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AS Level Biology

Topic 2: Nucleic Acids, ATP and Water

AQA Biology (7401) | Mark Scheme | 100 marks

Instructions

- Answer **all** questions.
- In calculations show your working and give your answer to an appropriate number of significant figures.
- In extended-response questions you should write in clear, well-organised continuous prose.
- There are 16 questions in this paper. The total mark is **100**.

1. This question is about the components of nucleotides.

(a) Name the three components that make up a single DNA nucleotide. **(3)**

✓ a (deoxyribose) pentose sugar (1)
✓ a phosphate group (1)
✓ a (nitrogen-containing) organic base (1)

(b) Name the four bases found in DNA. **(2)**

✓ adenine, thymine (1)
✓ cytosine, guanine (1)

(c) State which one of the DNA bases is replaced in RNA, and name the base that replaces it. **(2)**

✓ thymine is replaced (1)
✓ by uracil (1)

2. This question is about the structure of DNA.

(a) Name the type of reaction that joins two nucleotides together. **(1)**

✓ condensation (1)

(b) Name the bond that forms between the phosphate of one nucleotide and the sugar of the next in a polynucleotide strand. **(1)**

✓ phosphodiester bond (1)

(c) Name the type of bond that holds the two strands of a DNA molecule together. **(1)**

✓ hydrogen bond(s) (1)

(d) State the base-pairing rules in DNA. **(2)**

✓ adenine pairs with thymine (1)
✓ cytosine pairs with guanine (1)

3. A sample of DNA was analysed and found to contain 28% adenine.

(a) State the percentage of thymine present in this DNA sample, and explain your answer. **(2)**

✓ 28% (1)
✓ because adenine pairs with thymine (in equal amounts) (1)

(b) Calculate the percentage of cytosine present in this DNA sample. Show your working. **(2)**

✓ A + T = 56%, so G + C = 100 - 56 = 44% (1)
✓ C = 44/2 = 22% (1)

4. This question is about the role of DNA.

(a) Explain how the structure of DNA makes it a stable molecule suitable for storing genetic information. **(3)**

✓ the sugar-phosphate backbone protects the bases / the bases are on the inside (1)
✓ there are many (cumulative) hydrogen bonds between the two strands (1)
✓ the double helix / large number of hydrogen bonds makes it stable (1)

(b) DNA in eukaryotic cells is described as a double helix. State two further features of eukaryotic DNA. **(2)**

✓ it is (long and) linear (1)
✓ it is associated with (histone) proteins / wound around proteins (1)

(c) State two ways in which the DNA found in the nucleus of a eukaryotic cell differs from the DNA found in prokaryotic cells. **(2)**

✓ eukaryotic DNA is linear, prokaryotic DNA is circular (1)
✓ eukaryotic DNA is associated with proteins/histones, prokaryotic DNA is not (1)

5. This question is about semi-conservative replication of DNA.

(a) Name the enzyme that breaks the hydrogen bonds between the two strands of DNA at the start of replication. **(1)**

✓ DNA helicase (1)

(b) Name the enzyme that joins adjacent nucleotides together on the new strand. **(1)**

✓ DNA polymerase (1)

(c) Describe the process of semi-conservative replication of DNA. **(5)**

✓ DNA helicase breaks the hydrogen bonds between the two strands (1)
✓ the two strands unwind/separate (1)
✓ each strand acts as a template (1)
✓ free (DNA) nucleotides line up / bind to the exposed bases by complementary base pairing (1)
✓ DNA polymerase joins the nucleotides (by phosphodiester bonds) to form the new strand (1)

(d) Explain why this method of DNA replication is described as 'semi-conservative'. **(2)**

✓ each new DNA molecule contains one original (parental) strand (1)
✓ and one newly synthesised strand (1)

6. Meselson and Stahl provided evidence for semi-conservative replication using nitrogen isotopes. Bacteria were grown in a medium containing the heavy isotope ^{15}N, then transferred to a medium containing the light isotope ^{14}N.

