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EDEXCEL A LEVEL BIOLOGY B: QUESTIONS BY TOPIC

Origins of Genetic Variation (8)

A Level Biology B Topic 8

38 questions · 401 marks · Mark schemes included

Pearson Edexcel AS (8BI0) and A Level (9BI0) Biology B, June 2016 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

38 questions · 401 marks · grouped by sub-topic, lowest tariff first



SUB-TOPIC 8(a)

MUTATION

14 questions in this sub-topic · 126 marks · lowest tariff first



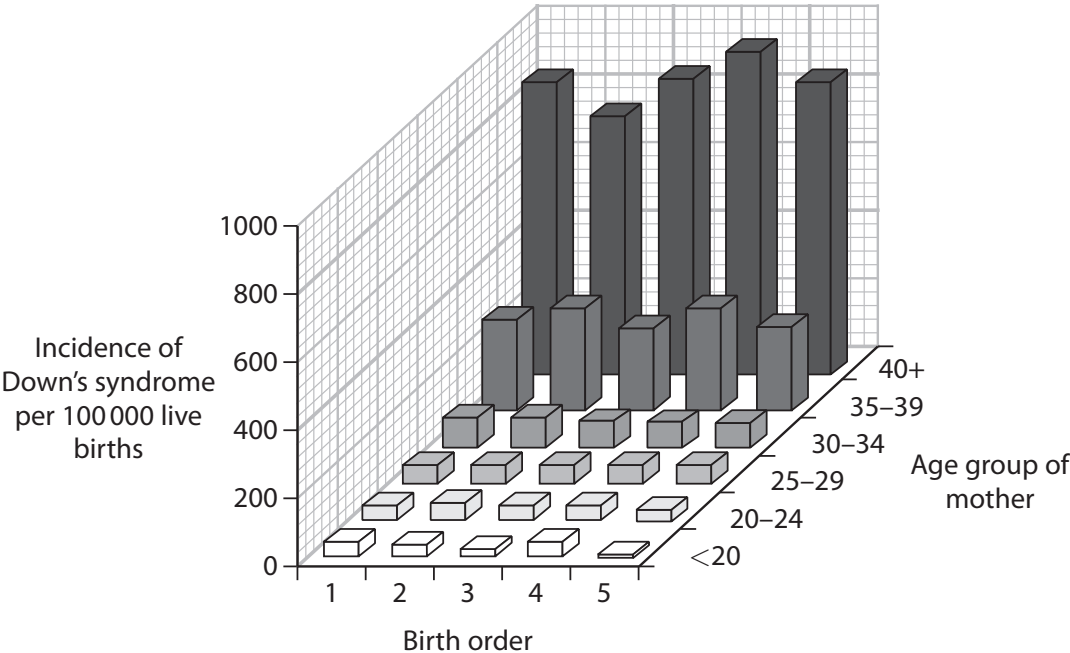
1 Down’s syndrome is a genetic condition.

(a) Which row in the table describes the cause of Down’s syndrome?

(1)

	Type of mutation	Result of non-disjunction
☐ A	chromosome	monosomy
☐ B	chromosome	polysomy
☐ C	gene	monosomy
☐ D	gene	polysomy

(b) The graph shows the effect of the age of the mother and the order in which babies are born in a family (birth order) on the incidence of Down’s syndrome.



Determine the effects of birth order and age of the mother on the incidence of Down’s syndrome.

(3)

2 Some genetic disorders result from chromosome mutations.

(a) Translocation is one type of chromosome mutation.

Describe how translocation occurs.

(2)

(b) Name the type of chromosome mutation that results in Down's syndrome.

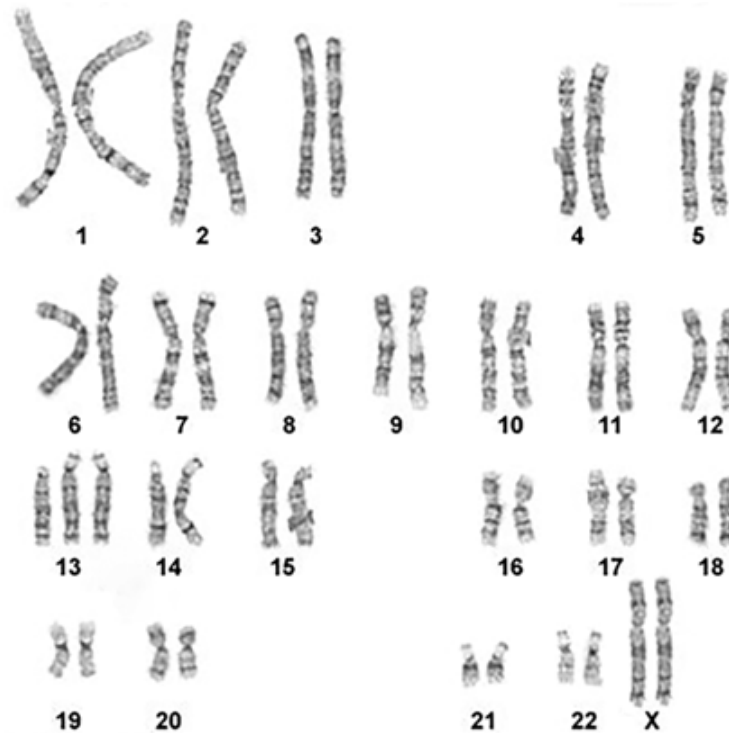
(1)



(c) Genetic disorders can be diagnosed by looking at an individual's karyotype.

A karyotype shows the number of each type of chromosome present in a cell.

The diagram shows the karyotype of the cells taken from a female embryo.



Explain what conclusion can be made about this female embryo.

(2)

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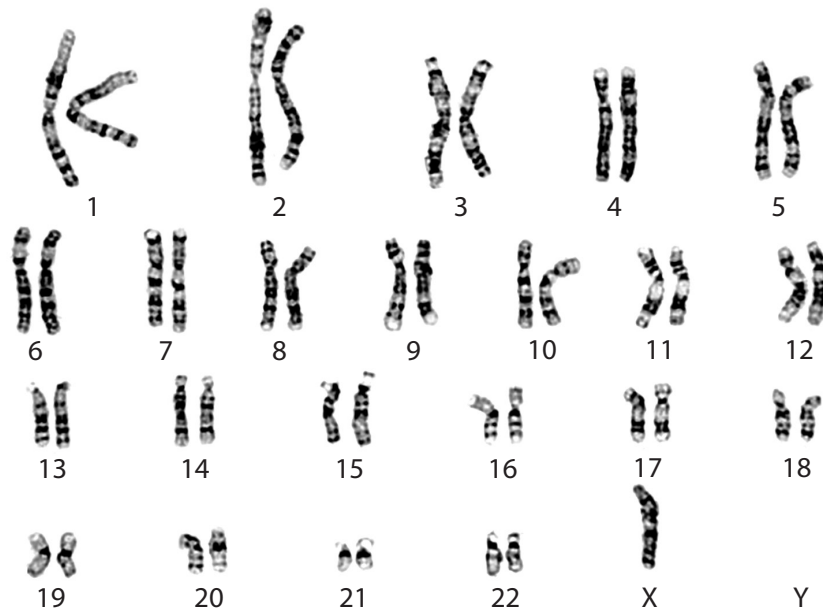
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1 A karyotype shows the chromosomes found in the cells of an individual.

The photograph shows a karyotype from a child with a genetic condition.



(Source: © Dept. of Clinical Cytogenetics, Addenbrookes Hospital / Science Photo Library)

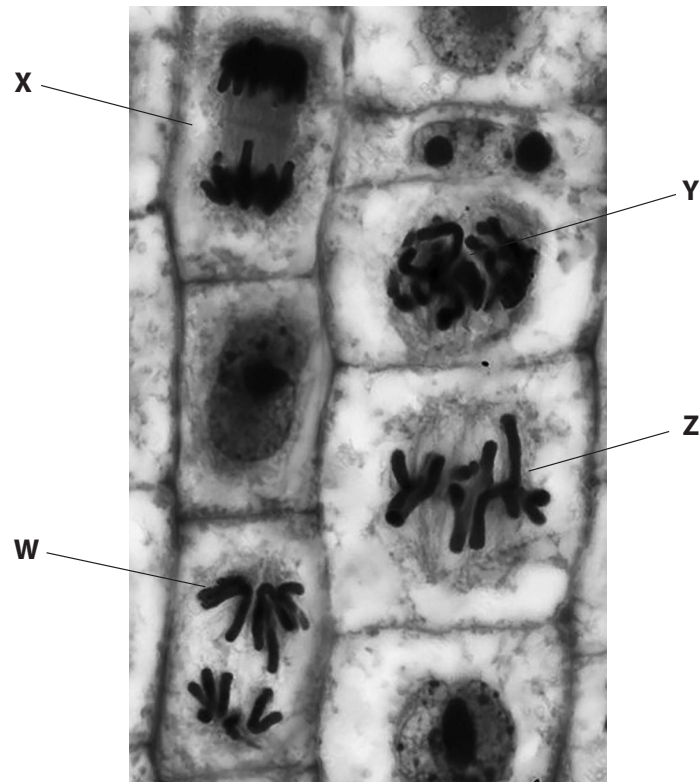
(a) (i) Which of the following identifies the genetic condition shown in the photograph? (1)

- ☐ A Down's syndrome due to monosomy
- ☐ B Down's syndrome due to polysomy
- ☐ C Turner's syndrome due to monosomy
- ☐ D Turner's syndrome due to polysomy

(ii) Which process would have caused the genetic condition shown by this karyotype? (1)

- ☐ A base insertion
- ☐ B base substitution
- ☐ C non-disjunction
- ☐ D translocation

(b) The photograph shows cells in different stages of mitosis.



(Source: © STEVE GSCHMEISSNER / Science Photo Library)

(i) Which of the following correctly identifies the stages shown in the photograph?

(1)

	W	X	Y	Z
☐ A	anaphase	telophase	prophase	metaphase
☐ B	anaphase	prophase	telophase	metaphase
☐ C	prophase	anaphase	metaphase	telophase
☐ D	telophase	metaphase	anaphase	prophase

(ii) Colchicine is a chemical that inhibits mitosis.

A student investigated the effect of colchicine on mitosis.

Two sets of genetically identical cells were grown in culture. Colchicine was added to one culture of cells but not to the other culture of cells.

Six hours after treatment, the mean percentages of cells in each stage of mitosis were determined.

The results are shown in the table.

Mitosis stage	Mean percentage of cells in stage $\pm$ Standard Deviation	
	cells cultured without colchicine	cells cultured with colchicine
interphase	84.8 ± 4.2	82.8 ± 3.2
prophase	10.2 ± 2.2	16.3 ± 3.1
metaphase	1.8 ± 0.4	0.8 ± 0.2
anaphase	1.8 ± 0.2	0.7 ± 0.1
telophase	1.4 ± 0.3	0.4 ± 0.1

Analyse the data to comment on how colchicine affects mitosis.

(4)

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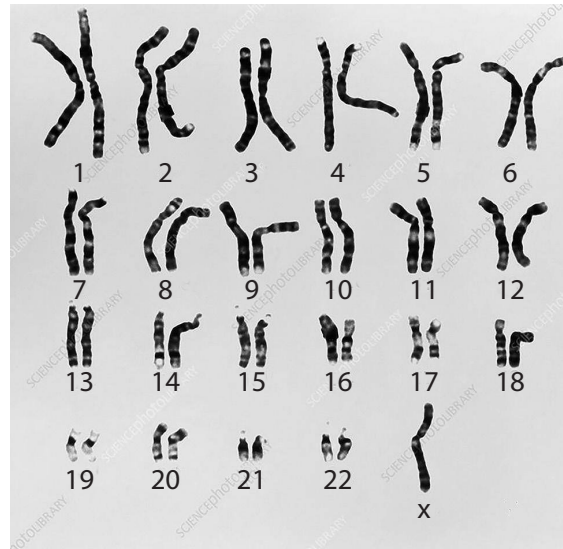
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2 (a) The diagram shows a human karyotype.



(Source: © DEPT. OF CLINICAL CYTOGENETICS, ADDENBROOKES HOSPITAL/SCIENCE PHOTO LIBRARY)

(i) Which of the following identifies the human with this karyotype?

(1)

- ☐ A female with Down's syndrome
- ☐ B female with Turner's syndrome
- ☐ C male with Down's syndrome
- ☐ D male with Turner's syndrome

(ii) Which of the following would cause the karyotype in the diagram?

(1)

- ☐ A non-disjunction producing a monosomy
- ☐ B non-disjunction producing a polysomy
- ☐ C translocation producing a monosomy
- ☐ D translocation producing a polysomy

- (b) (i) The table shows the chromosome number and chromatid number of some of the cells formed during oogenesis in humans.

Cell type	Chromosome number	Chromatid number
ovum	23	23
primary oocyte	46	92
secondary oocyte	23	46

Which of the cells are haploid?

(1)

- ☐ **A** ovum and primary oocyte
- ☐ **B** ovum and secondary oocyte
- ☐ **C** primary oocyte and secondary oocyte
- ☐ **D** ovum alone

- (ii) Explain how meiosis produces new combinations of alleles in gametes.

(4)

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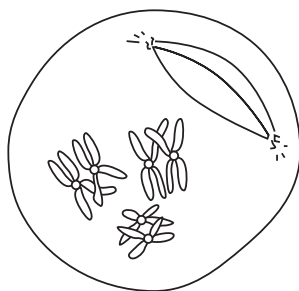
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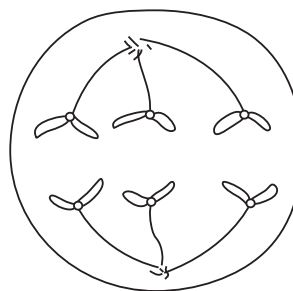
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- 6 (a) Mosquitoes have cells with a diploid number ($2n$) of six.

The diagram shows two cells from a male mosquito at different stages of meiosis.



P



Q

- (i) Which row of the table shows the stages of meiosis of cells P and Q?

(1)

	P	Q
☐ A	anaphase II	anaphase I
☐ B	metaphase I	prophase I
☐ C	prophase I	anaphase II
☐ D	prophase II	metaphase II

- (ii) Non-disjunction occurred during meiosis I.

Which of the following shows the number of chromosomes in each of the four sperm cells produced?

(1)

- ☐ **A** 4, 3, 3, 2
- ☐ **B** 4, 4, 2, 2
- ☐ **C** 6, 6, 7, 5
- ☐ **D** 7, 7, 5, 5

(b) Down's syndrome in humans is caused by non-disjunction.

The chance of having a baby with Down's syndrome increases as the age of the mother increases.

At age 40, the probability of having a baby with Down's syndrome is 0.018.

In 2016 the number of women aged 40 in the UK was estimated to be 500 000.

The pregnancy rate for women in the UK aged 40 is 14 pregnancies per 1000 women per year.

Calculate the number of babies with Down's syndrome that were expected in 2016 in the UK.

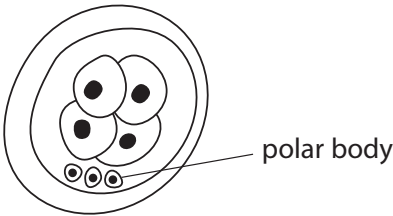
(2)

Answer



(c) *In vitro* fertilisation (IVF) is a technique in which eggs are taken from the ovaries and fertilised with sperm in a laboratory.

The resulting embryos are cultured until the four-cell stage, as shown in the diagram.



Two screening techniques used to identify embryos with chromosomal abnormalities are:

- polar body biopsy in which the polar bodies are removed and the chromosomes analysed
- pre-implantation genetic diagnosis (PGD) in which one cell from the four-cell stage embryo is removed and the chromosomes analysed.

Embryos without chromosome abnormalities are placed into the mother’s uterus.

The success rates of both techniques are shown in the table.

Technique	Percentage of embryos that survive screening (%)	Percentage of embryos transferred to the uterus that lead to the birth of baby (%)
Polar body biopsy	87	21
PGD	74	29
Control	IVF with no screening	16

Analyse the data to comment on the effectiveness of the two techniques.

(4)

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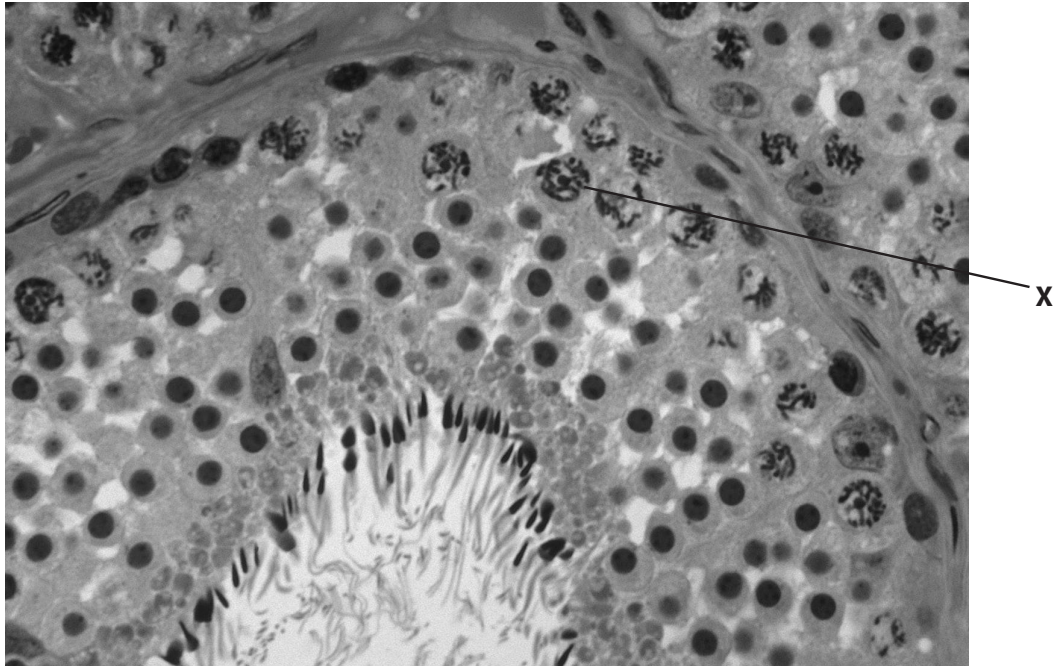
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- 3 The photograph shows part of a testis, as seen using a light microscope.



(Source: © M. I. WALKER / SCIENCE PHOTO LIBRARY)

- (a) The cell labelled X is a primary spermatocyte.

- (i) At which stage of cell division is cell X?

(1)

- ☒ **A** prophase I of meiosis
- ☒ **B** prophase II of meiosis
- ☒ **C** prophase I of mitosis
- ☒ **D** prophase II of mitosis

- (ii) In the photograph, cell X has a width of 0.8 cm.

The magnification of the photograph is $\times 1500$.

Calculate the actual width, in micrometres (μm), of cell X.

Give your answer to one decimal place.

(2)

Answer μm

- (b) Some pregnancies do not develop to full term, so no baby is born.

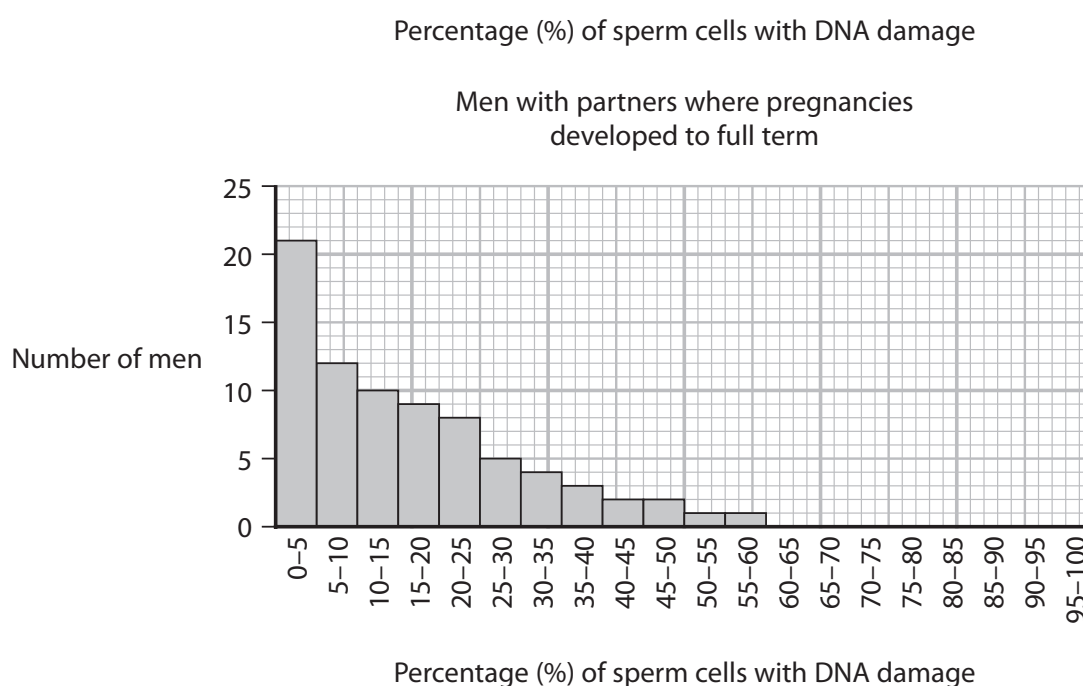
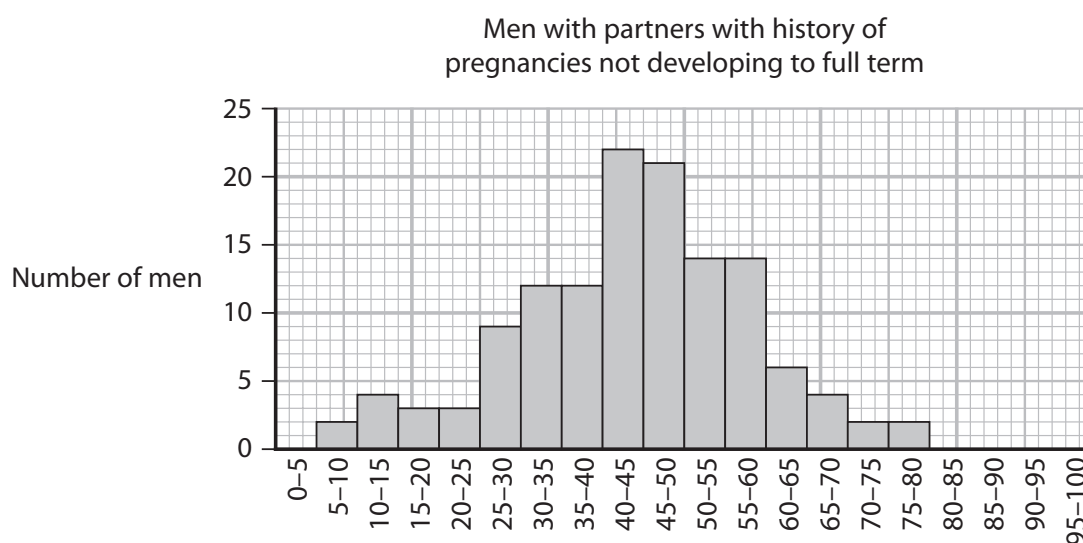
Damage to the DNA of sperm is thought to be one cause of pregnancies not developing to full term.

Scientists investigated if there is an association between the production of sperm with damaged DNA and the risk of pregnancies not developing to full term.

The percentage of sperm cells with DNA damage was determined for 130 men where there was a history of pregnancies not developing to full term.

The percentage of sperm cells with DNA damage was measured for 78 men where pregnancies developed to full term.

The graphs show the results of this investigation.



- (i) Calculate the number of men with partners that have a history of pregnancies not developing to full term that had 25% or less of sperm with DNA damage.

