HL Paper 2

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.

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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.

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.

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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.

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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.

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

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

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

Markscheme

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

cell wall; *(with some thickness)*

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

cytoplasm;

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

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

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

nucleoid / naked DNA;

approximate width 0.5 μm / approximate length 2.0 μm;

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

Award [3 max] if any eukaryotic structures included.

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

antisense stand acts as template/is transcribed;

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

RNA polymerase separates the two strands of DNA;

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

RNA nucleotides matched to complementary bases;

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

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

(RNA) nucleoside triphosphates used;

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

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

terminator is sequence of DNA signaling end of transcription;

RNA molecule separates completely from DNA;

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

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

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

presents antigen/MHC on cell surface;

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

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

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

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

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

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

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

(Plus up to [2] for quality)

Examiners report

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

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

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

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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 <u>meiosis</u>;

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. 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 antibodies 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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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.

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

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

Markscheme

a. water has a high specific heat capacity;

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

water has a high latent heat of vaporization;

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

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

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

water molecules are polar;

this makes water a good solvent;

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

c. process of water balance is called osmoregulation;

water passes into the kidney tubules by ultrafiltration;

water is reabsorbed in the proximal convoluted tubule;

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

process by osmosis;

transport of salts into the medulla of kidney;

changes salt concentration so water is reabsorbed;

ADH released into blood when water is required;

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

this causes more reabsorption of water from the collecting duct;

excess water is released as urine;

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

drinking a lot gives dilute urine;

Examiners report

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

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

Describe the role of ADH in human osmoregulation.

Markscheme

a. secreted when blood/plasma is hypertonic/too concentrated/water content too low

b. makes walls of collecting duct/distal convoluted tubule «more» permeable to water

c. more aquaporins in membranes «of collecting duct cells»

d. more water reabsorbed from filtrate/from urine/more water returned to blood

e. small volume of concentrated urine excreted

[Max 3 Marks]

Examiners report

[N/A]

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]

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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.

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

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

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

Markscheme

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

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

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

high specific heat capacity causes it to maintain environmental temperatures;

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

transparency for photosynthesis;

transparency for vision in animals;

solvent properties make it the medium for metabolic reactions;

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

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

ADH regulates water levels/solute concentration of the blood;

produced/released when water in blood is too low;

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

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

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

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

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

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

osmotic pressure moves water into the xylem;

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

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

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

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

it passes out through the stomata by evaporation/transpiration;

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

guard cells control the rate of transpiration pull/evaporation;

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

Examiners report

a. Many did not understand the difference between heat capacity and specific heat capacity. Heat capacity is a property of a quantity of matter. For example, two litres of water has a greater heat capacity than one litre of water. Specific heat capacity is a property of certain substance. Water has a greater specific heat capacity than iron. Nor did they understand why water made for a good coolant. Many focused too narrowly on an aspect of

thermal, cohesive or solvent properties rather than discussing these properties from a more "big picture" perspective.

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

c. This question was generally well answered.

---

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

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

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

Markscheme

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

Reject if only peripheral proteins are shown.

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

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

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

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

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

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

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

Reject answers based on water concentrations.

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

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

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

Reject plant cells shrink or shrivel.

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

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

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

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

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

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

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

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

Ascending limb is impermeable to water

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

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

Water reabsorbed in collecting duct

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

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

Examiners report

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

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

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

c. Answers to this question were very varied. The functions expected were osmoregulation and excretion thus the focus should have been on how the nephron can vary the volume and concentration of urine so as to bring the blood back to normal levels, and on how waste products can be concentrated in urine to conserve water. Some teachers commented on G2 forms that is was unreasonable to expect details of the structure of associated blood vessels but all that was required was the structure of the glomerulus. Able candidates who had prepared carefully were able to score highly but weaker candidates tended to be very muddled.

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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. Draw a labelled diagram of a mature sperm. [5]

b. Outline the formation of chiasmata during crossing over. [5]

c. Explain how an error in meiosis can lead to Down syndrome. [8]

Markscheme

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

head and midpiece/mid-section/body;

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

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

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

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

centriole; (*between head and midpiece*)

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

microtubules; (*in 9 plus 2 array*)

b. crossing over/chiasmata formed during prophase I of meiosis;

pairing of homologous chromosomes/synapsis;

chromatids break (at same point); (*do not accept chromatids overlap*)

non-sister chromatids join up/swap/exchange alleles/parts;

X-shaped structure formed / chiasmata are X-shaped structures;

chiasma formed at position where crossing over occurred;

chiasmata become visible when homologous chromosomes unpair;

chiasma holds homologous chromosomes together (until anaphase);

Accept the above points in an appropriately annotated diagram.

c. non-disjunction;

chromosomes/chromatids do not separate / go to same pole;

non-separation of (homologous) chromosomes during anaphase I;

due to incorrect spindle attachment;

non-separation of chromatids during anaphase II;

due to centromeres not dividing;

occurs during gamete/sperm/egg formation;

less common in sperm than egg formation / function of parents' age;

Down syndrome due to extra chromosome 21;

sperm/egg/gamete receives two chromosomes of same type;

zygote/offspring with three chromosomes of same type / trisomy / total 47 chromosomes;

Accept the above points in an appropriately annotated diagram.

Examiners report

a. In part (a) the sperm drawings were mostly neat but few candidates scored full marks. Five structures shown realistically and correctly labelled were needed. The nucleus was often shown insufficiently large. Fibres and microtubules were missing from the tail. Centrioles were missing from many drawings and the plasma membrane, head and mid-piece of the sperm were often not labelled

b. Many candidates also lost marks in part (b) by giving insufficient detail or by including errors in their answers. Candidates were expected to use the terms *meiosis*, *homologous chromosomes* and *non-sister chromatids*. A frequent error was to suggest that the tight linkage between sister chromatids that exists when crossing over takes place is broken prior to crossing over, and that regions of non-sister chromatids become linked instead. This would of course not result in the chiasmata that remain clearly visible throughout metaphase I of meiosis.

   Candidates should be taught that crossing over occurs by breakage of non-sister chromatids and their connection to each other, forming a knot-like chiasma. Chiasmata serve the essential function of preventing non-disjunction by holding homologous chromosomes together when the tight pairing or synapsis has ended.

c. Answers to part (c) were good in most cases. Diagrams were often included, candidates need to label them fully if they are to help answer the question. Some included more details of the normal process of meiosis than was expected and also symptoms of Down syndrome that were not really relevant.

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---

a. Outline the structure and functions of nucleosomes. [4]

b. Explain how DNA is used to pass on genetic information to offspring accurately but also produce variation in species. [8]

c. Accurate transmission of base sequences to offspring depends on successful gamete production. Describe how spermatogenesis occurs in humans. [6]

Markscheme

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

   a. found in eukaryotes;
   b. consists of DNA wrapped around proteins/histones;
   c. histones are in an octamer/group of eight;
   d. are held together by another histone/protein;
   e. in linker region;
   f. help to supercoil chromosomes / to facilitate DNA packing;
   g. (function is to) regulate transcription / gene expression;

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

a. DNA is replicated/copied semi-conservatively/from a template;
b. mutations can be a source of variation / resulting protein has new or different functions;
c. mutations/changes in the DNA may not result in changes in the amino acid for which the triplet codes;
d. genetic code is redundant;
e. genes occur as paired alleles which can be different;
f. crossing-over occurs;
g. recombines linked alleles producing new combinations;
h. random orientation of bivalents / homologous chromosomes (in metaphase I);
i. large genetic variation in (haploid) gametes / 2^n / 2^{23};
j. random recombination of alleles during fertilization (leads to variation);
k. different phenotypes among members of the same population;
l. natural selection may lead to enhanced survival of recombinants;

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

a. germinal cells / spermatogonia undergo mitosis to keep a supply of germinal cells present;
b. some germinal cells / spermatogonia grow larger to become primary spermatocytes;
c. primary spermatocytes go through meiosis I;
d. to form secondary spermatocytes;
e. these secondary spermatocytes go through meiosis II;
f. to produce spermatids;
g. spermatids differentiate/grow a tail and reduce their cytoplasm
h. spermatids associated with nurse cells (Sertoli cells);
i. sperm detach from Sertoli cells and enter lumen of the seminiferous tubule;
j. testosterone stimulates sperm production;

Examiners report

a. It was common for four marks to be awarded. Students knew this topic well.

b. Many candidates appeared to be giving memorized responses from past mark schemes without recognizing the subtleties of what the question demanded. Better prepared candidates used language carefully. Some muddled the discussion by referring to mitosis.

c. Candidates struggled to use terminology correctly. The greatest confusion occurs in discussing the beginning stages of spermatogenesis.

