HL Paper 3

Cells on the surface of intestinal villi have microvilli, which provide a large surface area for absorption. State another structural characteristic of these villus cells that adapts them to the absorption of nutrients.

Markscheme

a. tight junctions

b. protein channels / membrane pumps

c. large number of mitochondria

Examiners report

[N/A]

Explain the role of receptors in mediating the action of both steroid and protein hormones.

Markscheme

a. receptors are proteins

steroid hormones: ***[3 max]***

b. steroid hormones cross plasma membrane

c. bind to receptor «proteins» in the cytoplasm of the target cell

d. to form a receptor–hormone complex

e. «the receptor–hormone complex» promotes the transcription of specific genes

peptide hormones: ***[3 max]***

f. peptide hormones bind to receptors in the plasma membrane of the target cell

g. binding of hormones to «membrane» receptors activates a cascade of reactions

h. mediated by a second messenger inside the cell

i. such as cAmp or Ca^{2+} calmodulin

Examiners report

[N/A]

Outline the ways in which the liver regulates the chemical and cellular composition of the blood.

Markscheme

Stores glucose as glycogen

OR

Releases glucose from glycogen

Under influence of insulin/glucagon «respectively» depending on blood glucose levels

Some nutrients in excess can be stored in the liver (*Accept vitamin A or D stored*)

The liver detoxifies blood
OR
The liver removes/breaks down toxins/alcohol/drugs «from the blood»

Kupffer cells engulf bacteria

Kupffer cells breakdown erythrocytes/red blood cells/hemoglobin by phagocytosis

Hemoglobin is split into heme and globin

Iron from heme/hemoglobin breakdown is carried to the bone marrow «to produce new hemoglobin in new red blood cells»
OR
Excess iron stored in liver

Surplus cholesterol is converted to bile salts
OR
Cholesterol is synthesized

«Hepatocytes» produce plasma proteins (*Accept specific plasma proteins such as albumin*)

Examiners report

Variations on this question have been asked in examinations for the past syllabus so candidates seemed well prepared on the functions of the liver.

Many candidates were able to get full marks although often irrelevant material, such as discussion on bile or details of glucose control, was included.

Candidates needed to focus on regulation of chemical and cellular composition of the blood and only stronger candidates did both.

Explain the process of erythrocyte and hemoglobin breakdown in the liver.

Markscheme

a. erythrocytes rupture when they reach the end of their life span / after 120 days

b. «erythrocytes» absorbed by phagocytosis

c. Kupffer cells ingest/take in erythrocytes

d. Kupffer cells in sinusoids in the liver

e. hemoglobin split into globin and heme groups

f. amino acids from the globin are recycled

g. heme group is further broken down into iron and bilirubin / bile pigment

h. iron stored in liver / transported to bone marrow/spleen

i. bilirubin released into alimentary canal/becomes part of bile

Examiners report

[N/A]

Discuss high altitude training for athletes.

Markscheme

benefits:

a. improved performance/endurance at lower oxygen levels

OR

improved performance/endurance when returning at low altitude

b. due to higher concentration erythrocytes/red blood cells/hemoglobin

c. more oxygen transported/circulating «due to increase in hemoglobin/RBC number»

d. improved metabolic/lung efficiency/gas exchange

e. increase in myoglobin/number of capillaries/mitochondria

risks:

f. altitude sickness/stroke/lower immunity

g. increased muscle tissue breakdown

h. effects are not immediate/not permanent/extended training at high altitude required

i. may be unfair to competitors who cannot train at high altitude

[Max 6 Marks]

Examiners report

[N/A]

Outline how infection by *Vibrio cholerae* can lead to dehydration.

Markscheme

a. *V. cholerae* produces toxin

b. «toxin» causes ions to be pumped into «small» intestine

c. drawing water into the intestine

d. through osmosis

e. leading to water loss through diarrhea/vomiting
OR
leading to dehydration

Examiners report

[N/A]

Describe a method that could be used to measure the energy content of a sample of food.

Markscheme

a. determine the initial and final/change in mass of the food sample

b. determine initial and final/change in temperature of water

c. ignite sample and place burning sample under a known volume/mass of water

d. energy content is determined using formula

$$\Delta T \times \text{mass of water} \times \text{specific heat capacity of water}$$

e. divide energy of water by mass of the food sample *OWTTE*

Examiners report

[N/A]

Explain how and why ventilation rate varies with exercise.

Markscheme

during exercise the rate of tissue respiration increases/more carbon dioxide produced;

carbon dioxide production in the tissues exceeds the rate of breathing it out;

increase in carbonic acid / increase in H^+ ions / pH drops in the blood plasma;

lactic acid (in strenuous exercise) reduces pH;

chemoreceptors/chemosensors detect change in pH/increase in carbon dioxide/ decrease in oxygen;

receptors in the carotid/aortic bodies;

nerve impulses sent to the breathing centres of the brain;

nerve impulses then sent to diaphragm/intercostal muscles;

negative feedback control;

Examiners report

Many candidates, that had studied this in detail, could explain how and why ventilation rate varies with exercise in detail, with many candidates gaining four or five marks here.

---

a (i). State **one** example of a steroid hormone. [1]

a (ii). State **one** example of a hormone that is a tyrosine derivative. [1]

b. Outline the hormonal control of digestive juice secretion in the stomach. [2]

c. Outline how exercise causes an increase in the ventilation rate. [3]

Markscheme

a (i). estrogen / testosterone / progesterone

Accept other verifiable examples.

a (ii). thyroxine/thyroid hormones / epinephrine / adrenaline / noradrenaline

Accept other verifiable examples

b. gastrin is secreted when food is in the stomach/chemoreceptors/stretch receptors are stimulated;

stimulates gastric acid/pepsinogen production;

when pH drops too low, gastrin secretion is inhibited by (secretin and somatostatin) hormones;

c. exercise uses energy/ATP/increases metabolic rate/aerobic respiration;

which causes increased CO_2 which lowers blood pH;

detected by chemosensors in aorta/carotid arteries;

stimulate medulla/breathing centre of brain;

nerve impulses to diaphragm and intercostal muscles increase contraction (rate);

Examiners report

a (i). Most candidates had no difficulty to state the required factual information.

a (ii). Most candidates had no difficulty to state the required factual information in part (a).

b. Most gained marks in part (b) as well, but some parts of answers were irrelevant (e.g. smell and taste) whereas other answers lacked precision (e.g. *hormone* instead of *gastrin*; *gastric juice* instead of *HCl*/*pepsin*).

c. It was similar in part (c), where some candidates had difficulty incorporating enough precision to gain some of the marks, for instance mentioning *aerobic* cell respiration, chemosensors in *aorta* or *carotid arteries*, naming the medulla of the breathing center instead of the brain only, the appropriate respiratory muscles, etc.

Describe how the liver regulates nutrient levels.

Markscheme

a. storage of glucose as glycogen

OR

breakdown of glycogen to glucose

Do not accept "sugar".

b. deamination/breakdown of «excess» amino acids

c. storage/recycling of iron/copper

d. produces/eliminates cholesterol «as necessary»

e. storage of vitamin A/vitamin D/vitamin B12/vitamin K

Examiners report

[N/A]

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a.i. Jaundice causes a yellow discolouration of the skin, mucous membranes and sclera of the eyes. State the bile pigment causing this discolouration. [1]

a.ii. Explain how the normal production of bile pigments changes with the development of jaundice. [4]

b. Distinguish between the structure of liver sinusoids and capillaries. [2]

Markscheme

a.i. bilirubin

a.ii. *normal production:* **[2 max]**

a. **red** blood cells/erythrocytes/hemoglobin broken down «in the liver»

b. hemoglobin/heme «from red blood cells» is converted to bilirubin/bile pigment

c. bilirubin/bile pigment transferred to bile and «normally» eliminated in the feces

change with jaundice:

d. «in jaundice» liver does not excrete/eliminate bilirubin/bile pigments

e. caused by immaturity/dysfunction/disease «of the liver»

OR

blockage of bile ducts

OR

increase in red blood cells breakdown

f. therefore bilirubin/bile pigment accumulates in the blood

[Max 4 Marks]

b. a. sinusoids have open pores/fenestrations/discontinuous endothelium and capillary endothelium is continuous/does not contain fenestrations

b. Kupffer cells are located inside sinusoids but not in capillaries

c. sinusoids larger in diameter/wider than capillaries

[Max 2 Marks]

Examiners report

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

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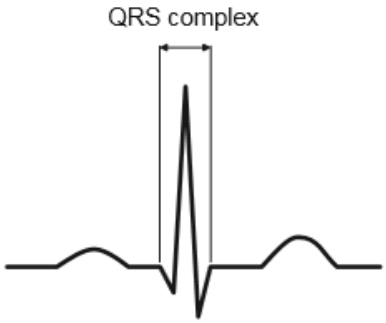
a. The diagram shows an ECG trace with the QRS complex indicated. [2]



Outline the events of the cardiac cycle that are occurring during this QRS interval.

b. Heart rate is affected by the hormone epinephrine. The action of epinephrine is mediated by a chemical called a second messenger. Explain the mechanism of action of a second messenger. [3]

c. During cardiac arrest, the ventricles of the heart might begin to contract in an uncoordinated fashion. Outline the treatment used for this condition. [1]

d. Explain the role of chemoreceptors in the regulation of ventilation rate. [3]

Markscheme

a. Septum depolarizes

OR

Signal from AVN/atrioventricular node

Conducting fibers carry impulses through the ventricle wall
OR
Carry impulse through Bundle of His/Purkinje fibers

Ventricles depolarize
OR
Atrioventricular valves close *Do not accept the alternative mp if other valves closing is mentioned as well*.

Atria repolarize

Ventricle contraction/systole initiated

b. Epinephrine/peptide/protein/hydrophilic hormones bind to «receptors in» plasma membrane

Involves synthesis/release/activation of second messenger/cyclic AMP/cAMP

Triggers cascade of events

Leads to promotion/inhibition of enzymes
OR
Causes activation of protein kinase

Causes the hormone effect

c. Use a defibrillator to restore/reset normal rhythm/to shock the heart/restore heart beat (*Do not accept pacemaker*)

OR

Application of an electric discharge to the chest to restore normal rhythm

Need something more than one word answer as this is an "outline".

d. High CO_2 levels lead to decrease in pH/increased acidity *(Accept inverse statements using low CO_2 concentration/higher pH)*

Chemoreceptors found in the medulla oblongata/aorta/carotid artery

They are able to detect a change in blood pH/CO_2 concentration

«Chemoreceptors» send message/impulse to the respiratory centre

Respiratory centre «in medulla oblongata» controls ventilation rate

Triggers an increase in the ventilation rate to rid the body of CO_2

Examiners report

a. Many candidates were awarded one mark for noting that ventricular systole occurred in the QRS interval but few could go further than that.

b. This was discriminating with stronger candidates able to achieve the 2 marks but some confused protein and steroid hormone actions and others tried to explain the effect of epinephrine on the heart. There were several comments on the G2 forms that the reference to epinephrine was not needed and may have confused candidates who were learners of English as an additional language.

c. Most were able to outline the use of a defibrillator but some only stated the name of the instrument so did not receive the mark as this question asked them to ‘outline’ the treatment. While some teachers on G2 forms indicated this was not on the syllabus, one of the applications in D.4 is “Application: Use of defibrillation to treat life-threatening cardiac conditions”.

d. Most candidates were able to score one or 2 marks with stronger candidates awarded full marks but good clear answers were not that common.

Explain the role of the SA (sinoatrial) node in the cardiac cycle.

Markscheme

SA node is located in the wall of right atrium of heart muscle;

has characteristics of both nerve and muscle tissue;

SA node initiates each impulse;

acts as pacemaker of the heart;

no nerve impulses needed for contraction / myogenic;

connected to nerves which slow/accelerate heart rate;

impulses spread out in all directions through walls of atria;

stimulates atrial systole/contraction;

fibres in walls of atria prevent impulses from reaching ventricles;

impulses reach AV node (after atrial contraction);

Examiners report

There were variable responses from very poor to very good. Many confused the role of the SA node as the pacemaker with the actual opening and closing of the valves in the heart. Candidates did seem to do marginally better on this question 3 than in the other options.

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a.i. Thyroxin is a hormone produced in the thyroid gland. State **one** function of thyroxin. [1]

a.ii. The action of thyroxin is similar to steroid hormones. Describe the action of steroid hormones. [3]

b. The World Health Organization recommends that the iodine intake should be supplemented in pregnant women due to their increased requirements. Outline the need for iodine supplementation. [2]

Markscheme

a.i. a. regulates the «basal» metabolic rate/BMR

b. controls body temperature

[Max 1 Mark]

a.ii. a. steroid hormone passes through cell/plasma membrane

b. binds to receptor «proteins» in cytoplasm

c. receptor–hormone complex travels to nucleus

d. binds to DNA/chromatin

e. promotes/inhibits the transcription of specific genes

f. codes for/produces specific proteins

[Max 3 Marks]

b. a. iodine is an essential nutrient/cannot be synthesized by the body

b. iodine is required for thyroid hormones/thyroxin production

c. some areas in the world have iodine deficient soil/low iodine in their diet

d. supplementation will reduce stunted growth and mental development/cretinism in babies born to mothers associated with thyroid deficiency

e. thyroid deficiency will lead to health problems

[Max 2 Marks]

Examiners report

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

Explain the oxygen dissociation curves of adult hemoglobin, fetal hemoglobin and myoglobin.

Markscheme

adult hemoglobin: [2 max]

a. rapid saturation of oxygen in the lungs;

b. rapid dissociation of oxygen as the oxygen concentration decreases;

c. oxygen released in the tissues where needed;

fetal hemoglobin: [2 max]

d. fetal hemoglobin curve to the left of adult hemoglobin;

e. higher affinity for oxygen than adult hemoglobin;

f. oxygen moves from adult hemoglobin to fetal hemoglobin;

myoglobin: [2 max]

g. myoglobin to the left of fetal hemoglobin;

h. higher affinity for oxygen than adult hemoglobin;

i. only releases oxygen at very low oxygen concentrations/in tissues;

j. oxygen reserve;

Examiners report

There were some very complete answers and some very weak ones. Many talked about Bohr shift instead of explaining the graphs.

Describe how the liver helps to maintain human health.

Markscheme

a. helps regulate blood glucose level / converts glucose to glycogen and back;

b. prevents excess glucose that could damage cells / lack of glucose could limit cell growth/activity / *OWTTE*;

c. stores/recycles iron;

d. stores vitamin A/vitamin D;

e. synthesizes plasma proteins/cholesterol;

f. provides essential substances for cell growth/hormone production;

g. detoxifies substances / protects the body from damage from toxic substances (as alcohol);

h. breaks down erythrocytes/hemoglobin;

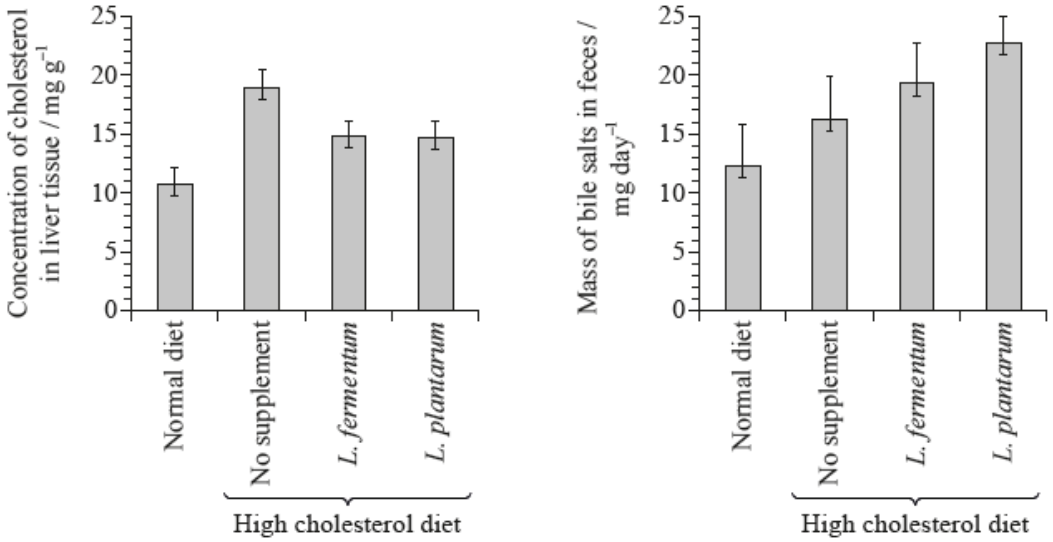
i. production of bile for digestion (of fats);

j. (production of bile) reduces build-up of bilirubin in the blood / prevents jaundice;

Examiners report

Many of the answers were excellent and most candidates provided complete answers. Some went into far too much detail on some aspects, including the control of glucose levels, but nevertheless included enough material for their answer to be complete.

The cholesterol-lowering effect of *Lactobacillus* bacteria was studied. Forty rats were divided into groups and fed either a normal or high cholesterol diet. Some rats fed the high cholesterol diet were also supplemented with *L. fermentum* or *L. plantarum*. After a six week feeding period, the concentration of cholesterol in liver tissue and the mass of bile salts in feces were measured.



