HL Paper 2

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.

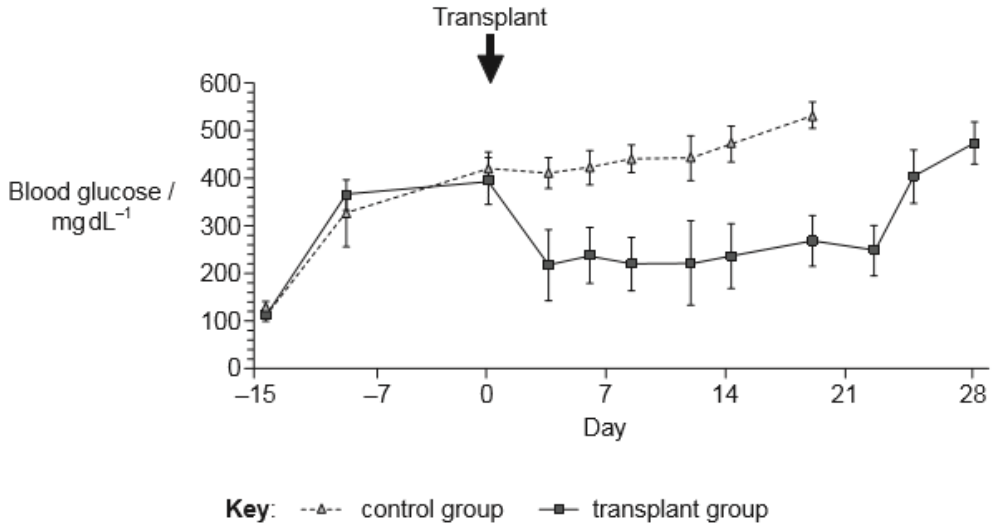
In part b, the knowledge of students was adequate. The challenge for this question was structuring the response to address the demands of the question as the events within the ovary had to be linked to the events within the uterus. The role of estrogen in developing the uterine lining was well known 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.

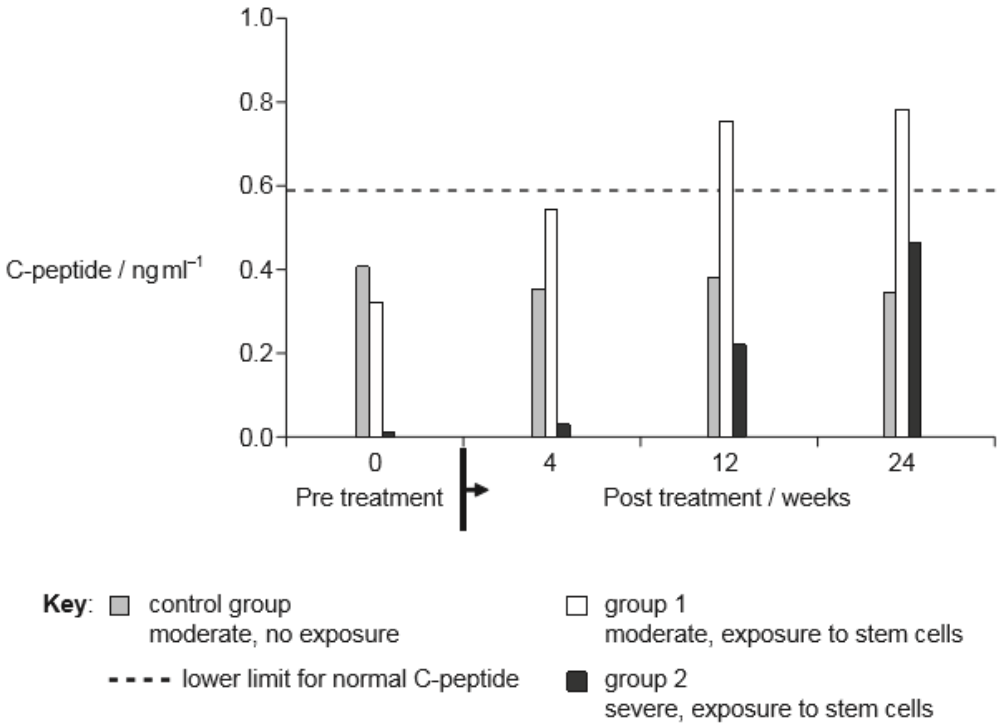
Type I diabetes is a leading cause of death in advanced countries and is associated with various severe or fatal complications, including blindness, kidney failure, heart disease, stroke, neuropathy, and amputations. Embryonic stem cells are considered to be a powerful tool in the treatment of diabetes.

In a study, embryonic stem cells were grown in culture and tested for insulin mRNA. A drug was injected into two groups of healthy mice in order to simulate type I diabetes 15 days prior to the transplant of embryonic stem cells. The mice in the transplant group received embryonic stem cells that produce insulin mRNA. The control group did not receive the transplant. The graph shows the blood glucose concentration in both groups.



[Source: Reprinted from *The American Journal of Pathology*, Vol 106, no. 6, Takahisa Fujikawa *et al.*, "Teratoma Formation Leads to Failure of Treatment for Type I Diabetes Using Embryonic Stem Cell-Derived Insulin-Producing Cells", pp. 1781–1791, Copyright © 2005 American Society for Investigative Pathology. Published by Elsevier Inc. All rights reserved.]

A few years later, a third study used a treatment with umbilical cord stem cells on patients who had suffered from moderate or severe type I diabetes for an average of 8 years. They were divided into two groups: group 1 had moderate diabetes and group 2 had severe diabetes. The patients' blood was circulated outside the body and exposed to umbilical cord stem cells before returning to the patients' circulation. The control group had moderate diabetes and received the same treatment but without umbilical cord stem cells.



[Source: doi:10.1186/1741-7015-10-3
Zhao *et al.*: Reversal of type 1 diabetes via islet ß cell regeneration following immune modulation by cord blood-derived multipotent stem cells. *BMC Medicine* 2012 10:3.]

a. State the highest mean concentration of blood glucose in the mice with transplants. [1]

.....mg dL^{-1}

b. Outline the cause of type I diabetes in humans. [1]

c. Describe the reason for testing for insulin mRNA in the embryonic stem cell cultures. [1]

d. Compare and contrast the concentration of blood glucose resulting from the embryonic stem cell transplant with the control. [2]

e. Evaluate the effectiveness of the embryonic stem cell treatment in controlling blood glucose. [2]

h. Compare and contrast the results of the treatment on group 1 with the results of the treatment on group 2. [3]

i. Suggest an ethical advantage of using this type of therapy over embryonic stem cell therapy. [1]

j. Using the data from all three studies, evaluate the use of embryonic stem cells as a treatment for type I diabetes. [4]

Markscheme

a. 470. *Accept answers in the range of 460 to 480 «mg dL^{-1}»*.

b. «Autoimmune» destruction of beta/β cells. (*Accept B cells instead of β cells).*

Reduced/insufficient/no production of insulin

c. Indicates «stem» cells can produce insulin

OR

is needed for insulin production

OR

shows insulin gene is working/being translated.

Insulin is needed to treat type I diabetes
OR
insulin is needed to bring blood glucose level down

Answers must relate to insulin mRNA.

d. Decrease in transplant group «after treatment» in contrast to control group which does not decrease/decreases only very slightly

«initially»/increases/is higher than treatment group

Glucose «remains» lower in transplant group «than control group» for 2 max 2 weeks/3 weeks/for a time

«in the 4th week» transplant group rises back to level before transplant/to higher level than before transplant/to «near» level of control group

The answer must include some indication of time or non-permanency.

e. Glucose level still higher than normal/higher than 100 «mg»/higher than it was before the drug injection

Effective/lowers blood glucose for 3 weeks/temporarily/for a short time. *This can either be positive (the treatment is effective for a while) or negative (it isn't effective permanently).*

OR
glucose level rises back in 4th week/by day 28
OR
rises back to level of control group
OR
rises again but not above control group

There must be a correct indication of the timing of the effects.

h. C-peptide increases after treatment in both groups. *There must be an explicit comparison.*

OR

treatment effective in both groups

OR

both groups rose higher than the control

Similar/same overall/total increase «in both groups»
OR
quoted figures to show this

Smaller percentage/% increase «pre to post treatment» in group 1 «than group 2» *Reject answers relating to rates of increase*.
OR
quoted figures to show this

Initial increase is greater in group 1
OR
increases slowing/finished/rate of increase reduced by end of study/by week 24 in group 1 but continuing in group 2

Group 1 rose above lower limit «by week 12» and group 2 remained below it «even at week 24»

i. Umbilical cord «stem» cells are discarded/die if not harvested

OR

harvesting umbilical cord cells does not harm the baby

OR

taking «stem» cells from an embryo may harm/kill it

Do not accept answers relating to consent.

j. Study 1/study with mice/embryonic stem cell study shows treatment can cause increased insulin production/ reduce blood glucose levels

«Insulin production/reduction in blood glucose in study 1 was» only temporary/did not reduce glucose to normal levels

Study 2 shows increases in C-peptide/insulin
OR
some type I diabetes patients required no insulin after treatment

Study 2 shows treatment effective for a long time/2 years

«Stem cell treatment in study 2» was more successful in some patients than others
OR
more successful for moderate «than more severe» diabetes

Study 3 shows that stem cells can cause C peptide/insulin levels to double/rise significantly/rise above lower limit «for normal C-peptide»/rise and stay raised

«Study 3» does not give evidence for embryonic stem cells
OR
used umbilical cord rather than embryonic stem cells

Examiners report

a. Most candidates successfully identified the highest mean blood glucose concentration.

b. Answers here were varied with many candidates correctly stating either that insulin is not produced or that beta cells are destroyed. A common

incorrect answer was to state that diabetes is a purely genetic disease.

c. There were also varied answers here with some candidates not appreciating the significance of the presence of insulin mRNA or not stating it clearly enough.

d. Many candidates failed to pick out more than one significant trend here. The data before the transplant was not relevant so the three phases that could have been described were the initial drop in blood glucose in the transplant group, the period when both groups remain relatively constant but the transplant group stayed lower and finally the rise in the transplant group to the original level before the transplant. For the latter two points the timing was expected.

e. Very few candidates scored both marks here. The point commonly made was that the drop in the transplant group is temporary. Very few candidate also made the significant point that the transplant did not cause the blood glucose concentration to drop down to the level before diabetes had been induced, so even in the early stages the treatment was not fully effective.

h. This was another place where many candidates failed pick out enough significant similarities and differences. One similarity and four significant differences were included in the mark scheme but most candidates scored only one or two marks (out of three).

i. Most realised that there are ethical concerns if an embryo is damaged or killed and not if stem cells are taken from the placenta and umbilical cord before they are discarded, but the phrasing of answers was often too imprecise for a mark to be awarded. Terminology was frequently vague or incorrect. The terms embryo and fetus are not interchangeable, for example.

j. Many teachers correctly commented on G2 forms that there was an ambiguity in this question. It instructed candidates to use data from all three studies and also to evaluate the use of embryonic stem cells. Only study 1 had specifically been carried out using embryonic stem cells and study 3 was certainly done with umbilical cord rather than embryonic stem cells. It was therefore very important for candidates to quote which study they were using for a particular point and not all did this. Another weakness of some answers was to mention trends in the data without making them clearly a strength or weakness as is expected in an evaluation. The best answers coped well with the ambiguity in the question and scored full marks.

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a. Define the term *passive immunity*. [1]

b. State **one** use of monoclonal antibodies in diagnosis. [1]

c. Define the term *pathogen*. [1]

d. Outline why antibiotics are effective against bacteria but not against viruses. [2]

Markscheme

a. the acquisition of <u>antibodies</u> from another organism

b. An example, *e.g. detection of (antibodies to) HIV (reject AIDS) / isoenzyme in heart attack / (HCG in) pregnancy test kits / blood and tissue typing / detection of malarial parasites*

Accept any other valid examples.

c. an organism/virus that causes a disease

d. a. antibiotics block/inhibit specific metabolic pathways/cell functions found in bacteria;

Accept specific examples of inhibition such as cell protein synthesis, cell wall formation.

b. viruses must use host/eukaryotic cell metabolism / viruses do not have their own metabolic pathways;

c. host/eukaryotic cell metabolism/pathways not blocked/inhibited by antibiotics;

Examiners report

a. The two definitions of passive immunity and pathogen were quite well known.

b. The topic of monoclonal antibodies was very centre specific, with some centres missing it out of their schemes of work.

c. The effectiveness of antibodies against bacteria due to specific metabolic inhibition, as opposed to viruses (or their hosts), whose metabolism is not inhibited was not always fully understood.

d. [N/A]

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a. Draw a labelled diagram of the heart showing the chambers, associated blood vessels and valves. [4]

b. Describe the processes involved in blood clotting. [6]

c. Discuss the benefits and risks associated with vaccination programmes. [8]

Markscheme

a. *Award **[1]** for each structure clearly drawn and correctly labelled. Schematic diagrams are acceptable.*

right and left ventricles – not connected shown larger than atria;

right and left atrium – not connected, thinner walls than ventricles;

right ventricle has thinner walls than left ventricle / *vice versa*;

atrio-ventricular valves / tricuspid and bicuspid valves – shown between atria and ventricles;

aorta and pulmonary artery – shown leaving the appropriate ventricle with semilunar valves shown;

pulmonary vein and vena cava – shown entering appropriate atrium;

Vessels must join unambiguously to correct chamber.

b. cells/tissue is damaged/cut/bruised;

damaged cells/platelets release clotting factors;

(clotting factors cause the) production of thrombin;

blood plasma contains soluble fibrinogen;

fibrinogen converted into fibrin;

by thrombin;

forms a net of fibres trapping blood cells;

forming a clot / prevents blood loss / entry of bacteria/pathogens;

cascade of reactions/series of stages prevent accidental clotting/speed up clotting;

c. *benefits:* ***[6 max]***

immunity results

can limit pandemics/epidemics/spread of (infectious) diseases;

diseases can be eradicated/smallpox eliminated;

reduces mortality/deaths due to disease;

can protect vulnerable groups/young/old/with other conditions;

decreases crippling effects of diseases (such as polio);

decreased health care costs;

risks: ***[6 max]***
may produce (mild) symptoms of the disease;
human error in preparation/storage/administration of vaccine;
individual may react badly to vaccine / defective immune system / hypersensitive/allergic reaction;
immunity may not be life-long / booster required;
possible toxic effects of mercury-based preservatives/thimerosal;

Examiners report

a. Candidates are often pleased to be able to demonstrate their knowledge of heart structure and many were able to do so successfully here. The commonest errors were to misrepresent the relative sizes of the atria and ventricles, or relative thickness of the walls of the four chambers. Weaker candidates were confused about the connections of vessels to chambers, with vessels connected to the wrong chamber or to the muscle in the wall, rather than the lumen through which blood flows. There were some truly impressive diagrams that were a pleasure to mark and a demonstration of the quality of many of this year's generation of IB biology candidates.

b. The requirement was only to give an outline of the process of blood clotting. Some candidates gave far more detail than this and had already scored six marks in the first paragraph of their answer. The most frequent errors were to state that thrombin is converted to prothrombin or fibrin to fibrinogen. A point that might be stressed more in teaching is how clot formation is localised in a cut or other wound. The mechanism described by some candidates would lead to clotting throughout the blood system!

c. The last part of this question proved problematic for many candidates. There was no difficulty in giving enough benefits of vaccination. The problem came with finding enough genuine risks. Many of the answers given by candidates were simply untrue or were so unlikely that they should not be taught as risks or dangers of vaccination. There are of course some mild and temporary side effects at the site of the vaccination and rare allergic reactions. Also, some vaccinations have to be repeated or booster shots are necessary. There were dangerous misunderstandings in some candidates' answers, for example that there is a significant risk of actually contracting the disease from the vaccine or that multiple vaccines

weaken the immune system. Some answers were not risks of the actual process of vaccination, for example its unaffordability in poorer countries, the fact that used hypodermic needles could spread disease, or that there are irrational fears about particular vaccines. Risks of vaccination are so much fewer and less significant than benefits that risks should probably not be included in future versions of the IB Biology programme. To be fair to candidates, it was challenge to express more than one or two risks in a way that was accepted by examiners, so part (c) was more discriminating than teachers commenting on G2 forms expected. One teacher commented that 8 marks was too much for this question and in retrospect this is possibly true.

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a. Outline how antibiotic resistance in bacteria can arise in response to environmental change. [5]

b. Outline the principle of immunity. [6]

c. Discuss the benefits and dangers of vaccination. [7]

Markscheme

a. antibiotic resistance can be inherited;

alleles for resistance can be passed from one cell to another by exchange of plasmids/conjugation;

some varieties are more resistant than others;

bacteria reproduce very rapidly and have high mutation rate;

evolution can occur rapidly;

increased exposure to antibiotics is the environmental change that selects for resistant varieties;

for example, in hospitals / animal feed / inappropriate prescriptions / not finishing prescriptions;

bacteria without resistance die / resistant bacteria survive and pass on genes to next generation;

results in change in genetic makeup of population;

b. immunity is the ability of an organism to resist infection;

due to presence of (specific) antibodies;

immunity can be active or passive;

passive due to receiving antibodies from external sources/across placenta/from breast milk/injection;

active results from facing an infection directly/through vaccination;

pathogen/foreign cell invades body;

leads to clonal selection/formation of B memory cells;

B-cells produce specific antibodies;

if same pathogen enters body again memory cells activated/stimulated to divide;

antibodies produced faster and in greater amounts;

c. *Benefits:* ***[4 max]***

immunity results

can limit pandemics/epidemics/spread of (infectious) diseases;

diseases can be eradicated/smallpox eliminated;

reduces mortality/deaths due to disease;

can protect vulnerable groups/young/old/with other conditions;

decrease crippling effects of diseases (such as polio);

decreased health care costs;

Dangers: ***[4 max]***
may produce (mild) symptoms of the disease;
human error in preparation/storage/administration of vaccine;
individual may react badly to vaccine / defective immune system / hypersensitive/allergic reaction;
immunity may not be life-long/booster required;
possible toxic effects of mercury-based preservatives/thimerosal;

Examiners report

a. Most candidates scored few marks, failing to mention gene transmission in bacteria, variation, or widespread use of antibiotics as the environmental change.

b. Surprisingly few candidates could define immunity well. Some detailed accounts of how immunity is gained were given, but failure to describe accurately what happens if the same pathogen enters again or the different types of immunity meant that many candidates gained a low score.

Vague, rambling accounts about T and B cells were provided quite often. There was too much detail on the sequence of events leading to the development of memory cells (named as T or B) and less on how this resulted in immunity. Antibodies and antigens were sometimes confused.

c. Candidates were generally better at giving the benefits rather than the dangers, but few candidates could give four of both. Misunderstanding about vaccinations was common which is quite a worry for candidates who have been through an advanced biology course. Many mentioned autism without substantiation.