---

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

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

c. Describe the process of endocytosis. [5]

Markscheme

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

a. sarcomere – clearly indicated between Z lines (whether Z lines named or not);
b. Z lines – shown at the ends of a sarcomere;
c. actin (filaments) – drawn as thin lines attached to Z lines;

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

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

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

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

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

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

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

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

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

g. sodium ions diffuse/move in;

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

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

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

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

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

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

b. fluidity of the membrane allows endocytosis;

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

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

e. vesicle/vacuole formed;

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

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

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

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

Examiners report

a. Most candidates scored three or four marks for the drawing of a sarcomere. The Z lines, actin filaments and myosin filaments were usually recognisable. Myosin heads were shown clearly in some diagrams. Light and dark bands were often incorrect. Some candidates showed but did not label titin filaments between the ends of the myosin and filaments and the Z lines. Usually these were distinguished from the myosin by being shown narrower and without heads.

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

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

a. 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 fertilization in humans. [6]

b. Explain how the structure and function of the placenta helps to maintain pregnancy. [8]

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

Markscheme

a. sperm breaks through follicle cells/cells surrounding the ovum;

triggers acrosome reaction;

proteases/hydrolytic enzymes (of acrosome) released;

digestion of zona pellucida;

plasma membranes of sperm and egg fuse;

sperm nucleus enters egg;

cortical reaction;

hardening/cross linking of glycoproteins in zona pellucida;

preventing sperm from entering;

b. disc-shape organ that attaches to (inside of) uterus;

connected to the fetus by the umbilical cord;

produces hormones/HCG that maintain pregnancy;

estrogen and progesterone maintain uterine lining;

nutrients/oxygen from mother's blood transferred to fetal blood;

antibodies from mother's blood transferred to fetal blood (through umbilical vein);

waste products transferred from fetal blood to maternal blood (through umbilical artery);

embryonic tissue invades/grows into the uterine wall;

placental/chorionic 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 / mother and fetal bloods do not mix;

Allow reference to embryo instead of fetus throughout.

c. level of progesterone decreases (drastically) just before birth;

removing inhibition of oxytocin secretion;

oxytocin produced by pituitary gland;

oxytocin causes contractions of uterus;

uterine contractions cause impulses to be sent leading to more oxytocin secretion;

positive feedback;

Examiners report

a. Part (a) was another question where it rapidly became clear to examiners how well the candidate understood the biology involved. Weaker answers often included many details of how sperm travel from the male reproductive system to the oviduct of the female. This was not needed as the events of fertilization were considered to start with the arrival of sperm at the surface of the oocyte. There were many full accounts, including the acrosome reaction and the cortical reaction.

b. A full range of answers to (b) was seen, from muddled brief accounts confusing the placenta with the amniotic sac, to very full and detailed explanations of structure and function. The best answers included accurate descriptions of blood flow, with a clear distinction between fetal blood flow through capillaries in the placenta and maternal blood flow through the sinuses.

c. Part (c) of the question also elicited answers of very variable quality. Many candidates remembered that a positive feedback mechanism was involved but not all could describe it correctly. Some discussed cervical dilation but did not mention uterine contraction. In questions of this type it is always worth mentioning the source of the hormones involved, in this case the pituitary gland as the source of oxytocin.

---

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.

---

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. 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 <u>with heads</u>;
(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.

---

a. Draw a labelled diagram of a mature human egg. [5]

b. Outline a technique used for gene transfer. [5]

c. Explain how evolution may happen in response to environmental change with evidence from examples. [8]

Markscheme

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

a. haploid nucleus;

b. cytoplasm – with nucleus-to-membrane distance >4 times nucleus diameter;

c. centrioles – two must be shown but only one needs to be labelled;

d. cortical granules – needs to be drawn in vicinity of plasma membrane;

e. plasma membrane – shown as a single line and approximately circular overall;

f. polar cell / (first) polar body – needs to be drawn outside the egg cell;

g. zona pellucida / layer of gel (outside the cell membrane);

h. follicle cells / corona radiata (outside the cell membrane);

i. size shown as 100 μm/0.1mm; *(accept 90 μm to 120 μm)*

b. a. plasmid used for gene transfer/removed from bacteria;

b. plasmid is a small/extra circle of DNA;

c. restriction enzymes/endonucleases cut/cleave DNA (of plasmid);

d. each restriction enzyme cuts at specific base sequence/creates sticky ends;

e. same (restriction) enzyme used to cut DNA with (desired) gene;

f. DNA/gene can be added to the open plasmid/sticky ends join gene and plasmid;

g. (DNA) ligase used to splice/join together/seal nicks;

h. recombinant DNA/plasmids inserted into host cell/bacterium/yeast;

c. a. variation in population;

b. (variation is) due to mutation/sexual reproduction;

c. valid example of variation in a specific population;

d. more offspring are produced than can survive / populations over-populate;

e. competition / struggle for resources/survival;

f. example of competition/struggle for resources;

g. survival of fittest/best adapted (to the changed environment)/those with beneficial adaptations / converse;

h. example of changed environment and adaptation to it;

i. favourable genes/alleles passed on / best adapted reproduce (more) /converse;

j. example of reproduction of individuals better adapted to changed environment;

k. alleles for adaptations to the changed environment increase in the population;

l. example of genes/alleles for adaptations increasing in a population;

m. evolution by natural selection;

n. evolution is (cumulative) change in population/species over time / change in allele frequency;

Suitable examples are antibiotic resistance and the peppered moth but any genuine evidence-based example of adaptation to environmental change can be credited.

Examiners report

a. Of the four drawings on this exam, the egg drawings were in general the weakest. The nucleus was in almost all cases far too large and cortical granules were often distributed throughout the cytoplasm rather than being located close to the plasma membrane. Structures outside the plasma membrane were often muddled, perhaps because it was necessary to use three or more concentric circles to represent them.

b. Strong candidates had no difficulty in scoring full marks here by describing gene transfer using plasmids, restriction enzymes and DNA ligase. The weakest candidates wrote on a wide range of other topics.

c. Answers ranged from impressive, with a secure understanding of evolution by natural selection and effective use of examples, to very confused. In contrast to some previous exams most candidates chose appropriate examples such as the evolution of antibiotic resistance in bacteria or the development of melanism in peppered moths. Descriptions of the development of the giraffe's neck or speciation in Galapagos finches were not accepted because they do not correspond with any specific environmental change for which we have good evidence. It is particularly important to base accounts of evolution on strong evidence rather than speculation, because of the objections to the theory that are still being raised.

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.

