

PLUMI PRACTICE PACK

A Level Biology A

OCR-style practice pack (H420)

Mark scheme | Total 373 marks

Q	Section	Level	Topic	Specification	Marks
1	A	Easy	Cell ultrastructure and magnification: a pancreatic acinar cell	2.1.1(e), 2.1.1(f), 2.1.1(g), 2.1.1(i)	11
2	A	Medium	Water potential: potato tissue in sucrose solutions	2.1.5(e), 1.1.3, 1.1.1	10
3	A	Medium	The cardiac cycle: pressure changes in the left side of the heart	3.1.2(f), 3.1.2(g)	13
4	A	Medium	Transport of oxygen: llama and human haemoglobin	3.1.2(i), 3.1.2(j)	11
5	A	Hard	Transpiration: measuring water uptake with a potometer	3.1.3(c), 3.1.3(d), 1.1.3, 1.1.4	15
6	A	Hard	Nerve impulses: the squid giant axon	5.1.3(b), 5.1.3(c)	15
7	A	Hard	The kidney: reabsorption and a desert mammal	5.1.2(c), 5.1.2(d), 2.1.5(d)	13
8	A	Super hard	Photosynthesis: limiting factors and the Calvin cycle in <i>Chlorella</i>	5.2.1(e), 5.2.1(g)	15
9	A	Super hard	Respiration practical: oxygen uptake and RQ of castor bean seeds	5.2.2(h), 5.2.2(j), 5.2.2(k), 5.2.2(l), 1.1.1	15
10	A	Super hard	Enzyme inhibition: treating ethylene glycol poisoning with ethanol	2.1.4(c), 2.1.4(d), 2.1.4(f), 5.1.2(b)	14
11	B	Easy	Biological molecules: measuring glucose with a colorimeter	2.1.2(q), 2.1.2(r), 1.1.2	10
12	B	Medium	Biodiversity: Simpson's index in two meadows	4.2.1(b), 4.2.1(c), 4.2.1(d), 4.2.1(f)	10
13	B	Medium	The immune response: vaccination and antivenom	4.1.1(f), 4.1.1(g), 4.1.1(h), 4.1.1(j), 4.1.1(l)	11
14	B	Medium	Sex linkage: tortoiseshell cats	6.1.2(b)	10
15	B	Hard	Epistasis and the chi-squared test: fruit colour in summer squash	6.1.2(b), 6.1.2(c)	13
16	B	Hard	Variation and the t-test: limpet shells on a rocky shore	4.2.2(f), 4.2.2(g), 1.1.3, 1.1.4	13
17	B	Hard	Natural selection and Hardy-Weinberg: warfarin resistance in rats	6.1.2(e), 6.1.2(f), 4.2.2(h), 4.2.2(i)	11
18	B	Super hard	PCR and DNA profiling: finding the father of a kākāpō chick	6.1.3(c), 6.1.3(d), 6.1.3(e), 6.1.2(b), 6.1.2(e)	14
19	B	Super hard	Succession on sand dunes: planning, choosing and using a statistical test	6.3.1(d), 6.3.1(e), 4.2.1(b), 1.1.1, 1.1.3	15
20	B	Super hard	Gene regulation: diauxic growth of <i>E. coli</i> and the <i>lac</i> operon	6.1.1(b), 6.2.1(h)	13
21	C	Easy	Practical skills: chromatography of photosynthetic pigments	2.1.2(s), 5.2.1(c), 1.1.2	8
22	C	Medium	Cell division: mitotic index in an onion root tip	2.1.6(a), 2.1.6(c), 2.1.6(d), 2.1.1(b)	12
23	C	Medium	Ecosystems: energy transfer and the nitrogen cycle	6.3.1(b), 6.3.1(c)	13
24	C	Medium	Protein synthesis and gene mutation	2.1.3(f), 2.1.3(g), 6.1.1(a)	11
25	C	Hard	Ectotherms and enzymes: temperature control in a desert lizard	5.1.1(d), 2.1.4(d), 2.1.4(c)	14
26	C	Hard	Plant hormones: gibberellin and dwarf peas	5.1.5(d), 5.1.5(e), 4.2.2(f), 6.1.1(a), 1.1.4	11
27	C	Hard	Blood glucose: identifying type 1 and type 2 diabetes	5.1.4(d), 5.1.4(e), 2.1.5(d)	13
28	C	Super hard	Cystic fibrosis: inheritance, membranes and gas exchange	6.1.2(b), 6.1.1(a), 2.1.5(d), 2.1.5(e), 3.1.1(b), 6.1.3(h)	13
29	C	Super hard	Speciation: cichlid fish in a crater lake	4.2.2(d), 4.2.2(e), 6.1.2(g), 6.1.3(a)	12
30	C	Super hard	Photosynthesis, respiration and temperature: coral bleaching	5.2.1(a), 5.2.1(g), 2.1.4(d), 6.3.1(a)	14
Total (A: 132, B: 120, C: 121)					373

OCR-style practice written by Plumi. Not produced or endorsed by OCR. Every numerical answer, statistic, critical value and genetic ratio in this scheme follows from the values printed on the question paper.



Annotations used in this mark scheme

Annotation	Meaning
✓	Marking point: one mark. Points are numbered where the Guidance refers to them.
max n	The marking points listed are worth more than the tariff: award up to n marks.
FIRST CHECK THE ANSWER	For calculations: if the answer on the answer line is correct (within any range stated on the FIRST CHECK line), award the marks stated; otherwise credit the working shown.
AO element	The assessment objective each mark targets: AO1 knowledge and understanding; AO2 application (in theoretical and practical contexts, and when handling qualitative and quantitative data); AO3 analysis, interpretation and evaluation.
*	Level of Response item, marked by levels (see below).
/	Alternative and acceptable answers for the same marking point.
()	Words which are not essential to gain credit.
<u>underline</u>	The underlined word (or a correct spelling of it) must be used to gain the mark.
ALLOW	Answers that can be accepted.
DO NOT ALLOW	Answers which should not be credited.
IGNORE	Statements which are irrelevant: they neither gain nor lose credit.
ECF	Error carried forward: credit for correct working that uses an incorrect earlier answer.
AW, ORA	Alternative wording; or reverse argument.
mp	Marking point (the numbered points in the Answer column).

Subject-specific marking instructions

- **Calculations.** First check the answer on the answer line: a correct final answer gains full credit unless the question asks for working to be shown. An incorrect answer can gain marks for the correct working shown.
- **Significant figures and units.** Unless the question states a number of significant figures or decimal places, a correct final answer to 2 or 3 significant figures (or to the number of significant figures in the data) gains full marks; the same value given to more than 3 significant figures, or to a number of decimal places or significant figures different from the one the question asks for, loses 1 mark (a rounding error). Ignore significant figures in intermediate values. Where the unit is printed on the answer line it need not be repeated.
- **Readings from graphs.** Values read from a figure are accepted within the range stated on the FIRST CHECK line or in the Guidance, and ECF applies to later steps.
- **Lists.** Where a question asks for a set number of answers, mark the first answers given; a contradictory extra answer cancels a correct one.
- **Describe and explain.** 'Describe' needs a statement of the pattern or the process, with data where asked. 'Explain' needs the biological reason: a description alone does not gain explanation marks.
- **Precision of terms.** Credit only correct biological terms: for example, water moves by osmosis down a water potential gradient (not a 'concentration of water'), energy is released (not produced), and enzymes are denatured (not killed).

Level of Response items (*)

Read the whole answer. Decide the level from the science content against the level descriptors, then award the higher mark in the level if the communication statement for that level is met, otherwise the lower mark. The indicative scientific points are not a checklist; credit any valid biology. Level 0 (0 marks): no response, or no response worthy of credit.

SECTION A: BIOLOGICAL PROCESSES

Question 1 Biological processes · Easy · Cell ultrastructure and magnification: a pancreatic acinar cell

Question	Answer	Marks	AO element	Guidance
1(a)	1 A rough endoplasmic reticulum ✓ 2 B Golgi apparatus ✓	2	1.1 ×2	1 ALLOW rough ER / RER DO NOT ALLOW endoplasmic reticulum without 'rough', or smooth ER 2 ALLOW Golgi / Golgi body / Golgi complex IGNORE vesicles
1(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = × 11 500 to × 12 500 award 2 marks 1 scale bar = 24 mm = 24 000 μm (measured) ✓ 2 magnification = 24 000 ÷ 2 = × 12 000 ✓	2	2.4 ×2	1 ALLOW 23 to 25 mm Both lengths must be in the same unit 2 ALLOW × 11 500 to × 12 500 ALLOW without the × sign DO NOT ALLOW × 12 (units not converted) Correct answer with no working scores 2 marks
1(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 2.4 to 2.6 μm award 2 marks 1 D measures 30 mm = 30 000 μm; actual length = 30 000 ÷ 12 000 ✓ 2 2.5 μm ✓	2	2.4 ×2	1 ALLOW 29 to 31 mm ECF from (b) 2 ALLOW 2.4 to 2.6 μm Correct answer scores 2 marks
1(d)	1 the light microscope has a lower <u>resolution</u> / the electron microscope has a higher <u>resolution</u> ✓ 2 electrons have a much shorter wavelength than light, so (organelles / membranes) closer together than about 0.2 μm cannot be distinguished with light ✓	2	1.2 ×2	1 IGNORE references to magnification DO NOT ALLOW 'the electron microscope has a higher magnification' as the only answer 2 ALLOW limit of resolution of a light microscope is about 200 nm ALLOW structures are smaller than the limit of resolution
1(e)	1 ribosomes on A (rough ER) synthesise the enzyme / polypeptide (by translation) ✓ 2 polypeptide enters A where it is folded and transported (in vesicles) to B ✓ 3 B modifies / processes the protein (e.g. adds carbohydrate) and packages it into vesicles ✓ 4 vesicles C move to and fuse with the cell surface membrane, releasing the enzyme by <u>exocytosis</u> ✓	max 3	1.1 ×3	1 Mark the first answer for each structure 2 ALLOW 'pinched off in vesicles' from A 3 ALLOW glycosylation 4 DO NOT ALLOW 'diffuses out' or 'excreted'
	Total	11		



Question 1 notes continued

Examiner notes

(d) Examiners report that many candidates answer in terms of magnification. Magnification without resolution only makes a blurred image larger: the mark is for resolution, linked to wavelength.