(1)

Answer

- (ii) The scientists concluded that having more than 25% of sperm with damaged DNA leads to a high risk of pregnancies not developing to full term.

Analyse the data to evaluate this conclusion.

(4)

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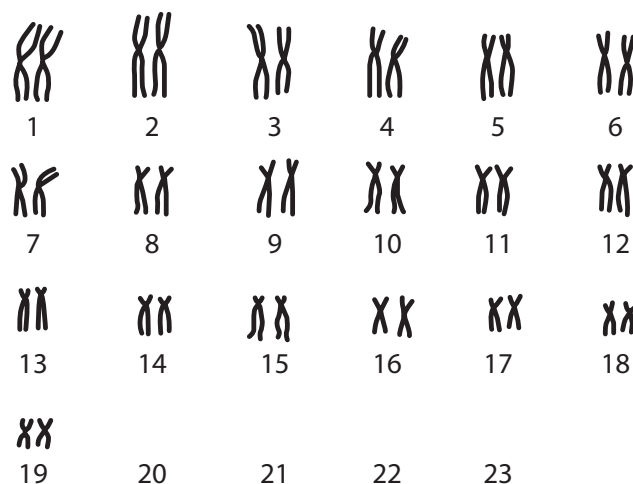


2 Chromosome mutations include non-disjunction and translocation.

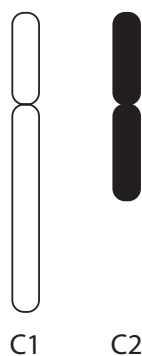
(a) The diagram shows part of a karyotype from a female with Down's syndrome.

Complete the diagram to show the full karyotype of a female with Down's syndrome.

(2)



(b) The diagram shows two chromosomes, C1 and C2, before translocation.



Draw a diagram to show the appearance of these two chromosomes after translocation has occurred.

(1)

(c) The table shows some features of a control group of females without Turner’s syndrome and a group of females with Turner’s syndrome.

Feature	Control group n = 11	With Turner’s syndrome n = 37
Mean mass / kg ± SD	45.2 ± 19.3	36.7 ± 14.8
Mean height / cm ± SD	146.3 ± 21.3	134.8 ± 20.0
Body mass index (BMI)		20.2

(i) Complete the table to show the BMI for the control group, using the formula:

BMI = mass in kg ÷ (height in metres)²

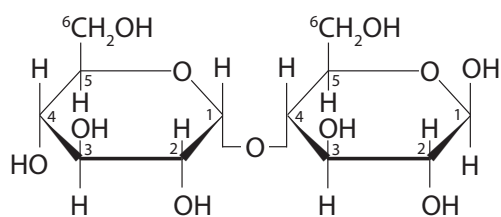
(2)

(ii) Analyse the data to comment on the conclusions that could be made about the effect of Turner’s syndrome on these features.

(4)

4 Enzymes are involved in a wide range of metabolic reactions.

(a) The diagram represents the structure of a maltose molecule.



Draw a diagram to show the hydrolysis of maltose.

(3)

(b) Catalase is an enzyme found in potato cells.

It catalyses the breakdown of hydrogen peroxide.

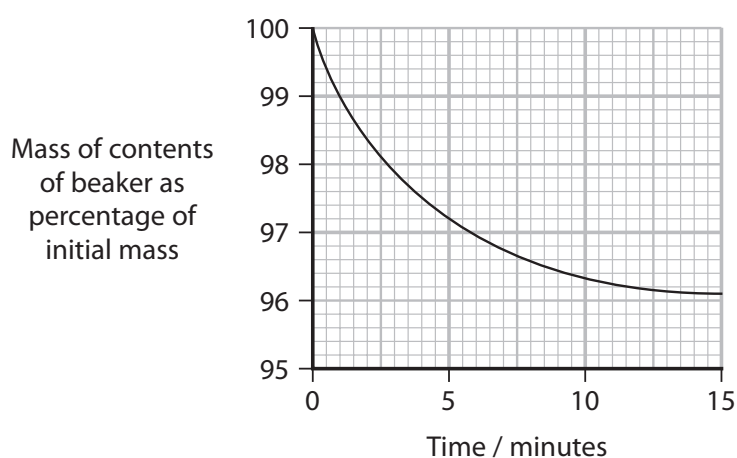


In an investigation, cylinders of potato were cut with a cork borer.

The cylinders were then sliced into discs with the same thickness and put into a small beaker containing 50 cm³ of hydrogen peroxide.

The mass of the beaker and its contents was recorded over a period of 15 minutes.

The graph shows the results of the experiment.



Explain the relationship shown in the graph.

(4)

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(c) Explain how a gene mutation can prevent the production of catalase in potato cells.

(3)



5 (a) (i) Which bonds join the nucleotides in a single strand of DNA?

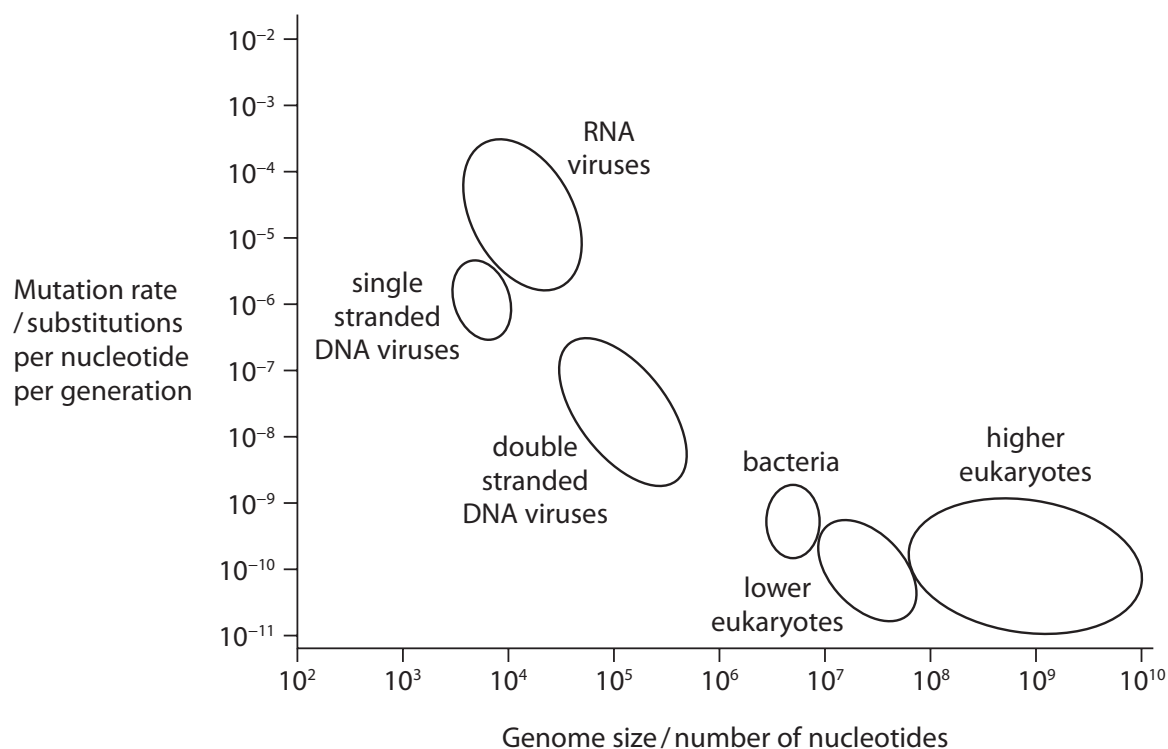
(1)

- ☐ A peptide
- ☐ B disulfide
- ☐ C glycosidic
- ☐ D phosphodiester

(ii) Describe how the process of DNA replication produces two identical DNA molecules.

(4)

(b) The graph shows the relationship between genome size and mutation rates of organisms.



(i) Analyse the graph to determine the approximate mutation rate for tobacco mosaic virus (TMV).

(2)

Answer.....

(ii) Comment on the relationship between genome size and mutation rate of the organisms shown in the graph.

(3)

- 7** Mitochondrial disorders may be caused by mutations in the genes coding for mitochondrial components. Some of these genes are found in mitochondrial DNA (mtDNA) and some are found in nuclear DNA.

Leigh syndrome is an example of a mitochondrial disorder. In this syndrome, a number of different proteins involved in respiration are affected.

These mutations may be inherited or may occur when DNA replicates.

- (a) Explain why mutations in nuclear DNA can be inherited from either the mother or the father whereas mutations in mtDNA are only inherited from the mother.

(2)

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- (b) Some people with Leigh syndrome have a mutation in the MT-ATP6 gene. This gene codes for ATP synthase.

This is a point mutation at nucleotide 8993 that changes thymine to guanine.

- (i) What type of mutation is this?

(1)

- ☐ **A** insertion
- ☐ **B** monosomy
- ☐ **C** substitution
- ☐ **D** translocation

- (ii) Explain how this mutation could affect oxidative phosphorylation.

(3)

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(c) Leigh syndrome can also be due to a mutation in the SURF1 gene.

This mutation results in a shortened protein.

Explain how a mutation can result in a shortened protein being produced.

(2)

(d) Some people with Leigh syndrome have mutations that affect proteins involved in the electron transport chain.

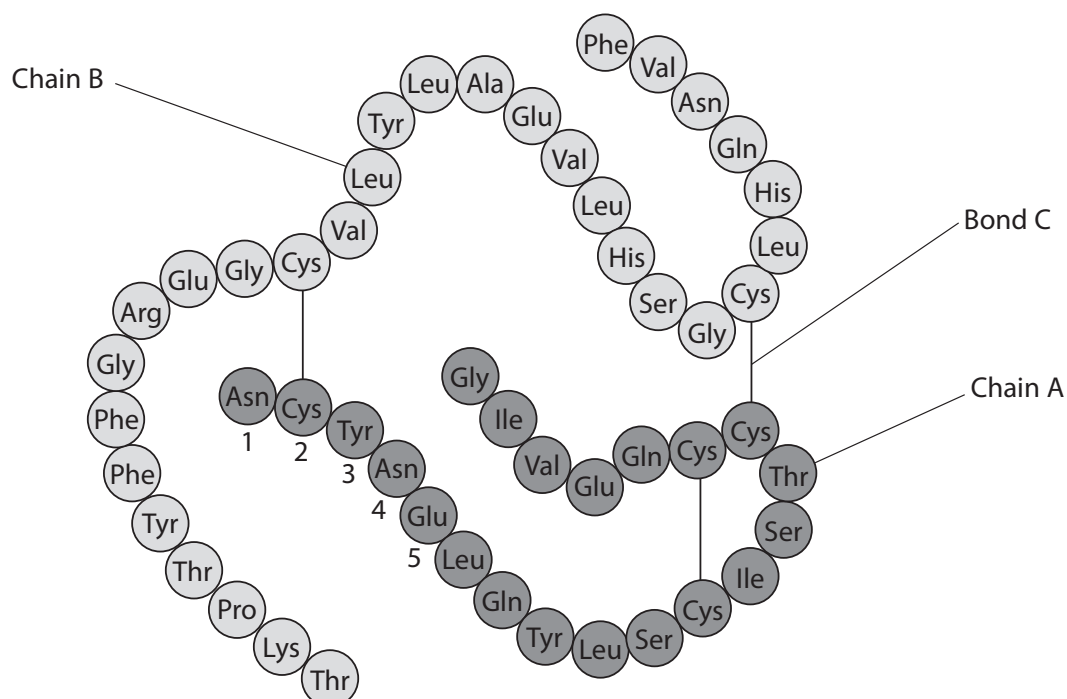
Explain why these mutations lead to a build-up of lactate.

(3)



- 4 Insulin is a protein that is composed of two polypeptide chains, chain A and chain B.

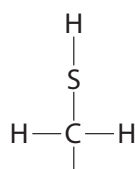
The diagram shows the amino acid sequence of these two polypeptide chains and some of the bonds involved in the folding of this protein.



- (a) Cysteine (Cys) is one type of amino acid found in insulin.

The presence of cysteine in insulin is important in determining the structure of this protein.

The R group of cysteine is:



- (i) Draw a diagram to show the structure of the amino acid cysteine.

(3)

(ii) Name the covalent bond labelled C in the diagram.

(1)

(b) The table shows the DNA genetic codes on the anti-sense DNA strand (template strand) for amino acids.

Genetic code	Amino acid	Genetic code	Amino acid	Genetic code	Amino acid	Genetic code	Amino acid
AAA AAG	Lys	CAA CAG	Gln	GAA GAG	Glu	TAC TAT	Tyr
AAC AAT	Asn	CAT CAC	His	GAC GAT	Asn	TCA TCC TCG TCT	Ser
ACA ACC ACG ACT	Thr	CCA CCC CCG CCT	Pro	GCA GCC GCG GCT	Ala	TGG	Try
AGA AGG	Arg	CGA CGC CGG CGT	Arg	GGA GGC GGG GGT	Gly	TGC TGT	Cys
AGC AGT	Ser	CTA CTC CTG CTT	Leu	GTA GTC GTG GTT	Val	TTA TTG	Leu
ATA ATC ATT	Ile					TTC TTT	Phe
ATG	Met						

The genetic codes TAA, TAG and TGA are stop codons.

(i) Complete the diagram to show one base sequence in the antisense DNA strand (template strand) coding for the five amino acids numbered in the diagram of insulin.

(1)

Amino acid number	1	2	3	4	5
Amino acid abbreviation	Asn	Cys	Tyr	Asn	Glu
Base sequence on the antisense DNA strand		TGT			



*(ii) Analyse the information to deduce how gene mutations in the DNA base sequence for Cys (amino acid number 2) could affect the structure of insulin.

(6)



6 In a cell, DNA is found in both the nucleus and the mitochondria.

(a) Where is DNA found in mitochondria?

(1)

- ☐ A cytoplasm
- ☐ B intermembrane space
- ☐ C matrix
- ☐ D nucleus

(b) Which row of the table describes DNA found in the mitochondria?

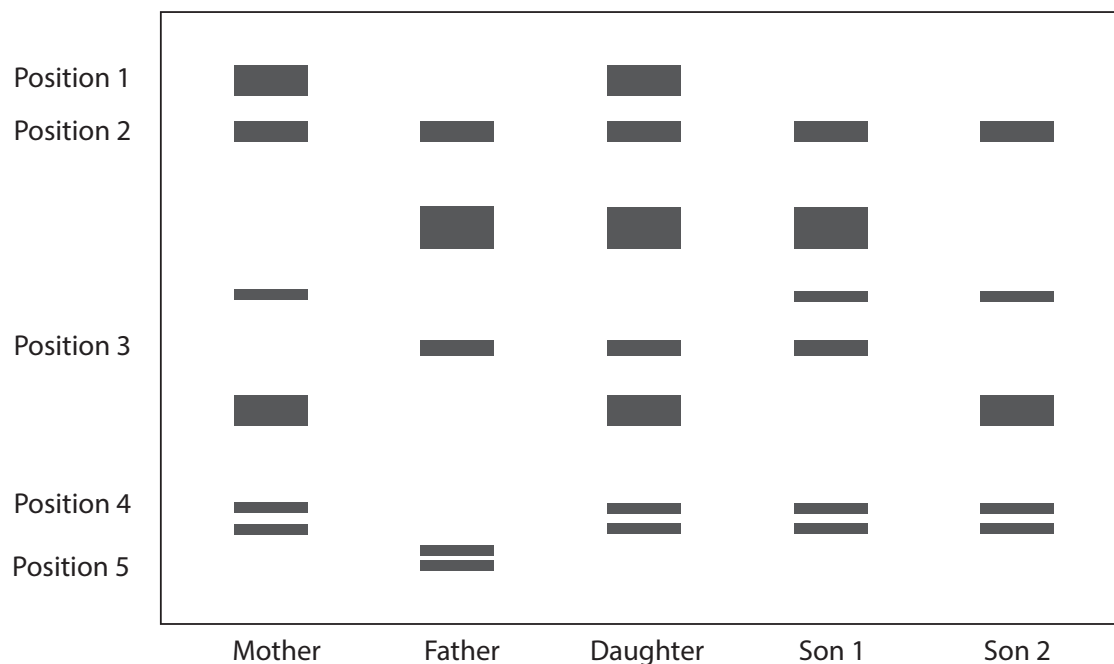
(1)

	Shape	Ratio of phosphodiester bonds : pentose sugars
☐ A	circular	higher than nuclear DNA
☐ B	circular	lower than nuclear DNA
☐ C	linear	higher than nuclear DNA
☐ D	linear	lower than nuclear DNA



(c) Gel electrophoresis can be used to analyse the DNA of a person.

The diagram shows some of the bands produced when the DNA of a family was analysed using gel electrophoresis.



Analyse the information to explain the bands found at positions 1 to 5 in this family.

(4)

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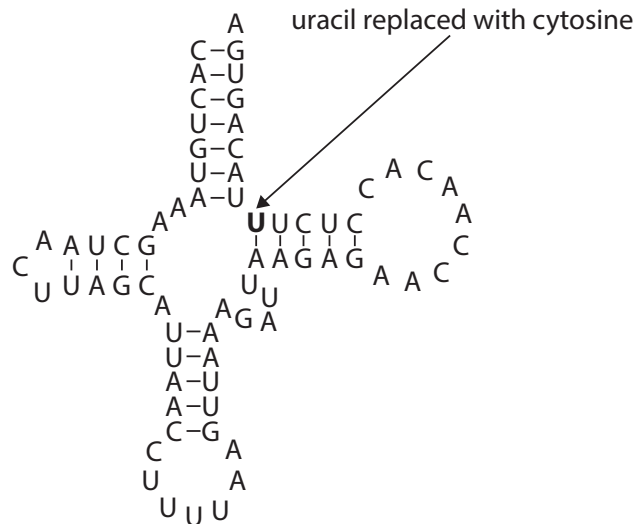
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- (d) A mutation in the tRNA^{Lys} gene in the mitochondria replaces one uracil with a cytosine in the resulting tRNA molecule.

The diagram shows the position of the uracil that is replaced with cytosine in a tRNA^{Lys} molecule.



- (i) Name this type of mutation.

(1)

- (ii) Explain how this mutation could affect the structure of the tRNA^{Lys} molecule shown in the diagram.

(2)

- (iii) Explain how this mutation could affect the role of the tRNA^{Lys} molecule.

(2)



5 Turner's syndrome (TS) results from a chromosome mutation.

People with TS are at a higher risk of developing autoimmune disorders than people without TS.

An autoimmune disorder results when a person's immune system attacks their own body.

(a) Which of the following describes the chromosome mutation that causes TS?

(1)

- ☐ **A** non-disjunction leading to monosomy
- ☐ **B** non-disjunction leading to polysomy
- ☐ **C** translocation leading to monosomy
- ☐ **D** translocation leading to polysomy

(b) There were 613 936 babies born in the UK in 2020.

The ratio of baby boys to baby girls is 1.05 : 1.

The incidence of TS is between 1 in 2 000 and 1 in 2 500 in baby girls.

Calculate the **minimum** number of baby girls born with TS in the UK in 2020.

(2)

Answer

(c) Scientists studied a group of girls with TS and a group of girls without TS.

They recorded physical features and immunological markers such as antibodies and lymphocytes.

(i) Girls who had recently been vaccinated were excluded from this study.

Explain why these girls were excluded.

(3)

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(ii) The table shows some of the physical features of the two groups of girls.

Physical features	Mean value ± SD for each group of girls	
	With TS	Without TS
Age / years	11.9 ± 4.1	12.5 ± 4.0
Mass / kg	36.7 ± 14.8	45.2 ± 19.3
Height / cm	134.8 ± 20.0	146.3 ± 21.3
Standardised height score	−2.16 ± 0.95	−0.41 ± 0.50
Body mass index (BMI)	19.2 ± 3.3	19.7 ± 4.6

Only one of these features was significantly different between the two groups of girls.

Explain which was the significantly different feature.

(2)

(iii) The table shows the levels of four immunological markers in the blood of each group of girls.

Immunological marker	Mean value ± SD for each group of girls	
	With TS	Without TS
IgA antibody / g dm ⁻³	1.08 ± 0.39	1.15 ± 0.42
IgG antibody / g dm ⁻³	9.14 ± 2.10	11.15 ± 3.29
CD4 lymphocytes / cells per µl	656.3 ± 227.3	817.3 ± 350.1
CD8 lymphocytes / cells per µl	597.6 ± 272.6	494.8 ± 188.3

Analyse the data to describe the conclusions that can be made about the immunological markers in girls with TS.

(2)

(iv) The scientists also determined the number of a type of cell called T regulatory cells in the blood of these two groups of girls.

They found that the numbers of these cells were very similar.

People with autoimmune diseases have been shown to have a decreased number of T regulatory cells.

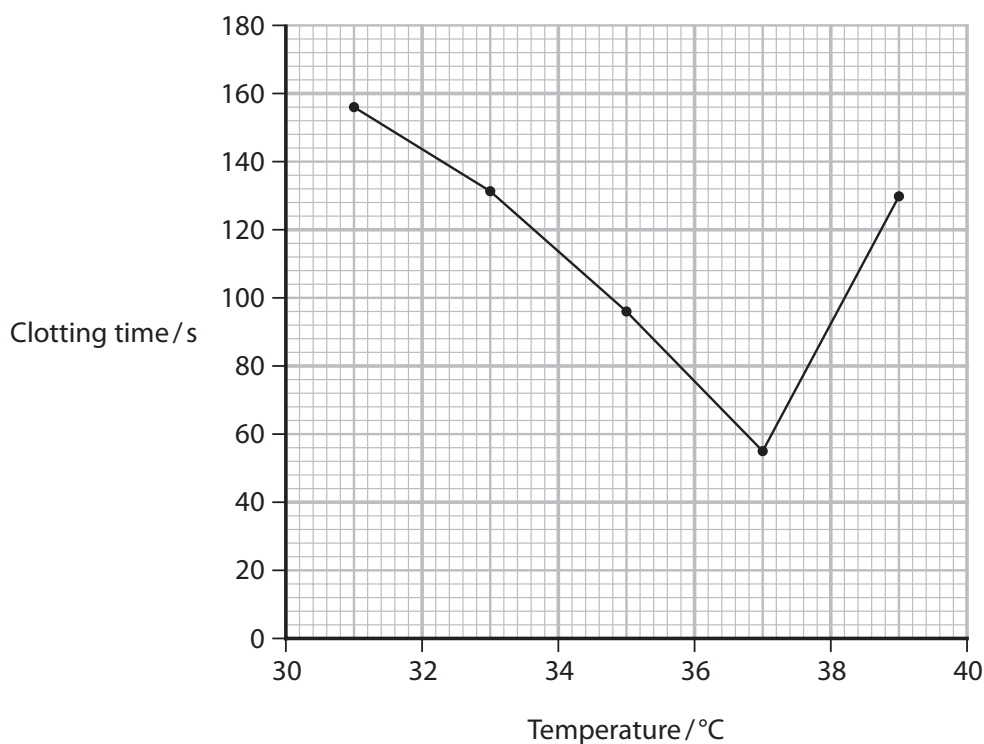
Explain how this study could be modified to show that a decreased number of T regulatory cells is linked to the risk of autoimmune disease in girls with TS.

(2)



- 4 A scientist investigated the effect of temperature on the time it takes for blood to clot.

The graph shows the results of this investigation.



- (a) Explain how these results show that enzymes are involved in blood clotting.

(3)

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- (b) Prothrombin is involved in the blood clotting process.

The *F2* gene codes for the synthesis of prothrombin.

This gene is located from base pair 46 719 191 to base pair 46 739 504 on chromosome 11.

Determine the number of codons in this gene.

(1)

Answer

- (c) A mutation of the *F2* gene causes thrombophilia, a condition that results in the production of excess prothrombin.

In this gene mutation, guanine is replaced with adenine.

- (i) Name this type of mutation.

