HL Paper 2

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]

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a. Draw a labelled diagram of the structure of a chloroplast as seen with an electron microscope. [4]

b. Describe how water is carried by the transpiration stream. [7]

c. Explain how flowering is controlled in long-day and short-day plants. [7]

Markscheme

a. *Award **[1]** for each of the following clearly drawn and correctly labelled. Label lines must be unambiguous in terms of what they are indicating.*

double/inner and outer membrane/envelope – shown as two concentric <u>continuous</u> lines close together;

granum/grana – shown as a stack of several disc-shaped subunits;

(intergranal) lamella – shown continuous with thylakoid membrane;

thylakoid – one of the flattened sacs;

stroma;

(70S) ribosomes/(circular) DNA / lipid globules / starch granules / thylakoid space;

b. transpiration is water loss (from plant) by evaporation;

flow of water through xylem from roots to leaves is the transpiration stream;

evaporation from spongy mesophyll cells;

replaced by osmosis from the xylem;

(diffusion of water vapour) through stomata;

water lost replaced from xylem / clear diagram showing movement of water from xylem through cell(s) (walls) to air space;

water pulled out of xylem creates suction/low pressure/tension; transpiration pull results;

water molecules stick together/are cohesive;

due to hydrogen bonding/polarity of water molecules;

xylem vessels are thin (hollow) tubes;

adhesion between water and xylem due to polarity of water molecules;

creates continuous column/transpiration stream;

c. flowering affected by light;

phytochrome;

exists in two (interconvertible) forms/P_{fr} and P_r;

P_r (red absorbing/660 nm) converted to P_{fr} (far-red/730 nm absorbing) in red or day light;

sunlight contains more red than far red light so P_{fr} predominates during the day;

gradual reversion of P_{fr} to P_r occurs in darkness;

P_{fr} is active form / P_r is inactive form;

in long-day plants, flowering induced by dark periods shorter than a critical length / occurs when day is longer than a critical length;

enough P_{fr} remains in long-day plants at end of short nights to stimulate flowering;

P_{fr} acts as promoter of flowering in long-day plants;

short-day plants induced to flower by dark periods longer than a critical length/days shorter than a critical value;

at end of long nights enough P_{fr} has been converted to P_r to allow flowering to occur;

P_{fr} acts as inhibitor of flowering in short-day plants;

Examiners report

a. Diagrams were variable in quality. The poorest were very unclear and labelling was often inaccurate. The double membrane, grana, stroma and thylakoid were most often correctly labelled. The connection between the thylakoid and intra-lamellar membrane was often not shown.

Failing to close lines when drawing membranes was also problematic. In some cases thylakoids were coloured in obscuring connections.

b. The importance of adhesion and cohesion was covered well, although these were not often related to the molecular properties of water.

It was the process of transpiration and the resultant force created that was less often mentioned or just given a brief treatment, losing marks for many candidates. Commonly, how water moves from soil into the root was detailed.

c. Phytochrome was known about and that it exists in 2 interconvertible forms. A number showed evidence of memory of facts but with lack of understanding because details were confused and terms interchanged.

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b. Outline the metabolic processes that occur in starchy seeds during germination. [6]

c. Explain the light-independent processes of photosynthesis in plants. [8]

Markscheme

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

a. water absorbed by the seed / seed rehydrated;
b. water activates metabolism;
c. gibberellin synthesized/produced/secreted;
d. gibberellin stimulates the production of amylase;
e. amylase digests/hydrolyses starch to maltose;

f. maltose converted/hydrolysed to glucose (by maltase);
g. glucose used in aerobic respiration;
h. glucose used in synthesis/production of cellulose;

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

a. occurs in stroma (of chloroplast);
b. energy/ATP and NADPH provided by the light-dependent reactions;
c. Calvin cycle;
d. carbon dioxide fixed to RuBP / carboxylation of RuBP/ribulose bisphosphate;
e. by RuBP carboxylase/rubisco;
f. forms unstable 6C compound / forms 6C compound which splits;
g. glycerate 3-phosphate (is produced by carbon fixation);
h. (glycerate phosphate) to triose phosphate/3C sugar by reduction/adding hydrogen;
i. using NADPH/reduced NADP;
j. triose phosphate/3C sugar converted to form hexose/glucose (phosphate);
k. most/$^{5}/_{6}$ of triose phosphate used for regeneration of RuBP;
l. ATP used to regenerate RUBP/convert glycerate 3-phosphate to triose phosphate;

Examiners report

b. Well prepared candidates gave thorough and high scoring accounts of metabolic processes that follow water uptake in geminating seeds.

c. This was another high scoring part of the question for stronger candidates. A few misread the question and wrote about light-dependent reactions.

The use of the abbreviation GP is discouraged as it is ambiguous in accounts of the Calvin cycle.

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a. Draw a labelled diagram to show the molecular structure of a membrane. [4]

b. Some proteins in membranes act as enzymes. Describe a model that accounts for the ability of enzymes to catalyse reactions. [6]

c. Membranes of pre-synaptic and post-synaptic neurons play an important role in transmission of nerve impulses. Explain the principles of synaptic transmission. [8]

Markscheme

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

phospholipid bilayer; *(double row of opposing phospholipids, tails to inside)*

hydrophilic/phosphate/polar (heads) and hydrophobic/hydrocarbon/fatty acid/nonpolar (tails) labeled;

integral protein; *(embedded in the phospholipid bilayer)*

protein channel/channel protein; *(integral protein showing clear channel/pore)*

peripheral protein; *(shown on surface or slightly embedded on either side)*

glycoprotein*; (with carbohydrate attached on outer side)*

cholesterol; *(shown embedded in bilayer and smaller than the hydrophobic tail)*

b. induced fit model; (do not accept lock and key hypothesis)

accounts for ability of some enzymes to bind to several substrates;

enzyme with active site to which substrate(s) binds;

enzyme active site and substrate do not match up exactly;

enzyme-substrate complex forms;

enzyme changes shape once bound / enzyme moulds to substrate/ hand in glove;

change in shape strains bonds/facilitates bonds breaking/product formation;

reduces activation energy;

once reaction is complete, products leave and enzyme can work again;

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

c. synapse is gap between adjacent neurons;

(arriving) action potential depolarizes pre-synaptic membrane;

opens (voltage-gated) calcium channels in membrane;

causes influx of calcium ions;

causes synaptic vesicles to fuse with pre-synaptic membrane;

vesicles release/exocytose neurotransmitter into the synaptic cleft;

neurotransmitter diffuses/moves across synaptic cleft;

neurotransmitter binds to receptors on post-synaptic membrane;

opens channels allowing sodium ions/potassium ions to diffuse;

initiation of action potential/depolarization in post-synaptic membrane;

removal/breakdown of neurotransmitter stops effect on post-synaptic membrane;

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 score some marks for a reasonable diagram.

b. Some weaker candidates were confused by the link between parts a and b and thought that they had to describe membrane enzymes. A description of the induced fit model of enzyme action was required. The markers were amazed at the lack of detail in the answers, with many not mentioning active site, substrate or ES complex.

c. Many candidates gave a full account of the synaptic transmission. Weaker candidates knew that calcium ions were somehow involved, but little more.

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.

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

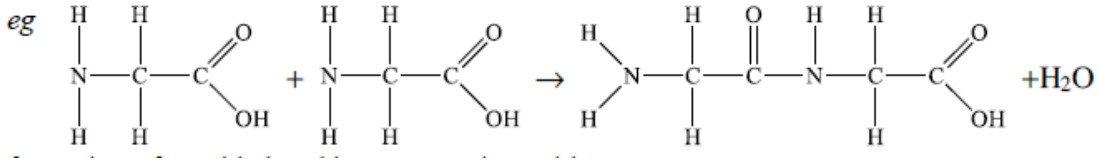
b. The protein hemoglobin transports oxygen to cells. Describe the processes that occur in the mitochondria of cells when oxygen is present. [8]

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)

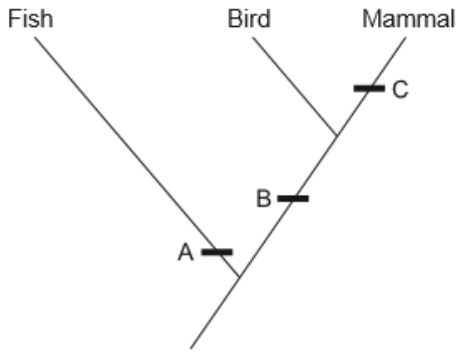
Examiners report

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. The image shows part of a cladogram. [3]



Using the cladogram, identify one diagnostic feature that characterizes the given groups of vertebrates at A, B and C.

A: .....
B: .....
C: .....

b. Starting from the concept of gene pool, explain briefly how populations of early vertebrates could have evolved into different groups. [3]

c. Mitochondria are thought to have evolved from prokaryotic cells. Describe **two** adaptations of the mitochondria, each related to its function. [2]

Markscheme

a. A: gills **or** fins **or** scales **or** no limbs **or** external fertilization

B: homeothermic **or** warm-blooded **or** endothermic **or** lungs **or** tetrapod **or** four limbs **or** pentadactyl limbs **or** internal fertilization

C: hair **or** fur **or** mammary glands **or** milk

b. Gene pool is all genes/all alleles. *Reject all alleles/genes in a species.*

Geographic isolation *Reject isolation if no type of isolation given*.
OR
migration to different areas
OR
temporal isolation
OR
behavioural isolation

Speciation/gene pool split if populations are reproductively isolated/do not interbreed

In different environments there are different selection pressures/opportunities/natural selection/adaptations/niches «to exploit»

Allele frequencies change/diverge *Reject gene frequencies*.

c. Double membrane/small intermembrane space/small gap between inner and outer membrane for a gradient «of protons» to develop

Accept only the first two adaptations in the answer.

Cristae/folds in inner membrane/large surface area of inner membrane for ATP synthesis/chemiosmosis/proton pumping/electron transport chains

ATP synthase/stalked particles generates ATP from ADP + phosphate/Pi. *Reject ATPase. Allow ATP* synthetase.

Electron transport chains for generating a proton gradient/for releasing energy from reduced NAD

Matrix contains enzymes for Krebs cycle/link reaction/oxidation of fats/oxidation of substrates/aerobic respiration

Ribosomes/DNA for protein synthesis/replication

Examiners report

a. There was much criticism of the cladogram from teachers in G2 forms and predictions that candidates would not understand it. In practice, most candidates realized for point A, they were expected to give a feature of fish that is absent in birds and mammals, the reverse of this for B, and for C a characteristic of mammals that is absent in birds and fish. This was an effective test of candidates' knowledge of the characteristics of these three chordate groups.

b. In this question candidates were expected to apply their understanding of evolution and speciation to the context of the early evolution of vertebrates. All that was expected was a methods of reproductive isolation, differential natural selection and divergence until the differences between populations and their gene pools were great enough to prevent interbreeding. Candidates mostly got at least part of this.

c. Question setters try to include some stimulus material to make questions more interesting but the first sentence of this question proved to be a distraction rather than a help. Candidates only really needed to think about the second sentences and so describe two structures and explain how they help the mitochondrion to carry out its function of producing ATP.

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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. Draw a labelled diagram of the ultrastructure of *Escherichia coli* as an example of a prokaryote. [4]

b. Describe the events that occur in the four phases of mitosis in animals. [6]

c. Explain the process of aerobic cell respiration after glycolysis has occurred. [8]

Markscheme

a. *Award [1] for each structure clearly drawn and correctly labelled.*

a. cell wall; *(with some thickness)*

b. plasma membrane; *(shown as single line or very thin)*

c. cytoplasm;

d. pilus/pili; *(shown as single lines)*

e. flagellum/flagella; *(shown as thicker and longer structures than pili and embedded in cell wall)*

f. 70S ribosomes;

g. nucleoid / naked DNA;

h. approximate width 0.5μm / approximate length 2.0μm;

Award [4 max] if the bacterium drawn does not have the shape of a bacillum (rounded-corner rectangle with length approximately twice its width).