Question 2 Biological processes · Medium · Water potential: potato tissue in sucrose solutions

Question	Answer	Marks	AO element	Guidance
2(a)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = -12.4 (%) award 2 marks 1 $(1.77 - 2.02) \div 2.02 \times 100 \checkmark$ 2 -12.4 (%) $\checkmark$	2	2.4 × 2	1 Change in mass must be divided by the <u>initial</u> mass 2 Must be negative ALLOW 'a decrease of 12.4%' Correct answer to the wrong number of decimal places (e.g. -12 or -12.38) scores 1 mark -14.1 (divided by final mass) scores 1 mark
2(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = -790 to -850 kPa award 3 marks 1 reads the concentration at which the curve crosses 0% change (0.30 mol dm^{-3}) because there is no net movement of water at this concentration, so the water potential of the tissue = the water potential of the sucrose solution $\checkmark$ 2 uses Table 2.2: 0.30 mol dm^{-3} has a water potential of -820 kPa (interpolating between neighbouring values if the reading is not 0.30) $\checkmark$ 3 -820 kPa $\checkmark$	3	2.4 × 3	1 ALLOW 0.29 to 0.31 2 e.g. 0.29 gives $-540 - (0.9 \times 280) = -792$ 3 ALLOW -790 to -850 kPa Must be negative ECF from an incorrect reading of Fig. 2.1
2(c)	the cylinders had different initial masses, so percentage change allows (valid) comparison $\checkmark$	1	3.3	IGNORE 'more accurate' / 'fair test' unqualified
2(d)	1 distilled water has a higher water potential than the potato cells / tissue $\checkmark$ 2 water enters the cells by <u>osmosis</u> down the water potential gradient $\checkmark$ 3 cells become turgid; the cell wall prevents bursting, limiting the gain in mass $\checkmark$	max 2	1.2 × 2	1 ALLOW 0 kPa is higher than the water potential of the cells ALLOW 'less negative' 2 DO NOT ALLOW water moves from high to low concentration of water ALLOW 'through a partially permeable membrane'
2(e)	1 volume of sucrose solution $\checkmark$ 2 size (length / diameter / surface area) of the cylinders $\checkmark$ 3 time in the solution $\checkmark$ 4 source / variety / age of potato $\checkmark$ 5 method of blotting $\checkmark$	max 2	3.3 × 2	1 IGNORE 'mass of potato' (it varies and is allowed for by percentage change) IGNORE temperature (given in the question) Mark the first two answers

Question 2 continued

Question	Answer	Marks	AO element	Guidance
	Total	10		

Examiner notes

(b) The curve of best fit crosses zero at $0.298 \text{ mol dm}^{-3}$, giving -815 kPa . A candidate who joins the 0.2 and 0.4 mol dm^{-3} points with a straight line obtains $0.303 \text{ mol dm}^{-3}$ and -829 kPa , within the allowed range. This is a typical water potential for potato tuber tissue.

(d) 'Describe' answers (the mass increased) gain no credit: the marks are for the water potential gradient and osmosis.

Question 3 Biological processes · Medium · The cardiac cycle: pressure changes in the left side of the heart

Question	Answer	Marks	AO element	Guidance
3(a)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 73 to 77 (beats min^{-1}) award 2 marks 1 one cardiac cycle lasts 0.80 s (e.g. from the start of one rise in ventricular pressure to the next) ✓ 2 $60 \div 0.80 = 75 \text{ (beats min}^{-1}\text{)}$ ✓	2	2.4×2	1 ALLOW 0.78 to 0.82 s 2 ALLOW 73 to 77 Correct answer scores 2 marks
3(b)	1 valve opens when ventricular pressure rises above aortic pressure (0.15 s) and closes when it falls below aortic pressure (0.37 s) ✓ 2 0.22 s ✓	2	2.3 2.4	1 ALLOW where the ventricle and aorta curves meet / separate ALLOW 0.14 to 0.16 s and 0.36 to 0.38 s 2 ALLOW 0.20 to 0.24 s
3(c)	1 wall of aorta contains <u>elastic</u> tissue / fibres, which stretch when the ventricle ejects blood ✓ 2 elastic recoil of the aorta wall (when the ventricle relaxes) maintains the pressure (above about 11 kPa) ✓	2	1.2×2	1 IGNORE muscle 2 ALLOW the closed semilunar valve prevents backflow into the ventricle as the alternative for this mark; the two ideas are alternatives, not both required ALLOW smooths the flow of blood DO NOT ALLOW the aorta wall contracts / pumps blood
3(d)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 5.25 (ALLOW 5.3) $\text{dm}^3 \text{ min}^{-1}$ award 2 marks 1 $70 \times 75 = 5250 \text{ cm}^3 \text{ min}^{-1}$ ✓ 2 $5.25 \text{ dm}^3 \text{ min}^{-1}$ ✓	2	2.4×2	1 ECF from (a) 2 ALLOW 5.3 5250 with no conversion scores 1 mark



Question 3 continued

Question	Answer	Marks	AO element	Guidance
3(e)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 71 (%) award 3 marks 1 stroke volume during exercise = $18\,000 \div 150 = 120\text{ cm}^3$ ✓ 2 increase = $120 - 70 = 50\text{ cm}^3$; $50 \div 70 \times 100$ ✓ 3 71 (%) ✓	3	2.4 ×3	1 Unit conversion needed: $18.0\text{ dm}^3 = 18\,000\text{ cm}^3$ 2 ECF from an incorrect stroke volume 3 ALLOW 71.4 71.43 (more than 3 significant figures) scores 2 marks 41.7 (divided by 120) scores 1 mark
3(f)	1 <u>SAN</u> (sinoatrial node) sends a wave of excitation / depolarisation across the atria, which contract ✓ 2 non-conducting tissue (collagen) between atria and ventricles stops the wave passing directly to the ventricles ✓ 3 <u>AVN</u> (atrioventricular node) delays the impulse (about 0.1 s) so the atria finish contracting first ✓ 4 impulse passes down the bundle of His / Purkyne fibres to the apex of the ventricles ✓ 5 ventricles contract from the apex upwards ✓	max 2	1.1 ×2	1 ALLOW pacemaker for SAN IGNORE signals / messages / electrical waves 4 ALLOW Purkinje
Total		13		

Examiner notes

(e) The stroke volume rises by about 71%: the increase in cardiac output ($\times 3.4$) comes from both the heart rate and the stroke volume.

Question 4 Biological processes · Medium · Transport of oxygen: llama and human haemoglobin

Question	Answer	Marks	AO element	Guidance
4(a)	1 binding of the first oxygen molecule (to a haem group) is difficult, so saturation rises slowly at low partial pressure ✓ 2 binding of the first oxygen changes the (tertiary / quaternary) shape of haemoglobin, making it easier for further oxygen molecules to bind (cooperative binding) ✓ 3 at high partial pressure most binding sites are occupied, so the curve levels off ✓	max 2	1.2 ×2	
4(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 10.4 to 11.4 cm³ award 3 marks 1 readings for llama: 92% at 6.0 kPa and 38% at 2.0 kPa ✓ 2 difference = 54% of 20.0 cm^3 ✓ 3 10.8 cm^3 ✓	3	2.4 ×3	1 ALLOW 91 to 93% and 37 to 39% 2 ALLOW 0.54×20.0 3 ALLOW 10.4 to 11.4 cm^3 Correct answer scores 3 marks

Question 4 continued

Question	Answer	Marks	AO element	Guidance
4(c)	1 llama curve is to the left: llama haemoglobin has a higher affinity for oxygen ✓ 2 llama haemoglobin is more saturated at the low partial pressure of oxygen in the lungs (e.g. 92% compared with 80% at 6.0 kPa), so more oxygen is loaded ✓	2	2.1 × 2	1 ORA for human 2 Comparative statement with or without data IGNORE 'and still unloads at the low partial pressure in respiring tissue'
4(d)(i)	curve drawn to the right of (below) the human curve, S-shaped, approaching the same maximum ✓	1	2.1	Curve must not cross the original
4(d)(ii)	1 carbon dioxide enters red blood cells, where <u>carbonic anhydrase</u> catalyses the formation of carbonic acid ✓ 2 carbonic acid dissociates into hydrogen ions and hydrogencarbonate ions ✓ 3 hydrogen ions bind to haemoglobin (forming haemoglobinic acid), changing its tertiary / quaternary structure ✓ 4 this lowers the affinity of haemoglobin for oxygen, so more oxygen is released (Bohr effect) ✓	max 3	1.2 × 3	3 ALLOW H⁺ DO NOT ALLOW hydrogen atoms / molecules 4 IGNORE 'Bohr shift' unqualified
Total		11		

Examiner notes

(b) Fig. 4.1 gives about 92% and 38%. Candidates who read the human curve (80% and 17%) obtain 12.6 cm³: no credit beyond the method mark for the difference.

Question 5 Biological processes · Hard · Transpiration: measuring water uptake with a potometer

Question	Answer	Marks	AO element	Guidance
5(a)	1 prevents air entering the xylem (vessels) ✓ 2 an air bubble would break the continuous column of water, so cohesion between water molecules could not pull water up the stem ✓	2	1.2 × 2	1 ALLOW prevents an air lock / air bubble in the xylem 2 ALLOW hydrogen bonds between water molecules
5(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 217 or 220 mm³ h⁻¹ award 3 marks 1 mean distance = 36.0 mm ✓ 2 volume = $\pi \times 0.40^2 \times 36.0 = 18.1 \text{ mm}^3$ in 5.0 minutes ✓ 3 217 mm³ h⁻¹ ✓	3	2.4 × 3	2 Radius = 0.40 mm 869 mm³ h⁻¹ (diameter used as the radius) scores 1 mark 3 ALLOW 217 or 220 Answer given to more than 3 significant figures (e.g. 217.15): max 2 Correct answer scores 3 marks

Question 5 continued

Question	Answer	Marks	AO element	Guidance
5(c)	1 mean in moving air = 52.3 mm, so the increase is $(52.3 - 36.0) \div 36.0 = 45\%$: less than 50%, so the means do not support the conclusion ✓ 2 the ranges of the repeats (35 to 37 and 51 to 54) do not overlap, so moving air does increase the rate ✓ 3 the increase could be as large as 54% ($54 \div 35$) or as small as 38% ($51 \div 37$), so the size of the increase is uncertain ✓ 4 only three repeats; each reading is to the nearest 1 mm, about 3% of each distance ✓	max 3	3.2 ×3	1 ALLOW 45.4% 4 ALLOW more repeats needed
5(d)	1 moving air removes water vapour from around the leaf / stomata ✓ 2 steeper diffusion gradient (concentration gradient) of water vapour between the air spaces in the leaf and the air outside ✓ 3 faster diffusion of water vapour out through the stomata, so more evaporation from (the cell walls of) mesophyll cells ✓ 4 mesophyll cells have a lower water potential, so more water moves into them (from the xylem) ✓ 5 greater tension in the xylem; water column pulled up by <u>cohesion</u> (and adhesion), so more water is drawn in from the potometer ✓	max 4	2.1 ×4	1 ALLOW removes the layer of humid air 2 ALLOW water potential gradient DO NOT ALLOW 'concentration of water' or 'water vapour potential' 5 ALLOW transpiration pull
5(e)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 73 (%) award 2 marks 1 mean with lower surfaces coated = 14.0 mm; $(52.3 - 14.0) \div 52.3 \times 100$ ✓ 2 73 (%) ✓ 3 assumption: water uptake equals the rate of water loss / the jelly blocks all the stomata on the lower surface / coating does not change loss through the upper surface ✓	3	2.4 ×2 3.3	1 ECF from the moving-air mean in (c) The distances can be used directly: the capillary is the same 2 ALLOW 73.2 27% (the share through the upper surface) scores 1 mark
Total		15		

Examiner notes

What makes this hard: You have to turn bubble distances into volumes using the radius, not the diameter, then judge a '50%' claim from both the means and the spread of the repeats. In (d) every link from moving air to water entering the stem is needed, not just 'more transpiration'.

(b) $217 \text{ mm}^3 \text{ h}^{-1}$ follows from the mean of 36.0 mm; using each repeat separately gives the same mean.

(e) Most of the water is lost through the lower surface, where most stomata are found in a typical dicotyledon leaf.

(d) Examiners look for each link from moving air to the uptake of water: a candidate who writes only 'more transpiration so more water uptake' scores 0.

