HL Paper 2

a. Outline the structure of a ribosome. [4]

b. Distinguish between fibrous and globular proteins with reference to **one** example of each protein type. [6]

c. Auxin is a protein. Explain its role in phototropism. [8]

Markscheme

a. small subunit and large subunit;

mRNA binding site on small subunit;

three tRNA binding sites / A, P and E tRNA binding sites;

protein and RNA composition (in both subunits);

b. fibrous proteins are strands/sheets whereas globular proteins are rounded;

fibrous proteins (usually) insoluble whereas globular proteins (usually) soluble;

globular more sensitive to changes in pH/temperature/salt than fibrous;

fibrous proteins have structural roles / other specific role of fibrous protein;

globular proteins used for catalysis/transport/other specific role of globular protein;

another role of globular protein;

named fibrous proteins *e.g.* keratin/fibrin/collagen/actin/myosin/silk protein;

named globular protein *e.g.* insulin/immunoglobulin/hemoglobin/named enzyme;

Do not accept statements about fibrous proteins having only secondary structure and globular proteins having only tertiary structure.

c. auxin is a plant hormone;

produced by the tip of the stem/shoot tip;

causes transport of hydrogen ions from cytoplasm to cell wall;

decrease in pH / H^+ pumping breaks bonds between cell wall fibres;

makes cell walls flexible/extensible/plastic/softens cell walls;

auxin makes cells enlarge/grow;

gene expression also altered by auxin to promote cell growth;

(positive) phototropism is growth towards light;

shoot tip senses direction of (brightest) light;

auxin moved to side of stem with least light/darker side

causes cells on dark side to elongate/cells on dark side grow faster;
Accept clearly annotated diagrams for phototropism marking points.

Examiners report

a. Part (a) was generally well answered with many candidates scoring marks by including annotated drawings of ribosomes.

b. Part (b) was also answered well in many cases with most giving acceptable examples of globular and fibrous proteins and their roles. There were some doubtful statements about levels of protein structure. Although tertiary structure is more significant in globular than in fibrous proteins, it is not true to say that fibrous proteins have secondary structure and globular proteins have tertiary and quaternary structure. Most globular proteins have regions of secondary structure. Collagen, perhaps the best example of a fibrous protein, has neither α-helices nor β-pleated sheets within its structure and as it has three polypeptides wound together collagen has quaternary structure.

c. There was an error in (c) for which the examiners apologise: auxin is of course not a protein and is instead indole ethanoic acid in its naturally occurring form. Unfortunately this mistake was propagated in many candidates" answers. Knowledge of the physiology of phototropism was good. The best answers included details of how auxin is moved between cells and its effects on cell walls and growth of cells.

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b. Outline the light-dependent reactions of photosynthesis. [6]

c. Explain the effect of light intensity and temperature on the rate of photosynthesis. [8]

Markscheme

b. (chlorophyll/antenna) in photosystem II absorbs light;

absorbing light/photoactivation produces an excited/high energy/free electron;

electron passed along a series of carriers;

reduction of $NADP^+$ / generates $NADPH + H^+$;

absorption of light in photosystem II provides electron for photosystem I;

photolysis of water produces H^+/O_2 ;

called non-cyclic photophosphorylation;

in cyclic photophosphorylation electron returns to chlorophyll;

generates ATP by H^+ pumped across thylakoid membrane / by chemiosmosis / through ATP synthetase/synthase;

c. both light and temperature can be limiting factors;

other factors can be limiting;

graph showing increase and plateau with increasing light / description of this;

graph showing increase and decrease with increasing temperature / description of this;

light:
affects the light-dependent stage;
at low intensities insufficient ATP;
and insufficient NADPH + H^+ produced;
this stops the Calvin cycle operating (at maximum rate);

temperature:
affects light-independent stage / Calvin cycle;
temperature affects enzyme activity;
less active at low temperatures / maximum rate at high temperatures;
but will then be denatured (as temperature rises further);
*Award **[5 max]** if only one condition is discussed*

Examiners report

b. This gave the stronger candidates an opportunity to demonstrate the sophistication of their understanding of the photochemistry of the light-dependent reactions. There were some exemplary answers. Weaker candidates tended to give partial accounts with errors of understanding and the weakest candidates gave only a broad outline of what is achieved by photosynthesis.

c. The challenge was to explain in sufficient detail the effects of light intensity and temperature on the rate of photosynthesis. Weaker candidates tended outline the effects (assessment statement 3.8.8) rather than explain them (assessment statement 8.2.8), which often only gave them two marks. Rather few candidates gave convincing explanations of light intensity and temperature in terms of rate-limiting steps. This question was therefore highly discriminating, helping to separate the most able and best prepared candidates from others.

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a. Distinguish between RNA and DNA. [3]

b. Explain the process of DNA replication. [8]

c. Outline how enzymes catalyse reactions. [7]

Markscheme

a. DNA is double-stranded while RNA is single-stranded;

DNA contains deoxyribose while RNA contains ribose;

the base thymine found in DNA is replaced by uracil in RNA;

one form of DNA (double helix) but several forms of RNA (tRNA, mRNA and rRNA);

b. occurs during (S phase of) interphase/in preparation for mitosis/cell division;

DNA replication is semi-conservative;

unwinding of double helix / separation of strands by helicase (at replication origin);

hydrogen bonds between two strands are broken;

each strand of parent DNA used as template for synthesis;

synthesis continuous on leading strand but not continuous on lagging strand;

leading to formation of Okazaki fragments (on lagging strand);

synthesis occurs in 5'→3' direction;

RNA primer synthesized on parent DNA using RNA primase;

DNA polymerase III adds the nucleotides (to the 3' end)

added according to complementary base pairing;

adenine pairs with thymine and cytosine pairs with guanine; (*Both pairings required. Do not accept letters alone.*)

DNA polymerase I removes the RNA primers and replaces them with DNA;

DNA ligase joins Okazaki fragments;

as deoxynucleoside triphosphate joins with growing DNA chain, two phosphates broken off releasing energy to form bond;

Accept any of the points above shown on an annotated diagram.

c. they increase rate of (chemical) reaction;

remains unused/unchanged at the end of the reaction;

lower activation energy;

activation energy is energy needed to overcome energy barrier that prevents reaction;

annotated graph showing reaction with and without enzyme;

substrate joins with enzyme at active site;

to form enzyme-substrate complex;

active site/enzyme (usually) specific for a particular substrate;

enzyme binding with substrate brings reactants closer together to facilitate chemical reactions (such as electron transfer);

induced fit model / change in enzyme conformation (when enzyme-substrate/ES complex forms);

making the substrate more reactive;

Examiners report

a. Many of the candidates scored full marks.

b. Despite some confusion about which enzyme does what and confusing DNA replication with transcription/translation, many candidates managed to gain full marks. A good number indicate that an RNA primer begins replication on the lagging strand only. Another common error was to refer to the gaps rather than the fragments as Okazaki fragments. Some candidates confused replication with translation.

c. Many candidates lost marks by focusing on factors affecting the rate of enzyme controlled reactions and inhibition and missed the basics. Nearly all mentioned the lowering of activation energy, but many were not able to describe how this is done. Diagrams that were included could have earned more marks if they were more carefully drawn, with axes labels being more carefully included and differences in energy between reactants and products being more accurately represented. Few indicated that the enzyme was not used up in the reaction.

a. Define the *active site* of an enzyme. [1]

b. Explain how the active site promotes enzyme–substrate specificity. [2]

c. Outline possible effects of acids on enzyme activity. [2]

Markscheme

a. region/site where a substrate binds

b. a. shape of active site matches that of the substrate;

b. chemical properties/charges of active site attract the substrate;

c. active site can change to induce fit of substrate;

c. a. changes the charge/ionization of amino acids/R-groups;

b. changes 3-D structure (of active site)/tertiary structure / denatures enzyme;

c. substrate no longer binds/fits so decreases activity;

d. could increase activity if optimum pH of enzyme is acidic;

Examiners report

a. Most students knew the correct definition of active site.

b. Better prepared candidates got full marks discussing induced fit. Chemical compatibility was discussed more rarely. Students had surprising difficulty describing the relationship between the shape of the substrate and the shape of the active site.

c. This question differentiated performance well. Many stated that acids denature enzymes. Better prepared candidates mentioned increased activity for enzymes with an optimum pH that was acidic. Better prepared candidates also referenced the altered shape of the active site.

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a. Draw a labelled diagram showing **two** different complementary pairs of nucleotides in a molecule of DNA. [4]

b. Outline the structure of nucleosomes. [2]

c. Explain primary structures and tertiary structures of an enzyme. [3]

Markscheme

a. *The structures underlined must be labelled.*

at least one nucleotide with deoxyribose linked to base and phosphate;{ *Labels need not be on the same nucleotide. Do not allow sugar.*

phosphate and deoxyribose linked C_3 to C_5;{ *Position required, not label. Straight line from C_4 to phosphate is acceptable. Do not penalize if the second strand is not antiparallel and the bonding is therefore incorrect on it.*

(complementary) bases labelled with at least one of each of A, G, T and C correctly linked to C_1;

hydrogen bonds between correct complementary bases;{ *Bond numbers not required.*

correct antiparallel orientation shown; (*as seen by shape or orientation of sugar*)

b. (eight) histone (proteins);

DNA wrapped around histones/nucleosome;

further histone holding these together;

Do not allow histone wrapped around DNA.

c. primary structure is (number and) sequence of amino acids;

joined by peptide bonds;

tertiary structure is the folding of the polypeptide/secondary structure/alpha helix;

stabilized by disulfide/ionic/hydrogen bonds/hydrophobic interactions;

tertiary structure gives three dimensional globular shape/shape of active site;

Examiners report

a. This was often well answered, with many candidates scoring four marks. The sugar was sometimes labelled as ribose rather than deoxyribose, or simply as sugar. Another common error was to link the phosphate groups to the oxygen in the sugar ring, rather than to C_4 via C_5.

Stronger candidates often drew impressively detailed and accurate diagrams, with the antiparallel orientation of the strands, the numbers of hydrogen bonds and the molecular structure of deoxyribose and phosphate groups correctly shown. It was possible to score four marks without all of this detail, but it was good to see such high quality answers.

b. This was also well answered by properly prepared candidates. A few misread the question and outlined the structure of nucleotides rather than nucleosomes.

c. This was more poorly answered than expected. Perhaps candidates who knew about the primary and tertiary structure of proteins were unable to transfer this knowledge to a question about enzymes, though they surely knew that enzymes are globular proteins. Many of the candidates who did write about primary and tertiary structure failed to include the essential detail that primary structure is the sequence or order of amino acids. There was some confusion between secondary and tertiary structure and also some over-simplified accounts of tertiary structure. Some candidates stated simply that tertiary structure is three-dimensional structure. It was expected that candidates should at least include the idea that enzymes are globular in their three-dimensional structure.

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a. Draw a labelled diagram of a prokaryotic cell. [4]

b. Outline transcription in prokaryotes. [6]

c. Some prokaryotes cause infectious disease in humans. Explain the principles of vaccination. [8]

Markscheme

a. *Award [1] for each structure clearly drawn and correctly labelled, up to [4 max].*

a. cell wall – a uniformly thick wall;

b. pili – hair-like structures connected to cell wall / flagellum – at least length of the cell;

c. plasma/cell membrane – represented by a continuous single line; *(may be labelled as the innermost wall line)*

d. ribosomes (70S) – drawn as small discrete dots;

e. naked DNA/nucleoid – region with DNA not enclosed in membrane;

f. plasmid – circular ring of DNA;

g. cytoplasm – the non-structural material within the cell;

Award [2 max] if any eukaryotic structure is shown.

b. a. transcription is the copying of a strand of DNA into RNA/RNA formation;

b. RNA polymerase binds to promoter region of DNA;

c. anti-sense strand as template / only one strand copied;

d. RNA polymerase unwinds DNA/separates the strands;

e. RNA nucleotides/nucleoside triphosphates pair with complementary bases on DNA;

f. Adenine to Thymine, Cytosine to Guanine, and Uracil to Adenine; *(do not accept letters alone)*

g. added at 3' end / strand grows 5' to 3' ;

h. RNA nucleotides joined with covalent/sugar-phosphate bonds;

i. RNA polymerase separates from DNA when reaches terminator/termination sequence;

j. no introns/post-transcriptional modification/RNA splicing (as occurs in eukaryotes);

c. a. vaccines contain a dead/weakened form of the pathogen/bacteria/virus;

b. vaccine introduced to the body by injection/on surface of skin/orally;

c. antigens in the vaccine cause antibody production;

d. antigen/pathogen engulfed by macrophage/phagocyte;

e. each type of lymphocyte recognizes specific antigen;

f. macrophages activate helper T-cells;

g. which activate B-cells;

h. B-cells divide to form clones/memory cells;

i. B-cells divide to form plasma cells/antibody producing cells;

j. result is (specific) immunity;

k. vaccination/first exposure causes slow production of antibodies and lower level of antibodies; *(this idea can be illustrated on a diagram or graph)*

l. contact with the disease leads to rapid production and higher level of antibodies; *(this idea can be illustrated on a diagram or graph)*

m. second/booster shot to stimulate memory cells/more production of antibodies;

Examiners report

a. Overall, candidates performed very well on this question.

The diagram in 5a was well drawn by most. A number of students included eukaryotic structures in their drawings. Flagella were often drawn too short in relation to the overall length of the cell. Pilli were often poorly drawn being shown not connected to the cell. The diameter of ribosomes was often too large in relation to the rest of cell structures.

b. Overall, candidates performed very well on this question.

Many were able to outline transcription successfully. Some confused transcription with replication. A number referred to helicase as the enzyme responsible for separating and unwinding the helix.

c. Overall, candidates performed very well on this question.

Most scored well on part c of the question. An area of misunderstanding surrounds what happens upon second exposure to the antigen. It should be noted that antibodies are produced more rapidly and to a higher level.

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a. Describe how plants carry out gas exchange in the leaves. [5]

b. Outline the causes and consequences of the enhanced greenhouse effect. [5]

c. Explain the role of limiting factors in photosynthesis. [8]

Markscheme

a. gases/O_2 and CO_2 enter/exit the leaf through the stomata;

by diffusion / down the concentration gradient;

photosynthesis maintains concentration gradients/high O_2 and low CO_2 in the leaf;

guard cells open the stomata during the day / close the stomata at night;

gases/O_2/CO_2 move through air spaces in the spongy (mesophyll);

CO_2 dissolves in moisture in (mesophyll) cell walls;

b. burning of (fossil) fuels/coal/oil/gas releases carbon dioxide;

deforestation/loss of ecosystems reduces carbon dioxide uptake;

methane emitted from cattle/livestock/melting permafrost/waste dumps;

heating of the atmosphere/global warming/climate change;

melting of ice caps/glaciers/permafrost / sea level rise / floods / droughts / changes in ocean currents / more powerful hurricanes / extreme weather events / other abiotic consequence;

changes in species distributions/migration patterns / increased decomposition rates / increases in pest/pathogen species / loss of ice habitats / other biotic consequence;

c. factor nearest its minimum/furthest from its optimum is limiting;

increasing a limiting factor with other factors constant increases the rate;

increasing a non-limiting factor with other factors constant has no effect on rate;

light intensity is limiting in dim/low intensity light / at night;

photosynthesis (directly) proportional to intensity up to plateau / graph to show this;

light intensity affects the light-dependent reactions/production of ATP/NADPH;

temperature limiting at low and high temperatures;

optimum temperature with lower rates above and below plateau / graph to show this;

low temperatures limit the rate of light-independent reactions/Calvin cycle;

RuBP carboxylase/rubisco does not fix carbon dioxide at high temperatures;

carbon dioxide concentration is limiting in bright light and warm temperatures;

photosynthesis is (directly) proportional to CO_2 concentration up to plateau / graph to show this;

low CO_2 concentration limits carbon fixation/reaction between CO_2 and RuBP;

Examiners report

a. This question was based on assessment statement 9.1.3, which includes the relationship between the structure of the leaf and its role in gas exchange. All that was needed was an outline of the structure of the spongy mesophyll, guard cells and stomata, in relation to the diffusion of carbon dioxide into the leaf and oxygen out. Scores were typically poor, with many candidates missing the basic points. More candidates for example for example seemed to state that CAM plants open their stomata for gas exchange at night than that most plants open their stomata in the day.

b. Scores were mostly much better in this part of the question, with nearly all candidates at least mentioning warming due the enhanced greenhouse effect and an example of the abiotic and biotic consequences. The cause of the enhanced greenhouse effect was less well understood, with vagueness about what is causing carbon dioxide levels to increase and other greenhouse gases often not mentioned. There was considerable confusion, as so often, between ozone depletion and the greenhouse effect. It is easy to assume that candidates will be able to distinguish between these two phenomena easily and that little teaching is required, but all those who marked this exam will know that careful teaching is very much required.

c. This was another area of relatively poor understanding, perhaps because weaker candidates tended to choose question 7. A basic minimum was to know that light intensity, temperature and carbon dioxide concentration are the three main limiting factors of photosynthesis. Many failed at this first hurdle, omitting one or more of the main three and including instead pH, water availability or various other biotic and abiotic factors. Perhaps some candidates were confusing enzyme activity with photosynthesis. What was required for each of the three factors was a clear statement of the relationship between the level of the variable and the rate of photosynthesis, ideally by means of an annotated sketch graph, and then some details of the reasons for the rate of photosynthesis changing as the level of the variable changed. A common misconception was to say that the rate reduces at higher temperatures because of enzyme denaturation when in fact the rate reduction occurs at much lower temperatures than those at which this would happen. The problem at higher temperatures is due to RuBP carboxylase failing to fix carbon dioxide effectively.

a. Outline the thermal, cohesive and solvent properties of water. [5]

c. Explain the role of the kidney in maintaining water balance in humans. [9]

Markscheme

a. water has a high specific heat capacity;

a large amount of heat causes a small increase in temperature;

water has a high latent heat of vaporization;

a large amount of heat energy is needed to vaporize/evaporate water;

hydrogen bonds between water molecules make them cohesive/stick together;

this gives water a high surface tension / explains how water rises up xylem;

water molecules are polar;

this makes water a good solvent;

*Award **[4 max]** if thermal, cohesive and solvent properties are not all mentioned.*

c. process of water balance is called osmoregulation;

water passes into the kidney tubules by ultrafiltration;

water is reabsorbed in the proximal convoluted tubule;

water reabsorbed into blood from the (descending limb) of the loop of Henle;

process by osmosis;

transport of salts into the medulla of kidney;

changes salt concentration so water is reabsorbed;

ADH released into blood when water is required;

ADH causes concentrated urine / no/low ADH causes dilute urine;

this causes more reabsorption of water from the collecting duct;

excess water is released as urine;

urine concentration depends on the body's need for water;

drinking a lot gives dilute urine;

Examiners report

a. Many candidates missed out on one of the thermal marks as they omitted the large specific heat capacity. Very few students failed to gain a mark in this section.

c. Only very few candidates scored full marks in this section. There were few correct mentions of ultrafiltration, and many some candidates who described it correctly were more determined to describe the reabsorption of glucose and salts rather than water. The role of ADH was well understood, although weaker candidates were confused as to its actual site of action.

a. Outline the bonding between DNA nucleotides. [2]

b. Explain how chemical bonding between water molecules makes water a valuable coolant in living organisms. [2]

c. State a word equation for anaerobic cell respiration in humans. [1]

Markscheme

a. hydrogen bonds between nucleotides on opposite strands/ complementary bases/adenine and thymine and cytosine and guanine;

(*reject letters instead of base names*)

covalent bonds between nucleotides within strands/between sugar/deoxyribose and phosphate;

b. hydrogen bonding between water molecules;

breaking (hydrogen bonds) needs/removes energy/heat;

hydrogen bonds must break when water evaporates/vaporizes;

c. pyruvate/pyruvic acid →lactate/lactic acid;

glucose → (pyruvate/pyruvic acid) → lactate/lactic acid;

Accept correct chemical equation with formulae.

