2018 Cell and Nuclear Division STQ MS

2018 / H2 / ACJC PRELIM / P2 Q6 (Mutations)

1 Many diseases arise due to gene mutations and/or chromosomal aberrations.

(a) Distinguish between gene mutations and chromosomal aberrations.

	Gene mutation	Chromosomal aberration
1. Definition	**1a. Change in nucleotide sequence**	**1b. Change in chromosomal structure or number;**
2. No. of genes affected	**2a. Affects a single gene**	**2b. Usually affects multiple genes (because involves a segment or an entire chromosome hence);**
3. Mechanisms	**3a. Substitution, deletion or addition of nucleotides (any 2)**	**3b. Translocation, deletion or inversion of chromosomal structures or non-disjunction events during nuclear division (any 2);**

Any 2@1m each

[2]

Fig. 6.1 shows an error occurring during meiosis II.

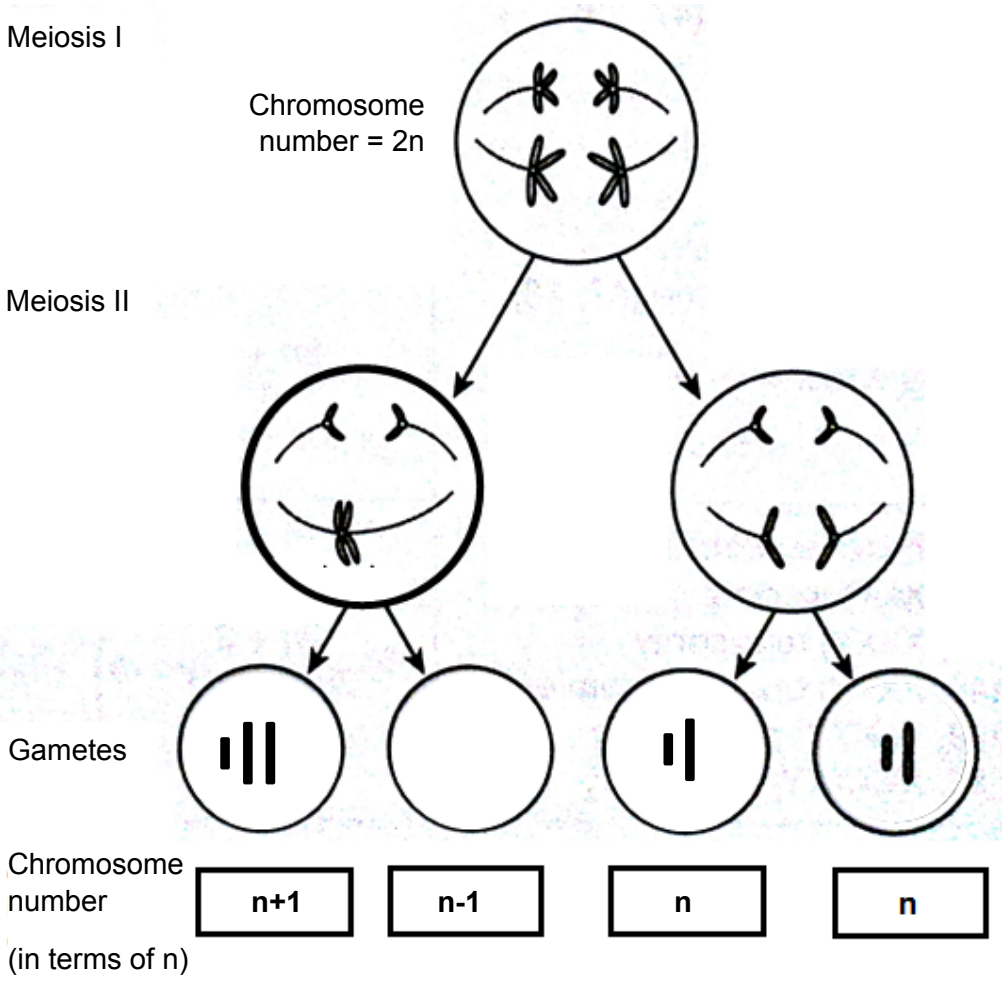


Fig. 6.1

(b) (i) Complete Fig. 6.1 with the correct chromosome structures and chromosome number (in terms of n) in the gametes. [2]

(ii) Explain the error shown in Fig. 6.1.

1. **Non-disjunction caused by the failure of sister chromatids to separate during anaphase II;**
2. **due to problems in the shortening of the spindle fibres/ centromeres fail to divide;**

[2]

(iii) Predict the chromosomal number (in terms of n) in each of the four gametes if a similar error had occurred in meiosis I instead of meiosis II.

n+1, n+1, n-1, n-1

[1]

(c) Such errors can occur during mitosis too. Comment on whether this would lead to changes in the gene pool of a population.

1. **If this occurs in somatic cells only / does not affect the germ line cells, it only affects the individual / not passed down to offspring, so no effect on overall gene pool in population; OR**
2. **If this occurs in germ line cells, it will be passed to gametes, and possibly to offspring, so gene pool of a population will be affected;**
3. **If this occurs in zygotic / embryonic stem cells, the whole individual will be affected, so gene pool of a population will be affected;** [1]

[Total: 8]

2018 / H2 / EJC PRELIM / P2 Q3 (Stem Cells)

3 Bone marrow contains stem cells that divide by mitosis to form blood cells. The fate of a stem cell was tracl and it was recorded that during the observed duration the stem cell divided asymmetrically each time.

