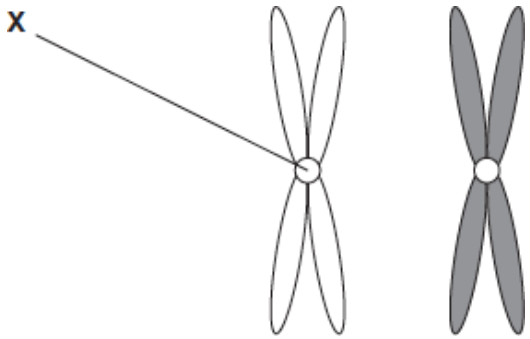
Q1. (a) **Figure 1** shows one pair of homologous chromosomes.

Figure 1



(i) Name **X.**

.....

(1)

(ii) Describe the role of **X** in mitosis.

.....

.....

.....

.....

.....

(2)

(iii) Homologous chromosomes carry the same genes but they are **not** genetically identical.Explain why.

.....

.....

.....

(1)

(b) **Figure 2** shows three pairs of homologous chromosomes in a cell at the end of cell division.

Figure 2

(i) The appearance of each chromosome in **Figure 2** is different from those shown in **Figure 1.** Explain why.

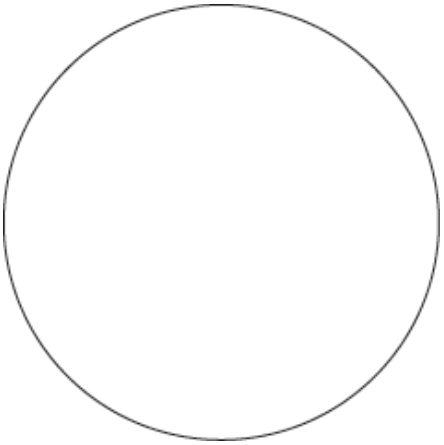
.....

.....

.....

(1)

(ii) Complete the diagram to show the chromosomes in one cell that could be produced from the cell in **Figure 2** as a result of meiosis.



(2)

(iii) Other than independent segregation, give **one** way in which meiosis allows the production of genetically different cells.

.....

.....

.....

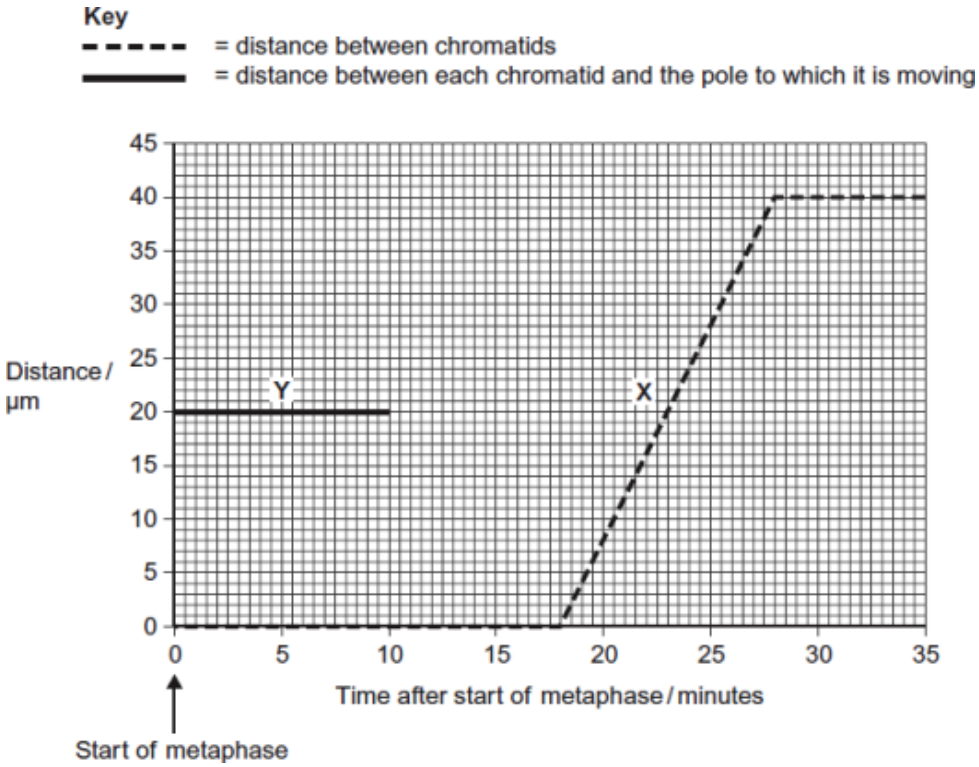
(1)

(Total 8 marks)

Q2. (a) Describe how DNA is replicated.

