SL Paper 2

a. Milk contains lactose which some people can digest but some cannot. [1]

State what type of sugar lactose is.

b. Milk contains lactose which some people can digest but some cannot. [1]

State a function of lactose.

c. Milk contains lactose which some people can digest but some cannot. [3]

Explain the production of lactose-free milk.

Markscheme

a. disaccharide.

b. provide energy (for young mammals)

Do not accept energy storage.

c. a. lactase added to milk / lactase immobilised;

b. lactose hydrolysed/broken down into glucose and galactose;

c. for people who are lactose intolerant/lack lactase;

d. increases sweetness/solubility/smooth texture (in processed foods);

Examiners report

a. Most candidates got this one right. Wrong answers included answers like polysaccharide, sucrose, monosaccharide and ribose.

b. Too many missed the idea of "function" here. Even after getting the answer to part (a) right, some candidates confused lactose with lactase citing that it as an enzyme, or suggesting that it digests. Others gave a nutrient value of milk rather than recognizing that lactose is a component of milk with a singular function.

c. This question could be interpreted as asking for the steps in a procedure (an acceptable expectation from Topic 3 AS 3.6.5) or it could be seen as asking the purpose of production of lactose-free milk (as found in the teacher's notes). Marking points were given for both possibilities. Most candidates earned one mark for statements about how lactose free milk is made and one mark for a reason for making it.

The old lactose/lactase/lactate confusion arose for weaker candidates. There was quite a bit of evidence for strict memorization here.

Many creative incorrect answers such as genetic modification of cows so they don't produced lactose or lactose is an enzyme that makes digestion difficult so lactose must be denatured.

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a. Draw a labelled diagram to show the human ventilation system. [4]

b. Outline anaerobic cell respiration in plant cells. [5]

c. Explain the concept of homeostasis, using the control of blood sugar as an example. [9]

Markscheme

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

trachea;

bronchi;

bronchioles;

lungs;

alveoli – shown enlarged as inset;

diaphragm;

intercostal muscles;

abdominal (wall) muscles;

*Award **[3 max]** for diagrams that do not show correct connections or proportions.*

b. anaerobic (cell) respiration in the absence of oxygen;

glycolysis / breakdown of glucose molecules;

leads to the production of pyruvate;

also known as fermentation;

production of small yield/two ATP (molecules per molecule of glucose respired);

produces ethanol;

produces carbon dioxide;

occurs in cytoplasm;

example of anaerobic respiration in plants (*e.g.* waterlogged roots);

c. maintaining the internal environment constant/between narrow limits;

example (other than blood sugar) of blood pH / oxygen and carbon dioxide concentrations / body temperature / water balance;

involves negative feedback;

where a variation from the normal (blood sugar level) triggers the correction mechanisms;

controlled by both nervous and endocrine systems;

blood sugar above normal stimulates insulin release;

insulin secreted by β cells in the (islets of the) pancreas;

insulin lowers blood sugar;

by converting to glycogen/fat / increased respiration;

blood sugar below normal stimulates glucagon release;

glucagon secreted by α cells in the (islets of the) pancreas;

glycogen converted to glucose; causes increased level of glucose in the blood;

Examiners report

a. In the diagram of the human ventilation system, alveoli needed to be shown as an inset to gain their mark. This was consistent with the Teacher's notes for A.S. 6.4.4 in the Subject Guide. Many candidates included intercostal muscles but it was difficult to show them clearly. Abdominal (wall) muscles were not shown. The quality of the ventilation diagrams was generally lower than for the membrane diagrams. Correct labels must correspond to recognizable structures.

b. Uncertainty as to the type of anaerobic respiration found in plants may have put off some candidates since, for A.S. 3.7.3., the Teacher's notes only mention yeast and humans. Nonetheless, some candidates gained full marks knowing those aspects common to both pathways. Also, candidates may have associated yeast with plants, thereby describing the alcohol fermentation pathway. At least one candidate was able to cite waterlogged roots as a place where anaerobic respiration would occur in plant cells.

c. Many candidates did quite well on this question, showing good knowledge and understanding of homeostasis. The mark scheme provided ample opportunities for many high scoring answers. Negative feedback was frequently included but "controlled by both nervous and endocrine systems" was rarely seen.

---

a. State the type of bonds that [2]

(i) connect base pairs in a DNA molecule.

(ii) link DNA nucleotides into a single strand.

b. Distinguish between DNA and RNA nucleotides by giving **two** differences in the chemical structure of the molecules. [2]

c. Explain the role of transfer RNA (tRNA) in the process of translation. [2]

Markscheme

a. (i) hydrogen

(ii) covalent / phosphodiester linkage

b. DNA has deoxyribose, RNA has ribose;

DNA has base T/thymine, RNA has base U/uracil;

Do not accept double or single strands as chemical structure.

c. tRNA attaches to (specific) amino acid;

tRNA (with amino acid) moves to the ribosome;

anticodon of tRNA binds with codon of mRNA;

Examiners report

a. (i) Most were correct.

(ii) Less success was seen here. A number of students mistakenly wrote phosphate bonds or peptide bonds. “Covalent bonds” was commonly stated for the mark and, sometimes, even the more sophisticated answer of phosphodiester linkage was given.

Occasionally, candidates reversed hydrogen and covalent for parts (i) and (ii) and lost both marks.

b. Easy marks for many candidates. However, some misread the questions and described differences in the physical/molecular structure of DNA and RNA molecules. Rather than restricting answers to nucleotide differences, double and single strands were described resulting in no credit.

c. This question was worth only two marks but explaining the role of tRNA during translation could easily have been worth more. A few candidates wrote stellar answers that far exceeded the two mark maximum. The marking points most often awarded were that tRNA attaches to an amino acid and that tRNA has an anticodon complementary to the mRNA codon. Many candidates provided inaccurate information.

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a. Distinguish between ventilation, gas exchange and cell respiration. [4]

b. Outline the process of aerobic respiration. [6]

c. Respiration and other processes in cells involve enzymes. Explain the factors that can affect enzymes. [8]

Markscheme

a. ventilation is moving air into and out of lungs/inhalation and exhalation;

involves (respiratory) muscle activity;

gas exchange involves movement of carbon dioxide and oxygen;

between alveoli and blood (in capillaries) / between blood (in capillaries) and cells;

cell respiration is the release of energy from organic molecules/glucose;

(aerobic) cell respiration occurs in mitochondria;

*To award **[4 max]** responses must address ventilation, gas exchange and cell respiration.*

b. during glycolysis glucose is partially oxidized in the cytoplasm;

(small amount/yield of) ATP produced;

(two) pyruvate formed by glycolysis;

pyruvate absorbed into/broken down in the mitochondrion;

requires oxygen;

carbon dioxide is produced;

water is produced;

large amount/yield of energy/ATP molecules (per glucose molecule);

c. collisions between enzyme/active site and substrate;

enzyme activity increases as temperature rises;

more frequent collisions at higher temperatures;

each enzyme has an optimum temperature / enzymes have optimal temperatures;

high temperatures (above optimum) denature enzymes;

each enzyme has an optimum pH / enzymes have optimal pHs;

increase or decrease from optimum pH decreases rate of reaction/activity;

extreme pH alters/denatures the tertiary/3D protein/enzyme structure;

increasing substrate concentration increases the rate of reaction;

higher substrate concentration increases chance of collision;

until plateau;

when all active sites are busy;

Accept clearly annotated graph.

Examiners report

a. As candidates distinguished between ventilation, gas exchange and cell respiration (A.S. 6.4.1), certain ideas keep reappearing and others were infrequently expressed. Among the former were inhalation and exhalation; movement of carbon dioxide and oxygen; and release of energy from organic molecules. Less common were involvement of muscle activity for ventilation; exchange between alveoli and blood or between blood and cells; and that cell respiration occurs in mitochondria. “Ventilation is moving air into the lungs” was not enough for a mark, nor was “cell respiration is release of energy from food” which was too general.

b. With this question on aerobic respiration (A.S. 3.7.2, 3.7.3), many candidates easily earned four of the six available marks. These were that aerobic respiration requires oxygen, produces carbon dioxide, produces water and produces a large yield of energy/ATP. Additional marks were earned with commentary on glycolysis, since it produces the pyruvates that are eventually broken down aerobically.

c. Factors that affect enzyme activity (A.S. 3.6.1-3.6.4) is another topic that has appeared repeatedly on past IB exams. Furthermore, the topic is often visited during IA investigations. Details on how changes in temperature and pH affect enzyme activity formed the heart of most answers. Denaturation of enzyme structure that alters the active site was usually included in those answers. The effect of substrate concentration on enzyme activity was less common. Higher quality answers mentioned collisions between enzyme and substrate and linked enzyme activity to the frequency of collisions at different temperatures or substrate concentrations. Many written passages were supported with annotated graphs that also earned

marks. However, some candidates confused the graph for enzyme activity vs temperature with the graph of enzyme activity vs. substrate concentration. They show a plateau in the temperature curve and declared that the plateau represented denaturation of the enzyme at that temperature.

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a. Describe the genetic code and its relationship to polypeptides and proteins. [5]

b. Outline the role of proteins in active and passive transport of molecules through membranes. [5]

c. Many cell functions, like synthesis of macromolecules and transport, require energy in the form of ATP. Explain how ATP is generated in animal cells. [8]

Markscheme

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

a. (the genetic code is based on) sets of three nucleotides/triplets of bases called codons;
b. bases include adenine, guanine, cytosine and thymine in DNA / adenine, guanine, cytosine and uracil in RNA; (do not accept ATCG)
c. each codon is code for one amino acid;
d. some codons are (start or) stop codons;
e. DNA is transcribed into mRNA by base-pair matching/complementary base pairing;
f. mRNA is translated into a sequence of amino acids/polypeptide;
g. each gene codes for a polypeptide;
h. polypeptides may be joined/modified to form proteins;

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

a. channel proteins allow diffusion/osmosis/passive transport;
b. large/polar molecules cannot cross the (hydrophobic) membrane freely;
c. facilitated diffusion involves moving molecules through proteins down their concentration gradient/without requiring ATP;
d. aquaporins (specific integral membrane proteins) facilitate the movement of water molecules/osmosis;
e. some proteins (for facilitated diffusion) are specific to molecule/ions;
f. active transport involves moving molecules through proteins against their concentration gradient/requiring ATP;
g. (some) proteins in the membrane are pumps / pumps perform active transport / sodium potassium pump;

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

a. ATP is a form of energy currency/immediately available for use;
b. ATP is generated in cells by cell respiration (from organic compounds);
c. aerobic (cell respiration) requires oxygen;
d. anaerobic (cell respiration) does not require oxygen;
e. glycolysis breaks down glucose into pyruvate;
f. glycolysis occurs in cytoplasm;
g. (by glycolysis) a small amount of ATP is released;
h. ADP changes into ATP with the addition of a phosphate group/phosphoric acid / accept as chemical equation;
i. in mitochondria/aerobic respiration produces large amount of ATP / 38 mols (for the cell, per glucose molecule);
j. oxygen/aerobic respiration is required for mitochondrial production of ATP;
k. in mitochondria/aerobic respiration pyruvate is broken down into carbon dioxide and water;

Examiners report

a. Many mentioned codons and anticodons, but few explained what they are. Most gained marks from stating that one gene codes for one polypeptide, and that polypeptides can be linked or modified to form proteins.

b. Many were confused by the differences between channel proteins (passive) and protein pumps (active).

c. There were several comments about how the students could gain 8 marks on a question about ATP. It was obvious that some students had studied option C, but this should not really have given them an advantage. In fact the students found this question much easier than the teachers thought, scoring well in this section.

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a. Describe the structure and function of starch in plants. [3]

b. Outline the production of carbohydrates in photosynthesis. [4]

c. Discuss the processes in the carbon cycle that affect concentrations of carbon dioxide and methane in the atmosphere and the consequences for climate change. [8]

Markscheme

a. *Structure*:

a. «starch» is a polysaccharide/is composed of glucose molecules

b. contains amylose which is a linear/helical molecule

c. contains amylopectin which is a branched molecule

Function:

d. storage of glucose/energy in plants

e. storage form that does not draw water

b. a. light is absorbed by chlorophyll

OR

chlorophyll absorbs more red and blue light

b. «absorbed» light energy is converted to chemical energy

c. some of the energy is used for production of ATP

d. water molecules are split/photolysis

e. produces oxygen «as waste product»/hydrogen/NADPH

f. plants absorb/fix CO_2 «from air or water»

g. ATP/energy is needed to produce carbohydrates/starch

c. a. CO_2 is produced from respiration in organisms/combustion of biomass/fossil fuels

b. CH_4 is produced by anaerobic respiration of biomass/«methanogenic» bacteria

c. CH_4 is oxidized to CO_2 and water

d. CO_2 is converted into carbohydrates/organic compounds by autotrophs/producers/photosynthesis

e. CO_2 can be converted to calcium carbonate/fossilized into limestone

f. «partially» decomposed organic matter/biomass can be converted into peat/coal/oil/gas/fossil fuels

g. CO_2 and CH_4 are both greenhouse gases/increase greenhouse effect

h. both absorb long-wave radiation from the earth and retain the heat in the atmosphere

i. increased CO_2 concentrations in the atmosphere correlate with increased combustion of fossil fuels

j. rising average global temperatures correlate with more greenhouse gases in the atmosphere

k. cattle production/rice paddy/defrosting of tundra increase CH_4 in the atmosphere
OR
increasing CO_2 leads to acidification of marine/aquatic environments

l. the global temperature increase influences/disrupts climate patterns

OWTTE

Examiners report

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

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a. Explain why DNA must be replicated before mitosis and the role of helicase in DNA replication. [4]

b. Explain how the base sequence of DNA is conserved during replication. [5]

c. Describe the events that occur during mitosis. [9]

Markscheme

a. two genetically identical nuclei/daughter cells formed during mitosis (so hereditary information in DNA can be passed on);

two copies of each chromosome/DNA molecule/chromatid needed;

helicase unwinds the DNA/double helix;

to allow the strands to be separated;

helicase separates the two (complementary) strands of DNA;

by breaking hydrogen bonds between bases;

b. DNA replication is semi-conservative;

DNA is split into two single/template strands;

nucleotides are assembled on/attached to each single/template strand;

by complementary base pairing;

adenine with thymine and cytosine with guanine / A with T and C with G;

strand newly formed on each template strand is identical to other template strand;

DNA polymerase used;

Marks may be awarded for any of the above points if clearly presented in a well-annotated diagram.

c. sequence of stages is prophase → metaphase → anaphase → telophase;

chromosomes condense/supercoil/become shorter and fatter in prophase;

spindle microtubules grow (from poles to equator) in prophase/metaphase;

nuclear membrane breaks down in prophase/metaphase;

spindle microtubules attach to the centromeres/chromosomes in metaphase;

chromosomes line up at equator in metaphase;

centromeres divide / (paired) chromatids separate / chromosomes separate into two chromatids in metaphase/anaphase;

(sister) chromatids/chromosomes pulled to opposite poles in anaphase;

spindle microtubules disappear in telophase;

nuclear membrane reforms around chromosomes/chromatids in telophase;

chromosomes/chromatids decondense in telophase;

Examiners report

a. Practically everybody knew the role of helicase in DNA replication. Extremely few could clearly explain the need for mitosis.

b. The question was often confused with other details of DNA replication, transcription and even translation. Though DNA replication was correctly described as semiconservative, further expansion of that term became muddled. Most knew A-T and G-C base pairing but the idea of complementarity was not always included. Diagrams were drawn but lacked labels and annotations most of the time. Occasionally, candidates mentioned that DNA polymerase was used

c. Of all the parts in Section B, this one (describe the events of mitosis) was answered best. Many candidates earned close to the maximum number of marks. A few candidates thought that interphase is a part of mitosis.

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a. Define metabolism. [1]

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

Process	Anabolism	Catabolism
Photosynthesis	☐	☐
Glycolysis	☐	☐

c. Describe cell respiration in terms of metabolism. [2]

Markscheme

a. (the web of all) the enzyme-catalyzed reactions in a cell/organism

OR

the totality of an organism's chemical reactions (consisting of catabolic and anabolic pathways which manage the material and energy resources of the cell)

b.

process	*anabolism*	*catabolism*
photosynthesis	☑	☐
glycolysis	☐	☑

c. a. «cell respiration is metabolism because» enzymes control the reactions

b. energy is released from complex molecules «to make ATP»

c. respiration is catabolic (metabolism)
OR
complex molecules become simpler
OR
$C_6H_{12}O_6$ to $CO_2 + H_2O$

Examiners report

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

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a. State **one** disaccharide and the **two** monomers from which it can be synthesized. [2]

Disaccharide:

1:

Monomers:

1:

and 2:

b. Discuss the roles of the enzymes secreted by the pancreas during digestion. [3]

c. Compare and contrast cis-fatty acids and trans-fatty acids. [2]

Markscheme

a. a. disaccharide name

eg: lactose, glucose and galactose

b. both monomers that make up mpa

eg: maltose, glucose and glucose

eg: sucrose, glucose and fructose

b. a. amylase breaks down/catalyzes/hydrolyses starch to maltose

b. lipase breaks down/catalyzes/hydrolyses fats to fatty acids and glycerol

c. proteases/peptidases break down/catalyze/hydrolyze proteins into smaller polypeptides/dipeptides/amino acids

Award [2] if all three enzymes and substrates named correctly and one further mark for all three products named correctly.