Fig. 3.1 shows changes in the mass of DNA in a human stem cell from bone marrow during three cell cycles

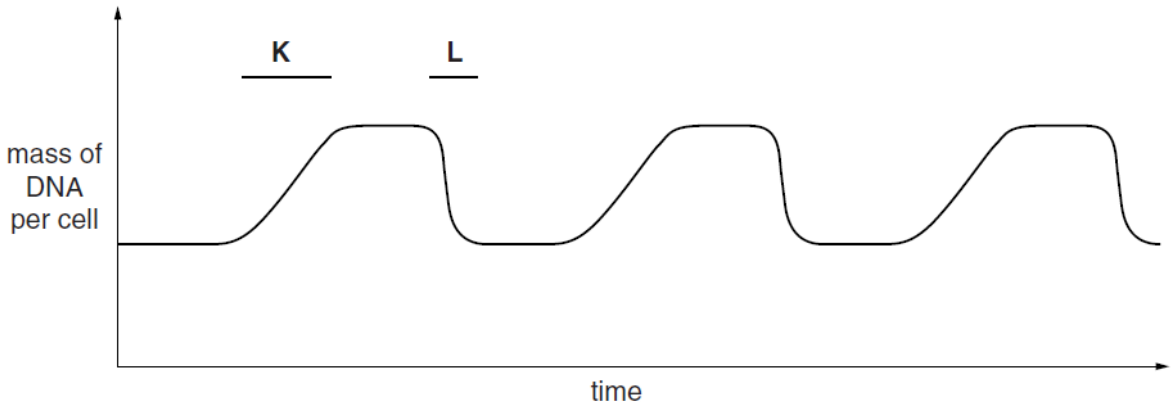


Fig. 3.1

(a) With reference to the information provided above,

(i) Describe what happens to bring about the changes in the mass of DNA per cell at time period **K** an at time period **L**.

K ……

……

L ……

……..[2]

1. **K: DNA replication/ synthesis during S phase of interphase;**
2. **L : cytoplasmic division during cytokinesis;**

(ii) State one function of these stem cells undergoing the above type of cell division.

……

……..[1]

1. **To replace blood cells that die due to injury/ wear and tear/ disease;**

(iii) The process of meiosis is significant to natural selection in evolution.

Explain this significance.

……

……

……

……..[2]

1. **Meiosis gives rise to genetically different haploid gametes;**
2. **During Prophase I of meiosis, crossing over between chromatids of homologous chromosom would give rise to different combinations of alleles**

OR

During Metaphase I and Anaphase I, independent assortment and separation of homologous chromosomes would give rise to different combinations of maternal and paternal chromosomes;

3. **Resulting in genetic variation in diploid organisms leading to different phenotypes/ variation phenotypes;**

4. **those with advantageous phenotypes are selected for, resulting in change in allele frequency in the population over time;**

(1 and 2 + 3 / 4 OR 1+ 3 and 4)

A bone marrow cell was extracted and observed under the electron micrograph shown in Fig. 3.2. The stud focused on an organelle which he described as having "an envelope surrounding genetic material contain both darker and lighter stained patches, distinct from the site where ribosomal subunits were assembled".

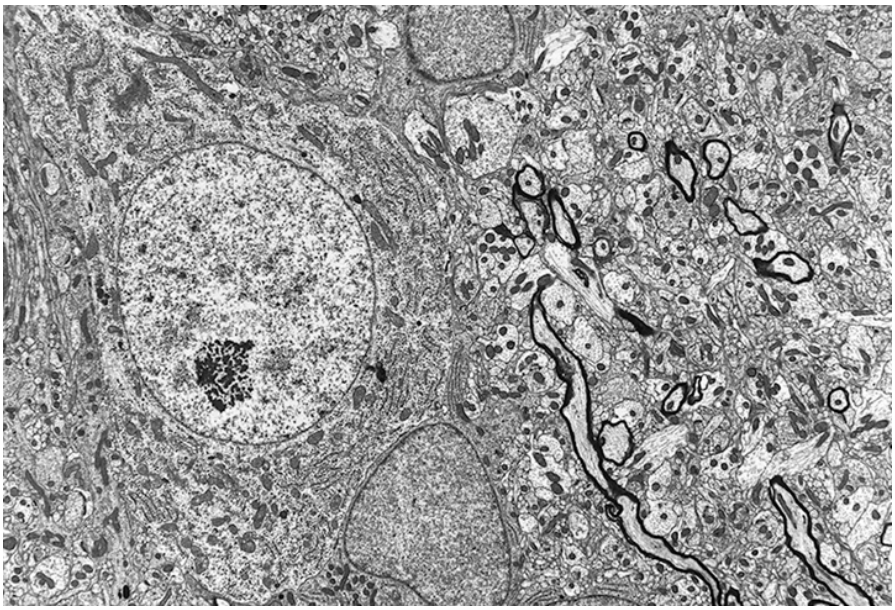


Fig. 3.2

(b) Explain the significance of the "darker and lighter stained patches" that the student referred to, in a undergoing differentiation.

……

……

……

……

……

……[3]

1. **The darker stained patches are heterochromatin while the lighter stained patches are euchromat**
2. **The genes that are found within heterochromatin are transcriptionally inactive/not expressed wh the genes found in euchromatin are transcriptionally active/are expressed;**
3. **Thus producing specific proteins that allow the differentiated cell to perform specific functions;**

The use of embryonic stem cells (ESCs) for stem cell therapy and research is controversial and considered

many people as unethical. Scientists have circumvented this issue through the use of induced pluripotent stem cells (iPSCs) as an alternative to ESCs.

