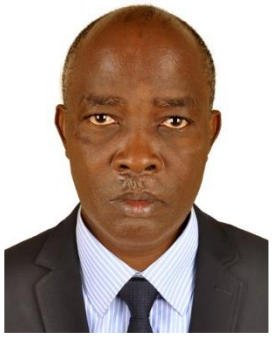


Dr. Bbosa Science

Cell division

Specific objectives
The learner should be able to:

(i) Describe mitosis and meiosis
(ii) Compare mitosis and meiosis
(iii) Explain the significance of the changes in the nucleus during cell division
(iv) State the significance of mitosis and meiosis to living organisms.
(v) Identify stages of mitosis from prepared slides
(vi) Draw cells at different stages of mitosis and meiosis

Overview
Growth, reproduction and replacement of old cells involve the multiplication cells. In order to multiply cells under cell division: there are two types of cell division.

Mitotic cell division

This type of cell division; leads to the formation of two daughter cell each with exactly the same number of chromosomes as the parent cells.

Mitosis takes place in five stages. Interphase, prophase, metaphase, anaphase and telophase. At each of these stages certain crucial events take place, particularly in regards to chromosome. It is a continuous process that takes about an hour.

1. Interphase

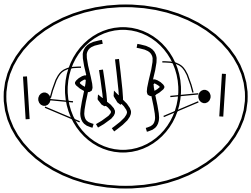
It is some times described as a resting stage. During this stage, there is protein synthesis, formation of organelles and replication of DNA. It also builds up a sufficiently large store of energy to carry the cell through the remaining stage of mitosis.

During interphase the chromosomes are not visible or distinct bodies either under light microscope or electron microscope. Just before mitosis begin the centrioles are among the most prominent organelles in the cell.

2. **Prophase**

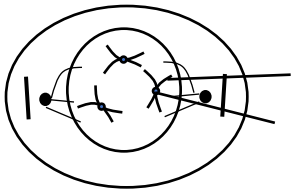
(i) Early prophase

Chromosomes become visible as they contract, and nucleus shrinks, centrioles move to the opposite sides of nucleus. Spindle fiber start to form



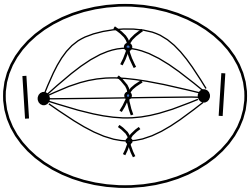
(ii) Late prophase

Chromosomes become shorter and fatter-each seen to consist of a pair of chromatid joined at the centromere. Nucleolus disappears. Prophase ends with the breakdown of the nuclear envelop.



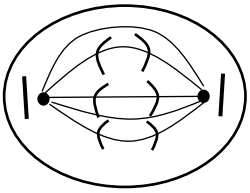
3. **Metaphase**

Chromosomes arrange themselves on the equator of a spindle



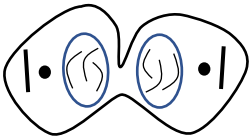
4. **Anaphase**

Chromatid separate and migrate to opposite pol of the cell. The centromere leading



5. **Telophase**

Chromosomes unwound. Nuclear envelope and nucleoli form.



The two silent features of mitosis that ensure that chromosome constitution of the cell is preserved are

a. DNA replicates before mitosis
b. The chromosomes arrange themselves at the equator before migration to opposite side.

Importance of mitosis

1. Genetic stability: It ensures that the daughter cells carry the exact genetic material as the parent cells
2. Growth: growth results in increase in the number of cells by mitosis.
3. Body repair: worn out cells are replaced b the cells produced by mitosis
4. Asexual reproduction

Meiosis

This is a type of cell division where each parent cell divides into four haploid cells. The leads to formation of gametes. By having the number of chromosomes prior to fertilization, meiosis ensure that the zygote has normal diploid condition

Meiosis occurs into two successive divisions, the parent cell splints into two (first meiotic division) and the product then divides again (second meiotic division) giving a total of four daughter cells.

