# Basic components of living systems

## Section Summary

Make sure you know:

- What prokaryotes and eukaryotes are.
- The ultrastructure of eukaryotic cells, such as animal and plant cells, and the cellular components that they contain, e.g. the different organelles that are present in different eukaryotic cells.
- The structure and function of the following cellular components: the plasma membrane, cell wall, nucleus, nuclear envelope, nucleolus, lysosomes, ribosomes, rough and smooth endoplasmic reticulum, vesicles, Golgi apparatus, mitochondria, chloroplasts, centrioles, cilia and flagella.
- That organelles work together to make proteins. Proteins are made at the ribosomes, then folded and processed in the rough endoplasmic reticulum. They are then transported to the Golgi apparatus in vesicles, processed further, and are transported around the cell before being secreted.
- That in eukaryotes the cytoplasm contains protein threads known as the cytoskeleton — arranged as microfilaments and microtubules. The cytoskeleton supports organelles, provides strength to the cell and maintains its shape, transports organelles and material within the cell and enables cell movement.
- The similarities and differences between the ultrastructure of prokaryotes and eukaryotes.
- How to use the magnification formula: magnification = image size ÷ object size. You also need to know how to manipulate this formula, e.g. how to rearrange it to calculate object size or image size.
- The difference between magnification (how much bigger the image is than the sample) and resolution (how detailed the image is).
- How microscopy allows the study of cells and cell structure.
- That a laser scanning confocal microscope uses laser beams to scan a specimen which is tagged with fluorescent dyes. The images produced result from fluorescent light emitted by specimens.
- That a transmission electron microscope (TEM) transmits a beam of electrons through a specimen and produces micrographs that show 2D images of the specimen.
- That a scanning electron microscope (SEM) scans a beam of electrons across a specimen and produces micrographs that show 3D images of the surface of the specimen.
- How to interpret photomicrographs of cellular components, including photos from TEMs and SEMs.
- The different magnification and resolution that can be achieved from a light microscope, a transmission electron microscope and a scanning electron microscope.
- How to understand drawings and annotated diagrams of whole cells or cells in sections of tissue as seen under the light microscope.
- That staining is often required before using a light microscope in order to see the different cellular structures and organelles, and that more than one stain can be used to highlight different parts.
- How to prepare slides for use in light microscopy (dry and wet mounts) and how to examine specimens and work out their size using an eyepiece graticule and stage micrometer.

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# Exam-style Questions

1 Abnormal mitochondria have been found in diseased heart tissue, suggesting a link between mitochondria and heart disease. To investigate this further, a group of scientists produced a strain of mice with abnormal mitochondria.

The abnormal mice developed symptoms of heart disease after just one year. Normal mice showed similar symptoms after two years.

**(a) (i)** Describe the main function of mitochondria.

*(1 mark)*

**(ii)** Suggest why abnormal mitochondria might be problematic in heart tissue.

*(2 marks)*

**(b)** **Fig. 1.1** shows mitochondria in the normal mice and the abnormal mice.

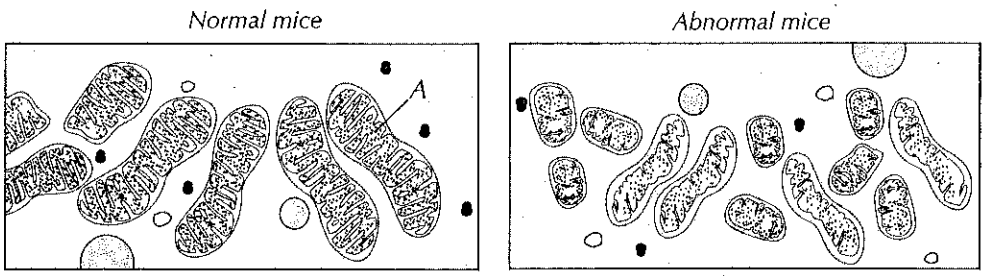


**Fig. 1.1**

**(i)** Describe **two** differences between the mitochondria found in the abnormal and normal mice.

*(2 marks)*

**(ii)** The mitochondrion labelled **A** in the normal mouse is about 1.5 μm in length. Calculate the magnification of the image.

*(2 marks)*

2 A scientist is studying secretory epithelial cells from the stomach under a light microscope.

The microscope has a magnification of × 100 and a resolution of 0.2 μm.

**(a) (i)** The ribosomes in the epithelial cells are 25 nm in diameter. Will the scientist be able to see them using the light microscope? Explain your answer.

*(2 marks)*

**(ii)** Explain the difference that you would expect to see if the ribosomes in the stomach cells were compared to those in bacterial cells.

*(2 marks)*

**(iii)** State **two** differences the scientist would observe if he compared the stomach cell to a plant cell.

*(2 marks)*

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(iv) Before looking at the epithelial cells under the microscope the scientist applies two stains to the specimen.
Suggest why the scientist has done this.

*(1 mark)*

**(b)** The scientist sees an image of an epithelial cell that is 4 mm in diameter. Calculate the actual diameter of the cell. Give your answer in millimetres.

*(2 marks)*

**(c)*** One of the main functions of secretory epithelial cells in the stomach is to produce and secrete digestive enzymes.
Describe the role of each organelle involved in the production and secretion of these proteins.

*(6 marks)*

**3** Penicillins are a group of antibiotics that are only effective against prokaryotic cells. They work by inhibiting cell wall synthesis, leading to cell lysis (bursting).

**(a)** Explain why penicillin antibiotics can clear bacterial infections in humans without harming the infected individual's cells.

*(2 marks)*

**(b)** The electron micrograph in **Fig. 3.1** shows an intact *Staphyloccus aureus* bacterium (right) and one undergoing lysis (left).

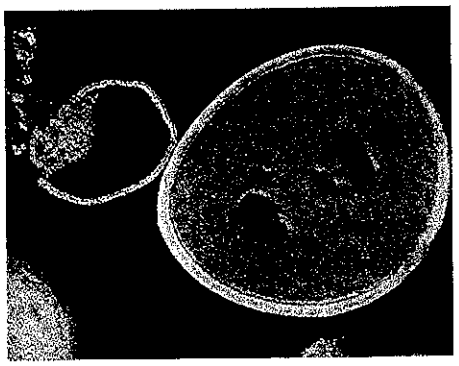


**Fig. 3.1**

**(i)** Suggest **one** reason why an electron microscope was used to view these cells rather than a light microscope.

*(2 marks)*

**(ii)** Name the type of electron microscope that was used to produce the micrograph seen in **Fig 3.1**. Give a reason for your answer.

*(2 marks)*

**(c)** Give **two** ways in which you could distinguish between a prokaryotic cell and a eukaryotic cell in an electron micrograph.

*(2 marks)*

* The quality of your response will be assessed in this question.

# Basic components of living systems – answers

1 a) i) Production of ATP ***(1 mark)***.

ii) Abnormal mitochondria might not produce as much ATP as normal mitochondria ***(1 mark)***. This means the heart tissue may not have sufficient energy to work properly/for muscle contraction ***(1 mark)***.

b) i) Any two from: abnormal mice have more mitochondria ***(1 mark)*** / smaller mitochondria ***(1 mark)*** / mitochondria with a smaller/lighter/less dense matrix ***(1 mark)*** / mitochondria with fewer cristae ***(1 mark)***.

ii) object size is 1.5 μm = 1.5 μm ÷ 1000 = 0.0015 mm
magnification = image size ÷ object size
= ~23 mm ÷ 0.0015 mm = **× 15333** (allow values between × 14667 to × 15333)
***(2 marks for correct answer, 1 mark if only working is correct.)***

2 a) i) No ***(1 mark)***. The microscope has a resolution of 0.2 μm/200 nm so it can't be used to distinguish between objects that are smaller than 0.2 μm/200 nm — such as the ribosomes ***(1 mark)***.

