M1. (a) breed together;
if fertile offspring, then same species;

2

(b) isolation of two populations;
variation already present due to mutations;
different environmental conditions / selection pressures;
selection of different features and hence different alleles;
different frequency of alleles;
separate gene pools / no interbreeding;

4 max

(c) selection of mate dependent on colour pattern;
prevents interbreeding / keeps gene pools separate;

2

[8]

M2. (a) gene located on X / Y/ one sex chromosome;
(allow gene on X or Y chromosome, not X and Y)

1

(b) (i) black;

1

(ii) $\mathbf{X^GX^g}$;
(lose this mark if the wrong genotype is given for the female in (iii))
(must show X chromosomes to gain the mark)

1

correct parent gametes
($\mathbf{X^g}$ and **Y** from male, $\mathbf{X^G}$ and $\mathbf{X^g}$ from female);
correct offspring genotypes ($\mathbf{X^gX^g}$, $\mathbf{X^GX^g}$, $\mathbf{X^GY}$, $\mathbf{X^gY}$);
correct link of offspring genotypes with phenotypes;
$\mathbf{X^gX^g}$ black female
$\mathbf{X^GX^g}$ tortoiseshell female
$\mathbf{X^GY}$ ginger male
$\mathbf{X^gY}$ black male
(correct gametes, offspring genotypes and link with phenotypes based on incorrect parent genotype = 3 marks)

3

(c) **X^GY dd**;

correct male kitten genotypes (**X^gY Dd** and **X^gY dd**);
correct link of kitten genotypes with phenotypes;

(ignore female kittens)

X^gY Dd black

X^gY dd grey

(correct kitten genotypes and phenotypes based on incorrect parent genotype = 2 marks)

3

[9]

M3. (a) discontinuous, as discrete groups;

1

(b) (i) in woods low percentage of banded yellow shells / in grassland/hedgerows high percentage of banded yellow shells;

(gains 2 marks)

low percentage of yellow shells in woods/higher percentage of yellow shells in grassland/hedgerows / low percentage of banded shells in woods/ higher percentage of banded shells in grassland/hedgerows / distribution similar in grassland and hedgerows;

(gains 1 mark)

2

(ii) due to natural selection;
in their habitat they are better camouflaged ;
therefore less predation (by birds);
so higher proportion of these survive;
and pass on their alleles/genes;

4 max

[7]

M4. (a) mutations;
which are different/at different positions in the gene;

2

(b) (i) either dominant or recessive allele;

1

(ii) a^ha^h BB, a^haBB, a^ha^h Bb, a^haBb;;

(allow 1 mark for 2 or 3 correct answers)

2

(iii) temperature lower at extremities;
enzyme active/ not denatured;

2

(c) if allele A is present (normal) tyrosinase/enzyme is produced, so it does not matter what other allele is present / explanation of why heterozygote is same phenotype as double dominant in terms of enzyme produced;
phenotype/rabbit is black as both have alleles A and B**;**

2

[9]

M5. (a) variation present in (original population);
(copper) tolerant individuals more likely to survive;
(these reproduce and) pass on genes (to next generation/offspring);
more/increase (in frequency) of copper tolerance alleles/genes;

4

(b) 1. reproductively isolated / no interbreeding (due to different flowering times);
2. conditions different for two populations / different selection pressures;
3. different features or plants are selected or survive /different adaptations;
4. populations become (genetically) different;
5. unable to produce fertile offspring;

4

[8]

M6. (a) 1 4 year cycles;
2 predator/stoat peaks after prey/lemming;
3 lemmings increase due to low numbers of stoats/available food;
4 more food for stoats so numbers increase;
5 increased predation reduces number of lemmings;
6 number of stoats decreases due to lack of food/starvation;

6

(b) smaller populations have fewer different alleles/more homozygosity/less heterozygosity/smaller gene pool/lower genetic variability;
migrants bring in new alleles/increase gene pool;

2

(c) geographical isolation of populations;
variation present in population(s);
different environmental conditions;
different selection pressures/different phenotypes selected;
change in genetic constitution of populations/gene pools/allele frequency; (two populations) so unable (to breed) to produce fertile offspring;

4 max

[12]

M7. (a) (i) black;

1

(ii) chocolate;

1

(b) **BE**, **Be**, **bE**, **be** and **be**;
BbEe, Bbee, bbee, bbEe;
1 black: 2 yellow: 1 chocolate;

