HL Paper 2

a. Outline the various stages of the cell cycle. [4]

c. Define the term *transpiration* and explain the factors that can affect transpiration in a typical terrestrial plant. [9]

Markscheme

a. G_1 the cell grows/duplication of organelles;

S is synthesis stage when DNA is synthesized/replicated;

G_2 the chromosomes begin condensing/preparation for cell division;

G_1 , S and G_2 make up interphase;

during mitosis nuclear division occurs/all four stages listed;

during cytokinesis cytoplasm/cell divides/daughter cells formed;

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

temperature, humidity, light (intensity) and wind <u>all affect</u> transpiration;

high temperatures increase evaporation rate of water/transpiration; *(accept converse)*

high humidity lowers the rate of water evaporation/transpiration; *(accept converse)*

air currents/wind increase water evaporation/transpiration; *(accept converse)*

high light (intensity)/sunlight (usually) increases photosynthesis/water evaporation through the stomata/transpiration;

stomata open to allow gaseous exchange/entry of CO_2;

abscisic acid stimulates closing of stomata;

guard cells open/close the stomata;

adaptations of (xerophyte) plant structures reduce water loss/transpiration;

one example;

(thicker leaf cuticle / reduced surface area/rolled leaves/spines / sunken/reduced stomata / close stomata in day / low growth form / CAM / C4 physiology)

second example; *(of above)*

*Award **[8 max]** if definition is missing.*

Examiners report

a. In part (a) many students knew the cell cycle and its parts, but did not fully describe each one. Some students went into very detailed descriptions of the stages of mitosis, only worth one mark, instead of describing the others.

c. Part (c) was often well answered with candidates write detailed accounts of the effects of the different factors on plant transpiration. However, some described the effects of evaporation of the water in anthropogenic terms of cooling the plant. Also some students wasted valuable time describing the transpiration stream in great detail.

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a. Describe the characteristics of stem cells that make them potentially useful in medicine. [5]

b. Outline a technique of gene transfer resulting in genetically modified organisms. [5]

c. Explain the use of karyotyping in human genetics. [8]

Markscheme

a. (stem cells) have/retain the capacity to divide;

can be used to produce cell cultures/large number of identical cells;

can be used to repair/replace damaged/lost cells/tissue;

(stem cells) are undifferentiated / have not yet differentiated/specialized;

can differentiate/specialize in different ways / are pluripotent/totipotent;

can be used to form a variety of different tissues / form organs;

used in medical research;

used in treatment of (named) disease;

b. gene transfer takes a gene from one species/organism and inserts it into another;

using plasmid/viral vector/ballistic impregnation/electroporation;

use of reverse transcriptase to obtain gene from mRNA;

restriction enzyme/endonuclease used to cut out/excise gene;

(same) restriction enzyme used to cut open plasmid;

sticky ends used to link DNA/link gene to plasmid;

DNA ligase used to seal nicks/splice;

bacterium takes in plasmid / plasmid transferred to bacterium/plant/host cell;

valid documented example (*e.g.* human insulin from bacterium/yeast / salt-tolerant tomato plant / carotene/vitamin A in rice / herbicide/Roundup/glyphosate resistance in crop plants / factor IX/clotting factor in sheep milk / low phosphate feces in pigs;

c. *Definition and construction of karyotypes:*

karyotype is the number and type / image of chromosomes in a cell;

cells collected from chorionic villus / by amniocentesis;

requires cells in metaphase / stimulate cells to divide and reach metaphase;

burst cells and spread chromosomes / photo taken of chromosomes;

chromosomes are arranged in pairs;

according to size/structure/position of centromere/banding pattern;

Uses for karyotypes:
karyotypes used to identify sex/gender;
male is XY and female XX;
used to identify chromosome mutations/abnormal numbers/non-disjunction;
Down syndrome due to extra chromosome 21 / other trisomy/aneuploidy example;
used for pre-natal diagnosis of chromosome abnormalities;
may lead to a decision to abort the fetus;
prepare for consequences of abnormality in offspring;

Examiners report

a. The characteristics of stem cells and their uses were generally well known. Almost all candidates mentioned that they are undifferentiated cells and that they can differentiate in different ways. Some distinguished pluripotent from totipotent stem cells which was impressive. Fewer candidates than expected mentioned the ability of stem cells to divide repeatedly. Some candidates who were struggling to find much to include in their answer wrote extensively about the ethics of stem cell research, which was not required.

b. This was answered more poorly than expected. The examining team was anticipating thorough accounts of gene transfer using reverse transcriptase, restriction enzymes, plasmids, sticky ends and plasmids but few of these were seen. In many cases the techniques were not well understood, with errors and omissions in candidates" answers. The word splice was often used to mean slice or cut, when it actually means linking together. One use of this word before the days of molecular biology was the act of joining the ends of ropes by weaving together their strands –this image might help candidates see the word splice is used for joining together fragments of DNA using sticky ends and DNA ligase.

c. Despite an apparently narrow focus, this was one of the better answered questions in Section B. Most candidates at least knew that Down syndrome is due to trisomy of chromosome 21. The best answers included details both of how karyotypes are prepared and also what can be learned from them. The weakest candidates mostly wrote in vague terms about testing for genetic defects and did not appreciate the difference between gene and chromosome mutations.

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a. Explain how minerals move into plants. [8]

b. Outline the conditions needed for the germination of a typical seed. [3]

c. Following germination of seeds, plants undergo a rapid increase in the number of cells. Describe stages in the cell cycle that result in this increase of cells. [7]

Markscheme

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

a. minerals bound to soil particles;
b. examples of three nutrients from: phosphate, nitrate, magnesium, iron, calcium, potassium, sodium, magnesium;
c. minerals dissolve in water;
d. mass flow causes movement of minerals with movement of water through soil;
e. minerals diffuse down a concentration gradient towards roots (as the mineral concentration next to the roots is continuously decreasing);
f. minerals enter the plant through roots;
g. by active transport / use of ATP;
h. branching of roots increases surface area for absorption of minerals;
i. root hairs increase surface area (for the absorption of minerals);
j. hypha of (mutualistic) fungi may enhance movement of selected ions into roots / increase surface area;
k. root hairs have many mitochondria to provide energy/ATP for active transport;
l. export of H+ creates electrochemical gradient / displaces ions bound to soil/clay;
m. that causes positive mineral ions to diffuse into (root) cells;
n. negative mineral ions cross membrane linked to H+ ions moving down (H+) gradient;

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

a. water to rehydrate the seed / activate metabolic processes;
b. oxygen for aerobic respiration as seed germinates;
c. suitable temperature for enzyme activity;
d. each type of seed has specific temperature requirements / temperature requirements ensure that seeds germinate at the correct time of year;
Do not accept a simple list of factors without details.

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

a. growth phase/G-1: synthesis of proteins/cytoplasm/organelles;
b. synthesis phase/S-phase: replication of DNA;
c. second growth phase/G-2: continued growth of cytoplasm/molecular synthesis/duplication of organelles;
d. prophase: chromosomes super-coil to prepare for mitosis / nuclear envelope disappears / spindle fibres form;
e. metaphase: chromosomes line up at equatorial/metaphase plate / spindle fibres attach to centromeres/chromosomes;
f. anaphase: chromatids move along microtubules/spindle fibres move chromatids toward opposite poles;
g. telophase: nuclear membranes form around each cluster of chromosomes;
h. cytokinesis: new plasma membrane forms between the nuclei / cell plate forms;
i. a new cell wall forms;
j. (mitosis) results in two cells with identical nuclei;

Names of phases are required to earn the mark.
Award marks for a clearly drawn correctly annotated diagram.

Examiners report

a. Students tended to perform well on this question though it was rare for students to demonstrate detailed knowledge of the mechanism of active transport in terms of ion exchange.

b. Students found it easier to list the conditions required for germination rather than outlining the conditions required.

c. Many students earned marks by outlining the stages of mitosis though a number were not clear on when spindle fibres form and when they attach, commonly indicating that this occurs in metaphase. Some students muddled the mechanisms of meiosis and mitosis. The distinctions between cytokinesis in plant and animal cells does not seem to be well understood. The events that occur in the different stages of interphase appears to be less well known.

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. 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.

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a. Draw a labelled diagram that shows the positions of proteins within the cell membrane. [3]

b. Outline the effects of putting plant tissue in a hypertonic solution. [4]

c. Explain how the structure of the nephron and its associated blood vessels enable the kidney to carry out its functions. [8]

Markscheme

a. Phospholipid bilayer drawn and labelled with at least one protein labelled and drawn embedded either in one or both halves of the bilayer

Reject if only peripheral proteins are shown.

Integral/intrinsic/transmembrane/carrier/pump/channel/pore protein labelled and shown crossing the membrane

Extrinsic/peripheral protein labelled and shown on membrane surface/not embedded in bilayer

Glycoprotein labelled and shown integral and with a clear carbohydrate region projecting out on one side of the membrane

The carbohydrate should be shown differently from the protein but need not be labelled specifically.
The protein part can be embedded in one or both phospholipid layers.

b. Hypertonic solution has more solutes/higher solute concentration «than the tissue/cells/cytoplasm»

Water moves out of the cells/tissue by osmosis «into the hypertonic solution»

Water moves from lower solute concentration to higher solute concentration/up the solute concentration gradient

Reject answers based on water concentrations.

Pressure inside cell drops
OR
cell no longer turgid
OR
cell becomes flaccid

Reject cell decreases in size.
Reject plant wilts and other answers about whole plants.

Volume of cytoplasm drops
OR
«plasma» membrane retracts from the cell wall
OR
cell is plasmolysed

Reject plant cells shrink or shrivel.

c. Osmoregulation/excretion of nitrogenous waste/urea «is a function of the» kidney

Ultrafiltration in the glomerulus/smaller molecules filtered out in the glomerulus
OR
capillary walls/glomerulus permeable to smaller molecules
Reject ultrafiltration in the Bowman's capsule.

Basement membrane/filtration slits/podocytes act as filter/prevent loss of «large» «proteins»/prevent loss of blood cells

High «blood» pressure in glomerulus due to larger afferent than efferent arteriole

«Selective» reabsorption of glucose/useful substances in proximal convoluted tubule

Microvilli/coiling/convolutions give large surface area
OR
pump proteins to reabsorb specific solutes «in proximal convoluted tubule»

Water reabsorbed in descending limb «of loop of Henle»
OR
descending limb permeable to water

Active transport/active pumping of sodium ions/Na^+ out of ascending limb «from filtrate to medulla»

Ascending limb is impermeable to water

Loop of Henle creates solute gradient/high solute concentration/hypertonic conditions in medulla

Distal convoluted tubule adjusts pH/adjusts concentration of $Na^+/K^+/H^+$

Water reabsorbed in collecting duct

Collecting duct permeability to water varies due to number of aquaporins/ADH

Osmoregulation by varying the amount of water reabsorbed «in the collecting duct»

Examiners report

a. There were many neat and accurate diagrams of membrane structure showing a variety of proteins. It was not difficult to earn the three marks.

Peripheral proteins should be shown on the surface of the phospholipid bilayer, not embedded in it.

b. This part was less well answered, with candidates failing to make the basic points about the events caused by putting plant tissue into a hypertonic solution. Some candidates misunderstood the term 'tissue' and talked instead about placing whole plants in a solution. Candidates should be careful to state that hypertonic means a higher solute concentration, not just a high concentration. Explanations of osmosis in terms of water concentration should be discouraged as there are no units for measuring such concentrations. Water potential terminology is not expected as it is not part of the new programme.

c. Answers to this question were very varied. The functions expected were osmoregulation and excretion thus the focus should have been on how the nephron can vary the volume and concentration of urine so as to bring the blood back to normal levels, and on how waste products can be concentrated in urine to conserve water. Some teachers commented on G2 forms that is was unreasonable to expect details of the structure of

associated blood vessels but all that was required was the structure of the glomerulus. Able candidates who had prepared carefully were able to score highly but weaker candidates tended to be very muddled.