If you convert the diameter of the ribosomes and the resolution of the microscope into the same units, (e.g. both nm or both μm) it's easier to see that the ribosomes are too small for the microscope to pick up.

ii) The ribosomes in the bacterial cells would be smaller than those in the stomach cells ***(1 mark)***. This is because bacteria are prokaryotic cells which have smaller ribosomes than the eukaryotic stomach cells ***(1 mark)***.

iii) Any two from, e.g. the stomach cell would not have chloroplasts / a vacuole / a cell wall / plasmodesmata ***(2 marks)***.

iv) Using more than one stain would allow the scientist to see specific parts of the cell ***(1 mark)***.

b) object size = image size ÷ magnification
= 4 ÷ 100 = **0.04 mm**
***(2 marks for correct answer, 1 mark if only working is correct)***

c) **5-6 marks:**
The answer describes the full process of production and secretion of proteins (the digestive enzymes) that are to be released from the cell. There is a full explanation of the role of the ribosome(s), rough endoplasmic reticulum (RER), vesicle(s), Golgi apparatus and plasma membrane. The answer has a clear and logical structure. The information given is relevant and detailed.

**3-4 marks:**
The answer describes most of the process of production and secretion of proteins (the digestive enzymes) that are to be released from the cell. There is some explanation of the roles of the different organelles in the process. The answer has some structure. Most of the information given is relevant and there is some detail involved.

**1-2 marks:**
One or two steps involved in the process of production and secretion of proteins (the digestive enzymes) are referenced. The answer has no clear structure. The information given is basic and lacking in detail. It may not all be relevant.

**0 marks:**
No relevant information is given.

Here are some points your answer may include:
New proteins are made at the ribosomes on the rough endoplasmic reticulum. They're then folded and processed (e.g. sugar chains added) in the rough endoplasmic reticulum before being transported to the Golgi apparatus in vesicles. Here the proteins may undergo further processing (e.g. sugar chains trimmed). The proteins then enter vesicles to be transported to the plasma membrane where the proteins are secreted.

3 a) Bacteria are prokaryotic cells, so the penicillin inhibits the synthesis of their cell walls, eventually leading to cell lysis and death ***(1 mark)***. Human cells are eukaryotic animal cells, and so have no cell wall, so penicillin antibiotics leave these cells unaffected ***(1 mark)***.

b) i) E.g. because electron microscopes have a higher resolution ***(1 mark)*** so they can be used to look at smaller objects (like bacteria) in more detail ***(1 mark)***.

ii) A transmission electron microscope/TEM ***(1 mark)***. Transmission electron micrographs show a 2D cross section through a sample as seen in Fig 3.1 ***(1 mark)***.

c) Any two from, e.g. a prokaryotic cell is smaller than a eukaryotic cell ***(1 mark)***. / There is no nucleus present in a prokaryotic cell ***(1 mark)***. / There are fewer organelles present in a prokaryotic cell ***(1 mark)***. / There are no mitochondria present in a prokaryotic cell ***(1 mark)***. / Ribosomes are smaller in a prokaryotic cell than in a eukaryotic cell ***(1 mark)***. / The DNA in a prokaryotic cell is circular, not linear ***(1 mark)*** / A prokaryotic cell may contain plasmids ***(1 mark)***.

# Biological Molecules.

## Section Summary

Make sure you know...

- That water molecules are polar (they have a slight negative charge on one side and a slight positive charge on the other).
- That a hydrogen bond is a weak bond between a slightly positively-charged hydrogen atom in one molecule and a slightly negatively-charged atom in another molecule.
- The properties of water (high specific heat capacity, high latent heat of evaporation, very cohesive, lower density when solid, good solvent) and how they relate to the functions of water.
- That polymers are big molecules made from large numbers of smaller units called monomers.
- What is meant by a condensation reaction and a hydrolysis reaction, and how each one works.
- The chemical elements that make up carbohydrates, lipids and proteins.
- The molecular structures of the monosaccharides α-glucose and β-glucose, and how they differ.
- The molecular structure of ribose (a pentose monosaccharide) and how it differs from glucose (a hexose monosaccharide).
- That glycosidic bonds are formed between monosaccharides during condensation reactions to form disaccharides (e.g. maltose) and polysaccharides (e.g. amylose), and broken during hydrolysis reactions.
- The structure of starch (amylose and amylopectin), glycogen (long, branched chains of α-glucose) and cellulose (long, unbranched chains of β-glucose held together by hydrogen bonds to form microfibrils), and how their structures and properties are related to their functions.
- The structure of a triglyceride (one molecule of glycerol with three fatty acids) and a phospholipid (one molecule of glycerol, two fatty acids and a phosphate group) as examples of macromolecules.
- That ester bonds are formed between glycerol and fatty acids during condensation reactions (to form triglycerides) and are broken during hydrolysis reactions.
- The general structure of a saturated and an unsaturated fatty acid.
- How the properties of a triglyceride, phospholipid and cholesterol are related to their functions.
- The structure of an amino acid (carboxyl group, amino group and R group).
- That peptide bonds are formed between amino acids during condensation reactions (to form dipeptides and polypeptides) and broken during hydrolysis reactions.
- That a protein's primary structure is the sequence of amino acids, held together by peptide bonds.
- That a protein's secondary structure is an alpha (α) helix or beta (β) pleated sheet, held together by hydrogen bonding between the -NH and -CO groups of amino acids in the chain.
- That a protein's tertiary structure is the further coiling or folding of the polypeptide chain, held together by ionic bonds, disulfide bonds, hydrophobic and hydrophilic interactions, and hydrogen bonds.
- That a protein's quaternary structure is the way in which two or more polypeptide chains are assembled together.
- That haemoglobin (a conjugated protein), insulin and most enzymes (e.g. amylase) are globular proteins and how their structures relate to their functions.
- That collagen, keratin and elastin are fibrous proteins and how their properties relate to their functions.
- The key inorganic ions that are involved in biological processes, including their chemical symbols.
- How to test a substance for the presence of proteins (biuret test), starch (iodine test), lipids (emulsion test) and sugars (Benedict's test and reagent test strips) and interpret the results.
- How to use a colorimeter to determine the concentration of a substance (e.g. glucose) in a solution.
- How biosensors can be used to determine the concentration of a chemical substance (e.g. glucose).
- How to use paper and thin-layer chromatography to separate biological molecules in a solution.
- How to calculate retention ($R_f$) values from chromatogram results and use these values to identify the molecules present in a solution.

# Biological Molecules - nucleotides + nucleic acids.

## Section Summary

Make sure you know...