3

(c) (i) no enzyme coded for when no dominant / **E** allele;
phaeomelanin not converted – (remains yellow);

2

(ii) **E** allele results in enzyme producing eumelanin;
B allele - more eumelanin deposited in hairs;

2

[9]

M8. (a) males are XY and females XX / males have one X chromosome and females two X chromosomes;
males only have one allele (of the gene) present / recessive allele always expressed;
colour blindness is masked in heterozygote / female needs 2 recessive alleles to be colour blind;

2 max

(b) (i) 5 - hh X^b Y;
6 - Hh X^B X^b;

2

(ii) h X^b , h Y, and H X^B, h X^B, H X^b , hX^b;

1

(iii) 1/8 or 12.5% or 0.125;;

either
genetic diagram to show genotypes Hh X^b X^b , Hh X^BY, hh X^B X^b, hh X^BY, HH$X^b$$X^b$, Hh X^bY, hh X^b X^b; hh X^bY;
1/8;
or
P (boy) = 0.5, P (colour blind) = 0.5, P (white streak) = 0.5;
(0.5 × 0.5 × 0.5 =) 0.125;

2

[7]

M9. (a) (i) paternal grandmother: $\mathbf{X^GX^G}$ or $\mathbf{X^GX^g}$

1

(ii) grandparent genotypes: [$\mathbf{X^gY}$] [$\mathbf{X^gX^g}$] [$\mathbf{X^gY}$];
gametes: [$\mathbf{X^G}$ and $\mathbf{X^g}$, or $\mathbf{X^G}$ only] [$\mathbf{X^g}$ and **Y**] [$\mathbf{X^g}$] [$\mathbf{X^g}$ and **Y**];
parents genotypes: [$\mathbf{X^GY}$] [$\mathbf{X^gX^g}$]
gametes: [$\mathbf{X^G}$ and **Y**] [$\mathbf{X^g}$]
daughter: [$\mathbf{X^GX^g}$];
(all correct = 3 marks);
(max 2 if no distinction between pairs of gamete genotypes, e.g. comma, space or circle);
(allow omission of gametes clearly not involved in next generation);
(all males XY and females XX = 1 mark, if no other marks);

3

(iii) nil;
X chromosome, without **G** allele, inherited from mother / Y must be inherited from father, not $\mathbf{X^G}$;

2

(b) X and Y chromosomes are different sizes / shapes;
chromatids unable to line up and form bivalent / only short pairing region / most of length not homologous;

2

[8]

M10. (a) genetic variation/ variation in gene/allele(s) in populations for cyanide production; colder/below 0°C (January) areas,
cyanogenic plants die in this cold/acyanogenic survive;
non-cyanogenic allele/gene passed on more often/its frequency increases;
warmer (January) areas cyanogenic plants at advantage,
because of less herbivore selection pressure/feeding;
so cyanogenic survive more often to pass on cyanogenic allele/gene.

4 max

(b) large (and equal) number of quadrats in each area;
(reject several)
random sampling method, described;
(accept described 'systematic' method)
percentage cover/point hits per quadrat/count plants;
mean/average value for each area;
statistics test to see if differences significant.

4 max

[8]

M11. (a) is always expressed(in the phenotype) / produces (functional) proteins;

1

(b) codominance;

1

(c) *Parental geneotypes* - hhC^RC^w, HhC^wC^w;

Gametes- 

Offspring geneotypes - HhC^RC^w, hhC^RC^w, HhC^wC^w, hhC^wC^w;

Offspring pheneotypes - hornless roan, horned roan, hornless white, horned white

Ratio of offspring - 1 1 1 1;

4

(d) (i) sperm(with more DNA) have X chromosome;
X is larger / has more genes than Y;

2

(ii) female for milk / males for meat / male or female for breeding;

1

[9]

M12. parental genotypes correct: $\mathbf{X^RX^r}$ AND $\mathbf{X^RY}$;
gametes correct for candidate's parental genotypes;
offspring genotypes correct and colourblind male identified as $\mathbf{X^rY}$ /
correct genotypes derived from cand's gametes <u>and</u> identify $\mathbf{X^rY}$;
<u>correct</u> probability = ¼ / 0.25 / 25% / 1 in 4 / 1:3 ;

[4]