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. Describe **four** different types of transport of substances across a membrane. [4]

b. Hormones such as FSH (follicle stimulating hormone) and LH (luteinizing hormone) affect the development of certain cells by binding to receptors in the plasma membranes. Outline the role of FSH and LH in the menstrual cycle. [6]

c. In the placenta, many substances are transported across membranes. Explain the structure and role of the placenta. [8]

Markscheme

a. *Must be description of types not a list.*

a. (simple) diffusion when molecules move down a concentration gradient directly through membrane/unaided by carrier molecule;

b. (passive transport by) facilitated diffusion through (specific) channel proteins;

c. osmosis of water via aquaporins/from area of low solute concentration to area of high solute concentration;

d. active transport against a concentration gradient using protein pumps/ATP;

e. vesicles attach to plasma membrane and release materials to exterior/ exocytosis;

f. cell membrane invaginates/pinches off to bring material to interior / endocytosis / phagocytosis;

b. a. FSH stimulates estrogen secretion by follicle cells;

b. at start of menstrual cycle;

c. leading to development of endometrium;

d. (FSH and) LH (rise to a peak and) causes egg to be released/ovulation;

e. causes follicle cells to secrete less estrogen/more progesterone;

f. progesterone maintains endometrium/uterine lining

g. LH promotes change of follicle to corpus luteum;

h. secretion of LH and FSH regulated by negative feedback;

i. regulated/inhibited by high estrogen and progesterone levels;

j. low progesterone levels cause menstruation;

c. a. disc shaped structure

b. embedded in uterus wall;

c. connected to fetus by umbilical cord;

d. contains fetal and maternal structures/tissues;

e. placental villi/maternal intervillous space provide large surface area for exchange of materials;

f. blood of fetus and mother flow close to each other (but no mixing);

g. materials exchanged/diffuse (through membranes) between mother and fetal blood;

h. oxygen/nutrients/antibodies/other substances diffuse (through membranes) to fetus;

i. CO_2 and wastes diffuse (through membranes) to mother;

j. caffeine/drugs/alcohol/viruses from mother may damage fetal development;

k. takes over role of corpus luteum (to produce hormones);

l. produces hormones/estrogen/progesterone/HCG;

Examiners report

a. Question 8 was the least popular question.

In part a, few discussed exocytosis and endocytosis. The distinction between simple diffusion and passive diffusion was often confused. Reference to aquaporins was rare. Discussion of osmosis was generally well done.

b. Question 8 was the least popular question.

In part b, the knowledge of students was adequate. The challenge for this question was structuring the response to address the demands of the question as the events within the ovary had to be linked to the events within the uterus. The role of estrogen in developing the uterine lining was well known as was the role of progesterone in maintaining the lining. They were also reasonably successful in discussing the role of LH. Students were less commonly successful with discussing the specific actions of FSH and the regulation of hormone levels.

c. Question 8 was the least popular question.

Answers to part c were adequate, though it was common for the use of terminology to be poor. Most candidates were able to identify the placenta as a disc shaped structure embedded in the uterine wall that was connected to the mother via the umbilical cord. Most showed adequate understanding of the types of material exchanged within the placenta. Fewer showed adequate comprehension of the mechanism of materials exchange between the mother and the fetus. Few adequately described the structure of the placental villi or the relationship between maternal and fetal blood flow.

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a. Draw a labelled diagram of a eukaryotic plant cell as seen in an electron micrograph. [4]

b. Outline how the energy flow through food chains limits their length. [3]

c. In hot, dry conditions plants lose water rapidly due to transpiration. Explain how the structures and processes of the plant allow this water to be replaced. [8]

Markscheme

a. Cell wall shown with two continuous lines to indicate the thickness

Plasma membrane/cell membrane shown as a single continuous line

Accept inner line of wall as membrane if clearly labelled.

Nuclear membrane/nucleus shown with double membrane and nuclear pores

Vacuole «membrane»/tonoplast shown as a single continuous line

Chloroplast/plastid shown with a double line to indicate the envelope and thylakoids/grana

Mitochondrion shown with double membrane/cristae

b. Only a small proportion/20 %/10 % «of energy» can pass from one trophic level to the next *Accept named trophic levels or named stages in a food chain in place of "trophic levels"*.

OR

large proportion/80 %/90 % lost between one trophic level and the next *Accept if clearly shown in a diagram such as a pyramid of energy*.

Energy released by respiration ***AND*** lost as heat *Not just respiration or heat*.

Energy losses due to uneaten parts/undigested parts/feces/egestion

Not enough energy for 4th/5th/later stages of a food chain
OR
more energy available if feeding at an earlier stage in a food chain

c. Evaporation of water «in leaf/mesophyll» creates tension/low pressure/negative pressure «potential»/pulling force/transpiration pull

Water drawn through cell walls/out of xylem «in leaf» by capillary action/adhesion «to cellulose»

Low pressure/tension/suction/pulling force in xylem

Hydrogen bonds make water cohesive/allow water to be pulled up under tension/allow the transpiration pull «to move water»

Xylem resists tension/low pressure/collapse with thickened/lignified walls

Water travels from the roots to the leaves in xylem

Water absorbed in roots by osmosis

Active transport of ions/solutes into roots «enabling osmosis»

Deep/wide ranging/extensive root systems/taproots/many root hairs

Thick/waxy cuticle reduces transpiration/water loss/evaporation

Small/no leaves/reduced surface area of leaves/thorns instead of leaves

Few stomata/stomata in pits/rolled leaves

Hairs on leaf surface «to reduce air flow near the leaf/reflect sunlight»

Stomata open at night/CAM physiology to reduce water loss

Examiners report

a. Diagrams of plant cell structure were mostly rather poor and few candidates scored full marks. The question specified 'as seen in an electron micrograph'. Many diagrams showed the appearance of plant cells in a light micrograph. This allowed marks for cell wall and cell membrane to be awarded, but not for internal structures such as the nucleus as their representation was not detailed or accurate enough. In contrast to the membrane diagrams in 6(a), many of these cell diagrams were carelessly drawn with overlapping, multiple or discontinuous lines used for structures that have a single continuous edge.

b. This is a familiar question, though there was a slight twist in that candidates were expected to explain specifically why food chains cannot be long. Nearly all candidates wrote about energy losses between trophic levels and many mentioned the '10% rule' though in some cases got it the wrong way round and stated that 10% of energy is lost. Too few candidates mentioned the most important idea – that release of energy by cell respiration

and its use is accompanied by loss of energy from a food chain in the form of heat.

c. This question caused some problems. It was another case where a sentence had been added to set the scene, but it proved a distraction rather than an aid to focus. The wording of the question as a whole was clear, but many candidates seemed not to have read to the end of the second sentence and they did not therefore explain how losses of water by transpiration are replaced. Some answers were concerned exclusively with xerophytic adaptations. An extensive markscheme was devised that allowed these answers to score up to five marks. Those candidates who did actually describe the uptake and transport of water within the plant were able to score full marks. There were few really strong answers and many misunderstandings. One in particular is worth mention: capillary action due to adhesion of water to xylem walls only helps to refill xylem vessels when they are air-filled. If a plant is transpiring the xylem will be filled with water under tension and adhesion cannot cause upward movement.

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

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

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

Markscheme

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

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

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

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

ribosome; (*dots in cytoplasm*)

cytoplasm;

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

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

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

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

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

primer allows attachment of (DNA) polymerase;

DNA polymerase III copies DNA;

adds nucleotides in the 5′ to 3′ direction;

uses deoxynucleoside triphosphates/nucleotides that are free in cell;

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

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

(leading) strand replication towards the replication fork;

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

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

(DNA) ligase joins short fragments/seals nicks;

by making sugar-phosphate bond;

c. translation is protein/polypeptide synthesis;

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

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

organized into a tertiary structure/globular shape;

a small subunit and a large one;

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

A, P and E sites;

binding site for mRNA on surface/in small subunit;

two tRNA can bind at the same time;

ribosomal RNA catalyses formation of peptide bond;

Examiners report

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

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

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

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

b. Explain how an impulse passes along the axon of a neuron. [8]

c. Describe the process of endocytosis. [5]

Markscheme

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

a. sarcomere – clearly indicated between Z lines (whether Z lines named or not);

b. Z lines – shown at the ends of a sarcomere;

c. actin (filaments) – drawn as thin lines attached to Z lines;

d. myosin (filaments) – drawn as thick lines interdigitating with thin/actin filaments;

e. myosin heads – on both sides of at least one myosin filament;

f. light band and dark band – indicating regions of actin only and myosin plus actin;

b. a. resting potential is –70mV / relatively negative inside in comparison to the outside;

b. Na^+/K^+ pumps maintain/re-establish (the resting potential);

c. more sodium ions outside than inside (when at the resting potential);

d. more potassium ions inside than outside (when at the resting potential);

e. nerve impulse is an action potential that stimulates a (wave of) depolarization along the membrane/axon;

f. if neuron is stimulated/threshold potential/–50mV is reached sodium ion channels open;

g. sodium ions diffuse/move in;

h. (Na^+ move in) causing depolarization;

i. potassium ion channels open / potassium ions diffuse/move out;

j. (K^+ move out) causing repolarization;

k. local currents / description of Na^+ ion diffusion between depolarized region and next region of axon to depolarize;

Accept any of the above points clearly explained in an annotated diagram.

c. a. (plasma) membrane encloses/engulfs solid particles/droplets of fluid/molecules;

b. fluidity of the membrane allows endocytosis;

c. plasma membrane forms pit/forms indentation/pulled inwards/invaginates;

d. membrane pinches off/seals back on itself/edges fuse;

e. vesicle/vacuole formed;

f. inside of plasma membrane becomes outside of vesicle membrane / converse;

g. vesicle breaks away from plasma membrane/moves into cytoplasm;

h. active process / endocytosis/vesicle formation requires energy;

Accept any of the above points clearly described in an annotated diagram.

Examiners report

a. Most candidates scored three or four marks for the drawing of a sarcomere. The Z lines, actin filaments and myosin filaments were usually recognisable. Myosin heads were shown clearly in some diagrams. Light and dark bands were often incorrect. Some candidates showed but did not label titin filaments between the ends of the myosin and filaments and the Z lines. Usually these were distinguished from the myosin by being

shown narrower and without heads.

b. There were relatively few really strong accounts of the passage of an impulse along an axon. Some candidates described synaptic transmission instead and others were confused about the sequence of events. Very few candidates explained how the impulse is propagated along the axon by local currents.

c. Almost all candidates knew something about endocytosis, describing the invagination of the plasma membrane and the formation of vesicles. A few had confused endo and exocytosis and included descriptions of vesicle movement from the rough ER to the Golgi and on to the plasma membrane.