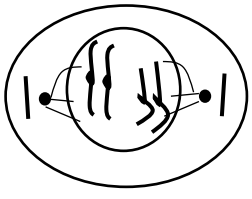
Stages in meiosis

Meiotic division 1

1. Interphase
   Cells in normal non-dividing conditions with chromosomes long and threadlike.
2. Prophase 1
   This is the longest phase and is subdivided into 5 stages
   (a) Leptotene
   (b) Zygotene
   (c) Pachytene
   (d) Diplotene
   (e) Diakinesis

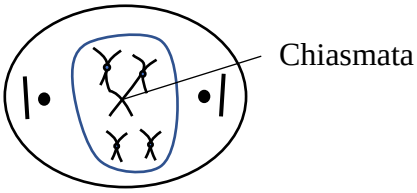
(a) Leptotene
The chromosomes are single, long and scattered

(b) Zygotene
The single chromosomes begin to pair up with homologous chromosome the process called **synapsis** and each pair is called a **bivalent**



(c) Pachytene

Chromosomes become intimately coiled around each other. The chromosomes replicate into chromatids that move slightly apart. The chromatids of homologous chromosomes remain in contact at certain points called the **chiasmata**. The chiasmata is the site of genetic exchange called **crossing over**.



(d) Diplotene

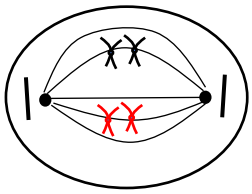
Chromosomes in the bivalents begin to separate but remain joined at the chiasmata in each bivalent. The number of chiasmata in each bivalent varies but they tend to be more on long chromatids.

(e) Diakinesis

Internal coiling continues and the bivalents are most contractive stage.

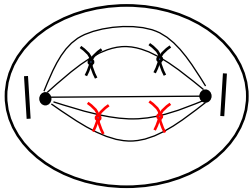
Metaphase 1

The homologous chromosomes (bivalents) arrange themselves opposite each other on the equator of the spindle



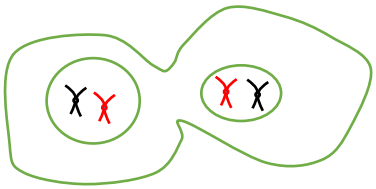
Anaphase 1

The homologous chromosomes each made up a pair of chromatid joined at the centromere move towards opposite pole of the spindle. The sister chromatids also separate from each other's along their length except at the centromere.



Telophase 1

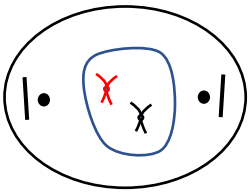
When the chromosomes reach their respective pole, the cell start to divided across the middle, and as in mitosis, nuclear envelop form around the two new nuclei



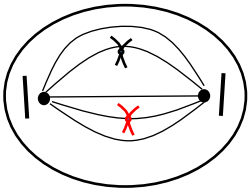
Meiotic division II

Separation of homologous chromosomes that make up a bivalent is achieved by the first meiotic division. The purpose of the second division is to separate the chromatids from one another

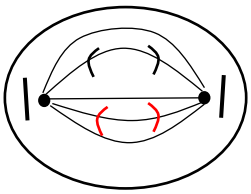
Prophase II
The two daughter cells prepare for the second meiotic division: centrioles have replicated and a new spindle is formed.



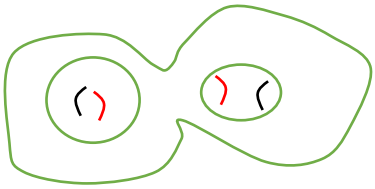
Metaphase II
The chromosomes move to the equator of the spindle, the chromatids orienting towards opposite pole.



Anaphase II
Chromatid separate and move apart from each other



Telophase II
When the chromosomes reach the end of the spindle the cell divides, the spindle apparatus disappear and chromosome begin to regain their threadlike form. New nuclear envelops and nucleoli form.