---

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

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

Markscheme

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

good solvent;

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

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

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

*heat: **[2 max]***
high heat capacity / large amounts of energy needed to change temperature;
energy needed to break hydrogen bonds;

important habitat as temperature more stable / blood disperses heat through body;

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

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

(Accept first two properties only)

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

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

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

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

loop of Henle creates hypertonic conditions in medulla;

water moves from tubule to hypertonic more concentrated medulla;

ascending loop (of Henle) impermeable to water;

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

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

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

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

collecting duct passes through increasing gradient in kidney/medulla;

gradient causes reabsorption of more water by osmosis;

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

(Plus up to [2] for quality)

Examiners report

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

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

---

a. 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. 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.

---

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. Outline the process of spermatogenesis in humans. [5]

c. Explain the structure and function of the placenta during pregnancy. [9]

Markscheme

b. production of sperm/spermatozoa in the testes/seminiferous tubules;

first stage of sperm production requires divisions by mitosis;

cells then undergo a period of growth;

future sperm cells then undergo two meiotic divisions;

cells then differentiate to form sperm cells;

nourished by Sertoli cells number becomes haploid / chromosome number halved / 46 to 23 chromosomes;

c. embryonic/disc shaped structure that nourishes the developing embryo;

starts forming at implantation of the blastocyst/embryo;

embryonic tissue invades/grows into the uterine wall;

fetal capillaries exchange material with maternal blood/lacunae;

allows exchange of food/oxygen/antibodies from mother's blood to fetus;

allows exchange of carbon dioxide/waste products from fetal blood to mother;

connected to the embryo/fetus by an umbilical cord;

placenta takes over hormonal role of ovary;

indication of time this happens / at approximately 12 weeks;

secretes estrogen/progesterone;

hormone secretion maintains pregnancy;

expelled from uterus after childbirth;

Examiners report

b. The process of spermatogenesis was well known.

c. Many candidates become confused between the amniotic sac and the placenta. Marks were lost for imprecise statements about what actually passes between the mother and fetus and how it is transferred.

---

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

b. Outline transcription in prokaryotes. [6]

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

Markscheme

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

a. cell wall – a uniformly thick wall;

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

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

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

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

f. plasmid – circular ring of DNA;

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

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

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

b. RNA polymerase binds to promoter region of DNA;

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

d. RNA polymerase unwinds DNA/separates the strands;

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

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

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

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

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

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

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

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

c. antigens in the vaccine cause antibody production;

d. antigen/pathogen engulfed by macrophage/phagocyte;

e. each type of lymphocyte recognizes specific antigen;

f. macrophages activate helper T-cells;

g. which activate B-cells;

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

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

j. result is (specific) immunity;

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

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

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

Examiners report

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

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

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

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

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

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

---

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

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

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

Distinguish between transcription and translation.

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

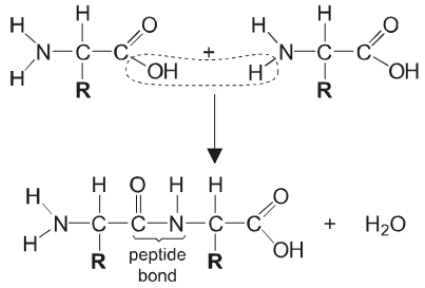
Explain how insects excrete nitrogenous wastes.

Markscheme

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

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

c. release of water clearly shown



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

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

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

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

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

e. tRNA needed for translation but not transcription

f. nucleotides linked in transcription and amino acids in translation

OR

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

[Max 4 Marks]

c. a. excreted as uric acid

b. excretion by Malpighian tubules

c. nitrogenous waste/ammonia «accumulates» in hemolymph

d. nitrogenous waste/ammonia absorbed by Malpighian tubules

e. ammonia converted to uric acid

f. conversion to uric acid requires energy/ATP

g. high solute concentration in Malpighian tubules

OR

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

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

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

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

k. uric acid excreted/egested with the feces

l. water conservation/osmoregulation

OR

reduces mass of water «in body»

m. uric acid is non-toxic

[Max 8 Marks]

Examiners report

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

---

a. Outline pollination, fertilization and seed dispersal. [4]

b. Compare the processes of spermatogenesis and oogenesis. [8]

Markscheme

a. pollination is the transfer of pollen to the stigma/carpel/pistil of a flower;

pollen grains grow a pollen tube down the style to the ovule;

male and female gametes/nuclei join/fuse (in the ovule/ovary) during fertilization;

the ovary matures into a fruit;

dispersal of seeds depends on the fruit;

example of seed dispersal; (*e.g. pods split open to scatter seeds, e.g. animal eats fruit / ingests and egests seed*)

b.

	spermatogenesis	*oogenesis*
a.	both start with germ cells/germinal epithelium (of gonad);	
b.	both start with mitosis to produce many cells;	
c.	both involve cell growth before mitosis;	
d.	both involve meiosis/reduction division/create haploid cells;	
e.	occurs in testes	occurs in ovaries;
f.	millions/large numbers produced daily	one/few produced per month;
g.	released during ejaculation	released during ovulation/mid-way through cycle;
h.	begins during puberty	egg production begins before birth;
i.	continues throughout life	production stops at menopause;
j.	four sperm made per meiosis	only one egg produced per meiosis;
k.	polar bodies not produced/equal division	polar bodies produced/uneven division of cytoplasm;
l.	cytoplasm is reduced in sperm	cytoplasm is enhanced in eggs;
m.	sperm are motile	eggs are not motile;

*To award **[8 max]**, responses must provide at least one similarity. Responses do not need to be shown in a table format.*

Examiners report

a. This part of the question was an area of strength in terms of student understanding of concepts and structure of answers. The most likely aspect to cause problems was the distinction between pollination and fertilization.

b. This question was answered reasonably well with improvements seen over previous years in terms of the degree to which candidates carried out a comparison throughout. There was occasionally a digression into irrelevant aspects of the menstrual cycle.

---

a. Draw a labelled diagram of the human adult male reproductive system. [5]

b. Compare the processes of spermatogenesis and oogenesis [8]

c. Describe the consequences of the potential overproduction of offspring. [5]

Markscheme

a. a. scrotum – *shown around testes*;

b. testes/testis/testicles – *shown inside scrotum*;

c. epididymis – *shown adjacent to testis and connected to sperm duct*;

d. sperm duct/vas deferens – *double line connecting testis/epididymis to urethra*;

e. seminal vesicle – *sac shown branched off sperm duct (not off the urethra);*

f. prostate gland – *shown positioned where sperm duct connects with urethra*;

g. urethra – *shown as double line linking bladder to end of penis*;

h. penis – *with urethra passing through it*;

*Award **[1]** for each structure clearly drawn and labelled that conforms to the italicized guidelines given.*

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

a. both produce haploid cells / both produce (mature/male/female) gametes;
b. both have mitosis at start/in epithelium / both involve mitosis and meiosis;
c. both have cell growth before meiosis;
d. both involve differentiation (to produce a specialised gamete);

	Comparison	*Oogenesis*	*Spermatogenesis*
e.	what is produced where	eggs/ova produced in the ovaries	sperm (atozoa) produced in the testes;
f.	when the process starts/is initiated	during development of embryo/fetus	during puberty/adolescence;
g.	if there are breaks in meiosis	breaks occur in prophase I/ prophase II/ metaphase II	no breaks;
h.	if cytokinesis during meiosis is equal	cytoplasm split unequally / larger cell and smaller cells	equal division of cytoplasm;
i.	number of gametes per meiosis	one cell/egg (per meiosis) / some become polar bodies	four sperm (per meiosis) / all cells become sperm;
j.	number of gametes produced/released	one (usually) at a time/per month/per menstrual cycle	many/far more/(hundreds of) millions daily/at a time;
k.	timing of release	on about Day 14/in middle of menstrual cycle/at ovulation	continuously (from testis) / by ejaculation/intercourse;
l.	if gametogenesis ever stops	stops (at menopause)	goes on (throughout adult life/until death);

A table is not required but both statements in one row of the table above must either be explicitly stated or clearly implied for each mark awarded.