(1)

- (ii) People without this mutation have a 1 in 1000 risk of producing a blood clot in an artery.

The mutation increases this risk by 20 times.

State the probability of producing a blood clot for people with this mutation.

(1)

- (iii) Explain why thrombophilia increases the risk of producing a blood clot in an artery.

(3)



(d) A genetic test can be used to find out if a person has thrombophilia.

The test involves using a restriction endonuclease to obtain genetic material from white blood cells.

This genetic material is then used in the polymerase chain reaction (PCR).

(i) State the role of a restriction endonuclease.

(1)

(ii) Describe the process of PCR.

(3)



SUB-TOPIC 8(b)

INHERITANCE AND GENETIC CROSSES

12 questions in this sub-topic · 125 marks · lowest tariff first



- 4 The photograph shows a maize cob with smooth, wrinkled and different coloured grains.



© W.P. Armstrong 2001

The shape and colour of maize grains are controlled by two unlinked genes.

The allele for smooth seeds (A) is dominant to the allele for wrinkled seeds (a).

The allele for purple seeds (B) is dominant to the allele for yellow seeds (b).

- (a) State all the possible genotypes of a smooth, purple grain.

(1)

- (b) Two maize plants, grown from grains that were both wrinkled and purple, were cross-pollinated.

In the F_1 generation, some grains were wrinkled and purple and some were wrinkled and yellow.

Which of the following shows the genotypes of the parent plants?

(1)

- ☒ A $AaBb \times AaBb$
- ☒ B $aaBB \times aaBB$
- ☒ C $AABb \times AABb$
- ☒ D $aaBb \times aaBb$

- (c) A student cross-pollinated a maize plant grown from a smooth, purple grain (heterozygous for both pairs of alleles) with a maize plant grown from a wrinkled, yellow grain.

Using a genetic diagram, determine the probability that this cross will produce grains that are wrinkled and purple.

(4)

Answer

(Total for Question 4 = 6 marks)



- 3 Recombination of alleles can be due to the crossing over that occurs during meiosis. This process results in gametes with different combinations of alleles and genetic variation in the offspring.

(a) When does crossing over first take place?

(1)

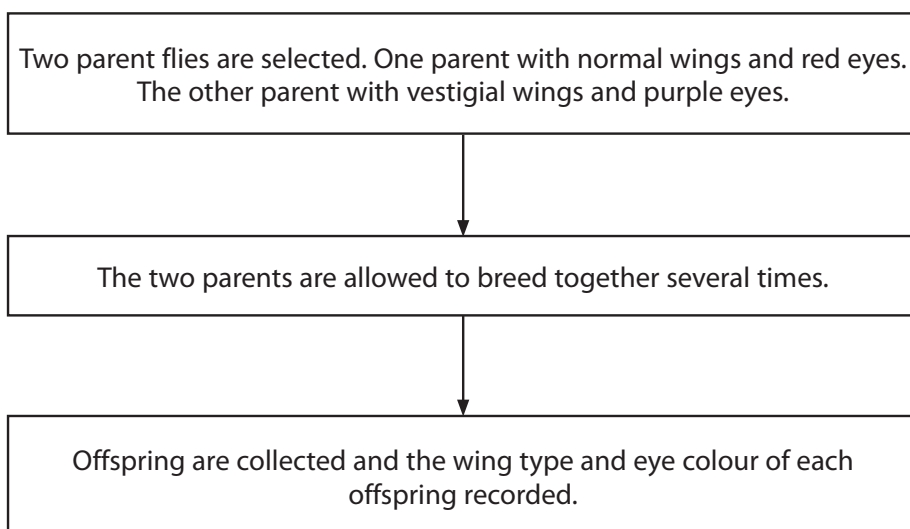
- ☒ A metaphase I
- ☒ B metaphase II
- ☒ C prophase I
- ☒ D prophase II

(b) Crossing over occurs between two genes found on the same chromosome.

The recombination frequency reflects the likelihood of crossing over occurring. It depends on how close the genes are on the chromosome.

In fruit flies, the gene for wing type is located on the same chromosome as the gene for eye colour.

The flow diagram shows an experiment used to calculate the recombination frequency for these two genes.



The table shows the results of one experiment.

Description of offspring	Number recorded
Normal wings and red eyes	672
Vestigial wings and purple eyes	592
Normal wings and purple eyes	75
Vestigial wings and red eyes	69

The recombinant frequency is the percentage of offspring that have a different combination of characteristics compared with the parents. It is the proportion of the total number of offspring.

Calculate the recombinant frequency for this pair of genes.

Give your answer to three significant figures.

(1)

Answer %

- (c) The table shows the recombinant frequencies between four genes, J, K, L and M, located on the same chromosome.

Pairs of genes	Recombinant frequency (%)
J and K	12.0
J and M	15.0
L and K	3.0
L and M	6.0

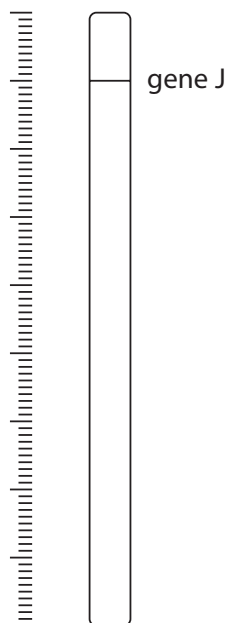
A genetic map can be produced by drawing a scale diagram to show the location of these genes.



The diagram shows the position of gene J on a chromosome.

Complete the diagram to show the position of genes K, L and M on this chromosome.

(3)



- (d) Explain why crossing over between two different genes, located on a pair of homologous chromosomes, results in a maximum of 50% of gametes with the recombinant alleles.

(3)

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7 The diagram shows four varieties of rabbit.



Brown



Chinchilla



Himalayan



Albino

Fur colour in rabbits is controlled by four different alleles:

- the allele for brown fur, C , is dominant to all other alleles
- the allele for chinchilla fur, c^{ch} , is dominant to the alleles for Himalayan and albino
- the allele for Himalayan fur, c^{h} , is dominant to the allele for albino
- the allele for albino fur, c , is recessive to all other alleles

(a) (i) Describe how new combinations of alleles are produced in meiosis.

(2)

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(ii) State all the possible genotypes of a rabbit with brown fur.

(1)

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(iii) Two parent rabbits with brown fur were mated. Two of the F_1 offspring had chinchilla fur.

The F_1 rabbit offspring with chinchilla fur were mated.

The F_2 generation consisted of some rabbits with chinchilla fur and the rest having Himalayan fur.

Use genetic crosses to deduce the genotypes of the two parent rabbits with brown fur. (3)

Answer



(b) The fur colour of animals can be affected by natural selection.

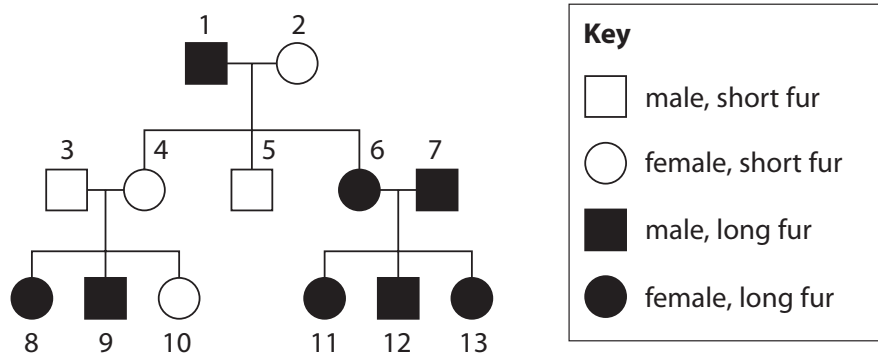
Compare and contrast stabilising selection with disruptive selection.

(3)



- 4 In cats, the gene for fur length is not located on the X chromosome. The allele for short fur (F) is dominant to the allele for long fur (f).

The pedigree diagram shows the inheritance of fur length in a family of cats.



- (a) Explain how one piece of evidence from the diagram shows that the allele for short fur is dominant to the allele for long fur.

(2)

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- (b) A gene for fur colour in cats is located on the X chromosome.

The alleles for black fur (X^B) and orange fur (X^o) are codominant.

Tortoiseshell cats have areas of black and orange fur.

- (i) Give all the possible genotypes of a male, black cat with short fur.

(1)

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(ii) Explain why all tortoiseshell cats are female.

(2)

(iii) In a genetic cross, a tortoiseshell cat with long fur was mated with an orange male cat, heterozygous for fur length.

Deduce the probability of producing a tortoiseshell cat with long fur from this cross.

Use a genetic diagram to support your answer.

(4)

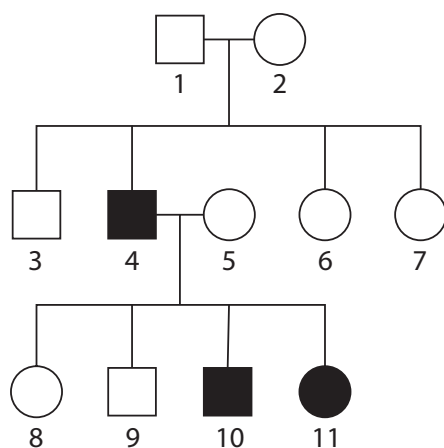


- 8 (a) Haemophilia is a sex linked, genetic condition that prevents blood clotting.

X^H is the allele for blood clotting

X^h is the allele for haemophilia

The pedigree diagram shows a family that has individuals who have haemophilia.



Key



male with haemophilia



male without haemophilia



female with haemophilia



female without haemophilia

- (i) What are the genotypes of individuals 1 and 2?

(1)

- ☐ **A** $X^H Y$ and $X^H X^H$
- ☐ **B** $X^h Y$ and $X^H X^h$
- ☐ **C** $X^h Y$ and $X^H X^H$
- ☐ **D** $X^H Y$ and $X^H X^h$

- (ii) Use a genetic diagram to determine the probability that the next child of individuals 4 and 5 will be a boy without haemophilia.

(3)

Answer.....



- (b) Kidney dialysis machines are used to remove urea from the blood of patients who are suffering from kidney disease.

Anti-clotting drugs are given to patients to reduce the risk of blood clot formation whilst undergoing kidney dialysis.

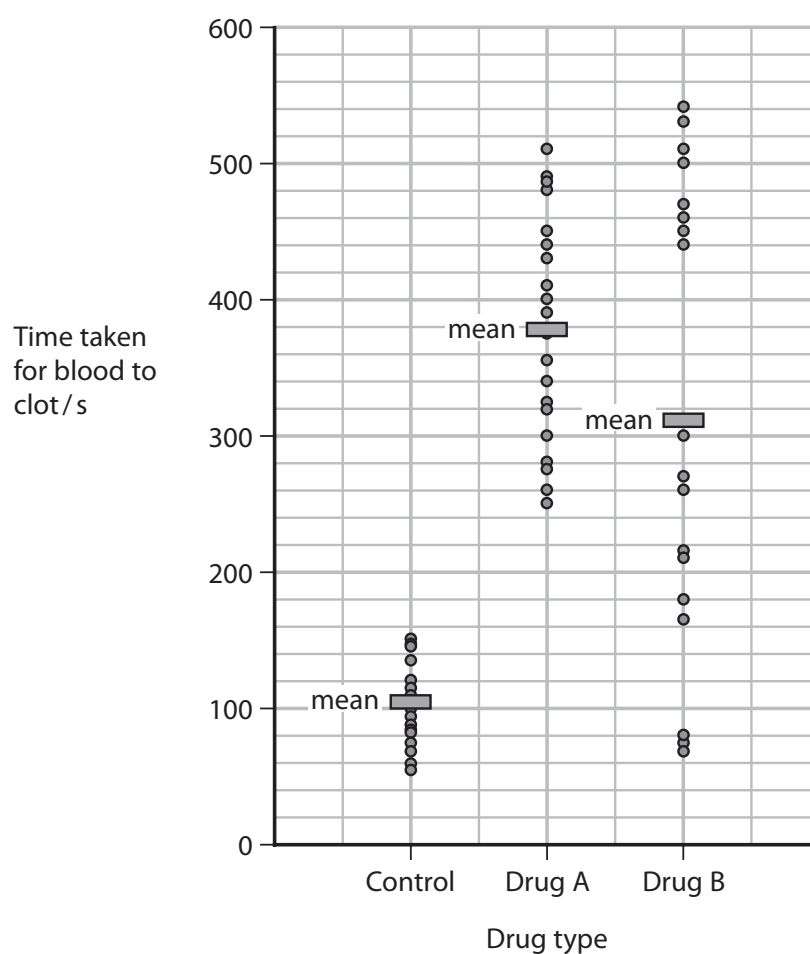
The potential use of two anti-clotting drugs, Drug A and Drug B, was investigated.

Blood samples were taken from 20 healthy adults and placed into test tubes.

The times taken for the blood samples to clot after addition of 2 mg dm^{-3} of Drug A were recorded.

This was repeated with Drug B and again with a control.

The results are shown in the graph.



It takes 40 minutes for Drug A to become inactive in a person and 110 minutes for Drug B to become inactive.

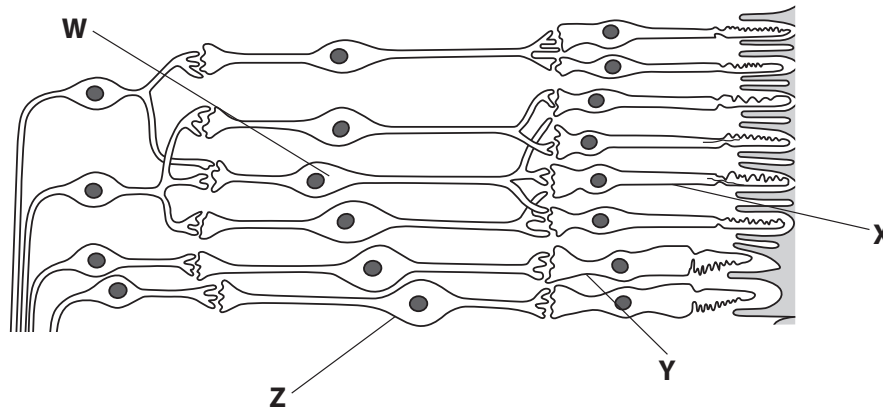
Analyse the data to discuss the use of Drug A and Drug B to prevent the formation of blood clots.

(5)



4 The retina is the light sensitive structure in the eye.

(a) The diagram shows some of the cells in a human retina.



(i) Which row in the table correctly identifies the cells **W**, **X** and **Y**?

(1)

	Cell W	Cell X	Cell Y
☐ A	bipolar cell	cone cell	rod cell
☐ B	bipolar cell	rod cell	cone cell
☐ C	ganglion cell	cone cell	rod cell
☐ D	ganglion cell	rod cell	cone cell

(ii) Draw an arrow on the diagram to show the direction of the light passing through the retina.

(1)

(iii) Explain why a higher light intensity is required to produce an action potential in cell **Z** than in cell **W**.

(3)

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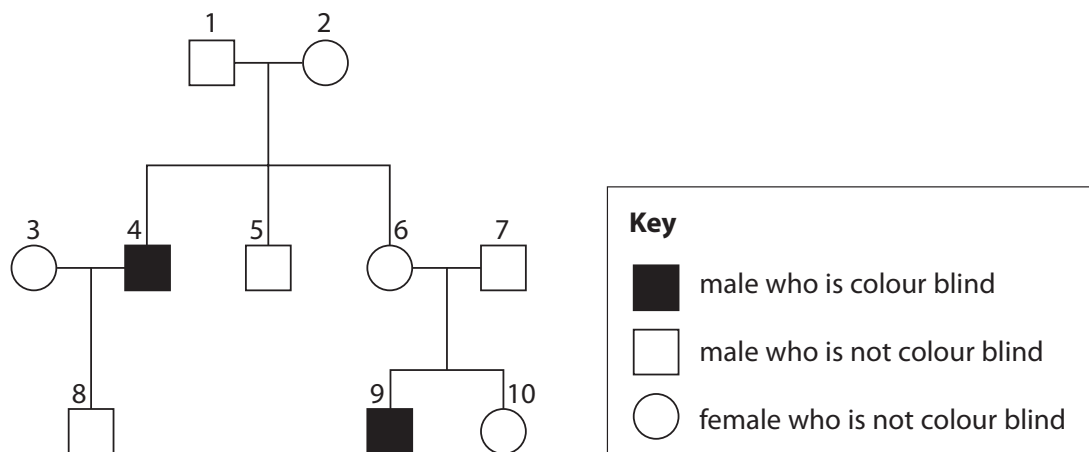
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- (b) Red-green colour vision is controlled by a single gene located on the X chromosome. Colour blindness is caused by a recessive allele for the red-green colour vision gene. The diagram shows the inheritance pattern of colour blindness for a family.



- (i) Explain how the diagram shows that red-green colour blindness is caused by a recessive allele.

(2)

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- (ii) Use a genetic diagram to determine the probability that the next child of individuals 6 and 7 is a male who is colour blind.

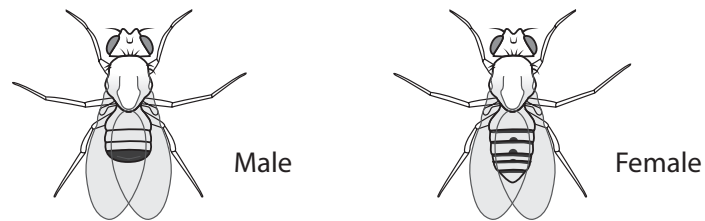
(3)

Answer

(Total for Question 4 = 10 marks)



- 4 Fruit flies, *Drosophila melanogaster*, are often used in genetics investigations. The diagrams show male and female flies.



Actual size = 3 mm

- (a) Give one feature, visible in the diagrams, that you could use to distinguish between male and female flies and state how it differs between them.

(1)

Feature

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Difference

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- (b) A scientist investigated the inheritance of several genes in fruit flies.

- (i) A grey-bodied fly was crossed with a black-bodied fly.

All the offspring in the F_1 generation were grey-bodied.

Two of the grey-bodied flies from the F_1 generation were then crossed.

Determine the expected ratio of phenotypes of the offspring in the resulting F_2 generation by using a genetic diagram.

(2)

Answer

- (ii) Normal fruit flies have long wings but some flies have very short wings called vestigial wings.

The allele for long wing (L) is dominant to the allele for vestigial wing (l).

The gene for wing length is located on chromosome 2.

The allele for normal antennae (A) is dominant to the allele for bushy antennae (a).

The gene for antennae shape is located on chromosome 3.

Two flies which are heterozygous for both characteristics are crossed.

Determine the ratio of phenotypes that you would expect in the next generation, using a genetic diagram.

(3)

- (iii) The allele for red eyes (R) is dominant to the allele for white eyes (r).

The scientist investigated the inheritance of eye colour.

The crosses used were:

cross 1 – a red-eyed female fly was crossed with a white-eyed male fly: half of the offspring were red-eyed females and half were red-eyed males

cross 2 – a white-eyed female fly was crossed with a red-eyed male fly: half of the offspring were red-eyed females and half were white-eyed males.

Explain the results of these crosses.

(4)



2 The photograph shows tomato flowers.



(Source: © NIGEL CATTLIN / HOLT STUDIOS / SCIENCE PHOTO LIBRARY)

- (a) (i) Describe how an embryo sac, containing eight haploid nuclei, is formed inside the ovary of a flower.

(3)

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(ii) Which row gives the correct chromosome number in these structures?

(1)

	endosperm cell	generative nucleus of pollen grain	embryo cell
☐ A	n	n	2n
☐ B	2n	2n	2n
☐ C	3n	n	2n
☐ D	3n	2n	n

(b) Cereal grains, such as barley, start to germinate after exposure to water.

Which growth substance is released by the embryo during germination to stimulate enzyme production?

(1)

- ☐ **A** auxin
- ☐ **B** cytokinin
- ☐ **C** gibberellin
- ☐ **D** phytochrome

(c) The colour of tomato fruits is controlled by two genes, each on a different chromosome.

- The flesh colour gene has two alleles, a dominant allele for red flesh (**R**) and a recessive allele for white flesh (**r**).
- The skin colour gene has two alleles, a dominant allele for yellow skin (**T**) and a recessive allele for white skin (**t**).

If a tomato plant has an allele for red flesh (**R**), the tomatoes will always have a red colour regardless of the skin colour.

(i) Which are the possible genotypes for a yellow-coloured tomato?

(1)

- ☐ **A** **RrTT** only
- ☐ **B** **rrTt** only
- ☐ **C** **rrtt** only
- ☐ **D** **rrTt** and **rrTT**



- (ii) A tomato breeder crosses a yellow tomato plant with a red tomato plant that is heterozygous for both genes.

Some of the F1 generation tomatoes are white.

Determine the expected ratios of all the phenotypes of the F1 generation, using a genetic diagram.

(4)

Answer

(Total for Question 2 = 10 marks)



5 The human retina contains photoreceptors called rod cells and cone cells.

(a) (i) Which of the following occur in the rod cell when it is stimulated by light?

(1)

- 1 rhodopsin breaks down into retinal and opsin
- 2 there is a decrease in the release of neurotransmitter molecules
- 3 there is more diffusion of sodium ions into the rod cell

- ☐ **A** 1 and 2
- ☐ **B** 1 and 3
- ☐ **C** 1, 2 and 3
- ☐ **D** 2 and 3

(ii) Explain why the centre of the retina is less sensitive to low intensity light than the outer areas.

(2)

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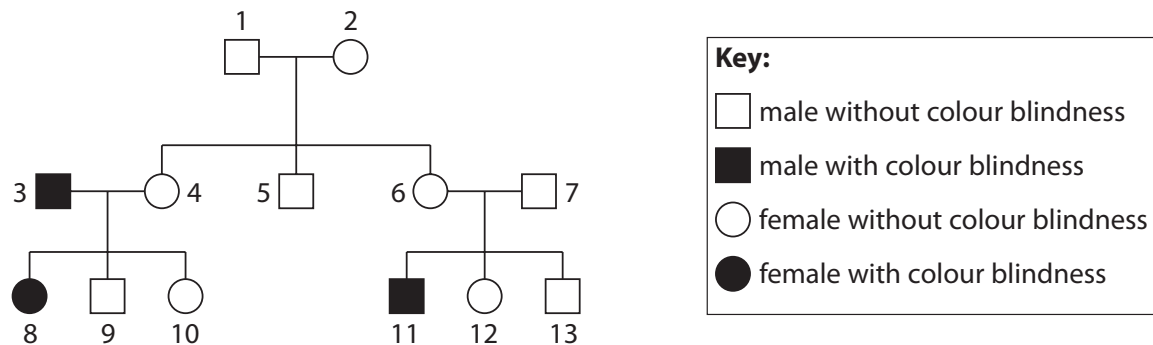
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- (b) Red-green colour blindness is a sex-linked genetic condition. People with this condition are unable to detect differences between red and green colours.

The pedigree diagram shows the inheritance of red-green colour blindness in a family.

The allele for red-green colour blindness, X^r , is recessive to the allele for colour vision, X^R .



- (i) How many of the individuals in the family must have a genotype of $X^R X^r$?

(1)

- ☐ A 2
- ☐ B 3
- ☐ C 4
- ☐ D 5

- (ii) Explain how this pedigree diagram demonstrates that red-green colour blindness is caused by a recessive allele.

(2)

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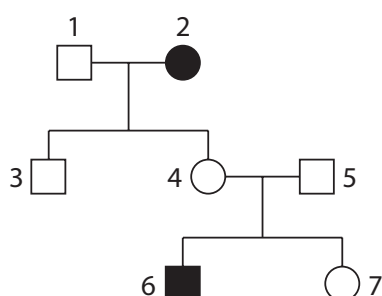
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(c) Pingelap is an isolated island in the Pacific Ocean.

On Pingelap, between 4% and 10% of the population has a condition called achromatopsia. This means that they are unable to see any colour.