Allow specific enzymes

c. a. both are unsaturated fatty acids

OR

both have two carbon atoms joined by a double bond

b. in cis-fatty acids the two H atoms are on the same side while in trans-fatty acids they are on opposite sides

OR

cis-fatty acids are healthier than trans-fatty acids

OR

cis-fatty acids have a lower boiling/melting point than trans

OR

cis-fatty acids have a kink «in the chain» but trans do not

Accept answer in an annotated diagram

Examiners report

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

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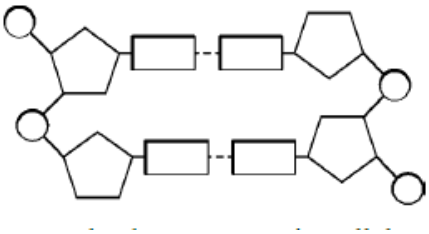
a. Draw a labelled diagram of the structure of DNA, showing the arrangement of subunits. [3]

b. Explain DNA replication. [3]

Markscheme

a.



correctly shows two antiparallel sugar-phosphate strands/backbones with linkages between phosphates and sugars connected through bases;
(phosphate and simple names such as sugar and base are acceptable labels. They must be given at least once.)
correctly labeled phosphate and deoxyribose and base;
sugar linked to phosphates through correct pentagon corners/(5'–3') linkages;
shows complementary base pairs of A-T/Adenine–Thymine and G-C/Guanine–Cytosine;
correctly indicates both covalent/phosphodiester and hydrogen bonds.

b. DNA replication is semi-conservative/daughter DNA molecule contains one parent strand and one new strand;

unwinding of double helix/separation of two strands by helicase;

separated (parent) strands become templates for new strands;

free/single nucleotides join (parent/template) strands through complementary base pairing;

DNA polymerase joins nucleotides in new strands;

Award [3] for the above points clearly shown in an annotated diagram.

Examiners report

a. The DNA diagram provided many ways to earn three marks. Complementary base pairing was an easy mark. Roughly 20% of the candidates failed to draw two strands. Most candidates did not show the anti-parallel nature of DNA and very few had the correct linkage at the pentagon corners.

b. It seems that every candidate knew about helicase and stated its function correctly. Thus, few zero answers appeared. DNA polymerase was also mentioned by many, but without the correct function. A few candidates confused replication with translation.

DNA research, involving biotechnology, has led to benefits for society but has given rise to some controversy.

a. Outline how translation depends on complementary base pairing. [3]

b. Describe the polymerase chain reaction (PCR), including the role of Taq DNA polymerase. [4]

c. Explain benefits and risks of using genetically modified crops for the environment and also for human health. [8]

Markscheme

a. a. translation converts a sequence of mRNA nucleotides/codons to a sequence of amino acids/polypeptide/protein

b. «triplets of» nucleotides/bases on «activated» tRNAs pair with complementary «triplets of» nucleotides/bases on mRNA / *vice versa*

c. base pairing occurs when adenine/A pairs with uracil/U and guanine/G pairs with cytosine/C

d. specific amino acids are attached to specific of tRNA

e. mRNA has codons ***AND*** tRNA has anticodons

b. a. PCR is process by which a small sample of DNA can be amplified/copied many times

b. PCR involves repeated cycling through high and lower temperatures «to promote melting and annealing of DNA strands»

c. «mixture» is heated to high temperatures to break «hydrogen» bonds between strands of DNA/to separate the double-stranded DNA

d. Taq DNA polymerase can withstand high temperatures without denaturing

e. primers bind to «targeted» DNA sequences at lower temp

f. Taq DNA polymerase forms new «double-stranded» DNA by adding «complementary» bases/nucleotides

c. *Environment benefits:*

a. pest-resistant crops can be made

b. so less spraying of insecticides/pesticides

c. less fuel burned in management of crops

d. longer shelf-life for fruits and vegetables so less spoilage

e. greater quantity/shorter growing time/less land needed

f. increase variety of growing locations / can grow in threatened conditions

Environment risks:

g. non-target organisms can be affected

h. genes transferred to crop plants to make them herbicide resistant could spread to wild plants making super-weeds

i. GMOs (encourage monoculture which) reduces biodiversity

j. GM crops encourage overuse of herbicides

Health benefits:

k. nutritional value of food improved by increasing nutrient content

l. crops could be produced that lack toxins or allergens

m. crops could be produced to contain edible vaccines to provide natural disease resistance

Health risks:

n. proteins from transferred genes could be toxic or cause allergic reactions

o. antibiotic resistance genes used as markers during gene transfer could spread to «pathogenic» bacteria

p. transferred genes could cause unexpected/not anticipated problems
OR
health effects of exposure to GMO unclear

Examiners report

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

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a. State **four** elements that are needed by living organisms, other than carbon, hydrogen and oxygen, giving **one** role of each. [4]

b. Outline how light energy is used and how organic molecules are made in photosynthesis. [6]

c. Explain the significance of complementary base pairing for replication, transcription and translation. [8]

Markscheme

a. a. nitrogen – structure of organic molecules/proteins/nucleotides;

b. sulfur – amino acid / protein structure;

c. phosphorus – nucleic acids / energy carriers;

d. calcium – bone structure / trigger exocytosis (*e.g.* neurotransmitters);

e. iron – prosthetic groups / hemoglobin;

f. sodium – membrane potential;

Accept other valid roles for those elements already listed.

Accept other valid examples of elements with their roles.

*To award **[4 max]**, responses need an appropriate role for each element stated.*

b. a. chlorophyll is the (main) photosynthetic pigment;

b. absorbs (mainly) red and blue light;

c. green light is reflected;

d. light energy absorbed is converted into chemical energy;

e. ATP produced;

f. water split;

g. to form oxygen and hydrogen;

h. ATP and hydrogen used to fix carbon dioxide to make organic molecules;

c. a. A-T and C-G in DNA;

b. A-U and C-G in RNA;

c. complementary base pairing in replication ensures identical nucleotide sequence of new complementary strands;

d. semi-conservative replication;

e. transcription produces RNA sequence complementary to the DNA sequence (of the gene);

f. triplets of nucleotides on mRNA are codons;

g. translation converts mRNA sequence of information into a specific amino acid chain (polypeptide);

h. (each class of) tRNA carries a specific triplet of (three) bases called an anticodon;

i. anticodons bind to codons by complementary base pairing;

j. (each class of) tRNA with specific complementary anticodons carry specific amino acids;

k. sequence of mRNA codons translates into specific amino acid sequence;

l. enables conservation of information transfer from DNA to RNA to polypeptide;

Examiners report

a. In general, well answered by those candidates who attempted the question. The syllabus content appeared to be well understood.

b. Most candidates mentioned the conversion of light energy into chemical energy during photosynthesis. Many candidates also referred to events of photolysis for additional marks. A common omission was reference to the wavelengths absorbed or reflected by chlorophyll. Finally, candidates wrote about fixation of carbon dioxide to make organic molecules but neglected to mention that the process requires ATP and hydrogen.

c. Reasonable accounts were given, though more emphasis was placed on replication than the other processes. Weaker candidates failed to mention identical nucleotide sequences in replication. For most candidates, the importance of complementary base pairing needed more development in transcription and translation. The complementarity of codons and anti-codons was often missed. Many times valid ideas were left undeveloped but then continued elsewhere in the essay. Some essays were embellished by good quality illustrations. Occasionally, understanding of the three processes was very muddled with some candidates describing mRNA as going into the nucleus to copy DNA.

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a. Outline the role of hydrolysis in the relationships between monosaccharides, disaccharides and polysaccharides. [4]

b. Describe the use of biotechnology in the production of lactose-free milk. [6]

c. Explain the importance of enzymes to human digestion. [8]

Markscheme

a. monosaccharides are single sugars and disaccharides are two sugars and polysaccharides are multiple sugars;
hydrolysis is the addition of water to split a molecule into smaller fragments;
–OH and –H are added to the fragments;
disaccharides are split/digested into two single sugars;
polysaccharides are broken/digested into smaller fragments (*e.g.* diasaccharides);
process depends on enzyme control (in organisms);

b. a particular yeast (growing in natural milk) contains lactase;
biotechnology companies can grow/culture the yeast;
lactase (an enzyme) is extracted from the yeast;
natural milk contains lactose/milk sugar;
when added directly to milk, lactase converts lactose into simpler forms;
same effect when milk is passed past immobilized (on surface or beads) lactase;
simpler forms of sugar (glucose and galactose) are easily absorbed (in the small intestine);
a commercial market exists for lactose-free milk / lactose-free milk is example of biotechnology's economic impact;
some people are lactose intolerant/cannot digest lactose in milk/have lost lactase activity in intestinal cells;

consuming lactose-free milk allows lactose intolerant people to be nourished by milk without discomfort (abdominal cramps and diarrhoea);

many Asians are lactose intolerant whereas less common among other groups (northern Europeans and some Africans);

biotechnology produced in one part of world is more useful in another;

c. food must be in a small enough form to leave the gut and enter the bloodstream;

physical breakdown is not enough / chemical breakdown is necessary;

enzymes are required for the chemical breakdown of food;

enzymes increase the rate of digestion;

enzymes are biological catalysts;

enzymes allow digestion to occur at body temperature;

enzymatic digestion is a sequential process *e.g.* from protein to peptide to amino acid;

specific location for each reaction with specific conditions/environments *e.g.* stomach high acidity;

most enzymes work extracellularly / some enzymes work intracellularly;

variations in pH throughout digestive tract promote the activity of different digestive enzymes / different enzymes have different optimal pHs;

amylases digest carbohydrate to monosaccharides;

proteases digest proteins to amino acids;

lipases digest fats to fatty acids and glycerol;

Examiners report

a. Candidates generally understood the process of hydrolysis but had difficulty applying it to the relationship between monosaccharides, disaccharides and polysaccharides.

b. The production of lactose free milk was well understood by many candidates, but most left out basic points such as the fact that lactose is found in milk and that lactase is the enzyme that breaks it down. Sometime these fundamental points, which are worth marks, are skipped. Candidates should fully explain their answers and not take any response for granted as "too obvious for a mark".

c. This section was generally well done with candidates demonstrating a good understanding of enzyme function in the context of the human digestive tract. The best responses named specific enzymes, the location of release and the substrate and products of the reaction catalysed. As in 5 (b), many candidates did not indicate that enzymes are biological catalysts and that they increase the rate of digestion. Candidates should fully explain their answers and not take any response for granted as "too obvious for a mark".

b. Outline the process of gas exchange necessary for aerobic respiration in a unicellular eukaryotic organism. [3]

c. Explain how the process of evolution occurs. [8]

Markscheme

b. Oxygen must be taken up ***AND*** carbon dioxide must be released (*Both needed*)

Gases pass through a cell membrane by simple diffusion

Require a concentration gradient
OR
pass from high concentration to low concentration

Without requiring energy
OR
passive process

Large SA: vol ratio

c. Evolution is «cumulative» change in population/species over time

OR

change in allele frequency

A population has variations amongst the individuals

Due to meiosis
OR
sexual reproduction

Due to mutations

Certain variations give an advantage to some organisms over others in certain environments

Populations/species produce more offspring than the environment can support

Individuals of the species compete for the same resources

The better-adapted organisms tend to survive and reproduce
OR
less adapted organisms tend to die or reproduce fewer offspring

Individuals «that reproduce» pass on their «heritable» characteristics/alleles/genes to their offspring (*"Traits" is an acceptable alternative to "characteristic"*)

Natural selection increases the frequency of «heritable» characteristics/alleles/genes of the better-adapted organisms (*Accept "genes"*)

Specific example described (*Example must be "described" to award marks*)

*Award **[7 max]** if no reference to heritable characteristics or alleles.*

Examiners report

b. Gas exchange and simple diffusion – Most candidates knew what aerobic respiration was, but could not apply it to the question. Perhaps under the pressure of the examination, candidates many did not progress to the second line and therefore missed the expression 'unicellular eukaryotic organism'. Detailed knowledge of the alveoli and the Krebs cycle did not gain marks.

c. Evolution – Several G2 comments were made which questioned whether the candidates should be answering a question on evolution. It is a topic that has appeared on the examination many times and well prepared candidates had no trouble answering it. The number of 'Lamarckian' answers where individuals instead of populations or species were evolving showed the continued decrease shown over the last few years.

---

a. Outline the difference in absorption of red, blue and green light by chlorophyll. [4]

b. Explain how the process of photosynthesis affects carbon dioxide concentrations in the atmosphere during a typical year **and** the likely consequences on Earth of the yearly rises in carbon dioxide concentrations. [8]

Markscheme

a. a. blue and red light absorbed (the most);

b. greatest absorption in blue light;

c. red light absorbed in high amounts;

d. least/no absorption of green light / green light is reflected/transmitted;

Allow answers shown in an annotated diagram/graph.

b. *Relationship between photosynthesis and carbon dioxide concentration:* ***[4 max]***

a. photosynthesis uses carbon dioxide;

b. CO_2 fixed/made into organic molecules/compounds by photosynthesis;

c. lowering carbon dioxide level in atmosphere;

d. annual/seasonal fluctuations of carbon dioxide levels could be related to photosynthesis;

e. caused by increased photosynthesis during spring/summer;

Consequences: ***[5 max]***
f. enhanced greenhouse effect caused by raised levels of carbon dioxide;
g. causing global warming;
h. rising of ocean levels / melting of polar ice caps/glaciers;
i. changes in weather (patterns);
j. ocean acidification;
k. alter food webs;
l. changes/loss of habitat;
m. changes in distribution of plants and animals;
n. may lead to extinction;

Examiners report

a. Question 6 appeared to be the most difficult question for candidates.

Most candidates knew that chlorophyll absorbs blue and red light and virtually no green light which is consequently reflected. Very few candidates knew that blue light is absorbed most and that red light is absorbed in high amounts.

b. Question 6 appeared to be the most difficult question for candidates.

Candidates frequently began with the idea that plants take in CO_2 through photosynthesis and that levels of atmospheric CO_2 can be lowered as a result. After that changes in atmospheric levels as a result of seasonal fluctuation was left undeveloped or confused with human production of CO_2 through deforestation etc. Candidates did know about global warming resulting from rising levels of CO_2. They knew a variety of consequences related to global warming which reflected awareness of similar IB questions on past exams. Some candidates still think that CO_2 weakens the ozone layer. It seems that no candidate knew about the enhanced greenhouse effect.

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

a. Explain the processes by which energy enters and flows through ecosystems. [8]

b. Producers extract phosphates and nitrates from soil. Outline how these ions are used in the synthesis of organic molecules. [3]

c. Draw a labelled diagram of a pyramid of energy. [4]

Markscheme

a. a. light energy is the initial energy source for (all) organisms

b. producers/autotrophs change light/radiant energy into chemical energy
OR
producers/autotrophs convert/trap light/radiant energy by photosynthesis

c. producing $C_6H_{12}O_6$ /sugars/carbohydrates

d. carbon/organic compounds used for energy/growth/repair/storage

e. compounds/energy pass as food along food chains/trophic levels WTTE

f. cellular respiration releases energy as ATP from food

g. energy is lost as heat (during cellular respiration)

h. loss of energy at each trophic level
OR
only approximately 10% of energy is passed to the next trophic level / 90% is lost at each trophic level

i. energy lost in bones/hair when they die/not fully eaten by the next trophic level

j. energy lost in feces/urine

k. decomposers/saprotrophs remove energy from wastes/bodies

l. energy is not recycled

b. a. by photosynthesis / using energy from light

b. attached to carbon compounds

c. phosphates used to make phospholipids/nucleotides/nucleic acids/DNA/RNA/ATP

Other phosphorus-containing metabolites are acceptable if verified.

d. nitrates are used to make amino acids/proteins/nucleotides/nucleic acids/DNA/RNA/ATP

Other nitrogen-containing metabolites are acceptable if verified.

e. transported from roots to leaves (in xylem)

c. a. drawn in steps rather than triangle

b. drawn to scale (should be at least 1/5 of the box below it)
OR
annotated with appropriate numeric values

c. producer

d. primary consumer

e. secondary consumer

Award no marks if a drawing has not been made.

"Appropriate numeric values" should indicate scale so accept percentage or numbers.

Examiners report

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

---

a. State **one** role in living organisms for each of the following: sulfur, calcium, phosphorus and iron. [4]

b. Outline the role of condensation and hydrolysis in the relationship between fatty acids, glycerol and triglycerides. [6]

c. Explain the relationship between the properties of water and its uses in living organisms as a coolant, a medium for metabolic reactions and a transport medium. [8]

Markscheme

a. *sulfur*: (structural element in some) amino acids/proteins/enzymes;

calcium: (structural element in) bones/teeth/shells / signal for cellular processes/ neurotransmitter release/muscle contraction/electrical conduction system of the heart/blood clotting;

phosphorus: (structural element in) ATP/DNA/RNA/phospholipids/bones;

iron: carries oxygen / formation of hemoglobin/myoglobin/cytochrome / cofactor of enzymes;

b. *hydrolysis:* ***[3 max]***

when larger molecules are broken to smaller molecules/subunits;

with the addition of water;

fatty acids produced by the hydrolysis of fats/triglycerides;

breaking of ester bonds;

with release of glycerol;

condensation: ***[3 max]***
when molecules/subunits are joined to form a larger molecule;
water formed/removed;
fatty acids linked to glycerol;
up to three fatty acids can be linked to each glycerol;
through formation of ester bonds;

c. water is a polar molecule;

oxygen has a partial negative charge / hydrogen has a partial positive charge;

hydrogen bonds form between adjacent water molecules;

water remains liquid over wide range of temperatures/0 to 100 °C ;

moderates temperature fluctuation / stable environment;

accurate reference to specific heat;

sweating/evaporation cools organisms;

accurate reference to high heat of vaporization;

polarity makes water a good/universal solvent for polar/ionic substances;

(all) metabolic reactions of cells take place in (aqueous) solutions;

blood/xylem/phloem transport solutes in water;

cohesive properties allow capillary action/transpiration stream/water column in xylem;

Examiners report

a. Stating a role for sulphur, calcium, phosphorus, and iron (A.S. 3.1.1) allowed candidates to easily gain four marks. Sulphur was slightly problematic because its structural role in amino acids or proteins or enzymes is somewhat abstract.

b. The question required an outline of condensation and hydrolysis with reference to fatty acids, glycerol and triglycerides (A.S. 3.2.5). This was often done quite well. Some answers were accompanied by carefully annotated diagrams.

c. This part had the poorest achievement among candidates. The polarity of water molecules with hydrogen bonding as the basis for many of its properties (A.S. 3.1.4, 3.1.5, 3.1.6) was either overlooked or inadequately explained. The concept of water providing a stable environment over a broad temperature range also challenged candidate understanding. However, as always, some candidates were totally competent in their answers which even integrated accurate reference to specific heat. Ideas about water as a solvent and transport medium, water as a medium for metabolic reactions and how cohesion properties in water relate to transpiration were scattered among candidate answers.