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

a. more (offspring) than the environment can support / carrying capacity reached;
b. increased mortality/lower life expectancy/more deaths;
c. <u>competition</u> (for resources) / struggle for survival;
d. food/mates/nest sites/territory/other example of resource shortage / example of greater need;
e. variation between members of population / example of variation;
f. better adapted more likely to survive / converse; (reject Lamarckian statements such as those who adapt survive)
g. better adapted reproduce / pass on (favourable) genes/traits / converse;
h. natural selection / (survival of fittest) leads to evolution;

Examiners report

a. Structure of the male reproductive system

As so often in past papers, the diagrams of the male reproductive system were very poor. Many candidates were worryingly ignorant about the internal structure, with organs shown incorrectly or not at all. Connections between the parts of the reproductive system were often incorrect and the position of the prostate gland was almost always wrong. Many male students in later life will suffer from an enlarged prostate with difficulties in urination because the urethra passes through the prostate. For this and other obvious reasons, students should learn in detail about the structure of the male and female reproductive systems. Too many students are too ignorant in this area, despite what they and their teachers may think they know.

b. Spermatogenesis and oogenesis compared

Most candidates found at least one or two similarities or differences between gamete production in males and females but very few scored really highly on this question. Many answers were constructed in the form of a table with two columns, which made it easier to confine the answer to genuine comparisons, but even so in some answers the statements in the left and right column did not correspond. Other answers consisted of long paragraphs about spermatogenesis and then separate paragraphs about oogenesis. The onus is then on the examiner to find the comparisons within the answer when this is actually the candidate's task. Few candidates reached 8 marks on this question, which was a challenge but perfectly possible.

c. Consequences of overproduction of offspring

Some candidates wrote only about humans, with the focus on large families and overcrowded housing. They should have realised that this is not a biological answer to the question and that a general answer about all species was expected. There were some very good answers that tied in populations rising above the carrying capacity to competition for resources, increased mortality, variation and the survival and reproduction of the better adapted individuals, hence evolution of the species by natural selection.

---

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

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

c. Explain the production of antibodies. [7]

Markscheme

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

Both needed.

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

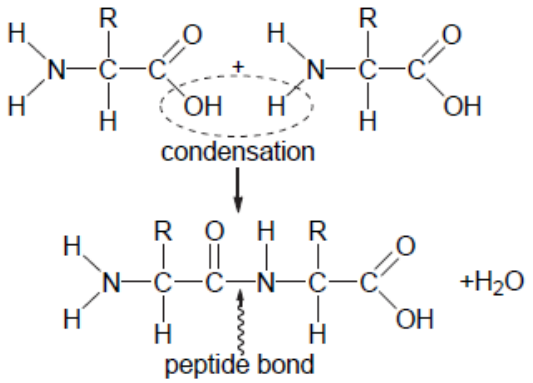
b. CH in middle with H or R group attached

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

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

e. loss of water

eg:



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

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

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

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

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

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

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

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

Accept annotated diagrams of the sites.

c. a. each antibody corresponds to a specific antigen

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

c. macrophage/phagocyte ingests/engulfs pathogen

d. macrophage/phagocyte digests pathogen

e. macrophage/phagocyte displays antigen from pathogen

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

g. T lymphocytes/cells activate B lymphocytes/cells

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

i. plasma cells secrete specific antibody

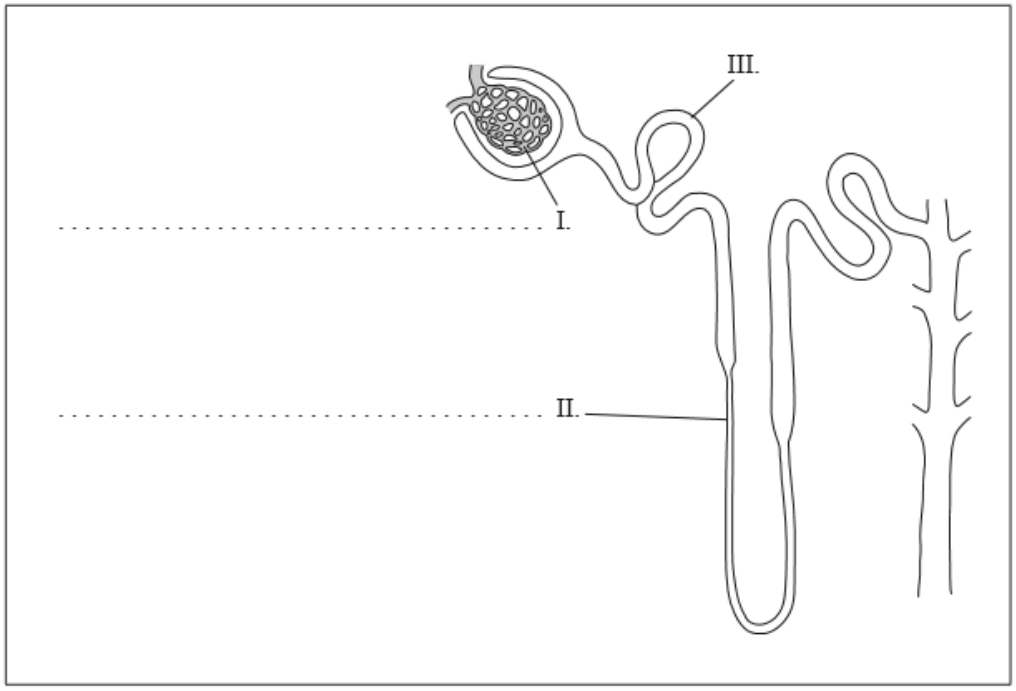
j. some «activated» B lymphocytes/cells act as memory cells

Accept annotated diagrams of the process

Examiners report

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

The diagram shows the structure of a nephron.



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a (i) Label I and II. [1]

a (ii) Outline the function of III. [1]

b. Estimate the content of glomerular filtrate and urine of a healthy person by completing the following table. [2]

	Plasma proteins / mg 100 ml^{-1}	Glucose / mg 100 ml^{-1}	Urea / mg 100 ml^{-1}
Blood plasma in renal artery	740	90	30
Glomerular filtrate		90	
Urine			

c. Explain the role of the medulla and the collecting duct of the kidney in the maintenance of the water balance in blood. [3]

Markscheme

a (i) I: glomerulus;

II: (descending limb of) loop of Henle;

(*both needed*)

a (ii) I: <u>selective</u> re-absorption of glucose/minerals/amino acids/water/ useful substances;

absorption by active transport/using ATP of glucose/minerals/ amino acids/useful substances;

b.

	plasma proteins / mg 100 ml^{-1}	*glucose / mg 100 ml^{-1}*	*urea / mg 100 ml^{-1}*
blood plasma in renal artery	*(740)*	*(90)*	*(30)*
glomerular filtrate	0	*(90)*	30 (or slightly less);
urine	0	0	(much) greater than 30;

*Award **[1]** for each correct row.*

c. collecting duct has <u>water</u> channels/aquaporins/is permeable to water;

high solute concentration of medulla / medulla is hypertonic;

reabsorption of water allows excretion of concentrated urine (antidiuresis);

secretion of ADH/vasopressin increases permeability of collecting duct to water / *vice versa*;

