Pages 53-55: More Exchange and Transport Systems — 3

1.1 They prevent the backflow of blood ***[1 mark]*** into the atria when the ventricles contract ***[1 mark]***.

1.2 They open when pressure is greater below the valve / in the ventricle than in the artery ***[1 mark]***.

1.3

	Standing up	Lying down
Mean heart rate / bpm	74	57
Mean cardiac output / $cm^3\ min^{-1}$	4700	4700
Mean stroke volume / cm^3	63.5 (3 s.f.)	82.5 (3 s.f.)

[1 mark]

Stroke volume = cardiac output ÷ heart rate, so when standing up it's 4700 ÷ 74 = 63.5, and when lying down it's 4700 ÷ 57 = 82.5.

1.4 It gives the heart rate time to stabilise, as the act of changing position could cause it to increase ***[1 mark]***.

1.5 Heart rate is lower when lying down as blood does not have to be pumped above the level of the heart / against gravity ***[1 mark]***.

The heart has to work harder when a person is standing up, because blood has to flow against gravity. When you're lying down, the force of gravity is evenly distributed across the body.

1.6 Taking multiple measurements and calculating the mean reduces the effect of random error, so makes the results more precise ***[1 mark]***.

2.1 60 ÷ 0.55 = 109.0909...
109 beats per minute ***[1 mark]***

2.2 0.13 seconds or 0.68 seconds ***[1 mark]***

The left atrium contracts before the left ventricle in the cardiac cycle, so you need to find a point on the graph where the pressure of the atrium increases before the pressure of the ventricle increases.

2.3 Any six from: at point A, pressure in the left ventricle exceeds pressure in the left atrium ***[1 mark]***, because the left ventricle is contracting and the left atrium is relaxing ***[1 mark]***. This causes the atrioventricular valve/the valve between the left atrium and left ventricle to close, preventing the backflow of blood into the left atrium ***[1 mark]***.
At point B, pressure increases in the left ventricle to above that of the aorta ***[1 mark]***, which forces the semi-lunar valve/the valve between the left ventricle and aorta open ***[1 mark]***.
At point C, the left ventricular pressure falls below that of the aorta ***[1 mark]***, because blood has moved into the aorta from the ventricle and the left ventricle is relaxing ***[1 mark]***. As a result, the semi-lunar valve/the valve between the left ventricle and the aorta closes ***[1 mark]***.
Finally, at point D, pressure has been increasing in the left atrium as blood has been returning to the atrium from the body ***[1 mark]***. As the atrial pressure exceeds ventricular pressure ***[1 mark]***, the atrioventricular valve/valve between the left atrium and left ventricle opens, allowing blood to flow into the left ventricle ***[1 mark]***.
[Maximum of 6 marks available]

2.4 The left ventricle has a higher maximum pressure than the left atrium because it has a thicker muscle wall and so is able to generate more force when it contracts ***[1 mark]***.

2.5 The wall of the aorta is thick and muscular / the wall of the aorta contains elastic tissue to stretch and recoil / the inner lining of the aorta is folded so it can stretch ***[1 mark]***, which helps to maintain the high pressure of the blood coming out of the left ventricle ***[1 mark]***.

Pages 56-58: More Exchange and Transport Systems — 4

1.1 Water on the leaves would reduce the water potential gradient between inside the leaf and outside ***[1 mark]***, reducing water loss/transpiration ***[1 mark]***.

1.2 The higher the temperature, the faster the rate of transpiration ***[1 mark]***. At higher temperatures, water molecules have more kinetic energy so they evaporate more quickly from the cells inside the leaf ***[1 mark]***. This increases the water potential/concentration gradient between the inside and outside of the leaf, so water diffuses out of the leaf faster ***[1 mark]***.

2.1 Light intensity is higher at 12:00, so more stomata are open ***[1 mark]***, which increases the transpiration rate ***[1 mark]***. This draws water molecules up the xylem at a quicker rate, due to cohesion and tension ***[1 mark]***.

At 00:00, it would be dark, whereas there is sunlight at 12:00.

2.2 To prevent the plant tissue from drying out ***[1 mark]***.

2.3 Dyeing the tissue with a stain/named stain ***[1 mark]***.

3.1 Translocation requires energy/ATP ***[1 mark]***. If metabolism stops, respiration cannot occur so ATP is not produced / energy is not released ***[1 mark]***.