M13. (a) Mutation/(spontaneous) change in a gene/change in DNA;

1

(b) (i) Correct answer: 0/6;; 2 marks
OR

Use of 56 <u>and</u> $\frac{176}{2}$ or 88 / <u>56 × 2</u> or 112 <u>and</u> 176; 1 mark

max 2

(ii) 64;

1

(c) (i) Correct answer = 42%;;; (only if $q^2 = 0.49$) 3 marks
OR 0.42;; 2 marks
OR
$p + q = 1$ / $p^2 + 2pq + q^2 = 1$ / $p = 1 – 0.7$ / $q^2 = 0.49$ / $q = 0.7$;

Answer = 2pq / use of appropriate numbers; 2 marks

max 3

(ii) 1. Parental genotypes correct: both $\mathbf{W^RW^S}$
(ACCEPT 'RS')

AND

W^S (*ACCEPT 'S'*) /gamete from each parent;

2. $\mathbf{W^SW^S}$ (*ACCEPT 'SS'*) / offspring formed and identified as susceptible;
If different symbols:
– defined : max 2 marks
– not defined max 1 mark (= pt.2)

2

(iii) 1. Description: decrease + rate of decrease slows with time;

Explanation: Any **three** from:

2. Resistant rats/rats with $\mathbf{W^R}$ allele survive
OR susceptible / $\mathbf{W^SW^S}$ rats killed

3. (more likely) to pass on $\mathbf{W^R}$ allele to offspring/less likely to pass on $\mathbf{W^S}$/ higher proportion of next generation has $\mathbf{W^R}$ allele/lower proportion has $\mathbf{W^S}$;

4. Chance of mating with $\mathbf{W^SW^S}$ is reduced / $\mathbf{W^SW^S}$ becomes rare;

5. Rate of selection against $\mathbf{W^S}$ slows because $\mathbf{W^S}$ allele is in heterozygotes;

max 4

(iv) No selective advantage / All genotypes equally fertile;
Large population;
Random mating; (IGNORE 'random fertilisation')
No mutation;
No emigration/immigration;

max 2

[15]

M14. (i) female XX, male XY;
Y <u>shorter/smaller</u> than X;

2

(ii) haemophilia is a recessive allele;
defective allele (gene) present on X, missing from Y;
male 0.5(50%/½) probability of haemophilia;
female 0/no chance;
(0.25(25%/¼) first baby having haemophilia);

or
X^HX^h X^HY;
$X^HX^H + X^HX^h + X^HY + X^h Y$;
X^hY is a sufferer

3 max

[5]

M15. (a) Parents genotypes Aabb aaBb ;

Gametes formed Ab ab aB ab ;
if parental genotypes wrong allow correctly derived gametes only

Offspring genotypes AaBb Aabb aaBb aabb

and

Offspring phenotypes 1 Walnut ; 1 Pea : 1 Rose : 1 single ;
*Just **one** mark for offspring genotypes **and** phenotypes*
If parents not diploid, no marks gained

3

(b) Correct answer 0.6, however derived, scores 2 marks
Wrong answer, but evidence of correct working
(e.g. $p^2/q^2 = 0.36$) scores 1 mark

2

[5]

M16. (a) (i) Only seen in males / not in females;

1

(ii) Unaffected parents/mother → child with M.D./
(1 ×)2 → 5 / (3 ×) 4 → 11 / 8 (× 9) → 13;

1

(b) 5 = X^dY

6 = X^DY

7 = X^DX^d AND X^DX^D

8 = X^DX^d;;

All 4 correct = 2 marks

2 or 3 correct = 1 mark

max 2

(c) ¼ / 0.25 / 25% / 1:3 / 1 in 4; (*NOT* '1:4')

1

[5]

M17. (a) group of organisms with similar features;
can (interbreed to) produce fertile offspring;

2

(b) directional selection;
any TWO from
selection against one extreme / for one extreme;
against broadest beaks in B and narrowest beaks in **A** / for narrowest in **B** and broadest in **A**;
whole distribution / range / mean / mode / median is shifted towards favoured extreme;

3 max

[5]

M18. (a) (i) Two, as white blood cells are diploid cells/alleles are present on each chromosome of an homologous pair/one maternal and one paternal;

1

(ii) A **and** B

(reject I^A and I^B)

