AQA A-LEVEL · 7402

BIOLOGY



MARK SCHEME

3.4.3 GENETIC DIVERSITY VIA MUTATION AND MEIOSIS

SCORE	PERCENTAGE
/561	%

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Q1.

(a) 1. (Presence of) antigen of the (pathogenic) bacteria;
Assume bacteria are pathogenic unless otherwise stated

2. (Causes) more T cells produced / faster T cell production;

3. Against (the pathogen and) normal bacteria;

4. (Long lasting as) cells do not die / live for longer;

5. (More) cytokines / chemicals causing swelling are produced;

3 max

(b) 1. (Some people) have a mutation / allele / gene;

2. (That) increases the chances / risk / makes it more likely for / causes them to have an unusually large T cell response;
OR
(That) lowers / removes tolerance to (normal) intestinal bacteria;

2

(c) 1. (Some people might) produce (very) large amounts of cytokine / have large amounts of swelling;

2. (That) 5-ASA drugs cannot control / reduce;

OR

3. Some people may be allergic to / cannot tolerate 5-ASA;

4. So cannot take it;
Award 1 and 2
OR
Award 3 and 4

2

(d) 1. (Lack of adenine and guanine) will slow / stop DNA synthesis / replication (in T cells);

2. Affects T cells **more** as they cannot recycle nucleotides;
Needs idea of more / greater effect.
Accept converse idea that 'other' cells not as affected as they can recycle nucleotides.

3. (6-MP therefore) suppresses / slows the (unusually large) T cell / immune response
OR
(6-MP causes) fewer / no T cells (to be) produced;
Accept (6-MP) acts as an immunosuppressant drug

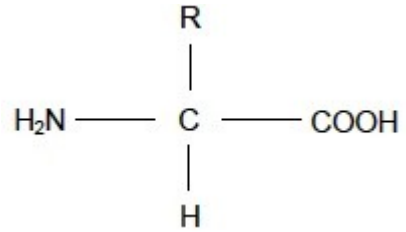
4. (So) less cytokine is produced (and therefore less swelling);

3 max

[10]

Q2.

(a)



Accept other correct representations.

1

(b) 1. More than one codon codes for a single amino acid;

Accept 'triplet' or 'sequence of 3 bases/nucleotides' for 'codon'.

Reject 'production/produces' for 'codes for'.

Do not infer mp1 from mp2.

2. Suitable example selected from Table 1;

2

(c) 1395;

Accept 1398 and 1401 (for those that include start and/or stop codons)

Allow 2796 or 2802 or 2790

Ignore 'bases/base pairs/bp/bps' written after the numerical answer.

1

(d) ✔CAA → CGA

1

(e) 1. (Both) negatively charged to positively charged change in amino acid;

2. Change at amino acid 300 does not change the shape of the <u>active site</u>
OR
Change at amino acid 300 does not change the tertiary structure OR Change at amino acid 300 results in a similar tertiary structure;

Reference to 'shape' of active site only needed once.

3. Amino acid 279 may have been involved in a (ionic, disulfide or hydrogen) bond **and** so the shape of the active site changes
OR
Amino acid 279 may have been involved in a (ionic, disulfide or hydrogen) bond **and** so the tertiary structure changed;
OR
Amino acid 279 may be in the active site **and** be required for binding the substrate;

Reference to 'shape' of active site only needed once.

Both parts are required for each mark option.

For 'a bond' reject peptide bond.

3

[8]

Q3.

(a) 1. 1 long and 1 short chromosome, each made up of 2 chromatids held (by centromere), in each cell of 1st division;

2. 1 long and 1 short (separate) chromosome in each cell of 2nd division;

Allow ECF for correct chromosomes shown in each cell from candidate's 1st division cells.

Ignore drawing of centromere.

2

(b)

52	4

;;

Allow 1 mark for numbers totalling 56 except 14/42 - repetition of observed values.

If table is blank, award 1 mark for evidence of 56.

Both 52 and 4 required in table for two marks, do not credit 52 or 4 for one mark.

Award 1 max for answers not given as whole numbers.

2

(c) 1. There is a less than 0.05/5% probability that the difference(s) (between observed and expected) occurred by chance;

Reject 'results (without reference to difference) occurring by chance'. Overall max 1 with this statement.

*Accept 'there is a greater than 0.95/95% probability that the difference did **not** occur by chance'.*

Ignore 'difference is significant'

2. Calculated value is greater than critical value so the null hypothesis can be rejected;

Ignore 'difference is significant'

Do not accept 'P value' for 'critical value'.

3. (The scientists can conclude that) the proportion of plants that produce 2n gametes does change from one breeding cycle to the next;

2 max

(d) 1. The scientists selected/used for breeding plants that produced 2n gametes;

Answer must be in context of the scientists selecting plants to breed. Accept 'artificial selection' or 'selectively bred'.

2. (So these plants) passed on their alleles (for production of 2n gametes to the next generation);

Both mark points can be awarded if one correct reference is made to alleles (in either context).

3. The frequency of alleles for production of 2n gametes increased (in the population).

Both mark points can be awarded if one correct reference is made to alleles (in either context).

For 'production of 2n gametes' accept 'abnormal meiosis'.

Do not accept 'number' for frequency.

Accept converse answers linked to plants that produce n gametes.

3

[9]

Q4.

(a) Lowercase a in both boxes

1

(b) Tick in box next to 'Crossing over';

1

(c) 32.73 / 32.7 / 32 / 33;;

Award 1 max for either

409 (409.2) for difference in volume (but incorrect number of mitochondria);

OR

Answer of 262 (261.9) (using diameter, rather than radius);

2

(d) 1. Egg (created) has nucleus / DNA / genes of (affected) woman / mother;

Accept ref. to zygote / embryo / child for egg

Accept genetic information

Ignore references to alleles

Reject if nucleus from wrong egg / woman

2. It has mostly / many / lots of normal mitochondria (of unaffected woman)
OR
There are few faulty mitochondria;

*Reject ref. to **production** of healthy mitochondria as result of treatment*

2

(e) 1. Not enough / little ATP produced;

One reason asked for, so list rule applies

Ignore ref. to no ATP produced

2. ATP provides **energy** for (enzyme) reactions
OR
ATP phosphorylates substrates / enzymes, **so** making them (more) reactive;

Accept (leads to) lower activation energy for reaction

Reject if mention energy produced

2 max

[8]

Q5.

(a) D;

1

(b) 1. Homologous chromosomes (pair);

2. One of each (pair) goes to each (daughter) cell / to opposite poles;

Ignore descriptions of the second division of meiosis.

2

(c) 6;

1

(d) 1. Homologous pairs of chromosomes associate / form a bivalent;
2. Chiasma(ta) form;
3. (Equal) lengths of (non-sister) chromatids / alleles are exchanged;
4. Producing new combinations of alleles;

1. Accept descriptions of homologous pairs

2. Accept descriptions of chiasma(ta) e.g. chromatids / chromosomes entangle / twist

2. Neutral Crossing / cross over

3. Reject genes are exchanged

3. Accept lengths of DNA are exchanged

4. Do not accept references to new combinations of genes unless qualified by alleles

4

[8]

Q6.

(a) Three of chromosome 13 / an extra chromosome 13;

Accept trisomy 13

*Accept circle around three chromosomes or any other correct indication on **Figure 1***

Do not allow references to any other chromosomes.

Do not accept chromatids for chromosomes.

1

(b) 1. In meiosis;
2. Homologous chromosomes / sister chromatids do not separate;

2. Accept non-disjunction

2 max

(c) 1. Mutation / extra chromosome in gamete / egg / sperm (that formed zygote);
2. All cells derived (from a single cell / zygote) by mitosis;

OR

3. All cells derived from a single cell / zygote by mitosis;
4. Mitosis produces genetically identical cells / a clone;

*Mark points 1 and 2 **OR** 3 and 4*

4. Accept: have same DNA / same alleles

2

(d) 1. (Some) oxygenated blood (from the aorta) flows into pulmonary artery;
OR
Less oxygenated blood flows out through aorta;
OR
Lower blood pressure in aorta;
2. Less oxygen delivered to cells / tissues / organs / named organ / via named blood vessel;
3. So less / not enough oxygen for <u>aerobic</u> respiration (in cell / tissue /

organ);

4. Tissue / organ doesn't grow / develop properly (causing death);
   OR
   Tissue dies / organ stops working (causing death);

   1. *Accept mixing of deoxygenated with oxygenated blood in pulmonary artery*
   2. *Do not accept "no oxygen"*
   3. *Do not accept "produce energy"*

3 max

[8]

Q7.

(a)
1. TEM use electrons **and** optical use light;
2. TEM allows a greater resolution;
3. (So with TEM) smaller organelles / named cell structure can be observed
   OR
   greater detail in organelles / named cell structure can be observed;
4. TEM view only dead / dehydrated specimens **and** optical (can) view live specimens;
5. TEM does not show colour **and** optical (can);
6. TEM requires thinner specimens;
7. TEM requires a more complex/time consuming preparation;
8. TEM focuses using magnets **and** optical uses (glass) lenses;

   3. *'clearer' is not equivalent to 'detail'*
   4. *Accept 'Only optical can view live specimens'*
   5. *Accept 'Only optical can show colour'*
   7. *Accept 'TEM requires a more difficult preparation'*

   Ignore references to artefacts

6 max

(b)
1. **W** has 4 cells / nuclei since it is at the (end of) 2nd division (of meiosis);
2. **Z** has 2 cells/nuclei since it is at the (end of) 1st division (of meiosis);
3. **W** shows haploid cells / cells containing n chromosomes;
4. (Cells in) **W** contain half the (mass of) DNA of (Cells in) **Z**;
   OR
   (between **Z** and **W**) chromatids have separated;
   OR
   In **Z** homologous chromosomes have separated;

   *Ignore '**Z** shows diploid cells / contains 2n chromosomes'*

   4. *Accept '**W** contains half the amount of DNA of **Z**'*

4

(c)
1. Use random sample of seeds (from each population);
2. Use (large enough) sample to be representative of whole population;
3. Indication of what size was measured e.g. mass;
4. Calculate a mean and standard deviation (for each population);
5. Use the (Student's) t-test;
6. Analyse whether there is a significant difference between (the means of) the two populations;

   1. *Accept described, suitable method of random sampling.*
   1. *Reject description of inappropriate method of random sampling (e.g. random coordinates in the field / use of quadrats)*

2. Accept 'running mean does not change'

*2. For representative accept 'reliable, reproducible, repeatable' **OR** a mean close to the true value.*

5. Accept 'Use 95% confidence limits'

6. Reject unqualified references to results being significant

5 max

[15]

Q8.

(a) (During prophase)

1. Chromosomes
coil / condense / shorten / thicken / become visible;

2. (Chromosomes) appear as (two sister) chromatids joined at the centromere;

(During metaphase)

3. Chromosomes line up on the equator / centre of the cell;

4. (Chromosomes) attached to spindle fibres;

5. By their centromere;

(During anaphase)

6. The centromere splits / divides;

7. (Sister) chromatids / chromosomes are pulled to opposite poles / ends of the cell / separate;

(During telophase)

8. Chromatids / chromosomes
uncoil / unwind / become longer / thinner.

No marks for naming the stages

Reject references to homologous chromosomes / pairing of chromosomes

Ignore references to spindle formation during prophase

5 max

(b) 1. Homologous chromosomes pair up;

2. Independent segregation;

3. Maternal and paternal chromosomes are re-shuffled in any combination;

4. Crossing over leads to exchange of parts of (non-sister) chromatids / alleles between homologous chromosomes;

5. (Both) create new combinations of alleles;

5

[10]

Q9.

(a) Phylum;

1

(b) **M** placed correctly between zygote and zygospore;

1

(c) Any valid reasons, e.g.

Asexual

Fewer stages so quicker
OR
Only one parent involved so can colonise new environment
OR
Produces clone so successful (geno / pheno)type maintained;

Sexual

increases genetic diversity so greater chance of survival / success.

2

(d) Spores spread / dispersed further;

1

(e) 1. Measure diameter of large number of spores;

2. Divide measured values by 700 (to find true diameter);

3. Reference to using volume of sphere.

3

[8]

Q10.

(a) 1. Replacement of a base by a different base (in DNA);

1

(b) 1. (Depends on) size / mass (of protein);

2. (Depends on) charge (of protein);

Accept for 2 marks 'Smaller / more highly charged move further'

2 max

(c) 1. Each protein has a different tertiary structure;

2. (Each) antibody has a specific antigen / binding / variable region / site;

3. So, (each antibody) forms different antigen-antibody complex
OR
(each antibody) only binds to complementary (protein);

3

(d) 1. Less NL3;

2. More NR2A **and** NR2B;

2

(e) 1. Higher ratio NR2B to NR2A with mutation;
Accept 'more' as equivalent to 'ratio'

2. (Perhaps) better memory in mice with mutation;

2

[10]

Q11.

(a) 1. Chromosome is formed of two chromatids;
2. (Because) DNA replication (has occurred);
3. (Sister) chromatids held together by centromere.

3

(b) 1. Chromosomes in homologous pair;
2. One of each into daughter cells / haploid number.

2

(c) Separation of (sister) chromatids / division of centromere.

1

(d) 1. Independent segregation (of homologous chromosomes);
Accept random assortment
2. Crossing over / formation of chiasmata.

2

[8]

Q12.

(a) PKNJ.

1

(b) *Lutra lutra.*

1

(c) Bone / skin / preserved remains / museums.

1

(d) 1. (Hunting) reduced population size(s), so (much) only few alleles left;
Accept bottleneck

2. Otters today from one / few surviving population(s);
Accept founder effect

3. Inbreeding.
*Allow any **two***

2 max

(e) 1. Population might have been very small / genetic bottleneck;
2. Population might have started with small number of individuals / by one pregnant female / founder effect;
3. Inbreeding.
*Allow any **two***

2 max

[7]

Q13.

(a) Translation.

1

(b) Transfer RNA / tRNA.

1

(c) TAC;

UAC.

2

(d) Have different R group.

Accept in diagram

1

(e) 1. Substitution would result in CCA / CCC / CCU;
2. (All) code for same amino acid / proline;
3. Deletion would cause frame shift / change in all following codons / change next codon from UAC to ACC.

3

[8]

Q14.

(a) (No – no mark)
Graph / bar chart only shows number of species, not the name of the species.

1

(b) (No – no mark)
1. Mutations are spontaneous / random;
2. Only the rate of mutation is affected by environment;
3. Different species do not interbreed / do not produce fertile offspring;
4. So mutation / gene / allele cannot be passed from one species to another.

Ignore references to correlation does not prove causation

4

(c) 1. Initially one / few insects with favourable mutation / allele;
2. Individuals with (favourable) mutation / allele will have more offspring;
3. Takes many generations for (favourable) mutation / allele to become the most common allele (of this gene).

3

[8]

Q15.

(a) 1. Kingdom, Phylum, Class, Order, Family;
2. *Luscinia svecica.*

1 mark for each correct column

Allow Genus and Species if both placed in box for species but not if both placed in genus box

2

(b) Number of different alleles of each gene.

Accept number of different base sequences (found) in each gene

1

(c) 1. Has greater proportion of genes / percentage of genes showing diversity;
2. Percentage is 35% compared with 28% / proportion is 0.35 compared with 0.28.

Allow correct figures that are not rounded up, i.e., 34.9% / 0.349 and 27.8% / 0.278

2

[5]

Q16.

(a) (D)CBEA.

1

(b)

Step	Reason
(Taking cells from the root tip)	Region where mitosis / cell division occurs;
(Firmly squashing the root tip)	To allow light through / make tissue layer thin;

2

(c) (Increase)
1. Chromosomes / DNA replicates;
(First decrease)

2. Homologous chromosomes separate;
(Second decrease)

3. Sister chromatids separate.

3

(d) 1. (DNA would) double / go to 2 (arbitrary units).

