Bio Factsheet

Number 4

Structure to function in eukaryotic cells

The cell surface membrane and the membranes which form organelles in eukaryotic cells all have the same basic structure, known as the **fluid mosaic model**. Such membranes provide control of the entry and exit of substances into cells and organelles and such control is a result of the phospholipid bilayer and membrane proteins.

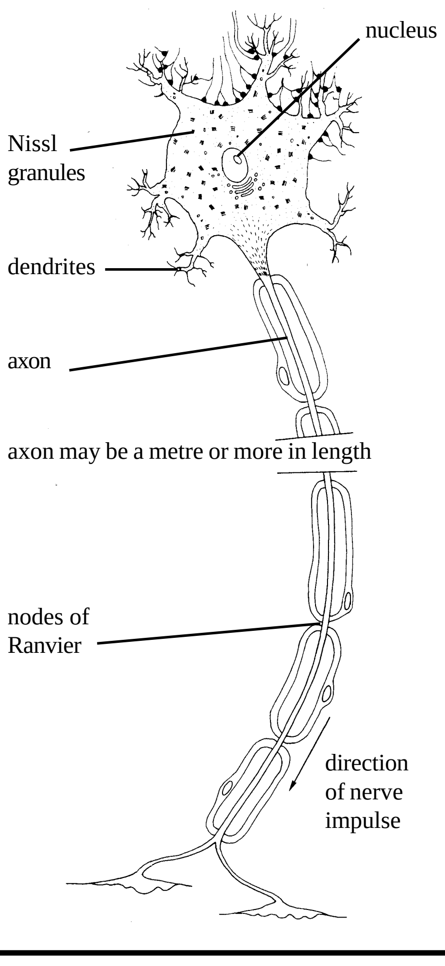
In eukaryotic cells, such membranes divide the cytoplasm into multiple compartments (organelles). Organelles allow different functions to occur efficiently and simultaneously in different parts of the cell. For example, the outer double membrane of the mitochondrion separates out those reactions which occur in mitochondria from those in the general cytoplasm. Furthermore, the internal membranes of the mitochondria allow the enzymic reactions of the Kreb's cycle to be kept quite separate from the electron transfer chain reactions (ETC). This is essential since both sets of reactions have different enzymes, hence different pH optima. By splitting up the cytoplasm of the mitochondria, the membranes which form the crista allow enzymes and substrates to be concentrated and pH to be optimised. Membranes can therefore be said to **compartmentalise** the interior of eukaryotic cells.

The relationship between structure and function can be described in terms of the whole cell or in terms of the individual organelles of the eukaryotic cell.

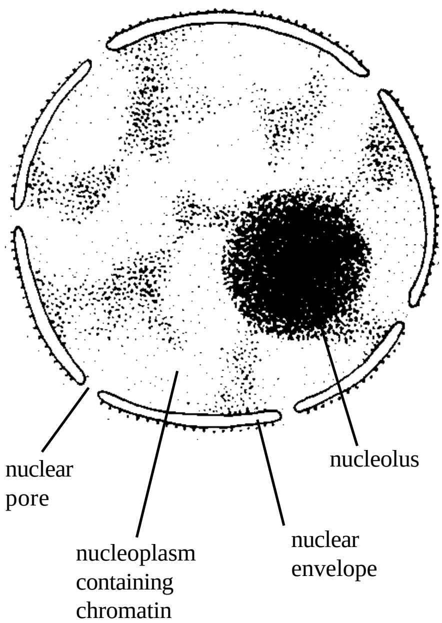
Table 1 describes the structure and function of a motor neuron cell which is commonly featured in examination questions. The structure and function of eukaryotic organelles is described overleaf.

> ***Exam Hint*** *- Structure to function questions are very commonly set on all A level Biology syllabuses. They are one of the syllabus areas where all candidates should be capable of gaining the highest marks. Once the functions of organelles have been memorised, candidates should become confident at interpreting the function of unknown cells.*

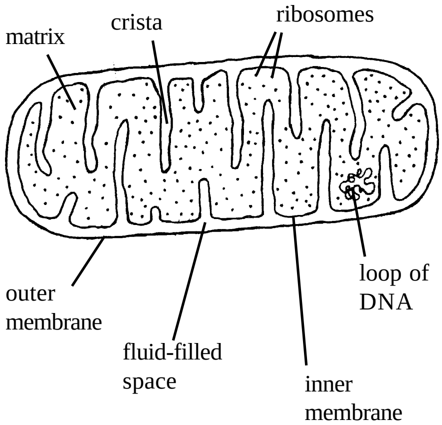
Table 1.