Examiners report

a. Almost all candidates knew something about the bonding between nucleotides but in some cases the answers were not precise enough to be awarded marks. A common fault was to describe bonding within nucleotides rather than between nucleotides.

b. Many candidates knew that hydrogen bonds form between water molecules, but often the remainder of the answer was weak. A common misunderstanding was revealed by candidates who stating that hydrogen bonds are strong and therefore take large amounts of energy to break. It should be stressed that individual hydrogen bonds are in fact weak, but because water molecules are small, large numbers of hydrogen bonds are formed within water so collectively they have significant effects. Another area of misunderstanding was the difference between the energy needed to heat up water (heat capacity) and the energy needed to evaporate water. Sweating and transpiration have cooling effects because of the energy needed for evaporation, not raising the temperature of water.

c. Less than half of candidates were able to give an equation for anaerobic cell respiration in humans. Many included oxygen, carbon dioxide or water in their equation and so were not awarded the mark. Others gave an equation for yeast rather than humans. In some cases the answer was not given in the form of an equation but as long as the substrate and product was correct, the mark was awarded. Both pyruvate and glucose were accepted as the substrate, though glucose was preferable.

a. Draw a labelled diagram to show the structure of the plasma membrane. [5]

b. The light-dependent reactions in photosynthesis take place on the thylakoid membranes. Explain the light-dependent reactions. [8]

c. Outline two factors that affect the rate of photosynthesis. [5]

Markscheme

a. **Remember, up to TWO "quality of construction" marks per essay.**

*Award **[1]** for each structure clearly drawn and correctly labelled.*
a. phospholipid bilayer – *with head and tails*;
b. hydrophilic/phosphate/polar heads and hydrophobic/hydrocarbon/fatty acid/non-polar tails labelled;
c. integral/intrinsic protein – *embedded in the phospholipid bilayer*;
d. protein channel – *integral protein showing clear channel/pore*;
e. peripheral/extrinsic protein – *not protruding into the hydrophobic region*;
f. glycoprotein with carbohydrate attached – *carbohydrate should be outside the bilayer*;
g. cholesterol – *positioned across one half of bilayer and not protruding*;
h. thickness indicated (10 nm); *(allow answers in the range of 7 nm to 13 nm)*

b. **Remember, up to TWO "quality of construction" marks per essay.**

a. (chlorophyll/pigments/antenna complex) in photosystem II absorb light;
b. light/photoactivation produces an excited/high energy/free electron;
c. electrons pass from carrier to carrier/along electron transport chain/e.t.c.;
d. protons pumped across thylakoid membrane/into thylakoid space;
e. ATP produced (by the light dependent reactions);
f. ATP production by chemiosmosis/by ATP synthase/ATP synthetase;
g. electrons from photosystem II passed to photosystem I;
h. light/photoactivation excites electrons in photosystem I (to higher energy level);
i. production of NADPH/reduction of $NADP^{(+)}$ (using electrons from photosystem I); (reject NAD in place of NADP. Accept reduced NADP instead of NADPH)
j. electrons from photolysis (needed) for photosystem II;
k. oxygen from photolysis is a waste product/by-product/passes out/excreted;
l. in cyclic photophosphorylation electrons from photosystem I return to it;

c. **Remember, up to TWO "quality of construction" marks per essay.**

a. (increase in) light (intensity) increases rate (of photosynthesis);
b. until a plateau is reached at higher light intensities/when another factor is limiting;
c. light needed for light dependent reactions/example of light dependent reaction;
d. (increase in) temperature/heat increases the rate (of photosynthesis);
e to an optimum temperature above which the rate drops;
f. temperature/heat affects rate of Calvin cycle/enzyme activity/rubisco activity;
g. (increase in) carbon dioxide (concentration) increases rate (of photosynthesis);
h. until a plateau is reached at higher CO_2 levels/when another factor is limiting;
i. CO_2 needed for light independent reactions/Calvin cycle/carboxylation of RuBP/production of glycerate phosphate;

If the candidate outlines more than two factors, only mark the first two.
Accept the first two points relating to each factor if clearly shown on a graph with both axes appropriately labelled.
Accept level instead of concentration, intensity or rate.
Do not accept enzyme denaturation as a reason for reductions in photosynthesis at higher temperatures.

Examiners report

a. Structure of the plasma membrane

Of the three diagrams tested on this exam paper, this was drawn most successfully with many candidates scoring full marks. Some candidates misinterpreted the question and drew a diagram of a whole eukaryotic cell with a plasma membrane around its margin. On diagrams showing the expected structure the commonest errors were to place particular types of proteins or cholesterol in the wrong position.

b. Light-dependent reactions of photosynthesis

Answers were polarised with strong candidates writing accurate and detailed accounts of the light dependent reactions but other candidates revealing very little knowledge. Diagrams were sometimes included at the start of the answer but they often didn't help because they were not annotated fully enough to make any of the points on the mark scheme.

c. Factors affecting the rate of photosynthesis

Only light intensity, temperature and carbon dioxide concentration were accepted here. Candidates could score two marks for any two of these factors by showing the trend in a graph or by describing it in text but for other marks the answer had to include a cause of the effect of the factor, for example rising temperature increasing the activity of enzymes in the Calvin cycle. Denaturation was not accepted as a cause of decreasing photosynthesis at higher temperatures because the decreases happen at much lower temperatures than would cause denaturation.

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a. State **four** functions of proteins, giving a **named** example of each. [4]

b. Outline the structure of ribosomes. [6]

c. Explain the process of transcription leading to the formation of mRNA. [8]

Markscheme

a. a. structure – collagen;

b. transport – transthyretin / hemoglobin;

c. enzyme/catalyst – lysozyme;

d. movement – actin / tubulin;

e. hormones – insulin;

f. antibodies – immunoglobulin;

g. storage – albumin;

Accept any other valid function of proteins with a named example.

For example sodium potassium pump, but do not accept simply "in membranes" without a clear function.

To award [4 max], responses need a function of protein and a named example.

Only accept the first four answers.

b. a. made of protein;

b. made of rRNA;

c. large subunit <u>and</u> small subunit;

d. three tRNA binding sites;

e. Aminacyl/A, Peptidyl/P and Exit/E;

f. mRNA binding site (on small subunit);

g. 70S in prokaryotes / 80S in eukaryotes;

h. can be free / bound to RER (in eukaryotes);

c. a. RNA polymerase; *(polymerase number is not required)*

b. binds to a promoter on the DNA;

c. unwinding the DNA strands;

d. binding nucleoside triphosphates;

e. to the antisense strand of DNA;

f. as it moves along in a 5'→3' direction;

g. using complementary pairing/A-U and C-G;

h. losing two phosphates to gain the required energy;

i. until a terminator signal is reached (in prokaryotes);

j. RNA detaches from the template and DNA rewinds;

k. RNA polymerase detaches from the DNA;

l. many RNA polymerases can follow each other;

m. introns have to be removed in eukaryotes to form mature mRNA;

Examiners report

a. Most candidates gained some marks here with knowledge of functions of proteins with examples. However many answers were very descriptive rather than “stating with an example” as asked.

b. Most knew about the two ribosome subunits and the mRNA binding site. Very few knew that they were made from protein and rRNA. Several answered that there were 3 binding sites, but not what was bound there (tRNA) or what they were called.

c. The process of transcription was well known by most candidates who attempted this question.

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a. Outline the role of condensation and hydrolysis in the relationship between amino acids and polypeptides. [4]

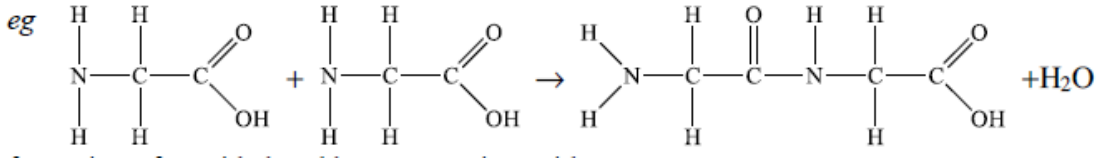
b. The protein hemoglobin transports oxygen to cells. Describe the processes that occur in the mitochondria of cells when oxygen is present. [8]

c. Sickle-cell anemia affects the ability of red blood cells to transport oxygen.Explain the consequence of the mutation causing sickle-cell anemia in relation to the processes of transcription and translation. [6]

Markscheme

a. *Award [3 max] for condensation reactions*

Condensation reactions:
condensation is two molecules joining (by a covalent bond) with the loss of a water molecule;
example of condensation reaction;



formation of peptide bond between amino acids;
(covalent) bond between carboxyl end of one amino acid molecule and amino end of other;
many amino acids joined by condensation to form polypeptide;

Hydrolysis reactions:
hydrolysis is the addition of water to break a large molecule into smaller ones;
polypeptide broken down into amino acids/dipeptides by hydrolysis;
Award any of the above points for a clearly drawn correctly annotated diagram.

b. pyruvate decarboxylated/CO_2 is removed and reduced NAD/NADH + H^+ is formed (when entering mitochondrion);

(both needed)

2-C molecule/acetyl group reacts with (reduced) coenzyme A to form acetyl CoA;

acetyl CoA enters Krebs cycle;

2 CO_2 molecules removed (as waste);

energy/electron rich NADH + H^+/$FADH_2$ formed;

for each turn of cycle/each pyruvate, 3 NADH + H^+ and 1 $FADH_2$ formed;

1 ATP formed per pyruvate each turn (by substrate-level phosphorylation);

reduced NAD/NADH + H^+ and $FADH_2$ enter electron transport chain/ETC;

oxidative phosphorylation uses energy released by ETC to synthesise ATP;

as electrons move along ETC, protons/H^+ move into intermembrane space;

creates H^+ gradient across the membrane;

ATP synthesized by flow of H^+ back across membrane through ATP synthase;

ATP synthesized by chemiosmosis;

ETC reduces oxygen/oxygen is final hydrogen (and electron) acceptor forming water;
Award any of the above points for a clearly drawn correctly annotated diagram.
Accept reduced NAD and $NAD^+ + H^+$ as alternatives to each other.

c. caused by single base substitution (mutation);

mutation in gene coding for (one of) polypeptide chain in hemoglobin/HbA;

GAG (on sense strand of DNA) mutated to GTG;

when transcribed, RNA sequence/codon becomes GUG rather than GAG;

during translation, have one amino acid substituted for another;

causes glutamic acid/glutamate to be replaced by valine;

change alters folding of Hb protein/makes RBCs sickle-shaped (in low oxygen);

sickle shaped cells block capillaries/cause tissue damage and pain;

Award any of the above points for a clearly drawn correctly annotated diagram.

(Plus up to [2] for quality)

Examiners report

a. Most were able to gain some marks on hydrolysis and condensation. Very few diagrams/ structures were completely correct.

b. The processes inside the mitochondria were well known by the better prepared candidates, who were able to explain in detail. Several candidates just tried to draw a diagram of the Krebs cycle without any annotation, hoping that the examiners would find some marks. A well annotated diagram can achieve full marks, but it must be clear. Many risked losing the quality marks by describing glycolysis in great detail, thus giving the impression that they were simply writing down everything they knew instead of answering the question.

c. Most knew that Sickle Cell Anaemia is due to a mutation, but only the better ones were able to correctly state that it was a single base substitution. Few correctly described that the mutation was in (one of) the polypeptide chain of Haemoglobin(A), with many vague statements attributing it to erythrocyte instead. Nearly every candidate remembered that glutamic acid was replaced by valine. Unfortunately this was the only mark gained by many.

---

a. Draw a labelled diagram of the digestive system. [4]

b. Many people cannot digest lactose and benefit from a diet containing no lactose. Outline the production of lactose-free milk. [6]

c. Explain how the kidney helps to retain useful substances in the blood and eliminate substances which the body does not need. [8]

Markscheme

a. *Award **[1]** each for the following structures clearly drawn and correctly labelled.*

esophagus – connected to top of stomach;

stomach – connected to small intestine;

small and large intestines – connected to each other;

liver shown as larger than the stomach with gall bladder shown under/embedded in liver;

gall bladder – connected to the small intestine (via bile duct);

pancreas – connected to small intestine (via pancreatic duct);

b. milk contains lactose / lactose is milk sugar;

lactose is broken down to glucose and galactose;

by (the enzyme) lactase;

which is lacking in people with lactose intolerance;

lactose-free milk is sweeter than milk containing lactose;

lactase produced by small intestine / produced by yeast sometimes found in milk;

can be added directly to milk;

immobilized in beads / biotechnological techniques;

ultrafiltration of milk to remove lactose;

c. ultrafiltration occurs in the glomerulus;

basement membrane acts as a filter;

preventing proteins/cells from passing;

(filtered) substances pass to the Bowman's capsule;

to proximal convoluted tubule (PCT);

(where there is) selective reabsorption;

(in PCT) all glucose/amino acids are reabsorbed;

(in PCT most) water reabsorbed;

surrounding the loop of Henle, is an area of high solute concentration;

in distal convoluted tubule, ions are exchanged between filtrate and blood;

collecting duct has role in osmoregulation;

ADH regulates the amount of water reabsorbed;

substances not reabsorbed are eliminated as urine;

Examiners report

a. The examiners do realise that they are not testing artistic ability. However all diagrams should be large enough and clear enough to show the connections between the parts. In addition, as the papers are now scanned, the lines should be bold, as should the labelling arrows. Marks were lost for not clearly showing that the oesophagus connected to the stomach, the stomach connected to the small intestine and the small intestine to the large. The location of the connection between the large and small intestine was not well known. The pancreas seemed to float around without any duct leading to the small intestine as did the liver and gall bladder. The liver was often drawn too small.

b. Most students were quite knowledgeable about lactose intolerance though there were a lot of misspelled words as well as incorrectly applied terms.

c. The knowledge of the workings of the kidney seemed to be very school-specific, with whole schools seeming to know little more than there is some filtering at the start and urine is produced in the end. Well-prepared candidates produced some impeccable answers.

---

a. List the general functions of non-membrane proteins. [4]

b. Outline the digestion, absorption and assimilation of proteins in humans. [6]

c. Actin and myosin are two proteins found in muscles. Explain how skeletal muscle contracts, including the interaction of these proteins. [8]

Markscheme

a. contraction / movement;

acts as a catalyst/enzymes / specific example of an enzyme function;

structure / support / specific example of a structural/support role;

transport;

defence / immunity;

as hormones / communication;

DNA packing / histones;

other function;

b. large molecules (proteins) must be digested into small molecules;

a protease/pepsin digests proteins into polypeptides;

pepsin works in the stomach / requires an acid/low pH/pH 2 to work;

polypeptides are digested by a protease/trypsin into amino acids;

trypsin acts in the small intestine / requires a basic pH/pH 8/high pH;

amino acids absorbed by diffusion/active transport;

absorption occurs in the villus/microvilli of the small intestine;

(amino acids absorbed) into capillaries;

blood carries amino acids throughout the body;

amino acids diffuse into cells/are absorbed by active transport;

cells use amino acids to build proteins;

assimilation is when amino acids become part of a cell;

proteins are synthesized at the ribosomes/ER of the cell;

c. motor neuron stimulates the muscle fibre;

calcium ions are released (from sarcoplasmic reticulum);

calcium ions bind to troponin;

tropomyosin moved / binding sites of actin revealed;

ATP binds (to myosin) causing cross-bridges to break;

ATP becomes ADP causing myosin heads to change angle/become cocked;

(myosin) heads attach to (new) actin sites/form cross-bridge;

ADP released;

myosin heads move actin filaments toward centre;

making sarcomere shorter;

calcium ions are reabsorbed (into the sarcoplasmic reticulum);

muscle fibre relaxes;

Award the above points if shown in a clearly drawn, correctly annotated diagram.

Examiners report

a. The two most common errors for this question occurred when students listed functions of proteins that were membrane proteins and when students were too vague regarding the statement of protein function.

b. Candidates here strayed from the reference to protein and did not correctly state the breakdown to polypeptides before amino acids. Candidates understood absorption but rarely showed understanding of assimilation. Candidates showed a surprisingly poor ability to summarize the processes involved in protein digestion. Frequently irrelevant aspects of digestion were included such as in the processes involved in digestion of fats and carbohydrates.

c. This question was generally well answered by the majority though the sequencing was often incorrect. The ATP cycle was poorly outlined in the majority of answers.

---

b. Explain how abiotic factors affect the rate of transpiration in terrestrial plants. [8]

c. Describe the importance of water to living organisms. [5]

Markscheme

b. a. less transpiration/water loss as (atmospheric) humidity rises;

b. air spaces inside leaf are saturated/nearly saturated (with water vapour);

c. smaller concentration gradient with higher atmospheric humidity;

d. more transpiration/water loss as temperature rises/with more heat;

e. faster diffusion / more kinetic energy (of water molecules);

f. faster evaporation (due to more latent heat available);

g. more transpiration/water loss as wind (speed) increases;

h. humid air/water vapour blown away from the leaf;

i. increasing the concentration gradient (of water vapour);

j. more transpiration/water loss in the light;

k. light causes stomata to open / stomata closed in darkness;

l. low CO_2 concentration inside leaf in bright light so stomata open wider;

Accept any of the points if clearly made on an annotated graph.

c. a. coolant in sweat/in transpiration;

b. water has a high heat of vaporisation / heat taken when hydrogen bonds break;

c. water is cohesive so can pulled up/so can be moved under tension in xylem;

d. water is an excellent/universal solvent/dissolves many different substances;

e. medium for transport in blood/xylem/phloem;

f. medium for metabolic reactions / (metabolic) reactions happen dissolved in water;

g. surface tension due to cohesion allows organisms to live on water surface;

h. water has high heat capacity so much energy required to change its temperature;

i. ice floats so lakes/oceans do not freeze allowing life under the ice;

j. high heat capacity so stable habitat/so temperature of water changes slowly;

k. used in chemical reactions/photosynthesis/hydrolysis in organisms;

Examiners report

b. Accounts of the effects of abiotic factors on the rate of transpiration were mostly good. Few candidates made the point that the air spaces inside the leaf are at or close to saturation with water vapour and very few knew that carbon dioxide concentration can influence transpiration rates through changes in stomatal aperture. Many accounts could have been improved by mentioning how steep concentration gradients are between the air spaces in the leaf and the air outside. This was relevant in relation to both atmospheric humidity and wind speed.

c. There were a lot of possible answers to this question on the importance of water so strong candidates had no difficulty in reaching five marks. Weaker answers were vague and incomplete and sometimes muddled up the properties of water such as coherence and adherence and the various thermal properties.

---

a. Outline the action of enzymes. [4]

b. Explain the roles of specific enzymes in prokaryote DNA replication. [7]

c. Many genetic diseases are due to recessive alleles of autosomal genes that code for an enzyme. Using a Punnett grid, explain how parents who do not show signs of such a disease can produce a child with the disease. [4]

Markscheme

a. Catalyse/speed up reactions

Substrate-specific

Lower the activation energy «of a chemical reaction»

Substrate collides with/binds to <u>active site</u>

Enzyme–substrate complex formed
OR
transition state formed
OR
bonds in substrate weakened

b. «DNA» gyrase/topoisomerase «II» prepares for uncoiling/relieves strains «in the double helix»

Helicase uncoils/unwinds the DNA/double helix

Helicase separates/unzips/breaks hydrogen bonds between the two strands of DNA

«DNA» primase adds an RNA primer/short length of RNA *Accept RNA primase.*

DNA polymerase III adds «DNA» nucleotides/replicates DNA/synthesizes complementary strand in a 5' to 3' direction

DNA polymerase III starts replication/adding nucleotides at the primer

DNA polymerase I removes the primer
OR
replaces RNA with DNA

«DNA» ligase seals the nicks
OR
links sections of replicated DNA
OR
links Okazaki fragments

DNA polymerase I/DNA polymerase III proofreads for mistakes

c. Key or text giving alleles with upper case for dominant allele and lower case for recessive allele/allele causing disease

Reject key showing a sex linked gene such as hemophilia.
Reject if X or Y chromosomes are shown with the alleles.
Accept Aa or any other upper and lower case letters.

Punnett grid showing that both parents can pass on either a dominant or a recessive allele in their gamete

For example row and column headings with A and a.
This mark can be awarded if X or Y chromosomes are shown but each parent has one recessive and one dominant allele as if for autosomal inheritance.

Four possible genotypes for child correctly shown on grid

AA, Aa, aA and aa for example.
This mark can be awarded if X or Y chromosomes are shown but the genotypes are correct for autosomal inheritance.

Double/homozygous recessive shown having the disease

Cannot be awarded with sex linkage.

25 % or 0.25 or 1/4 chance of inheriting the disease

This mark can be awarded if X or Y chromosomes are shown but the ratio is correct for autosomal inheritance.

Examiners report

a. This was generally well answered with most candidates able to give enough of the important features of enzyme action to score well. One mistake seen in a number of responses was to state that the active site is on the substrate rather than on the enzyme.

b. Knowledgeable candidates had no difficulty in scoring full marks by giving an accurate description of the role of enzymes in DNA replication. It was not necessary to focus on the leading and lagging strands as the action of the various enzymes is largely the same, though of course primers are repeatedly added to the lagging strand and then replaced. Some candidates were obviously concerned that they were being asked about prokaryote DNA replication. This is of course the type of DNA replication that is specified by the programme and has been for many years. It is worth making sure that candidates know that they have learned about this rather than eukaryote replication.

c. This part was very well answered with many candidates scoring full marks. There were a few errors in notation with different letters of the alphabet used for alleles of the same gene or X and Y chromosomes indicating confusion between autosomal and sex-linked genes.

Oxygen is needed to complete aerobic cell respiration.

a. Explain how chemical energy for use in the cell is generated by electron transport and chemiosmosis. [8]

b. Outline **four** different functions of membrane proteins. [4]

c. Distinguish between anabolism, catabolism and metabolism. [3]

Markscheme

a. a. NAD/FAD carries/is reduced by gaining «two» H «atoms»/«two» electrons

b. reduced NAD produced in glycolysis/link reaction/Krebs cycle

c. reduced NAD/FAD delivers electrons/hydrogen «atoms» to ETC

d. ETC is in mitochondrial inner membrane/cristae

e. electrons release energy as they flow along the chain/from carrier to carrier

f. electrons from ETC accepted by oxygen/oxygen is the final electron acceptor

g. proteins in the inner mitochondrial membrane/electron carriers act as proton pumps

h. protons pumped into intermembrane space/proton gradient across inner mitochondrial membrane/proton concentration higher in intermembrane space than in matrix

i. energy «from electrons» used to pump protons into intermembrane space/generate a proton gradient / high H^+ concentration is a store of «potential» energy

j. ATP synthase in inner mitochondrial membrane/cristae

k. energy released as protons pass down the gradient/through ATP synthase

l. ATP synthase converts ADP to ATP/phosphorylates ADP

m. oxidative phosphorylation «is ATP production using energy from oxidizing foods»

Accept H+ but not H/hydrogen in place of protons in any part of the answer.