(a) Explain why the DNA grown in ^{15}N medium was heavier (more dense) than DNA grown in ^{14}N medium. **(2)**

✓ the nitrogen is found in the (bases of the) nucleotides (1)
✓ ^{15}N is heavier than ^{14}N so DNA containing it is more dense (1)

(b) After one round of replication in ^{14}N medium, all the DNA was of intermediate density. Explain how this result supports semi-conservative replication. **(3)**

✓ each DNA molecule has one original ^{15}N strand and one new ^{14}N strand (1)
✓ so each molecule is of intermediate density (between heavy and light) (1)
✓ this would not occur if replication were conservative (which would give one heavy and one light molecule) (1)

7. This question is about ATP.

(a) State what the abbreviation ATP stands for. **(1)**

✓ adenosine triphosphate (1)

(b) Name the three components of a molecule of ATP. **(3)**

✓ adenine (base) (1)
✓ ribose (sugar) (1)
✓ three phosphate groups (1)

(c) Name the reaction by which ATP is broken down to release energy, and name the enzyme that catalyses it. **(2)**

✓ hydrolysis (1)
✓ ATP hydrolase / ATPase (1)

(d) Write a word equation for the hydrolysis of ATP. **(2)**

✓ ATP + water → ADP + inorganic phosphate (P_i) (1)
✓ (and) energy is released (1)

8. ATP is described as the 'universal energy currency' of cells.

(a) Explain why ATP is a suitable molecule for transferring energy in cells. **(4)**

✓ it releases a relatively small/manageable amount of energy (per molecule) so little is wasted (1)
✓ it is hydrolysed in a single (rapid) reaction so energy is released quickly (1)
✓ it is soluble / can be used in many reactions / used inside the cell (1)
✓ it can be rapidly re-synthesised (from ADP and P_i) (1)

(b) Name the reaction by which ATP is re-synthesised from ADP and inorganic phosphate. **(1)**

✓ condensation (phosphorylation) (1)

(c) State two processes in a cell for which the energy released from ATP can be used. **(2)**

✓ active transport (1)
✓ muscle contraction / synthesis of large molecules (any suitable) (1)

9. This question is about the structure of a water molecule.

(a) Explain why a water molecule is described as *polar*. **(3)**

✓ the oxygen atom is more electronegative / shared electrons are pulled towards oxygen (1)
✓ the oxygen has a slightly negative (δ-) charge (1)
✓ and the hydrogen atoms have a slightly positive (δ+) charge (1)

(b) Name the type of bond formed between adjacent water molecules. **(1)**

✓ hydrogen bond (1)

10. Water has a number of properties that make it important for living organisms.

(a) Water is described as a metabolite. State what this means and give one example of a reaction in which water is involved. **(2)**

✓ it takes part in (many) metabolic/chemical reactions (1)
✓ e.g. condensation or hydrolysis reactions / photosynthesis (1)

(b) Explain why water is a good solvent for many substances in living organisms. **(3)**

✓ water is polar (1)
✓ the positive and negative regions attract / surround charged particles (ions) or other polar molecules (1)
✓ so the substances dissolve and can be transported / react more easily (1)

(c) Water has a high specific heat capacity. Explain why this is important for organisms living in water. **(3)**

✓ a large amount of energy is needed to raise the temperature of water (1)
✓ because hydrogen bonds must be broken (restrict movement of molecules) (1)
✓ so the temperature of the water (habitat) remains relatively stable, providing a stable environment (1)

11. Water has a high latent heat of vaporisation and strong cohesion between molecules.

(a) Explain how the high latent heat of vaporisation of water helps organisms to cool down. **(3)**

✓ much energy/heat is needed to evaporate water (break the hydrogen bonds) (1)
✓ so when water evaporates (e.g. in sweat/transpiration) a lot of heat is removed (1)
✓ this cools the organism without much water being lost (1)

(b) Explain how cohesion between water molecules is important in the transport of water in plants. **(3)**

✓ water molecules are attracted to each other by hydrogen bonds (cohesion) (1)
✓ so water molecules stick together / form a continuous column (1)
✓ allowing water to be pulled up the xylem (as a column) (1)

(c) State how the high surface tension of water, caused by cohesion, is useful to some organisms. **(1)**

✓ allows some (small) organisms to walk/move on/across the surface of water (1)