[Source: adapted from Ning Xie, Yi Cui, Ya-Ni Yin, Xin Zhao, Jun-Wen Yang, Zheng-Gen Wang, Nian Fu, Yong Tang, Xue-Hong Wang, Xiao-Wei Liu, Chun-Lian Wang, Fang-Gen Lu (2011) Effects of two *Lactobacillus* strains on lipid metabolism and intestinal microflora in rats fed a high-cholesterol diet. *BMC Complementary and Alternative Medicine*, **11**, pp. 53–64.]

a. State the concentration of cholesterol in liver tissue and the mass of bile salts in feces for the normal diet, giving the units. [2]

Concentration of cholesterol:

Mass of bile salts:

b. Calculate the percentage increase in the concentration of cholesterol in liver tissue, caused by feeding the rats a high cholesterol diet without supplementing with bacteria. Show your workings. [1]

c. Deduce the effects of supplementing the diet with *Lactobacillus* on the concentration of cholesterol in liver tissue and on the mass of bile salts in feces. [2]

d. Scientists hypothesized that *Lactobacillus* could be used in diets to reduce the incidence of coronary heart disease (CHD). Evaluate the evidence for and against this hypothesis provided by the data. [3]

Markscheme

a. *concentration of cholesterol:* $11\ \text{mg}\,\text{g}^{-1}$;

(accept answer in the range of 10.5 mg g^{-1} to 11.5 mg g^{-1})

mass of bile salts: 12 mg day^{-1};

(accept answers in the range of 11.5 mg day^{-1} to 12.5 mg day^{-1})

Units are required.

b. $19 - 11 = \frac{8}{11} = 73(\%)$ *(accept answers in the range of 72.7(%) to 81.0(%))*

c. supplementation decreases liver cholesterol in high cholesterol diet;

not enough to bring it to the level of a normal diet;

no difference between *L. plantarum* and *L. fermentum* in the decrease of liver cholesterol;

supplementation increases bile salts levels;

greater increase in bile salts levels with *L. plantarum* / lesser/(perhaps) non-significant increase with *L. fermentum*;

d. *Evidence for hypothesis:*

Lactobacillus/supplements lower liver cholesterol (in high cholesterol diet) which is a risk factor for CHD;

Lactobacillus/supplements increase bile salts in feces which implies some cholesterol may be eliminated;

Evidence against hypothesis:

not known if cholesterol ends up in blood instead thus increasing risk for CHD;

no data about benefit for normal diet/actual decrease of incidence of CHD;

data/results based on rat experiments / may not apply to humans;

WTTE of taking into account difference in bile salt level between *L. fermentum* and *L. plantarum*;

Examiners report

a. Most candidates could provide the values, but fewer could calculate the percentage increase correctly. Most could deduce the effects of the supplement to gain the two marks, but many candidates didn't realize that supplements applied to high cholesterol diets only or failed to mention that cholesterol applied to liver tissue. This had consequences on their evaluation of usage of supplements to treat CHD; many considered only the evidence provided by the cholesterol concentrations supporting the hypothesis.

b. Most candidates could provide the values, but fewer could calculate the percentage increase correctly. Most could deduce the effects of the supplement to gain the two marks, but many candidates didn't realize that supplements applied to high cholesterol diets only or failed to mention that cholesterol applied to liver tissue. This had consequences on their evaluation of usage of supplements to treat CHD; many considered only the evidence provided by the cholesterol concentrations supporting the hypothesis.

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d. Most candidates could provide the values, but fewer could calculate the percentage increase correctly. Most could deduce the effects of the supplement to gain the two marks, but many candidates didn't realize that supplements applied to high cholesterol diets only or failed to mention that cholesterol applied to liver tissue. This had consequences on their evaluation of usage of supplements to treat CHD; many considered only the evidence provided by the cholesterol concentrations supporting the hypothesis.

Explain the role of the liver in regulating and storing nutrients.

Markscheme

a. all nutrients arrive at the liver (from small intestine) via hepatic portal vein;

b. liver stores (excess) glucose as glycogen and releases it as needed / *OWTTE*;

c. process is (respectively) under the control of insulin/glucagon;

d. (glucose levels) controlled by negative feedback;

e. amino acids are deaminated in the liver;

f. liver produces plasma proteins/albumin/fibrinogen;

g. synthesizes/stores cholesterol;

h. liver stores iron from the breakdown of hemoglobin in red blood cells;

i. liver stores vitamin A/vitamin D;

Examiners report

Most answers were excellent, but many candidates did not focus on what was asked and provided further details about other roles of the liver, such as detoxification. Although there were some very vague answers and some that did not go beyond storage of glucose, most in general provided sufficient details about glucose regulation and addressed the storage of iron and Vitamins A and D.

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a. Distinguish between the mode of action of steroid and peptide hormones. [2]

b. Outline the control of gastric juice secretion. [2]

Markscheme

a. a. peptide hormones do not enter the cell whereas steroid hormones do;

   b. peptide hormones bind to a cell surface receptor whereas steroid hormones bind to a receptor in the cytoplasm;

   c. peptide hormones act through a secondary messenger/cAMP whereas steroid hormones have (direct) effect on DNA;

   d. steroid hormones have effect on gene transcription whereas peptide hormones change activities of cell/influence enzyme activity;

b. a. involves both nerve impulses and the hormone gastrin;

   b. sight/smell of food causes nerve impulses to be sent/reflex action;

   c. food in stomach stimulates touch receptors/chemoreceptors/stretchreceptors releasing more gastric juice;

   d. stretching of stomach wall stimulates secretion of the hormone gastrin;

Examiners report

a. The better candidates were able to clearly distinguish between steroid and peptide hormones

b. The control of gastric juice secretion by nerve impulses and the hormone gastrin was poorly done in general with few getting the 2 marks.

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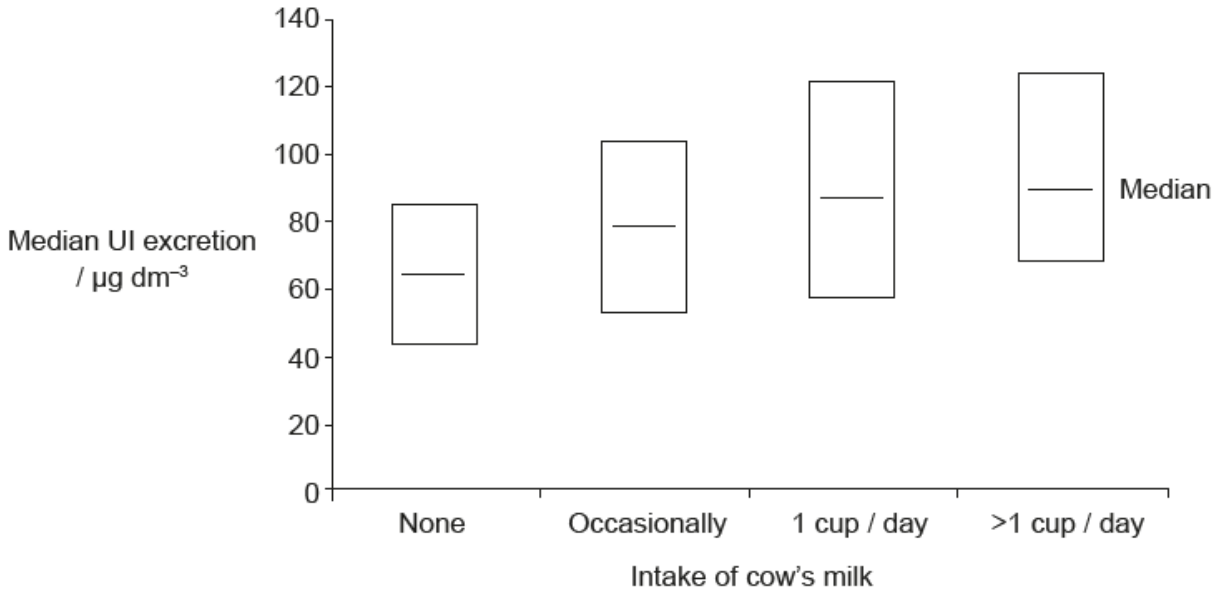
a. A good marker of dietary intake of iodine is the urinary iodine level (UI). A study was carried out in the UK to establish urinary iodine levels and milk intake in schoolgirls aged 14–15 years. [2]



[Source: M Vanderpump (2014) *Clinical Medicine* 2014, Vol 14, No 6, Royal College of Physicians, pages 7–11. Reproduced with permission of ROYAL COLLEGE OF PHYSICIANS, via Copyright Clearance Center.]

Urinary iodine values from 50 to 99 μg dm^{-3} are considered to be mild iodine deficiency. Deduce the effect of milk intake on the iodine status of schoolgirls in the UK.

b. Outline the need for iodine in the endocrine system. [2]

c. Growth hormones are examples of peptide hormones. Explain the mechanism of action of peptide hormones. [3]

Markscheme

a. a. the more milk taken in, the higher the iodine levels

b. when no milk consumed all girls «in study» were iodine deficient

c. in all cases median value is mildly deficient so milk may have no effect

d. increase above 1 cup/day may have no/little effect

Accept answers in the converse.

b. a. iodine is absorbed/used/needed by the thyroid

b. «needed» to synthesise thyroxin

c. lack of iodine causes swelling of thyroid gland/goiter/hypothyroidism
OR
thyroxin used to regulate metabolic rate/generate heat

c. a. «peptide hormones» do not enter cells

b. bind to «specific surface» receptors in plasma membrane

c. leads to production /release of a secondary messenger inside cell

d. triggers a cascade of reactions in the cytoplasm

e. usually involves activating or inhibiting enzymes

Examiners report

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

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c. Outline how bile helps in lipid digestion. [1]

d. Describe how bile pigment is formed. [3]

Markscheme

c. bile emulsifies/*OWTTE* lipids so enzymes can act on them

d. a. hemoglobin from the red blood cells is absorbed/phagocytosed in the liver/by Kuppfer cells;

b. hemoglobin is broken down into heme and globin groups;

c. iron is removed from the heme groups;

d. (residue from) heme becomes bilirubin/bile pigment (in hepatocytes);

Examiners report

c. This part was relatively easy for the candidates, but some missed some marks due to incorrect answers or lack of detail. We have seen non-hormone peptides in (a), no mention of stomach in (b), no enzymes in (c), and short cuts, inappropriate terminology (e.g. protein instead of globin) or misconceptions (e.g. heme is the bile pigment) in (d).

d. This part was relatively easy for the candidates, but some missed some marks due to incorrect answers or lack of detail. We have seen non-hormone peptides in (a), no mention of stomach in (b), no enzymes in (c), and short cuts, inappropriate terminology (e.g. protein instead of globin) or misconceptions (e.g. heme is the bile pigment) in (d).

Explain the mechanisms used by the ileum to absorb and transport food.

Markscheme

absorption occurs through epithelial cells on villi/tiny projections;

microvilli/brush border on cell membrane increase surface area;

tight junctions prevent leakage of nutrients;

lipids/fat soluble/non-polar substances diffuse across membranes;

converted into tryglicerides / coated with proteins to form chylomicrons/lipoproteins;

which enter into lacteals/lymphatic system by exocytosis;

fructose/hydrophilic food enters by facilitated diffusion/through channel proteins;

active transport requires ATP (from many mitochondria in cells) / against concentration gradient through pump proteins;

e.g. glucose/amino acids/minerals enter through co-transported sodium carriers;

endocytosis of large molecules (*e.g.* vitamin B12) / pinocytosis of liquids;

capillaries (close to epithelial cells) transport substances (to body via bloodstream);

Examiners report

Most candidates gained a range of marks for this question, but most answers lacked enough precision to gain all of them, being limited to generalities about absorption and transport of nutriments by the ileum and/or addressing only core assesment statements instead of option H's. Many candidates used inappropriate terminology (e.g. *membrane* instead of *epithelium*; *blood vessel* when *capillary* is meant) and limited themselves to stating factual knowledge without providing an actual explanation of the mechanisms (e.g. glucose is actively transported *through sodium carriers*). Many students reported epithelial cells having pinocytic vesicles to absorb various types of molecules, not realizing that these vesicles are the result of endocytosis and not the cause.

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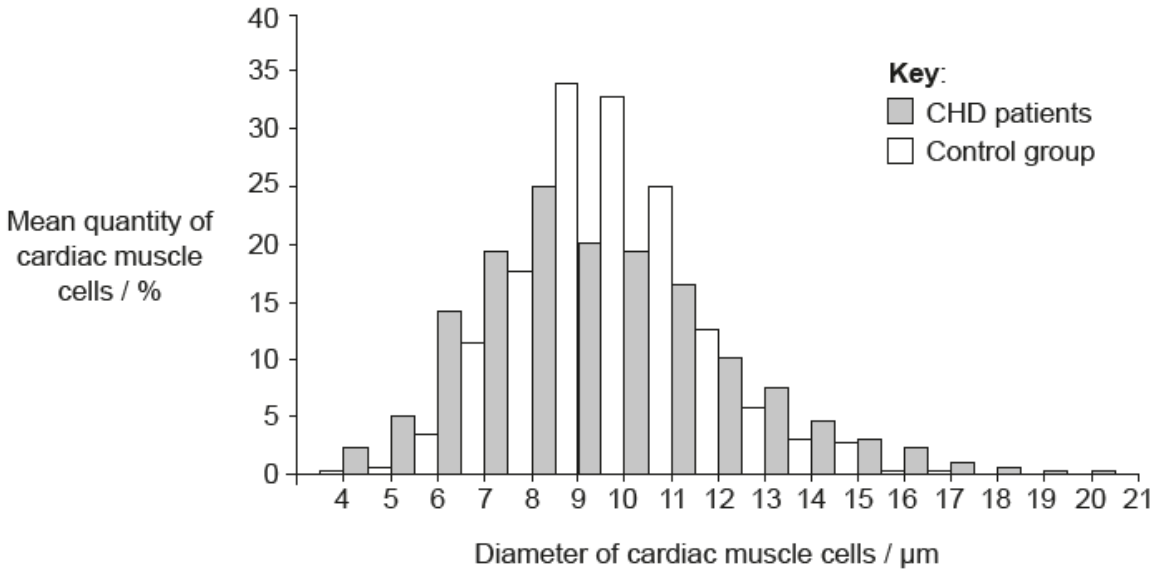
a. Samples from cardiac muscle were taken during autopsies from individuals who had coronary heart disease (CHD) and a control group. The histogram shows the relationship between the quantity of cardiac muscle cells and their diameter in the left ventricle in the two groups. [1]



[Source: A Karaskov, *et al.*, (2011), *Health 3*, pages 263–270]

Distinguish between the distribution of cardiac muscle cell diameters in the CHD and control groups.

b. Describe how the structure of cardiac muscle cells allows them to transmit impulses. [3]

c. Explain the reason for the delay between contractions of the atria and of the ventricles. [2]

Markscheme

a. a. CHD has wider range/spread/more variation of diameter values / vice versa

b. control has higher percentage/proportion/peak in middle values (accept numbers between 8–12)

Accept numerical statement supporting this

b. a. are branched/ have a Y-shape/ interconnected / connect to several neighbouring «cardiac» cells

b. intercalated discs are special regions of/junctions between plasma membranes

c. provide electrical coupling / enable rapid transmission of «electrical» impulses «between cells»

d. ion channels in membranes

e. «ease of» flow of ions allows action potentials to spread «between cardiac cells»
OR
«ease of» flow of ions allows rhythmic depolarization

f. trigger action potentials without nervous input

Accept annotated drawings.

c. a. impulses from atria do not pass directly to ventricles «due to layer of fibrous material»

b. travel to ventricle via atrio-ventricular node/AVN in wall of right atrium

c. impulses from AVN sent along Bundle of His /conducting fibres/Purkinje fibres

d. ensures that the atria have ejected their blood into the ventricles first before the ventricles contract

Examiners report

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

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a (i) Define *hormones*. [1]

a (ii) State **one** type of hormone, giving an example. [1]

b. Compare gastric juice and pancreatic juice. [3]

Gastric juice	Pancreatic juice

c. Outline the reason for **one named** substance found in food not being digested and absorbed by humans. [2]

Markscheme

a (i) chemical messengers secreted by endocrine glands/specialized cells directly into the blood/body fluid (and transported to specific target cells);

a (ii) steroid hormone *e.g.* testosterone / peptide hormone *e.g.* insulin / tyrosine derivatives *e.g.* thyroxine;

b.

Gastric juice	*Pancreatic juice*
produced by glands in stomach wall	produced by pancreas;
low pH / acidic	high pH / alkaline;
contains hydrochloric acid	contains HCO_3^-;
pepsinogen	trypsinogen;
no enzymes for lipid/starch digestion	lipase/amylase;
contains mucus	no mucus;

*Award **[1]** for each pair.*

c. cellulose / lignin;

cellulase not present / no enzymes for digesting lignin;

Accept any other reasonable substance.

Examiners report

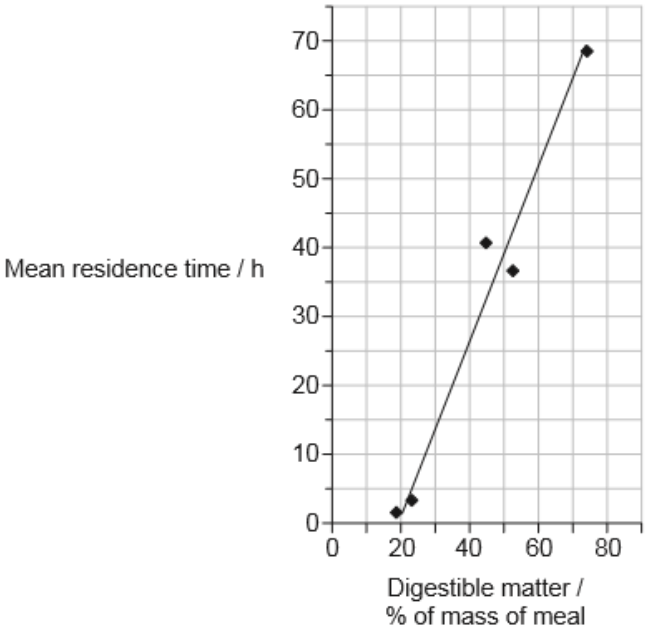
a (i) Most gave an incomplete definition of a hormone in (i) and therefore did not get the mark.

a (ii) Part (ii) was often well-answered although some indicated the type of hormone as a sex hormone rather than stating it was a steroid hormone.

b. This was very poorly done by the majority of candidates. Those candidates that did know some facts about the two digestive juices did not make point by point comparisons despite the table provided. The table did seem to discourage better candidates from giving a similarity which would be expected for a comparison of two things. This was not penalized.

c. Many were able to get the 2 marks here for cellulose and lack of cellulose.