Significance of meiosis

1. Sexual reproduction: Meiosis results in half the number of chromosomes, during fertilization the nuclei of the two gametes fuse to form a zygote restore the diploid number of chromosomes for its species.
2. Genetic variation: Meiosis provided opportunities for new recombination of genes to occur in the gametes and off springs in two ways
   (i) Crossing over
   (ii) Independent assortment i.e., random distribution of chromosomes into the gametes at metaphase 1

Differences between mitosis and meiosis

	Mitosis	meiosis
1.	Homologous chromosomes remain separate	Homologous chromosomes pair up
2	There no crossing over	Crossing over occurs
3.	No formation of chiasmata	Formation of chiasmata
4.	Single division	Two series of division
5.	Results into two diploid daughter cells	Results in four haploid daughter cells
6.	Occurs in somatic cells	Occurs in gonards

Exercise

1. Which one of the following events occurs both in mitosis and meiosis?
   A. Synapsis
   B. DNA synthesis
   C. Crossing over
   D. Halving of chromosomes number

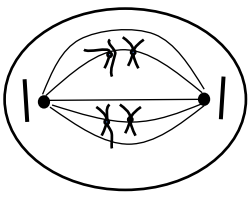
2. The function of meiosis in gamete formation is to
   A. Maintain the chromosome number and produce genetically similar gametes
   B. Halve the chromosome number and produce genetically similar gametes
   C. Halve the chromosome number and produce genetically variable gametes
   D. Maintain the chromosome number and produce genetically variable gametes

3. At which one of the following stages of cell division does a cell have the same nucleic content as that in metaphase I?
   A. Anaphase I
   B. Metaphase II
   C. Telophase II
   D. Prophase II

4. Gametes are haploid because
   A. Two replications of DNA occur during meiosis
   B. Homologous chromosomes separate during meiosis
   C. Crossing over during prophase I
   D. Chromatids do not separate during meiosis
5. It is difficult to observe individual chromosomes during interphase because
   A. The DNA is not yet replicated
   B. They uncoil to form long thin strands
   C. They are dispersed
   D. Homologous chromosomes do not pair up until division starts

6. Which of the following statements is true?
   A. Meiosis produces gametes for sexual reproduction or spores for asexual reproduction
   B. Only diploid cells can divide by meiosis but both haploid and diploid cells can divide by mitosis
   C. If mitosis produces a multicellular organism after fertilization, but before meiosis, that organism is haploid
   D. If mitosis produces a multicellular organism but meiosis occurs before fertilization, that organism is haploid

7. The figure below represents a stage of cell division.



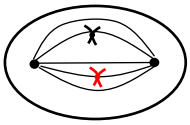
Which one of the following stage is represented in the figure?

A. Metaphase of mitosis
B. Interphase
C. Anaphase of mitosis
D. Metaphase I of meiosis

8. Which one of the following is true of the first meiotic division but untrue for mitosis?
   A. The chromosome number is maintained in the daughter cells
   B. Four daughter cells are formed
   C. The chromosome number is doubled in daughter cells
   D. Homologous chromosomes come together at the equator

9. In sexually reproducing organism, maintenance of a species is achieved at meiosis by
   A. Halving DNA
   B. Doubling DNA
   C. Maintaining DNA amount
   D. Increasing DNA amount by two fold

10. The figure below shows animal cell during meiosis



Which one of the following stage is illustrated?

A. Prophase I
B. Prophase II
C. Metaphase I
D. Metaphase II

11. During what stage of prophase 1 of meiosis are homologous chromosomes attracted to each other and come together?
   A. Leptotene
   B. Zygotene
   C. Pachytene
   D. diplotene

12. During meiosis crossing over occurs between one of the following
   A. two centromeres of homologous chromosomes
   B. two homologous chromosomes
   C. two non-homologous chromatids
   D. two homologous chromatids

13. Which of the following is correct about the first division of meiosis but not that of mitosis?
    A. Nucleolus disappears
    B. Spindle is formed
    C. Centrioles move to opposite pole of the nucleus
    D. Homologous chromosomes associate to form bivalents

14. Which of the following is synthesized at interphase during mitosis?
    A. tRNA
    B. mRNA
    C. DNA
    D. tRNA

15. Which one of the following events occur during telophase of mitosis in the meristematic cell of a root tip?
    A. Cleavage of the cytoplasm
    B. Replication of the centrioles
    C. Replication of the cell plate