12. This question is about inorganic ions in organisms.

(a) State the role of iron ions (Fe^{2+}) in the human body. **(1)**

✓ found in haemoglobin / used to bind/transport oxygen (1)

(b) State the role of hydrogen ions (H^{+}) in determining the properties of solutions. **(1)**

✓ their concentration determines the pH (of a solution) (1)

(c) State the role of phosphate ions (PO_4^{3-}) in living organisms. **(2)**

✓ used to form the (sugar-)phosphate backbone of DNA/RNA / part of nucleotides (1)

✓ part of ATP / phospholipids in membranes (1)

(d) State the role of sodium ions (Na^{+}) in the absorption of glucose. **(2)**

✓ sodium ions are co-transported with glucose (1)

✓ into cells (e.g. epithelial cells of the ileum) by co-transport (1)

13. This question is about the comparison of DNA and RNA.

(a) State two ways in which the structure of an RNA molecule differs from that of a DNA molecule. **(2)**

✓ RNA contains ribose, DNA contains deoxyribose (1)

✓ RNA contains uracil, DNA contains thymine / RNA is a single strand, DNA is a double strand (1)

(b) State one structural feature that DNA and RNA have in common. **(1)**

✓ both are polymers of nucleotides / both have a phosphate group / pentose sugar / nucleotides joined by phosphodiester bonds (any one) (1)

(c) mRNA is a relatively short-lived molecule. Suggest why this is an advantage to a cell. **(2)**

✓ the (gene/protein) products are only made when needed / for a short time (1)

✓ so the cell can control which proteins are made and stop production when no longer needed (1)

14. A scientist analysed the base composition of a length of double-stranded DNA. The DNA contained 600 base pairs in total, of which 180 were guanine-cytosine pairs.

(a) Calculate the number of cytosine bases present in this length of DNA. Show your working. **(2)**

✓ each G-C pair has 1 cytosine, so cytosine = 180 (1)

✓ (180 cytosine bases in total) (1)

(b) Calculate the number of adenine bases present in this length of DNA. Show your working. **(3)**

✓ total bases = 600 × 2 = 1200 (1)

✓ G + C bases = 180 × 2 = 360, so A + T bases = 1200 - 360 = 840 (1)

✓ adenine = 840/2 = 420 (1)

15. This question is about the energy released from ATP and its re-synthesis in a cell.

(a) Explain why cells contain only small amounts of ATP at any one time, even though large amounts are used. **(2)**

✓ ATP is constantly broken down and re-synthesised (recycled) (1)
✓ so it does not need to be stored in large amounts (it is made as needed) (1)

(b) The phosphorylation of ADP to form ATP is described as an energy-requiring reaction. Suggest where the energy for this comes from in a respiring cell. **(1)**

✓ from (the breakdown of glucose in) respiration (1)

(c) Explain why a small, soluble molecule such as ATP, rather than glucose, is used as the immediate source of energy for processes such as active transport. **(3)**

✓ the energy from glucose is released slowly / in many steps, ATP releases energy in one quick step (1)
✓ ATP releases a small/usable amount of energy so little is wasted (1)
✓ ATP can be readily hydrolysed at the site where energy is needed (1)

16. This question is about the importance of hydrogen bonding in biological molecules.

(a) Explain how hydrogen bonding contributes to the stability of a DNA molecule, even though each individual hydrogen bond is weak. **(2)**

✓ there are many/a large number of hydrogen bonds (between the two strands) (1)
✓ so cumulatively/together they hold the strands firmly / make the molecule stable (1)

(b) Explain why DNA molecules with a higher proportion of cytosine-guanine pairs are more stable (and have a higher melting temperature) than those with more adenine-thymine pairs. **(3)**

✓ cytosine and guanine form three hydrogen bonds between them (1)
✓ whereas adenine and thymine form only two hydrogen bonds (1)
✓ so more energy is needed to separate the strands / break the (greater number of) hydrogen bonds (1)

(c) Explain how hydrogen bonding between water molecules gives water a high specific heat capacity, which buffers temperature changes in cells. **(2)**

✓ hydrogen bonds must be broken before water molecules can move faster / gain kinetic energy (1)
✓ so a lot of energy is needed to raise the temperature, keeping the cell temperature stable (1)