Fig. 3.3 summarises the procedure for obtaining iPSCs and its use.

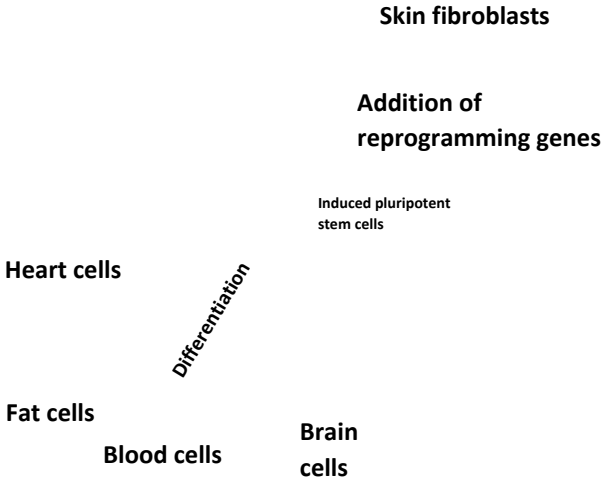


Fig. 3.3

(c) Explain why the use of iPSCs is preferred over ESCs.

……

……

……

……[2]

1. **Since iPSCs can be derived directly from adult tissues/specialised somatic cell/ skin cells, it do not destroy any human embryos unlike ESCs;**
2. **iPSCs from adult/specialised somatic cell/ skin cell can be easily obtained without risk to the donor, whereas obtaining the embryo to isolate ESCs is more invasive;**
   (R: easy vs difficult because no elaboration)
3. **In contrast to ES cells extracted from human embryos, iPSCs derived from a patient's own ce would open the possibility of generating patient-specific cells, which will not be rejected by t immune system upon transplantation; (A: idea of iPSCs obtained from self vs embryos not fr self thus contain antigens that will be rejected by immune system);**
4. **Sources of obtaining iPSCs is more easily accessible compared to the source of obtaining ESC obtaining the embryo;**
   (any one, answer must make comparison with ESCs)

[Total:

2018 / H2 / JJC PRELIM / P2 Q7

3 Fig. 7.1 shows an electron micrograph of a chromosome in prophase II.

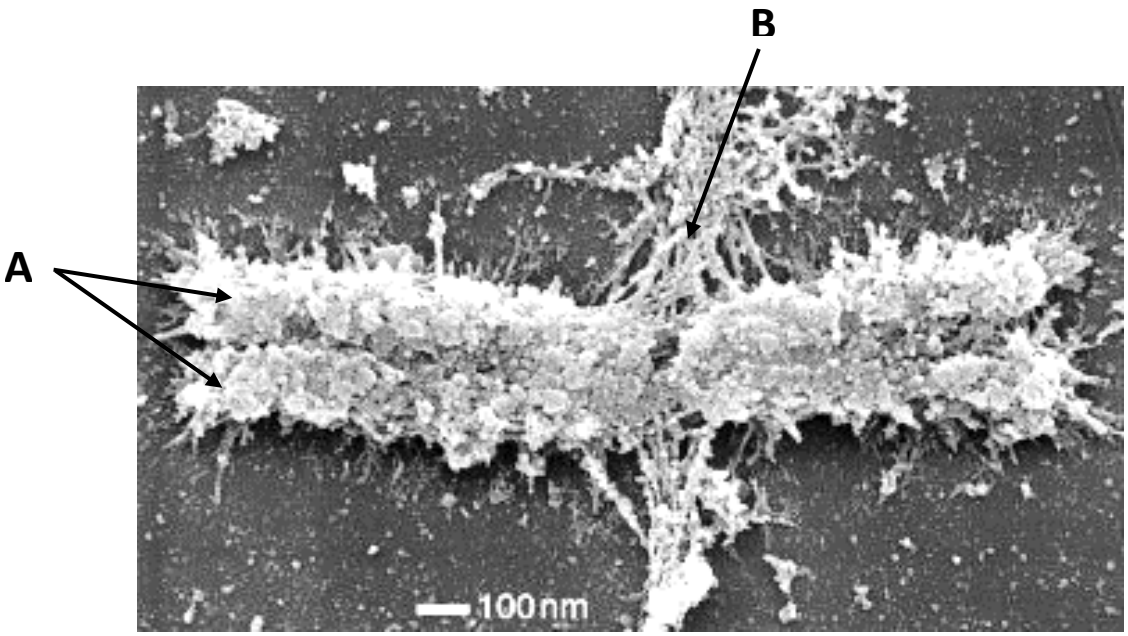


Fig. 7.1

(a) Name the structures **A** and **B**. [2]

A: (a pair of recombinant) chromatids ; [R: sister chromatids / chromosomes]
B: (kinetochore) spindle fibre ;

(b) Explain why the chromosome occurs as a double structure. [2]

1. **<u>Semi-conservative DNA replication</u> occurred during S phase of interphase, producing <u>two identical DNA molecules</u> ;**
2. **which coil and <u>condense</u> during prophase I of meiosis I to form a chromosome consisting of <u>2 (identical) sister chromatids</u> <u>held together at the centromere</u> before crossing over occurred. ;**

The risk of mis-segregation of chromosomes increases with age among women. This can lead to aneuploid embryos. Fig. 7.2 shows an oocyte undergoing nuclear division with mis-segregated and lagging chromosomes.