Award [4 max] if any eukaryotic structures included.

b. *Accept the following points as a diagram if clearly drawn and correctly labelled.*

a. supercoiling of chromosomes in prophase;

b. chromosomes consist of sister chromatids in prophase;

c. formation of mitotic spindle / centrosomes/centrioles move away in prophase;

d. nuclear membrane breaks down in (late) prophase/(early) metaphase;

e. attachment of spindle microtubules to centromeres;

f. chromosomes on metaphase plate/equator/centre of cell in metaphase;

g. parting of (sister) chromatids at onset of anaphase;

h. movement of sister chromosomes *(accept chromatids)* to opposite poles in anaphase;

i. re-formation of nuclear membranes in telophase;

Award [5 max] if response does not mention all four phases of mitosis.

c. a. pyruvate produced by glycolysis;

b. pyruvate enters mitochondrion/mitochondria;

c. pyruvate loses CO_2 in link reaction;

d. and $NADH+H^+$;

e. with formation of acetyl CoA;

f. to take part in Krebs cycle;

g. where two CO_2 are produced (per molecule of pyruvate);

h. one ATP from ADP+Pi;

i. along with (three) $NADH+H^+$ (and one $FADH_2$);

j. $NADH+H^+$ provide electrons circulating in the electron transport chain on the inner mitochondrial membrane;

k. allowing H^+ to accumulate in the intermembrane space;

l. and come back to the matrix through ATP synthase/synthetase to produce ATP (by chemiosmosis);

m. presence of O_2 required as the final electron acceptor for the electron transport chain;

n. producing water with H^+;

Examiners report

a. Many candidates automatically lost points for not showing the bacillus shape and/or including eukaryotic organelles. Diagrams are meant to be an accurate representation of the organism. Pilli and flagellae floating around outside the cell, not even touching the cell wall did not gain marks.

b. The process of mitosis was well known by the majority of candidates answering this question. Common errors were pairing the homologous chromosomes and explaining meiosis rather than mitosis. Many candidates included neat labelled diagrams for which marks could be awarded.

c. Many candidates were able to describe the link reaction, Krebs cycle, electron transport and chemiosmosis with almost textbook precision. Others tried to draw half remembered diagrams, hoping for the best and not scoring many, if any, marks.

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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. Draw a labelled diagram of a mitochondrion as seen in an electron micrograph. [4]

b. A supply of oxygen is needed for aerobic respiration in mitochondria. Describe the featuresofalveoliinhumanlungsthatadaptthemforefficient absorptionofoxygen. [6]

c. Explain the mechanism of ventilation of human lungs. [8]

Markscheme

a. *Award **[1]** for each one of the following labelled structures*.

a. outer membrane and inner membrane shown as two separate lines;

b. inter-membrane space / space between inner and outer membranes;

c. cristae (shown as projections of inner membrane);

d. matrix;

e. (70S) ribosomes (shown as dots in the matrix);

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

a. large surface area from having many alveoli;
b. single/flattened layer of (thin) cells in wall;
Reject one-cell membrane/thin membrane.
c. (surrounded by) dense network of capillaries/capillary bed;
d. short distance for gases/oxygen/carbon dioxide to diffuse;
e. moist lining / film of moisture on inside of alveolus;
f. moisture allows oxygen/gases to dissolve;
g. diffusion of oxygen down concentration gradient;

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

Award these points either for inspiration or expiration but not both:
a. ventilation is movement of air into and out of lungs;
b. volume of thorax/lungs/chest increased/decreased;
c. pressure in thorax/lungs/chest decreased/increased;
d. air flows from higher to lower pressure / air flows until the pressures are equal;

During inspiration/inhalation:
e. external intercostal muscles contract so ribcage moved up/out;
f. diaphragm contracts so moves down/becomes flatter;
g. internal intercostal/abdomen (wall) muscles relax;

During expiration/exhalation:
h. external intercostal muscles relax so ribcage moved down/in;
i. diaphragm relaxes;
j. recoil of elastic fibres that stretched during inspiration;
k. internal intercostal muscles contract (during forced ventilation);
l. abdomen (wall) muscles contract (during forced ventilation);

Examiners report

a. There were some excellent diagrams of mitochondria that scored full marks but also many incorrect ones. A frequent fault was to show the cristae as an extra membrane, rather than as part of inner membrane. Some diagrams showed so many gaps and overlaps in the membranes that a mark was lost. The weakest candidates depicted in their diagrams whole cells with eukaryote features.

b. There were some strong answers to this relatively easy question that quickly gained the six marks. Other answers lacked precision and so scored less highly. One common misunderstanding is that it is the spherical shape of alveoli that give the lungs a large surface area for gas exchange. In fact a sphere has the less surface area for a given volume of any shape and it is the small size and large number of alveoli that gives the large surface area.

c. This was a standard and relatively straightforward question and strong candidates scored full marks. As with other questions on this paper, the weaker candidates revealed a wide range of misunderstandings. Cause and effect were confused in some answers, so it is that movement of air into the lungs that causes the diaphragm to move down rather than vice versa. One particularly common misapprehension is that pure air is breathed in and pure carbon dioxide breathed out. Were this to be possible it would make gas exchange much more efficient but unfortunately it is not.

---

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. 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. Outline the process of glycolysis. [5]

b. Describe how pancreatic cells directly affect blood glucose levels. [5]

c. Explain why diabetes could be detected through the analysis of urine. [8]

Markscheme

a. occurs in cytoplasm;

hexose is phosphorylated using ATP;

hexose phosphate is split into two triose phosphates;

oxidation by removal of hydrogen; (*do not accept hydrogen ions/protons*)

conversion of NAD to NADH ($+H^+$);

net gain of two ATP / two ATP used and four ATP produced;

pyruvate produced at the end of glycolysis;

Accept glucose/fructose/6C sugar instead of hexose.

Accept 3C sugar/glyceraldehyde instead of triose.

b. α cells (of pancreas) produce glucagon;

glucagon promotes release of glucose/breakdown of glycogen by liver cells;

glucagon secreted when blood glucose levels are low / raises blood glucose levels;

β cells (of pancreas) produce insulin;

insulin promotes glucose uptake/storage of glycogen by liver/body/muscle cells;

insulin secreted when blood glucose levels are high / lowers blood glucose levels;

negative feedback mechanism;

Do not accept answers implying that insulin or glucagon catalyse glucose-glycogen conversions directly.

*Award **[3 max]** if the response suggests that the hypothalamus has a role in regulation of blood glucose.*

c. urine of diabetics contains glucose;

whereas urine of non-diabetics contains no glucose;

glomerular filtrate contains glucose / glucose filtered out;

glucose (normally) reabsorbed from filtrate/into blood;

through wall of / in the proximal convoluted tubules;

blood glucose concentration higher than normal in diabetics;

reabsorption not completed / pumps cannot reabsorb all glucose in diabetics;

glucose in urine can be detected using test strips;

type I diabetes is lack of insulin secretion / lack of β cells;

type II diabetes is body cells not responding to insulin / not absorbing glucose;

Examiners report

a. This question was answered by large numbers of candidates. The better-prepared ones had little difficulty in scoring highly in both parts (a) and (b). As in part (a) of Question 5, it was possible to score marks in 6(a) with a clearly annotated drawing, in this case a flow diagram of glycolysis. The only caveat is that one of the quality marks for Section B questions depends on at least two of the three parts being written in continuous prose. In weaker answers there was confusion about what was being oxidized and what reduced. Teachers should stress that oxidation in respiration is achieved by removal of hydrogen from respiratory substrates, because each removed hydrogen has an electron. Oxidation is loss of electrons.

b. In part (b) a familiar problem was in the spelling of glucagon and glycogen. This is one place where terms do need to be spelt correctly to avoid confusion. Two other common errors were the implication that insulin and glucagon catalyze interconversions between glucose and glycogen directly and the suggestion that the hypothalamus controls hormone secretion by the pancreas.

c. Part (c) was often well answered, with candidates write detailed accounts of cause and effect, linking the high blood glucose levels that characterize diabetes with the presence of glucose in urine.

Describe the process of photolysis in photosynthesis.

Markscheme

a. water is split/breaks

b. using energy from light

c. electrons «from photolysis» pass to photosystem II

d. oxygen is a «waste» product

e. hydrogen ions/protons are produced

Allow answer given as an equation

[Max 3 Marks]

Examiners report

[N/A]

Photosynthesis and transpiration occur in leaves. Explain how temperature affects these processes.

Markscheme

photosynthesis rate increases as temperature rises (up to an optimum temperature);

(due to) increase in the rate of enzyme catalysed reactions/light independent reactions/the Calvin cycle;

(steep) drop in rate of photosynthesis above the optimum;

at high temperatures enzymes/Rubisco/RuBP carboxylase denature(s);

graph with correctly labelled axes showing relationship between temperature and rate of photosynthesis;

transpiration rate increases as temperature rises;

(energy/heat leads to more) to more evaporation of water (in the leaf);

faster diffusion of water vapour at higher temperatures;

relative humidity falls as temperature rises / warmer air can hold more water vapour;

stomata may close at very high temperatures reducing the transpiration rate;

some plants open their stomata at very high temperatures to cool by transpiration;

Examiners report

Here candidates were able to outline the effects of temperature on photosynthesis and transpiration, but explanations failed to adequately address mechanisms such as the role of enzymes in photosynthesis and the role of evaporation in transpiration.

A very high number of candidates stated that higher temperatures meant more light and it was this that increased the rate of photosynthesis. Others went off into the idea that transpiration was a type of sweating and was used **normally** by plants to keep them cool. Few linked increased rate to enzyme activity and a further increase beyond optimum to a decrease in rate because of denaturation.

---

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.

---

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.

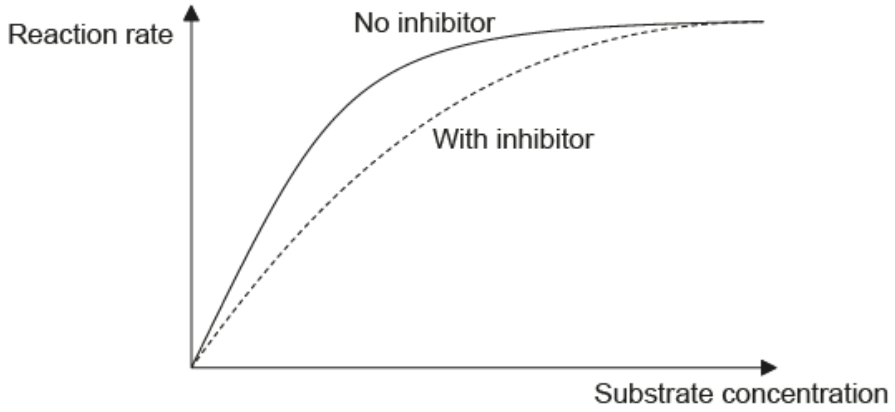
However, many mentioned similar structure to the substrate in the first but there was no equivalent comment for the second, thus no mark.

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.

The enzyme ATP synthase has an essential role in aerobic cell respiration.

a. The sketch shows the relationship between the reaction rate and substrate concentration in the presence and the absence of a competitive inhibitor. [2]



Explain the effect of the competitive inhibitor on the reaction rate.

b.i. Describe its location. [1]

b.ii. Describe its function. [2]

Markscheme

a. a. competitive inhibitor «slows the reaction rate as it» competes for the active site

OR

competitor has similar shape/structure/composition to substrate «and slows the reaction rate»

b. binding of competitor is reversible

c. «as the substrate concentration increases» more substrate binds to the active site than the competitor «and reaction rate increases»

d. «as the substrate concentration increases» the reaction rate reaches the maximum plateau «same as with no inhibitor»

b.i. the inner mitochondrial membrane critstae/thylakoid membrane

b.ii. a. protons build up in the intermembrane space due to electron transport chain *OWTTE*

b. protons move through ATP synthase down the concentration gradient
Accept H^+ ions in place of protons

c. catalyses formation of ATP *OWTTE*

Examiners report

a. [N/A]
b.i. [N/A]
b.ii. [N/A]

---

a. Identify the following processes as **either** anabolism **or** catabolism by placing a tick (√) in the correct box. [2]

Process	Anabolism	Catabolism
Light-independent reactions of photosynthesis	☐	☐
Glycolysis	☐	☐

b. Outline the importance of enzymes to metabolic processes. [4]

Markscheme

a.

process	*anabolism*	*catabolism*
light independent reactions of photosynthesis	☑	☐
glycolysis	☐	☑

b. a. increase rate of reaction/speed up reaction

b. lower activation energy

c. a specific enzyme for each reaction/substrate

d. metabolic process/pathway blocked if an enzyme is inhibited/absent

e. end-product inhibition can control metabolic pathways

f. differences in metabolism as cells produce different enzymes during differentiation

Examiners report

a. [N/A]
b. [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]

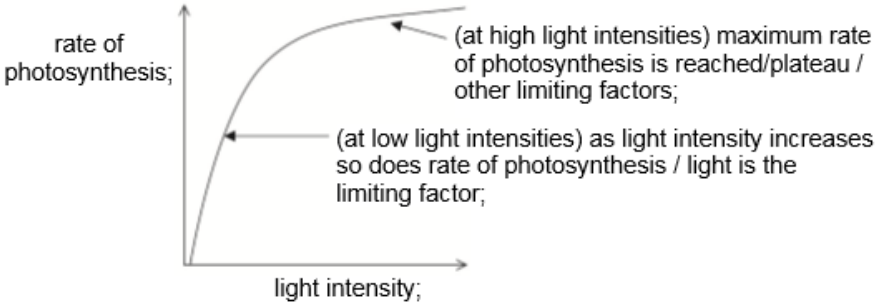
Markscheme

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.