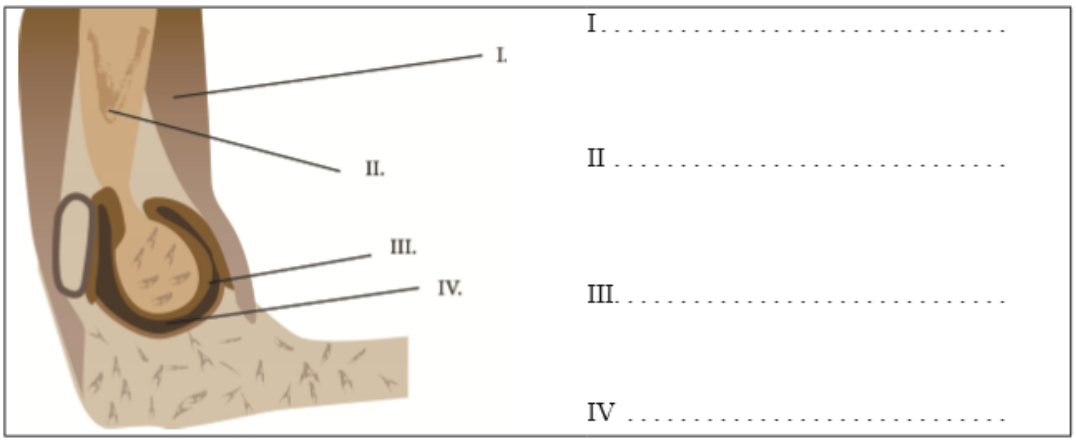
Examiners report

a (i) Many candidates were able to name the glomerulus and the loop of Henle in (a)(i).

a (ii) Part (a) (ii) is another question where brief answers did not always gain the mark. A simple statement that glucose is reabsorbed in the proximal convoluted tubule was not enough. Two types of qualification were needed; either that reabsorption is selective or that nutrients are reabsorbed by active transport.

b. For part (b) there were some comments from teachers suggesting that knowledge of actual concentrations of solutes in glomerular filtrate and urine should not be expected. The question did not expect concentrations to have been memorized. Both of the marks could be gained if the candidate knew that protein is not filtered out of the blood, but that urea is, and that glucose is all reabsorbed but urea becomes more concentrated as water is reabsorbed from the filtrate.

c. There was some confusion among candidates in part (c) about the meaning of the word medulla in this question. A common error was to assume that it meant the medulla oblongata and ascribe a role in the maintenance of water balance to this part of the brain. In fact the question referred to the medulla of the kidney, with the hypothalamus and pituitary gland as the regulatory centres. There were some excellent answers to this question showing a very secure understanding of kidney physiology.



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a. Label I, II, III and IV on the diagram of the human elbow. [2]

b. Outline the functions of I and III. [2]

I. .....
III. .....

Markscheme

a. *Award **[1]** for two correct labels.*

I. biceps;

II. humerus;

III. cartilage;

IV. synovial fluid/synovial cavity;

b. I. (contracts to) move/raise forearm/lower arm/radius / flex/bend arm at elbow;

II. reduces friction / prevents bone rubbing on bone / absorbs shock;

Do not accept answers that do not specify the movement caused by I, or state that I lifts the arm.
Do not allow ECF answers.

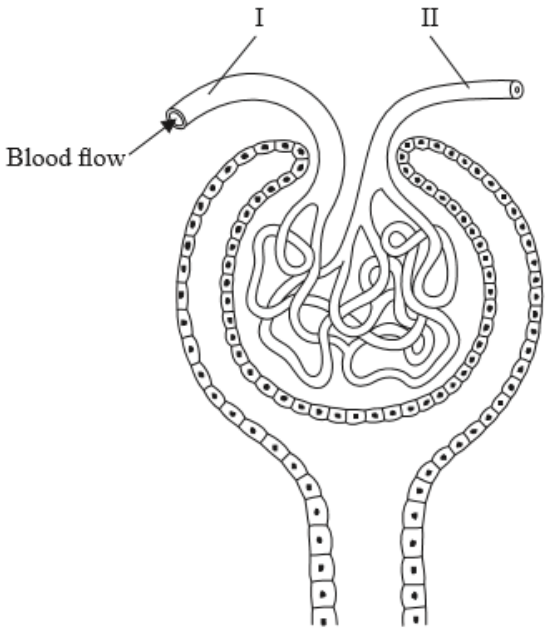
Examiners report

a. Part (a) involved labelling a diagram of the elbow joint. Most candidates were able to do this successfully, but some confused synovial fluid and cartilage. The specific names of the bone and muscle were expected, which not all gave.

b. In part (b) the functions of the biceps and cartilage were needed. Only about half of the candidates got both of these adequately. In many cases the function of the biceps given was rather vague. Lifting the arm was not accepted; bending the arm was, though flexing the arm at the elbow was preferred. Some candidates were unaware that muscles only do work when they contract.

b. Explain the process of ultrafiltration. [2]

c. The diagram below shows part of the human kidney. The arrow shows the direction of blood flow. [2]



Compare the composition of the fluids found in the regions labelled I and II by giving **one** difference and **one** similarity.

Difference: .....
Similarity: .....

Markscheme

b. blood (in the glomerulus) under high pressure caused by difference in diameter of (afferent and efferent) arterioles;

fluid plasma and small molecules forced into kidney tubule/Bowman's capsule/ through fenestrations/basal membrane;

which prevent larger molecules/blood cells from passing through;

c. *difference:* fluid at II has <u>less</u> urea/glucose/oxygen/salts/ions/water;

similarity: fluid at II has <u>same</u> (amount of) proteins/blood cells as fluid at I;

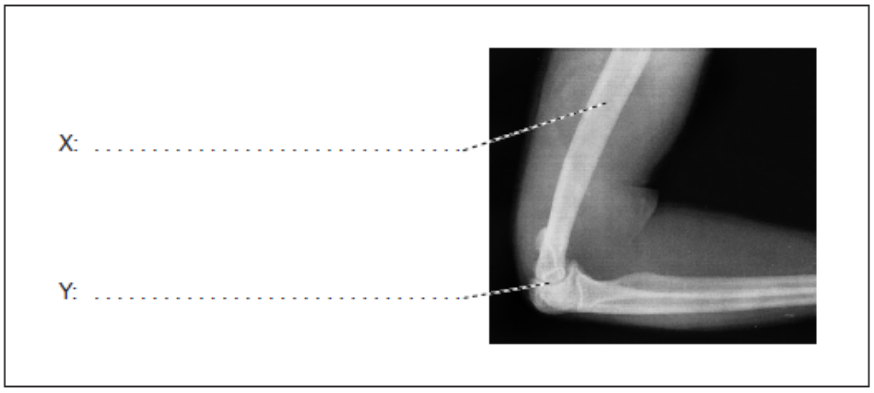
Accept converse for both marking points.

Examiners report

b. Many candidates had general knowledge of ultrafiltration but did not express it clearly and concisely. They mentioned high pressure without explaining the causes or that there was filtration of some substances and not others, but again without an explanation.

c. Many candidates lost marks here for lack of precision in their answers. To get marks, they had to refer to amounts, or the composition of the fluids in zones I and II. Many said there was no glucose or urea in II instead of smaller concentrations. Others said there were blood cells or large proteins in both, but did not state that there were present in the same amounts.

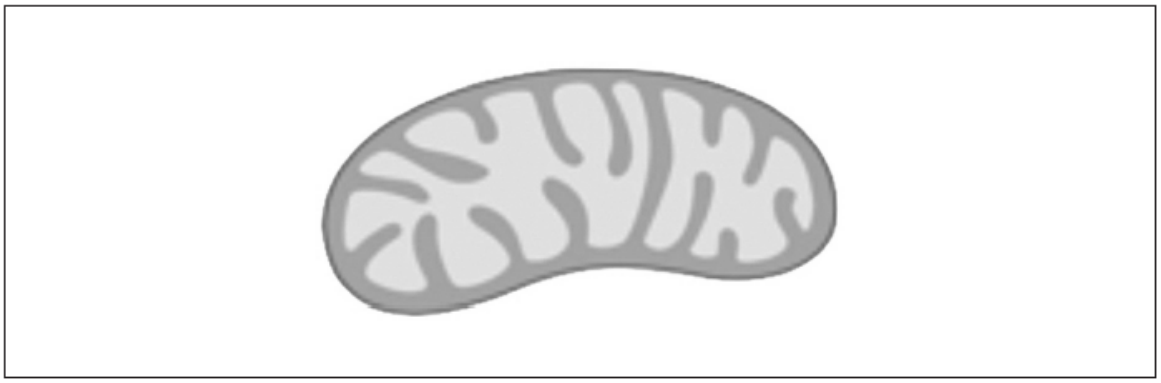
a(i). Label the structures indicated on the X-ray of a human elbow. [2]



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

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

Label the diagram to indicate where the link reaction occurs.