- That nucleotides are made up of a pentose sugar, a nitrogenous (nitrogen-containing) base (adenine, cytosine, guanine, thymine or uracil) and a phosphate group.
- That nucleotides are the monomers that make up nucleic acids, such as DNA and RNA.
- The differences between DNA and RNA nucleotides, including bases (RNA contains uracil instead of thymine) and type of pentose sugar (RNA contains ribose instead of deoxyribose).
- That there are two types of nitrogenous base in nucleotides, pyrimidines (cytosine, thymine and uracil) and purines (guanine and adenine), which have different structures.
- That ADP and ATP are both phosphorylated nucleotides made up of the base adenine and the sugar ribose, but that ADP contains two phosphate groups, while ATP contains three phosphate groups.
- That polynucleotides (polymers made up of nucleotides) are made by the formation of phosphodiester bonds, and are broken up by the breakage of these bonds.
- That DNA is made up of two antiparallel polynucleotide strands with hydrogen bonds between complementary base pairs (A and T, G and C).
- That the two antiparallel DNA strands twist together forming a double-helix.
- How to carry out an experiment to purify DNA using a precipitation reaction.
- Understand how semi-conservative DNA replication works and the roles that the enzymes DNA helicase and DNA polymerase play in this process.
- That the process of DNA replication is very accurate and that this is important for the conservation of genetic information.
- That random, spontaneous mutations can occur in DNA replication that alter DNA's base sequence.
- That a gene is a sequence of DNA nucleotides and how this sequence determines the order of amino acids in a polypeptide (which is a protein's primary structure).
- That each amino acid is coded for by a sequence of three bases called a triplet.
- That mRNA molecules carry the genetic code from the DNA in the nucleus to the cytoplasm, where it's used to make a protein during translation.
- That tRNA molecules carry amino acids to the ribosomes during translation.
- That rRNA in ribosomes catalyses the formation of peptide bonds between the amino acids.
- That the genetic code is the sequence of base triplets (codons) in DNA or mRNA which codes for specific amino acids.
- That the genetic code is non-overlapping (triplets don't share bases), degenerate (there are more possible combinations of triplets than there are amino acids) and universal (the same base triplets code for the same amino acids in all living things).
- That polypeptide (protein) synthesis involves the transcription and translation of genes.
- That transcription is the first stage of protein synthesis and involves the production of an mRNA copy of a gene in the nucleus.
- That during transcription the enzyme RNA polymerase attaches to the DNA double helix and the two DNA strands separate. RNA polymerase then lines up free RNA nucleotides alongside the DNA template strand and assembles the mRNA strand.
- That translation is the second stage of protein synthesis in which amino acids are joined together by ribosomes to make a polypeptide strand (protein) based on the order of codons in mRNA. .

Biological Molecules.

# Exam-style Questions

1 Photosynthesis is the process by which plants synthesise glucose from carbon dioxide and water using light as an energy source. Glucose is stored as starch in a plant.

**(a)** A student investigating photosynthesis kept two plants, A and B, under different conditions. They tested a leaf from each plant for the presence of starch, using the iodine test. **Table 1.1** below shows the results of the test. Complete the table to show the observation from the iodine test on each of the leaves.

| | *Observation* | *Starch present* |
|---|---|---|
| *Leaf A* | | *Yes* |
| *Leaf B* | | *No* |

**Table 1.1**

*(2 marks)*

**(b)** Amylose is one of the polysaccharides that forms starch.

**(i)** Name the other polysaccharide present in starch molecules.

*(1 mark)*

**(ii)** Describe the structure of amylose and explain how its structure makes it suited to its function.

*(3 marks)*

**(c)** Cellulose is also a polysaccharide found in plants.

**(i)** Describe **three** ways in which cellulose differs from starch.

*(3 marks)*

**Fig. 1.1** shows a glucose molecule that makes up cellulose.

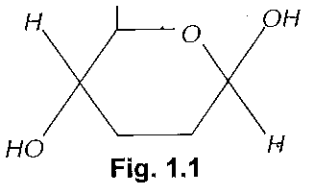



**Fig. 1.1**

**(ii)** Draw how two molecules of glucose link together to form part of a cellulose molecule.

*(1 mark)*

**(iii)** Describe how a cellulose molecule is broken apart into molecules of glucose.

*(3 marks)*

2 The human body contains many different proteins.
Each of these proteins has a primary, secondary and tertiary structure.

**(a)** Describe the primary structure of a protein.

*(2 marks)*

# Biological Molecules

**(b)** The tertiary structure of a protein is held in place by different types of bonds. Complete the following passage about these bonds.

To form the tertiary structure of a protein, ..... bonds form between negatively and positively charged R groups on different parts of the polypeptide chain. Whenever two molecules of the amino acid cysteine come close together they can become joined by their sulfur atoms to form ..... bonds. Weak bonds called ..... bonds also form between slightly .....-charged hydrogen atoms in some R groups and slightly .....-charged atoms in other R groups on the polypeptide chain.

*(5 marks)*

**(c)** The biuret test can be used to test for the presence of protein in a urine sample. Describe how this test would be carried out, including what observations would indicate positive and negative results.

*(4 marks)*

**3** Plants use a variety of pigments in their leaves to capture sunlight for photosynthesis. A scientist uses thin-layer chromatography to separate out the photosynthetic pigments from a mixture obtained from plant leaves. **Fig. 3.1** shows the thin-layer chromatogram that he produces.

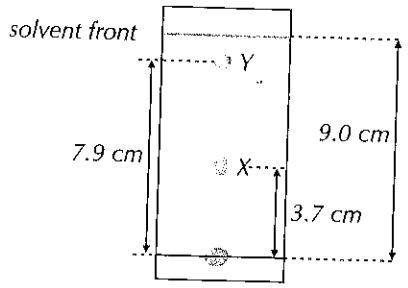



**Fig. 3.1**

**(a)** Explain why the different pigments separate as they travel up the plate.

*(2 marks)*

**(b)** The equation for calculating $R_f$ values is given below.

$$R_f \text{ value} = \frac{\text{distance travelled by spot}}{\text{distance travelled by solvent}}$$

Calculate the $R_f$ value of **spot X**.

*(1 mark)*

**(c)** Another scientist repeats the experiment above using the same mixture of pigments but the chromatogram does not give the same $R_f$ values.

Suggest **two** possible variations in the method that could have produced these different results.

*(2 marks)*

Biological Molecules - nucleotides + nucleic acids

# Exam-style Questions

1 Which of the following statements about semi-conservative replication is/are correct?

**Statement 1:** DNA helicase breaks hydrogen bonds between the two polynucleotide DNA strands.

**Statement 2:** DNA polymerase attaches to the original template strand by complementary base pairing.

**Statement 3:** Free-floating RNA nucleotides join to the exposed bases on each original template strand.

**A** 1, 2 and 3

**B** Only 1 and 2

**C** Only 2 and 3

**D** Only 1

*(1 mark)*

2 Which of these statements correctly describes the components of a molecule of ATP?

**A** Ribose, adenine and three phosphate groups.

**B** Deoxyribose, thymine and three phosphate groups.

**C** Deoxyribose, adenine and two phosphate groups.

**D** Ribose, thymine and two phosphate groups.

*(1 mark)*

3 Researchers have been studying a genetic disease with the aim of developing a treatment for it. The genetic disease is caused by the production of a specific enzyme.

**(a)** Part of the DNA sequence for the enzyme is shown in **Fig. 1.1**.

T C G C C A A C A A C A C T C

**Fig. 1.1**

State the complementary mRNA sequence to the sequence shown in **Fig. 1.1** **and** how many amino acids this DNA sequence would code for.
(Assume there are no start or stop codons present).

*(2 marks)*

**(b)** The researchers are exploring a possible treatment for the genetic disease that would involve disrupting the process of translation.

**(i)** Name the organelle that mRNA attaches to during translation.

*(1 mark)*

**(ii)*** Once mRNA has attached to this organelle, translation begins. Describe the process of translation from this point, including the roles of rRNA and tRNA.

*(6 marks)*

*The quality of your response will be assessed in this question.

# Biological Molecules - nucleotides + nucleic acids

**4 (a)** DNA is a polynucleotide.
State the **three** components that make up a DNA nucleotide.

*(3 marks)*

**(b) (i)** Urea is a weak alkali. Adding urea to a solution of double-stranded DNA will severely disrupt the hydrogen bonding in the DNA.
Explain what effect this will have on the structure of the DNA.

*(2 marks)*

**(ii)** Depurination of DNA results in the loss of purine bases.
Name the **two** DNA bases that would be lost during depurination.

*(2 marks)*

**(c) (i)** Use the most appropriate terms to complete the passage on DNA replication below.

Hydrogen bonds between the two polynucleotide strands break and the DNA double-helix ..... to form two separate strands. Each original strand acts as a ..... for the new strand. Free-floating DNA nucleotides join on to the exposed bases by ..... base pairing — for example, thymine pairs with ..... . The nucleotides on the new strands are then joined together by the enzyme ..... ..... and bonds form between the new and original strands.