Question 6 Biological processes · Hard · Nerve impulses: the squid giant axon

Question	Answer	Marks	AO element	Guidance
6(a)	(stimulus causes) some voltage-gated sodium ion channels to open, and sodium ions diffuse into the axon ✓ - down their electrochemical gradient ✓ - at threshold (about -55 mV) more sodium ion channels open: positive feedback, rapid depolarisation ✓ - inside becomes positive relative to outside, reaching $+40$ mV, when sodium ion channels close ✓	max 3	1.2×3	- DO NOT ALLOW sodium ions pumped in ALLOW Na^+ - ALLOW concentration gradient - ALLOW potential reverses
6(b)	- peak is lower: $+10$ mV compared with $+40$ mV ✓ - depolarisation is slower / peak is reached later (1.6 ms compared with 1.4 ms) ✓ - smaller sodium ion concentration gradient across the membrane ✓ - so fewer sodium ions diffuse in (per unit time) when the channels open ✓	max 3	2.3 1.2×2	Data must be comparative
6(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 30 m s^{-1} award 2 marks $45 \text{ mm} \div (2.7 - 1.2) \text{ ms} = 30 \text{ mm ms}^{-1}$ ✓ 30 m s^{-1} ✓	2	2.4×2	- ALLOW $0.045 \text{ m} \div 0.0015 \text{ s}$ - DO NOT ALLOW 17 or 38 (one time used) Correct answer scores 2 marks
6(d)	- axon is <u>myelinated</u>: myelin sheath (Schwann cells) insulates the axon ✓ - depolarisation only occurs at nodes of Ranvier, so the impulse jumps from node to node (saltatory conduction) ✓	2	2.1×2	ALLOW local circuits form between nodes
6(e)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = -29 (%) award 2 marks - speed = $45 \div (3.5 - 1.4) = 21.4 \text{ m s}^{-1}$ ✓ $(21.4 - 30) \div 30 \times 100 = -29$ (%) ✓ - fewer sodium ions enter, so the depolarisation is smaller and slower ✓ - the local currents (of sodium ions) to the next region of membrane are weaker ✓ - so it takes longer for the next region of membrane to reach the threshold ✓	max 4	2.4×2 3.1×2	- ECF from (c) - ALLOW -28.6 ALLOW 'a decrease of 29%' $+40\%$ ($30 \div 21.4$) scores 1 mark - ALLOW fewer ions diffuse along the axon Award the 2 calculation marks within the 4
6(f)	$1 \div 0.0025 = 400 \text{ impulses s}^{-1}$ ✓	1	2.4	ALLOW 400 Hz DO NOT ALLOW 0.4 (ms not converted)
Total		15		



Question 6 notes continued

Examiner notes

What makes this hard: You have to read both action potentials accurately and explain the lower, slower peak in terms of the sodium ion gradient. The speed needs the time and the distance between the two recording electrodes, and (e) asks you to connect a smaller depolarisation to a slower impulse.

(b) 'Describe and explain' needs both: a candidate who quotes the peaks but not the gradient, or the gradient but no data, scores at most 2.

(c) Distance and time must both be differences between R_1 and R_2 ; the position of the stimulating electrode is not needed.

Question 7 Biological processes · Hard · The kidney: reabsorption and a desert mammal

Question	Answer	Marks	AO element	Guidance
7(a)	1 Q (proximal convoluted tubule) ✓ 2 sodium ions are actively transported out of the cells into the blood / tissue fluid (by sodium-potassium pumps in the basal membrane) ✓ 3 this lowers the sodium ion concentration inside the cells ✓ 4 sodium ions diffuse into the cells from the filtrate through <u>co-transporter</u> proteins, carrying glucose with them ✓ 5 glucose diffuses out of the cells into the blood by facilitated diffusion ✓ 6 microvilli increase the surface area; many mitochondria supply ATP ✓	max 4	2.3 1.2 × 3	1 ALLOW PCT 4 ALLOW secondary active transport / symport Award the letter mark as one of the 4
7(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 99.2 (%) award 2 marks 1 $(125 - 1.0) \div 125 \times 100$ ✓ 2 99.2 (%) ✓	2	2.4 × 2	2 ALLOW 99
7(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 48 (%) award 3 marks 1 urea filtered = $125 \times 5.0 \div 1000 = 0.625 \text{ mmol min}^{-1}$ ✓ 2 urea excreted = $1.0 \times 325 \div 1000 = 0.325 \text{ mmol min}^{-1}$, so $0.300 \text{ mmol min}^{-1}$ reabsorbed ✓ 3 48 (%) ✓	3	2.4 × 3	1 ALLOW in any consistent units 3 Correct answer scores 3 marks A comparison of concentrations only ($325 \div 5.0 = 65$) scores 0

Question 7 continued

Question	Answer	Marks	AO element	Guidance
7(d)	1 sodium (and chloride) ions are actively transported out of the ascending limb ✓ 2 the ascending limb is impermeable to water ✓ 3 this lowers the water potential of the tissue fluid in the medulla ✓ 4 water leaves the descending limb by osmosis, so the filtrate becomes more concentrated towards the bottom of the loop ✓ 5 countercurrent multiplier: a longer loop builds up a steeper gradient / a lower water potential deep in the medulla ✓ 6 more water leaves the <u>collecting duct</u> by osmosis into the medulla, so urine has a lower water potential ✓	max 4	1.2 ×4	1 ALLOW pumped for actively transported ALLOW Na⁺ / Cl⁻ IGNORE sodium / salt (without 'ions') 3 ALLOW makes the medulla more concentrated 6 ALLOW reference to ADH making the collecting duct (more) permeable to water ALLOW down a water potential gradient
	Total	13		

Examiner notes

What makes this hard: The amount of urea filtered is not given: you have to work it out from the filtration rate and the plasma concentration before you can compare it with the amount excreted. In (d) you have to explain, step by step, why a longer loop gives a lower water potential deep in the medulla.

(c) Urea is filtered freely, so the filtrate has the plasma concentration. Of $0.625 \text{ mmol min}^{-1}$ filtered, 0.325 is excreted: 48% is reabsorbed, by diffusion, because water reabsorption concentrates the urea in the tubule.

Question 8 Biological processes · Super hard · Photosynthesis: limiting factors and the Calvin cycle in Chlorella

Question	Answer	Marks	AO element	Guidance
8(a)	1 the claim is about photosynthesis, so use gross rates: net rate + 8 (respiration), i.e. $27.2 + 8 = 35.2$ at 0.04% and $30.8 + 8 = 38.8$ at 0.20% ✓ 2 so the rate increases by only about 10% (10.2%): it does not double ✓ 3 at this light intensity light is the (main) limiting factor, not carbon dioxide ✓ 4 doubling or more occurs only at high light intensity, e.g. gross rates of about 47 and 95 at 900 (net rates 39 and 87) ✓ 5 results are for <i>Chlorella</i> at 20 °C; lettuce / glasshouse temperature may differ ✓	max 3	3.2 ×3	1 ALLOW a comparison of net rates (27.2 and 30.8, an increase of about 13%) 2 ALLOW 8 to 15% if gross rates are used (35 to 39 gives 11%); ALLOW 10 to 20% if net rates are compared 4 ALLOW above about 600 if net rates are compared The claim must be judged (not supported) for full marks
8(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 44 to 46 award 2 marks 1 net rate at 400 = 37; rate of respiration = 8 (from the rate at zero light intensity) ✓ 2 gross rate = $37 + 8 = 45$ ✓	2	2.4 ×2	1 ALLOW 36 to 38 The respiration rate must be read from the intercept 2 ALLOW 44 to 46 37 (net rate only) scores 0

Question 8 continued

Question	Answer	Marks	AO element	Guidance
8(c)	1 40 $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ✓ 2 rate of photosynthesis equals the rate of respiration (no net oxygen production) ✓ 3 at such a low light intensity light limits the rate of photosynthesis, not carbon dioxide ✓	3	2.4 2.1 × 2	1 ALLOW 35 to 45 3 ALLOW the rate of respiration is the same at both concentrations as an alternative explanation for the same mark
8(d)	1 X is RuBP and Y is GP ✓ 2 less carbon dioxide, so less RuBP is combined with carbon dioxide by <u>rubisco</u> (less carbon fixation) ✓ 3 RuBP is still regenerated from TP, so RuBP accumulates ✓ 4 less GP is made, but GP is still converted to TP using ATP and reduced NADP, so GP falls ✓ 5 ATP and reduced NADP are still supplied by the light-dependent stage, as the light intensity did not change ✓	max 4	2.3 2.1 × 3	1 Both needed ALLOW ribulose biphosphate and glycerate 3-phosphate 2 ALLOW RuBisCO 4 ALLOW triose phosphate
8(e)	1 X (RuBP) falls and Y (GP) rises ✓ 2 the light-dependent stage stops, so no ATP or reduced NADP is made ✓ 3 GP is no longer reduced to TP, so it accumulates ✓ 4 RuBP is not regenerated from TP, but the RuBP left still combines with carbon dioxide, so RuBP is used up ✓	max 3	3.1 × 3	1 Both needed; ECF from the identities in (d)
	Total	15		

Examiner notes

What makes this hard: You have to realise the graph shows net, not gross, photosynthesis before you compare, and that at 200 $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ light, not carbon dioxide, limits the rate. X and Y are not named, so you work out which is RuBP and which is GP from how they change, then predict what happens when the light goes off.

(b) The intercept of -8 at zero light intensity is the rate of respiration. A candidate who quotes the net rate as the gross rate has not added the rate of respiration.

(d) RuBP rises because its use (fixation) falls while its formation (regeneration) continues.

Question 9 Biological processes · Super hard · Respiration practical: oxygen uptake and RQ of castor bean seeds

Question	Answer	Marks	AO element	Guidance
9(a)*	Level 3 (5 or 6 marks) A detailed method that controls variables and would give valid measurements of oxygen uptake at a range of at least five temperatures, and clear processing to a rate per unit mass per unit time, with repeats and a graph. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 or 4 marks) A method with some detail and some control of variables, and some processing of the results; or a detailed method with little processing; or clear processing with a limited method. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 or 2 marks) A simple method or a limited description of processing. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	1.2 ×2 2.2 ×2 3.3 ×2	Indicative scientific points may include: Method • Same mass of seeds (e.g. 5.0 g) and the same volume of potassium hydroxide solution in each trial • Tube B with an equal volume of glass beads (thermobarometer) compensates for changes in temperature and atmospheric pressure • Leave the tubes in the water bath for about 10 minutes with the tap open to reach the temperature of the bath (equilibrate) • Close the tap, start the stopwatch; record the distance moved by the coloured liquid in a set time (e.g. 10 minutes) • Reset the liquid with the syringe; repeat at least three times at each temperature • At least five temperatures, e.g. 10, 15, 20, 25, 30, 35 °C, checked with a thermometer in the bath • Safety: potassium hydroxide is corrosive (eye protection, gloves); seeds kept on the gauze away from the solution Processing • Volume of oxygen = $\pi r^2 \times \text{distance moved}$ (or read the volume from the syringe needed to return the liquid) • Divide by time and by mass of seeds: rate in $\text{mm}^3 \text{g}^{-1} \text{min}^{-1}$ (or h^{-1}) • Calculate the mean of the repeats at each temperature, identifying anomalous results • Plot rate (y-axis) against temperature (x-axis); calculate Q_{10} if required
Question	Answer	Marks	AO element	Guidance
9(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $99.0 \text{ mm}^3 \text{g}^{-1} \text{h}^{-1}$ award 3 marks 1 volume in 20 minutes = $\pi \times 0.50^2 \times 42 = 33.0 \text{ mm}^3$ ✓ 2 per hour = $33.0 \times 3 = 99.0 \text{ mm}^3 \text{h}^{-1}$ ✓ 3 rate = $99.0 \div 1.0 = 99.0 \text{ mm}^3 \text{g}^{-1} \text{h}^{-1}$ ✓	3	2.4 ×3	1 Radius = 0.50 mm 2 The mass is 1.0 g, so the value per gram is the same 3 ALLOW 99 98.96 (more than 3 significant figures) scores 2 marks 396 (1.0 mm used as the radius) scores 2 marks



Question 9 continued

Question	Answer	Marks	AO element	Guidance
9(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 0.71 award 3 marks 1 with water, the movement (12 mm) is oxygen taken up minus carbon dioxide released ✓ 2 carbon dioxide released is equivalent to $42 - 12 = 30$ mm ✓ 3 $RQ = 30 \div 42 = 0.71$ ✓ 4 lipid / fat / oil (RQ about 0.7) ✓	4	2.4 ×3 3.1	1 The liquid still moves towards tube A because less carbon dioxide is released than oxygen is taken up 2 ALLOW in volumes: 23.6 mm³ carbon dioxide, 33.0 mm³ oxygen 3 ALLOW 0.714 or 0.7 $12 \div 42 = 0.29$ scores 0 for this mark 4 ECF from an incorrect RQ: carbohydrate for about 1.0, protein for about 0.9
9(d)	1 lipids contain more hydrogen atoms (C-H bonds) per gram ✓ 2 so more reduced NAD (and reduced FAD) is formed when lipids are respired ✓ 3 more hydrogen ions / electrons for the electron transport chain, so more ATP is made by oxidative phosphorylation (chemiosmosis) ✓	max 2	1.2 ×2	3 DO NOT ALLOW lipids 'produce' or 'contain more' energy as the only point
	Total	15		

Examiner notes

What makes this hard: With water in place of potassium hydroxide, the liquid moves by the difference between the oxygen taken in and the carbon dioxide given out: you have to see this before you can find the RQ. The plan in (a) has to cover equilibration, a control tube and turning distances into a rate per gram per hour.