Accept NADH or FADH in place of reduced NAD or FAD.

b. a. receptor/binding site for hormone/neurotransmitter

b. cell-to-cell communication / cell recognition

c. channels «for passive transport» / facilitated diffusion

d. pumps / active transport

e. cell adhesion

f. «immobilized» enzymes/enzymes embedded in the membrane

g. electron transport / electron carriers

c. a. metabolism is all enzyme-catalyzed reactions in a cell/organism/is anabolism plus catabolism

b. anabolism is synthesis of polymers/complex/larger molecules/larger substances «from smaller molecules/monomers»

c. catabolism is breaking down «complex» molecules/substances «into simpler/smaller ones/into monomers»

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

---

a. Water is essential to life on Earth. Outline **two** properties of water that are important for living organisms. [4]

c. Explain the roles of the structures in the kidney that maintain the water balance of the blood in humans. [8]

Markscheme

a. *solvent:* ***[2 max]***

good solvent;

due to polarity of water molecules many different substances dissolve in it;

most chemical reactions of living organisms occur in solution / transport medium;

cohesion: ***[2 max]***
cohesive/cohesion between adjacent water molecules;
due to hydrogen bonds;
long columns of water in xylem/transpiration stream / surface tension;

heat: ***[2 max]***
high heat capacity / large amounts of energy needed to change temperature;
energy needed to break hydrogen bonds;
important habitat as temperature more stable / blood disperses heat through body;

cooling: ***[2 max]***
evaporative cooling / high heat of vaporization/latent heat;
heat used to break hydrogen bonds so water can change to gas;
cooling effect of transpiration on leaves/sweat evaporation from skin/dogs panting;

greatest density at 4°C:
allows ice to form on top of water;
fish/living organisms are insulated below; [**4 max]**

(Accept first two properties only)

c. water is filtered freely from blood to Bowman's capsule;

majority/80 % of water in filtrate reabsorbed in proximal convoluted tubule;

water balance in blood controlled as filtrate passes through collecting duct;

descending loop of Henle has water channels/aquaporins/is permeable to water;

loop of Henle creates hypertonic conditions in medulla;

water moves from tubule to hypertonic more concentrated medulla;

ascending loop (of Henle) impermeable to water;

Na+/NaCl actively transported out of (thick portion of) ascending limb;

anti-diuretic hormone/ADH controls permeability of collecting duct to water;

ADH released when blood too concentrated/hypertonic / *vice versa;*

aquaporin channels (in collecting duct) allow water to exit;

collecting duct passes through increasing gradient in kidney/medulla;

gradient causes reabsorption of more water by osmosis;

small volumes excreted if solute concentration too high/blood too concentrated / *vice versa*;

(Plus up to [2] for quality)

Examiners report

a. Most knew something about the properties of water, with very weak candidates simply saying that we cannot live without it. Some confused high (specific) heat capacity and high (latent) heat of vaporisation.

c. The functioning of the kidney did not seem to have been taught in some centres, with some weaker candidates not knowing much more than the fact that it is where urine is produced.

---

a. Outline the effect of temperature and substrate concentration on the activity of enzymes. [4]

b. Distinguish between competitive and non-competitive enzyme inhibition of chemical reactions, giving an example of each. [5]

c. Explain the light-independent reactions of photosynthesis. [9]

Markscheme

a. enzymes most active at one temperature/optimum temperature;

any deviation from that temperature lowers the enzyme activity;

denaturing/change in active site/no activity at higher temperatures / inactivated at (very) low temperatures;

increasing the substrate concentration increases the enzyme activity/more enzyme-substrate complex formed/more collisions between enzyme and substrate;

eventually no increase in enzyme activity with increased substrate concentration / plateau when enzymes are working to the maximum/when all active sites occupied/saturated;

Accept answers shown graphically.

b. example of competitive; *(e.g. malonate competes with succinate dehydrogenase)*

example of non-competitive; *(e.g. opioids inhibit nitric oxide synthase)*

Competitive	Non-competitive
attaches to active site	attaches at place other than active site;
similar in structure to substrate	not similar to substrate;
does not change shape of enzyme	changes shape of enzyme;
increase in substrate concentration increases rate of reaction	increase in substrate concentration does not affect rate of reaction;

*Award **[2 max]** for examples and **[1]** for each correct paired statements up to **[3 max]**.*
Answers do not need to be shown in a table format.

c. take place in the stroma of the chloroplast;

produce carbohydrates;

ribulose bisphosphate/RuBP is a five carbon compound;

carbon dioxide fixed/added to RuBP / carboxylation;

by RuBP carboxylase (enzyme)/Rubisco;

forms unstable six carbon compound;

this splits into (two molecules of) glycerate-3-phosphate/GP;

ATP and NADPH produced in light-dependent reaction;

ATP provides the energy;

GP reduced to triose phosphate/TP;

NADPH provides hydrogen;

some three carbon sugars go to form hexose sugars;

some go to making more RuBP;

called the Calvin (Benson) cycle;

Examiners report

a. Was generally well answered with many candidates scoring marks by including annotated drawings of the changes in enzyme activity.

b. Was answered much more poorly, not due to a lack of understanding of the different types of inhibition, but due to not comparing equivalent factors. For example, most gained the mark for mp (c) for inhibitor attaching to the active site in competitive and to another site in non-competitive.

However, many mentioned similar structure to the substrate in the first but there was no equivalent comment for the second, thus no mark.

Few students could give specific examples of either. It was insufficient to say a heavy metal is a non-competitive inhibitor without specifying the metal and the enzyme.

c. Was generally well answered, with students showing very good understanding of the light-independent reaction. Many included clear, annotated diagrams to support their answers. A few students mistakenly described the light dependent reaction and a few respiration.

---

a. Describe **four** properties of water that are due to hydrogen bonding and polarity. [4]

b. Describe how water is carried through a flowering plant. [6]

c. Some of the water carried to the leaves of a plant is used in photosynthesis. Explain the role of water in the light-dependent reactions of photosynthesis. [8]

Markscheme

a. *Descriptions of properties expected not lists of properties.*

hydrogen bonding:
a. high specific heat capacity requiring large amounts of energy to break the H-bonds/to raise the temperature;
b. boiling point is high/100°C as H-bonds must be broken to change from liquid to gas;
c. cooling effect of evaporation due to H-bonds taking energy from liquid water to break / high latent heat of evaporation;
d. water molecules on surface resistant to forces because of surface tension;
e. water is most dense at 4°C due to more regular hydrogen bonding;

polarity:
f. water molecules stick together through cohesion; (*full idea required*)
g. water molecules stick to other polar molecules through adhesion; (*full idea required*)
h. good solvent of polar organic molecules

b. a. active transport of solutes from soil into roots;

b. draws water by osmosis

c. root hairs provide a large surface area for water uptake;

d. carried through xylem vessels;

e. transpiration is the loss of water (vapour) from leaves and stems / stomata;

f. (transpiration) creates suction/pull/negative pressure;

g. cellulose wall with rings of lignin give strength to resist (low) pressure;

h. water pulled up due to capillary action/cohesion/adhesion;

i. continuous column of molecules/transpiration stream;

c. a. water only plays a role in non-cyclic photophosphorylation;

b. chlorophyll absorbs light/photons and activates electrons of photosystem II;

c. excited/active electrons of photosystem II are passed to carriers;

d. photolysis is the splitting of water;

e. produces O_2 and H^+/proton and electrons;

f. O_2 released (as waste);

g. electrons (from water) replace lost electrons in photosystem II;

h. electrons from photosystem II pass (through carriers) to photosystem I;

i. electrons from photosystem I pass to $NADP^+$ (in stroma);

j. $NADP^+$ accepts H^+/proton (from water) to form NADPH;

k. electron flow causes protons pumped across thylakoid membranes/into the thylakoid space;

l. creating a proton concentration gradient;

m. chemiosmosis couples electron transport to ATP synthesis;

n. protons pass through ATP synthase/synthetase;

o. NADPH/H^+/proton is passed to the light-independent reactions (to fix carbon);

Examiners report

a. This was a popular question.

7a, few completely related hydrogen bonding to surface tension. In discussing solvent properties, a number neglected to draw in that water performed best at dissolving polar substances. When discussing adhesion, students should have referenced the polarity of molecules.

b. This was a popular question.

In part b, many referenced the role of xylem. Many used terminology correctly in this section making reference to transpiration pull, cohesion, adhesion and the transpiration stream. The stages of water uptake that occur in the root was covered in less detail and with less accuracy in general.

c. This was a popular question.

Part c was in general poorly done as the question required students to discuss the role of water. The details of photolysis were often excluded as were the correct details of chemiosmosis.

---

a. Outline how **three** properties of water enhance its use by living organisms. [6]

b. Describe the role of ADH in osmoregulation. [4]

c. Explain how water is moved from roots to leaves in terrestrial plants. [8]

Markscheme

a. cohesive properties help in transpiration pull/movement of water in plants;

high surface tension allows some animals to stride across its surface;

high latent heat of evaporation/large amounts of energy required for evaporation makes it a good coolant;

high specific heat capacity causes it to maintain environmental temperatures;

low density as ice forms insulation of lakes allowing life below;

transparency for photosynthesis;

transparency for vision in animals;

solvent properties make it the medium for metabolic reactions;

solvent properties allow transport of (soluble) molecules/food;

b. osmoregulation is control of water balance in organisms/blood/tissues/ cytoplasm;

ADH regulates water levels/solute concentration of the blood;

produced/released when water in blood is too low;

it increases the permeability of the collecting ducts / increase in the reabsorption of water;

leads to more aquaporins (in collecting duct cell membranes);

lower volume/less urine is produced/urine more concentrated;

c. water enters roots through the root hairs by osmosis;

root hairs provide an extended surface area (for active transport and osmosis);

active transport of ions from soil into the roots (enhances osmotic pressure);

osmotic pressure moves water into the xylem;

water is carried (in a transpiration stream) in the xylem;

adhesion of water to the inside of the xylem helps move water up;

cohesion of water to itself enhances water movement up the xylem;

water diffuses into air spaces (in spongy mesophyll) of leaves;

it passes out through the stomata by evaporation/transpiration;

evaporation sets up a transpiration pull that keeps the water moving;

guard cells control the rate of transpiration pull/evaporation;

xylem vessels are tubes with helical rings to enhance water movement/resist low pressure;

Examiners report

a. Many did not understand the difference between heat capacity and specific heat capacity. Heat capacity is a property of a quantity of matter. For example, two litres of water has a greater heat capacity than one litre of water. Specific heat capacity is a property of certain substance. Water has a greater specific heat capacity than iron. Nor did they understand why water made for a good coolant. Many focused too narrowly on an aspect of thermal, cohesive or solvent properties rather than discussing these properties from a more "big picture" perspective.

b. The role of ADH was well described an many candidates scored full marks here. Students need to take greater care when using the term concentration as water represents the solvent.

c. This question was generally well answered.

---

a. Outline, with examples, the types of carbohydrate found in living organisms. [4]

b. Describe the importance of hydrolysis in digestion. [6]

c. Explain the effect of inhibitors on the activity of enzymes. [8]

Markscheme

a. (mono-, di- and polysaccharides) consist of one, two and many units;

example of monosaccharide (e.g. glucose/ribose/galactose/fructose);

example of disaccharide (e.g. maltose/lactose/sucrose);

example of polysaccharide (e.g. starch/glycogen/cellulose)

b. digestion is the breakdown of large molecules into small molecules;

to allow diffusion / to make food soluble;

so foods can be absorbed into the bloodstream/body;

so foods can move from bloodstream into cells;

small molecules can be joined to form the organism's (unique) macromolecules;

hydrolysis is aided by enzymes;

hydrolysis requires water;

polysaccharides (hydrolysed) to disaccharides/monosaccharides/specific example;

proteins/polypeptides (hydrolysed) to amino acids;

fats/lipids/triglycerides (hydrolysed) to fatty acids and glycerol;

c. inhibitors reduce enzyme activity/reduce the rate of reaction;

Competitive inhibitors:
have a similar shape to the substrate;
bind to/attach to/enter the active site;
block/compete for occupation of the active site / prevent substrate binding;
example (*e.g.* succinate dehydrogenase by malonate);
increase in substrate concentration reduces inhibition / graph showing this;

Non-competitive inhibitors:
not chemically similar / different shape to substrate;
attach to a different part of the enzyme/allosteric site;
shape of the active site changes preventing/reducing substrate binding;
example of non-competitive inhibition (*e.g.* respiratory enzymes by cyanide);
increases in substrate concentration do not reduce inhibition / graph showing this;
end-product inhibitors are non-competitive;

Examiners report

a. The types of carbohydrate referred to in this question were structural. Candidates who outlined monosaccharides, disaccharides and polysaccharides, with examples of each were able to score the marks quite easily. Those who classified carbohydrates according to function without any reference to structural differences did not fare so well.

b. The examining team adopted a broad interpretation of the meaning of this question, as it would have been difficult to sustain an answer of its literal meaning beyond a few marks. Many candidates wrote good answers, explaining both the need for digestion and the relationship between hydrolysis and digestion.

c. This was well answered by many of the stronger candidates, with detailed accounts of competitive and non-competitive inhibition. The only common omissions were end product inhibitors and examples of each type of inhibitor. Although not specifically requested in this question, examples are always worth including and are often rewarded with marks.

---

a. State the role of **four named** minerals needed by living organisms. [4]

b. Explain the processes by which minerals are absorbed from the soil into the roots. [8]

c. In anaerobic conditions, plants release energy by glycolysis. Outline the process of glycolysis. [6]

Markscheme

a. sulfur – part of amino acids / proteins;

calcium – strengthening/formation of bones / muscle contraction / synaptic transmission;

phosphorus – formation of nucleic acids / ATP / GTP / NADP / phospholipids;

iron – formation of hemoglobin / transport of oxygen;

sodium – nerve impulse / sodium-potassium pump / osmoregulation;

potassium – nerve transmission / sodium-potassium pump / osmoregulation;

magnesium – part of chlorophyll molecule;

b. plants absorb minerals in ionic form/mineral ions;

nitrate / phosphate / potassium / other example of mineral;

minerals can be absorbed by (facilitated) diffusion;

(diffusion is) movement of ions from high to low concentration/down concentration gradient;

root hair cells provide a large surface area for absorption;

fungal hyphae help to absorb minerals/phosphate;

minerals absorbed by active transport;

as mineral ion concentration is smaller outside the root than inside / absorbed against a concentration gradient;

active transport requires energy/ATP;

occurs through pump/carrier proteins;

proton pump transports hydrogen ions/H^+ out of cell (allowing mineral movement in);

c. occurs in cytoplasm (of cell);

substrate is hexose/glucose/fructose;

phosphorylation of glucose/fructose/hexose;

to form hexose diphosphate/glucose 6-phosphate;

requires ATP;

glucose/fructose/hexose (diphosphate) converted into (two) pyruvates/three carbon compounds;

oxidation;

to produce (two) NADH + H^+/ (two) reduced NADs;

net gain of two ATP (per glucose);

Examiners report

a. In part (a), most candidates had no difficulty in naming four mineral elements that are needed by living organisms and giving a role for each. Carbon was not accepted as an answer, as conventionally it is not regarded as a mineral. In plants minerals are absorbed from soil or water. In animals minerals are absorbed in an inorganic form from food or drinking water.

b. Part (b) of the question was not answered as well as expected. There was some confusion between absorption from the soil into roots and movement through the soil to the roots. As a result, many candidates suggested that minerals could be absorbed by mass flow along with the water that was being absorbed. This shows that the selective nature of mineral absorption has not been understood. Another common fault was to suggest that diffusion is the main method of mineral absorption. If plants are able to absorb water by osmosis, they must have higher solute concentrations inside their cells than outside and this can only be achieved by active transport.

c. There was generally good knowledge of the stages of glycolysis in part (c). To make the marking of this question fair in relation to other choices, there was a restricted set of points on the marking scheme, but the more able candidates were still easily able to score full marks.

---

a. Draw a labelled diagram of the ultrastructure of a prokaryote. [4]

b. Explain the process of DNA replication. [8]

c. Outline how the structure of the ribosome is related to its function in translation. [6]

Markscheme

a. *Award any of the following clearly drawn and correctly labelled.*

cell wall; (*shown as a double line*)

plasma membrane; (*less than the width of wall*) (*reject inner surface of cell wall labelled as cell membrane*)

nucleoid/(region containing) naked DNA (distinguished from rest of cytoplasm)

ribosome; (*dots in cytoplasm*)

cytoplasm;

flagella; (*at least a quarter as long as the cell*)

pili; (*less than a quarter as long as the cell*)

*Award **[3 max]** if any specifically eukaryotic structure shown.*

b. helicase uncoils DNA/splits DNA into two strands;

(RNA) primase adds short length of RNA/primer;

primer allows attachment of (DNA) polymerase;

DNA polymerase III copies DNA;

adds nucleotides in the 5′ to 3′ direction;

uses deoxynucleoside triphosphates/nucleotides that are free in cell;

two phosphates removed to release energy (required for the process);

(complementary base pairing of) adenine with thymine and guanine with cytosine; (*reject A with T and C with G*)

(leading) strand replication towards the replication fork;

short pieces of daughter DNA / Okazaki fragments (on lagging strand);

DNA polymerase I removes the RNA primers/replaces them with DNA;

(DNA) ligase joins short fragments/seals nicks;

by making sugar-phosphate bond;

c. translation is protein/polypeptide synthesis;

formed by (ribosomal) RNA and proteins; (*both needed*)

about 20nm/30nm / 80S in eukaryotes;

organized into a tertiary structure/globular shape;

a small subunit and a large one;

(three) binding sites for tRNA on/in large subunit;

A, P and E sites;

binding site for mRNA on surface/in small subunit;

two tRNA can bind at the same time;

ribosomal RNA catalyses formation of peptide bond;

Examiners report

a. In part (a), most candidates drew an appropriate diagram of a prokaryote cell and there was a continuation of the improvement in the quality of diagrams that has been seen over recent years. In a few cases, eukaryote structures such as mitochondria had been included. Pili and flagella were not always distinguishable.

b. Replication is a complicated process and candidates were expected to be able to describe it in detail in (b). The strongest candidates did this admirably well, but weaker ones tended to reveal misunderstandings or gaps in knowledge. It is usually possible for examiners to distinguish between those who have developed a genuine understanding and others who may have memorized some key phrases but are unable to use them correctly in context.

c. The emphasis in the answer to part (c) of the question needed to be on ribosome structure, rather than the process of translation. There were some detailed descriptions of translation that made only passing reference to structure and so scored poorly. Diagrams were often included but they needed to be annotated fully to gain marks for a particular idea. Some of the best answers included the idea that ribosomes are composed of both protein and ribosomal RNA, with the RNA having a catalytic role in translation.

---

a. Nitrogen is part of many important substances in living organisms. [3]

Draw labelled diagrams to show a condensation reaction between two amino acids.

b. Nitrogen is part of many important substances in living organisms. [4]

Distinguish between transcription and translation.

c. Nitrogen is part of many important substances in living organisms. [8]

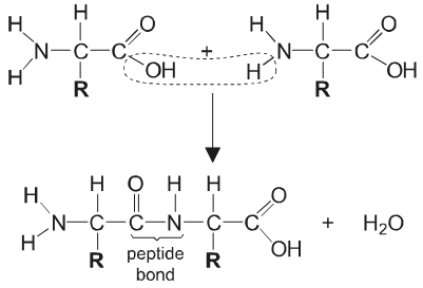
Explain how insects excrete nitrogenous wastes.

Markscheme

a. a. at least one of the amino acid structures completely correct

b. peptide bond shown with N–C and C=O and N–H correct

c. release of water clearly shown



b. a. DNA is transcribed ***AND*** mRNA is translated

Disallow the first mark, if a candidate gets transcription and translation the wrong way round, but allow marks after that up to ***[3 max]***

b. transcription produces RNA ***AND*** translation produces polypeptide/protein

c. RNA polymerase used in only in transcription and ribosomes only in translation

d. transcription in the nucleus «of eukaryotes» and translation in the cytoplasm

e. tRNA needed for translation but not transcription

f. nucleotides linked in transcription and amino acids in translation

OR

sugar-phosphate/phosphodiester bonds in transcription and peptide bonds in translation

[Max 4 Marks]

c. a. excreted as uric acid

b. excretion by Malpighian tubules

c. nitrogenous waste/ammonia «accumulates» in hemolymph

d. nitrogenous waste/ammonia absorbed by Malpighian tubules

e. ammonia converted to uric acid

f. conversion to uric acid requires energy/ATP

g. high solute concentration in Malpighian tubules

OR

active transport of ions/Na+/K+ into Malpighian tubules

h. water absorbed by osmosis flushes uric acid/nitrogenous waste to «hind» gut

i. water/ions reabsorbed from the feces and returned to hemolymph

j. uric acid precipitates/becomes solid/forms a paste so can pass out with little water

k. uric acid excreted/egested with the feces

l. water conservation/osmoregulation

OR

reduces mass of water «in body»

m. uric acid is non-toxic

[Max 8 Marks]

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

Defence occurs on the micro and macro levels.

a. Describe the functioning of immunoglobulins. [3]

b. Outline how antibiotics offer protection from certain forms of infectious disease. [4]

c. Coughing to clear the airways is accomplished by muscle contractions. Explain muscle contraction. [8]

Markscheme

a. a. «immumoglobulins are/function as» antibodies

b. variety of binding sites / variable regions for binding

c. specific to antigens on bacteria/viruses/pathogens

d. constant region aids destruction of the bacteria/virus/pathogen

e. attracts phagocytes/macrophages to engulf pathogen

f. bursting pathogen cells/agglutination/neutralizing toxins/other example of the action of antibodies

Award marks for an annotated diagram.

b. a. protect against/kill/inhibit growth of microorganisms/bacteria/prokaryotes

b. bacteria/prokaryote processes blocked but not processes in eukaryotes/other organisms

c. block metabolic pathways/DNA replication/DNA transcription/translation/ribosome functioning/cell wall formation

d. do not protect against viruses as they have no metabolism/are non-living

e. antibiotics fail to protect if bacteria have resistance

f. can be used in humans/animals because antibiotics do not affect eukaryotic cells/bacterial metabolism is different

c. a. myofibrils «in muscle fibers/cells»

b. sarcomeres «are the repeating units in muscle/myofibrils» □

c. sarcomeres arranged end to end / sarcomeres shorten during muscle contraction

d. actin and myosin/overlapping protein filaments/diagram to show sarcomere with actin and myosin overlapping

e. dark and light bands «in sarcomeres»/diagram to show this/light bands narrower when muscle is contracted

f. thick filament is myosin and thin filament is actin/diagram to show this

g. nerve impulses stimulate contraction/cause depolarization of sarcolemma/T-tubules/trigger release of calcium from sarcoplasmic reticulum

h. calcium ions released from sarcoplasmic reticulum/bind to troponin

i. troponin causes tropomyosin to move/exposes binding sites on actin

j. myosin «heads» form cross bridges with/bind to actin

k. myosin heads move/change angle/swivel/cock / myosin heads cause the power stroke

l. myosin filaments pull actin towards center of sarcomere/more overlap between actin and myosin/Z-lines move closer

m. ATP is used «to provide energy»/cause cross-bridges to break/cause movement of myosin heads/cause filaments to slide/cause muscle contraction

n. intercostal/abdominal/diaphragm muscles contract «to cough»

Marks can be awarded for any point made clearly on an annotated diagram.