James Beard, a famous chef, once said “Food is our common ground, a universal experience.”

a. Explain how the small intestine moves, digests and absorbs food. [8]

b. Distinguish between the structures of the different types of fatty acids in food. [4]

c. Outline how leptin controls appetite. [3]

Markscheme

a. a. contraction of muscle «layers»/peristalsis helps move food

OR

circular muscle contraction prevents backward movement of food

OR

longitudinal muscle contraction moves food along gut

b. peristalsis/muscle contractions mix food with intestinal enzymes

c. enzymes digest macromolecules into monomers

Accept an example for mp c

d. pancreatic enzymes/amylase/lipase/endopeptidase «chemically» digest food in«lumen of» small intestine

e. «pancreatic» amylase digests starch
OR
lipases digest lipids/fats/triglycerides
OR
endopeptidases/dipeptidases digest proteins/polypeptides

f. bile/bicarbonate secreted into the small intestine creates favorable pH for enzymes
OR
bile emulsifies fat

g. some final digestion into monomers is associated with epithelial cells/epithelium «of small intestine»

h. mucosa layer/inside surface/lining of small intestine contains villi/finger-like projections

i. villi/microvilli increase surface area for better absorption

j. villi absorb products of digestion/monomers/mineral «ions»/vitamins

k. glucose/amino acids enter blood «capillaries»
OR
lipids enter lymph vessels/lacteals

l. absorption involves active transport/diffusion/facilitated diffusion

m. different nutrients are absorbed by different transport mechanisms

b. a. fatty acids can be saturated or unsaturated

b. unsaturated can be monounsaturated or polyunsaturated

c. saturated fats have no double bonds/have maximum number of hydrogen atoms
OR
unsaturated fatty acids have «at least one» double C=C bond
OR
polyunsaturated fatty acids have more than one double bond / OWTTE

d. cis-form has hydrogen atoms on same side of carbon double bond
OR
cis-form has bend at carbon double bond

e. trans-form has hydrogens on opposite sides of carbon double bond
OR
trans-form makes a straight carbon chain

f. length of hydrocarbon chain can vary
OR
position/number of carbon double bonds can vary

Accept labeled diagrams that illustrate these marking points

c. a. leptin suppresses/inhibits appetite

b. is secreted by adipose tissue/fat «storage» tissue

c. level is controlled by amount of adipose tissue/«ongoing» food intake

d. leptin targets cells in hypothalamus/appetite control centre in brain

e. causes hypothalamus/control centre in brain to inhibit appetite

f. if amount of adipose tissue increases, blood leptin concentration rises

Examiners report

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

---

a. Draw a molecular diagram of an amino acid to show its general structure. [3]

b. Outline the role of ribosomes in translation. [4]

c. Some blood proteins are involved in defence against infectious disease. Explain the roles of **named** types of blood proteins in different defence mechanisms. [8]

Markscheme

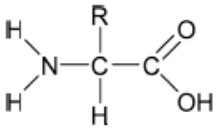
a. a. COO– ***or*** COOH group at one end

b. NH_2 ***or*** NH_3^+ at the other

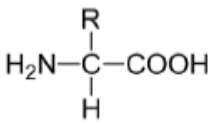
c. CH in middle with H or R group attached

If shown expanded, then carbonyl oxygen must attach to C
If shown non-expanded, N of amine group must attach to C

eg:



OR



b. a. translation is the production of polypeptides/proteins

b. mRNA binds to the ribosome

c. tRNA binds to the ribosome

d. at the site where its anti-codon corresponds to the codon on the mRNA

OWTTE

e. amino acids of «consecutive tRNAs» bind by a peptide link «in the ribosomes»

f. the ribosome moves along the mRNA
OR
continues with elongation of polypeptide chain

Accept annotated diagrams of the process.

c. a. clotting factors «are proteins» that initiate the clotting cascade/process

b. fibrin «is a protein that» permits blood clotting
OR
allows the formation of a clot

c. «the protease» thrombin converts fibrinogen to fibrin

OWTTE

d. fibrin forms a mesh/clot that prevents the entry of pathogen/antigen into the blood

e. antibodies are «specific» proteins that lymphocytes make

f. each antibody corresponds to a specific pathogen/antigen
OR
antibodies are specific «to certain pathogens/antigens»

g. antibodies create specific immunity

h. plasma cells produce large amounts of «specific» antibodies
OR
memory cells retain the ability to produce «specific» antibodies

i. immunoglobulins are antibodies against pathogens

j. enzymes in phagocytic white blood cells may digest pathogens

Accept annotated diagrams of the process.

Examiners report

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

---

a. Outline the role of condensation and hydrolysis in metabolic reactions involving carbohydrates. [4]

b. Metabolic reactions are catalysed by enzymes. Explain how enzymes catalyse reactions and how a change in pH could affect this. [8]

c. Describe the digestion of food in the human digestive system. [6]

Markscheme

a. condensation is joining together molecules with the release of water;

(in general) two monosaccharides join to form a disaccharide / many mono-saccharides/disaccharides form polysaccharides;

example; (*eg. two glucose from maltose*)

hydrolysis is the breaking down of molecules with the addition of water;

(in general) disaccharides break into monosaccharides / polysaccharides break into disaccharides/monosaccharides;

example; (*eg. maltose forms two glucose*)

b. enzymes speed up the rate of chemical reactions;

lock and key model;

substrate fits into active site;

enzyme-substrate specificity;

enzymes work best at optimal pH/different enzymes have different optimal pHs;

increase/decrease from optimum pH decreases activity;

change in pH changes structure/charge of active site;

changing three-dimensional structure of enzyme/protein;

not allowing substrate to fit in active site;

enzymes can be denatured if change is extreme;

denaturing is loss of its biological properties;

sketch graph showing pH versus enzyme activity;

c. chewing food makes smaller particles/increases surface area of food;

starch digestion (begins) in the mouth/by saliva/(salivary) amylase/ptyalin;

digestion of proteins in stomach;

acid condition in stomach provides optimum pH for enzymes;

stomach muscle contraction causes mechanical digestion;

enzymes in small intestine complete digestion;

alkaline condition in small intestine provides optimum pH for enzymes;

bile salts help to emulsify fats;

example of amylase with source, substrate and products;

example of protease with source, substrate and products;

example of lipase with source, substrate and products;

Examiners report

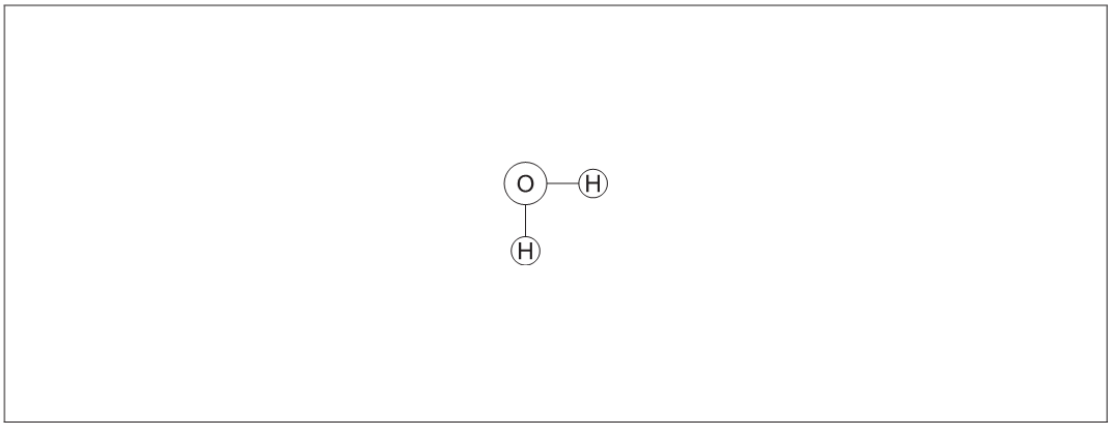
a. In 5(a), most candidates clearly distinguished condensation and hydrolysis. A few candidates did not read the questions properly, giving examples of lipids or proteins instead of carbohydrates. Some marks were always scored.

b. Part 5(b) was an easy question for those who were well-prepared and most handled it well. Some candidates seemed to try to write everything they knew. They gave long explanations of factors beyond pH which can influence how enzymes catalyze reactions. In contrast, other candidates simply wrote that pH change can cause denaturation, without any further reference to change in active site or loss of biological function.

c. The weakest answers for question 5 appeared in 5 (c). The passage of food through various parts of the digestive system was frequently given rather than the breakdown of food. Accurate detailed information was scarce. Although digestion in the mouth was accurately discussed, there was a lack of clarity on digestion in the stomach and intestine. Most candidates discussed mechanical digestion without any attention to chemical digestion. Information on the conditions in each part of the digestion was sketchy. Very few candidates correctly included an example of enzyme source, substrate and product. The role of bile was not clear in most. Some made reference to absorption and egestion, instead of sticking to the question. Sadly, there were candidates who thought that as food progresses through the digestive tract, it stops at the pancreas.

---

a. The figure represents a water molecule. [2]



Draw a second water molecule to show how bonds can form between water molecules, including the name of the bond.

b. Water has important solvent properties. Explain these properties using an example to illustrate your answer. [3]

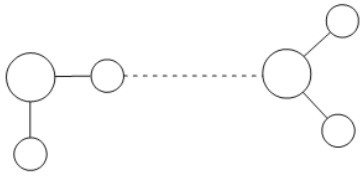
Markscheme

a. a. similar water molecule drawn with oxygen on one molecule facing hydrogen on the other water molecule

b. one hydrogen bond drawn as a dotted/dashed line between the two water molecules and labelled

O and H do not have to be labelled but must be positioned correctly

eg :



Can get this mark even if atoms incorrect

b. a. water molecule is polar

OR

water has «weak» positive and negative charges

c. water forms hydrogen bonds with **polar** substances

d. positive/hydrogen side/pole of water attracted to negative **ions**

OR

negative/oxygen side/pole attracted to positive **ions**

e. glucose/other example dissolves because it is polar

OR

sodium chloride/other example dissolves because ions are attracted to water

[Max 3 Marks]

Examiners report

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

---

a. List **two** functions of membrane proteins. [2]

b. Explain why digestion of large food molecules is essential. [1]

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

d. Outline the use of polymerase chain reaction (PCR) to copy and amplify minute quantities of DNA. [2]

Markscheme

a. a. hormone binding sites / receptors;

b. (immobilized) enzymes;

c. cell adhesion;

d. cell (to cell) communication;

e. passive transport/channels;

f. active transport/pumps;

g. facilitate diffusion;

h. carry electrons;

b. a. many molecules are too large to be absorbed (by the villi) / small molecules are soluble and can be absorbed;

b. large food molecules are broken down so they can be reorganized/rearranged;

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

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

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

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

d. a. strands of DNA (fragments) split/denatured with heat;

b. complementary nucleotides added to split stands (when cooling);

c. with the use of (DNA) polymerase (and primers);

d. process/heating and cooling cycle is repeated (until enough DNA is obtained);

Accept example of PCR application e.g. paternity cases or forensic investigations.

Examiners report

a. Functions were asked for, not named structures. “Channels” and “pumps” by themselves were too vague to gain marks.

b. The idea of food breakdown to a small enough size for absorption was the easier mark achieved by many. Some candidates wrote that food had to be “digested” but “digestion” was written in the stem of the question and too vague for credit.

The idea of food breakdown for eventual reorganization/rearrangement rarely appeared in any answer, perhaps indicating a conceptual gap in candidate understanding of digestion.

c. There was a complete misunderstanding of this question. Almost no candidate seemed to realize that the question was asking for how the PCR can copy and amplify minute quantities of DNA. Thus, the process was either unknown or ignored so marking points were immediately lost. In contrast, almost every candidate knew forensic science as a use of PCR, thereby salvaging one mark.

d. [N/A]

---

a. Explain how materials are moved across membranes of cells by active transport. [2]

b. Explain the effects of pH on enzyme catalysed reactions. [3]

c. Distinguish between the process of anaerobic respiration in yeast and humans. [2]

Markscheme

a. transport against a concentration gradient / from low to high concentration;

through protein pumps;

uses energy/ATP;

b. enzymes have a pH optimum;

active site works best at this pH;

activity decreases above and below the optimum;

by interfering with H-bonding/active site structure;

denaturing by extremes of pH so enzyme activity/reaction stops;

c. *yeast*: pyruvate to ethanol and carbon dioxide;

humans: pyruvate to lactic acid;

*Award **[1 max]** if products are appropriately linked to organisms without the mention of pyruvate.*

Examiners report

a. Knowledge of the characteristics of active transport was generally well expressed. Many candidates understood that protein pumps, requiring energy were required as opposed to protein channels that may be used in facilitated diffusion.

b. This question was answered well with candidates aware of the concept of an optimal pH with activity trailing off on either side. The best answers liked this to the structure of the enzyme active site being changed by the changing pH.

c. Most candidates had no difficulty indicating the end products of respiration. A large number of answers indicated that pyruvate was a common source in each case of respiration, though weaker answers did not.

---

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

b. Outline how **three** different environmental conditions can affect the rate of photosynthesis in plants. [6]

c. Explain how the emission of gases, both naturally and through human activity, can alter the surface temperature of the Earth. [8]

Markscheme

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

cell wall – a uniformly thick wall;

pili – hair-like structures / flagellum – at least length of the cell;

plasma membrane – represented by a continuous single line; *May be labelled as the innermost wall line.*

ribosomes – drawn as small discrete circles/shaded circles;

nucleoid – region with DNA not enclosed in membrane;

plasmid – circular ring of DNA;

cytoplasm – the non-structural material within the cell;

*Award **[3 max]** if one eukaryote structure is shown, **[2 max]** for two eukaryote structures, **[1 max]** for three eukaryote structures and **[0]** if four or more eukaryote structures are shown.*

b. *light: **[2 max]***

rate increases with increasing light;

it reaches maximum then plateaus;

as all chloroplast molecules are working at optimal pace;

*temperature: **[2 max]***
rate increases with increasing temperature;
to a maximum/optimum temperature;
but then falls off rapidly;
as enzymes are denatured above the optimal temperature;

*carbon dioxide: **[2 max]***
rate increases with increasing carbon dioxide level;
it reaches maximum then plateaus;
as photosynthesis operating at optimal level;

Award any of the above points if clearly drawn in a diagram.

c. increase in temperature is called global warming;

this is caused by the greenhouse effect;

a natural phenomenon that has occurred over millions of years;

main gas responsible is carbon dioxide;

other gases like methane/nitrous oxide also cause effect;

shortwave radiation from the Sun enters atmosphere;

warms the surface of the Earth;

longwave radiation emitted by the surface of the Earth;

is absorbed by carbon dioxide/greenhouse gases;

human use of fossil fuels has increased levels of atmospheric carbon dioxide;

rapid rise in temperatures over (approximately) hundred years;

cows/animals/peat bogs release methane;

greenhouse gases emitted by volcanic activity;

Examiners report

a. On the whole the diagrams of a prokaryotic cell were well drawn receiving full marks. A sizable number of candidates drew hybrid cells with features of prokaryote and eukaryotes. Contradictions in answers cannot be rewarded and such answers did poorly. As with other questions, some candidates squandered the opportunity for marks by drawing small or untidy diagrams

b. This question was straight from the subject guide but many candidates were unable to identify the relevant factors. Those who could generally did well. Many good answers used annotated graphs to illustrate the changing effect of the factor on photosynthesis.

c. The impact of gases on the Earth's temperature was, in most cases, not well answered with many candidates confusing the greenhouse effect with the hole in the ozone layer.

---

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

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

c. Explain the flow of energy between trophic levels in ecosystems. [8]

Markscheme

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

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

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

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

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

to allow diffusion / to make food soluble;

so foods can be absorbed into the bloodstream/body;

so foods can move from bloodstream into cells;

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

hydrolysis is aided by enzymes;

hydrolysis requires water;

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

proteins/polypeptides (hydrolysed) to amino acids;

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

c. sunlight is the initial source of energy for (most) ecosystems;

sunlight (energy) is converted (through photosynthesis) into chemical/potential energy by producers/plants/autotrophs;

energy escapes from an ecosystem (as heat) / is not recycled;

flow of energy through an ecosystem can be represented as a pyramid of energy; (*allow a suitable diagram*)

energy flow in an ecosystem is measured as energy per unit area/volume, per unit time, for example kJ m^{-2} yr^{-1}/ kJ m^{-3} day^{-1} / other valid unit;

(chemical) energy is passed along the food chain/trophic levels;

primary consumer/herbivores obtain energy from plant food;

secondary/tertiary consumer/carnivores obtain energy by eating other (animals);

energy transfer between trophic levels is not 100 % efficient / is only about 10% efficient;

some energy is lost as heat through respiration;

decomposers obtain energy from waste products/dead bodies/leaf litter;

Examiners report

a. Well answered except for the absence of understanding about the prefixes: mono-, di-, and poly- when preceding the word saccharide.

b. Candidates who did well understood that hydrolysis falls within the context of digestion rather than thinking that hydrolysis is synonymous with digestion. Their answers began with the notion that only small molecules can diffuse and be absorbed into the bloodstream and that hydrolysis is a step in the digestive process. Often those candidates went on to describe that hydrolysis requires water and gave examples of how polysaccharides or proteins are hydrolyzed to named sub-units. Even among stronger responses, lipid hydrolysis was not mentioned very often nor was the idea that hydrolysis is aided by enzymes. This question was an interesting link between Topic 3.2 and Topic 6.1

c. The best answers started out with the sun as the ultimate source of energy and how light energy is converted to chemical energy through photosynthesis by autotrophs/plants. This led naturally to how energy passes from one tropic level to the next. By including that energy transfer is only about 10% efficient and that it is not recycled, candidates gained the max of 8 marks. Some candidates included pyramids of energy. Less commonly mentioned was the loss of energy through metabolic heat or that decomposers obtain energy from waste products, dead bodies/leaf litter. Only the rare candidate mentioned how energy flow is measured in energy per unit area/volume per unit time.