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a. Outline the mechanisms involved in the control of heartbeat. [3]

b. Explain how the direction of blood flow in the heart is controlled. [2]

Markscheme

a. myogenic contraction / muscles contract without stimulus from a nerve;

pacemaker/SA node initiates each heart beat/stimulates atria to contract;

nerves carry impulses from the brain to speed up and slow down the heart;

medulla (of the brain) monitors blood pressure;

epinephrine/adrenaline increases rate/strength of contractions;

b. valves open/close due to blood pressure differences;

valves prevent backflow/only allow unidirectional flow;

atrioventricular valves between ventricles and atria;

semilunar valves between arteries and ventricles;

Accept mitral/bicuspid and tricuspid in place of atrioventricular.

Accept aortic and pulmonary in place of semilunar valves.

Examiners report

a. This question could perhaps have been worded more clearly as many candidates described the electrical stimulation of contraction of the atria and ventricles of the heart. What was required was a description of how the rate of beating of the heart is controlled, as in assessment statement 6.2.4, with the teacher notes for that statement giving all the points that were expected.

b. This was answered more successfully, with many candidates explaining that heart valves prevent backflow and giving details of specific valves. Few candidates explained that pressure differences on the two sides of a heart valve cause opening and closing, but it was still possible to score two marks without including this.

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a. Draw a labelled diagram of a mature sperm cell. [4]

b. Outline the role of hormones in the menstrual cycle. [6]

c. Discuss the cause, transmission and social implications of AIDS. [8]

Markscheme

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

a. head and midpiece/mid-section/body;

b. tail/flagellum; *(at least four times length of the head and containing fibres)*

c. acrosome; *(shown as distinct structure near front of head)*

d. nucleus; *(occupying more than half the width or length of head)*

e. mitochondria; *(as repetitive structures inside membrane of mid piece)*

f. centriole; *(between head and midpiece)*

g. (plasma) membrane; *(shown as single line covering whole cell)*

h. microtubules; *(in 9 plus 2 array)*

b. a. FSH promotes development of a new follicle;

b. also leads to the production of estrogen;

c. estrogen brings about repair and growth of uterine wall;

d. estrogen causes negative feedback of FSH;

e. estrogen brings about LH production;

f. LH stimulates follicle growth;

g. LH triggers ovulation;

h. estrogen contributes to the proliferative phase of the uterine cycle / triggers LH surge;

i. progesterone contributes to the secretory phase of the uterine cycle/maintains uterus wall;

j. lowered level of progesterone (due to degeneration of corpus luteum) leads to menstruation;

c. *cause: [4 max]*

a. AIDS caused by HIV;

b. penetrates (T) lymphocytes;

c. (envelope) (glyco)protein and cell receptors involved;

d. reverse transcriptase enables DNA to be produced from viral RNA; *(reject DNA transformed into RNA)*

e. number of lymphocytes reduced over years;

f. results in lower immunity;

g. other illnesses develop (as result of lower immunity);

h. AIDS is the observed syndrome when final stages of infection develop / *OWTTE*;

transmission: [3 max]

i. HIV transmitted through blood/sexual contact/body fluids/placenta/childbirth/ breastfeeding;

j. distribution/transmission uneven around the world;

k. transmission risk increased depending on society's traditions/beliefs/behaviour;

l. (rare minority of) individuals do not have cell receptors and do not develop AIDS;

m. condoms/latex barriers only protection against transmission through sexual contact;

social implications: [3 max]

n. treatment expensive;

o. discrimination against victims;

p. moral obligation of wealthy countries to help poorer countries;

q. economic consequences / loss of wage earners etc.;

r. increase in the number of orphans;

s. comment on traditions/beliefs/behaviour; *(if not already awarded in transmission) [8 max]*

Examiners report

a. For assessment statement 11.4.6, candidates should be able to draw a labelled diagram of a mature sperm. These were 4 straightforward marks for well-prepared candidates, others gaining no marks. One common mistake was the drawing of a small nucleus, rather than one filling at least half of the head.

b. Well prepared candidates were able to explain the roles of FSH, estrogen, LH and progesterone. Others were totally confused. Many tried to answer with the textbook graph of the monthly hormone levels. An answer like this is acceptable if it includes sufficient annotation and can be clearly read.

c. Most candidates knew about transmission of HIV, although many still think that AIDS not the HIV is transmitted. The social implications were also quite well known, but correct biological answers gaining full marks for the cause were rare.

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

b. Outline how skeletal muscle contracts. [5]

c. Explain how nerve impulses are transmitted along and between neurons. [9]

Markscheme

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

Sarcomere – clearly indicated between Z lines;
Z lines;
actin filaments attached to Z line;
myosin filaments with heads;
(two) light bands;
dark band;

b. calcium ions are released from the sarcoplasmic reticulum;

they expose the myosin binding sites (on actin) / cause movement of blocking molecules/troponin;
cross-bridges form between actin and myosin molecules;
ATP provides energy;
for actin filaments to slide over the myosin filaments / for myosin to push actin;
ATP provides energy to release myosin from binding site;
action can be repeated further along the molecule;

c. the resting potential of cell is negative inside compared with outside;

stimulation causes depolarization/reversal of charge on each side;
due to Na^+ channels opening / Na^+ flowing into the cell;
which causes an action potential;
K^+ channels open / K^+ flows out of the cell;
sodium potassium pump restores resting potential;
transmitted between neurons across a synapse;
neurotransmitter released into synaptic cleft;
diffuse across cleft to postsynaptic membrane;

where they bind to receptors;

influx of Na^+ into cell;

which may initiate action potential;

Examiners report

a. Most candidates who answered this question knew about the structure of the sarcomere, and the diagrams were generally good.

b. If the candidates could draw the sarcomere they could also explain muscle contraction.

c. There were many full and complete answers, although many weaker students became confused between the sodium and potassium ions, and although many remembered the -70mV, they did not mention that the inside of the axon is negative. Most were able to explain what happened at the synapse, but often failed to say what a synapse is.

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a. Draw a labelled diagram of the human heart showing the attached blood vessels. [6]

b. Describe the action of the heart in pumping blood. [5]

c. All parts of the body change the composition of the blood. Explain how the nephron changes the composition of blood. [7]

Markscheme

a. ***NB:*** *Drawings must be correctly proportioned and clearly drawn showing connections between structures. The drawing may show the heart without contraction or in any stage of contraction. Award [1] for any correctly labelled part that has been drawn to the stated standards.*

a. atria/right atrium/left atrium – *shown above the ventricles and must not be bigger than ventricles*;

b. ventricle/left ventricle/right ventricle – *below the atria, must have thicker walls than atria*;

c. vena cava/superior vena cave/inferior vena cava – *connected to right atrium*;

d. pulmonary artery – *shown from right ventricle (to lungs);*

e. pulmonary vein(s) – *shown (from lungs) to left atrium*;

f. aorta – *shown as large artery from left ventricle out of heart*;

g. AV valves/atrioventricular valves / mitral/bicuspid and tricuspid – *named correctly and shown between both atria and ventricles and labelled at least on one side*;

h. semilunar valves – *shown in aorta/pulmonary artery*;

Valves need to open in correct direction.

b. a. (both) atria collect blood (from veins);

b. sinoatrial/SA node sends impulses to muscle/fibres initiating contraction;

c. blood is pushed to ventricles by contraction of atria/atrial systole;

d. AV (atrioventricular) valves are open (as atria contract);

e. semilunar valves are closed so that ventricles fill with blood;

f. ventricles contract / ventricular systole;

g. AV (atrioventricular) valves close (preventing backflow);

h. (blood is pushed through the) semilunar valves/pulmonary artery and aorta;

i. when ventricles relax /diastole, semilunar valves close preventing backflow of blood;

Do not accept the description of blood flow without a clear action.
Do not accept general statements such as systole = heart contraction and diastole = heart relaxation.
***[4 max]** if answer suggests that left and right sides are contracting at different times or simultaneous contraction not indicated.*

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

a. higher nitrogen/urea as blood enters nephron/Bowman's capsule than when it leaves the nephron (in the renal vein);
b. most small soluble molecules/glucose/nutrients/ions are removed from blood in Bowman's capsule;
c. through ultrafiltration;
d. proteins / blood cells / large molecules remain in the blood;
e. as filtrate moves through the nephron (tubule), water is returned to the blood (by osmosis);
f. glucose/nutrients is returned to blood by active transport (and diffusion) / selective reabsorption;
g. in the proximal convoluted tubule;
h. urea / uric acid remain in the filtrate / removed from blood;
i. sodium is pumped into the medulla in the loop of Henlé;
j. water reabsorption is enhanced by a high sodium gradient (in the medulla);
k. permeability of the collecting duct membrane is regulated by hormones / ADH;
l. water concentration in urine is variable to maintain homeostasis in the blood;
m. more oxygen/less carbon dioxide in blood entering (kidney) than in blood leaving (kidney);

Examiners report

a. Common problems in student diagrams included: errors in representing the relative size of chambers, errors in representing the relative thickness of walls, failing to show connections of vessels to the correct chambers and representing those connections. Lastly drawing valves with care including their correct orientation.

b. It was rare for students to discuss simultaneous contractions within the cardiac cycle. Most framed their answers as a sequential flow of blood.

c. Students appear to know this topic well as many full mark answers were awarded.

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a. Draw a labelled diagram of the adult female reproductive system. [4]

b. Outline the roles of progesterone and estrogen in the human menstrual cycle [6]

c. Explain the function and structure of the placenta. [8]

Markscheme

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

ovary – shown adjacent to but not joined to oviduct/fallopian tube;

oviduct/fallopian tube – shown as a tube leading into a uterus;

uterus – shown with a thicker wall than oviduct/fallopian tube;

vagina – shown leading from the uterus, connected to the cervix;

cervix – shown as a constriction between the vagina and uterus;

endometrium – shown as inner lining of uterus;

b. follicles secrete estrogen / FSH stimulates secretion of estrogen;

(rapid) increase in estrogen stimulates FSH/LH production;

estrogen also stimulates repair/thickening of endometrium/uterus lining;

LH causes follicle to produce less estrogen/more progesterone;

corpus luteum secretes more estrogen/progesterone;

progesterone maintains/stimulates thickening of endometrium/uterus lining;

estrogen/progesterone inhibit FSH/LH secretion;

estrogen/progesterone levels fall after day 21–24 if no embryo/fertilization;

lower concentration of estrogen/progesterone allows disintegration of endometrium/uterus lining / menstruation occurs;

*Award **[4 max]** if only one hormone is explained.*

c. transfer of foods/nutrients/glucose from mother to fetus;

fetal gas exchange/transfer of oxygen from mother to fetus;

transfer of excretory products/CO_2 from fetus to mother;

transfer of antibodies/hormones from mother to fetus;

secretion of estrogen/progesterone;

from approximately 12 weeks / when ovary/corpus luteum stops secretion;

disc shaped structure;

connected to the fetus by an umbilical cord;

embryonic tissue invades/grows into the uterine wall;

placental villi increase the surface area (for exchange);

fetal capillaries in placenta/placental villi;

inter-villous spaces/sinuses through which mother's blood flows;

small distance between fetal and mother's blood/narrow placental barrier;

Allow reference to embryo instead of fetus throughout.

Examiners report

a. Whenever the structure of the male or female reproductive system has been set in IB Biology exams, the quality of drawings has ranged from excellent to worryingly inaccurate. There were a few drawings in this session that displayed almost total ignorance, but most were largely correct in the relative positions of the organs. In some cases marks awarded were still low, as the details were so unrealistic. Oviducts often led into the wall of the uterus rather than the lumen. The cervix would often have been unable to carry out its functions if it had the structure represented. Ectopic pregnancies would have been the norm rather than the exception in many cases. Most diagrams were drawn as a view from the front. The minority of diagrams were drawn as a side view tended to be better in terms of proportions and relative positions.

b. Many answers were unfocused, with candidates recalling their knowledge of the whole of the hormonal control of the menstrual cycle, rather than extracting the roles of progesterone and estrogen, as required by the question. Answers therefore tended to be over-long, with examiners having to pick out the relevant points. Quality marks for Section B questions are reduced if there are significant amounts of irrelevant material.

c. This was also answered more poorly than expected, perhaps because most of the stronger candidates did not choose this question. There were few answers that earned all of the eight marks, despite both structure and function of the placenta being included. In many cases answers were too vague and failed to make it clear what is transferred from maternal to fetal blood and vice versa.

---

a. Outline the process of glycolysis. [5]

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

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

Markscheme

a. occurs in cytoplasm;

hexose is phosphorylated using ATP;

hexose phosphate is split into two triose phosphates;

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

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

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

pyruvate produced at the end of glycolysis;

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

Accept 3C sugar/glyceraldehyde instead of triose.

b. α cells (of pancreas) produce glucagon;

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

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

β cells (of pancreas) produce insulin;

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

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

negative feedback mechanism;

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

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

c. urine of diabetics contains glucose;

whereas urine of non-diabetics contains no glucose;

glomerular filtrate contains glucose / glucose filtered out;

glucose (normally) reabsorbed from filtrate/into blood;

through wall of / in the proximal convoluted tubules;

blood glucose concentration higher than normal in diabetics;

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

glucose in urine can be detected using test strips;

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

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

Examiners report

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

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

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

---

a. Outline the role of the skin in temperature regulation. [5]

b. Outline the role of hormones in the process of birth in humans [4]

c. Explain the principles of vaccination. [9]

Markscheme

a. heat causes vasodilation of arterioles;

blood closer to surface so heat loss from skin;

heat causes sweating (from sweat glands);

evaporation of sweat leads to cooling;

cold causes vasoconstriction of arterioles;

less blood at surface so less heat loss from skin;

cold leads to less sweating/evaporation of water from skin / hair becomes erect and traps air/goose bumps appear;

temperature receptors in skin transmit impulses to the hypothalamus;

b. level of progesterone falls before birth;

oxytocin secreted;

from pituitary;

this stimulates contractions of uterus;

uterine contraction/stretching of cervix/vagina stimulates secretion of (more) oxytocin;

form of positive feedback;

c. vaccine is a modified/weakened/attenuated form of a pathogen / contains antigens from pathogens;

vaccine injected/ingested/introduced to patient;

pathogen/antigens stimulates specific immune response called primary/initial responses;

antigens stimulate macrophages/lymphocytes/T-cells;

which stimulate cloning of B-cells/plasma cells;

including development of memory (B-)cells;

that produce specific antibodies;

(upon second exposure) production of antibodies is much faster;

higher level of antibody production / person has immunity;

called secondary response;

labelled graph showing curve with higher slope/peak for secondary response than primary response;

may need booster shot to maintain immunity;

this is an example of active/artificial immunity;

Examiners report

a. Answers to part (a) were varied but mostly lacked precision of terms, using blood vessels instead of arterioles, etc. Some students still believe the arterioles move towards or away from the surface. The description of the role of sweating was often incomplete.

b. Part (b) was also poorly answered on the whole, with many students discussing hormonal changes throughout the pregnancy and/or confusing the names of the hormones involved in the birth process.

c. Part (c) of this question was very well answered by many candidates, showing good understanding of the processes involved in vaccination. Other candidates' answers, however, were vague and confused and in some cases with poor use of terminology and the order of the processes. Others spent time writing at length about the ethics of the use of vaccinations.

---

a. Outline a possible cause of Down syndrome. [4]

b. Outline the processes involved in oogenesis within the human ovary. [8]

c. Discuss the ethical issues surrounding IVF. [6]

Markscheme

a. non-disjunction (can cause Down syndrome);
   occurs when pair of homologous chromosomes fails to separate during meiosis;
   one gamete/daughter cell receives two chromosomes / diagram showing this;
   occurs in anaphase I/II of meiosis;
   fertilization involving this gamete leads to change in chromosome number/47 chromosomes;
   most common form of Down is trisomy 21/extra chromosome 21;
   increase risk of Down syndrome with increased age of mother;

b. oogenesis is process by which female gametes/eggs are produced;
   begins during fetal development; oogonia/large number of cells formed by mitosis;
   oogonia/cells enlarge/undergo cell growth/become primary oocytes;
   begin first meiotic division but stop in Prophase I;
   until puberty;
   (at puberty) some follicles develop each month in response to FSH;
   (primary oocyte) completes first meiotic division;
   forms two cells of different/unequal sizes / unequal distribution of cytoplasm;
   (creating a) polar body;
   polar body eventually degenerates;
   larger cell/secondary oocyte proceeds to meiosis II;

stops at prophase II;

meiosis II completed if cell is fertilized;

ovum and second polar body formed;

c. *To award full marks, discussion must contain both pro and con considerations.*

pros/positive considerations: ***[3 max]***
chance for infertile couples to have children;
decision to have children is clearly a conscious one due to difficulty of becoming pregnant;
genetic screening of embryos could decrease suffering from genetic diseases;
spare embryos can safely be stored for future pregnancies/used for stem cell research;

cons/negative considerations: ***[3 max]***
IVF is expensive and might not be equally accessible;
success rate is low therefore it is stressful for the couple;
it is not natural/cultural/religious objections;
could lead to eugenics/gender choice;
could lead to (unwanted) multiple pregnancies with associated risks;
production and storage of unused embryos / associated legal issues / extra embryos may be used for (stem cell) research;
inherited forms of infertility might be passed on to children;
Accept any other reasonable answers.

Examiners report

a. Most of the candidates gave trisomy 21 and non-disjunction, but fewer were able to accurately describe how it comes about. Confusion between genetic mutation and chromosome mutation was common especially when discussing causes.

b. Quite a few candidates described the process of ovulation in detail, gaining no marks. Most candidates did refer to the formation of the polar body in oogenesis, but missed out on many of the changes given in the mark scheme. Detailed discussions of the menstrual cycle were common. Some obviously understood it but could not write clearly and logically/a general lack of detail.

c. Most candidates gained a fair number of marks, but often limited their score by focusing on the negatives of IVF rather than the positives. But then again, the mark scheme only listed 4 pros vs 7 cons.