(c) The commonest error is to divide the two readings directly. The water experiment does not measure carbon dioxide on its own: the difference between the two experiments does.

(d) Examiners penalise 'energy is produced': energy is released and transferred to ATP.

Question 10 Biological processes · Super hard · Enzyme inhibition: treating ethylene glycol poisoning with ethanol

Question	Answer	Marks	AO element	Guidance
10(a)	1 ethanol is a <u>competitive</u> inhibitor ✓ 2 the rate is much lower with ethanol at low concentrations of ethylene glycol, but the curves approach the same maximum rate (about $10 \mu\text{mol dm}^{-3} \text{s}^{-1}$) at high concentrations ✓ 3 ethanol has a similar shape to ethylene glycol and binds to the <u>active site</u>, so fewer enzyme-substrate complexes form ✓ 4 at high ethylene glycol concentration, ethylene glycol molecules outcompete ethanol for the active sites ✓	max 3	3.1 2.3 1.2	2 Data needed 3 ALLOW complementary to the active site 4 ALLOW are more likely to collide with the active site
10(b)	1 denaturation changes the shape of the active site (tertiary structure), so fewer enzyme molecules could work and the maximum rate would be lower at all concentrations ✓ 2 with ethanol the rate still approaches the same maximum, so the active sites are still functional / ethanol binds reversibly ✓	2	2.3 1.2	2 IGNORE 'ethanol kills the enzyme'
10(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 13 to 17 (%) award 2 marks 1 readings: 9.1 without ethanol and 7.7 with ethanol; $(9.1 - 7.7) \div 9.1 \times 100$ ✓ 2 15 (%) ✓	2	2.4×2	1 ALLOW readings of 9.0 to 9.2 and 7.6 to 7.8 2 ALLOW 13 to 17 18% (divided by 7.7) scores 1 mark
10(d)(i)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 2.8 to 3.6 $\mu\text{mol dm}^{-3} \text{s}^{-1}$ award 3 marks 1 tangent drawn to the curve at 600 s ✓ 2 gradient calculated from a large triangle, e.g. $(4000 - 2120) \div (893 - 300)$ ✓ 3 3.2 $\mu\text{mol dm}^{-3} \text{s}^{-1}$ ✓	3	2.4×3	1 Tangent must touch the curve at 600 s only 3 ALLOW 2.8 to 3.6
10(d)(ii)	1 substrate (ethylene glycol) is being used up: about 3100 $\mu\text{mol dm}^{-3}$ of product has formed, so only about 0.9 mmol dm^{-3} remains ✓ 2 so fewer collisions between substrate molecules and active sites per second / fewer enzyme-substrate complexes ✓	2	2.1×2	1 Reference to the remaining substrate needed 2 IGNORE 'enzyme used up'

Question 10 continued

Question	Answer	Marks	AO element	Guidance
10(e)	1 ethanol is also oxidised by the enzyme / metabolised, so its concentration falls ✓ 2 inhibition is only effective while there is plenty of ethanol compared with ethylene glycol ✓ 3 this gives time for the ethylene glycol to be excreted unchanged by the kidneys ✓	max 2	2.1 × 2	
	Total	14		

Examiner notes

What makes this hard: You are not told the type of inhibition: you have to spot that the two curves meet at high substrate concentration and argue from that. The rate in (d)(i) needs a tangent on a different graph, and (e) asks you to think about what happens to the ethanol itself in the body.

(a) The convergence of the curves at high substrate concentration is the evidence; a candidate who names non-competitive inhibition scores 0 for mp 1 and mp 3.

(d)(i) The gradient at 600 s, $3.2 \mu\text{mol dm}^{-3} \text{ s}^{-1}$, equals the rate in Fig. 10.1 at the substrate concentration remaining ($0.93 \text{ mmol dm}^{-3}$), which links the two figures.

Marked by hand here. On iPad, Plumi marks questions like this one for you: tryplumi.app



SECTION B: BIOLOGICAL DIVERSITY

Question 11 Biological diversity · Easy · Biological molecules: measuring glucose with a colorimeter

Question	Answer	Marks	AO element	Guidance
11(a)	1 glucose is a reducing sugar and reduces copper(II) ions to copper(I) (forming a brick-red precipitate of copper(I) oxide) ✓ 2 more glucose reduces more copper(II) ions, so fewer copper(II) ions remain: the solution is less blue and absorbs less (red) light ✓	2	1.2 × 2	1 ALLOW Cu^{2+} to Cu^+ 2 IGNORE references to the colour of the precipitate
11(b)	1 stock solution: $4.0 \div 10.0 \times 20 = 8.0 \text{ cm}^3$ ✓ 2 distilled water: $20 - 8.0 = 12.0 \text{ cm}^3$ ✓	2	2.4 × 2	2 ECF from an incorrect volume of stock
11(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 440 to 470 mmol dm⁻³ award 2 marks 1 reading for the diluted juice = 4.6 mmol dm^{-3} ✓ 2 $\times 100 = 460 \text{ mmol dm}^{-3}$ ✓	2	2.4 × 2	1 ALLOW 4.4 to 4.7 2 ALLOW 440 to 470 (e.g. 455) 4.6 (not multiplied by 100) scores 1 mark
11(d)	1 volume / concentration of Benedict's reagent ✓ 2 temperature of heating ✓ 3 time of heating ✓ 4 time between heating and reading the absorbance ✓ 5 same colorimeter, filter and cuvette ✓	max 2	3.3 × 2	1 ALLOW volume of glucose solution Mark the first two answers
11(e)	1 heat (boil) with dilute hydrochloric acid, to <u>hydrolyse</u> the (glycosidic bond in) sucrose ✓ 2 neutralise with an alkali, e.g. sodium hydrogencarbonate / sodium hydroxide ✓ 3 then heat with Benedict's reagent: more precipitate / lower absorbance than before hydrolysis ✓	max 2	1.1 × 2	2 DO NOT ALLOW adding Benedict's reagent to the acidified solution 3 Must be compared with the result before hydrolysis
	Total	10		

Examiner notes

(c) Fig. 11.2 gives $4.55 \text{ mmol dm}^{-3}$ at an absorbance of 0.40, so the juice contains about 0.46 mol dm^{-3} of reducing sugar, typical of a fruit juice. Fructose is also a reducing sugar, which is why the answer is in glucose equivalents.

Question 12 Biological diversity · Medium · Biodiversity: Simpson's index in two meadows

Question	Answer	Marks	AO element	Guidance
12(a)	1 set up a grid / lay out two tape measures at right angles to each other ✓ 2 use random coordinates (from random number tables / a random number generator) to place the quadrats ✓	2	3.4 × 2	1 ALLOW lines / string for tape measures ALLOW an annotated diagram 2 DO NOT ALLOW systematic sampling / transects / stratified sampling IGNORE throwing quadrats
12(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 0.42 award 3 marks 1 $N = 130$ ✓ 2 $\Sigma(n/N)^2 = 0.5453 + 0.0286 + 0.0038 + 0.0005 + 0.0001 = 0.578$ ✓ 3 $D = 0.42$ ✓	3	2.4 × 3	2 IGNORE decimal places in $\Sigma(n/N)^2$ 3 Correct answer to the wrong number of decimal places (e.g. 0.4 or 0.4217) scores 2 marks 0.58 ($\Sigma(n/N)^2$ given as D) scores 2 marks
12(c)	1 meadow A has a higher D (0.85 compared with 0.42) so it is more diverse ✓ 2 species richness: A has 8 species, B has 5 ✓ 3 species evenness: numbers are more even in A; B is dominated by perennial rye-grass (96 of 130 plants, 74%) ✓	3	2.3 × 3	3 ALLOW 'most of the plants in B are rye-grass'
12(d)	1 fertiliser benefits fast-growing species (grasses such as rye-grass) most ✓ 2 these grow taller and outcompete / shade other species for light ✓ 3 species adapted to low-nutrient soils (e.g. yellow rattle) lose their advantage and are lost ✓	max 2	2.1 × 2	
	Total	10		

Examiner notes

(b) The value of D for meadow A, 0.85, follows from Table 12.1 (0.855).

Question 13 Biological diversity · Medium · The immune response: vaccination and antivenom

Question	Answer	Marks	AO element	Guidance
13(a)	1 antigens (from the vaccine) are engulfed and presented by phagocytes / antigen-presenting cells ✓ 2 T helper cells with complementary receptors bind to the presented antigen and release cytokines (interleukins), which activate B cells ✓ 3 B cells with complementary antibodies (receptors) are selected (<u>clonal selection</u>) ✓ 4 they divide by mitosis (clonal expansion) and differentiate into plasma cells, which secrete antibody: this takes time ✓	max 3	1.2 × 3	
13(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 15 to 17 (times) award 2 marks 1 640 ÷ 40 ✓ 2 16 (times) ✓	2	2.4 × 2	1 ALLOW 620 to 660 and 38 to 42 2 ALLOW 15 to 17
13(c)	1 (B and T) memory cells were made in the first (primary) response ✓ 2 memory cells recognise the antigen and divide rapidly into plasma cells, so the second response is faster and larger ✓	2	1.2 × 2	1 IGNORE antibodies remain in the blood 2 Both 'faster' and 'larger' needed with an explanation
13(d)	1 E antigen-binding site ✓ 2 G disulfide bridge / bond ✓	2	2.3 × 2	1 ALLOW variable region 2 ALLOW hinge region IGNORE 'bond' alone
13(e)	1 antibodies are already made, so they act at once: <u>passive</u> immunity ✓ 2 no memory cells are made, and the antibodies are broken down (within weeks) ✓	2	2.1 × 2	
	Total	11		

Examiner notes

(c) A description of the graph (the second peak is higher) scores 0: the marks are for memory cells and why they give a faster, larger response.