---

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

b. Outline transcription in prokaryotes. [6]

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

Markscheme

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

a. cell wall – a uniformly thick wall;

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

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

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

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

f. plasmid – circular ring of DNA;

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

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

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

b. RNA polymerase binds to promoter region of DNA;

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

d. RNA polymerase unwinds DNA/separates the strands;

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

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

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

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

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

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

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

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

c. antigens in the vaccine cause antibody production;

d. antigen/pathogen engulfed by macrophage/phagocyte;

e. each type of lymphocyte recognizes specific antigen;

f. macrophages activate helper T-cells;

g. which activate B-cells;

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

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

j. result is (specific) immunity;

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

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

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

Examiners report

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

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

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

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

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

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

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b. Outline, with an example, the process of exocytosis. [5]

c. Translation occurs in living cells. Explain how translation is carried out, from the initiation stage onwards. [9]

Markscheme

b. vesicles carry material to plasma membrane;

vesicle fuses with membrane;

(by joining of) phospholipid bilayers;

aided by the fluidity of the membrane;

material released/expelled from the cell;

membrane flattens;

name of example e.g. exocytosis of neurotransmitter / exocrine secretion/endocrine secretion / hormone secretion / release of cortical granules;

outline of example: (in the presence of calcium), neurotransmitter vesicles release their contents into the synapse / hormones released from one cell have an effect on another cell etc.;

Accept these points if clearly made in an annotated diagram. ***[4 max]*** *if no example given.*

c. translation involves initiation, elongation/translocation and termination;

mRNA binds to the small sub-unit of the ribosome;

ribosome slides along mRNA to the start codon;

anticodon of tRNA pairs with codon on mRNA:

complementary base pairing (between codon and anticodon);

(anticodon of) tRNA with methionine pairs with start codon / AUG is the start codon;

second tRNA pairs with next codon;

peptide bond forms between amino acids;

ribosome moves along the mRNA by one codon;

movement in 5' to 3' direction;

tRNA that has lost its amino acid detaches;

another tRNA pairs with the next codon/moves into A site;

tRNA activating enzymes;

link amino acids to specific tRNA;

stop codon (eventually) reached;

Examiners report

b. There were some very good answers to this section which included all possible marking points, but far too many only knew one fact, that it expelled material form a cell. A large number of candidates summarized intracellular vesicle traffic which again suggests that candidates have memorized mark schemes rather than applying what they know to novel questions. In this question, the details of a specific example were rarely included.

c. It was surprising that so many managed to omit the basic facts on codon/anticodon binding by complementary base pairing. Some explained DNA replication and transcription instead. Answers were in general, poorer on this topic than they have been in the past which suggests that teachers are not spending adequate time on this topic.

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

b. Explain the process of transcription in prokaryotes. [8]

c. Some prokaryotes cause infectious diseases which stimulate the body's immune system. Outline the principles that form the basis of immunity. [6]

Markscheme

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

cell wall; *(with some thickness)*

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

cytoplasm;

pilus/pili; *(shown as single lines coming from the cell wall)*

flagellum/flagella; *(thicker and longer than pili and embedded in cell wall)*

70S ribosomes; *(shown as small dots)*

nucleoid / naked DNA;

approximate width 0.5 μm / approximate length 2.0 μm;

Award [3 max] if the bacterium drawn does not have the shape of a bacillus (rounded-corner rectangle with length approximately twice its width).

Award [3 max] if any eukaryotic structures included.

b. transcription, synthesis of RNA identical to one strand/coding strand of DNA;

antisense stand acts as template/is transcribed;

RNA polymerase attaches to sequence of DNA known as promoter (region);

RNA polymerase separates the two strands of DNA;

(unwinding) exposes (10–20) DNA bases for pairing with RNA nucleotides;

RNA nucleotides matched to complementary bases;

adenine with uracil and cytosine with guanine / uracil replaces thymine;

H bonds between RNA nucleotide and complementary base on DNA strand;

(RNA) nucleoside triphosphates used;

hydrolysis of (two) phosphate molecules provides energy for reaction;

adds nucleotides to the 3′ end of RNA molecule/in 5′ → 3′ direction;

terminator is sequence of DNA signaling end of transcription;

RNA molecule separates completely from DNA;

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

c. skin and mucous membranes form barriers to pathogens as first line of defence;

macrophage recognizes antigens and ingests pathogen (in blood/body tissues);

presents antigen/MHC on cell surface;

macrophage activates helper T-cells that are complementary to antigen;

complementary B-cell becomes activated/stimulated by T-helper cells;

activated B-cell increases in size and divides by mitosis / creates clone of B-cells;

B-cells differentiate into plasma cells and memory cells; (both needed) plasma cells secrete specific antibodies;

memory cells remain/form basis of long-term immunity;

polyclonal response / multiple B-cells activated by different molecules of antigen;

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

(Plus up to [2] for quality)

Examiners report

a. Although the general level of diagrams has been improving, there were still a few poorly labelled ones, especially not distinguishing clearly between the cell wall and the plasma membrane. There were many pili and flagella seemingly floating in space, and many with eukaryotic structures. Most correctly drew the bacillus shape correctly.

b. Well prepared candidates gave a very clear and precise account of transcription. However some still remain confused between transcription, translation and replication, so described the wrong process. One common error was to say that helicase instead of RNA polymerase separated the strands. At the end, many forgot that they were explaining the process in prokaryotes and described the mRNA leaving the nucleus.

c. Most knew that the stimulation of the immune system involved macrophages, and T and B cells, but only the better candidates could explain the process clearly.

---

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

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

c. Explain prokaryotic DNA replication. [8]

Markscheme

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

(plasma) membrane – single line surrounding cytoplasm;

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

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

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

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

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

lysosome;

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

b.

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

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

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

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

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

on one strand DNA polymerase III builds continuous strand;

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

each short chain starts with RNA primer;

added by RNA primase;

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

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

DNA ligase joins DNA fragments together forming complete strand;

replication only occurs at a single replication fork;

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

Examiners report

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

one of each organelle type, accurately drawn, was needed.

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

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

---

a. 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.

---

a. Cells go through a repeating cycle of events in growth regions such as plant root tips and animal embryos. Outline this cell cycle. [4]

b. Draw a labelled diagram of the formation of a chiasma by crossing over. [3]

c. Explain the control of gene expression in eukaryotes. [8]

Markscheme

a. a. mitosis is the division of a nucleus to produce two genetically identical daughter nuclei

b. consists of four phases: prophase, metaphase, anaphase, telophase

c. cytokinesis occurs after mitosis

d. interphase is the metabolically active phase between cell divisions *OWTTE*

e. the interphase consists of the S phase, G1 and G2

f. DNA replicates in the S phase

g. cell growth
OR
preparation for mitosis
OR
duplication of organelles in G1 and G2

b. a. «crossing over/chiasmata shown between» homologous chromosomes

b. centromere drawn and labelled

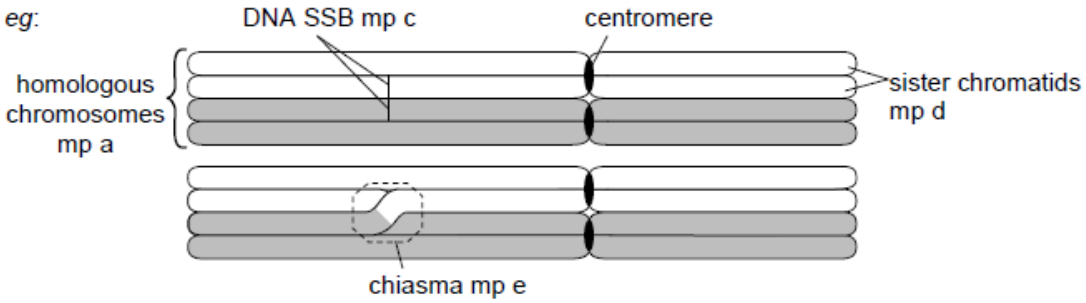
c. single strand break «SSB»/DNA cut between homologous chromosomes

d. non-sister chromatids labelled
OR
sister chromatids labelled

e. chiasma between homologous chromosomes labelled «shown forming after SSB»

Homologous chromosomes must be labelled and correctly drawn.

It is likely that more than one diagram will need to be included to demonstrate the stages.



c. a. mRNA conveys genetic information from DNA to the ribosomes «where it guides polypeptide production»

b. gene expression requires the production of specific mRNA «through transcription»

c. most genes are turned off/not being transcribed at any one time/regulated
OR
some genes are only expressed at certain times

d. some genes are only expressed in certain cells/tissues
OR
«cell» differentiation involves changes in gene expression

e. transcription factors/proteins can increase/decrease transcription

f. hormones/chemical environment of cell can affect gene expression

g. example of cell environment
eg: auxin/insulin/cytoplasmic gradient in embryo

h. transcription factors/proteins may prevent or enhance the binding of RNA polymerase

i. nucleosomes limit access of transcription factors to DNA/regulate gene expression/transcription
OR
activate or silence genes

j. DNA methylation/acetylation appears to control gene expression «as epigenetic factor»
OR
methylated genes are silenced

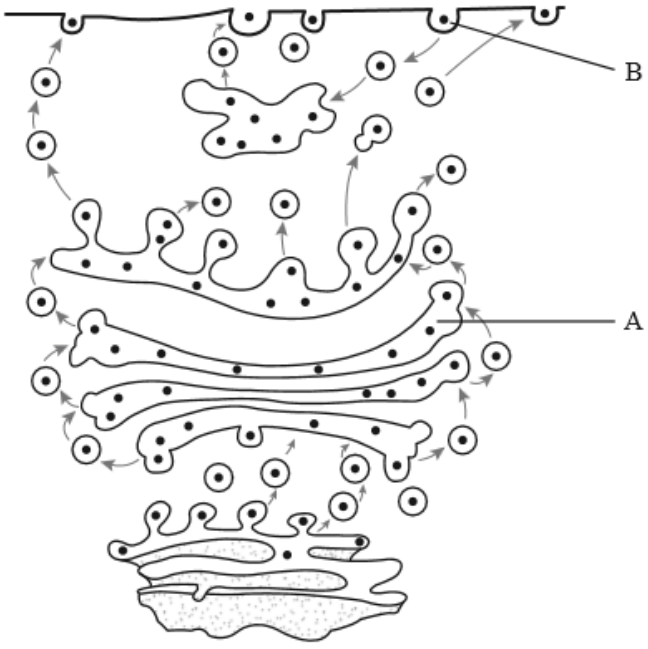
k. «some» DNA methylation patterns are inherited

l. introns may contain positive or negative gene regulators
OR
gene expression can be regulated by post-transcriptional modification/splicing/mRNA processing

Examiners report

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

The diagram shows how vesicles are used to transport materials in a cell.



a (i) State the name of organelle A. [1]

a (ii) State the process occurring at B. [1]

b. Describe how the structure of the membrane allows the formation of vesicles. [2]

Markscheme

a (i) Golgi apparatus/complex/body

Reject Golgi vesicle and Golgi unqualified.

a (ii) endocytosis/phagocytosis/pinocytosis

Reject exocytosis.

b. fluidity of membrane allows change of shape/invagination/formation of vesicles;

phospholipids can move / phospholipid bilayer makes membrane fluid/flexible;

weak bonding between phospholipid tails;

bends/kinks in the phospholipid tails prevent close packing;

cholesterol affects membrane fluidity;

Examiners report

a (i) About half of the candidates identified the structure correctly as Golgi apparatus, with the others mostly suggesting rough endoplasmic reticulum even though there were no ribosomes on the outside.

a (ii) Again about half of candidates answered correctly with endocytosis or a variant of this process. A wide range of other answers was given by other candidates.

b. This question was answered moderately well. Candidates were expected to link the fluidity of the phospholipid bilayer to the movement involved in vesicle formation.

The diagram shows a human karyotype.

[Source: http://en.wikipedia.org/wiki/File:NHGRI_human_male_karyotype.png, courtesy of the National Human Genome Research Institute.]

a. Analyse this karyotype. [2]

b. Outline the inheritance of hemophilia in humans. [2]

c. Using an example, describe polygenic inheritance. [3]

Markscheme

a. Male has (one X and) one Y chromosome / X chromosome is bigger than Y chromosome;

non-disjunction leads to three copies of chromosome 13/trisomy 13.

b. sex-linked/on X chromosome;

recessive allele / Xh;

more common in males than females;

heterozygous females are carriers / only females can be carriers;

c. more than one gene contribute to/control same characteristic;

as number of genes increase so does possible number of phenotypes;

leads to continuous variation;

specific example; *(eg human skin color (due to differing amounts of melanin))*

*Award **[2 max]** for general points with no example.*

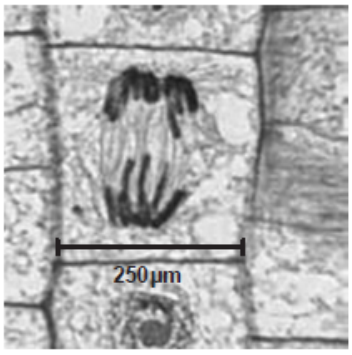
Examiners report

a. The fact that there was a trisomy 13 as a result of non-disjunction eluded the majority, who seemed to register that pair 21 was OK, therefore nothing else could be wrong. Many lost a mark for not explaining why it was a male. Better prepared candidates were able to explain haemophilia and polygenic inheritance. For some candidates it seemed to be the first time that they had encountered them.

b. The fact that there was a trisomy 13 as a result of non-disjunction eluded the majority, who seemed to register that pair 21 was OK, therefore nothing else could be wrong. Many lost a mark for not explaining why it was a male. Better prepared candidates were able to explain haemophilia and polygenic inheritance. For some candidates it seemed to be the first time that they had encountered them.

c. The fact that there was a trisomy 13 as a result of non-disjunction eluded the majority, who seemed to register that pair 21 was OK, therefore nothing else could be wrong. Many lost a mark for not explaining why it was a male. Better prepared candidates were able to explain haemophilia and polygenic inheritance. For some candidates it seemed to be the first time that they had encountered them.