---

a. Describe the relationship between genes, polypeptides and enzymes. [4]

b. Outline control of metabolic pathways. [6]

Markscheme

a. gene is a sequence of DNA bases;

DNA/gene codes for a specific sequence of amino acids/polypeptide;

enzymes are proteins/composed of polypetides;

sequence of amino acids determines tertiary structure/folding/shape of active site;

change in the gene/mutation will affect the active site/function of an enzyme;

enzymes are involved in replication/transcription of genes;

enzymes are involved in synthesis of polypeptides;

b. metabolic pathways can be a sequence/chain of reactions;

they can be cycles of reactions;

different enzymes control each reaction in the sequence/cycle;

accumulation of an end-product can inhibit the first enzyme of the sequence/ pathway;

(an end-product inhibitor) joins an allosteric site/a site separate from active site;

attachment at the allosteric site changes the shape of the active site;

preventing the binding of substrate;

until the level of the end-product is reduced (and the inhibition removed);

this is an example of negative feedback;

Examiners report

a. This part of the question was poorly answered. Candidates were usually able to relate genes to translation but were less likely to adequately relate their responses specifically to polypeptides beyond that.

b. Aspects of allosteric inhibition were usually a strength within student responses to this question. Answers for this question were generally not very well constructed.

---

a. Draw the absorption spectrum of chlorophyll. [4]

b. Explain the process of photophosphorylation in chloroplasts. [8]

c. Outline how the glucose produced as a result of photosynthesis is transported and stored in plants. [6]

Markscheme

a. *labelled x-axis*: wavelength / colour;

labelled y-axis: absorbance / <u>%</u> absorption;

peak between 400 and 500 nm / blue light;

peak between 600 and 700 nm / red light;

blue peak higher than red peak;

b. using energy from light to provide energy;

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

absorption of light in <u>photosystem II</u> gives electron to chain of carriers;

photolysis;

H^+ pumped across <u>thylakoid</u> membrane;

protons pass through <u>ATP synthetase</u>/<u>synthase</u>;

producing ATP;

chemiosmosis;

(chlorophyll/antenna of) <u>photosystem I</u> absorbs light;

cyclic and non-cyclic photophosphorylation;

(in non-cyclic photophosphorylation) photolysis of water produces H^+/O_2/e^-;

in <u>cyclic</u> photophosphorylation electron returns to photosystem I;

Accept any of the above points shown in a clearly annotated diagram.

c. glucose transformed to sucrose;

<u>translocation</u> of sugars/sucrose;

by phloem;

active process / requires energy;

from source to sink;

source is photosynthetic tissue/leaves;

sink is fruits/seeds/roots/storage organs;

(sucrose) converted to starch;

stored in storage organs/roots/tubers;

Examiners report

a. The syllabus statement for 8.2.7 does say "explain" as a command term for absorption spectrum. Draw is a lower level skill, and students should be able to draw the typical absorption spectrum. The x-axis is commonly not understood conceptually. If the axis is "wavelength", then red should be shown as longer wavelength than blue. This was commonly reversed. The y-axis was often insufficiently labelled as absorption. Absorbance or percent absorption was required.

b. Most of the better students who attempted this question explained photophosphorylation very well. Students who had done poorly on the rest of the paper avoided this question.

c. As mentioned before, some centres seem to have regarded the plant topic as optional, so the function of phloem was not well known. Many did not demonstrate awareness that sugars are translocated as sucrose, not glucose.

In ecosystems, energy is used to convert inorganic compounds into organic matter. Energy enters ecosystems through producers.

a. Explain the processes by which light energy is converted into chemical energy. [8]

c. Describe how energy flows through and is used by organisms in ecosystems. [4]

Markscheme

a. a. plants/producers/autotrophs convert light to chemical energy by photosynthesis

b. chlorophyll/photosynthetic pigments absorb light

c. electrons are excited/raised to higher energy level

d. excited electrons pass along chain of electron carriers

e. energy from electrons used to pump protons across thylakoid membrane/into thylakoid space

f. chemiosmosis/proton gradient used to make ATP

g. ATP synthase generates ATP

h. pigments arranged in photosystems

i. electrons from Photosystem II flow via the electron chain to Photosystem I

j. electrons from Photosystem I are used to reduce NADP

k. ATP and reduced NADP used in the light independent reactions/Calvin cycle

l. carbohydrate/glucose/carbon compounds produced containing energy

Award marking points for any point made on a clearly annotated diagram.

c. a. producers/plants/autotrophs obtain energy from light/sun/inorganic sources

b. food contains energy / energy passed in the form of food/carbon compounds (along food chains/between trophic levels)

c. consumers obtain energy from other organisms/from previous trophic level

This mark point distinguishes consumers from producers.

d. energy released (in organisms) by (cell) respiration

Reject energy used in respiration.

e. ATP produced

f. energy/ATP used for biosynthesis/movement/active transport/other valid use of ATP

g. less energy available / energy lost at each trophic level

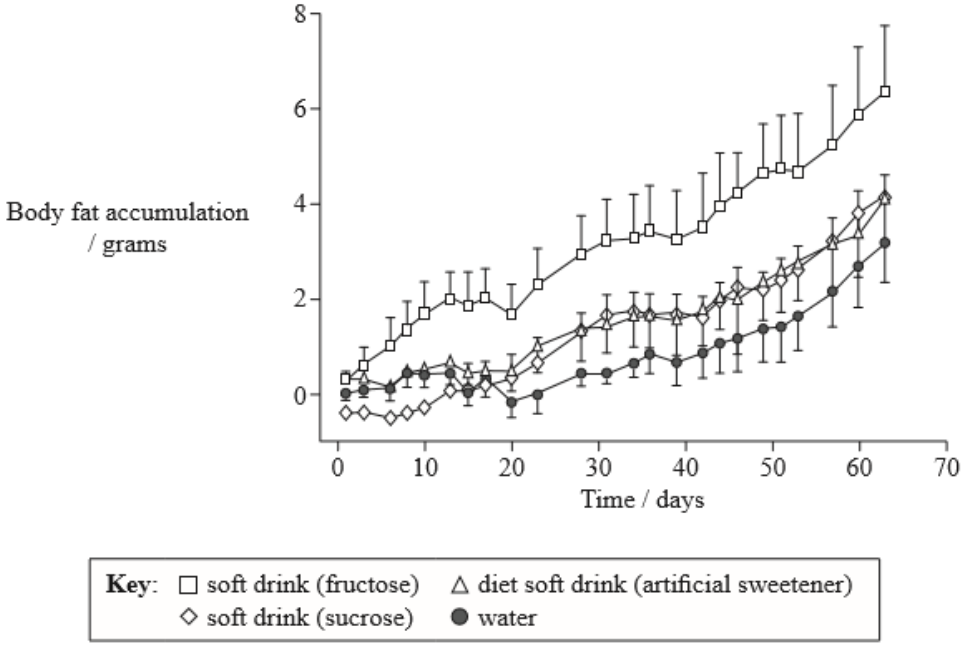
Examiners report

a. [N/A]

c. [N/A]

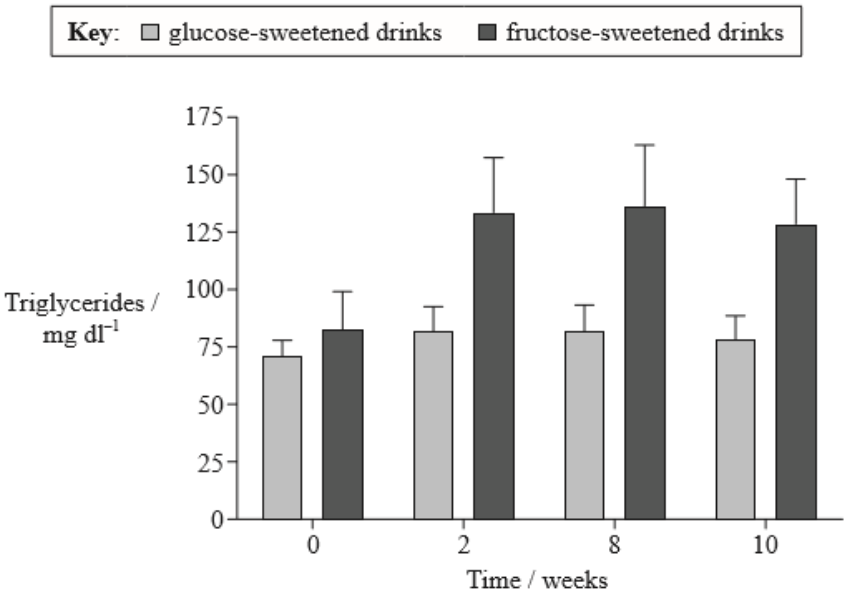
Obesity (excessive weight) is recognized as a global health problem and has been correlated with a large number of health issues, diseases and deaths. The increased consumption of fructose, now widely used as a sweetener, has been associated with the increase in obesity.

In a study, mice were divided into four groups. Each group was given the same amount of food and either a soft drink with a different sweetener or water.



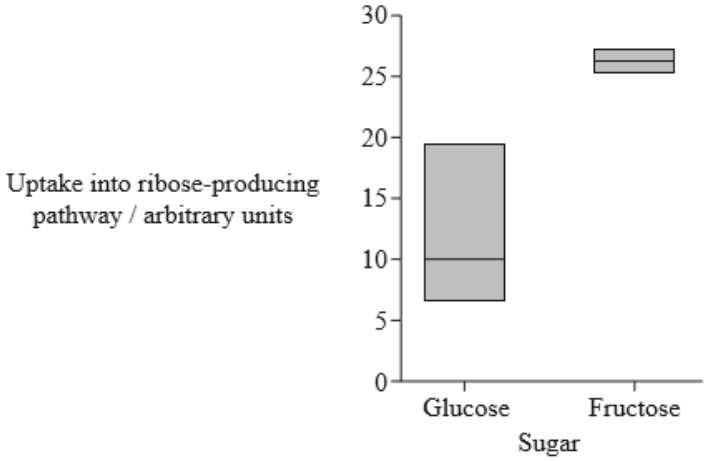
[Source: H. Jürgens et al. (2005) "Consuming fructose-sweetened beverages increases body adiposity in mice", *Obesity Research*, 13 (7), pages 1146–1156.]

As it has been shown that high triglyceride levels correlate to obesity, another study was undertaken with humans. Over a ten-week period, one group was given glucose-sweetened drinks and the other fructose-sweetened drinks. Triglyceride levels in blood were measured throughout the study.



[Source: Adapted from Stanhope KL, Schwarz JM, Keim NL, Griffen SC, Bremer AA, Graham JL, Hatcher B, Cox CL, Dyachenko A, Zhang W, McGahan JP, Seibert A, Krauss RM, Chiu S, Schaefer EJ, Ai M, Otokozawa S, Nakajima K, Nakano T, Beysen C, Hellerstein MK, Berglund L, Havel PJ. Consuming fructose-sweetened, not glucose-sweetened, beverages increases visceral adiposity and lipids and decreases insulin sensitivity in overweight/obese humans. *The Journal of Clinical Investigation*, 119 (5), pages 1322–1334.]

