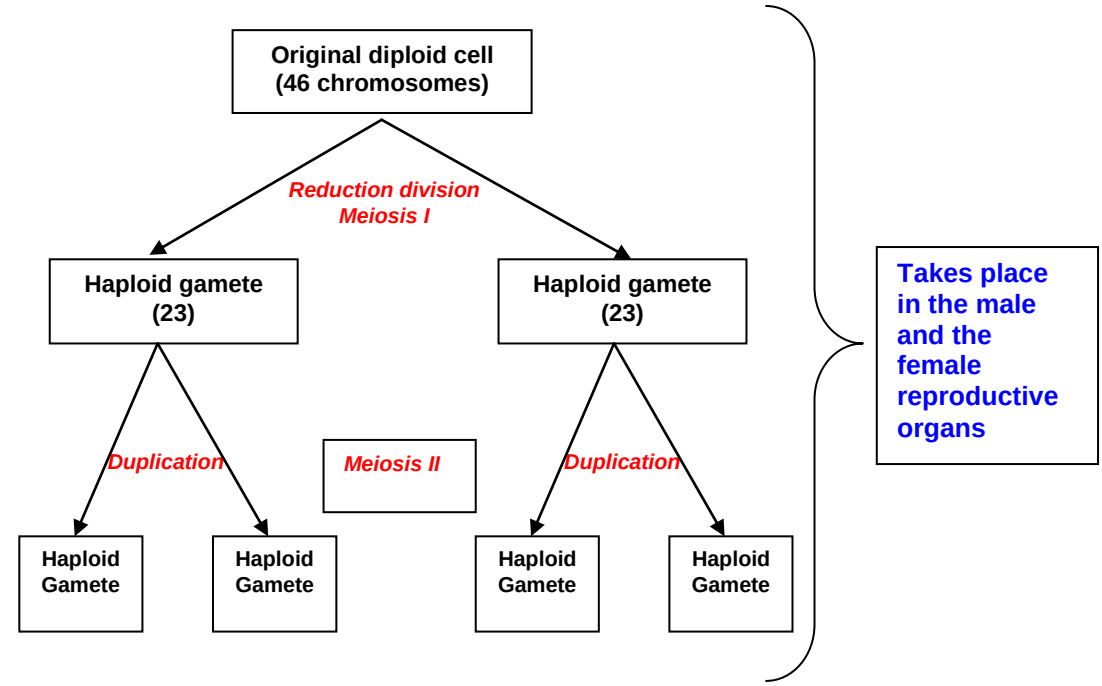
X-Sheet 3
Cell Division: Mitosis and Meiosis

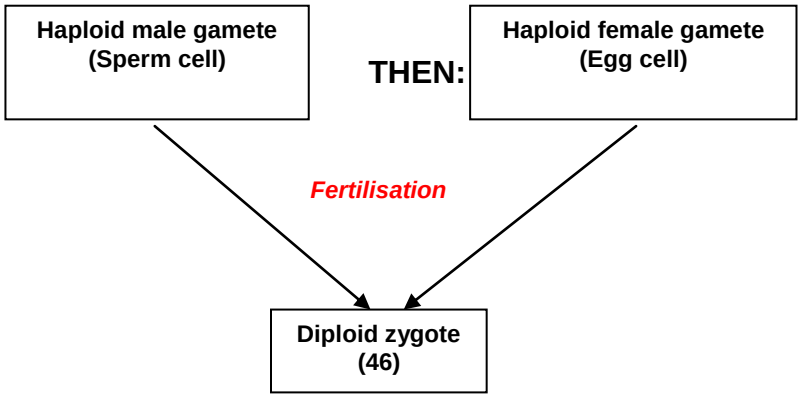
Key Concepts
In this session we will focus on summarising what you need to know about: Revise Mitosis (Grade 11), the process of meiosis, First Meiotic division, Second meiotic division, significance of Meiosis, production of sex cells, diseases and syndromes.