In most other countries, the incidence of achromatopsia is around 0.003%.

(i) The pedigree diagram shows the people who are and are not affected with achromatopsia in a family.



Key:

- ☐ male without achromatopsia
- ☒ male with achromatopsia
- ☐ female without achromatopsia
- ☒ female with achromatopsia

Deduce how achromatopsia is inherited.

Use the information in the pedigree diagram to support your answer.

(3)

(ii) In 1755, a tsunami reduced the population to 20 people and there has been little immigration to the island.

In 2022, the human population of Pingelap was approximately 250.

Explain why the incidence of achromatopsia is higher in Pingelap than in other countries.

(2)



- 10** In the fruit fly, *Drosophila*, the allele for normal wings (**N**) is dominant to the allele for vestigial (small) wings (**n**).

The allele for red eyes (**R**) is dominant to the allele for sepia eyes (**r**).

In an investigation, students crossed homozygous parent flies. Flies with normal wings and red eyes were crossed with flies with vestigial wings and sepia eyes.

All the F_1 offspring of this cross had normal wings and red eyes.

Flies from this F_1 generation were crossed and the phenotypes of their offspring (F_2 generation) were counted.

The results for the F_2 generation are shown in the table.

<i>Drosophila</i> phenotype	Number of <i>Drosophila</i> with each phenotype
normal wings and red eyes	885
normal wings and sepia eyes	322
vestigial wings and red eyes	286
vestigial wings and sepia eyes	107

The students thought that the genes for wing length and eye colour were on different chromosomes.

- (a) (i) State a null hypothesis for this investigation.

(1)

- (ii) A Chi squared test was carried out to test this hypothesis.

Complete the table.

(1)

Phenotype	Expected ratio	Observed results (O)	Expected results (E)	(O – E)	(O – E) ²	$\frac{(O - E)^2}{E}$
normal wings and red eyes	9	885	900			
normal wings and sepia eyes	3	322	300	22	484	1.61
vestigial wings and red eyes	3	286	300	–14	196	0.65
vestigial wings and sepia eyes	1	107	100	7	49	0.49



(iii) Calculate the value of Chi squared using the formula

(1)

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Answer

(iv) The table shows some critical values of Chi squared at different degrees of freedom.

Degrees of freedom	<i>p</i> value				
	0.900	0.500	0.100	0.050	0.010
1	0.016	0.455	2.706	3.841	6.635
2	0.211	1.386	4.605	5.991	9.210
3	0.584	2.366	6.251	7.815	11.345
4	1.064	3.357	7.779	9.488	13.277

Use this table to comment on the results of the investigation.

(3)

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*(b) In *Drosophila*, the allele for grey bodies (**G**) is dominant to the allele for black bodies (**g**).

In a second investigation, students crossed homozygous parent flies. Flies with normal wings and grey bodies were crossed with flies with vestigial wings and black bodies.

All the F₁ offspring had normal wings and grey bodies.

Flies from this F₁ generation were crossed and the phenotypes of their offspring (F₂ generation) were counted.

The results are shown in the table.

<i>Drosophila</i> phenotype	Number of <i>Drosophila</i> with each phenotype
normal wings and grey body	1105
normal wings and black body	85
vestigial wings and grey body	72
vestigial wings and black body	338

Explain the results of this second investigation.

(6)

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4 Red-green colour blindness is a sex-linked condition.

(a) In humans, the gene for colour vision is located on the X chromosome.

The allele for red-green vision (X^B) is dominant to the allele for red-green colour blindness (X^b).

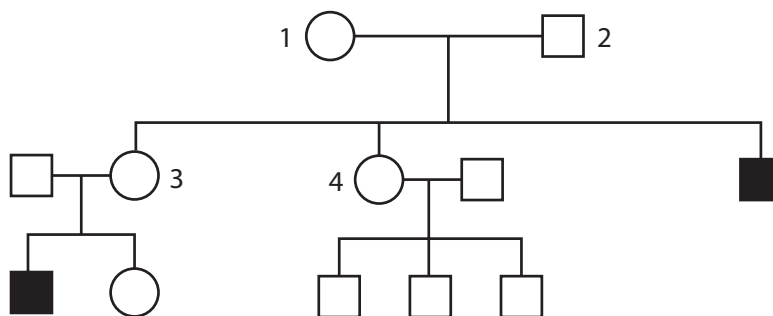
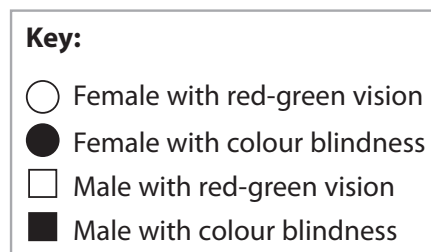
(i) State all the possible genotypes of females.

(1)

(ii) State all the possible genotypes of males.

(1)

(iii) The diagram shows a family tree for a family where some individuals have this condition.



Give all the possible genotypes for each of the following individuals.

(4)

1

2

3

4

(b) Squirrel monkeys are found in the forests of Central and South America.

The photograph shows a squirrel monkey.



(Source: Adrian Hepworth / Alamy Stock Photo)

Squirrel monkeys have a varied diet, including leaves, fruits and insects.

In squirrel monkeys, the production of the pigments needed for red and green vision is determined by two alleles of a single gene.

This gene is located on the X chromosome.

Female squirrel monkeys have two X chromosomes, male squirrel monkeys have one X chromosome and one Y chromosome.

The colour red can be seen only if the allele X^R is present.

The colour green can be seen only if the allele X^G is present.

Scientists have studied the inheritance of colour vision in squirrel monkeys.

- (i) A female monkey able to see both red and green is mated with a male monkey able to see only green.

Determine the ratio of phenotypes you would expect in their offspring.

Use a genetic diagram to support your answer.

(2)

- (ii) In separate crosses two monkeys were mated.

Half of the offspring were females with the ability to see both red and green colours and half were males able to see red only.

Determine the genotypes of these parents.

Use a genetic diagram to support your answer.

(3)

- (iii) State why it would be an advantage for monkeys living in forests in South America to be able to see both red and green colours.

(1)

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- (iv) In 2009, scientists successfully used gene technology on some squirrel monkeys unable to see the colour red.

The scientists identified the gene for the protein that is sensitive to red light in humans. This gene was transferred to cells in the retina of these monkeys.

Describe how the scientists may have carried out this gene technology.

(3)

- 3 Anthocyanin is a purple pigment found in a range of vegetable plants.
The photograph shows some carrots from a variety called Purple Haze.



- (a) Describe how you would investigate the effect of temperature on the permeability of the membranes in the root cells of these purple carrots.

(5)

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- (b) The anthocyanins in purple carrots are used as antioxidants in the food industry.

Purple Haze carrots with a mass of 750g contain 1265.25 mg of anthocyanin.

Calculate the percentage of anthocyanin in these carrots.

Give your answer to two decimal places.

(2)

Answer

- (c) Purple cauliflower plants also contain anthocyanins.

Cauliflowers can be light purple, dark purple or white.

The photograph shows a dark purple cauliflower.



The colour in cauliflowers is controlled by a single gene with two alleles.

Purple colour is controlled by the allele P_r .

White colour is controlled by the allele p_r .

In an investigation, dark purple cauliflowers were crossed with pure bred white cauliflowers.

The F1 generation cauliflowers were all light purple in colour.

(i) State the genotype of the F1 generation.

(1)

(ii) The F1 generation was then self-fertilised to produce the F2 generation.

The numbers observed (O) in the F2 generation were:

31 white cauliflowers, 52 light purple and 20 dark purple cauliflowers.

It was concluded that the purple colour in cauliflowers is controlled by a single gene with two codominant alleles.

State the expected (E) number of each of the three phenotypes in the F2 generation.

(2)

(iii) Calculate the value for Chi squared using these results.

Use the formula for Chi squared:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

(3)

Answer



(iv) The table shows some critical values for Chi squared.

Degrees of freedom	<i>p</i> value				
	0.900	0.500	0.100	0.050	0.010
1	0.016	0.455	2.706	3.841	6.635
2	0.211	1.386	4.605	5.991	9.210
3	0.584	2.366	6.251	7.815	11.345
4	1.064	3.357	7.779	9.488	13.277

Explain why the conclusion that colour in cauliflowers is controlled by a single gene with two codominant alleles is likely to be valid.

(3)

SUB-TOPIC 8(c)

POPULATION GENETICS AND EVOLUTION

12 questions in this sub-topic · 150 marks · lowest tariff first



6 The photograph shows a brown rat, *Rattus norvegicus*.



(Source: © DK IMAGES/SCIENCE PHOTO LIBRARY)

(a) The classification hierarchy for the brown rat is:

- Domain: Eukarya
- Kingdom: Animalia
- Phylum: Chordata
- Mammalia
- Rodentia
- Muridae
- Genus: *Rattus*
- Species: *norvegicus*.

(i) Which family, order and class does the brown rat belong to?

(1)

	Family	Order	Class
☐ A	Mammalia	Muridae	Rodentia
☐ B	Mammalia	Rodentia	Muridae
☐ C	Muridae	Rodentia	Mammalia
☐ D	Muridae	Mammalia	Rodentia

(ii) State **one** method that scientists use to determine the evolutionary relationships of the brown rat compared with other species.

(1)

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(b) Warfarin is a poison that is often used to control brown rat populations.

In areas where large amounts of warfarin have been used, many rats have developed resistance to warfarin.

Three genotypes occur in rat populations:

$W^N W^N$ – rats that are not resistant to warfarin

$W^R W^R$ – rats that are resistant to warfarin but require large amounts of vitamin K in their diet to survive

$W^N W^R$ – rats that are resistant to warfarin and **do not** require large amounts of vitamin K to survive.

After the introduction of warfarin, scientists determined the change in numbers of rats that were resistant to warfarin, and the number that were not resistant to warfarin.

The table shows their results.

Type of rat	Genotypes of rats	Number of rats		
		before warfarin was used	two years after warfarin use started	five years after warfarin use started
Resistant to warfarin	$W^R W^R$ and $W^N W^R$	35	195	180
Not resistant to warfarin	$W^N W^N$	265	105	120

(i) Calculate the expected number of rats that would be resistant to warfarin but **do not** require large amounts of vitamin K to survive, before warfarin was used.

Use the Hardy-Weinberg equation

$$p^2 + 2pq + q^2 = 1$$

(3)

Answer



- (ii) Explain why, after two years, there is a change in the number of rats that are resistant to warfarin.

(2)

- (iii) Warfarin is highly toxic to rats that have no resistance.

Explain why, after five years, there are still many rats that are not resistant to warfarin.

(2)



- 1 Cholera is a disease caused by a bacterial infection that affects the absorption of water in the small intestine.

(a) The photograph shows part of one epithelial cell from the wall of the small intestine.



This cell is adapted to absorb substances by active transport.

State what is meant by the term **active transport**.

(2)

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(b) The bacteria that cause cholera release a toxin.

This toxin affects the CFTR protein found in the membrane of intestinal epithelium cells.

The toxin causes the CFTR protein to pump more chloride ions out of these cells into the intestine. This causes a lot of water to be lost in the faeces.

Explain how the toxin causes this water loss.

(3)

(c) The CFTR protein is also found in the membrane of epithelial cells in the lungs.

Cystic fibrosis is a recessive genetic condition caused by mutations of the allele for the CFTR protein.

This can result in the production of thick, highly viscous mucus in the bronchioles and bronchi.

Explain why the blood of people with cystic fibrosis has a low oxygen concentration.

(2)



(d) There is a high frequency of mutated CFTR alleles in some human populations.

In an experiment, three groups of genetically modified mice were infected with cholera bacteria.

The relative volume of water in their faeces was measured.

The results are shown in the table.

Group	Relative volume of water in faeces
Mice with two normal CFTR alleles	1.0
Mice with one normal and one mutated CFTR allele	0.5
Mice with two mutated CFTR alleles	0.1

Use the information in the table to explain why the mutated CFTR allele has a high frequency in some human populations.

(3)

(Total for Question 1 = 10 marks)

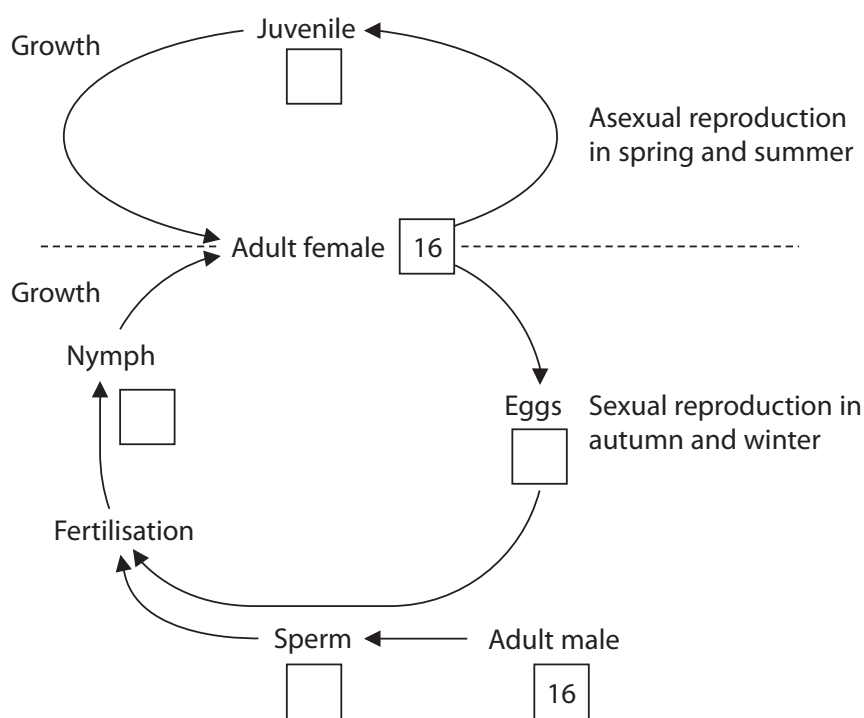
- 3 Adult female cabbage aphids (*Brevicoryne brassicae*) undergo either asexual reproduction or sexual reproduction depending on the time of year.

The photograph shows some cabbage aphids on a cabbage leaf.



Source: © Denis Crawford/Alamy Stock Photo

Some of the boxes in the diagram show the number of chromosomes present in a single cell from a particular stage of each of the alternative methods of reproduction.



- (a) (i) Complete the empty boxes in the diagram to show the number of chromosomes present in a single cell at that stage of reproduction.

(2)

- (ii) Label the arrows on the diagram with the letter **M** to show where meiosis takes place.

(1)

(b) Explain why a juvenile aphid is genetically identical to its parent.

(3)

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(c) (i) Complete the table with a ✓ or ✗ to compare the events during mitosis and meiosis. The first row in the table has been completed for you.

(3)

Event	Mitosis	Meiosis I	Meiosis II
chromosomes shorten and thicken	✓	✓	✗
homologous chromosomes pair together			
crossing over can cause genetic variation			
homologous chromosomes separate			
sister chromatids separate			

(ii) Which of the following increases the number of different alleles in a population?

(1)

- ☐ A crossing over
- ☐ B gene mutation
- ☐ C independent assortment of chromosomes during nuclear division
- ☐ D random fusion of gametes

(Total for Question 3 = 10 marks)



- 7** Cystic fibrosis is a recessive inherited condition where the cells in the lungs produce sticky mucus. This mucus builds up in the airways, causing breathlessness and chest infections.

People with cystic fibrosis often need treatments such as physiotherapy and antibiotics.

- (a) The incidence of babies born with cystic fibrosis in Australia is 1 in 2500.

Use the Hardy Weinberg equation, $p^2 + 2pq + q^2 = 1$, to calculate the percentage of Australians who are carriers of cystic fibrosis.

(4)

Answer%

- (b) A woman is a carrier of the cystic fibrosis allele. Her partner does not have cystic fibrosis and is not a carrier.

Use a genetic cross to determine the probability of this woman producing a child who is also a carrier.

(4)

Probability



- (c) Australian scientists observed that people with cystic fibrosis who went surfing had fewer symptoms than people with cystic fibrosis who did not go surfing.

The scientists carried out a trial on 164 people with cystic fibrosis.

These people were placed at random into either the experimental group or the control group.

The experimental group inhaled a fine spray of 7.0% salt solution and the control group inhaled a fine spray of 0.9% salt solution.

The scientists found that the mucus in the experimental group contained more water and became less sticky than the mucus in the control group.

- (i) Explain why only the fine spray of 7.0% salt solution resulted in mucus that contained more water.

(2)

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- (ii) Explain why the control group inhaled a fine spray of 0.9% salt solution, rather than a fine spray of pure water.

(2)

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- 4 The photograph shows an insect fossilised in amber resin.



(Source: Bjoern Wylezich. 123rf.com/PAL)

Scientists have classified another fossilised insect found in amber resin as a new species of mosquito, *Priscoculex burmanicus*.

This mosquito is anatomically very similar to modern species of mosquito.

- (a) (i) Which of these processes produces new species without geographically separating populations?

(1)

- ☐ A allopatric speciation
- ☐ B genetic speciation
- ☐ C stabilising speciation
- ☐ D sympatric speciation

- (ii) *Priscoculex burmanicus* became extinct about 100 million years ago.

State why it was difficult for scientists to decide if this insect belonged to a different species from modern mosquitoes.

(1)

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(iii) State how scientists would have reached agreement on classifying this mosquito.

(1)

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(iv) Complete the classification table for *Priscoculex burmanicus*.

(2)

Taxon	Name
Domain	Eukarya
Kingdom	Animalia
	Arthropoda
	Diptera
Order	Culicidae
Family	Anophelinae
Genus	
Species	

- (b) Mosquito populations are often controlled using pesticides that inhibit the enzyme acetylcholinesterase.

Long-term use of pesticides often leads to the development of resistance in these mosquitoes.

The ace-1 gene codes for the enzyme acetylcholinesterase.

The ace-1^r allele is a recessive form of this gene that gives resistance to pesticides.

The changes in the numbers of resistant and non-resistant mosquitoes in an area of farmland where pesticides were used in 2007 was investigated.

The use of the pesticides was stopped in 2016.

The table shows the results of this investigation.

Mosquito type	Number of mosquitoes		
	2005	2015	2018
resistant	125	5250	4120
non-resistant	8755	1250	3950

- (i) Calculate the number of heterozygous mosquitoes in 2015.

Use the Hardy-Weinberg equation

$$p^2 + 2pq + q^2 = 1$$

(3)

Answer.....



(ii) Explain why the changes in the numbers of the resistant and non-resistant mosquitoes, from 2005 to 2018, are related to the function of the *ace-1* gene.

(4)



- 7 The photograph shows a tawny owl. These owls live in areas close to the Arctic Circle.



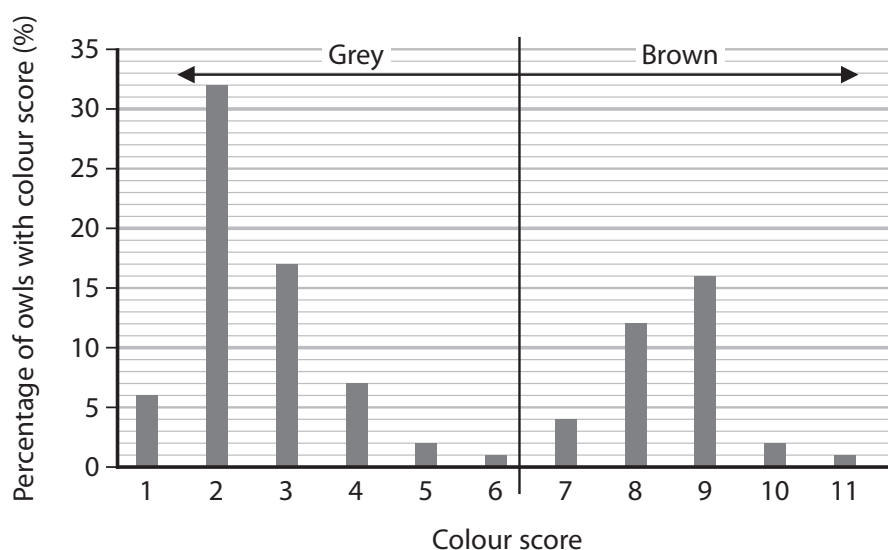
(Source: © LINDA WRIGHT/SCIENCE PHOTO LIBRARY)

Scientists investigated the feather colours of a population of tawny owls. Feather colours of the owls were scored on a scale of 1 to 11, according to how grey or brown they were.

Grey feathered owls were given a score between 1 and 6, with 1 being the most grey.

Brown feathered owls were given a score between 7 and 11, with 11 being the most brown.

The graph shows the percentages of owls in the population with each of the colour scores.



- (a) The scientists concluded that feather colour in owls is controlled by a single genetic locus. The brown allele is dominant to the grey allele.
- (i) State what is meant by a dominant allele.

(1)

- (ii) Explain the range of feather colours, shown in the graph, in this population of owls.

(2)

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- (iii) In this population of 120 owls, 84 of them were grey.

Calculate the number of owls that are heterozygous for feather colour.

Use the Hardy-Weinberg equation

$$p^2 + 2pq + q^2 = 1$$

(3)

Answer



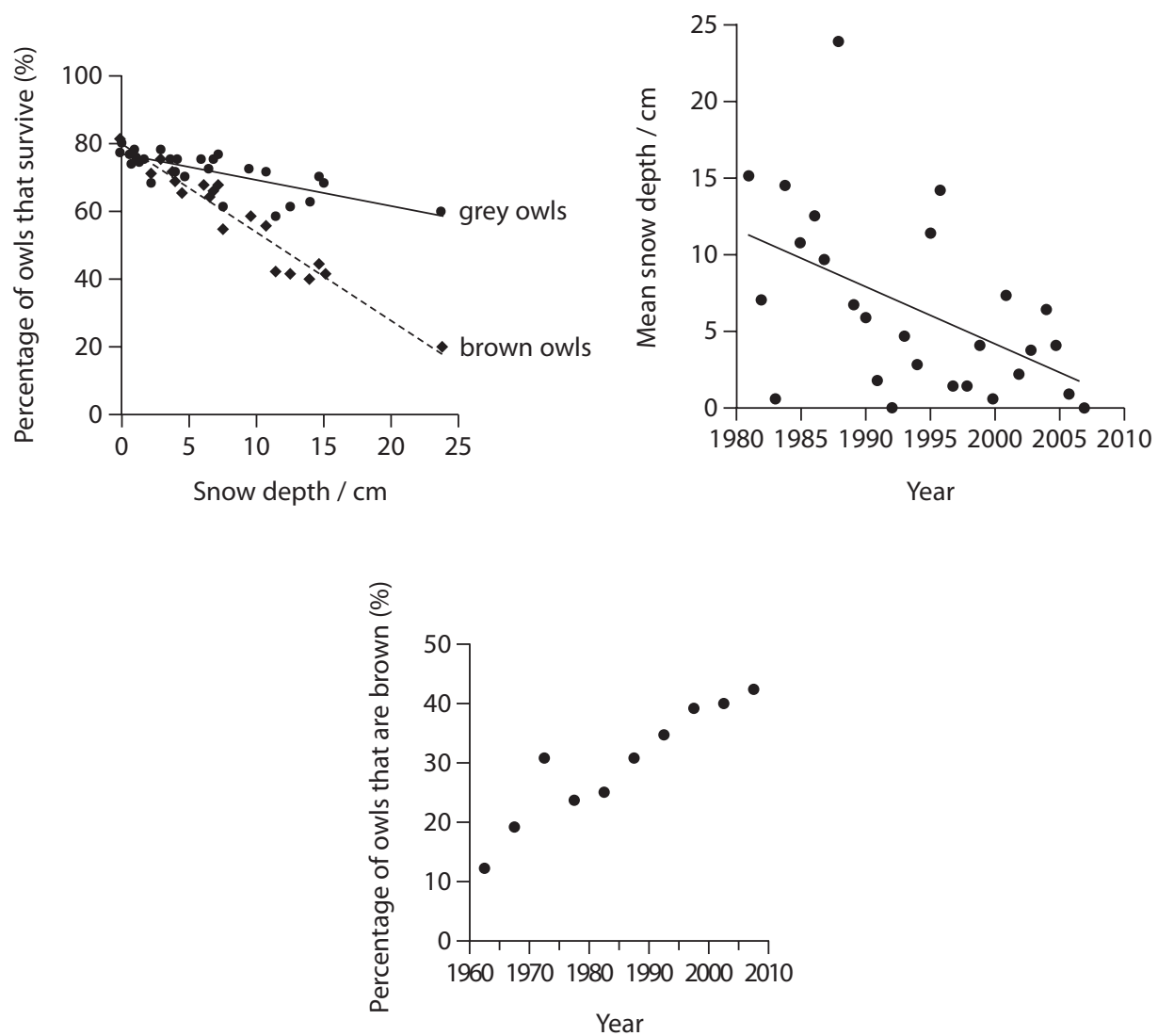
*(b) The scientists investigated the effect of climate change on the frequencies of these two alleles for feather colour in populations of tawny owls.