---

a. Describe the properties of water that make it a useful component of blood. [4]

b. Explain the relationship between structure and function of arteries, capillaries and veins. [8]

c. Outline how leucocytes defend the body against pathogens. [6]

Markscheme

a. a. water is a polar molecule / hydrogen bonding;

b. (makes it) (versatile) solvent;

c. example of dissolved substance (eg salts/proteins or other example);

d. (water is) fluid/liquid at body temperature;

e. example of transported material (eg nutrients/metabolic wastes/gases/hormones/blood cells or other example);

f. high heat capacity/specific heat allows water to carry heat without warming up;

g. (allows) blood to move heat (for warming/cooling/homeostasis);

b. *Arteries:* **[3 max]**

a. thick walls to withstand high pressure/maintain blood flow/pressure;

b. collagen fibres/elastic fibres/connective tissue (in outer layer) give wall strength/flexibility/ability to stretch and recoil;

c. (smooth) muscle layer (contracts) to maintain pressure;

d. narrow lumen maintains high pressure;

e. smooth endothelium for efficient transport/reduced friction;

Capillaries: **[3 max]**
f. wall has one layer of cells allowing (fast) diffusion of substances;
g. pores to allow lymphocytes/plasma to exit / to increase permeability;
h. extensive branching increases surface area for exchange of materials;
i. small diameter allows them to fit between cells/perfuse tissue;
j. narrow diameter increases oxygen diffusion from RBC;

Veins: **[3 max]**
k. thin walls allow (skeletal) muscles to exert pressure on veins;
l. thin outer layer of collagen/elastic/muscle fibres provide structural support;
m. wide lumen allows great volume of blood to pass;
n. valves prevent backflow;
NB *Every structure requires a function for the mark.*

c. a. leucocytes/phagocytes/macrophages can recognize pathogens/foreign matter;

b. (phagocytes) engulf pathogens by endocytosis/phagocytosis;

c. migration to tissues/squeezing out of capillaries;

d. each pathogen has specific antigens;

e. leukocytes/lymphocytes produce antibodies by reacting to specific antigen/ pathogens;

f. antibody joins to (specific) antigen inactivating/destroying them;

g. lymphocyte makes a clone/copies itself;

h. thus increasing the total number of (specific) antibodies;

Examiners report

a. This question troubled the rote learner who was unable to apply a general idea to a specific case. Candidates knew key properties of water but could not specifically relate them to blood. Most candidates correctly answered that the polarity of water molecules makes water a good solvent but forgot to give examples of dissolved substances in blood or materials that blood transports. High specific of water was cited but not how blood temperature can remain steady because of it.

b. Many candidates only wrote about the direction of blood flow through arteries, the heart veins. They completely missed out on the link between structure and function. Other candidates who did write about structural features of blood vessels failed to relate the features to function. Many confused the size of lumen with the degree of pressure in the vessels. Understanding of capillary structure and function appeared to be less than that of arteries or veins. Pores to increase permeability and allow lymphocytes to escape, extensive branching to increase surface area for exchange, and small diameters to allow capillaries to penetrate spaces between cells are examples of ideas often missed.

c. Many candidates knew that leucocytes can recognize pathogens and engulf them by phagocytosis/endocytosis. More knowledgeable candidates mentioned production of antibodies with specificity to antigens on pathogens. Further details about antigen inactivation and lymphocyte cloning to amplify antibody production were seen only in the very best answers.

---

a. State the source, substrate, products and optimal pH condition for lipase in the human digestive system. [4]

b. Outline the use of **named** enzymes in gene transfer using plasmids. [6]

c. Explain the effect of changes of pH, substrate concentration and temperature on enzyme activity. [8]

Markscheme

a. *eg source:* pancreas;

substrate: triglycerides / lipids / fats / oils;

product: glycerol and (three) fatty acids; (*both needed*)

optimal pH: 8; (accept answers in the range of 7 to 8)

Accept other correct examples.

b. a. plasmids are removed/obtained from bacteria;

b. endonuclease/restriction enzymes cut the plasmids at target sequences;

c. DNA fragments of other organism are cut with the same restriction enzymes;

d. in both DNA and plasmid, complementary sticky ends/staggered cut are produced;

e. DNA segment added to the opened plasmid;

f. spliced together by ligase;

g. reverse transcriptase makes DNA copies of mRNA / DNA polymerase to increase the amount of DNA;

h. recombinant plasmids inserted into new/host cells;

i. cultured/cloned to produce the new genes/more genetically modified cells;

Award [3 max] if no specific enzyme names are given.

Do not accept the word “enzyme” on its own.

c. *pH:*

a. enzymes have an optimal pH/work best at a given pH;

b. activity increases as pH gets closer to optimal pH;

c. extreme pH denatures enzymes;

d. by breaking bonds / changing enzyme shape/structure / active site shape/structure;

substrate:
e. as substrate concentration increases, activity increases;
f. as substrate concentration increases, the collisions between substrate and enzyme increase;
g. up to a maximal level of action / reaching a plateau;
h. all active sites are saturated/occupied;

temperature:
i. enzymes have an optimal temperature (where they work most effectively);
j. activity increases as it gets closer to optimal temperature;
k. high temperatures stop enzyme activity due to irreversible changes in structure / denaturation;
l. by breaking bonds / changing enzyme shape/structure / active site shape/structure;
Award any of the above points in an annotated graph.
*Award up to **[8]** if all three addressed and **[6 max]** if only two addressed.*

Examiners report

a. Clear answers were given by most of the students that had the knowledge.

b. Some students got confused with other biological techniques, making reference to PCR for example, apart from explaining correctly some steps in gene transfer. There was often no mention of reverse transcriptase.

c. Most of the students scored marks for this answer, some of them confused the graphs of temperature and pH with the one of substrate concentration, consequently their explanations were incorrect. A number of students incorrectly wrote that the enzyme denatures once it reaches its optimal temperature or pH, so marks were not awarded.

---

a. Draw a labelled diagram of the molecular structure of DNA including **at least four** nucleotides. [5]

b. A small DNA sample found at a crime scene can be used in an investigation. Describe the steps taken in the processing of this small sample of DNA. [6]

c. Discuss the relationship between **one** gene and **one** polypeptide. [7]

Markscheme

a. *The diagram must show four nucleotides shown with two on each side showing phosphate-sugar backbones and nitrogen base pairs bonded between them.*

*Award **[1]** for each of the following clearly drawn and correctly labelled.*
phosphate – shown connected to deoxyribose;
deoxyribose – shown connected to phosphate;
(nitrogenous) bases – shown bonded to deoxyribose;
base pairs – shown with labels adenine/A bonded to thymine/T and cytosine/C bonded to guanine/G;
hydrogen bonds – shown connecting bases;
covalent bonds – shown connecting deoxyribose to phosphates;
nucleotide – clearly identified by the candidate;
*Award **[4 max]** if diagram is not shown double stranded.*

b. DNA samples are taken from crime scene, suspects and victims;

polymerase chain reaction/PCR used to increase the amount of DNA;

restriction enzymes used to cut DNA;

electrophoresis involves electric field/placing sample between electrodes;

used to separate DNA fragments according to size;

creating DNA profiles/unique patterns of bands;

comparison is made between the patterns;

criminals/victims can be identified in this way;

DNA is (quite) stable / DNA can be processed long after the crime;

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

the DNA code for one polypeptide is a gene;

DNA is transcribed into mRNA;

mRNA moves to a ribosome;

where mRNA is translated into a polypeptide;

originally it was thought that one gene always codes for one polypeptide;

some genes do not code for a polypeptide;

some genes code for transfer RNA/tRNA/ribosomal RNA/rRNA;

some sections of DNA code for regulators that are not polypeptides;

antibody production does not follow this pattern (of simple transcription-translation); (*allow other examples*)

change in the gene/mutation will affect the primary structure of the polypeptide;

Examiners report

a. Most candidates correctly answered this question with diagrams that were well done and appropriately labelled.

b. Many candidates did this question well; most candidates did not mention that DNA samples are taken from the crime scene, the victims and the suspects however; they only mentioned suspects. Many of the candidates were not fully familiar with the actual technique involved in DNA profiling; this might be due to lack of exposure of students to the laboratory working with steps involved in DNA profiling.

c. This was one of the tough questions for most of the candidate since candidates thought "one gene one polypeptide" scope was only up until explaining the DNA-Gene-codon-polypeptide, most of the students did not mention the involvement of transcription and translation and exceptions to one gene one polypeptide hypothesis. In other cases, candidates went into great detail to explain transcription and translation (which was not asked for) and completely forgot about the purpose of the question.

---

a. All organisms take in and also release carbon compounds. Draw a labelled diagram of the carbon cycle. [5]

b. Describe how the rate of photosynthesis can be measured. [6]

c. Explain the mechanism of ventilation in humans. [7]

Markscheme

a. CO_2 in atmosphere/air;

plants/producers linked to carbon in air/CO_2 with arrow labeled photosynthesis;

plants/consumers linked to animals/consumers with arrow labeled feeding;

plants/producers and animals/consumers linked to carbon in air/CO_2 with arrow labeled (cell) respiration;

plants/producers and animals/consumers linked to decomposers/bacteria/fungi with arrow labeled death;

decomposers/bacteria/fungi linked to carbon in air/CO_2 with arrow labeled (cell) respiration;

plants/producers connected to carbon in air/CO_2 with arrow labeled combustion/forest fire;

decomposers/bacteria/fungi linked to fossil fuels/coal/oil/natural gas with arrow labeled (partial) decomposition;

fossil fuels/coal/oil/gas linked to carbon in air/CO_2 with arrow labeled

combustion;

Award marking points only if arrows point in correct direction.

b. correct equation for photosynthesis in words or symbols;

measure production of oxygen;

example of method to measure oxygen production;

(eg count bubbles from water plant/collect oxygen data per unit of time using electronic sensors/probes)

measure uptake of CO_2;

example of method; *(eg method of measuring (aquatic) pH changes/shift per unit time)*

measure increase in biomass;

example of method; *(eg sample (dry) mass of crop before and after timed period)*

not possible to measure water uptake since water is transpired/used in turgidity/many chemical processes;
another valid method if concept of rate (measurements per time) is included;

c. air enters/exits lungs through trachea, bronchi and bronchioles;

during inspiration/inhalation external intercostal muscles contract;

causing ribs to move upwards/outwards;

during inspiration diaphragm contracts/flattens;

causes increase in volume of thorax/lungs;

decrease in pressure allows air to enter (passively);

during expiration internal intercostal muscles contract/external intercostal muscles relax;

causing ribs to move down/in;

diaphragm relaxes/returns to original domed position;

abdominal muscles contract to push diaphragm up;

causes decrease in volume of thorax/lungs;

increase in pressure forces air out of lungs;

Award [5 max] for inhalation or exhalation only.

(Plus up to [2] for quality)

Examiners report

a. Many candidates spent considerable time drawing beautiful trees, rabbits, and factories but labels on the arrows that connected the various components of the carbon cycle. Some candidates never showed CO_2/carbon in the air.

b. Many candidates could name production of O_2, uptake of CO_2, and an increase in biomass as methods to measure the rate of photosynthesis. This meant an easy three marks. Gaining marks beyond that became very difficult. The primary reason was that when candidates gave details about the method, they failed to mention rate, as in a unit of time for the measurement e.g. bubbles of O_2 released per minute. The equation for photosynthesis was rarely given by any candidate.

c. The mechanism of ventilation in humans was generally explained well. Some accounts were flawed when specific intercostals muscles contracting or relaxing were not identified. More serious problems occurred when candidates mixed up ventilation with gas exchange at the level of alveoli or dwelled on cell respiration.

---

a. Outline the bonding between DNA nucleotides. [2]

b. Explain how chemical bonding between water molecules makes water a valuable coolant in living organisms. [2]

c. Describe the movement of water across membranes. [2]

d. Outline the role of water in photosynthesis. [2]

Markscheme

a. <u>hydrogen bonds</u> between nucleotides of opposite strands/complementary bases/adenine and thymine <u>and</u> cytosine and guanine;

covalent bonds between nucleotides within strands/between sugar/deoxyribose and phosphate;

b. hydrogen bonding between water molecules;

breaking (hydrogen bonds) needs/removes energy/heat;

hydrogen bonds must break when water evaporates/vaporizes;

c. osmosis / moves passively;

from regions of low solute/high water potential/concentration to high solute concentration / low water potential/concentration;

passes through protein channels/aquaporins/selectively-permeable membrane;

d. water molecules undergo photolysis/are split by light energy;

forms oxygen as a by-product;

hydrogen helps power the fixation of carbon (into organic molecules);

Examiners report

a. This question was well answered with the best responses clearly indicating the location of both hydrogen and covalent bonds. Almost all candidates discussed hydrogen bonding, but many did not discuss the use of covalent bonds.

b. Again, this was generally well answered with the best responses indicating that the breaking of hydrogen bonds occurs when water evaporates and removes a great deal of energy.

c. Many candidates answered this well, demonstrating a good knowledge of the movement of water across membrane.

d. Many candidates did not appear to be aware that water played a role in the reaction of photosynthesis. Better answers used the term photolysis and explained it appropriately.

---

a. Draw a labelled diagram to show how **two** nucleotides are joined together in a single strand of DNA. [3]

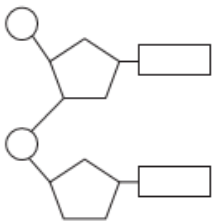
b. Outline a basic technique for gene transfer. [6]

c. Explain the process of translation. [9]

Markscheme

a.

e.g.




phosphate;


deoxyribose;


(nitrogenous) base / specific name *e.g.* adenine, thymine, guanine, cytosine;

covalent bond;

*Award **[1]** for each labelled item shown above.*
*Award **[2 max]** if the two nucleotides are not shown in a single strand.*

b. plasmid removed from bacteria;

plasmid cleaved/cut open by restriction enzymes;

desired gene/DNA extracted from donor;

DNA from donor cleaved using same restriction enzyme;

results in sticky ends;

with complementary base sequences;

pieces of DNA from two organisms mixed;

ligase used to splice pieces (DNA);

recombinant plasmids formed;

insertion into host cells;

c. translation is the synthesis of proteins/polypeptide chain/specific sequence of amino acids;

translation occurs in cytoplasm/ribosomes;

uses information on the mRNA;

mRNA carries the genetic information of DNA;

mRNA binds to ribosome;

mRNA contains series of codons/base triplets;

tRNA binds with an amino acid and carries it to the ribosome;

tRNA has the anticodon that is complementary to the codon on the mRNA;

two tRNAs bind to a ribosome/mRNA at the same time;

(peptide) bond forms between two amino acids (carried by tRNA molecules to the ribosome);

the first tRNA detaches, ribosome moves along mRNA and another tRNA carrying an amino acid binds;

process repeats forming chain of amino acids/polypeptides;

Examiners report

a. Many candidates gained full marks for their diagrams of joined DNA nucleotides. As mentioned earlier, the problem for some candidates was their misinterpretation of “a single strand of DNA.” Though appropriate shapes were given, the bonding was improper.

b. In their outlines of gene transfer, candidates (as a group) eventually included each of the ten marking points. A number of candidates thoroughly understood the topic, while others wrote about meiosis and crossing over! The nature of the topic allowed candidates to express their ideas in a logical sequence.

c. The process of translation has been examined frequently on past papers. Though the topic involves many different molecular structures and events, some candidates seemed to correctly grasp much of the detail and overall result. Some excellent answers appeared. However, as in previous years, there were candidates who confused translation with transcription (perhaps a reading error after glancing at the question?) and those who mixed accurate with inaccurate information.

---

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

b. Some proteins in membranes act as enzymes. Outline enzyme-substrate specificity. [6]

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

Markscheme

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

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

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

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

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

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

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

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

b. enzyme shape is specific to (particular) substrate;

lock and key analogy/model;

example of specific enzyme and substrate;

has specific 3-D/tertiary configuration/3-D/tertiary shape essential to functioning;

active site on enzyme binds to substrate;

substrate and active site complementary/fit together;

(substrate and active site) are complementary due to structure/chemical attraction;

enzyme-substrate complex forms;

denaturation changes enzyme's binding ability (to specific substrate);

Award [6] for the above points clearly shown in an annotated diagram.

c. synapse is gap between adjacent neurons;

(arriving) action potential depolarizes pre-synaptic membrane;

opens (voltage-gated) calcium channels in membrane;

causes influx of calcium ions;

causes synaptic vesicles to fuse with pre-synaptic membrane;

vesicles release/exocytose neurotransmitter into the synaptic cleft;

neurotransmitter diffuses/moves across synaptic cleft;

neurotransmitter binds to receptors on post-synaptic membrane;

opens channels allowing sodium ions/potassium ions to diffuse;

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

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

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

(Plus up to [2] for quality)

Examiners report

a. There were many clear diagrams showing the molecular structure of a membrane. A labelled phospholipid bilayer always seemed to be shown. 'Intrinsic and extrinsic proteins' are terms still used by candidates. The marking criteria for glycoprotein and cholesterol discriminated against some who included them. Cholesterol molecules were sometimes incorrectly placed next to the phosphate heads rather than being embedded in the bilayer and appearing smaller than the hydrophobic tails. Overall, however, candidates earned maximum credit for this question.

b. The topic of enzymes has been visited many times on exams and is usually studied in depth. Though the question was narrowed to an outline of enzyme-substrate specificity, many candidates were able to get three of the six available marks. Specificity of enzyme shape to substrate, the lock and key model and the binding of enzyme active site to substrate were the marking points frequently awarded. Sometimes irrelevant information was given, as when enzyme activity under different environmental conditions was described.

c. Unfortunately, candidates who showed thorough understanding of the principles of synaptic transmission were few and far between. Insufficient accurate detailed information was a common problem, along with an incorrect sequence of events. Other answers were laden with generalities, vagueness, or confusion. Many candidates scored poorly on this question.

---

a. Define *active site*. [1]

b. Explain enzyme-substrate specificity. [3]

Markscheme

a. site on surface/portion of the enzyme/protein to which the substrate binds

b. enzymes fit together with substrates similar to a lock and key;

active site has shape that gives specificity;

enzymes catalyze a reaction with a specific substrate;

example of named enzyme and its substrate;

substrate held precisely in (optimum) position to make/break bonds/carry out reaction / chemical interaction occurs between enzyme and substrate;

Accept these points shown in an annotated drawing.