The graph shows the length of time that the content of a meal takes to pass through the gut as a function of digestible matter content. The more digestible matter present in the meal, the lower the dietary fibre content.



[Source: © International Baccalaureate Organization 2016]

a. Estimate the mean residence time of a meal with 50 % digestible matter. [1]

b. Explain the relationship between percentage of digestible matter and mean residence time. [3]

Markscheme

a. 38 hours

Accept 38 hours to 40 hours. Units required.

b. Higher digestible matter content, longer residence time

Slower movement/peristalsis due to lack of fiber

Fiber/indigestible material attracts water to feces/lumen/intestinal contents

More digestible material increases water absorption «into large intestine»

Hardens stool/constipation and further increases residence time

Examiners report

a. Almost all were able to correctly read the graph and estimate the mean residence time.

b. Most candidates received one mark for noting the relationship between percentage digestible matter and mean residence time but only better candidates were able to explain this. Many were misled into talking about the time taken for digestion to occur rather than mentioning fibre increasing water absorption into the feces and aiding movement by peristalsis.

Explain how the liver stores and regulates levels of nutrients in the body, including details of the circulation of blood through the liver in your answer.

You may use a diagram to illustrate your answer.

Markscheme

(*circulation of blood through liver tissues – accept properly annotated diagram*)

hepatic artery brings oxygenated blood;

hepatic portal vein brings nutrients (from small intestine);

merge to form sinusoids where liver cells/hepatocytes store and regulate nutrients;

blood leaves through hepatic vein;

(*storage and regulation of nutrients*)

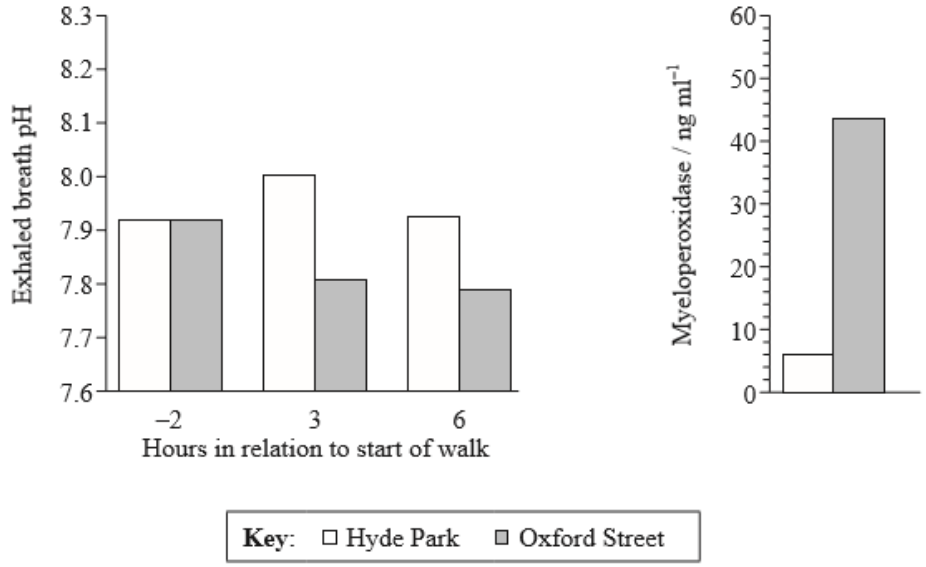
one named stored nutrient; (*e.g. carbohydrates*/*glycogen* / *iron* / *vitamin A*/*retinol* / *vitamin D*/*calciferol*)
(*award **[1 max]** for naming nutrients*)

hepatocytes regulate blood sugar level by storing glucose as glycogen / releasing glucose from breakdown of glycogen (facilitated by arrival from portal vein);
under influence of insulin/glucagon (respectively) (carried by hepatic artery);
blood lipids/cholesterol synthesized/broken down if required / secreted through bile;
iron stored from breakdown of hemoglobin/released when Po_2 is low;

Examiners report

The majority of candidates scored high marks for this question and many covered a sufficient number of elements to gain all the marks despite too vague or incorrect statements in some of their answers. Candidates overall had a good understanding of the blood vessel connections to the liver. The only confusion was sometimes mixing up glycogen with glucagon. Several went well beyond the mark scheme (and sometimes the syllabus) with descriptions of hemoglobin breakdown, bile production and treatment of amino acids.

Researchers explored the effects of roadside traffic exposure in London on people with asthma. Each participant walked for two hours through Hyde Park, a large traffic-free park, and on a separate occasion along Oxford Street, where diesel-powered buses and taxicabs are permitted. The researchers measured the pH of the participants' exhaled breath two hours before each walk and three hours and six hours after the start of each walk. The level of an inflammation indicator, myeloperoxidase, was also measured the day after the experiment.



[Source: From *The New England Journal of Medicine*, James McCreanor, Paul Cullinan, Mark J. Nieuwenhuijsen et al., Respiratory Effects of Exposure to Diesel Traffic in Persons with Asthma, 357, 23. Copyright © (2007) Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society]

a. Calculate the percentage increase of myeloperoxidase between Hyde Park and Oxford Street for participants. [1]

b (i) Compare the changes in exhaled breath pH caused by walking through Hyde Park and along Oxford Street. [2]

b (ii) Explain the changes in exhaled breath pH caused by walking along Oxford Street in people with asthma. [2]

Markscheme

a. 625 % (*percentage required*) (*accept answers in the range of 600 % to 650 %*)

b (i) pH rises in Hyde Park and falls along Oxford Street;

back to pre-walk level in six hours in Hype Park but not along Oxford Street;

b (ii) asthma (attack) constricts bronchioles (while walking);

exercise/walking increases cell respiration producing more CO_2;

lower ventilation causes CO_2 build-up thus lower pH;

CO_2/pollutants in the air could be causing/triggering acidification;

inflammation (by-products) lower pH;

Examiners report

a. Many candidates calculated the correct percentage increase, but also many did not know how to carry out the calculation.

b (i) Most candidates could state that one pH increased while the other decreased, but found it more difficult to state that it returned to the original value only in Hyde Park and to explain these changes.

b (ii) Most explanations related to CO_2 triggering acidification.

Explain the events of the cardiac cycle, including the heart sounds.

Markscheme

a. during diastole the heart muscles/atria/ventricles are relaxed;

b. blood enters the atria;

c. during atrial systole the atria contract and blood moves into the ventricles;

d. pressure (in ventricles) causes bicuspid/tricuspid/AV valves to close;

e. (this) closing of valves causes first heart sound;

f. during ventricular systole the ventricles contract causing blood to flow to aorta/pulmonary artery/arteries/out of heart;

g. semilunar valves close so blood does not return to the ventricles;

h. this causes the second heart sound;

i. blood leaving atria/ventricles during contraction is caused by increased pressure which reduces volume;

Examiners report

Most candidates demonstrated a sound understanding of this topic and scored high for this question, but many did not distinguish between the events of the cardiac cycle and the mechanisms that control the heartbeat, including everything in their answer and perhaps losing precious time. Many answers incorporated the same unnecessary details, probably learned from the same manual. Sometimes the weaker candidates only described the events on one side of the heart and did not refer to pressure, systole or diastole. There was also sometimes some confusion about the opening and closing of the valves.

The liver is a complex organ with a wide range of functions. Outline the functions of the liver.

Markscheme

a. produces bile for digestion/emulsification of fats/lipids;

b. regulates blood glucose level through glucose-glycogen reaction;

c. detoxification/example of detoxification (eg contains catalase for the breakdown of hydrogen peroxide);

d. manufactures plasma proteins/albumins/fibrinogen;

e. manufactures cholesterol;

f. destroys red blood cells by phagocytosis;

g. breaks down haemoglobin from red blood cells;

h. stores iron;

i. stores vitamin A and D;

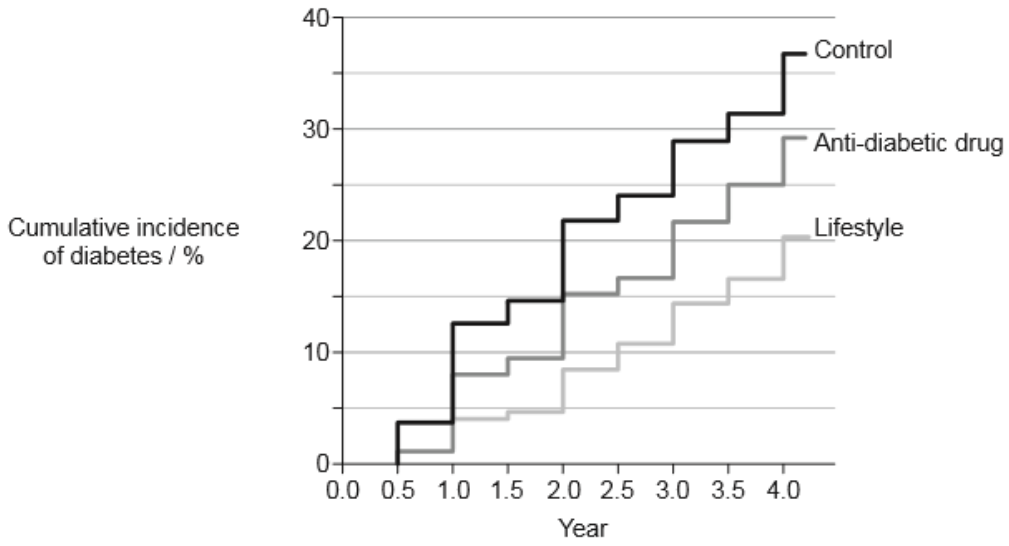
j. deaminates excess amino acids/formation of urea;

Examiners report

Some candidates did well on this longer response question with many scoring 3 marks. However, there were also many responses that were vague and lacked detail.

---

a. A study was undertaken to determine the most effective method to delay the onset of type II diabetes in high-risk patients. Three groups were given either a placebo (control), a medicine that suppresses glucose production by the liver (anti-diabetic drug) or a lifestyle-modification program (lifestyle). The results for four years are shown in the graph. [2]



[Source: adapted from Berry, Colin, Jean-Claude Tardif, and Martial G. Bourassa. "Coronary Heart Disease in Patients With Diabetes." *Journal of the American College of Cardiology* 49.6 (2007): 631-642. Web. 19 Jan. 2017.]

Analyse the use of the anti-diabetic drug in delaying the onset of type II diabetes.

b. List features that would increase a person's risk of developing diabetes. [2]

Markscheme

a. a. less incidence of diabetes/more effective than placebo/control

b. but less effective than change in lifestyle

c. incidence nevertheless increases over the years

d. possibly ideal would be to combine both «anti-diabetic drugs and lifestyle»
OR
lifestyle and anti-diabetic drugs not tried together «so we do not know the outcome»

b. a. overweight patients

OR

obesity

b. sedentary lifestyle

c. high glucose diet
OR
high glucose level in blood

d. genetic predisposition

e. other valid risk factor

Examiners report

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

---

a. In healthy adults, there are heart sounds during the cardiac cycle. Outline the causes of **two** of these sounds. [2]

b. State **two** products resulting from the breakdown of erythrocytes (red blood cells) in the liver. [2]

1. .....

2. .....

c. Compare gastric juice and pancreatic juice. [3]

	Gastric juice	Pancreatic juice
Acidity or alkalinity		
Enzymes		
Site of action		

d. List **one** material that is egested after human digestion. [1]

Markscheme

a. changing pressure of blood in heart automatically opens and closes the valves / the closing of valves generates the heart sounds;

first heart sound (S_1) is produced by the closing of the AV valves/mitral and tricuspid valves;

second heart sound (S_2) produced by the closing of semilunar valves/aortic and pulmonary valves;

b. iron;

bile pigments/bilirubin;

globin/amino acids;

c.

	Gastric juice	*Pancreatic juice*
Acidity or alkalinity	1–2/acidic/hydrochloric acid	7–8/slightly alkaline/ HCO_3^-/hydrogen carbonate;
Enzymes	pepsin(ogen) / rennin	mixture of (many) enzymes/amylase / lipase / carboxypeptidase / trypsin(ogen); *Do not award mark if incorrect enzyme listed for either.*
Site of action	stomach	small intestine / duodenum;

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

d. cellulose / lignin / bile pigments / intestinal cells / bacteria

Examiners report

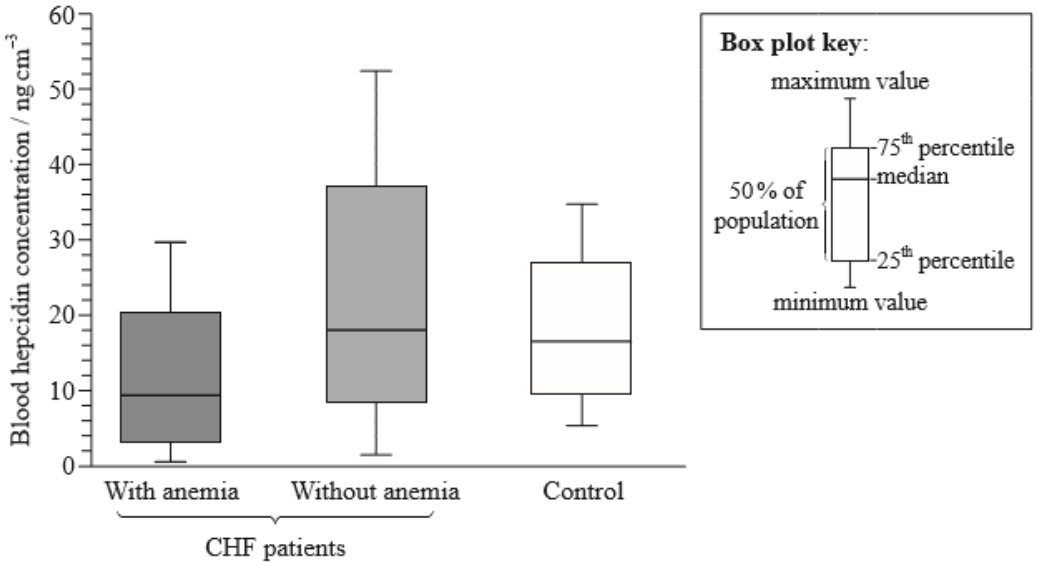
a. Many understood the role of the valves in causing the heart sounds although few referred to changing pressure in the heart causing this to occur.

b. This was fairly well done with most candidates obtaining one mark and a very good number receiving two marks for products from the breakdown of hemoglobin.

c. Although this table seemed very straightforward to fill in, many candidates wrote vague responses, incorrectly said that pancreatic juice worked in the pancreas and listed incorrect substances in the spaces for the enzymes in each digestive juice.

d. Almost all were correctly able to list one material egested; usually cellulose was the reply.

In patients with coronary heart failure (CHF), the presence of anemia can increase the risk of mortality. Anemia is a shortage of red blood cells or a reduced concentration of hemoglobin in the blood. Hepcidin is a peptide that is synthesized in the liver to suppress iron absorption in the intestine. The blood hepcidin concentration in CHF patients with anemia and without anemia was measured. The control group did not have cardiac disease or anemia.