Studies investigated the role of glucose and fructose in the development of pancreatic cancer cells. Pancreatic cancer cells were grown in equal concentrations of each sugar and the uptake of each into ribose-producing pathways was measured. The graph shows the range of uptake of sugars and the mean value.



[Source: H. Liu et al.(2010) *Cancer Research*, 70 (15), pages 6368–6376.]

a. Describe the overall trend in body fat accumulation for the four groups of mice. [1]

b. Compare the body fat accumulation between the four groups. [2]

c. Distinguish between the results for the two groups. [2]

d. This study also showed a significant reduction in insulin sensitivity when participants were given fructose-sweetened drinks, but not when they were given glucose-sweetened drinks. [2]

Describe possible effects of the reduction of insulin sensitivity.

e. Discuss whether the results provide clear evidence of a difference in uptake. [2]

f. Determine which sugar is **primarily** used in the production of ribose. [1]

h. Using all of the data, evaluate the evidence that suggests the consumption of large amounts of fructose poses a risk to human health. [3]

Markscheme

a. positive/direct relationship / correlation (in all four groups) / (all four groups) accumulated fat over time

b. a. body fat accumulation increased over time for all four groups;

b. fructose caused the (significantly) greatest accumulation of fat and water the least;

(both needed)
c. sucrose and artificial sweetener/diet soft drink had the same increase;
d. sucrose, artificial sweetener and water did not start accumulating fat until after 20 days while fructose increased from the beginning;

c. a. glucose-fed group has no/little increase in triglycerides while fructose-fed group has a (large) increase;

b. glucose-fed group has smaller variability than the fructose-fed group;

c. more triglycerides in fructose-fed group than glucose-fed group (from week 2 to week 10);

d. a. raised blood glucose/sugar levels/higher glucose in the urine;

b. decreased glycogen;

c. excess glucose will be converted to fat/increase obesity;

d. possibility of developing diabetes type II / late/adult onset diabetes; (*do not award this mark if answer refers to type 1 diabetes*)

e. a. glucose has a much greater range of uptake / *vice versa*;

b. but a (much) lower mean/uptake / *vice versa*;

c. there is no overlap (so there is clear evidence);

f. fructose

h. a. evidence that fructose causes (body) fat accumulation/obesity;

b. evidence that fructose is related to increased (blood) triglycerides which are correlated with obesity/coronary heart disease;

c. evidence that fructose is related to reduced insulin sensitivity/diabetes;

d. evidence that fructose is used in ribose synthesis but no clear evidence that fructose causes pancreatic cancer;

Examiners report

a. Most were able to describe the overall trend.

b. Most candidates successfully compared the two groups, though weaker candidates gave descriptive answers without using comparative term.

c. This was another question that was effectively answered though students tended to give descriptive answers.

d. This question tended to differentiate in terms of preparation as better prepared candidates drew in a discussion of type 2 diabetes, reduced glycogen levels, higher blood sugar and sugar in the urine.

e. Most believed that the data supported the conclusion that a difference existed. The lower mean and the lack of overlap was noted by most.

f. Answers were roughly split between both sugars suggesting that students had difficulty making the link that higher rates of uptake suggest higher rates of use.

h. Prepared candidates were able to draw in the link to fructose and type 2 diabetes. Fewer acknowledged that the link between cancer and fructose was difficult to establish. Most were able to summarize the data but fewer were able to make a link to health effects.

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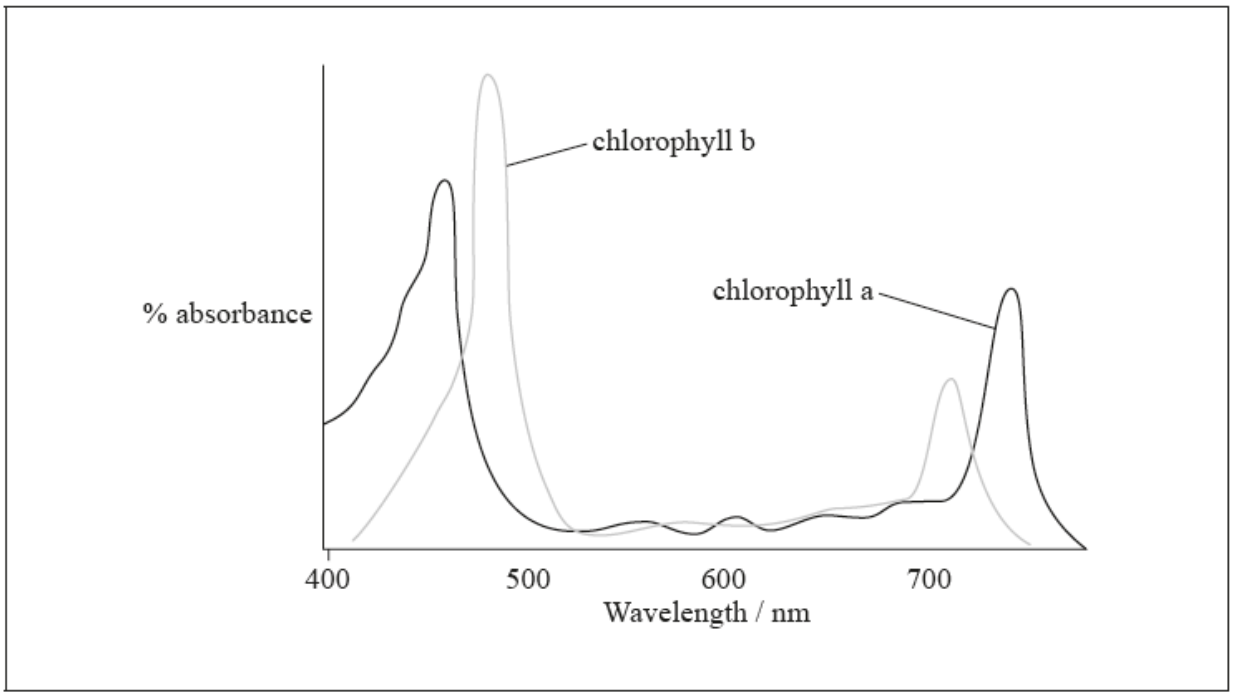
a. The graph shows the absorption spectrum for two types of chlorophyll. [3]



[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 above 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;

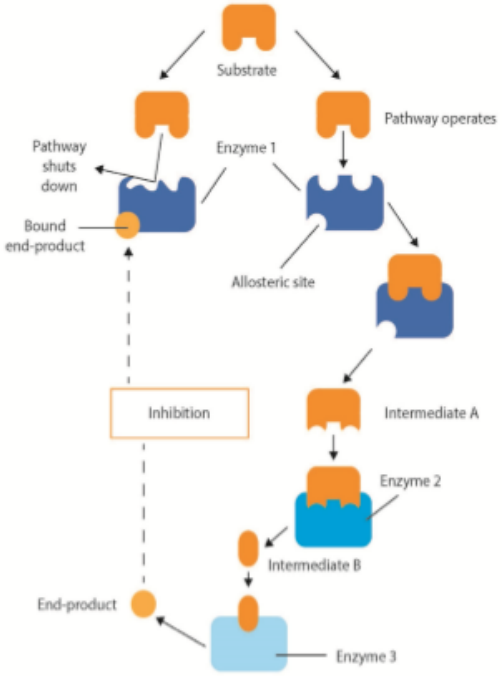
   this electron passed along chain of carrier molecules in photosystem II;

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 following diagram shows the synthesis and regulation of some amino acids.



[Source: © International Baccalaureate Organization 2013]

a. State the type of inhibition shown in this diagram. [1]

b. Explain how this type of regulation could affect the synthesis of an amino acid. [2]

Markscheme

a. end-product/non-competitive/(negative) feedback inhibition

b. amino acid/end product produced if used up/not enough present;

production stops if amino acid/end product unused/accumulates/in excess;

amino acid/end product changes active site of (first) enzyme of pathway;

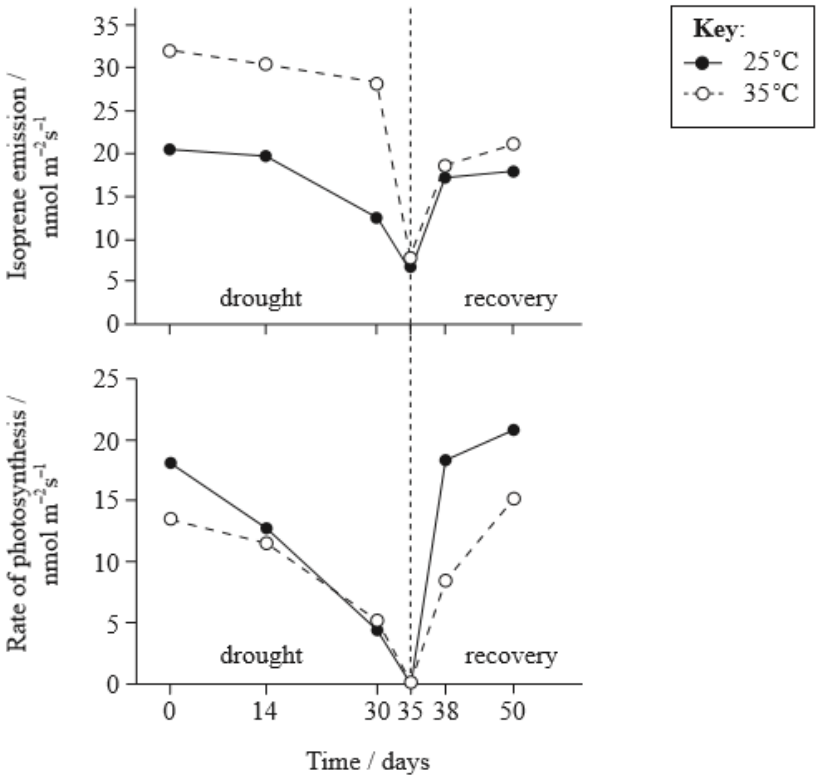
(this is an example of) negative feedback;

Examiners report

a. Almost all candidates gave a correct answer, probably because there was a strong hint in the diagram. End-product or non-competitive inhibition was accepted, or references to feedback.

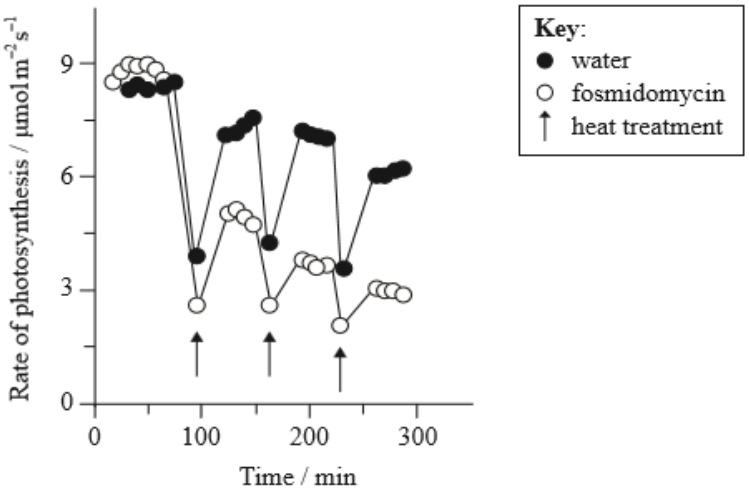
b. Candidates found this part of the question quite hard and it exposed a wide variety of misunderstandings of the interactions between enzymes, substrates, active sites, allosteric sites and end-product inhibitors. Many candidates failed to relate their answer to pathways used to synthesise essential metabolites in cells.

Isoprene is a chemical synthesized and emitted in large amounts by some plant species, especially oak (*Quercus sp.*) and poplar (*Populus sp.*) trees. It has been suggested that isoprene increases the tolerance of plants to high temperatures, which can cause a decrease in photosynthesis rates. Black poplar (*Populus nigra*) plants were subjected to two raised temperatures and to drought. Measurements of photosynthesis and isoprene emission were made during a 35-day-long drought stress (drought period) and 3 and 15 days after re-watering stressed plants (recovery period). The rate of photosynthesis was recorded as the carbon dioxide taken up per unit of leaf area per second.