1

[7]

Q17.

(a) 0.32.

Correct answer = 2 marks

Accept 32% for 1 mark max

Incorrect answer but identifying 2pq as heterozygous = 1 mark

2

(b) 1. Mutation produced *KDR minus* / resistance allele;
2. DDT use provides selection pressure;
3. Mosquitoes with *KDR minus* allele more likely (to survive) to reproduce;
4. Leading to increase in *KDR minus* allele in population.

4

(c) 1. Neurones remain depolarised;
2. So no action potentials / no impulse transmission.

2

(d) 1. (Mutation) changes shape of sodium ion channel (protein) / of receptor (protein);
2. DDT no longer complementary / no longer able to bind.

2

[10]

Q18.

(a) 1. Reduction in ATP production by aerobic respiration;
2. Less force generated because fewer actin and myosin interactions in muscle;
3. Fatigue caused by lactate from anaerobic respiration.

3

(b) Couple **A**,
1. Mutation in mitochondrial DNA / DNA of mitochondrion affected;
2. All children got affected mitochondria from mother;
3. (Probably mutation) during formation of mother's ovary / eggs;

Couple **B**,
4. Mutation in nuclear gene / DNA in nucleus affected;
5. Parents heterozygous;
6. Expect 1 in 4 homozygous affected.

4 max

(c) 1. Change to tRNA leads to wrong amino acid being incorporated into protein;
2. Tertiary structure (of protein) changed;

3. Protein required for oxidative phosphorylation / the Krebs cycle, so less / no ATP made.

3

(d) 1. Mitochondria / aerobic respiration not producing much / any ATP;
2. (With MD) increased use of ATP supplied by increase in anaerobic respiration;
3. More lactate produced and leaves muscle by (facilitated) diffusion.

3

(e) 1. Enough DNA using PCR;
2. Compare DNA sequence with 'normal' DNA.

2

[15]

Q19.

(a) 1. (So) age not a factor in female choice;

2. (So) will attract a mate;

3. (So similar) sexual maturity;

4. (So) have the correct feathers;

4. Accept 'have blue feathers'

2 max

(b) Number the birds, then numbers out of hat / random number generator;

Both aspects needed for mark

1

(c) 1. That movement was not related to some other factor (than the male);

2. That movement (towards the male) indicated mating behaviour;

3. (Females) only respond to throat feathers (of the male) / do not respond to other visual display / sounds / calls (by the male);

2 max

(d) 1. Change in sequence of bases / nucleotides;

2. (As a result of a) deletion / substitution;

3. Change in amino acid sequence / primary structure;

4. Change in tertiary structure of protein;

1. Do not accept 'change in the DNA sequence'

2. Accept e.g. addition / inversion / duplication / translocation

3

(e) **Yes**

1. (From resource A) birds can detect UV light;

2. (From resource B) difference between UVR and NR significant / not due to chance;

3. As error bars do not overlap;

*3 max if only **No** marks awarded*

2. Reject idea that 'results' in resource B are significant / not due to chance, must include idea of 'difference'

3. Reject 'as standard deviations do not overlap'

No

4. UV light may not be involved in mating / other factors may be involved in mating;

5. Some birds in UVR group were attractive to females;

6. (Experiment in resource B) carried out in artificial conditions / only 40 birds used / small sample size;

6. Neutral: idea that this is only one study / that there are no repeats

4 max

[12]

Q20.

(a) 1. Different parts/areas/amino acid sequences (of amyloid-precursor) protein;

Accept APP

2. Each enzyme is specific/fits/binds/complementary to a different part of the APP;

Point 2 subsumes point 1 and is worth 2 marks total.

2

(b) 1. Peptide bond broken;
2. Using water;

Hydrolysis in stem

2

(c) 1. Mutations prevent production of enzyme(s)/functional enzyme;
2. (Increase in β-secretase) leads to faster/more β-amyloid production
OR
(Decrease in α-secretase) leads to more substrate for β-secretase;

'This' must refer to α-secretase

3. (Leads to) more/greater plaque formation;

3

(d) 1. (Inhibitor) binds to/blocks active site of β-secretase/enzyme;
2. Stops/reduces production of β-amyloid/plaque;

2

(e) 1. Some β-amyloid required/needed (to prevent side effects)
OR
(Some) β-secretase needed;

Accept 'Both enzymes needed'

2. Leads to build-up of amyloid-precursor protein (that causes harm)
OR
Too much product of α-secretase (causes harm);

Accept build-up of substrate (leads to harm)

1 max

[10]

Q21.

(a) 1. Change in <u>DNA</u> base/nucleotide (sequence);

Accept: mutation in <u>DNA</u> base (sequence).

Accept: deletion/substitution/addition of a <u>DNA</u> base/nucleotide.

2. Change in amino acid (sequence)/primary structure;

Reject: different amino acid formed.

Ignore: change in code for amino acid.

3. Alters (position of) hydrogen/ionic/disulfide bonds;
4. Change in <u>tertiary</u> structure (of receptor);

Reject: any reference to active site.

Ignore: 3°.

4

(b) 1. (Receptor) is not <u>complementary</u>
OR
(HIV) cannot bind/attach <u>and</u> enter/infect (helper) T cell;

Accept: 'complimentary'.

Accept: invade as alternative to infect.

2. No replication (of virus)
   OR
   No destruction of (helper) T cell;
   Accept: reproduction (of virus).

2

(c) 1. Low/lower exposure to HIV (in Europe)
   OR
   Low/lower number of HIV/AIDS (infections/cases);
   Accept: converse.
2. (HIV) has only been present for a short time period
   OR
   (HIV relatively) recently evolved;
3. Mutation/CCR5 has been around for many years;
   Accept: frequency of mutation has always been high.
4. Mutation/CCR5 is advantageous (for something else);

2 max

[8]

Q22.

(a)

	Cell B	Cell C	Cell D
homologous chromosomes are present	✔	✔	
a stage of mitosis		✔	

Mark horizontally

1 mark for each correct row

2

(b) Mark as pairs, do not mix and match

1. (Chromosomes consist of) two chromatids connected at centromere;
   Accept: sister chromatids for two chromatids
2. (Because) DNA has replicated;

OR

3. K is on equator of spindle;
   Ignore: 'middle'
4. (because) attached at centromere;
   Ignore reference to meiosis / bivalents / homologous pairs

2

(c) 1. Crossing over / exchange of alleles /lengths of DNA / recombination;
   Accept: description of crossing over eg sections of chromatids break and re-join
   Accept: reference to chiasma/ chiasmata
2. Between (chromatids of) homologous chromosomes;
   Accept: 'between non-sister chromatids'
   Accept: 'bivalent' for homologous
   Ignore: genes exchanged

2

(d) Separation/segregation of pairs/homologous chromosomes;

Accept: result of meiosis I / result of division of cell B

Accept: pulled to opposite poles for 'separation'

Ignore ref to chromatids

1

(e) (DNA) replication taking place/not finished;

Accept: they are cells in S phase

1

[8]

Q23.

(a) 1. Change / mutation in base / nucleotide sequence (of DNA / gene);

Q.

Ignore: references to changing base-pairing

Accept: affect for change, if in correct context

Accept: changes triplets / codons

2. Change in amino acid sequence / primary structure (of enzyme);

Accept: different amino acid(s) coded for

***Q** Reject: different amino acids produced / formed / made*

3. Change in hydrogen / ionic / disulfide bonds;

Accept: references to sulfur bonds

4. Change in the tertiary structure / shape;

Neutral: alters 3D structure / 3D shape

5. Change in active site;

6. Substrate not complementary / cannot bind (to enzyme / active site) / no enzyme-substrate complexes form.

Accept: no E S complexes form

6

(b) 1. Non-SR strain falls more / SR strain falls less / up to 10(µg / cm−3);

Must include 10 but only required once in either MP1 or MP2

Ignore: units or absence of

This must be a comparative statement

2. Above 10(µg / cm^{-3}), SR strain levels out / off and non-SR strain continues to decrease;

3. Greater difference between strains with increasing concentration of antibiotic.

This must be a comparative statement

2 max

(c) 1. Division stopped (of both strains by scientist);

Reject: references to mitosis stopping

2. SR strain still more resistant / fewer die / none die (at higher concentrations of antibiotic).

Accept: SR strain and non-SR strain would be similar if resistance is due to only stopping division

Need some comparison with non-SR

2

(d) 1. Make a competitive / non-competitive inhibitor;

Mark in pairs

either MP1 <u>and</u> MP2 OR MP3 <u>and</u> MP4

2. Competitive competes with / blocks active site / non-competitive inhibitor affects / changes <u>active site</u>;

Do not mix and match

OR

3. (Make a drug) that inhibits / denatures / destroys enzyme / stringent response;

Accept: drug that 'knocks out' / destroys enzyme

4. Give at the same time as / before an antibiotic.

2 max

(e) (SR strain)

1. Fewer free radicals (than non-SR);

Note: has to be comparative statement

2. Produces more catalase (than non-SR);

Accept converse statements for non-SR.

3. Catalase (might be) linked to production of fewer free radicals / breaking down / removing free radicals.

Accept: hydrolysis of radicals by catalase.

3

[15]

Q24.

(a) (i) 1. Groups within groups;

*Accept: idea of larg<u>er</u> groups at the top **or** small<u>er</u> groups at the bottom*

2. No overlap (between groups);

2

(ii) **3**;

1

(iii) Chordata;

Accept: if phonetically correct eg 'Cordata'

1

(b) (i) 1. (To provide) genetic variation;

Genetic variation must be directly stated and not implied

2. (Allows) different combinations of maternal and paternal chromosomes / alleles;

Accept: any allele of one gene can combine with any allele of

another gene

2

(ii) 1. (Zedonk has) 47 / odd / uneven number of chromosomes;

Accept: diploid number would be odd

Reject: if wrong number of chromosomes is given

2. Chromosomes cannot pair / are not homologous / chromosome number cannot be halved / meiosis cannot occur / sex cells / haploid cells are not produced;

Accept: cannot have half a chromosome

***Q** Reject: meiosis cannot occur **in** sex cells*

2

[8]

Q25.

(a) 1. Sugar-phosphate (backbone) / double stranded / helix **so** provides strength / stability / protects bases / protects hydrogen bonds;

Must be a direct link / obvious to get the mark

Neutral: reference to histones

2. Long / large molecule **so** can store lots of information;

3. Helix / coiled **so** compact;

Accept: can store in a small amount of space for 'compact'

4. Base sequence allows information to be stored / base sequence codes for amino acids / protein;

Accept: base sequence allows transcription

5. Double stranded **so** replication can occur semi-conservatively / strands can act as templates / complementary base pairing / A-T and G-C so accurate replication / identical copies can be made;

6. (Weak) hydrogen bonds **for** replication / unzipping / strand separation / many hydrogen bonds **so** stable / strong;

Accept: 'H-bonds' for 'hydrogen bonds'

6

(b) 1. (Mutation) in **E** produces highest risk / 1.78;

2. (Mutation) in **D** produces next highest risk / 1.45;

3. (Mutation) in **C** produces least risk / 1.30;

Must be stated directly and not implied

***E** > **D** > **C** = 3 marks*

Accept: values of 0.78, 0.45 and 0.30 for MP1, MP2 and MP3 respectively

If no mark is awarded, a principle mark can be given for the idea that all mutant alleles increase the risk

3

(c) **180**;

1

(d) **(Similarities):**

1. Same / similar pattern / both decrease, stay the same then increase;

2. Number of cells stays the same for same length of time;
Ignore: wrong days stated

(Differences):

(Per unit volume of blood)

3. Greater / faster decrease in number of healthy cells / more healthy cells killed / healthy cells killed faster;
Accept: converse for cancer cells
Accept: greater <u>percentage</u> decrease in number of cancer cells / greater <u>proportion</u> of cancer cells killed

4. Greater / faster increase in number of healthy cells / more healthy cells replaced / divide / healthy cells replaced / divide faster;
Accept: converse for cancer cells
*For **differences**, statements made must be comparative*

3 max

(e) 1. More / too many healthy cells killed;

2. (So) will take time to replace / increase in number;
Neutral: will take time to 'repair'

3. Person may die / have side effects;

2 max

[15]

Q26.

(a) (i) (In all organisms / DNA,) the same triplet codes for the same amino acid;
Accept codon / same three bases / nucleotides
Accept plurals if both triplets and amino acids
Reject triplet<u>s</u> code for an amino acid
Reject reference to producing amino acid

1

(ii) 64;

1

(b) Splicing;
Ignore deletion references
Accept RNA splicing

1

(c) (i) 1. (Mutation) changes triplets / codons after that point / causes frame shift;
Accept changes splicing site
Ignore changes in sequence of nucleotides / bases

2. Changes amino acid sequence (after this) / codes for different

amino acids (after this);

Accept changes primary structure

Reject changes amino acid formed / one amino acid changed

3. Affects hydrogen / ionic / sulfur bond (not peptide bond);

4. Changes tertiary structure of protein (so non-functional);

Neutral 3-D structure

3 max

(ii) 1. Intron non-coding (DNA) / only exons coding;

*Context is the **intron***

Do not mix and match from alternatives

Neutral references to introns removed during splicing

1.and 2. Ignore ref. to code degenerate and get same / different amino acid in sequence

2. (So) not translated / no change in mRNA produced / no effect (on protein) / no effect on amino acid sequence;

Accept does not code for amino acids

OR

3. Prevents / changes splicing;

4. (So) faulty mRNA formed;

Accept exons not joined together / introns not removed

5. Get different amino acid sequence;

2 max

[8]

Q27.

(a) (i) Centromere;

Accept: if phonetically correct

Reject: centriole

1

(ii) 1. Holds chromatids together;

2. Attaches (chromatids) to spindle;

3. (Allows) chromatids to be separated / move to (opposite) poles / (centromere) divides / splits at metaphase / anaphase;

*3. **Q** Neutral: chromosomes or chromatids split / halved / divided*

3. Reject: reference to homologous chromosomes being separated

Accept 'chromosomes' instead of 'chromatids'

*Ignore incorrect names for **X***

2 max

(iii) (Homologous chromosomes) carry different alleles;

Accept alternative descriptions for 'alleles' eg different forms of a gene / different base sequences

Neutral: reference to maternal and paternal chromosomes

1

(b) (i) (In **Figure 2**)

1. Chromatids have separated (during anaphase);

*1. **Q** Neutral: split / halved / divided*

1. Reject: reference to homologous chromosomes being separated

or

2. Chromatids have not replicated;

1. & 2. Accept 'chromosomes' instead of 'chromatids'

or

3. Chromosomes formed from only one chromatid;

*Accept converse arguments for **Figure 1***

Ignore references to the cell not dividing as in the question stem

Ignore: named phases

1 max

(ii) 1. Three chromosomes;

Ignore shading

2. One from each homologous pair;

Only one mark for three chromosomes shown as pairs of chromatids

2

(iii) Crossing over / alleles exchanged between chromosomes or chromatids / chiasmata formation / genetic recombination;

Accept: description of crossing over eg sections of chromatids break and rejoin

Neutral: random fertilisation

Reject: reference to sister chromatids

***Q** Neutral: genes exchanged*

Neutral: mutation

1

[8]

Q28.