[Source: Matsumoto *et. al*, Iron Regulatory Hormone Hepcidin Decreases in Chronic Heart Failure Patients With Anemia, *Circulation Journal*, December 18, 2009. Reproduced with permission.]

a. State which group has the greatest range of blood hepcidin concentration. [1]

b. Calculate the difference in median blood hepcidin concentration for CHF patients with anemia and without anemia, giving the units. [1]

c. Using the data, deduce whether the incidence of CHF **or** the incidence of anemia has a greater effect on the blood hepcidin concentration. [3]

d. Iron is necessary for hemoglobin to carry oxygen so low iron levels cause low levels of hemoglobin. Suggest reasons for the levels of hepcidin found in CHF patients with anemia. [2]

Markscheme

a. CHF without anemia

b. 9 ng cm^{-3} (*calculation not required, accept answers in the range of 8.5 ng cm^{-3} to 9.2 ng cm^{-3}*)

c. median of CHF without anemia greater than median of CHF with anemia;

median of CHF without anemia similar to median of control;

median of CHF with anemia lower than median of control;

anemia (with CHF) appears to be more significant than CHF (without anemia) in affecting hepcidin concentrations;

difficult to determine as overlaps of ranges/population sizes not given/no control with anemia;

d. low hepcidin levels in CHF patients with anemia;

low hepcidin allows more iron intake/absorption;

more iron allows more hemoglobin so less anemia / low iron leads to anemia;

low iron levels exert negative feedback on hepcidin production;

Examiners report

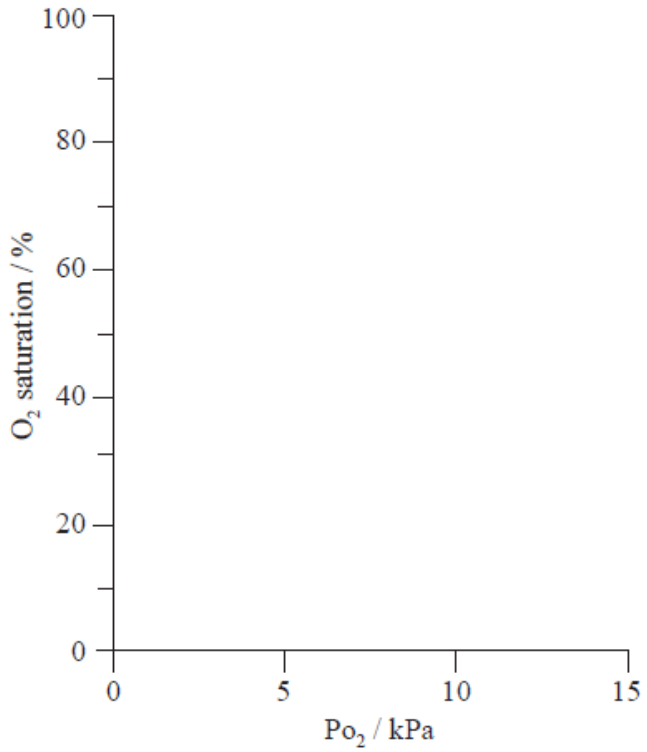
a. It seems that this question was extremely difficult for many students. In part (a) the majority read the graph as "without anemia" being the group with the greatest range of hepcidin concentrations, but only a part of them added "CHF patients" to gain the mark, since the control group was also without anemia.

b. Most calculated the difference correctly for part (b), but a certain number of answers were out of acceptable range, probably due to a too imprecise reading of values.

c. For part (c), only a part of candidates gained their only mark for deducing that anemia with CHF was more significant in affecting hepcidin concentration; many failed to consider medians when comparing the data, in spite of the focus on the median of the part (b), and many also only compared differences in values without stating if it was higher or lower than the control median value. Some candidates nevertheless noticed how the ranges overlapped and that the data could therefore not be completely trusted.

d. For part (d), candidates could say that the CHF patients with anemia had lower hepcidin levels, but they often misunderstood the mechanism of why that was true and did not seem to understand that iron could be obtained from nutrition and could be absorbed when hepcidin levels were low to restore iron deficiencies and low hemoglobin. Many stated that the iron was coming from the breakdown of hemoglobin in anemic patients.

Explain the oxygen dissociation of **myoglobin**, completing the graph below to support your answer. Po_2 is the partial pressure of oxygen.



Markscheme

myoglobin is specialized for oxygen storage;

myoglobin has a single heme/globin unit/polypeptide chain;

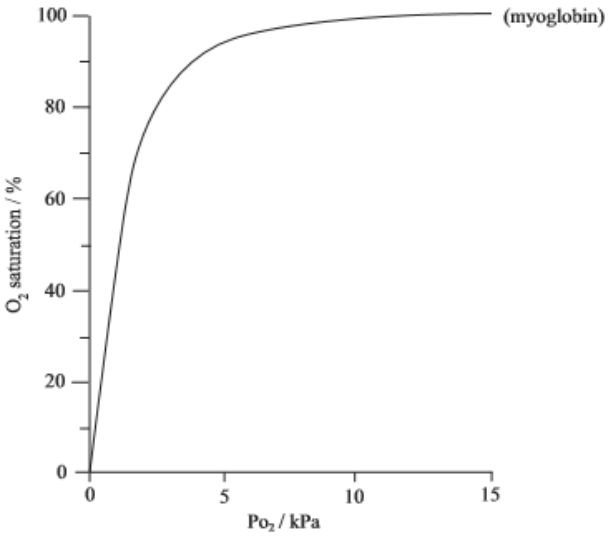
found in muscle;

myoglobin has a higher affinity for oxygen than haemoglobin; (*allow this point if haemoglobin dissociation curve correctly drawn to right of myoglobin curve and labelled*)

in normal conditions/at rest myoglobin is saturated with oxygen;

used during intense muscle contraction when the oxygen supply is insufficient/whenmuscle is very active its oxygen concentration may fall (below 0.5 kPa);

when this happens myoglobin releases oxygen;

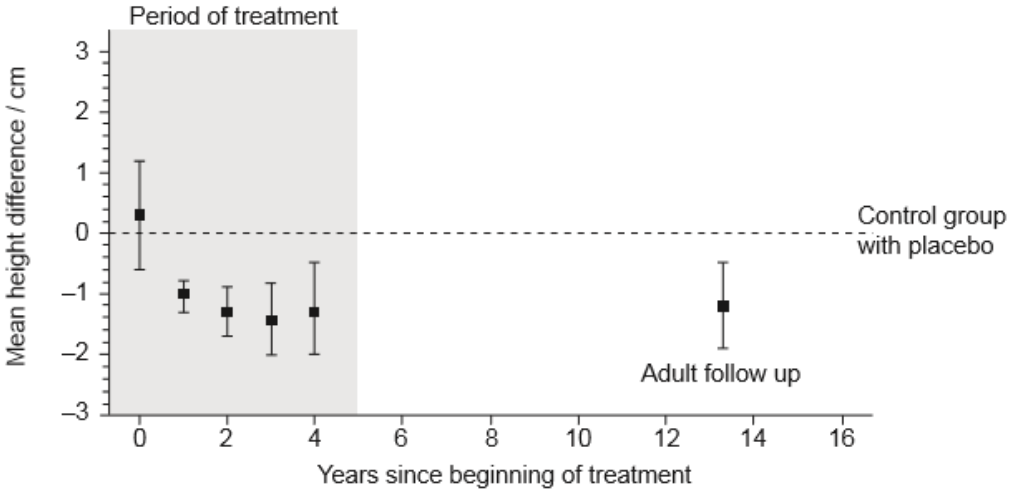


steep rise below 5 kPa with no lag/not sigmoid;
slower rise approaching 100 % above 5 kPa;

Examiners report

There were variable responses from very poor to very good. Many could draw the oxygen dissociation curve of myoglobin correctly although many had it looking vaguely sigmoid. Many understood that myoglobin was found in muscle, was used for oxygen storage and that it had a higher affinity for oxygen than hemoglobin. Few could actually discuss its saturation with oxygen or its release of oxygen in active muscles.

For children suffering from persistent asthma, budesonide may be used in inhalers to suppress airway inflammation. This therapy may continue for many years, so its long-term effect on growth was studied. One thousand children were randomly assigned to receive either budesonide or a placebo, a neutral substance used as the control, and were monitored until adulthood. The graph shows the difference in height between the group who received the drug and others who received the placebo (the control group). The same treatment group was measured at the start of the treatment period, four times during the treatment period and then once again about eight years later.



[Source: H Kelly *et al.*, (2012), *New England Journal of Medicine*, **367** (10), pages 904–908]

a. State the mean height difference between the budesonide group and the placebo group at the start of the study. [1]

b. The mean age for starting the treatment was nine years. Suggest a reason for the choice of this age. [1]

c. Describe the effect of budesonide on the mean difference in height, during the period of treatment. [2]

d. Evaluate the long-term after-effect of budesonide treatment on height. [2]

e. Suggest one significant shortcoming in the data. [1]

Markscheme

a. a. 0.3 cm (*allow 0.2 to 0.4*);

b. no difference (because of large error bars);

b. growing spurt not yet started/prepuberty

c. a. causes a reduction in height;

b. biggest drop in first year (of treatment);

c. levelling off after two years;

d. no apparent drop after year two because of overlapping error bars;

d. a. height difference (seen during treatment period) persists into adulthood;

b. budesonide group on average about 1.3 cm/13 mm shorter than placebo group / height difference is (likely) unnoticeable/insignificant compared to placebo group;

c. benefit from budesonide treatment (probably) outweighs (slight) loss of height;

e. no information on male versus female/diet/ethnic background/health status/medical treatment or history before study/effects on growth at other ages

Examiners report

a. Almost all were able to use the graph to correctly identify the mean height difference of the two groups.

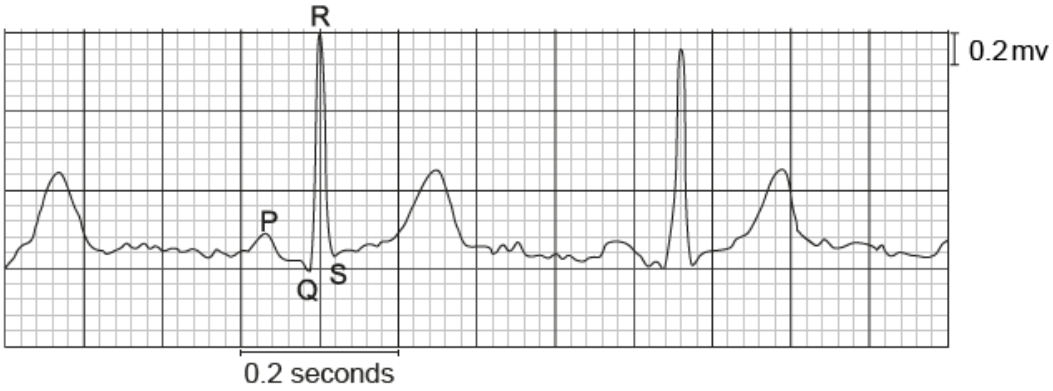
b. Most saw that the starting age of participants in the trial was related to puberty as children at 9 years had not yet started their growing spurt.

c. Candidates struggled to word this answer correctly. Many could get one mark for seeing that it caused a reduction in height but only the better candidates were able to get a second mark. Many seemed to confuse decrease in height with change in height difference between the groups.

d. Many were able to get one mark for seeing that the height difference persisted into adulthood but few got a second mark.

e. There were many possible suggestions for shortcomings of the data but there were few good responses.

The electrocardiogram (ECG) of a normal patient after exercise is shown.



[Source: © International Baccalaureate Organization 2016]

a. Using the R–R interval in this ECG, calculate the heart beats per minute (bpm) of this patient. Show your working. [2]

. . . . . bpm

b. Describe the electrical activity that occurs in the heart during the P wave. [1]

c. Explain why the QRS wave has a larger amplitude than a P wave. [2]

Markscheme

a. a. determining time of 1 beat = 0.46 «seconds»

b. correct calculation of heart rate/beats per minute = 130 «bpm»

Other possible calculations

eg:

23 «squares» × 0.02 «sec» = 0.46

OR

2.3 × 0.2 «sec» = 0.46

OR

$\frac{60\ «sec»}{0.46\ «sec»} «= 130»$.

b. atrial depolarization/electrical impulse travels from the sinoatrial/SA node to the atrioventricular/AV node

Accept atrial systole.

c. a. atrium has a small contraction requiring low electrical charge/OWTTE

b. the QRS complex shows the depolarization of the «right and left» ventricles

Accept ventricular systole.

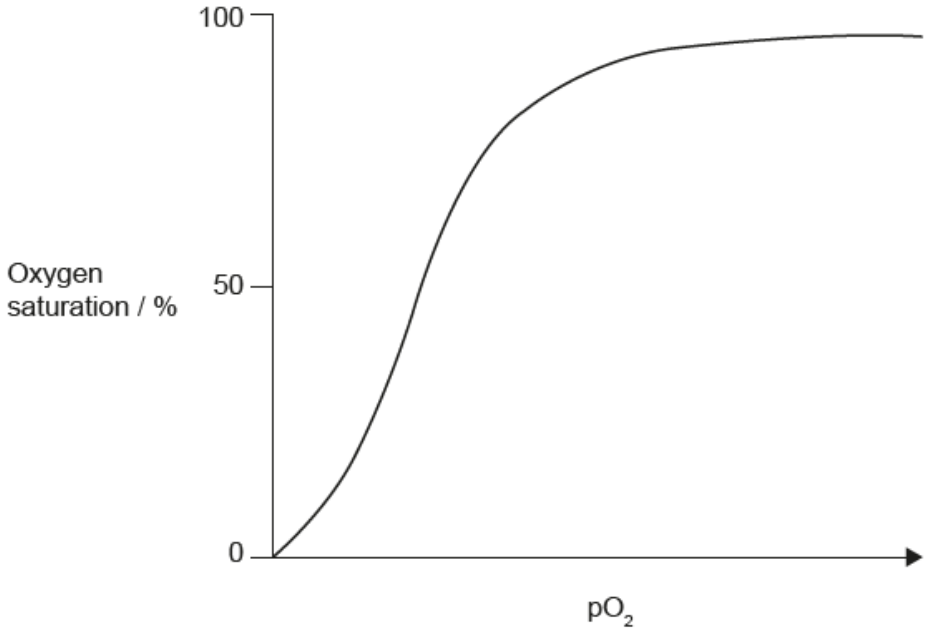
c. the ventricles have a large muscle mass compared to the atria, so the QRS complex has a larger amplitude than the P wave/OWTTE
OR
ventricle contraction needs more electricity than atrial contraction/OWTTE

Accept answers implying large muscle mass eg, stronger contraction, more pressure, etc.

Examiners report

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

The graph below shows the oxygen dissociation curve at a low CO_2 concentration.



a.i. Outline the main changes in the lungs that occur in patients with emphysema. [2]

a.ii. State a treatment for emphysema. [1]

b.i. An increase in metabolic activity results in greater release of CO_2 into the blood. On the graph, draw the oxygen dissociation curve during intense exercise when the CO_2 concentration of the blood is high. [1]

b.ii. Explain how the increase in CO_2 concentration affects the release of oxygen to respiring cells. [2]

Markscheme

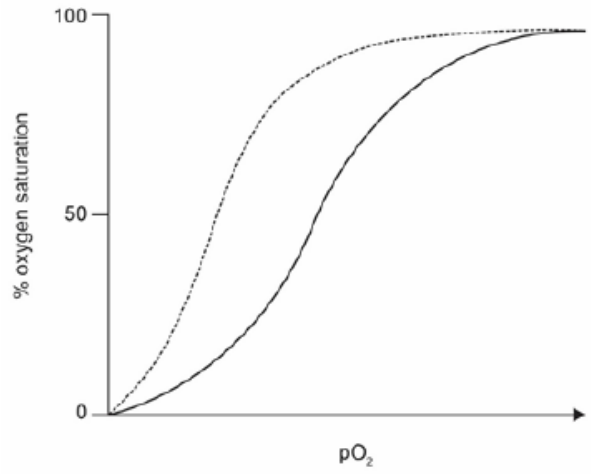
a.i. a. air sacs/alveoli break down/rupture

b. creating one larger air space instead of many small ones / reduces the surface area of the lungs

c. loss of elasticity of lung tissue

a.ii. supplemental oxygen / breathing techniques / bronchodilators / inhaled steroids / lung surgery to remove damaged tissue / lung transplant

b.i. curve has to be towards the right and starting together



Must start together but can finish slightly below the original curve.

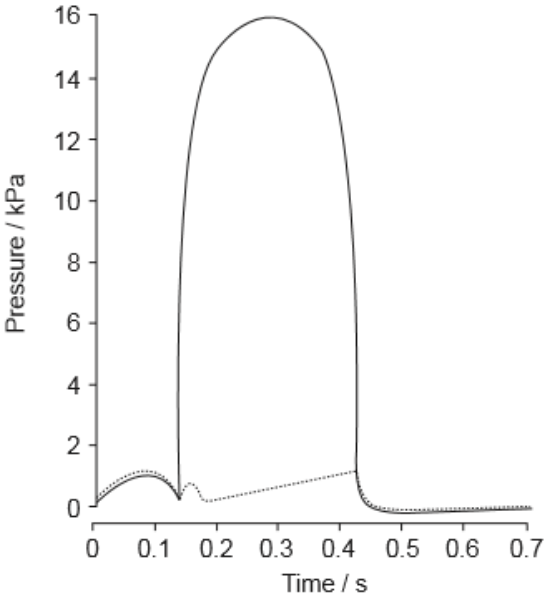
b.ii a. increased levels of CO_2 lower the pH of the blood

b. «which results in» decreased affinity of the hemoglobin for oxygen / greater release of oxygen

c. this shifts the oxygen dissociation curve to the right/Bohr shift

Examiners report

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



a (i) State **one** mechanism the ileum uses to absorb digested food into the bloodstream. [1]

a (ii) State the role of the hepatic portal vein. [1]

b (i) Label the line that represents the ventricle. [1]

b (ii) Estimate the total time the atrioventricular valves are open. [1]

c (i) Although some CO_2 entering the blood simply dissolves in the plasma, most enters the erythrocytes (red blood cells). [1]

Outline how CO_2 interacts with hemoglobin once it enters erythrocytes.

c (ii) Describe the formation of HCO_3^- in erythrocytes. [2]

Markscheme

a (i) active transport/facilitated diffusion/endocytosis

a (ii) transports blood from (capillaries of) small intestine to (capillaries/sinusoids of) liver

b (i) label should connect to solid line on graph.

Candidates should not use region with overlap of dotted and solid lines.

b (ii) 0.4 (s) (allow 0.38 to 0.43)

c (i) CO_2 attaches to protein portion (not Fe) in heme/carbaminohemoglobin formed;

c (ii) a. CO_2 diffuses into erythrocytes;

b. joins water to form carbonic acid/H_2CO_3;

c. catalyzed by carbonic anhydrase (inside erythrocytes);

d. H_2CO_3 dissociates into H^+ and HCO_3^-;

Examiners report

a (i) Many were able to state one mechanism for absorption used by the ileum with facilitated diffusion and active transport being most common. The most common incorrect response was microvilli.

a (ii) Surprisingly the role of the hepatic portal vein was poorly understood by many.

b (i) Most could correctly identify the line on the graph representing ventricular pressure.

b (ii) Even the better candidates struggled to use the graph correctly to find the total time the atrioventricular valves are open.

c (i) Very few answered this section correctly; instead many repeated what was required in section (ii). Few mentioned carbaminohemoglobin.

c (ii) Many were able to get the 2 marks for describing the formation of hydrogencarbonate ions in erythrocytes, usually giving the correct equations.