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

---

a. Draw a labelled diagram showing the ultra-structure of a liver cell. [4]

b. Distinguish between prokaryotic cells and eukaryotic cells. [6]

c. Explain prokaryotic DNA replication. [8]

Markscheme

a. *Award **[1]** for each structure clearly drawn and correctly labelled. Whole cells not necessary.*

(plasma) membrane – single line surrounding cytoplasm;

nucleus – with a double membrane and pore(s) shown;

mitochondria(ion) – with a double membrane, the inner one folded into internal projections, shown no larger than half the nucleus;

rough endoplasmic reticulum – multi-folded membrane with dots/small circles on surface;

Golgi apparatus – shown as a series of enclosed sacs with evidence of vesicle formation;

ribosomes – dots/small circles in cytoplasm/ribosomes on rER;

lysosome;

*Award **[0]** if plant cell is drawn. Award **[2 max]** if any plant cell structure (e.g. cell wall) is present.*

b.

prokaryotic	eukaryotic
naked DNA	protein associated with DNA;
DNA in cytoplasm / nucleoid / no nucleus	DNA in nucleus / nucleus present;
circular DNA	linear chromosomes/DNA molecules;
no mitochondria	mitochondria;
70S ribosomes present	80S ribosomes present;
no membrane bound organelles	internal membranes form organelles;
pili present	pili absent;
plasmids (sometimes) present	plasmids absent;
cell wall present	cell wall only present in plants/fungi; *Do not accept cell wall sometimes present.*
flagella solid	flagella flexible/membrane-bound;

c. DNA replication is semi-conservative / each strand of DNA acts as template;

(DNA) helicase separates two strands/forms a replication fork;

new strand built / nucleotides added in a 5' to 3' direction;

(deoxy)nucleoside triphosphates hydrolysed to provide energy for nucleotide formation/base pairing;

on one strand DNA polymerase III builds continuous strand;

on other strand short chains of DNA/Okazaki fragments are formed;

each short chain starts with RNA primer;

added by RNA primase;

then remainder of chain of DNA built by DNA polymerase III;

DNA polymerase I removes RNA primer and replaces it by DNA;

DNA ligase joins DNA fragments together forming complete strand;

replication only occurs at a single replication fork;

Award credit for any of the above points clearly drawn and accurately labelled.

Examiners report

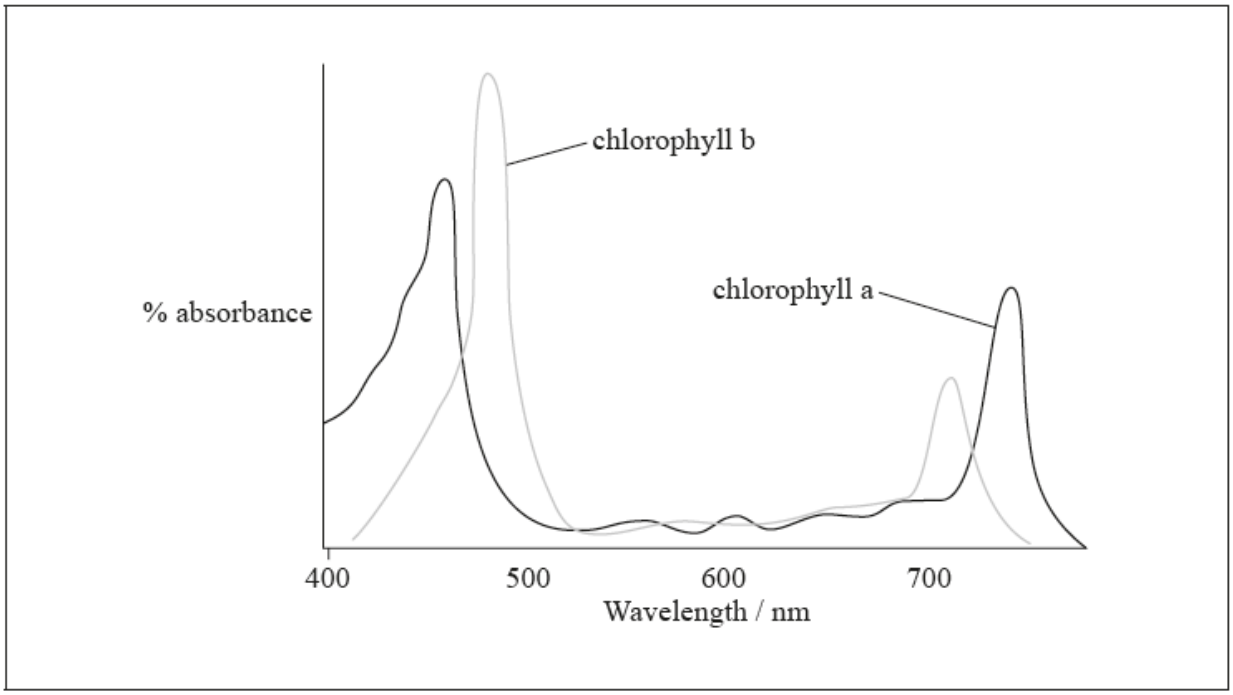
a. In the light of answers seen by examiners, perhaps the question should have given candidates a clearer pointer to what was expected. The quality of drawings was very variable. Marks were only awarded for structures clearly drawn and labelled. The mark scheme for this paper gives details of the criteria that examiners used. It was not necessary to draw a whole cell, as this would have involved drawing organelles repeatedly, but at least one of each organelle type, accurately drawn, was needed.

b. This was often answered by means of a table. This was particularly appropriate here as the question asked for prokaryote and eukaryote cell structure to be distinguished, rather than compared, so only differences were required. Tables help to ensure that candidates give both sides of a distinguishing feature. This approach only works if candidates fully understand the features, which they did not in some cases. For example, naked DNA in prokaryotes was often matched with DNA enclosed in a nucleus in eukaryotes, rather than with DNA associated with histone proteins. Mesosomes were given as an equivalent of mitochondria although most bacteriologists now regard the mesosome as an artefact of preparation for electron microscopy, rather than as a functionally significant structure. The current IB Biology programme does not refer to mesosomes.

c. This may also have discouraged answers from some candidates, as it referred to DNA replication in prokaryotes. This is how assessment statement 7.2.2 is phrased, so the wording of the question was acceptable, but there were some answers that showed some candidates had been confused. Some wrote about binary fission, about the replication of a circular DNA molecule, or even about the cell cycle and mitosis. However, stronger candidates coped extremely well and quickly amassed eight marks. The best answers explained the method of replication on the leading strand and then explained how and why the process was different on the lagging strand.

---

a. The graph shows the absorption spectrum for two types of chlorophyll. [3]



[Source: © International Baccalaureate Organization 2014]

(i) Sketch on the graph, the action spectrum of photosynthesis.

(ii) Explain the relationship between the absorption spectrum for chlorophyll and action spectrum of photosynthesis for green plants.

b. Outline photoactivation of photosystem II in the light-dependent reaction of photosynthesis. [2]

Markscheme

a. (i) line slightly <u>above</u> absorption spectrum with peaks in red and blue and a trough between but not as low as for absorption spectrum

(ii) energy/light absorbed by pigments/chlorophyll is used for photosynthesis;

peaks in action spectrum correspond to peak absorption by chlorophyll;

differences due to absorption by accessory/other pigments (*eg* carotene);

least absorption in green range/approximately 600nm as most light reflected;

b. light/photon absorbed by pigment molecules (in photosystem II)/chlorophyll;

energy/electrons passed to chlorophyll molecule at the reaction centre;

causes electron to be raised to higher energy level / electron is excited;

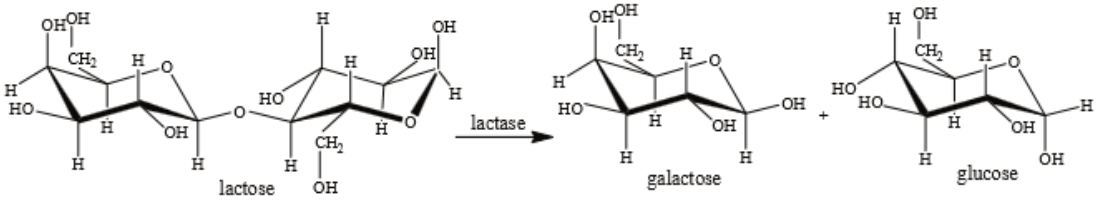
this electron passed along chain of carrier molecules in photosystem II;

Examiners report

a. A line above and including all the peaks was required for (a)(i). Most candidates were familiar with the terms absorption and action spectra, but could not explain the relationship between the two in 4(a)(ii). In part (b) most knew that an electron became excited, but how or why this came about was not well explained.

b. A line above and including all the peaks was required for (a)(i). Most candidates were familiar with the terms absorption and action spectra, but could not explain the relationship between the two in 4(a)(ii). In part (b) most knew that an electron became excited, but how or why this came about was not well explained.

The equation below shows the production of glucose and galactose from lactose.



a. Glucose and galactose are examples of monosaccharides. State **one** other example of a monosaccharide. [1]

b (i) There are several different types of carbohydrate. State which type of carbohydrate lactose is. [1]

b (ii) State the type of chemical reaction that occurs when lactose is digested into glucose and galactose. [1]

d. Simple laboratory experiments show that when the enzyme lactase is mixed with lactose, the initial rate of reaction is highest at 48°C. In food processing, lactase is used at a much lower temperature, often at 5°C. Suggest reasons for using lactase at relatively low temperatures. [2]

Markscheme

a. fructose/ribose/ribulose/deoxyribose other monosaccharides apart from glucose and galactose

b (i) disaccharide

b (ii) hydrolysis

d. less denaturation / enzymes last longer at lower temperatures;

lower energy costs / less energy to achieve 5°C compared to 48°C;

reduces bacterial growth / reduces (milk) spoilage;

to form products more slowly / to control the rate of reaction;

Examiners report

a. This was a question which illustrated clearly the difference between different centres. Most had obviously been well prepared and found the factual elements simple.

b (i) This was a question which illustrated clearly the difference between different centres. Most had obviously been well prepared and found the factual elements simple.

b (ii) This was a question which illustrated clearly the difference between different centres. Most had obviously been well prepared and found the factual elements simple.

d. This was better answered than part (c) with the use of the lower temperature often being understood to relate to less denaturation of enzymes or longer lasting enzymes or less spoilage, but some considered that it changed the amount of the monosaccharides produced rather than the rate of production.

---

a. Most of the DNA of a human cell is contained in the nucleus. Distinguish between unique and highly repetitive sequences in nuclear DNA. [5]

b. Draw a labelled diagram to show **four** DNA nucleotides, each with a different base, linked together in **two** strands. [5]

c. Explain the methods and aims of DNA profiling. [8]

Markscheme

a. *Award **[1]** for each pair of statements in the table and **[1]** for any statement below the table.*

Unique sequences	Highly repetitive sequences
occur once in genome	occur many times;
long base sequences	short sequences/5–300 bases;
(may be) genes	not genes;
(may be) translated / coding sequences	never translated;
small differences between individuals	can vary greatly;
exons (are unique sequences)	introns (may be repetitive);
smaller proportion of genome	higher proportion of genome;

satellite DNA is repetitive;
repetitive sequences are used for profiling;
prokaryotes do not (usually) contain repetitive sequences

b. *Award **[1]** for each of these structures clearly drawn and labelled.*

four nucleotides shown in diagram with one nucleotide clearly labelled;

base, phosphate and deoxyribose (shown as pentagon) connected between the correct carbons and labelled at least once;

backbone labelled as covalent bond between nucleotides correctly shown as 3' to 5' bond;

two base pairs linked by hydrogen bonds drawn as dotted lines and labelled;

two H bonds between A and T and three H bonds between C and G;

adenine to thymine and cytosine to guanine; *do not accept initials of bases*

antiparallel orientation shown;

c. DNA sample obtained;

from hair/blood/semen/human tissue;

DNA amplified / quantities of DNA increased by PCR/polymerase chain reaction;

satellite DNA/highly repetitive sequences are used/amplified;

DNA cut into fragments;

using restriction enzymes/restriction endonucleases;

gel electrophoresis is used to separate DNA fragments;

using electric field / fragments separated by size;

number of repeats varies between individuals / pattern of bands is unique to the individual/unlikely to be shared;

*Award **[5 max]** for methods*

forensic use / crime scene investigation;
example of forensic use *e.g.* DNA obtained from the crime scene/victim compared to DNA of suspect / other example of forensic use;
paternity testing use *e.g.* DNA obtained from parents in paternity cases;
biological father if one half of all bands in the child are found in the father;
genetic screening;
presence of particular bands correlates with probability of certain phenotype / allele;
other example;
brief description of other example;
*Award **[4 max]** for aims*

Examiners report

a. Knowledge of the nature of unique and repetitive sequences of DNA was very poor. Very few scored anywhere near full marks. Often odd marks could be picked up by linking widely separated comments, as descriptions of the two types were attempted. Where candidates possessed knowledge, some did not follow the command to distinguish the two types of sequences.

b. This was a difficult diagram to draw unless it had been well learnt and many showed that this had not been achieved. A few were good enough to get every possible mark and exceed the maximum. The antiparallel nature of the two strands, arrangement of base, phosphate and deoxyribose and the base pairing relationship were widely known. Individual nucleotides were almost never identified. Hydrogen bonds were indicated with a solid line suggesting that they were equivalent to covalent bonds. Sometimes the bases were only given as letters. Commonly, more than four nucleotides were shown.

c. It was clear that this was a popular section but accounts were still rather vague and unscientific. “Suspects can be identified” and “paternity can be decided” but without any indication of having a DNA sample first and then another with which to compare.
Very few mentioned using satellite /repetitive sequences in creating a DNA profile. Gel electrophoresis was often outlined but specifics were missing such as the use of restriction enzymes and the creation of a pattern of DNA fragments. Some accounts confused karyotyping and amniocentesis with DNA profiling.

---

a. Draw molecular diagrams to show the condensation reaction between two amino acids to form a dipeptide. [4]

b. Outline the roles of the different binding sites for tRNA on ribosomes during translation. [4]

c. Explain the production of antibodies. [7]

Markscheme

a. a. each amino acid with a COO–/COOH group at one end ***AND*** a NH_2/NH_3^+ at the other

Both needed.

mp a requires the double bond to be shown between the C and O.

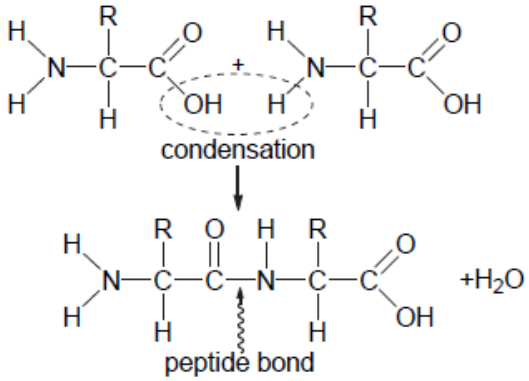
b. CH in middle with H or R group attached

c. peptide bond correctly drawn between N and C=0

d. COO–/COOH group at one end of dipeptide ***AND*** NH_2/NH_3^+ at other end
Both needed.

e. loss of water

eg:



b. a. A, P and E binding sites are on the large subunit of the ribosome

b. initiation of translation starts with binding of met-tRNA to the start codon

c. large sub-unit binds with «start» tRNA in the P site

d. A binding site holds the tRNA with the next amino acid to be added

e. peptide bond is formed between the amino acids of the A site and the polypeptide at the P site

f. polypeptide is transferred to the tRNA in the A site

g. the tRNA «with polypeptide» in A site then moves to P site
OR
P binding site holds the tRNA attached to the growing polypeptide

h. E binding site «exit» is where the tRNA «from P site without amino acid» leaves the ribosome

Accept annotated diagrams of the sites.

c. a. each antibody corresponds to a specific antigen

b. antibodies are necessary for immunity/resistance to «infectious» disease

c. macrophage/phagocyte ingests/engulfs pathogen

d. macrophage/phagocyte digests pathogen

e. macrophage/phagocyte displays antigen from pathogen

f. antigens of a pathogen correspond to a specific T lymphocytes/cells
OR
T lymphocytes/cells are activated by antigen binding

g. T lymphocytes/cells activate B lymphocytes/cells

h. «B cells» divide by mitosis to form many/clones of plasma cells

i. plasma cells secrete specific antibody

j. some «activated» B lymphocytes/cells act as memory cells

Accept annotated diagrams of the process

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

---

a. Explain chemiosmosis as it occurs in photophosphorylation. [8]

b. Draw an annotated graph of the effects of light intensity on the rate of photosynthesis. [4]

c. Using a **named** example of a genetically modified crop, discuss the specific ethical issues of its use. [6]

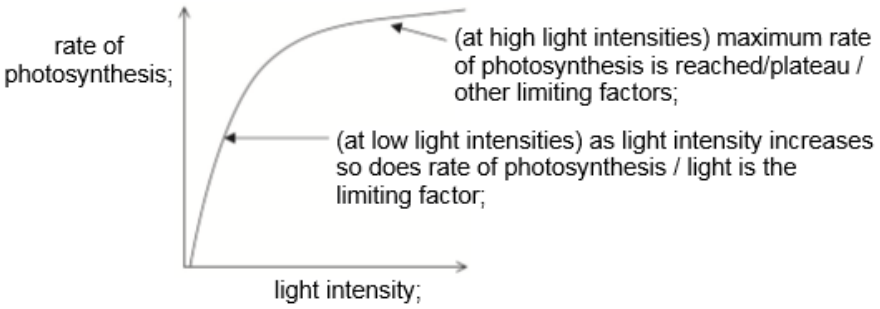
Markscheme

a. *Remember, up to TWO "quality of construction" marks per essay.*

a. photophosphorylation is the production of ATP;
b. (some of the) light absorbed by chlorophyll / photosystem II;
c. photolysis/splitting of water separation of hydrogen ion from its electron;
d. the electron transport system moves the electrons through a series of carriers;
e. (electron transport system occurs) in the thylakoid membrane;
f. electron transport linked to movement of protons into thylakoid space;
g. a proton gradient builds up (in the thylakoid space);
h. small thylakoid space enhances the gradient;
i. hydrogen ions move by diffusion through the ATP synthase;
j. ADP + inorganic phosphate (Pi) forms ATP;
k. (the kinetic energy from) movement of hydrogen ions (through ATP synthase) generates ATP;
l. ATP synthase is a protein complex in the thylakoid membrane;
m. formation of proton gradient / ATP synthesis linked to electron transport is chemiosmosis;

Award marks for a clearly drawn correctly annotated diagram.

b.



a. vertical axis labelled as “rate of photosynthesis” and horizontal axis labelled as “light intensity”;
b. drawn showing that at low light intensities, increased intensity leads to increased rate of photosynthesis (sharply);
c. drawn with plateau formed at high light intensities;
d. plateau annotated as maximum rate of photosynthesis;
e. curve intersecting horizontal axis at a value above zero;
f. arrows added to axes or student annotates axis with “rate of photosynthesis increases” and “light intensity increases”

c. *Remember, up to TWO “quality of construction” marks per essay.*

a. named example of verified genetically modified crop; *eg*, Bt corn / golden rice;
Example must be verifiable.
b. specific gene added / new protein synthesized by the crop plant / specific modification; *eg* gene from *Bacillus thuringiensis* / cry protein;
c. biological effect of the modification; *eg*, makes the plant toxic to (herbivorous) insects / insect pests / corn borers;
[2 max] *for benefits and* ***[2 max****] for harmful effects / costs;*

d. a benefit of specific genetic modification; *eg*, increased crop yields / less land needed;
e. a second benefit of this specific modification; *eg*, reduced need for use of chemical pesticides;
f. a harmful effect of specific genetic modification; ingestion of toxin by nontarget species;
g. another specific harmful effect; *eg*, concerns about contamination of neighbouring non-GMO crops affecting trade;

To award ***[6]*** *responses need to address the name, description and the effect of the modification. Effects have to be linked to the specific example discussed. Marks have to be all linked to one example. Assistant examiners are required to research examples.*

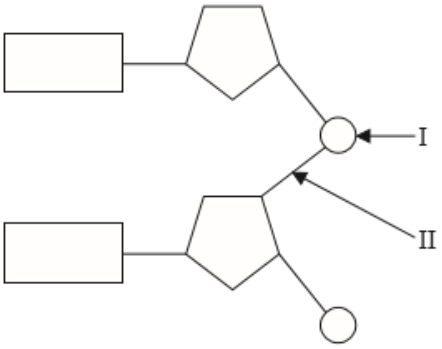
Examiners report

a. Students appear to have a general understanding of mechanisms but make a number of errors in terms of the location of events such as where the proton gradient builds up.

b. This was well answered by most students. Many did not draw the curve intersecting the horizontal axis at a value above zero. Many constructed a diagram of the curve but provided text below the curve in a paragraph rather than annotating the curve itself with explanations of what was occurring at various levels of light intensity.

c. The best answers outlined the biology of the example well though a very large number dealt in hypothetical or speculative costs and benefits of genetic modification.