16. (a) Illustrating with a cell of one pair of homologous chromosome, draw diagrams in the space below to show
    (i) Mitotic metaphase (2marks)
    (ii) Meiotic metaphase I (2marks)
    (iii) Meiotic metaphase II (2marks)

(b) Explain how meiosis contribute to genetic variation (4marks)

18. (a) outline the function of the cell nucleus. (2marks)
    (b) Describe the changes that occur in the nucleus during meiosis (13marks)
    (c) Explain the significance of meiosis and mitosis in organisms. (5marks).

19. Give an account of meiosis in a reproductive cell. (Diagrams not required) (20mark)

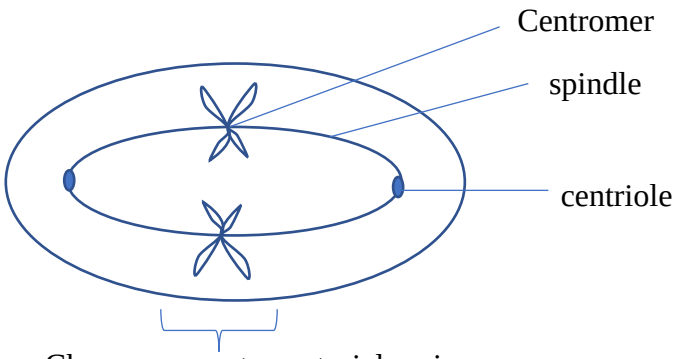
20. How does the behavior of chromosomes in mitosis differ from that in the 1^{st} meiotic division (20marks)

Answers to objective

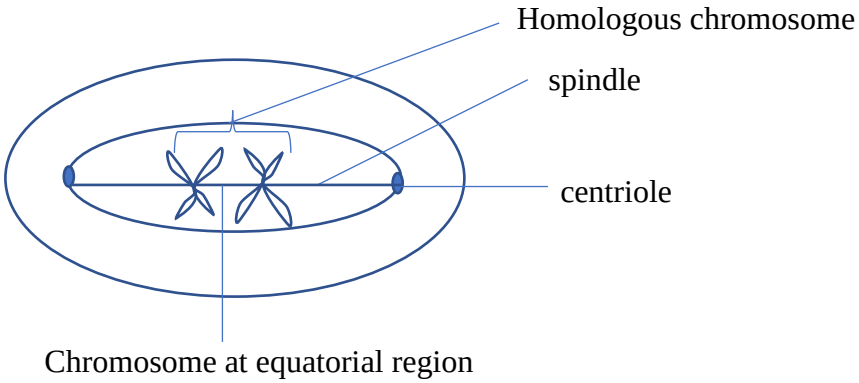
1	B	5	B	9	A	13	D		
2	C	6	A	10	D	14	C		
3	A	7	D	11	C				
4	B	8	D	12	D				

17. Solution

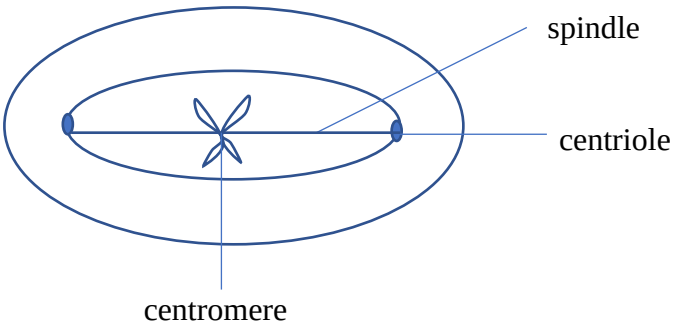
(i) Mitotic metaphase.



(ii) Meiotic metaphase



(iii) Meiotic metaphase II



(b) During prophase of meiosis I, homologous chromosomes pair, from chiasmata and there is subsequent crossing over, this result in exchange of genetic material between the two homologues. The bivalents are randomly oriented and distributed in metaphase 1 and anaphase 1 respectively. This leads to new combinations of genetic material leading to genetic variation in the population.