Examiners report

a. A few candidates mixed up the location by stating that the active site was on the substrate.

b. Many answers simply mentioned a compatible fit such as a “lock and key.” More marks could have been gained by also mentioning specificity of shape or any reference to the result of the specificity in terms of catalysis or breaking of bonds to form products. Few candidates gave an example of an enzyme and its substrate.

Plants have widespread influences, from food chains to climate change.

a. Draw a diagram of a palisade mesophyll cell labelling only the structures that would not be present in a pancreatic cell. [3]

b. Explain the process of photosynthesis. [8]

c. Describe the process of peat formation. [4]

Markscheme

a. a. cell wall

Must be shown as a double line

b. large vacuole

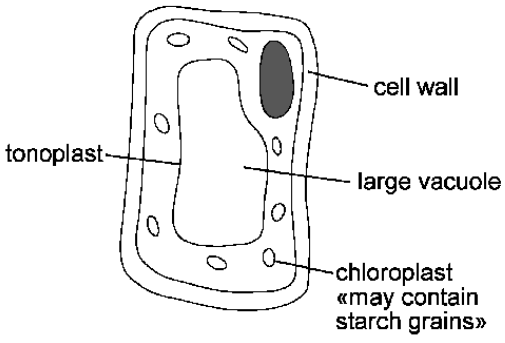
Labelled either inside or on the membrane

c. chloroplast/plastid

d. starch grain

e. tonoplast

*Allow **[2 max]** if any features common to both plant cells and animal cells are labelled*



[Max 3 Marks]

b. a. autotrophs perform photosynthesis

b. carbon dioxide and water are the reactants/raw materials required for «photosynthesis»

c. light splits water molecules/causes photolysis

d. «photolysis» releases oxygen as a «waste» product

e. light energy is converted into chemical energy

f. «photosynthesis» produces organic compounds/glucose/carbohydrates

g. photosynthesis occurs in chloroplasts

h. chlorophyll «photosynthetic pigment» absorbs light

i. different pigments absorb different wavelengths «of light»

j. chlorophyll absorbs red and blue light/ends of the spectrum

k. carbon dioxide concentration/temperature/light intensity are limiting factors

*Award only **[1]** for correct display of equation unless further annotated or explained*

*Allow up to **[2]** for correct use of understandings specified as AHL topic 8*

[Max 8 Marks]

c. a. formed from dead plant material/leaves/mosses/Sphagnum

b. formed in waterlogged sites/bogs/mires/swamps

c. where bacteria/fungi/saprotrophs are not active/are inhibited

d. organic matter not fully decomposed

e. «occurs» in acidic conditions

f. «occurs» in anaerobic conditions

Reject anaerobic respiration

g. «very» slow process/takes a long time

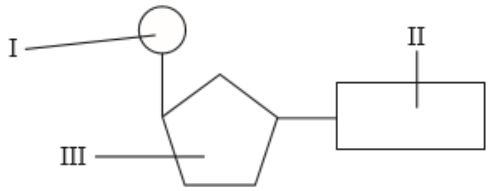
[Max 4 Marks]

Examiners report

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

---

a. The diagram below represents a DNA nucleotide. [1]



Identify the phosphate group and deoxyribose.

Phosphate group: .....
Deoxyribose: .....

b. Draw a labelled diagram to show how four nucleotides are joined together to form a double-stranded DNA molecule with two base pairs. [3]

c. State **two** differences between RNA and DNA nucleotides. [2]

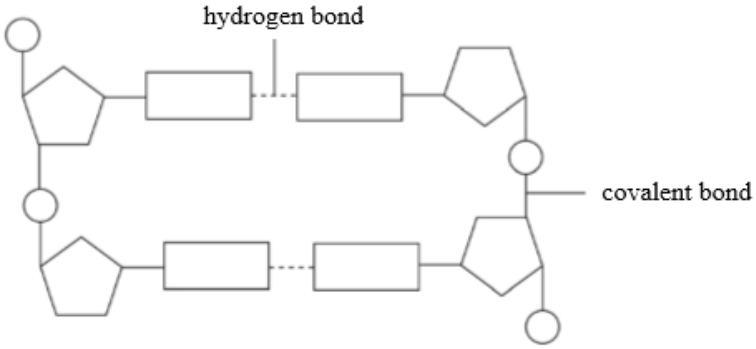
Markscheme

a. *Phosphate*: I

Deoxyribose: III

Both correct for one mark.

b.



two sugar-phosphate strands shown connected through bases;
a sugar-phosphate bond labeled as a covalent bond;
hydrogen bonds labeled on line between bases;
boxes labeled as (nitrogenous) bases;
complementary base pairing/A–T/G–C;
(5'–3') linkages correctly shown; (*no label required*)

c. RNA nucleotides contain ribose and DNA nucleotides contain deoxyribose;

(some) RNA nucleotides contain uracil and (some) DNA nucleotides contain thymine;

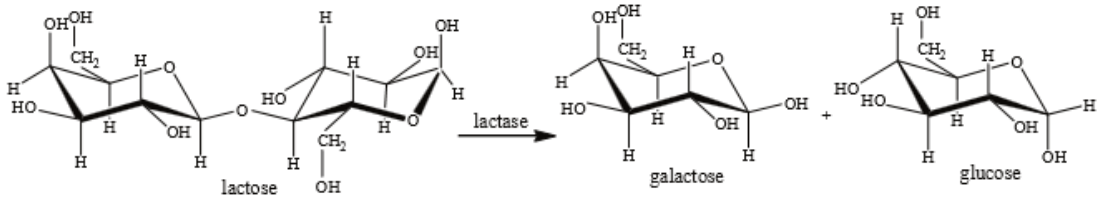
Examiners report

a. Most candidates had no problem identifying the phosphate group and deoxyribose in a diagram of a DNA nucleotide.

b. Although many drawings were dreadful in appearance, at least three marking points could be found to earn maximum credit. Surprisingly, the nucleotide diagram that appeared in the previous question was not used by many candidates as the first nucleotide in their DNA drawings which eventually had to show four nucleotides arranged in a double strand connected through two bases.

c. Astute candidates who spotted the word “nucleotide” in the question earned an easy two marks by stating that RNA nucleotides contain ribose and uracil whereas DNA contains deoxyribose and thymine. Those candidates who thought in terms of a helix talked about single and double strand molecules without earning any mark. In this question, names were expected rather than letters to identify the nitrogenous bases.

The equation below shows the production of glucose and galactose from lactose.



a. Glucose and galactose are examples of monosaccharides. State **one** other example of a monosaccharide. [1]

b (i) There are several different types of carbohydrate. State which type of carbohydrate lactose is. [1]

b (ii) State the type of chemical reaction that occurs when lactose is digested into glucose and galactose. [1]

d. Simple laboratory experiments show that when the enzyme lactase is mixed with lactose, the initial rate of reaction is highest at 48°C. In food processing, lactase is used at a much lower temperature, often at 5°C. Suggest reasons for using lactase at relatively low temperatures. [2]

Markscheme

a. fructose/ribose/deoxyribose/ribulose/other monosaccharides apart from glucose and galactose

b (i) disaccharide

b (ii) hydrolysis

d. less denaturation / enzymes last longer at lower temperatures;

lower energy costs / less energy to achieve 5° C compared to 48° C;

reduces bacterial growth / reduces (milk) spoilage;

to form products more slowly / to control rate of reaction;

Examiners report

a. Candidates were often correct, but some stated a disaccharide instead of a monosaccharide. Common errors were sucrose or maltose.

b (i) Most candidates correctly identified lactose as a disaccharide.

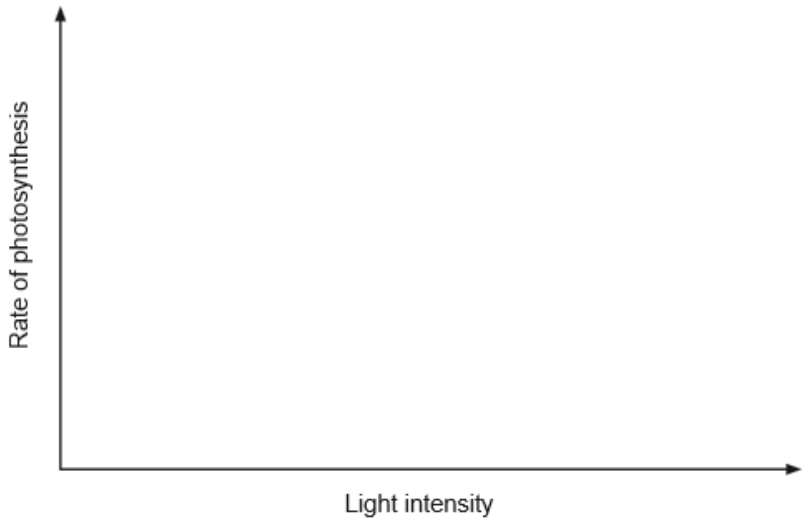
b (ii) Hydrolysis was often given, yet some erred by stating decomposition.

d. Generally answered well with most candidates referring to denaturation and/or controlling the rate of reaction.

---

a. Distinguish between absorption of red, green and blue light by chlorophyll. [2]

b (i) Draw a graph to show the effect of increasing light intensity on the rate of photosynthesis. [1]



b (ii). Explain one way of directly measuring the rate of photosynthesis. [2]

Markscheme

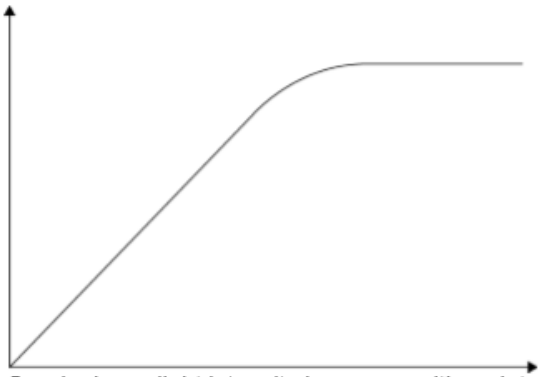
a. a. absorbs at blue and red (in high amount);

b. greatest absorption is of blue light / more blue light than red light absorbed;

c. low absorption of green light / green light is reflected;

Allow above points in an annotated diagram.

b (i).



Graph shows light intensity increases with a plateau shown as a flat line parallel to the x-axis. Do not accept sigmoid curves.

b (ii). *either:*

a. production of oxygen (which is a by-product of photosynthesis);

b. outline of method to collect gas/monitor gas production per unit of time/over time (*eg* count bubbles/collect in syringe/oxygen sensors over a time period);

or:

c.uptake of carbon dioxide (as carbon dioxide used as raw material for photosynthesis);

d. outline of method to detect uptake of carbon dioxide over time (*eg* change/rise in pH of water surrounding a water plant using pH meter or paper/CO_2 sensor over time);

Examiners report

a. Most candidates earned two marks for this two mark question. Most stated that blue and red are absorbed (one mark), but that green is reflected (another mark). Thus, they distinguished green from the other two colors. Very few candidates distinguished red from blue, which was listed as a third marking point.

b (i). A whole variety of poor drawings was seen from straight lines starting from 0,0 and going up at a 45° angle to sigmoid curves to bell-shaped curves. Many drawings lacked straight sections for the increase or plateau portions.

b (ii). Few candidates earned both marks here. The most common answers suggested measuring oxygen production or carbon dioxide uptake. Some added a method for doing so; others gave the rationale for doing so. Only a handful suggested taking the measurements for a set amount of time, or taking a reading before and after a time interval. Hence, rate could not be calculated and the second marking point was not earned. As a teaching point, it could be observed that many of the experiments in our practical programmes involving rates, do not insist on rate calculations because a divisor of one (time unit) has been set in the procedure. That kind of shortcut hurt candidates in this examination.

---

a. Draw a labelled diagram to show the fluid mosaic structure of a plasma membrane, indicating the hydrophilic and hydrophobic regions. [5]

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

c. Explain how the properties of water are significant to living organisms. [9]

Markscheme

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

phospholipid bilayer – with head and tails;

hydrophilic/phosphate/polar heads and hydrophobic/hydrocarbon/fatty acid/ non-polar tails labelled;

integral protein – embedded in hydrophobic region of the phospholipid bilayer;

protein channel – integral protein showing clear channel/pore;

peripheral protein – on the surface;

glycoprotein with carbohydrate attached on outside;

cholesterol – shown embedded in bilayer; thickness indicated (10 nm); *(allow 7 nm to 13 nm)*

b.

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

Both the passive and active movements must be contrasted to receive a mark.

*Award **[3 max]** if no examples are given.*

Responses do not need to be shown in a table format.

c. water is transparent / light passes through water;

this allows organisms to live below the surface / plants to photosynthesize;

hydrogen bonds between water molecules make water cohesive;

this gives water a high surface tension allowing animals to live on the surface / maintains lung structure (pleural membranes);

helps in water movement through plants/transpiration;

water has a high latent heat of vaporization / *OWTTE*;

evaporation/sweating/transpiration leads to cooling;

water has a high specific heat capacity / *OWTTE*;

this provides a stable environment for water organisms;

water is a universal solvent; can transport materials around organisms/plants/animals;

can be a solvent for chemical reactions in organisms;

ice is less dense than water / water has a maximum density at 4°C surface (pond/lake/ocean) freezes first, allowing organisms to survive in the water below;

Accept hydrogen bonds between water and other substance makes water adhesive from AHL.

Examiners report

a. Many drawings were of reasonably good quality and gained at least three marks. Glycoprotein was a challenging structure for candidates to draw. Often the glycoprotein did not show anything resembling a carbohydrate chain attached to the protein. Also, the phospholipid bilayer was somewhat problematic. Sometimes, peripheral proteins were drawn in the hydrophobic region and, quite often, cholesterol molecules which should have appeared in the hydrophobic region were not totally embedded there. It was good to see that candidates almost always showed two-tailed phospholipid molecules. It was a rare candidate who indicated any reference to membrane thickness.

b. A few candidates did well on this question, but it was disappointing to see the lack of comparison skills among most candidates. Interpretation of the command terms distinguish and compare needs clarification for students, so that clear answers with opposing criteria are given and expected. Virtually all candidates wrote separate paragraphs about active and passive movement with indirect or incomplete pairings of ideas.

c. Candidates showed a wide range of understanding of how the properties of water are significant to living organisms. Every marking point was eventually awarded by the examiners. There was limited use of the terms latent heat of vaporization and specific heat, though candidates could receive the mark using other wording. Those who did use the terms only gained credit if the terms were qualified such as “high specific heat”. Just saying that water has specific heat was insufficient. Unfortunately, mistakes such as “water is soluble” were seen too often. Sometimes, a named property of water was linked to a wrong significance.

---

a. State the functions of the following organelles of a eukaryotic animal cell: lysosome, Golgi apparatus, free ribosomes, plasma membrane, rough endoplasmic reticulum. [5]

b. Distinguish between anaerobic and aerobic cell respiration in eukaryotes. [4]

c. Explain the mechanism of ventilation in the lungs in order to promote gas exchange for cell respiration. [9]

Markscheme

a. *lysosome:*

a. (from Golgi apparatus) with digestive enzymes / break down food/organelles/ cell;

Golgi apparatus:
b. site that processes/modifies/packages and releases proteins;

free ribosomes:
c. site of synthesis of proteins (released to cytoplasm);

plasma membrane:
d. controls entry and exit of materials/substances in cell;

rough endoplasmic reticulum:
e. synthesis and transport of proteins; (*both needed*)

b.

	aerobic	anaerobic
a.	requires oxygen	no oxygen;
b.	(in cytoplasm and) mitochondria	in cytoplasm;
c.	Krebs cycle	no Krebs cycle;
d.	large yield of ATP/energy	small yield of ATP;
e.	CO_2 and water *(both needed)*	lactate (animals);
f.		ethanol + CO_2 (yeast/plants); *(both needed)*

*Award **[1]** for each contrasting characteristic.*

Table format is not necessary for the marks.

c. a. inspiration/inhalation brings air into lungs;

b. external intercostal muscles contract;

c. and move rib cage upwards and outwards;

d. diaphragm flattens/contracts;

e. increasing thoracic volume;

f. pressure decreases from atmospheric pressure so air rushes into lungs;

g. expiration/exhalation forces air out;

h. internal intercostal muscles contract / external intercostal muscles and diaphragm relax;

i. abdominal/abdomen wall muscles contract and push diaphragm upwards;

j. decreasing thoracic volume;

k. increasing pressure in lungs so air is forced out;

l. a concentration gradient between air sacs and blood needs to be maintained;

Examiners report

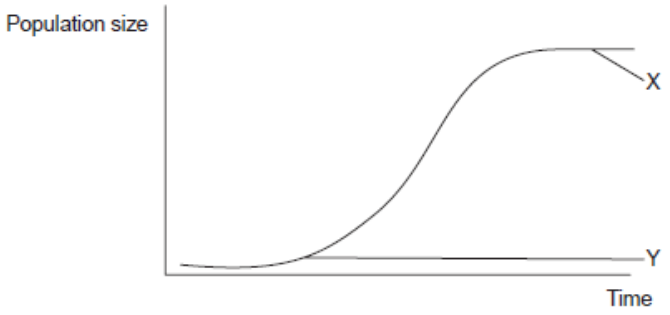
a. Question 6 was the most popular to answer.

The major confusions were found when explaining the functions of the Golgi Apparatus and the rough endoplasmic reticulum. Some candidates did not make any reference to proteins when explaining the function of the Golgi, for which they did not receive the mark.

b. Marks were not awarded generally for incomplete answers. E.g. Not mentioning one of the end products of anaerobic respiration, either CO_2 or ethanol or in products of aerobic respiration, water was often omitted. The comparisons were sometimes difficult to spot, given that they did not use a chart or did not follow a proper order. Finally some candidates simply failed to compare, explaining only one type of cell respiration.

c. There were quite a few students who gave very good descriptions of gas exchange and even respiration in some cases, and the properties of the alveoli that made them well adapted for gas exchange. Unfortunately the question was "Explain the mechanism of ventilation in the lungs in order to promote gas exchange for cell respiration". Many candidates did not read the question correctly. Some candidates even gave more detail of aerobic respiration here than they did in part b. Among the most common errors found were to say that "...inspiration brings oxygen into the lungs" and that "...expiration releases CO_2". In some of the answers there was no differentiation between external and internal intercostal muscles. Some candidates referred to changes in the lung volume, instead of thoracic volume.

