CELLS AS THE BASIS OF LIFE

Prokaryotic, Eukaryotic Cells and Microscopes

Cell Theory

- All living things are made up of one or more cells
- Living things have
  - Movement
  - Respiration
  - Sensitivity
  - Growth
  - Reproduction
  - Excretion
  - Nutrition

1. Cells arise from existing cells
2. All living things are made up of cells
3. Cells are the basic structure and function unit of organisms

**Prokaryotic and Eukaryotic Cells**

**Prokaryotic cells:**

- Name means before the nucleus
- 0.1-5µm
- DNA is located in a single chromosome and in rings called plasmids
- There are no membrane bound organelles
- No multicellular organisms can form
- E.Coli bacteria, cyanobacteria

**Eukaryotic cells:**
- name means true nucleus
- 10-100µm
- DNA located with nucleus
- there are membrane bound organelles e.g. nucleus
- multicellular organisms can form
- unicellular - amoeba
- multicellular - animals, fungi, plants

A Comparison of Microscopes:
<table>
<thead>
<tr>
<th>Feature</th>
<th>Light Microscope</th>
<th>Electron Microscope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnification</td>
<td>up to 1500X</td>
<td>up to 1,000,000X</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.2µm</td>
<td>0.0002µm</td>
</tr>
<tr>
<td>Advantages</td>
<td>- samples</td>
<td>- high magnification and resolution shows an enormous amount of detail. - This leads to much greater understanding of the structure and function of organelles.</td>
</tr>
<tr>
<td></td>
<td>prepared quickly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and cheaply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Coloured stains can be used for contrast - Living cells can be viewed</td>
<td></td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Limited magnification</td>
<td>- Only non-living sections can be viewed as specimens are mounted in a vacuum chamber - Heavy metals must be used for staining. - Expensive, large size, lots of maintenance (must be kept at constant temperature and pressure - Takes a long time to prepare materials for viewing</td>
</tr>
<tr>
<td></td>
<td>Resolves some</td>
<td></td>
</tr>
<tr>
<td></td>
<td>but not all parts of cell</td>
<td></td>
</tr>
</tbody>
</table>

**Size of cells:**

- Average cell size = field of view ÷ number of cells that fit across the field of view.

**Field of view:**

- low x40 =4500
- med x100 =1800
- high x400 =450

**How to draw a diagram:**

1. what is my field of view (x400)
2. count along the diameter 3x
3. size of 1 cell = 450/#
4. 1cm =#µm

▼ Cell Structure in Detail
module 1 CELLS AS THE BASIS OF LIFE

Animal Cell

- Cell membrane
- lysosome
- vacuole
- cytoplasm
- mitochondria
- Ribosomes
- Rough Endoplasmic Reticulum
- Free ribosomes

- Golgi Body
- Nuclear membrane
- Nucleolus
- Chromatin (DNA)
- Nuclear pore
- Nucleus
- Centriole

Plant Cell

- Cell wall
- Cytoplasm
- Cell membrane

- Vacuole
- Chloroplast
- Golgi Body
- Vesicle

- Nuclear membrane
- Nucleolus
- Nuclear pore
- Smooth Endoplasmic Reticulum
- Rough Endoplasmic Reticulum
- Ribosomes
- mitochondria
- Free ribosomes
Cell membrane:
- controls the entry and exit of substances to and from the cell wall
- separates the contents of the environment
- structure - phospholipid bilayer

Nucleus:
- stores the genetic information (DNA) needed to control all the cell's activities in chromosomes
- The nuclear membrane has pores so substances can move in and out of the nucleus from the cytoplasm.