(6)

(b) The graph shows information about the movement of chromatids in a cell that has just started metaphase of mitosis.



(i) What was the duration of metaphase in this cell?

☐ minutes

(1)

(ii) Use line **X** to calculate the duration of anaphase in this cell.

☐ minutes

(1)

(iii) Complete line **Y** on the graph.

(2)

(c) A doctor investigated the number of cells in different stages of the cell cycle in two tissue samples, **C** and **D.** One tissue sample was taken from a cancerous tumour. The other was taken from non-cancerous tissue. The table shows his results.

	Percentage of cells in each stage of the cell cycle	
Stage of the cell cycle	Tissue sample **C**	Tissue sample **D**
Interphase	82	45
Prophase	4	16
Metaphase	5	18
Anaphase	5	12
Telophase	4	9

(i) In tissue sample **C**, one cell cycle took 24 hours. Use the data in the table to calculate the time in which these cells were in interphase during one cell cycle. Show your working.

Time cells in interphase ..... hours

(2)

(ii) Explain how the doctor could have recognised which cells were in interphase when looking at the tissue samples.

.....

.....

.....

(1)

(iii) Which tissue sample, **C** or **D**, was taken from a cancerous tumour? Use information in the table to explain your answer.

.....

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(2)

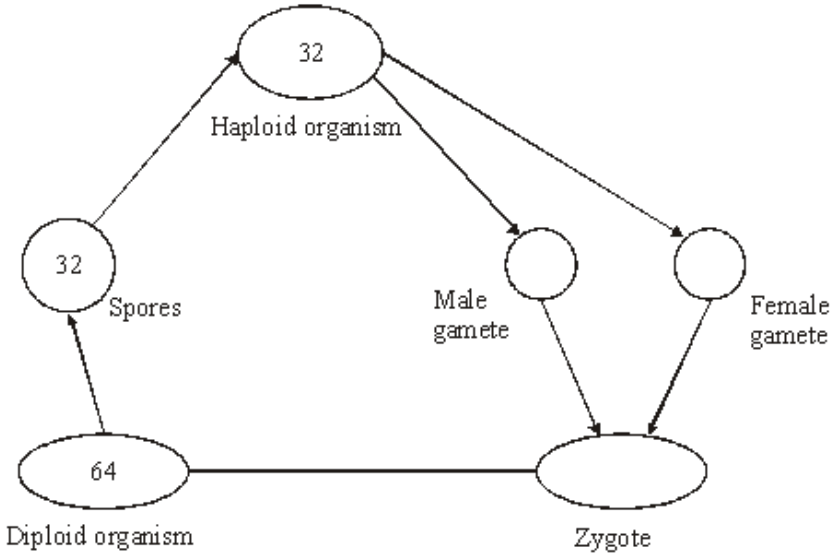
(Total 15 marks)

Q3. (a) Complete the table to describe some of the events during the cell cycle.

Stage of cell cycle	Main event which takes place
Metaphase	
	Chromosomes coil and shorten
	Daughter chromosomes move to poles of the cell
S-phase	
	Nuclear envelope re-forms

(5)

(b) The diagram shows the life cycle of an organism. The numbers show how many chromosomes are present in one cell at each stage of the life cycle.



(i) Name the type of cell division that must be involved in producing the spores.

.....

(1)

(ii) How many chromosomes are there in a male gamete from this organism?

.....

(1)

(Total 7 marks)

Q4. (a) Explain how the structure of DNA is related to its functions.

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(Extra space) .....

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(6)

Scientists investigated three genes, **C**, **D** and **E**, involved in controlling cell division.
They studied the effect of mutations in these genes on the risk of developing lung cancer.

The scientists analysed genes **C**, **D** and **E** from healthy people and people with lung cancer.

- If a person had a normal allele for a gene, they used the symbol N.
- If a person had two mutant alleles for a gene, they used the symbol M.