*(5 marks)*

**(ii)** What is the name given to the method by which DNA replicates itself?

*(1 mark)*

**5** mRNA and DNA both play important roles in protein synthesis.

**(a)** Give **three** ways in which the structure of mRNA is different to the structure of DNA.

*(3 marks)*

**(b)** Describe the role of mRNA in protein synthesis.

*(2 marks)*

**(c)** DNA contains genes.

**(i)** Give the definition of a **gene**.

*(1 mark)*

**(ii)** Suggest how random, spontaneous mutations in a gene during DNA replication could affect the protein produced.

*(3 marks)*

**(d)** DNA carries the genetic code.
Explain why this code is described as being degenerate.

*(1 mark)*

# Biological Molecules - answers

1 a)

| | Observation | Starch present |
|---|---|---|
| Plant A | **dark, blue-black colour** | Yes |
| Plant B | **browny-orange colour** | No |

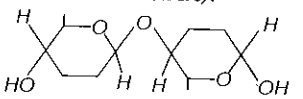
***(1 mark for each correct answer)***

Make sure you emphasise that a positive result would be a dark colour — you won't get a mark in the exam if you just say it turns blue.

b) i) amylopectin ***(1 mark)***

ii) Amylose is a long, unbranched chain of α-glucose ***(1 mark)***. It has a coiled structure/cylindrical shape ***(1 mark)***. These features make it compact meaning it's good for storage ***(1 mark)***.

c) i) Any three from: e.g. starch is used to store energy whereas cellulose is used to strengthen cell walls. / Starch is made from α-glucose whereas cellulose is made from β-glucose. / Starch has a compact shape whereas cellulose is a long, straight molecule. / The bonds between the glucose molecules in starch (amylose) are angled whereas the bonds between glucose molecules in cellulose are straight ***(3 marks for 3 correct answers)***.

ii)  ***(1 mark)***

You have to flip the glucose molecule on the right-hand side, so that the –OH groups of both glucose molecules are close together — this is where the glycosidic bond forms and a molecule of water is lost.

iii) During hydrolysis reactions ***(1 mark)*** molecules of water ***(1 mark)*** break apart the glycosidic bonds ***(1 mark)***.

2 a) It is the sequence of amino acids in the polypeptide chain ***(1 mark)*** joined together with peptide bonds ***(1 mark)***.

b) ionic ***(1 mark)***, disulfide ***(1 mark)***, hydrogen ***(1 mark)***, positively ***(1 mark)***, negatively ***(1 mark)***

c) Add a few drops of sodium hydroxide solution to the test sample ***(1 mark)***. Then add some copper(II) sulfate solution ***(1 mark)***. If protein is present, the solution will turn purple ***(1 mark)***. If there's no protein present, the solution will stay blue ***(1 mark)***.

3 a) Different pigments will be spend different amounts of time in the mobile phase ***(1 mark)***. The pigments that spend longer in the mobile phase will travel further, so the pigments separate out ***(1 mark)***.

b) $R_f$ value = 3.7 cm ÷ 9.0 cm = **0.41** ***(1 mark)***

c) Any two from: e.g. a different solvent was used / a different stationary phase was used / the experiment was carried out at a different temperature ***(1 mark for each correct answer. Maximum of 2 marks available.)***.

# Biological molecules - nucleotides + nucleic acids.

1 D ***(1 mark)***

2 A ***(1 mark)***

3 a) AGCGGUUGUUGUGAG ***(1 mark)***
5 amino acids ***(1 mark)***

b) i) ribosome ***(1 mark)***

ii) ***5-6 marks:***
The answer describes the full process of translation with full and correct references to the roles that tRNA and rRNA play in the process.
The answer has a clear and logical structure.
The information given is relevant and detailed.
***3-4 marks:***
The answer describes most of the process of translation with some references to tRNA and rRNA.
The answer has some structure. Most of the information given is relevant and there is some detail involved.
***1-2 marks:***
One or two steps involved in the process of translation are given, but with lack of reference to both tRNA and rRNA.
The answer has no clear structure. The information given is basic and lacking in detail. It may not all be relevant.
***0 marks:***
No relevant information is given.
**Here are some points your answer may include:**
tRNA molecules carry amino acids to the ribosome.
A tRNA molecule with an anticodon that's complementary to the start codon on the mRNA attaches itself to the mRNA by complementary base pairing. A second tRNA molecule attaches itself to the next codon on the mRNA in the same way and rRNA in the ribosome catalyses the formation of a peptide bond between the two amino acids. The first tRNA molecule moves away, leaving its amino acid behind. A third tRNA molecule binds to the next codon on the mRNA, its amino acid binds to the first two and the second tRNA molecule moves away.
This process continues until there's a stop codon.

4 a) Deoxyribose sugar ***(1 mark)***, a phosphate group ***(1 mark)*** and a nitrogenous base ***(1 mark)***.

b) i) The DNA will lose its double-helix structure/the two DNA strands will unravel ***(1 mark)***. This is because the double helix/two DNA strands are held together by hydrogen bonding between the base pairs ***(1 mark)***.

ii) adenine ***(1 mark)***, guanine ***(1 mark)***

*If you get a question in the exam that says, 'Name two...' don't hedge your bets and write down three or four possible answers — any wrong answers will cancel out the correct answers and you won't pick up any marks at all.*

c) i) unzips ***(1 mark)***, template ***(1 mark)***, complementary ***(1 mark)***, adenine ***(1 mark)***, DNA polymerase ***(1 mark)***

ii) semi-conservative replication ***(1 mark)***

5 a) The sugar in mRNA is ribose not deoxyribose ***(1 mark)***. Uracil replaces thymine as a base in mRNA ***(1 mark)***. mRNA is a single polynucleotide strand — a DNA molecule is made up of two polynucleotide strands ***(1 mark)***.

b) mRNA carries a complementary copy of a gene/section of DNA ***(1 mark)*** out of the nucleus to the ribosomes (in the cytoplasm) ***(1 mark)***.

c) i) A sequence of DNA nucleotides that codes for a protein/polypeptide ***(1 mark)***.

ii) E.g if there is a mutation in the sequence of DNA nucleotides, it could affect the amino acid sequence ***(1 mark)***. This can cause an abnormal protein to be produced ***(1 mark)***. The abnormal protein might function better than the normal protein — or it might not work at all ***(1 mark)***.

d) The genetic code is described as degenerate because some amino acids are coded for by more than one base triplet ***(1 mark)***.

# Enzymes

## Section Summary

Make sure you know:

- That an enzyme is a biological catalyst (a substance that speeds up chemical reactions in living organisms without being used up in the reaction itself).
- That an enzyme can affect both the structure and function of an organism.
- That enzyme action may be intracellular (within cells) or extracellular (outside cells).
- That catalase is an enzyme that catalyses intracellular reactions and amylase and trypsin are enzymes that catalyse extracellular reactions.
- That enzymes are globular proteins with a specific tertiary structure and that the active site is the part of the enzyme that binds to a substrate to form an enzyme-substrate complex.
- That an enzyme's active site has a specific shape complementary to the shape of the substrate, and so enzymes will usually only work with one substrate.
- That the formation of an enzyme-substrate complex lowers the activation energy needed for a reaction, and the reasons why.
- That an enzyme-product complex is formed when the substrate has been converted into its products, but the products are still bound to the enzyme's active site.
- How to describe the 'lock and key' model and the 'induced fit' model of enzyme action.
- That increasing the temperature increases the rate of an enzyme-controlled reaction by:
  - increasing the kinetic energy of substrate and enzyme molecules, which increases the likelihood of a collision between them.
  - increasing the energy of collisions between substrate and enzyme molecules, which means collisions are more likely to result in a reaction.
- That enzymes have an optimum temperature and if the temperature becomes too high, the enzyme will become denatured.
- That the temperature coefficient ($Q_{10}$) value for a reaction is a way of showing how much the rate of the reaction changes in response to the temperature being raised by 10 °C.
- That enzymes have an optimum pH at which the rate of an enzyme-controlled reaction is at its fastest and that if the pH is too high or too low, the enzyme will become denatured.
- That increasing enzyme concentration will increase the rate of a reaction until the amount of substrate becomes the limiting factor.
- That increasing substrate concentration will increase the rate of a reaction until the saturation point is reached and all active sites are full (enzyme concentration is the limiting factor). And that over the course of a reaction substrate concentration will decrease, decreasing the rate of reaction.
- How to describe experiments that investigate the effects of pH, temperature, enzyme concentration and substrate concentration on the rate of an enzyme-controlled reaction.
- How to draw a tangent to a graph and use it to work out the initial rate of a reaction.
- That cofactors and coenzymes are non-protein substances needed to activate some enzymes, and are able to explain how they work. $Cl^-$ ions are an example of a cofactor (for amylase).
- That prosthetic groups are a type of cofactor that is tightly bound to an enzyme and that $Zn^{2+}$ ions are an example of a prosthetic group for the enzyme carbonic anhydrase.
- That competitive inhibitors have a similar shape to a substrate and inhibit enzymes by binding to the active site and that non-competitive inhibitors inhibit enzyme activity by binding to them away from the active site, causing the active site to change shape.
- That some enzyme inhibitors are reversible and some are irreversible, and are able to explain why.
- That some metabolic poisons and medicinal drugs work by inhibiting enzymes.
- That product inhibition is when a product inhibits the enzyme that has catalysed its formation and end-product inhibition is when the final product in a metabolic pathway inhibits an enzyme that acts earlier in the pathway.

Enzymes

# Exam-style Questions

**1** Apples contain a substance called catechol and the enzyme catecholase. When an apple is cut open and exposed to oxygen, the following chemical reaction takes place:

$$\text{catechol} + \tfrac{1}{2}O_2 \xrightarrow{\text{catecholase}} \text{benzoquinone} + H_2O$$

**(a) (i)** What effect do enzymes have on the activation energy of a reaction?

*(1 mark)*

**(ii)** Explain why enzymes have this effect.

*(2 marks)*

**(b) (i)*** Use the '**induced fit' model** of enzyme activity to explain how catecholase catalyses the reaction shown above.

In your answer you should make clear how the shape of the enzyme relates to its function.

*(6 marks)*

**(ii)** Name **another model** of enzyme action not mentioned in part **(i)** and describe how it differs to the induced fit model.

*(2 marks)*

**(c)** Benzoquinone has a brown colour and its production is responsible for the 'browning' of apples once they have been cut.

To reduce the browning of an apple once it has been cut, would it be best to store the apple at room temperature or in a fridge? Explain your answer.

*(4 marks)*

**(d)** Catecholase uses copper as a cofactor.

**(i)** Describe how copper enables catecholase to function.

*(3 marks)*

**(ii)** Give **two** differences between organic and inorganic cofactors.

*(2 marks)*

**(e)** Copper binds more easily to a chemical called PTU than it does to catecholase.

Suggest why the rate of apple browning would be **lower** in the presence of PTU.

*(3 marks)*

* The quality of your response will be assessed in this question.

Enzymes

**2** Triglycerides are a type of fat found in foods. In the stomach, gastric lipase acts as a catalyst to break triglycerides down into diglycerides and fatty acids.

$$\text{triglyceride} \xrightarrow{\text{gastric lipase}} \text{diglyceride} + \text{fatty acid}$$

**(a)** Fig. 2.1 shows the rate of reaction for gastric lipase at different pH values.

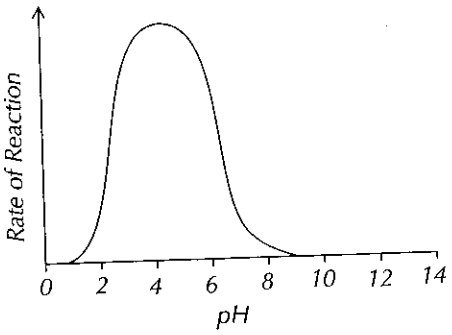



**Fig. 2.1**

**(i)** What is the **optimum pH** of gastric lipase?

*(1 mark)*

**(ii)** At what pH value(s) is gastric lipase **denatured**? Give a reason for your answer.

*(2 marks)*

**(iii)** Explain what happens when an enzyme is denatured by an extreme pH value.

*(3 marks)*

**(iv)** Suggest **two** variables you would control if you were investigating the activity of gastric lipase at different pH values.

*(2 marks)*

**(b)** The weight-loss drug, orlistat, stops triglycerides from being broken down. Orlistat is a competitive inhibitor of gastric lipase.

Fig. 2.2 shows the reaction with and without orlistat present.

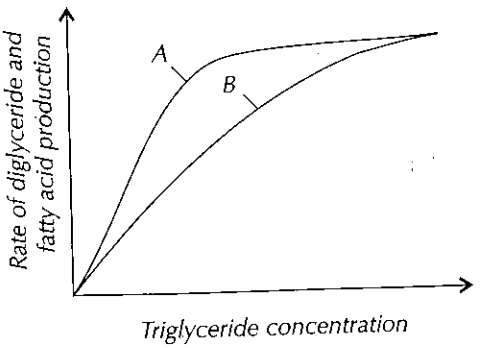



**Fig. 2.2**

**(i)** Which curve on Fig 2.2 shows the reaction **without** the presence of orlistat? Give a reason for your answer.

*(1 mark)*

**(ii)** Explain the action of orlistat in this reaction.

*(3 marks)*

# Enzymes - answers

1 a) i) They lower it ***(1 mark)***.

ii) In synthesis reactions, attaching to the enzyme holds the substrate molecules close together, reducing any repulsion between them ***(1 mark)***. In breakdown reactions, fitting into an enzyme's active site puts a strain on the bond in the substrate, causing it to break more easily ***(1 mark)***.

b) i) ***5-6 marks:***
The answer fully describes the induced fit model in reference to the context of the question.
The answer has a clear and logical structure.
The information given is relevant and detailed.
***3-4 marks:***
The answer describes most of the features of the induced fit model with some reference to the context of the question.
The answer has some structure. Most of the information given is relevant and there is some detail involved.
***1-2 marks:***
Only one or two of the features of the induced fit model are referenced, and not in the context of the question.
The answer has no clear structure. The information given is basic and lacking in detail. It may not all be relevant.
***0 marks:***
No relevant information is given.
**Here are some points your answer may include:**
Catechol and oxygen have a complementary shape to catecholase's active site. This lets them bind to the enzymes's active site. This forms an enzyme-substrate complex. Catechol and oxygen cause the active site to change shape slightly. This means that they bind more tightly to the enzyme. The enzyme-product complex is formed and then benzoquinone and water are released from catecholase.

ii) The 'lock and key' model ***(1 mark)***. In this model the active site does not change shape ***(1 mark)***.

c) In a fridge. At cooler temperatures the catechol, oxygen and catecholase molecules have less kinetic energy than they would at room temperature ***(1 mark)***. This makes the substrate molecules/catechol and oxygen less likely to collide with the catecholase active sites ***(1 mark)***. Also, the energy of the collisions is lower, meaning each collision is less likely to result in a reaction ***(1 mark)***. Therefore, in a fridge the rate of the reaction would be lower/benzoquinone would be produced more slowly, so the apple would brown more slowly ***(1 mark)***.
***Accept reverse theory, i.e. more kinetic energy at higher temperatures.***

d) i) Copper is an inorganic cofactor ***(1 mark)*** which binds to catecholase ***(1 mark)*** and helps it form an enzyme-substrate complex with catechol and oxygen more easily ***(1 mark)***.