The diagram below shows two nucleotides linked together to form a dinucleotide.



a (i). Identify the chemical group labelled I. [1]

a (ii). State the type of bond labelled II. [1]

b. Distinguish between the sense and antisense strands of DNA during transcription. [1]

c. Compare the DNA found in prokaryotic cells and eukaryotic cells. [2]

Markscheme

a (i). phosphate

a (ii). covalent / phosphodiester

b. only the antisense strand is transcribed / the antisense strand is transcribed to mRNA and the sense strand is not transcribed/has the same base sequence as mRNA (with uracil instead of thymine)

To award [1], reference must be made to both strands and transcription.

c.

prokaryotic DNA	eukaryotic DNA
circular	linear;
in cytoplasm/nucleoid region	enclosed in nuclear membrane / in nucleus;
naked	associated with proteins/histones;
plasmids	no plasmids;
both prokaryotic and eukaryotic DNA consist of a double helix of (deoxy)nucleotides / phosphate, deoxyribose and base/ATC and G;	

Award marks for paired statements only. Answers do not need to be shown in a table format.

Examiners report

a (i). In part (i), virtually all students identified the phosphate group.

a (ii). Most were also able to identify the covalent or phosphodiester bond, although some stated it was an H bond.

b. This question was difficult for most students, although some wrote correct answers. In some scripts, students answered in terms of 3' → 5', whereas others did not refer to the two strands, nor did they relate them to transcription.

c. Few students got full marks as they did not compare relative characteristics. For example, it appears that many candidates interpret "naked" DNA as not being within a nuclear envelope. With this assumption, it is more difficult for them to gain mark on correct pairs of statements.

Cells in the alveolus wall produce a surfactant. Its function is to prevent alveoli collapse at the end of expiration. Surfactants are used in the treatment of respiratory system disease in premature babies.

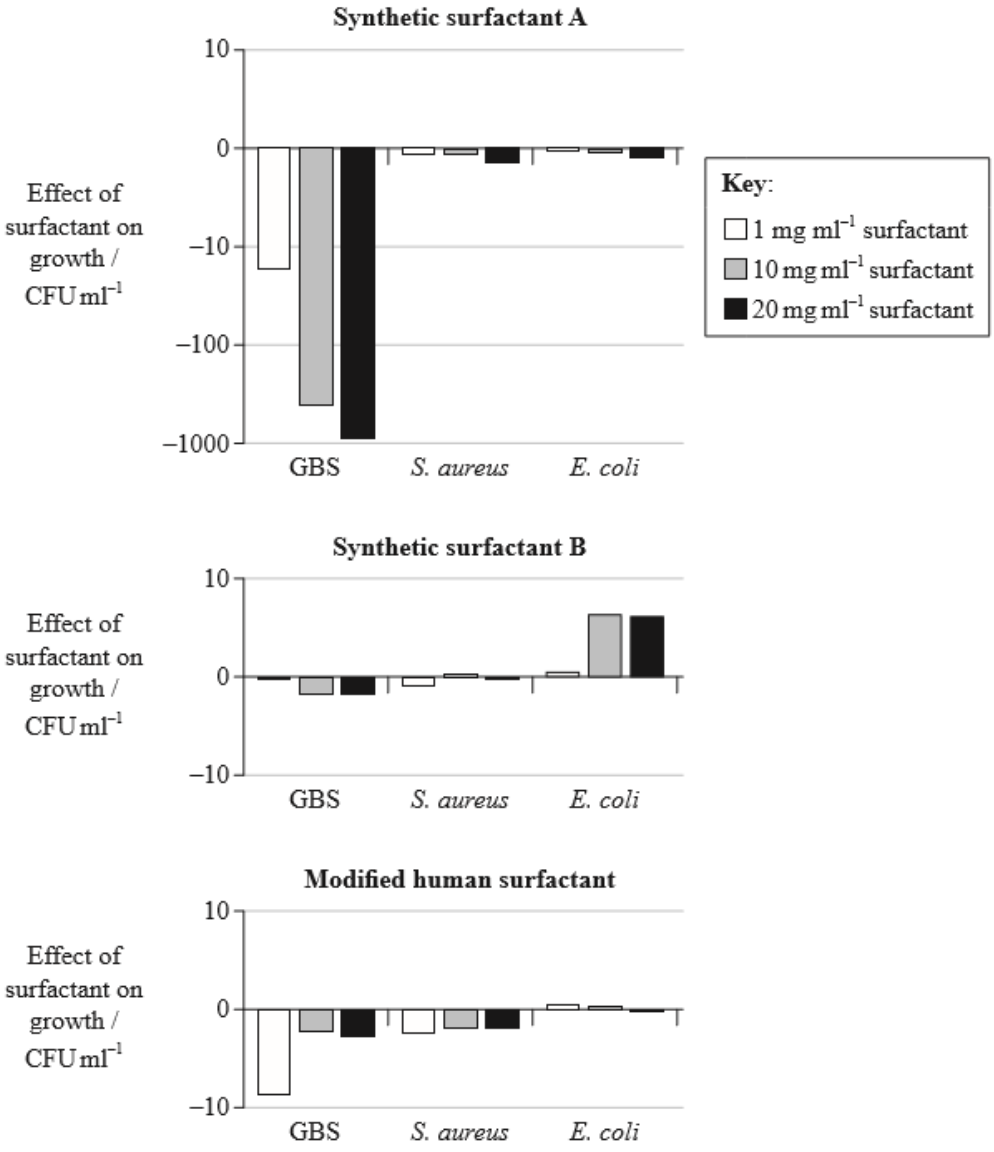
The table shows some of the components of different surfactant preparations.

	Percentage composition by mass			
Component	**Synthetic surfactant A**	**Synthetic surfactant B**	**Natural human surfactant**	**Modified human surfactant**
Phospholipids	99	84	81	100
Cholesterol	0	not stated	5 to 10	0
Fatty acids	<0.5	6	1.5	0
Proteins	1	0.5 to 1	5 to 10	0

[Source: *Clinical and Diagnostic Laboratory Immunology*, 2000, 7(5), pp. 817–822, 2012, January 9, 2013]

The effect of three different surfactants on the growth of three types of bacteria was assessed. Group B streptococci (GBS), *Staphylococcus aureus*, and *Escherichia coli* were incubated with three different concentrations of surfactant (1, 10 and 20 mg ml^{-1}).

The bar charts show whether each concentration of surfactant increased or decreased bacterial growth, compared with the growth without surfactant. The difference in growth is shown as colony forming units (CFU) per millilitre.



[Source: *Clinical and Diagnostic Laboratory Immunology*, 2000, 7(5), pp. 817–822, 2012, January 9, 2013]

a. State the surfactant that contains the least amount of phospholipids. [1]

b. Compare the composition of natural human surfactant with synthetic surfactants. [2]

c. Phospholipids found in the surfactants form a surface film on the moist lining of the alveoli. Outline how the hydrophilic and hydrophobic parts of the phospholipids in the surfactants are aligned on the alveolar surface. [1]

d. Identify the effect of increasing the concentration of synthetic surfactant A on the growth of GBS. [1]

e. Compare the effect of the three surfactants, synthetic surfactants A and B and the modified human surfactant, on the growth of the different bacteria at a concentration of 20 mg ml^{-1}. [3]

f. Using all the data provided, evaluate the hypothesis that the presence of proteins in surfactants can decrease bacterial growth. [3]

Markscheme

a. natural human (surfactant)

b. main component of all surfactants is phospholipids;

(natural human surfactant) has less phospholipids (than synthetic surfactants);

(natural human surfactant) has more cholesterol (than (synthetic surfactant) A);

(natural human surfactant) has more free fatty acids than (synthetic surfactant) A and less than (synthetic surfactant) B; (*comparison with both synthetic surfactants required*)

(natural human surfactant) has more proteins (than synthetic surfactants);

c. hydrophilic groups facing the surface/are in the moist lining/water and hydrophobic tails facing outwards/are in the air

*Award **[0]** for a description of a phospholipid bilayer. The orientation of both hydrophilic and hydrophobic parts must be included.*

d. growth reduced (by increases in concentration)/negative correlation

e. *The question asks to compare how each surfactant affects each bacterium. However, some responses will instead compare how each bacterium is affected by each surfactant. Accept both types of answer.*

(synthetic surfactant) A decreases growth of GBS most and *S. aureus* and *E. coli* much less/slightly;
(synthetic surfactant) B decreases the growth of GBS (and of *S. aureus* slightly) but increases the growth of *E. coli*;
modified human surfactant decreases growth of GBS (and *S. aureus*) but no (significant) effect on *E. coli*;
GBS greatly inhibited by (synthetic surfactant) A but less/slightly by (synthetic surfactant) B and modified human surfactant;
S. aureus (slightly) inhibited by all three surfactants;
E. coli increased by (synthetic surfactant) B but (synthetic surfactant) A and modified human surfactant have no significant effect;

f. (*hypothesis supported as*)

(synthetic surfactant) A has proteins and decreases bacterial growth;

(*hypothesis not supported as*)
modified human surfactant has no proteins and decreases bacterial growth;
(synthetic surfactant) B has proteins and enhances growth (of *E. coli*);
GBS inhibited more by modified human surfactant which has no protein than (synthetic surfactant) B which has protein;
S. aureus inhibited more by modified human surfactant which has no protein than by the other (surfactants) which have protein;
Do not accept answer without reference to proteins.

Examiners report

a. Part (a) was an easy first question to give candidates confidence. Almost all answered it correctly.

b. Most candidates also answered part (b) successfully. There were plenty of possible comparisons to make and only two acceptable ones were needed for full marks.

c. Part (c) was the hardest part of Question 1. Most candidates described or drew a diagram of a phospholipid bilayer. This was not accepted as the question stated that the phospholipids formed a film on the surface of the moist lining of the alveoli. The phospholipids will therefore be in contact with the aqueous solution on one side and air in the alveolus on the other side. The expected answer was a phospholipid monolayer with the hydrophilic heads facing the water and the hydrophobic tails facing the air. Even the strongest candidates struggled with this.

d. In part (d) there were some very clear and accurate answers, but also many that showed either imperfect understanding of the data or ambiguous phrasing of the answer. The data showed that increases in the concentration of surfactant A caused greater and greater decreases in the growth of GBS. The ambiguous answers included statements such as “Surfactant A increased negative growth”.

e. The problem in part (e) was to cope with the large amount of data: the effects of three concentrations of three surfactants on the growth of three types of bacteria, though candidates should have only considered the highest of the three concentrations. The best answers worked systematically through the data by comparing either the effects of each surfactant in turn or the effects of the surfactants on each bacterium in turn. A fault in some answers was failure to make genuine comparisons and instead to describe only a single part of the data at once. Another common fault was to ignore the sizes of the effects on the bacteria and thus whether they were significant or not. Given that the y-axis scales were logarithmic, small bars above or below the zero line were not significant.

f. Part (f) was quite challenging. Some candidates failed at the first hurdle, which was to look at the table of data at the start of Question 1 to find out the protein content of each of the three surfactants expected in the answer here. Having done this, it was not too difficult to see that there was some evidence for the hypothesis from surfactant A. It contained the most protein and inhibited the growth of each species of bacterium, albeit only to a small extent with Staphylococcus aureus and Escherichia coli. The remainder of the data did not fit the hypothesis.

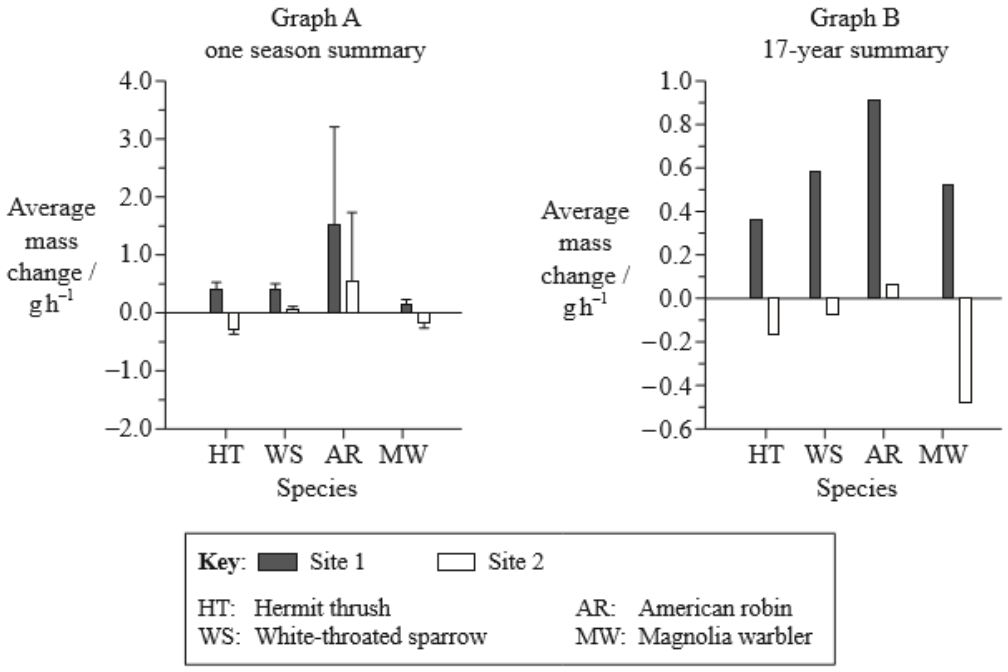
Migrating birds must refuel along the way in order to continue flying. A field study was conducted among four different species of migrating birds known to stop at high quality and low quality food sites. Two techniques were used to assess food quality in the stopover sites. Birds were captured and weighed at the two sites. Blood samples were taken from the birds to determine nutrient levels in their blood. The two techniques were compared for their effectiveness.

The table below shows data collected from the two sites during one season.

Species	Site 1		Site 2	
	N **(number captured)**	**Mean bird mass / g**	***N*** **(number captured)**	**Mean bird mass / g**
Hermit thrush	46	29.8	28	28.3
White-throated sparrow	47	27.9	48	27.2
American robin	8	78.3	10	77.6
Magnolia warbler	30	8.4	10	8.2

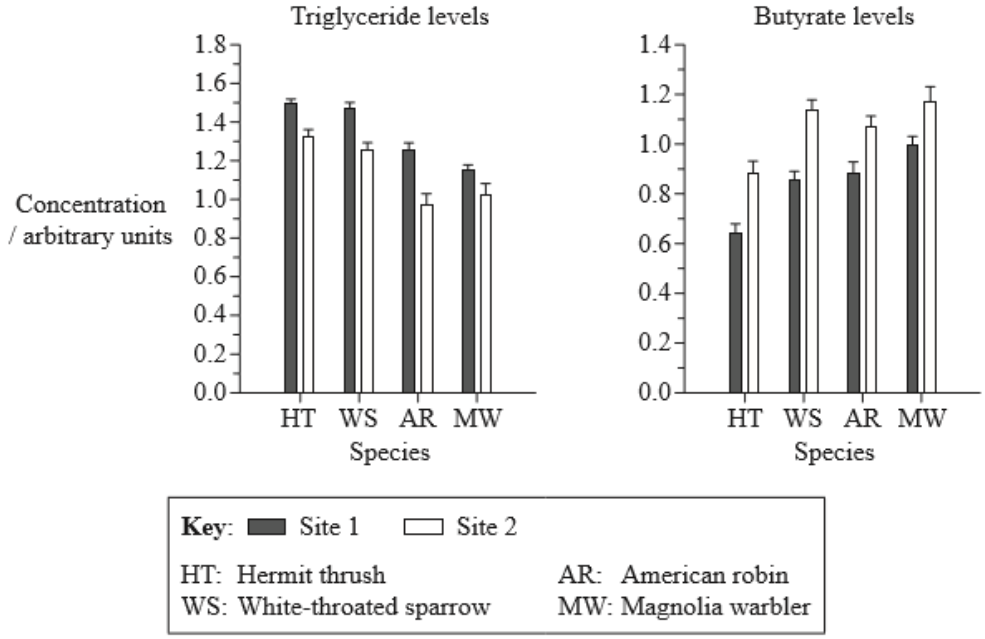
[Source: adapted from C Guglielmo, *et al.*, (2005), *Physiological and Biochemical Zoology*, **78**(1), pages 116–125]

A method was used to determine the average mass change in grams per hour (gh^{-1}) during the study. Graph A represents a summary of data collected during one season whereas Graph B represents a summary of data collected over 17 years.



[Source: adapted from C Guglielmo, *et al.*, (2005), *Physiological and Biochemical Zoology*, **78**(1), pages 116–125]

Among birds, high triglyceride concentration in blood plasma indicates fat deposition whereas high butyrate concentration in blood plasma indicates fat utilization and fasting. The following data summarizes triglyceride levels and butyrate levels measured for the same groups of birds.



[Source: adapted from C Guglielmo, *et al.*, (2005), *Physiological and Biochemical Zoology*, **78**(1), pages 116–125]

a. Considering all the birds sampled, identify which species was sampled the most and which was sampled the least. [1]

Most:

Least:

b. Using the data from the table, calculate the percentage difference in mean bird mass for the hermit thrushes refueling at Site 1 compared to those refueling at Site 2. [1]

c. Compare the 17-year summary data for the hermit thrush and the magnolia warbler. [2]

d. Evaluate the one season data for the hermit thrush and the American robin with regard to average mass change per hour at Site 1. [2]

e. Describe, using the triglyceride levels graph, the results at Site 1 and Site 2 for all of the birds. [2]

f. Explain the differences in the triglyceride level and butyrate level for the hermit thrush at Site 1 and Site 2. [2]

g. Scientists have hypothesized that the food quality is better at Site 1 than at Site 2. Evaluate this hypothesis using the data provided. [2]

h. Suggest **one** advantage and **one** disadvantage for blood sampling rather than weighing birds to assess food quality at stopover sites. [1]

Markscheme

a. *most*: white-throated sparrow/WS

least: American robin/AR

(*both needed to award the mark*)

b. 5% / 5.03% / 5.3% (*unit required*) (*Accept answers in the range of 5 % and 5.3 %*)

No indication needed of whether percentage difference is an increase or decrease.

c. both birds show an increase in mass at Site 1 and a decrease at Site 2;

MW has a greater increase than HT at Site 1; (*do not accept larger/greater change*)

MW has a greater decrease than HT at Site 2; (*accept negative change*)

MW has larger mass change at both sites/Site 1 and Site 2;

Do not accept answers quoting only numerical statements.

d. HT data is reliable whereas AR data is unreliable / differences not significant / uncertainty higher with AR;

(because) error bars/variation/range/standard deviation large for AR / larger for AR than for HT;

(because) smaller sample of AR than of HT;

Do not accept comments about whether the data is accurate or not.

e. all have a higher concentration of triglyceride at Site 1 than at Site 2;

HT (and WS) highest at both sites/at Site 1;

MW lowest at Site 1 and AR lowest at Site 2;

Do not allow answers quoting only numerical statements.

f. triglyceride higher at Site 1 because more fat deposition / HT eats more;

butyrate higher at Site 2 because more fat/triglyceride utilized / HT fasts more;

g. (data supports hypothesis) because mean mass at Site 1 is greater than at Site 2 (for all birds);

because mass gained at Site 1 but mass falls (mostly) at Site 2 (over 17 years);

because triglyceride levels higher at Site 1 / butyrate levels higher at Site 2 / more fat deposited at Site 1 / more fat utilized at Site 2 / more fasting

at Site 2;

h. *advantage:*

need to capture bird only once to get data / no need to mark and catch birds again;

more informative data can be gathered; (*do not accept unqualified "more precise"*)

disadvantage:
removal of blood is more stressful/risky for the bird than weighing;
danger of infection / spread of disease / harm to birds;
extra time/money/laboratory equipment is needed to analyse results;
could include fat/triglyceride/butyrate from previous/long-term feeding;
nutrients from food eaten at these sites may not have been absorbed yet;
*Award **[1]** for one advantage and one disadvantage that are not the converse of each other. Do not allow a second advantage or second disadvantage given in the answer.*

Examiners report

a. Part (a) was intended to be an easy start to the question and almost all candidates answered it correctly.

b. The percentage calculation in (b) was only answered by about half of candidates, perhaps because of the wording of the question, which did not make it clear whether the difference should be calculated as a percentage of that at Site 1 or at Site 2. Candidates were expected to calculate the difference between the two masses by subtraction and then divide either by the mass at Site I or at Site 2. Candidates performed many other calculations, but as only one mark was available, no credit was given for these.

c. The best answers in (c) made it clear whether the mass changes were increases or decreases, but many answers were vaguer, referring only to mass changes. There was some confusion between mass and mass change, with some some candidates implying that a negative mass change was a low mass. In some cases answers to this question consisted only of figures quoted from the bar chart, rather than a genuine comparison and so did not score any marks.

d. In (d) candidates were asked to evaluate data. The command term evaluate is defined as assessment of the implications and limitations. In this case it was the limitations of the data that were relevant. Candidates were expected to use the size of error bars and the sample sizes to assess the reliability of the data. Many candidates wrote instead about the differences between the data for the hermit thrush and American robin, without any actual evaluation.

e. Part (e) of question 1 tested a different skill in data analysis. Candidates were expected to pick out the most significant features of the data and as in (c), answers that merely quoted numerical figures from the bar chart mostly scored few marks. The points that the stronger candidates were made were that the triglycerides level at Site 1 was higher than that at Site 2 in all bird species and that the hermit thrush had the highest levels at both sites, whereas the Magnolia warbler was lowest at Site 1 and the American robin was lowest at Site 2.

f. 1(f) was another part of the question where it was important to pay attention to the command term. The term explain indicates that causes, reasons or mechanisms are required. In this case the causes of triglycerides levels being higher at Site 1 and of butyrate levels being higher at Site 2 were expected. The stem of the question had given the explanations that should have been given –fat deposition or fat utilisation.