---

a. Describe the process of blood clotting. [4]

b. Factor IX is a blood clotting protein which some hemophiliacs lack. In the future hemophilia could be treated using clotting factors synthesized by genetically modifiedbacteria.Outlinethebasictechniqueusedforthisgenetransfer. [6]

c. Explain how males inherit hemophilia and how females can become carriers for the condition. [8]

Markscheme

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

a. clotting factor released by platelets/damaged tissue/cells;
b. cascade/series of reactions;
c. prothrombin (activated) to thrombin;
d. soluble fibrinogen to insoluble fibrin / thrombin converts fibrinogen to fibrin;
e. mesh of fibrin/fibres seals wound/traps platelets/red blood cells;

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

a. mRNA/gene coding for factor IX extracted from human cell/tissue;
b. mRNA copied to DNA/cDNA (using reverse transcriptase);
c. plasmids used (for gene transfer);
d. restriction enzyme/endonuclease used to open plasmid/cut DNA;
e. complementary bases/sticky ends on gene and plasmid/link gene to plasmid;
f. sealed using ligase;
g. recombinant plasmid/plasmid containing desired gene taken up by bacteria;
h. isolate/clone the recombinant/transformed bacteria;
i. bacteria cultured/grown in fermenter to produce factor IX;

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

a. hemophilia is due to a recessive allele/is a recessive trait / X^H is normal allele and X^h is hemophilia allele;
b. hemophilia is sex linked;
c. allele/gene is on the X chromosome;
Reject disease/hemophilia carried on X chromosome.
d. (sex chromosomes in) females are XX while males are XY;

e. Y chromosomes do not have the allele/hemophiliac males are X^hY;
f. males inherit their X chromosome from their mother/do not pass the allele to sons;
g. males have only one copy so recessive trait/allele is not masked;
h. males have a 50% chance of hemophilia/receiving the allele if mother is a carrier;

i. carrier is heterozygous for the gene/is X^HX^h;
j. dominant/normal allele masks the recessive allele (so clotting is normal);
k. females inherit one X chromosome from father and one from mother;
l. affected/hemophiliac males have carrier daughters;
m. hemophilia allele could have been inherited from either parent;

Accept the points above explained either in text or clearly using a Punnett grid or genetic diagram, but not for simply reproducing an unlabeled Punnett grid or diagram without explanation.

Examiners report

a. There were many general accounts of the sealing up of cuts with clotted blood but what was needed here was the process that leads to clotting. The programme specifies which stages in the cascade of reactions are expected and better answers included these and scored full marks without difficulty.

b. Marks for this part of the question covered the whole range. Among weaker candidate there were various misunderstandings about gene transfer and many confused gene transfer with gene therapy, describing the transfer of the Factor IX gene to haemophiliacs rather than to bacteria. In almost every case the method of gene transfer described in successful answers was that using plasmids. There were some detailed and accurate accounts of this process.

c. Almost all candidates knew something about the inheritance of hemophilia. The mark scheme rewarded a wide range of relevant points as long as they were clearly made. Punnett grids could be used to illustrate particular points but they did not score marks in themselves. One area of confusion among weaker candidates was the difference between genes and chromosomes, with answers referring to dominant or recessive X

chromosomes or implying that X was the gene for hemophilia.

---

c. State the role of plasma cells in the immune system. [1]

d.i. Describe the production of hybridoma cells. [2]

d.ii. State **one** possible use of hybridoma cells. [1]

Markscheme

c. produce/secrete antibodies

d.i. a. antigen injected into mouse/mammal/host

Accept animal

b. B cells/B lymphocytes/plasma cells «obtained/extracted from host»

c. fusion «of plasma cell» with myeloma cell/tumour cell

d. division «of hybridoma cells» to produce a clone

[Max 2 Marks]

d.ii. produce monoclonal antibodies

OR

diagnosis of diseases/malaria/cancer/HIV

OR

treatment of rabies

OR

blood and tissue typing

OR

pregnancy testing

OR

targeting of cancer cells «with a chemotherapy drug»

OR

treatment of infection if too late for vaccination/successful immune response

Only accept the first use of hybridoma cells given in the answer

Not treatment of malaria

Examiners report

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

---

a. Blood is a liquid tissue containing glucose, urea, plasma proteins and other components. List the other components of blood. [5]

b. Outline how the human body prevents blood glucose concentration from rising excessively. [5]

c. Blood plasma, glomerular filtrate and urine have different concentrations of solutes, such as glucose, protein and urea. Explain the processes occurring in the kidney that cause differences in the concentrations of these solutes between blood plasma, glomerular filtrate and urine. [8]

Markscheme

a. plasma/water;

dissolved gases / CO_2 / O_2;

erythrocytes / red blood cells;

leucocytes / white blood cells;

lymphocytes and phagocytes;

platelets;

hormones / named hormone(s);

amino acids / albumin / antibodies;

salts / minerals / ions other named solute in plasma apart from glucose, urea and plasma proteins;

b. blood glucose concentration monitored by pancreas/islets/beta cells;

(more) insulin secreted in response to high blood glucose / glucose above threshold level;

insulin stimulates cells to absorb glucose;

glucose used in cell respiration (rather than lipids);

glucose converted to glycogen;

by liver/muscle cells;

glucose converted to fatty acids / triglycerides / fat;

negative feedback process;

Accept these points if clearly made in an annotated diagram.

c. (filtrate formed by) ultrafiltration;

glucose / amino acids / soluble components enter Bowman's capsule;

proteins in blood plasma but not in filtrate / proteins not filtered out (of blood);

glucose not in urine (normally);

(selective) reabsorption (of glucose);

in the proximal convoluted tubule;

by active transport / microvilli increase the surface area;

little/no urea reabsorbed

concentration increases / urea more concentrated in urine than in blood plasma;

water reabsorbed from filtrate;

by osmosis;

in descending limb of nephron / in proximal convoluted tubule;

salts actively transported into the medulla (from filtrate);

creating concentration gradient/hypertonic medulla;

collecting duct permeability altered depending on blood solute concentration;

Examiners report

a. The command word **list** was understood by most candidates but many wrote long descriptions of the components and their action. This would have been more appropriate if the command term had been "outline". Also "**other**" was sometimes ignored and those elements in the stem were used in their answers.

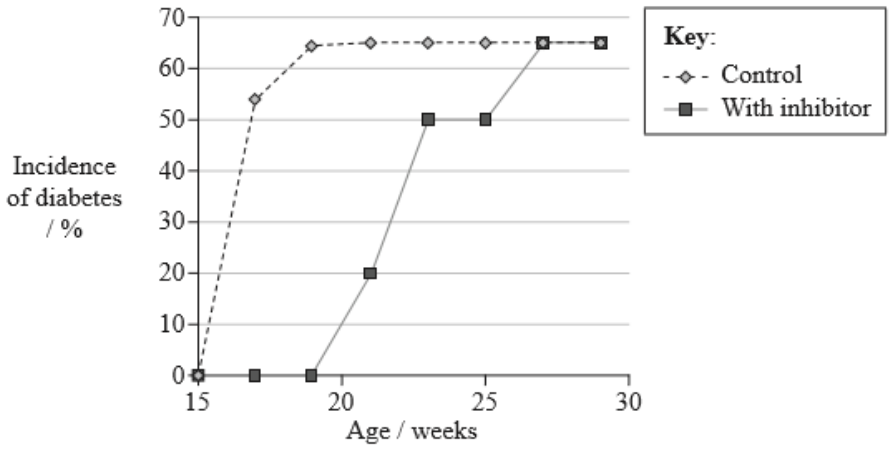
b. Although there were many excellent accounts which easily scored maximum marks, there were a large number where the hypothalamus or liver were considered to be responsible for the regulation of blood sugar.

The answers here indicated an unfortunate tendency to write down answers based on memorized mark schemes from past exams, without addressing what was being asked for. For example, answers including the actions of glucagon or alpha cells are irrelevant to rising glucose concentrations. This would affect quality of construction marks due to the inclusion of irrelevant material.

c. Again there were many excellent answers which scored maximum marks well before reaching the end, but there were also a large number, where their knowledge was so fragmentary and scanty that very little was credit worthy. Common misconceptions included the fate of proteins and blood cells. This was another sub-question where many candidates wrote down answers based on memorized mark schemes from past exams without addressing what was being asked for. The list of elements in 4 (a) were meant to be used to guide the construction of the answer to 4 (c). However, many candidates simply summarized the processes that occurred in the nephron without referencing these elements.

Type I diabetes is an autoimmune disease resulting from destruction of the insulin-producing β cells in the islets of Langerhans. Islet regeneration can occur when stem cells reach the pancreas after leaving the bone marrow.

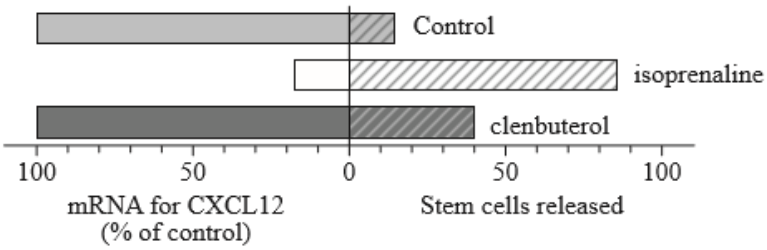
Studies have shown a link between CXCL12 and type I diabetes. Mice predisposed to develop the disease were given an inhibitor of CXCL12 for 3 weeks. The incidence of diabetes was measured after 28 weeks and compared to control mice that were not given the inhibitor.



[Source: adapted from Q Leng, *et al.*, (2008), *BMC Immunology*, **9**, page 51]

One important chemical in the mobilization of stem cells is a protein, CXCL12, which maintains the stem cells inside the bone marrow. The breakdown of CXCL12 causes the mobilization of stem cells to the blood vessels.

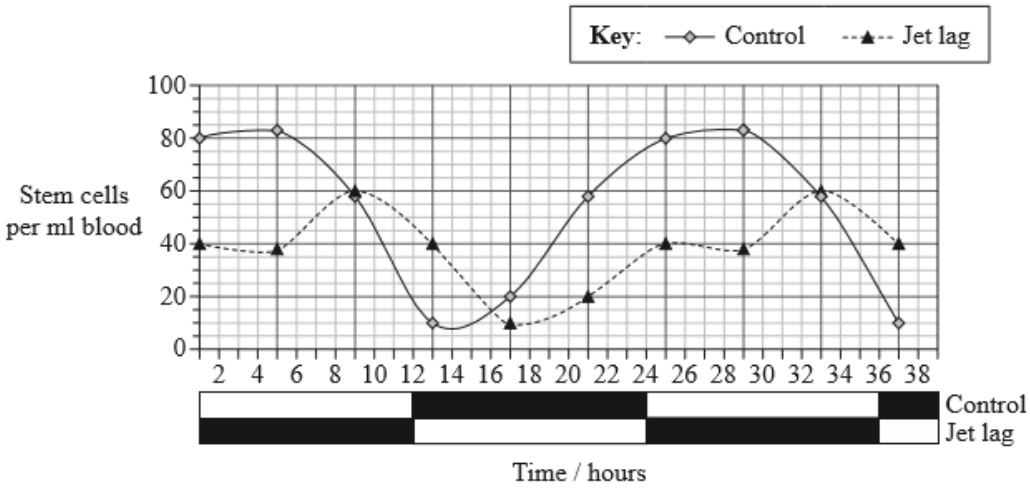
The graph below shows the mobilization of stem cells and the production of mRNA for CXCL12 when the bone marrow is treated with two different chemicals (isoprenaline and clenbuterol).



Méndez-Ferrer, S., Lucas, D., Battista, M. and Frenette, P.S. (2008) 'Haematopoietic stem cell release is regulated by circadian oscillations'. Nature 452: 442–447.

Stem cells in the bone marrow can be forced into blood vessels in a process called mobilization. Mobilization of stem cells from the bone marrow into the blood vessels represents the basis for modern bone marrow transplantation procedures.

To test the effect of light on the mobilization of stem cells, mice were subjected to a simulated "jet lag" by advancing the light-dark cycle by 12 hours. This was done by subjecting mice to a 24-hour light period before the results shown in the graph were recorded. The results were compared to the stem cells in control mice under normal conditions of 12 hours of light (▭) and 12 hours of darkness (■).



f (i). Outline the effect of CXCL12 inhibition on the incidence of diabetes. [2]

f (ii). Suggest how the breakdown of CXCL12 in the bone marrow may be related to diabetes. [1]

g. Evaluate the possible use of isoprenaline in the treatment of diabetes. [2]

h. Research is being conducted into treatment for diabetes based on stem cells. Discuss the ethical issues involved in stem cell research. [3]

a (i). State the maximum number of stem cells per ml blood in the control mice. [1]

a (ii). Determine the number of hours of light needed to release the maximum number of stem cells in blood in control mice. [1]

b. Distinguish between the trends shown in the number of stem cells per ml blood by the mice subjected to jet lag and the control mice. [2]

c. Other studies suggest that a greater number of blood stem cells for transplantation may be obtained if they are harvested during darkness. [2]

Evaluate this hypothesis.

d. Explain how the amount of mRNA for CXCL12 gives an indication of the amount of protein CXCL12 produced. [1]

e. Compare the effect of isoprenaline and clenbuterol with the normal release of stem cells and the production of mRNA for CXCL12. [3]

Markscheme

f (i). CXCL12 inhibition initially decreases occurrence of diabetes;

in the first 25 / up to 26/27/28 weeks;

CXCL12 inhibition does not prevent occurrence of diabetes (just delays it) / eventually the same level of diabetes

f (ii). CXCL12 breakdown allows stem cell mobilization reducing incidence of diabetes / stem cells from the bone marrow can regenerate the islets (in pancreas)

g. isoprenaline is an inhibitor of CXCL12 / inhibits synthesis of CXCL12 mRNA;

delays onset of diabetes / allows stem cell mobilization / allows islet regeneration;

does not cure the disease;

h. suffering of patients could be reduced / diseases could be cured / better treatments developed / might replace treatment with cure;

(possibly) less cost than treating disease/diabetes;

specific example of ethical conflict; (*e.g. patient groups support use of embryotic stem cells but religious groups oppose* / *different views on the moral status of an embryo*)

restrictions on research in some countries due to cultural/religious traditions;

still in experimental stages / risk to patient;

specific example of risk; (*e.g. stem cells developing into tumours* / *rejection* / *need for immunosuppressants*)

death of early-stage embryos / production of embryos for stem cell research;

use of stem cells from adults/patients could overcome these objections;

a (i) 83 (*allow whole number answers in the range of 82 to 84*)

a (ii) 5 (*allow 4*)

Do not allow answers with two different numbers.

b. more stem cells are formed in control / jet lag reduces the release of stem cells into blood stream / greater range in control;

graph is rhythmic in control / control has more regular pattern;

greater number of stem cells produced in light period in control, whereas greater number in dark period in jet lag;

graph is shifted to the right in jet lag / stem cells are released later in time in jet lag;

c. (hypothesis supported in control) if stem cells are harvested towards the end of the dark period / (hypothesis supported) as stem cells start increasing in dark period;

(hypothesis not supported) <u>in control</u> as peak of stem cells occurs during light period/lowest number during dark period;

(hypothesis supported) if patient is jet-lagged as more stem cells are produced in dark period;

d. mRNA is translated to protein / involved in protein synthesis.

e. clenbuterol <u>and</u> isoprenaline both produce more stem cells than control;

clenbuterol releases fewer stem cells than isoprenaline / isoprenaline releases the most stem cells;

isoprenaline produces the least mRNA for CXCL12;

clenbuterol produces the same amount of mRNA for CXCL12 as control;

Examiners report

f (i) A similar pattern of student answers was seen in f, where many were picking each individual point on the graph, rather than giving an outline as asked. Students need to pay attention to the distinction between a "describe" and an "outline".

f (ii). In f(ii) students muddled the distinction between stem cells being produced and stem cells being released.

g. N/A

h. The ethical discussions in h were somewhat weak, with most gaining a mark for the death of early-stage embryos. Students appear to be using "fetus" and "embryo" interchangeably. Many statements were nebulous, for example referring to "playing God" without adequately unpacking its meaning. In bioethics, "playing God" refers to undertaking a controversial action unilaterally without adequate consultation with stakeholders and runs counter to the precautionary principle. In this expanded form, the notion of playing God would make for a good answer to a discuss question. Few mentioned the positive ideas of reduction of suffering.

a (i). In part a most students managed to give the correct answers for maximum number (between 82-84) of stem cells per ml of blood, though some misread the graph. The maximum number needed to be a whole number.

a (ii). The number of hours (5) needed to release the maximum number of cells was correctly identified by most, though some provided a longer amount of time.

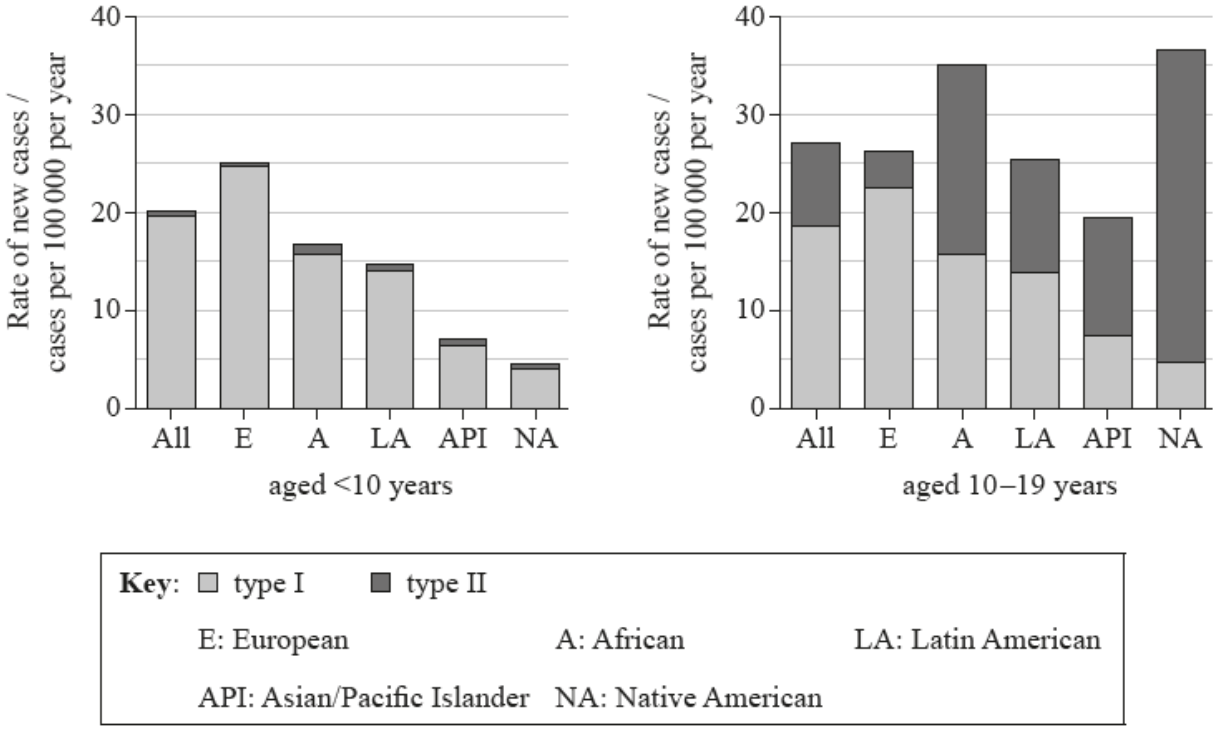
b. In b most gained either 1 or both marks. Some students described similarities when only the distinctions were required.

c. In c, weaker answers failed to state whether or not the hypothesis was supported or not. In addition others lost marks by failing to state whether they were referring to the control or the jet-lagged mice.

d. In d many candidates failed to make the connection between mRNA and translation, with the weakest answers describing a numerical relationship. A number misread the graph in terms of under what conditions the peaks and lowest points occurred.