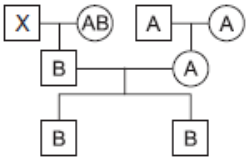
The graph shows a sigmoid population growth curve.



The table summarizes the genome size of several organisms.

Organism type	Organism	Genome size / base pairs
Bacterium	*Helicobacter pylori*	1667867
Fruit fly	*Drosophila melanogaster*	130000000
Rice	*Oryza sativa*	420000000
Human	*Homo sapiens*	3200000000

The figure shows a pedigree chart for the blood groups of three generations.



a. Identify the phases labelled X and Y. [1]

X:

Y:

b. Outline how fossil records can provide evidence for evolution. [2]

c(i). Distinguish between the terms genotype and phenotype. [1]

c(ii). Outline a structural difference between the chromosomes of *Helicobacter pylori* and *Homo sapiens*. [1]

c(iii). Deduce the percentage of adenine in *Oryza sativa* if the proportion of guanine in that organism is 30 %. [1]

d(i). Deduce the possible phenotypes of individual X. [1]

d(ii). Describe ABO blood groups as an example of codominance. [1]

Markscheme

a. X: plateau phase

Y: exponential growth / log phase

(both needed)

b. a. the sequence in which fossils appear matches the expected sequence of evolution;

b. comparisons with fossils and living organisms (morphology) shows change in characteristics from an ancestral form / *OWTTE*;

Vestigial organs and homologous structures are acceptable answers.

c. fossils of extinct species show that (evolutionary) change has occurred;

d. fossils can be dated with radioisotopes / geological depth/strata indicates (relative) age/date of organism;

e. can yield DNA for molecular clock analysis;

f. example of any of the above can earn one mark (*eg*: reptiles follow amphibians);

c(i). genotype is the genetic make-up/set of alleles (of an organism) while phenotype is the characteristics (expressed/shown in an organism)

c(ii). chromosome from bacteria has no protein associated/naked DNA / bacteria is circular, H. sapiens is linear / (chromosomes of) H. sapiens are much bigger/have many more base pairs than bacteria

N.B.: Answer must refer to "chromosomes" not genomes of the two organisms.

c(iii). 20 %

d(i). A, B, AB and O

All four phenotypes must be shown to award the mark.

d(ii). allele I^A and the allele I^B are (co)dominant as they are both expressed in the heterozygote/AB type blood / *OWTTE*

Examiners report

a. Well prepared candidates could state ‘plateau phase and exponential growth or log phase’. A surprising number reversed the answers, probably due to carelessness.

b. There were many convoluted answers without substance. Most gained the marks by stating that fossils can be compared with living organisms with an example.

c(i). Most managed to give a reasonable explanation of genotype and phenotype.

c(ii). Many missed the word 'chromosomes' in the stem. The knowledge of naked v proteins or circular v linear was expected from the core. Using the data it was expected that the candidates could state that the human chromosomes were <u>much</u> bigger (divide by 46) or that there were many more base pairs as there was about 3 X 10^3 difference.

c(iii). Considering that everyone on the IB diploma course studies maths at some level, a surprising number left (iii) blank or gave answers that did not make sense.

d(i). A pleasing number were able to state that all 4 blood groups were possible in (i), and most had a reasonable attempt at explaining codominance in part (ii).

d(ii). A pleasing number were able to state that all 4 blood groups were possible in (i), and most had a reasonable attempt at explaining codominance in part (ii).

---

a. Draw a labelled diagram showing the **interconnections** between the liver, gall bladder, pancreas and small intestine. [2]

b. Outline the role of glucagon in homeostasis of glucose. [2]

c. List **two** examples of polysaccharides. [1]

Markscheme

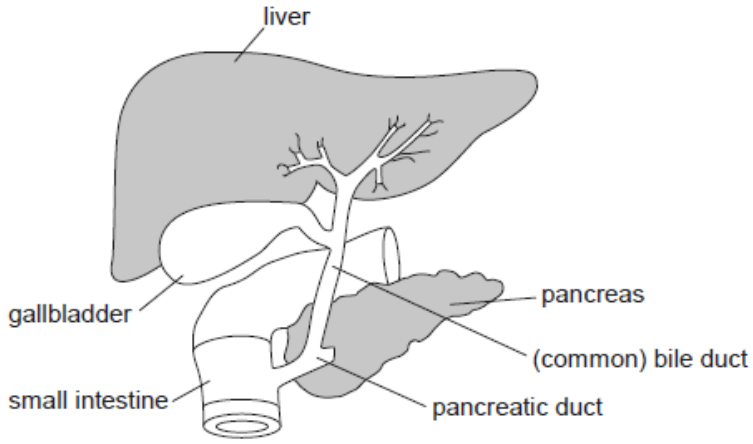
a. a. pancreas linked to small intestine by (pancreatic) duct (pancreas and small intestine both must be labelled);

b. gall bladder shown associated with liver and linked to small intestine by (bile) duct, (gall bladder and small intestine must be labelled);

c. showing (bile and pancreatic) ducts joined together before discharging in small intestine;

Ducts are to be drawn as double line structures.

eg:



b. a. (glucagon) released in response to low blood glucose levels;

b. (glucagon) increases blood glucose levels;

c. glucagon leads to conversion of polysaccharides/glycogen (in the liver) to glucose;

Do not accept implication that glucagon directly converts glycogen to glucose.

c. starch / glycogen / cellulose

*Award **[1]** for any two polysaccharides.*

Examiners report

a. "Well I will just draw a diagram of the gastro intestinal tract and hope for the best", seemed to be the idea of many, resulting in no marks. The connection from the pancreas and the gall bladder to the small intestine had to be shown clearly as ducts, not random lines. The indecision manifested itself in the fact that many candidates drew very feint diagrams, resulting in scanning problems. Point 6.1.4 from the guide states that the interconnections should be clearly shown.

b. Most well prepared candidates could outline the role of glucagon.

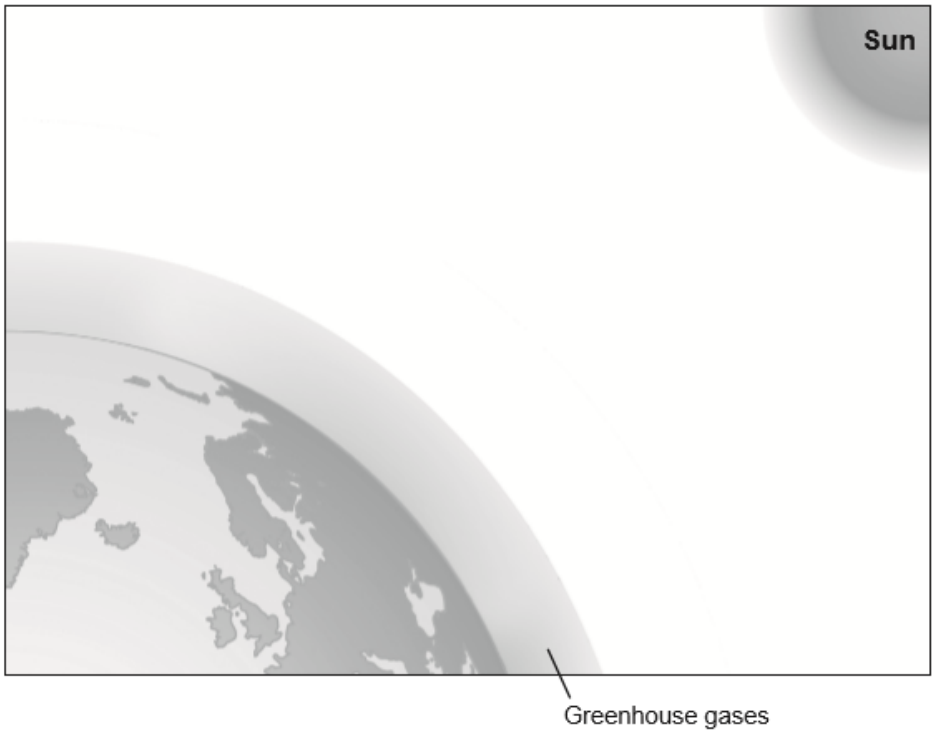
c. A disturbing number could not name two polysaccharides.

---

a. (i) Distinguish between the thermal properties of water and methane. [4]

(ii) Explain the reasons for the unique thermal properties of water.

b. Using the diagram, explain the interaction of short and long wave radiation with greenhouse gases in the atmosphere. [3]



[Source: © International Baccalaureate Organization 2016]

Markscheme

a. (i)

Boiling point of water is greater than methane

Melting point of water is greater than methane

Latent heat of vaporization of water is greater than methane
OR
specific heat capacity of water is greater than methane

(ii)

Water is polar
OR
O atom more negative
OR
H atoms more positive

This causes «strong» hydrogen bonds to form between the molecules

Which require more/high amount of energy to break

Which increases the melting/boiling/latent heat properties

b. Short wave radiation/UV «shown as» having its origin in the Sun gives off light as short radiation

Short wave radiation/UV «shown as» passing through the greenhouse gases «some reflected»

Some short wave radiation/UV is absorbed by the Earth and some is reflected

The reflected radiation is long wave radiation «reflected as heat»

Long wave radiation/IR «shown as» being unable to pass through/being absorbed/reflected by the greenhouse gases

Award marks for diagrammatic explanations of these marking points.
Accept UV and IR as long as they are drawn with the correct wavelength.

Examiners report

a. (i) The expression ‘thermal properties’ seemed to confuse weaker candidates, who looked ahead to part b and tried to compare them as greenhouse gases. Perhaps the use of ‘physical properties’ might have been better. Many were able to state, for example, that water has a high boiling point, but did not get the mark as they did not continue to say that it was much higher than methane.

(ii) Most remembered about hydrogen bonds, but lost the mark for forgetting to state that they are between molecules.

b. The writer of this question presumed that the more visual learners would use the diagram to produce an annotated response. In fact, very few used the diagram at all. The difference between long and short wavelengths was very confused, and weaker candidates were obsessed with explaining the composition of the greenhouse gases, and the role of the ozone layer (usually incorrectly). As a major problem affecting the planet, there seemed to be a lot of confusion.

---

a. Outline the stages of the cell cycle. [5]

b. Explain the process of translation in cells. [8]

c. Outline the production of a dipeptide by a condensation reaction, showing the structure of a generalized dipeptide. [5]

Markscheme

a. a. interphase is the longest phase;

b. interphase includes G_1, S and G_2;

c. in G_1 and G_2 /G phases, cell performs normal functions/protein synthesis/cell grows/organelles are replicated;

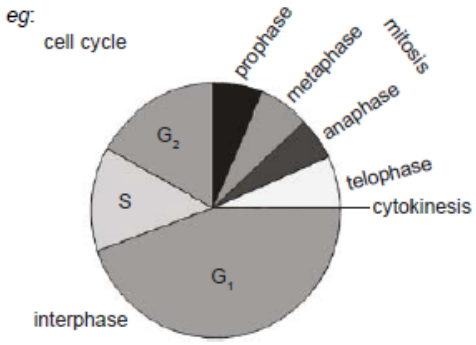
d. S/synthesis phase when the DNA replicates;

e. mitosis is when nucleus/genetic material divides;

f. named/described stages of mitosis;

g. cytokinesis: the division of the cytoplasm / formation of two daughter cells;

*Award **[3 max]** if all three stages (interphase, mitosis and cytokinesis) are not mentioned.*



b. a. translation is the conversion of base sequence on mRNA into an amino acid sequence / *OWTTE*;

b. messenger/mRNA attaches to ribosome (small unit);

c. many ribosome/polyribosomes bind to same mRNA;

d. (mRNA) carries codons/triplet of bases each coding for one amino acid;

e. transfer/tRNA each have specific anticodon;

f. tRNA carries specific amino acid;

g. tRNA anticodon binds to codon in the mRNA;

h. to corresponding triplet base/codon by complementary base pairing / *OWTTE*;

i. a second tRNA (anticodon) binds to next codon;

j. two amino acids bind together / peptide linkage is formed;

k. first tRNA detaches;

l. ribosome moves along mRNA;

m. another tRNA binds to next codon;

n. continues until stop codon is reached;

o. stop codon has no corresponding tRNA (anticodon)/amino acid/causes release of polypeptide;

c. a. condensation is joining together two amino acids to form a dipeptide;

b. carboxyl/COOH group of one amino acid reacts with amine/NH_2 group of another / diagrams of two (generalized) amino acids correctly shown;

c. water/H_2O is eliminated;

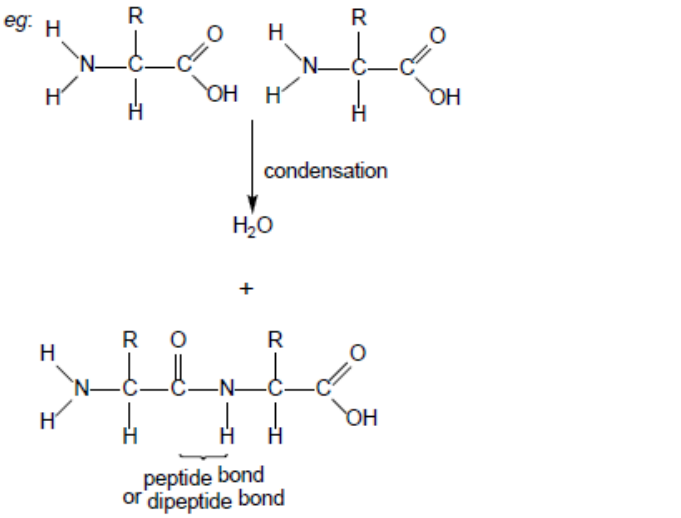
d. diagram of dipeptide correctly shown;

e. peptide/covalent bond is produced / peptide bond correctly labelled;

f. occurs at the ribosomes;

The above marking points can be award to a clearly annotated diagram.

eg:



Examiners report

a. Few managed to state that mitosis is the division of the nucleus/ genetic material and also lumped in cytokinesis as a part of mitosis.

b. Better candidates were able to explain the process of translation in very clear detail. It was good to see that very few candidates confused transcription and translation.

c. Most gained the mark for stating that water is eliminated in a condensation reaction. Unfortunately they could not explain the process in sufficient detail to gain any more marks. Even although the stem was about dipeptides, weaker candidates wrote about carbohydrates. There were some G2 comments that asking SL candidates to draw a dipeptide was beyond expectations. It is indeed on the limit of what could be expected from 3.2.2 and 3.2.5. However the candidates did have a choice of Section B questions.

---

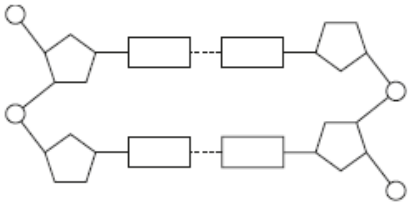
a. Draw a labelled diagram of a section of DNA showing four nucleotides. [5]

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

c. Explain how evolution may happen in response to an environmental change. [8]

Markscheme

a. Award [1] for each labelled item shown correctly connected.



a. phosphate;

b. deoxyribose;

c. (nitrogenous) base / specific name *eg*: adenine/thymine/guanine/ cytosine shown connected to carbon-1;

d. covalent bond / phosphodiester bond;

e. hydrogen bond;

f. nucleotide shown to include phosphate, sugar and base by (shape or label);

g. diagram shows complementary base pairing or A bonded to T, C with G.

*Award **[3 max]** if the nucleotides are shown in a single strand.*
*Award **[4 max]** if antiparallel structure is not shown.*

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

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

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

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

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

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

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

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

c. a. (genetic) variation in population;

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

c. valid example of variation in a specific population;

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

e. competition / struggle for resources/survival;

f. example of competition/struggle for resources;

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

h. example of changed environment and adaptation to it;

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

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

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

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

m. evolution by natural selection;

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

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

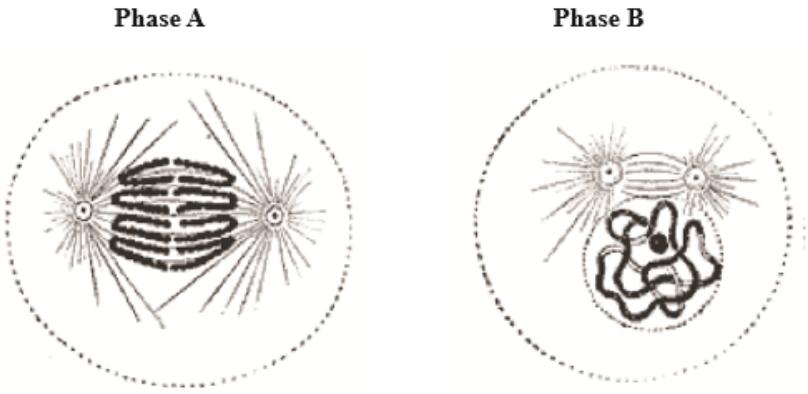
Examiners report

a. Most gained some marks for the diagram. As it was DNA the nucleotides should be in two strands joined by H bonds. Many drew only one strand.

b. Marks were lost through lack of precision. The names of the enzymes were expected. Few stated that the same restriction enzyme was required for the plasmid and gene.

c. This was answered well by the better candidates. There were also disappointing numbers of Lamarkian answers from weaker candidates trying to explain the adaptation of individuals. Many answers were very general and would have benefitted from concrete examples.

The electron micrographs show mitosis in a cell at an early stage and an intermediate stage.