They used their data to calculate the risk of developing lung cancer for people with different combinations of N and M alleles of the genes. A risk value of 1.00 indicates no increased risk.
The following table shows the scientists' results.

Gene C	Gene D	Gene E	Risk of developing lung cancer
N	N	N	1.00
M	N	N	1.30
N	N	M	1.78
N	M	N	1.45

N = at least one copy of the normal allele is present
M = two copies of the mutant allele are present

(b) What do these data suggest about the relative importance of the mutant alleles of genes **C**, **D** and **E** on **increasing** the risk of developing lung cancer? Explain your answer.

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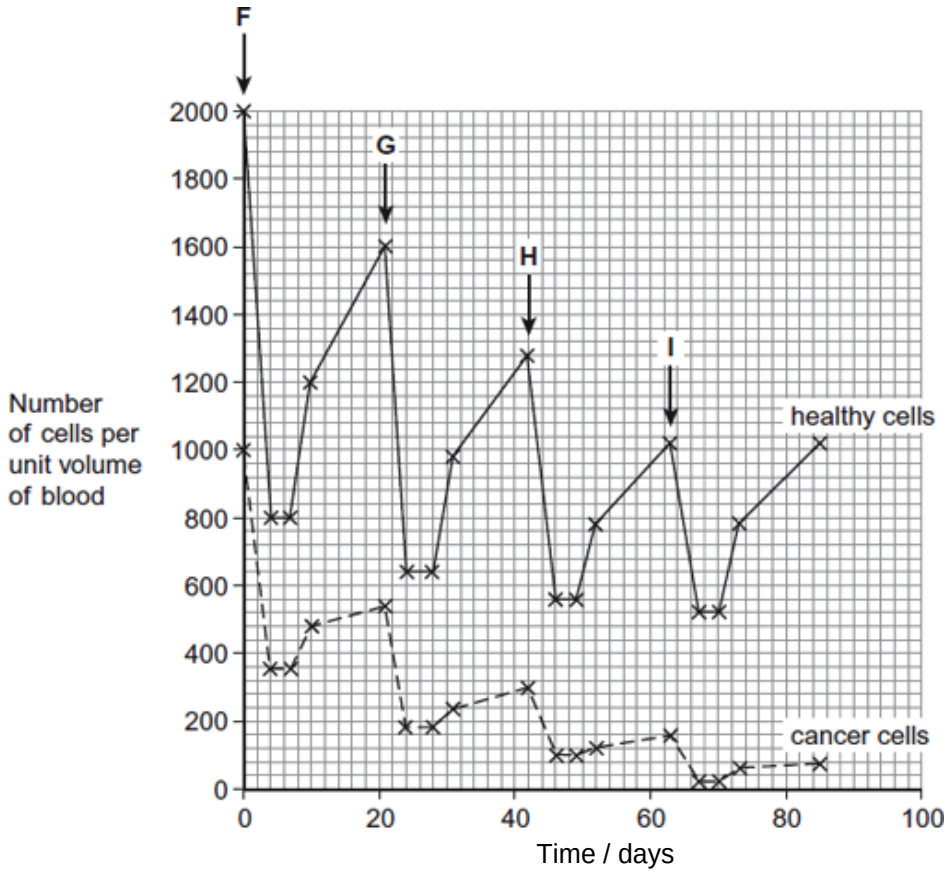
(3)

Chemotherapy is the use of a drug to treat cancer. The drug kills dividing cells.
The figure below shows the number of healthy cells and cancer cells in the blood of a patient receiving chemotherapy. The arrows labelled **F** to **I** show when the drug was given to the patient.



(c) Calculate the rate at which healthy cells were killed between days 42 and 46.

..... cells killed per unit volume of blood per day

(1)

(d) Describe similarities and differences in the response of healthy cells and cancer cells to the drug between times **F** and **G**.

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(Extra space) .....

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(3)

(e) More cancer cells could be destroyed if the drug was given more frequently.

Suggest why the drug was **not** given more frequently.

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(2)
(Total 15 marks)

Q5. (a) The drawing shows a stage of mitosis in an animal cell.

(i) Name this stage of mitosis.

.....

(1)

(ii) Describe and explain what happens during this stage which ensures that two genetically identical cells are produced.

.....