Question 14 Biological diversity · Medium · Sex linkage: tortoiseshell cats

Question	Answer	Marks	AO element	Guidance
14(a)	1 males have only one X chromosome (XY), so they carry only one allele of the coat colour gene ✓ 2 tortoiseshell needs both alleles (heterozygous, codominant), which needs two X chromosomes ✓	2	1.2 × 2	1 The Y chromosome does not carry the gene 2 ALLOW only females can be heterozygous
14(b)	1 parental genotypes $X^O X^B \times X^B Y$ ✓ 2 gametes X^O, X^B and X^B, Y ✓ 3 offspring genotypes $X^O X^B$, $X^B X^B$, $X^O Y$, $X^B Y$ ✓ 4 tortoiseshell female : black female : orange male : black male = 1 : 1 : 1 : 1 ✓	4	2.5 × 2 2.6 × 2	1 Sex chromosomes must be shown If incorrect symbols are used throughout: max 3 2 If a full genotype (e.g. $X^O X^B$) is written as a single gamete, no further marks 3 ALLOW a Punnett square for the gamete and offspring marks ALLOW ECF for offspring genotypes and phenotypes from incorrect gametes 4 Phenotypes must be linked to genotypes and sexes
14(c)	1 one parent produced a gamete with two sex chromosomes (sex chromosomes did not separate in meiosis I / II) ✓ 2 a gamete with two sex chromosomes fused with a normal gamete, e.g. an $X^O Y$ sperm (orange father) with an X^B egg, an $X^B Y$ sperm (black father) with an X^O egg, or an $X^O X^B$ egg with a Y sperm ✓	2	2.1 × 2	1 ALLOW non-disjunction 2 Genotypes must give both alleles
14(d)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $\frac{1}{16}$ (0.0625) award 2 marks 1 $P(X^O X^B) = \frac{1}{4}$ and $P(dd) = \frac{1}{4}$ ✓ 2 $\frac{1}{16}$ (0.0625) ✓	2	2.4 × 2	1 ALLOW a correct genetic diagram or Punnett square 2 ALLOW 1 in 16 or 6.25% $\frac{1}{8}$ (probability among female kittens only) scores 1 mark
Total		10		

Examiner notes

(d) The genes are on different chromosomes, so the probabilities multiply: listing all 16 combinations of gametes gives 1/16.



Question 15 Biological diversity · Hard · Epistasis and the chi-squared test: fruit colour in summer squash

Question	Answer	Marks	AO element	Guidance
15(a)	1 two genes (on different chromosomes / unlinked) control fruit colour ✓ 2 the ratio is about 12 : 3 : 1 (208 : 57 : 15 = 11.9 : 3.3 : 0.9), a modified 9 : 3 : 3 : 1 ratio ✓ 3 <u>epistasis</u>: a dominant allele of one gene masks the expression of the other gene ✓ 4 green fruit only when both genes are homozygous recessive ✓	max 3	2.1 ×3	2 Ratio must be supported with a calculation 3 ALLOW dominant epistasis
15(b)	1 F₁ genotypes WwYy × WwYy ✓ 2 gametes WY, Wy, wY, wy (from each parent) ✓ 3 offspring genotypes shown, e.g. 16-square Punnett square ✓ 4 W_ _ _ white (12), ww Y_ yellow (3), wwyy green (1) ✓	4	2.5 ×2 2.6 ×2	1 If incorrect symbols are used throughout: max 3 2 If a full genotype (e.g. WwYy) or a pair of alleles of one gene (e.g. Ww) is written as a single gamete, no further marks 3 ALLOW a Punnett square for the gamete and offspring marks ALLOW ECF for offspring genotypes and phenotypes from incorrect gametes 4 ALLOW the symbols used the other way round if consistent
15(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 0.76 award 2 marks 1 expected numbers: 210, 52.5 and 17.5 ✓ 2 $\chi^2 = 0.019 + 0.386 + 0.357 = 0.76$ ✓ 3 degrees of freedom = 3 – 1 = 2; critical value = 5.99 (at $p = 0.05$) ✓ 4 0.76 is less than 5.99, so there is no significant difference: the null hypothesis is accepted and the results fit a 12 : 3 : 1 ratio (differences due to chance) ✓	4	2.4 ×2 3.1 ×2	1 280 × 12/16, 280 × 3/16, 280 × 1/16 2 ALLOW 0.762 3 DO NOT ALLOW 3 degrees of freedom (7.81) 4 ECF from an incorrect χ^2 value
15(d)	1 the dominant allele Y codes for an enzyme that converts a green pigment (precursor) into a yellow pigment ✓ 2 the dominant allele W codes for a product (e.g. an inhibitor) that blocks an earlier step, so no pigment is made (white) ✓ 3 in ww plants the pathway works; wwyy lacks the enzyme, so the green precursor remains ✓	max 2	2.1 ×2	2 ALLOW W codes for a transcription factor that switches off the pathway
	Total	13		

Question 15 notes continued

Examiner notes

What makes this hard: You have to recognise a 12 : 3 : 1 ratio from raw counts and link it to one gene masking another. The test needs three expected numbers, the right degrees of freedom (2, not 3) and a conclusion in words.

(c) Three phenotype classes give 2 degrees of freedom. Using 3 (7.81) happens to give the same conclusion here but loses the mark.

(a) A 9 : 3 : 4 ratio (157.5 : 52.5 : 70) gives χ^2 far above the critical value: the data point to dominant, not recessive, epistasis.

Question 16 Biological diversity · Hard · Variation and the t-test: limpet shells on a rocky shore

Question	Answer	Marks	AO element	Guidance
16(a)	there is no (significant) difference between the mean height to base ratio of limpet shells on the upper and lower shore ✓	1	3.2	ALLOW any difference is due to chance DO NOT ALLOW 'there is no correlation'
16(b)	1 means: upper shore 0.604, lower shore 0.509 ✓ 2 standard deviation, upper shore = 0.037 ✓ 3 standard deviation, lower shore = 0.043 ✓	3	2.4 × 3	1 ALLOW 0.60 and 0.51 (2 s.f.) 2 ALLOW 0.0366 0.034 (divided by n) scores 0 for this mark 3 ALLOW 0.0432
16(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 4.7 award 2 marks 1 $t = \frac{0.604 - 0.509}{\sqrt{0.037^2/8 + 0.043^2/8}}$ ✓ 2 $t = 4.7$ ✓ 3 degrees of freedom = $8 + 8 - 2 = 14$; critical value = 2.145 (at $p = 0.05$) ✓ 4 4.7 is greater than 2.145 (and than 2.977 at $p = 0.01$), so there is a significant difference: reject the null hypothesis; less than 5% (1%) probability that the difference is due to chance ✓	4	2.4 × 2 3.1 × 2	1 ECF from (b) 2 ALLOW 4.74 3 DO NOT ALLOW 7 or 16 degrees of freedom 4 ECF from an incorrect t value DO NOT ALLOW 'the null hypothesis is proved wrong'
16(d)	1 a smaller base relative to the volume of the shell: smaller surface area to volume ratio ✓ 2 less water is lost by evaporation (desiccation) when the tide is out ✓ 3 a taller shell can hold more water ✓	max 2	2.1 × 2	



Question 16 continued

Question	Answer	Marks	AO element	Guidance
16(e)	1 the <i>t</i>-test shows a significant difference, but not what causes it ✓ 2 the difference could be genetic: natural selection favours taller shells on the upper shore ✓ 3 other factors differ between the shores (e.g. wave action, age or size of limpets, food) ✓ 4 small sample (8) from one shore ✓ 5 a transplant experiment (move limpets between shores and measure new shell growth) is needed to test the cause ✓	max 3	3.2 ×3	2 ALLOW the limpets may have settled there because of their shape
	Total	13		

Examiner notes

What makes this hard: Every statistic is worked out by hand from raw data, and the standard deviation must use $n - 1$. In (e) a significant difference does not tell you why the shells differ: you have to separate a genetic cause from the effect of growing on the upper shore.

(c) With the means and standard deviations rounded to 3 d.p., $t = 4.74$; unrounded values give the same result. The difference is significant even at $p = 0.01$.

(b) Dividing by n instead of $n - 1$ is the commonest error in standard deviation calculations.

Question 17 Biological diversity · Hard · Natural selection and Hardy-Weinberg: warfarin resistance in rats

Question	Answer	Marks	AO element	Guidance
17(a)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 288 award 3 marks 1 $q^2 = 216 \div 600 = 0.36$, so $q = 0.60$ ✓ 2 $p = 1 - 0.60 = 0.40$; $2pq = 2 \times 0.40 \times 0.60 = 0.48$ ✓ 3 $0.48 \times 600 = 288$ ✓	3	2.4 ×3	1 Susceptible rats are rr 3 Correct answer scores 3 marks Starting from $p^2 = 384 \div 600$ scores 0
17(b)	1 the principle assumes no selection, but warfarin kills susceptible rats (selection for R) ✓ 2 migration of rats into or out of the town ✓ 3 mating may not be random / the population may be small ✓	max 2	2.1 ×2	

Question 17 continued

Question	Answer	Marks	AO element	Guidance
17(c)	1 without warfarin, the R allele no longer gives an advantage ✓ 2 RR rats (need more vitamin K so) are more likely to suffer bleeding / vitamin K deficiency and die ✓ 3 rr rats are more likely to survive and reproduce, passing on the r allele ✓ 4 so the frequency of R falls over generations: selection against R (directional selection) ✓	max 3	2.1 × 3	
17(d)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = -34 (%) award 3 marks 1 before: $q = 0.60$, resistant = $1 - 0.36 = 0.64$ ✓ 2 after: $q = 0.76$, resistant = $1 - 0.5776 = 0.4224$ ✓ 3 $(0.4224 - 0.64) \div 0.64 \times 100 = -34$ (%) ✓	3	2.4 × 3	1 ALLOW $p^2 + 2pq = 0.16 + 0.48$ 2 ALLOW $0.0576 + 0.3648$ 3 ALLOW 'a decrease of 34%' -40% (change in the frequency of R) scores 0
	Total	11		

Examiner notes

What makes this hard: Only the susceptible rats (rr) can be recognised, so you have to start from q^2 , not p^2 . In (d) you compare the proportion of resistant rats at two times, not the frequency of the allele.

(d) The proportion of resistant rats falls by less (34%) than the frequency of R (40%), because most R alleles are in heterozygotes.

Question 18 Biological diversity · Super hard · PCR and DNA profiling: finding the father of a kākāpō chick

Question	Answer	Marks	AO element	Guidance
18(a)(i)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 5.37×10^{10} award 2 marks 1 50×2^{30} ✓ 2 5.37×10^{10} ✓	2	2.4 × 2	2 ALLOW 5.4×10^{10} or the exact value 53 687 091 200
18(a)(ii)	primers / nucleotides are used up / not every strand is copied in every cycle / the DNA polymerase loses activity ✓	1	2.1	IGNORE 'errors' unqualified
18(b)	1 DNA is negatively charged (phosphate groups), so it moves towards the positive electrode (anode) ✓ 2 smaller fragments move faster / further through the gel ✓	2	2.1 × 2	1 DO NOT ALLOW DNA is positively charged 2 ALLOW fragments separate by length / size / number of base pairs DO NOT ALLOW lighter fragments move further unless linked to size

Question 18 continued

Question	Answer	Marks	AO element	Guidance
18(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 59 to 61 award 4 marks 1 the distance is not proportional to size (16.0 mm from 100 to 200 bp but only 9.5 mm from 200 to 300 bp), so a calibration curve is drawn: distance against size (smooth curve) or against log (size) ✓ 2 size of W = 256 bp ✓ 3 number of repeats = $(256 - 136) \div 2$ ✓ 4 60 ✓	4	2.4 × 4	1 ALLOW a calculated interpolation using $\log_{10}(\text{size})$ 2 ALLOW 254 to 258 bp 3 ECF from an incorrect size 4 ALLOW 59 to 61; must be a whole number Straight-line interpolation between the 200 and 300 bp bands gives 261 bp and 62 or 63 repeats: scores 1 mark (mp 3)
18(d)	1 F₂ ✓ 2 the chick's two bands that are not in the mother's lane (W, at 256 bp, and the band at about 228 bp) must have come from the father, and F₂ has both of them ✓ 3 the father passes on one allele at each locus: F₁ shares only the locus 1 band and F₃ shares only W, so they are excluded ✓	3	2.3 1.2 × 2	2 ALLOW bands identified by position
18(e)	1 to avoid breeding closely related birds (inbreeding) ✓ 2 inbreeding increases homozygosity, so harmful recessive alleles are expressed more often ✓ 3 to keep as much genetic diversity (as many different alleles) as possible in a very small population that has been through a genetic bottleneck ✓	max 2	2.1 × 2	2 ALLOW reduces fitness / increases genetic disease
	Total	14		

Examiner notes

What makes this hard: The ladder bands are not evenly spaced, so a straight line between two of them gives the wrong size: you need a calibration curve. To find the father you first take the mother's bands away from the chick's, then match what is left.