Terminology & definitions:
Somatic cells:
Centromere: structure that holds two chromatids together to form a chromosome.
Chromatid: one half of a chromosome consisting of a protein core surrounded by DNA that carries the hereditary characteristics. Two chromatids are joined by a centromere to form a chromosome.
Chromosome: a structure made up of two chromatids joined by a centromere that carries the hereditary characteristics within the DNA.
Homologous chromosomes: a pair of chromosomes containing 23 pairs of similar chromosomes with genes for the same characteristics or traits.
Gene: the unit of heredity transmitted in the chromosome which controls the development of the characteristics.
Centriole: an organelle in the cytoplasm of the cell which forms the spindle pole during meiosis and mitosis.
Spindle fibres: micro tubules that form during cell division which radiate out from the centrosomes and draw the chromosomes to the poles
Haploid number (n): half the number of chromosomes present in the human cells (23) and present in gametes after meiosis has occurred.
Diploid number (2n): complete chromosomal number represented in pairs, which is characteristic of an organism.
Maternal: from the mother (female parent).
Paternal: from the father (male parent).
Meiosis: a process of cell division whereby the chromosomal number is halved for the production of haploid gametes (sperm cells and egg cells).
Mitosis: a process of cell division where the resulting daughter cells have the same diploid chromosomal number as the original parent cell.
Chiasma: crossover of chromatids during meiosis I, resulting in a mixing of the maternal and paternal alleles of the homologous chromosome.
Gametes: haploid cells which contain half the chromosome number of the diploid generation. Egg cells and sperm cells are haploid and necessary in sexual reproduction where the fusion of the two gametes results in a new individual.
Zygote: the resulting cell after fertilization has occurred
Variation: the morphological and physiological differences that can be seen between members of the same species
Karyotype is a set of chromosomes from a human cell, that shows the chromosomes arranged in pairs, according to numbers.Pair 1 is always the largest while pair 22 is the smallest. The female karyotype will have XX as pair 23 and the male will show XY as pair 23.

Key Concepts & Diagrams:

The process of Meiosis simplified:





The 1st Meiotic division halves the chromosome number so that gametes are haploid.
The 2nd Meiotic division duplicates the gametes so 4 sperm cells result in males. In females, 1 structure forms the egg cell and the remaining 3 structures provide nutrition for the egg cell.
When fertilization takes place, the two haploid gametes fuse to form 1 diploid zygote.

haploid	**+**	**haploid**	**= diploid**
half	**+**	**half**	**= whole**

Please note: when the homologous chromosomes crossover during late Prophase I, segments of the daughter chromosomes are exchanged. This results in genetic variation.

Comparison between Mitosis and Meiosis:

	Mitosis	Meiosis
Where process occurs	• In every living organism, in the somatic (body) cells	• Specialised cells in the testes and ovaries of animals • Specialised cells in the anthers and ovules in plants
Why process occurs	• Production of genetically identical cells, which specialise and differentiate for growth, repair and replacement of cells • Mitosis will take place as binary fission in unicellular organisms during asexual reproduction	• Reduction division resulting in haploid gametes for sexual reproduction so that the chromosome number will remain the **same** in the offspring as in the adult (n + n = 2n) once fertilisation takes place
Similarities	• The transformation of the chromatin network to chromosomes • Karyokinesis takes place • Cytokinesis takes place	• The transformation of the chromatin network to chromosomes • Karyokinesis takes place • Cytokinesis takes place
Differences	• One nuclear division • No crossing-over • Daughter chromosome is pulled to opposite poles • Two identical cells are produced with identical chromosomes to the original cell	• Two nuclear divisions • Crossing-over takes place to ensure a different combination of genes when genetic information is exchanged • Daughter chromatids do not separate, one entire chromosome of each homologous pair is pulled to the pole **–** each chromosome pair separates independently • Four cells are produced, each containing half the original number of chromosomes in the gametes

Biotechnology: is the use of micro-organisms or biological substances like enzymes, to perform specific industrial or manufacturing processes in agriculture, food science and medicine. Scientists use biotechnology to **artificially select** characteristics in plants and animals that suit our needs. The result can be classed as an **evolutionary**

mechanism, where the hybrid results in a new genetically engineered species.It will have **new characteristics**, as the gene frequency in the DNA changes.
New breeds (animals), **strains** (micro-organisms) and **varieties** (plants) are created and produced relatively quickly.The hybrid will have the following advantages:
–increased size of body (cows, pigs, sheep)
–increased production of eggs, offspring or seeds
–increased resistance to disease
–reach maturity quickly (plants and chickens).