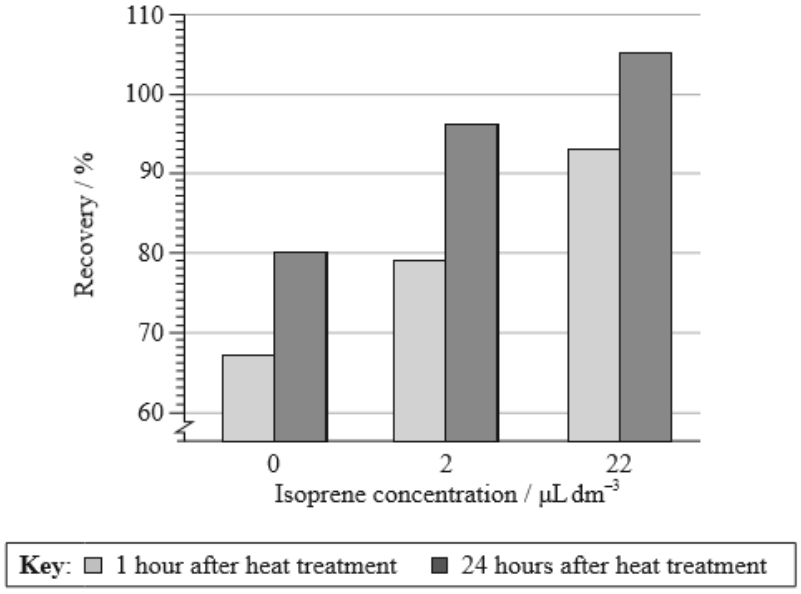
[Source: A. Fortunati et al. (2008) "Isoprene emission is not temperature-dependent during and after severe drought-stress: a physiological and biochemical analysis", *The Plant Journal*, 55, pages 687–697]

The effect of isoprene on photosynthesis was assessed in detached oak leaves that were supplied either water (control) or fosmidomycin dissolved in water. Fosmidomycin inhibits the emission of isoprene without affecting photosynthesis. The measurements were taken at 30°C, but at three points in the experiment the leaves were subjected to heat treatment of 46°C (indicated on the graph by the arrows). The rate of photosynthesis was measured as uptake of CO_2 in $\mu molm^{-2}\ s^{-1}$



[Source: Sharkey, T.D., X.Y. Chen, and S. Yeh. Isoprene increases thermotolerance of fosmidomycin-fed leaves. *Plant Physiology*, April 2001, vol. 125, no. 4, 2001–2006. www.plantphysiol.org © American Society of Plant Biologists.]

To test the effect of isoprene on a plant that does not normally produce it, leaves of common beans (*Phaseolus vulgaris*) were treated with heat stress at 46°C and were supplied with isoprene in the airstream. The percentage recovery compares the rate of photosynthesis before and after heat treatment. The data show the recovery of photosynthesis at different isoprene concentrations 1 hour and 24 hours after the heat treatment.



[Source: Sharkey, T.D., X.Y. Chen, and S. Yeh. Isoprene increases thermotolerance of fosmidomycin-fed leaves. *Plant Physiology* April 2001, vol. 125, no. 4, 2001–2006. www.plantphysiol.org © American Society of Plant Biologists.]

a. Suggest **one** method other than measuring CO_2 uptake by which the rate of photosynthesis could have been measured in these experiments. [1]

b. Suggest why heat treatment may reduce photosynthesis rates. [2]

c. Outline the effect of drought and of re-watering on the rate of photosynthesis. [1]

d. Describe the isoprene emissions during the drought and recovery periods at 25°C. [2]

e. Compare the effect of the two temperatures on the emission of isoprene. [2]

f. State the effect of heat treatment on the rate of photosynthesis. [1]

g. Using the results in the graph, deduce the effect of the presence of fosmidomycin on the rate of photosynthesis in the leaves. [2]

h. Suggest possible conclusions for this experiment. [2]

i. State the difference in percentage recovery of photosynthesis 1 hour after heat treatment between the 22 μLdm^{-3} isoprene treatment and the 0 μLdm^{-3} isoprene treatment. [1]

j. Explain the evidence provided by the data in the bar chart for the hypothesis that isoprene improves plants' tolerance to high temperatures. [2]

k. Suggest **two** reasons for some plant species synthesizing and emitting isoprene, but not other plant species such as common beans. [2]

Markscheme

a. oxygen production/release; (*not count bubbles*)

production/increase/change/ measurement of biomass;

b. high/higher than optimum temperatures denature enzymes (of Calvin cycle);

ribulose bisphosphate carboxylase/rubisco stops working/does not bind substrate;

wilting / withering / loss of water / decrease in turgor / increased transpiration;

closure/reduced aperture of stomata;

lower CO_2 level inside leaf / reduced CO_2 diffusion/uptake into leaf;

c. rate decreases/drops (to zero) with drought and increases when re-watered/recovering

d. slight decrease/constant initially then falls / falls increasingly rapidly / decreases exponentially (in drought/up to Day 35);

increases almost to original level/ but doesn't reach original level / rapidly at first then less rapidly / increases then reaches plateau (during recovery/after Day 35);

e. higher/greater (emission) at 35°C than 25°C during both drought and recovery;

both at (approximately) same level at end of drought period/at 35 days;

both increase during recovery but not to original level;

less/little difference in emission between temperatures during recovery/after watering / converse;

f. decreases (rate of photosynthesis);

g. no effect before (the first) heat treatment;

lower rate/greater reduction in rate during heat treatments with fosmidomycin;

lower photosynthesis/fosmidomycin reduces recovery after heat treatments;

Ignore statements that fosmidomycin reduces the rate of photosynthesis if this is not related to heat treatments.

h. high temperature/heat stress/treatment reduces rate of photosynthesis;

repeated heat treatments cause greater reduction in photosynthesis;

isoprene causes less change/less reduction in photosynthesis due to heat/46°C /higher rate of photosynthesis during heat treatment with isoprene

(than without);

isoprene helps photosynthesis to rise again after heat (treatments);

i. 26 (%) (*Allow a range of 25 % to 27 %*)

j. faster recovery with isoprene than without/than with water treatment;

recovery faster/better/improved with higher isoprene concentration (than lower);

after both time periods / after 24 hours and 1 hour;

k. different plants live in/evolved in/are adapted to different temperature regimes;

(selective) advantage for plants that produce isoprene in high temperature regions;

isoprene synthesis uses energy/materials/only beneficial at high temperatures;

some plants do not have the enzymes/genes for making isoprene;

Examiners report

a. This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

In (a) candidates were tested on their knowledge of methods of measuring the rate of photosynthesis. Most answered it correctly. A few candidates made vague statements about growth or suggested that use of water could be a measure of photosynthesis. Neither of these answers was accepted.

b. This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

Part (b) was also testing knowledge rather than data analysis skills. There were some good explanations of why heat may reduce photosynthesis rates, including the idea that stomatal closure would reduce carbon dioxide uptake. Enzyme denaturation was accepted although photosynthesis rates drop at much lower temperatures in most plants than could be due to denaturation. Candidates were not expected to know about photorespiration and the reactions that are catalysed by rubisco at high temperatures.

c. This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

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

d. Question 1: This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

Answers to (d) were more mixed. The command term "describe" requires a detailed account so the marks were not awarded simply for stating that there was a fall in isoprene emissions during drought and a rise during recovery. There had to be some qualification, such as the changes in the rate of rise or fall, or an indication of whether recovery was complete. Some candidates stated that the emissions "spiked upwards" during recovery. This was allowed but strictly speaking a spike is a sharp rise and fall, not just a rise.

e. Question 1: This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

Part (e) was quite well answered but relatively few candidates scored both marks. Fewer candidates than in the past simply described the results for 25°C and then for 35°C, without proper comparison, but there were some simple comparisons on the mark scheme that most candidates missed. The best approach was to think about the difference between the results at each time during drought and recovery, not to overcomplicate things by trying to compare rates of change.

f. Question 1: This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

Part (f) was intended to be an easy lead in to the third graph, but a higher than expected proportion of candidates stated that heat treatment increased the rate of photosynthesis rather than decreased it. The arrows on the graph show when the heat treatments were administered and at these times there is clearly a decrease but some candidates thought that the rise following the times indicated with an arrow showed that the heat treatment had positive effects on photosynthesis.

g. Question 1: This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

   By part (g) of the question some candidates were starting to struggle. There were two independent variables in this experiment; temperature and presence or absence of fosmidomycin. Marks were only awarded if the effects of fosmidomycin were related to the heat treatments.

h. Question 1: This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

   Part (h) of the question was also found difficult by some candidates. Marks were awarded for conclusions about the effect of heat on photosynthesis, but not for conclusions about fosmidomycin. This chemical was used in the experiment as a means of investigating the effects of isoprene so the expected conclusions were about the protective effect of isoprene during heat treatments. There were some excellent answers from the stronger candidates who understood the experiment and were able to analyse its results effectively.

i. Question 1: This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

   Few candidates had any problem with part (i) and calculated the difference in percentage recovery successfully.

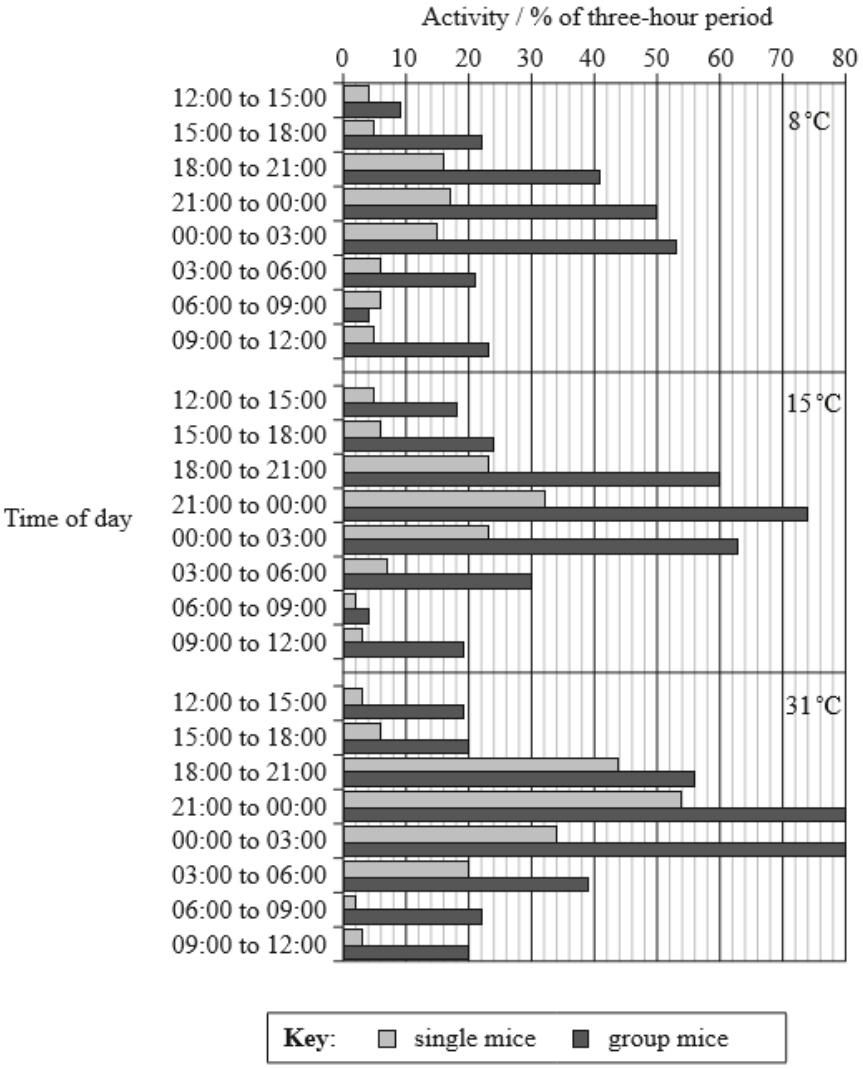
j. Question 1: This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

   Answers to part (j) were very varied, with fewer candidates scoring both marks than expected. There were separate marks for stating that recovery was faster with isoprene than without (an all or nothing effect) and for stating that the higher the isoprene concentration the faster the recovery. There was also a mark for stating that these trends were evident both after one hour and 24 hours.

k. Question 1: This question had parts that ranged from easy to very challenging and there was a wide range of scores on it.