(a) (i) 4;

1

(ii) 1. Change in amino acid / (sequence of) amino acids / primary structure;

1. Reject = different amino acids are 'formed'

2. Change in hydrogen / ionic / disulphide bonds alters tertiary

structure / active site (of enzyme);

2. Alters 3D structure on its own is not enough for this marking point.

3. Substrate not complementary / cannot bind (to enzyme / active site) / no enzyme- substrate complexes form;

3

(b) 1. Lack of skin pigment / pale / light skin / albino;

2. Lack of coordination / muscles action affected;

2 max

(c) Founder effect / colonies split off / migration / interbreeding;

Allow description of interbreeding e.g. reproduction between individuals from different populations

1

[7]

Q29.

(a) (i) (Human cells) don't have a cell wall;

Accept "they" refers to human cells.

1

(ii) (Affects) protein synthesis;

Allow description e.g. 'amino acids not joined together / translation.

Reject: affects transcription.

1

(b) 1. Mutation present / occurs;

Ignore antibiotic causes mutation.

2. Resistance gene / allele;

1. or 2.

Reference to immunity disqualifies first credited marking point.

3. Resistant bacteria (survive and) reproduce;

Reference to mitosis negates marking point 3.

2

[4]

Q30.

(a) Difference in DNA / base sequence / difference in alleles / genes / gene pool;

Neutral: 'fewer alleles' unless qualified e.g. fewer different alleles.

1

(b) Environmental;

Accept: Environment

1

(c) Reduced (genetic diversity);

As fewer different / varied alleles / genes / reduced gene pool;

2

[4]

Q31.

(a) (i) Antibiotics kill other bacteria / *Clostridium* is resistant;

Less / no competition so (*Clostridium*)
reproduces / replicates / multiplies / increases in number;

Reference to bacteria being 'immune' negates first marking point.

Reference to mitosis negates second marking point.

2

(ii) Immune system less effective / more likely to have other infections / been in hospital;

Accept: 'Weak / lower' immune system'.

1

(b) Attaches to <u>active</u> <u>site</u> (of enzyme);
(Methicillin) is a competitive inhibitor / prevents monomers / substrate attaching (to enzyme);

'Competes for active site' = 2 marks.

Neutral: 'Prevents monomers joining / attaching to each other'.

Allow one mark max for answers relating to non-competitive inhibitor changing active site / preventing substrate attaching.

Do not penalise Methicillin forms an enzyme / substrate complex.

2

(c) (i) Have other illness / medical condition / 'weak' immune system / disease / infection;

Reject: Due to 'other factors', 'are smokers', 'are obese' unless related to disease or illness.

1

(ii) Increase up to 2006 / 20 (per 100 000) then decreases;

1

(iii) Correct answer in range of 52 – 59.1% = two marks;

Incorrect answer but shows change as between 4.8 – 5.2 / shows correct subtraction giving this change e.g. 14 – 9 = one mark.

2

[9]

Q32.

(a) (i) 22;

1

(ii) 1. Odd number of chromosomes / 33 chromosomes (in leaf cell);

2. Chromosomes cannot pair / cannot undergo meiosis / would result in half chromosomes / cannot form haploid cells;

2

(b) (i) Fast growth / produces crop fast / produces large crop;

Do not insist on relative statement.

Accept similar terms for fast. E.g. "better" growth

Do not accept unqualified references to profit.

1

(ii) Leaves less likely to break / higher breaking strength;

1

(c) Low genetic diversity because they are produced by mitosis;

Will all have the same DNA / genes / alleles / will be genetically identical / will be clones;

OR

Low genetic diversity because they are not produced by meiosis;

No crossing over / independent segregation / will not be genetically different;

Independent segregation is the specification term. Accept other such as random assortment.

2

[7]

Q33.

(a) **Shape**

1. Different penicillin has different shape / structure / enzyme / active site has specific shape / structure;

Not different

Binding

2. No longer fits / binds to active site / not complementary to active site / does not form E-S complex;

Consequence

3. (Different) penicillin not broken down;

3

(b) (i) 1. Kills pathogenic / harmful bacteria / pathogens;

2. Disease less likely / improves health / animals healthier / reduces spread of infection;

3. Faster growth / more productive animals / more food converted to meat / greater survival / lower vet's bills / increased yield / less energy (for "fighting infection");

Principles:

Action of antibiotic. Do not accept stops all disease

Action on health

Effect on production

2 max

(ii) 1. (Adding antibiotics) selects in favour of antibiotic resistance / resistant bacteria more likely to survive;

2. Increase in numbers / higher proportion of resistant bacteria;

Penalise immune only on the first occasion it occurs in this part of the question.

2

[7]

Q34.

(a) (So results) can be compared / so measurement is the same each time / because eye is not perfectly round / uniform;

Accept eye opens to different amounts

1

(b) (i) 1. Eye (diameter) is smaller and antennae longer;

2. Antennae detecting touch;

3. Data only refers to shrimps / data may not apply to all animals / only in one area;

The principle here is that candidate has recognised that both features confirm suggestion. Exact wording does not matter.

2 max

(ii) 1. Standard deviation gives a measure of spread / variation;

2. More standard deviations overlap, the less likely it is that differences are real / significant / the more likely they are caused by chance;

Do not accept range

Accept converse.

Although we are looking for the idea of significance, we cannot require this term.

2

(c) (i) Qualitative statement about

difference in size /

difference in variation /

overlap in size;

Quantitative statement about

difference in size /

difference in variation /

overlap in size;

Supported by relevant two sets of figures from graph;;

Note simplistic answer involving a quantitative statement gains 1 mark.

More specific answer involving quantitative information gains 2 marks.

2

(ii) (No) for same body length, antenna are longer / antenna are shorter / some with longer body have short antennae / some with shorter body length have longer antennae;

OR

(Yes) positive correlation in open / in cave;

Habitat not critical as a term.

Must refer to idea of same habitat

Accept description

1

(d) More alleles of each gene / shrimps in open have all the alleles;

Candidates are required to use the information from the table. Must therefore refer to alleles.

1

(e) 1. A small number of shrimps were / went into the cave;

2. All / high proportion of shrimps had allele L;

3. Cave population descended from these / these reproduce;

3

(f) (i) 1. Cross shrimps from two sites / watch courtship;

2. Breed young together / observe mating;

3. Allow 1 mark for any method of improving quality of results e.g. carry out reciprocal crosses / large number of crosses / isolate beforehand;

Other valid equivalent suggestions should be accepted.

(ii) If same species the shrimps would breed, producing fertile young / courtship species specific;

Accept any form of evidence – mating / laying eggs / giving birth to young.

3

[15]

Q35.

(a) Introns;

1

(b) Ile Gly Val Ser;

1

(c) (i) Has no effect / same amino acid (sequence) / same primary structure;

Q *Reject same amino acid formed or produced.*

1

Glycine named as same amino acid;

1

It still codes for glycine = two marks.

(ii) Leu replaces Val / change in amino acid (sequence) / primary structure;

Change in hydrogen / ionic bonds which alters tertiary structure / active site;

Q *Different amino acid formed or produced negates first marking point.*

Substrate cannot bind / no longer complementary / no enzyme-substrate complexes form;

Active site changed must be clear for third marking point but does not need reference to shape.

3

(d) (i) Interphase / S / synthesis (phase);

1

(ii) DNA / gene replication / synthesis occurs / longest stage;

Allow 'genetic information' = DNA.

Allow 'copied' or 'formed' = replication / synthesis

1

[9]

Q36.

(a) (Different) form / type / version of a gene / different base sequence of a gene;

1

(b) Two / sister <u>chromatids</u> joined by a <u>centromere</u>;

Due to <u>DNA</u> replication;

2

(c) (i) Crossing over;

1

Exchange (of alleles) between chromatids / chromosomes;

Negate first marking point for answers which refer to independent segregation.

Chiasma / chiasmata = first marking point

1

(ii) Is infrequent / rare;

References to it being 'random', 'occurs by chance' or 'doesn't always occur' should not be credited without a clear idea that it is rare or infrequent.

1

(d) (i) Three chromosomes shown;

1

One from each homologous pair;

For first mark point allow drawings showing three chromosomes as single or double structures.

1

(ii) 8;

1

[9]

Q37.

(a) Isolation / quarantine / 'kept separate';

Screening / testing (of patients / doctors etc);

Sterilisation of wards / equipment / method to improve hygiene;

Do not allow improve 'hygiene' or 'cleanliness' without named example such as 'washing hands' use of gloves etc.

2 max

(b) May not all be absorbed;

May be broken down / metabolised / excreted quickly;

To kill the microorganisms / bacteria;

Reference to antibiotic resistance;

Reference to becoming 'immune' negates last marking point.

2 max

(c) (i) P;

1

(ii) S;

1

(d) (i) Prevents bias;

Vested interest (of scientists);

Prevents 'placebo' / positive / negative / psychological effects / 'demand characteristics' (in volunteers);

2 max

(ii) Age;

Ethnicity;

Lifestyle;

Body mass;

Health;

Sex of person;

Ignore references to same or different

2 max

(e) Gradual / slight increase followed by rapid / greater increase;

Allow more detailed descriptions which describe similar trend of gradual increase followed by rapid increase.

1

[11]

Q38.

(a) (i) Faster / greater / more effective response in children;

Do not accept children have more haemoglobin

1

(ii) Use line of best fit;

1

Extrapolate / extend line (and read from graph);

Allow calculation using rate of increase per day = one mark. However for both marks this must be linked to line of best fit.

1

(iii) More than one polypeptide chain;

Allow many polypeptide chains.

'Haemoglobin has four polypeptide chains' must be in correct context to gain mark.

1

(b) (i) Has same <u>water potential</u>;

Allow converse for effect of using distilled water or a concentrated solution.

1

No (net) water movement / osmosis;

1

Cells will not swell / burst / change size;

No osmotic lysis = two marks

1

(ii) Pernicious anaemia (cells) greater range / spread / variation of diameters / widths;

Some pernicious anaemia (cells) wider than 9 (μm) / some less than 5.5 (μm) / without pernicious anaemia none more than 9 (μm) / none less than 5.5 (μm);

Pernicious anaemia (cells) peak / most frequent at 8.5 (μm) / peak / most frequent at higher diameter / / without pernicious anaemia peak / most frequent at 7 (μm) / peaks at lower diameter;

There are several alternatives for marking points 2 and 3

2 max

[9]

Q39.

(a) Cannot make (active) enzyme A (which converts precursor to linamarin) / cannot make linamarin;

1

(b) (i) **AL** + **Al** + **aL** + **al** ;

1

(ii) Meiosis separates alleles / homologous chromosomes / pairs of chromosomes;
Independent assortment / means either of **A** / **a** can go with either of **L** / **l**;

Accept "random segregation" but cancel if reference to crossing-over

2

(c) From parental genotypes: **AaLl** × **AaLl** (no mark)
Note: If wrong parental genotypes / wrong gametes: ALLOW correct derivation of offspring genotypes = 1 max

Correct derivation of offspring genotypes; max 2 marks if error in Punnett square

	AL	**Al**	**aL**	**al**
AL	AALL	AALl	AaLL	AaLl
Al	AALl	AAll	AaLl	Aall
aL	AaLL	AaLl	aaLL	aaLl
al	AaLl	Aall	aaLl	aall

Correct identification of offspring genotypes with at least one **A** and two **l** alleles (= grey cells in above table);
Correct proportion: 3 / 16 / 3:13 / 18.75% ;

3

(d) (i) There was no (significant) difference in damage between cyanogenic and acyanogenic / being cyanogenic has no effect;

1

(ii) The difference (from expected / from chance variation) is significant / difference / results not just due to chance;
Reject null hypothesis;
Being cyanogenic does help protect from slug damage;

3

(e) High slug population:
1. Find only cyanogenic plants / only cyanogenic plants survive;
2. (Cyanide release) limits / stops feeding by slugs / slugs killed;

Accept: converse argument re. acyanogenic plants

Low slug population:
3. Find both types of plant;
4. Less selection pressure on plants from slugs / no selective advantage / no selection / described;

4

[15]

Q40.

(a)
1. Homologous chromosomes pair up / bivalents form;
2. Crossing over / chiasmata form;
3. Produces <u>new combination</u> of **alleles;**
4. Chromosomes separate;
5. At random;
6. Produces varying combinations of chromosomes / genes / alleles (*not twice*) ;
7. Chromatids separated at meiosis II / later;

Independent assortment / random segregation = marking points 4 and 5

6 max

(b) (i)

Parental phenotypes	Agouti	White	
Parental genotypes	BbAa	bbaa	;
Gamete genotypes	BA Ba bA ba	ba	;
Offspring genotypes	BbAa Bbaa	bbAa bbaa	;
Offspring phenotype	Agouti Black	White White	;

Phenotypes must match genotypes

Allow marking points 2 and 3 if correctly derived from wrong parental genotypes

4

(ii)

Colour of offspring	***Observed (O)***	***Expected (E)***	***(O-E)***	***$(O-E)^2$***	***$\frac{(O-E)^2}{E}$***
Agouti	34	30	4	16	0.53
Black	35	30	5	25	0.83
White	51	60	9	81	1.35
			$\Sigma \frac{(O-E)^2}{E}$ = 2.71 or 2.72		

;; 2

(χ^2 correct = 2 marks)

($(O-E)^2$ all correct = 1 mark)

p = 0.05;
2 degrees of freedom;
Differences due to chance / no significant difference as χ^2 less than / to left of critical value OR Not due to chance / difference is significant as χ^2 greater than to right of critical value;

(as appropriate for candidates χ^2)

3

[15]

Q41.

(a) Chromosomes: **C** = 8 *and* **D** = 4;
DNA: **C** = 300 *and* **D** = 150;

2

(b) (i) testis / ovary;
accept anther / carpel / stamen / testicle

1

(ii) to make chromosomes / chromatids / DNA / genetic material visible;

1

[4]

Q42.

(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]

Q43.

(a) (variation in) temperature will affect the solubility of oxygen / rate of respiration / use of oxygen by cells / diffusion / gas exchange;
to gain credit point made must concern oxygen

1

(b) (i) there is no difference between the partial pressure of oxygen in the two groups / the partial pressure of oxygen is the same in each group;

1

(ii) results may have been due to <u>chance</u> and statistical test allows us to determine the <u>probability</u> of this / of the difference between results being significant;
enables acceptance or rejection of null hypothesis;
The key points here are chance and probability used in the correct context.

2

(c) **A**;
because partial pressure of oxygen only reduced when zinc in water / in **Y** / because when injected zinc / in **X** has no effect on partial pressure of oxygen in blood;

2

(d) less oxygen transport to cells / in fish / in blood;
anaerobic respiration;
lactic acid produced / less carbon dioxide removed (from gills);
more H^+;

3 max

(e) (i) copper;
calculation based on comparing concentration in woodlice with that in leaves;
accept any suitable method here, giving marks for the method and explanation. For example, calculating ratio of concentration in woodlice to concentration in leaves.

2

(ii) not absorbed from gut / passes out in faeces / egested / urine / excreted;

1

(iii) woodlice eat large amount of leaves;
copper stored / accumulates in body;

2

(f) (i) mutation;

1

(ii) (as a component of) nucleic acids / DNA / RNA / nucleotides;
phospholipids;
ATP / ADP;

2 max

(iii) arsenic-tolerant plants would not be able to take up phosphates / take up a little phosphate;
since likely to involve same mechanism / same carrier / protein;
(process of) growth would be poorer than non-tolerant plants;

3

[20]

Q44.

(a) Interphase / S-phase;

1

(b) **A D C E B;**

1

(c) Attachment of centromeres / chromosomes / chromatids; Separation of centromeres / chromatids / chromosomes;

2

(d) Halves chromosome number / haploid;

Diploid / full number restored at fertilisation;
Allow correct reference to variation

max 2

[6]

Q45.