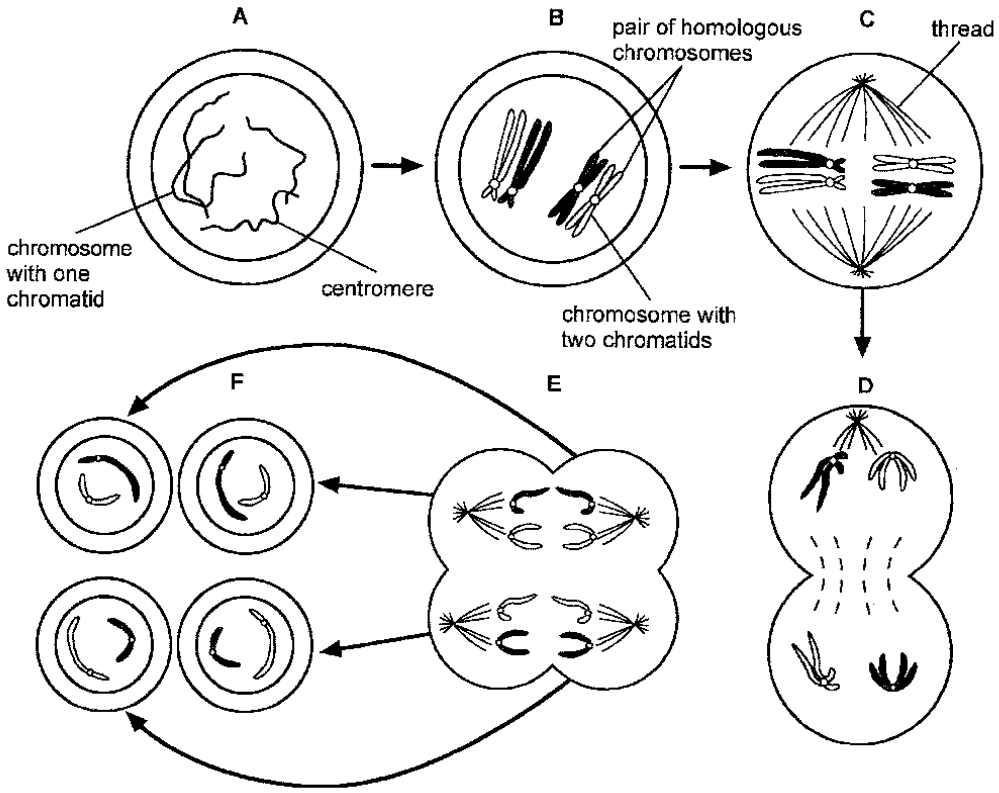
Polyploidy: (*poly* = many and *ploidy* = the number of complete sets of chromosomes in a biological cell) is where all cells have **multiple pairs** of chromosomes beyond the basic set. So, polyploidy refers to the changes in the **gene frequency** and the **chromosome numbers** – altering the species at a genetic level. When chromosomes are different, bivalents cannot be formed properly during meiosis, so **gametes** cannot be produced. In animals, a polyploidy hybrid mule results when a donkey is crossed with a horse. A mule is infertile and cannot produce gametes for sexual reproduction. Polyploidy is common in plants and does not affect reproduction but it does result in a new species.Sometimes, sterile polyploid crops are preferred, like in the cultivation of many seedless fruit varieties. These crops are propagated using **asexual techniques** such as grafting, cuttings and stolons.Polyploidy in crop plants can be induced by treating seeds with a chemical called **colchicine** – it inhibits chromosome segregation during meiosis. So, half of the gametes will contain **no chromosomes**, while half will contain **double** the usual number of chromosomes. The resulting embryos will have double the usual number of chromosomes and be tetraploid instead of diploid. This type of genetic manipulation in animal cells would be fatal. The results are plants that are bigger, tougher and faster growing.