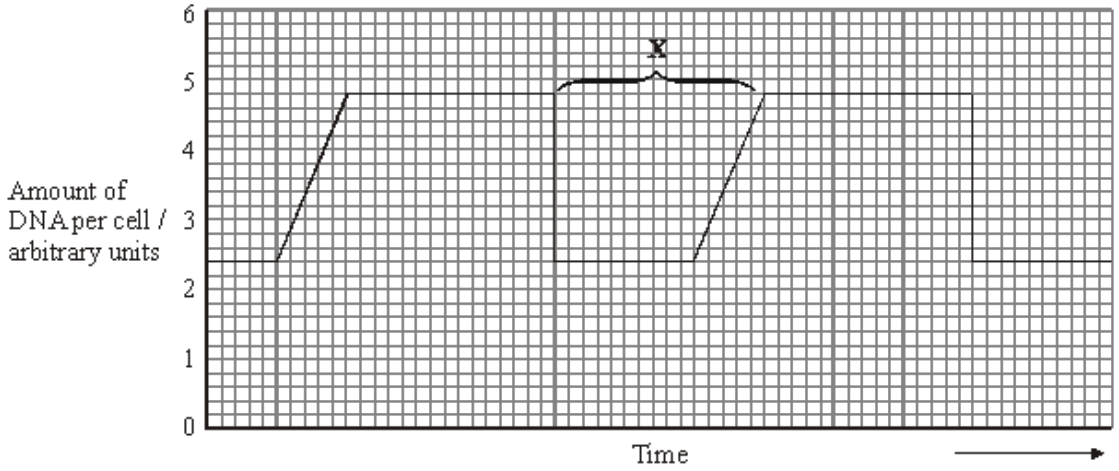
.....

.....

.....

(2)

(b) The graph shows the relative amounts of DNA per cell during two successive cell divisions in an animal.



(i) What stage of the cell cycle is shown by **X**?

.....

.....

(1)

(ii) Apart from an increase in the amount of DNA, give **one** process which occurs during stage **X** which enables nuclear division to occur.

.....

.....

(1)

(iii) How many units of DNA would you expect to be present in a gamete formed in this animal as a result of meiosis?

.....

(1)

(c) The table shows the average duration of each stage of the cell cycle in the cells of a mammalian embryo.

Stage	Mean duration/ minutes
Interphase	12
Prophase	50
Metaphase	15
Anaphase	10
Telophase	42

Give **one** piece of evidence from the table which indicates that these cells are multiplying rapidly.

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(1)

(Total 7 marks)

Q6. (a) Describe what happens to chromosomes in meiosis.

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(6)

(b) Meiosis results in genetic variation in the gametes which leads to variation in the offspring formed by sexual reproduction. Describe how meiosis causes this variation and explain the advantage of variation to the species.

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(5)

(c) An old form of wheat, emmer wheat (*Triticum turgidum*), has a diploid chromosome number of 28 (2n = 28). A wild wheat, einkorn wheat (*Triticum tauschii*), has a diploid chromosome number of 14 (2n = 14). These two species occasionally crossed and produced sterile hybrid plants. Due to an error during cell division, one of these hybrid plants formed male and female gametes with 21 chromosomes. Fusion of these gametes resulted in viable offspring. These plants were a new species, *Triticum aestivum* (2n = 42), our modern bread wheat.

(i) How many chromosomes would there have been in each of the cells of the hybrid plant produced by crossing *Triticum turgidum* with *Triticum tauschii*?

.....

(1)

(ii) Explain why *Triticum aestivum* is fertile while the majority of hybrid plants were not.

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(3)
(Total 15 marks)

M1. (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]

M2. (a) 1. Strands separate / H-bonds break;

*1. **Q** Neutral: strands split*

1. Accept: strands unzip

2. DNA helicase (involved);

3. Both strands / each strand act(s) as (a) template(s);

4. (Free) nucleotides attach;

4. Neutral: bases attach

4. Accept: nucleotides attracted

5. Complementary / specific base pairing / AT <u>and</u> GC;

6. DNA polymerase joins nucleotides (on new strand);

6. Reject: if wrong function of DNA polymerase

7. H-bonds reform;

8. Semi-conservative replication / new DNA molecules contain one old strand and one new strand;

8. Reject: if wrong context e.g. new DNA molecules contain half of each original strand

6 max

(b) (i) 18;

Do not accept 17.5

1

(ii) 10;