(c) The ladder bands do not lie on a straight line against size, nor exactly on a straight line against $\log_{10}(\text{size})$, so a smooth calibration curve is the expected method; interpolating against $\log_{10}(\text{size})$ between the 200 and 300 bp bands gives 256 bp. A straight line between 200 and 300 bp against size gives 261 bp.

(d) Locus 1 bands are 170 to 230 bp and locus 2 bands are 250 to 330 bp, so each bird shows at most two bands for each locus.

Question 19 Biological diversity · Super hard · Succession on sand dunes: planning, choosing and using a statistical test

Question	Answer	Marks	AO element	Guidance
19(a)*	Level 3 (5 or 6 marks) A clear sampling plan along a transect with valid methods of measuring both variables at the same points, and clear steps that make the data valid and repeatable. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 or 4 marks) A sampling plan with some detail and some description of how both variables are measured, and some steps for valid data; or a clear plan with few steps for validity. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 or 2 marks) A limited plan or a limited description of the measurements. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	1.2 ×2 2.2 ×2 3.3 ×2	Indicative scientific points may include: Sampling - Line transect from the strand line inland, across the dune ridges and slacks - Interrupted belt transect: quadrat (e.g. 1 m²) placed at regular intervals (e.g. every 20 m) so that all zones are sampled - At each point, identify and count the number of plant species in the quadrat (identification key) Measurements - Soil sample from the same quadrat, at the same depth and volume, with a soil corer - Organic matter: dry the soil to constant mass, weigh, heat strongly in a crucible to constant mass, reweigh; loss in mass ÷ dry mass × 100 Validity and repeatability - Repeat with further parallel transects and use mean values at each distance - Sample on the same day / same season; same person identifies species; same quadrat size - Record other abiotic factors that change along the transect (e.g. pH, water content) as possible confounding variables - Safety near the sea and on unstable sand; avoid trampling; permission from the landowner
Question	Answer	Marks	AO element	Guidance
19(b)	1 Spearman's rank correlation coefficient ✓ 2 the students are looking for a correlation / relationship between two variables measured at the same sampling points (paired data), not a difference between two means or between observed and expected numbers ✓	2	3.1 ×2	1 DO NOT ALLOW chi-squared or <i>t</i>-test 2 ALLOW at least 5 (here 10) pairs of values; data need not be normally distributed

Question 19 continued

Question	Answer	Marks	AO element	Guidance
19(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 0.91 award 3 marks 1 both variables ranked; the tied species counts (8 and 8) are both given the mean rank 6.5 ✓ 2 $\Sigma d^2 = 15.5$ ✓ 3 $r_s = 1 - \frac{6 \times 15.5}{10 \times 99} = 0.91$ ✓ 4 0.91 is greater than the critical value 0.648 ($n = 10$, $p = 0.05$): significant positive correlation; reject the null hypothesis of no correlation ✓	4	2.4 ×3 3.1	1 Ranks shown in a table or list 2 ECF from ranks with a single error 3 ALLOW 0.906 or 0.9 Ranking the tie as 6 and 7 (instead of 6.5 and 6.5) gives 0.89 or 0.92: scores 2 marks 4 ECF from an incorrect r_s DO NOT ALLOW 'proves that organic matter causes...'
19(d)	1 the significant positive correlation supports a link between the two variables ✓ 2 but correlation does not show that one causes the other ✓ 3 plants that die and decompose add organic matter, so more species could cause more organic matter (reverse causation) ✓ 4 both increase with the age of the dune / other factors change along the transect (e.g. pH, water content, shelter from salt spray) ✓ 5 a plausible mechanism exists: organic matter (humus) holds water and nutrients ✓ 6 only one transect / ten points / one dune system ✓	max 3	3.2 ×3	
	Total	15		

Examiner notes

What makes this hard: You choose the test yourself from three formulae, rank both variables and deal with two tied values. In (d) a correlation does not show cause: either variable could affect the other, and both change with the age of the dune.

(c) With the tie given mean ranks, $\Sigma d^2 = 15.5$ and the coefficient is 0.906 (the same to 3 s.f. if the ranks are correlated directly). The critical value 0.648 for $n = 10$ is the exact two-tailed value at $p = 0.05$.

(b) Candidates are expected to select an appropriate statistical test (H420 mathematical skill M1.9); only Spearman's rank tests for a correlation between paired values.

Question 20 Biological diversity · Super hard · Gene regulation: diauxic growth of *E. coli* and the *lac* operon

Question	Answer	Marks	AO element	Guidance
20(a)	1 lag phase: the bacteria are synthesising enzymes / proteins (and taking up water) before they divide ✓ 2 (so) few cells divide / the rate of division is low ✓	2	2.1 × 2	1 IGNORE 'adjusting to the new conditions' unqualified 2 ALLOW no division yet
20(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 28 to 33 min award 3 marks 1 two points on the straight part of the first rise, e.g. $\log_{10}$ 5.3 at 1.5 h and 6.5 at 3.5 h: an increase of 1.2 in 2.0 h ✓ 2 number of generations = $1.2 \div \log_{10} 2 = 4.0$ (16-fold increase = 2^4) ✓ 3 $120 \div 4.0 = 30$ min ✓	3	2.4 × 3	1 Any two points on the straight section 2 ALLOW $1.2 \div 0.301$ 3 ALLOW 28 to 33 min An increase in $\log_{10}$ used as the number of generations (100 min) scores 1 mark
20(c)	1 the glucose has been used up (it is used first) ✓ 2 when the glucose runs out, very little β-galactosidase / lactose permease is present, so lactose cannot be used at once ✓ 3 lactose binds to the repressor protein, changing its shape so it no longer binds to the operator ✓ 4 RNA polymerase binds to the promoter and the structural genes (<i>lacZ</i>, <i>lacY</i>) are transcribed and translated ✓ 5 β-galactosidase and lactose permease are made, which takes time: a second lag ✓ 6 lactose is then taken up and hydrolysed to glucose and galactose, which are respired, so growth resumes ✓	max 4	2.1 × 4	2 DO NOT ALLOW a repeat of the stem (glucose lowers transcription) without this consequence 3 ALLOW allolactose
20(d)	1 these bacteria already contain β-galactosidase and lactose permease (made while growing on lactose) ✓ 2 so they can use lactose as soon as the glucose runs out: little time is needed to make new enzymes ✓	2	2.1 × 2	1 ALLOW the operon was already switched on
20(e)	1 no further growth after 4 hours (the number of cells stays the same, or falls) ✓ 2 the repressor stays bound to the operator, so β-galactosidase is never made and lactose cannot be used ✓	2	3.1 × 2	
Total		13		

Question 20 notes continued**Examiner notes**

What makes this hard: You have to turn a log scale into a number of doublings before you can find a generation time. The flat part of the curve is not explained for you: you have to see that the glucose has run out and the *lac* operon is only now being switched on.

(b) A $\log_{10}$ increase of 1.2 is a $10^{1.2} = 16$ -fold increase, which is 4 doublings in 120 minutes. Fig. 20.1 is drawn from a 30-minute generation time in the first growth phase and 45 minutes in the second.

(c) The stem gives the effect of glucose on transcription, but not the role of lactose: candidates must explain how lactose induces the operon once the glucose has gone.

Marked by hand here. On iPad, Plumi marks questions like this one for you: tryplumi.app



SECTION C: UNIFIED BIOLOGY

Question 21 Unified biology · Easy · Practical skills: chromatography of photosynthetic pigments

Question	Answer	Marks	AO element	Guidance
21(a)	ink would dissolve in the solvent and move up the paper / would separate and confuse the results ✓	1	1.2	ALLOW pencil (graphite) is insoluble in the solvent
21(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 0.44 to 0.46 award 1 mark 1 $R_f = 36 \div 80 = 0.45$ (distances measured from the origin to the centre of the spot and to the solvent front) ✓ 2 chlorophyll <i>b</i> ✓	2	2.4 3.1	1 ALLOW 0.44 to 0.46 (measurements ± 1 mm) 2 ECF from an incorrect R_f value
21(c)	xanthophyll ($R_f = 57 \div 80 = 0.71$) ✓	1	2.3	ALLOW 0.70 to 0.73 with xanthophyll
21(d)	so that the position of the solvent front can be marked (it is needed to calculate R_f) / so that pigments do not run off the paper ✓	1	3.3	IGNORE 'to stop the pigments mixing'
21(e)	1 each pigment absorbs a different range of wavelengths of light ✓ 2 so a wider range of wavelengths is absorbed and more light energy is trapped ✓ 3 accessory pigments pass energy to chlorophyll <i>a</i> at the reaction centre (of the photosystem) ✓	max 2	1.2 $\times 2$	
21(f)	use thin-layer chromatography / a longer strip of paper / a different solvent (mixture) / two-way chromatography with a second solvent ✓	1	3.4	
Total		8		

Examiner notes

(b) and (c) The chromatogram is drawn actual size, so candidates measure the distances themselves: the solvent front is 80 mm, spot S 36 mm and spot Q 57 mm from the origin. The R_f values in Table 21.1 differ by at least 0.06, so each measured value identifies one pigment.

Question 22 Unified biology · Medium · Cell division: mitotic index in an onion root tip

Question	Answer	Marks	AO element	Guidance
22(a)	1 A metaphase ✓ 2 B anaphase ✓	2	1.1 $\times 2$	
22(b)	C, A, B, D ✓	1	1.1	

Question 22 continued

Question	Answer	Marks	AO element	Guidance
22(c)	1 centromeres divide / split ✓ 2 sister chromatids separate and are pulled to opposite poles ✓ 3 by the shortening of spindle fibres (attached at the centromeres), centromere first ✓	max 2	1.1 × 2	2 DO NOT ALLOW homologous chromosomes separate
22(d)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 0.14 award 2 marks 1 number in mitosis = $15 + 6 + 4 + 3 = 28$; total = 200 ✓ 2 $28 \div 200 = 0.14$ ✓	2	2.4 × 2	2 ALLOW 14% $28 \div 172 (0.16)$ scores 1 mark
22(e)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 39.6 min (ALLOW 40) award 2 marks 1 $6 \div 200 \times 22 \times 60$ ✓ 2 39.6 min ✓ 3 assumption: the number of cells at each stage is proportional to the time spent in that stage / the cells are not dividing in step (not synchronised) ✓	3	2.4 × 2 3.1	2 ALLOW 40 min
22(f)	1 acid breaks down the middle lamella / pectin holding the cells together (and stops further division) ✓ 2 squashing spreads the cells into a single layer so light passes through and chromosomes can be seen ✓	2	1.2 × 2	1 ALLOW hydrolyses
Total		12		

Examiner notes

(e) 6 of 200 cells in metaphase means metaphase takes 3% of the 22-hour cycle: 39.6 minutes.