Even though the question doesn't tell you what type of cofactor copper is, you can work out that it must be inorganic because copper is a metal.

ii) E.g. inorganic cofactors don't directly participate in the reaction but organic cofactors do ***(1 mark)***. Inorganic cofactors aren't used up or changed during the reaction but organic factors are changed/recycled ***(1 mark)***.

e) E.g. there would be less copper to bind to catecholase ***(1 mark)*** so fewer enzyme molecules would be able to form enzyme-substrate complexes ***(1 mark)***. This would decrease the rate of the reaction, slowing the browning of the apple ***(1 mark)***.

2 a) i) ***(1 mark for a value between pH 4 and pH 5)***

ii) pH 1 and pH 9 ***(1 mark)***. There is no reaction at these pH levels ***(1 mark)***.

iii) The $H^+$ and $OH^-$ ions found in acids and alkalis can break the weak ionic bonds/hydrogen bonds that hold the enzyme's tertiary structure in place ***(1 mark)***. This changes the shape of the active site ***(1 mark)*** so it is no longer complementary in shape to the substrate/will not bind to the substrate to catalyse the reaction ***(1 mark)***.

Remember, it's the change in shape of the active site that means the reaction can't be catalysed.

iv) E.g. temperature ***(1 mark)*** and substrate concentration ***(1 mark)***.

b) i) A. The rate at which diglycerides and fatty acids are produced/the reaction rate is higher without the presence of orlistat ***(1 mark)***.

ii) Molecules of orlistat have a similar shape to triglycerides ***(1 mark)***. They bind to the active sites of gastric lipase and block the entry of triglycerides ***(1 mark)***. This means the reaction that produces diglycerides and fatty acids can't take place as quickly ***(1 mark)***.

Membranes

## Section Summary

Make sure you know...

- That plasma membranes are partially permeable and have a range of functions including: controlling which substances enter and leave the cell, allowing recognition by other cells, and allowing cells to communicate.
- That membranes within cells are also partially permeable and have a range of functions including: surrounding an organelle and acting as a barrier between the organelle and the cytoplasm, controlling what substances enter and leave an organelle, acting as the site of chemical reactions, and (for membranes within organelles) acting as a barrier between the membrane contents and the rest of the organelle.
- The fluid mosaic model of cell membrane structure, including the roles of phospholipids (form a barrier to dissolved substances), cholesterol (gives the membrane stability), proteins (control what enters and leaves the cell, act as receptors), glycolipids and glycoproteins (stabilise the membrane, act as receptors/antigens).
- That some solvents, such as ethanol, dissolve the lipids in a cell membrane, causing it to lose its structure and become more permeable.
- That temperature influences how much the phospholipids in the bilayer of a cell membrane can move, affecting the membrane's structure and permeability.
- How to investigate the effect of a variable, such as solvent concentration or temperature, on cell membrane structure and permeability, e.g. by using cubes of beetroot.
- That cells communicate with each other through cell signalling using messenger molecules, and that messenger molecules bind to membrane-bound receptors on target cells.
- That membrane-bound receptors are sites where hormones and drugs bind.
- That diffusion is the passive movement of particles from an area of higher concentration to an area of lower concentration.
- That the rate of diffusion is affected by concentration gradient, thickness of the exchange surface, surface area and temperature.
- How to investigate the effect of a variable, such as concentration gradient, surface area or temperature, on the rate of diffusion in model cells, e.g. by using cubes of agar jelly and a pH indicator such as phenolphthalein.
- That osmosis is diffusion of water molecules across a partially permeable membrane down a water potential gradient, from an area of higher water potential to an area of lower water potential.
- How animal and plant cells behave in isotonic, hypotonic and hypertonic solutions.
- How to investigate the effect of water potential on plant and animal cells, e.g. by using potato cylinders or a chicken's egg with the shell dissolved and a range of sucrose or salt solutions.
- That facilitated diffusion (a passive process) uses carrier proteins and channel proteins to move large molecules and charged particles, e.g. ions and polar molecules, down a concentration gradient.
- That active transport uses carrier proteins and energy (from ATP) to actively move molecules against a concentration gradient.
- That cells can take in large substances by endocytosis using energy from ATP — the plasma membrane surrounds the substance and then pinches off, forming a vesicle inside the cell.
- That cells can secrete substances by exocytosis also using energy from ATP — vesicles containing substances for release outside the cell fuse with the plasma membrane, then release their contents.

Membranes

# Exam-style Questions

1 **Fig. 1.1** shows normal onion cells under a light microscope. The cytoplasm appears dark grey. **Fig. 1.2** shows the same onion cells after they have been placed in a **weak salt solution**. The solution has a lower water potential than the onion cells.

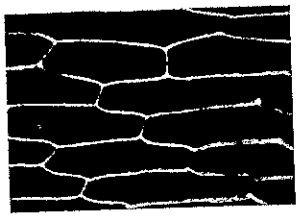


**Fig. 1.1**

**Fig. 1.2**

**(a) (i)** Explain what is meant by the term water potential.

*(1 mark)*

**(ii)** Describe and explain the changes seen between **Fig. 1.1** and **Fig. 1.2**.

*(3 marks)*

**(iii)** Describe what might happen if animal cells were placed in a solution with a lower water potential than the cell contents.

*(1 mark)*

**(b)** In **Fig. 1.2** it is possible to see the cells' plasma membranes.

**(i)** Describe the fluid mosaic structure of the plasma membrane.

*(4 marks)*

**(ii)** State **two** functions of the plasma membrane.

*(2 marks)*

2 Glucose is a product of digestion. It is also a relatively large polar molecule. Once glucose has been digested, it must be absorbed into the bloodstream from the cells of the small intestine. Part of the absorption process happens by facilitated diffusion.

**(a) (i)** Suggest why facilitated diffusion is necessary for glucose to cross the plasma membranes of the intestinal cells.

*(3 marks)*

**(ii)** Does this process require energy? Explain your answer.

*(1 mark)*

**(iii)** State the type of molecule that facilitates the diffusion of glucose across plasma membranes in the small intestine, and briefly describe how it does so.

*(2 marks)*

**(b)** Another stage of the absorption process uses active transport. Explain what is meant by the term active transport.

*(2 marks)*

Membranes

3 A group of students investigated the water potential of potato cells.

They cut cubes of potato of the same size and shape, weighed them and placed a single cube into each of four different concentrations of sucrose solution.
One cube was placed in pure water.

They re-weighed each of the cubes every hour, and after 12 hours the mass of all the cubes remained constant.
The overall change in mass for each cube is shown in **Fig. 3.1**.