The micrograph shows a cell from the root of an onion (*Allium cepa*) during mitosis.



[Source: adapted from http://img.ehowcdn.com]

a(i). Calculate the magnification of the image. [1]

a(ii). Deduce the stage of mitosis shown in the micrograph. [1]

a(iii). The onion (*Allium cepa)* is an angiospermophyte. The honey bee (*Apis mellifera*) is an arthropod. State **three** structural differences between the cells of an onion and a honey bee. [2]

b. State what is indicated by the presence of polysomes in a cell. [1]

Markscheme

a(i). 136 *(accept answers in the range of 132 to 140)*

a(ii). anaphase

a(iii)

onion cell	honey bee
cell wall	no cell wall;
chloroplast	no chloroplast;
large vacuole	no large vacuole;
fixed shape	no fixed shape;
starch stored	glycogen stored;
no centrioles/no centrosomes	has centrioles / has centrosomes;

*Award **[1]** for two correct, **[2]** for three correct answers.*

To award the mark both parts of a comparison must be stated explicitly or unambiguously implied.

b. much protein of one type needed/produced by polysomes;

mRNA is being repeatedly translated;

Examiners report

a(i) About half of candidates calculated the magnification of the image correctly. Those that did not were usually one more orders of magnitude away from the answer. A common problem was the use of centimetres rather than millimetres to measure the size of the scale bar image. This very often leads to an error of one order of magnitude.

a(ii) This was well answered with more than 90% of candidate recognising that the cell was in anaphase.

a(iii) This was also well answered by many candidates with each of the three statements in the answer referring both to honey bee cells and to onion cells. A few only mentioned one organism or the other so failed to score any marks. It is not enough to imply a difference in questions such as this – the difference should be stated explicitly.

b. This was very poorly answered with fewer than 25% of candidates knowing that polysomes are groups of ribosomes that are translating the same mRNA, which indicates that the cell needs multiple copies of one particular polypeptide.

Hypoxia is a condition in which tissues of the body are deprived of an adequate oxygen supply. A study was carried out in rats to examine the effects of continuing hypoxia on the structure of the diaphragm, and to determine whether nitric oxide is implicated in adaptation of the diaphragm to hypoxia. The diaphragm helps to supply oxygen to tissues and organs in the body by ventilating the lungs.

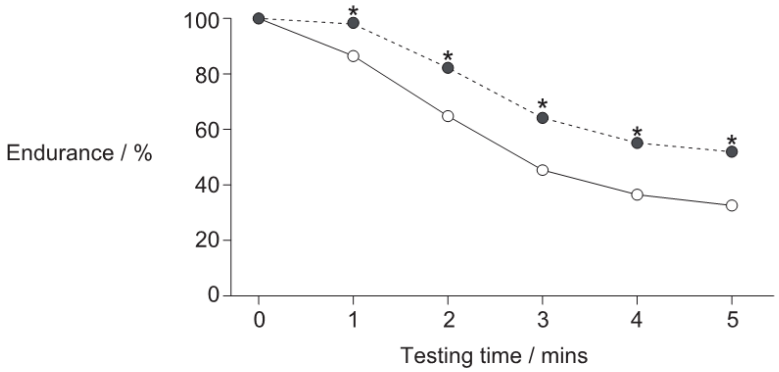
A group of 36 adult male rats were kept for 6 weeks in low oxygen while 36 adult male rats were kept in normal oxygen levels.

		Body mass / g	Erythrocytes / % of total blood volume	Mass of right ventricle muscle / mg
1 week	Control	305.7 ± 7.4	39.3 ± 1.7	154.3 ± 7.4
	Hypoxia	*238.3 ± 5.0	*62.6 ± 1.9	*194.8 ± 8.9
2 weeks	Control	302.3 ± 5.0	39.6 ± 1.1	157.8 ± 3.4
	Hypoxia	*229.7 ± 4.6	*70.1 ± 1.0	*204.7 ± 11.2
3 weeks	Control	325.0 ± 10.3	45.0 ± 0.7	166.8 ± 3.6
	Hypoxia	*255.0 ± 8.3	*71.3 ± 1.0	*238.7 ± 18.9
6 weeks	Control	369.8 ± 5.9	43.0 ± 2.6	164.7 ± 3.9
	Hypoxia	*277.5 ± 7.9	*75.1 ± 1.4	*251.3 ± 8.0

Key: * indicates significant difference from corresponding control value (student's *t*-test, $p < 0.05$)

[Source: Reproduced with permission of the © ERS 2011. European Respiratory Journal June 2011, 37 (6) 1474–1481; DOI: 10.1183/09031936.00079810]

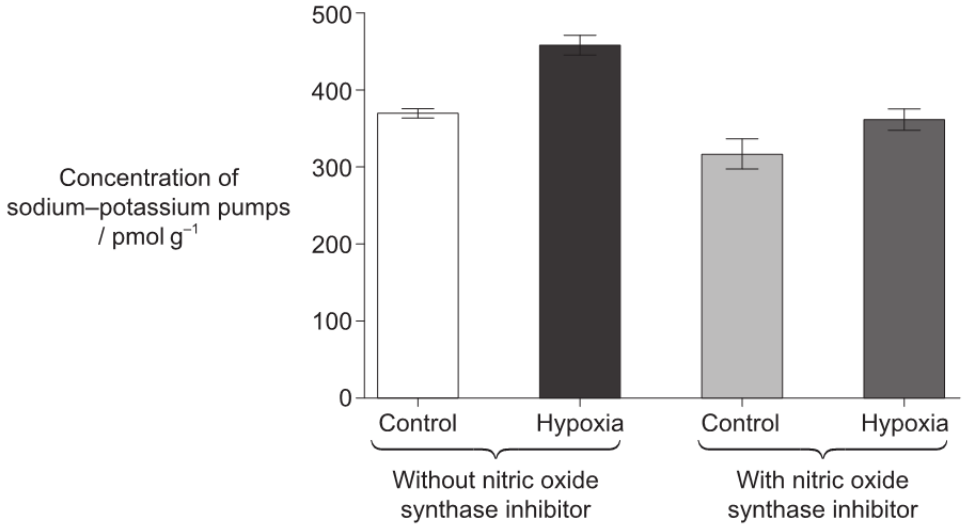
The graph shows the effect of hypoxia on the endurance of rats' diaphragm muscle after 6 weeks. Endurance is the change in force measured as a percentage of the initial force.



Key: * indicates significant difference from control ($p < 0.0001$)
hypoxia
control

[Source: Reproduced with permission of the © ERS 2011. European Respiratory Journal June 2011, 37 (6) 1474–1481; DOI: 10.1183/09031936.00079810]

The sodium–potassium pump plays a role in muscle activity. Nitric oxide may have a role in the recovery of hypoxic muscles. The production of nitric oxide can be blocked with an inhibitor of the enzyme nitric oxide synthase. The graph shows the concentration of sodium–potassium pumps in the diaphragm of control and hypoxic rats without and with nitric oxide synthase inhibitor.



[Source: Reproduced with permission of the © ERS 2011. European Respiratory Journal June 2011, 37 (6) 1474–1481; DOI: 10.1183/09031936.00079810]

Skeletal muscle contractions can take two different forms: if they are stimulated by a single action potential they take the form of a twitch and if they are stimulated by a series of action potentials the contraction is longer lasting (tetanic). The table shows the effects of hypoxia on the force of twitch and peak tetanic contraction in the diaphragm.

		Twitch contraction / N cm^{-2}	**Peak tetanic contraction / N cm^{-2}**
Diaphragm	Control	4.0 ± 0.7	20.0 ± 2.3
	Hypoxia	2.8 ± 0.4	14.2 ± 1.8

[Source: Reproduced with permission of the © ERS 2011. European Respiratory Journal June 2011, 37 (6) 1474–1481; DOI: 10.1183/09031936.00079810]

a. Outline the effect of hypoxia on body mass and erythrocyte percentage. [1]

b. Using the data in the graph, deduce whether hypoxia increases **or** decreases the endurance of the rats' diaphragm muscle. [2]

c. Using the data presented in this question, explain the effect of hypoxia on the body. [2]

d.i. Analyse the graph to obtain **two** conclusions about the concentration of sodium–potassium pumps. [2]

d.ii. Muscle fibres are stimulated to contract by the binding of acetylcholine to receptors in their membranes and the subsequent depolarization. [1]

Suggest a reason for increasing the concentration of sodium–potassium pumps in the membranes of diaphragm muscle fibres.

e.i. Outline the effect of hypoxia on the force of contraction of the diaphragm. [1]

e.ii. Hypoxia caused a 13 % increase in the surface area to volume ratio of the diaphragm. Suggest a reason for this change. [1]

f. Using all relevant data in the question, evaluate the effectiveness of the rats' adaptation to hypoxia. [3]

g. Discuss the advantages and disadvantages of using rats as models in this investigation. [2]

Markscheme

a. Erythrocyte percentage increased **AND** body mass reduced/smaller increase in mass

b. a. increases endurance «in relation to the control»

b. higher force/endurance at every testing time/throughout

OR

smaller decreases in **force** «over time»

c. the magnitude of the difference is similar throughout the five minutes experiment/testing

d. differences are «statistically» significant

e. endurance of control is «approximately» 35 % versus endurance of hypoxia «approximately» 55 % «after 5 minutes»

Accept ±5 % for both percentages

[Max 2 Marks]

c. a. diaphragm more endurance/stronger/generates more force for more ventilation/inspiration

b. right ventricle mass increases to pump more blood

c. erythrocyte percentage increases to transport oxygen

d. less growth/body mass which reduces oxygen demand

Reject "loss of body mass"

The physiological reason is required for each mark

[Max 2 Marks]

d.i. a. hypoxia increases the concentration of sodium–potassium pumps

b. nitric oxide needed for/stimulates «production of» sodium-potassium pumps

c. nitric oxide synthase inhibitor reduces the concentration of pumps

OR

concentration of pumps reduced by inhibiting nitric oxide production

*Award up to **[1]** for a conclusion on lines labelled 1 and up to **[1]** for a conclusion on the lines labelled 2*

[Max 2 Marks]

d.ii. a. <u>resting potential</u> restored faster

b. increases the «maximum» frequency/rate of contractions

OR

can contract again sooner

Accept shorter refractory period for mpa

Do not accept faster contraction/depolarization/ repolarization

[Max 1 Mark]

e.i. reduces «force of» twitch ***AND*** peak tetanic contraction

e.ii. a. decrease in volume/atrophy/loss of cells/less muscle fibres/less tissue in the diaphragm

b. SA to volume ratio increased to make oxygen uptake into muscle/cells faster

Do not accept reduction in area of diaphragm

[Max 1 Mark]

f. a. not effective because body mass lost

b. effective because body mass still increases/rats still grow

c. not effective because contractions/force exerted by diaphragm decreases

d. effective because more sodium-potassium pumps so more/faster rate of diaphragm/muscle contractions

e. effective because endurance of diaphragm increases

f. effective because mass of right ventricle increases

g. effective because erythrocyte percentage increases

For each marking point the candidate must make it clear whether they are arguing for adaptation being effective or not. This can be done by giving the physiological benefit of a change, for example greater mass of right ventricle so more blood pumped.