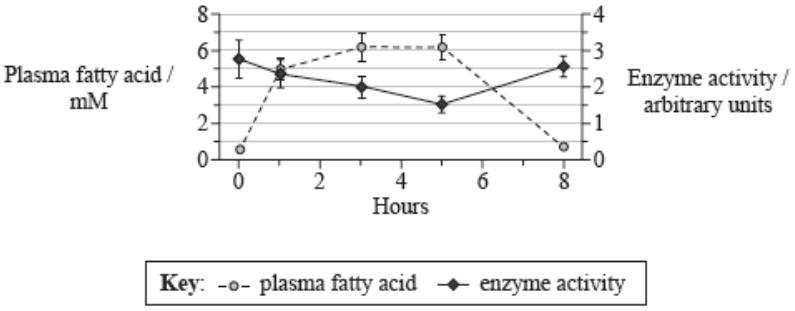
e. In e there was a tendency to give descriptive answers, stating figures from the graph, without drawing a comparison using comparative terms. As an example, "clenbuterol releases 40 stem cells" would not earn a mark, but "isoprenaline releases more stem cells than clenbuterol" is. Students must use clear comparative terms and be specific in their comparisons when there are multiple treatment groups.

Diabetes in Youth is a study that examined diabetes (type I and type II) among children and adolescents in the United States. The graphs show the rate per year of new cases of type I and type II diabetes among young people (aged less than 20 years) by ethnicity between 2002–2005.



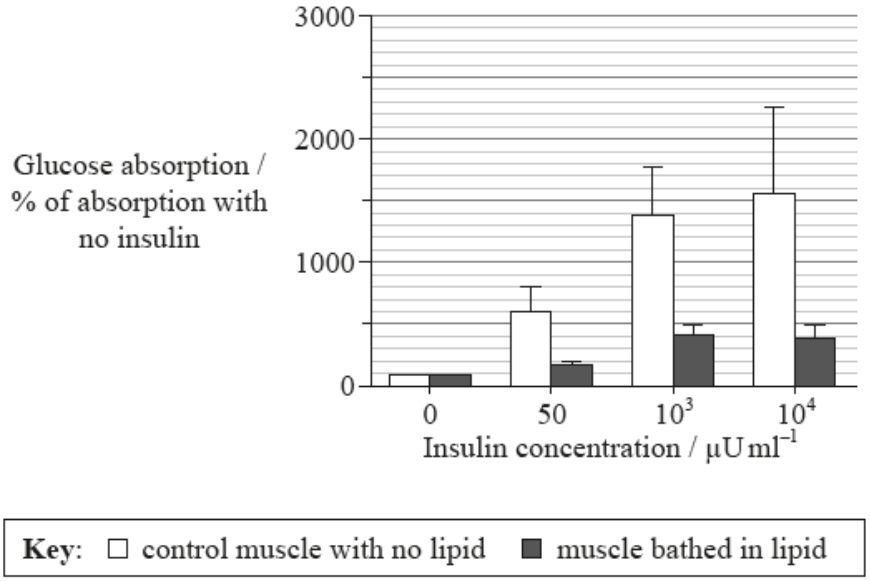
[Source: Adapted from www.cdc.gov/diabetes/pubs/estimates11.htm#fig2]

Skeletal muscle fibres normally respond to insulin by absorbing glucose. Failure of skeletal muscle to respond to insulin is a major factor in the development of type II diabetes. A study was undertaken to investigate the effect of plasma lipids on the process of glucose absorption in response to insulin by muscle fibers. Muscle was bathed in a lipid solution for 5 hours. The lipid was then washed out over the next 3 hours. The graph shows the level of plasma fatty acids and the activity of an enzyme involved in glucose absorption in response to insulin over the period of the study. (Values are means ± standard error)



[Source: Chunli Yu, *et al.* (2002), *The Journal of Biological Chemistry*, 277, pp. 50 230–50 236]

A further study was undertaken to look at the effect of increasing the concentration of insulin on glucose absorption in muscle bathed in lipids. A wide range of insulin concentrations were used in the same type of muscle. Glucose absorption was then measured after 5 hours.



[Source: Chunli Yu, *et al.* (2002), *The Journal of Biological Chemistry*, **277**, pages 50 230–50 236]

a. Identify, among young people aged 10–19 years, which ethnic group showed the highest rate of new cases of type I diabetes and type II diabetes. [1]

Type I diabetes:

Type II diabetes:

b. Determine the rate of new cases of type II diabetes among children of African ethnicity aged 10–19 years. [1]

c. Compare rates of diabetes between the two age groups studied. [2]

d. (i) Compare the relative proportions of type I and type II diabetes between the different ethnic groups. [3]

(ii) Suggest a reason for the different rates of type II diabetes among the ethnic groups.

e. State the relationship between plasma fatty acid level and enzyme activity. [1]

f. Calculate the percentage change of enzyme activity after 5 hours exposure to lipids. [1]

g. Discuss, using the data, whether the effect of lipids on this enzyme is reversible. [2]

h. Comment on the effect of increased insulin concentration on glucose absorption in the muscle bathed in lipid. [2]

i. Some investigators suggest that there is a strong relationship between high lipid diet and the body's response to insulin. Using the data provided, evaluate this hypothesis. [2]

Markscheme

a. *type I*: European / E

type II: Native American / NA

Both needed

b. *(accept range)* 18–20 (cases per 100 000)

c. type I shows same/similar pattern of rate in both age groups;

rates of type II were (much) greater among those aged 10–19 years than <10 years

d. (i) Europeans/E have lowest rate of type II / only Europeans/E (10+) have a higher rate for type I (than type II);

API/NA 10+ rate higher for type II (than type I);

LA/A rates for both similar at 10+;

NA(10+) has the lowest cases of type I but highest number of type II / NA under 10 have lowest rates for both types;

(ii) different genetic factors (affect fat metabolism);
(rise) due to increase in fat/carbohydrate intake/junk food/low in fibre;
"western" diet (in US) very different from traditional diets;

e. negative/inverse relationship/negative correlation / as one variable increases the other decreases / as plasma fatty acid increases, enzyme activity decreases / *vice versa*

f. (a decrease of) 45 (%) (accept answers in the range of 44 (%) to 47 (%))

g. yes, effect is reversible as activity returns to (approximately) original level (when lipids/fatty acids decrease);

when lipid/fatty acids washed out enzyme is more active/activity increases;

difference between starting and final levels of enzyme activity is insignificant because of error bars;

three hours/experimental time may be insufficient to reverse the effect;

h. increased insulin concentration causes more glucose absorption (up to 10^3 μU ml^{-1});

glucose absorption in muscle bathed in lipid always less than control;

no further increase/slight decrease in glucose absorption beyond 103 (μU ml^{-1}) insulin;

i. *Referring to first graph:*

plasma lipids lower activity of enzyme (needed for glucose absorption);

Referring to second graph:
more/higher glucose uptake with higher insulin levels in muscles without lipids
(compared to muscles bathed in lipids);
lipids reduce glucose absorption (even at raised insulin concentrations);
isolated muscle used in experiments so results may differ in whole organisms;

Examiners report

a. This was a data analysis question based around diabetes. Most gained the mark for the correct ethnic groups in (a), however, part (b) proved surprisingly difficult, with less than half of the candidates correctly calculating 19 cases (per 100, 000). In (c) most gained the mark for the (much) greater incidence of Type II amongst 10-19 year olds, but only the better candidates spotted the similarity between the incidences of Type I in both age groups. In the first part of (d) the better candidates could find at least one good comparison between the ethnic groups. The answer 'due to different diets' was a common vague answer in (d)(ii). More precision was expected, e.g. greater fat/carbohydrate intake.

   Most were able to state that the relationship was negative/inverse in (e), with weaker candidates trying to describe it using numbers from the graph. Stronger candidates correctly calculated the 45% decrease in part (f). There was no mark for the workings, but the numbers should have been taken from the right hand axis. Most were able to gain at least one mark for the discussion of reversibility in (g). Similarly in (h) most were able to link increased insulin concentration with more glucose absorption and in (i) most gained a mark, although the fact that the plasma lipids lowered the activity of the enzyme was not well spotted.

b. This was a data analysis question based around diabetes. Most gained the mark for the correct ethnic groups in (a), however, part (b) proved surprisingly difficult, with less than half of the candidates correctly calculating 19 cases (per 100, 000). In (c) most gained the mark for the (much) greater incidence of Type II amongst 10-19 year olds, but only the better candidates spotted the similarity between the incidences of Type I in both age groups. In the first part of (d) the better candidates could find at least one good comparison between the ethnic groups. The answer 'due to different diets' was a common vague answer in (d)(ii). More precision was expected, e.g. greater fat/carbohydrate intake.

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f. [N/A]

g. This was a data analysis question based around diabetes. Most gained the mark for the correct ethnic groups in (a), however, part (b) proved surprisingly difficult, with less than half of the candidates correctly calculating 19 cases (per 100, 000). In (c) most gained the mark for the (much) greater incidence of Type II amongst 10-19 year olds, but only the better candidates spotted the similarity between the incidences of Type I in both age groups. In the first part of (d) the better candidates could find at least one good comparison between the ethnic groups. The answer ‘due to different diets’ was a common vague answer in (d)(ii). More precision was expected, e.g. greater fat/carbohydrate intake.

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h. This was a data analysis question based around diabetes. Most gained the mark for the correct ethnic groups in (a), however, part (b) proved surprisingly difficult, with less than half of the candidates correctly calculating 19 cases (per 100, 000). In (c) most gained the mark for the (much) greater incidence of Type II amongst 10-19 year olds, but only the better candidates spotted the similarity between the incidences of Type I in both age groups. In the first part of (d) the better candidates could find at least one good comparison between the ethnic groups. The answer ‘due to different diets’ was a common vague answer in (d)(ii). More precision was expected, e.g. greater fat/carbohydrate intake.

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i. This was a data analysis question based around diabetes. Most gained the mark for the correct ethnic groups in (a), however, part (b) proved surprisingly difficult, with less than half of the candidates correctly calculating 19 cases (per 100, 000). In (c) most gained the mark for the (much) greater incidence of Type II amongst 10-19 year olds, but only the better candidates spotted the similarity between the incidences of Type I in both age groups. In the first part of (d) the better candidates could find at least one good comparison between the ethnic groups. The answer ‘due to different diets’ was a common vague answer in (d)(ii). More precision was expected, e.g. greater fat/carbohydrate intake.

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a. Outline how and where energy is stored in plants. [4]

b. Ecologists sometimes display data from an ecosystem using a diagram called a pyramid of energy. Describe what is shown in pyramids of energy. [6]

c. Explain the control of body temperature in humans. [8]

Markscheme

a. a. glucose (from photosynthesis) stored as starch;

b. starch stored (as granules) in chloroplast/in plastids;

c. (starch stored) in seeds/storage roots/stem tubers;

d. stored as lipids/oils;

e. (lipid/oils storage) in seeds;

f. lipids store twice as much energy per gram as starch;

b. a. pyramid of energy shows the flow of energy from one trophic level to the next (in a community);

b. units of pyramids of energy are energy per unit area per unit time/kJ m^{-2} yr^{-1};

c. bar width is proportional to the energy stored (in the biomass) in that trophic level;

d. the first/lowest trophic level is producers;

e. second level is primary consumers/herbivores;

f. third level of secondary consumers/carnivores;

g. only a small amount (10 to 20 %) of energy of one level is passed to the next;

h. bar width/energy stored in the trophic level decreases (proportionally) as you go up each level;

i. pyramid shows that there is a limit to the length of food chains;

Award any of the above marking points to a correctly drawn and clearly labelled pyramid.

c. a. normal body core temperature constant/36.5 to 37.5°C; (*accept single values within this range*)

b. regulated by negative feedback/homeostatic mechanisms;

c. hypothalamus is the centre of thermoregulation;

d. hypothalamus sends impulses to the body to increase/decrease temperatures;

e. release of sweat (by sweat glands in the skin) if skin temperature rises;

f. evaporation of water cools the body; (*concept of evaporation must be mentioned*)

g. heat is transferred by blood;

h. transfer of heat from body core in blood to surface;

i. if temperature rises, increased flow of blood/heat to the skin/vasodilation of skin blood vessels/arterioles; (*do not accept veins, arteries or capillaries*)

j. if temperature drops, decreased flow of blood/heat to the skin/vasoconstriction of skin blood vessels/arterioles; (*do not accept veins, arteries or capillaries*)

k. shivering increases heat production (in muscles);

l. example of one behavioural mechanism; (*eg reducing activity (to lower body temperature) / reducing exposed surfaces (to reduce heat loss*)

Examiners report

a. This was a popular question among candidates.

For part a, many did not earn full marks and this appeared to be due to a lack of knowledge of this part of the syllabus.

b. This was a popular question among candidates.

For b, many candidates easily earned the marks for parts d, e and f requiring them to identify examples of organisms that occupy the various trophic levels of organisms. A number lost marks due to poorly constructed diagrams especially in relation to the bars not being drawn proportionately. Few correctly indicated the correct units for productivity of the various trophic levels.

c. This was a popular question among candidates.

Part c was generally well done. Most used the term homeostasis and negative feedback in their answers. A number have a misconception regarding vasodilation and vasoconstriction as they are writing that arterioles move toward and away from the skin surface. Few discussed the role of the hypothalamus in regulated body temperature.

---

a. Describe the production of semen. [6]

b. Explain the structure and function of the placenta. [8]

c. Outline the hormonal control of birth. [4]

Markscheme

a. sperm produced by meiosis;

in testis/seminiferous tubules;

sperm are stored/mature in the epididymis;

sperm able to swim;

seminal vesicles add fluid;

(seminal) fluid rich in fructose;

prostate gland adds fluids;

fluid rich in proteolytic enzymes/citric acid/acid phosphatase/lipids/minerals;

(semen) contains basic amines/alkaline substances;

which neutralizes acid/hostile environment of the vagina;

b. disc-shaped structure;

connected to the fetus by an umbilical cord;

placenta is embryonic and maternal tissue;

placental villi increase the surface area (for exchange);

fetal capillaries in placenta/placental villi;

inter-villous spaces/sinuses through which mother's blood flows;

fetal and mother's blood do not mix / small distance between fetal and mother's blood;

transfer of foods/nutrients/glucose from mother to fetus;

fetal gas exchange/transfer of oxygen from mother to fetus;

transfer of excretory/waste products/CO_2 from fetus to mother;

transfer of antibodies/hormones from mother to fetus;

secretion of estrogen/progesterone/HCG;

Allow reference to embryo instead of fetus throughout.

c. at about 38 to 40 weeks pregnancy/end of pregnancy/progesterone levels decrease;

removes inhibition of oxytocin secretion;

(oxytocin) released from (posterior) pituitary;

oxytocin stimulates uterus contraction;

cervix widens/dilates;

increase in oxytocin increases rate and intensity of contractions;

positive feedback;

Examiners report

a. The production of semen and spermatogenesis were confused by many candidates. Better candidates were able to give a very impressive account of the process, though many focused too much on spermatogenesis rather than on the other components of semen.

b. In spite of the fact that the structure and function of the placenta seem to have been on several papers in the last few years, they were not very well-known at all. Most gained some function marks for gas exchange and transfer of nutrients and waste, but the structure was not well known.

c. Most knew something of the hormonal control of birth. However weaker candidates started at conception and seemed intent on explaining the whole process.

---

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

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

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

Markscheme

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

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

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

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

d. matrix;

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

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

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

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

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

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

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

Examiners report

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

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

surface area.

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

---

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

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

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

Markscheme

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

esophagus – connected to top of stomach;

stomach – connected to small intestine;

small and large intestines – connected to each other;

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

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

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

b. milk contains lactose / lactose is milk sugar;

lactose is broken down to glucose and galactose;

by (the enzyme) lactase;

which is lacking in people with lactose intolerance;

lactose-free milk is sweeter than milk containing lactose;

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

can be added directly to milk;

immobilized in beads / biotechnological techniques;

ultrafiltration of milk to remove lactose;

c. ultrafiltration occurs in the glomerulus;

basement membrane acts as a filter;

preventing proteins/cells from passing;

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

to proximal convoluted tubule (PCT);

(where there is) selective reabsorption;

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

(in PCT most) water reabsorbed;

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

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

collecting duct has role in osmoregulation;

ADH regulates the amount of water reabsorbed;

substances not reabsorbed are eliminated as urine;

Examiners report

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

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

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

---

a (i) Blood transports molecules throughout the body. State where the blood absorbs hormones. [1]

a (ii) Blood transports molecules throughout the body. State where the blood absorbs carbon dioxide. [1]

b. Describe **three** features of alveoli that adapt them to gas exchange. [3]

c. Explain how the structure of capillaries relates to their functions. [3]

Markscheme

a (i) endocrine glands / named endocrine gland (*e.g. pancreas/hypothalamus/pituitary/ovary/testes*)

Do not accept gland alone.

a (ii) cells / tissues / named cells/tissue (*e.g. muscles* / *muscle tissue* / *muscle cells* / *epithelial tissue* / *other reasonable example*)

Do not accept alveolus or named organ.

b. high density of capillaries surrounding alveoli;

large surface area due to shape / large number of alveoli;

thin walls / walls one cell thick; (*do not accept membranes*)

moist layer covering the (inner) surface of the alveoli;

*Award **[2 max]** for a list of features.*

c. capillaries' walls thin/one cell thick for better diffusion; (*do not accept membranes*)

small diameter/narrow lumen to fit into small places/between cells;

small diameter for greater surface area for molecular exchange;

pores between cells of the walls so plasma can leak out;

pores between cells of the walls allow phagocytes/immune components to enter tissues;

only one red blood cell allowed to pass at a time for efficient oxygen uptake;

Examiners report

a (i) 3 a (i) and (ii) were well answered by many though a significant minority wrote only "gland" in 3 a (i).

a (ii) A surprising number of candidates incorrectly wrote the alveoli as the source where carbon dioxide is brought into the blood.

b. Candidates did well on this question. Many mistakenly wrote that mucus was secreted by alveoli which would impact gas exchange negatively and many failed to appreciate the collective impact of many alveoli giving rise to a larger surface area. In both b and c, many students referred to membranes as being one cell thick. The term alveolar membrane is ambiguous as many students do not sufficiently differentiate between cell membranes and the wall of the alveolus. The term "wall" is preferable to membrane. Again students must not confuse this with cell walls.

c. Candidates did reasonably well here though answers were poorly articulated when describing pores and many referred to leakage only rather than indicating the materials including plasma and phagocytes that would leave through the pores. Many did not specifically link the structures of capillaries to their functions. Students need to recognize that an explanation requires reasons and mechanisms so the demands of question 3c were greater than those of 3b where only a description was required. In both 3b and 3c many students needed to more careful with word choice as they referred to the alveolus and capillary as being one cell thick when both structures have thin walls that are one cell thick.