Question 23 Unified biology · Medium · Ecosystems: energy transfer and the nitrogen cycle

Question	Answer	Marks	AO element	Guidance
23(a)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 1.22 (%) award 2 marks 1 $20\,800 \div 1\,700\,000 \times 100$ ✓ 2 1.22 (%) ✓	2	2.4 × 2	2 ALLOW 1.2
23(b)	$20\,800 - 11\,970 = 8830 \text{ kJ m}^{-2} \text{ year}^{-1}$ ✓	1	2.4	
23(c)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 16.8 (%) award 2 marks 1 $1480 \div 8830 \times 100$ ✓ 2 16.8 (%) ✓	2	2.4 × 2	1 ECF from (b) 2 ALLOW 17 7.1% (GPP used) scores 1 mark

Question 23 continued

Question	Answer	Marks	AO element	Guidance
23(d)	1 light reflected from leaves / passes through leaves ✓ 2 light of wavelengths not absorbed by the pigments (e.g. green) ✓ 3 light does not hit chlorophyll / chloroplasts ✓ 4 another factor (carbon dioxide, temperature) limits photosynthesis ✓	max 2	1.1 × 2	1 IGNORE 'lost as heat' unqualified Mark the first two answers
23(e)	1 efficiency from primary to secondary consumers = $270 \div 1480 \times 100 = 18.2\%$, which is greater than 16.8% ✓ 2 animal tissue is more digestible than plant tissue (plants contain cellulose and lignin) ✓ 3 so less energy is lost in faeces (egestion) by carnivores ✓ 4 animal food contains more protein and fat, which are absorbed more efficiently ✓	max 3	2.4 1.2 × 2	1 ECF from (c) mp1 is required for the maximum of 3 marks Award mp1, then any two from mp2 to mp4. Without mp1: max 2
23(f)	1 saprobionts / decomposers break down proteins (and nucleic acids) releasing ammonium ions (ammonification) ✓ 2 nitrifying bacteria (<i>Nitrosomonas</i>) oxidise ammonium ions to nitrite ions ✓ 3 nitrifying bacteria (<i>Nitrobacter</i>) oxidise nitrite ions to nitrate ions ✓ 4 nitrification needs aerobic conditions (oxygen) ✓	max 3	1.1 × 3	1 ALLOW putrefying bacteria ALLOW ammonia for ammonium ions throughout 3 DO NOT ALLOW nitrogen-fixing bacteria / <i>Rhizobium</i> / <i>Azotobacter</i> for mp 2 or mp 3
Total		13		

Examiner notes

(c) The efficiency uses the energy available to the consumers, NPP. Candidates who divide by GPP obtain 7.1%.

Question 24 Unified biology · Medium · Protein synthesis and gene mutation

Question	Answer	Marks	AO element	Guidance
24(a)	AUG CCA GAU UUU GGC ✓	1	2.1	ALLOW 5' AUG CCA GAU UUU GGC 3'
24(b)	Met Pro Asp Phe Gly ✓	1	2.3	ECF from (a)
24(c)	1 the mRNA codon changes from CCA to CCG, which still codes for proline ✓ 2 no change in the amino acid sequence: the genetic code is degenerate (silent mutation) ✓	2	1.2 × 2	

Question 24 continued

Question	Answer	Marks	AO element	Guidance
24(d)	1 Met Pro Ile Leu ✓ 2 frameshift: every codon after the deletion is changed ✓ 3 the primary structure changes, so the tertiary structure / shape (e.g. of an active site) changes, or a premature stop codon may form: the protein may be non-functional ✓	3	2.1 × 3	1 IGNORE the incomplete codon (GC) at the end
24(e)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 939 award 2 marks 1 $(312 + 1) \times 3$ ✓ 2 939 ✓	2	2.4 × 2	2 936 (no stop codon) scores 1 mark
24(f)	1 the gene contains introns (non-coding sequences), which are removed from pre-mRNA (splicing) ✓ 2 the gene also contains non-coding DNA outside the coding sequence, e.g. a promoter / regulatory sequences before the start codon ✓	2	1.2 × 2	
	Total	11		

Examiner notes

(c) and (d): every codon in the original and mutated sequences is in Table 24.1, so no other codons are needed.

Question 25 Unified biology · Hard · Ectotherms and enzymes: temperature control in a desert lizard

Question	Answer	Marks	AO element	Guidance
25(a)	1 the lizard basks in the sun / absorbs (infrared) radiation from the sun ✓ 2 orientates its body so that a large surface area faces the sun's rays ✓	2	2.1 × 2	1 IGNORE heat from the air 2 ALLOW darkens its skin IGNORE conduction from the ground
25(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 0.20 to 0.27 °C min⁻¹ award 3 marks 1 tangent drawn to the body temperature curve at 07:30 ✓ 2 gradient from a large triangle, e.g. 14 °C rise in 1 hour ✓ 3 0.23 °C min ⁻¹ ✓	3	2.4 × 3	2 ALLOW 12 to 16 °C h ⁻¹ 3 ALLOW 0.20 to 0.27 An answer in °C h ⁻¹ scores 2 marks
25(c)	1 moves into the shade / into a burrow when it is too hot, and back into the sun when it cools ✓ 2 turns to face the sun to reduce the surface area exposed / raises its body off the hot ground ✓	2	2.1 × 2	

Question 25 continued

Question	Answer	Marks	AO element	Guidance
25(d)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 2.3 award 2 marks 1 Q_{10} = rate at 35 °C ÷ rate at 25 °C = 9.7 ÷ 4.2 ✓ 2 2.3 ✓	2	2.4 ×2	2 ALLOW 2.31
25(e)	1 between 25 and 35 °C, molecules have more kinetic energy, so there are more frequent successful collisions between substrate molecules and active sites ✓ 2 more enzyme-substrate complexes form per unit time ✓ 3 above 45 °C bonds (hydrogen / ionic bonds) in the tertiary structure break ✓ 4 the active site changes shape and is no longer complementary to the substrate: the enzyme is <u>denatured</u> ✓	max 3	1.2 ×3	4 DO NOT ALLOW 'the enzyme is killed'
25(f)	1 an endotherm uses (much) of its respiration to generate heat to keep its body temperature constant ✓ 2 an ectotherm gains heat from the environment, so it has a lower metabolic rate and needs less respiratory substrate ✓	2	2.1 ×2	
	Total	14		

Examiner notes

What makes this hard: You need a tangent at 07:30 and a change of units from °C per hour to °C per minute. In (a) you have to notice that the lizard is warmer than the air, so its heat cannot be coming from the air.

(b) The gradient of the curve plotted in Fig. 25.1 at 07:30 is about 14 °C per hour, which is about 0.23 °C min⁻¹.



Question 26 Unified biology · Hard · Plant hormones: gibberellin and dwarf peas

Question	Answer	Marks	AO element	Guidance
26(a)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If mean = 144 (mm) and standard deviation = 8.9 (ALLOW 8.92) award 3 marks 1 mean = $864 \div 6 = 144$ mm ✓ 2 $\Sigma(x - \bar{x})^2 = 4 + 144 + 169 + 36 + 9 + 36 = 398$ ✓ 3 $s = \sqrt{(398 \div 5)} = 8.9$ mm ✓	3	2.4 ×3	1 ALLOW 144.0 3 ALLOW 8.92 8.1 (divided by n) scores 1 mark (mp 2)
26(b)	1 the mean is higher at 1×10^{-4} (152 mm compared with 144 mm), a difference of 8 mm ✓ 2 the standard deviations (12 mm and 8.9 mm) are large compared with the difference ✓ 3 the ranges of mean $\pm$ 1 standard deviation overlap (140 to 164 mm and 135 to 153 mm), so the difference may be due to chance / may not be significant ✓ 4 a statistical test (t-test) is needed; only 6 plants per concentration ✓	max 3	3.2 ×3	1 ECF from (a) 4 ALLOW $t = 1.3$, below the critical value 2.23 (10 degrees of freedom) The conclusion must be judged (not supported) for full marks
26(c)	1 gibberellin causes the cells (in the internodes) to elongate / grow longer ✓ 2 gibberellin stimulates cell division (in the meristems / internodes), so the internodes become longer ✓	2	1.1 ×2	1 ALLOW cell expansion 2 IGNORE references to DELLA proteins (not required)
26(d)	1 GA₂₀ has no effect on dwarf plants (43 mm compared with 41 mm) but GA₁ raises the height of dwarf plants (149 mm) to about that of tall wild-type plants (158 mm) ✓ 2 so the dwarf plants can respond to (active) gibberellin: they are not insensitive to it ✓ 3 they cannot convert GA₂₀ to GA₁: the le allele codes for a non-functional enzyme ✓ 4 so they lack active gibberellin, and the internodes do not elongate ✓	max 3	2.3 3.1 ×2	1 Data from Table 26.2 needed
	Total	11		

Examiner notes

What makes this hard: The mean and standard deviation are worked out by hand from six values, then used to judge whether an 8 mm difference means anything. In (d) you use the two gibberellins to decide whether dwarf plants cannot make active gibberellin or cannot respond to it.

(b) A t -test on the summary data gives $t = 1.3$ with 10 degrees of freedom (critical value 2.23): the difference is not significant.

Question 27 Unified biology · Hard · Blood glucose: identifying type 1 and type 2 diabetes

Question	Answer	Marks	AO element	Guidance
27(a)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 58 (%) award 2 marks 1 $(7.6 - 4.8) \div 4.8 \times 100 \checkmark$ 2 58 (%) $\checkmark$	2	2.4 ×2	2 ALLOW 58.3
27(b)	1 Q has type 1 and R has type 2 $\checkmark$ 2 Q: insulin stays very low (12 to 14 pmol dm ⁻³) and does not rise, so β cells are not producing insulin $\checkmark$ 3 so Q's glucose rises highest (18.5 mmol dm ⁻³) and stays high $\checkmark$ 4 R: insulin is higher than P's (fasting 120 compared with 40; peak 420 compared with 350 pmol dm ⁻³) but glucose stays high (14.0 mmol dm ⁻³) $\checkmark$ 5 so R's cells are less sensitive / do not respond to insulin (insulin resistance / fewer or less responsive receptors) $\checkmark$	max 4	2.3 ×2 3.1 ×2	1 Both needed 2 Data needed 4 Data needed 5 ALLOW 'target cells' for 'cells' Award the identification mark as one of the 4
27(c)	1 insulin binds to (specific) receptors on the cell surface membranes of liver and muscle cells $\checkmark$ 2 in muscle cells, vesicles containing glucose channel (transporter) proteins fuse with the cell surface membrane, so more glucose enters by facilitated diffusion $\checkmark$ 3 in liver and muscle cells, enzymes that convert glucose to glycogen (<u>glycogenesis</u>) are activated $\checkmark$ 4 rate of respiration of glucose increases / more glucose is converted to fat $\checkmark$	max 3	2.1 ×3	2 ALLOW increases the permeability of the cell surface membrane to glucose ALLOW GLUT4 3 DO NOT ALLOW glucagon for glycogen DO NOT ALLOW insulin converts glucose to glycogen
27(d)	1 glucose enters the β cell (through transporter proteins) and is respired, increasing the concentration of ATP $\checkmark$ 2 ATP causes ATP-sensitive potassium ion channels to close $\checkmark$ 3 potassium ions no longer diffuse out, so the membrane depolarises $\checkmark$ 4 voltage-gated calcium ion channels open and calcium ions diffuse in $\checkmark$ 5 calcium ions cause vesicles containing insulin to fuse with the cell surface membrane: <u>exocytosis</u> $\checkmark$	max 4	1.2 ×4	
	Total	13		



Question 27 notes continued

Examiner notes

What makes this hard: Both people with diabetes have high blood glucose, so you can only tell them apart by using the insulin graph as well. In (d) you need the full sequence inside the β cell, from glucose entering to insulin leaving by exocytosis.