18. Solution

(a) The nucleus contains the DNA
- It controls the process of the cell division.
- It controls all the metabolic activities of the cell by controlling the synthesis of the enzyme required (protein synthesis)
- The nucleus manufactures ribosomes.

(b) This question requires that you point out what happens in the nucleus in all stages of meiosis. That is identify the stage of meiosis in a chronological order and state what happens in the nucleus at each stage.

Interphase

DNA replication occurs.

Prophase 1

- Chromosomes condense and become visible.
- Homologous chromosomes pair up.
- Chromatids of homologous chromosomes crossover at chiatsmata. This produces gene recombination.
- The nucleus fades.

Metaphase 1

Nuclear envelop breaks down and disappears.

Microtubules of the spindle attach to the centromere and the pairs of homologous chromosomes move to the equator.

Anaphase 1

Homologous chromosomes part company. One of a pair of homologous chromosomes is pulled to opposite pole by the micro tubules of the spindle attached to their centromeres.

Telophase 1

- Chromosomes separate into two different cells.
- Chromosomes disappear and the nuclear membrane reforms in either cell.

Prophase II

Chromosomes condense.

Metaphase II

Nuclear envelops breaks down and disappear.

Chromosomes move to the equator

Aanpahse II

Chromatids separate.

Telophase

Sister chromatids now called chromosomes condense.

Nuclear envelope appears and the cells divided leading to formation of four daughter cells.

(c) Significance of meiosis

- It helps to maintain the diploid condition in sexually reproducing organisms. Meiosis results in formation of haploid (n) gametes which fuse during fertilization to form a diploid (2n) zygote, restoring the diploid condition.
- It leads to genetic variation in the offspring of sexually reproducing organisms. This occurs as a result of independent assortment and crossing over during meiosis I.

Significance of meiosis.

- Growth in multicellular organisms occur by meiosis. Cells within multicellular orgainsms divide mitotically thereby increasing in number. This leads to increase in size (growth) of the organisms.
- Repair and replacement of worn out cells occur by mitosis. This is possible because mitosis producers daughter cells which are identical to the parent cell.

Others

- A sexual reproduction is unicellular organisms like amoeba occurs by mitosis. This is possible because mitosis ensures that the daughter cells are identical to the parent cell.
- Regeneration of body parts, such as whole legs in organisms like crustaceans occur by a process which involves mitosis.

6. (a) Explain the meaning of the following

(i) Genetic isolation

(ii) Reproductive isolation

(b) Explain how the gene frequency of a population may be altered.

Solution

(a) (i) Genetic isolation occurs when mating can occur but fertilization is not possible and/or even when it occurs, the product is a sterile or inferior offspring. This is due to incompatible genetic constitution between organisms of a population.

(ii) Reproductive isolation involves failure of interbreeding among organisms of population. This may be as a result of lack of attractiveness between males and females or non-correspondence of genitals.

(b) Change in gene frequency of a population occurs when;

- There is non-random breeding. In such cases sexual selection occurs whenever the presence of one or more inherited characteristics increases the likelihood of bringing about successful fertilization of gametes. As a result, the frequency of some genes increases while that of others reduces in the population.

- The population is small and leads to genetic drift. There is usually chance appearance or disappearance of genes in a small population, leading to change in frequency of the gene in question.
- Genotypes are not equally fertile. In this case, the more advantageous (fertile) alleles are transferred to offspring at the expense of other alleles. This leads to change in frequency of such genes.
- Gene flow occurs between populations. Interbreeding between populations always leads to flow of genes within the populations involved. This causes instability in the gene frequency of the populations.
- Mutations occur. Occurrence of a mutant gene in the population can lead to change in frequency of the gene over generations.

Gene reshuffling occurs. During meiosis, crossing over occurs that results in new gene recombination. At fertilization, these altered alleles are transmitted to offspring and over generations, the allele frequency of a gene changes.