[Source: Phase A from: http://upload.wikimedia.org/wikipedia/commons/f/f5/Anaphase.jpg
Phase B from: http://upload.wikimedia.org/wikipedia/commons/d/db/Prophase.jpg]

a (i) State the name of each phase shown, recording whether each phase has taken place at an early or intermediate stage of mitosis. [2]

Phase A: . . . . . .occurs at an. . . . . stage
Phase B: . . . . . .occurs at an. . . . . stage

a (ii) Outline the events occurring in phase A. [2]

b. State what results when there is an uncontrolled division of cells in living organisms. [1]

c. DNA in chromosomes undergoes replication before mitosis. Outline how complementary base pairing is important in this process. [2]

Markscheme

a (i) *phase A*: anaphase (*occurs at an*) intermediate (*stage*); (*both needed*)

phase B: prophase (*occurs at an*) early (*stage*); (*both needed*)

a (ii) centromeres split/break;

(sister) chromatids/chromosomes separate;

dragged/pulled/movement to separate poles;

by shortening of spindle microtubules;

Do not allow events other than those in anaphase

b. tumours / cancer

c. conservation of the base sequence of DNA;

adenine pairs with thymine and cytosine pairs with guanine; (*do not accept initials only*)

both (daughter) cells/DNA strands produced have identical genetic information;

Examiners report

a (i) Many correctly identified Phase A in 3(a)(i) but often missed Phase B.

a (ii) Part 3(a)(ii) was usually well answered. Unfortunately, some candidates referred to homologous chromosomes when they meant sister chromatids; homologous chromosomes separate in Anaphase I of meiosis. Few mentioned centromeres splitting.

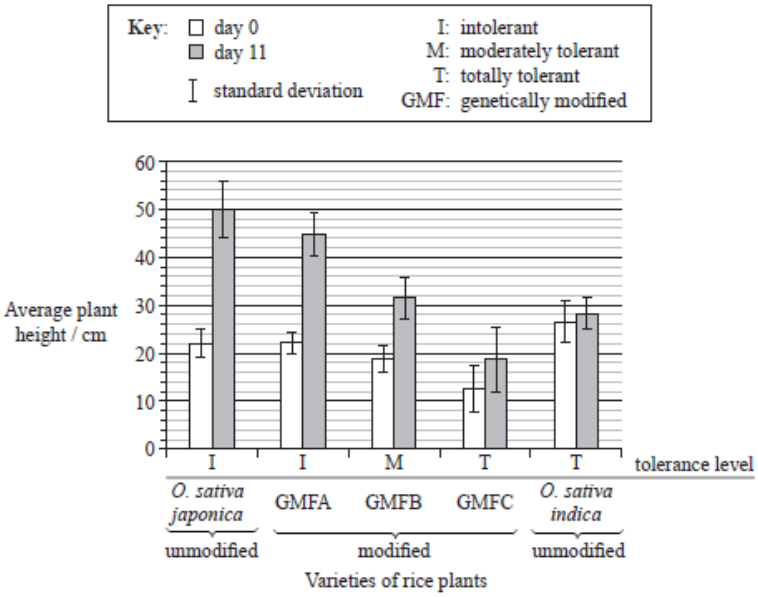
b. Part 3(b) was very successfully answered. No credit was given for “mutation.”

c. Some candidates just wrote that “an exact copy of DNA is made” in 3(c) which is ambiguous and gained no credit; it was not clear that they knew that replication is a semi-conservative process where each of the new DNA molecules has a parent strand (conserved) and a new strand made by complementary base pairing. Also, full names, rather than just letters were required for the nitrogenous bases and both pairs were required.

Rice (*Oryza sativa*) is usually intolerant to sustained submergence under water, although it grows rapidly in height for a few days before dying. This is true for one variety, *Oryza sativa japonica*. The variety *Oryza sativa indica* is much more tolerant to submergence.

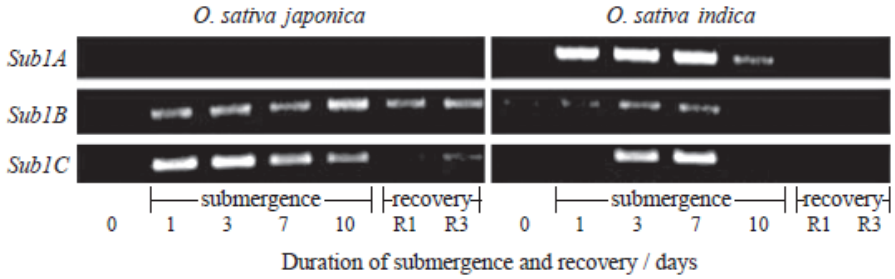
Three genetically modified forms of *O. sativa japonica*, GMFA, GMFB and GMFC, were made using different fragments of DNA taken from *O. sativa indica*.

The plants were then submerged for a period of 11 days. The heights of all the plants were measured at the beginning and at the end of the submergence period.



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

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



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

a(i). State which group of rice plants were the shortest at the beginning of the experiment. [1]

a(ii). Calculate the percentage change in height for the *O. sativa japonica* unmodified variety during the submergence period. Show your working. [2]

c. Deduce the general relationship between the growth of all the *japonica* varieties and their stated tolerance level. [1]

d. Outline the use of the binomial system of nomenclature in *Oryza sativa*. [2]

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

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

e(iii) Compare the mRNA production for the three genes during the submergence period between the two varieties. [2]

f. Deduce, using all the data, which gene was used to modify GMFC. [2]

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

Markscheme

a(i). (GMF) C

a(ii). $\frac{(50-22)}{22} \times 100$;
$= 127\%$; *(units required) (allow answers in the range of 127 to 127.3)*

c. inversely proportional / the higher the tolerance, the less the growth / *vice-versa*

d. a. first name/*Oryza* for genus / second name/*sativa* for species;

b. (all) members of *Oryza satica* share special/unique features;

c. two names make a unique combination to designate species / worldwide recognizable nomenclature;

d. varieties (*japonica* and *indica*) have some (consistent) differences (in tolerance);

e(i). *Sub1C*

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

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

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

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

e(iii) a. *Sub1A* only expressed/produces mRNA in *indica* / not/never expressed/ never produces mRNA in *japonica*;

b. *Sub1C* expressed/produces mRNA from day 1 in *japonica*, but not *indica*;

c. *Sub1B* has lower expression/production of mRNA than *Sub1C* in both varieties;

*Award **[1 max]** for other accurate comparisons between japonica and indica*.

f. a. *Sub1A*;

b. is only expressed in *indica*;

c. *indica* is the variety showing submersion tolerance;

g. a. genetically modified rice/rice with *Sub1A* is more tolerant to submersion;

b. can withstand seasonal flooding/torrential rain;

c. GMF/tolerant rice ensures greater harvest/provides more food during flooding;

Examiners report

a(i). Generally well done. A few wrote only GMF.

a(ii) Little understanding shown. Many divided the difference in height by 50 instead of 22.

c. Many candidates worded generalized relationships such as the higher the tolerance, the less the growth or growth and tolerance were inversely proportional. Sometimes “height” was given rather than “growth”.

d. The designation of *Oryza* as genus and *sativa* as species was the only marking point that many candidate got correct in this question, although some candidates mixed up the terms calling *Oryza* the species and *sativa* the genus. Very few candidates went beyond to mention that *O. sativa* shared special features. Even fewer candidates mentioned that the varieties *japonica* and *indica* had differences in tolerance. Occasionally, a candidate mentioned that binomial nomenclature helps scientists communicate about the same plant or the worldwide acceptance for the terminology.

e(i). Some candidates did not appreciate that the actual production of each gene was indicated by the intensity of the bands shown on the photograph of electrophoresis.

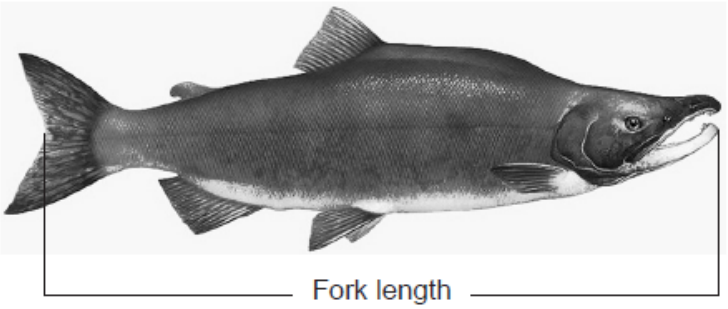
e(ii) Since the question asked for differences in mRNA production for the three genes, it was important that candidates used quantitative wording such as *Sub1A* produces the “most” mRNA or that *Sub1B* produces the “lowest” or “least” mRNA to convey a sense of comparison. A few candidates noted that *Sub1A* produced mRNA for the “longest” time/days 1 to 0 and/or that *Sub1C* produced mRNA for the “shortest” time/days 3 to 7.

e(iii) Many valid comparisons could be made comparing the mRNA production for the three genes. Most often given was that *Sub1A* only produced mRNA in *japonica* and/or never in *indica*. The two mark maximum was achieved frequently.

f. The question was poorly answered. Though *Sub1A* was sometimes correctly identified as the gene to modify GMFC, reasoning to support that answer was usually incorrect or missing.

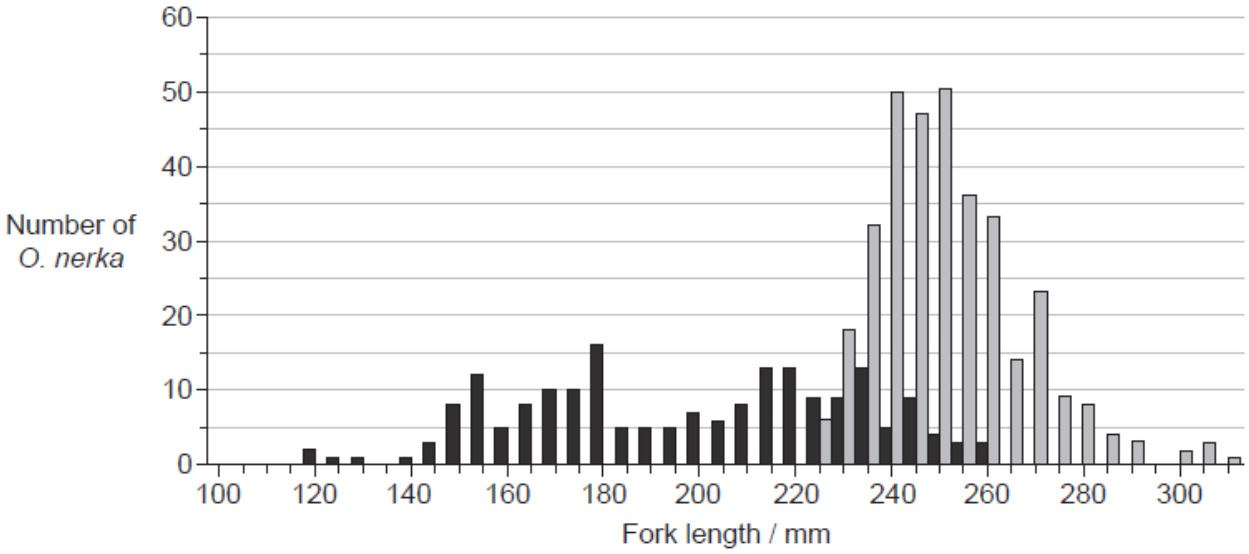
g. Many candidates missed the question by trying to relate GMFs to drought conditions rather than flooding. GMFs offered tolerance to submersion enabling them to withstand flooding so that greater harvests/food production were ensured during flooding.

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



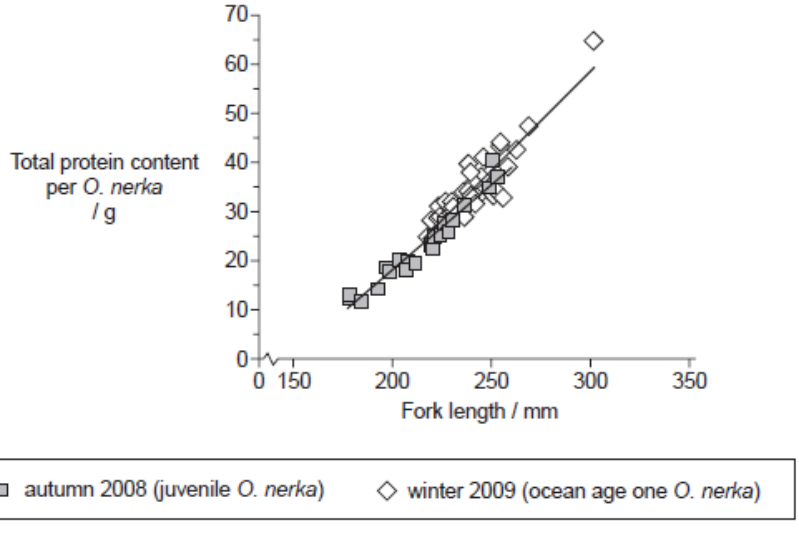
[Source: adapted from http://pnwfolklore.org]

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



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

Protein content in *O. nerka* was measured to evaluate possible differences during their first 15 months at sea. The graph shows the relationship between fork length and total protein content per *O. nerka* caught during autumn 2008 and winter 2009.



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

Scientists measured mercury levels in different fish. The table shows the results.

	Mercury / $\mu g\,g^{-1}$				
	Mean	**Standard deviation**	**Minimum**	**Maximum**	**Number of samples**
Cod	0.111	0.066	0.001	0.989	115
Monkfish	0.181	0.075	0.056	0.289	9
Shark	0.979	0.626	0.001	4.540	356
Trout	0.071	0.025	0.001	0.678	35

a. Identify the most frequent fork length for *O. nerka* caught during autumn 2008 and winter 2009. [1]

Autumn 2008:

Winter 2009:

b. Distinguish between the fork lengths of *O. nerka* in autumn 2008 and winter 2009. [2]

c. Suggest a reason for the variation in fork length of ocean age one *O. nerka*. [1]

d(i). Compare the protein content for *O. nerka* caught during autumn 2008 and winter 2009. [2]

d(ii). Outline the difficulty in predicting the age of *O. nerka* from fork length. [1]

e. Using the data, suggest **one** reason for the relationship between protein content and fork length. [1]

f(i). Compare the results shown in the table for monkfish and shark. [2]

f(ii). Suggest additional information that would be helpful in evaluating these data. [1]

g. State which type of fish shows the most variation. [1]

Markscheme

a. *autumn 2008*: 175mm or 180mm; *(accept either 175mm or 180mm – do not accept in between values)*

winter 2009: 250mm or 255mm; *(accept either 250mm or 255mm – do not accept in between values) (both needed)*

b. a. shorter salmon in autumn 2008 / longer salmon in winter 2009;

b. wider range of length in fish collected during autumn;

c. higher peaks in winter compared to autumn;

Accept numerical values if clearly stated that one is bigger than the other.

c. genetics/gender/ food availability/diet/water temperature/predators/age

d(i). a. both show direct/positive correlation/linear relationship;

b. values for fish collected in winter 2009 are higher than for autumn 2008;

c. many common values in both sets of data;

d. differences between winter and autumn may not be significant because of the overlapping data;

*Award **[1 max]** if only similarity or difference provided.*

d(ii). Difficult because of overlap in fork length between juvenile and ocean age one *O. nerka* / total protein depends on fork length/size, not (only) age, so difficult to predict

e. Growth is a result of incorporating protein / larger fish have more protein/more muscle/more cells.

f(i). a. average/mean mercury concentration is higher for shark/lower for monkfish;

b. small number of samples for monkfish (so data less reliable) / large number of samples for shark (so data more reliable);

c. minimum for shark is well below minimum for monkfish / maximum for shark is well above maximum for monkfish;

d. range/standard deviation/variation is greater for sharks;

f(ii). a. age of fish / details of the method used / chemical form of mercury / part of fish analysed / gender / trophic level of fish;

b. statistical calculations *eg*: t-test/mode;

c. exact location of sampling as some areas of environment may have more mercury pollution than others;

g. shark (shows the most deviation/variation)

Examiners report

a. Most candidates were able to identify the most frequent fork lengths as 175 or 180 and 250 or 255. Weaker candidates lost the mark for stating values in between.

b. Most were able to spot that the salmon were longer in Winter 2009. Weaker candidates just stated figures without qualification.

c. Many candidates compared the two ages of salmon, rather than answering the question.

d(i). As a compare question, at least one difference and one similarity were needed. Most commented that the values for 2009 were greater than 2008. Surprisingly few noted that they <u>both</u> showed positive correlation. Similarly in the second part the large amount of overlap between the two ages was not well spotted.

d(ii). As a compare question, at least one difference and one similarity were needed. Most commented that the values for 2009 were greater than 2008. Surprisingly few noted that they <u>both</u> showed positive correlation. Similarly in the second part the large amount of overlap between the two ages was not well spotted.

e. An answer that implied knowledge that protein was a structural component of the fish was sought, so more protein as part of the fish meant a bigger fish.

f(i). Many lost a mark for not stating that shark had a larger mean mercury content. Large numbers commented that there were many more sharks than monkfish in the survey, but did not extend it to say that this meant that the data was more reliable for the shark.

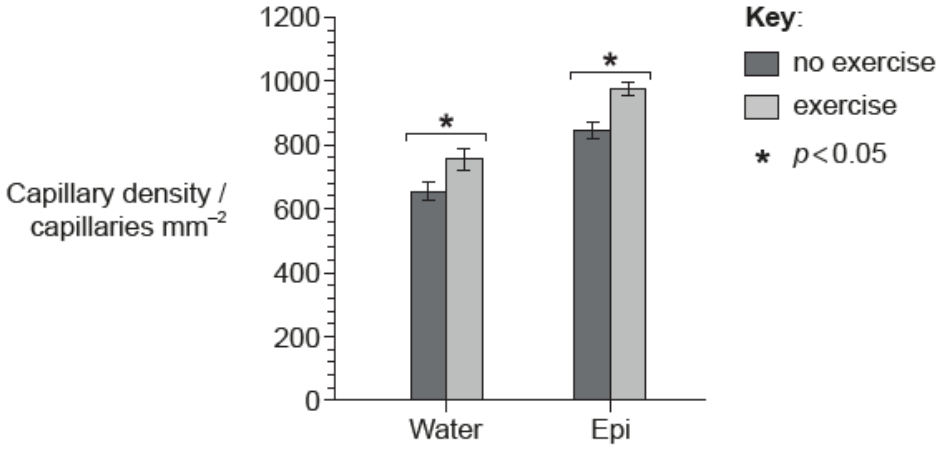
f(ii). Many lost a mark for not stating that shark had a larger mean mercury content. Large numbers commented that there were many more sharks than monkfish in the survey, but did not extend it to say that this meant that the data was more reliable for the shark.

g. Most, but certainly not all, were able to state that the shark showed the most variation.