Nucleolus:
- small structure within the nucleus
- contains a large amount of RNA
- manufactures ribosomes

Rough endoplasmic reticulum:
- flattened series of membranes which extend from the nuclear membrane with ribosomes attached
- function to transport substances through the cytoplasm including proteins made in the ribosome
- folded structure increases their surface area so they can be more efficient

Smooth endoplasmic reticulum:
- flattened series of membranes with a large surface area
- function is to transport substances through the cytoplasm and to manufacture lipids
- they also have a role in inactivating drugs/alcohol

Ribosomes:
- small round structures made up of RNA and protein
- found floating in cytoplasm or attached to ER
function to manufacture proteins

**Golgi body:**
- flat membrane with 4-10 vesicles budding off
- large surface area
- process, packages and sort products made by the cell into vesicles to move within or out of the cell

**Vacuole:**
- fluid filled sac used to store salt, sugars, amino acids and water
- very small in animal cells or absent
- large in plant cells as they play a role in support of the cell and plant

**Lysosome:**
- fluid filled small organelles which are a product of the Golgi body
- contains digestive enzymes to break down substances or worn out organelles within the cells

**Mitochondria:**
- the process of respiration occurs here
- produces energy for the cell to carry out all its functions
- surrounded by a double membrane and the inner membrane is folded so there is a large surface area for maximum rate of respiration to occur
- contains mitochondrial DNA
- Glucose + oxygen → energy (ATP) + carbon dioxide + water

**Chloroplast:**
- only found in plants - photosynthesis occurs here
- contains the green pigment chlorophyll that absorbs light energy
- surrounded by a double membrane and inside there are stacks of membranes called Grana which provide a large surface area for maximum photosynthesis
- carbon dioxide + water $\rightarrow$ oxygen + glucose (food)

**Cytoplasm:**
- Liquid based content of cells which is made up of 90% water and dissolved salts.
- Many chemical reactions take place in the cytoplasm
- The organelles are suspended in the cytoplasm by a network of microtubules and filaments called a cytoskeleton

**Cell wall:**
- found around plant cells
- made up of cellulose
- the cell wall is rigid and provides the cell with protection and support
- it gives the cell its regular shape
- also found in fungi cells and bacteria cells

► **Chemical Requirements in Cells**
  - the smallest unit of living things’ $\rightarrow$ cells
  - the smallest unit of all substances $\rightarrow$ atoms
  - biomolecules $\rightarrow$ molecules that make up a living thing
    - carbohydrates $\rightarrow$ monosaccharide $\rightarrow$ C, H, O
    - lipids $\rightarrow$ fatty acid with glycerol $\rightarrow$ C, H, O
    - proteins $\rightarrow$ amino acid $\rightarrow$ C, H, O, N
    - nucleic acid $\rightarrow$ nucleotide $\rightarrow$ C, H, O, N, P

**organic compounds:**
- compounds that contain the elements carbon and hydrogen-bonded together
- ONLY FOUND IN LIVING THINGS
- e.g. carbohydrates, proteins, lipids and nucleic acid
inorganic compounds:

- do not contain the elements carbon and hydrogen-bonded together
- can be found in BOTH LIVING AND NON-LIVING things
- e.g. water, mineral salts (sodium ions, chloride ions), gases (carbon dioxide, oxygen)

▼ Carbohydrates:

- C = carbon
- H = hydrogen
- O = oxygen
- carbohydrates a source of quick energy
- They breakdown into glucose and are converted into ENERGY in the process of respiration
- Cellulose is found in plant cell walls giving them strength and support.
- Starch is a source of stored energy for animals.
- Monosaccharides Consist of a single unit of sugar

Eg. Glucose  fructose

- Disaccharides Consist of two units of sugar
  - Eg. Sucrose = glucose + fructose
  - Eg. Lactose = glucose + galactose
Polysaccharides Complex carbohydrates consist of multiple sugar units. They are insoluble in water. Eg. Starch = 2000 x glucose
  - Cellulose in plant cell walls

\textbf{Lipids:}

- C = carbon
- H = hydrogen
- O = oxygen
- lipids consist of:
- 1 glycerol molecule + 3 fatty acid chains E.g. Fats (solid at RT), oils (liquids at RT), steroids

\begin{center}
\includegraphics[width=0.5\textwidth]{glycerol_fatty_acids.png}
\end{center}

- Lipids are used as ENERGY STORES. They can be broken down and used in respiration to produce energy.
- Lipids contain more than twice the energy of carbohydrates
- Lipids also make up the structure of all cell membranes.

\textbf{Proteins}

- C = carbon
- H = hydrogen
- O = oxygen
• N = nitrogen

• There are 20 different amino acids, and these can combine in many different ways to form chains between 50 and 1000 amino acids long which are then twisted in a variety of ways. This is why so many different proteins exist.