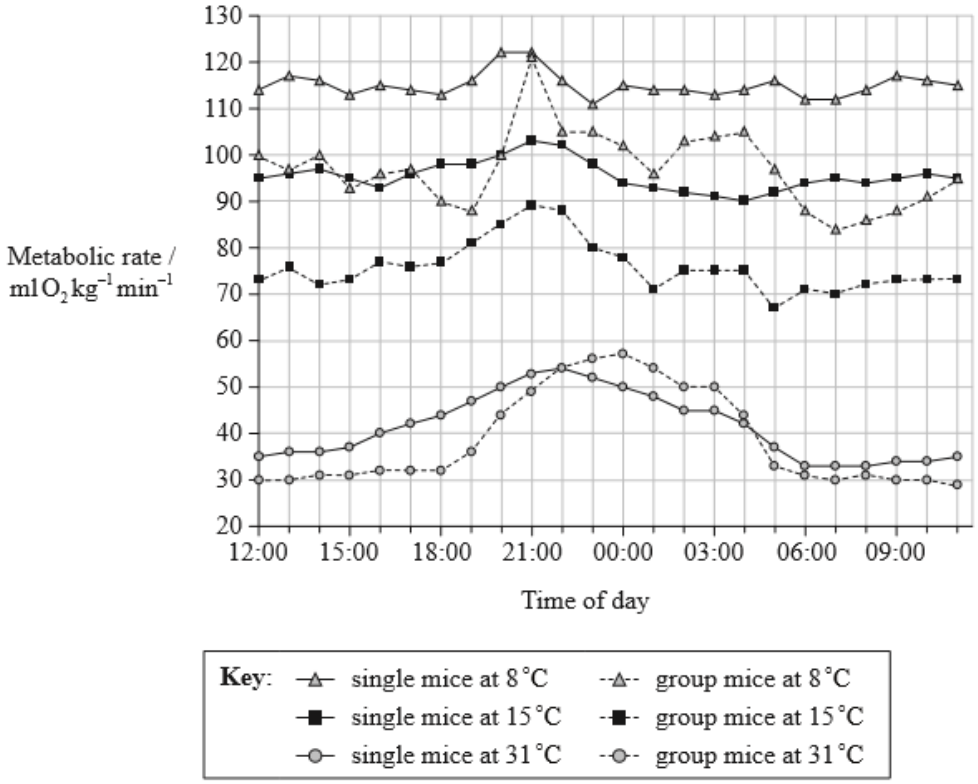
   Part (k) was another two mark question where most candidates scored either one or no marks. Two reasons were required, with four interrelated reasons on the mark scheme. Few candidates suggested that some plants might lack the genes for isoprene synthesis and almost none that there is a cost to synthesis in terms of energy or resources so there will be selection against it in areas where hot conditions are never experienced.

Investigators carried out experiments to find the relationship between the energy used by mice (the metabolic rate) and their activity. They found that the amount of time mice are active depends on the time of day, whether they are single or in groups and on the temperature of their surroundings. The bar chart below shows the percentage of time mice were active during three-hour periods at three different temperatures.



L. E. Mount and J. V. Willmott (1967) Journal of Physiology, 190, pages 371–380. Published by Wiley-Blackwell. Used with permission.

The investigators also found that the metabolic rate of the mice changed at different times of the day. Mice were kept at one of the three constant temperatures for 24 hours and their oxygen consumption was measured. The graph below shows the results for single mice and the mean values for group mice.



a. Calculate how many minutes the group mice are active between 21:00 and 00:00 at 8°C. [1]

b. Outline the relationship between activity and temperature from 21:00 to 03:00 in all of the mice. [1]

c. Animals which are active at night are nocturnal. Suggest **one** advantage for mice being nocturnal. [1]

d. State the relationship between temperature and metabolic rate. [1]

e. Compare the results for the single mice at 15°C with those for the group mice at 15°C. [2]

f. Suggest **one** reason why the results differ for single mice and group mice. [1]

g. Explain why oxygen consumption is used as a measure of metabolic rate. [2]

h. Using the data from both graphs, evaluate the hypothesis that increased activity causes an increase in metabolic rate in mice. [2]

Markscheme

a. 90 (minutes)

b. as temperature increases activity increases/positive correlation.

c. avoid predators / less competition for food

d. as temperature increases metabolic rate decreases/negative correlation (*accept converse*)

e. metabolic rate of group mice is always less than single mice; (*accept converse*)

   both follow similar pattern of increases/decreases/fluctuations at same time of day;

   fluctuations greater in group mice;

   both most active/higher metabolic rate during evening/21:00; (*accept any reference to times between 18:00 and 00:00*)

f. single mice need to produce more heat/have greater heat loss because of greater surface exposed to air / group mice huddle together to reduce the surface exposed to air

   Allow any other reasonable answer.

g. oxygen is required for (aerobic) respiration;

   respiration produces ATP/releases energy/heat in the mice;

   metabolic rate is a measure of total energy released/consumed in the body / oxygen consumption is proportional to energy released/consumed in body/ proportional to metabolic rate;

h. metabolic activity high when mice more active supports the hypothesis;

   activity is normally correlated with energy consumption;

   but another factor may be causing both to increase at the same time / correlation does not always establish cause and effect;

   grouping/environmental temperature also affect metabolic rate;

Examiners report

a. Part (a) was an easy start to the question and almost all candidates gave the correct value.

b. In (b) most students correctly identified the relationship between activity and temperature at the given time, although there was a low but significant number of students who only described the data without being able to state a trend or a relationship.

c. The most common answers in (c) were that they were more protected from predators or that there was less competition for food although some students said it was easier for them to find their prey at night (mice are rodents).

d. In (d) candidates were again asked to identify the relationship, this time between temperature and the metabolic rate. Most were able to do this although some inverted the relationship.

e. In part (e) of question 1, candidates were expected to compare the results of the single and group mice. However, many listed values without making the comparisons.

f. In part (f) there were some correct answers related to the sharing of heat in a group of mice and thus a lower metabolic rate, but many referred to groups of mice having less oxygen or that the sharing of tasks diminished the metabolic rate or that the value was a mean, implying a lower value could be expected.

g. There was good general comprehension in (g) of the use of oxygen consumption to measure metabolic rate but many students had difficulty providing clear answers, although most gained at least one mark by saying that respiration requires oxygen.

h. Most students had difficulty in (h) relating the data on the two graphs. Some were able to see that both metabolic activity and activity increased at the same times but others were not able to do so, simply restating data. Many did not make any evaluation of the data. Many implied that temperature was a factor, but not with sufficient clarity.

---

a. Draw a labelled diagram to show the ultrastructure of *Escherichia coli*. [5]

b. Distinguish between active and passive movements of materials across plasma membranes, using **named** examples. [4]

c. Explain how chemiosmosis assists in ATP production during oxidative phosphorylation. [9]

Markscheme

a. *Award **[1]** for each structure clearly drawn and correctly labelled.*

cell wall – with some thickness;

plasma membrane – shown as single line or very thin;

cytoplasm; pilus/pili – shown as single lines;

flagellum/flagella – shown as thicker and longer structures than pili and embedded in cell wall;

70S ribosomes; nucleoid / naked DNA;

approximate width 0.5 μm / approximate length 2.0 μm;

*Award **[4 max]** if the bacterium drawn does not have the shape of a bacillum (rounded-corner rectangle with length approximately twice its width).*

*Award **[4 max]** if any eukaryotic structures included.*

b.

passive	active
diffusion / osmosis / facilitated diffusion	active transport / ion pumps / exocytosis / pinocytosis / phagocytosis
a second passive method *(from above)*	a second active method; *(from above)*
does not require energy	requires energy/ATP;
down concentration gradient	against concentration gradient;
no pumps needed	requires protein pumps;
oxygen across alveoli / other example	glucose absorption in ileum / other example;

*Both the passive and active movements must be contrasted to receive a mark. Award **[3 max]** if no examples are given. Responses do not need to be shown in a table format.*

c. occurs during aerobic respiration;

oxidative phosphorylation occurs during the electron transport chain;

hydrogen/electrons are passed between carriers;

releasing energy;

finally join with oxygen (to produce water);

occurs in cristae of mitochondria;

chemiosmosis is the movement of protons/hydrogen ions;

protons move/are moved against their concentration gradient;

into the space between the two membranes;

protons flow back to the matrix;

through the ATP synthase/synthetase (enzyme);

energy is released which produces more ATP/combines ADP and Pi;

Examiners report

a. Most of the diagrams were of a pleasing standard. Marks were lost by drawing an oblong rather than a bacillus shape, including eukaryotic organelles and showing the flagellum as an extension of the cell wall, rather than embedded within it.

b. In a “distinguish” question, points should be contrasted, rather than writing about passive movement and then active movement.

c. There were a few comments from the G2 forms about the difficulty of gaining nine marking points. Better candidates obtained these with ease. Many of the better candidates' answers incorporated clear, annotated diagrams. Weaker candidates tried to use half-remembered diagrams without any explanation and failed to gain many marks.

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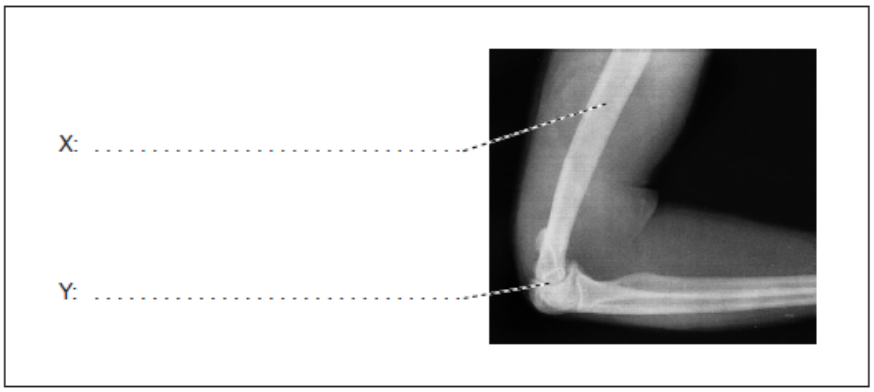
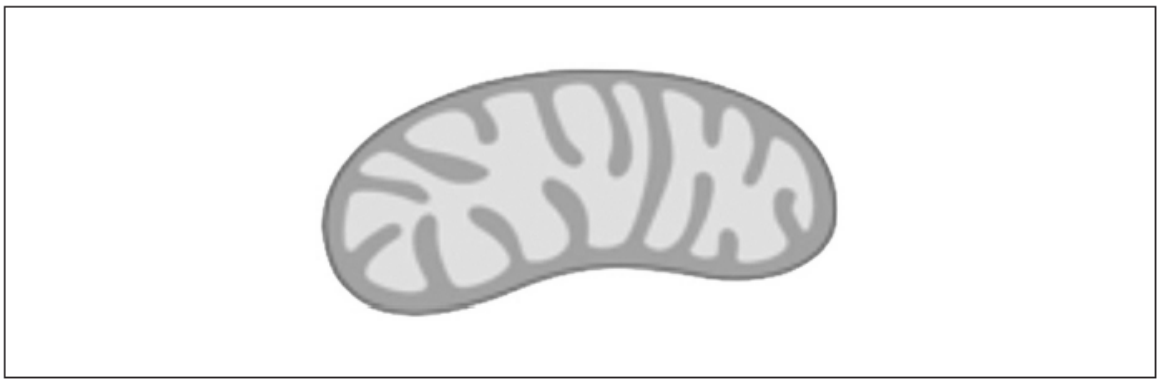
a(i) Label the structures indicated on the X-ray of a human elbow. [2]



b. Explain the role of calcium in muscle contraction. [3]

c(i) One of the stages of aerobic respiration is called the link reaction. [1]

Label the diagram to indicate where the link reaction occurs.



c(ii) Outline the role of coenzyme A in aerobic respiration. [2]

Markscheme

a(i) *X*: humerus;

Y: synovial fluid / cartilage / joint capsule / elbow joint;

b. action potential/nerve impulse/motor neuron causes release of calcium;

calcium released from sarcoplasmic reticulum;

calcium causes binding sites on actin to be exposed;

myosin heads bind to binding sites/to actin and push actin (inwards);

c(i).

