscle contraction and hence muscle cells are seen to be abundant in muscle cells.

The *Golgi body/apparatus/complex* is a stack of flattened sacs called cisternae. There may be multiple of these in a single cell, and the stack is constantly forming at one end from vesicles which bud off of the ER, and are broken down again at the other end to form *Golgi vesicles*. It is responsible for collecting and processing certain molecules, especially proteins from the RER. It contains hundreds of enzymes for this purpose, and after processing the molecules are transported away in Golgi vesicles. The release of these molecules is called secretion and the pathway taken by these molecules is called the secretion pathway. Some of the functions of the Golgi apparatus are as follows:

- Making lysosomes.

- Sugars are added to proteins making molecules called glycoproteins.
- Sugars are added to lipids making glycolipids.
- Golgi enzymes are involved in the synthesis of new cell walls during plant cell division.
- Mucin in the respiratory tract is released by the Golgi apparatus.

The *mitochondrion* (plural: mitochondria), is bound by two membranes, where the inner one forms various finger-like projections called *cristae* (singular: crista), which stick into the inside of the mitochondrion, which is called the matrix. The number of mitochondria in a cell directly corelates to how much energy its processes require. Mitochondria perform aerobic respiration, releasing energy from high-energy molecules, transferring it to molecules of *ATP (adenosine triphosphate)*, which is known as the universal energy carrier, which carries the energy in all living cells. The ATP produced spreads to any part of the cell where it is needed, being a soluble molecule, where it is broken down to adenosine diphosphate (ADP), releasing energy.

Ribosomes are structures that are only visible under an electron microscope. They are seen to consist of two subunits: one large and one small. They are measured in S units, which are a measure of how rapidly substances centrifuge, where the the faster the sedimentation, the larger the S number. *Eukaryotic ribosomes are 80S whereas prokaryotic ribosomes are 70S.* Mitochondria and chloroplasts contain 70S ribosomes, showing that they were once prokaryotic.

Lysosomes are sacs bound by a single membrane. In plant cells, the large central vacuole *may* act as the lysosome. They contain digestive enzymes which can engulf and destroy unwanted cell components such as molecules or organelles. They play a major role in endocytosis which is the process that occurs when a cell takes in or engulfs an external body. Lysosomal enzymes may be released from the cell for extracellular digestion, which is called *exocytosis*. Lysosomal enzymes may even be released into the cell itself, resulting in the digestion of the whole cell, called *autolysis*.

Microtubules are long, rigid and hollow tubes found in the cytoplasm. They make up the cytoskeleton, which is the structural component of cells that determines cell shape. They are made of tubulin, which is of two forms: α-tubulin and β-tubulin which combine to form dimers. These dimers join end to end forming protofilaments, thirteen of which line up alongside each other in a ring to form a cylinder with a hollow centre, which is the microtubule. Microtubules also:

- Secretory vesicles and other organelles and cell components are transported along the exterior of microtubules, forming an intracellular transport system.
- A spindle of microtubules is used for the separation of chromosomes during nuclear division.
- Microtubules form part of the structure of centrioles.
- Microtubules are essential in the beating movements of cilia and flagella.

Microtubules are assembled at special locations within the cell called *microtubule organising centres (MTOCs)*.

A *centriole* is a hollow cylinder about 500 nm long, formed from a ring of nine triplets of microtubules. Just outside the animal nucleus, there are two centrioles, perpendicular to one another, in a region known as the *centrosome*[1]. The centrosome is the MTOC, where centrioles are needed for the production of cilia. Centrioles are found at the bases of cilia and flagella, where they are known as basal bodies acting as MTOCs.

Cilia are whip-like beating extensions of eukaryotic cells. Cilia have two central microtubules and a ring of nine microtubule doublets (MTDs) around the outside. This is referred to as the $9 + 2$ structure. Each MTD has an A and a B microtubule, which have a rings of of 13 protofilaments and 10 protofilaments respectively. The A microtubules have arm-like structures, made of the protein dynein which connect with the B molecules of neighbouring MTDs during beating. There exists a basal body at the base of the cilia,

[1] Extension content, out of syllabus.

identical to centrioles, from which cilia grow. The beating motion of the cilia is caused by the dynein arms making contact with and sliding along neighbouring MTDs. This sliding motion is then converted to bending. This can cause liquid along the cell to move, or the cell to move through the liquid. Single celled organisms use these structures for locomotion. They are present lining the respiratory tract.