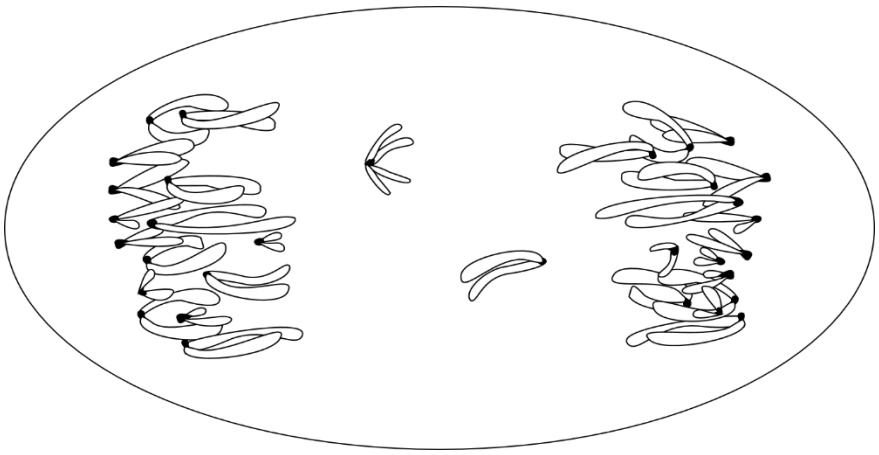


Fig. 7.2

(a) Identify the stage in meiosis as shown in Fig. 7.2. [1]

Anaphase II ;

(b) With reference to Fig. 7.2, suggest how aneuploid embryos are formed. [3]

1. **Mis-segregation of chromosomes arose when <u>centromeres did not divide properly</u> / <u>recombinant chromatids did not separate at their centromeres</u>. ;**
   OR
2. **Lagging chromosomes arose when the kinetochore <u>spindle fibres</u> attached to the centromeres <u>failed to shorten and contract</u> to pull the daughter recombinant chromosomes to opposite poles of the cell. ;**

3. **These processes may (lead to chromosomal/numerical aberrations) resulting in oocytes with <u>extra / less / n + 1 / n - 1 chromosomes</u>. [No credit for mentioning "*chromosomal/numerical aberrations*" alone];**
4. **<u>Fusion of these oocytes with a normal haploid sperm</u>, results in aneuploid embryos. ;**

[Total: 8]

1
2
3

4 **Fig. 2.1** shows some *Allium sp.* plant cells in various stages of the mitotic cell cycle.

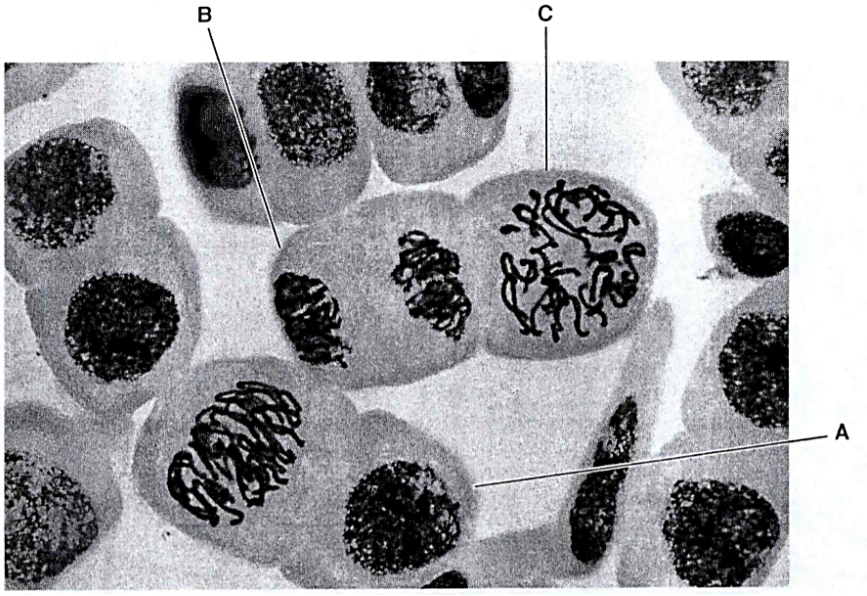


Fig. 2.1

(a) **(i)** Identify the three stages shown by the labelled cells.

A Interphase

B Anaphase

C Prophase

[3]

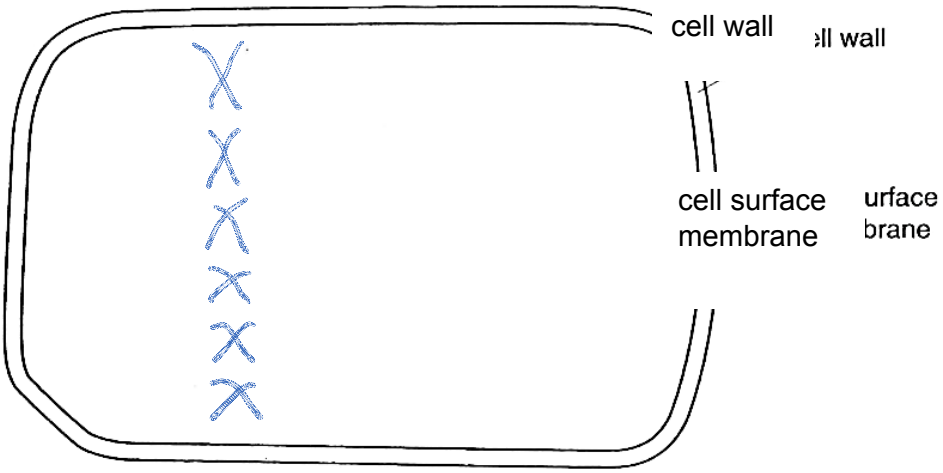
(ii) Identify the stage of mitosis that follows that shown in cell **C**.