Consumption of dark chocolate has been shown to have health benefits. A study was undertaken to see the effects of epicatechin (Epi), a substance in dark chocolate, on the aerobic capacity of leg muscles of mice.

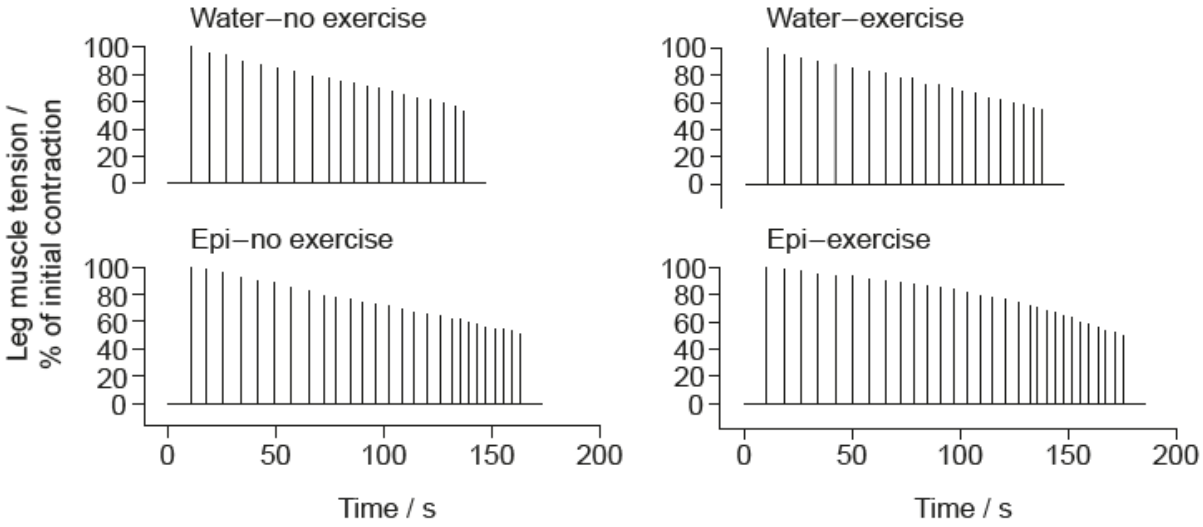
A group of adult mice was used to measure the effects of a low dose of Epi given over 15 days. The mice were divided into four groups and given either water or Epi and were either kept idle (no exercise) or made to exercise on a treadmill.

After 15 days, the results were analysed. The blood capillary density in leg muscle was measured under the light microscope.



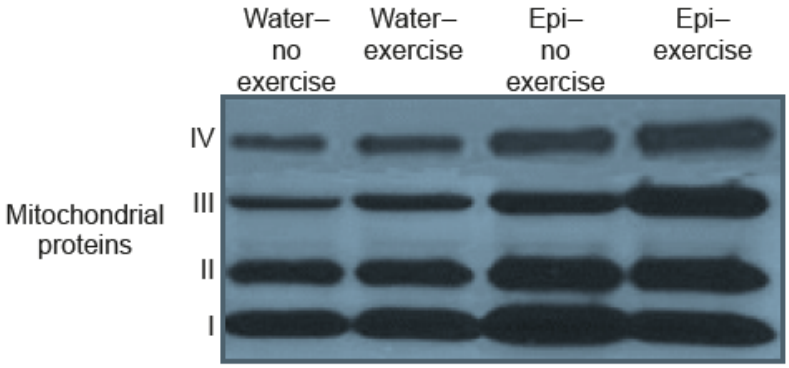
[Source: adapted from L Nogueira, *et al*., (2011), *The Journal of Physiology*, **589** (part 18), Wiley, pages 4615–4631]

Leg muscle tension was measured over time during a treadmill exercise in all four groups. The muscle is considered to reach a point of fatigue when there is a decrease in tension to 50 % of the initial tension.



[Source: adapted from L Nogueira, *et al*., (2011), *The Journal of Physiology*, **589** (part 18), Wiley, pages 4615–4631]

The scientists tested the expression of four different mitochondrial proteins. The protein samples were taken from leg muscles. The technique that was used to quantify the amount of protein expressed was Western blotting. In this procedure the thickness of the band is an indicator of the amount of protein.



[Source: adapted from L Nogueira, *et al.*, (2011), *The Journal of Physiology*, **589** (part 18), Wiley, pages 4615–4631]

a.i. State the significance of the statement: $p<0.05$. [1]

a.ii. Outline the trends in capillary density in the results of this experiment. [2]

b. Describe how increased capillary density could affect the aerobic capacity of muscle. [2]

c.i. State the time when the point of fatigue occurred in the Epi–exercise group. [1]

c.ii. Compare and contrast the results for the water–no exercise group and the Epi–no exercise group. [3]

d. Discuss the effect of exercise on the results of the experiment. [2]

e. Analyse the effect of exercise on the presence of the mitochondrial proteins in the leg muscle. [2]

f. Mitochondria are essential for aerobic respiration. Suggest **one** possible role of the proteins that were studied. [1]

g. The scientists concluded that Epi significantly increased aerobic capacity in leg muscle. [3]

Evaluate the strength of the evidence provided by all of the data for dark chocolate improving the aerobic capacity of athletes.

Markscheme

a.i. there is a significant «statistical» difference between two experimental values

OR

there is a less than 5 % chance that the difference is random

OR

95 % or more probability that results are due to the experiment «IV» and not random/can reject the null hypothesis

OR

there is a relationship/correlation between doing exercise and capillary density

OWTTE

a.ii. a. exercise «significantly» increased the density with both water and Epi

"both" or OWTTE must be mentioned

b. Epi «significantly» increased the density with and without exercise

c. Epi–exercise had the greatest increase in the density
OR
Epi increases the density more than exercise alone

b. a. increases amount of blood taken to the muscle

b. increases the delivery of oxygen/glucose/nutrients for aerobic respiration

c. increases the removal of carbon dioxide/wastes
OR
increased gas exchange

c.i. 175 «seconds»

Accept 170 to 180 «seconds».

c.ii. a. in both cases the tension decreased over time

b. Epi–no exercise lasts longer/more time until «onset of» fatigue «than water–no exercise»

c. the rate of decrease in tension is the same/similar in both

d. Epi–no exercise has more contractions per second before fatigue point «than water–no exercise»

Do not accept numerical comparisons without justification.

d. a. «exercise with» water has no impact

b. «exercise with» Epi promotes higher levels of tension for more time

c. «exercise with» Epi increases the time to fatigue

e. a. exercise has no/very little effect with water

b. exercise with Epi increased III/IV

c. «it appears that» exercise with Epi has no/very little effect on II
OR
Epi relative to water increases all 4
OR
exercise has little/no effect on protein I/II

d. exercise with Epi «appears to» decrease I

f. a. protein channels

OR

pumps in membranes of mitochondria

OR

hormone binding sites

b. structural/integral/peripheral/glyco/surface proteins

c. enzymes/catalysts

Accept verifiable names of specific membrane enzymes.

d. electron transport chain proteins

g. *Limitations*:

a. study done on mice and may not apply to humans

b. levels of Epi administered in experiment may exceed levels in a sample of dark chocolate
OR
levels of Epi administered in experiment may have different levels in a sample of dark chocolate
OR
chocolate may have other components with unknown effects on aerobic capacity

c. mitochondrial proteins may not improve aerobic capacity

Strengths:

d. data supports as dark chocolate contains EPI

e Epi improves capillary density and would therefore increase aerobic capacity

f. Epi improves fatigue resistance

g. Epi in combination with exercise improves it further

h. Epi increases mitochondrial proteins therefore/presumably increasing aerobic capacity

OWTTE

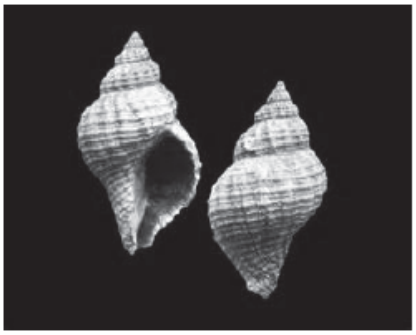
Examiners report

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

Native oyster populations are decreasing where rivers meet the ocean along the northwest coast of North America. These oyster populations are being attacked by a gastropod.

Adult oyster, *Ostrea lurida*

[Source: © International Baccalaureate Organization 2017]



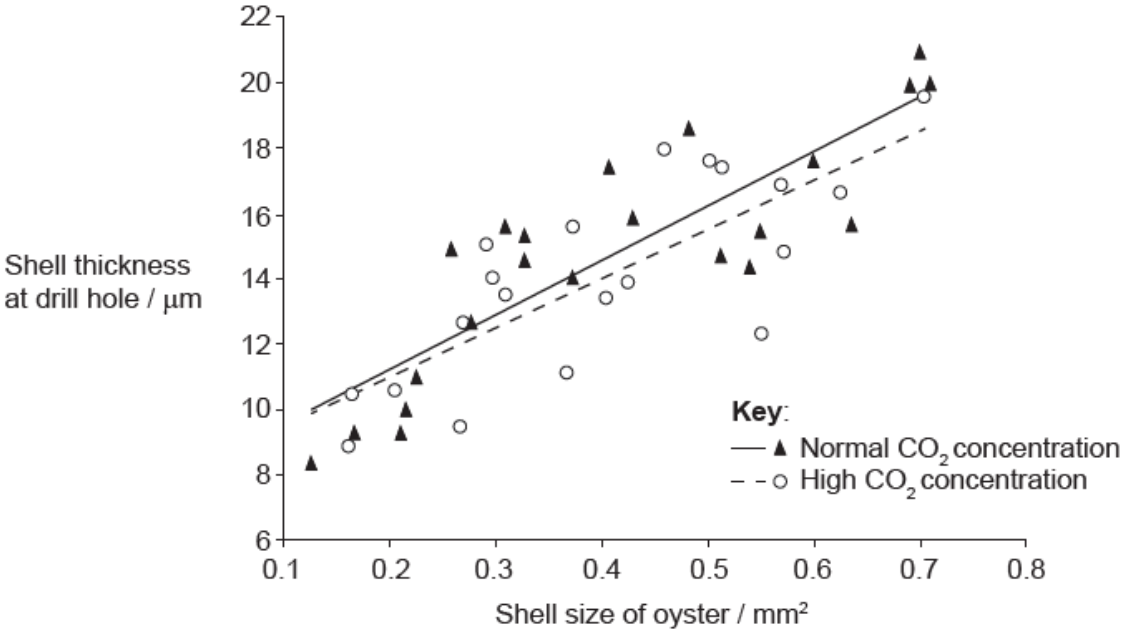
Adult gastropod shell, *Urosalpinx cinerea*

[Source: © International Baccalaureate Organization 2017]

It is known that oysters and gastropods have hard parts composed of calcium carbonate and that ocean acidification is increasing. Studies were carried out using juvenile oysters and gastropods to investigate the effects of acidification on the decrease in the population of oysters.

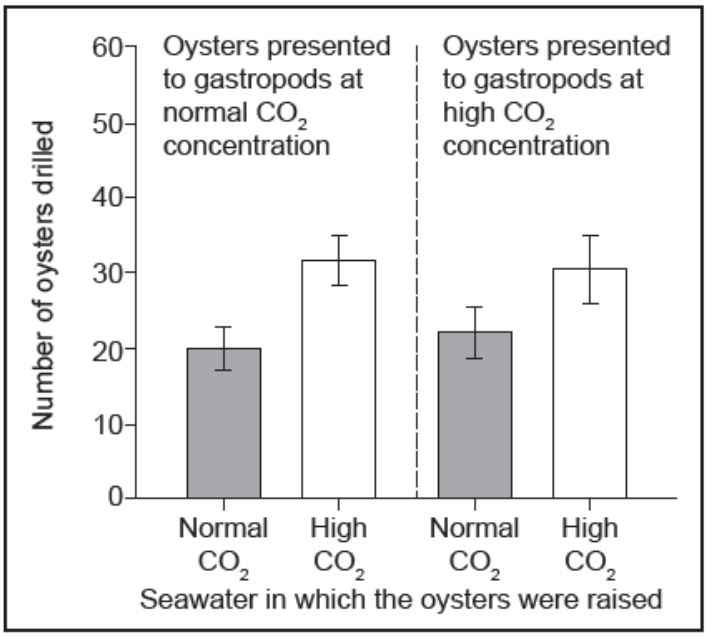
The first step was to raise oysters in two different mesocosms. One had seawater at a normal concentration of CO_2 and the other had sea water with a high concentration of CO_2. Gastropods were raised in two further mesocosms with normal and high CO_2 concentrations respectively.

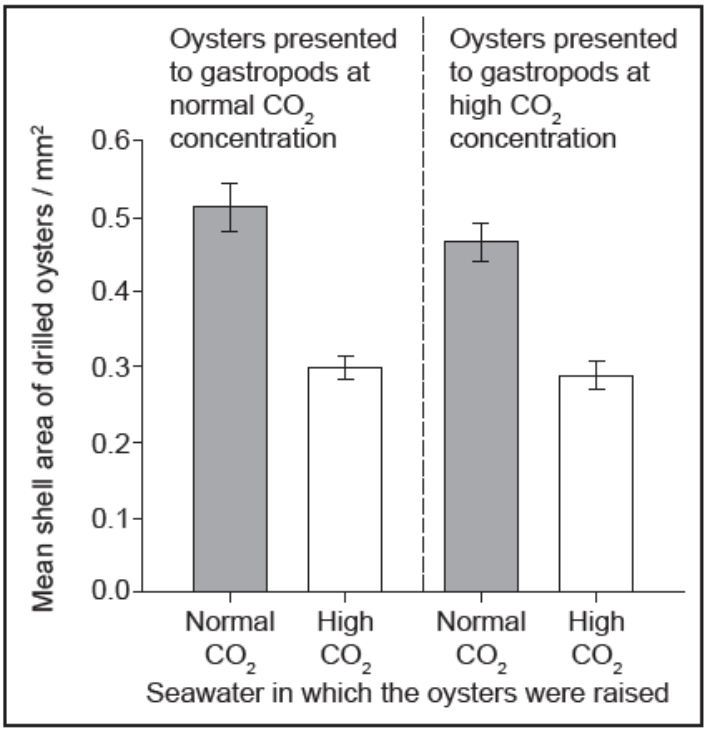
A juvenile gastropod will attack a juvenile oyster by using its tongue-like structure (radula) to drill a hole through the oyster shell. Once the hole has been drilled, the gastropod sucks out the soft flesh. Researchers investigated the shell thickness at the site of the drill hole in relation to the size of the oyster. The results are seen in this graph.



[Source: E Sanford *et al.* (2014) *Proceedings of the Royal Society B*, 281, by permission of the Royal Society.]

Equal numbers of oysters raised in seawater with a normal CO_2 concentration and in seawater with a high CO_2 concentration were then presented together to the gastropod predators in seawater with a normal CO_2 concentration. The same numbers of oysters from the two groups were also presented together to the gastropods in seawater with a high CO_2 concentration. The bar charts show how many of the oysters were drilled by the gastropods and the mean size of drilled oysters.





[Source: © International Baccalaureate Organization 2017]

a. Outline how acidified sea water could affect the shells of the oyster. [1]

b. Outline the trends shown in the data in the graph. [2]

c. Estimate how much smaller drilled oysters raised in seawater at a high CO_2 concentration were than drilled oysters raised in seawater at a normal CO_2 concentration. [1]

d.i. Deduce from the data in the bar charts which factors were and were not correlated significantly with the number of oysters drilled by the gastropods. [2]

d.ii. Suggest reasons for the differences in the numbers of oysters drilled, as shown in the bar charts. [2]

d.iii. The radula in a gastropod is hard but not made of calcium carbonate. Outline how this statement is supported by the drilling success of the gastropods in seawater with normal or high CO_2 concentrations. [2]

e. Using all the data, evaluate how CO_2 concentrations affect the development of oysters and their predation by gastropods. [2]

Markscheme

a. Shells might dissolve/deteriorate / become smaller/thinner/weaker / OWTTE

OR

shell formation reduced / more difficult

b. a. positive correlation between shell thickness and shell size

OR

as shell thickness increases, shell size «also» increases

b. (positive correlation) occurs at two different CO_2 concentrations / both high and normal concentrations

c. trend for thickness is «slightly» lower with high CO_2

c. «approximately» 0.2 mm^2

OR

«approximately» 40 % «smaller»

unit required

d.i. a. significant factor: concentration of CO_2 in which oysters were raised

b. insignificant factor: concentration of CO_2 at which oysters were presented to gastropods

d.ii. a. (because) shells are thinner/smaller when the oyster is raised in high CO_2/lower pH

OR

«because» lower pH/higher acidity prevents/reduces deposition of calcium carbonate

b. gastropods target smaller/thinner-shelled oysters more

c. gastropods can eat/drill thin-shelled/smaller oysters at a faster rate (and move onto another)

d. eating smaller oysters «from high CO_2 environments» means given population of gastropods require more oysters for same food intake

d.iii. a. data shows that similar numbers are drilled regardless of conditions

b. since radulas are not affected by acidification

OR

radulas not made of calcium carbonate so (remain) strong/successful at drilling

e. a. the data/trend lines indicate that a higher CO_2 concentration diminishes the shell thickness, making gastropod predation more successful

OR

the bar graphs suggest that oysters raised in a higher CO_2 concentration are smaller, making gastropod predation more successful

b. CO_2 concentrations «during feeding» do not change the occurrence of drilling/predation «by gastropods»

c. «limitation» no information about how exaggerated the CO_2 concentrations were
OR
«limitation» no information about numbers of gastropods used «in each setting»

Examiners report

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