Microvilli (singular: microvillus) are finger-like extensions of the cell surface membrane. They are typical of certain animal cells such as the epithelial cells. They increase the surface area of the cell.

Chloroplasts are structures found in plant cells that are the site of photosynthesis in plants. Light energy is absorbed by photosynthetic pigments, chlorophyll, that are found on the membranes of the chloroplast. The membrane consists of fluid-filled sacs called *thylakoids* which are flattened, membrane-bound, and stack up like piles of coins, forming structures called grana (meaning granular). This absorption of light is called the *light-dependent* stage of photosynthesis. The *light-independent* stage uses the energy and reducing power generated during the first stage to convert carbon dioxide into sugars, a process that takes place in the *stroma*, where the sugars formed are stored in the form of starch grains. Lipid droplets are also found here, which are reserves to make membranes or are the residues of membranes broken down. Chloroplasts also have 70S ribosomes and circular DNA.

2 Biological molecules

2.1 Testing for biological molecules

Describe and carry out the Benedict's test for reducing sugars, the iodine test for starch, the emulsion test for lipids and the biuret test for proteins

Benedict's test for reducing sugars

We are required to mix equal volumes of given sample and Benedict's solution (copper (II) sulphate) and heat for a period of time. The solution is initially blue in colour, but it changes colour after heating, which is usually done in a water bath. Following are the colours gotten and their implications:

colour	implication
blue	reducing sugar absent
green	low concentration of reducing sugar
orange	medium concentration of reducing sugar
red	high concentration of reducing sugar

Iodine test for starch

Adding aqueous iodine to sample will cause the colour to change from dark brown to blue-black in presence of starch in the sample. Otherwise the aqueous iodine remains dark brown.

Biuret test for proteins

Adding biuret solution to a sample changes its colour to mauve (a shade of purple) in presence of protein. Otherwise colour remains unchanged as blue.

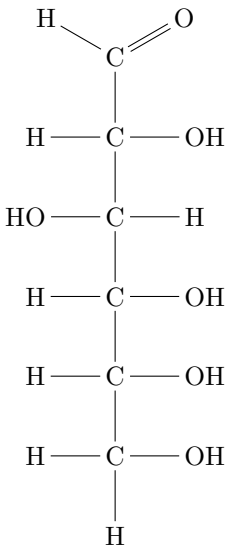
Describe and carry out a test to identify the presence of non-reducing sugars, using acid hydrolysis and Benedict's solution

For concentrations very close together in value, the above results for Benedict's solution are not enough. For this, we observe the solution as it is being heated and record the time required for it to first change colour.

Describe and carry out a test to identify the presence of non-reducing sugars, using acid hydrolysis and Benedict's solution

2.2 Carbohydrates and lipids

Describe and draw the ring forms of α-glucose and β-glucose



Define the terms monomer, polymer, macromolecule, monosaccharide, disaccharide and polysaccharide

Monomers are small single subunits which bond with many repeating subunits to form large molecules called *polymers*.

A *monosaccharide* is a molecule consisting of a single sugar unit with the general formula $(CH_2O)_n$. A *disaccharide* is a sugar molecule consisting of two monosaccharides joined together by a glycosidic bond. A *polysaccharide* is a polymer whose subunits are monosaccharides joined together by glycosidic bonds.

State the role of covalent bonds in joining smaller molecules together to form polymers

State that glucose, fructose and maltose are reducing sugars and that sucrose is a non-reducing sugar

Describe the formation of a glycosidic bond by condensation, with reference to disaccharides, including sucrose, and polysaccharides

3 Enzymes

3.1 Mode of action of enzymes

State that enzymes are globular proteins that catalyse reactions inside cells (intracellular enzymes) or are secreted to catalyse reactions outside cells (extracellular enzymes)

Explain the mode of action of enzymes in terms of an active site, enzyme–substrate complex, lowering of activation energy and enzyme specificity, including the lock-and-key hypothesis and the induced-fit hypothesis