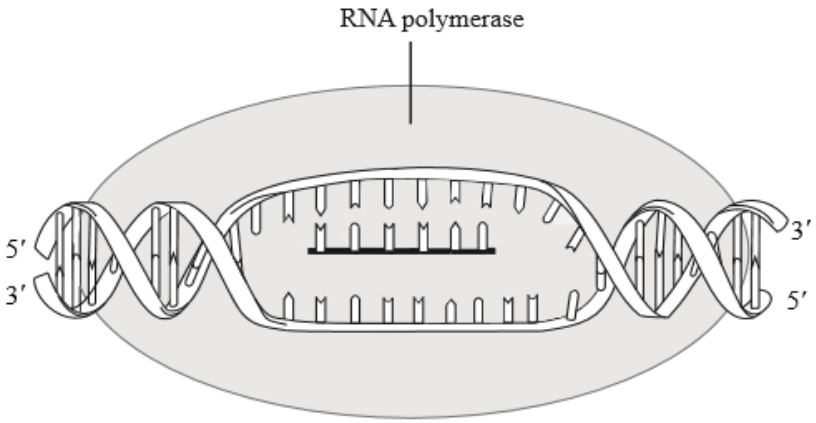
g. Part (g) involved another evaluation, in this case of a hypothesis. Candidates were expected to conclude that the data supported the hypothesis.

No mark was given this and instead marks were awarded for evidence.

Most candidates only considered the butyrate and triglycerides levels and so scored a maximum of one mark. The second mark was only awarded if candidates gave a broader answer by referring back to differences given earlier in the question for mean mass or mass change between Site 1 and Site 2.

h. The last part of the question involved suggesting and advantage and a disadvantage of blood sampling. A huge variety of answers were given but few candidates gave both an advantage and a disadvantage that the examiners considered acceptable. The disadvantage was the easier of the two and many candidates wrote about the stress of the procedure for wild birds or harm that the loss of blood might cause. The advantage that was most often given was the opportunity to obtain precise measurements for many different nutrients in blood, compared to the rather blunt assessment of food quality that weighing gives. There was some confusion about the meanings of terms such as precision and accuracy. Birds can of course be weighed accurately with great precision, whereas some candidates implied that blood tests were inherently more accurate and precise.

The diagram below shows the process of transcription.



a. DNA replication involves a number of enzymes including DNA polymerase. Identify **one** other enzyme involved in DNA replication. [1]

b. Explain the role of Okazaki fragments in DNA replication. [2]

c (i) Label the sense and antisense strands. [1]

c (ii) Draw an arrow on the diagram to show where the next nucleotide will be added to the growing mRNA strand. [1]

Markscheme

a. helicase / RNA primase / (DNA) ligase

b. DNA fragments/sections (formed) on the lagging strand;

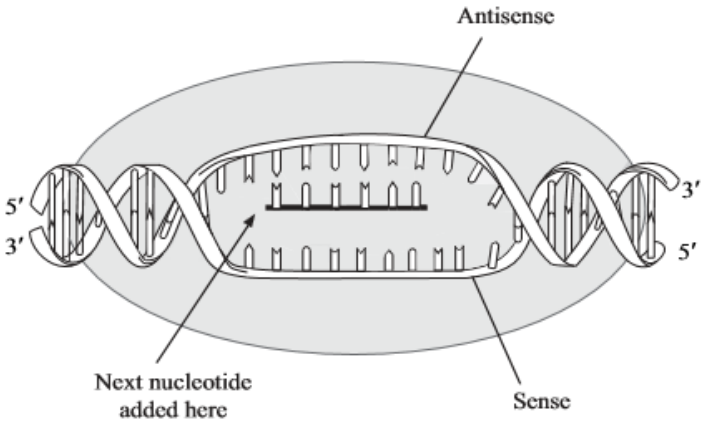
because replication must be in the 5' –3' direction;

replication starts repeatedly and moves away from replication fork;

c (i) both strands clearly labelled

Check carefully whether the correct strand has been labelled if the labels are shown in helical parts of the DNA.

Reject if the sense strand label points to the mRNA.



c (ii) a clearly drawn arrow pointing at the free 3' end of the mRNA strand or to the first free nucleotide on the antisense strand to the left of the mRNA

or to a nucleotide added by the candidate to the left hand end of the mRNA

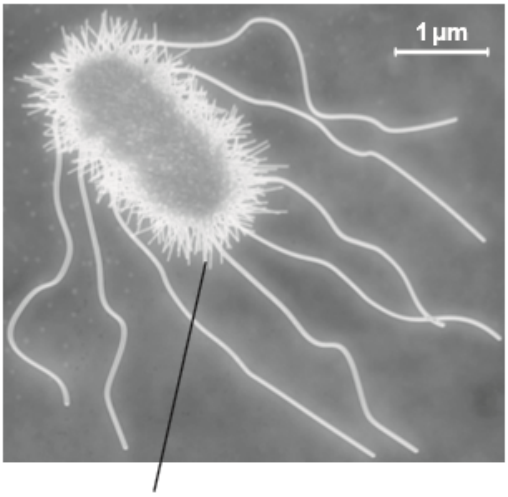
Examiners report

a. All but the weakest candidates were able to name an enzyme involved in DNA replication.

b. This question discriminated very well with the best candidates writing authoritatively about Okazaki fragments, but weaker candidates struggling. Some teachers felt that the word role was inappropriate here, but any answer explaining that Okazaki fragments are formed on the lagging strand because nucleotides can only be added in a 5' to 3' direction would have scored both marks. A common error was to refer to the lagging strand as the antisense strand. This is not correct -on a DNA molecule the lagging strand is the antisense strand for some genes and the sense strand for others.

c (i) About half of the candidates knew that the transcribed strand is the antisense strand, with the others either getting the strands the wrong way round or thinking that the mRNA was either the sense or the antisense strand.

c (ii) When asked in part (ii) to show where the next nucleotide will be added to the mRNA strand the weakest candidates labelled various places other than an end of the mRNA; of the other candidates, more than half labelled the right hand end, whereas the left hand was the 3' terminal so that is where the 5' end of a nucleotide would be added.



. . . . . .

a. Outline the cell theory. [2]

b (i). Annotate the electron micrograph of the *Escherichia coli* cell with the function of the indicated structure. [1]

b (ii). Calculate the magnification of the electron micrograph. [1]

c (i). Explain the role of the following enzymes in DNA replication. [1]

Helicase

c (ii). Explain the role of the following enzymes in DNA replication. [1]

DNA ligase

Markscheme

a. a. living things are composed of cells;

b. cells are the basic/smallest unit of life;

c. cells come from pre-existing cells;

Do not accept cells are the "smallest organisms".

Do not accept "cells are the building blocks" of life on its own.

b (i). attachment to surfaces / holds bacteria together / conjugation

Do not accept "exchange material" on its own.

If more than one function is given, mark the first answer only.

b (ii). 15 000 *(accept answers in the range of × 14 000 to × 16 000)*

c (i). helicase: unwinds /unzips the DNA (into two strands) / breaks H bonds;

c (ii). DNA ligase: joins/seals the nick between the (Okazaki) fragments;

Examiners report

a. Most students earned these marks. A small number demonstrated knowledge of the properties of cells but seemed to be unfamiliar with the cell theory itself.

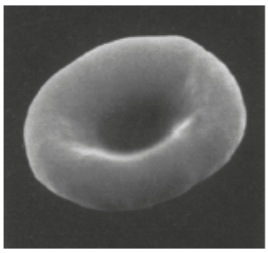
b (i) A number failed to state a correct function. The pilus plays a role in adhering to surfaces and in bacterial conjugation. A number annotated the picture with the name of the structure without stating a function.

b (ii) About half of candidates correctly answered this question. A number were making order of magnitude errors such as writing 150 000x and 1500x. Some were unfamiliar with the interpretation of the metric prefix.

c (i) Most were able to explain the function of helicase.

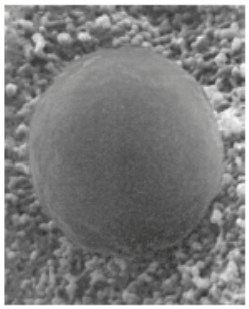
c (ii) Similar to primase, the mechanism of action of ligase was very rarely accurately described, most limiting it to bond formation between Okazaki fragments, not acknowledging that ligase has a role on the leading strand as well.

This image shows a normal red blood cell.

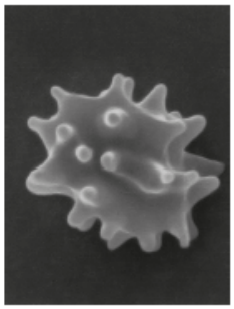


These images show two red blood cells that have been placed in solutions with different concentrations of solutes.

Red blood cell 1



Red blood cell 2



[Source: adapted from www.acbrown.com]

a. Outline the properties of water molecules that permit them to move upwards in plants. [2]

b. Define osmolarity. [1]

c. Deduce, with a reason, which red blood cell has been placed in a hypertonic solution. [1]

d. State what change there has been in the cell surface area to volume ratio in red blood cell 1. [1]

Markscheme

a. a. water molecules are polar

OR

can form hydrogen bonds

b. cohesion between water molecules allows continuous water columns

OR

cohesion between water molecules allows transpiration stream «to form in xylem»

c. adhesion of water to the walls of xylem vessel «helps water rise»

d. water evaporates at environmental temperatures allowing transpiration pull *OWTTE*

b. «measurement of» solute concentration of a solution *OWTTE*

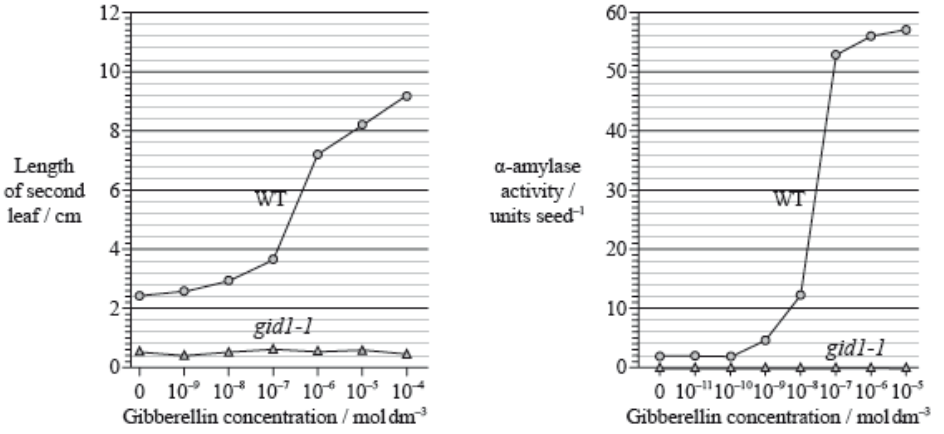
c. cell 2 because it has plasmolized/lost water/volume has decreased

d. decreased

Examiners report

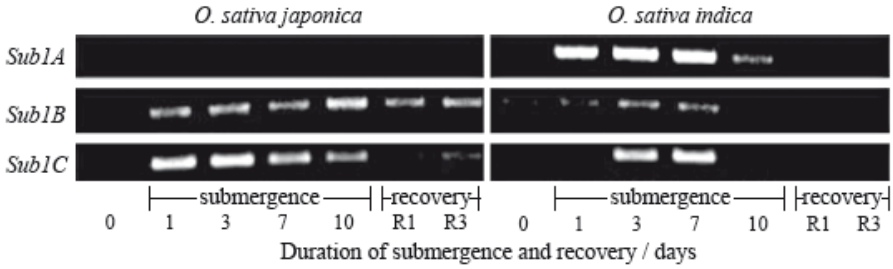
a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

Gibberellin promotes both seed germination and plant growth. Researchers hypothesize that the gene *GID1* in rice (*Oryza sativa*) codes for the production of a cell receptor for gibberellin. The mutant variety *gid1-1* for that gene leads to rice plants with a severe dwarf phenotype and infertile flowers when homozygous recessive. It is suspected that homozygous recessive *gid1-1* plants fail to degrade the protein SLR1 which, when present, inhibits the action of gibberellin. The graphs show the action of gibberellin on the leaves and α-amylase activity of wild-type rice plants (WT) and their *gid1-1* mutants.



[Source: adapted from M. Ueguchi-Tanaka et al. (2005) 'Gibberellin-insensitive dwarf1 encodes a soluble receptor for gibberellin'. Nature, 437, pp. 693—698. Adapted by permission from Macmillan Publishers Ltd (c) 2005.]

Most rice varieties are intolerant to sustained submergence under water and will usually die within a week. Researchers have hypothesized that the capacity to survive when submerged is related to the presence of three genes very close to each other on rice chromosome number 9; these genes were named *Sub1A*, *Sub1B* and *Sub1C*. The photograph below of part of a gel shows relative amounts of messenger RNA produced from these three genes by the submergence-intolerant variety, *O. sativa japonica*, and by the submergence-tolerant variety, *O. sativa indica*, at different times of a submergence period, followed by a recovery period out of water.



[Source: Adapted from "Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice" (2006) Kenong Xu, Xia Xu, Takeshi Fukao, Patrick Canlas, Reycel Maghirang-Rodriguez et al. Nature, 442, pp. 705—708. Adapted by permission from Macmillan Publishers Ltd (c) 2006.]

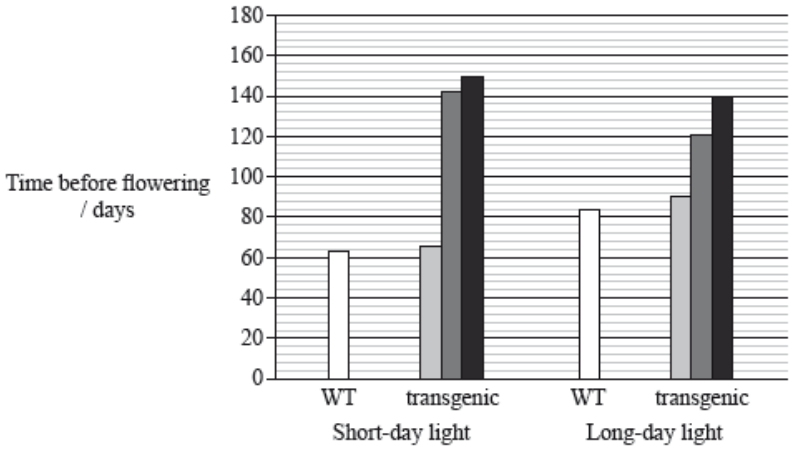
The *OsGI* gene causes long-day flowering and the effect of its overexpression has been observed in a transgenic variety of rice. Some wild-type rice (WT) and transgenic plants were exposed to long days (14 hours of light per day) and others to short days (9 hours of light per day).

The shades of grey represent the genotypes of the transgenic plants, where:

–/– do not have the overexpressed *OsGI* gene

+/– are heterozygous for the overexpressed *OsGI* gene

+/+ are homozygous for the overexpressed *OsGI* gene.



[Source: adapted from R. Hayama, S. Yokoi, S. Tamaki, M. Yano and K. Shimamoto (2003) 'Adaptation of photoperiodic control pathways produces short-day flowering in rice.' Nature, 422, pp. 719—722. Adapted by permission from Macmillan Publishers Ltd (c) 2003.]

a(i). State which variety of rice fails to respond to gibberellin treatment. [1]

a(ii). The activity of α-amylase was tested at successive concentrations of gibberellin. Determine the increment in gibberellin concentration that produces the greatest change in α-amylase activity in wild-type rice plants (WT). [1]

b. Discuss the consequence of crossing *gid1-1* heterozygous rice plants amongst themselves for food production. [3]

c(i). Determine which gene produced the most mRNA on the first day of the submergence period for variety *O. sativa japonica*. [1]

c(ii). Outline the difference in mRNA production for the three genes during the submergence period for variety *O. sativa indica*. [2]

d. Using only this data, deduce which gene confers submersion resistance to rice plants. [2]

e(i). State the overall effect of overexpression of the *OsGI* gene in plants treated with short-day light. [1]

e(ii). Compare the results between the plants treated with short-day light and the plants treated with long-day light. [2]

e(iii). State, giving **one** reason taken from the data opposite, if unmodified rice is a short-day plant **or** a long-day plant. [1]

g. Evaluate, using all the data, how modified varieties of rice could be used to overcome food shortages in some countries. [2]

Markscheme

a(i). *gid1-1*

a(ii). between 10^{-8} and 10^{-7} mol dm^{-3} *(units required)*

b. a. 25% / 1 in 4 / 1:3 seeds produced would be homozygous recessive;

b. no response to/inhibits gibberellin in homozygous recessives results in less germination;

c. less growth / dwarf plants produced; *(must be in context)*;

d. would produce plants with infertile flowers that cannot produce rice grains;

e. would lower rice production/less yield because infertile plants cannot produce seeds (that humans can eat);

c(i) *Sub1C*

c(ii) a. *Sub1A* is expressed strongly/the most / *Sub1A* produces the most RNA;

b. *Sub1B* (always) has the lowest expression/produces least mRNA;

c. *Sub1A* expressed/produces mRNA for the longest time/days 1 to 10;

d. *Sub1C* expressed/produces mRNA for the shortest time/days 3 to 7;

d. a. *Sub1A*;

b. is only expressed in *indica* / *Sub1B* and *SubC* are expressed in both rice varieties;

c. *indica* is the variety showing submersion tolerance / vice versa for *japonica*;

e(i) it increases the length of time <u>before</u> flowering

e(ii) a. long-day light exposure increases time before flowering only if (*OsGI*) gene is not overexpressed/in WT and –/–;

b. long-day light exposure decreases time before flowering for +/– and/or +/+;

c. length of day does not make much difference/makes least difference for +/+;

d. overexpression for +/– reduces time before flowering;

e. –/– acts as a control / has nearly the same length of time before flowering as WT;

Accept numerical answers if they are making a clear comparison.

e(iii) is a short-day plant <u>because</u> WT has shortest time/shorter time before flowering in shorter days than longer days / as it takes less time to flower under short day conditions;

g. a. the mutant *gid1-1* would not be useful because it produces sterile plants;

b. genetically modified rice/rice with *Sub1A* is more tolerant to submersion/can withstand seasonal flooding/torrential rain;

c. *OsGI*+ varieties adapted to different latitudes / day length could be produced (to overcome food shortages);

d. short flowering time possibly means more crops per year;

Examiners report

a(i) The word “increment” seemed to confuse the weaker candidates who stated a value rather than a range. In addition there were a large number who omitted or misquoted the units. In spite of being clearly stated in topic 9.3.5, very few candidates correctly gained the mark in part (iii) for saying that the amylase catalysed the breakdown of starch to maltose. Many answered glucose instead of maltose, but a surprising number did not even realise that amylase is an enzyme.

a(ii) The word “increment” seemed to confuse the weaker candidates who stated a value rather than a range. In addition there were a large number who omitted or misquoted the units. In spite of being clearly stated in topic 9.3.5, very few candidates correctly gained the mark in part (iii) for saying that the amylase catalysed the breakdown of starch to maltose. Many answered glucose instead of maltose, but a surprising number did not even realise that amylase is an enzyme.

b. Most of the better candidates realised that it was a simple monohybrid cross (although several thought it was dihybrid) and realised that 25% would produce dwarf plants, but did not explain the consequences on potential yield in sufficient detail for the third mark.

c(i). In spite of doubts from the G2 forms, candidates had little difficulty in interpreting the photograph.

In part (i) most correctly answered *Sub1C*.

c(ii). The answers to (ii) tended to be descriptive, not making clear <u>differences</u>, as asked.

d. Most candidates correctly identified *Sub1A* with a correct reason.

e(i). Most answered correctly that it increased the time <u>before</u> flowering.

e(ii). In (ii) almost every correct answer was from the first two mark points.

e(iii). In (iii) most candidates identified it as a short-day plant with reasons.

g. In spite of the stem saying “using all the data”, most of the answers were very vague and did not use the data. The ideas that the mutant *gid1-1* should be avoided as it produces sterile plants and those modified with *Sub1A* would withstand seasonal flooding were missed by most candidates.

The diagram below shows the structure of lactase

[Source: Kindly provided by RL Miesfeld, The University of Arizona, Tucson, AZ USA]

a (i). A study of 600 adolescents in Sweden showed that milk consumption has a positive effect on height which shows continuous variation. [1]

However, milk contains lactose which some people can digest but some cannot.

State the pattern of inheritance that contributes to continuous variation.

a (ii). Explain the production of lactose-free milk. [3]

b (i). Identify the protein structures indicated by I and II. [1]

I: .....
II: .....

b (ii). Describe how structure I is held together. [2]

b (iii). This protein is described as a globular protein. Distinguish between globular and fibrous proteins. [2]

Markscheme

a (i). polygenic / more than one gene

Accept polygenetic. Mark only first answer if more than one answer given.

a (ii). lactase added to milk / lactase immobilised;

lactose hydrolysed/broken down into glucose and galactose;

for people who are lactose intolerant/lack lactase;

increases sweetness/solubility/smooth texture (in processed foods);

b (i). I is alpha helix and II is beta pleated sheet

Reject (α) double helix but accept α/A/a and β/B/b instead of alpha and beta.

b (ii). hydrogen bonds;

Reject hydrogen and covalent bonds unqualified and hydrogen bonds between bases.

(hydrogen bonds) between N–H and C=O (on different amino acids);

Reject between amine and carboxyl groups.

(hydrogen bonds) between adjacent turns of the helix/every fourth amino

acid;

Accept above points in an annotated diagram.

b (iii).

Globular	*Fibrous*
water soluble (mostly)	not (water) soluble;
rounded shape/tertiary structure	long/narrow shape / no tertiary structure;
enzymes/hormones/catalysis/transport /defence functions	structural/movement functions;

A table is not required but for each feature the difference between globular and fibrous proteins must be made clear.