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

Markscheme

a(i). *X*: humerus;

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

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

calcium released from sarcoplasmic reticulum;

calcium causes binding sites on actin to be exposed;

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

c(i).

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

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

passes acetyl group/acetate to Krebs cycle;

Examiners report

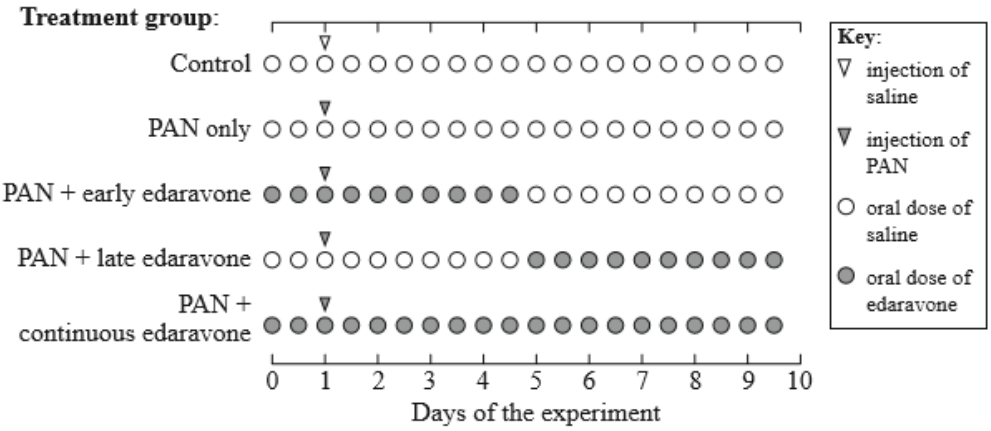
a(i). Well prepared candidates had no difficulty in naming the humerus and the synovial fluid. For the latter structure certain other answers were accepted because, given the three dimensional structure of the joint, it wasn't entirely clear what the labelling line was touching.

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

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

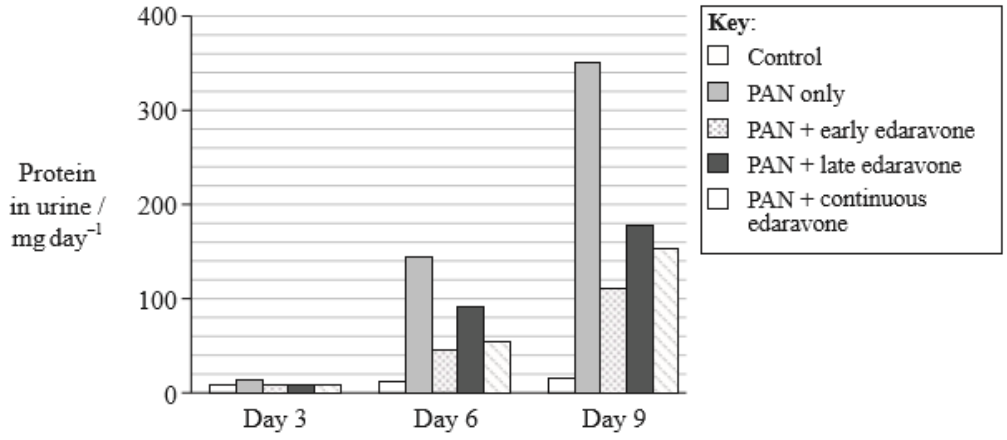
c(ii). There were few really strong answers to this question. A common misconception was to think that coenzyme A is an enzyme, rather than a carrier of the acetyl group that acts as a substrate of enzymes. In many answers it was not clear that coenzyme A first accepts an acetyl group and then passes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

Medical scientists investigated the development of nephrotic syndrome, a kidney disease that results in the abnormal presence of protein in the urine. This symptom of the disease can also be caused by injecting puromycin aminonucleoside (PAN) into rats. The drug edaravone, a proposed treatment for the disease, was studied. The experimental timetable for the different treatment groups is summarized below. Edaravone was given by mouth (oral dose). Saline is a solution with the same concentration of solutes as blood plasma.



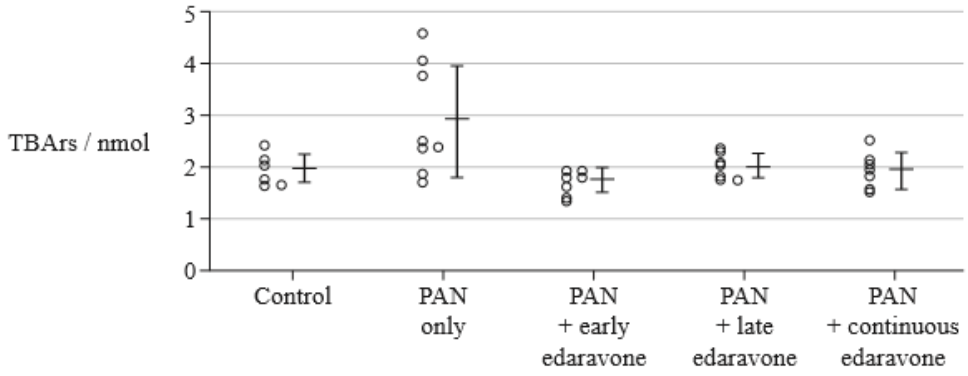
[Source: H Matsumura, *et al.*, (2006), *Clinical Nephrology*, **66** (6), pages 405–410]

The graph below shows the levels of protein found in the urine of the rats on day 3, day 6 and day 9 of the experiment.



[Source: H Matsumura, *et al.*, (2006), *Clinical Nephrology*, **66** (6), pages 405–410]

Oxidation reactions can cause damage to cells. Thiobarbituric acid reactive substances (TBArs) are produced when membrane lipids are damaged by oxidation. Experiments were carried out to investigate the effect of edaravone on the production of TBArs.



[Source: H Matsumura, *et al.*, (2006), *Clinical Nephrology*, **66** (6), pages 405–410]

a. State when PAN was injected into the rats. [1]

b. Outline the treatment given to the control group. [2]

c. Distinguish between the treatment received by the PAN only group and the PAN + early edaravone group. [1]

d. State the increase in protein in the urine of rats treated with PAN only between day 6 and day 9. [1]

e. Compare the levels of protein during the experiment in the urine of rats treated using PAN only with those treated using PAN + early edaravone. [3]

f. Evaluate whether the results support the hypothesis that a continuous dose of edaravone is better than the same drug administered over shorter periods. [3]

g. Analyse the results of this experiment. [3]

h. Suggest why oxidation of membrane lipids may lead to increased protein loss in the urine. [3]

Markscheme

a. on Day 1 / at end of Day 1 / after one day / after the first day / at start of second day

*Award **[0]** for on Day 2 or after Day 1.*

b. two oral doses daily of saline (for ten days);

one saline injection on Day 1/at end of Day 1/after one day/after the first day/at start of second day;

*Award **[0]** for on Day 2 or after Day 1.*

c. PAN + early edaravone group received edaravone for the first five days/first half of experiment/from Day 0 to Day 4 and PAN-only group did not.