Metaphase

[credit will be given as long as the stated answer follows their answer in a(i)C]

[1]

(iii) In the cell outline below, draw and label the structures visible in a cell that is in the stage you have named in **(ii)**. 2n for this plant is 6.



Drawing within cell outline; label chromosomes; 2n=6;

® asters / centrioles which are absent in plants [3]

(b) Uncontrolled cell division can result in cancer. Some types of cancer can be treated by chemotherapy, which involves the injection of chemicals into the bloodstream.

One chemical used for chemotherapy is called Methotrexate. This is a reversible competitive inhibitors of one of the enzymes in the metabolic pathway that results in the formation of purines.

Explain how the use of Methotrexate will slow down the mitotic cell cycle.

(Due to competition, less purines formed) so less nucleotides synthesised ;

Leading to less DNA replication ; (slowing down mitotic cell cycle)

[2]

(c) Prokaryotic organisms such as *Escherichia coli* divide by simple cell splitting (binary fission), not mitosis.

Apart from ribosomes, prokaryotes have no organelles comparable to those found in eukaryotes and have a circular 'chromosome' with no centromere.

With reference to the information above and your knowledge of mitosis, suggest why mitosis does **not** occur in prokaryotes.

Lack of centrioles / microtubules to separate the chromosomes during anaphase ;

Circular chromosomes does not allow for separation unlike linear chromosomes ;

[2]

[Total: 11]

2018 / H2 / PJC PRELIM / P2 Q4

5 There have been many breakthroughs in stem cell research in the recent years. It has been discovered that stem cells are involved in the replacement of worn-out cells and repair of damaged tissues. Further research is being conducted to better understand the mechanism involved in controlling the behaviour of stem cells in order to better manipulate them to treat various diseases and disorders.

Stem cells undergo cell division to produce genetically identical daughter cells. Fig. 4.1 shows two cells, each at a different stage of cell division.

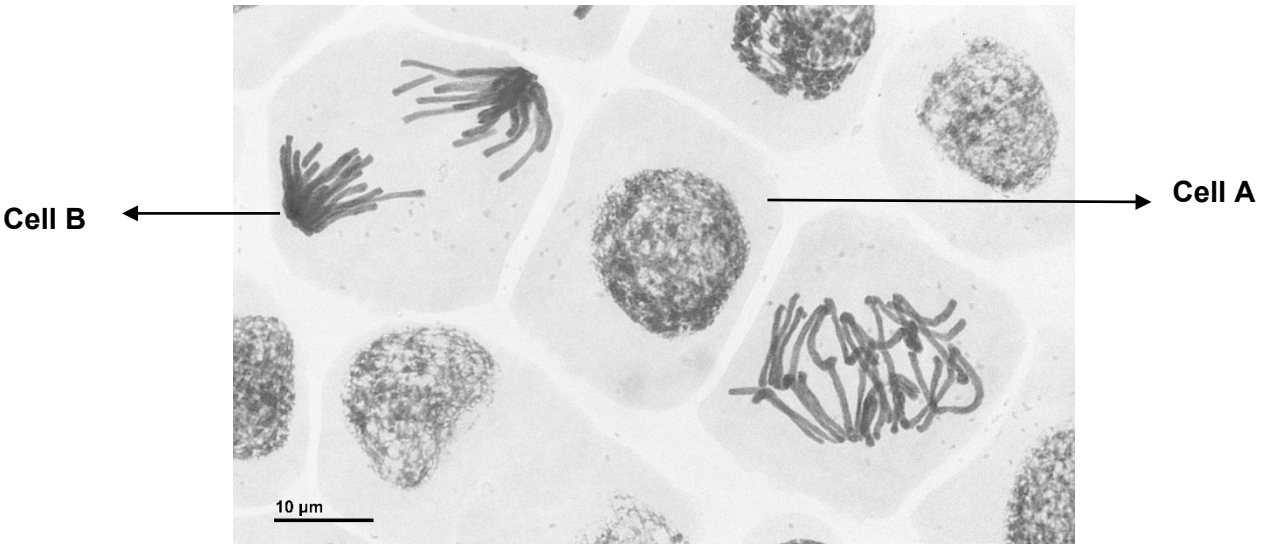


Fig. 4.1

(a) With reference to Fig. 4.1, state the stages of cell division in Cell **A** and Cell **B.** [1]

Cell **A** **Interphase/Prophase;**

Cell **B** **Anaphase;**

[Turn over

Fig. 4.2 shows information about the movement of chromatids in a cell that has just started metaphase of mitosis.