---

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.

Defence occurs on the micro and macro levels.

a. Describe the functioning of immunoglobulins. [3]

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

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

Markscheme

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

b. variety of binding sites / variable regions for binding

c. specific to antigens on bacteria/viruses/pathogens

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

e. attracts phagocytes/macrophages to engulf pathogen

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

Award marks for an annotated diagram.

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

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

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

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

e. antibiotics fail to protect if bacteria have resistance

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Examiners report

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

---

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

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

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

Markscheme

a. contraction / movement;

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

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

transport;

defence / immunity;

as hormones / communication;

DNA packing / histones;

other function;

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

a protease/pepsin digests proteins into polypeptides;

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

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

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

amino acids absorbed by diffusion/active transport;

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

(amino acids absorbed) into capillaries;

blood carries amino acids throughout the body;

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

cells use amino acids to build proteins;

assimilation is when amino acids become part of a cell;

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

c. motor neuron stimulates the muscle fibre;

calcium ions are released (from sarcoplasmic reticulum);

calcium ions bind to troponin;

tropomyosin moved / binding sites of actin revealed;

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

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

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

ADP released;

myosin heads move actin filaments toward centre;

making sarcomere shorter;

calcium ions are reabsorbed (into the sarcoplasmic reticulum);

muscle fibre relaxes;

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

Examiners report

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

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

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

The human circulatory system is structured to serve the organs and tissues of the body efficiently.

a. Explain how circulation of the blood to the lungs and to other systems is separated in humans and what the advantages of this separation are. [8]

c. Distinguish between the composition of the blood of the renal artery and the blood of the renal vein. [3]

Markscheme

a. a. double circulation / pulmonary and systemic circulations

b. heart is a double pump / heart has separate pumps for lungs and other systems / left and right sides of heart are separate / no hole in heart (after birth)

c. deoxygenated blood pumped to the lungs and oxygenated to other organs/tissues/whole body (apart from lungs)

d. each side of the heart has an atrium and a ventricle

e. left ventricle/side pumps blood to the systems/tissues and right ventricle/side pumps blood to the lungs

f. left atrium receives blood from the lungs and right atrium receives blood from systems/tissues

g. left ventricle pumps blood via the aorta and right ventricle pumps blood via the pulmonary artery

h. left atrium receives blood via the pulmonary vein and right atrium receives blood via the vena cava

i. lungs require lower pressure blood / high pressure blood would damage lungs

j. high pressure required to pump blood to all systems/tissues apart from lungs

k. pressure of blood returning from lungs not high enough to continue to tissues / blood has to be pumped again after returning from lungs

l. oxygenated blood and deoxygenated blood kept separate / all tissues receive blood with high oxygen content/saturation

Points may be earned using an annotated diagram.

c. a. less urea/excretory waste products/creatinine in renal vein

b. less oxygen in the renal vein

c. more carbon dioxide in renal vein

d. less glucose in renal vein

e. concentration of sodium ions/chloride ions/pH at normal level in the renal vein whereas it is variable in renal artery

f. solute concentration/osmolarity/water balance at normal level in the renal vein whereas it is variable in renal artery

Allow answers in a table format. For all these mark points accept the converse as long as it is clear whether the artery or vein has the higher amount.

Answers relating to volume and pressure are not relevant to the question.

Examiners report

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

---

a. Predict the genotypic and phenotypic ratios of the possible offspring of a male hemophiliac and a female carrier using suitable symbols for the [3]

alleles in a Punnett grid.

Genotypic ratio:

Phenotypic ratio:

b. Hemophilia is a disorder where the ability to control blood clotting or coagulation is impaired. Describe the process of blood clotting. [2]

Markscheme

a. correctly constructed Punnett square with correct gamete genotypes;

e.g.

(male gametes) \ (female gametes)	X^H	X^h
X^h	X^HX^h	X^hX^h
Y	X^HY	X^hY

genotypic ratio: 1 X^HX^h : 1X^hX^h : 1 X^HY : 1 X^hY; (can be inferred from cells of Punnett square)

phenotypic ratio: 1 female hemophiliac : 1 female carrier/non-hemophiliac :
1 male hemophiliac : 1 male normal/non-hemophiliac / 50 % hemophiliac :
50 % non-hemophiliac;

*Allow ECF. Award **[2 max]** if notation used does not indicate sex linkage, i.e. if cross is Hh×hh.*

b. release of clotting factors from platelets/damaged cells;

conversion of prothrombin to thrombin;

thrombin catalyses the conversion of fibrinogen into fibrin;

(insoluble) fibrin (net) captures blood cells;

Examiners report

a. The words "hemophiliac" and "female carrier" should have been enough to remind the students of sex linkage. Many did not know that hemophilia was sex-linked The candidates were allowed an "error carried forward" mark if they had completed the Punnett square correctly but with the incorrect parents.

b. The blood clotting process was not at all well known. Many interchanged fibrin and fibrinogen in terms of function and properties.

---

a. Outline what is meant by homeostasis. [4]

b. Describe how body temperature is maintained in humans. [6]

c. Explain the processes occurring in the kidney that contribute to osmoregulation. [8]

Markscheme

a. maintaining (stable) internal environment/conditions;

within (narrow) limits;

example (*e.g.* body temperature / blood pH / blood glucose / water / CO_2 concentration);

levels of these variables are monitored (internally);

negative feedback mechanisms / *OWTTE*; (*reject if positive feedback included*)

involves hormonal / nervous control;

b. maintained close to 36.7/37°C/98.6°F ;

heat is transferred/distributed in body by blood;

hypothalamus contains thermoreceptors;

hypothalamus monitors temperature/sends message to effectors/causes response;

(vaso) dilation of skin arterioles warms skin/cools body;

(vaso) constriction of skin arterioles retains body heat;

skin/sweat glands produce sweat to cool the body when overheated;

removal of heat through evaporation of sweat;

shivering generates heat / increased metabolism / hair erection to retain heat;

example of behavioural change to warm/cool the body to thermoregulate;

c. osmoregulation is maintenance of water balance of blood/tissues;

loop of Henle creates hypertonic conditions in the medulla;

water reabsorbed as filtrate passes through collecting duct;

hypothalamus monitors/controls water balance/content of blood;

controls secretion of ADH by (posterior) pituitary gland;

ADH is released when blood too concentrated/too little water/hypertonic;

ADH makes the collecting duct more permeable to water;

due to more aquaporins;

more water reabsorbed (in response to ADH);

less water in urine/urine more concentrated/urine hypertonic;

no/less ADH when blood too dilute/too much water/hypotonic;

collecting duct less permeable/less water reabsorption/more water in urine;

Examiners report

a. Answers were variable here with some exemplary accounts but also some very vague ones. Weaker candidates tended to omit the idea that homeostasis is control of the internal environment. Some candidates suggested instead that it involves a person controlling their external environment. There was also some confusion between homeostasis and response to external stimuli such as touching a hot object.

b. There were some relatively easy marks to be earned here but even so answers ranged from zero to five. A persistent area of confusion is vasoconstriction and dilation. Fewer candidates than at one time now write about blood vessels moving closer to the skin or further away but some still suggest that it is capillaries in the skin that actively constrict or dilate, rather than the arterioles that serve them.

c. There were some long and detailed answers to this part of the question, although the eight marks could be scored in relatively short answers if they were confined to the processes in the kidney that vary depending on the condition of the blood. There was no need to write about ultrafiltration in the glomerulus or selective reabsorption in the proximal convoluted tubule. Processes occurring in the loop of Henle should have been mentioned, but only so as to explain how they establish hypertonic conditions in the medulla and allow the production of hypertonic urine. The main focus of the answer should have been on how the secretion of ADH is regulated and how this hormone controls the rate of water reabsorption in the collecting duct.

---

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

b. Outline how the human body responds to high blood glucose levels. [5]

c. Explain the role of the nephron in maintaining the water balance of the blood in the human body. [8]

Markscheme

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

a. left ventricle/right ventricle – both left and right ventricles must be shown but the mark can be awarded if either is correctly labelled. The left must be thicker walled than right and both must be larger than the atria;

b. left atrium/right atrium – both left and right atria must be shown with thinner walls than ventricles, but the mark can be awarded if either atrium is correctly labelled;

c. atrio-ventricular valves/tricuspid and bicuspid valves – positioned between atria and ventricles, with both labelled and tri/bicuspid correct if these names are used;

d. semi-lunar valves –shown at the start of the aorta and pulmonary artery, with the cusps facing in the right direction;

*Award **[1]** for any two blood vessels clearly drawn and correctly labelled.*

aorta – shown connected to the left ventricle;

pulmonary artery – shown connected to the right ventricle;

pulmonary vein – shown connected to the left atrium;

vena cava – shown connected to the right atrium;

b. a. (high blood glucose levels) detected by pancreas islet cells/beta cells;

b. insulin secreted in response (to high blood glucose/glucose above threshold level);

c. insulin stimulates cells to absorb glucose;

d. glucose used in cell respiration (rather than lipids);

e. glucose converted to glycogen (in liver/muscle cells);

f. glucose converted to fatty acids/triglycerides/fat;

g. negative feedback process;

c. a. ultrafiltration in the glomerulus produces (large volumes of) filtrate;

b. 80%/most of water in filtrate is (always) (re)absorbed in proximal convoluted tubule;

c. water reabsorbed from filtrate in descending loop of Henle;

d. pituitary gland secretes ADH if blood solute concentration is too high;

e. ADH makes the collecting duct/distal convoluted tubule more permeable to water;

f. ADH moves aquaporins into the membranes (of cells in the tubule wall);

g. more water reabsorbed from filtrate/into blood due to ADH;

h. blood becomes more dilute / small volume of urine with high solute concentration;

i. with low/no ADH less water is reabsorbed in the collecting duct;

j. blood becomes more concentrated / large volume of dilute urine;

k. water reabsorption in collecting duct due to high solute concentration of medulla;

l. active transport of Na^+ ions from filtrate in ascending limb of loop of Henle;

Examiners report

a. Drawings of the structure of the heart were variable. Given the complexity it is not surprising that there were few flawless drawings. Common errors were to make the walls of left and right ventricles equal in thickness and in some cases also to make the atrium walls no less thick than the ventricles. A curious feature of some diagrams was to show a thin vertical ruled line instead of the septum between the left and right hand sides of the heart. This is not the ideal way to show the structural relationship between left and right sides and of course leaves nowhere for conducting fibres to run. Sections through the left and right ventricles of the heart show that the septum is equal in thickness to the rest of the left ventricle wall. Most candidates named at least some of the attached blood vessels correctly, though in some cases marks were lost because it wasn't clear enough which chamber was served by which vessel.

b. There was another very common error in this part of Question 8: many candidates stated that the hypothalamus monitors blood glucose concentration and when the concentration is high sends messages to the pancreas to stimulate insulin secretion. This is incorrect. The beta cells in the pancreatic islets monitor blood glucose concentration directly and the hypothalamus is not involved. This mistake might have been due to confusion with ADH secretion, but it was so common that it seems likely that teaching material used in some schools includes the error.

c. Many candidates found this question hard and answers were varied but mostly not very strong. Candidates were expected to describe the formation of glomerular filtrate by ultrafiltration and the reabsorption of nearly all water from it in the proximal convoluted tubule and the descending limb of the loop of Henle. They were then expected to explain the secretion of varying amounts of ADH and the effect this has on the reabsorption of water in the collecting duct and changes to the volume and concentration of urine excreted. Many candidates included a diagram of the nephron but did not use it to help answer the question. Some candidates did score full marks but in other answers there were many gaps and misunderstandings, which perhaps we should expect because of the complexity of kidney physiology.

a. Outline how reproductive isolation can occur in an animal population. [3]

b. Describe the different cell types in the seminiferous tubules that are involved in the process of spermatogenesis. [4]

c. Explain the roles of specific hormones in the menstrual cycle, including positive and negative feedback mechanisms. [8]

Markscheme

a. a. can be sympatric or allopatric

b. temporal isolation by members of difference populations reproducing at different times *OWTTE*

c. behavioural isolation by difference in courtship behaviours *OWTTE*

d. geographic isolation by a population being separated by river/mountain/barrier to contact
An example of a geographic barrier is required.

e. polyploidy

b. a. spermatogonia «2n» are undifferentiated germ cells *OWTTE*

b. spermatogonia mature and divide «by mitosis» into primary spermatocytes «2n»

c. primary spermatocytes divide by meiosis I into secondary spermatocytes «1n»

d. secondary spermatocytes divide by meiosis II into spermatids «1n»

e. spermatids differentiate/mature into spermatozoa/sperm

f. Sertoli/nurse cells provide nourishment/support to these developing cells

g. Leydig/interstitial cells produce testosterone

c. a. anterior pituitary/hypophysis secretes FSH which stimulates ovary for follicles to develop

b. follicles secrete estrogen

c. estrogen stimulates more FSH receptors on follicle cells so respond more to FSH

d. increased estrogen results in positive feedback on «anterior» pituitary

e. estrogen stimulates LH secretion

f. estrogen promotes development of endometrium/uterine lining

g. LH levels increase and cause ovulation

h. LH results in negative feedback on follicle cells/estrogen production

i. LH causes follicle to develop into corpus luteum
OR
follicle cells produce more progesterone

j. progesterone thickens the uterus lining

k. high progesterone results in negative feedback on pituitary/prevents FSH/LH secretion

l. progesterone levels drop and allow FSH secretion

m. falling progesterone leads to menstruation/degradation of uterine lining

*Award **[5 max]** if no reference to feedback is made*.

Examiners report

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

---

b. Explain how skeletal muscle contracts. [8]

c. Active skeletal muscle requires a good supply of oxygen. Outline the mechanism of ventilation in the lungs. [6]

Markscheme

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

a. sliding filament model / filaments/actin and myosin slide past each other;
b. action potential/depolarisation/nerve impulse arrives at end of motor neurone;
c. neurotransmitter/acetylcholine released causing action potential (in muscle fibre);
d. sarcoplasmic reticulum releases calcium ions;
e. calcium ions cause binding sites on actin/for myosin to be exposed;
f. myosin heads bind to sites on actin/form cross-bridges;
g. myosin (head) moves actin filament using energy from ATP;
h. actin moved towards the centre of sarcomere/M line/M band;
i. sarcomeres shortened;
j. (binding of) ATP causes release of myosin head from actin;
k. conversion of ATP to ADP and Pi causes myosin heads to change angle;
l. cycle (of events) repeated (during muscle contraction);
Accept the above points in annotated diagrams.

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

during inhalation:
a. external intercostal muscles contract moving rib cage up and out;
b. diaphragm contracts becoming lower/flatter;
c. increase in volume and decrease in pressure (of thorax);
d. air flows into lungs as atmospheric pressure is higher;

during exhalation:
e. internal intercostal muscles contract so ribs move in and down;
f. diaphragm relaxes and returns to domed shape;
g. decrease in volume and (therefore) increase in pressure (of thorax);
h. air moves out until pressure in lungs falls/is equal to atmospheric pressure;
i. abdominal muscles can be used to make a stronger/forced exhalation;

Examiners report

b. Contraction of muscles

Perhaps because Question 6 tended to attract many of the weaker candidates, accounts of muscle contraction were mostly very poor. Some candidates missed the point and wrote about reflex arcs instead. The way in which ATP releases its energy and how this energy is then used was very rarely correct. Diagrams helped with some answers but only where there was full annotation.

c. Ventilation

Stronger candidates wrote full and accurate accounts and often scored full marks but others wrote error-strewn and confused accounts. A popular misconception was that the gas breathed in is oxygen and the gas breathed out is carbon dioxide.

---

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.

HIV was discovered in 1981 and is now one of the most serious causes of disease in the world. It causes the immune system to fail, leaving the patient vulnerable to other infections.

b. Outline how monoclonal antibodies are produced. [2]

c. Discuss how the HIV virus is transmitted. [2]

d. Explain why antibiotics are ineffective against viruses. [2]

Markscheme

b. B lymphocytes are produced in laboratory animal after injection with an antigen;

animal cells/these cells are fused with tumour cells (to form hybridomas which) produce antibodies;

c. HIV virus transmitted by body secretions/semen/blood/across placenta;

transmitted by infected blood transfusions/intravenous drug users;

mainly by sexual activity/promiscuity;

d. antibiotics block metabolic pathways / work only on bacteria;

viruses reproduce using their hosts' metabolic pathways / do not have their own metabolic pathways;

Examiners report

b. The topic of monoclonal antibodies was not well known by the candidates of many centres. Well prepared candidates gained the two marks, although some lost a mark for fusing antibodies rather than B lymphocytes with the tumor cell.

c. With some very weak candidates this part gave them nearly all of their marks.

d. As with part b, some candidates did not know why antibiotics are ineffective against viruses.