Examiners report

a (i). About half of candidates knew that polygenic inheritance contributes to continuous variation.

a (ii) This question was generally well answered with stronger candidates able to score full marks. A few confused lactase with lactose and the products of lactose hydrolysis were not always known.

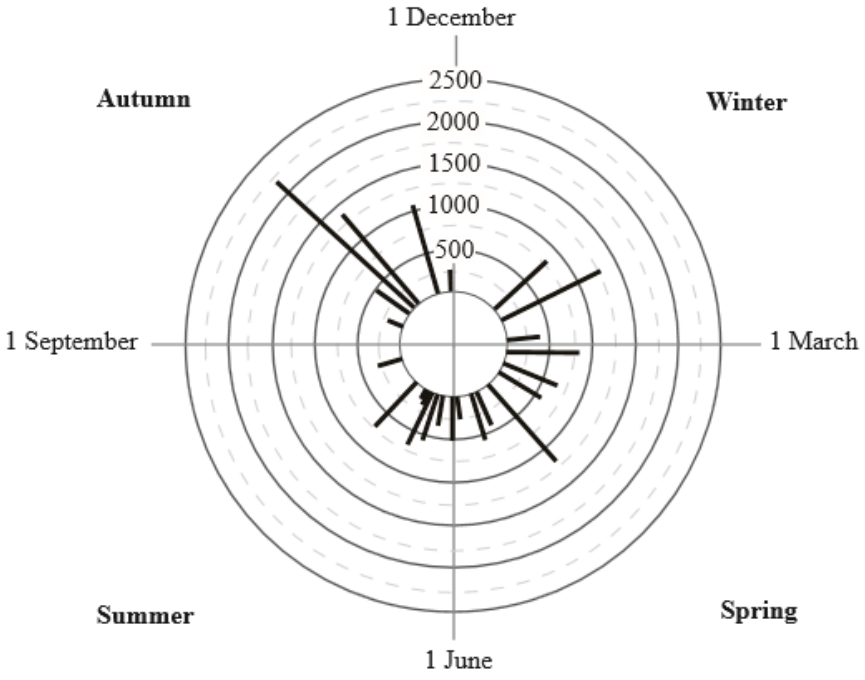
b (i) About a quarter of candidates knew the names of the two secondary structures.

b (ii) Few candidates stated that hydrogen bonds stabilise secondary structures and even fewer earned a second mark for giving a detail of the hydrogen bonding.

b (iii) N/A

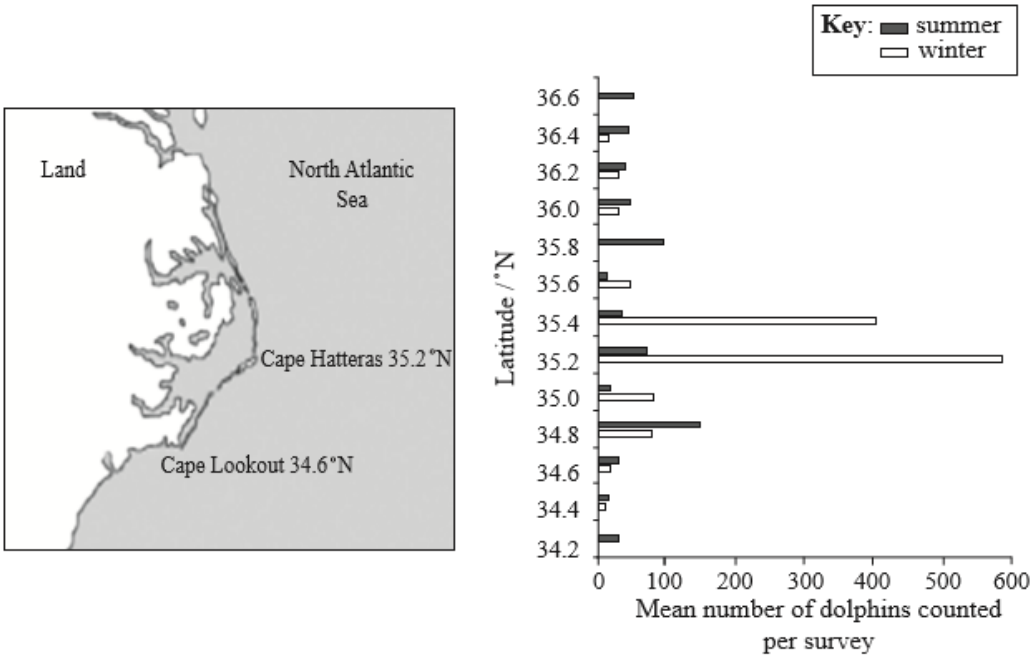
Bottlenose dolphins (*Tursiops truncatus*) inhabit almost all tropical and temperate oceans between 45°N and 45°S. Over a two-year period, aerial surveys were carried out to investigate the seasonal distribution of these animals along the mid-Atlantic and eastern coastal waters of the USA. Sightings were recorded using a global positioning system (GPS) while flying in a regular pattern within approximately 65 km of the shore. A total of 12 760 dolphins were sighted over the two-year period and the data are summarized in the chart below.

Each bar corresponds to a single survey and the length of the bar corresponds to the total number of bottlenose dolphins counted in that survey. The circles with numbers indicate numbers of dolphins.



[Source: adapted from Leigh G. Torres, William A. McLellan, Erin Meagher and D. Ann Pabst (2005) 'Seasonal distribution and relative abundance of bottlenosedolphins, *Tursiops truncatus*, along the US mid-Atlantic Coast.' *Journal of Cetacean Research and Management*, 7 (2), pp. 153–161.]

As part of the same study, coastal aerial surveys were carried out over the same time period by flying parallel to the coast approximately 500 m offshore. The diagram below shows a map of the section of coast surveyed. The bar graph shows the seasonal data for summer and winter at the corresponding latitudes (°N). A total of 5431 bottlenose dolphins were sighted during these surveys.



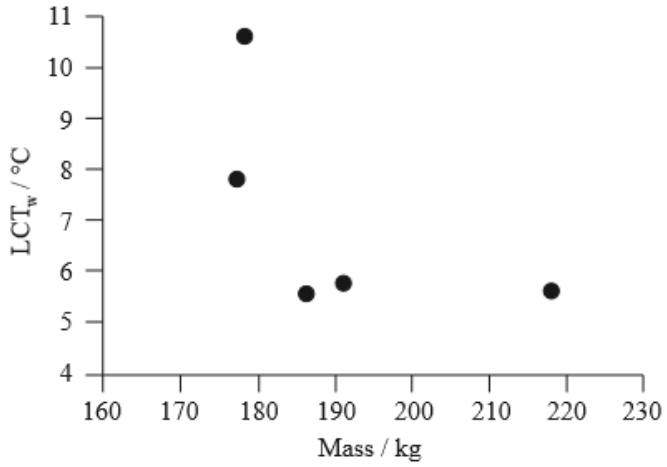
[Source: adapted from Leigh G. Torres, William A. McLellan, Erin Meagher and D. Ann Pabst (2005) 'Seasonal distribution and relative abundance of bottlenosedolphins, *Tursiops truncatus*, along the US mid-Atlantic Coast.' *Journal of Cetacean Research and Management*, 7 (2), pp. 153–161.]

In a different study, researchers investigated the role of water temperature as a possible factor in the distribution of bottlenose dolphins. The rate of metabolism (measured as the rate of oxygen uptake per unit mass) of five captive adults was measured under a range of water temperatures. The rate of metabolism was found to increase significantly when the water temperature fell below a certain value known as the lowest critical water temperature (LCT_w). Below this temperature the body uses more energy to combat the cooling effect of the surrounding water. The data for these animals are summarized below.

Animal	Sex	Age / years	Mass / kg	LCT_w / °C
1	male	27	177.3	7.8
2	male	24	191.4	5.7
3	male	26	219.7	5.6
4	male	14	187.0	5.5
5	female	33	178.2	10.6

Adapted with permission from L.C. Yeates and D.S. Houser (2008) 'Thermal tolerance in bottlenose dolphins (*Tursiops truncatus*).' *Journal of Experimental Biology*, 211, pp. 3249–3257, Table 1. doi:10.1242/jeb.020610: The Journal of Experimental Biology: jeb.biologists.org

The graph below summarizes the relationship between LCT_w and body mass.



[Adapted with permission from L.C. Yeates and D.S. Houser (2008) 'Thermal tolerance in bottlenose dolphins (*Tursiops truncatus*).' *Journal of Experimental Biology*, 211, pp. 3249–3257, Figure 4. doi:10.1242/jeb.020610: The Journal of Experimental Biology: jeb.biologists.org.]

a. State the largest number of dolphins counted in a single survey. [1]

b. Calculate the mean number of dolphins counted per survey for the winter season. [1]

c. Compare the data for the dolphin populations in winter and summer. [2]

d (i) Compare the distribution of dolphins in summer and winter. [2]

d (ii) Suggest **one** reason for the differences in distribution. [1]

e. Outline the relationship between body mass and LCT_w for male dolphins. [2]

f. Suggest **one** reason for the high LCT_w measured for the female dolphin. [2]

g. Evaluate the hypothesis that water temperature determines the range and distribution of bottlenose dolphins in the wild. [2]

h. Explain how an increase in water temperature due to global warming could affect the distribution of bottlenose dolphins along the eastern coast of the USA. [2]

Markscheme

a. 2200 (*allow answers in the range 2175–2225*)

b. 800 (*allow answers in the range 750–850*)

c. more surveys in summer / fewer in winter;

larger average/biggest number sighted (per survey) in winter / converse;

larger <u>total</u> number of dolphins (from adding up all surveys) in summer;

variation in both seasons / overlap in numbers between summer and winter;

Do not accept answers relating to distribution.

Do not accept answers stating that the dolphin population is higher in winter.

d (i) more evenly distributed in summer than in winter (across latitudes);

many near Cape Hatteras/35.0/2–35.4/6 °N in winter/more than in summer;

more dolphins overall in the survey area in winter than in summer;

wider summer range / reaches 36.6 and 34.2 °N/ less far N and S in winter;

unimodal distribution in winter versus bimodal in summer / *OWTTE*;

d (ii) seasonal variation in food supply/prey/predators/water temperatures;

migration to find food/prey/warmer water/mates;

migrating dolphins rest/congregate near Cape Hatteras/35.2 – 35.4°N;

Cape Hatteras /35.2 – 35.4°N may be a mating area in the winter;

seasonal variation in human activity / valid example;

more food/warm water between mainland and Cape Hatteras in winter;

e. male dolphin with the lowest body mass has the highest LCT_w;

with larger dolphins/above 180/185/187 kg no change in LCT_w with body mass;

weak negative correlation / as mass increases LCT_w drops / *vice versa*;

uncertainty due to small amount of data;

f. *Accept any of the following points about the female:*

older so (possibly) has a lower metabolic rate / other result of age;

higher surface area to volume ratio (than male);

less active than males so releasing less metabolic heat;

less insulation due to subcutaneous fat/adipose tissue;

suckling / pregnant / part of mass was fetus;

g. supported as water temperature affects metabolic rate;

supported as dolphins will avoid areas with water below their LCT_w;

water temperature is unlikely to be a factor for bigger males;

wide (latitude) range in summer suggests temperature does not determine range;

few animals / only one female / only narrow range of latitudes investigated;

data may not be reliable since the study was conducted in captivity;

h. may migrate/move range further north;

migrate to area with cooler/suitable water temperature;

ocean currents may change;

most productive waters/food supply may be further north;

distribution more spread out (due to warmer waters in more areas);

Examiners report

a. The unusual circular form of the graph made it more difficult to read off the value for the largest number of dolphins in a single survey and only about two thirds of candidates did this carefully enough to earn the mark.

b. There was quite a lot to do here; three values had to be read from the graph and then a mean value calculated. Again about two thirds of candidates scored the mark.

c. There were plenty of valid comparisons for candidates to make and most scored two marks. Some candidates failed to understand that the results are merely sightings of dolphins and not total population counts; they therefore incorrectly implied that the population size varied considerably during each season.

d (i) Candidates found this question more challenging and in some cases it was clear that they had not studied the data carefully enough. As in all compare questions, the answer should make genuine comparisons and not describe the two things separately, in this case the winter and summer distributions. Some candidates did not understand that a population is a number of organisms and a distribution is where those organisms live.

d (ii) A huge variety of suggestions for the difference between the summer and winter differences was given by candidates and many of these answers were considered valid. The answer could have been based either on possible differences in dolphin behaviour between summer and winter for example breeding, or possible differences in the environment such as water temperature.

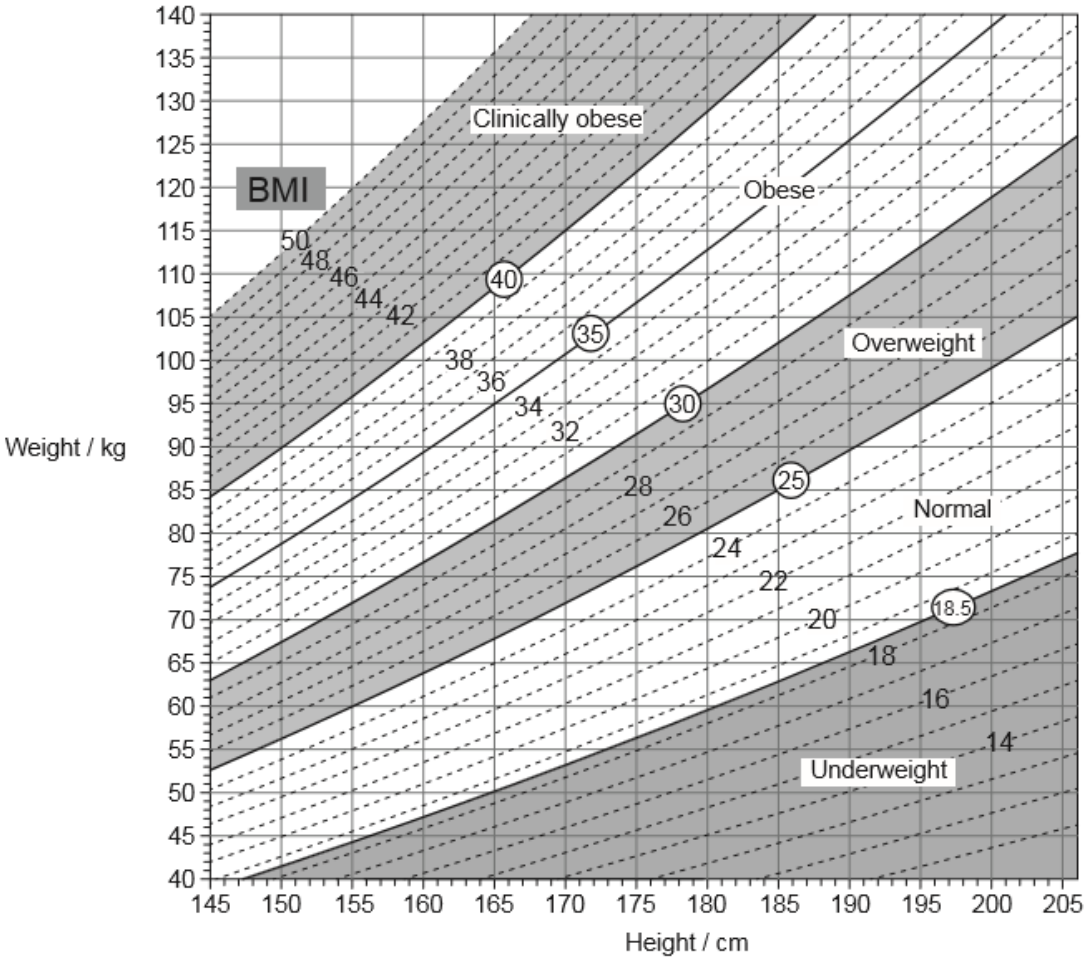
e. Answers were in many cases weaker than expected. Most candidates stated that as mass increased, the LCT_w of make dolphins decreased, which earned one mark. The difficulty came in earning the second mark. The mark scheme gives a variety of other points that can be made, for example that the individual dolphin with the lowest mass had the highest LCT_w or that above 187kg there does not seem to be much if any further decrease in LCT_w. Many candidates seemed to realize that to get the second mark they needed to give more than the negative correlation but then merely restated the correlation in different phraseology.

f. Any possible reason for the high LCT_w in females was accepted, though not simply that she was older –some reason for higher LCT_w in an older female was required.

g. Candidates found this question hard and the examining team had some sympathy with them as there isn"t very much basis in the data for evaluation of the hypothesis. The most effective answers concentrated on the graph of mass against LCT_w as this shows that the metabolic rate of dolphins will have to increase if dolphins are in cold water. Some candidates realized this, but few then went on to comment on the small sample size or the fact that this data was obtained with dolphins in captivity and that in the wild there could be a different trend.

h. This was expected to be an easy and high scoring question, but many candidates struggled with it and revealed gaps in their understanding of the data given earlier in the question. It is important to read all of the text in a data-based question, as it places the data in context and often gives information without which the data cannot be understood properly. In many cases candidates based their answer on faulty understanding. For example, a surprisingly large number decided that Cape Hatteras was on the equator and that to find cooler water dolphins could move north or south. No detailed geographical knowledge was needed to score two marks, but geographical misunderstandings did not help. The answer expected in advance by the examining team was that the dolphins population would move north in response to global warming to find cooler water. It was given be a minority, but other valid answers were accepted.

The image shows a nomogram.



a. (i) Using the nomogram, state the lower weight limit for a woman with the height of 155 cm who is classified as overweight, giving the units. [2]

Lower weight limit: .....

(ii) State a major health problem of the circulatory system that is correlated with obesity.

b. Draw the structure of a saturated fatty acid. [2]

c. Describe how the hormone leptin helps to prevent obesity. [3]

Markscheme

a. (i) 60 kg *Units required*.

(ii) coronary heart disease ***or*** coronary artery disease ***or*** thrombosis ***or*** stroke ***or*** hypertension ***or*** high blood pressure ***or*** atheroma ***or*** fatty deposits in arteries ***or*** plaque «in arteries» ***or*** arteriosclerosis ***or*** atherosclerosis

b. $[CH_2]_n$ / hydrocarbon chain with single bonds and at least four carbons

COOH head at one end ***AND*** three hydrogens on other end

The minimum of four carbons includes the end of the hydrocarbon chain and the COOH group.

c. Hormone produced by adipose/fat cells/adipose tissue. *Reject produced by fat. Reject produced by pituitary.*

Acts on/target cells are in the hypothalamus «of the brain»

Inhibits/reduces appetite/hunger
OR
causes feeling of satiety
OR
makes you feel full

More leptin with more adipose tissue/fat «storage» tissue/cells

Eat less/decreases/reduces food intake/in humans obese people can have leptin resistance

Examiners report

a. (i) Teachers expressed fears in G2 forms that candidates would be unable to use the nomogram through unfamiliarity. In fact most candidates successfully read off the value as instructed.

(ii) Many candidates could name a health problem of the circulatory system correlated with obesity, but vague terms, such as clogged arteries, were not allowed.

b. This was generally well answered. Most candidates showed a saturated hydrocarbon chain correctly and many also showed the carboxyl group.

c. Despite the fact that the hormone leptin is a new concept in the syllabus many candidates were able to answer this question accurately. In weak answers there was some confusion over the origin of leptin and its role.

The Chinese soft-shelled turtle, *Pelodiscus sinensis*, lives in salt water marshes. The turtle can live under water and out of water.

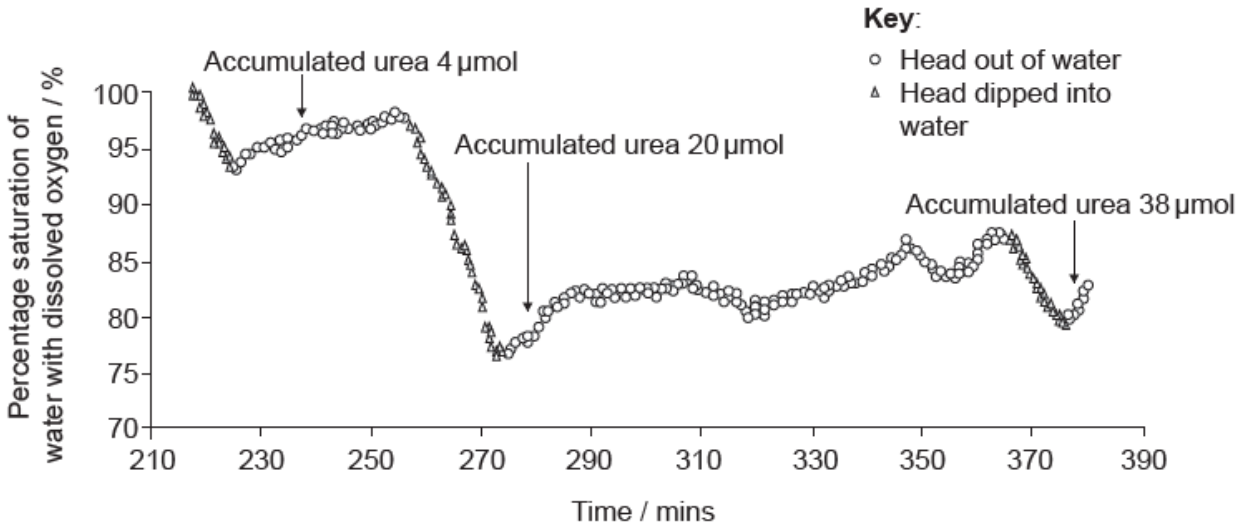
These turtles have fully developed lungs and kidneys, however, many microvilli have been discovered in the mouth of *P. sinensis*. A study was undertaken to test the hypothesis that oxygen uptake and urea excretion can simultaneously occur in the mouth.