• Protein molecules have a 3D shape. When a protein is heated or in the wrong pH environment this shape may be altered, and the protein will be DENATURED. E.g. When the egg white is cooked.

Made up of small units called **AMINO ACIDS**.

Amino acids join to form a **POLYPEPTIDE** chain joined together with peptide bonds

• Proteins are the most abundant organic molecule in cells.

• They are needed for body growth and repair. Proteins also make up the structure of cell membranes and hair, skin, and nails.

• Some proteins have a functional role. E.g. Enzymes are proteins. Enzymes enable chemical reactions to take place.

• Hormones are proteins. E.g. insulin, oestrogen, testosterone.

• Haemoglobin which transports oxygen in red blood cells is a protein.

▼ Nucleic Acid:
- C = carbon
- H = hydrogen
- O = oxygen
- N = nitrogen
- P = phosphorus
- The basic unit is a NUCLEOTIDE. This is made up of:
  - 1 sugar (5C)
  - 1 phosphate
  - 1 base

There are 2 types of nucleic acids:
- DNA – deoxyribonucleic acid, found in the Chromosomes - Stores all the genetic information that controls the cell functions and characteristics of the organism.
RNA – ribonucleic acid is found throughout the cell and is needed for protein synthesis.

Cell Membrane - Fluid Mosaic Model

**SUBSTANCES TRANSPORTED IN AND OUT OF THE CELL:**

<table>
<thead>
<tr>
<th>into cell</th>
<th>out of cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>water</td>
<td>water</td>
</tr>
<tr>
<td>glucose</td>
<td>waste products</td>
</tr>
<tr>
<td>oxygen</td>
<td>carbon dioxide</td>
</tr>
<tr>
<td>salts</td>
<td>salts</td>
</tr>
<tr>
<td>amino acids</td>
<td>proteins</td>
</tr>
</tbody>
</table>

**SELECTIVELY-PERMEABLE MEMBRANE:**

- This means that the membrane does not let all substances travel across the cell membrane in or out of the cell.
- Some substances pass through easily whilst others are blocked completely.

**FLUID MOSAIC MODEL:**

- A flexible double layer of phospholipids with proteins embedded in the bilayer.

**WHY IS IT FLUID?**

**PHOSPHOLIPID BILAYER**

- Flow and change shape
- Flexible
- Can repair itself

**PROTEINS AND CARBOHYDRATES**

- **PROTEIN CHANNELS AND CARRIER PROTEINS**

  - Some proteins travel all the way through the lipid bilayer and act as channels to allow substances to pass through the membrane or change their shape to ‘carry’ substances through the bilayer.

  - Some proteins are suspended in the bilayer and have carbohydrate chains attached. These are involved in cell recognition.

  - Some proteins are receptor proteins

- **PROTEIN**

  - Embedded throughout the membrane

  - Different types with different roles
    - Protein channels – transport
    - Peripheral proteins (with carbohydrates) – cell recognition

  - Some are fixed, others are floating
WHY DO WE USE MODELS IN SCIENCE?

- Models are used to help our understanding of scientific ideas, for example
- to represent something too large or small to be seen
- to explain a complex concept in a simple manner to increase our understanding to make predictions of expected results

- Models also have limitations
- they may be oversimplified
- not moving or in 3D
- incorrect scale

∇ Diffusion and Osmosis

Define the term diffusion:

Diffusion is the passive movement of particles down a concentration gradient from an area where they are in high concentration to an area where they are in low concentration until the particles are evenly spread (reached an equilibrium)

- Small particles and those that are lipid-soluble move easily across the membrane by diffusion
The particles in the top box are more concentrated on the left-hand side of the box. After time for diffusion to take place, the particles have moved from the area where they are in high concentration to the area where they are in low concentration (down a concentration gradient) until they are evenly spread throughout the box (reached an equilibrium).

Define the term osmosis:
Osmosis is the passive movement of WATER across a SEMI-PERMEABLE MEMBRANE down a concentration gradient from an area where water is in high concentration to an area where water is in low concentration until solutions are evenly concentrated (an equilibrium is reached).