(a) Excitation of chlorophyll molecule / electrons / energy of (pairs of) electrons raised to higher energy level;

Electron(s) emitted from chlorophyll molecule;

Electron(s) to electron transport chain;

Loss of energy by electron(s) along electron transport chain;

Energy lost by electron(s) is used to synthesise ATP;

From ADP + Pi;

"By electrons" need not be stated in each marking point if it can be reasonably inferred that the candidate is referring to electrons

max 5

(b) Little green light reaches bottom as absorbed by surface dwellers / water;
Red and blue not absorbed and so penetrate;
Variation in pigments of sediment dwellers;
Bacteria with chlorophyll at an advantage as chlorophyll absorbs red and blue;
(Survive to) reproduce in greater numbers and pass on advantageous alleles / genes in greater numbers / increase in frequency of advantageous alleles in subsequent generations;
Increase in frequency / numbers of bacteria with chlorophyll;

6

[11]

Q46.

(a) (meiosis) anaphase I;
chromosomes are moving apart;
chromosomes still double structures;

3

(b) chromosomes in each (homologous) pair twist around each other;
chromatids break and rejoin to chromatid on sister chromosome;

(accept points from a suitable diagram)

2

[5]

Q47.

(a) (i) Continuous variation – range of values / not discrete categories / many categories / no gaps;

1

(ii) Crossing over / chiasmata;
Random segregation / independent assortment;
In meiosis I and meiosis II;

max 2

(b) Range influenced by single 'outlier' (*accept anomaly*) / converse for S.D.;
S.D. shows dispersion / spread about mean / range only shows highest and lowest values / extremes;
Or
S.D. allows statistical use;
Tests whether or not differences are significant;

max 2

[4]

Q48.

(a) Chromosomes attach to equator / middle of cell / spindle;
Prophase;

Anaphase;
DNA replication / synthesis / chromosome copying / duplication;
Telophase;

5

(b) (i) Meiosis;

1

(ii) 32;

1

[7]

Q49.

(a) Later fertilisation / cell fusion; (NOT just 'sexual reproduction')
Restoring diploid / original number / not doubling chromosome number;
ALLOW ref '½ + ½'

2

(b) Any three pairs from:
need comparison of meiosis and mitosis each time

Meiosis	Mitosis
(Homologous) chromosomes associate in pairs	(Homologues) independent / do not pair (IGNORE ref. separation
Crossing-over / chiasmata formation	No crossing-over;
Two / (nuclear stages) divisions / → 4 offspring cells	One / (nuclear stage) division / → 2 offspring cells;
Genetically different (product)	Genetically identical (product);

IGNORE refs. To location

max 3

[5]

Q50.

(a) replication / duplication / doubling of chromosomes /
replication of DNA / transcription of DNA;

1

(b) (i) cell to show correct number of chromosomes;
correct shape and position of centromere;

2

(ii) as (i) except everything halved – *Ignore crossing over*;
(if mitosis and meiosis reversed, allow 1 if otherwise correct)

2

(c) to replace cells;

1

[6]

Q51.

(a) 1. Chromosomes shorten / thicken / condense;
2. Chromosomes associate in homologous / (described) pairs / formation of bivalents / tetrads;
3. Crossing-over / chiasma formation;
4. Join to spindle (fibres) / moved by spindle;(*)
5. (At) equator / middle of cell;(*)
6. (join via) centromere / kinetochore;(*)
7. (Homologous) chromosomes move to opposite poles / chromosomes separate / move apart; (*ALLOW* 'are pulled apart')
8. (Pairs of) chromatids separated in 2nd division;

(*) OR " independent assortment"
unqualified = 1 mark

max 6

(b) 1. Crossing-over; [*IGNORE* any wrong ref. to timing]
2. Independent / random assortment / orientation / segregation of (homologous) chromosomes in meiosis I;
3. Independent / random assortment / orientation / segregation of chromatids in meiosis II;

+ Any **three** from:
4. Different adaptations / some better adapted;
5. Some survive / example described;
6. To reproduce;
7. Pass on gene / allele;
8. Allows for changing environment / different environment / example described;

max 5

(c) (i) 21;

1

(ii) 1. *T. aestivum* has 2 copies of each type of chromosome / is diploid;
2. *T. aestivum's* chromosomes can form bivalents / can assort in meiosis / can produce haploid gametes;
3. *T. aestivum's* gametes receive a copy of every chromosome / receive all the genetic information;

ACCEPT converse argument for hybrid plants

3

[15]

Q52.

(a) *Two linked points:*

Crossing over / exchange of material (between chromatids);
Different combinations of alleles / linkage groups changed / broken;

OR

Independent assortment / alignment of (homologous) chromosomes;
Different combinations of (maternal and paternal) chromosomes / alleles;

2 max

(b) Gamete genotype

Offspring genotype

$\frac{D}{M} \mid \frac{d}{m}$;

Offspring phenotypes Abnormal males / (all) (no females);

3

[5]

Q53.

(a) (i) join / attach nucleotides, to form a strand / along backbone / phosphodiester bonds;

(reject reference to H bonds, complementary base pairing)

1

(ii) ribosome / RER;

1

(b) (i) CGTTACCAA;

1

(ii) CGU UAC CAA;

1

(c) substitution;

1

(d) (i) alanine;

1

(ii) (mutation 1)
no change(to sequence of amino acids);
codon for alanine / degenerate codon / same amino acid coded for;

2

(mutation 2)
(change in sequence) valine replaced by alanine / codon for alanine;
folding / shape / tertiary structure / position of bonds may change;

(reject peptide bonds)

2

[10]

Q54.

(a) haploid cells produced / halves chromosome number;
fertilisation / fusion of gametes, diploid number restored;
chromosome number constant at each generation;

2 max

(b) principle of 2 chromosomes per cell;
4 correct combinations, long with short;

2

(c) (i) 8;

(ii) 8;

2

(d) (in males) more gametes produced / rapid gamete production / more lost;

1

[7]

Q55.

(a) (i) TB Tb tB tb;

1

(ii) homologous chromosomes appropriately labelled;

1

(iii) separation of chomatids;

1

(b) (i) crossing over occurs;
between **D** and **G**;
sections of chromatids / chromosomes / DNA / genes exchanged;

3

(ii) crossing over is infrequent(between close genes);

1

[7]

Q56.

(a) high energy radiation / ionising particles;
named particles / α, β, γ;
colchicine;
x rays / cosmic rays;
uv (light);
carcinogen / named carcinogen;
mustard gas / phenols / tar (qualified);

1 max

(b) (i) removal of one or more bases / nucleotide;
frameshift / (from point of mutation) base sequence change;

2

(ii) sequence of bases in mRNA would change;
(sequence of) amino acids different / different primary structure;
(active site / enzyme 1) changed tertiary shape / changed active sites;
white pigment does not bind;
lilac pigment not produced / white pigment remains unchanged / enzyme 1 does not function;

4 max

(iii) blue and lilac; white;

colour of petal
(white)

blue
lilac;
white;

2

[9]

Q57.

(a) different form of a gene;

1

(b) hydrogen bonds broken;
semi-conservative replication / both strands used (as templates);
nucleotides line up complementary / specific base pairing / A and T / C and G;
DNA polymerase;

4

(c) deletion causes frame shift / alters base sequence (from point of mutation);
changes many amino acids / sequence of amino acids (from this point);
substitution alters one codon / triplet / one amino acid altered / code degenerate / same amino acid coded for;

3

[8]

Q58.

(a) (i) 8 ‘chromatids’ each side;
spindle drawn;

2

(ii) 4 chromosomes;
1 from each homologous pair;

2

(b) produces haploid cells / chromosome number halved;
fertilisation maintains the diploid / chromosome number (in next generation);

2

[6]

Q59.

(a)



1

(b) bivalent;

1

(c) (i) Ab, aB;

(ii) AB, ab;

2

(d) mutation;
different / new allele formed / genes deleted or duplicated / sequence of genes changed *(reject genetic information)*;
<u>random</u> fusion of gametes / fertilisation;
new combination of alleles;
independent assortment (of chromosomes) *(accept random)*;
shuffling of maternal and paternal chromosomes / new combination of alleles;
(ignore references to stages of meiosis)
any 2 × 2

4 max

[8]

Q60.

(a) to get haploid / n / half number of chromosomes (in cells);
so that each cell gets one copy of each chromosome / gene / full set of genes / so that fertilisation produces diploid / constant chromosome number; results in independent assortment;

2

(b) (i) 4;

1

(ii) <u>meiosis</u> (has halved the chromosome number);

1

(ii) (mitosis because) zygote gets two chromosomes from each gamete / has four chromosomes;

accept haploid for two and diploid for four

gamete-producing plant has two chromosomes,
so mitosis to produce gametes with two;

2

[6]

Q61.

(a) sections of chromatids exchanged;
sections have different alleles;
new combinations of (linked) alleles;

(allow 1 mark for idea that 'genes' are exchanged, if no other marks gained)

3

(b) (i) length controlled by many genes / polygenes;
each gene may have different alleles / idea of additive effects;
OR
environmental factors / or named factor;
how named factor may affect growth of seeds;

2 max

(ii) 1. selection of large seeds for sowing;
2. higher proportion of alleles for long length / loss of alleles for short seeds from population;
3. (possible appearance of) new alleles through mutation;

4. process repeated over many generations;
(G - allow 1 mark idea for that 'largeness' selected, survives and inherited)

4

[9]

QWC 1

Q62.

(a) limited genetic diversity in modern varieties / greater genetic diversity in old varieties / older varieties contain other (useful) alleles / genes;
old varieties useful for future breeding programmes;

2

(b) (i) seeds lose viability / will not germinate / develop after long storage;

1

(ii) preserve variety of alleles / different genotypes / maintain genetic variation;
prevent inbreeding / reduces the chance of homozygosity;

2

[5]

Q63.

(a) meiosis halves the chromosome number / from diploid to haploid / produces haploid / n cells;
when gametes fuse / at fertilisation, the diploid number is restored / this keeps the chromosome number constant / correct from one generation to the next / after sexual reproduction;
introduces genetic variation / independent assortment / crossing over;

3

(b) **M** between moss plant and spore;

1

[4]

Q64.

(a) mutation changes the amino acid sequence / primary structure of Factor VIII protein;
changes the tertiary structure / 3D shape;

2

(b) (mutant) Factor VIII protein is non-functional / does not work with Factor IX;
so no conversion of Factor X to active form and pathway blocked;

2

(c) boy's blood contains (active) Factor VIII;
Factor VIII haemophiliac's blood contains (active) Factor IX;
the mixture has both Factors and so the pathway can complete / blood clots;

2 max

[6]

Q65.

(a) 6;

1

(i) chromosomes are arranged in (homologous) pairs / bivalents;
crossing over / chiasma present / exchange of genetic information;
bivalents arranged independently;

2 max

(ii) separation / spliting / pulling apart of homologous chromosomes / pairs of chromosomes;

(must give indication that one chromosome moves to each side)
(must be in the context of meiosis – not chromatid movements and not chromosomes separate)

pulled at centromere / by spindle / fibres;

2

(c) (i) the short arm of both chromosomes labelled on the middle homologous pair;

*(**B** and **b** must be labelled on separate chromosomes)*

1

(ii) 8 = 2 marks;
working showing genotypes with 1 allele from each pair
(for example, **B C D**) = 1 mark

2

[8]

Q1.

Generally, the comprehension was far better answered than in 2017. This may be partly due to the specification content included this year compared with last. The main issue, as with last year, is that students attempted to answer the question without using the passage. However, these are true comprehension questions. This was the main issue with question (a), though 70.7% of students did score at least one mark. Many students appreciated that the presence of an antigen caused the production of more T cells which resulted in increased amounts of cytokines being produced. Other students appreciated the former but attributed the swelling to the accumulation of T cells. There were some spurious arguments based on alteration of water potential resulting in accumulation of water, and hence swelling.

(b) was similarly well answered, but those students who failed to score (28.8%) gave vague responses, such as 'it is passed on' and also thought that those with Crohn's disease had genes to make bacteria pathogenic instead of normal.

(c) was poorly answered, with nearly 80% scoring zero marks. Students failed to get from the passage that 5-ASA is a drug that reduces swelling. Incorrect answers centred round "the body seeing the drug as foreign", "being immune to the drug", "making antibodies against the drug", "digesting the drug", "having no receptors for the drug" or, as 5-ASA is an acid, it "denaturing protein/cytokines". A significant number of students attempted to relate their argument to an allergy to the drug, but many expressed this in terms of suffering side-effects.

(d) was better answered, with the majority of students able to follow the idea that DNA replication will slow, meaning fewer T cells and less cytokine. The question gave guidance not to include details of enzyme inhibition or protein synthesis. This was to help guide students to the correct answer; many based their arguments on a failure to form enzyme-substrate complexes, despite the advice. There was some confusion of cytokine and cytosine, and some students thought that 6-MP would have stopped bacteria or "Crohn's" reproducing, not T cells.

Q2.

64.5% of students could answer question (a), a test of recall from section 3.1.4.1 of the specification.

For question (b), 67.5% of students achieved both marks. Those who could not define 'degenerate' in the context of the genetic code often failed to gain credit through not using appropriate terminology, for example referring to 'bases' rather than 'base triplets/codons' or stating that base triplets 'produce' amino acids rather than 'code for' amino acids.

Question (c) was an interesting question as it could be interpreted as a straightforward 465 amino acids multiplied by three to give the 1395 bases of the gene. Students could also add three or six bases to this, for a start and/or stop codon. Some students appreciated that a gene would be made up of double-stranded DNA so would comprise double this number of bases – this was also awarded credit. 67% of students could complete this calculation.

Question (d) showed that multiple-choice questions are not always simplistic or based on recall. This question required students to interpret **Table 1**, convert the mRNA codon to a DNA base triplet, and also notice in the question that this was a single base substitution. Only 9.6% successfully achieved all of this. The majority of students ticked box 2 that did

show a Val to Ala change, but with a mutation in the mRNA (not DNA) and of 2 bases.

The answers to question (e) revealed much misunderstanding of the principles of the link between DNA, polypeptides and proteins, as many students discussed the changes in amino acid in terms of silent mutations or frameshift mutations. The instruction to use all the information required the students to look back at **Table 1** and use the key showing the properties of the R group of the amino acid. Very few students could apply this information and link the reduction in rate of reaction with the R group of amino acid 279 changing from being negatively-charged to being positively-charged. Imprecise biological language was also often seen, for example omitting to reference the 'shape' of the active site and discussing the 3-D structure of the protein rather than its tertiary structure. Just over half of the students (54.2%) managed to score at least one mark here; only 3.2% gained maximum credit.

Q3.

47.2% of students achieved both marks for question (a). Many did not use the parent cell in **Figure 1** as their starting point, so did not include one long and one short chromosome in their cells (an 'error carried forward' was allowed if the correct daughter cells were then drawn from the student's own cell as shown after the first division of meiosis).

Question (b) tested students' understanding of the chi-squared test. The null hypothesis stated 'the proportion of plants will not change from one breeding cycle to the next'. Students, therefore, needed to maintain the proportions from breeding cycle 0 into breeding cycle 1, taking into account that the total number of plants had changed from 54 to 56. 22.3% of students could successfully combine this understanding of chi-squared with their maths skills, using proportions to achieve both marks.

Question (c) showed that questions relating to P values are still not being answered well. Too many students still write that the 'results' are due to chance, omitting the essential aspect of it being the 'difference' in the results that is or isn't due to chance. It was rare to see the concepts of probability and chance being appropriately applied. It may be that students have only used chi-squared in relation to genetic crosses and this novel context caused confusion, but students should be introduced to the use of all three required statistical tests in a range of contexts.