---

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

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

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

Markscheme

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

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

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

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

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

to allow diffusion / to make food soluble;

so foods can be absorbed into the bloodstream/body;

so foods can move from bloodstream into cells;

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

hydrolysis is aided by enzymes;

hydrolysis requires water;

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

proteins/polypeptides (hydrolysed) to amino acids;

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

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

Competitive inhibitors:
have a similar shape to the substrate;
bind to/attach to/enter the active site;

block/compete for occupation of the active site / prevent substrate binding;
example (*e.g.* succinate dehydrogenase by malonate);
increase in substrate concentration reduces inhibition / graph showing this;

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

Examiners report

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

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

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

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

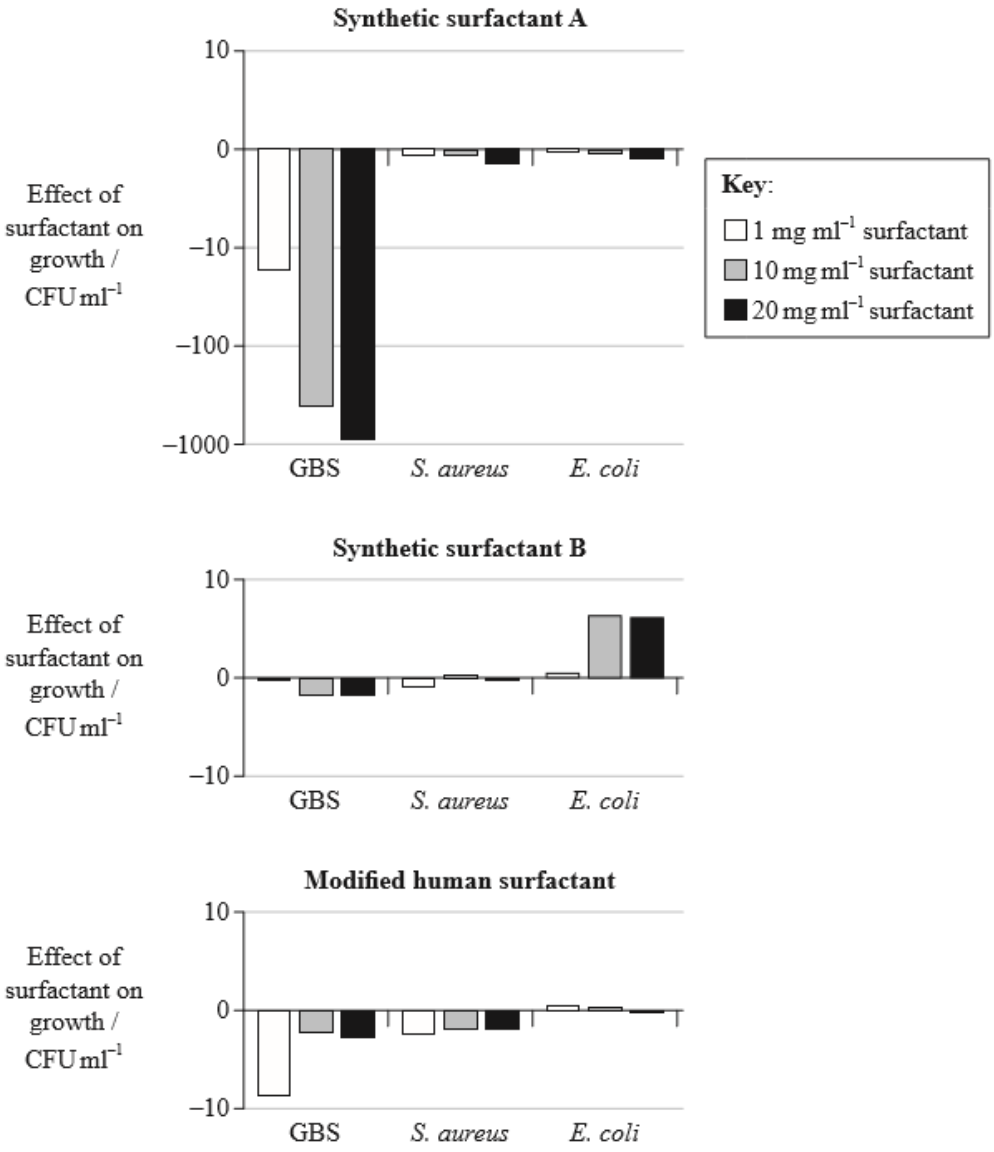
The table shows some of the components of different surfactant preparations.

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

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

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

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



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

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

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

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

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

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

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

Markscheme

a. natural human (surfactant)

b. main component of all surfactants is phospholipids;

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

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

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

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

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

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

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

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

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

f. (*hypothesis supported as*)

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

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

Examiners report

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

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

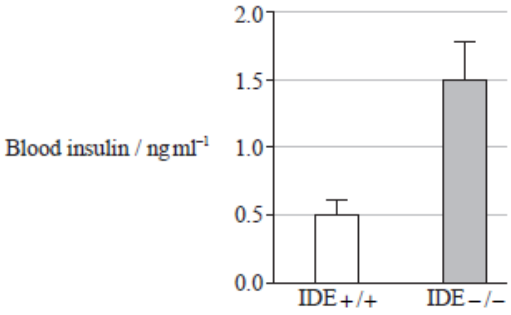
c. Part (c) was the hardest part of Question 1. Most candidates described or drew a diagram of a phospholipid bilayer. This was not accepted as the question stated that the phospholipids formed a film on the surface of the moist lining of the alveoli. The phospholipids will therefore be in contact with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

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

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

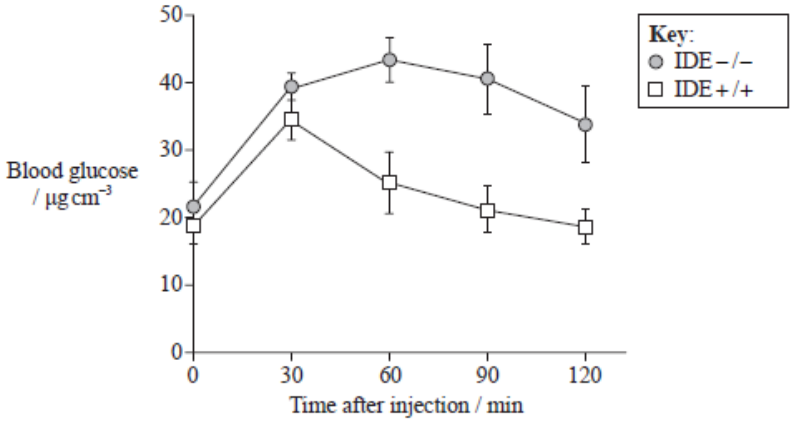
f. Part (f) was quite challenging. Some candidates failed at the first hurdle, which was to look at the table of data at the start of Question 1 to find out the protein content of each of the three surfactants expected in the answer here. Having done this, it was not too difficult to see that there was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

Type II diabetes is having an impact on the health of many individuals worldwide. The condition is characterized by elevated levels of both insulin and glucose in the bloodstream. Some animals produce an insulin-degrading enzyme (IDE) which breaks down the insulin molecule. In an attempt to develop a model of type II diabetes, genetically modified mice have been developed. In these mice, both copies of the IDE gene have been removed (IDE – /–) and the enzyme is not produced. The bar chart below shows the mean concentration of insulin in the bloodstream of IDE – /– mice and that of control mice (IDE + /+).



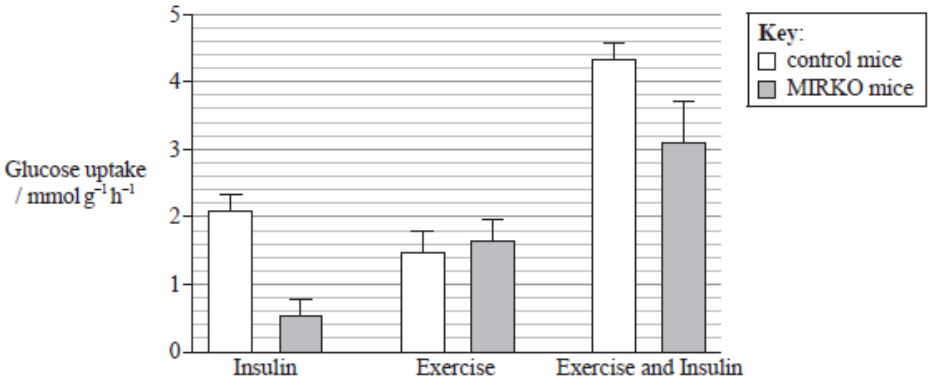
[Source: adapted from R W Farris, *et al.*, (2003), *PNAS*, **100**, pages 4162– 4167]

In another experiment, groups of IDE – /– and IDE + /+ mice were injected with a fixed amount of glucose. The levels of blood glucose were measured at various time intervals following glucose injection. The data are shown in the graph below.



[Source: adapted from R W Farris, *et al.*, (2003), *PNAS*, **100**, pages 4162–4167]

In animals that do not have type II diabetes, insulin stimulates glucose uptake into skeletal muscle. Glucose uptake into skeletal muscle is also stimulated when skeletal muscle is exercised. Genetically modified mice have been developed in which the insulin receptor is not produced in skeletal muscle and these are known as MIRKO mice. In another experiment, the effect of insulin and exercise on glucose uptake in skeletal muscle from control and MIRKO mice was examined. The results are shown in the bar chart below.



[Source: adapted from J F Wojtaszewski, *et al.*, (1999), *Journal of Clinical Investigation*, **104**, pages 1257–1264]

a. Calculate the percentage increase between mean blood insulin levels in IDE + /+ mice and those in IDE – /– mice. [1]

b. Explain the difference in blood insulin concentrations between the two groups of mice. [2]

c. Distinguish between the response of the two groups of mice to the injection of glucose. [2]

d. Deduce, with a reason, whether transgenic IDE –/– mice are an appropriate model of type II diabetes. [2]

e. Explain the reason for the differences in insulin-stimulated glucose uptake between control mice and MIRKO mice. [2]

f. Distinguish between the effects of insulin alone and exercise alone on glucose uptake in skeletal muscle of MIRKO mice. [1]

g. Evaluate, using the data, whether exercise would be an appropriate therapy for human patients with type II diabetes. [3]

h. State which cells secrete insulin and the organ in which they are located. [2]

Cells:

Organ:

i. State the name of **one** hormone other than insulin involved in the regulation of blood glucose. [1]

Markscheme

a. 200 %

b. IDE -/- mice do not have the enzyme to break down insulin; *(accept converse)*

therefore insulin levels higher in IDE -/- mice / lower in IDE +/+ mice;

c. in IDE +/+ mice, glucose (levels in the blood) peaks / starts to reduce after 30 minutes / in IDE -/- mice, glucose levels remain high for longer / continues to rise for 60 minutes;

blood glucose level is always higher in IDE -/- mice than in IDE +/+ mice / blood glucose level in IDE +/+ mice decreases rapidly to original level but remains high in IDE -/- mice ;

d. both blood glucose and insulin levels are higher in IDE -/- mice / high blood glucose levels and insulin levels are seen in type II diabetes;

due to this, IDE -/- mice are a good model for type II diabetes; *(to award this mark answer needs justification)*

e. (in both cases) when insulin is present control mice are better at taking up glucose than MIRKO mice;

no insulin receptors in skeletal muscle of MIRKO mice; *(accept converse)*

f. exercise increases glucose uptake more than insulin

*Award **[0]** for simply just restating figures.*

g. exercise stimulates glucose uptake into muscle / exercise lowers blood glucose;

exercise is more effective in reducing blood glucose in MIRKO mice (than in control mice);

exercise and insulin combined are more effective in both (MIRKO and control) mice;

exercise combined with insulin would be an appropriate therapy;

h. *cells*: β cells (in islets of Langerhans);

organ: pancreas;

i. glucagon / adrenaline / cortisol

Examiners report

a. Over half of the candidates failed to calculate the percentage increase of 200%.

b. The majority of candidates made the correct conclusion about insulin levels. However the second mark was often missed through lack of reference to the enzyme.

c. The action verb 'distinguish' was poorly understood, with too many candidates simply restating the figures. Surprisingly the mark for stating that the concentration was always higher for the IDE -/- mice was rarely seen.

d. Many candidates missed the fact that both blood glucose concentration and insulin concentration are elevated in type II diabetes (stated in the introduction to the question), as happens in the IDE -/- mice, so they are a good model.

e. Weaker candidates did not read the question correctly, also writing about exercise which was not required.

f. As in part e, weaker candidates did not distinguish between the correct bars, answering for the control mice.

g. Most gained a mark for saying that exercise does stimulate uptake. However only the better candidates took this further to say that the combined effect of insulin and exercise were far better than the insulin alone.

h. A surprising number of candidates were not able to state beta cells and the pancreas.

i. Most gave glucagon (although not always spelled correctly) some also correctly gave adrenalin/epinephrine or cortisol.

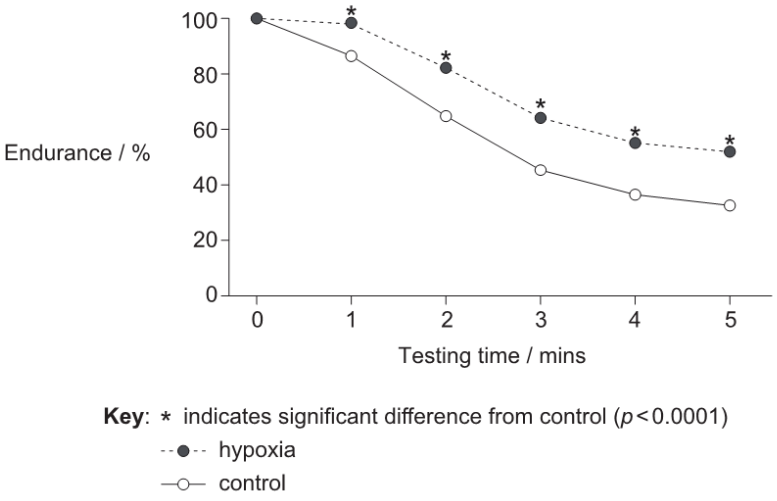
Hypoxia is a condition in which tissues of the body are deprived of an adequate oxygen supply. A study was carried out in rats to examine the effects of continuing hypoxia on the structure of the diaphragm, and to determine whether nitric oxide is implicated in adaptation of the diaphragm to hypoxia.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

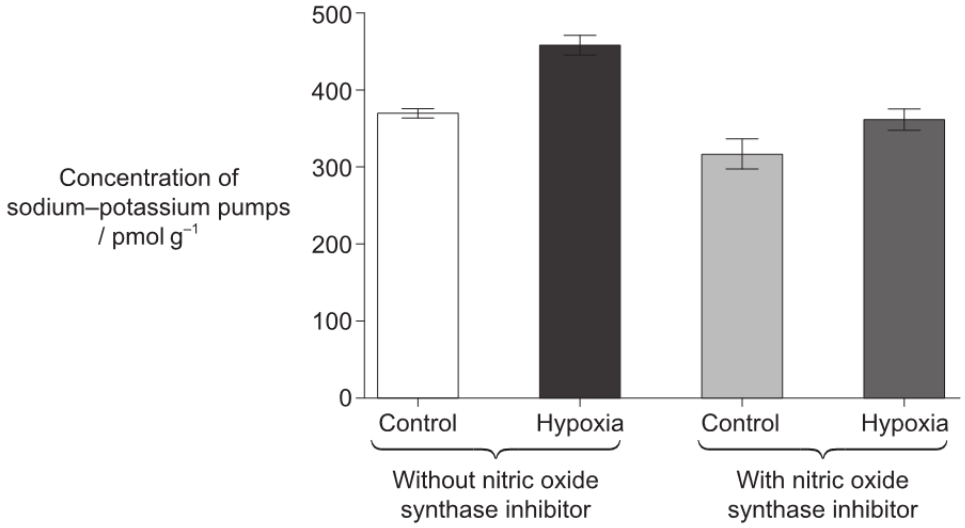
Key: * indicates significant difference from corresponding control value (student's *t*-test, $p < 0.05$)

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.



[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

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. resting potential 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

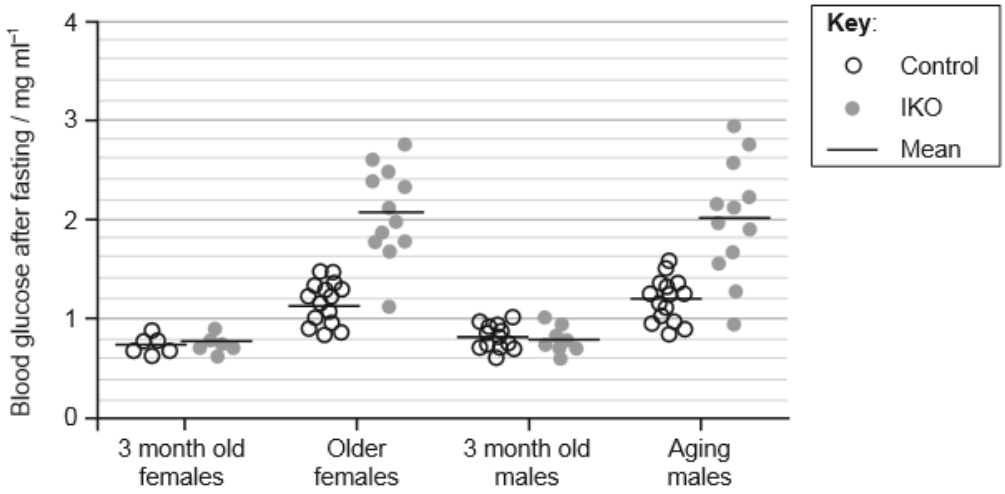
[Max 2 Marks]

Examiners report

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

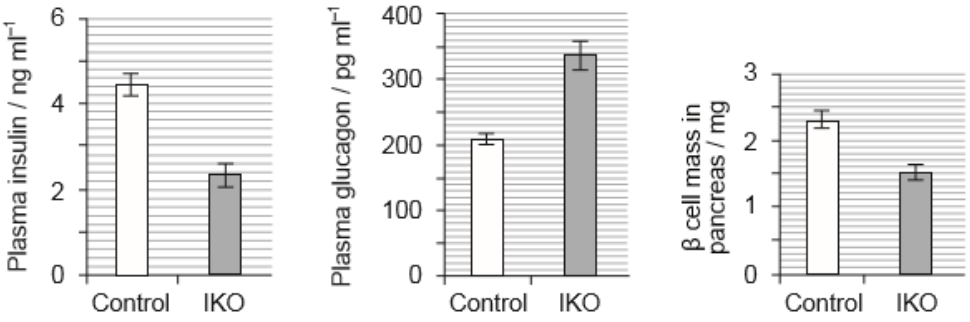
Diabetes is often associated with the failure of the β (beta) cells in the pancreas, but it is unclear what actually causes this failure. FoxO1 is a protein which acts as a transcription factor to regulate the expression of genes involved in cell growth. FoxO1 also regulates increase in number and differentiation in cells such as pancreatic β cells.

A study was conducted using mice lacking the gene for FoxO1 in β cells (IKO) as well as normal (control) mice. Blood glucose levels after fasting were compared for four groups of mice: young (3 months old) male mice, young (3 months old) female mice, older females (who have had several pregnancies) and aging males (16–20 months).