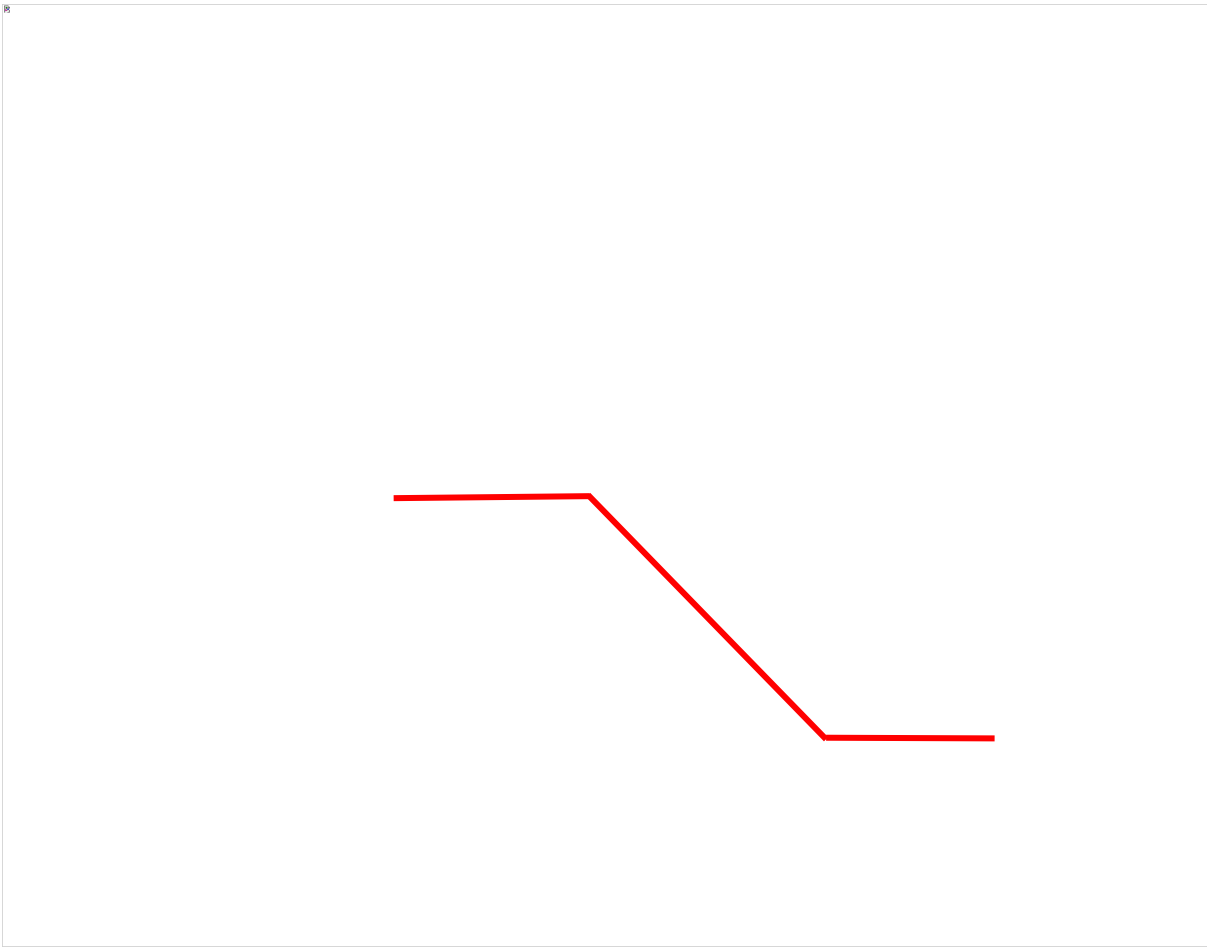


Fig. 4.2

(b) **(i)** With reference to Fig. 4.2, state the duration of metaphase in the cell. [1]

- **18 min;;**

(ii) Complete line **Y** on the graph. [1]

(iii) Account for your answer in **(b)(ii).** [3]

a. **Chromosomes align singly at the metaphase plate during metaphase of mitosis OR sister chromatids are attached to microtubules from opposite poles at metaphase;;**
b. **Sister chromatids start to separate to become daughter chromosomes and migrate towards the opposite poles in anaphase, as shown at 18th min of line X when distance between chromatids starts to increase. Hence distance between chromatid and pole will start to decrease at 18th min;;**

c. **Distance between chromatids reach a plateau/maximum at 28th min, chromosomes arrived at opposite poles. Hence, distance between chromatid and pole will be minimum at 28th min;;**

The movement of chromatids is dependent on spindle fibres, which are made up of many tubulin subunits. Spindle fibres are lengthened at one end during mitosis by the polymerisation of tubulin subunits through GTP hydrolysis.

(c) Contrast between the structure of tubulin with that of DNA. [2]

Tubulin	DNA
• Tubulin is a polypeptide and hence made up of amino acid subunits;	• DNA is made up of deoxyribonucleotides;
• Subunits by peptide bonds;	• Subunits joined by phosphodiester bonds;
• Globular;	• Helical;
• AVP;	• AVP;

Any 2

[Total: 8]

2018 / H2 / RI PRELIM / P2 Q3 (Inheritance)

6

(a) Discuss the role of centromere in the production of gametes. [3]

1. They allow (proteins called kinetochore proteins, and subsequently) spindle fibres, to attach; (MUST HAVE)
2. resulting in proper alignment of bivalents on equator in metaphase I/meiosis I;
3. so that homologous chromosomes can be equally separated to opposite poles during anaphase I/meiosis I;
4. resulting in proper alignment of chromosome singly in on equator in metaphase II/meiosis II;
5. so that sister chromatids / daughter chromosome can be equally separated to opposite poles during anaphase II/meiosis II;

Note : point 1 is compulsory and from points 2-5 any two. Without point 1, maximum marks that can be obtained is 2.