Cell	Structure	Function
Motor Neuron 	Cell body contains: (i) Nucleus	Provides the genetic code for the production of neurotransmitter substances, e.g. acetylcholine and enzymes, eg. cholinesterase.
	(ii) dense groups of ribosomes and endoplasmic reticulum called Nissl granules	For production and transport of proteins and neurotransmitters.
	Long axons	For rapid transmission of nerve impulse. Synapses, where two nerves join, is the slowest part of transmission, so the longer the axon, the fewer the synapses and the faster the impulses transmitted.
	Axon contains axoplasm	Allows transport between cell body and axon
	Nodes of Ranvier between Schwann cells	Allows Na^+ /K^+ pump to operate which sets up resting potential. Schwann cells of myelin sheath speed up the impulse because they increase the surface area for transmission of current.
	High phospholipid content in membrane of Schwann cell	Provides electrical insulation.
	Synaptic knob at end of dendrite contains: (i) many mitochondria	To provide ATP for active refilling of synaptic vesicles.
	(ii) numerous vesicles	For modification and release of chemical transmitters across the synapse.
	Many dendrites	To allow communication with other neurons.

<table>
<tr><th>Structure and Function of Organelles</th><th>Structure</th><th>Function</th></tr>
<tr><td rowspan="6">Nucleus

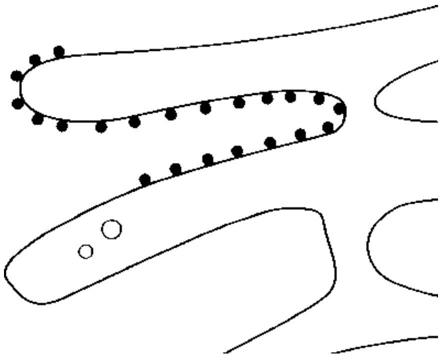
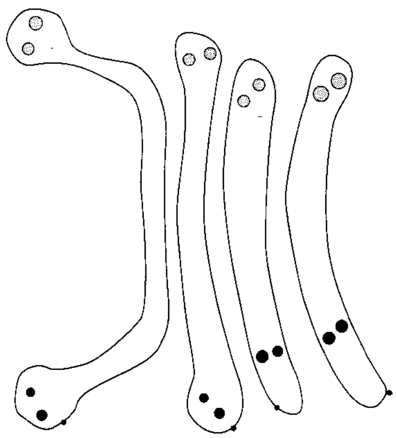
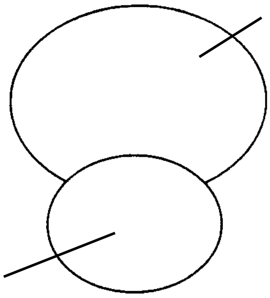