[Max 3 Marks]

g. *Advantages:*

a. small size

OR

easy to look after in research labs

b. short lifespan

OR

study can extend over several generations

c. can be killed «to get experimental results» if benefits of research justify it

d. «mammalian» so similarities with humans

e. fewer ethical objections than if humans are used/not ethical to subject humans to hypoxia/does not cause harm to humans

Accept any one of the advantages

Disadvantages:

f. ethical objections

OR

wrong to cause suffering to animals/rats

g. rat physiology/anatomy not same as human

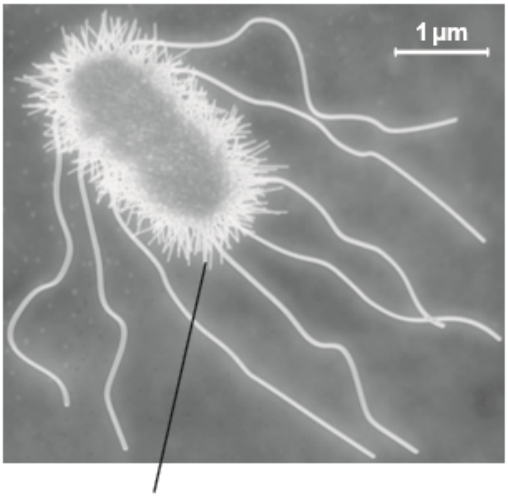
Accept any one of the disadvantages

[Max 2 Marks]

Examiners report

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

e.ii. [N/A]
f. [N/A]
g. [N/A]



. . . . . .

a. Outline the cell theory. [2]

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

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

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

Helicase

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

DNA ligase

Markscheme

a. a. living things are composed of cells;

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

c. cells come from pre-existing cells;

Do not accept cells are the "smallest organisms".

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

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

Do not accept "exchange material" on its own.

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

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

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

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

Examiners report

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

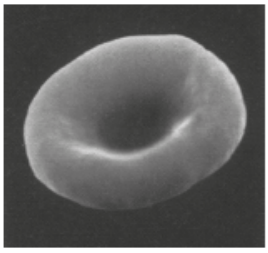
b (i). A number failed to state a correct function. The pilus plays a role in adhering to surfaces and in bacterial conjugation. A number annotated the picture with the name of the structure without stating a function.

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

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

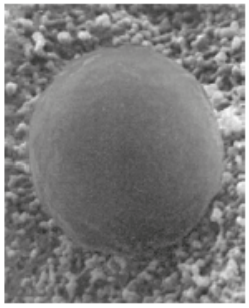
c (ii). Similar to primase, the mechanism of action of ligase was very rarely accurately described, most limiting it to bond formation between Okazaki fragments, not acknowledging that ligase has a role on the leading strand as well.

This image shows a normal red blood cell.

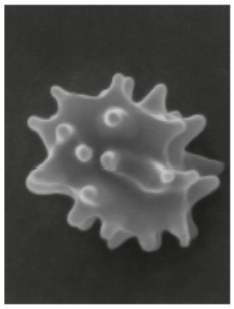


These images show two red blood cells that have been placed in solutions with different concentrations of solutes.

Red blood cell 1



Red blood cell 2



[Source: adapted from www.acbrown.com]

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

b. Define osmolarity. [1]

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

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

Markscheme

a. a. water molecules are polar

OR

can form hydrogen bonds

b. cohesion between water molecules allows continuous water columns

OR

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

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

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

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

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

d. decreased

Examiners report

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

The Chinese soft-shelled turtle, *Pelodiscus sinensis*, lives in salt water marshes. The turtle can live under water and out of water.

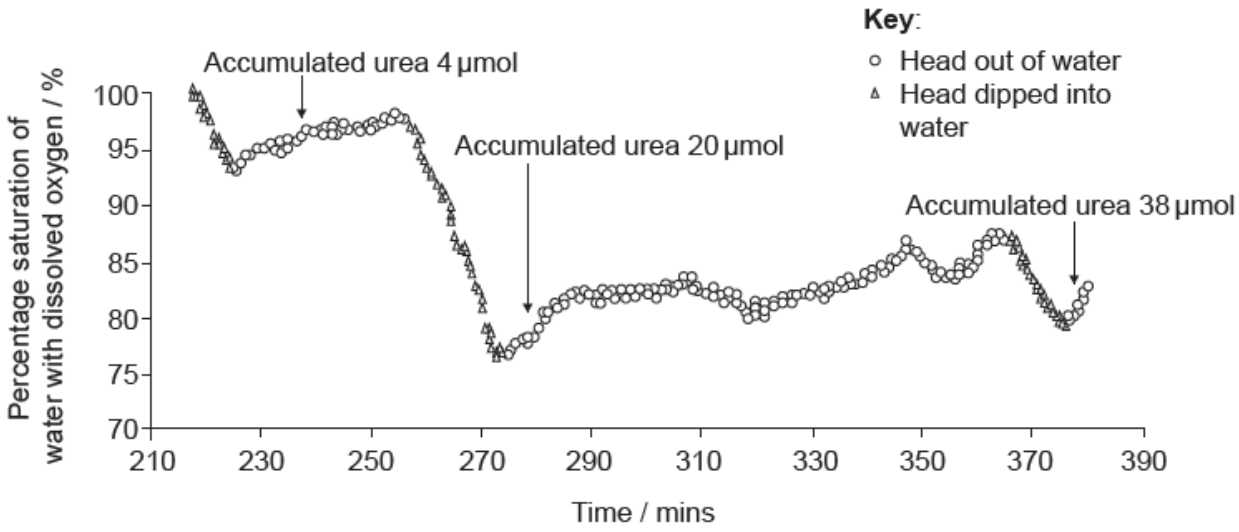
These turtles have fully developed lungs and kidneys, however, many microvilli have been discovered in the mouth of *P. sinensis*. A study was undertaken to test the hypothesis that oxygen uptake and urea excretion can simultaneously occur in the mouth.

Initial experiments involved collecting nitrogen excretion data from *P. sinensis*. The turtle urinates both in water and out of water. When in water it allows waste products to be washed out of its mouth. When out of water it regularly dips its head into shallow water to wash its mouth. The table shows the mean rates of ammonia and urea excretion from the mouth and kidney over six days.

	Excretion of nitrogen by the mouth / μmol day^{-1} g^{-1} turtle		Excretion of nitrogen by the kidney / μmol day^{-1} g^{-1} turtle	
	Turtle submerged in water	Turtle out of water	Turtle submerged in water	Turtle out of water
Ammonia	0.29	0.30	0.63	0.54
Urea	0.90	1.56	0.07	0.73

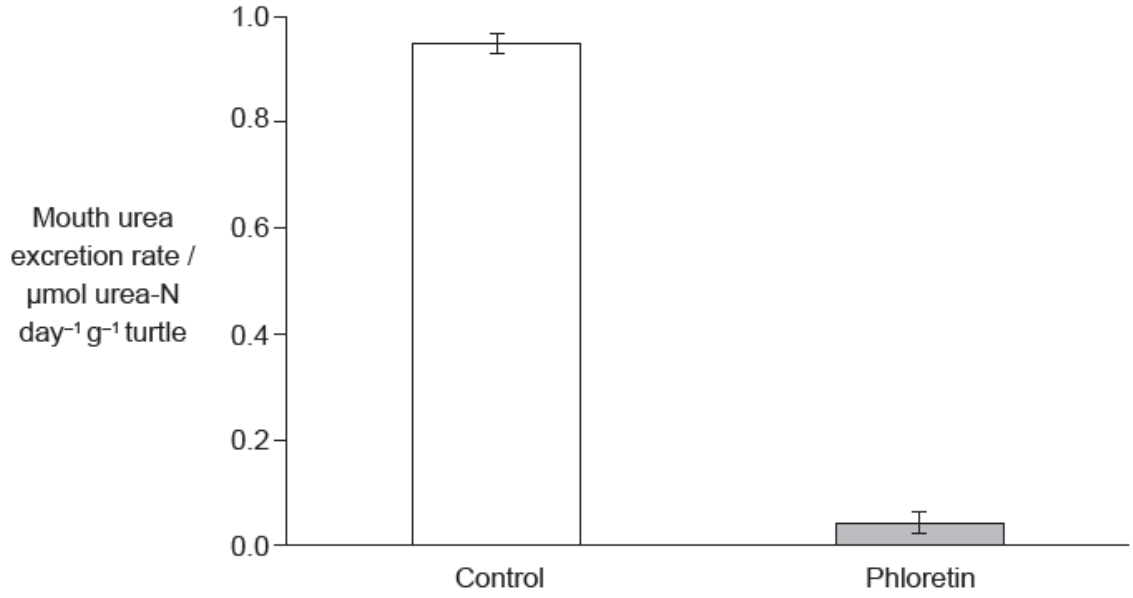
[Source: Reproduced with permission, Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723—3733. jeb.biologists.org. doi: 10.1242/jeb.068916]

It was noted that during long periods out of water, turtles rhythmically moved their mouths to take in water from a shallow source and then discharge it. Changes in the dissolved oxygen and the quantity of accumulated urea in the rinse water discharged by the turtles were monitored over time as shown in this graph.



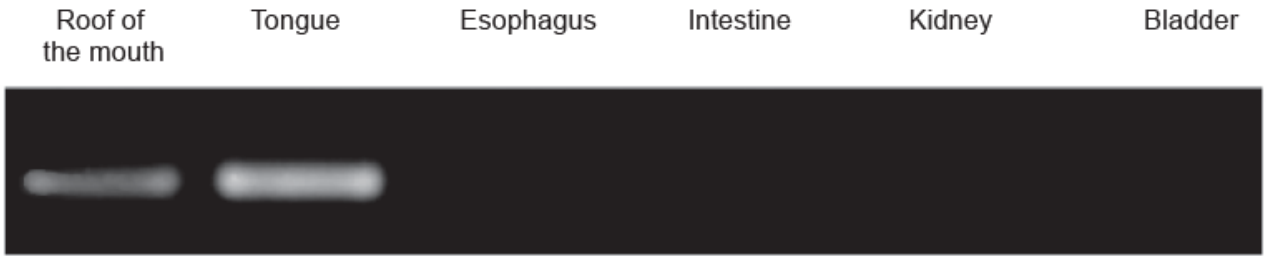
[Source: adapted with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733.]

In order to test whether a urea transporter was present in the mouth tissues of the turtles, phloretin (a known inhibitor of membrane proteins that transport urea) was added to the water in which a further set of turtles submerged their heads. The results of that treatment are shown.