1

(b) 1 in 8/ 1/8 / 12.5%/ 1:7/ 0.125;
(*Reject 1:8*) parents I^AI^O and I^BI^O;
give 1:3/ ¼ / 1 in 4/ 25% probability of blood group A and half will be male;

(accept 2nd and 3rd points from a suitable genetic diagram)

3

[5]

M19. (a) (i) Accurate means without error/free from mistakes when callipers used;
Reliable means that figure can be reproduced when measurement
Repeated/show little variation about true value;

2

(ii) If data unreliable, there will be a wide range of values;
Large standard deviation;
The higher the figure on the top line of the equation, the greater
The percentage measurement error;

2 max

(b) (i) Plot graph of mean skull breadth against mean cranial volume/ scatter diagram;
Draw line of best fit / calculate coefficient of correlation;
Look for figures close to +1 or –1;

2

(ii) Skull breadth is a linear measurements/can be measured with a single measurement/less prone to error/Cranial volume more difficult to measure because…;

1

(iii) Could distinguish between large male polecats and small female ferrets;
Little overlap in standard deviations;
Mean measurements for female polecats and male ferrets are very similar;

3

(c) Scientists could use method suggested/protocol established in earlier paper (thus saving time);
Findings more likely to be reliable if they replicate the findings of others;

2

(d) Some stomachs may contain more than one type of prey item;

1

(e) Unidentified bird remains small percentage of total prey/found in few stomachs;
Significant numbers of rabbits/rats eaten and these are pests;

2

[15]

M20. (a) (i) 1. Parents are heterozygous;

2. Kittens receive white allele from parents /black cat;

1. Accept carriers/carries white allele

1 max

(ii) 1:1;

Answer must be expressed as a ratio that could be reduced to 1 : 1

1

(b) (i) Black,
Chocolate,
Black;

All three correct for the mark

1

(ii) Parental phenotypes Chocolate male Black female

1. Parental genotypes bb^i Bb^i;

1

2. Parental gametes b b^i B b^i;

1

3. Offspring genotypes Bb, Bb^i bb^i b^ib^i;

1

Offspring phenotypes Black Chocolate cinnamon;

1. Both genotypes needed for the mark.

2. Allow credit if gametes are correctly derived from candidate's incorrect parental genotypes.

3. Genotype(s) must be with correct phenotype.

Allow credit if symbols other than B/b/b^i have been used correctly.

Ignore genetic diagrams unless clearly annotated.

(iii) 1. Offspring ratios are a probability/not fixed/arise by chance/

2. gametes may not be produced in equal numbers/

3. fertilisation/fusion of gametes is random/

4. small sample;

1

(iv) 1. Possible if parents homozygous/ bb;

2. Don't know genotype of chocolate cat / chocolate cat could be homo- or heterozygous / chocolate cat could be bb or bb^i;

3. Two chocolate cats could give cinnamon kittens;

2 max

[9]

M21. (a) 1. frequent use of antibiotic creates selection pressure/ antibiotic kills bacteria;
2. bacteria with mutation/ resistance have (selective) advantage over others / described;
3. (survive to) reproduce more than other types;
4. pass on advantageous allele/ mutated allele in greater numbers;
5. frequency of (advantageous) allele increases in subsequent generations;

(penalise use of "gene" instead of allele once only)

6. frequency of resistant types increases in subsequent generations;

5 max

(b) correct answer = 0.18;
And three marks for three of:
$p + q = 1$ and $p^2 + 2pq + q^2 = 1$;
$0.01 = q^2$;
$q = 0.1$;
$p = 0.9$
frequency of heterozygotes = $2pq = 2 \times 0.1 \times 0.9$/ 2 × candidates
p × candidates q;

4 max

[9]

M22. (a) Normal sight;

1

(b) **Nn**;
Must have at least one **N** allele as she has the condition and must pass on an **n** allele to her normal sighted children;

2

(c) Two marks for correct answer of ¼ / 0.25 / 25%;
One mark for incorrect answer that determines probability of next child having night blindness as ½ / 0.5 / 50%;

2 max

[5]

M23. (a) (i) Avoid bias/can only apply statistical test/Hardy-Weinberg expression to randomly collected data;

1

(ii) Give credit for any method which would ensure collection of a random sample from trees e.g. beating tray;

Q *Note that specification does not require specific knowledge therefore the use of specific terminology such as "beating tray" is not required here.*