(b) The graph in Fig 3.1 shows the length of the spindle fibres during meiosis.

(i) In which regions of the graph did the centromeres detach from the spindle fibres. [1]

D and H

(ii) Which region on the graph corresponds to the stage shown in the Fig 3.2. [1]

F

(iii) Name and identify the 2 corresponding stages on the graph in Fig 3.1 that contributes to genetic variation in gametes, and explain how they bring about genetic variation. [6]

Stage :

1. Prophase I, A
2. ***Crossing over**** of segments of ***non-sister chromatids of homologous chromosomes**** at prophase I of meiosis I.
3. This leads to new combinations of alleles on chromosomes of gametes.

Stage :

4. Metaphase I, B
5. ***Independent assortment**** of ***homologous chromosomes**** occurs where arrangement of one pair of homologues at metaphase plate is independent of the arrangement of the other pairs of homologues;
6. This results in different combinations of maternal and paternal chromosomes in daughter cells;
7. there are 2^n possible combinations of gametes where n is number of homologous pairs. / 2^{23} possible combinations of gametes in human ;

A: Metaphase II, F;
only if answer clearly makes ref to;
random arrangement of /independent orientation of ***non-identical sister chromatids**** ***(R;chromosome)*** of each chromosome at the metaphase plate & their subsequent separation during metaphase II and anaphase II respectively

(c) **(i)** What is the mode of inheritance of the disease WAS? [1]
Sex-linked recessive ;

(ii) Use suitable symbols to represent the alleles of the gene controlling the disease WAS [1]
$\mathbf{X^{\underline{W}}}$: Dominant allele that codes for **no WAS** on X chromosome
$\mathbf{X^{w}}$: recessive allele that codes for **disease WAS** on X chromosome;

Must show both alleles
Must have X chromosome on symbol

(iii) Use a genetic diagram to explain the results of **couple 2.** [4]

1. [1] parental phenotype and genotype;

P phenotype: wavy-hair female WAS sufferer x wavy-hair normal male ;
P genotype: $X^wX^wH^SH$ x $X^{\underline{W}}YH^SH^C$

Gametes (n): X^wH^S X^wH^C x $X^{\underline{W}}H^S$ YH^S $X^{\underline{W}}H^C$ YH^C

2. *[1] all correct gametes (circled) in P **and** punnet square*

		Male gamete			
		$X^{\underline{W}}H^S$	YH^S	$X^{\underline{W}}H^C$	YH^C
Female gamete	X^dH^S	$X^{\underline{W}}X^wH^SH^S$ Normal Straight hair female	$X^wYH^SH^S$ WAS sufferer, straight hair male	$X^{\underline{W}}X^dH^SH^C$ Normal wavy hair female	$X^wYH^SH^C$ WAS sufferer, wavy hair male
	X^dH^C	$X^{\underline{W}}X^wH^SH^C$ Normal wavy hair female	$X^wYH^SH^C$ WAS sufferer, wavy hair male	$X^{\underline{W}}X^dH^CH^C$ Normal curly hair female	$X^wYH^CH^C$ WAS sufferer, curly hair male

3. [1] Punnett square with correct genotypes and related phenotypes

offspring genotypic ratio	$X^{\underline{W}}X^dH^SH^S$	$X^{\underline{W}}X^wH^SH^C$	$X^{\underline{W}}X^wH^CH^C$	$X^wYH^SH^S$	$X^wYH^SH^C$	$X^wYH^CH^C$
offspring phenotypic ratio	Normal Straight hair female	Normal wavy hair female	Normal curly hair female	WAS sufferer, straight hair male	WAS sufferer, wavy hair male	WAS sufferer, curly hair male
	1	2	1	1	2	1

4. [1] Correct offspring genotypic and phenotypic ratio

[Total : 17]

2018 / H2 / RVHS PRELIM / P2 Q6

7 A germline cell is undergoing meiosis to produce gametes. Fig. 6.1 shows a stage in this process.

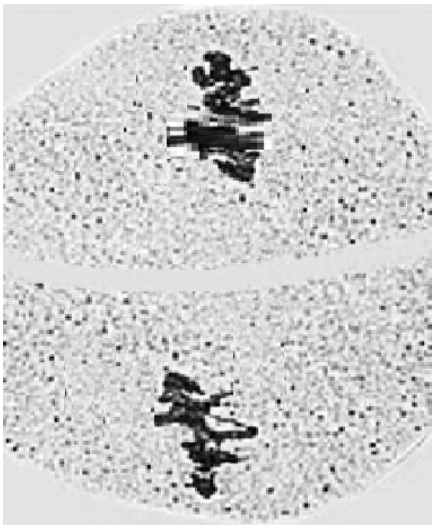


Fig. 6.1

(a) (i) Identify the stage of meiosis shown in Fig. 6.1 [1]

Metaphase II

(ii) Explain you answer in **(a)(i)**. [2]

1. **Cytoplasm / chromosomes has separated into two**
2. **Chromosomes are gathered at the centre of each cell**

(b) Describe the role of centrioles in the next stage of meiosis. [3]

1. **Centrioles organise spindle fibres**
2. **that shortens**
3. **to separate sister chromatids**
4. **to opposite poles of the cell**
5. **Centrioles move apart**
6. **as (interpolar) microtubules lengthen**
7. **to elongate cell**

Fig. 6.2 shows an error in anaphase II.