The percentage survival rates of both colours of owl were measured when there were different depths of snow.

The mean depth of snow was recorded each year between 1980 and 2007.

The percentage of owls that were coloured brown between 1960 and 2007 was also recorded.

The graphs show the results.



The scientists concluded that increased greenhouse gases from human activity are resulting in an increase in the frequency of the brown allele.

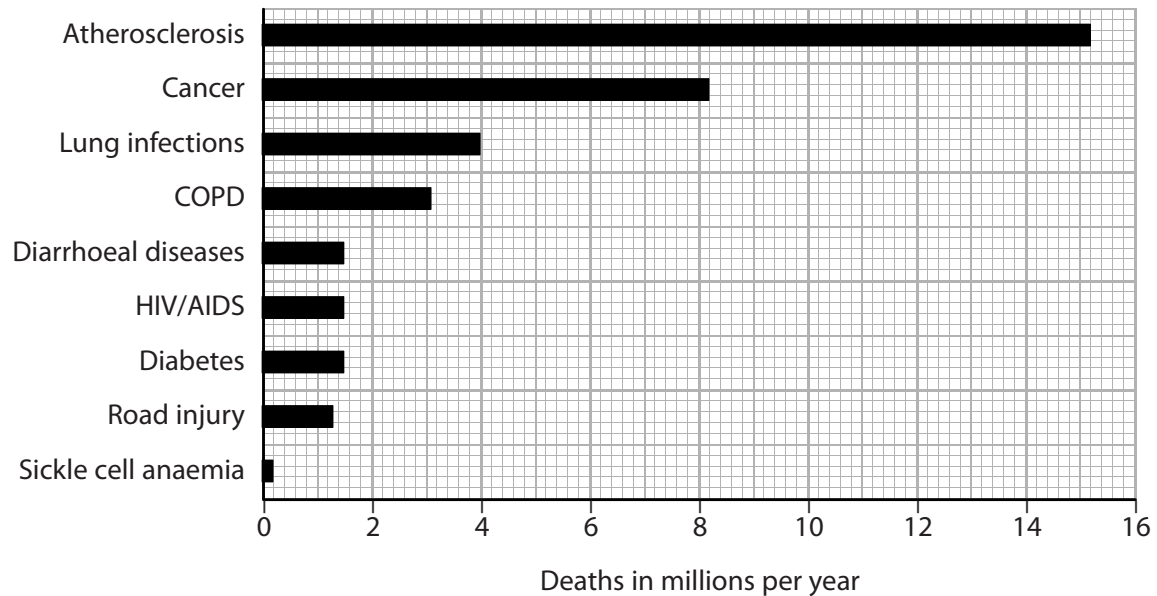
Analyse the data to evaluate this conclusion.

(6)



8 There are many disorders that affect the health of people.

The graph shows the number of people in the world who die each year from different health disorders.



(a) The graph shows that atherosclerosis kills more people than any of the other disorders.

This is mainly due to its development in the coronary arteries.

(i) State the number of deaths caused by atherosclerosis.

Give your answer in standard form.

(1)

Answer

(ii) Describe how atherosclerosis develops in the coronary arteries.

(3)

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*(b) Some health disorders, such as sickle cell anaemia, have a genetic basis.

People who are at risk of these disorders can be identified using genetic tests.

Hospital managers need to predict the future cost of treating people with health disorders.

It has been claimed that the Hardy-Weinberg equation ($p + q = 1$ or $p^2 + 2pq + q^2 = 1$) could be used to predict the number of people who would need treatment for health disorders.

Discuss the validity of this claim.

(9)



7 Adrenaline is a hormone that stimulates the breakdown of glycogen into glucose.

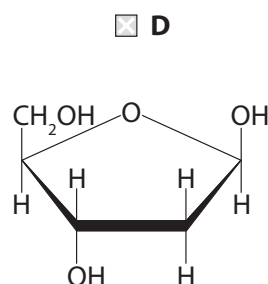
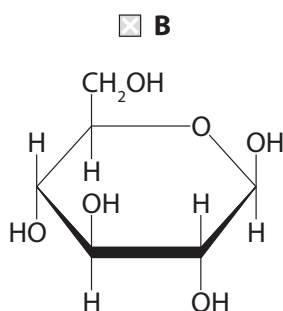
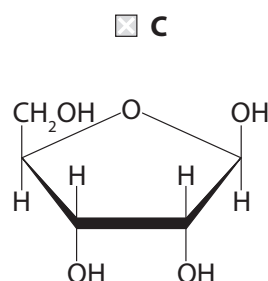
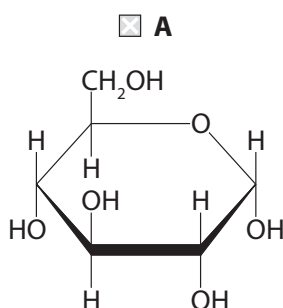
(a) (i) Which of the following describes this breakdown?

(1)

- ☐ **A** condensation reaction breaking glycosidic bonds
- ☐ **B** condensation reaction breaking phosphodiester bonds
- ☐ **C** hydrolysis reaction breaking glycosidic bonds
- ☐ **D** hydrolysis reaction breaking phosphodiester bonds

(ii) Which diagram shows the structure of the glucose produced?

(1)



(iii) Explain how the structure of glycogen is related to its function.

(3)

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- (b) The hormone adrenaline is unable to pass through cell membranes.

When liver and muscle cells are exposed to adrenaline, the enzyme glycogen phosphorylase breaks down glycogen in these cells.

Describe how adrenaline causes liver cells to increase the concentration of glucose in the blood.

(3)

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- (c) The genetic condition Hers disease is caused by a recessive allele of the glycogen phosphorylase gene.

In an isolated population of 1400 people in the USA, 15 people have Hers disease.

- (i) Calculate the number of heterozygous individuals in this population.

Use the Hardy-Weinberg equation

(4)

$$p^2 + 2pq + q^2 = 1$$

Answer



(ii) The frequency of Hers disease in most human populations is 1 in 40 000.

Explain why the frequency of Hers disease is higher in the isolated population.

(2)

- 9 Gilbert's potoroo is one of the most critically endangered species in the world.

Gilbert's potoroo was thought to be extinct until one was found in 1994.

It is thought that there are only 70 individuals.

The photograph shows a potoroo and its pouched baby feeding on berries.



The map shows the only part of Australia where Gilbert's potoroo is found.



The diet of Gilbert's potoroo is about 90% fungi.

Analysis has shown that the fungal spores are spread in the faeces of the potoroos.

These spores then germinate.

(a) Explain the advantage to the ecosystem of fungal spores being spread by potoroos.

(2)

(b) In 1994, there were only 20 Gilbert's potoroo individuals, 12 of which were in a captive colony.

A captive breeding programme was set up using:

- four adult females and one young female
- one adult male, two young males and one young male still in its mother's pouch.

(i) Explain why allele frequencies may cause problems in this population of potoroos.

(3)

- (ii) Foxes and feral cats, which are predators of potoroos, were introduced into Australia by settlers.

The photograph shows a feral cat with its prey.



The Australian government is using poisoned sausages in an attempt to kill 2 million feral cats by 2020.

The sausages contain chunks of kangaroo meat combined with chicken fat, herbs, spices and a poison.

The content of the sausages was based on flavours irresistible to cats.

The poison used is produced by the Swan River pea plant that is found in Western Australia. Other Australian plants that contain the poison are: *Acacia*, *Wedge Peas* and *Nemcia*.

This poison is a natural toxin that biodegrades rapidly and the native wildlife in Australia has evolved natural resistance to it.

A group of 160 000 people in Australia have signed a petition against the plan to poison feral cats.

Discuss whether the plan to poison feral cats is justified.

(9)

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8 Haemoglobin transports oxygen around the human body.

- (a) (i) Explain how the structure of haemoglobin enables it to combine with oxygen in the blood vessels of the lungs.

(3)

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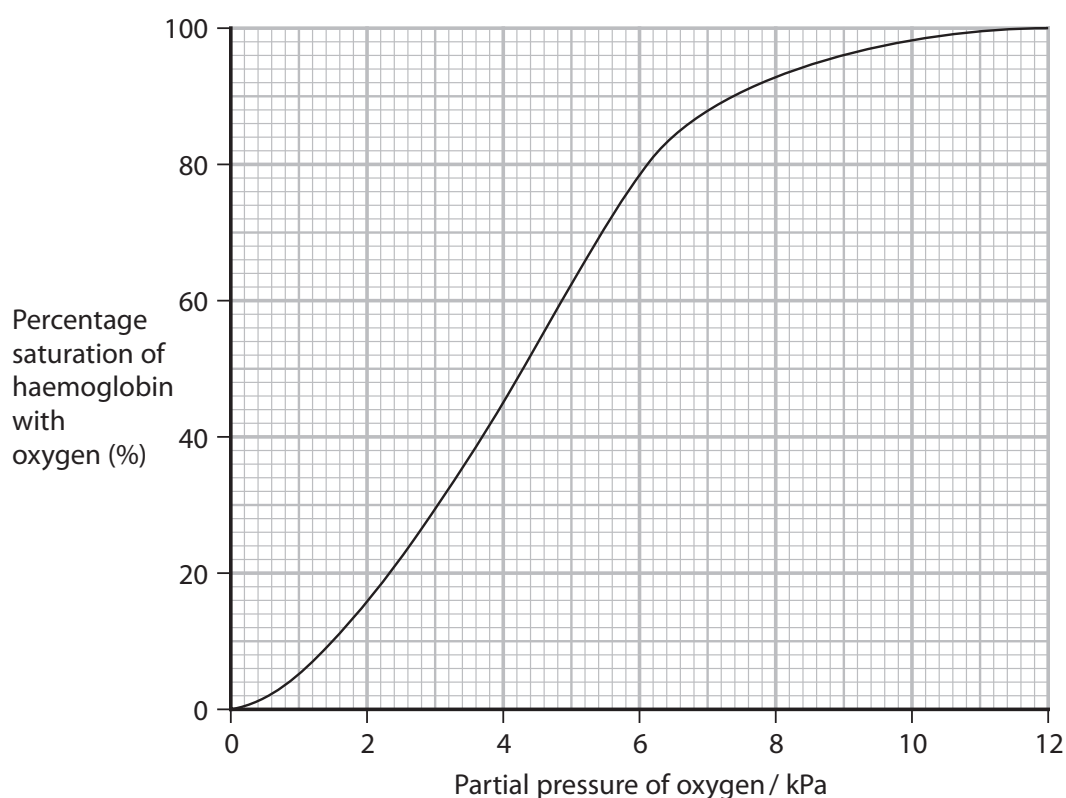
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- (ii) The partial pressure of carbon dioxide affects how readily haemoglobin picks up and releases oxygen.

The graph shows an oxygen dissociation curve for haemoglobin in blood in the lungs.



The oxygen dissociation curve for haemoglobin in blood in the tissues of respiring muscle is different.

Sketch this curve onto the axes.

(1)



- (iii) Explain the advantage of this change in the position of the oxygen dissociation curve.

(2)

- (b) Beta thalassaemia is an inherited condition affecting the gene for beta-globin (HBB gene).

People with beta thalassaemia have less or no beta-globin.

The most common form is a recessive condition caused by a mutation in the HBB gene.

- (i) State the probability that two parents who are heterozygous for this condition would have a child who has beta thalassaemia.

(1)

- (ii) Explain why a person who is heterozygous does not show the symptoms of beta thalassaemia.

(2)

(c) Overall, the proportion of people with beta thalassaemia is 30 in 1000.

In some parts of the world it is much higher.

In one Mediterranean island, 280 in 1000 people have beta thalassaemia.

(i) Calculate the probability that a person on this island is heterozygous for beta thalassaemia.

Use the Hardy–Weinberg equation

$$p^2 + 2pq + q^2 = 1$$

Give your answer to two significant figures.

(3)

Answer

(ii) Give **two** reasons why this value may not be accurate.

(2)

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- 9 Asiatic lions are endangered animals. Some of these lions have been kept in zoos for many years.

The photograph shows a group of Asiatic lions.



(Source: © FELIS IMAGES / NATURE PICTURE LIBRARY / SCIENCE PHOTO)

In 2017, a European zoo stated that 392 lions in captivity had died over a period of 14 years. Of these, 80% were less than one year old.

- (a) (i) The population of Asiatic lions in the zoo was initially started by breeding from nine lions.

Explain why many of the next generations of lions died before they were one year old.

(2)

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- (ii) Some of the young lions have a condition of the nervous system caused by a recessive allele.

In wild populations of Asiatic lions, this recessive allele has a frequency of 0.02.

In zoo populations of Asiatic lions, the recessive allele has a frequency of 0.30.

Determine the frequency of heterozygous Asiatic lions in **zoo** populations.

Use the Hardy-Weinberg equation

$$p^2 + 2pq + q^2 = 1$$

(2)

Answer

- (iii) State **two** conditions that must occur for allele frequencies to stay constant over several generations.

(2)

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- (iv) Describe how CITES helps to maintain populations of Asiatic lions in the wild.

(2)

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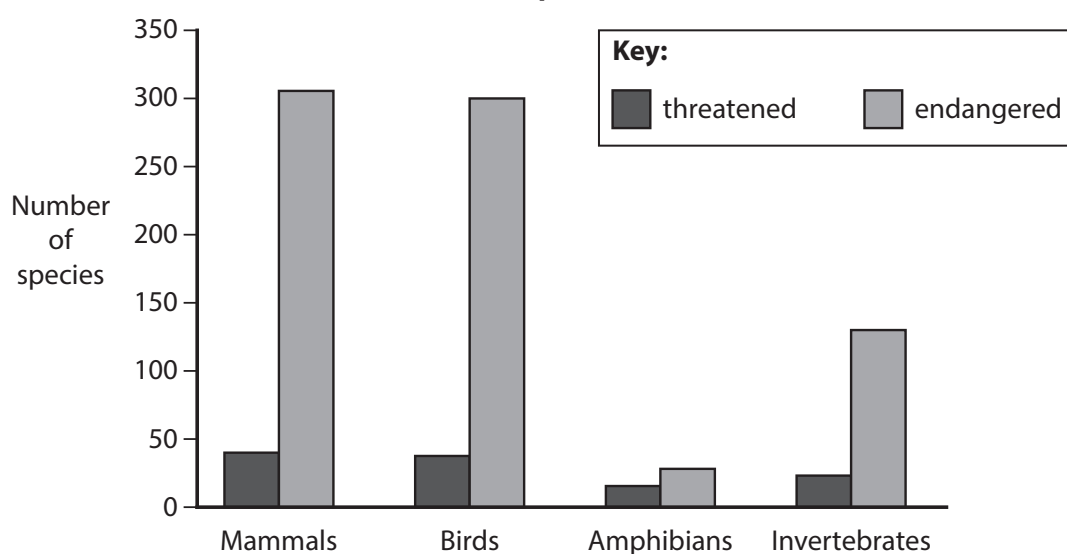
- *(b) Zoos keep many species in captivity and also engage in research, ex-situ conservation, and in-situ conservation.

Scientists investigated the roles of zoos in the conservation of different species of mammals, birds, invertebrates, and amphibians.

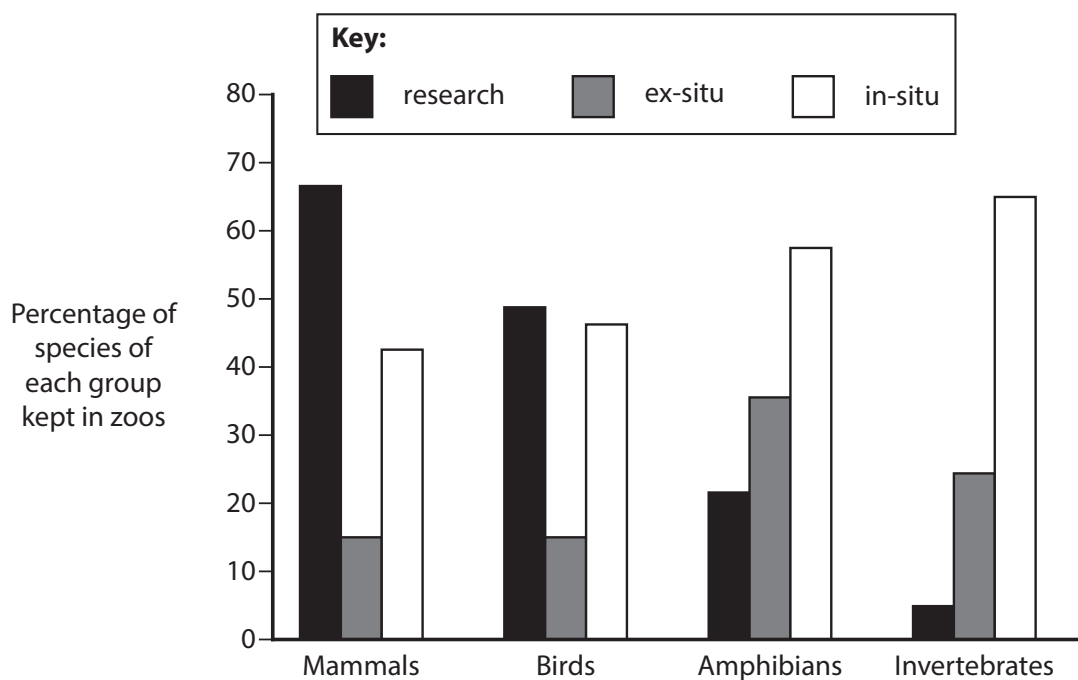
Graph 1 shows the numbers of species of each group that are kept in zoos and listed as being endangered or threatened with becoming endangered.

Graph 2 shows the percentages of species of each group kept in zoos that are used by the zoos for research, for ex-situ conservation, and are overseen for in-situ conservation.

Graph 1



Graph 2

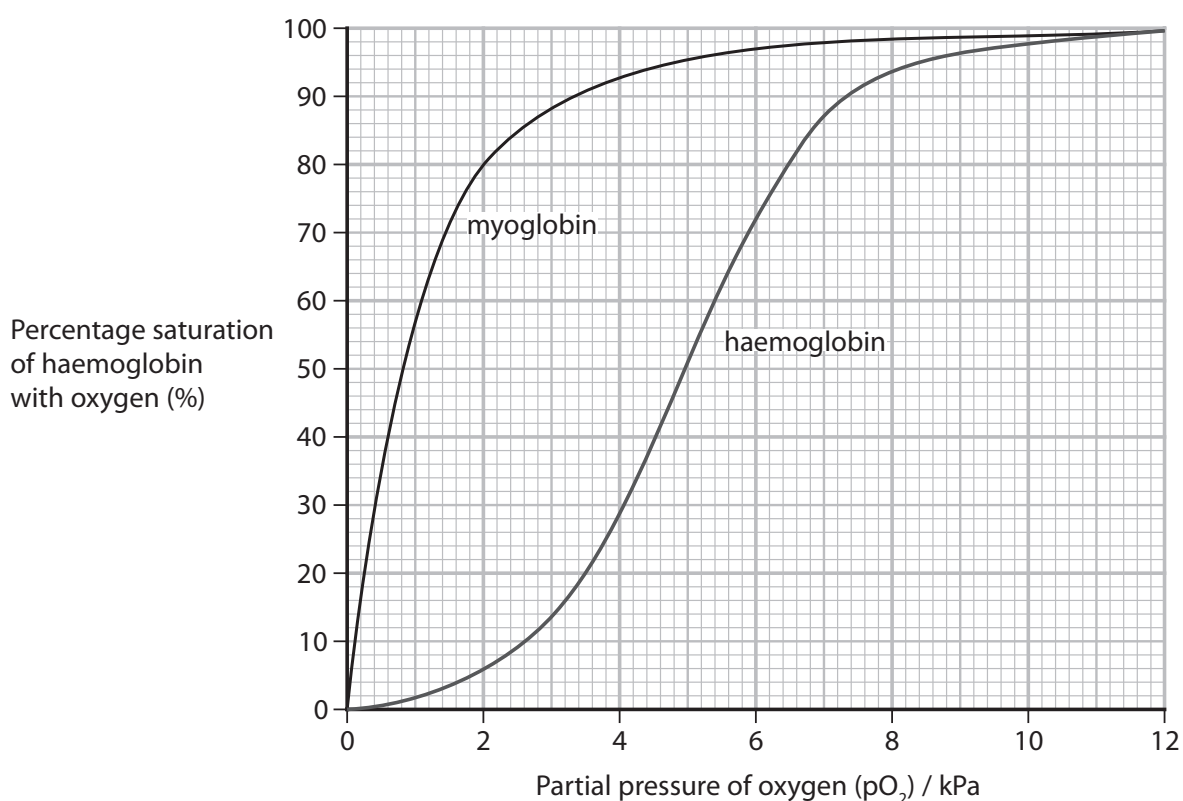


Analyse the data and use your own knowledge to discuss the effectiveness of zoos as centres for the conservation of animals.

(6)



- 8 The graph shows the oxygen dissociation curves of human haemoglobin and human myoglobin.



- (a) (i) Calculate the volume of oxygen bound to haemoglobin at a partial pressure of oxygen of 6 kPa in 100 cm³ blood.

The concentration of haemoglobin is 15 g per dm³ blood.

When fully saturated, there is 1.36 cm³ oxygen per g of haemoglobin.

(3)

Answer

(ii) Explain why the oxygen dissociation curves for haemoglobin and myoglobin are different.