3.2 The level of pressure at point A is higher than that at point B ***[1 mark]***. This is because, at point A, the water potential is being lowered by the solutes entering from the companion cell, causing water to enter from the xylem and companion cell ***[1 mark]***, and raising the pressure ***[1 mark]***.

3.3 The concentration of solutes at point A would increase because the solutes are still being loaded from the companion cell and can't flow down the phloem ***[1 mark]***, as phloem is removed when a ring of bark is taken ***[1 mark]***.

3.4 E.g. in a tracer experiment, a leaf could be supplied with radioactively labelled CO_2 ***[1 mark]***, which would then be incorporated into the organic substances produced by the leaf ***[1 mark]***. The movement of these substances around the plant could then be tracked by detecting the radioactively labelled carbon ***[1 mark]***.

Topic Four — Genetic Information and Variation

Pages 59-62: DNA, RNA and Protein Synthesis

1.1 The DNA is wound around histone proteins ***[1 mark]*** and then tightly coiled into compact chromosomes ***[1 mark]***.

1.2 Any one from: e.g. prokaryotic DNA is not associated with proteins ***[1 mark]***. / Prokaryotic DNA is condensed by supercoiling ***[1 mark]***.

1.3 The total length of DNA is 2 m.
1.5% of the DNA encodes proteins.
Therefore, (1.5 ÷ 100) × 2 = 0.03 m of DNA corresponds to protein-encoding genes.
There are 20 000 protein-encoding genes.
Therefore, the average length of a gene is:
0.03 ÷ 20 000 = **0.0000015 m** or **1.5×10^{-6} m**
[2 marks for the correct answer, 1 mark for 0.03 m]

1.4 genome ***[1 mark]***

1.5 proteome ***[1 mark]***

1.6 E.g. prokaryotes don't have introns/non-coding sequences within genes ***[1 mark]***. Prokaryotes have shorter/fewer multiple repeat sequences between genes ***[1 mark]***.

1.7 E.g. genes encoding ribosomal RNA ***[1 mark]***. Genes encoding tRNAs ***[1 mark]***.

2.1 Any two from: e.g. mitochondrial DNA is shorter while the DNA in the nucleus is longer ***[1 mark]***. / Mitochondrial DNA is circular while the DNA in the nucleus is linear ***[1 mark]***. / Mitochondrial DNA is not associated with proteins, while DNA in the nucleus is associated with proteins/histones ***[1 mark]***.

2.2 D ***[1 mark]***

2.3 E.g. valine is coded for by four DNA codons ***[1 mark]***.

'Degenerate' means that multiple DNA codons can code for one amino acid, so any evidence that shows this from the table could gain a mark.

2.4 The mRNA codon GAC will become GCC / an A at mRNA codon position 156 will be swapped for a C ***[1 mark]***.

2.5 An arginine amino acid will be produced at position 156 instead of a leucine ***[1 mark]***.

2.6 It could change the shape of the enzyme ***[1 mark]*** so that the substrate is no longer able to fit into its active site ***[1 mark]***, preventing the enzyme from being able to catalyse the reaction ***[1 mark]***.

2.7 Any five from: e.g. the mRNA attaches to a ribosome ***[1 mark]***. tRNA molecules carry amino acids to the ribosome ***[1 mark]***. The tRNAs attach to the mRNA via complementary/specific base pairing ***[1 mark]***. The amino acids on adjacent tRNAs join together with peptide bonds ***[1 mark]***. ATP provides the energy for peptide bond formation ***[1 mark]***. The ribosome moves along the mRNA and the amino acid chain is extended ***[1 mark]***. The process continues until a stop signal on the mRNA is reached ***[1 mark]***. ***[Maximum of 5 marks available]***

1.1 Any four from: e.g. after the DNA has been unwound ***[1 mark]***, RNA polymerase lines up free RNA nucleotides along the template strand ***[1 mark]*** according to the rules of complementary base pairing ***[1 mark]***. RNA polymerase then joins the RNA nucleotides together as it moves along the DNA template strand ***[1 mark]***. Once RNA polymerase reaches a stop signal, it detaches and the mRNA is released ***[1 mark]***. ***[Maximum of 4 marks available]***

1.2 The original DNA contains introns, while the cDNA does not / the cDNA only contains exons ***[1 mark]***. This is because the cDNA is made from mRNA, which has been spliced / had the introns removed ***[1 mark]***.