Question (d) tested section 3.4.4 of the specification, specifically 'students should be able to use unfamiliar information to explain how selection produces changes within a population of a species'. Although the instruction to 'use your knowledge of directional selection' was intended to help students focus their answer, it led to many answers that simply described the outcome of directional selection with no explanation of how it comes about. When attempts were made to give explanations, they were often not linked to this example. Many students suggested that the environment had changed, so that the plants producing 2n gametes had a selective advantage, instead of using the information provided that the scientists used only these specific plants for breeding. The term 'allele', used in the correct context, was seen infrequently.

Q4.

In question (a), it was pleasing to find that 83% of students managed to complete the diagram correctly.

In (b), only 68% correctly identified crossing over as the process that produced the alleles in the first polar body. This was a little surprising, given how many correctly answered (a).

The calculation in (c) discriminated well. Two marks were obtained by 30% of students. A further 17% obtained one mark for making some progress with the calculation. This

included students who correctly calculated the difference in volume between the nucleus and the polar body, but could not then correctly calculate the number of mitochondria. Others used diameters instead of radii.

Question (d) was marred by the number of students who appeared not to have read the stem carefully enough. As in question 2, the information comes from a published scientific paper. The bullet points in the stem state that the nucleus is removed from a donor egg and this is replaced by the polar body from a woman affected by mitochondrial disease. Only 3% of students obtained both marks by noting that the egg produced by this process would contain a nucleus from the affected woman and very few faulty mitochondria. Very large numbers of students wrote about how the **nucleus from the donated egg** would not contain the genes to make faulty mitochondria and so this would be a cure. This would mean that the child produced would have the DNA of the donor, not the woman affected by mitochondrial disease. There would be little point in carrying out such a complex procedure to achieve this; a donor egg would suffice. Other students correctly spotted that the egg produced would contain the DNA of the affected woman but, having just calculated the number of mitochondria in a polar body, stated that the polar body contained no faulty mitochondria. This accounted for the 21% of students who obtained one mark. Many students thought that mitochondria are contained within nuclei, or that they are synthesised along with proteins at ribosomes, using mRNA from genes in the nucleus.

Question (d) produced an even spread of possible marks. About 40% of students obtained one mark for stating that the faulty mitochondria would produce less ATP. Some 29% obtained a second mark by linking ATP to the energy required for reactions. A few students did recall that ATP is used to phosphorylate substances, to make them more reactive, or helps to lower the activation energy for a reaction. There were pleasingly few references to ‘making energy’. Some students drifted into accounts of how ATP is made in mitochondria, which was more than the question required.

Q5.

59% of students failed to score the mark on question (a), suggesting a lack of understanding of the terms haploid and diploid.

Answered showed a lack of understanding of the concept behind question (b). Most students seem to think that it is the second meiotic division that halves the chromosome number; hence most answers referred to that, or referred to mitosis. Only 11% of students scored two marks.

62% of students scored the mark for question (c); again, a lack of understanding of the term haploid seemed to have been the main issue for the rest.

There was a severe lack of correct terminology and lots of confused terminology seen in the answers to question (d). There were responses discussing the idea of new combinations of genes, creation of new alleles, sister chromatids swapping, and swapping of genetic information between any two chromosomes. There were also many students discussing tension being created in chiasmata leading to snapping off sections; this appears to be a misinterpretation of the mechanism of crossing over. Only 5.3% of students scored all four marks, with just under a third scoring zero.

Q6.

Almost 60% of the students correctly identified the trisomy of chromosome 13 in question (a). Most of the incorrect answers referred to there being no Y chromosome.

In answers to question (b), there was evidence that students are less confident in their

knowledge of mutation involving a change in chromosome number. There was an assumption made by some that, as this was a mutation, it must involve a change in the base sequence – answers of this type gained no marks. At the other end of the spectrum, some excellent answers were seen in which students wrote about non-disjunction during meiosis.

Most students knew, in question (c), that body cells are produced by mitosis and often gained a mark for explaining that all cells are derived from a single cell, the zygote. Relatively few (17%) gained a further mark either for pointing out that the mutation would have been present in one of the gametes used in the formation of the zygote, or that mitosis produces genetically identical cells.

In answers to question (d), it was again evident that some students did not use the information given in the diagram, which clearly showed the direction of the blood flow. Some students wasted a lot of time writing about the functions of the aorta and pulmonary artery. The vast majority gained at least one mark for stating that there would be less oxygen delivered to the tissues, but fewer went on to explain that there would be less oxygen available for aerobic respiration, which would reduce growth or development of the tissue or organ.

Q7.

(a) The command word here was **contrast** and so statements showing clear differences between the use of the two microscopes were required to gain credit. Most students demonstrated sound knowledge of the optical and electron microscopes, but few managed to gain all six marks for relevant contrasting statements. Many suggested that no organelles could be seen with an optical microscope, rather than only larger organelles being visible. Some referred to SEMs and 3D images; neither was relevant here.

(b) There were many good answers here, with over 70% of students scoring 2 marks and over 40% gaining 3 marks. Mark point 4 was the least often awarded. Students often failed to gain mark point 3 because they stated that **W** contained half the genetic material of **Z**, rather than specifying half the DNA. Several students discussed these cells as if they were human cells rather than plant cells, mentioning 23 pairs of chromosomes originally, or 23 chromosomes in cells in **W**. Some students named stages of meiosis in their answer. These were ignored as this is not expected knowledge; we were only looking for the outcomes of 1st and 2nd meiotic divisions.

(c) The full range of 0 – 5 marks was seen in similar proportions here (although slightly fewer with full marks). The main reason for the discrimination was how fully each student used the information from the question stem. The two groups of seeds to be investigated had been collected already, and the investigation that was needed was simply to find out if there was a difference in size of these seeds. Many students gave extensive answers relating to how to collect the seeds from the environment, and how to measure the pollution – neither of which was relevant to the question. Many students selected an inappropriate statistical test or listed several options, which could not be given credit, even if t-test was amongst the list of possibilities (see note about the 'list rule' in the final paragraph of "General Comments" above).

Q19.

(a) There were some rather vague responses that made an attempt to suggest why it was important the birds were of similar age but did not really fulfil the marking points. For example, mark point 4 needed to refer to the feathers and references to "producing UV light" were generally not of an equivalent standard.

(b) This was well answered by the vast majority, although some answers simply stated "use a random number generator" without really explaining how this would be used to select the birds.

(c) Many good suggestions were made for the assumptions the scientists made.

(d) Although there were many very good responses to this question, there was still evidence of some confusion, for example, between the nucleotide sequence and the amino acid sequence. Mark point 3 required reference to the amino acid sequence as a whole, not just to a change in a single amino acid.

(e) Creditworthy "Yes" responses were more common than "No". Students who carefully studied both resources and used information from both in their responses were the most successful. Poor phrasing and terminology meant some responses did not achieve mark points 2 or 3; the idea of difference in the results was required for mark point 2 and mark point 3 had to refer to error bars not standard deviation.

Q20.

The questions here related to the passage and students who used information and ideas from the passage tended to do well. Many students appeared to attempt the questions without considering the contents of the passage. Students should be aware that great care is taken to reduce the length of the passage as far as possible, retaining only content that is useful and necessary.

In (a), the passage stated that amyloid-precursor protein is large, has a complex shape and is the substrate of two different enzymes. About 14% of students correctly suggested that each enzyme would have an active site that binds (specifically) to a different site on the amyloid-precursor protein. (This would be rather similar to endo and exopeptidases acting on a protein – see specification section 3.3.3.) Many students wrote about induced fit allowing an enzyme to adapt its active site to fit a/any substrate, so both enzymes would bind to the same place on the substrate. Others had active sites on the substrate that could adapt to the enzymes.

Question (b) produced more discrimination than expected. About 27% obtained both marks, for noting that a peptide bond is broken and water is used in the process. About 43% obtained one mark for one or other of these points, usually the use of water. The others either didn't know, or suggested water was given off in the reaction.

In (c), few students could string together all three points on the mark scheme. Many appeared to be unable to use information from the passage to come up with any sensible suggestion of how the mutations could lead to Alzheimer's disease, such as a faster/greater production of plaque.

In (d), about 46% obtained one mark for describing what a competitive inhibitor is and how it acts by binding to the enzyme's active site. About 30% were then able to go on and apply this knowledge to the context in the passage and suggest that the inhibitor would reduce or stop β-amyloid or plaque formation. Some students attempted to hedge their bets by saying that the inhibitor changes the enzyme's active site but not saying how. This approach was not given credit. Some students thought that active sites are on substrates and failed to obtain the first mark point. Students who could not remember what competitive inhibition of an enzyme entails were unable to access (d). 23% of students failed to score on (d).

Question (e) could only be answered using information from the passage. About 20% of students obtained this mark by noting that the brain normally has the enzymes, and produces the proteins, mentioned in the passage and they must, therefore, have some

necessary function (that the drugs blocked).

Q21.

(a) It was disappointing that less than 50% of students obtained two or more marks out of the four available on this question. Although the context of the question was novel the knowledge and understanding required have been regularly assessed on previous AS Biology papers with students achieving better outcomes. The fact that a mutation involves a change in the DNA base/nucleotide sequence was only appreciated by a minority of students, often the 5% of students who obtained maximum marks. Although most students appreciated that a different amino acid sequence would be coded for, a number of students incorrectly stated that different amino acids would be formed. Better answers did gain credit for references to changes in hydrogen, ionic or disulfide bonds. However, many students failed to gain a mark for a change in the tertiary structure as they incorrectly suggested that this changed 'the active site' of a receptor. 30% of students obtained no marks. These students often provided detailed accounts of translation or outlined the consequence of having a non-functional receptor which was required in the following question.

(b) Approximately half the students obtained at least one of the two marks available for this question. Usually this mark was awarded for appreciating that HIV would not be able to attach to the protein receptor and therefore could not enter the cell. Many other students omitted the latter part of this description. Again, many students referred to an active site on the receptor. Approximately 10% of students gained both marks by further explaining that HIV would not be replicated or that the T cells would not be destroyed.

(c) As expected, this question proved very difficult for the vast majority of students with less than 5% obtaining both marks. The most frequent correct response related to the low number of HIV infections in Europe compared with other parts of the world. A number of students did gain credit for outlining that HIV has only been present in humans for a relatively short time period. The other mark points were rarely awarded. A significant number of students appreciated that natural selection often occurs over a long time period but did not relate this information to the context of the question.

Q22.

(a) Approximately half of all students achieved one mark on this question and about a fifth achieved both.

A lack of awareness of homologous chromosomes and their role in cell division was a common feature throughout the different parts of this question.

(b) Some students gave a concise description for, and explanation of, the appearance of chromosome K, although few made a reference to DNA replication for the presence of two chromatids. Some students offered two points of description without giving an explanation of either.

(c) The idea of 'crossing over' is well understood, although not what structures it occurs between. Few stated that homologous chromosomes are involved (some referred vaguely to maternal and paternal chromosomes), although occasionally references to bivalent or non-sister chromatids demonstrated that there is an awareness of the principle. Independent assortment and crossing over are biological processes which some students confused.

(d) Some sensible suggestions gained credit, like cell D is the product of division in cell B, or cell D is the result of Meiosis I, but many answers included long and tortuous accounts that confused fundamental differences between mitosis and meiosis. Structures were inaccurately referred to as chromatids and the idea that a homologous chromosome 'is split' is a fairly common misconception.

Q23.

(a) There were many good answers to this part, with 25% of students obtaining all 6 marks. For the rest, it was a matter of how much of the story they gave. Some students failed to gain one of the marks because the examiners rejected references to changes in base sequences leading to different amino acids being produced or made. The most commonly missed point related to changes in bonding within the structure, due to a different primary structure. The examiners were also looking for changes in tertiary structure of the protein, rather than just changes in shape.

(b) In this part, many obtained one mark for noting the difference in response of SR and non-SR above 10 μg cm^{-3}. Fewer, about a third, noted the greater effect on the non-SR up to 10 μg cm^{-3} and obtained a second mark.

(c) The logic in this part defeated many students and nearly half failed to score. In the main stem, it says that the scientists stopped cell division before exposing the bacteria to the antibiotic. Despite stopping cell division in both SR and non-SR, the SR bacteria remained more resistant. This suggests something other than stopping cell division is involved. There were some very good answers (13%) that did follow the logic and obtained 2 marks. Some obtained 1 mark, usually for noting that cell division had been stopped.

(d) Many students obtained 1 mark for suggesting the development / use of either a competitive or non-competitive inhibitor of an enzyme involved in the stringent response. Surprisingly few were able to explain successfully how either of these would stop an enzyme working and thus obtain a second mark. A minority of students obtained a mark for just suggesting the use of an inhibitor (type unspecified) to block the enzyme pathway.

In this part, students illustrated something that is frequently seen in answers to exam questions. Information is provided in the question, students are instructed to use this information, but then go off on a different tangent. Students who did use the information often produced very good and very clear answers along the following lines. The SR bacteria contain fewer harmful free radicals. They also contain more of the enzyme catalase. (Perhaps) the catalase breaks down the free radicals (before they cause harm). Other students did not make comparisons between SR and non-SR but often tried explanations based around comparisons between free radicals and catalase within strains but with no sensible explanation of how this would help the bacteria. Some invented hypothetical effects of free radicals, or catalase, or both on antibiotics, or on bacterial cells.

Q24.

Given that this question was targeted at grade E, it was surprising that parts (a)(i), (b)(i) and (b)(ii) proved to be good discriminators.

(a) (i) Half of students were aware that a hierarchy contains groups within groups, with no overlap. However, the 'no overlap' concept was often missed. Similarly, it was disappointing that nearly 30% of students failed to score, considering that a simple definition from the specification was required. Weaker responses often referred to the idea of ranking, dominance or

importance.

(ii) Most students gave the correct answer of **3**.

(iii) Most students gave the correct answer of **Chordata**.

(b) (i) Just over half of students scored at least one mark. This was usually for relating independent segregation to genetic variation. Better responses showed an appreciation of how this is achieved. Typically, these referred to different combinations of maternal and paternal chromosomes, or the random arrangement of homologous chromosomes. Commonly seen responses that lacked the required precision included 'provides variation' and 'allows different combinations of chromosomes'. A minority of students failed to score due to writing about crossing over. The role of independent segregation in producing haploid cells was rarely seen.

(ii) One-third of students scored full marks. However, a number lost marks through a lack of precision; for example, 'there would be the wrong number of chromosomes' or 'they are different species so the offspring would be infertile'. The most common misconceptions seen were that 'the offspring would have 94 chromosomes' and 'meiosis would not be able to occur *in* the sex cells'.

Q25.

Parts (a), (b) and (d) proved to be good discriminators.

(a) It was disappointing that only just below 40% of students scored at least half marks. This was mainly due to simply describing the structure of DNA, without explaining how these features relate to its functions. Some students wrote about DNA structure and function in different paragraphs. This made it unclear which feature went with which function, as no direct links had been made. In contrast, there were some truly excellent responses, which had clearly been well planned before putting pen to paper. The most common mark points awarded were for the sugar-phosphate backbone providing strength or protecting bases, the helix allowing the molecule to be compact, weak hydrogen bonds allowing strand separation or replication and the two strands acting as templates or allowing semi-conservative replication. Relatively few students linked complementary base pairing with accurate replication or the production of identical copies of DNA. Similarly, few students referred to DNA as a large molecule that can store lots of information, or the base sequence coding for amino acids. Weaker responses often mentioned this in the context of the genetic code being degenerate. Indeed, some students thought that the base sequence causes amino acids to be *produced*. The ability to convey that *many* hydrogen bonds provide stability was rarely seen. It was also unfortunate that a number of students wasted their time by writing about irrelevant topics such as the differences between prokaryotic and eukaryotic DNA and the role of histones. There were also some lengthy accounts of DNA replication, enzyme structure and the different levels of protein structure.