Explain, using an oxygen dissociation curve, how hemoglobin supplies oxygen to respiring tissues and how the Bohr shift increases the supply.

Markscheme

How hemoglobin supplies oxygen to respiring tissues

a. properly labelled axes showing % saturation hemoglobin and partial pressure of oxygen

b. correct/sigmoid shape of «normal» oxygen dissociation curve

Do not accept concave curves. Curve should start at origin.

c. tissues use O_2 for «cellular» respiration thus lowering pO_2 at tissue level
OR
respiring tissues produce CO_2

d. O_2 dissociates more at lower pO_2 from Hb «than at higher pO_2» thus providing O_2 to «respiring» tissues/OWTTE

How Bohr shift increases the supply

e. CO_2 is converted to hydrogen carbonate ions/HCO_3^- and H^+

f. increase in H^+ lowers blood pH

g. H^+ combines with Hb / conformational change in Hb «in red blood cell» freeing some O_2

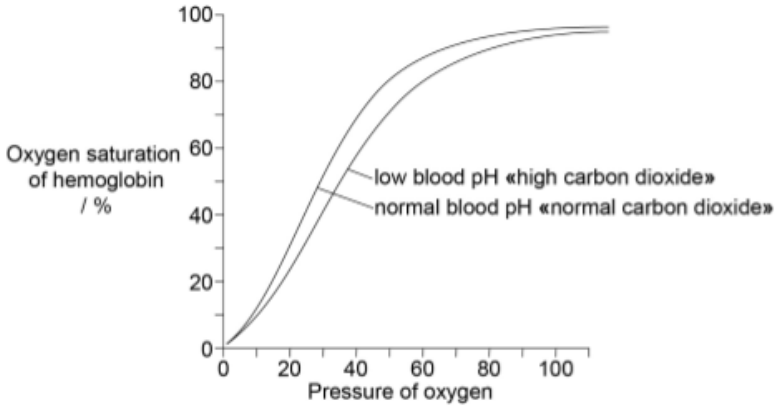
h. shifts the oxygen dissociation curve to the right «Bohr shift»
OR
shift to the right shown on diagram labelled Bohr shift

i. oxygen dissociation curve steeper at lower pO_2 «corresponding to respiring tissues»

j. lowers the affinity of hemoglobin for oxygen

k. means less oxygen can be carried for same pO_2 «as normal»
OR
«even» more oxygen available for respiring tissues for same pO_2

eg:

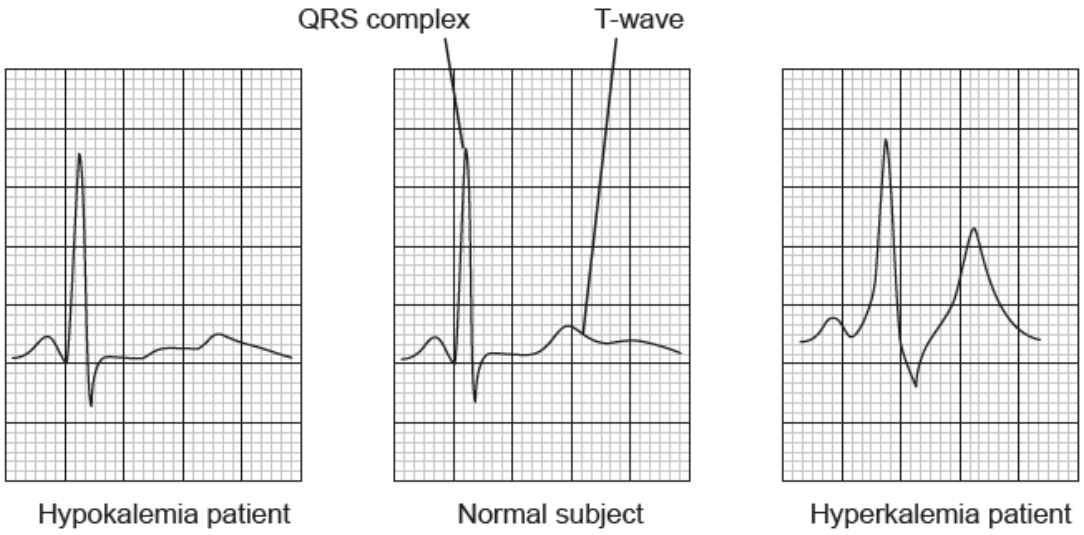


Accept any of the marking points in a clearly annotated diagram. Values not required.

Examiners report

[N/A]

In control subjects, blood potassium levels are maintained, through homeostasis,between 3.5 and 4.5 mmol litre^{-1}. In patients with anorexia, blood potassium canfall below this level. This is known as hypokalemia. In patients with kidney failure, levels can rise above this range, causing hyperkalemia. The traces show the electrocardiograms (ECGs) of a patient with hypokalemia, a normal subject and a patient with hyperkalemia.



[Source: Adapted from Gottdiener, JS, et al., Effects of self-induced starvation on cardiac size and function in anorexia nervosa, *Circulation*, Wolters Kluwer Health, Inc., Sep 1, 1978.]

b.i. Distinguish between the ECG trace of the patient with hypokalemia and the patient with hyperkalemia. [2]

b.ii. Outline the events that occur within the heart that correspond to the QRS complex. [3]

b.iii. Severe hypokalemia can lead to ventricular fibrillation. Describe the medical response to ventricular fibrillation. [3]

b.iv. Sometimes hyperkalemia occurs as a body tries to respond to low blood pH. State the normal range of blood pH in the human body. [1]

b.v. Explain how low blood pH causes hyperventilation (rapid breathing). [3]

Markscheme

b.i. a. hypokalemia has a flat T-wave whereas hyperkalemia has a heightened T-wave *OWTTE*

OR

hypokalemia S-T interval longer *Accept vice versa*

b. hypokalemia has narrower/faster QRS complex compared to hyperkalemia *Accept vice versa*

c. hypokalemia trace/baseline «overall» lower than hyperkalemia *Accept vice versa*

b.ii. a. arrival of signal at AV node

b. transmission via conducting fibres/bundle of His/Purkinje fibres

c. ventricles depolarize

d. atrioventricular valves close

OR

semilunar valves open

e. ventricular systole/contraction

f. contraction begins at apex/base

b.iii a. use a defibrillator

b. place electrodes on exposed chest of victim

c. in a line with the heart in the middle of a diagonal line between the two paddles

d. the device determines whether fibrillation is happening

e. if it is, an electric discharge is given off to restore a normal heart rhythm

b.iv around 7.4 or 7.35 to 7.45

b.v a. increased CO_2 lowers blood pH

b. chemoreceptors in carotid/aorta detect lower pH

c. signal/impulses to medulla «oblongata»
OR
signal/impulses to respiratory centre

d. «from medulla/respiratory centre» to intercostal muscles/diaphragm

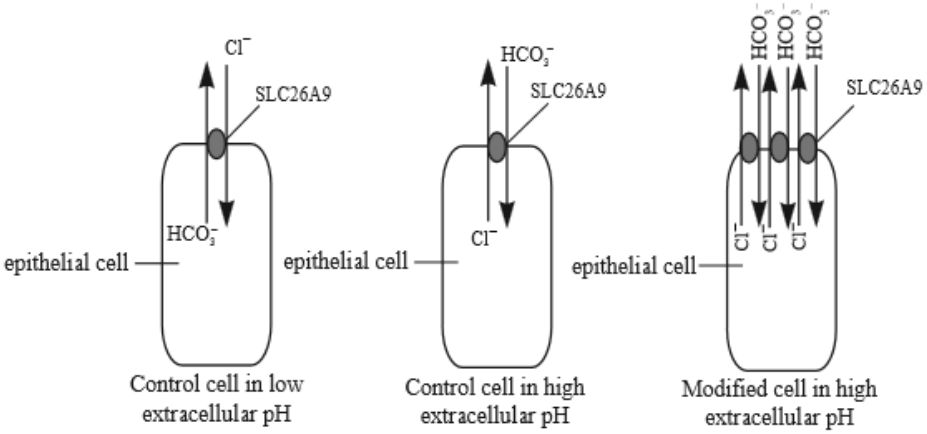
e. ventilation rate increase occurs to expel CO_2

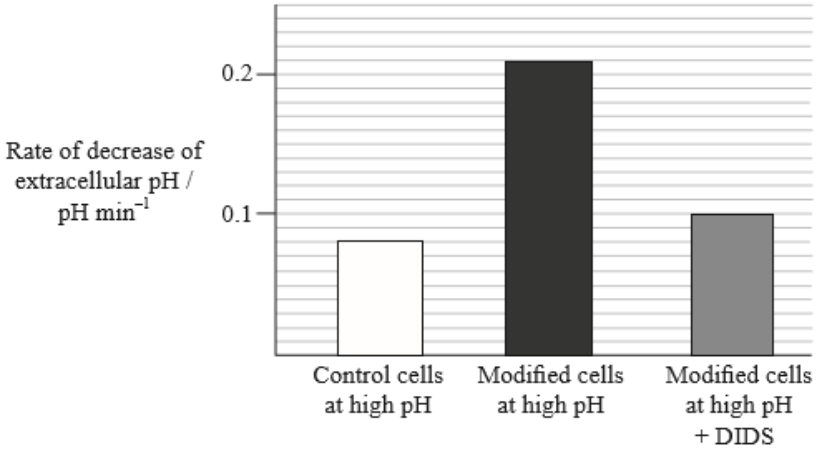
Examiners report

b.i. [N/A]
b.ii. [N/A]
b.iii. [N/A]
b.iv. [N/A]
b.v. [N/A]

Helicobacter pylori infection is a cause of stomach ulcers. It affects SLC26A9, which is a membrane protein present in the epithelial lining of the stomach. SLC26A9 takes part in the reversible transport of chloride and hydrogen carbonate ions into and out of the epithelial cells in order to raise the pH at the membrane to neutral levels. Entry of chloride ions into epithelial cells and removal of hydrogen carbonate ions both cause extracellular pH to increase.

To assess the function of SLC26A9, this process was reversed by artificially raising the external pH. The rate of change of extracellular pH was measured with normal epithelial cells and with modified cells with extra SLC26A9. The tests were also performed in the presence of DIDS, an inhibitor of SLC26A9.





a. Calculate the difference in the rate of decrease of pH between the control cells and the modified cells without DIDS. [1]

..... pH min^{-1}

b. State the effect of DIDS on the rate of decrease of the extracellular pH. [1]

c. Scientists hypothesized that *Helicobacter pylori* alters the ability to maintain neutral pH at the epithelial cell surface by inhibition of SLC26A9. [2]

Evaluate this hypothesis.

d. In further experiments, scientists observed that the levels of mRNA of SLC26A9 increased in epithelial cells when infected by *Helicobacter pylori.* Suggest a possible explanation for this increase. [1]

e. Predict, with a reason, the effect of DIDS on stomach pH if given to an experimental subject. [2]

Markscheme

a. 0.13 (pH min^{-1}) *(Allow values between 0.125 and 0.135)*

b. (DIDS) reduces the rate of decrease of (extracellular) pH;

rate of decrease reduced less than control cells / some SCL26A9 are not inhibited;

c. (hypothesis supported as) SCL26A9 in excess means more transport of ions;

(hypothesis supported as) when inhibited there is less transport of ions (needed to maintain neutral pH);

d. host cells increase transcription/ protein synthesis to make more carriers

e. pH will fall;

SLC26A9 transports less chloride/hydrogen carbonate ions;

Examiners report

a. Most were able to correctly do the calculation required.

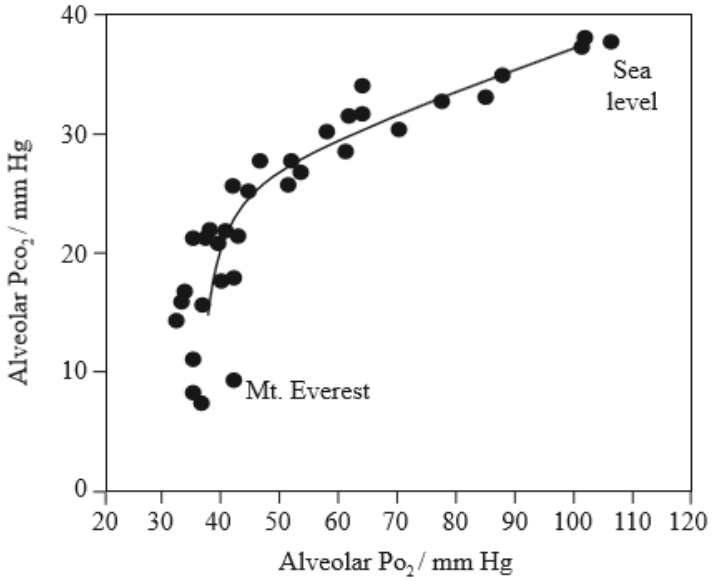
b. Most were able to correctly state that DIDS reduces the rate of decrease of pH.

c. Candidates struggled to evaluate the given hypothesis and most did not relate the support for the hypothesis to the movement of ions.

d. Some candidates were able to get the mark for indicating that a possible explanation for the observation was that host cells increased transcription to make more carriers.

e. Some candidates correctly predicted that pH will fall but few related this to transport of ions by SLC26A9.

The human body suffers significant physiological changes at extreme altitudes. Extensive scientific information has been obtained from medical research expeditions to Mount Everest (8848 m above sea level). The figure below shows the relationship between the partial pressures of oxygen (Po_2) and carbon dioxide (Pco_2) in the alveoli as altitude increases from sea level (at top right) to the summit of Mt. Everest (at bottom left).



[Source: adapted from JB West, (2006), *Integrative and comparative Biology*, **46** (1), pages 25–34]

The table below shows the data from the field study on the alveolar gas and arterial blood values for a climber at sea level and on the summit of Mt. Everest.

Altitude / meters	Inspired Pco_2 / mm Hg	Arterial Pco_2 / mm Hg	Arterial pH
Sea level (0)	2.50	40.0	7.40
Summit (8848)	0.83	7.5	>7.70

[Source: adapted from JB West, (2006), *Integrative and comparative Biology*, **46** (1), pages 25–34]

a. Outline the changes in the partial pressures of carbon dioxide and oxygen as altitude increases. [2]

b. Predict, with a reason, how the ventilation rate will change as a climber ascends from sea level to the summit of Mt. Everest. [2]

c (i) Calculate the percentage change in the arterial partial pressure of carbon dioxide (Pco_2) at the summit compared with that at sea level. [1]

c (ii) Suggest a reason for the low arterial partial pressure of carbon dioxide at the summit. [1]

d. State **one** adaptation of people who live permanently in high altitude areas. [1]

Markscheme

a. both Po_2 and Pco_2 fall with increasing altitude;

above certain altitude there is little change in alveolar Po_2 / Po_2 remains close to 37 mm Hg over a wide range of altitudes;

Pco_2 changes over the entire range of altitudes;

the Po_2 is always higher than Pco_2;

b. the rate of ventilation would increase;

expelling large quantity of CO_2 / causing fall in blood CO_2/Pco_2;

rise in blood pH hampers ventilation/inhibits chemoreceptors;

c (i).

(*Allow answers in the range 81–81.5 %*)

c (ii) low partial pressure/level of carbon dioxide in the air;

hyperventilation/high rate of ventilation;

d. high lung capacity;

larger tidal volumes;

high proportion of hemoglobin / high red blood cell count;

hemoglobin with higher affinity for oxygen;

Examiners report

a. Many were able to see that both PO2 and PCO2 fell with increasing altitude but only the best candidates could correctly identify another change.

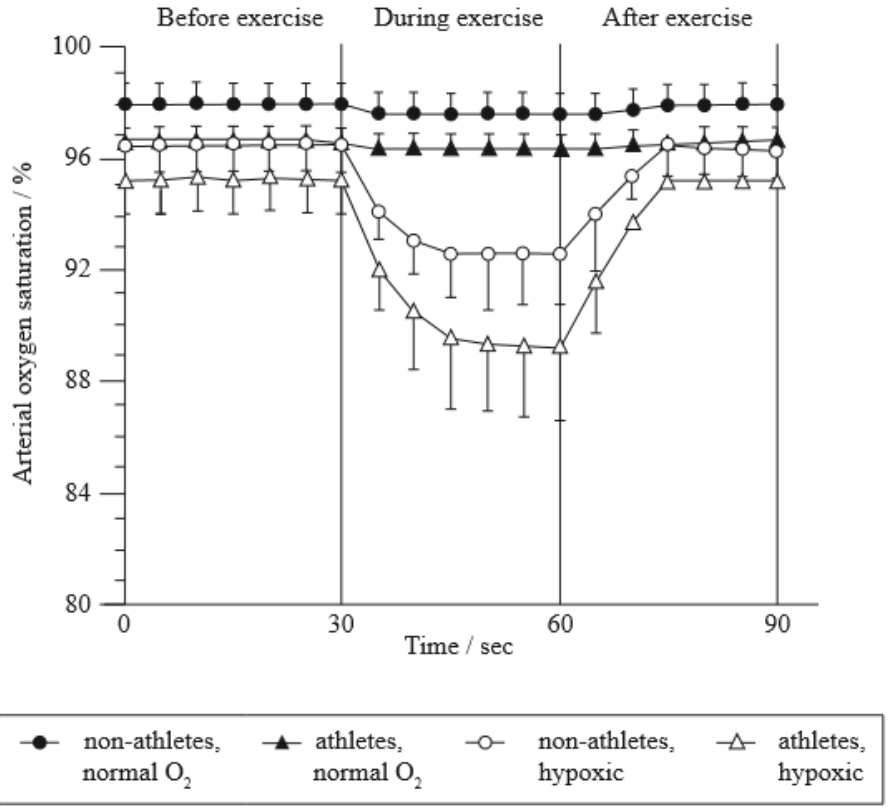
b. This was a very difficult section and many did not refer to the table provided when answering this question. Most of the candidates tended to refer to oxygen rather than carbon dioxide.

c (i) Many were able to calculate the percentage change correctly in (i). Those that didn"t usually had 18.7% rather than 81.3%.

c (ii) In (ii) many were able to get a mark for answering that the reason was due to the low partial pressure of carbon dioxide in the air.

d. The most common correct adaptation given was that those who live permanently at higher altitude had a larger lung capacity.