(4)

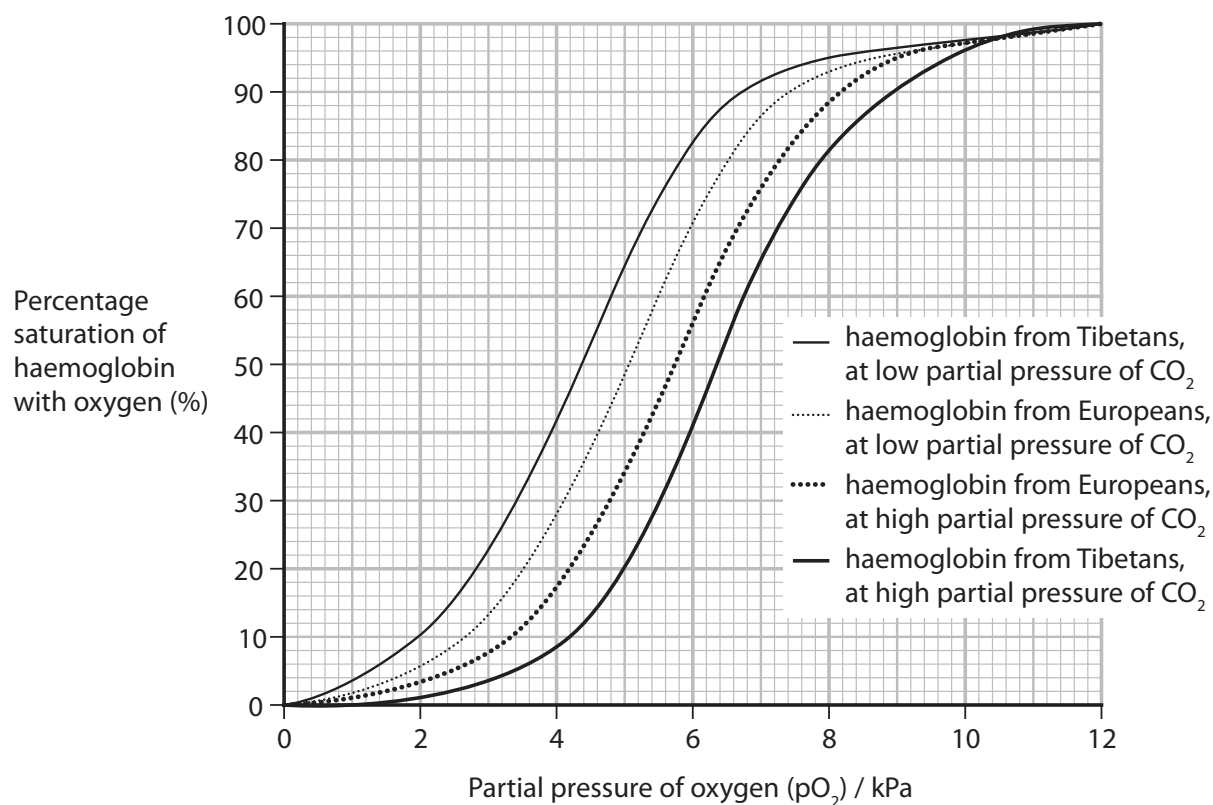


- (b) In an investigation, the oxygen dissociation of haemoglobin from Tibetan people and European people was compared.

The Tibetan people were living at high altitude.

The European people were living at low altitude.

The graph shows the results of this investigation.



Comment on the oxygen dissociation curves of the Tibetan people.

(4)

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(c) Tibetan populations have a recessive allele that helps them to survive at high altitude.

In a village in Tibet, 1950 people out of a population of 2500 people carry two copies of this allele.

(i) Calculate the number of heterozygous people in the village.

Use the Hardy-Weinberg equation

$$p^2 + 2pq + q^2 = 1$$

(3)

Answer



(ii) This allele is currently found only in human populations in Tibet.

The allele has also been found in the fossil bones of an extinct form of modern humans called the Denisovans.

Fossils of Denisovans have been found in Tibet.

Explain why scientists think that the Denisovans belonged to the same species as modern humans.

(2)

MARK SCHEMES

official Pearson Edexcel mark schemes



Question Number	Answer	Additional Guidance	Mark
1(a)	The only correct answer is B <i>A is incorrect because Down's syndrome is an example of polysomy not monosomy</i> <i>C is incorrect because Down's syndrome is caused by a chromosome mutation not a gene mutation</i> <i>D is incorrect because Down's syndrome is caused by a chromosome mutation not a gene mutation</i>		(1)

Question Number	Answer	Additional Guidance	Mark
1(b)	An answer that makes reference to the following: • birth order has no effect on the incidence (1) • the incidence increases with the age (of the mother) (1) • credit use of manipulated figures to support answer (1)	ACCEPT no pattern e.g. approx. 80 times greater chance if over 40 than under 20 approx. 4 times greater chance if over 40 than between 35 and 39 approx. 500 per 100 000 more if over 40 than between 35 and 39	(3)

Number	Answer	Mark
2(a)	A description that makes reference to the following: - part of a chromosome breaks off (1) - this then joins to another (non-homologous) chromosome (1)	ACCEPT one mark only for an answer that makes reference to {part of a chromosome / genes} being swapped between (non-homologous) chromosomes ACCEPT phosphodiester bonds break ACCEPT genes or section of DNA DO NOT ACCEPT parts of a gene DO NOT ACCEPT homologous chromosome (2)

Question Number	Answer	Mark
2(b)	Non-disjunction	ACCEPT Translocation, polysomy, aneuploidy, trisomy, partial trisomy, partial aneuploidy (1)

Question Number	Answer	Mark
2(c)	An explanation that makes reference to the following: - polysomy / not Down's Syndrome (1) - because {of chromosome 13 / more than two copies of one chromosome} (1)	ACCEPT trisomy, aneuploidy DO NOT ACCEPT has {Turner's / Down's} Syndrome ACCEPT chromosome 21 only two copies ACCEPT extra chromatid (2)

Total for Question 2 = 5 MARKS



1(a)(i)	<i>C Turner's syndrome due to monosomy</i> <i>A is incorrect because there are not three copies of chromosome number 21</i> <i>B is incorrect because there are not three copies of chromosome number 21</i> <i>D is incorrect because Turner's syndrome is a monosomy</i>		1
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Question Number	Answer	Additional Guidance	Mark
1 (a)(ii)	C non-disjunction <i>A because it is not a gene mutation</i> <i>B is incorrect because it is not a gene mutation</i> <i>D because there is a missing chromosome is incorrect</i>		1

Question Number	Answer	Additional Guidance	Mark
1 (b) (i)	A ☒ A anaphase telophase prophase metaphase B is incorrect because X is not prophase C is incorrect because W is not prophase D is incorrect because W is not telophase		1

Question Number	Answer	Additional Guidance	Mark
1 (b) (ii)	An answer that makes reference to four of the following: - colchicine has no effect on the percentage of cells in interphase (1) - colchicine arrests cells at prophase (1) - colchicine inhibits spindle (formation) (1) - fewer cells reach {metaphase / anaphase / telophase} with colchicine / more cells reach {metaphase / anaphase / telophase} without colchicine / more cells at prophase with colchicine / fewer cells at all phases except prophase (1) - correct reference to overlapping of standard deviations (1)	Accept colchicine stops (many) cells at prophase / cells can only reach prophase with colchicine Accept converse Accept converse	4

Question Number	Answer	Additional Guidance	Mark
	A description that makes reference to four of the following:		

Number	Answer	Additional Guidance	Mark
2(a)(i)	B Female with Turner's syndrome <i>A is incorrect because the human has one X</i> <i>B is incorrect because the human is female</i> <i>C is incorrect because the human is female</i>		1

Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	A Non-disjunction producing a monosomy B is incorrect because it is a monosomy C is incorrect because it is due to non-disjunction C is incorrect because it is due to non-disjunction		1

Question Number	Answer	Additional Guidance	Mark
2 (b)(i)	B ovum and secondary oocyte A is incorrect because secondary oocyte is diploid C is incorrect because the secondary oocyte is diploid D is incorrect because the primary oocyte is diploid		1

Question Number	Answer	Additional Guidance	Mark
2(b)(ii)	An explanation that makes reference to: - crossing over (1) - which swaps {alleles / DNA / genes} between {homologous chromosomes} (1) - independent / random assortment (1) - because it is random movement of homologous chromosomes to poles (1)	Allow random movement of paternal and maternal chromosomes / random combinations of paternal and maternal chromosomes	4

Question Number	Answer	Additional Guidance	Mark
	A CH ₃		

Number	Answer	Mark
6(a)(i)	The only correct answer is C A is not correct because P is in prophase I and Q is in metaphase II B is not correct because P is in prophase I and Q is in metaphase II D is not correct because P is in prophase I and Q is in metaphase II	(1)

Question Number	Answer	Mark
6(a)(ii)	The only correct answer is B A is not correct because if non-disjunction occurred in meiosis I, it would generate one cell with four chromosomes (each composed of two chromatids) and one cell with two chromosomes (each composed of two chromatids). These cells would divide in meiosis II to generate two cells with four chromosomes and two cells with two chromosomes. C is not correct because if non-disjunction occurred in meiosis I, it would generate one cell with four chromosomes (each composed of two chromatids) and one cell with two chromosomes (each composed of two chromatids). These cells would divide in meiosis II to generate two cells with four chromosomes and two cells with two chromosomes. D is not correct because if non-disjunction occurred in meiosis I, it would generate one cell with four chromosomes (each composed of two chromatids) and one cell with two chromosomes (each composed of two chromatids). These cells would divide in meiosis II to generate two cells with four chromosomes and two cells with two chromosomes.	(1)

Question Number	Answer	Additional Guidance	Mark
6(b)	An answer that makes reference to the following: - number of pregnancies calculated (1) - number of babies calculated (1)	Correct answer gains full marks $(500\,000 \div 1000) \times 14 = 7\,000$ $(1.8 \div 100) \times 7\,000 = 126$ or $14 \times 500 = 7000$ and then $7000 \times 0.018 = 126$	(2)

Question Number	Answer	Additional Guidance	Mark
6(c)	An answer that makes reference to four of the following: {screening / both techniques} are {more effective / produce more births} than control (1) - more embryos survive screening with polar body biopsy than PGD / polar body biopsy is less damaging than PGD (1) - PGD more effective (than polar body biopsy) / PGD produces more births (than polar body biopsy) (1) (because) PGD produces 21% births compared to 18% with polar body (1) - PGD detects abnormalities in both paternal and maternal chromosomes / polar body biopsy only checks for maternal chromosome abnormalities (1)	ACCEPT converse ACCEPT converse ACCEPT converse ACCEPT 21.46 / 21.5 / 18.27 / 18.3 ACCEPT 0.21 / 0.215 / 0.18 / 0.183 / 0.1827 DO NOT ACCEPT just 21% alone ACCEPT ideas that polar body biopsy only screens for abnormalities from mother / PGD screens both parents	(4)

Question Number	Answer	Mark
3(a)(i)	The only correct answer is A (Prophase I of meiosis) <i>B is incorrect as the primary spermatocytes do not have prophase II stage</i> <i>C is incorrect as primary spermatocytes do not perform mitosis</i> <i>D is incorrect as primary spermatocytes do not perform mitosis</i>	1

Question Number	Answer	Additional guidance	Mark
3(a)(ii)	- correct division of 0.8 cm by 1500 - correct conversion to micrometres and to one decimal place	$\div 1500$ or 5.333... = one mark 5.3 = 2 marks correct answer with no working gains full marks	2

Question Number	Answer	Additional guidance	Mark
3(b)(i)	12		1

Question Number	Answer	Additional guidance	Mark
3(b)(ii)	An answer that makes reference to four of the following: Support - for pregnancies not going full term there are {more men with sperm with greater than 25% DNA damage / few men have less than 25 % DNA damage} (1) - no men where pregnancies go full term have more than 60% damage / no men with 0-5% DNA damage where pregnancies do not go full term (1) Against - some men had partners with pregnancies that go full term with high % DNA damage (1) - small sample size / uneven group sizes (1) - other factors of men not accounted for e.g. age / diet / genetic conditions (1) - maternal factors affect pregnancy (1)	At least one from support and at least one from against Allow the majority of men (with pregnancies going full term) had less than 25% damage Allow correct numerical comparison e.g only 12(%) of men have less than 25(%) Allow converse Allow most men with pregnancies that go full term have between 0-5% damage Allow description (e.g. some with 55-60%, some with >25%)	4

Question Number	Answer	Additional Guidance	Mark
2(a)	An answer that makes reference to the following: - three identical chromosomes at position 21 (1) - two identical chromosomes at positions 20, 22 and 23 (1)		(2)

Question Number	Answer	Additional Guidance	Mark
2(b)	part of one chromosome drawn on the other chromosome (1)		(1)

Question Number	Answer	Additional Guidance	Mark
2(c)(i)	An answer that makes reference to the following: - height in m² calculated (1) - BMI calculated (1)	$(1.463 \times 1.463 =) 2.140369$ Accept rounding - 2.14, 2.1 21.1 (1) (=21.1178539) Accept (if rounded to 2.14) 21.1214953 Accept (if rounded to 2.1) 21.5238095/21.5 ECF for mp2 if height in cm ² used Correct answer with no working gains 2 marks	(2)

Question Number	Answer	Additional Guidance	Mark
2(c)(ii)	An answer that makes reference to the following: - females with Turner's syndrome have (slightly) lower mass and height (1) - but error bars overlap, so may be no difference/more data is needed (1) - cannot tell if BMI is significantly different as there are no error bars (1) - sample size is quite small (in both groups) (1)		(4)

Number	Answer	Additional Guidance	Mark
4(a)	A diagram showing the following: - two glucose molecules (1) - correct H and OH groups on each glucose (1) - water clear as substrate not product (1)	Accept two molecules of α -glucose	(3)

Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that includes four of the following: - mass of contents of the beaker reduce over time (1) - because oxygen is released (1) - the rate of decrease in mass is non-linear / loss of mass reduces over time (1) - because the substrate is used up / lower substrate concentration (1) - resulting in fewer collisions between the active site and the substrate (1)	Allow oxygen is a gas (NOT gas has no mass) Allow Rate of reaction decreases Allow fewer enzyme substrate complexes	(4)

Question Number	Answer	Additional Guidance	Mark
4(c)	An explanation that makes reference to the following: - change in the sequence of DNA (1) - results in {missing / different} {amino acid / codon} (1) - results in {different / missing / shorter} {protein / enzyme} (1)	Allow description e.g. frameshift, deletion Allow change to {start / stop} codons; different {amino acid sequence / primary structure}	(3)

Number	Answer	Additional Guidance	Mark
5(a)(i)	D phosphodiester <i>A is incorrect because peptide bonds are found in proteins</i> <i>B is incorrect because disulfide bonds are found in proteins</i> <i>C is incorrect because glycosidic bonds are found in carbohydrates</i>		1

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	A description that makes reference to four of: - hydrogen bonds between nucleotides broken by DNA helicase (1) - complementary nucleotides bind (1) - because {hydrogen bonds} will only form between cytosine and guanine and adenine and thymine (1) - phosphodiester bonds are formed by DNA polymerase (1) (the leading strand is synthesised continuously but lagging strand required) DNA ligase to join fragments (on lagging strand) (1)	Allow unzipped by helicase	4

Question Number	Answer	Additional Guidance	Mark
5(b)(i)	An answer that makes reference to: - correct indication of selection of RNA virus (for TMV) (1) - correct use of graph to identify intercept between 0.000001 and 0.0005 (1)	Allow correct use of standard form e.g. 10^{-4} Allow ecf for correct use of y axis with wrong selection of virus type correct answer gets both marks	2

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	An answer that makes reference to three from: - as genome size increases, mutation rate decreases (1) - RNA / ss DNA / ss nucleic acid has a higher mutation than ds DNA (1) - because it is single stranded template so does not produce copies with complementary bases / is less stable (1) - viruses have a higher mutation rate than bacteria / eukaryotes (1)	Allow converse / allow correlation Allow eukaryotes have lowest mutation rates Allow RNA viruses have highest mutation rates	3

Question	Answer	Additional Guidance	Mark
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Question Number	Answer	Additional Guidance	Mark
7(a)	An explanation that makes reference to the following: - because nuclear DNA is present in both the male and female {gametes / sex cells} (1) - because mitochondria are present in the { female gamete / ovum / secondary oocyte / egg cell} and not the sperm head (1)	Accept in male and female nuclei in the context of fertilisation Accept mitochondria are present in sperm {neck / mid piece} / mitochondria (DNA) not released by the sperm	(2)

Question Number	Answer	Mark
7(b)(i)	7(b)(i). The only correct answer is C <i>A is not correct because an insertion adds an additional base</i> <i>B is not correct because monosomy is a chromosome mutation</i> <i>D is not correct because translocation is a chromosome mutation</i>	(1)

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to three of the following: - it will change the {amino acid sequence / primary structure} of ATP synthase (1) - therefore the ATP synthase active site could be a different {structure / shape} so ADP cannot {bind / bind as well} (1) - therefore the {channel / ATP synthase} the wrong {structure / shape} so {hydrogen ions / protons} cannot {pass through / pass through as well} (1) - therefore { no / less} {ATP made / oxidative phosphorylation} (1)	Accept a stop codon could result changing the {length / shape / structure} of the protein	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)	An explanation that makes reference to the following: - the mutation may produce a stop codon (1) - therefore translation will stop {sooner / when the stop codon is reached} (1) Or {one / several} bases deleted (1) - therefore the mRNA is shorter (1)	Accept no more amino acids added to the peptide / peptide synthesis stops sooner	(2)

Question Number	Answer	Additional Guidance	Mark
7(d)	An explanation that makes reference to three of the following: - mutation may prevent {electrons being passed down the electron transport chain / ATPase from working properly} (1) - therefore {NADH / reduced NAD} cannot be oxidised (1) - therefore pyruvate and {NADH / reduced NAD} will produce lactate (1) - lactate produced at a faster rate than it can be removed (1)	Accept reformed / converted back	(3)

Total for Question 7 = 11 MARKS



4(a)(i)	• COOH and NH₂ group shown (1) • cysteine R group and H shown (1) • attached to central C (1)	ACCEPT charged groupings	(3) EXP
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Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	• disulfide (bond / bridge)	ACCEPT disulphide	(1) GRAD

Question Number	Answer					Additional Guidance	Mark
4(b)(i)	AAC / AAT/ GAC/ GAT	TGT	TAC / TAT	AAC / AAT/ GAC/ GAT	GAA / GAG		(1) GRAD

Question Number	Indicative content
*4(b)(ii)	Indicative content: • substitution mutation may result in no change of amino acid • TGT to TCC • so no effect on structure • substitution may change amino acid • e.g. TGT to TGG • inserting a try instead of Cys • no disulphide bond joining chain A and B together at that point • insertion / deletion will result in {frame shift mutation / change in amino acid sequence} • Cys no longer present in that position • no disulphide bond joining chain A and B together at that point • Cys may be inserted further down the chain so disulfide bond forming elsewhere • chain A will be shorter • change in bonding will affect {tertiary / quaternary} structure of insulin Level 1 : different types of mutation described but no link to insulin amino acids Level 2 : different types of mutation described with a link to insulin amino acids Level 3 : effects of mutations linked to possible changes in structure of insulin

Question Number	Answer	Additional Guidance	Mark
6(a)	The only correct answer is C A is incorrect because there is no cytoplasm in mitochondria B is incorrect because mitochondrial DNA is found in the matrix D is incorrect because mitochondria do not have a nucleus		(1)

Question Number	Answer	Additional Guidance	Mark
6(b)	The only correct answer is A B is incorrect because circular DNA has two more phosphodiester bonds than linear DNA with the same number of pentoses C is incorrect because mitochondrial DNA is circular D is incorrect because mitochondrial DNA is circular		(1)

Question Number	Answer	Additional Guidance	Mark
6(c)	An explanation that makes reference to four of the following: - position 1 : only the daughter has inherited this DNA from the mother (1) - position 2 : (genes located in) this DNA is common to all people (1) - position 3 : daughter and son 1 have inherited this DNA from their father but son 2 has not (1) - position 4 : this could be mitochondrial DNA as it is found in the mother and all children (1) - position 5 : this could be the mitochondrial DNA of the father as it is not present in any of the children (1)	IGNORE references to how the bands form Must refer to DNA in band at least once	(4)

Question number	Answer	Additional Guidance	Mark
6(d)(i)	substitution (1)	ACCEPT transition DO NOT ACCEPT insertion / addition / deletion / subtraction / chromosome mutation / frameshift / inversion / duplication / replacement	(1)

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	An explanation that makes reference to two of the following: - the cytosine will not bind with the adenine (1) - therefore the hydrogen bonds will not form (1) - so {the left hand loop will open up / other bonds may form} (1)	ACCEPT tRNA will be a different shape	(2)

Question Number	Answer	Additional Guidance	Mark
6(d)(iii)	An explanation that makes reference to two of the following: - the tRNA may not be able to bind with the ribosome (1) - and therefore not hold the amino acid in place (1) OR - the amino acid may not be able to bind to the tRNA (1) - and therefore {this amino acid cannot be / fewer of these amino acids} brought to the ribosome (1) OR - the anticodon may not be able to bind to the codon on the mRNA (1) - and therefore the amino acid will not be held in place (1)		(2)

Question Number	Answer	Additional Guidance	Mark
5(a)	The only correct answer is A B is incorrect because TS is monosomy not polysomy C is incorrect because TS is non-disjunction not translocation D is incorrect because TS is non-disjunction not translocation		(1)

Question Number	Answer	Additional Guidance	Mark
5(b)	- number of baby girls born calculated (1) (number of baby girls with TS) calculated (1)	$(613\,936 \div 2.05 =) 299\,481/299480.976$ $299\,481 \div 2500 = 119.7924$ 119/120 Correct answer 119/120 gains full marks	(2)

Question Number	Answer	Additional Guidance	Mark
5(c)(i)	An explanation that makes reference to the following: - because the vaccine will stimulate a (primary) immune response (1) - so there will be a higher number of {lymphocytes / antibodies} (1) - giving false-positive results (1)	Accept they will have memory cells Do Not accept a change in lymphocyte/antibody levels Accept {making the study/results of the study invalid/results skewed}	(3)

Question Number	Answer	Additional Guidance	Mark
5(c)(ii)	An explanation that makes reference to the following: - standardised height score (1) - because {the standard deviation values do not overlap/ the error bars do not overlap with the other group} (1)	Accept smallest value for group w/o TS is -0.91 and largest value with TS is -1.21	(2)

Question Number	Answer	Additional Guidance	Mark
5(c)(iii)	An answer that makes reference to the following: - girls with TS have lower levels of IgG/IgA (1) - girls with TS have fewer CD4 cells but {the same / more} CD8 cells (1) - No significant difference (in the levels of antibodies and lymphocytes)/ error bars overlap (1)	Do not piece together Accept: Apart from CD8 lymphocytes all the other markers are lower in girls with TS = 2 marks	(2)

Question Number	Answer	Additional Guidance	Mark
5(c)(iv)	An explanation that makes reference to two of the following: - Girls from both groups (from the study) divided into those with autoimmune disease and those without (1) - So that one group has TS and autoimmune disease/one group has TS and no autoimmune disease (1) - so that the numbers of T regulatory cells could be compared (1)		(2)



4 (a)	An explanation that makes reference to the following: - clotting takes longer at low temperature due to {low kinetic energy / fewer enzyme-substrate collisions} (1) - clotting time is least at {body/optimum} temperature (1) (clotting takes longer) at {temperatures above 37°C / high temperatures} (because) enzymes are denatured (1)	Accept clotting takes less time as temperature increases because {kinetic energy increases / more enzyme-substrate collisions}	(3)
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Question Number	Answer	Additional Guidance	Mark
4 (b)	6771		(1)

Question Number	Answer	Additional Guidance	Mark
4 (c)(i)	substitution	Accept point mutation	(1)
Question Number	Answer	Additional Guidance	Mark
4 (c)(ii)	1 in 50	Accept other correct probabilities e.g. 2% or 0.02	(1)

Question Number	Answer	Additional Guidance	Mark
4 (c)(iii)	An explanation that makes reference to the following: (excess prothrombin means) more thrombin (1) - therefore increased {conversion / catalysis} of fibrinogen to fibrin (1) - fibrin {is insoluble / traps blood cells / forms mesh / forms net} (1)	Accept if there is more fibrin it is more likely to clot	(3)

Question Number	Answer	Additional Guidance	Mark
4 (d)(i)	cut DNA to produce {short sections of DNA / short tandem repeats / mini satellites} (1)	Accept cut DNA into fragments / cut DNA to give sticky ends	(1)

Question Number	Answer	Additional Guidance	Mark
4 (d)(ii)	A description that makes reference to three of the following: - use (DNA) primers / nucleotides (1) - use {high temperature / 95 °C} for 30 seconds (to separate DNA strands) (1) - use {lower temperature / 55 °C} for 20 seconds (to bind primers) (1) - heat to 72°C with polymerase (to replicate DNA) (1) - repeat process (to obtain many copies of DNA) (1)		(3)