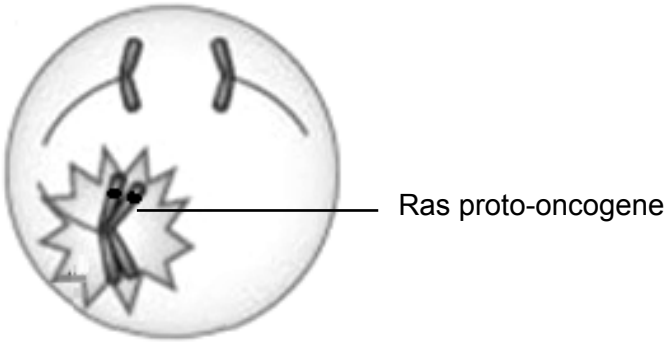


Fig. 6.2

(c) Explain why this error may increase the risk of cancer in a newborn. [3]

1. **Non-disjunction (in meiosis II)**
2. **results in <u>two</u> copies of (Ras) proto-oncogene in gamete**
3. **and <u>three</u> copies of (Ras) proto-oncogene in zygote (after fertilisation)**
4. **resulting in excessive Ras proteins**
5. **This causes overstimulation of cell cycle**
6. **resulting in uncontrolled cell proliferation**

(d) Kinase inhibitors are often used to target such cancers associated with Ras proto-oncogenes by interrupting their downstream signalling.

Suggest how kinase inhibitors can interrupt Ras signalling pathway. [1]

Prevent activation of <u>phosphorylation cascade</u>, thus prevent signal transduction

[Total: 10]

2018 / H2 / TJC PRELIM / P2 Q5

8 Fig. 5.1 shows a stage in the mitotic cell cycle in an animal cell.

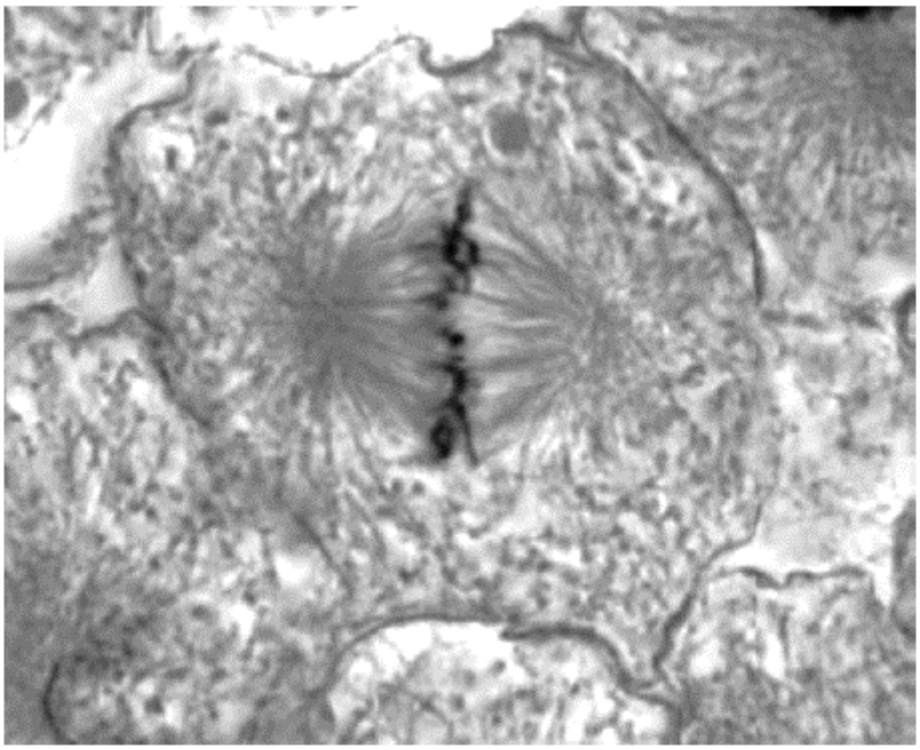


Fig. 5.1

(a) With reference of Fig. 5.1,

(i) identify the stage of mitosis; [1]

Metaphase

(ii) state two features which are characteristic of this stage. [2]

1. **Chromosomes line up at the equator of the cell/ metaphase plate. [1]**
2. **Centromere/kinetochore attached to spindle fibres/microtubles from the centrioles. [1]**
3. **Centrioles reach/located at poles of the cell. [1]**

(b) Distinguish between the terms haploid and diploid. [2]

1. **Haploid refers to only one set of chromosome being present in a cell,**
2. **Whereas diploid refers to cell having 2 sets of chromosomes,**

   OR
3. **Haploid condition consists of one member of each pair of homologous chromosome present.**
4. **Diploid condition consists of 2 sets of chromosomes, one set derived from each parent.**

(c) Explain the importance of mitosis in organisms. [3]

1. **maintains / same, genetic stability / number of chromosomes/ two sets of chromosomes / diploid / 2n /**
2. **produces daughter cells that are genetically identical**
3. **replacement of cells ;**
4. **repair of tissue ;**
5. **growth / increase in cell numbers ;**
6. **asexual reproduction;**

(d) In many multicellular organisms, such as mammals, the time taken for the mitotic cell cycle varies considerably between different tissues, but is very carefully controlled in each cell.

Suggest the importance of this control in mammals. [2]

1. **Prevent tumour/ cancer formation due to uncontrolled cell division. [1]**
2. **Only cells that are needed / functions are needed will be produced [1]**
3. **Allows for coordination of growth / limiting growth ; [1]**

[Total: 10]