Accept a line or arrow pointing to any part of the matrix, or a circle in it. It is not necessary to state link reaction unless more than one area is indicated.

c(ii) accept/bind acetyl group/acetate / acetyl coenzyme A/acetyl CoA formed;

passes acetyl group/acetate to Krebs cycle;

Examiners report

a(i). Well prepared candidates had no difficulty in naming the humerus and the synovial fluid. For the latter structure certain other answers were accepted because, given the three dimensional structure of the joint, it wasn't entirely clear what the labelling line was touching.

b. Some candidates confused synaptic transmission with muscle contraction and wrote about the former, but there were plenty of accurate explanations of how calcium is used within muscle fibres to trigger off contraction. Details of troponin and tropomyosin were not expected, but with the new program they will be.

c(i). Many candidates were able to label the matrix as the site of the link reaction.

c(ii). There were few really strong answers to this question. A common misconception was to think that coenzyme A is an enzyme, rather than a carrier of the acetyl group that acts as a substrate of enzymes. In many answers it was not clear that coenzyme A first accepts an acetyl group and then passes it to an intermediate (oxaloacetate) in the Krebs cycle.

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.

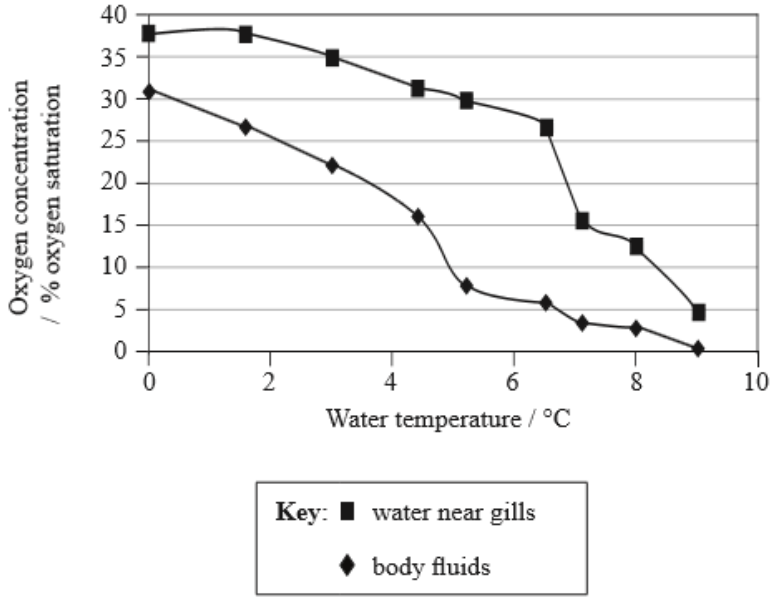
b (i). About a quarter of candidates knew the names of the two secondary structures.

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

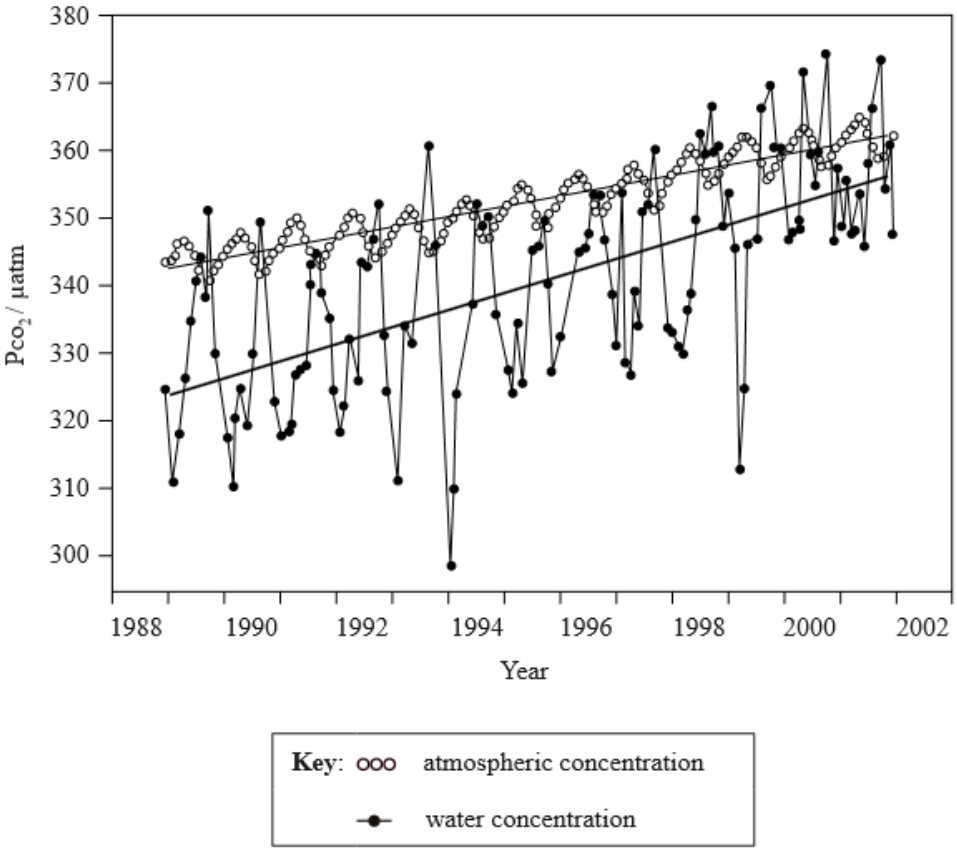
During aerobic cell respiration, oxygen is consumed and carbon dioxide is produced inside cells. This generates concentration gradients between respiring cells and the environment, which cause diffusion of oxygen and carbon dioxide. Both oxygen and carbon dioxide are soluble in water. As the temperature rises, water becomes saturated at a lower concentration of the gas.

Laternula elliptica is a mollusc that lives on the sea bed in Antarctica. Its body temperature is always similar to that of the environment around it. To investigate the effect of temperature on *Laternula elliptica*, specimens were kept in temperature-controlled aquaria. The oxygen concentrations of water near the gills and in the body fluids were measured, at a range of temperatures from 0°C to 9°C. The graph below shows the mean results.



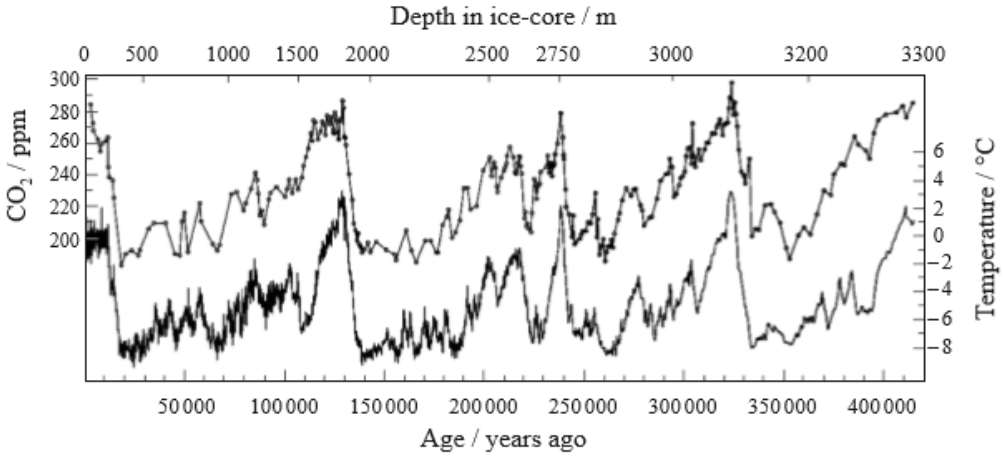
[Source: HO Pörtner, *et al.*, (2006), *Polar Biology*, **29** (8), pages 688–693]

The world's oceans can absorb large amounts of carbon dioxide. This process has been studied in the Pacific Ocean near Hawaii, by measuring carbon dioxide concentrations in the atmosphere and in surface water every month, from October 1988 onwards. The graph below shows the carbon dioxide concentration expressed as partial pressures (Pco_2).



[Source: JE Dore, *et al.*, (2003), *Nature*, **424**, pages 754–756]

The concentration of carbon dioxide in the atmosphere is currently 385 ppm (parts per million). Variations in the concentration of carbon dioxide in the atmosphere can be studied using ice-cores. An ice-core record covering the last 400 000 years has been obtained from Vostok in the Antarctic. The graph below shows the carbon dioxide concentrations that were measured at different depths in the ice. Atmospheric temperatures are also shown on the graph. These were deduced from ratios of oxygen isotopes. The upper line on the graph shows CO_2 concentrations and the lower line shows temperature.



[Source: L.R. Kump, (2002), *Nature*, **419**, pages 188–190]

a (i) Outline the relationship between temperature and oxygen concentration in the body fluids in *Laternula elliptica*. [2]

a (ii) Suggest **two** reasons for the relationship. [2]

b. In its natural environment, *Laternula elliptica* buries itself in the mud on the sea bed. In this investigation, it was found that above 6°C it is unable to bury itself. Suggest a reason for this. [1]

c (i) Describe the trends in atmospheric carbon dioxide concentration, shown in the graph. [2]

c (ii) Suggest **two** reasons for the trends that you have described. [2]

d (i) Diffusion of carbon dioxide only occurs when there is a concentration gradient. Deduce the pattern of carbon dioxide diffusion, between water and atmosphere, from 1988 to 2002. [2]

d (ii) The graph provides evidence for the hypothesis that there will be no net diffusion of carbon dioxide between water and atmosphere by 2020. Explain this evidence. [1]

e (i) State the highest carbon dioxide concentration shown on the graph. [1]

e (ii) State the highest temperature shown on the graph. [1]

f. Using the data in the graph, deduce the relationship between atmospheric carbon dioxide concentration and temperature. [1]

g. Using the data in this question, explain reasons for concern about the long-term survival of Antarctic species, such as *Laternula elliptica*. [3]

Markscheme

a (i) oxygen concentration falls as temperature rises / negative correlation/inverse relationship;

steady decline below 4.2/4.3/4.4°C / vice versa:

rapid decrease between 4.2/4.3/4.4 °C and 5°C;

zero oxygen concentration at/above 9°C;

a (ii) warmer water can hold less oxygen / lower oxygen solubility as temperature rises;

lower oxygen concentration of water reaching gills / less oxygen available from the water to diffuse into the gills;

higher metabolic rate / faster rates of respiration / more oxygen consumption as temperature rises;

b. not enough energy/ATP/aerobic respiration (for muscle contraction/movement)

c (i) rising trend overall;

annual rise and fall / fluctuations;

c (ii) (CO_2 emissions from) increased burning of fossil fuels/deforestation/other anthropogenic factor;

variation in photosynthesis rates during the year / variations in CO_2 uptake in the oceans;

d (i) diffusion in both directions during each year;

diffusion from atmosphere to water during most of the year;

diffusion from water to atmosphere for part of year/autumn/fall/seasonal;

increasing diffusion from water to atmosphere in later years;

d (ii) (no net diffusion because) concentrations will become equal / there will be no gradient;

water concentration higher than atmospheric concentration as often as atmospheric concentration higher than water concentration;

e (i) 300 ppm (*Allow answers in the range 295–305 ppm*) *unit must be included to earn mark*.

e (ii) 3.3°C (*Allow answers in the range 3.0–3.3°C*) *unit must be included to earn mark*.

***N.B**. A maximum of **[1]** per exam can be deducted for a missing unit.*

f. positive correlation / higher temperature with higher CO_2 concentration

g. oceans may cease to act as sink / store for CO_2;

atmospheric CO_2 concentration may then rise more rapidly;

atmospheric CO_2 concentration is higher than for at least 400 000 years/any time in recent (geological) time;

Antarctic temperatures will (probably) rise higher than at any time in 400 000 years/any time in recent (geological) time;

rising (sea water) temperature would reduce oxygen availability in water;

significant changes in habitat/abiotic factors;

populations may not be able to adapt;

Examiners report

a (i) Many candidates stopped at outlining one aspect of the data.

a (ii) Candidate's gave one factual statement rather than the required two.

b. Many were able to successfully link the concept of aerobic respiration to the question.

c (i) There was poor understanding of the second graph. Even those who spotted the regular oscillation usually linked this to a 2 year interval rather than an annual cycle.

c (ii) Some answers to (c) ii) were vague making reference to "pollution" as the cause. Some showed confusion by arguing that the general rise in CO_2 was caused by the greenhouse effect rather than being the cause of the greenhouse effect. Candidates should be familiar with the atmosphere data as this is required in the syllabus.

d (i) For the greatest number of candidates, the pattern discussed in (d) i) was that of concentration rather than the pattern of diffusion. There was very little reference to time data.

d (ii) Many were able to discern that the lines would intersect, so that there would be no net diffusion.