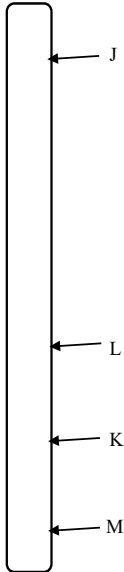
	Additional Guidance	Mark
in any order)		1

Answer	Mark
$\text{bb} \times \text{aaBb}$ <i>1 be round and yellow could be produced could be produced</i>	1

	Additional Guidance	Mark
the following: d aabb (1) f ab (1) aaBb and aabb (1)	ACCEPT correct answers from Punnett square	4

Question Number	Answer	Additional Guidance	Mark
3(a)	The only correct answer is C <i>A is incorrect because crossing over has taken place by metaphase I</i> <i>B is incorrect because crossing over takes place in meiosis I</i> <i>D is incorrect because crossing over takes place in meiosis I</i>		(1)

Question Number	Answer	Additional Guidance	Mark
3(b)	10.2		(1)

Question Number	Answer	Additional Guidance	Mark
3(c)	A diagram that shows the following: - L drawn below J (1) - K and M indicated correctly (1) - diagram drawn to (approximate) scale (9, 3, 3) (1)	 NB Everything must be correct to award all 3 marks	(3)

Question Number	Answer	Additional Guidance	Mark
3(d)	An explanation that makes reference to two of the following: - crossing over occurs between chromatids (between the same homologous chromosomes) (1) - therefore (only) half the chromosomes (produced by anaphase II) will be recombinant chromosomes (so maximum of 50 %) (1) - crossing over does not always take place (so can be less than 50 %) (1)	ACCEPT will have recombinant {genes / alleles}	(3)

Additional Guidance	Mark
Accept change gene pool Accept converse Accept alleles for phenotypes Do not accept genes Accept converse Accept alleles for phenotypes Do not accept genes Accept clear labelled diagrams	(3)

	Additional Guidance	Mark
lowing: hromosomes (1) ta formation}	Accept correct descriptions of crossing over between homologous chromosomes	(1)
	Additional Guidance	Mark
ving:	Accept alleles in different order e.g. c^hC	(1)
	Additional Guidance	Mark
ving: $c^h c^h$ (1))	Accept all mps from Punnett squares Accept any clear indication that $c^h c^h \times c^h c^h$ are crossed	(1)

4 (a)	- in cross 3 V 4 both parents must be {carriers / heterozygous} (1) - to produce individual {8 / 9 / offspring with long fur / offspring with long and short fur} (1)	Accept In cross 1 v 2 parent 2 must be heterozygous Accept To produce individual 6 / cat with long fur	2
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Question Number	Answer	Additional Guidance	Mark
4 (b)(i)	X^BY FF and X^BY Ff	Accept alleles in any combination	1

Question Number	Answer	Additional Guidance	Mark
4 (b)(ii)	An explanation that makes reference to following: - male cats only have one X chromosome / female cats have two X chromosomes (1) - so can have $\{X^B$ and X^o / both fur colour alleles} (1)	Accept males only have one fur colour allele / only X^B or X^o	2

Question Number	Answer	Additional Guidance	Mark
4 (b)(iii)	An answer that makes reference to the following: - correct parental genotypes X^BX^o ff x X^oYFf - correct gametes X^{Bf}, X^{of} and X^oF and X^{of}, (X^oF), YF, Yf - correct F_1 - correct probability (0.125/12.5% / $\frac{1}{8}$)	ECF for mp 3 only	4

Question	Answer	Additional Guidance	Mark
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Number	Answer	Additional Guidance	Mark
8 (a)(i)	D X^HY and X^HX^h A is incorrect because 4 must have inherited a haemophilia allele from 1 B is incorrect because 1 does not have haemophilia C is incorrect because 1 does not have haemophilia		1

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	An answer that makes reference to: - correct genotypes for 4 and 5 (X^HY and X^HX^h) (1) - correct gametes (1) - correct (genotypes of F_1 and) 0.25 / 25 % (1)	ecf for correct gametes only (mp2)	3

Question Number	Answer	Additional Guidance	Mark
8(b)	An answer that makes reference to 5 from: - the mean clotting time has increased for both drugs / for drug A and drug B (1) - there is little variation in the control group (1) - there is high variation with drug B (1) - drug B does not change clotting rate for some (blood types) as there is overlap with the control group (1) - drug B has a slower clearance time so patients would be at risk of bleeding (1) - drug A would be better as it works for all samples and is cleared from body faster / will allow blood to clot sooner after dialysis (1)	piece together Allow low range in control group / with no drug Allow largest range / drug B has more spread / variation than drug A Allow drug A increased clotting time for all samples as there is no overlap with control	5

ditional Guidance	Mark		ditional Guidance	Mark	ditional Guidance	Mark
ifferent letters e.g. X^{BX^b} or mp2 and mp3 for wrong sex-linked % if cross is not sex-linked	(3)	re following: r / 2 / 6) is not heterozygous /	Accept {4 / 9} is colour blind and the parents are not colour blind Accept {6 / 2} are not colour blind but have a son who is colour blind Do not accept both parents are heterozygous / carriers		cept converse for cones / cell Y	
ditional Guidance	Mark	chromosome is o they must be 6 / mother} be colour blind			cept converse for cell Z	
ium ions pass through apt calcium ions enter rotransmitters for	(4)				cept iodopsin (in cones / cell Y) is less sensitive to light	(3)

Number	Answer	Additional Guidance	Mark
4(a)	An answer that includes the following: Feature: shape (of abdomen / body) - pointed in female, rounded in male (1) OR Feature: banding pattern (on abdomen) - five bands on female, three bands on male / more bands on female (1)	Refer to both or use a comparative term Accept longer in female / shorter in male Accept description of pattern eg 2 narrow bands and one wide in male and five narrow in female / spots on female / dark tip on male	(1)

Question Number	Answer	Additional Guidance	Mark
4(b)(i)	An answer that includes the following: - genetic diagram showing (parents), gametes and genotypes of offspring (1) - ratio of named phenotypes of offspring (1)	Accept any letter with upper and lower case symbol eg Gg, not Gb / GB 3 grey (bodied) : 1 black (bodied) 75% grey (bodied) : 25% black (bodied) $\frac{3}{4}$ grey (bodied) : $\frac{1}{4}$ black (bodied)	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An answer that includes the following: - each parent produces four types of gametes; LA, La, lA, la (1) - correctly laid out Punnett square (1) - ratio of named phenotypes given (1)	Accept 4 x 4 grid with gametes shown and 16 cells 9 Long winged, normal antennae (accept 9/16) 3 long winged, bushy antennae (accept 3/16) 3 vestigial winged, normal antennae (accept 3/16) 1 vestigial winged, bushy antennae (accept 1/16)	(3)

Question Number	Answer	Additional Guidance	Mark
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4(b)(iii)	An explanation that includes the following: - gene for eye colour is sex linked (1) - females have two alleles for eye colour and males have only one (1) - cross 1: Parents are $RR / X^R X^R$ $rY / X^r Y$ (1) - cross 2: Parents are $rr / X^r X^r$ $RY / X^R Y$ (1)	Accept gene for eye colour is only on X chromosome Accept from diagram Accept allele for eye colour is sex linked Accept description or symbols in genetic diagram eg RR and RY / $X^R X^R$ and $X^R Y$ Accept as part of answer for mp3 or 4 Accept males have one X chromosome, females have two and gene for eye colour is on X chromosome	(4)
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Total for Question 4 = 10 marks

Question Number	Answer	Additional guidance	Mark
2(a)(i)	A description that makes reference to the following: (megaspore mother cell) meiosis producing <u>four</u> {haploid / n} {<u>nuclei</u> / <u>megaspores</u>} (1) - three (nuclei / megaspores) disintegrate / disappear (1) - only one (nucleus / megaspore) then undergoes mitosis (1) <u>three</u> (mitotic) divisions occur (to produce 8 nuclei) (1)	penalise cells once e.g. meiosis makes four haploid cells but three cells disintegrate = one mark Award marks from correct labelled diagrams	(3)

Question Number	Answer	Mark
2(a)(ii)	The only correct answer is C <i>A is incorrect as endosperm cells are $3n$</i> <i>B is incorrect as endosperm cells are $3n$</i> <i>D is incorrect as embryo cells are $2n$</i>	(1)

Question Number	Answer	Mark
2(b)	The only correct answer is C (gibberellin) <i>A is incorrect as auxin does not stimulate enzyme production</i> <i>B is incorrect as cytokinin does not stimulate enzyme production</i> <i>D is incorrect as phytochrome does not stimulate enzyme production</i>	(1)

Question Number	Answer	Mark
2(c)(i)	The only correct answer is D (rrTt and rrTT) <i>A is incorrect as RrTT is red</i> <i>B is incorrect as rrTT is also yellow</i> <i>C is incorrect as rrtt is white</i>	(1)

Question Number	Answer	Additional guidance	Mark
2(c)(ii)	An answer that makes reference to the following: • correct parent genotypes (rrTt, RrTt) (1) • correct gametes (rT, rt AND RT, Rt, rT, rt) (1) • correct genotypes of offspring (RrTT, RrTt, Rrtt, rrTT, rrTt, rrtt) (1) • correct ratios of phenotypes (4 red : 3 yellow : 1 white OR 8 red : 6 yellow : 2 white) (1)	Allow ECF for mp2 ONLY if wrong parental genotypes have been stated (max 1) Allow mp1,2,3 from Punnet square The three phenotype colours must be shown somewhere for mp4	(4)

(Total for Question 2 = 10 marks)

Question Number	Answer	Mark
5 (a)(i)	The only correct answer is A (1 and 2) <i>B is incorrect as there is reduced diffusion of sodium ions into the cell</i> <i>C is incorrect as there is reduced diffusion of sodium ions into the cell</i> <i>D is incorrect as there is reduced diffusion of sodium ions into the cell</i>	1

Question Number	Answer	Additional guidance	Mark
5 (a)(ii)	An explanation that makes reference to two of the following: - more cones in {centre / fovea} / fewer rods in {centre / fovea} (1) - cone cells are less sensitive (to low light levels) (1) - as (only) one (cone) attaches to each (bipolar) neurone / cones do not have {(spatial) summation / convergence} (1)	Allow fovea Allow more rods in periphery / fewer cones in periphery Allow rhodopsin is more sensitive (than iodopsin) / iodopsin is less sensitive (than rhodopsin) Allow several rods attach to one (bipolar) neurones / have {summation / convergence}	2

Question Number	Answer	Mark
5 (b)(i)	The only correct answer is C (4) <i>A is incorrect as 2, 4, 10 and 6 are heterozygotes</i> <i>B is incorrect as 2, 4, 10 and 6 heterozygotes</i> <i>D is incorrect as 2, 4, 10 and 6 heterozygotes</i>	1

Question Number	Answer	Additional guidance	Mark
5 (b)(ii)	An explanation that makes reference to the following: • cross 6 and 7 produces {11 who is colourblind / colourblind child} (1) • because 6 must be {a carrier / heterozygous / have a hidden recessive allele} (1) OR • cross 3 and 4 produces {8 who is colourblind / colourblind child} (1) • because 8 has inherited recessive alleles from both parents / 4 must {be a carrier / be a heterozygote} OR (it is not dominant because) • 10 (and 8) from cross 3 v 4 would be colour blind (1) • as they would inherit a (dominant) allele from 3 (1) OR (it is not dominant because) • neither 6 or 7 is colour blind (1) • and because {11 / one child} is colour blind 6 would have to be colour blind (1) OR • 1 and 2 produce 4/6 {who is a carrier} (1) • so 2 must have a recessive allele / is a carrier / 4/6 must have inherited a recessive allele from 2 (1)	Mark in pairs Allow 11 is colourblind but has parents who are not Do not accept both parents are carriers / heterozygotes Do not accept both parents are carriers / heterozygotes Allow 3 and 4 must both have recessive alleles	2

Question Number	Answer	Additional guidance	Mark
5(c)(i)	An answer that makes reference to three of the following: - the condition is recessive (1) - but not sex linked / is on an autosome (1) - because 4 and 5 are not affected but 6 is affected / 4 and 5 must both be {carriers / heterozygous} (1) - it cannot be sex linked as 3 is not affected (1)	autosomal recessive = 2 marks Allow not X-linked Allow from correct genetic diagram Allow 3 would be affected if the allele were sex linked	3

Question Number	Answer	Additional guidance	Mark
5(c)(ii)	An explanation that makes reference to two of the following: • there has been a (genetic / population) bottleneck / founder effect (1) • which increases frequency of affected allele / reduces the frequency of the unaffected allele (1) • few new alleles introduced (as little immigration) (1) • so there is a higher chance of two {heterozygotes / carriers} having children together (1)	Allow more people will carry the affected allele Allow small gene pool / little genetic variation Allow many people are {carriers / heterozygous} Allow high chance of inheriting two recessive alleles	2

Number	Answer	Additional Guidance	Mark
10 (a)(i)	An answer that makes reference to the following: there is no difference between the number of expected and observed phenotypes		(1)

Question Number	Answer	Additional Guidance	Mark
10 (a)(ii)	An answer that makes reference to the following: -15 225 0.25		(1)

Question Number	Answer	Additional Guidance	Mark
10(a)(iii)	An answer that makes reference to the following: 3		(1)

Question Number	Answer	Additional Guidance	Mark
10(a)(iv)	An answer that makes reference to the following: - the {null hypothesis / H_0} is {accepted / not rejected} (1) - critical value is 7.815 (1) - there is a more than {0.05 / 5%} probability that the difference is due to chance / no significant difference / not significant (1)	ACCEPT clear indication in table ACCEPT for critical value is 6.251 ACCEPT (for critical value of 6.251) there is a more than {0.1 / 10%} probability that the difference is due to chance / no significant difference	(3)

Question Number	Indicative content
*10 (b)	Answers will be credited according to candidates' deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. Indicative content: (P) - genotypes of the parents are NNgg and nngg - F₁ generation are all NnGg / heterozygous - the ratios are not in 9:3:3:1 ratio (L) - genes are linked / genes on same autosome / genes on same chromosome - crossing over has occurred / chiasmata (most) gametes are NG and ng on one chromosome - smaller number of gametes as nG and Ng on one (A) - correct use of genetic diagrams - correct genotypes of F₂ - the normal wing and black body are recombinants / vestigial wing and grey body are recombinants - small number of recombinants suggest genes are closer together

Level	Marks	
0	0	No awardable content
1	1-2	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. The explanation will contain basic information with some attempt made to link knowledge and understanding to the given context. minimum 1 comment from P or L: 1 mark
2	3-4	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts to provide the explanation being presented. Lines of argument occasionally supported through the application of relevant evidence (scientific ideas, processes, techniques and procedures). The explanation shows some linkages and lines of reasoning with some structure. minimum 3 comments from P AND L
3	5-6	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts to provide the explanation being presented. Line(s) of argument supported throughout by sustained application of relevant evidence (scientific ideas, processes, techniques and procedures). The explanation shows a well-developed and sustained line of reasoning which is clear, coherent and logically structured. minimum 2 comments from P AND 2 from L plus A with no major errors

Number	Answer	Additional Guidance	Mark
4(a)(i)	$X^B X^B$, $X^B X^b$, $X^b X^b$ (1)	Allow $X^b X^B$	(1)

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	$X^B Y$, $X^b Y$ (1)	Do not allow allele on Y chromosome	(1)

Question Number	Answer	Additional Guidance	Mark
4(a)(iii)	An answer that includes the following: 1 $X^B X^b$ (1) 2 $X^B Y$ (1) 3 $X^B X^b$ (1) 4 $X^B X^b$ and $X^B X^B$ (1)	For 1,2,3 one correct genotype only gets the mark Must have 2 correct genotypes and no other	(4)

Question Number	Answer	Additional Guidance	Mark
4(b)(i)	An answer that includes the following - correct genotypes of both parents used OR correct genotypes of offspring given in genetic diagram (1) - correct ratio of phenotypes given (1)	Accept parents: $X^R X^G$ and $X^G Y$ offspring: $X^R X^G$, $X^G X^G$, $X^R Y$, $X^G Y$ Do not allow allele on Y chromosome for mp1 Accept 1:1:1:1 of females able to see red and green females able to see green males able to see red males able to see green Accept 25% of each category / $\frac{1}{4}$ of each category / 0.25 of each category	(2)

Question Number	Answer	Additional Guidance	Mark									
4(b)(ii)	An answer that includes the following: • correct genotype of mother (1) • correct genotype of father (1) • correct genetic diagram to produce offspring as described (female, sees red and green) and Male, sees red only)(1)	Accept $X^R X^R$ Accept $X^G Y$ <table><tr><td></td><td>X^R</td><td></td></tr><tr><td>X^G</td><td>$X^R X^G$</td><td>(Female, sees red and green)</td></tr><tr><td>Y</td><td>$X^R Y$</td><td>(Male, sees red only)</td></tr></table> Do not allow allele on Y chromosome for mp2 and 3		X^R		X^G	$X^R X^G$	(Female, sees red and green)	Y	$X^R Y$	(Male, sees red only)	(3)
	X^R											
X^G	$X^R X^G$	(Female, sees red and green)										
Y	$X^R Y$	(Male, sees red only)										

Question Number	Answer	Additional Guidance	Mark
4(b)(iii)	more likely to be able to see {fruits / flowers / insects} (amongst leaves) / more likely to recognise poisonous {insects / fungi / snakes} (1)		(1)

Question Number	Answer	Additional Guidance	Mark
4(b)(iv)	A description that includes three of the following: - cut out gene (for required protein from human DNA) (1) - using restriction {enzyme / endonuclease} - introduce this gene to a vector (and transfer to retina of monkey) (1) - test the monkey for colour vision (1)	Ignore DNA ligase Allow {isolate / remove} for cut out Ignore desired characteristic Accept example of vector eg virus Accept appropriate process eg liposome wrapping / microinjection Ignore plasmid / gene gun	(3)

(Total for Question 4 = 15 marks)

Number	Answer	Additional Guidance	Mark
3(a)	A description that makes reference to five of the following: - equal mass and shape of carrot tissue cut (1) - carrot tissue submerged in (boiling tubes with) known volume of water (1) - placed in water baths at stated range of temperatures for a stated length of time (1) - contents {filtered / decanted} (1) - absorbance measured / colour charts used (1) - graph plotted / statistical analysis of results (1) - appropriate step to ensure validity (1)	Allow use of cork borer and same length Allow {same surface area / equal cubes} Allow 5 – 100°C (must be at least 5 temps), for 5 – 30 mins Allow transmission measured Allow all tissue from same {carrot / age of carrot} Allow repeats at each temperature and {mean / SD} calculated	(5)

Question Number	Answer	Additional Guidance	Mark
3(b)	An answer that makes reference to the following: - conversion of mg to g (1) - division by 750 and calculation of percentage (1)	1265.25 mg = 1.26525 g (0.1687 g in 100g) = 0.17 (%) Correct answer with no working gains 2 marks Otherwise correct answer to wrong power of 10 gains 1 mark Correct answer with wrong number of decimal place gains 1 mark	(2)

Question Number	Answer	Additional Guidance	Mark
3(c)(i)	An answer that makes reference to the following: Prpr (1)	Allow C ^{Pr} C ^{Pr}	(1)

Question Number	Answer	Additional Guidance	Mark
3 (c)(ii)	an answer that makes reference to the following: - number of each calculated (1) - number of each phenotype identified (1)	26:52:26 / 26:51:26 / 1 : 2 : 1 26 dark purple, 52 light purple, 26 white	(2)

Question Number	Answer	Additional Guidance	Mark
3(c)(iii)	An answer that makes reference to the following: - O – E calculated for each phenotype (1) - square the values for O-E and divide by E (1) χ^2 calculated (1)	Example calculation 5, 1, -6 0.961538462, 0.019231, 1.38462 2.37 / 2.4 / 2.365 Correct answer with no working gains full marks Allow ecf for expected numbers from cii	(3)

Question Number	Answer	Additional Guidance	Mark
3(c)(iv)	An explanation that makes reference to the following: - critical value (at $p = 0.05$) is 5.991 (1) - calculated value is less than the critical value (1) $p > 0.05$ so the conclusion is likely to be valid (1)	Allow correct number indicated in table Allow 2.37 is less than 5.991 (gets mp1 & 2) $p > 0.05$ / 5% that differences between observed and expected are due to chance (so it is valid) Allow $p > 0.05$ so purple colour is controlled by a single gene with two codominant alleles	(3)

Question Number	Answer	Mark
6 (a) (i)	The only correct answer is C <i>A is incorrect as Mammalia is not a family</i> <i>B is incorrect as Mammalia is not a family</i> <i>D is incorrect as Mammalia is not an order</i>	1

Question Number	Answer	Additional guidance	Mark
6(a)(ii)	gel electrophoresis / {DNA / base} sequencing / bioinformatics / protein sequencing / morphology / molecular phylogeny / anatomical features (1)	Allow amino acid sequences of proteins Allow DNA hybridisation Allow immunological comparison	1

Question Number	Answer	Additional guidance	Mark
6(b)(i)	An answer that makes reference to the following: 34 (3 marks) For one mark each, allow: 0.94 (1 mark) 0.06 (1 mark)	Allow 33 (3 marks) Allow two marks only for 0.1128 / 11.28(%) / 0.113 / 11.3 (%) Allow 0.939(85) Allow 0.060(15) Example of calculation $q^2 = 265 / 300 = 0.883$ $q = 0.93985...$ $p = 1 - 0.9395 = 0.0601$ $2pq = 2 \times 0.9395 \times 0.0601 = 0.1129279$ so, $0.1129279 \times 300 = 33.87$ Correct answer with no working gains full marks.	3

Question Number	Answer	Additional guidance	Mark
6(b)(ii)	An explanation that makes reference to the following: - resistant (rats) {survive / breed / produce offspring} (1) (resistant rats) pass on the allele (to offspring) (1)	Allow non-resistant rats {die / do not breed / do not produce offspring}	2

Question Number	Answer	Additional guidance	Mark
6(b)(iii)	An explanation that makes reference to two of the following: {heterozygotes / $W^R W^N$} survive (better) / {heterozygotes / $W^R W^N$} have advantage (1) - as $W^R W^N$ do not need extra vitamin K / $W^R W^R$ die as need more vitamin K (1) {heterozygotes / $W^R W^N$} pass on W^N allele / {heterozygotes / $W^R W^N$} produce $W^N W^N$ offspring (1)	Allow carriers Allow $W^R W^R$ rats need more vitamin K Allow carriers	2

(Total for Question 6 = 9 marks)

Guidance	Mark
use statement	
	(3)

Answer	Additional Guidance	Mark
the following: a gradient / from low to high	IGNORE from low concentration gradient to high concentration gradient	
(1)		(2)

Answer	Additional Guidance	Mark
a to the following: a) osmosis	ACCEPT converse for epithelial cells	
chloride ions / salt / solute}		(1)
the cell}	ACCEPT solute potential decreases {in intestine / outside the cell}	(1)
potential (in the intestine)		(1)
		(3)

Answer	Additional Guidance	Mark
a to the following: less air enters alveoli / less gas gradient / less diffusion (into	ACCEPT less space / reduced pathway	
(1)		(2)

Number	Answer	Additional Guidance	Mark
3(a)(i)	- juvenile and nymph both 16 (1) - eggs and sperm both 8 (1)		(2)

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	M on arrows before eggs and sperm		(1)

Question Number	Answer	Additional Guidance	Mark
3(b)	An explanation that makes reference to the three from the following: - Asexual reproduction occurs due to mitosis (1) - when DNA replication takes place (1) - so that, mitosis can divide sister chromatids equally into each cell (1) - therefore cells produced have no genetic variation (1)	Allow Cells receive identical chromosomes / {chromosomes or DNA } from only one parent Allow no {independent assortment of chromosomes or random fusion of gametes or crossing over} takes place	(3)