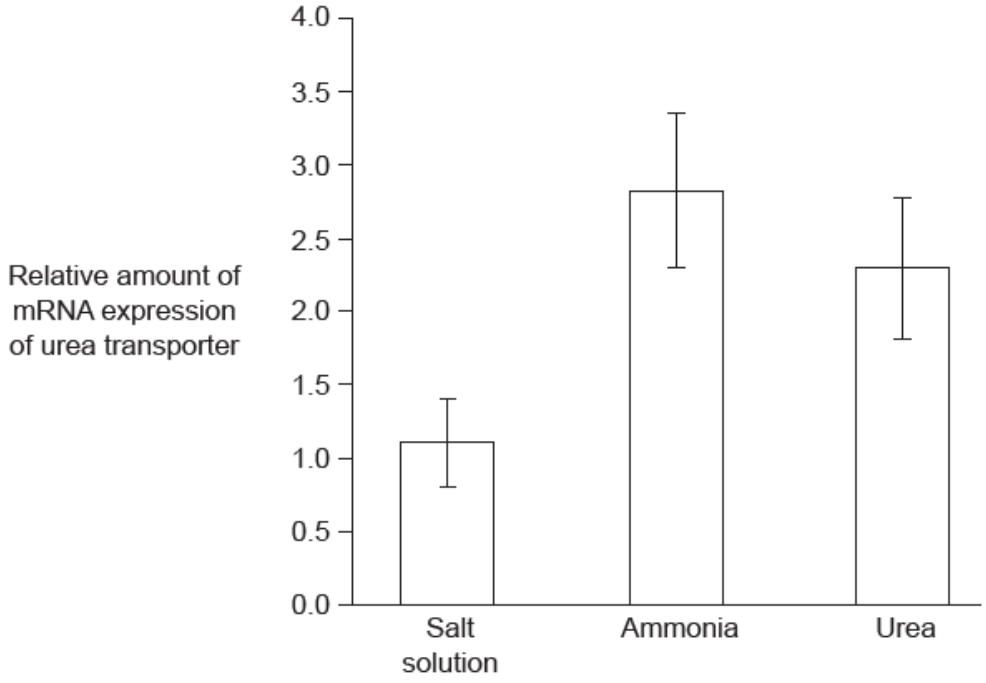
[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

Further research was conducted to determine where mRNA expression of a urea transporter gene might be occurring in *P. sinensis*. Gel electrophoresis was used to analyse different tissue samples for mRNA activity.



[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

Expression of the urea transporter gene by cells in the turtle's mouth was assessed by measuring mRNA activity. Turtles were kept out of water for 24 hours and then injected with either a salt solution that matched the salt concentration of the turtle, dissolved ammonia or urea, followed by another 24 hours out of water.



[Source: © International Baccalaureate Organization 2017]

a. Deduce whether the excretion of ammonia or urea changes more when a turtle emerges from water. [2]

b. Compare and contrast the changes in urea excretion in the mouth with the changes in urea excretion in the kidney when a turtle emerges from the water. [3]

c.i. Describe the trends shown by the graph for dissolved oxygen in water discharged from the mouth. [1]

c.ii. Suggest reasons for these trends in dissolved oxygen. [2]

d. Deduce with a reason whether a urea transporter is present in the mouth of *P. sinensis*. [2]

e. Outline the additional evidence provided by the gel electrophoresis results shown above. [2]

f.i. Identify which of these turtle groups represent the control, giving a reason for your answer. [1]

f.ii. Suggest a reason for the greater expression of the gene for the urea transporter after an injection with dissolved ammonia than an injection of urea. [2]

g. The salt marshes where these turtles live periodically dry up to small pools. Discuss the problems that this will cause for nitrogen excretion in the turtles and how their behaviour might overcome the problems. [3]

Markscheme

a. a. urea

b. for both mouth and kidney

c. percentage change/change in μmol day^{-1} g^{-1} greater with urea/other acceptable numerical comparison

b. a. both higher/increased on emergence from/with turtle out of water

b. both increased by 0.66 «$\mu mol^{-1}\ g^{-1}$ when turtle emerges from water»

c. % increase is higher in kidney / kidney 940% versus mouth 73/75% / increase is higher proportionately higher in kidney / kidney x10 versus mouth nearly double/x1.73

d. urea excretion by mouth greater than kidney out of water «despite larger % increase in kidney excretion»

c.i. decrease «when head is submerged» and increase when head is out of water

c.ii a. oxygen absorbed from water/exchanged for urea when head dipped in water«so oxygen concentration decreases»

b. lungs cannot be used with head in water / can «only» be used with head out of water

c. oxygen from water «in mouth» used in «aerobic cell» respiration

d. oxygen from air dissolves in water when head out of water «so oxygen concentration increases»

d. a. urea transporter is present

b. less urea «excreted»/ lower rate «of urea excretion» / excretion almost zero when phloretin/inhibitor was present

e. a. mRNA only in mouth and tongue/in mouth and tongue but not esophagus intestine kidney or bladder

b. bands / lines indicate mRNA for/expression of urea transporter gene

c. urea transporter gene expressed / urea transporters in mouth/tongue / not expressed/made in esophagus/intestine/kidneys/bladder

d. mRNA/transcription/gene expression/urea transporters higher in tongue/more in tongue «than mouth»

f.i. salt solution is control because it does not contain a nitrogenous/excretory waste product / it matches the salt concentration of the turtle / the turtle's body already contains salt / because the turtle lives in salt water/salt marshes / because nothing has been altered

f.ii. a. ammonia is «highly» toxic/harmful

b. ammonia is more toxic than urea/converse

c. ammonia converted to urea

d. urea concentration raised «by injecting ammonia»

e. difference between ammonia and urea «possibly» not «statistically» significant

g. *Problems:*

a. urea becomes more concentrated «in small pools» / lower concentration gradient «between tongue/mouth and water»

b. less water available for urine production/excretion by kidney
OR
less water in ponds for mouth rinsing/more competition for pools (to use for mouth rinsing)

Behaviour to overcome problems:

c. «still able to» dip mouth into/mouth rinse in water/pools

d. «still able to» excrete urea «though the mouth» in the small pools

e. more conversion of ammonia to urea/urea excretion rather than ammonia

f. more urea transporters/expression of urea transporter gene

g. urea excreted «in mouth/via microvilli» by active transport/using ATP

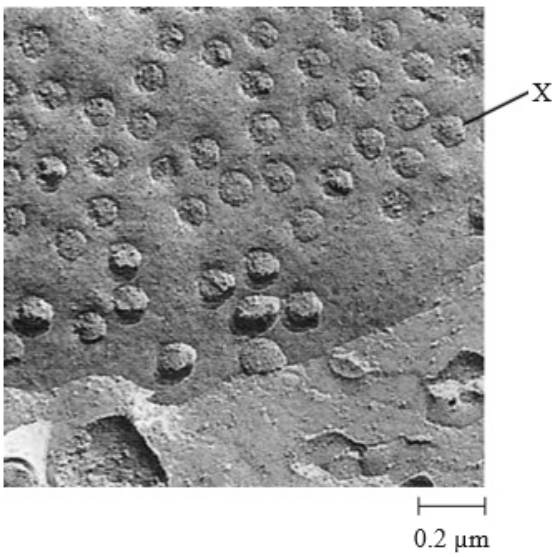
h. excretion with little/no loss of water

Examiners report

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

c.i. [N/A]
c.ii. [N/A]
d. [N/A]
e. [N/A]
f.i. [N/A]
f.ii. [N/A]
g. [N/A]

The scanning electron micrograph below shows the surface of the nuclear envelope with numerous nuclear pores.



[Source: adapted from D Nelson and M Cox, (2000), *Lehninger Principles of Biochemistry*, third edition, page 35]

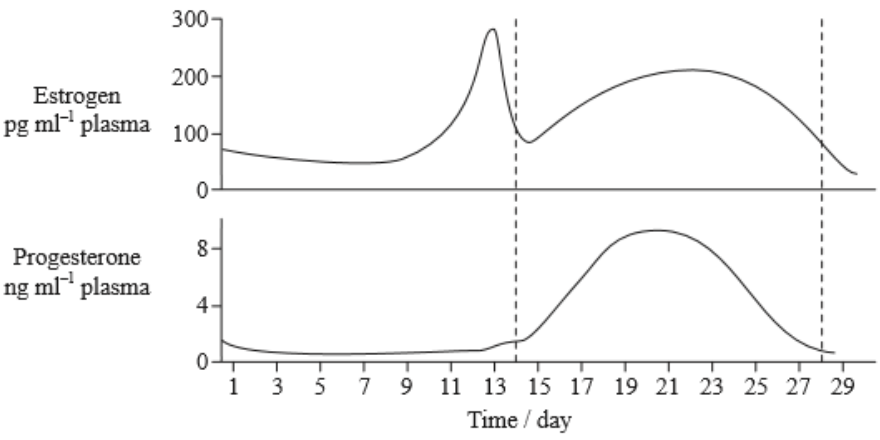
a (i) Calculate the power of magnification of the image. [1]

a (ii) State the diameter of the pore labelled X. [1]

b. List **two** examples of how human life depends on mitosis. [1]

c. Describe the importance of stem cells in differentiation. [3]

d (i) The graphs below show the normal menstrual cycle. [2]



[Source: adapted from www.mivf.com.au/ivf/infertility/images/cyclediagram.GIF]

Predict, with a reason, how the graphs will change if the woman becomes pregnant.

d (ii) List **two** roles of testosterone in males. [1]

Markscheme

a (i) 50 000 (*Accept answers in the range of 50 000 to 53 000*)

a (ii) 0.1 μm (*units required*)

Allow answers in the range of 0.09 μm to 0.12 μm.

b. *Award **[1]** for any two of the following.*

growth/production of (extra) body cells; (*do not accept cell growth*)

first stage of spermato/oo/gametogenesis / forming oogonia/spermatogonia;

embryo development;

wound healing / (tissue) repair / hair growth / replacement of skin cells; (*do not accept repairing cells*)

clonal selection / division of lymphocytes (for antibody production);

Do not accept asexual reproduction. Do not award a mark if one of the first two answers is incorrect.

c. stem cells are undifferentiated cells;

embryo cells are stem cells;

stem cells can differentiate in many/all ways / are pluripotent/totipotent;

differentiation involves expressing some genes but not others;

stem cells can be used to repair/replace tissues/heal wounds;

d (i) estrogen and progesterone do not drop/continue rising (after day 21);

because corpus luteum continues to secrete them / embryo secretes HCG;

to maintain/increase uterus lining/endometrium;

d (ii) *Award **[1]** for any two of the following.*

pre-natal development of male genitalia;

stimulates spermatogenesis / sperm production;

maintenance of sex drive/libido;

puberty / development of secondary sexual characteristics / penis growth / pubic hair / body hair / facial hair / beard / deeper voice;

Do not award the mark if one of the first two roles given is incorrect.

Examiners report

a (i) In part (a), only about half of candidates calculated the magnification of the electron micrograph correctly. This involved measuring the length of the scale bar in millimetres and multiplying by 1000, to convert the length to micrometres. Candidates then needed to know that magnification is calculated by dividing the size of the image, in this case the actual length of the scale bar, by the size of the specimen, in this case the length

indicated on the scale bar.

Some answers could not possibly have been correct and candidates should be encouraged to test whether their answer is sensible. This could have been done by using the answer to calculate the actual size of the nuclear pores on the micrograph, which were about five millimetres across or 5000 micrometres on the micrograph.

a (ii) This task was much easier as the nuclear pore labelled X was half of the diameter of the scale bar, so all that was necessary was to divide its length by two

b. A variety of answers was accepted here and many candidates gave two of these. Frequent answers that were not accepted were repair of cells, antibody production, production of gametes and production of zygotes. Although some of these processes involve mitosis, it was necessary to specify how.

c. The wording of this question was unusual and as a result answers were very varied. Marks were awarded for correct statements about the undifferentiated state of stem cells, their capacity to differentiate in different ways and their role in repair of tissues. Some candidates stated that stem cells could be used to treat leukemia or Parkinson's disease, but some details were required for a mark to be awarded.

d (i) This was based on AS 11.4.10 and AS 11.4.12. Many candidates used their understanding of the hormonal control of pregnancy to predict the changes in the levels of estrogen and progesterone correctly.

d (ii) About two thirds of candidates gave two roles of testosterone that examiners accepted. Where a limited number of answers is allowed, candidates should be advised to give the answers which they think are most significant. If candidates gave two secondary sexual characteristics, such as axillary hair and pubic hair, the mark was not awarded as other more important roles had been omitted.

---

a. Cell biologists play an important role in research into disease, fertility, evolution and many other areas of science. [4]

Describe the origin of eukaryotic cells according to the endosymbiotic theory.

b. Cell biologists play an important role in research into disease, fertility, evolution and many other areas of science. [8]

Compare and contrast the processes of spermatogenesis and oogenesis.

c. Cell biologists play an important role in research into disease, fertility, evolution and many other areas of science. [3]

Outline the evidence for evolution provided by selective breeding.