Initial experiments involved collecting nitrogen excretion data from *P. sinensis*. The turtle urinates both in water and out of water. When in water it allows waste products to be washed out of its mouth. When out of water it regularly dips its head into shallow water to wash its mouth. The table shows the mean rates of ammonia and urea excretion from the mouth and kidney over six days.

	Excretion of nitrogen by the mouth / μmol day^{-1} g^{-1} turtle		Excretion of nitrogen by the kidney / μmol day^{-1} g^{-1} turtle	
	Turtle submerged in water	Turtle out of water	Turtle submerged in water	Turtle out of water
Ammonia	0.29	0.30	0.63	0.54
Urea	0.90	1.56	0.07	0.73

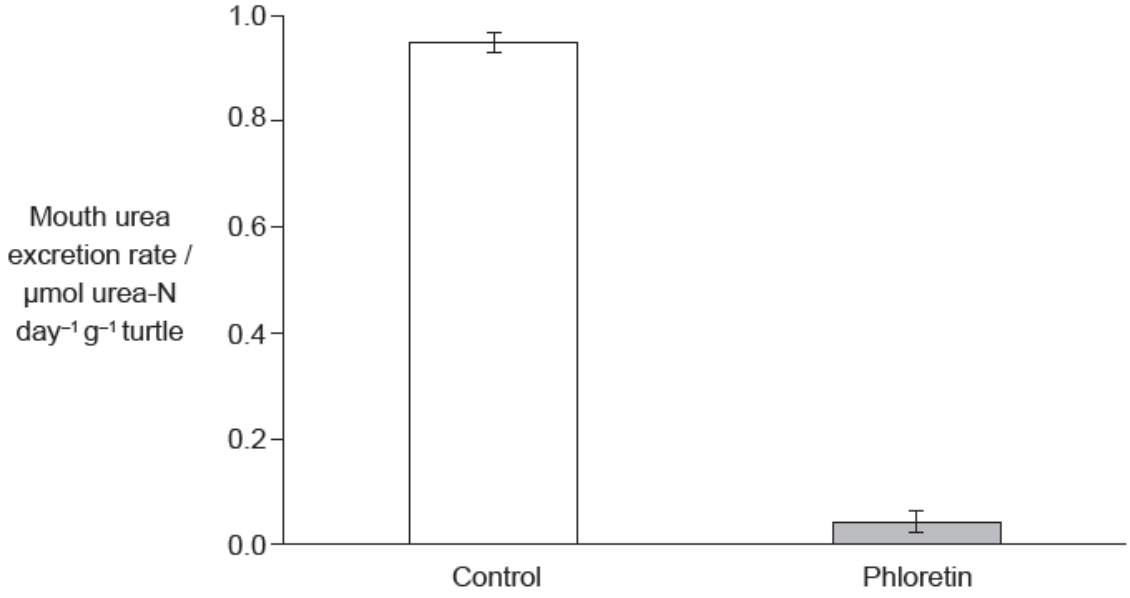
[Source: Reproduced with permission, Y. Ip *et al.* (2012) *The Journal of Experimental Biology*, 215, pages 3723—3733. jeb.biologists.org. doi: 10.1242/jeb.068916]

It was noted that during long periods out of water, turtles rhythmically moved their mouths to take in water from a shallow source and then discharge it. Changes in the dissolved oxygen and the quantity of accumulated urea in the rinse water discharged by the turtles were monitored over time as shown in this graph.



[Source: adapted with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733.]

In order to test whether a urea transporter was present in the mouth tissues of the turtles, phloretin (a known inhibitor of membrane proteins that transport urea) was added to the water in which a further set of turtles submerged their heads. The results of that treatment are shown.

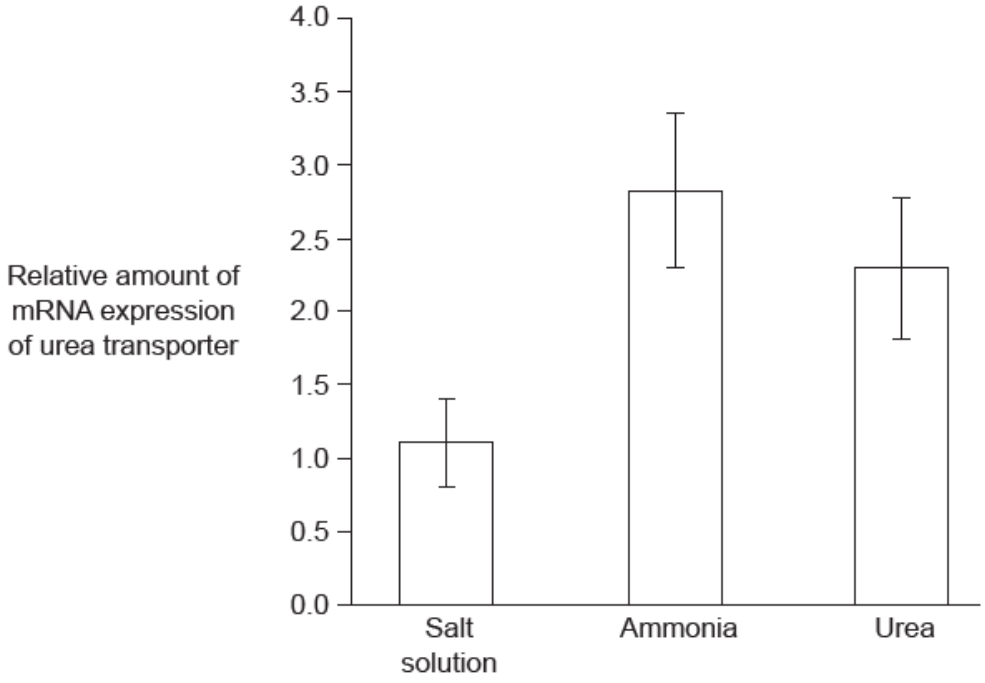


[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

Further research was conducted to determine where mRNA expression of a urea transporter gene might be occurring in *P. sinensis*. Gel electrophoresis was used to analyse different tissue samples for mRNA activity.

[Source: Reproduced with permission from Y. Ip *et al.* (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

Expression of the urea transporter gene by cells in the turtle's mouth was assessed by measuring mRNA activity. Turtles were kept out of water for 24 hours and then injected with either a salt solution that matched the salt concentration of the turtle, dissolved ammonia or urea, followed by another 24 hours out of water.



[Source: © International Baccalaureate Organization 2017]

a. Deduce whether the excretion of ammonia or urea changes more when a turtle emerges from water. [2]

b. Compare and contrast the changes in urea excretion in the mouth with the changes in urea excretion in the kidney when a turtle emerges from the water. [3]

c.i. Describe the trends shown by the graph for dissolved oxygen in water discharged from the mouth. [1]

c.ii. Suggest reasons for these trends in dissolved oxygen. [2]

d. Deduce with a reason whether a urea transporter is present in the mouth of *P. sinensis*. [2]

e. Outline the additional evidence provided by the gel electrophoresis results shown above. [2]

f.i. Identify which of these turtle groups represent the control, giving a reason for your answer. [1]

f.ii. Suggest a reason for the greater expression of the gene for the urea transporter after an injection with dissolved ammonia than an injection of urea. [2]

g. The salt marshes where these turtles live periodically dry up to small pools. Discuss the problems that this will cause for nitrogen excretion in the turtles and how their behaviour might overcome the problems. [3]

Markscheme

a. a. urea

b. for both mouth and kidney

c. percentage change/change in μmol day^{-1} g^{-1} greater with urea/other acceptable numerical comparison

b. a. both higher/increased on emergence from/with turtle out of water

b. both increased by 0.66 «μmol^{-1} g^{-1} when turtle emerges from water»

c. % increase is higher in kidney / kidney 940% versus mouth 73/75% / increase is higher proportionately higher in kidney / kidney x10 versus mouth nearly double/x1.73

d. urea excretion by mouth greater than kidney out of water «despite larger % increase in kidney excretion»

c.i. decrease «when head is submerged» and increase when head is out of water

c.ii. a. oxygen absorbed from water/exchanged for urea when head dipped in water«so oxygen concentration decreases»

b. lungs cannot be used with head in water / can «only» be used with head out of water

c. oxygen from water «in mouth» used in «aerobic cell» respiration

d. oxygen from air dissolves in water when head out of water «so oxygen concentration increases»

d. a. urea transporter is present

b. less urea «excreted»/ lower rate «of urea excretion» / excretion almost zero when phloretin/inhibitor was present

e. a. mRNA only in mouth and tongue/in mouth and tongue but not esophagus intestine kidney or bladder

b. bands / lines indicate mRNA for/expression of urea transporter gene

c. urea transporter gene expressed / urea transporters in mouth/tongue / not expressed/made in esophagus/intestine/kidneys/bladder

d. mRNA/transcription/gene expression/urea transporters higher in tongue/more in tongue «than mouth»

f.i. salt solution is control because it does not contain a nitrogenous/excretory waste product / it matches the salt concentration of the turtle / the turtle's body already contains salt / because the turtle lives in salt water/salt marshes / because nothing has been altered

f.ii. a. ammonia is «highly» toxic/harmful

b. ammonia is more toxic than urea/converse

c. ammonia converted to urea

d. urea concentration raised «by injecting ammonia»

e. difference between ammonia and urea «possibly» not «statistically» significant

g. *Problems:*

a. urea becomes more concentrated «in small pools» / lower concentration gradient «between tongue/mouth and water»

b. less water available for urine production/excretion by kidney

OR

less water in ponds for mouth rinsing/more competition for pools (to use for mouth rinsing)

Behaviour to overcome problems:

c. «still able to» dip mouth into/mouth rinse in water/pools

d. «still able to» excrete urea «though the mouth» in the small pools

e. more conversion of ammonia to urea/urea excretion rather than ammonia

f. more urea transporters/expression of urea transporter gene

g. urea excreted «in mouth/via microvilli» by active transport/using ATP

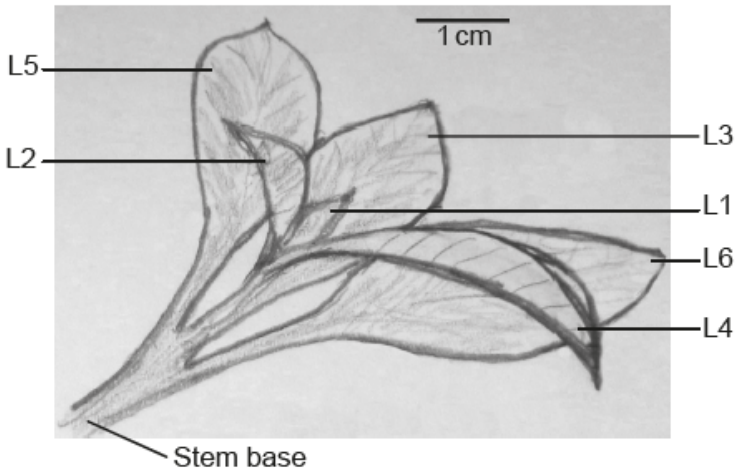
h. excretion with little/no loss of water

Examiners report

a. [N/A]
b. [N/A]
c.i. [N/A]
c.ii. [N/A]
d. [N/A]
e. [N/A]
f.i. [N/A]
f.ii. [N/A]
g. [N/A]

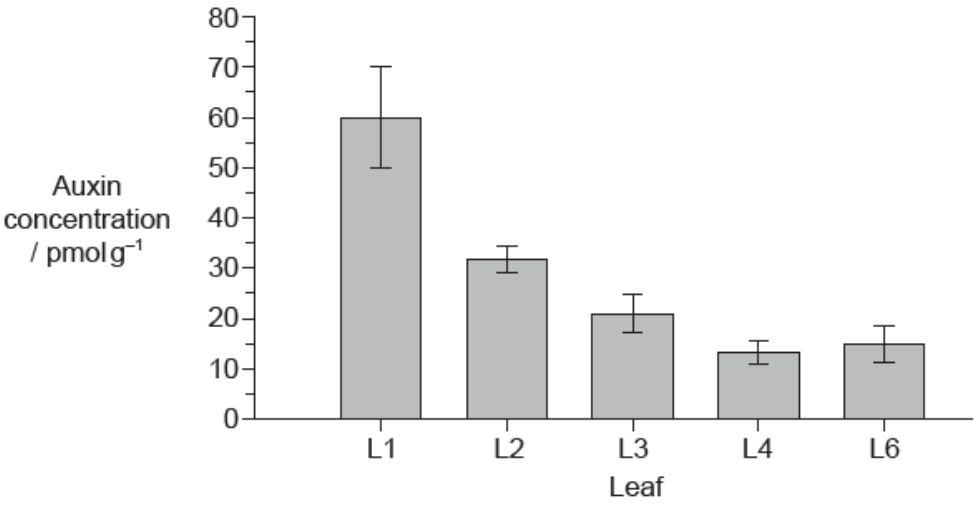
Auxin can be used to promote the development of roots from stem and leafy cuttings in some plants. In a study into the distribution of auxin in the development of these roots, scientists measured the amount of auxin in different leaves of a shoot tip of *Petunia hybrida*.

The figure indicates the numbering of leaves on the shoot, from L1 as the youngest and smallest to L6 as the largest and oldest leaf. The developmental stage of L5 and L6 was very similar, so L5 was not analysed. The stem base is the lowest part of the cutting where roots may form.



[Source: A. Ahkami *et al.* (2013) *Planta*, 238, pages 499–517]

The graph shows the auxin concentration in the different leaves.



[Source: A. Ahkami *et al.* (2013) *Planta*, 238, pages 499–517]

N-1-naphthylphthalamic acid (NPA) is an inhibitor used to block auxin transport. NPA was sprayed onto the leaves of a set of cuttings for 14 days.

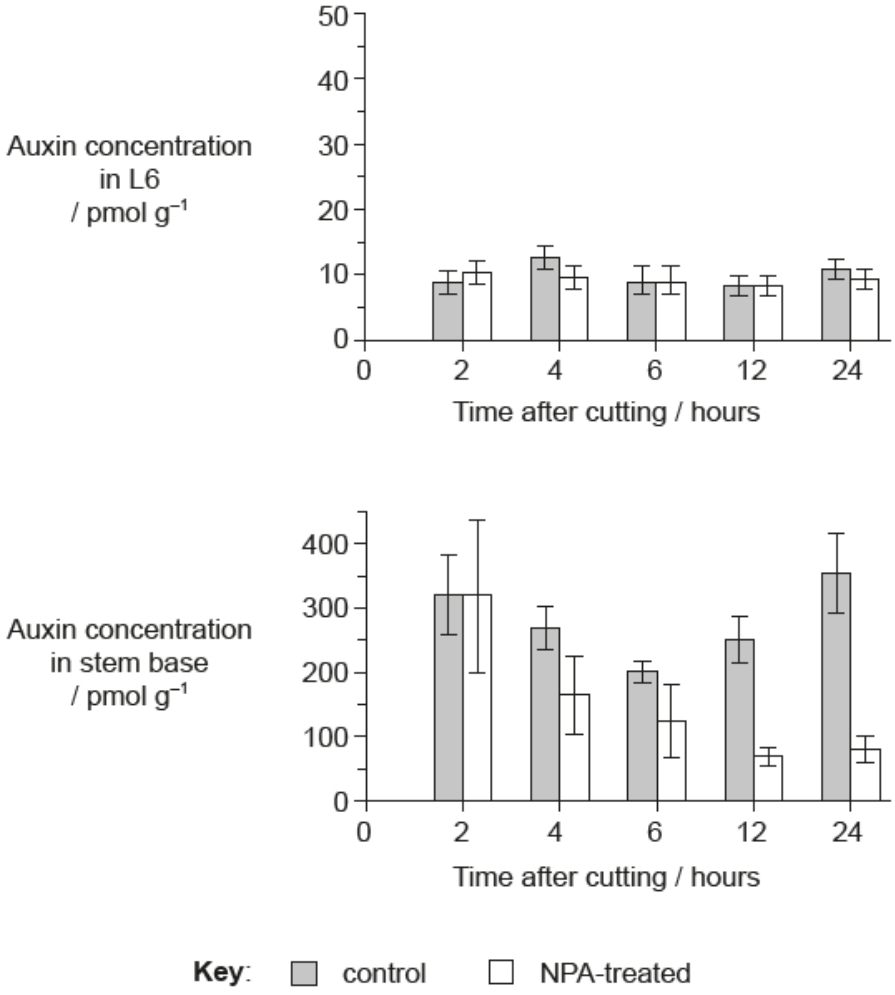
Development of the roots in control (non-treated) and NPA-treated cuttings was measured 14 days after taking the cuttings.

The table shows the influence of NPA on rooting.

	Mean number of roots per cutting	**Mean root length / cm**	**Mean total root length per cutting / cm**
Control	53.2	1.4	47.7
NPA-treated	8.0	0.6	1.0

[Source: adapted from A Ahkami, *et al.*, (2013), *Planta*, **238**, pages 499–517]

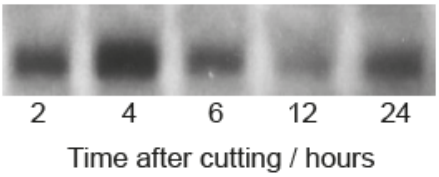
The scientists also measured the changes in auxin concentration in L6 and the stem base during the early period of root formation. They recorded the concentration in the control and NPA-treated cuttings for 24 hours after taking the cuttings.



[Source: adapted from A Ahkami, *et al*., (2013), *Planta*, **238**, pages 499–517]

The scientists wanted to know whether the accumulation of auxin over time in the stem base of the controls affected expression of the *GH3* gene, known to have a role in growth regulation in different plants. The technique that was used to quantify the level of transcription of the *GH3* gene was Northern blotting. In this procedure the darkness

and thickness of the band is an indicator of the level of transcription of a particular gene. The image shows the result of the Northern blot from 2 hours to 24 hours after cutting.



[Source: adapted from A Ahkami, *et al*., (2013), *Planta*, **238**, pages 499–517]

a. Calculate the difference in the concentration of auxin found in L1 and L6. [1]

. . . . . pmol g^{-1}

b. Identify the relationship between the concentration of auxin and the age of the different leaves. [2]

c. Analyse the effect of NPA on the formation of roots. [2]

d.i. Compare and contrast the changes in auxin concentration in the stem base over time for the control and NPA-treated cuttings. [2]

d.ii. Deduce the effect of NPA on auxin transport between L6 and the stem base. [2]

e. Based on all the data presented and your knowledge of auxin, discuss the pattern of auxin production and distribution in the leaves and the possible relationship to root formation in leafy cuttings of *Petunia hybrida*. [3]

f.i. State the name of the molecule which is produced by transcription. [1]

f.ii. Compare the pattern of *GH3* transcription with the pattern of auxin concentration in the stem base control cuttings. You may use the table provided to help you to record the patterns before you compare them. (Please note: a simple comparison in the table will not gain marks) [2]

	2–4 hours	4–6 hours	6–12 hours	12–24 hours
Auxin concentration				
***GH3* bands**				

f.iii. The scientists concluded that auxin activates the transcription of the *GH3* gene. Using the information on the auxin concentration in the stem base in the graph and the Northern blot, evaluate whether this conclusion is supported. [2]

Markscheme

a. 45 «pmol g^{-1}»

Allow answers in the range of 44 «pmol g^{-1}» to 46 «pmol g^{-1}».

b. less auxin as the leaves become older/larger *Vice versa*

OR

negative correlation from L1 to L4

L4 and L6 leaves have least auxin concentration
OR
L4 and L6/older leaves have about the same concentration of auxin/do not have significantly different concentrations

c. a. NPA decreased the «mean» number of roots per rooted cutting «by about 5» *OWTTE*

b. NPA decreased the «mean» length per root «by more than half»

c. NPA decreased the «mean» total root length per planted cutting «to about 2 % of control» *OWTTE*

d. NPA inhibited the formation of roots
OR
decreased all three measures

Accept other correct statements of overall changes in values.
The word "mean" is not required.

d.i. a. both decrease up to 6 hours/initially

b. NPA-treated decrease more/at a faster rate than control «up to 6 hours»

c. after 6 hours, control increases while NPA treated continues to fall

d.ii a. NPA «appears to have» no effect on concentrations/transport of auxin in L6 as control and NPA-treated remain at same «low» level

OWTTE

A valid reason must be given for the mark.

b. NPA «probably» inhibits the auxin efflux pumps/transport «in the leaves» as the levels drop in NPA-treated in stem base «but not in control»

OWTTE

A valid reason must be given for the mark.

c. the transport of auxin to the stem base must occur from younger leaves
OR
L6 is not the source of auxin in the stem base

d. NPA inhibits the auxin pumps/transport «in the leaves» as the levels drop in NPA-treated in stem base

e. a. L1 has the highest concentration of auxin so appears to be/is the main source/the producer of auxin

b. as leaves age, they «appear to» decrease the production of auxin

Vice versa

c. the stem base is an auxin sink as seen by the accumulation in the control stem base «where roots form»
OWTTE

d. high concentration of auxin «in the stem base» promotes root formation
Vice versa

f.i. mRNA/RNA

f.ii. a. at 2 and 24 hours, auxin levels are similar and at 2 and 24 hours *GH3* levels are similar

b. the pattern for the formation of auxin is similar to the pattern of transcription of the *GH3* gene
OR
both decrease and then increase

c. «however» there is a lag between the peaks of the *GH3* transcription and the peaks of auxin

A comparison must be made to award marks. Do not award marks for simple completion of the table.

f.iii a. the data «partially» supports the conclusion

OR

the relationship is not clear

b. the auxin concentration «seems to» rise before the transcription level increases

OR

there is a lag between auxin concentration changing and transcription level changing

OR

the auxin concentration falls before the transcription level falls

To award mp b, awareness of the lag should be demonstrated

c. more data is needed «before two hours/after 24 hours»
OWTTE

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d.i. [N/A]
d.ii. [N/A]
e. [N/A]
f.i. [N/A]
f.ii. [N/A]
f.iii. [N/A]