(b) Many students scored at least two marks for stating that a mutation in gene **E** produces the highest risk and a mutation in gene **C** produces the lowest risk. However, only the best responses also referred to gene **D**. Students who did not mention any of the genes usually picked up one mark for noting that all of the mutant alleles increase the risk of lung cancer. Surprisingly, some thought that a mutation in gene **D** produces the highest risk.

(c) Just fewer than 40% of students gave the correct answer of **180**.

(d) Two-thirds of students scored at least two marks. Many were able to identify the decrease, plateau and increase for healthy cells and cancer cells. However, relatively few made reference to the plateau occurring for the same length of time. Students who failed to gain a mark for a similarity usually ignored the plateau. Most students spotted that a greater number of healthy cells were killed or that they experienced a faster decrease in number. Similarly, it was impressive to see that some used data from the graph to calculate that a greater *proportion* of cancer cells were killed. Many students also noted the faster increase in the number of healthy cells.

(e) Half of students scored full marks. This was usually for mentioning that too many healthy cells would be killed, which could kill the patient or cause side effects. However, relatively few appreciated that it would take time to replace the healthy cells that had been killed.

Q26.

(a) (i) This part asked students why the genetic code is described as universal. Universal in this context means found in all organisms. A large percentage of students wrote that it is universal because it is found everywhere. Only a quarter of students made correct references to the triplet code used in DNA. Some had the correct idea but wrote things such as, 'The same triplet codes for all amino acids' and failed to score.

(ii) 50% of students gave the correct answer.

(b) This part discriminated well, but with over 40% getting all three marks. Most stated or described the idea of a frame shift. However, some wrote that this changed the sequence of bases afterwards, rather than the sequence of codons. Another fairly common misconception was that mRNA leads to the synthesis, or formation, of amino acids.

(c) This part proved more challenging and only about a third obtained both marks. Most correct answers revolved around the idea of introns being non-coding and thus not affecting an amino acid sequence. Students who failed to score often ignored the fact that the mutation was in an intron and wrote about possible effects of a substitution on amino acid sequences. In the figure, it clearly states that the intron is removed from pre-mRNA.

Q27.

Given that this question was targeted at grade E, it is surprising that all parts proved to be good discriminators.

(a) (i) Over three-quarters of students gained full marks. The most common incorrect response was 'centriole'.

(ii) Most students gained at least one mark for stating that the centromere attaches chromosomes to the spindle. However, the ability to tell the rest of the story, in terms of allowing the chromatids to be separated, discriminated well. Unfortunately, some students failed to read the question stem carefully enough. They instead described the role of the centromere in allowing homologous chromosomes to be separated during meiosis.

(iii) Many students were aware that homologous chromosomes carry different alleles. However, some failed to score through a lack of detail or poor expression. They typically mentioned maternal and paternal chromosomes,

crossing over of alleles or thought that the sequence of genes on each homologous chromosome is different.

(b) (i) It was disappointing that sixty percent of students failed to score. This was usually for simply repeating information from the question stem, in terms of the cell having finished cell division. However, some students did not appreciate that an explanation was required. They simply stated that the chromosomes in **Figure 2** lack a centromere. Only the best responses mentioned that the chromosomes had not replicated, or had separated.

(ii) Just over half of students gained full marks. However, it was disappointing that nearly one-third failed to score. A vast range of incorrect responses was seen, in relation to the number of chromosomes drawn in the cell. It was evident that some students did not realise that meiosis produces haploid cells. Similarly, some students drew chromosomes consisting of two chromatids joined by a centromere.

(iii) Most students gained this mark for ‘crossing over’ or ‘genetic recombination’. The most common response that failed to score was ‘random fertilisation’.

Q28.

(a) (i) Over 90% of students correctly determined that base sequence could code for a maximum number of four amino acids.

(ii) The vast majority of students gained at least one mark, often by mentioning a change in the sequence in amino acids. However, a significant number of students incorrectly referred to 'different amino acids being formed'. Most students gained a second mark for explaining that the active site/ tertiary structure would be altered. Over 50% of students gained maximum marks either by linking this to enzyme-substrate complexes not being formed or to changes in hydrogen bonds.

(b) Most students had little difficulty in using the information to give two symptoms of phenylketonuria and gained both marks.

(c) The majority of students obtained this mark, often by referring to migration or by describing interbreeding. However, over a third of students failed to gain credit and often accounted for the spread of phenylketonuria by horizontal or vertical gene transfer.

Q29.

(a) (i) Over 90% of students correctly explained that vancomycin does not affect human cells as these cells do not contain a cell wall.

(ii) Approximately two thirds of students gained this mark by outlining the role of ribosomes in protein synthesis.

(b) This proved to be an effective discriminator. Most students obtained at least one mark often by referring to vertical gene transmission. Many students then referred to the reproduction of resistant bacteria to gain a second mark. Over a third of students gained maximum marks by explaining that a mutation leads to resistant strains or by stating that a resistant gene or allele is produced. Unfortunately, some weaker students incorrectly referred to bacteria becoming 'immune' or to bacteria reproduction by 'mitosis'.

Q30.

(a) Over seventy percent of candidates were able to explain what is meant by genetic diversity. Weaker candidates confused genetic diversity with species diversity. A significant number referred to fewer alleles rather than fewer different alleles.

(b) Very few candidates did not refer to the environment as the other type of factor causing variation in a species.

(c) Very few candidates scored zero and fifty percent gained both marks in this question. Most candidates realised that genetic diversity would be reduced and many could explain this in terms of a genetic bottleneck or reduction in the variety of alleles in the population.

Q31.

(a) (i) This caused little difficulty for most candidates with the vast majority gaining at least one mark for suggesting that *C. difficile* is resistant to antibiotics. Although many candidates realised that the other bacterial species would be killed, they failed to gain a second mark by not stating that there would be an increase in the number of *C. difficile*.

(ii) Most candidates gained this mark by suggesting that the immune system would be less effective. There were several answers linked to older people taking lots of antibiotics. These responses were not credited.

(b) Although the majority of candidates obtained at least one of the two marks available, there was still some confusion, particularly with weaker candidates, about the precise role of methicillin. Most candidates realised it was a competitive inhibitor but a significant number referred to it possessing an active site. Approximately forty percent of candidates provided a clear accurate explanation of competitive inhibition by methicillin.

(c) (i) The majority of candidates had little difficulty explaining that some of these patients were already ill and this illness could be the cause of death.

(ii) The vast majority of candidates gained this mark by describing the increase in the number of deaths up to 2006 followed by a decrease.

(iii) Less than a third of candidates could correctly calculate the percentage increase in the number of deaths caused by MRSA in Wales from 1996 to 2006. A small percentage of candidates obtained a single mark for reading figures from the graph but almost sixty percent scored zero.

Q32.

(a) Most candidates correctly identified the number of chromosomes in a male gamete in part (i) and appreciated in part (ii) that a chromosome number of 33 could not lead to viable gametes. Not all were certain as to the reason for this, however. One frequent misconception was that it is not possible to have a gamete with an odd number of chromosomes. Weaker candidates often attempted to explain why the gametes that would be produced were unable to form a zygote. Their answers were often further marred by poor use of technical language. There was much confusion between the terms chromosome, gamete and zygote.

(b) There were some excellent answers to both parts of this question. Both parts again required candidates to use the data in the table and it was clear that some failed to take sufficient care with this. The breaking strength of the leaf, for example, was not

uncommonly expressed as the strength of the plant or even the breaking strength of the banana fruit. Candidates should be advised to use the wording provided in table headings and graph labels wherever possible.

(c) It was clear that some candidate's knowledge of cell division failed to extend to the use of such terms as mitosis and meiosis. The quality of many answers was also influenced by poor understanding of technical terms. Thus different varieties of bananas were not infrequently referred to as species and genetic diversity was equated with species diversity. Consequently what should have been a simple answer linking mitosis to genetically identical offspring not often involved irrelevant accounts of competition and speciation.

Q33.

(a) Better candidates accessed the full mark range and there were some excellent logical accounts based on the information provided. Less able candidates were generally able to recognise that they were expected to draw on their knowledge of enzymes. They experienced considerable difficulties, however, in identifying the enzyme and its substrate in the context of this question. Thus the enzyme was often incorrectly given as the penicillin molecule or equated with the gene encoding it. The substrate on the other hand was identified as either an antigen or an antibody or, more commonly, as a bacterium. Elsewhere, there were a number of answers which offered convincing detail of enzyme action but were totally unrelated to the situation presented in the question.

(b) Although part (i) revealed a general understanding that the addition of antibiotics would result in fewer cows becoming ill, candidates did not always link this to bacterial infection or could indicate with sufficient clarity how famers would benefit financially. In part (ii), the concept of selection proved to be very poorly understood by all but the best candidates. Where the concept was invoked, there was a widespread failure to appreciate that, in the context of this question, selection referred to antibiotic resistance in bacteria, not in cattle. Other candidates resorted to ethical considerations, many of which implied a total lack of consideration of animal welfare by farmers.

Q34.

(a) Although a considerable number of candidates gained credit for their answers to this part of the question, others offered inappropriate suggestions. Many of these were yet again centred on the converse and attempted to explain why they did not measure the minimum diameter.

(b) There was evidence from the answers to part (i) that many candidates still fail to absorb material presented in the stem of a question or look critically at data in tables and graphs. Thus, although most appreciated that shrimps that lived in caves had smaller eyes and longer antennae than those that lived in the open, they were unable to point out either that the antennae were responsible for detecting touch or that these data only referred to shrimps. More limited candidates often suggested that shrimps either had eyes or sense organs. Those candidates who avoided explaining standard deviation in terms of range, generally gained at least one mark for part (ii). Better candidates were also aware that overlap in the values of standard deviation was important in indicating whether differences were attributable to chance or were significant.

(c) In part (i), most candidates made an appropriate qualitative statement about the body lengths of the shrimps concerned but few supported this with data from the graph. Some appeared distracted by antennal length and failed to identify the thrust

of the question. Part (ii) was generally well answered.

(d) Most candidates appeared to have understood the information in the graph but could not always explain this with sufficient clarity to gain credit. Thus, although an answer relating to cave shrimps and ocean shrimps (interpreted as shrimps living in open streams) could be awarded credit, one that merely referred to shrimps in streams could not. There were also many sweeping statements such as that “the percentage of shrimps was higher in the open for all alleles”. This was clearly not correct. More credit might have been awarded had candidates based their wording more carefully on that supplied in the column headings in the table.

(e) One of the key phrases in this question was “Use your knowledge of the founder effect”. This should have indicated that candidates were required to apply this concept to the example provided in the question. A significant number failed to do this and opted instead to discuss the difference in percentages in terms of either natural selection or genetic bottlenecks. Such approaches rarely gained credit. Others offered extremely general explanations that made no reference either to shrimps or to allele L. These accounts often incorporated volcanic eruptions and hunting to extinction. Answers were further marred by imprecise language with the term “species” used in a variety of ways that had an adverse effect on the sense of the argument presented. Some candidates again turned the question round and attempted unsuccessfully to use their knowledge of the founder effect to explain the percentage of shrimps with the allele L in the open.

(f) Candidates who answered this question successfully either suggested breeding cave shrimps with those living in the open to see if fertile offspring were produced, or looking at whether courtship behaviour led to successful mating. Although both of these approaches were acceptable, those based on DNA hybridisation and protein analysis were not. Those candidates who chose to discuss crossing shrimps often suggested procedures that would not have guaranteed the relevant parentage. Attempts were made to add detail and there were some valid comments about repeats and carrying out reciprocal crosses. However, there was much discussion about the ethics of experimental work and the perceived cruelty of such experiments that could not be given credit.

Q35.

(a) Less than half the candidates correctly named introns as the non-coding sections of a gene.

(b) The vast majority of candidates correctly identified the amino acid sequence.

(c) (i) Most candidates obtained at least one mark for stating that the amino acid sequence would not change. However, less than half the candidates gained the second mark by explaining that the new base triplet would still code for glycine.

(ii) Most candidates gained at least one mark, often by mentioning a change in the sequence of amino acids. However, a significant number of candidates incorrectly referred to ‘different amino acids being formed’. Many candidates gained a second mark for explaining that the active site/ tertiary structure would be altered. The best candidates gained maximum marks either by linking this to enzyme-substrate complexes not being formed or to changes in hydrogen or ionic bonds.

(d) (i) Almost two thirds of candidates correctly identified the part of the cell cycle as being interphase or the synthesis stage. Anaphase was a common incorrect

response.

(ii) Most candidates obtained this mark, often by indicating that DNA replication occurs during interphase.

Q36.

(a) Approximately half the candidates obtained this mark. A common error was to suggest that an allele was part of a gene.

(b) Most candidates gained at least one mark, usually for referring to sister chromatids. Many of these candidates referred to the centromere for a second mark. Very few candidates explained the presence of two chromatids in terms of DNA replication. Weaker candidates confused centromeres with centrioles, the latter not being a term required on the specification.

(c) (i) Almost half the candidates gained both marks for this question. Candidates gaining a single mark often referred to crossing over but provided a poor explanation of the process. Weaker candidates often attempted to explain the new combinations of alleles in terms of random fusion of gametes or independent segregation.

(ii) Most candidates did not obtain this mark as they simply referred to crossing over being ‘random’ or occurring by ‘chance’. Better candidates clearly indicated that crossing over was rare or infrequent.

(d) (i) The vast majority of candidates gained one mark by showing three chromosomes. Approximately half the candidates obtained a second mark by clearly showing one member from each homologous pair of chromosomes.

(ii) Less than 10% of candidates obtained this mark. It was obvious from the vast range of answers that most candidates had no idea how to determine the answer.

Q37.

(a) The vast majority of candidates gained at least one mark often by describing a method to improve hygiene. The failure of many candidates to gain both marks was often due to providing two methods of improving hygiene rather than two distinct ways of reducing transmission of MRSA. Approximately a third of candidates did obtain a second mark, usually by referring to isolation of infected patients.

(b) Approximately two thirds of candidates obtained at least one mark by suggesting that higher doses than the minimum inhibitory concentration of antibiotic would kill microorganisms. Better candidates referred to the need to prevent antibiotic resistant bacteria surviving. Weaker candidates often incorrectly referred to bacteria ‘becoming immune’. There were few correct answers relating to some of the antibiotic not being absorbed or being broken down in the body.

(c) (i) The vast majority of candidates, almost 90 %, correctly named drug P as being most effective against Enteroccus faecalis.

(ii) A similar percentage of candidates correctly named drug S as being most effective against all the species of bacteria used.

(d) (i) The vast majority of candidates obtained at least one mark often by referring to the prevention of bias. Over a third of candidates gained a second mark

usually by commenting on the ‘placebo effect’.

(ii) This was well answered with almost 95 % of candidates gaining at least one mark and two thirds of candidates gaining both points. Age, sex and health were the most common responses. Failure to obtain both marks was often due to two health-related factors being provided.

(e) Conversely, this was not well answered with almost nine out of ten candidates failing to describe the results shown on the graph. Most candidates simply stated that there was an increase without referring to a gradual, followed by a rapid, increase.

Q38.

(a) (i) Most candidates gained this mark by indicating that the response was more effective in children. However, a significant minority of candidates interpreted the graph as showing that adults had a more effective response to the treatment.

(ii) Considering a similar question was asked on the January 2010 paper it was disappointing to note that less than half the candidates gained both marks. Most candidates did refer to a line of best fit but many then failed to explain that the line should be extended to predict the haemoglobin content after 40 days. Credit was also given for detailed answers using the rate of increase per day to predict haemoglobin content.

(iii) Only a third of candidates clearly explained what is meant by a quaternary structure. Most candidates suggested that it meant four polypeptide chains or many proteins were present.