1

(iii) 1. Horizontal until 18 minutes;

Allow + / - one small box

2. (Then) decreases as straight line to 0 μm at 28 minutes;

2. Allow lines that start from the wrong place, ending at 0 at 28 minutes

2

(c) (i) Two marks for correct answer of 19.68 or 19.7;;

Accept 19hrs 41mins

One mark for incorrect answers in which candidate clearly multiplies by 0.82;

Allow one mark for incorrect answers that clearly show 82% of 24 (hours)

2

(ii) 1. No visible chromosomes / chromatids / visible nucleus;

1

(iii) **D** (no mark)

1. Lower % (of cells) in interphase / higher % (of cells) in mitosis / named stage of mitosis;

1. Accept: 'less' or 'more' instead of '%'

1. Do not accept: higher % (of cells) in each / all stage(s)

2. (So) more cells dividing / cells are dividing quicker;

2. Accept: uncontrolled cell division

*2. Do not award if Tissue **C** is chosen*

2

[15]

M3. (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]

M4. (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]

M5. (a) (i) anaphase;

1

(ii) sister / identical <u>chromatids</u> (separate);
move to opposite poles / ends / sides;

2

(b) (i) interphase;

1

(ii) <u>ATP</u> production / protein synthesis / replication of centrioles;

1

(iii) 1.2;

1

(c) short duration of <u>interphase</u>;

1

[7]

M6. (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]

E1. 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'.

E2. (a) This proved to be an excellent discriminator. Just over 70% of students scored at least half marks. Many were aware of the breaking of hydrogen bonds, the role of DNA helicase and complementary base pairing. However, it was only better responses that referred to the attachment of free nucleotides (as opposed to free bases) and both strands acting as templates. DNA polymerase was frequently mentioned but its role was often confused in weaker responses. This enzyme joins nucleotides on the newly formed strand, it does not cause complementary base pairing. Some students negated the mark for semi-conservative replication through poor expression. The most common examples of this included 'each new DNA molecule contains half of the original strand' and 'new strands contain half of the original strand'. Very few students wrote about hydrogen bonds reforming.

(b) (i) Two-thirds of students correctly gave the duration of metaphase as **18** minutes.

(ii) 80% of students correctly calculated the duration of anaphase as **10** minutes.

(iii) This proved to be a good discriminator. Most students gained one mark for extending the horizontal line to 18 minutes, or decreasing this line to 0 μm at 28 minutes. Weaker responses often showed the horizontal line increasing.

(c) (i) 70% of students correctly calculated the time the cells were in interphase as **19.7** hours. Very few students gained the principle mark for multiplying by 0.82.

(ii) Just under half of students were aware that cells in interphase could be detected by a visible nucleus or the inability to see chromosomes. Weaker responses typically referred to the inability to see *DNA* or that the cells in interphase would contain twice the amount of chromosomes.

(iii) This proved to be a good discriminator. Most students were aware that cancer cells divide more rapidly than healthy cells. However, it was only better responses that referred to data in the table and correctly linked this to tissue **D**. Some students wrongly thought that more cells in interphase meant more rapid cell division due to increased DNA replication.

E3. 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.

E4. 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.

E5. Although this question produced a wide range of marks, many candidates were able to obtain at least three of the marks available.

(a) (i) The vast majority of candidates correctly named this stage as anaphase.

(ii) Although most candidates described the separation of the chromatids towards the two poles of the cell, only better candidates referred to ‘sister chromatids’ or indicated that the chromatids would be identical. A significant minority of candidates mistakenly referred to the separation of homologous pairs of chromosomes.

(b) (i) Most candidates correctly identified stage X as interphase.

(ii) This proved more difficult with many candidates simply referring to the replication of 'cell organelles'. Correct responses required specific references to the processes during interphase, which enable nuclear division to occur, such as ATP synthesis, protein synthesis and, in animal cells, replication of cell organelles.

(iii) It was surprising to find so many candidates giving the incorrect answer of 1.1, having read the graph as 2.2 units rather than 2.4. Another common incorrect response was 23 (i.e. chromosomes), due to candidates not reading the question carefully.

(c) Although as expected a number of candidates suggested that the short time spent in anaphase was significant, it was pleasing to find that many candidates correctly referred to the short duration of interphase.

E6. (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.