*To award **[1]** reference to both groups is required. Award **[0]** for 4 or 4 1 2 days.*

d. 205 mg day^{-1} (*units required*)

Allow answers in the range of 200 to 210 mg day^{-1} .

e. on Day 3 little/no difference / both levels very low;

protein increases in both during the experiment; *Can be mentioned in separate parts of the responses.*

protein higher in PAN-only group by an increasing amount / increases faster in PAN-only group;

protein levels are higher in the PAN-only group on all days / after Day 3 / on Day 6 and day 9; *Accept comparative statements such as more than double.*

145 versus 45 on Day 6 / 350 versus 110 on Day 9 / increase from Day 3 to Day 6 is 130 versus 35 / increase from Day 6 to Day 9 is 205 versus 65; *Allow answers in the range of 5%. Accept numerical comparisons expressed as percentages.*

f. lower (increase in) protein/greater reduction/best results with early dose rather than with continuous;

more (increase in) protein/smaller reduction/worse results with late dose than with continuous;

differences may not be significant;

partial support / does not fully support / comparison of continuous with late supports hypothesis but continuous with early does not;

timing of dose more important than duration;

g. PAN increases TBArs levels / TBArs levels highest in PAN-only group;

PAN causes oxidation of/damage to membrane (lipids);

edaravone reduces/prevents increase in TBArs levels;} *Do not allow PAN + edaravone lowers TBArs.*

edaravone prevents oxidation of membrane lipids / reduces/prevents effect of PAN;

early edaravone is more effective than late/continuous;

overlap of error bars shows differences may not be significant;

Do not allow late or continuous edaravone has no effect. Apart from the first marking point do not allow statements that are merely comparing the results.

h. proteins retained (in blood) during ultrafiltration (in a healthy person);

proteins are large (molecules);

proteins lost/leak from blood/into filtrate/into Bowman's/renal capsule;

large enough pores/holes/spaces formed for proteins to pass through;

glomerulus/capillary walls/podocytes/Bowman's/renal capsule damaged;

proteins are too big to be reabsorbed later/in proximal convoluted tubule;

Examiners report

a. This was intended to be an easy start to the question and almost all candidates answered it correctly. It was also intended to encourage candidates to think carefully about the time scale on the x-axis. It was clear that some candidates did not do this. The numbers 0, 1, 2 and so on could either be interpreted as the number of days after the start of the experiment, or the start of Day 0, Day 1, Day 2 and so on.

b. Many candidates scored a mark for stating that there was one injection of saline at the end of Day 0, the start of Day 1 or after one day. Far fewer pointed out that two oral doses of saline were given each day. This could be deduced from the twenty open circles in the ten-day period of the experiment.

c. This was answered correctly by about half of the candidates. The commonest fault was failure to state clearly when edaravone was administered. The answer, over the first 4½ days was not accepted, because there were two administrations per day and ten in total.

d. Most candidates correctly calculated the increase in protein and only a few forgot to give units. The question should probably have used the command term calculate rather than state but few candidates only stated the values without carrying out the subtraction.

e. Answers to were very varied, with marks evenly spread between 0, 1, 2 and 3. The question was easier to answer if the instruction to give similarities as well as differences in compare questions was remembered. Quotation of numerical values rarely gains many marks in IB Biology exams. Some answers consisted only of this, but scored a maximum of one mark.

f. It was essential to remember that in *evaluate* questions implications and limitations are the focus. The experimental results for late administration of edaravone supported the hypothesis, but those for early administration did not. Candidates were expected to explain this partial support. Few were able to evaluate this. They seemed reluctant to say that it was only "partially correct" opting to say either correct or incorrect instead. Questions are never set to trick candidates but they need to be aware that much data is inconclusive and requires further testing of a hypothesis before it can be confirmed or rejected.

g. Candidates mostly found the last two parts of the question difficult. As this was an *analyse* question, the expected answers were interpretations of the data to reach conclusions. This involved more than merely describing or comparing the results. In particular, it was essential to separate the effects of PAN and edaravone. PAN caused the highest TBArs levels, indicating damage to membranes by oxidation. When edaravone was also administered, it prevented this damage. Many candidates talked about the combined effects of the two drugs, even though the stem of the question, on page 2, explained that edaravone is a proposed treatment for nephrotic syndrome, and PAN causes symptoms of the disease so can be used to simulate it. Only a minority of candidates coped well with part (g) and this was the only part of the question that aroused critical comments from teachers on G2 forms. It was again necessary to bear in mind statements in the stem of the question, especially that the presence of protein in urine is a symptom of nephrotic syndrome. Candidates were expected to recall how the structure of the glomerulus normally prevents proteins passing from blood in the glomerular capillaries to filtrate in the Bowman's capsule. Candidates tended to score three marks or none, depending on whether they keyed in to the question correctly or not.

h. The examining team did not feel that this part was too hard. Partly because of (h) there was a better correlation between candidates' performance in Question 1 and their overall standard in this paper, than in some other recent papers.

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

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

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

other areas of science.

Compare and contrast the processes of spermatogenesis and oogenesis.

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

other areas of science.

Outline the evidence for evolution provided by selective breeding.

Markscheme

a. a. mitochondria and chloroplasts are similar to prokaryotes

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

Allow "taking in" in place of "engulfing"

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

OR

symbiotic/mutualistic relationship «between engulfed and host cell»

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

e. DNA «loop» in chloroplast/mitochondrion

f. division/binary fission of chloroplast/mitochondrion

g. double membrane around chloroplast/mitochondrion

h. 70s ribosomes «in chloroplast/mitochondrion»

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

[Max 4 Marks]

b. a. both result in haploid cells/gametes

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

c. both have cell growth «before meiosis»

d. both involve «two divisions of» meiosis

e. both involve differentiation to produce a gamete

f. both are stimulated by hormones

OR

spermatogenesis stimulated by testosterone and oogenesis stimulated by FSH

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

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

[Max 8 Marks]

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

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

OR

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

For example dogs have been developed from wolves

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

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

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

[Max 3 Marks]

Examiners report

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

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

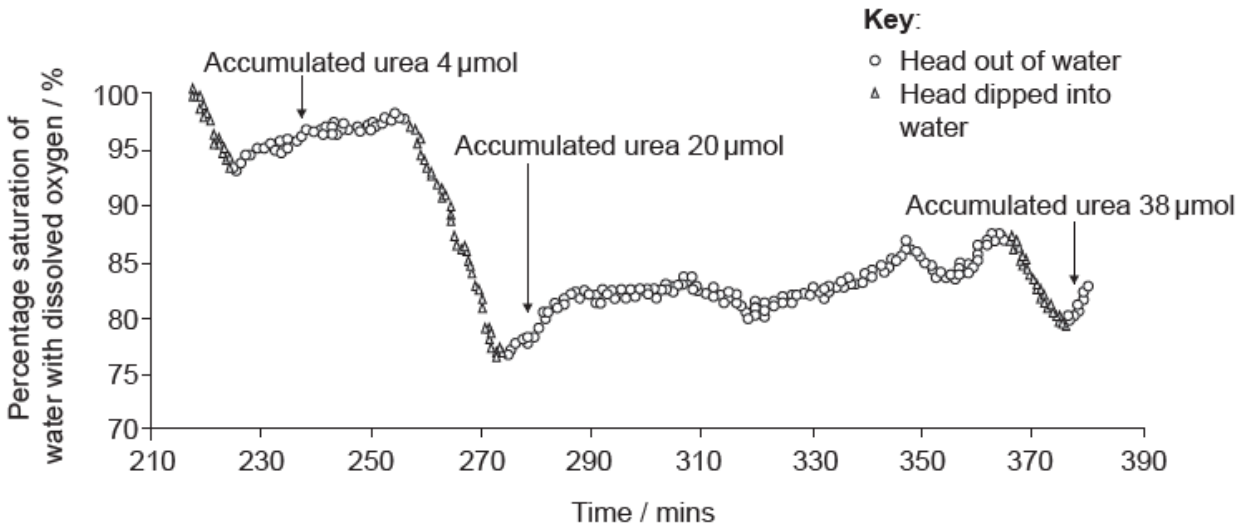
These turtles have fully developed lungs and kidneys, however, many microvilli have been discovered in the mouth of *P. sinensis*. A study was undertaken to test the hypothesis that oxygen uptake and urea excretion can simultaneously occur in the mouth.