The effects of normal and hypoxic (lower than normal) oxygen concentrations on the oxygen levels in blood and muscles of athletes were investigated in a study. Healthy male non-athletes and athletes performed 30 seconds of intense maximal exertion exercise on a stationary bicycle. The data displayed below show the arterial oxygen saturation levels before, during and after the exercise.



[Source: K. Oguri et al. (2008), "Pronounced muscle deoxygenation during supramaximal exercise under simulated hypoxia in sprint athletes", *Journal of Sports Science and Medicine*, 7 (4), 512–519: Figure 3. Reprinted with permission from the *Journal of Sports Science and Medicine*.]

a. Estimate the change in the arterial oxygen saturation between 30 and 60 seconds in non-athletes under hypoxic conditions. [1]

. . . . . %

b (i) Compare the effect of hypoxic concentrations on athletes and non-athletes during exercise. [2]

b (ii) Suggest a reason for the differences. [1]

c. Explain how the body prevents oxygen saturation levels from falling by more than a small amount during maximal exertion exercise. [2]

d. Hypoxic concentrations also occur at high altitudes. Explain one effect of high altitude on oxygen transport by blood. [1]

Markscheme

a. accept range 3.8–4.2 (%)

b (i) a. percentage saturation of O_2 drops in both during exercise;

b. decrease is greater/more rapid in athletes than in non-athletes;

b (ii) a. athletes exercise more vigorously/at higher intensity;

b. athletes use more oxygen during exercise;

c. a. ventilation rate/tidal volume increased;

b. more oxygen absorbed (per minute);

c. heart rate increased;

d. a. altitude causes formation of more red blood cells/more haemoglobin so/thus the capacity to carry oxygen increases; *Idea of capacity is essential although can be OWTTE.*

b. the % saturation of blood is lower <u>because</u> there is less oxygen in the atmosphere;

Examiners report

a. Most used the graph correctly to estimate the change in arterial saturation. However, some candidates are incorrectly giving a range of values rather than calculating a single value. Perhaps this comes from looking at past paper mark schemes in which a range of values is given within which examiners can accept an answer as correct.

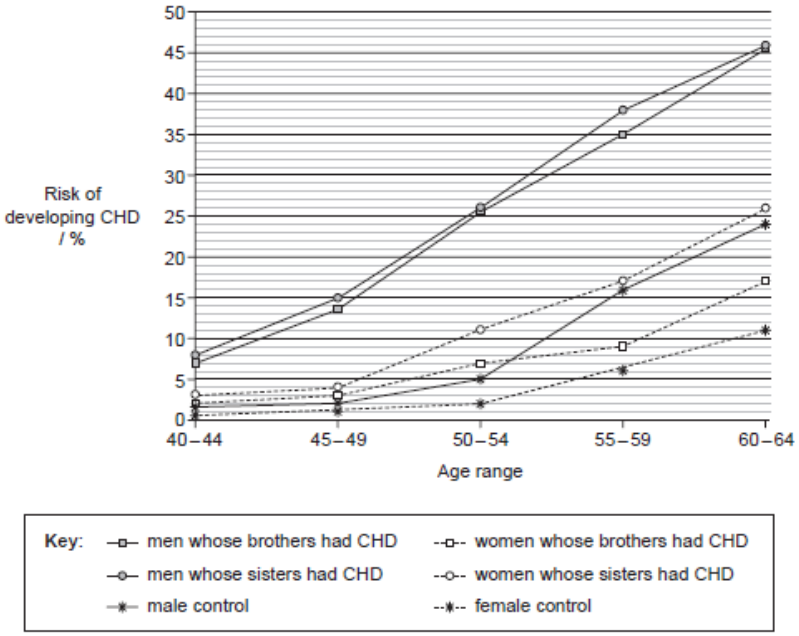
b (i) Most candidates earned 1 out of the 2 marks, and many received both marks.

b (ii) Fewer candidates were able to suggest a reason and get the mark for this section.

c. Some candidates were incorrectly discussing myoglobin and missed the simpler points available for such modifications as increased ventilation rate.

d. Few candidates could clearly explain an effect of high altitude on oxygen transport by the blood. Answers were vague or talked about symptoms of altitude sickness.

Coronary heart disease (CHD) is common in some families, with men being more susceptible to the disease than women. Researchers in Finland carried out an investigation to determine whether the pattern within families was the same for women as for men. The graph shows how the risk of developing CHD in men and women of certain ages depends on whether they had a brother or sister with the disease.



[Source: adapted from S Pohjola-Sintonen, *et al.*, (1998), *European Heart Journal*, **19**, pages 235–239]

a. State the risk of a man developing CHD between the ages of 55–59 if his brother had CHD. [1]

b. Calculate the increase in risk over the control group for a woman of 60–64 of developing CHD if her sister had the disease. [1]

c. Compare the results for the men and the women. [3]

d. Suggest **two** reasons why a man is more likely to develop CHD if his brother had the disease. [2]

Markscheme

a. 35 %

b. 15 %

c. a. both show an increase in the risk of CHD as age increases;

b. men/women with (either) siblings with CHD show an increased risk (relative to their control);

c. men have greater risk than women of developing CHD (at all ages);

d. both men and women/women only are more likely to develop CHD if their sister has the disease;

e. men with a brother with CHD have a greater risk than women with a brother with CHD;

Accept any other valid comparison using the graph.

d. a. hereditary/genetic predisposition;

b. similar (unhealthy) lifestyles/diets;

Examiners report

a. Most could read a value on the graph correctly, but many had difficulty calculating the increase in risk. Most gave clear, good comparisons, although some compared within groups of men and/or women, another case of not reading the question with sufficient care. Nearly all gave genetic conditions as a reason for developing CHD if a brother had it, but some tried to give inherited characteristics as a second reason instead of lifestyle related reason.

b. Most could read a value on the graph correctly, but many had difficulty calculating the increase in risk. Most gave clear, good comparisons, although some compared within groups of men and/or women, another case of not reading the question with sufficient care. Nearly all gave genetic conditions as a reason for developing CHD if a brother had it, but some tried to give inherited characteristics as a second reason instead of lifestyle related reason.

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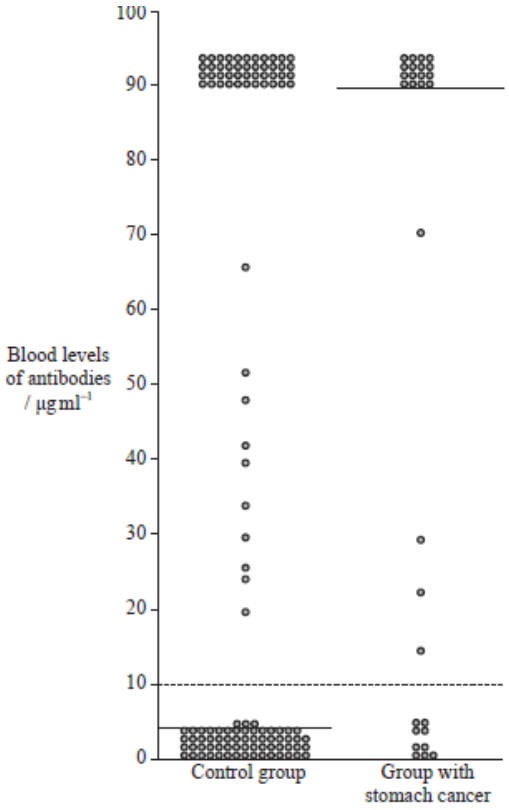
Helicobacter pylori is able to live inside the stomach wall of humans. This bacterium can cause inflammation of the stomach wall (gastritis). There may be a link between *H. pylori* and the development of stomach cancer.

The graph below shows the blood levels of antibodies resulting from *H. pylori* infection for a control group without stomach cancer and a group with stomach cancer. The solid lines show the median concentrations for the control group and the group with stomach cancer. Antibody concentrations above 10 μg ml^{-1} indicate that there has been infection with *H. pylori*.



[Source: Reproduced from D Forman, D G Newell, F Fullerton et al., "Association between infection with Helicobacter pylori and risk of gastric cancer: evidence from a prospective investigation", *Bristish Medical Journal*, Volume 302, Number 6788, (1991) with permission of BMJ Publishing Group Ltd.]

a. 47 % of the control group had been infected with *H. pylori*. Calculate the percentage of the group with stomach cancer that had been infected. [2]

Show your working.

b. Using all of the data, evaluate the hypothesis that *H. pylori* causes stomach cancer. [3]

c. A study in gerbils indicated that infection with *H. pylori* leads to a decrease in the secretion of hydrochloric acid. Discuss the consequences of this finding for the digestion of proteins in the stomach in humans. [2]

Markscheme

a. $\frac{20}{29} \times 100$;
$= 69\%$; *(accept correct answer that is not rounded up to 69%)*

b. higher percentage of those with stomach cancer have *H. pylori* infection;

higher median of those with stomach cancer have *H. pylori* infection;

infection/high level antibodies does not mean that gastric cancer will always result / many infected did not develop gastric cancer;

not all of those with stomach cancer had *H. pylori* infection;

c. pepsinogen would not be broken down to pepsin;

pepsin would not work as well due to incorrect pH;

it is not known if humans would respond in the same way as gerbils;

Examiners report

a. Overall, the calculation of a percentage of the group with *H. pylori* was calculated correctly.

b. Many did state that a higher percentage of those with stomach cancer have *H. pylori*. Few then went onto to also discuss the median. Many did though suggest that from the data, a high level of antibodies does not mean that gastric cancer will always result.

c. Some did suggest that a reduction in HCl production would disrupt the digestion of proteins, but only a few gained marks by giving reasons why this may happen and relating this to enzymes and protein digestion.

---

a. The table shows the death rate due to coronary heart disease (CHD) in two different countries. [3]

Country	Deaths / 10^{-5} individuals
USA	97.6
Japan	32.1

Using the table below, outline **three named** factors that could be responsible for the differences between the two populations.

Factor	Outline

b (i) State **four** glands secreting digestive juices into the alimentary canal. [2]

1. .....
2. .....
3. .....
4. .....

Markscheme

a.

factor	*outline*
parent/relative with coronary heart disease (CHD) / genetic	different populations may have different genetic backgrounds / *OWTTE*;
age	older population in some countries, CHD increases with age / *OWTTE*;
smoking	may be more widespread in some countries, smokers more prone to CHD;
obesity	maybe more widespread in some countries, obesity linked with CHD;
diet	high saturated fat/cholesterol (increases risk) / food habits/sources differ between countries;
lack of exercise	some populations may have a more sedentary lifestyle / *OWTTE*;
high blood pressure	populations with high rates of high blood pressure (caused by stress/salt consumption/other) more prone to atherosclerosis;
sex ratios	populations with higher proportion of males will have higher rates of CHD;
alcohol consumption	populations with high alcohol consumption have high rate of CHD;

*Award **[1]** for a factor and a corresponding outline.*

b (i) *Award **[1]** for two correct glands.*

salivary glands;

gastric glands;

pancreas;

wall of the small intestine;

Examiners report

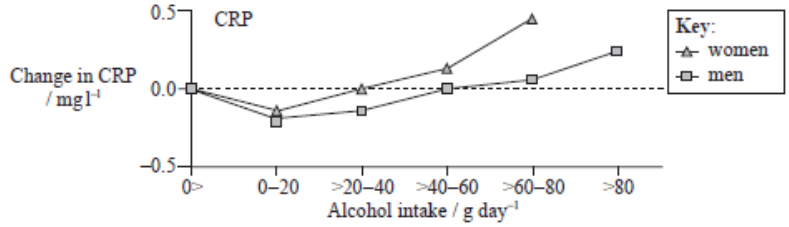
a. There was a wide range of answers about factors causing CHDs and the majority of candidates gained all marks despite the fact that many answers did not really outline how these factors acted and could differ between the different populations. Candidates were not penalized for their obvious and general lack of knowledge about the habits of the two populations.

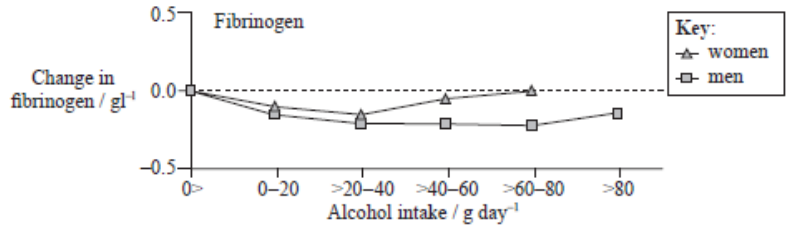
b (i) Most candidates gained at least one mark for the digestive glands, but many answers contained incorrect (e.g. endocrine gland, liver, bile duct) or too vague (e.g. intestine) elements.

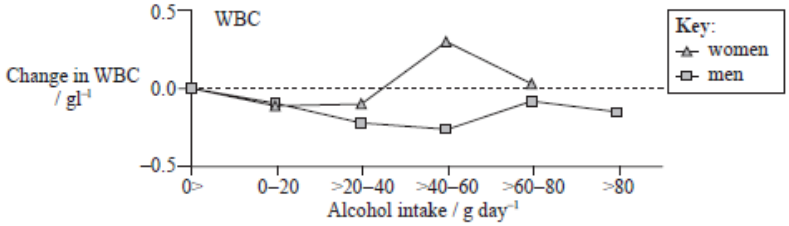
Alcohol is known to increase the risk of cardiovascular disease (CVD). An investigation was undertaken to look at the effects of drinking different amounts of alcohol in men and women.

C-reactive protein (CRP), fibrinogen and total white blood cell count (WBC) were measured. These are markers that can be used to measure the risk of cardiovascular disease (CVD).

Samples were taken from populations in three different countries and their drinking habits were determined and their blood was analysed.







[Overall alcohol intake, beer, wine, and systemic markers of inflammation in western Europe: results from three MONICA samples (Augsburg, Glasgow, Lille), A. Imhof, M. Woodward, A. Doering, N. Helbecque, H. Loewel, P. Amouyel, G.D.O. Lowe, W. Koenig. European Heart Journal, December 1, 2004, Oxford University Press]

a. State the overall trend for CRP for men and women over the range of alcohol consumption. [1]

b. Evaluate, using all the data, whether drinking small amounts of alcohol reduces the risk of CVD. [3]

c. Deduce which is the best marker to measure the risk of CVD. [1]

d. Outline atherosclerosis and the causes of CVD. [2]

Markscheme

a. a. for both men and women a decrease is seen at the lowest alcohol intake followed by an increase;

b. the level of CRP is higher in women than in men over the range of alcohol consumption / as the intake increases the difference between men and women increases, the CRP increase being greater in women;

b. a. drinking small amounts of alcohol seems to reduce the level of all markers / drinking none and/or high amounts of alcohol has higher levels of markers than moderate amount;

b. the effect of small amounts of alcohol is less in women than in men / the effect of large amounts of alcohol is greater in women than in men / women should consume less than men;

c. other effects of alcohol consumption are not measured;

d. other factors increasing risk of CVD are not measured;

e. the type of alcohol is not stated / the active factor in the drink is not seen;

c. CRP shows the decrease in risk for low amounts of alcohol then increases above the baseline for higher amounts

d. a. high blood pressure damages endothelial wall;

b. WBC/macrophages build up cholesterol;

c. plaque hardens arterial wall / blocks lumen / artery blocked by depositions in wall;

d. wall rough;

e. clots form;

Examiners report

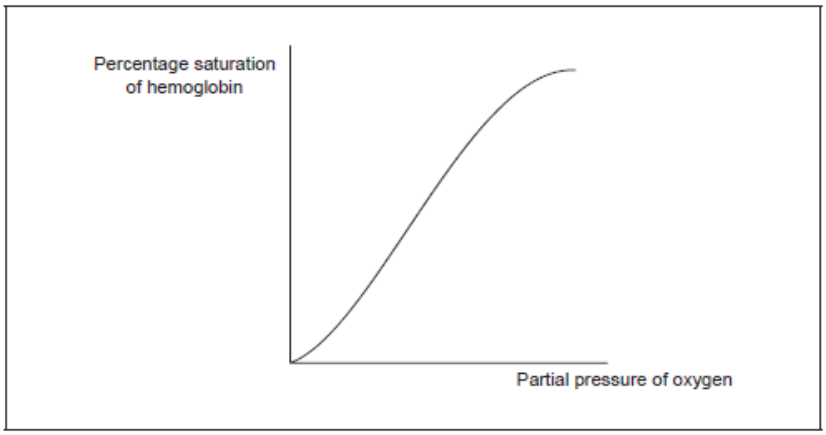
a. That initial dip in results was not recognized by a good number of candidates.

b. The effect of moderate amounts of alcohol was rarely complete, and although many deduced the best marker, few could give a reason.

c. Although many deduced the best marker, few could give a reason.

d. For part (d) candidates focused on the causes and prevention of CVD therefore scoring hardly any marks.