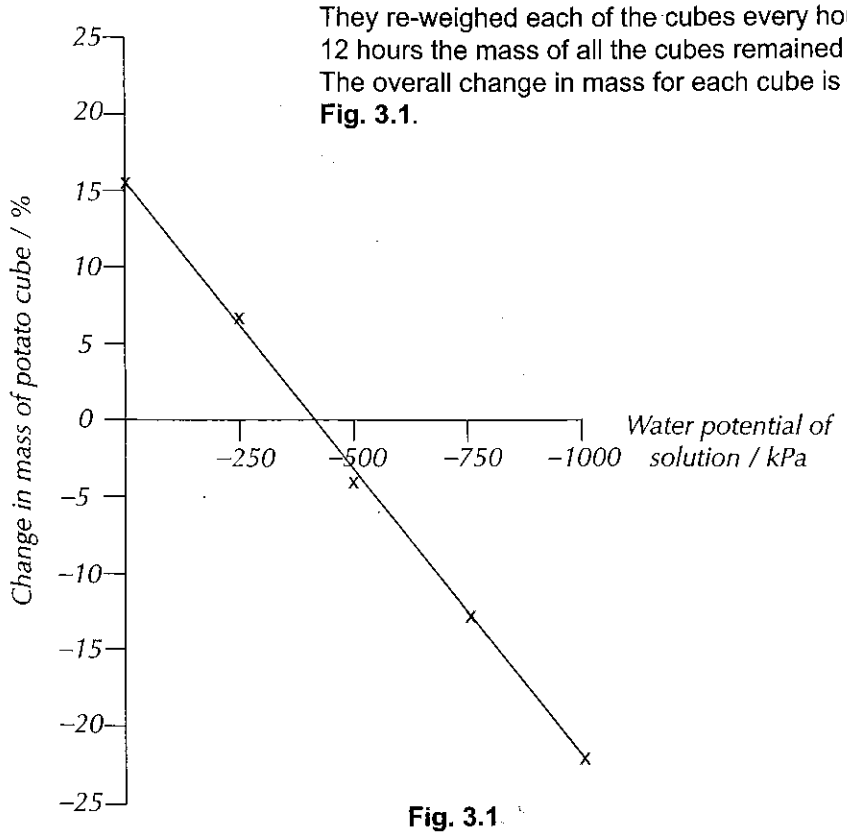



**Fig. 3.1**

**(a)** The students recorded the difference in mass between the cubes at the start and end of the experiment in grams, but plotted the overall change as a percentage. Suggest why the graph was plotted in this way.

*(1 mark)*

**(b)** What was the change in mass for the potato cube placed in pure water?

*(1 mark)*

**(c) (i)** Explain why the cubes in the **–500**, **–750** and **–1000 kPa** solutions lost mass.

*(2 marks)*

**(ii)** Use **Fig. 3.1** to estimate the water potential of the potato cells.

*(1 mark)*

**(d)** Suggest how the students could make their results more precise.

*(1 mark)*

**(e)** If the experiment was repeated with cubes that had a larger surface area, would you expect the mass of all the cubes to become constant before 12 hours, at 12 hours or after 12 hours? Explain your answer.

*(2 marks)*

# Membranes - answers

1 a) i) The potential/likelihood of water molecules to diffuse out of or into a solution ***(1 mark)***.

ii) The cells in Fig. 1.2 have lost water by osmosis ***(1 mark)***. This has caused the cytoplasm and plasma membranes to pull away from the cell walls ***(1 mark)***. The cells are plasmolysed ***(1 mark)***.

iii) The net movement of water molecules will still be out of the cell by osmosis, causing the cell to shrink ***(1 mark)***.

b) i) Any four from: In the fluid mosaic model, phospholipid molecules form a continuous double layer/bilayer ***(1 mark)***. Cholesterol molecules fit between the phospholipids, making the membrane less fluid and more rigid ***(1 mark)***. Protein molecules are scattered throughout the bilayer, like tiles in a mosaic ***(1 mark)***. Some protein molecules, called glycoproteins, have a polysaccharide/carbohydrate chain attached ***(1 mark)***. / Some lipids, called glycolipids, also have a polysaccharide/carbohydrate chain attached ***(1 mark)***.
***(Maximum of 4 marks available.)***

ii) E.g. any two from: Plasma membranes control which substances enter and leave the cell. / Plasma membranes allow recognition by other cells. / Plasma membranes allow cell communication.
***(2 marks for 2 correct answers.)***

2 a) i) The centre of the phospholipid bilayer is hydrophobic ***(1 mark)***. It forms a barrier to the diffusion of water-soluble substances including most polar molecules ***(1 mark)***. Glucose is a polar molecule that can't diffuse directly across the membrane ***(1 mark)***.

ii) No. The glucose moves down its concentration gradient/facilitated diffusion is a passive process ***(1 mark)***.

iii) It is a carrier protein ***(1 mark)*** that changes shape when glucose binds to it, causing the glucose to be released on the opposite side of the membrane ***(1 mark)***.

b) The movement of molecules against their concentration gradient ***(1 mark)*** using energy (from ATP) ***(1 mark)***.

3 a) E.g. in case the cubes did not all start out at exactly the same mass ***(1 mark)***. / To enable a fair comparison between the cubes ***(1 mark)***.

b) 16% (accept 15-17%) ***(1 mark)***

Don't forget that pure water is always 0 kPa.

c) i) The water potential in these three solutions must have been lower than the water potential of the potato cells ***(1 mark)***, so water moved out of the cells by osmosis ***(1 mark)***.

ii) –425 kPa (accept any answer between –400 and –450 kPa) ***(1 mark)***

The cells won't lose or gain any mass in an isotonic solution, so all you need to do is read the water potential off the graph where the change in mass equals zero.

d) E.g. they could do repeats of the experiment for each concentration of sucrose solution and calculate a mean percentage change in mass ***(1 mark)***.

There's more on precise results in Module 1 of this book.

e) Before 12 hours ***(1 mark)*** because the rate of osmosis will be faster due to the increase in surface area ***(1 mark)***.

# Cell Division

## Section Summary

Make sure you know:

- That most of the cell cycle is taken up by interphase — a period of cell growth, consisting of $G_1$, S and $G_2$ phases, during which the cell's genetic material is copied and checked for DNA damage.
- That a small percentage of the cell cycle is taken up by mitosis and cytokinesis, which produce two genetically identical daughter cells.
- How the cell cycle is regulated by checkpoints.
- That mitosis is needed for the growth of multicellular organisms and tissue repair.
- That some animals, plants and fungi also use mitosis to reproduce asexually.
- The stages of mitosis — prophase (chromosomes condense, the spindle forms and the nuclear envelope breaks down), metaphase (chromosomes line up along the centre of the cell and attach to the spindle), anaphase (the spindles contract, pulling chromatids to opposite ends of the cell) and telophase (chromatids reach the opposite ends of the cell and uncoil and a nuclear envelope forms).
- That cytokinesis is where the cytoplasm of a cell divides.
- How to prepare and examine stained sections and squashes of plant tissue, in order to produce labelled diagrams of cells at different stages of the cell cycle and mitosis.
- That the term 'homologous pair of chromosomes' refers to a pair of matching chromosomes.
- That gametes are produced by meiosis (a type of cell division that produces four genetically different cells). These gametes are haploid (they only have one copy of each chromosome).
- That in sexual reproduction two haploid gametes join together at fertilisation to form a diploid zygote (it has two copies of each chromosome). This then divides and develops into a new organism.
- The main stages of meiosis — interphase, prophase 1, metaphase 1, anaphase 1, telophase 1, prophase 2, metaphase 2, anaphase 2 and telophase 2.
- How genetic variation can be caused by independent assortment of chromosomes and crossing over.
- That stem cells are unspecialised cells that can develop into different types of cell and can also replicate themselves, so are a renewing source of undifferentiated cells.
- That differentiation is the process by which a cell becomes specialised.
- That erythrocytes and neutrophils are derived from stem cells in bone marrow and xylem and phloem are produced from stem cells found in meristems.
- That stem cells have a huge potential in medicine and could be used to repair damaged tissues or treat neurological conditions such as Parkinson's and Alzheimer's. They're also used in developmental biology research.
- How erythrocytes, neutrophils, ciliated and squamous epithelial cells and sperm cells in animals, and palisade mesophyll cells, root hair cells and guard cells in plants are specialised for their functions.
- That a tissue is a group of cells (plus any extracellular material secreted by them) that are specialised to carry out a particular function.
- These examples of tissues — squamous epithelium, ciliated epithelium, muscle tissue, cartilage, xylem tissue and phloem tissue.
- That an organ is a group of different tissues that work together to perform a particular function and that organ systems are organs which work together for a particular function.
- How cells, tissues, organs and organ systems work together so multicellular organisms can function.

Cell division

# Exam-style Questions

1 **Fig. 1.1** shows changes in the mass of a cell and its DNA during the cell cycle.