Question Number	Answer	Additional Guidance	Mark																								
3(c) (i)	<table border="1"> <thead> <tr> <th>Feature</th><th>Mitosis</th><th>Meiosis I</th><th>Meiosis II</th></tr> </thead> <tbody> <tr> <td>homologous chromosomes pair together</td><td>x</td><td>✓</td><td>x</td></tr> <tr> <td>crossing over can cause genetic variation</td><td>x</td><td>✓</td><td>x</td></tr> <tr> <td>homologous chromosomes separate</td><td>x</td><td>✓</td><td>x</td></tr> <tr> <td>sister chromatids separate</td><td>✓</td><td>x</td><td>✓</td></tr> <tr> <td></td><td>(1)</td><td>(1)</td><td>(1)</td></tr> </tbody> </table>	Feature	Mitosis	Meiosis I	Meiosis II	homologous chromosomes pair together	x	✓	x	crossing over can cause genetic variation	x	✓	x	homologous chromosomes separate	x	✓	x	sister chromatids separate	✓	x	✓		(1)	(1)	(1)		(3)
Feature	Mitosis	Meiosis I	Meiosis II																								
homologous chromosomes pair together	x	✓	x																								
crossing over can cause genetic variation	x	✓	x																								
homologous chromosomes separate	x	✓	x																								
sister chromatids separate	✓	x	✓																								
	(1)	(1)	(1)																								

Question Number	Answer	Mark
3 (c) (ii)	The only correct answer is B A is not correct because crossing over does not alter the DNA sequence of a gene to produce new alleles C is not correct because independent assortment does not alter the DNA sequence D is not correct because random fusion of gametes does not alter the DNA sequence	(1)

k

k

k

Answer	Additional Guidance	Mark
as reference to the following: {lowers the water potential / ates a concentration gradient / ntial gradient} (1) oves in (to mucus) by osmosis (1)	Accept out (of cells)	(2)

Answer	Additional Guidance	Mark
as reference to the following: no concentration gradient / isotonic } (1) ot move / no osmosis (1)	Do not accept references to pure water	(2)

Answer	Additional Guidance
ference to the following: (1) age of carriers (1)	<u>Example of calculation:</u> $q^2 = 0.0004 / 4 \times 10^{-4}$ $q = 0.02$ and $p = 0.98$ $2pq = 0.0392$ percentage of population who are carriers is 3.92% Correct answer with no working gains full marks

Answer	Additional Guidance
ference to the following: ather is) CC (1) each parent (1) ffspring are CC and Cc (1) ing a carrier is 50% / 0.5 / $\frac{1}{2}$ / 1:1 (1)	Minus 1 if same letter not used or more than one letter to represent allele Sex inheritance loses mp1 and loses 1 mark for not using same letter

9BIO3

9BI



Number	Answer	Additional Guidance	Mark
4(a)(i)	D sympatric speciation A is incorrect because allopatric speciation requires geographical separation B is incorrect because genetic speciation is the wrong term C is incorrect because stabilising selection is the wrong term		1

Question Number	Answer	Additional Guidance	Mark
4 (a)(ii)	An answer that makes reference to: have not seen if they can breed and produce fertile offspring with modern mosquitoes (1)		1

Question Number	Answer	Additional Guidance	Mark1
4(a)(iii)	An answer that makes reference to: peer review / published in journals / conferences (1)		1

Question Number	Answer	Additional Guidance	Mark
4(a)(iv)	- Phylum and class (1) - Prisoculex and burmanicus (1)		2

Question Number	Answer	Additional Guidance	Mark
4 (b)(i)	A calculation that makes reference to: - correct calculation to find q (1) - correct calculation to find p (1) - correct calculation to find 2pq and number of mosquitoes (1)	q = 0.899... Allow any dp p = 0.101... Allow any dp Allow ecf for mp2 and mp3 1183 = three marks Correct answer with no working gains full marks	3

Question Number	Answer	Additional Guidance	Mark
4 (b)(ii)	An explanation that makes reference to four of the following: - The frequency of the resistance allele increased in 2015 (1) - because the (resistant) acetylcholinesterase enzyme is not affected by the pesticide / enzyme still works (1) - acetylcholine is still broken down in synapses (1) - the mosquitoes survive and breed (1) - the resistance allele carries a cost as it is reduced when no pesticide is used / after 2015 (1)	Allow Number of resistant mosquitoes increases in 2015 Allow converse Allow converse Allow converse Allow resistant mosquitoes are at a selective advantage Allow lost by genetic drift / non-resistant mosquitoes out compete resistant ones after pesticide use stops Allow no selective pressure to retain the resistant allele	4

7(a) (i)	only one copy (of this allele) is required to affect the phenotype (1)	Accept (allele that is) always expressed / expressed in heterozygotes	(1)
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Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	An explanation that makes reference to two of the following: - there are two main peaks as there are only two different alleles (that are not codominant) (1) - environment affects the colour of the feathers (as there are intermediates) / (intermediates are due to) subjective scoring (1) - grey owls have a selective / survival advantage (1)	Accept grey peak are homozygous (recessive) owls and brown peak, owls have a dominant allele Accept named environmental factors e.g. diet Accept converse Accept grey survive better due to camouflage	(2)

Question Number	Answer	Additional Guidance	Mark
7 (a)(iii)	- correct calculation of q (1) - correct calculation of p (1) - correct calculation of number of heterozygotes (1)	Example calculation 0.84 (accept any number of dp) 0.16 (accept any number of dp) 33 (Accept 32) Correct answer with no working gains full marks	(3)

Question Number	Indicative content
7 (b)*	Answers will be credited according to candidate's deployment of knowledge and understanding of material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. - with increasing snow depth, there is higher survival of grey owls / fewer brown owls survive / more grey owls D - snow depth has decreased over time D - the percentage of brown owls has increased over time / percentage of grey owls has decreased D For - with less snow, more ground is visible / uncovered / more twigs and trees visible E - with less snow, grey owls more obvious (to predators / prey) / less camouflaged E - with less snow, natural selection would favour brown owls / more brown (advantageous) alleles passed on / fewer grey alleles passed on / brown owls outcompete grey owls E - enhanced greenhouse effect due to carbon dioxide emissions reflecting radiation back / absorbing radiation (causing melting) E Against - no direct measure of greenhouse gas / temperature / fossil fuel emissions A - graphs show correlations not causal links A - data for owl survival with snow depth is scattered / gaps in data / weak correlation A - data for mean snow depth has many outliers / anomalies / not all points are around line / data is scattered A - other factors (named factors) could be affecting the owl population A - reduced snow may not be due to greenhouse gas release A

Level 0	Marks	No awardable content
Level 1	1-2 (1-3)	Limited scientific judgement made with a focus on mainly just one method, with a few strengths/weaknesses identified. A conclusion may be attempted, demonstrating isolated elements of biological knowledge and understanding but with limited evidence to support the judgement being made. 1 mark : any 1 from D, E, A 2 marks : any 2 from D, E, A
Level 2	3-4 (4-6)	A scientific judgement is made through the application of relevant evidence, with strengths and weaknesses of each method identified. A conclusion is made, demonstrating linkages to elements of biological knowledge and understanding, with occasional evidence to support the judgement being made. D and, E OR A 3 marks : at least 3 points. Any combination of D, plus E, or A 4 marks : at least 4 points. Any combination of D, plus E, or A
Level 3	5-6 (7-9)	A scientific judgement is made which is supported throughout by sustained application of relevant evidence from the analysis and interpretation of the scientific information. A conclusion is made, demonstrating sustained linkages to biological knowledge and understanding with evidence to support the judgement being made. D, E, AND A 5 marks : at least 5 points. Must have combination of D, E, and A 6 marks : at least 6 points. Must have combination of D, E, and A



Number	Answer	Additional Guidance	Mark
8(a)(i)	1.52×10^7		(1)

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	A description that makes reference to three of the following: - damage to {endothelium} caused by {high blood pressure / toxins / smoking} (1) - inflammatory response and arrival of {macrophages / white blood cells} (1) - deposits of {cholesterol / calcium} (1) - formation of {atheroma / plaque} (1)	DO NOT ACCEPT fat / lipid	(3)

Question Number	Indicative content
*8(b)	Answers will be credited according to candidate's deployment of knowledge and understanding of material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. Candidates are expected to reach a decision/conclusion on whether the Hardy Weinberg equation could be used to predict the number of people in the future who would need treatment in the UK for health disorders. Lifestyle (L) - HW only predicts genetic disorders - many health disorders are not genetic / caused by lifestyle - example of a lifestyle disease Formula and Assumptions (A) - assumes frequency of alleles remains constant / $p + q = 1$ refers to allele frequency - assumes frequency of genotypes remains constant / $p^2 + 2pq + q^2 = 1$ refers to genotype frequency p^2 = homozygous dominant / $2pq$ = heterozygotes / q^2 = homozygous recessive - assumes no selection / random mating - assumes no mutation - assumes no migration - assumes large population / no genetic drift Problems (P) - recognises assumptions invalid - explain why assumptions are invalid - understands that countries have different population sizes - people unwilling to have a genetic test / risks with genetic tests / tests need to be done - genetic testing is expensive - cannot test for all alleles - understands that environment can affect gene expression

Level	Marks	
0	0	No awardable content
1	1-3	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. Vague statements related to consequences are made with limited linkage to a range of scientific ideas, processes, techniques and procedures. The discussion will contain basic information with some attempt made to link knowledge and understanding to the given context. 1 to 3 from L A or P (only one of L A or P)
2	4-6	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts. Consequences are discussed which are occasionally supported through linkage to a range of scientific ideas, processes, techniques and procedures. The discussion shows some linkages and lines of scientific reasoning with some structure. 4 to 6 from L A or P (from at least two of L A or P)
3	7-9	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts. Consequences are discussed which are supported throughout by sustained linkage to a range of scientific ideas, processes, techniques or procedures. The discussion shows a well-developed and sustained line of scientific reasoning which is clear and logically structured. 7 plus from L and A and P



Answer		Mark	Answer
	Additional Guidance	1	four of the following: cies / type} are kept / es / varieties} are kept / y are kept (1) perature (1) sture / dry} (1) xygen} containers (1) seeds to detect embryoc
/ protein	DO NOT ACCEPT in cells ACCEPT adenylate cyclase activated ACCEPT glycogen phosphorylase is phosphorylated	3	Additional Guidance DO NOT ACCEPT beta glucose once apid / easy {breakdown / hydrolysis} (1) s not {affect osmosis / leave cells / solute
			Answer olysis reaction breaking actions forms glycogen not phosphodiester bond not phosphodiester bond

	Additional Guidance	Mark
owing:	<u>Example of calculation</u> $15 \div 1400 = 0.0107$ $p = 0.897 \quad q = 0.103$ $2pq = 2 \times 0.897 \times 0.103 = 0.185$ $0.185 \times 1400 = 259$ Correct answer with no working gains full marks ACCEPT one mark for: $q^2 = 0.01$ to 0.0107 $p = 0.897$ to 0.9 and $q = 0.1$ to 0.103 ACCEPT $2pq = 0.18$ to 0.187 in final answer for 3 marks	4

Additional Guidance	Mark
ACCEPT low genetic diversity / small number of different alleles	2

Additional Guidance	Mark
IGNORE habitat / area	1

Number	Answer	Additional Guidance	Mark
9(a)	An explanation that makes reference to two of the following: • fungi colonise new areas (1) • fungi cause decomposition (1) • so mineral ions are recycled within the ecosystem (1)		(2)

Question Number	Answer	Additional Guidance	Mark
9(b)(i)	An explanation that makes reference to three of the following: • the numbers are very small causing a genetic bottle neck (1) • so that variation in the gene pool may have been reduced (1) • causing increased likelihood of inbreeding effects (1) • such as accumulation of disadvantageous mutations (1)	Allow reference to founder effect Allow small gene pool Allow inbreeding depression, Allow early offspring may have come from only one male Allow greater chance of receiving two recessive alleles	(3)

9(b)(ii)

Level	Marks	
0	0	No awardable content
1	1-3	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. Vague statements related to consequences are made with limited linkage to a range of scientific ideas, processes, techniques and procedures. The discussion will contain basic information with some attempt made to link knowledge and understanding to the given context.
2	4-6	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts. Consequences are discussed which are occasionally supported through linkage to a range of scientific ideas, processes, techniques and procedures. The discussion shows some linkages and lines of scientific reasoning with some structure.
3	7-9	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts. Consequences are discussed which are supported throughout by sustained linkage to a range of scientific ideas, processes, techniques or procedures. The discussion shows a well-developed and sustained line of scientific reasoning which is clear and logically structured.



9bii Applying marking points These are indicative marking points and other relevant information should be credited Level 1 1 mark: any point 2 marks: any two points 3 marks: any 3 points Level 2 4 marks: 4 points, must have + and - 5 marks: 5 points, must have + and - 6 marks: 6 points, must have + and - Level 3 Points must come from all three sections 7 marks: 7 points, must have + and - 8 marks: 8 points, must have + and - 9 marks: 9 points, must have + and -	Justification for using poison to kill feral cats 1. less potoroos killed (+) 2. potoroos less likely to become extinct (+) 3. feral cats are an introduced species (+) 4. there are very large numbers of feral cats (+) 5. increased fungal spread in ecosystem (by potoroos) (+) 6. introduced species will be killed but native species unharmed (+) 7. biodiversity remains higher if native species not killed (+) 8. sausages are designed to target cats (+) 9. native species less likely to become extinct (+) 10. poison is biodegradable (+) Reasons not to kill feral cats with poison 1. pets may be killed (-) 2. other animals may be killed (-) 3. lots of people object to this (petition) (-) 4. sausages could be attractive to wild species as well (-) 5. government could use other methods to reduce population of feral cats (-) 6. suggested other methods eg spaying, shooting (-) 7. killing cats does not deal with threat from foxes (-) 8. plants / kangaroos are killed to make the poison (-) 9. feral cats are behaving naturally and should not be punished for this (-) Wider points 1. poison made from native plants so less likely to kill native animals (+) 2. biodegradable poison so action now will not affect animals in the future (+) 3. potoroos require special protection as there are such small numbers / endangered (+) 4. idea of balance needed in ecosystem (+) 5. cats have no natural predators in Australia, so it is justified to kill them (+) 6. ethics of government choosing which species to kill (-) 7. government could continue the breeding programme for potoroos (-) 8. effect on food chain of killing 2m feral cats (positive or negative) 9. feral cats may develop resistance to the poison (-) 10. government could try a small-scale trial to find effects of cull (-)
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Number	Answer	Additional Guidance	Mark
8(a)(i)	An explanation that includes three of the following - four {polypeptide chains / subunits / haem groups / Fe^{2+}} (1) - haem groups {combine / bind} (reversibly) with oxygen (molecules) (1) - so can pick up four molecules of oxygen (1) - co-operative binding occurs (1) - because after first molecule of oxygen binds, the (3D) shape of the molecule changes (1)	Accept 2 alpha and 2 beta chains / subunits Accept iron {combines / binds} with oxygen Accept description eg after first molecule of oxygen binds {other oxygen molecules can be picked up more easily / there is a higher affinity for oxygen}	(3)

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	curve drawn lower and to the right of existing curve with same start and end point (1)	Sample graph	(1)

Question Number	Answer	Additional Guidance	Mark
8(a)(iii)	An explanation including two of the following: - oxygen more likely to be released (from Hb) at {respiring tissues / muscle} (1) - because {partial pressure / concentration} of carbon dioxide is {high / higher} in {respiring / muscle} tissues (1) {Bohr shift occurs / the affinity of haemoglobin for oxygen is reduced} when {partial pressure / concentration} of carbon dioxide is {high / higher} (1)	Accept haemoglobin gives up oxygen more easily when {partial pressure / concentration} of carbon dioxide is {high / higher} Accept when carbon dioxide concentration is high, carbonic acid (releases H^+ which) causes quaternary structure of Hb to change	(2)

Question Number	Answer	Additional Guidance	Mark
8(b) (i)	0.25	Accept 25% / $\frac{1}{4}$ / one in four / 1:3 Do not accept 1:4 / 3:1	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An explanation that includes the following (heterozygotes have) one {dominant / non-mutated} copy of the allele (1) - so {beta globin / the protein} can still be made (1)	Accept in heterozygotes the dominant allele is always expressed Accept both alleles must be recessive for the symptoms to be shown Ignore reference to carrier	(2)

Question Number	Answer	Additional Guidance	Mark
8(c)(i)	An answer including the following: - value for q^2 identified (1) - value for q or p calculated (1) - value for $2pq$ calculated to 2sf (1)	Example calculation 0.28 $q = 0.53 / 0.529$ or $p = 0.47 / 0.471$ (this gains mp1 & 2 if 0.28 not seen) 0.50 / 50% Correct answer with no working gains full marks	(3)

Question Number	Answer	Additional Guidance	Mark
8(c)(ii)	An answer including two of the following: - migration may occur (1) - mating may not be random (1) - population (on island) may be small (1) {selection may occur / beta thalassaemia may affect fertility} (1) - mutation may occur (1)	Accept population {is / may not be} isolated Accept may not be an equal chance of reproduction Accept population size {is not infinite / should be large} Accept genetic drift occurs Accept description of heterozygous advantage leading to higher number of heterozygotes	(2)

(Total for Question 8 = 14 marks)

Question Number	Answer	Additional guidance	Mark
9(a)(i)	An explanation that makes reference to two of the following: - a founder effect has occurred (1) - so only a small range of <u>alleles</u> / small gene pool / low <u>genetic</u> diversity / low <u>genetic</u> variation (1) - high chance that two (harmful) recessive alleles will be inherited / high chance both parents carry (harmful) recessive allele (1)	Accept bottleneck Do not accept small number of genes Accept high chance both parents are heterozygous (and have harmful alleles)	(2)

Question Number	Answer	Additional guidance	Mark
9(a)(ii)	- p calculated (1) 2pq calculated (1)	0.7 0.42 or 42 % (two marks) One mark for 0.7 in the working Correct answer gains both marks	(2)

Question Number	Answer	Additional guidance	Mark
9(a)(iii)	An answer that makes reference to two of the following: - no migration (1) - no sexual selection / natural selection (1) - no genetic drift / large population (1) - no mutation (1) - random mating / mixing (1)	Accept none leave population / none enter population Accept isolated population Accept no selection pressure	(2)

Question Number	Answer	Additional guidance	Mark
9(a)(iv)	A description that makes reference to two of the following: • ban on movement of lions (between countries) / ban on trade / control of trade (1) • by countries that {sign / agree} the treaties (1) • ban on {poaching / killing / hunting} of animals (1)		(2)

Question Number	Indicative content
*9(b)	Answers will be credited according to candidate's deployment of knowledge and understanding of material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. Descriptions of graphs (G) • all types of animals have more endangered species than threatened (G1) • more mammals / birds kept than invertebrates / amphibia (G1) • not that much difference between number of threatened and endangered amphibia / big difference between threatened and endangered for mammals / birds (G1) • zoos carry out research on many {mammals / birds} / little research on invertebrates (G2) • zoos support large amounts of in situ conservation for all species (G2) • high proportion of invertebrates have in situ conservation (G2) • ex situ conservation is low for {mammals / birds} / relatively high for amphibia (G2) Knowledge (K) • ex-situ conservation is keeping animals in zoos / in situ is keeping animals in habitats • zoos help prevent extinction of species / protect from poachers / predation ex-situ • leads to inbreeding / behaviour changes / ethical issues / unnatural environment • develops breeding programmes for release / allows scientific research / educational work • breeding programmes / stud books etc reduce genetic problems • modern zoos have enriched environments / more natural environments in-situ • expensive / may conflict with local people • also helps other species / habitats Discussion points (D) • some of the species in the zoos are just kept as exhibits rather than for conservation • the zoos raise money / awareness / research for in situ conservation / protect animals in habitats

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|--|--|
| | <ul style="list-style-type: none">• fewer invertebrates in the zoos are kept for 'exhibits' (as less popular with visitors) / most are kept for conservation• more conservation of invertebrates / amphibia could be carried out• clear statement that some of the ethical issues of zoos are outweighed by benefits for some species• more research / raising of awareness could be done on amphibia / invertebrates• difficult to make conclusion as no information about exact species / invertebrate grouping is very large• no information about the number / type of zoos assessed• only looks at numbers of threatened and endangered species / needs other categories / needs to include other groups e.g. fish / reptiles |
|--|--|

	Marks	AO2 discuss
0	0	No awardable content
1	1-2 (1-3)	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. Vague statements related to consequences are made with limited linkage to a range of scientific ideas, processes, techniques and procedures. The discussion will contain basic information with some attempt made to link knowledge and understanding to the given context. 1 mark: any two comments from any of G, K, D 2 marks: any three comments from any of G, K, D
2	3-4 (4-6)	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts. Consequences are discussed which are occasionally supported through linkage to a range of scientific ideas, processes, techniques and procedures. The discussion shows some linkages and lines of scientific reasoning with some structure. 3 marks: any four comments from at least two of G, K, or D 4 marks: any five comments from at least two of G, K, or D
3	5-6 (7-9)	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts. Consequences are discussed which are supported throughout by sustained linkage to a range of scientific ideas, processes, techniques or procedures. The discussion shows a well-developed and sustained line of scientific reasoning which is clear and logically structured. 5 marks: any five comments and must be from G, K, and D 6 marks: any six comments and must be from G, K, and D must have considered both graphs

(Total for Question 9= 14 marks)

Number	Answer	Additional Guidance	Mark
8 (a)(i)	- correct value from graph (1) - correct calculation of oxygen in 1 g of haemoglobin (1) - correct calculation of oxygen in 100 cm³ of blood (1)	72 % $72 / 100 \times 1.36 = 0.9792$ $1.47 / 1.469 / 1.4688 \text{ cm}^3$ Correct answer gains full marks	3

Question Number	Answer	Additional Guidance	Mark
8 (a)(ii)	An explanation that makes reference to four of the following: - myoglobin (is on the left because) has a higher affinity for oxygen / binds more tightly to oxygen (1) - therefore it acts as a store for oxygen / only releases oxygen when oxygen is low (1) - haemoglobin is sigmoidal / S shaped / myoglobin is not S shaped (1) - as oxygen binds cooperatively (1) - so that the affinity varies depending on how much oxygen is bound (1)	Accept converse for oxygen e.g. haemoglobin releases oxygen more easily Accept correct description	4

Question Number	Answer	Additional Guidance	Mark
8(b)	An answer that makes reference to four of the following: - the (Tibetan haemoglobin) has a higher affinity for oxygen (1) - so that it is more saturated at lower pressures of oxygen (1) - with high carbon dioxide, the Tibetan haemoglobin has a lower affinity for oxygen (than Europeans) (1) - because it has a {more pronounced / bigger} Bohr shift / shift to the right (1) - so that it will release oxygen more easily (1)	Accept converse Accept oxygen concentrations Accept can bind oxygen at low pressures / can bind oxygen when at altitude where there is less partial pressure of oxygen Accept with higher carbon dioxide, Tibetan haemoglobin is less saturated (than European haemoglobin)	4

Question Number	Answer	Additional Guidance	Mark
8 (c) (i)	- calculation of q (1) - calculation of p (1) - calculation of number of heterozygotes (1)	Correct answer: 516 Accept answers with range of 517 and 528 with incorrect rounding for two marks Correct answer gains full marks Accept ECF for mp3 for $2pq \times 2500$	3

Question Number	Answer	Additional Guidance	Mark
8 (c)(ii)	An explanation that makes reference to the following: - only Tibetans and Denisovans have the allele (1) - so (the presence of the allele) suggests that Denisovans and Tibetans must have interbred (1) - and produced fertile offspring (1)	Accept Allele is present in Tibetans and Denisovans	2