1.3 The levels of mRNAs 2 and 3 were only slightly affected by the drug ***[1 mark]***. If RNA polymerase was inhibited, the levels of all of the mRNAs would have decreased by a large amount ***[1 mark]***.

1.4 Only the level of mRNA 1 has been significantly reduced ***[1 mark]***. This indicates that mRNA 1 contains the particular sequence destroyed by the drug ***[1 mark]***.

Pages 63-65: Diversity, Classification and Variation — 1

1.1 A species is a group of similar organisms able to reproduce to give fertile offspring ***[1 mark]***.

1.2 four ***[1 mark]***

The genera shown on the phylogenetic tree are Panthera, Meles, Lutra and Canis. You know that these are the genera because the binomial name for a species is made up of two parts, e.g. Panthera leo, and the first part is always the genus.

1.3 *Canis aureus* and *Canis lupus* because they both belong to the same genus ***[1 mark]***.

1.4 Family ***[1 mark]***

2.1 Both types of selection increase the likelihood of organisms with the beneficial traits surviving ***[1 mark]***. However, the selection acting on population A increases the chances of organisms with an extreme phenotype surviving ***[1 mark]***, whereas the selection acting on population B increases the chance of organisms with an average trait surviving ***[1 mark]***.

2.2 Population A, because this is showing directional selection / selection for an extreme phenotype ***[1 mark]***. Taller plants are likely to be selected for in dense forest because these could more easily gain access to sunlight ***[1 mark]***.

2.3 E.g. the environmental conditions in the grassland and the forest are different. / In an open field, being too tall would be a disadvantage due to the risk of damage by wind. ***[1 mark]***

2.4 E.g. if a female lays too many eggs then she may be unable to care for them all ***[1 mark]***. If she doesn't lay enough eggs then there is a chance that no chicks would survive to adulthood ***[1 mark]***. So, an intermediate number of eggs is selected for, and variation in the clutch size decreases over time ***[1 mark]***.

Figure 3 shows that clutch size is undergoing stabilising selection — the mean stays roughly the same, but variation (shown by the error bars) is decreasing.

3.1 Proteins consists of amino acids which are encoded by DNA base sequences ***[1 mark]***. The more similar the proteins are, the more similar the DNA is between two species ***[1 mark]***, and so the more closely related they are ***[1 mark]***.

3.2 Species A is the least closely related to humans, as it has the greatest number of differences in amino acid sequence from the human protein ***[1 mark]***. Species C is the most closely related to humans as it's amino acid sequence has the fewest differences ***[1 mark]***.

3.3 E.g. both species have seven differences in their amino acid sequence from the human protein, but they could be unique differences / at different points in the sequence, so you can't tell how closely related they are to each other ***[1 mark]***.

Pages 66-69: Diversity, Classification and Variation — 2

1.1

Species	Number of individual plants counted in different quadrats					Mean number counted
Rapeseed	24	46	32	28	32	**32.4**
Common sunflower	1	0	2	1	1	**1**
Common poppy	8	12	6	10	8	**8.8**
Creeping thistle	13	14	7	15	13	**12.4**

[1 mark]

1.2 $N = 32.4 + 1 + 8.8 + 12.4$

$= 54.6$

$$d = \frac{54.6(54.6 - 1)}{32.4(32.4 - 1) + 1(1 - 1) + 8.8(8.8 - 1) + 12.4(12.4 - 1)}$$

$$= \frac{2926.6}{1227.4}$$

$d =$ **2.38** (to 3 s.f.)

[2 marks for the correct answer, otherwise 1 mark for $N(N - 1) = 2926.6$ or $\Sigma n(n - 1) = 1227.4$. Allow full marks if incorrect answers to 1.1 used correctly.]

1.3 The scientists could have used a t-test ***[1 mark]*** as this would have allowed them to compare two mean values ***[1 mark]***.

1.4 E.g. animal grazing prevents some plants from growing, reducing plant biodiversity ***[1 mark]***. This would mean there are fewer habitats and food resources to support other organisms, further reducing biodiversity ***[1 mark]***.

2.1 Because an index of diversity takes into account both the number of species and the number of individuals ***[1 mark]***, which means that it takes into account species that are only present in small numbers, which species richness does not ***[1 mark]***.