(b) (i) Almost a third of candidates obtained zero on this question, suggesting these candidates had not revised relevant principles from unit 1. A significant number of candidates interpreted isotonic as meaning a constant pH. Candidates who did know what isotonic meant were often able to provide a suitable explanation to gain at least two out of the three marks. However, there was still some confusion over the term osmosis with weaker candidates referring to salt moving by this process.

(ii) Most candidates were able to describe one difference between the two blood samples, often in relation to the variation in diameters. Many incorrectly referred to a difference in number of red blood cells, or their descriptions were too vague to gain a second mark point.

Q40.

(a) Many candidates produced stock answers to the question ‘describe how meiosis takes place’. By not concentrating on the key features, candidates are likely to produce responses that address those features in insufficient detail. Good candidates, however, were more selective and produced focused responses which described how crossing over between the non-sister chromatids of bivalents produced new combinations of alleles and how random segregation of homologous chromosomes reduced the chromosome number and produced different combinations of chromosomes. They usually also went on to describe the role of meiosis II in splitting the chromatids. A common omission from otherwise good answers was to fail to explain how the processes of crossing over and random segregation introduce variation.

(b) (i) Good candidates made use of all the information supplied and were able to

deduce that to produce black offspring the white parents must be aabb not AAbb and the agouti mice must be Aa not AA; to produce white offspring the agouti parents must be Bb, not BB. The good candidates then laid out the cross correctly and were able to show the correct ratio of genotypes. Some failed to gain a mark by not clearly showing which genotype produced which phenotype. Candidates who did not make use of all of the information, frequently began from wrong parental genotypes, and often ended with the wrong ratio. Oddly, they did not then attempt to correct this.

(ii) Most candidates were able to calculate χ^2 correctly, although many made a basic arithmetic error in calculating (O − E) for the white mice. These candidates correctly calculated E as 60, but then in subtracting 51 from 60 produced the answer 11.

(iii) Most candidates correctly stated that there would be two degrees of freedom. They were then able to correctly relate **their** calculated value of χ^2 to the critical value at a probability level of p = 0.05 and, from this, to correctly infer whether or not the results were, or were not, significantly different from the expected ratio.

Q41.

Unit 2

(a) Very few scored two marks for this question. Most missed the fact that the mass of DNA given was for a cell just before cell division and it had therefore already replicated its DNA. C = 600 and D = 300 was a common incorrect response.

(b) In (i), some good answers were found when candidates realised that the process was meiosis. Many just gave any organ where cell division takes place, misinterpreting the process as mitosis. So liver, skin or even roots were given by many. Part (ii) was again well answered when candidates realised that the purpose was to see the chromosomes. Poorer answers gave general purposes for staining, such as ‘to show the process’ or ‘to show up the cell/organe lles’.

Unit 3

(a) The accurate completion of the table proved challenging for all but a few candidates. ‘Immediately before division’ should have allowed the interpretation that chromosomes had replicated and would exist as a pair of chromatids. The chromosome number of an organism is not altered but the mass of DNA within the cell is temporarily doubled, and shown in the table. Few appreciated this and almost the whole cohort failed to link correctly change in chromosome number with mass of DNA.

(b) Weaker candidates failed to name an appropriate organ, or thought that meiosis might occur within the liver or skin, and many misinterpreted the question by identifying cells. Where, perhaps, candidates had investigated stages of cell division first-hand, the use of a stain to make chromosomes visible was appreciated more readily.

Q42.

(a) Nearly all candidates knew that members of the same species can reproduce to produce fertile offspring. Fewer, made the additional point that they shared similar features.

(b) Responses to this question were disappointing and were most likely due to candidates not really looking carefully at the evidence and realising that the means and ranges of beak depth of the two species on island 3 had shifted in opposite directions. A majority of candidates thought that the changes in distribution of beak depths of the two species on island 3 were an example of disruptive selection. It is likely that these candidates focused on the third graph, saw two distributions and assumed that there had been selection in favour of the two extremes of one distribution. Some even went as far as to say that sympatric speciation had occurred.

Q43.

Unit 8

(a) Most candidates were able to explain that an increase in water temperature would influence a relevant feature such as oxygen solubility or respiration. Answers based on the effect of temperature on the rate of enzyme activity or on metabolism were, however, a little too general, failing to relate to the specific investigation described in the question. There were a few references to ensuring “a fair test”, an entirely inappropriate response at this level.

(b) The responses to this section formed a sharp contrast to the high marks frequently awarded for statistical analysis in coursework. Answers to part (i) were often centre-dependent, some candidates being able to produce a sound null hypothesis; others clearly had little idea. These candidates frequently lacked understanding of the purpose of the investigation or of the concept of a null hypothesis. The weakest responses usually involved equating the expression with an inappropriate statistical formula. In part (ii), many candidates were aware that statistical tests are related to chance, but fewer were able to explain that such tests give a measure of the probability that chance might account for the results obtained.

(c) Most candidates correctly identified A as the more likely explanation and were able to justify their choice.

(d) Better candidates were able to produce in a logical account in which they successfully linked a lower oxygen concentration to anaerobic respiration and the production of lactic acid. Others revealed a disturbing lack of understanding of respiratory biochemistry, suggesting that the evolution of carbon dioxide was entirely independent of the consumption of oxygen. They inevitably based their answers on an argument that, despite reduced oxygen, fish must continue to respire aerobically, so there would be an increase in carbon dioxide. There were occasional references to supposed chemical effects of zinc.

(e) The best candidates used common sense in part (i) and, realising that the only elements that were concentrated were copper and cadmium, calculated appropriate ratios for these ions. Credit was also given to those who supported their conclusions by calculating the inverse. A significant number, however, merely subtracted the relevant values from each other, an approach which inevitably led to an incorrect answer. The examiners were instructed to be generous in marking the calculations and undertook much work in interpreting confusing presentation. Centres would do well to advise candidates that it is their responsibility to present material sufficiently clearly that the logic of the response can be followed. In part (ii), most recognised that lead ions would be egested or excreted, although there was some incorrect usage of these terms. Most candidates were aware, in part (iii), that woodlice would concentrate copper. The principle of bioaccumulation was often correctly described but not always related to eating a large number of leaves. Weaker candidates frequently referred to additional sources of copper ions or to the intriguing possibility

of copper ions multiplying within the body of the woodlouse.

(f) Mutation figured widely in the responses to part (i), although there were occasional incorrect references to natural selection or to the presence of arsenic causing the allele to first arise. Although there were a number of rather vague references to growth and formation of new cells, the majority of candidates were able to identify two specific effects of phosphates in part (ii). Answers to part (iii) were frequently marred by a failure to answer the question and explain why arsenic-tolerant plants were unable to compete in the conditions described. Candidates referred to both arsenic-tolerant and non-tolerant plants as “they” and it was often far from clear as to which they were referring. However, it was encouraging to note that, although this question was targeted specifically at Grade A candidates, many others were able to suggest that arsenic-tolerant plants would not grow as well because they were unable to take up sufficient phosphates.

Unit 9

(a) Candidates offered a range of explanations, suggesting that the air mixed the water, that it affected the zinc, and that it was needed to make the test fair. Few candidates earned a mark; those that did suggested that oxygen would no longer be a limiting factor. Links were rarely made with the effect it would have on the saturation of the haemoglobin.

(b) (i) A large number of individuals know from their coursework that the term ‘null hypothesis’ implies ‘no difference’, but they did not always recognise where this lack of difference might lie. Weaker candidates made comments about chance. The commonest error was to devise a hypothesis relating to gas exchange and respiration.

(ii) Many commented on the need to look for effects that are due to chance. Some quoted significance levels, but failed to mention probability. Many referred to establishing levels of accuracy, and a few made statements about the null hypothesis. It was disappointing to note that large numbers of candidates are able to suggest null hypotheses in their coursework but are unable to apply these statistical skills to material presented in an unfamiliar context.

(c) Most candidates recognised the answer as A, and were able to use the graph to explain their choice. Those that could not were vague in their answers.

(d) Unless candidates recognised that there was less oxygen available to the cells they were inclined to answer irrelevantly. The best recognised the anaerobic respiration that would ensue, and therefore lactic acid would be produced. Some wrote of haemoglobin as a buffer, but failed to recognise that it would be the extra hydrogen ions which affected the pH not those absorbed through the buffer. Weaker candidates were confused over the numbering of the pH scale. They thought that zinc affected the pH of the water, or that zinc caused haemoglobin to pick up fewer hydrogen ions from the water.

(e) (i) The calculations were absent in some cases, and very varied where present. Simple ratios were the best idea, but some even calculated standard deviations. Subtractions were also fine. Many candidates had no idea what to calculate. The commonest response was to find the mean concentration of cadmium and copper in shrews, without any reference to the levels in the source of food. Many gave calculations without saying what they were, leaving the examiner to guess. The weakest candidates mis-read the data as numbers of shrews or numbers of ions. Despite poor performances on the supporting mathematics, many candidates could comment on the relative concentrations.

(ii) The fate of the ions was mixed. There appears to be widespread confusion over egestion and excretion and the fact that ions have to be absorbed before they can be used appears to have escaped some. Weaker candidates were of the opinion that the copper ions could be broken down.

(iii) Candidates had little understanding of the ways in which ions accumulate through diet.

(f) (i) Most candidates correctly identified mutations as the cause of the allele arising, but some offered a choice to the examiner regarding natural selection.

(ii) Likewise, most candidates were able to name two functions of phosphates. A few were confused with protein synthesis. Some answered too vaguely with 'membranes', iii). This part of the question presented difficulties to many and only the better candidates directed their responses appropriately. There were many vague references to "fogs" and inappropriate set-piece answers on inheritance.

Q44.

Unit 2

(a) Most candidates knew that DNA replication occurs during interphase, or the S-phase, and could put the stages of mitosis in the right order.

(b) The commonest error here was to give ACDEB, i.e. failing to recognise that stage D came before stage C. Nevertheless, a few who did not read the question properly simple wrote "Interphase, prophase, metaphase' etc on the lines.

(c) The role of the spindle was well known although expression was clumsy.

(d) Many demonstrated full understanding. The terms haploid and diploid were confused by some and so fusion was described as producing the full set of haploid chromosomes. Variation was mentioned by some, but often vaguely suggesting that it occurred at fertilisation rather than during gamete formation. Confusion exists between meiosis and mitosis and a significant number of candidates explained that gametes were identical as a result of being formed by mitosis.

Unit 3

(a) This question was well answered with very few incorrect responses.

(b) Most candidates correctly identified the sequence of events. The most common error was to place **B** as the second event. Unfortunately some candidates did not follow the rubric and gave the stage names in sequence rather than the sequence of diagrams.

(c) Weaker candidates tended to confuse centrioles and centromeres and this led to some unacceptable responses. The idea that the spindle makes chromosomes move was well understood though some candidates did not appear to appreciate that the chromosomes are separated or moved to opposite poles.

(d) As is usual in January, there were many resit candidates who used information from module BYA5 in their answers to this question. Where correct, this was credited by the examiners.

Q45.

(a) Nearly all candidates were able to described photophosphorylation accurately and many scored full marks.

(b) A good number of candidates recognised the benefit of sediment-dwelling bacteria being able to absorb wavelengths of light that were not absorbed by the surface-dwelling bacteria. However they often then went on to suggest that the bacteria with this ability would out-compete the surface dwellers, rather than sediment dwellers without the ability to synthesise chlorophyll. As a result, some of the points they made about the process of natural selection were in the wrong context.

Q46.

(a) A good number of candidates knew that the diagram represented anaphase I of meiosis. Most of these were able to explain that it was anaphase because chromosomes were being pulled to the poles by the spindle fibres. Some went on to explain that it must be anaphase I because sister chromatids had not yet separated. However, there was a good deal of unclear use of terminology by some candidates, with the terms bivalents, chromosomes and chromatids being interchanged at will.

(b) Very few candidates were able to describe crossing over adequately and most responses could not begin an explanation without using the term ‘crossing over’. They were unsure as to when crossing over takes place, the mechanism by which it takes place and just what genetic material is exchanged. Some better candidates could describe the exchange of portions of non-sister chromatids between homologous chromosomes in a bivalent, but, again, most were unsure of the terminology. Most responses awarded full marks were given to candidates who had thought to include a series of labelled diagrams to explain the process.

Q47.

(a) Most candidates suggested crossing over in prophase I and independent assortment of chromosomes in anaphase I of meiosis. Some correctly suggested independent assortment of chromatids in anaphase II of meiosis.

(b) Explanations of standard deviation and range sometimes suffered as a result of vague and imprecise language. It is not helpful to use the term ‘range’ when trying to explain what range means. It is incorrect to say that standard deviation relates *each value* to the mean, as a good number of candidates suggested, and it is not enough to say that standard deviation describes the spread of data; it describes the dispersion or spread *about the mean*. Candidates need to be more precise in their answers.

Q48.

BYA2

The stages of mitosis were well known in part (a). Some candidates lost marks by referring to ‘replication’ in the S-phase, without stating what was being replicated. In part (b) (i), most candidates recognised that meiosis was involved in producing the spores, though the spellings were extremely varied. Examiners allowed phonetic misspellings, but had to reject “hybrid” spellings such as ‘meitosis’. In part (ii), about half the candidates gave the correct answer of 32. The commonest error was 16, though many gave 23.

BYA3

(a) A range of responses was seen here, with many completely correct.

(b) The examiners agreed to accept alternative spellings of ‘meiosis’ provided they were phonetically unambiguous. Had they demanded an exact spelling, the number gaining the mark would have plummeted. Various numbers of chromosomes were offered, 16, 32 and 64 being common, but many gave 23.

Q49.

(a) Many candidates presumably misinterpreted the question because, instead of explaining the biological importance of *reducing the chromosome number* in meiosis, they discussed the importance of the variation which meiosis produced. However, most answered appropriately with reference to fertilisation and the need to prevent doubling of the chromosome number from generation to generation.

(b) Relatively few candidates were able to make three correct comparisons between meiosis and mitosis. One problem was the belief that the two rounds of division in meiosis and the production of four cells from the original constituted *two* different features. Some candidates also repeated the example given in the table. The points most commonly missed were the association of homologous chromosomes (or formation of bivalents) in meiosis and the production of *genetically* different cells by meiosis. Candidates were required to make a comment on both the meiosis and on the mitosis side of the table in order to score each mark.

Q50.

BYA2

(a) Whilst replication of the genetic material was given in some form by many candidates, several failed to relate their answers to the nucleus or were unaware that most organelles are reproduced in the cytoplasm.

(b) A few candidates confused mitosis and meiosis but the majority failed to gain marks through careless drawing even when they had identified the correct number of chromosomes. A surprising number drew chromosomes in part (ii) which had been bisected so they had the centromere with one ‘arm’ attached.

(c) Many correctly discussed replacing cells although some thought they could be repaired by this process.

BYA3

(a) This was known by most candidates, though a small number referred to chromosomes appearing or to events, such as protein synthesis or production of organelles, happening outside the nucleus.

(b) Many students gained the mark for the correct number of chromosomes in (i) and (ii), showing that the basic ideas behind mitosis and meiosis are well understood. However, fewer gained the mark for drawing the chromosomes correctly: many drew all chromosomes as identical.

(c) Many candidates realised that mitosis would allow damaged cells to be replaced, although the less able referred to repair of cells damaged by acid or enzymes.

Q51.

(a) Many candidates had a clear picture of chromosome behaviour in the process of

meiosis and were able to give an unambiguous, detailed account of this. Others omitted certain details and some were very confused, for example believing that crossing-over occurred in meiosis II, even after the homologous chromosomes had been separated. The best accounts were from those who had a clear grasp of the correct terminology (for example, the terms *homologous*, *bivalent*, *chiasmata*, *centromere*, *spindle fibre*, *chromosome* and *chromatid*) and who were able to deploy this appropriately.