(b) Type 1 and type 2 both give a high glucose curve; the insulin curve is the evidence that separates them. A candidate who uses Fig. 27.1 only can score the identification mark and mp 2 only.

Question 28 Unified biology · Super hard · Cystic fibrosis: inheritance, membranes and gas exchange

Question	Answer	Marks	AO element	Guidance
28(a)	1 unaffected parents 1 and 2 (or 3 and 4) have an affected child, so both parents are carriers: the allele is recessive ✓ 2 affected female 5 has an unaffected father (1): if the allele were X-linked recessive, her father would also be affected ✓	2	2.1 × 2	1 Individuals must be identified 2 ALLOW her father would have to pass on an X chromosome with the allele
28(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $\frac{1}{9}$ (0.11) award 3 marks 1 probability that 6 is a carrier = $\frac{2}{3}$ (he is unaffected and both his parents are carriers) ✓ 2 probability that 7 is a carrier = $\frac{2}{3}$, and the probability that two carriers have an affected child = $\frac{1}{4}$ ✓ 3 $\frac{2}{3} \times \frac{2}{3} \times \frac{1}{4} = \frac{1}{9}$ (0.11) ✓	3	2.4 × 3	1 ALLOW a genetic diagram showing that 2 of the 3 unaffected genotypes are heterozygous 3 ALLOW 0.111 or 11% $\frac{1}{16}$ ($\frac{1}{2}$ used for each carrier) scores 1 mark $\frac{1}{4}$ scores 0

Question	Answer	Marks	AO element	Guidance
28(c)*	Level 3 (5 or 6 marks) A clear explanation of how the deletion changes the CFTR protein and a clear explanation of the steps from fewer chloride ions leaving the cells, through water potential, to thick mucus and how this reduces gas exchange. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 or 4 marks) Some explanation of the effect on the protein and some explanation of the thick mucus or of the reduced gas exchange; or a clear explanation of the mucus and gas exchange with little on the protein. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 or 2 marks) A limited explanation of the effect on the protein, the mucus or gas exchange. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	1.2 ×2 2.2 ×2 3.3 ×2	Indicative scientific points may include: Mutation and protein - Deletion of three bases removes one codon (triplet): there is no frameshift - One amino acid (phenylalanine) is missing from the primary structure - The polypeptide folds into a different tertiary structure - CFTR is broken down instead of being processed by the RER and Golgi, so it is not inserted into the cell surface membrane / the channel does not open Mucus - Fewer chloride ions leave the epithelial cells into the mucus (and more sodium ions are absorbed from it) - The water potential of the mucus is not lowered, so less water moves into the mucus by osmosis (water moves out of it) - The mucus is dehydrated, thick and sticky; cilia cannot move it Gas exchange - Mucus blocks bronchioles, so less air reaches the alveoli (reduced ventilation) - Fewer alveoli are ventilated, so the surface area for gas exchange is smaller - Mucus increases the diffusion distance; the concentration gradient of oxygen between the air and the blood is smaller - Trapped bacteria cause infections that damage (scar) the alveoli
Question	Answer	Marks	AO element	Guidance
28(d)	1 epithelial cells are replaced / have a short life, so new cells do not contain the normal allele ✓ 2 the gametes (germ-line cells) are not altered, so the CF alleles can still be passed on ✓	2	2.1 ×2	1 ALLOW somatic gene therapy
Total		13		

Examiner notes

What makes this hard: Individual 6 is unaffected, so he is a carrier with a probability of 2/3, not 1/2, and the same is true of 7. In (c) you have to follow one deletion all the way through the protein, chloride ions and water potential to the mucus and then to gas exchange.

(b) An unaffected child of two carriers is AA or Aa in the ratio 1 : 2, so is a carrier with probability 2/3; the answer is 1/9 exactly.

(c) Candidates often stop at 'the protein is the wrong shape'. Level 3 needs the chain through chloride ions and water potential to the mucus, and through ventilation and diffusion to gas exchange.



Question 29 Unified biology · Super hard · Speciation: cichlid fish in a crater lake

Question	Answer	Marks	AO element	Guidance
29(a)	1 Z and A in the two boxes that share the most recent branch point (5 differences) ✓ 2 N in the next box, L next, and O in the box that branches first (7, then 40, differences) ✓	2	2.3 ×2	1 Z and A either way round
29(b)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 1.5×10^4 years (ALLOW 15 000 to 15 100 years) award 3 marks 1 Z and A: $5 \div 16\,600 \times 100 = 0.030\%$ of bases differ ✓ 2 the differences have accumulated in both lines of descent since the common ancestor, so each has changed by 0.015% ✓ 3 time since Z and A diverged = $0.015 \div 1.0$ million years = 1.5×10^4 years (15 000 years) ✓ 4 this is less than 23 000 years, so <i>A. zaliosus</i> and Apoyo <i>A. citrinellus</i> diverged after the lake formed: the suggestion is supported ✓ 5 A and N: 7 differences gives 0.021% per line of descent, i.e. about 21 000 years: colonisation could have followed the formation of the lake ($21\,000 < 23\,000$) ✓ 6 these times are maximum estimates (the mitochondrial lineages may have separated before the populations did), based on few differences, and assume a constant rate ✓	max 4	2.4 ×2 3.2 ×2	3 ALLOW 15 000 to 15 100 years 4 ECF: 30 000 years (not halved) with the conclusion 'not supported' scores 2 marks (mp 1 and mp 4) 5 ALLOW 2.1×10^4 years
29(c)	1 variation in the ancestral population (e.g. in body shape or jaws), caused by mutation ✓ 2 fish feeding in open water and on the bottom face different selection pressures ✓ 3 fish mate with fish of their own type / in their own habitat, so gene flow between the groups is reduced ✓ 4 allele frequencies in the two groups change over many generations ✓ 5 until they can no longer interbreed to produce fertile offspring: reproductive isolation, a new species ✓ 6 this is sympatric speciation, as there is no geographical barrier ✓	max 4	2.1 ×4	2 ALLOW disruptive selection; the term is not required 3 ALLOW behavioural / ecological isolation 5 DO NOT ALLOW 'cannot breed' without 'fertile offspring'



Question 29 continued

Question	Answer	Marks	AO element	Guidance
29(d)	1 mitochondrial DNA is inherited from the mother only, so it is not mixed by crossing over / independent assortment in meiosis ✓ 2 it mutates faster, so recent divergences can be detected ✓ 3 there are many copies in each cell, so it is easy to extract and sequence ✓	max 2	2.1 × 2	
	Total	12		

Examiner notes

What makes this hard: Differences between two living populations build up along both branches since their common ancestor, so you have to halve them before you use the rate. You also build the whole tree from a table of differences, with the distant species branching first.

(b) The 5 differences between two living populations have accumulated along both branches since their common ancestor. Halving gives 15 000 years, inside the age of the lake; not halving gives 30 000 years and the opposite conclusion.

(b) Both divergence times (Z and A, then A and N) fall within the life of the lake, so the data are consistent with colonisation followed by speciation within the lake.

Question 30 Unified biology · Super hard · Photosynthesis, respiration and temperature: coral bleaching

Question	Answer	Marks	AO element	Guidance
30(a)	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 13.4 to 13.8 $\mu\text{mol O}_2 \text{ cm}^{-2} \text{ h}^{-1}$ award 2 marks 1 9.6 + 4.0 (net rate in the light + rate of uptake in the dark) ✓ 2 13.6 $\mu\text{mol O}_2 \text{ cm}^{-2} \text{ h}^{-1}$ ✓ 3 assumption: the rate of respiration in the light is the same as in the dark ✓	3	2.4 × 2 3.1	1 ALLOW 9.5 to 9.7 and 3.9 to 4.1 2 ALLOW 13.4 to 13.8
30(b)	1 oxygen produced in 12 hours of light = $4.5 \times 12 = 54 \mu\text{mol cm}^{-2}$ ✓ 2 oxygen used in 12 hours of darkness = $5.2 \times 12 = 62.4 \mu\text{mol cm}^{-2}$ ✓ 3 more oxygen is used than produced (by about 8 $\mu\text{mol cm}^{-2}$ each day), so the claim is not supported ✓	3	2.4 × 2 3.2	1 ALLOW 4.4 to 4.6 per hour 2 ALLOW 5.1 to 5.3 per hour 3 A conclusion based only on the net rate being positive scores 0



Question 30 continued

Question	Answer	Marks	AO element	Guidance
30(c)	1 the balance is positive only if $12 \times$ net rate in the light is greater than $12 \times$ rate of uptake in the dark, i.e. where the net rate is greater than the dark uptake ✓ 2 the two curves cross at 31.7°C ✓ 3 so the highest temperature is 31.7°C (below this the coral gains oxygen over 24 hours) ✓	3	2.3 3.1 $\times 2$	1 ALLOW gross photosynthesis must be more than twice the rate of respiration 2 ALLOW 31.5 to 31.9°C 3 An answer based on where the net rate falls to zero (above 34°C) scores 0 for mp 2 and mp 3
30(d)	1 respiration rate increases with temperature because molecules have more kinetic energy: more collisions between enzymes and substrates (respiratory enzymes are not yet denatured at 34°C) ✓ 2 photosynthetic enzymes (e.g. rubisco) / thylakoid membranes / photosystems are damaged or <u>denatured</u> above 29°C, so gross photosynthesis falls ✓ 3 the net rate = gross photosynthesis – respiration, so it falls as gross photosynthesis falls and respiration rises ✓ 4 photosynthesis has a lower optimum temperature than respiration, so above 29°C gross photosynthesis falls while respiration still rises ✓	max 3	2.1 $\times 3$	2 DO NOT ALLOW 'enzymes are killed' ALLOW rubisco combines with oxygen more at higher temperature (photorespiration)
30(e)	1 the coral depends on the algae for most of its organic compounds / respiratory substrate (sugars, amino acids) ✓ 2 so it cannot respire enough to make the ATP it needs for growth, repair and building its skeleton: it starves ✓	2	2.1 $\times 2$	
Total		14		

Examiner notes

What makes this hard: The graph shows net oxygen production in the light, so gross photosynthesis needs the dark uptake added on. Over 24 hours the coral also uses oxygen all night, so a positive net rate in the light is not enough on its own.

(c) A common error is to look for where the net rate falls to zero (above 34°C , beyond the plotted range). With equal periods of light and dark the coral needs its net daytime production to exceed its night-time uptake: the plotted curves cross at 31.7°C .

Marked by hand here. On iPad, Plumi marks questions like this one for you: tryplumi.app





Plumi

The iPad notebook for GCSE and A Level revision

Write your answers by hand. Each one is marked against that question's own mark scheme.

Stuck? The tutor nudges you with a hint before it gives anything away.

Practice adapts to you: the next question is chosen from what you have shown you can do.



Free on iPad · tryplumi.app

OCR-style practice written by Plumi. Not produced or endorsed by OCR.