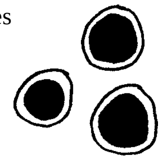
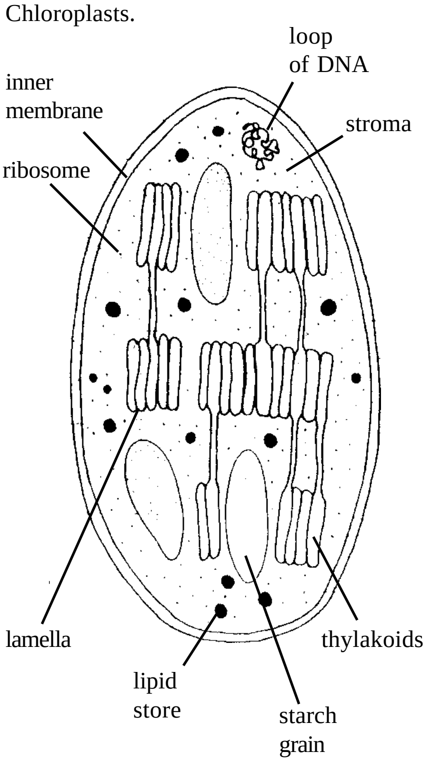
</td><td>Double nuclear envelope</td><td>To enclose and protect DNA (normally visible as chromatin granules).</td></tr>
<tr><td>Nuclear pores.</td><td>Allow entry of substances such as nucleotides for DNA replication and exit of molecules such as mRNA during protein synthesis.</td></tr>
<tr><td>Normally, the nuclear pores are plugged by an RNA/protein complex.</td><td>Small molecules pass through the pores by diffusion, whereas large molecules such as partly completed ribosomes pass through actively.</td></tr>
<tr><td>Nucleoplasm contains chromatin granules made of DNA and associated proteins.</td><td>It is these which, during cell division, condense to form chromosomes.</td></tr>
<tr><td>Nucleoplasm also contains nucleoli</td><td>Produces partly-completed ribosomes, coenzymes, nucleotides, proteins (including enzymes for nucleic acid synthesis) and RNA molecules.</td></tr>
<tr><td>The outer membrane of the nuclear envelope is continuous with the rough endoplasmic reticulum membranes.</td><td>This makes the perinuclear space continuous with the lumen of the endoplasmic reticulum, thus allowing easy transport of substances.</td></tr>
<tr><td rowspan="7">Mitochondrion



</td><td>Double membrane</td><td>Isolates reactions of the Kreb's cycle and electron transfer chain from the general cytoplasm. Such compartmentalisation allows high concentrations of enzymes and substrates to be maintained which increases the rate of respiratory reactions.

Whereas the outer membrane is permeable to small molecules such as sugars, salts and nucleotides, the inner membrane is selectively permeable. This enables the mitochondrion to control the chemical composition of the matrix, thus optimising conditions for enzyme activity.</td></tr>
<tr><td>The inner membrane is spanned by proteins (porins)</td><td>Allows entry of pyrovic acid and oxygen and the exit of ATP and carbon dioxide.</td></tr>
<tr><td>The inner membrane is folded to form cristae</td><td>Greatly increases the surface area for the attachment of enzymes and co-enzymes involved in the electron transfer chain and allows the sequential attachment of electron carriers in the ETC.</td></tr>
<tr><td>(i) The matrix contains 70S ribosomes</td><td>For protein manufacture eg. enzymes.</td></tr>
<tr><td>(ii) DNA</td><td>codes for proteins.</td></tr>
<tr><td>(iii) enzymes eg. decarboxylase</td><td>eg. in Kreb's cycle</td></tr>
</table>

Cell	Structure	Function
Endoplasmic Reticulum 	Endoplasmic reticulum is a system of hollow tubes and sacs.	Allows transport of substances within the cell.
	Rough endoplasmic reticulum (rer) is covered with ribosomes and consists of an interconnected system of flattened sacs,	The ribosomes on the rough endoplasmic reticulum may synthesise proteins which can then be transported through the cell in the cavities of the endoplasmic reticulum. The percentage of rer is high in cells which produce proteins for export e.g. - digestive enzymes, growth factors and serum proteins. The smooth endoplasmic reticulum can give rise to Golgi bodies and this allows the packaging of newly produced proteins in Golgi vesicles which can then move to the cell surface membrane for secretion.
	Smooth endoplasmic reticulum (ser) - which lacks ribosomes - is a system of interconnected tubules.	The smooth endoplasmic reticulum is the site of carbohydrate and lipid metabolism eg. it synthesises triglycerides, cholesterol and phospholipids which become part of the cell surface membrane and is also involved in the modification of substances such as steroid hormones which will then be secreted. The percentage of smooth endoplasmic reticulum is high in cells which are involved in the metabolism of lipids and drugs.
Golgi body 	Golgi body consists of flattened cisternae (membrane bound cavities) which may be stacked on top of each other and which may invaginate and fuse to form vesicles	Allows internal transport. Vesicles contain materials to be secreted. Vesicles protect the molecules as they are transported across the cytoplasm to the cell surface membrane.
	The Golgi body is connected to the rer	Proteins from the rer are modified before secretion. For example, carbohydrates may be added to proteins to form glycoproteins such as mucus which can then be enclosed in vesicles for secretion out of the cell. Golgi vesicles may also fuse with primary lysosomes which will then form secondary lysosomes capable of digesting food particles.
Ribosome 	Ribosomes consist of two sub-units both made of rRNA and protein. The rRNA part of the ribosome is formed in the nucleus and moves out of the nucleus via the pores. The protein part is then assembled in the cytoplasm. Ribosomes may occur in dense clusters in the cytoplasm where they are known as polysomes or may occur on the membranes of the endoplasmic reticulum.	Ribosomes provide: (i) Binding sites for the binding of mRNA which allows translation of the DNA code. (ii) Two sites for the binding of 2 tRNA molecules. (iii) The enzymes necessary for (i) and (ii). Ribosomes recognise the initiation and termination codons on mRNA. Ribosomes are capable of moving along the mRNA strand. This allows decoding of the mRNA and synthesis of a polypeptide chain.