(b) Unfortunately, many candidates concentrated on only part of the question, giving great detail about the generation of variation by crossing-over and by random assortment of chromosomes and/or chromatids. More marks were, in fact, available for the second aspect of the question, explaining the advantage of such variation. This involved the concepts of there being different phenotypes among the offspring and hence differential survival and reproduction and, consequentially, the passing on of only certain alleles to the offspring which might give a selective advantage should environmental conditions change. A common failing was to describe the 'species' as surviving due to variation rather than survival of certain well adapted individuals of that species.

(c) In (i), many candidates deduced that there would have been 21 chromosomes in the hybrid. Answers such as '10.5 chromosomes' beggared belief.

In (ii), those who thought they could remember an answer, rather than making use of the given information, centred their arguments around the concept that members of the same species would be able to produce fertile offspring. Although true, such answers did not actually explain *why* this was so. Many who did attempt to discuss chromosome numbers were often insufficiently precise. Better candidates referred to diploid (or even polyploid) parent plants whose chromosomes could form bivalents in meiosis and hence produce haploid gametes. Even here, some seemed to think that merely having an even number of chromosomes was sufficient, failing to realise that, unless the chromosomes could all pair up in meiosis, this would avail nothing. Very few candidates appreciated that a copy of *all* the genetic information would need to be present in *each* gamete if viable offspring were to result from their fusion.

Q52.

Most candidates could not apply the information given in the stem of the question in (b) and therefore limited the marks gained to two.

(a) The majority of candidates gained one mark for naming a process but poor expression marred the answers of weaker candidates, in particular the distinction between allele and gene and the concept of different combinations of alleles.

(b) Candidates did not have the confidence to answer the question set and gave all possible genotypes and phenotypes. The common error was to produce two different gametes from the male, as the vast majority of candidates failed to use the information given under the diagram in the stem of the question.

Q53.

Most candidates were able to apply their knowledge and gained credit but poor expression marred the answers of the weaker candidates.

(a) The role of RNA polymerase was not well known. There were very few answers worthy of credit. The majority of candidates described the role of RNA polymerase as catalysing complementary base pairing. Responses were often ambiguous and it was not clear if the enzyme was joining nucleotide to nucleotide along the

backbone. In contrast, the vast majority could name the ribosome.

(b) The majority of candidates gained both marks.

(c) Well answered.

(d) Most candidates recognised the amino acid alanine. Very few candidates scored full marks in part (ii) and a substantial minority gained only one. The most common point to gain credit was reference to mutation 1 having no effect. Weaker candidates described the change in the DNA triplet as causing a different amino acid to be made as the result of mutation 2 and then failed to relate description of the change to the polypeptide in terms of shape or tertiary structure.

Q54.

There were very few maximum marks for this question with most candidates scoring two or three.

(a) The majority of candidates recognised the importance of meiosis in halving chromosome content and scored one mark. Many then could not complete the story with sufficient precise detail to gain any further credit.

(b) Most candidates realised each gamete would contain two chromosomes. Many seemed unaware of the significance of homologous pairs and were content to draw any combination of two chromosomes and failed to gain the second mark.

(c) There was a disappointing number of correct responses. The most common error was to double the number of chromosomes during mitosis. Many candidates seemed unaware that mitosis maintains chromosome number even when the cell involved is haploid.

(d) The vast majority of candidates gained this mark.

Q55.

Most candidates were able to score at least two marks on this question. However, very few candidates obtained maximum marks.

(a) (i) Although most candidates gained this mark, weaker candidates often had alleles of the same gene in one gamete.

(ii) Most candidates gained this mark, displaying a good understanding of the segregation of homologous chromosomes.

(iii) This proved to be an effective discriminator with only the best candidates clearly relating the presence of one copy of the T allele to the separation of chromatids. Although some candidates did refer to ‘chromosomes splitting’ demonstrating some knowledge of the process, many erroneously referred to crossing over.

(b) (i) Most candidates obtained two marks by referring to crossing over and the exchange of alleles. Few candidates obtained the third mark for identifying where crossing over would occur to produce the new combination of alleles shown.

(ii) Many candidates simply stated ‘crossing over did not occur all the time’ rather than clearly stating it was infrequent.

Q56.

This question produced a very wide spread of marks. Candidates frequently failed to gain marks through their inability to select appropriate information to answer the specific question asked. This particularly applied to part (b) (ii). Again, inaccurate use of terminology compromised the marks gained by many candidates.

(a) The majority of candidates gained the mark, UV light being the most popular response. Vague reference to cigarettes or tar, without further qualification, did not gain credit.

(b) In part (i), most candidates recognised the loss of a base and the frame shift occurring in consequence and gained both marks. Weaker candidates confused the change in base sequence with amino acid sequence, seemingly unaware of the distinction between the two. Very few candidates scored full marks in part (ii) and a substantial minority gained only one. The most common point to gain credit was reference to the enzyme.s inability to function. Weaker candidates wrote in general terms about enzyme function and did not specifically refer to enzyme 1 in the question. Again, as in section (i), some candidates confused the structure of a gene with the structure of a protein and gained no marks. The change to the mRNA was rarely mentioned and descriptions of alteration to tertiary shape were too often vague and imprecise to gain credit. In part (iii), any candidates interchanged the lilac and blue colour when completing the table. Errors also included ‘no pigment’ and ‘albino’ for the unlabelled white petal.

Q57.

There were some excellent answers to this question with the most able candidates gaining maximum marks. Weaker candidates were often able to obtain some marks in parts (b) and part (c).

Surprisingly, explaining what is meant by an allele proved to be quite difficult for many candidates. There were many vague references to an allele ‘being part of a gene’ or ‘being a gene for eye colour’. The context provided by candidates often suggested that alleles were different genes.

As in previous years a significant number of candidates confused DNA replication with transcription. It was often difficult to give credit in these answers, except for the first mark point referring to hydrogen bonds being broken. As in previous years, there was considerable confusion concerning the role of DNA polymerase. However, naming the enzyme itself was credited in this answer to avoid a double penalty for incorrectly describing its role in question 6(b). There was also some confusion between bases and nucleotides. Nevertheless, better candidates had little difficulty obtaining maximum marks, some answers displaying knowledge well beyond the requirements of this specification. Weaker candidates often gained marks for referring to semi-conservative replication and

complementary base pairing.

In part (c) the effects of a mutation involving a deletion or a substitution were generally well known. Most candidates referred to ‘frame shifts’ and appreciated the degenerate nature of the genetic code. However, some weaker candidates referred to ‘amino acids in the DNA’ being deleted or substituted. Better candidates had little difficulty gaining maximum marks.

Q58.

This question was generally well answered by the majority of candidates, although few candidates gained maximum marks.

(a) In part (i), many candidates incorrectly drew a total of eight rather than sixteen chromatids. However, the vast majority did gain one mark for drawing a spindle. In part (ii), most candidates gained one mark by drawing four separate chromosomes. Only better candidates obtained the second mark by clearly showing that the four chromosomes represented one from each homologues pair.

(b) This caused few problems for the majority of candidates, many obtaining both marks. Candidates who obtained a single mark usually referred to the importance of meiosis in maintaining the chromosome number from generation to generation, but failed to mention that meiosis results in the production of haploid cells.

Q59.

Only the better candidates scored well on this question, with just a few scoring full marks.

(a) Only a minority of candidates were able to complete the diagram correctly. There was a large variety of incorrect answers, with many candidates having two alleles of the same gene on one chromosome or submitting incomplete answers.

(b) Many candidates correctly described the pair of chromosomes as a bivalent, others did not answer the question set and therefore gave chiasma, or crossing over as the answer.

(c) Surprisingly, this was answered quite well after the failure to complete the diagram correctly in (a), with many candidates scoring at least one mark. The most common incorrect answer given was that all four possible combinations could be formed. There were also many candidates who gave genotypes of gametes, which contained two alleles of the same gene.

(d) Most candidates correctly named two processes which would result in genetic variation. Few, however, went on to explain how they contributed to genetic variation. Most just described what the process involved, making no link to new alleles, new allele combinations or shuffling of maternal and paternal chromosomes. Alternative terms, such as ‘random segregation’, were often used to describe independent assortment of chromosomes. These terms often failed to explain clearly the process involved. These terms could not be given credit unless further explanations were present which described the process accurately.

Q60.

(a) The examiners were looking for answers that demonstrated candidates’ understanding of the importance of meiosis in eukaryotic organisms that have sexual reproduction in their life cycle. Meiosis produces haploid cells that contain one full set of chromosomes or genes. This results in the maintaining of the diploid

(or a constant) number of chromosomes after fertilisation. Many candidates obtained one mark for statements about the production of haploid cells. A minority obtained a second mark, usually for references to fertilisation producing diploid cells. Many candidates appeared to think that the main (or only) purpose of meiosis is to produce genetic variation through crossing over and independent assortment. One mark was awarded for clear references to independent assortment, since this does rely on one chromosome from each homologous pair going to each cell formed.

(b) This part of the question was poorly answered by many candidates and brought to light many common misconceptions and confusions.

(i) A majority of candidates correctly identified the diploid number as 4. The commonest wrong answer was 8, implying that pairs of chromosomes were shown at Stage **A**, rather than sister chromatids attached at centromeres.

(ii) To halve the chromosome number, meiosis must have taken place between Stage **A** and Stage **B**. There were quite a lot of correct answers but some were spoilt by implications, or statements, that meiosis was taking place at Stage **B**.

(iii) The best answers came from candidates who used the information and terminology from the diagram of the life cycle. They noted that the zygote must receive two chromosomes from each gamete. They then pointed out that the gamete-producing plant had two chromosomes and thus the gametes must be produced by mitosis. Very many candidates insisted that the gametes must be produced by meiosis, even those who correctly explained in (ii) that meiosis happened between Stage **A** and Stage **B**.

Q61.

(a) This question revealed an unexpected lack of understanding of how crossing over actually results in variation, despite the fact that is regularly cited as a cause. Very few referred to the exchange of parts of chromatids, and even fewer pointed out that variation resulted when sections with different alleles were recombined. Crude diagrams often indicated that it was thought that alleles of the same gene were at different loci. The only mark obtained by the majority was for the general principle that ‘genes’ are exchanged, which was credited despite the lack of precision. Many candidates revealed major misconceptions, such as that genes are exchanged at the point where ‘chromosomes’ cross over, and that as a result of crossing over cells ‘contain genes from different gametes’.

(b) (i) Most candidates did not appreciate that the question was asking about variation within each store, rather than the change over time. Many, therefore, gave mutation as an answer. Those who did try to explain continuous variation within a store of seeds explained it more often in terms of an environmental factor, which was credited, than there being several genes controlling length. Those who mentioned an environmental factor rarely went on to explain how it would result in variation.

(ii) Because only a few candidates understood that the variation involved many genes, each possibly with two or more alleles, there were few explanations which referred to the longer seeds having a higher proportion of alleles favouring length, with this proportion increasing as a result of regular selection. Most gave a vague general account of selection, often couched in terms which indicated scant regard for the role of seeds in the life of plants. It was frequently suggested that the seeds adapted to conditions, reproduced and then passed on their genes. A significant number of candidates

misinterpreted the graph, and thought that the mean length of the seeds increased up to AD 1000 and then decreased again.

Q62.

Very few candidates achieved all five marks for this question, but the more able candidates were able to demonstrate a sound understanding of genetics in relation to the conservation of breeding in plants. Many candidates confused the concept of species conservation with breeding programmes, giving answers about the process of evolution rather than concentrating on aspects of selective breeding.

(a) Many candidates gained a mark for explaining that old varieties of a plant could be used for producing new varieties, but few made any reference to the useful alleles they may contain. Often answers suggested the old and rare varieties could be used if the species became extinct, which suggested a poor understanding about the concept of extinction.

(b) (i) This was often the only mark achieved on this question by candidates.

(ii) Very few candidates seemed to appreciate that the question was asking about the advantage of crossing plants to obtain seeds for the seed collection and many took it as a reference to maintaining the viability of populations in the wild. As a result, many candidates discussed the advantage of crossing plants to improve evolutionary successes rather than to consider selective breeding. A few candidates did provide good descriptions about using crosses to avoid inbreeding, the deleterious effects of homozygous loci and to maintain genetic variation. A common misconception was observed in answers which referred to using selective breeding to increase the size of a gene pool or produce new alleles. This represented a poor understanding about the concept of mutation and the inappropriate use of some terminology used commonly in explaining the process of evolution.

Q63.

Many candidates had obviously learnt the importance of meiosis in organisms that reproduce sexually but most were unable to relate this to a diagram of a life cycle.

(a) Many candidates scored two marks, usually because they understood that meiosis halves the chromosome number and fertilisation restores the diploid number. Fewer obtained a third mark for clearly stating that meiosis results in the chromosome number remaining constant from one generation to the next. Some candidates obtained only one mark, because they wrote at length about the production of genetic variation by crossing over and independent assortment. It was not uncommon for candidates' answers to be marred by vague statements such as 'keeping the right chromosomes'.

(b) Very few candidates put the 'M' in the correct place between the spore-producing plant (marked 2n) and the spore (marked n). Most put it either between the spore and the gamete-producing plant, or between the gamete-producing plant and the gametes. This was even true of some candidates who had given very good answers to part (a).

Q64.

Quite a large number of candidates failed to perform well on this question because of poor use of language and terminology in parts (a) and (b).

(a) Most candidates obtained the mark for the idea that the mutation alters the amino acid sequence in Factor VIII protein. Good candidates then related this to a change in the tertiary structure (or three-dimensional shape) of the protein. Poorer candidates made vague references to changes in the protein, or it not being able to work.

(b) Most candidates scored one mark for the idea that the faulty Factor VIII leads to a failure of the activation of Factor X and blocking of the clotting pathway. Fewer candidates were able to give a reasonable description of Factor X not being activated, because non-functional Factor VIII cannot work with Factor IX. Weaker candidates misunderstood the diagram and thought that Factor IX and Factor VIII were used to make Factor X.

(c) Only the best candidates understood that the blood from each haemophiliac contained the functional factor that the other lacked. Some who understood this only gained one mark because they simply stated that the mixture contained both factors. The examiners wanted a clear statement for the second mark that blood from the boy with faulty Factor IX contained working Factor VIII and the blood from the haemophiliac with faulty Factor VIII contained working Factor IX. A common misconception was that the mutations to the genes for Factor VIII and Factor IX would produce proteins that were able to interact, because they were both the products of mutation.

Q65.

(a) This proved to be a discriminating question with few candidates giving the correct diploid number of chromosomes. Common incorrect answers included 46, 23, 12 and 3.

(b) (i) Most candidates correctly referred to crossing over or a chiasma (although many used the plural, when the diagram showed that a single event was present). A common misconception was observed when candidates described chromosome replication happening in meiosis and also that chromatids pair together.

(ii) A significantly high proportion of candidates failed to describe the movement of chromosomes in a way that distinguished meiosis from mitosis. Often, it was difficult to determine whether candidates meant chromosomes were separating from single pairs. Poor expression cost marks for some candidates, such as describing the separation of whole bivalents or the movement of pairs of chromatids.

(c) (i) Most candidates found this difficult. A common error was to label sister chromatids with different alleles.

(ii) Very few candidates achieved both marks for this question. Interestingly, a significant number of candidates who were able to give correctly the gametes from a dihybrid cross in the answer to question 5(c) could not extend the principle to three alleles in this question. Often, candidates correctly understood that these gametes contained three different alleles, but could not give the correct total for the number of different types of these gametes.