2.2 Any three from: e.g. there were fewer ladybird species on the conventional farm than on the organic farm. / The standard deviation bars do not overlap, so the difference was significant/the standard deviation bars are short, showing that the data is precise. / However, there is no indication of how many samples were taken, so the data may not be representative of all organic/conventional farms. / There may be factors other than the way in which the fields were farmed, which influenced the number of ladybird species present. / The scientists' conclusion is correct for this data, but further investigation is needed to ensure that these results are valid ***[1 mark for each correct answer]***.

2.3 E.g. the scientists could have taken random samples, to prevent sampling bias ***[1 mark]***. / They could have had a large sample size, to reduce the risk of results being due to chance ***[1 mark]***.

3.1 To sterilise it ***[1 mark]*** and prevent contamination of the investigation which could affect the results ***[1 mark]***.

3.2 Any five from: e.g. disinfect work surfaces/wash hands to prevent contamination of cultures ***[1 mark]***. Work near a Bunsen burner flame ***[1 mark]***. Flame the neck of the glass bottle of bacterial culture just before use ***[1 mark]***. Use a sterile pipette to transfer the bacteria from the broth to the agar plate ***[1 mark]***. Spread the bacteria over the plate using a sterile plastic spreader ***[1 mark]***. Soak a paper disc in each type of hand sanitiser and use sterile forceps to place each disc on the plate ***[1 mark]***. Lightly tape a lid onto the plate ***[1 mark]***. Invert and incubate at 25 °C for 48 hours ***[1 mark]***. ***[Maximum of 5 marks available]***

3.3 To act as a control ***[1 mark]*** and ensure that it was only the antibacterial hand sanitiser that was preventing growth, and not the paper disc itself ***[1 mark]***.

3.4

Disc	Area of Inhibition Zone / mm^2
B	**346** (to 3 s.f.)
C	**908** (to 3 s.f.)
D	**227** (to 3 s.f.)

[1 mark]

4.1 The crossing over of homologous chromosomes in meiosis I ***[1 mark]*** leads to the four daughter cells containing different combinations of alleles ***[1 mark]***. Independent segregation in meiosis I ***[1 mark]*** leads to the daughter cells containing any combination of maternal and paternal chromosomes ***[1 mark]***.

4.2 $n = 23$ in humans

$2^{23} =$ **8 388 608** ***[1 mark]***

4.3 Non-disjunction ***[1 mark]*** means that chromosome 13 ***[1 mark]*** fails to separate properly during meiosis, leaving one daughter cell/gamete with an extra copy of chromosome 13 and another with no copies ***[1 mark]***. If a gamete with an extra copy of chromosome 13 is fertilised, the resulting zygote will have three copies, leading to Patau syndrome ***[1 mark]***.

Pages 70-72: Diversity, Classification and Variation — 3

1.1 For species A, B, D and E, there is a less than 5% probability that the results are due to chance ***[1 mark]***. For species C, there is a greater than 5% probability that the results are due to chance ***[1 mark]***.

1.2 Any two from: e.g. the time of year the traps were set. / The length of time the traps were left for. / The depth at which the traps were set. / The type of traps used. / The age/size of the fish caught. / The health of the fish caught. ***[2 marks — 1 mark for each correct answer]***

1.3 E.g. the scientists could have compared the DNA/mRNA base sequence of the same gene in different individual fish ***[1 mark]***. This would have allowed them to estimate the number of different alleles the population has for that particular gene, giving them an indication of genetic diversity ***[1 mark]***.

1.4 E.g. it allows natural selection to take place. / It allows the population to adapt to environmental changes. ***[1 mark]***

2.1 E.g. from 0 to approximately 15 $\mu g\ cm^{-3}$, the number of strain B bacteria decreases more rapidly with increasing ampicillin concentration than the number of strain A bacteria ***[1 mark]***. Above an ampicillin concentration of approximately 15 $\mu g\ cm^{-3}$, the number of strain A bacteria remains fairly constant at about 1000 cells, but the number of strain B continues to decrease. ***[1 mark]***

2.2 E.g. ionising radiation is a mutagenic agent / increases the chance of mutations arising ***[1 mark]***. A mutation may have caused the active site of the strain A transpeptidase to change shape ***[1 mark]***, so that ampicillin could no longer bind to and inhibit the enzyme ***[1 mark]***. So strain A bacteria with the mutation were more likely to survive and reproduce in increasing ampicillin concentrations than strain B bacteria ***[1 mark]***.