Markscheme

a. a. mitochondria and chloroplasts are similar to prokaryotes

b. «host» cell took in another cell by endocytosis/by engulfing «in a vesicle»

Allow “taking in” in place of “engulfing”

c. but did not digest the cell/kept the «ingested» cell alive

OR

symbiotic/mutualistic relationship «between engulfed and host cell»

d. chloroplasts and mitochondria were once independent/free-living «organisms»

e. DNA «loop» in chloroplast/mitochondrion

f. division/binary fission of chloroplast/mitochondrion

g. double membrane around chloroplast/mitochondrion

h. 70s ribosomes «in chloroplast/mitochondrion»

*Award up to **[2]** for evidence from mpe to mph*

[Max 4 Marks]

b. a. both result in haploid cells/gametes

b. both involve mitosis at the start/in the «germinal» epithelium

c. both have cell growth «before meiosis»

d. both involve «two divisions of» meiosis

e. both involve differentiation to produce a gamete

f. both are stimulated by hormones

OR

spermatogenesis stimulated by testosterone and oogenesis stimulated by FSH

	Oogenesis	***Spermatogenesis***
g.	in the ovaries	in the testes
h.	starts **«**in germinal epithelium**»** during embryo/fetus development	starts during puberty/adolescence ***OR*** continuously starting **«**in germinal epithelium**»**
i.	pauses occur in prophase I/prophase II/ metaphase II	no pauses
j.	large quantity of cytoplasm in egg/ cytoplasm split unequally	small quantity of cytoplasm **«**per sperm**»**/equal division of cytoplasm
k.	one cell/egg **«**per meiosis**»** ***OR*** some become polar bodies	four sperm **«**per meiosis**»** ***OR*** all cells become sperm
l.	one **«**usually**»** at a time/per month/per menstrual cycle	many/far more/millions daily
m.	released on about Day 14/in middle of menstrual cycle/at ovulation	released continuously **«**from testis**»** ***OR*** by ejaculation/intercourse
n.	stops at menopause	goes on throughout adult life/until death

A table is not required but both statements in one row of the table must either be explicitly stated or clearly implied to award the mark

[Max 8 Marks]

c. a. crop plants/domesticated animals/livestock produced by selective breeding

b. specific example of a domesticated animal/crop plant and the wild species from which it was developed

OR

specific example of a domesticated animal/crop plant and the features in it which have been improved «compared with the wild species»

For example dogs have been developed from wolves

c. artificial selection/crossing selected varieties/eliminating undesirable varieties

d. «selective breeding/artificial selection can cause» significant/rapid change over time/from the original wild species

e. «changes due to selective breeding/artificial selection» shows natural selection can cause change/evolution «in a species»

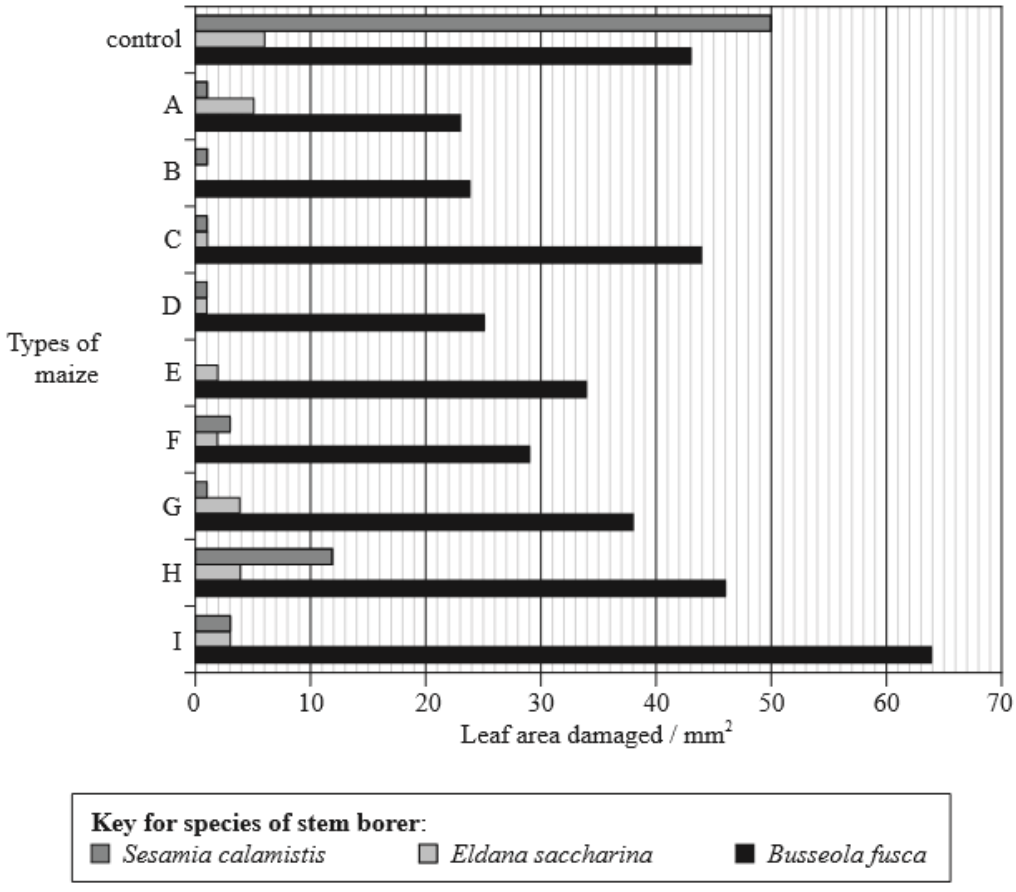
[Max 3 Marks]

Examiners report

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

Genetic engineering allows genes for resistance to pest organisms to be inserted into various crop plants. Bacteria such as *Bacillus thuringiensis* (Bt) produce proteins that are highly toxic to specific pests.

Stem borers are insects that cause damage to maize crops. In Kenya, a study was carried out to see which types of Bt genes and their protein products would be most efficient against three species of stem borer. The stem borers were allowed to feed on nine types of maize (A–I), modified with Bt genes. The graph below shows the leaf areas damaged by the stem borers after feeding on maize leaves for five days.

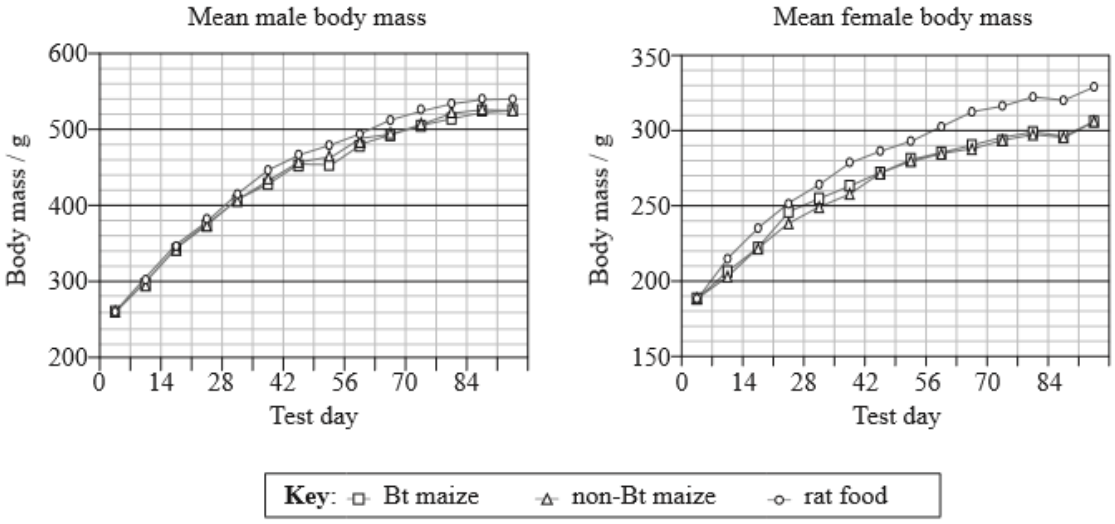


[Source: adapted from S Mugo, *et al.*, (2005), *African Journal of Biotechnology*, **4** (13), pages 1490–1504]

Before the use of genetically modified maize as a food source, risk assessment must be carried out. A 90-day study was carried out in which adult male and female rats were fed either:

- seeds from a Bt maize variety
- seeds from the original non-Bt maize variety
- commercially prepared rat food.

All the diets had similar nutritional qualities.

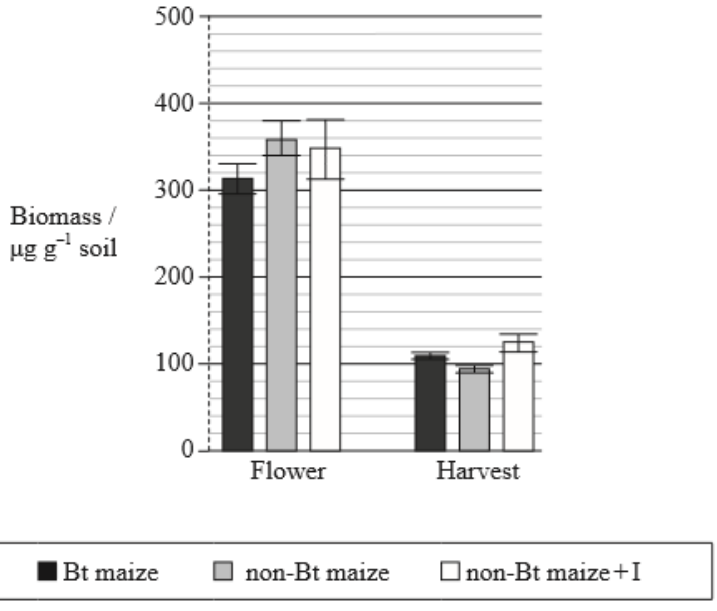


[Source: adapted from L A Malley, *et al.*, (2007), *Food and Chemical Toxicology*, **45**, pages 1277–1292]

Studies have shown that Bt proteins are released by plant roots and remain in the soil. One study looked at the biomass of microorganisms in soil surrounding the roots of:

- Bt maize
- non-Bt maize
- non-Bt maize with an insecticide (I).

The graph below shows the biomass of microorganisms at two different times in the growth cycle of the plants (Flower and Harvest). Error bars represent standard error of the mean.



[Source: adapted from M Devare, *et al.*, (2007), *Soil Biology and Biochemistry*, **39**, pages 2038–2047]

Bt proteins act as toxins to insects, primarily by destroying epithelial cells in the insect's digestive system. Below is the three-dimensional structure of one such protein.