The graph shows the oxygen dissociation curve for adult haemoglobin.



a. State the pathway by which hormones travel from the hypothalamus to the anterior pituitary gland. [1]

b. State the condition of the blood that would stimulate the release of ADH (vasopressin). [1]

d(i). Using the graph, draw a line to show how the oxygen dissociation curve changes with the Bohr shift. [1]

d(ii). Explain the role of the Bohr shift during vigorous exercise. [2]

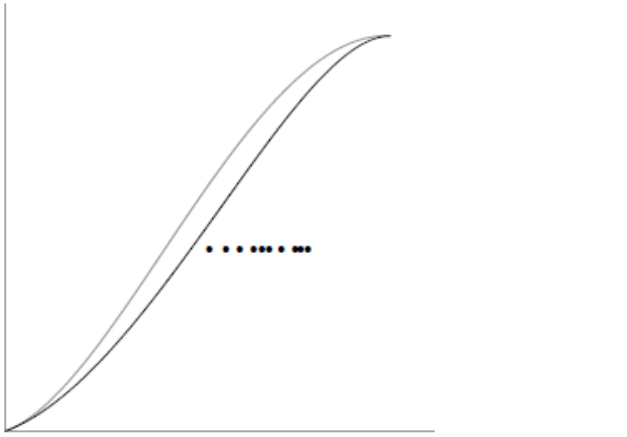
Markscheme

a. (pituitary) portal vein

Do not accept if portal vein is qualified as "hepatic".

b. low water content / high blood solute concentration

d(i).



similar shaped curve; *(drawn to the right of the curve, starting at 0, on the question paper)*

d(ii)a. more CO_2 is produced which lowers the pH of the blood;

b. hemoglobin releases more oxygen (at lower pH) for same partial pressure of oxygen;

c. more oxygen is available to respiring tissues;

Examiners report

a. Many candidates could not name the portal vein, but confused this with other neurosecretory paths. They provided good answers about the release of ADH. The answers about gastrin were often incomplete, with most recognizing gastrin as controlling the release of gastric juices, although some thought it was an enzyme; fewer candidates mentioned the need of the presence of food in the stomach for its release, some confusing it with the stimulus of the smell or sight of food and involving some control from the hypothalamus or medulla. Too many candidates do not understand the Bohr shift, incorrectly drawing it on the graph and/or being unable to explain it; many did not seem to understand the lowering of affinity of hemoglobin for oxygen is at the same partial pressure.

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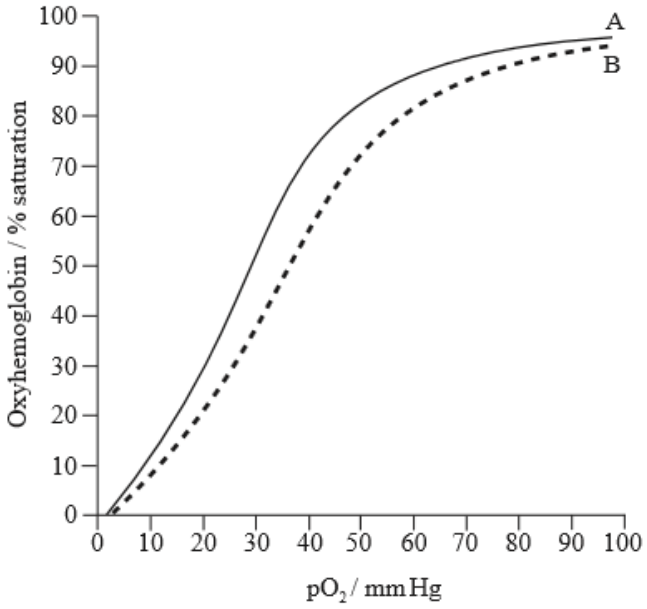
The oxygen dissociation curve is a graph that shows the percentage saturation of hemoglobin at various partial pressures of oxygen. Curve A shows the dissociation at a pH of 7 and curve B shows the dissociation at a different pH.



a. Outline how coronary thrombosis can be caused. [2]

b (i). State the possible cause of the curve shifting from A to B. [1]

b (ii). On the graph, draw the curve for myoglobin. [2]

c. Describe the breakdown of hemoglobin in the liver. [2]

Markscheme

a. atheroma/fatty deposits in arteries;

hardening of arteries/atherosclerosis/arteriosclerosis;

rough surface causes rupture of platelets;

clots form in coronary artery;

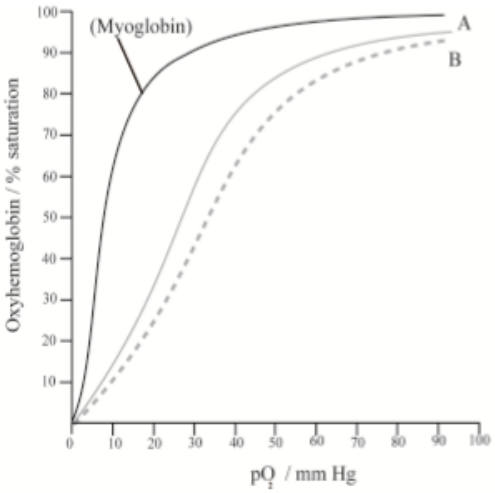
b (i) increase in CO_2 concentration;

decrease in pH;

b (ii) graph drawn to left of A;

curve not sigmoid;

As shown below.



c. hemoglobin absorbed by phagocytes/Kupffer cells;

split into heme and globins;

globin hydrolysed/broken down to amino acids;

iron removed from heme group / heme broken down to form bilirubin/bile pigment;

Examiners report

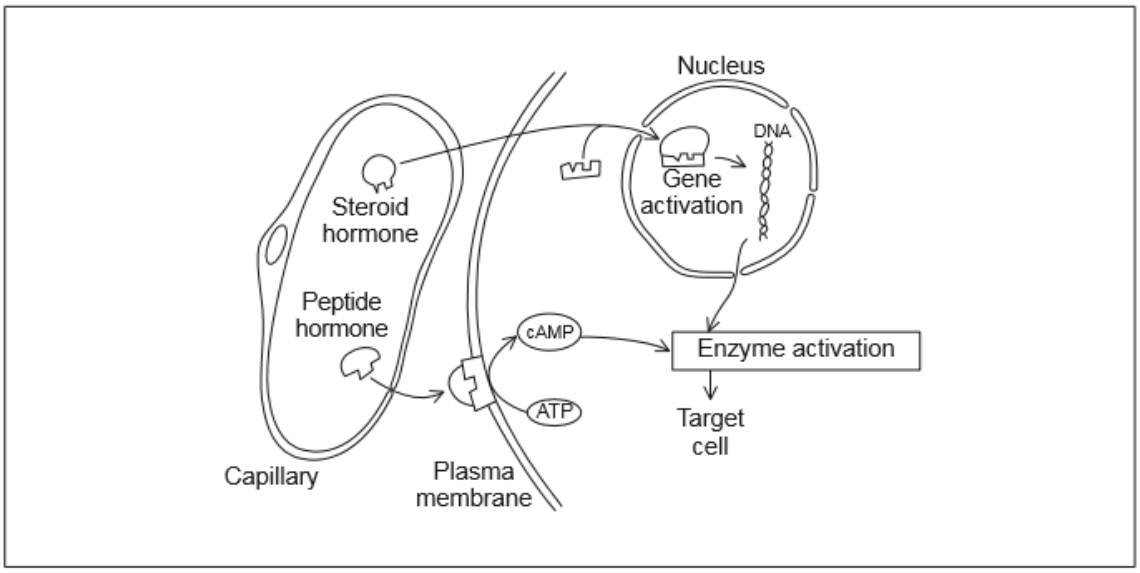
a. The outline of how coronary thrombosis can be caused was surprisingly poorly done. Most simply gave a list of risk factors without actually stating what caused the thrombosis.

b (i) This section on the oxygen dissociation curve was also poorly done. Few stated that the shift in the curve could be due to either an increase in CO_2 concentration or a decrease in pH.

b (ii) N/A

c. The full two marks for this section were often awarded as candidates seemed to know where and into what hemoglobin was broken down.

The diagram demonstrates the action of steroid and peptide hormones in a section of cell and adjacent capillary.



[Source: © International Baccalaureate Organization 2016]

a. On the diagram, label a [2]

(i) second messenger.

(ii) gene regulatory protein.

b. Outline **one** characteristic of steroid hormones that allows them to readily diffuse through cell membranes [1]

c. Compare and contrast the mechanisms of action of peptide and steroid hormones. [2]

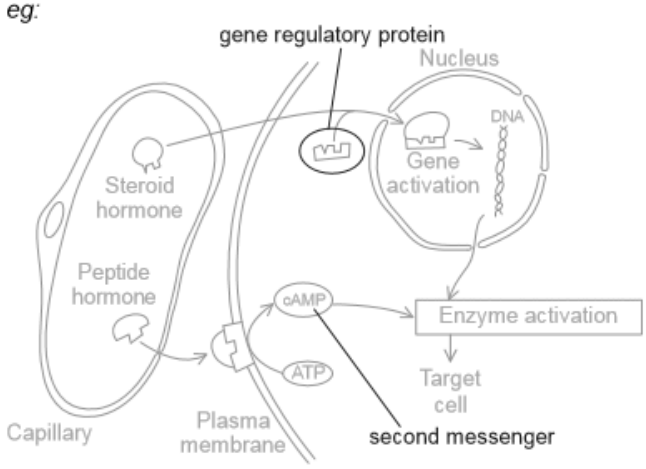
Markscheme

a. (i) a. second messenger correctly labelled

(ii) b. gene regulatory protein correctly labelled

Do not accept steroid hormone/protein complex.

eg:



b. a. lipid-soluble/non-polar/hydrophobic molecules «that readily diffuse through cell membranes»

b. small enough to diffuse through membrane

Since the questions asks to "outline" a brief account is necessary to gain the mark.

c.

	peptide hormones	steroid hormones
a.	receptor on plasma membrane ***OR*** do not enter cell	receptor within the cytoplasm ***OR*** enter the cell ✓
b.	activate second messenger/cyclic AMP/cascade of reactions	no second messenger ***OR*** bind to protein/gene activator ✓
c.	act at enzyme level	act at gene level ✓
d.	both regulate enzyme action ✓	

Answers do not need to be presented as a table. Award marks for pairs of corresponding elements on the same line of this table.

Examiners report

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

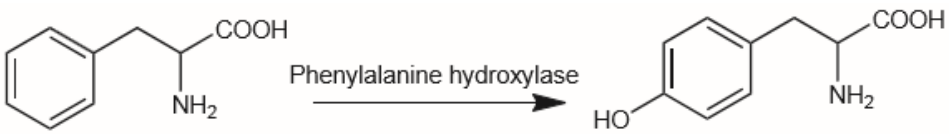
The table summarizes the relative content of essential amino acids in different foods. Cysteine and tyrosine are classified as being “conditionally essential”. The quantity of each amino acid in a hen egg is set as 1.0 and all other values are relative to the hen egg standard.

	Hen egg	Human milk	Cow milk
Isoleucine	1.0	1.1	1.1
Leucine	1.0	1.4	1.3
Valine	1.0	1.0	1.0
Threonine	1.0	1.0	0.9
Methionine and Cysteine	1.0	1.1	0.7
Tryptophan	1.0	1.6	1.3
Lysine	1.0	1.0	1.3
Phenylalanine and Tyrosine	1.0	1.0	0.9
Histidine	1.0	0.9	1.1

[Source: Data obtained from Robert McGilvery, *Biochemistry: A Functional Approach*, 1970, W. B. Saunders.]

a. Outline what is meant by the term essential amino acid. [2]

b. Phenylalanine is converted to tyrosine by the enzyme phenylalanine hydroxylase. [2]



Phenylalanine Tyrosine

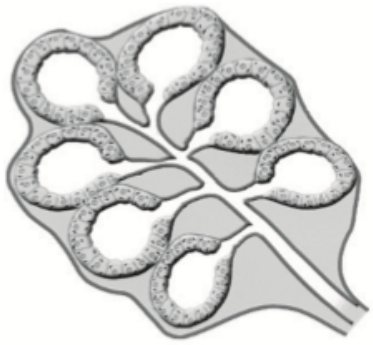
(i) Deduce the reason that tyrosine is considered to be a conditionally essential amino acid.

(ii) When infants with the condition phenylketonuria (PKU) are left untreated, they have a build-up of phenylalanine in the blood and high levels of phenylalanine in the urine. State the cause of this condition.

c. Evaluate human milk as an overall source of essential amino acids. [2]

d. Outline the control of milk secretion by oxytocin and prolactin. [3]

e. The diagram represents a lobule from a mammary gland. The mammary gland is an example of an exocrine gland. [2]



[Source: Luis A Bate, Professor of Physiology and Ethology, University of Prince Edward Island. Used with permission.]

Identify **two** features of an exocrine gland visible in the diagram.

Markscheme

a. «Essential amino acids» must be obtained from the diet

They cannot be synthesized by the body
OR
They cannot be synthesized from other amino acids

b. (i) Tyrosine can only be synthesized when phenylalanine is in the diet (*Accept inverse: if phenylalanine is not in the diet the person will not be able to synthesize tyrosine*).

(ii) Recessive inherited «genetic» condition
OR
They lack «the enzyme» phenylalanine hydroxylase
OR
Mutated form of PAH gene

c. Contain <u>all</u> of the essential amino acids

Human milk has higher levels of 5 «out of 9» essential amino acids than cow milk
OR
Human milk has the same or more of essential amino acids except histidine and lysine compared to cow milk

Human milk is the same or higher in all essential amino acids except histidine compared with hen egg
OR
Human milk has higher levels of 4 «out of 9» essential amino acids compared with hen egg

«Limitation» human milk contains less histidine than both hen egg ***AND*** cow milk (*Both needed*)

d. ***Prolactin***

Produced by the anterior pituitary

Stimulates mammary glands to grow

Stimulates the production of milk

Oxytocin

Produced in neurosecretory cells «in hypothalamus»
OR
stored/secreted by posterior pituitary

Suckling/nursing stimulates oxytocin release
OR
example of positive feedback

«Contractions» cause ejection/release of milk from mammary glands

*Award **[2 max]** if response only mentions one of the hormones*.

e. Presence of ducts

Presence acini/acinar/secretory cells

Ducts leads to a body surface/cavity/gut

Examiners report

a. Most were able to score 2 marks by outlining what is meant by an essential amino acid.

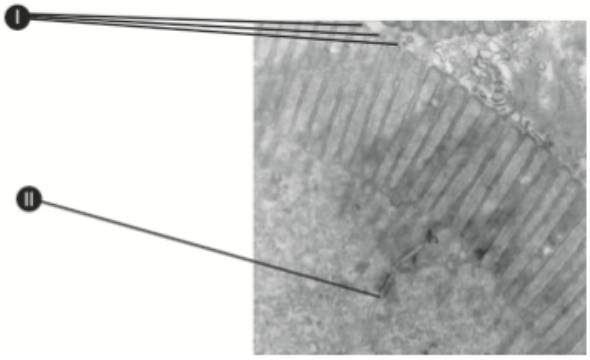
b. Most candidates showed a reasonable knowledge of PKU although many struggled to differentiate between what was required in (i) and (ii). Most were able to state the cause of PKU for part (ii) but fewer could deduce why tyrosine is considered to be a conditionally essential amino acid in (i). Many wrote the same answer in both sections.

c. There were many comments on this part of the question on G2 forms, some indicating that this was not on the syllabus. Content knowledge was not needed to answer the question as the data provided could be used to score full marks. This section was discriminating. Many candidates struggled to 'evaluate' human milk as a source of amino acids and did not use the data provided. Instead many wrote general statements about human milk, often talking about immunity.

d. Many were awarded 2 marks but good, clear answers were not common. Candidates sometimes confused oxytocin and prolactin and most seemed unsure where these hormones came from.

e. Teacher comments on the G2 form indicated that some thought this question outside the scope of the syllabus although exocrine glands are mentioned in D2. While the question was ostensibly about mammary glands, the diagram was generic and could have been any exocrine gland seen with a light microspore. Most candidates received one mark for identifying the ducts visible in this general diagram and better candidates mentioned the secretory cells or acini.

The electron micrograph shows the epithelial cells of the villus.



[Source: Courtesy of Dr John McNulty and the Loyola University Medical Center, Chicago
http://www.dartmouth.edu/~anatomy/Histo/lab_1/epithelium/DMS028/microvilli.jpg]

Identify the parts labelled I and II.

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

Markscheme

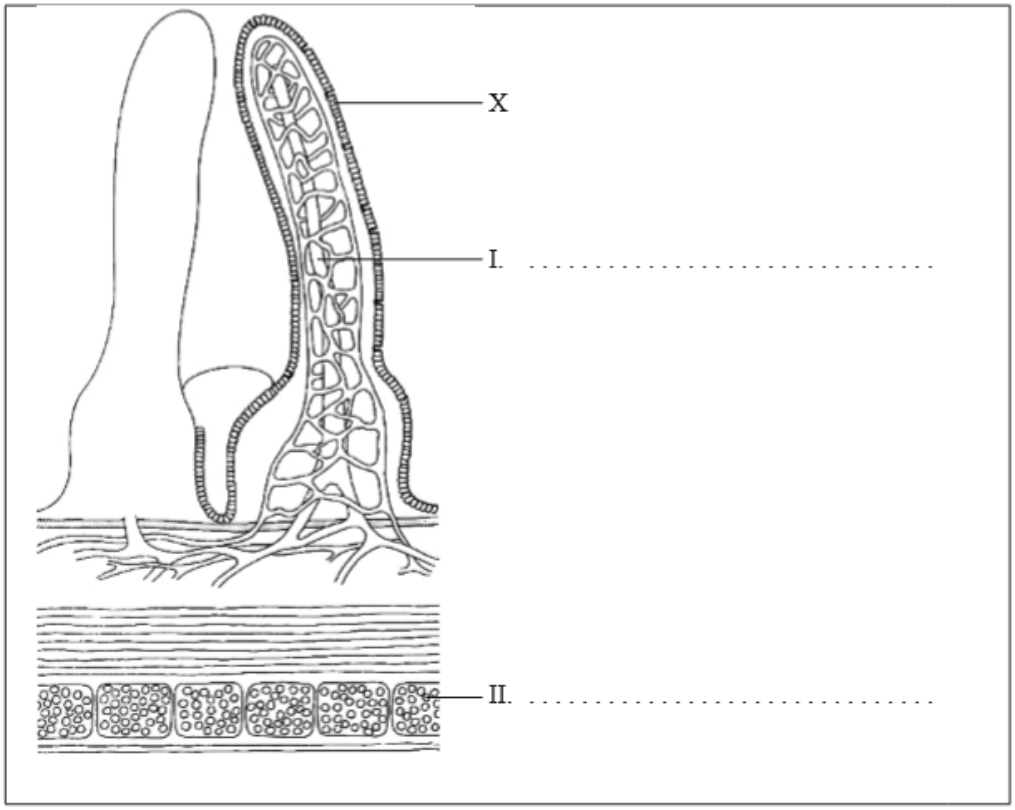
a. *I*: microvilli;

b. *II*: tight junction / plasma membrane;

Examiners report

Most candidates were able to identify microvilli but fewer identified the tight junction, not relating to structures that would be visible with an electronic microscope, as stated in the syllabus.