X-planation

- Learn to recognize and identify the phases of Meiosis I and Meiosis II.
- The significance of Meiosis is important to the section on Sexual reproduction and Genetics. Make sure that you learn and understand why this process must take place.
- You must be able to explain the production of sex cells in both animals and plants. In humans, 23 pairs of chromosomes result after fertilization in the diploid zygote:
    - 22 pairs of autosomes
    - 1 pair of sex chromosomes represented by **XX** in females AND **XY** in males

X-ample Questions

1. Study the diagrams below on the principle of meiosis. Answer the questions that follow:



1.1.	How many chromosomes does cell B have?	(1)
1.2.	Would this be n or 2n? Give a reason for your answer.	(2)
1.3.	How many chromosomes does each cell in F have?	(1)
1.4.	What would the ploidy of each cell in F be?	(1)
1.5.	Does each cell in F have exactly the same number of chromosomes?	(1)

2. The diagram below represents a process taking place during meiosis.

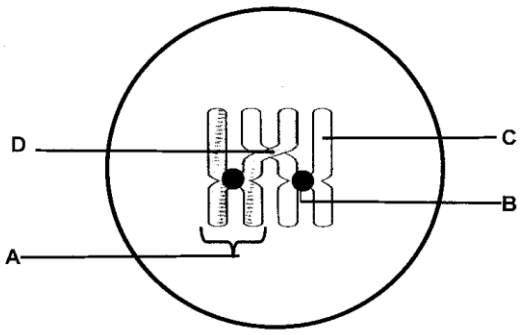


Diagram representing a process taking place during meiosis

2.1. Provide labels for parts A, B, C and D. (4)
2.2. Name the process in meiosis that is illustrated in the diagram above. (1)
2.3. State ONE importance of the process named in QUESTION 2.2. (2)
2.4. During which phase of meiosis does the process named in QUESTION 2.2 occur? (1)
2.5. Draw a diagram of the structure labelled **A** to show its appearance immediately after the process named in QUESTION 2.2. (2)

(Taken from the NSC Life Science examination Paper 1: February 2009)

X-ercise

1. The nucleus of the somatic cells of a human contains:
   A 46 identical chromosomes
   B 23 different chromosomes
   C 46 pairs of chromosomes
   D 23 pairs of chromosomes

2. Mitosis is responsible for the following in plants and animals:
   A growth and repair
   B gamete formation
   C reduction division
   D genetic variation

3. The number of chromosomes in a zygote….
   A diploid
   B half the number in a gamete
   C halpoid
   D triploid

4. Karyokinesis begins during which phase?
   A Prophase
   B Metaphase
   C Annaphase
   D Telophase

5. The most important reason for meiosis to take place is…..
   A the production of four gametes per mother cell to improve the chances of fertilization being successful
   B the doubling of the chromosome number of each cell
   C the production of haploid gametes to ensure that the chromosome number is diploid after fertilization
   D the production of a diploid number of chromosomes in the gamete

6. During the process of meiosis….
   A two identical daughter cells result
   B four identical daughter cells are formed
   C the chromosome number remains the same
   D four unidentical daughter cells result

7. Cytokinesis is the …...
   A division of the nucleus
   B fusion of the nuclei
   C division of the cytoplasm
   D cytoplasmic streaming

8. When daughter cells with 20 chromosomes are formed by cell division, the following will result:
   A 20 chromosomes after mitosis; 20 chromosomes after meiosis
   B 20 chromosomes after mitosis; 10 chromosomes after meiosis
   C 40 chromosomes after mitosis; 20 chromosomes after meiosis
   D 10 chromosomes after mitosis; 10 chromosomes after meiosis

9. Place the following steps that occur in meiosis in order:
   1. crossing over of the chromatids 2
   2. lining up of paired chromosomes at the equator 3
   3. pairing of homologous chromosomes 1
   4. complete seperation of chromatids 4

   A 1, 2, 3, 4
   B 2, 3, 4, 1
   C 3, 1, 2, 4
   D 4, 1, 2, 3

10. Why does crossing over /chiasma take place during meiosis?
    A to ensure that the chromosomes divide evenly
    B to ensure that characteristics from the mother are transferred to the father
    C to ensure that cell divisision can take place
    D to ensure that that genetic variation is passed on to all offspring

Answers to the X-ercise questions:

1. D
2. A
3. A
4. B
5. C
6. D
7. C
8. B
9. C
10. D