[Source: M Soberon, *et al.*, (2007), *Toxicon*, **49**, pages 597–600]

a. Calculate the percentage difference in leaf area damaged by *Sesamia calamistis* between the control and maize type H. Show your working. [2]

b. Discuss which species of stem borer was most successfully controlled by the genetic engineering of the maize plants. [3]

c. Calculate the change in mean mass of male and of female rats fed on Bt maize from day 14 to 42. [2]

d. Evaluate the use of Bt maize as a food source on the growth of the rats. [2]

e. Comment on the use of Bt maize as a food source compared to the other diets tested. [1]

g. Compare the biomass of microbes in the soils surrounding the roots of Bt maize and non-Bt maize. [2]

h. The researchers' original hypothesis stated that microorganisms would be negatively affected by the Bt protein released by the plant roots. [2]
Discuss whether the data supports the hypothesis.

i (i). State the type of structure shown in the region marked A in the diagram above. [1]

i (ii). Outline how this structure is held together. [2]

i (iii). Region A inserts into the membrane. Deduce, with a reason, the nature of the amino acids that would be expected to be found in this region. [2]

Markscheme

a. 50 12 38 (mm); *Accept 12 50 = 38*

(38 50) 100 ( )76(%); (ECF)

b. *Sesamia* (was most successfully controlled);

in control plants *Sesamia* caused most damage;

all types of Bt/genetically modified maize/A–I show (significant) decrease in damage by *Sesamia*;

mark for correct numerical comparison;

Sesamia caused no damage to type E/ in one instance;

Busseola not controlled/affected by Bt/genetically modified maize/caused largest amount of damage in types A–I/increased damage in some varieties;

Eldana controlled by some types of maize / B/C/D but not others / *Eldana* caused least damage in control and not much difference in many maize types;

c. *males*: (440 – 325 =)115g ; (*Accept answers in range 105–125 g*)

females: (268 – 215 =)53g ; (*Accept answers in range 51–57 g*)

Units required, no workings required.

d. (promotes) highest rate of growth at start of study / tapering off later in the study;

Bt maize appears to cause less growth/mass gain than rat food / vice versa;

more pronounced difference in females;

no difference in growth/mass gain between Bt and non-Bt maize;

e. (Bt) maize may not be as good as the (commercially prepared) rat food;

Bt maize appears to be as good a food source as non-Bt maize;

Bt maize an acceptable/safe food source;

Answers require a judgement about Bt maize as a food source rather than a description.

g. (for both groups) overall biomasses were higher during flowering than harvest / vice versa

the microbial biomass for the Bt crop was (slightly) lower than for the non-Bt crops at flower time;

the microbial biomass for the Bt crop was (slightly) higher than for the non-Bt crops at harvest time;

h. data does not support the hypothesis as there is little difference between biomass found in the soil (surrounding) roots (of the Bt and non-Bt) at either time;

data does not support the hypothesis as there is a slightly positive effect at harvest;

data supports hypothesis as there is a slightly negative effect at flowering;

i (i) helix / alpha helix

i (ii) hydrogen bonds;

between the turns of the helix (rather than between R-groups);

bonds between carboxyl and NH groups/C-O---H-N;

i (iii) non-polar amino acids/R-groups;

(inner part of phospholipid) bilayer is hydrophobic/non-polar;

Examiners report

a. In comparison to similar questions in previous years, candidates were relatively successful in answering this question. Where candidates did not answer correctly, it was due to a lack of ability to calculate percent difference rather than a problem with interpreting the data.

b. Most candidates scored at least one mark. A common error was to interpret the results without comparison to the control.

c. Most candidates calculated the mean masses correctly and included the correct units.

d. Most candidates scored at least one mark. A common error was to focus on the difference between male and female rats rather than the food source and to not make reference to growth.

e. Most candidates gained the mark, but some simply repeated their answer to (d). The command term "comment" requires candidates to give a judgment. Commonly, candidates mistakenly described the data in response to this command term.

g. Most candidates gained both the marks by recognizing the difference between harvest and flowering. Like answer (f), word choice affected performance with candidates referring to the biomass of flowers for example rather than biomass of soil microbes.

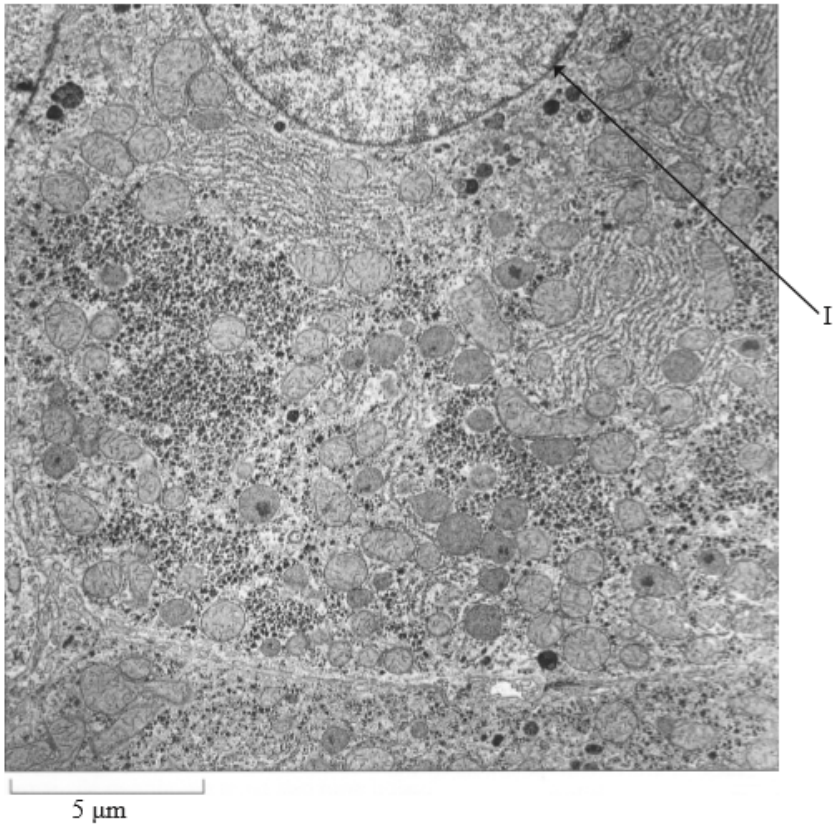
h. Many candidates scored both marks. A common error was to answer without reference to the hypothesis.

i (i). Many candidates identified the alpha helix, though a surprising number referred to the double helix.

i (ii) Most candidates identified hydrogen bonds as stabilizing the structure but very few could identify the parts of the molecule that were connected by H-bonds.

i (iii) Only a minority of candidates recognized the importance of the hydrophobic nature of membrane proteins.

The electron micrograph below shows a section of a liver cell.



[Source: D Friend, (2002), *Molecular Biology of the Cell*, 4th Edition, Garland Science Publishing, Fig. 12.2]

a (i). Identify the structure labelled I and state **one** function of this structure. [1]

a (ii). Calculate the magnification of this photograph. Show your working. [1]

a (iii). Explain the evidence from the electron micrograph that indicates that liver cells are very active. [2]

Markscheme

a (i). nucleus contains genetic information / is site of DNA replication / site of RNA transcription;

nuclear membrane/envelope (which has pores) allowing exchange of substances between nucleus and cytoplasm;

a (ii). magnification =

(*Accept answers in range 6000–6200 . Do not deduct for differences in precision in calculation.*)

a (iii). large number of mitochondria;

to meet energy demand/ATP production (needed for high metabolic activity);

or

large amount of rER;
indicates high rate of protein synthesis;

Examiners report

a (i). Most candidates identified the nucleus/nuclear membrane but did not accurately state its function.

a (ii) Relative to magnification questions on previous exams, this question was poorly answered. Correct measurement was common, though precision of measurements was a problem for some. Changing between units proved to be more difficult. Some candidates used the scale bar to determine the width of the micrograph without realizing that the magnification could be calculated from the scale bar itself.

a (iii) This question was correctly answered by most candidates with candidates both recognizing structures and correctly relating structures to evidence of activity.

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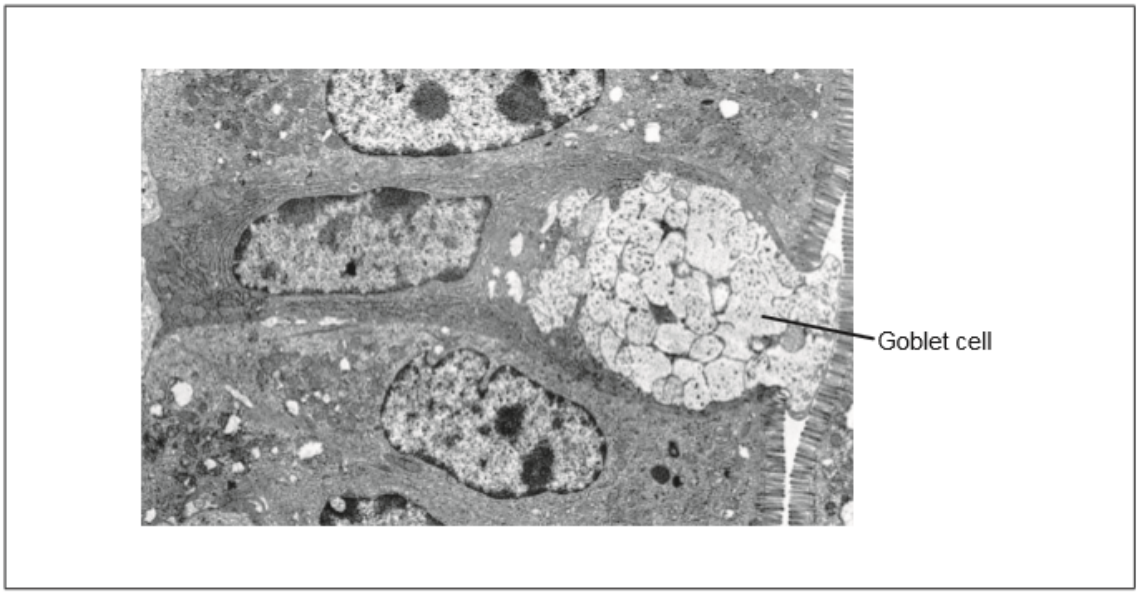
a. The image is an electron micrograph of the lining of the small intestine. [3]



[Source: adapted from A. L. Mescher (2009), *Junqueira's Basic Histology: Text and Atlas*, 12th Edition, © 2009 McGraw-Hill Education]

(i) Label the microvilli using the letter M and a nucleus using the letter N.

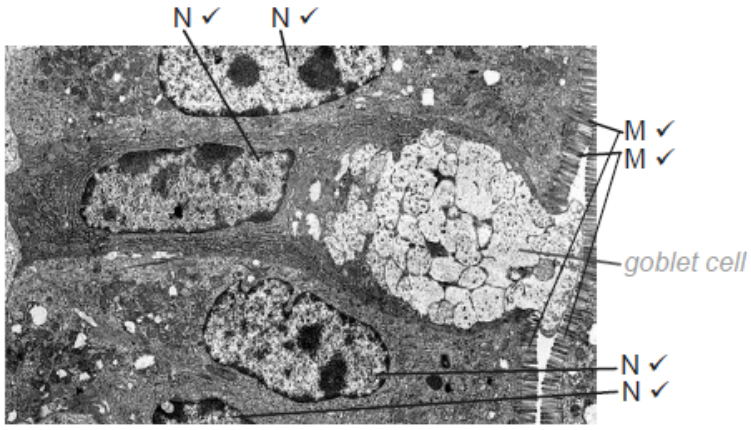
(ii) State the function of the goblet cell.

(iii) Deduce, with a reason, whether or not the goblet cell is likely to divide.

b. Explain how the cell cycle is controlled. [4]

Markscheme

a. (i)



*Award **[1]** for one microvillus labelled M and one nucleus labelled N.*

Both are essential for the mark.

Do not award the mark if any structure is labelled incorrectly.

(ii)

secretion/exocytosis / produce mucous

Candidates are not required to have studied goblet cells, so are just expected to deduce from the vesicles that the function is secretion; allow enzyme secretion but reject answers suggesting secretion of something that is clearly incorrect such as secretion of bile.

(iii)

not likely to divide as specialized/differentiated
OR
not likely to divide (as nucleus) is in interphase/not in mitosis

Do not award a mark for stating that the goblet cell lacks a nucleus.

b. a. cell cycle is a sequence of stages / cell cycle is G_1, S, G_2 and mitosis

b. (control of the cell cycle) by cyclins/cyclin

c. levels of cyclins rise (and fall)/fluctuate during the cell cycle/surge at different times/have to reach a certain concentration

d. conditions inside as well as outside the cell affect regulation

e. four cyclins/different cyclins to enter different stages of/events in the cell cycle / cyclins regulate the sequence/timing of the cell cycle / cyclins trigger the next stages

The idea of different cyclins acting at different phases must be clear.

f. cyclin-dependent kinases / cyclins bind to kinases and activate them

g. kinases phosphorylate other proteins

h. phosphorylated proteins perform specific functions in the cell cycle

Examiners report

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