[Source: Chutima Talchai, Shouhong Xuan, Hua V. Lin, Lori Sussel, Domenico Accili, "Pancreatic β Cell Dedifferentiation as a Mechanism of Diabetic β Cell Failure", *Cell*, Volume 150, Issue 6, 14 September 2012, Pages 1223–1234]

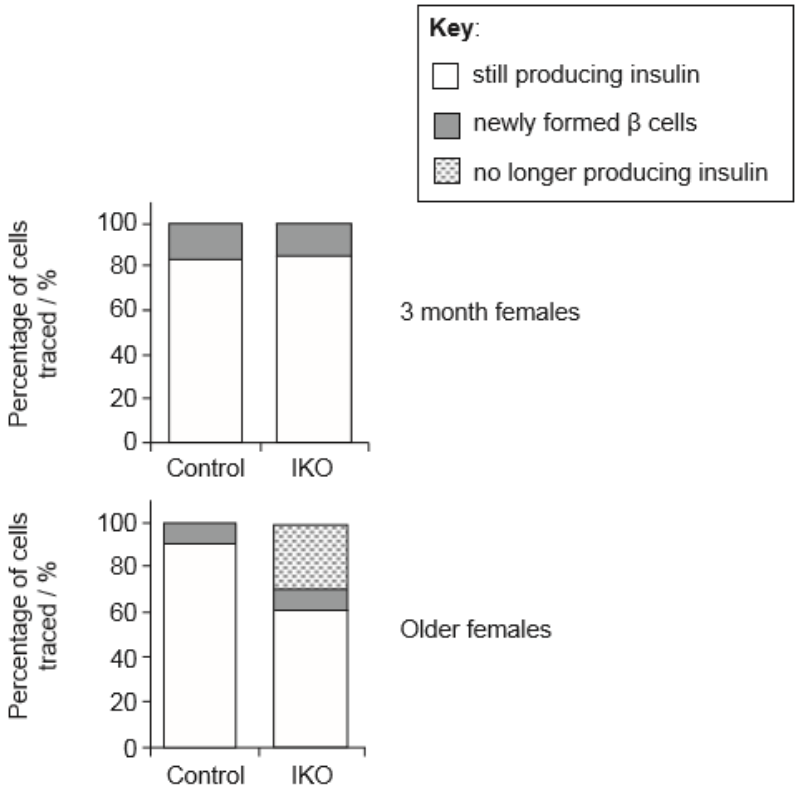
The levels of pancreatic hormones and β cell mass in older female control mice and older female IKO mice lacking FoxO1 were then investigated.



[Source: Chutima Talchai, Shouhong Xuan, Hua V. Lin, Lori Sussel, Domenico Accili, "Pancreatic β Cell Dedifferentiation as a Mechanism of Diabetic β Cell Failure", *Cell*, Volume 150, Issue 6, 14 September 2012, Pages 1223–1234]

To examine whether the changes observed were due to lack of β cell function or change in β cell number, investigators traced marked cells. They were able to determine if cells were:

- still producing insulin
- newly formed β cells
- no longer producing insulin.



[Source: Chutima Talchai, Shouhong Xuan, Hua V. Lin, Lori Sussel, Domenico Accili, "Pancreatic β Cell Dedifferentiation as a Mechanism of Diabetic β Cell Failure", *Cell*, Volume 150, Issue 6, 14 September 2012, Pages 1223–1234]

a. Compare blood glucose levels after fasting in young control mice and young IKO mice without FoxO1. [2]

b. Aging and having pregnancies are considered to be physiological stresses. Deduce the effect of stress on blood glucose levels. [2]

c. Outline the relationship between blood glucose levels after fasting and lack of FoxO1 in the mice studied. [2]

d. Calculate the percentage difference in β cell mass of the IKO mice compared to the control mice. [2]

e. State the correlation between lack of FoxO1 and pancreatic hormones in mice. [1]

f. State which group of cells showed the least change in the mice studied. [1]

g. Deduce the effects of aging on the distribution of cell types in mice. [2]

h. A hypothesis has been suggested that diabetes is caused by β cells losing their ability to act as β cells, not by the death of β cells. In other words they dedifferentiate. [2]

Using all the information provided, discuss whether the data support this hypothesis.

i. When there are high blood glucose levels, more FoxO1 is found in the nucleus of the cell than in the cytoplasm. Suggest a role of FoxO1 considering this and the data. [2]

Markscheme

a. similar/same/nearly same (means)/very small difference/both at a low level;

means/averages (all) close to 0.8 mg ml^{-1};

differences not (statistically) significant;

similar/same/nearly same range/spread of data;

All marking points are comparisons between control and IKO mice. Do not award marks for comparisons between male and female mice.

b. stress causes increase (in mean blood glucose/sugar);

older mice/males/females / aging mice show the increase;

*Reject answers that **only** compare control and IKO mice or **only** compare male and female mice.*

c. in young mice/3 month old mice lack of FoxO1/IKO/fewer beta cells does not affect/has little effect on blood glucose/sugar;

in older females/aging males blood glucose/sugar (much) higher with lack of FoxO1/IKO/fewer beta cells;

d. *Award **[1]** for an answer:*

accept either 35 / 34.8 / 34.78 *(this answer may be expressed as a negative)* **OR** 53 / 53.3 / 53.33;

Do not award the mark if more than two decimal places shown or if the answer is incorrectly rounded up or down.

*Award **[1]** for working, accepting any of the following:*

e. lack of FoxO1 (correlates) with low/decreased insulin and high/increased glucagon levels.

f. newly formed β cells

Accept if newly formed beta cells in IKO mice but not in control mice only.

Reject all answers apart from the first given and any comparisons between IKO and control mice, rather than between younger and older mice.

g. *All marking points are deductions based on comparing older females with 3 month females and on the assumption that any changes in % are due to aging.*

newly formed β cells fewer/reduced/smaller % (in control/IKO mice);

cells still producing insulin (slightly) more/increased/higher % in controls;

cells still producing insulin fewer/reduced/smaller % in IKO mice;

cells no longer producing insulin only in older IKO mice;

Accept answers where IKO mice are referred to as mice without FoxO1 and control mice are referred to as mice with FoxO1.

h. *supported in older IKO mice/older mice lacking FoxO1 by:*

cells no longer producing insulin present (only) in older IKO mice/mice lacking FoxO1;

(type 2) diabetes/high blood glucose/lower insulin in older IKO mice/mice lacking FoxO1;

not supported by:
lower mass of β cells in older IKO mice/mice lacking FoxO1;
no drop/small rise/small change in cells producing insulin in older control mice;

Candidates must make it clear in their answer to (h) whether the data is in support of the hypothesis or against. Evidence can be included for and against.
Answers should specify whether the data is from older IKO mice or from older control mice. If the age is not specified in the answer, penalise for one of the marking points but not any others.

i. promotes transcription of/expression of genes;

for differentiation/growth/mitosis/cell division in β cells / for making insulin;

represses transcription of/expression of genes;
for making glucagon;

Examiners report

a. This proved to be quite a discriminating first question with relatively few candidates scoring both marks. There were two common faults in answers: comparing males and females rather than control and IKO mice and describing very small differences in means as though they were significant. Candidates should be encouraged to pick out significant trends from data and here it was that the four means being compared were all almost the same.

b. Answers to this question were very varied and as in the previous question, some candidates made the wrong comparison. Here the comparison should have been between young and old mice, not between males and females or IKO and control mice. The data showed significantly higher blood glucose concentrations in older mice than in younger, leading to the deduction that stress increases blood glucose levels.

c. Generally candidates fared better here, with most making the correct comparison of IKO with control mice. However, the data showed a clear difference between younger and older mice and answers were expected to include it. As in (a) some answers did not distinguish between significant and insignificant differences. The mean in young females was higher in the IKO than the control groups but the difference was insignificant so it was not appropriate to say that all IKO means were higher than controls except in young males.

d. The wording of this question proved to be ambiguous, so a mark scheme was devised that allowed any valid interpretation and method of calculation. About half of candidates calculated one of the accepted answers. Marks were lost unnecessarily by some candidates, either for not showing any working, or for rounding up or down the answer in the wrong direction.

e. There was some concern among teachers that it is not possible to deduce a correlation from present/absent data, but candidates mostly did not have difficulty understanding what was expected here. A very common mistake was to give an answer for pancreatic hormones in general rather than for insulin and glucagon separately as was essential because the lack of Fox01 had opposite effects on the two pancreatic hormones.

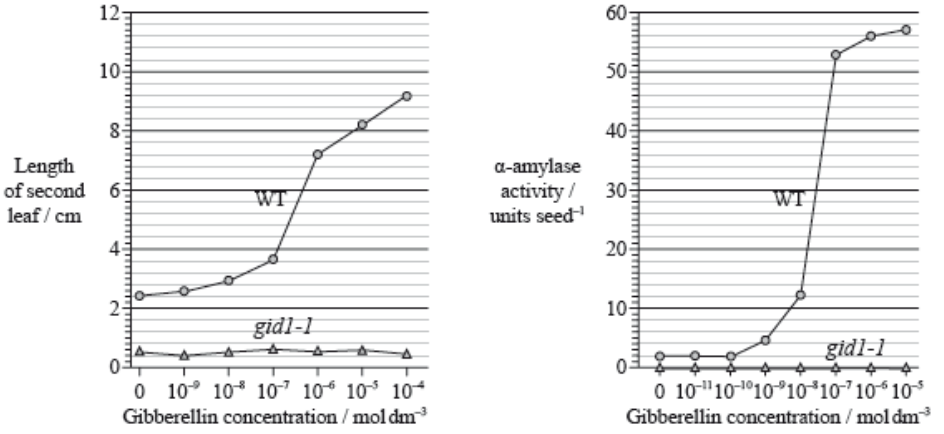
f. About half of candidates answered this question successfully. To answer it correctly candidates had to realise that the change referred to was between the younger and older mice and that the answer had to be valid for both control and IKO mice as neither was specified. A common error was to answer with a type of mouse, such as older females rather than a group of cells.

g. This question was generally well answered with candidates able to make at least one and sometimes two valid comparison between the percentages of cell types in younger and older mice and thus what the effects of aging are. For most of the answers it was necessary to specify either control or IKO mice as the trends were different.

h. This question was intended to encourage candidates to bring together conclusions from the various data sources in the question, in order to evaluate a hypothesis. For nearly all candidates this proved to be too hard a task. Nevertheless, many candidates made some valid points and these were rewarded with marks. As so often in discussing a hypothesis there were valid arguments both for and against the hypothesis.

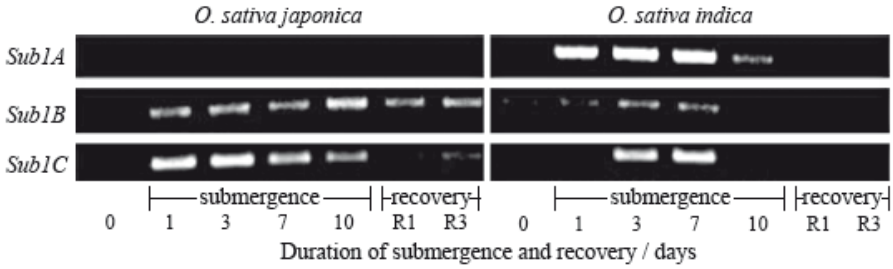
i. Candidates found this question very difficult and only a small number were able to use the information in the stem of the question about Fox01's role as a transcription factor, together with the effects of a lack of Fox01 shown by the data in the question, to suggest a possible role.

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



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

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

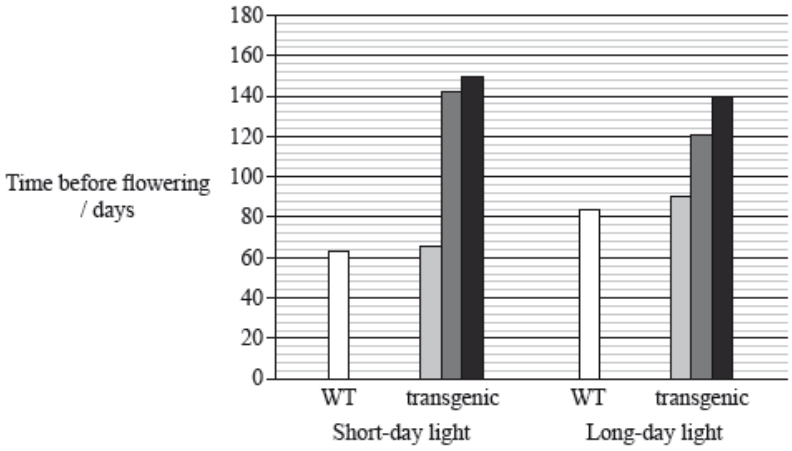


[Source: Adapted from "Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice" (2006) Kenong Xu, Xia Xu, Takeshi Fukao, Patrick Canlas, Reycel Maghirang-Rodriguez et al. Nature, 442, pp. 705—708. Adapted by permission from Macmillan Publishers Ltd (c) 2006.]

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

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

- –/– do not have the overexpressed *OsGI* gene
- +/– are heterozygous for the overexpressed *OsGI* gene
- +/+ are homozygous for the overexpressed *OsGI* gene.



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

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

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

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

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

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

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

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

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

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

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

Markscheme

a(i). *gid1-1*

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

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

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

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

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

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

c(i) *Sub1C*

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

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

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

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

d. a. *Sub1A*;

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

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

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

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

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

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

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

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

Accept numerical answers if they are making a clear comparison.

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

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

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

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

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

Examiners report

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

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

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

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

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

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

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

e(i). Most answered correctly that it increased the time before flowering.

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

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

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

---

a. The image shows a transverse section of an intestinal wall at 100 x magnification. [2]

[Source: Ed Reschke/Getty Images]

Identify the tissues labelled I and II on the image.

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

b. All motor neurons use acetylcholine to activate skeletal muscle. Explain the effect of neonicotinoid pesticides in insect synapses in the central nervous system. [3]

c. Resistance to neonicotinoid pesticides has been observed in some insects. [2]

Describe briefly how this resistance could have arisen in populations of insects.

Markscheme

a. I and II are both muscle

circular and longitudinal

b. Neonicotinoid pesticides are similar to nicotine «chemically»

Bind to nicotinic/acetylcholine receptors

Not broken down by «acetyl» cholinesterase
OR
binding is irreversible

Prevents/blocks acetylcholine binding

Blocks transmission from CNS *Reject slows transmission.*
OR
blocks signals going to muscle
OR
muscle contraction blocked
OR
causes paralysis

c. Mutations «for resistance in some insects» *Do not award mark if the answer implies directed mutations or that the pesticide causes the mutation.*

«Mutation causes» breakdown of pesticide/detoxification of pesticide/changes to receptor site

Natural selection for resistance *Do not accept natural selection if not in context.*
OR
resistant insects survive and reproduce
OR
non-resistant killed leaving only resistant insects

Do not accept answers that use the term immunity instead of resistance.

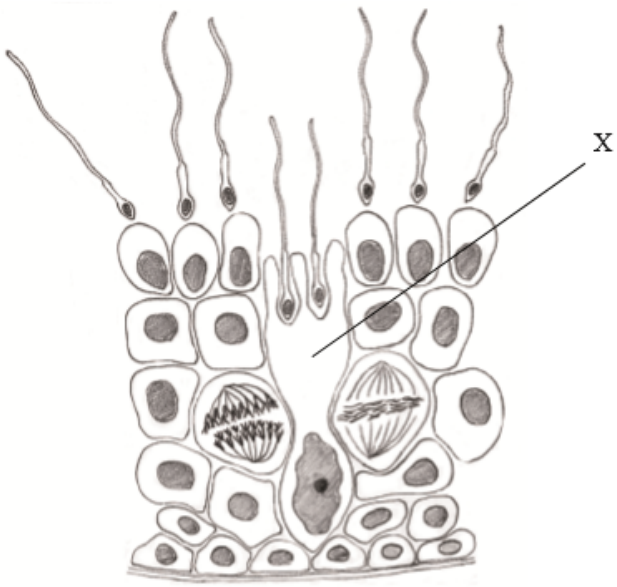
Examiners report

a. This was possibly the least successfully answered question on the paper. Very few candidates were able to name the two tissue layers. In retrospect it was probably unreasonable to use two marks for a small and perhaps insignificant aspect of the programme. Candidates were expected to see that layer II was circular muscle because of the orientation of the muscles cells in this transverse section. In practice almost no candidates did this. A few knew that I and II were circular and longitudinal muscle. No penalty was made for getting these layers the wrong way round but even so very few marks were awarded. Many candidates were clearly guessing and in some cases the answers showed a misunderstanding of the organs being a group of tissues. These candidates suggested a wide range of answers in including types of cells or parts of cells.

b. This application was not well known by the majority but even without specific knowledge of neonicotinoid pesticides it was possible to score some marks by sensible use of the information provided in the question and wider biological understanding. This type of pesticide is under intense research at the moment because of its effect on bees so it is a topical example of the nature of science.

c. Many candidates included the idea of a mutation in their answer and also that insects with genes for resistance would survive, breed and pass on these genes to their offspring. The only common mistake was to confuse resistance and immunity.