<table>
<tr><th>Cell</th><th>Structure</th><th>Function</th></tr>
<tr><td>Lysosomes
</td><td>Lysosomes are vesicles which contain hydrolytic enzyme, collectively known as lysozymes.</td><td>When released, these enzymes can break down old organelles, storage molecules or, indeed, the whole cell, when it dies.</td></tr>
<tr><td rowspan="3">Chloroplasts.

</td><td>Double Membrane</td><td>Allows the isolation of photosynthetic reactions.</td></tr>
<tr><td>The stroma contains a series of membrane-bound flattened sacs called thylakoid membranes. Thylakoid membranes may be stacked into grana.</td><td>Grana allow a huge surface area for the assembly of chlorophyll molecules for light absorption and also allow the sequential attachment of enzymes and co-enzymes involved in the electron transfer chain of the light-dependent stage. Such membranes also allow quite different chemical reactions to occur in different parts of the chloroplast.</td></tr>
<tr><td>The chloroplast stroma contains:

(i) Starch grains .

(ii) Lipid stores - otherwise known as plastoglobuli.

(iii) Pyrenoids - crystallised RuBPC.

(iv) DNA RNA and ribosomes.</td><td>

(i) Which act as a carbohydrate store.

(ii) Accumulate when membranes have been broken down, for example during senescence.

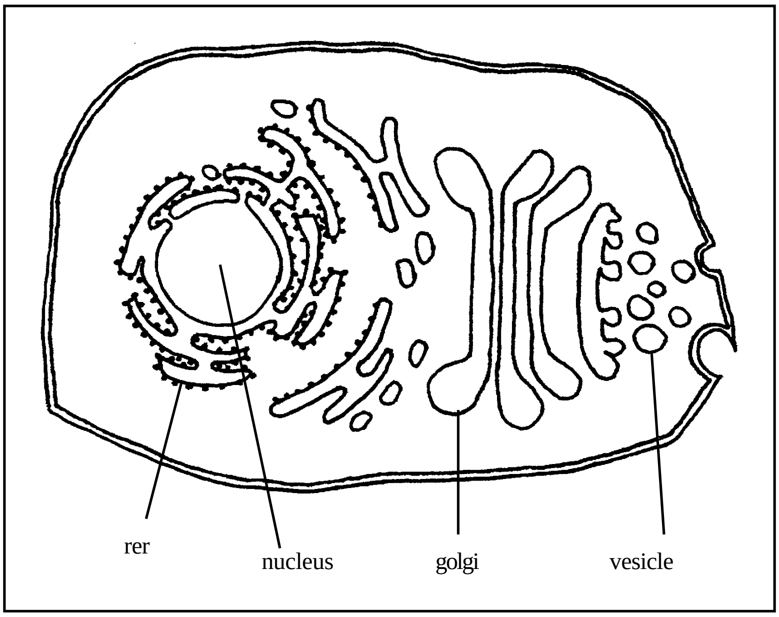
(iii) The enzyme which fixes carbon dioxide.

(iv) All involved in nucleic acid and protein synthesis.</td></tr>
</table>

Movement of substances within the cell.