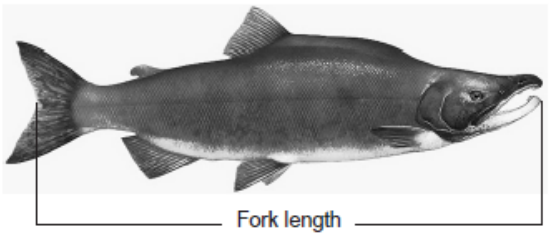
e (i) Very few failed to put in the correct units though many included the solidus in the units; i.e., the units were CO_2 / ppm rather than just ppm.

e (ii) Surprisingly some candidates managed to get the highest temperature wrong. Very few failed to put in the correct units though many included the solidus in the units; i.e., the units were CO_2 / ppm rather than just ppm.

f. The greatest number of candidates earned this mark. The graph suggests that CO_2 levels were the cause of the temperature. The markscheme did not penalize candidates for this, but candidates did confuse the dependent and independent relationship.

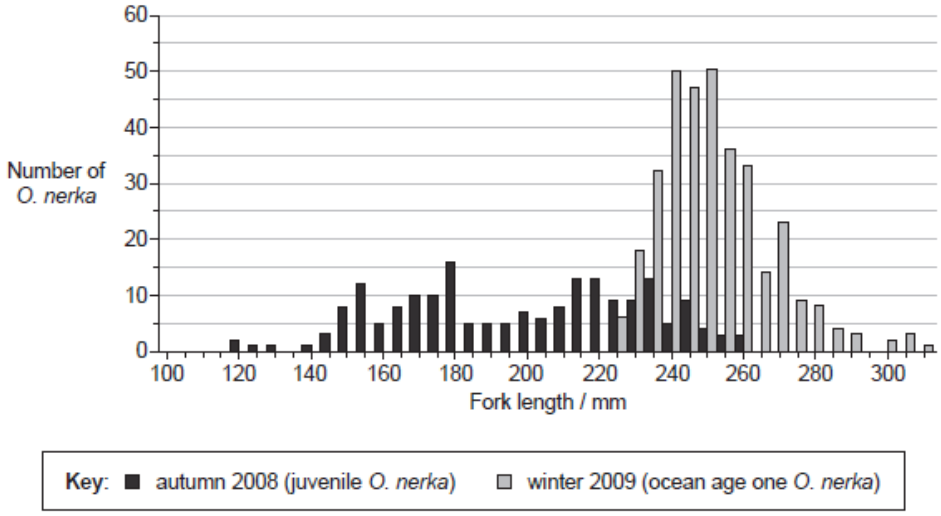
g. There were two aspects of the prompt that were commonly left unaddressed by candidates. “Using the data in this question....” invited the candidates to consider all of the data but many referenced just the first graph on page 2 of the booklet. “...Antarctic species, such as ...” was meant for candidates to discuss organisms more broadly than the particular species in the question. Some talked about habitats other than the Antarctic ocean.

Sockeye salmon (*Oncorhynchus nerka*) spend the first years of their lives in the freshwater lakes of Alaska before migrating to marine waters. Their first months in marine waters are spent foraging and growing near the shore line. They then move to offshore regions of the North Pacific Ocean for 2 to 3 years.



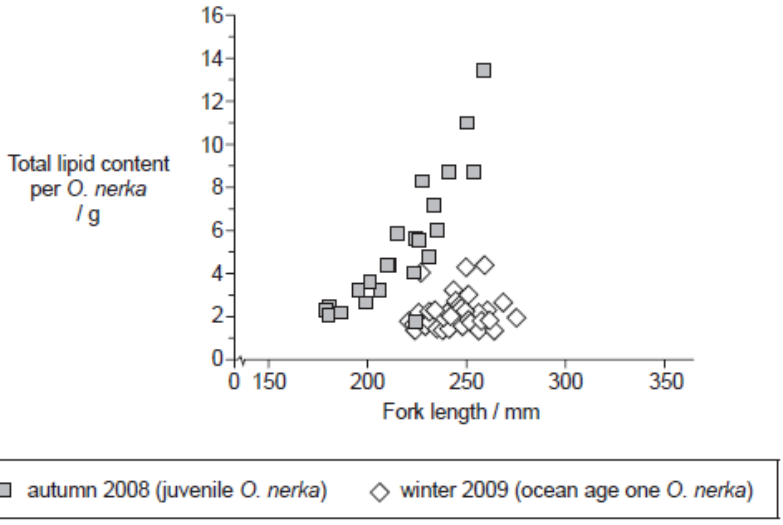
[Source: adapted from http://pnwfolklore.org]

The graph shows fork length frequency of juvenile *O. nerka* caught during their first months in marine waters in autumn 2008 and ocean age one *O. nerka* caught 15 months later during winter 2009 in the North Pacific Ocean.



[Source: adapted from EV Farley, *et al.*, (2011), *ICES Journal of Marine Science*, **68** (6), pages 1138–1146]

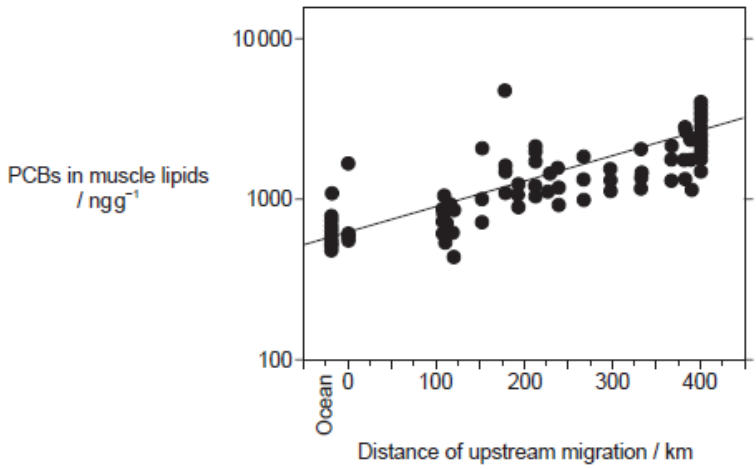
Lipid in *O. nerka* was measured to evaluate possible differences in energy status during their first 15 months at sea. The graph shows the relationship between fork length and lipid content for *O. nerka* caught during autumn 2008 and winter 2009.



[Source: adapted from EV Farley, *et al.*, (2011), *ICES Journal of Marine Science*, **68** (6), pages 1138–1146]

Persistent organic pollutants, such as polychlorinated biphenyls (PCBs), have been shown to reach unpolluted arctic areas by air currents. Another method of transport of these pollutants into these ecosystems is provided by migrating *O. nerka*.

Pollutant transport was studied in a population of *O. nerka* in the Copper River (Alaska). The graph shows concentration of PCBs in muscle lipids of *O. nerka* in relation to the distance of upstream migration.



[Source: adapted from G Ewald, *et al.*, (1998), *Arctic*, **51** (1), pages 40–47]

a. Identify the **total** number of *O. nerka* with fork length from 240 to 245 mm caught in autumn 2008 and winter 2009. [1]

b. Compare the data in the graph for autumn 2008 and winter 2009. [3]

c. Suggest **two** factors that could affect the distribution of *O. nerka* in the North Pacific Ocean. [2]

d. State the range of lipid content measured in *O. nerka* caught during autumn 2008. [1]

.....g

e. Outline any correlation between total lipid content and fork length in autumn 2008 and in winter 2009. [2]

Autumn 2008:

Winter 2009:

f. Suggest reasons for the differences in lipid content. [2]

g. Describe the relationship between the distance of upstream migration and the concentration of PCBs in *O. nerka*. [1]

h. State the concentration of PCBs in muscle lipids at 125 km from the ocean estimated by the correlation line. [1]

i. As the *O. nerka* migrate upstream they no longer feed. Suggest a reason for the relationship of distance of upstream migration and concentration of PCBs in muscle lipids. [1]

Markscheme

a. 59 ***or*** 50 + 9

b. higher average/mean/mode/median length in winter;

higher minimum length in winter / none below 225 mm in winter;

higher maximum length in winter / none above 260 mm in autumn;

smaller range (of length) in winter;

higher peaks in winter;

overlap between lengths of 260 and 225 mm;

more data/more caught in winter than in autumn;

Allow the converse for any of the mark points.

Allow size instead of length and allow the two groups to be referred to either by season (autumn/winter) or year (2008/09).

c. migration;

ocean currents;

food availability/distribution;

predation / fishing;

temperature;

location of rivers (flowing into the ocean);

depth of (sea)water;

Reject "pollution" and mark only the first two responses.

d. 11.7 g; *(accept answers in the range of 11.4 to 13.0 g)*

1.8 to 13.5 g; *(accept answers in the range of 1.6 to 2.0 g and 13.4 to 13.6 g)*

e. *autumn 2008:*

positive correlation / fork length increases as lipid content increases;

winter 2009:

no correlation / no overall trend; *(reject "constant" or "almost same")*

f. lipid stores accumulated during summer/in freshwater/before moving out to sea;

food resources/availability may decline rapidly during autumn/winter;

more food close to the shore (than in offshore water);

lipid stores used up during winter / more active/migrating in winter;

Do not accept answers relating to the size of O. nerka because O. nerka with similar sizes showed different lipid content values.

g. direct/positive correlation / higher PCB concentration further up the river

h. 1000 ng g^{-1} *(accept answers in the range 950 ng g^{-1} to 1050 ng g^{-1})*

Do not award the mark if the units are missing or incorrect.

Allow units shown as ng g^{-1}.

i. lipids used up so same quantity of PCB in smaller amount of lipid;

no excretion of lipids so same quantity of PCB in smaller amount of lipid;

PCB absorption through gills;

Examiners report

a. Most candidates read off the two numbers from the bar chart and added them together correctly, though some misread the intervals on the x-axis

or read off the values on the y axis incorrectly.

b. The essential skill in questions such as this is to pick out significant features in the data. The answer should tell the reader the overall differences between the two populations and not simply quote values. There was some overlap between the two populations in fork length but the winter 2009 population had a larger sample size, larger average length and larger maximum and minimum fork lengths. It also had a smaller range of fork lengths than the autumn 2008 population. In future exams the command term ‘compare’ will mean only similarities, not similarities and/or differences.

c. Most candidates suggested two acceptable factors that could affect distribution.

d. Candidates found it hard to read off values from this scatter graph, perhaps because of the large size of the squares and diamonds used for the data points. Candidates should be reminded that it is the centre of any data point that indicates the precise value, not the upper or lower edges. Because of the difficulties, a relatively wide range of answers was accepted, but even so only about half of candidates gave an acceptable range.

e. This was generally well answered with candidates stating that there was a positive correlation in Autumn 2008 and no correlation in Winter 2009. The commonest mistake was to state that there was no variation in total lipid content in Winter 2009: there was, but no clear trend lipid content according to fork length.

f. Candidates gave a wide range of reasons for the differences in lipid content. The best answers were from candidates who had read all the information in the question about the biology of Sockeye salmon and had used it to deduce the reason for depletion of lipids in the salmon in winter.

There was confusion in some candidates’ minds between cause and effect, with statements such as that the sea water is colder in winter so the salmon are less active, need less energy and therefore have smaller stores of lipid. If we applied this sort of logic to humans, the reason for obesity would be a need for more stored energy reserves in obese people because they are more active. Some candidates assumed erroneously that the physiology of fish is the same as that of mammals, with constant high body temperature and subcutaneous storage of lipids for heat insulation.

g. Most candidates correctly stated that there is a positive correlation between PCB concentration and distance upstream.

h. [N/A]

i. This proved to be quite a discriminating question, with the strongest candidates working out that if lipids are used up, but PCBs cannot be removed from the body, then the concentration of PCBs in lipids will increase.