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

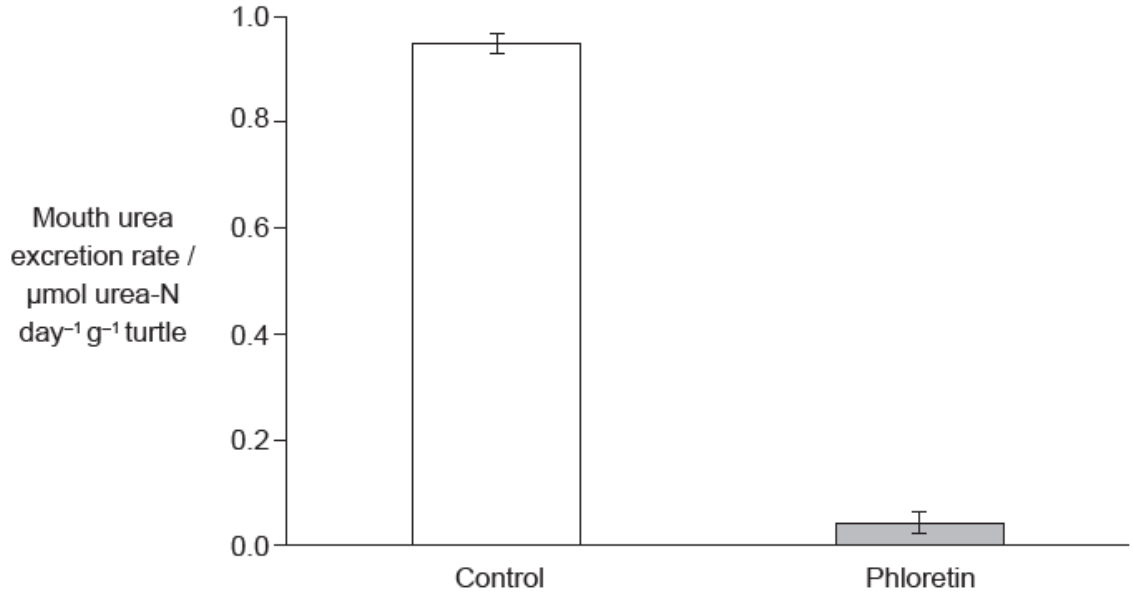
[Source: Reproduced with permission, Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723—3733. jeb.biologists.org. doi: 10.1242/jeb.068916]

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.



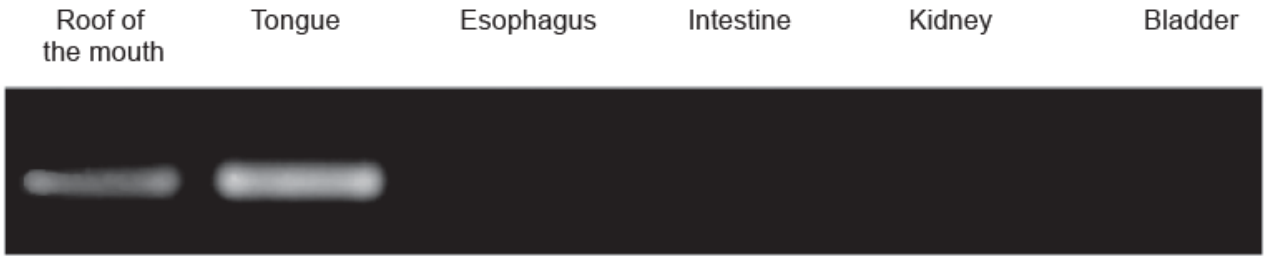
[Source: adapted with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733.]

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.



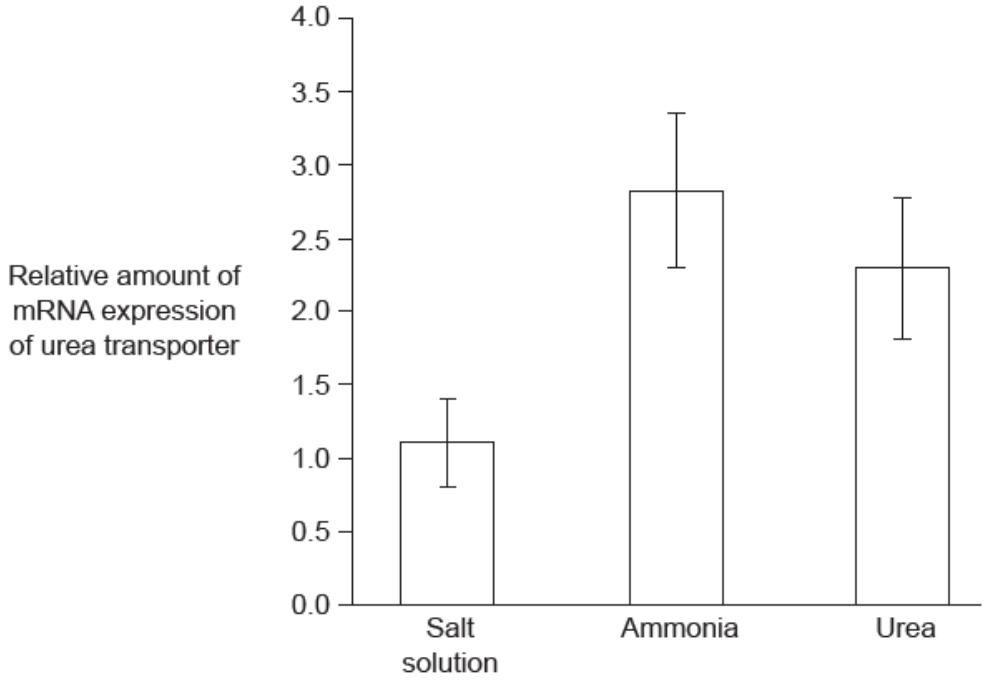
[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

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

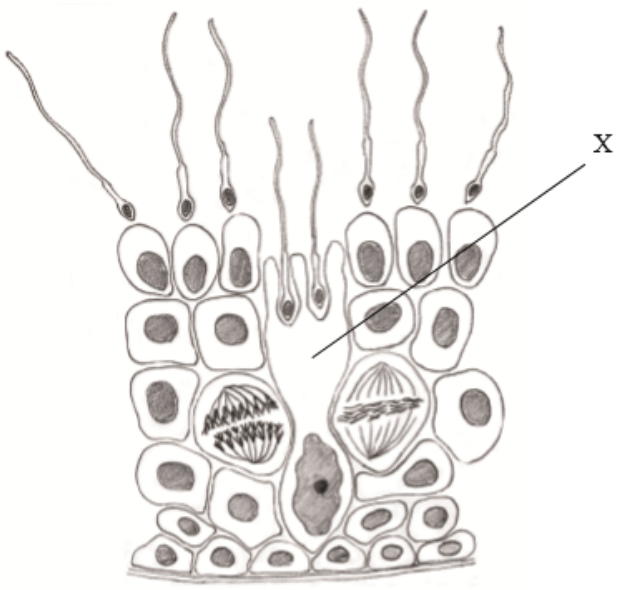
h. excretion with little/no loss of water

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 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.