The diagram below shows a section through the ileum.



Roland Soper, Nigel P. O. Green, G. Wilfred Stout and Dennis J. Taylor, *Biological Science*, 1990, p. 316, Cambridge University Press. Used with permission.

a (ii) Outline **two** important structural features of cell X. [2]

b. Explain the role of bile in lipid digestion. [2]

c. Explain why trypsin is initially synthesized as an inactive precursor and how it is activated. [3]

Markscheme

a (ii) microvilli/brush border to increase surface area;

enzymes (peptidases and disaccharase) bound to membranes (of microvilli) to complete hydrolysis/digestion;

tight junctions separate fluid of intestinal lumen from intercellular fluid/ impermeable barrier;

large number of mitochondria as high energy demand for active transport;

pinocytotic vesicles formed by endocytosis/uptake of fluid with products of digestion;

b. bile contains bile salts (and pigments);

bile salt molecules have both a hydrophilic and hydrophobic end;

reduces size of fat/lipid globules / emulsifies fats;

causes increase in total surface area so acted on more effectively by enzyme (lipase);

c. trypsin is protein-digesting enzyme/protease;

trypsinogen is inactive form produced by pancreas;

produced in inactive form to prevent it digesting cells of pancreas;

converted to active form trypsin in small intestine by enterokinase/ enteropeptidase;

enterokinase/enteropeptidase secreted by intestinal mucosa/wall of small intestine;

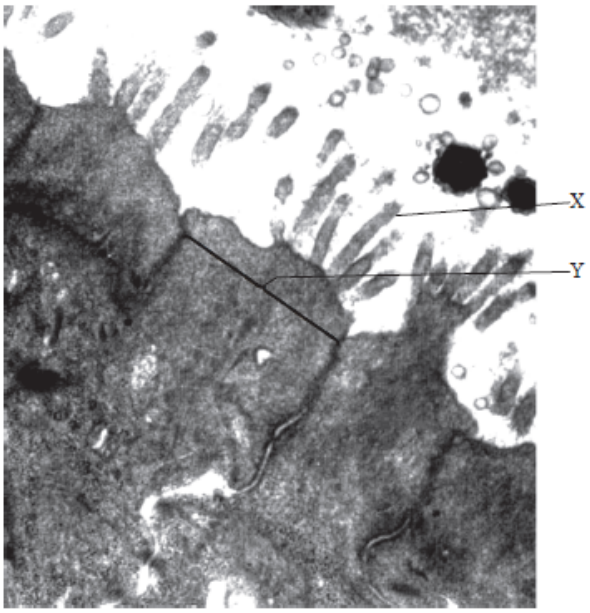
Examiners report

a (ii) Several answers related to having protein channels which was not credited with a mark but most scored at least one.

b. Many good answers were seen but also a large number which did not refer to bile salts being present, so losing marks.

c. Again, some good scores but a large number of candidates lost marks because of imprecise answers such as not mentioning the pancreas as the trypsin source and often incorrectly saying it was activated by HCl in the stomach.

The electron micrograph below shows cells from the intestine.



[Source: C Candalh, Inserm, magnification ×10 000]

a. In the electron micrograph above, state the name of the [2]

(i) structure labelled X.

(ii) type of cells labelled Y.

b. Define *hormone*. [2]

c. Outline the circulation of blood through liver tissue. [3]

Markscheme

a. (i) microvilli/microvillus

(ii) epithelial cell/enterocyte

b. chemical (messengers) secreted by (endocrine) glands;

into the blood / transported by the blood;

act on target organs/cells;

c. hepatic artery carries oxygenated blood;

hepatic portal vein carries blood from gut/deoxygenated blood;

blood from hepatic portal vein and hepatic artery mix;

flows through sinusoids;

hepatic vein carries blood away from liver;

Examiners report

a. (i) Too many candidates wrote villus (or villi) instead of microvillus (or microvilli) here.

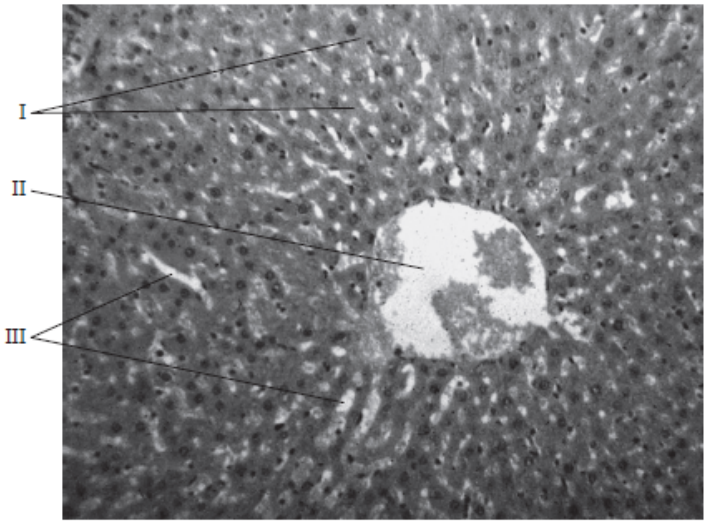
(ii) Most candidates successfully answered epithelial cell.

b. [N/A]

c. [N/A]

---

a. Label the section of healthy liver tissue below. [3]



[P. Billiet et al. (2000) Further Investigations in Biology, 4, p. 64, IBID Press. Reproduced with permission.]

I.

II.

III.

b. Outline **two** roles of the liver. [2]

c. List **two** materials that are not absorbed but are egested by the body. [1]

d. State an example of a protein hormone. [1]

Markscheme

a. I. hepatic cells / hepatocytes / liver cells / liver tissue;

II. hepatic vein / blood cells;

III. sinusoids;

b. a. storage of nutrients;

b. detoxification of poisons;

c. breakdown of hemoglobin;

d. production of bile pigments;

e. synthesis of plasma proteins;

f. synthesis of cholesterol;

c. *Award [1] for two of the following.*

cellulose / lignin / bile pigments / bacteria / intestinal cells

Do not accept fibre.

d. insulin / glucagon / prolactin / somatotrophin

Award other suitable examples.

Examiners report

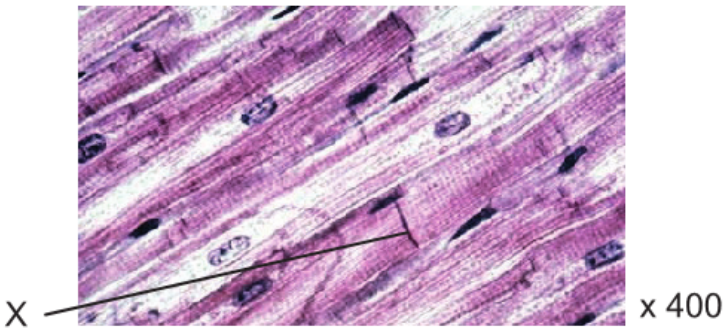
a. The cell types and structures in the micrograph of the liver were not well identified. The other parts of this question were answered well enough.

b. The cell types and structures in the micrograph of the liver were not well identified. The other parts of this questions were answered well enough.

c. The cell types and structures in the micrograph of the liver were not well identified. The other parts of this question were answered well enough.

d. The cell types and structures in the micrograph of the liver were not well identified. The other parts of this question were answered well enough.

The micrograph shows a section of cardiac muscle.



[Source: Musculocardiaco by Goyitrina (https://commons.wikimedia.org/wiki/File:Musculocardiaco.jpg)]

a. Identify the structure labelled X. [1]

b. Describe the unique properties of cardiac muscle cells. [4]

c. State an early invention that led to improved knowledge of the heart. [1]

Markscheme

a. intercalated disc

b. a. cells are myogenic/self-excitatory

b. cells are joined end to end

OR

cells are joined by intercalated disc

c. «intercalated discs» allow for faster propagation «of signal»

d. cells contract together for coordinated contraction

e. contain many mitochondria

f. cells are branching/Y-shaped

g. controlled by pacemaker/sinoatrial/SA and atrioventricular/AV nodes

[Max 4 Marks]

c. stethoscope

OR

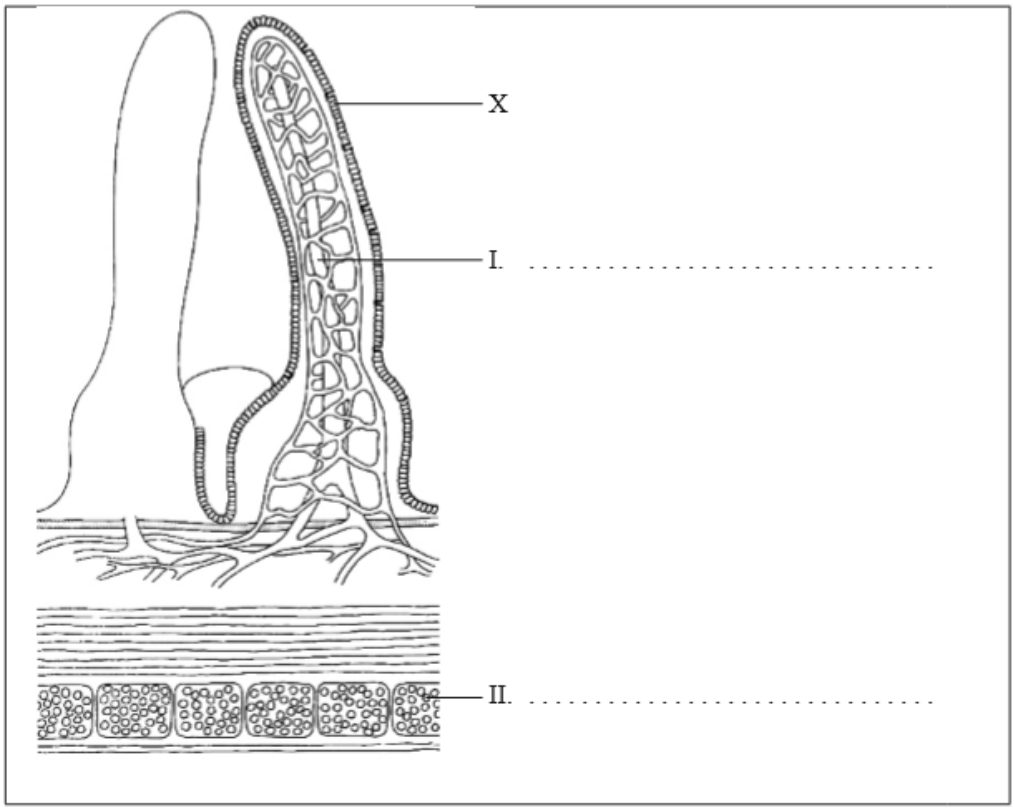
electrocardiograph/ECG

Allow other valid example.

Examiners report

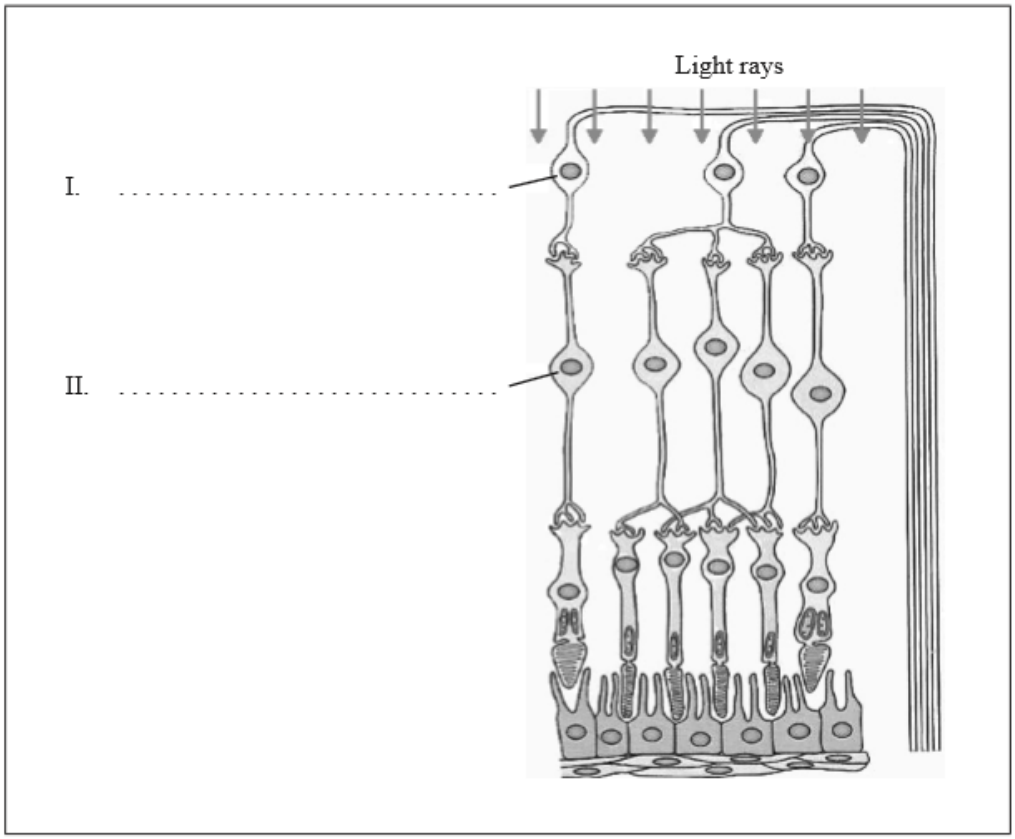
a. [N/A]
b. [N/A]
c. [N/A]

The diagram below shows a section through the ileum.



Roland Soper, Nigel P. O. Green, G. Wilfred Stout and Dennis J. Taylor, *Biological Science*, 1990, p. 316, Cambridge University Press. Used with permission.

a (i)The diagram below shows the structure of the retina. Label I and II. [1]



C. J. Clegg, *Introduction to Advanced Biology*, 2000, p. 285. Reproduced by permission of Hodder Education.

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

a (ii) Distinguish between rods and cones. [2]

b. Outline the pupil reflex. [2]

c. Discuss the use of the pupil reflex in testing for brain death. [3]

Markscheme

a (i) I: ganglion cell

II: bipolar cell/neuron

(both needed)

a (i) I: lacteal

II: longitudinal/smooth muscles / muscularis mucosa

(both needed)

a (ii).

rods	*cones*
used in dim light	used in bright light;
black and white vision / one type sensitive to all wavelengths of light	colour vision / three types sensitive to red, blue and green light;
passage from group of rod cells to single bipolar neuron/nerve fibre in optic nerve	passage of impulse from single cone cell to a single bipolar neuron/ nerve fibre;
detect shape and movement	perception of fine detail;
found all along the retina	found in fovea / concentrated in one region;

*To award **[2 max]** responses need to be compared.*
Responses do not need to be shown in a table format.

b. rapid unconscious response to change in light intensity / controls amount of light entering eye to prevent damage to retina/to see in darkness;

in bright light circular muscles in iris contract causing pupil to constrict / in dim light longitudinal/radial muscles in iris contract causing pupil dilation;

constriction by parasympathetic NS / dilation by action of sympathetic NS;

c. pupil reflex is a brain stem reflex / shows activity in the medulla oblongata;

pupil reflex must be absent in brain death;

pupil reflex is possible in coma victims where motor function is absent;

pupil reflex alone not enough to diagnose brain death;

other criteria include coma/absence of response to pain in all extremities/ absence of brain stem reflexes/lack of respiratory movements;

some cases of coma irreversible / some cases may recover;

doctors need to diagnose damage to decide treatment/long-term life support /organ donation;

Examiners report

a (i) Good answers.

a (i) Very few identified the muscle correctly. There was some complaint about the fact that what was tested was a longitudinal section of the villus instead of a transverse section as stated in the guide. The complaint is reasonable, nevertheless, the candidates should have known the order in which the muscle layers appear and could have inferred the answer to the question. As a matter of fact, the more able candidates answered this question correctly.

a (ii) Good answers.

b. Several answers described the pupil reflex arc/pathway which was sometimes sufficient to gain one mark.

c. Few answers related to coma victims, dismissing almost half of the possible marking points but leaving sufficient possibilities to score well. Many candidates considered that if no pupil reflex is present, brain death is sure. Some stated the role of brain stem. Vegetative state was confounded with brain death. Several candidates repeated part of the information given in the previous question.