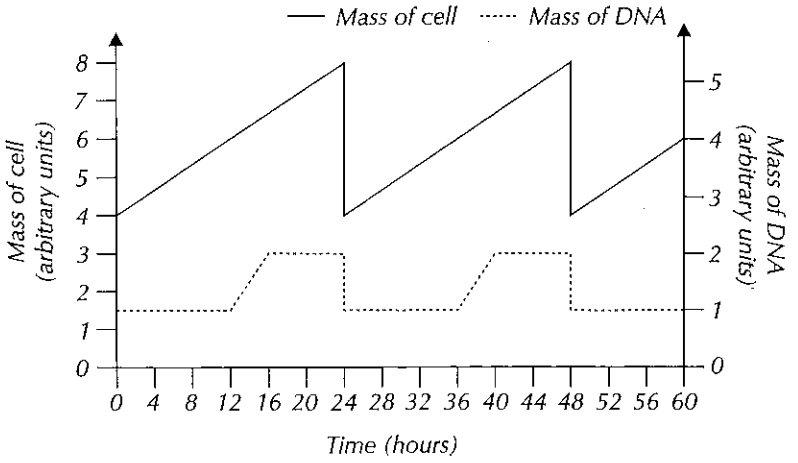



**Fig 1.1**

**(a)** During which hours does synthesis take place? Explain your answer.

*(2 marks)*

**(b)** At which hours does mitosis take place? Explain your answer.

*(2 marks)*

**(c)** Describe what is happening within the cell between 0 and 24 hours.

*(4 marks)*

**(d) (i)** How many cell divisions are shown on the graph? Explain your answer.

*(2 marks)*

**(ii)** At what time will the next cell division take place?

*(1 mark)*

**(e) (i)** Telophase is a phase of mitosis. Describe what happens during telophase in animal cells.

*(2 marks)*

**(ii)** Give **three** reasons why mitosis is important for organisms.

*(3 marks)*

2 A doctor was studying a sperm sample using a microscope. He observed that a large proportion of the sperm cells in the sample had abnormally shaped tails.

**(a)** Explain why the patient whose sample the doctor was studying may experience reduced fertility.

*(2 marks)*

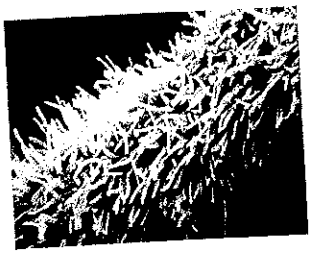
**(b)** Other than having a tail, give **two** other ways in which sperm cells are adapted for their function.

*(2 marks)*

# Cell division

3 Water enters the plant through its root hair cells and is transported around the plant in the xylem. **Fig. 3.1** on the right shows some root hair cells on the root of a plant.

**Fig 3.1**



**(a)** Give **two** ways in which the structure of a root hair cell is specialised for its role. *(2 marks)*

**(b) (i)** Stem cells differentiate into xylem cells. Where are these stem cells found? *(1 mark)*

**(ii)** Explain why xylem can be considered a tissue. *(2 marks)*

4 **Fig 4.1** shows the average DNA content of a group of cells that are undergoing meiosis:

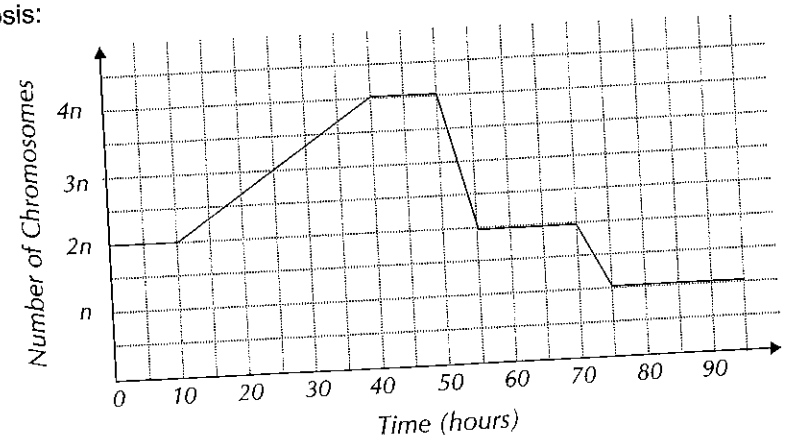



**Fig 4.1**

**(a)** Explain what is happening:

**(i)** between 10 hours and 40 hours. *(1 mark)*

**(ii)** between 40 hours and 50 hours. *(1 mark)*

**(iii)** between 50 hours and 55 hours. *(1 mark)*

**(iv)** between 70 hours and 75 hours. *(1 mark)*

**(b) (i)** Describe how daughter cells produced by meiosis differ to their parent cell. *(2 marks)*

**(ii)** Explain how crossing over during meiosis can give rise to genetic variation. *(3 marks)*

# Cell division - answers.

1 a) 12-16 hours and 36-40 hours ***(1 mark)***, because the mass of DNA doubles ***(1 mark)***.

b) 24 hours and 48 hours ***(1 mark)***, because the mass of DNA halves / the mass of the cell halves ***(1 mark)***.

c) E.g. the cell is growing ***(1 mark)*** and new organelles and proteins are made ***(1 mark)***. The cell replicates it's DNA ***(1 mark)*** and checks the DNA for damage ***(1 mark)***.

d) i) Two (at 24 and 48 hours) ***(1 mark)*** because the mass of the cell and its DNA doubles and halves twice ***(1 mark)***.

ii) At 72 hours ***(1 mark)***.

*In graphs with two scales, make sure you match the correct line (or bar) to the correct scale before you read off a value.*

e) i) At opposite poles, chromatids uncoil and become long and thin again ***(1 mark)***. A nuclear envelope forms around each group of chromosomes, so there are two nuclei ***(1 mark)***.

ii) Mitosis is important for growth ***(1 mark)***, repair ***(1 mark)***, and asexual reproduction ***(1 mark)***.

*Don't forget that mitosis is not just used for growth and repair in multicellular organisms — some organisms use it for asexual reproduction too.*

2 a) Sperm cells use their tails to swim to the egg ***(1 mark)***. If a large proportion of sperm cells can't do this successfully, there's less chance of a sperm cell successfully fertilising the egg ***(1 mark)***.

b) They have lots of mitochondria to provide the energy to swim ***(1 mark)*** and they have an acrosome, which contains digestive enzymes to enable the sperm to penetrate the surface of the egg ***(1 mark)***.

3 a) Any two from: e.g. it has a large surface area for absorbing water and mineral ions from the soil ***(1 mark)***. / It has a thin, permeable cell wall for absorbing water and mineral ions from the soil ***(1 mark)***. / The cytoplasm contains extra mitochondria to provide the energy needed for active transport ***(1 mark)***.

b) i) In meristems / the vascular cambium ***(1 mark)***.

ii) Xylem is a group of cells, including xylem vessel cells and parenchyma cells ***(1 mark)***, that are specialised to work together to transport water around the plant and support the plant ***(1 mark)***.

4 a) i) The DNA is being replicated to produce two copies of each chromosome ***(1 mark)***.

ii) The chromosomes are condensing and are arranging themselves into homologous pairs ***(1 mark)***.

iii) Meiosis 1 occurs — the homologous pairs are separated, halving the chromosome number ***(1 mark)***.

iv) Meiosis 2 occurs — the pairs of sister chromatids are separated, generating haploid cells ***(1 mark)***.

b) i) E.g. the daughter cells are genetically different ***(1 mark)*** and are haploid/contain half the number of chromosomes as the parent cell ***(1 mark)***.

ii) When homologous chromosomes come together in meiosis 1, the chromatids are able to twist around each other and bits of the chromatids can swap over ***(1 mark)***. Each of the chromatids now has a different combination of alleles ***(1 mark)***, which means that each of the four daughter cells resulting from meiosis contain chromatids with different alleles ***(1 mark)***.