- Water particles are not lipid-soluble but move easily through the membrane via tiny channels called aquaporins

how does the membrane determine what substances it will be permeable to:

- size
- liquid solubility
- electric charge

Facilitated Diffusion:
- some substances are unable to dissolve in the lipid bilayer
they need some assistance in diffusing across the membrane
carrier proteins and channel proteins
help large molecules like amino acid and charged ions like chloride ions move across the cell membrane
down the gradient concentration H-L

Active Transport:
requires energy input of APT
goes against the gradient concentration L-H
or when a substance is charged (sodium ion – Na+) or is too big to diffuse across
substances move across the cell membrane by binding to carrier proteins
the carrier proteins change shape and transport the substances across the membrane

Endocytosis:
taking substances into the cell by means of folding pockets (engulfing)
The cell membrane surrounds the substance and engulf it taking it into the cytoplasm
phagocytosis - 'cell eating' soild
pinocytosis - fluids
Exocytosis (reverse endocytosis):

- membrane surrounds substance fuses with membrane forcing contents out of cell
- Exocytosis is the process whereby large substances are transported out of the cell. (exo – external)
- A membrane bound vesicle moves to the edge of the cell, fuses with the cell membrane and then the substance in the vesicle is released
Rate of transport across the membrane

why are cells so small:

- As a cell gets larger in size, the rate of diffusion and osmosis gets slower and less efficient.
- This prevents the cell functioning as it cannot get the chemical nutrients it needs or get rid of wastes quickly

Why does this happen?:

- As a cell gets larger, the surface area increases
- As a cell gets larger, the volume of the cell increases
- BUT when we compare the SA and V......
- In small cells the SA/V ratio is high
- In large cells the SA/V ratio is low meaning there is not enough SA to allow enough transport for the cell to function efficiently

Enzymes

- protein molecules that control all the chemical processes of living systems
- produced within living cells
- Intracellular or extracellular
- organic catalysts, also known as biological catalysts
• responsible for increasing the rate of reactions that occur in living organisms, without enzymes metabolism would be so slow at body temperature that insufficient energy would be available to maintain life Catalysts

• is a general term for any substance that speeds up or brings about a chemical change

• remain unchanged at the end of a reaction

• can be reused

• enable reactions to occur at lower temperatures, thus body temperatures do not need to be so high Composition of enzyme

• Enzymes are globular proteins as they consist of long chains of amino acids that have been folded into a specific shape.

• Each enzyme contains a specific active site and catalyses a distinct chemical reaction

• The molecule on which an enzyme acts is called a substrate.

• The interaction occurs between the enzyme’s active site and the substrate. Enzymes are substrate specific Simple model enzyme

• One compound (or a very few compounds) can react with a particular enzyme, this is specificity

• Each enzyme catalyses a distinct chemical reaction in which the compound/substrate are changed into other compounds

• Enzymes are only required in minute amounts

• The original model was a lock (enzyme) and key (substrate)

• Current model induced-fit Enzymes:

• Enzymes are protein molecules that control all metabolic reactions in living cells.

• Without them, chemical reactions in your body would be very slow.

• They are catalysts (speed up the rate of reaction)

• They control the rate of reactions

• Enzymes are composed of protein molecules that are often highly folded to create a particular shape.
The surface of the enzymes with a specific shape is called the ‘active site’ which is where the reactants (substrates) in a chemical reaction bind to.

They are substrate specific Factors affecting enzymes:

Enzymes are temperature sensitive and function best at the body temperature of the organism in which they occur (usually 40°C)

Enzyme activity slows until it stops at its optimum level (the highest it can function)

At high temperatures, the motion associated with heat energy can make the protein structure change the shape of the active site causing the enzyme to denature. Change is irreversible.

Excessive cold also causes the enzyme to change shape and its functioning to slow down or stop. This change is reversible.

Enzymes are pH-sensitive

A catalyst increases the rate of reaction as temperature increases until the optimal temperature is reached The importance of shape in enzymes:

Enzymes are substrate-specific.

Only particular enzymes can fit each substrate.

Enzymes will denature (stop working) if there is a change in pH value or temperature change.