The organelles within eukaryotic cells work closely together. For example, in the production of a secretary protein such as a digestive enzyme:

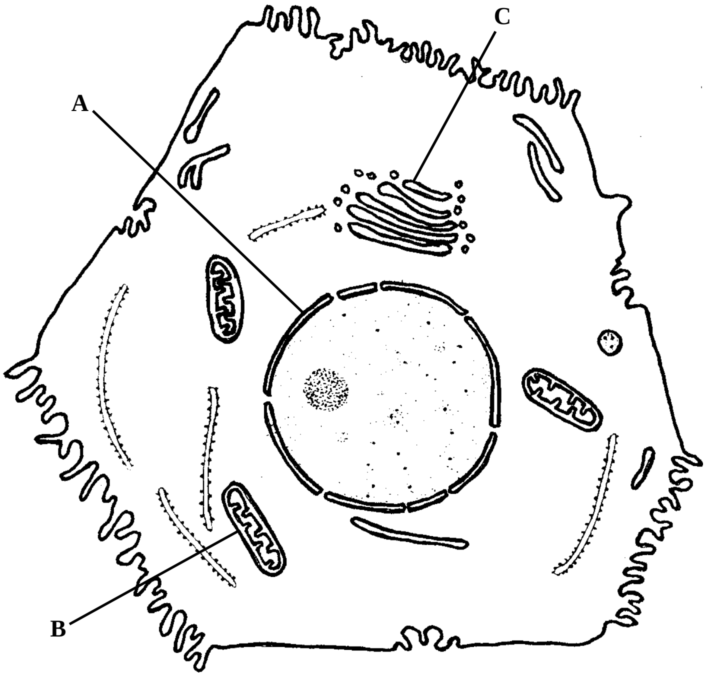
1. The genetic code for the protein lies in the chromatin granules in the nucleoplasm of the nucleus.
2. This code, now in the form of mRNA, moves through the nuclear pores.
3. The mRNA attaches itself to ribosomes on the rough endoplasmic reticulum which is continuous with the outer membrane of the nuclear envelope.
4. The code is translated into a polypeptide chain.
5. The polypeptide pass into the lumen of the endoplasmic reticulum.
6. The polypeptide is transferred to the golgi body and packaged in a vesicle.
7. The vesicle merges with the cell surface membranes and the protein is released.



Practice Questions

1. Outline the similarities between chloroplasts and mitochondria.

2. The diagram shows a generalised eukaryotic cell.



Identify structure:

(i) A
(ii) B
(iii) C

3. Explain how the structure of each of the following organelles aids its function:

(i) chloroplast
(ii) mitochondrion

4. Complete the table below by filling in the blanks:

Organelle	Structure/Features	Function
.....(i)............	Flattened cisternae	Carbohydrate and lipid metabolism
.....(ii)............	Internal membranes greatly folded into cristae	Increases surface area for .....(iv)...........
.....(iii)............	Pores normally blocked by an RNA/protein complex	.....(v)............
Chloroplast	Thylakoid membranes stacked into grana	.....(vi)............
Rough endoplasmic reticulum	Flattened interconnecting sacs covered in ribosomes	.....(vii)............

Answers

Marking points are shown by semicolons

1. Both organelles are surrounded by two membranes;
Both show internal compartmentalisation - i.e. internal membranes which allow different reactions to occur in different parts of the organelle;
Both have DNA;
Both have ribosomes;
Both are therefore capable of enzyme synthesis;
Both possess a readily permeable outer membrane and a selectively permeable inner membrane;
In both cases, permeability is brought about by proteins (porins) which span the membrane;

2. (i) Nuclear membrane;
(ii) Mitochondrion;
(iii) Golgi body;

3. See text

4. (i) Golgi body;
(ii) Mitochondrion;
(iii) Nucleus;
(iv) Electron transfer chain reactions/enzymes;
(v) Control of entry/exit of substance;
(vi) Increases surface area for chlorophyll to absorb light/allows sequential arrangement of electron carriers;
(vii) Ribosomes synthesise protein which can be transported through the endoplasmic reticulum

Acknowledgements;
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