The diagram below shows a small portion of the tissue in a transverse section of a testis.



a. Outline the process of *in vitro* fertilization (IVF). [3]

b (i). Identify the cell labelled X. [1]

b (ii). Outline the function of this cell. [1]

c. Explain how meiosis results in genetic variation in gametes. [2]

Markscheme

a. mother receives hormone treatment/FSH to stimulate egg development;

eggs and sperm collected/harvested / eggs taken from ovary;

egg fertilized outside the body/in a dish/in a lab;

develops into embryo;

embryo(s) implanted (artificially) in mother's body/uterus;

Do not accept egg/fertilized egg/zygote implanted.

b (i). Sertoli cell / nurse cell

b (ii). nourishes maturing sperm(atozoa) / protects sperm from lymphocytes

c. crossing over in prophase 1/between chromatids;

random orientation of bivalents/homologous pairs in metaphase 1;

random orientation of chromatids/chromosomes in metaphase 2;

Examiners report

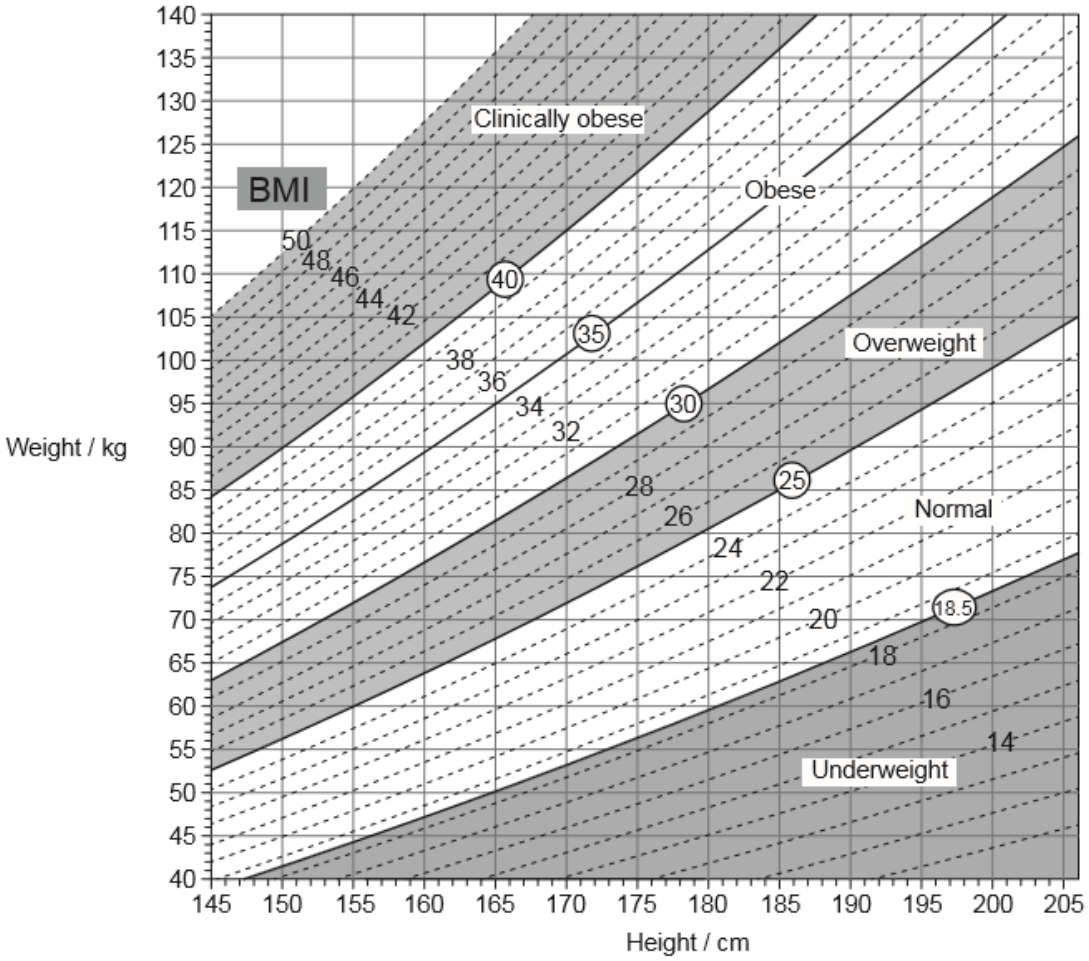
a. *In vitro* fertilization was understood well by many, though some answers were too vague to score some of the marks. The main area of misunderstanding was over what is put into the mother"s uterus. Many candidates thought that it was fertilized eggs or zygotes and others thought that it was blastocysts. The latter was accepted as they are at least embryos, but much older than the stage usually implanted; embryos at the four cell stage.

b (i) Many candidates were able to identify X as a Sertoli cell.

b (ii) Many candidates were able to identify X as a Sertoli cell, but not all could then state the function correctly.

c. This is a question that has often been asked but it is still an area that many candidates find difficult. Crossing over and independent orientation have sometimes been awarded marks in previous papers, if the terms are stated without any understanding of them being shown. In this paper the stage of meiosis was also required or some details of what the processes involve. As a result many candidates scored one mark only or none. Candidates should be encouraged to develop deep understanding of biological processes and not merely learn names; this will very much be the focus of the new IB Biology programme currently under development.

The image shows a nomogram.



a. (i) Using the nomogram, state the lower weight limit for a woman with the height of 155 cm who is classified as overweight, giving the units. [2]

Lower weight limit: .....

(ii) State a major health problem of the circulatory system that is correlated with obesity.

b. Draw the structure of a saturated fatty acid. [2]

c. Describe how the hormone leptin helps to prevent obesity. [3]

Markscheme

a. (i) 60 kg *Units required*.

(ii) coronary heart disease ***or*** coronary artery disease ***or*** thrombosis ***or*** stroke ***or*** hypertension ***or*** high blood pressure ***or*** atheroma ***or*** fatty deposits in arteries ***or*** plaque «in arteries» ***or*** arteriosclerosis ***or*** atherosclerosis

b. $[CH_2]_n$ / hydrocarbon chain with single bonds and at least four carbons

COOH head at one end ***AND*** three hydrogens on other end

The minimum of four carbons includes the end of the hydrocarbon chain and the COOH group.

c. Hormone produced by adipose/fat cells/adipose tissue. *Reject produced by fat. Reject produced by pituitary.*

Acts on/target cells are in the hypothalamus «of the brain»

Inhibits/reduces appetite/hunger
OR
causes feeling of satiety
OR
makes you feel full

More leptin with more adipose tissue/fat «storage» tissue/cells

Eat less/decreases/reduces food intake/in humans obese people can have leptin resistance

Examiners report

a. (i) Teachers expressed fears in G2 forms that candidates would be unable to use the nomogram through unfamiliarity. In fact most candidates successfully read off the value as instructed.

(ii) Many candidates could name a health problem of the circulatory system correlated with obesity, but vague terms, such as clogged arteries, were not allowed.

b. This was generally well answered. Most candidates showed a saturated hydrocarbon chain correctly and many also showed the carboxyl group.

c. Despite the fact that the hormone leptin is a new concept in the syllabus many candidates were able to answer this question accurately. In weak answers there was some confusion over the origin of leptin and its role.

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

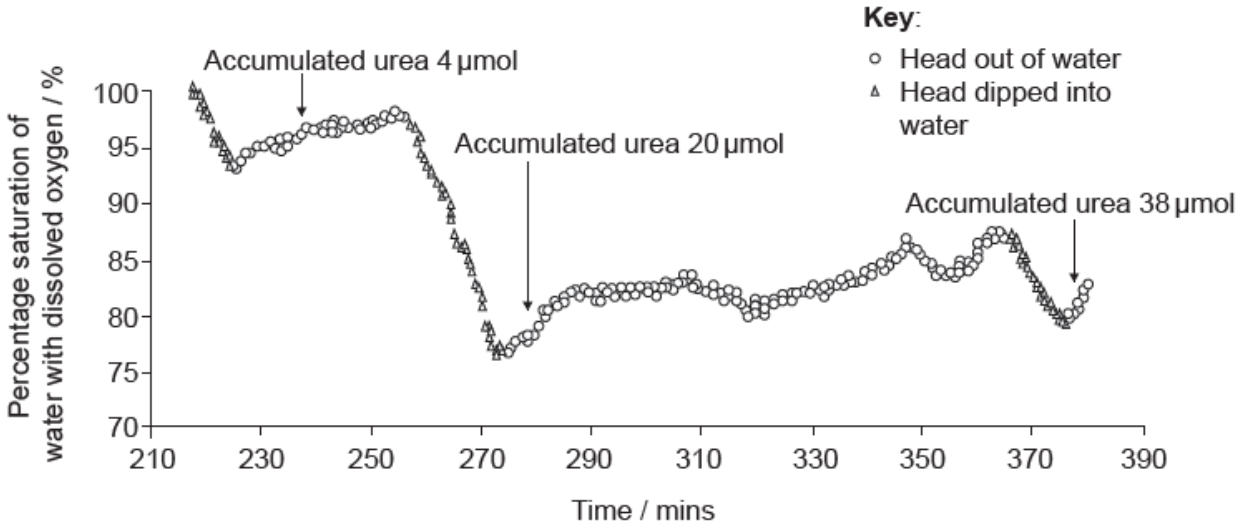
These turtles have fully developed lungs and kidneys, however, many microvilli have been discovered in the mouth of *P. sinensis*. A study was undertaken to test the hypothesis that oxygen uptake and urea excretion can simultaneously occur in the mouth.

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

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

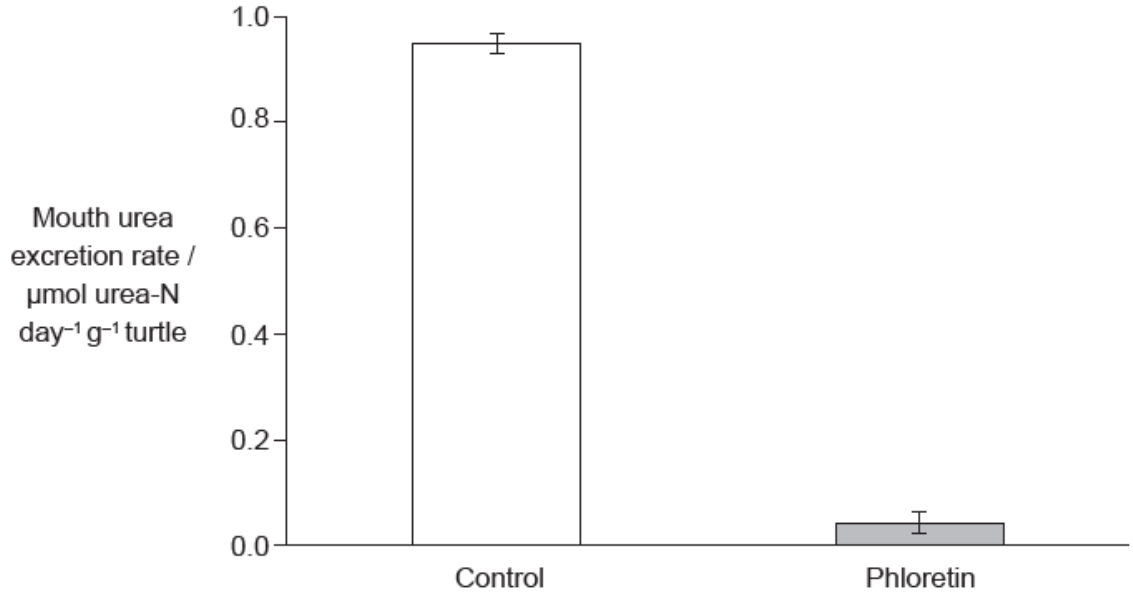
[Source: Reproduced with permission, Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723—3733. jeb.biologists.org. doi: 10.1242/jeb.068916]

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



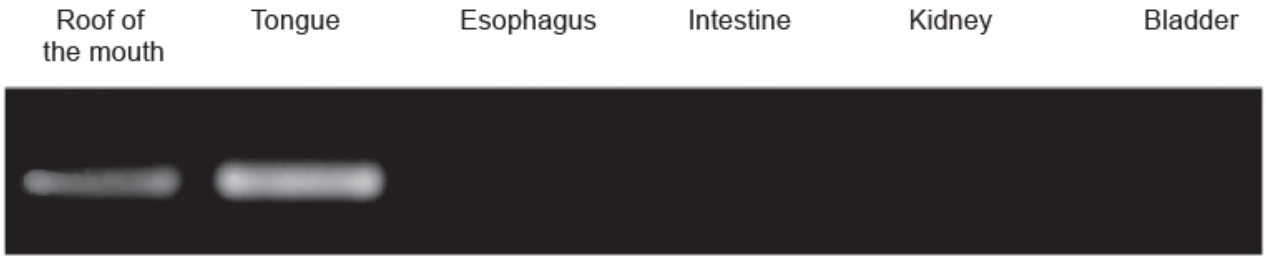
[Source: adapted with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733.]

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



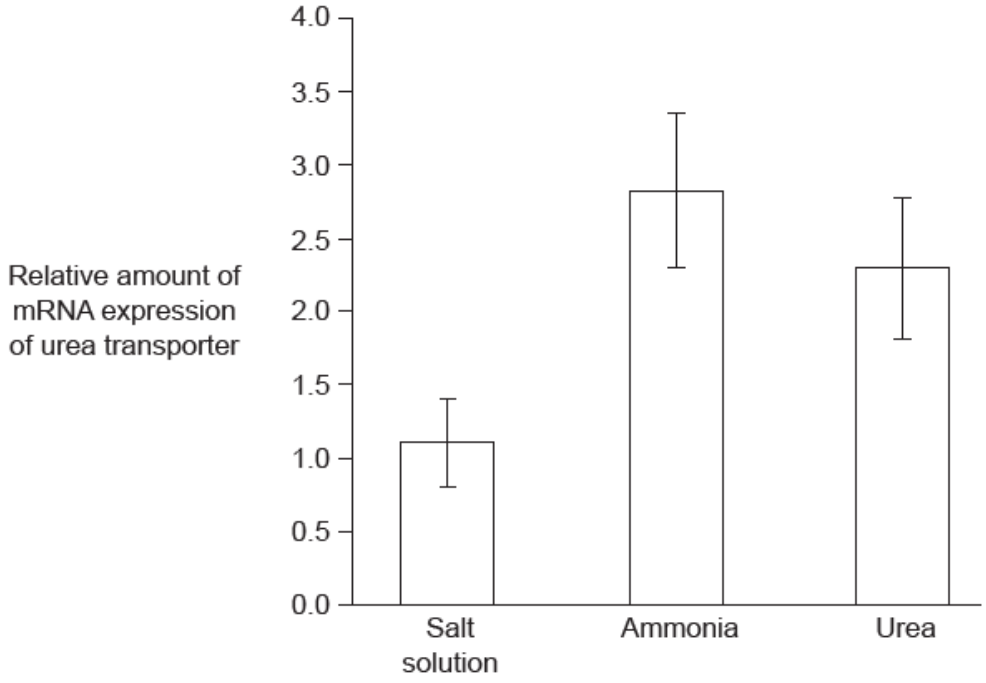
[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

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



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

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



[Source: © International Baccalaureate Organization 2017]

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

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

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

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

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

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

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

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

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

Markscheme

a. a. urea

b. for both mouth and kidney

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

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

b. both increased by 0.66 «$\mu mol^{-1}\ g^{-1}$ 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

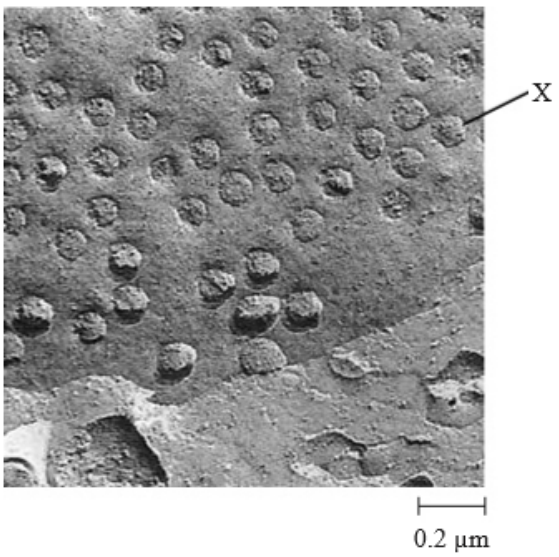
h. excretion with little/no loss of water

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]

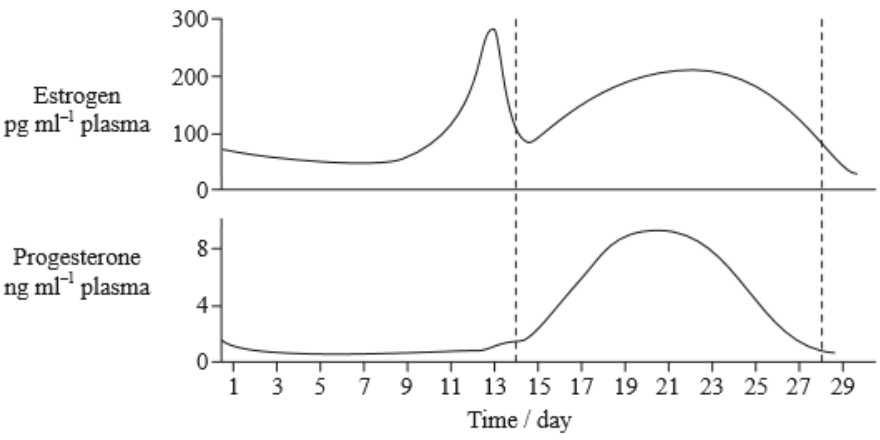
a (i) Calculate the power of magnification of the image. [1]

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.

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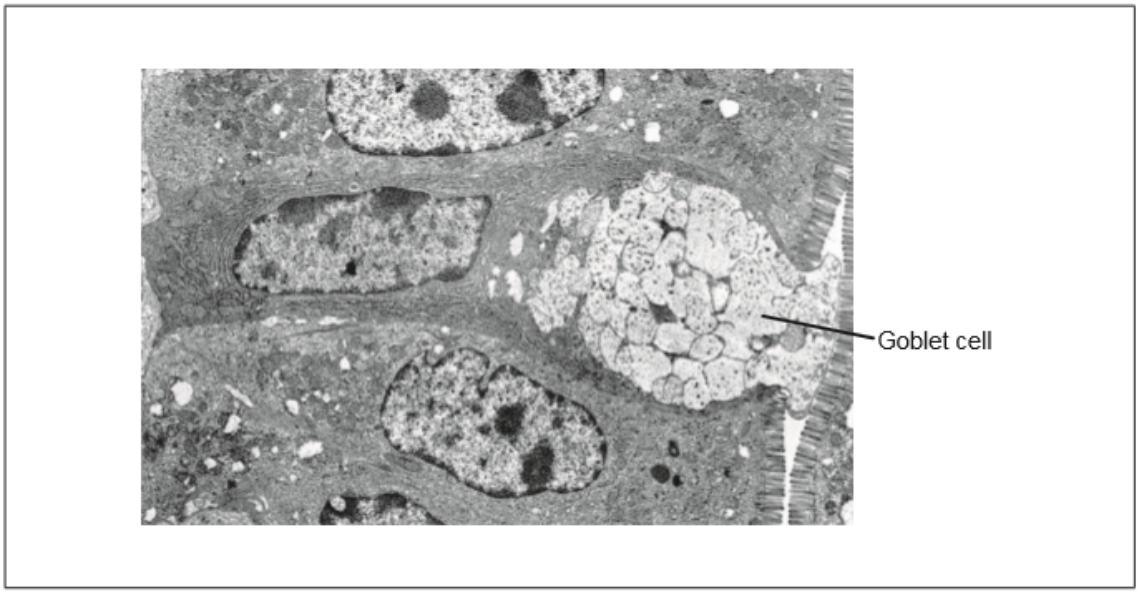
a. The image is an electron micrograph of the lining of the small intestine. [3]



[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.

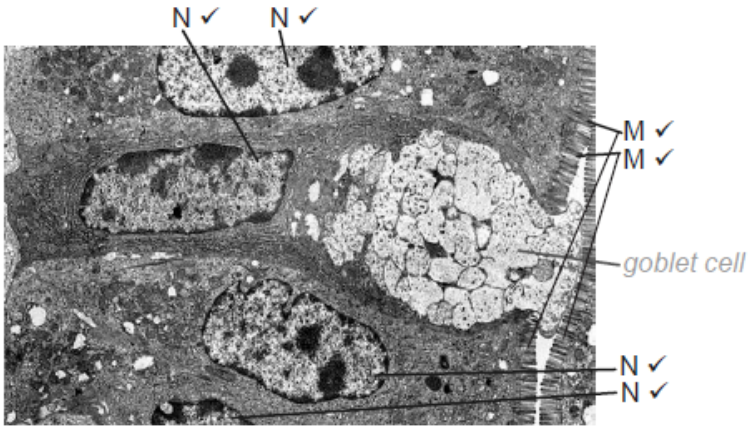
(ii) State the function of the goblet cell.

(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]