1

(b) Two marks for correct answer of 49% red and 51% black;
One mark for incorrect answer in which p/frequency of black allele/B is Identified as 0.3 and q/frequency of black allele/B as 0.7;

2

(c) (i) Increase in the frequency of the red/b allele from autumn to spring/in all years;
Therefore frequency of black/B allele decreased and fewer black ladybirds in spring;

Q *The terms allele and gene must be used correctly but penalise only once*

2

(ii) Black ladybirds would become more active so respiration rate increases;
Deplete food reserves;

2

[8]

M24. (a) (i) Two marks for correct answer of 4;;

One mark for calculation involving 0.2 × 0.2 or 0.04;

2

(ii) 0.2/ the frequency remains the same;

Reject if wrong frequency is quoted

1

(b) (i) 1. There is a <u>probability</u> of 5%/0.05;

2. That difference in frequencies / difference in results are due to <u>chance</u>;

Accept 95% probability changes in frequencies not different as a result of chance

2

(ii) 1. Directional;

2. The recessive allele confers disadvantage/ the dominant allele confers advantage/more likely to survive / reproduce;

Assume "it" to refer to the recessive allele

2. References to selection do not gain credit as the term is in the question. Allow reference to phenotype / enzyme functionality (instead of allele) when describing advantage/disadvantage.

2

[7]

M25. (a) (i) Only expressed/shown (in the phenotype) when homozygous/two (alleles) are present/when no dominant allele/is not expressed when heterozygous;

1

(ii) Both alleles are expressed/shown (in the phenotype);

1

Allow both alleles contribute (to the phenotype).

(b) (i) Evidence (not a mark)

3 and 4/two Rhesus positives produce Rhesus negative child/children/7/9;

Explanation (not a mark)

Both Rhesus positives/3 and 4 carry recessive (allele)/are heterozygous/if Rhesus positive was recessive, all children (of 3 and 4) would be Rhesus positive/recessive;

Do not negate mark if candidate refers to gene rather than allele.

Answers including correct and incorrect evidence = zero marks evidence and explanation.

2

(ii) Evidence (not a mark)

3 would not be/is Rhesus positive/would be Rhesus negative;

Explanation (not a mark)

3 would receive Rhesus negative (allele) on X (chromosome) from mother/3 could not receive Rhesus positive (allele) from mother/3 would not receive Rhesus positive (allele)/ X (chromosome) from father/1/3 will receive Y (chromosome) from father/1;

OR

Evidence (not a mark)

9 would be Rhesus positive/would not be/is Rhesus negative/ 8 and 9/all daughters of 3 and 4 would be Rhesus positive;

Explanation (not a mark)

As 9 would receive X chromosome/dominant allele from father/3;

Do not negate mark if candidate refers to gene rather than allele.

One mark for evidence and one mark for explanation linked to this evidence.

Any reference to allele being on Y chromosome negates mark for explanation.

2

(c) Correct answer of 48(%) = 3 marks;;;

q^2/p^2= 16%/0.16 / p/q = 0.4;

Shows that 2pq = heterozygotes/carriers;

Final answer of 0.48 = 2 marks

Allow mark for identifying heterozygotes if candidate multiplies incorrect p and q values by 2.

3

[9]

M26. (a) The frequency/proportion of alleles (of a particular gene);

Will stay constant from one generation to the next/over generations/no genetic change over time;

Providing no mutation/no selection/population large/population genetically isolated/mating at random/no migration;

The three principles for marking are:
What feature
What happens to it
Providing . . .

Accept: genotype/explanation of genotype

Accept: alternative wording, e.g. there is no gene flow/genetic drift for genetically isolated.

3

(b) White/deaf cats unlikely to survive/selected against;

Will not pass on allele (for deafness/white fur) (to next generation)/will reduce frequency of allele;

Accept: alternative wording, e.g. have a disadvantageous phenotype

Neutral: will not breed

2

(c) In Paris/London frequencies (of these alleles) add up to more than 1;

Can be shown by correct figures to be more than 1
e.g. 0.71 + 0.78 = 1.49
Accept: more than 100%

1

(d) Two marks for correct answer of 44(.22);;

One mark for incorrect answer in which p/frequency of H determined as 0.67 and q/frequency of h as 0.33

OR

Answer given as 0.44(22);

2

[8]