**The module: Molecules, Genes and Diseases (MGD)**

**Session 6**

**Lecture 11**

**Duration: 1 hour**

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# Lecture Title: Mitosis and meiosis, genotypes and phenotypes

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- **Relevant reading can be found in, for instance:**
- ***Human Heredity Chapters 2, 3, 4, 5***
- ***Lippincott's Illustrated Reviews: Cell and Molecular Biology Chapter 20***

***For more detailed instruction, any question, cases need help please post to the group of session.***

# The Learning Outcomes

- Describe the process and role of mitosis. (LO 11.1)
- Describe the process and role of meiosis. (LO 11.2)
- Distinguish clearly between genotype and phenotype. (LO 11.3)
- Distinguish clearly between dominant and recessive trait. (LO 11.4)
- Distinguish clearly between gene and allele. (LO 11.5)

# The Cell Cycle

LO. 11.1

Cells in the body alternate between two states:

- ✓ Division and
- ✓ Non-division.

The sequence of events from one division to the next is called: The Cell Cycle.

A cell cycle consists of three parts:

1. Interphase (cell growing and preparing to divide).
2. Mitosis (nuclear division).
3. Cytokinesis (cytoplasmic division)

LO. 11.1

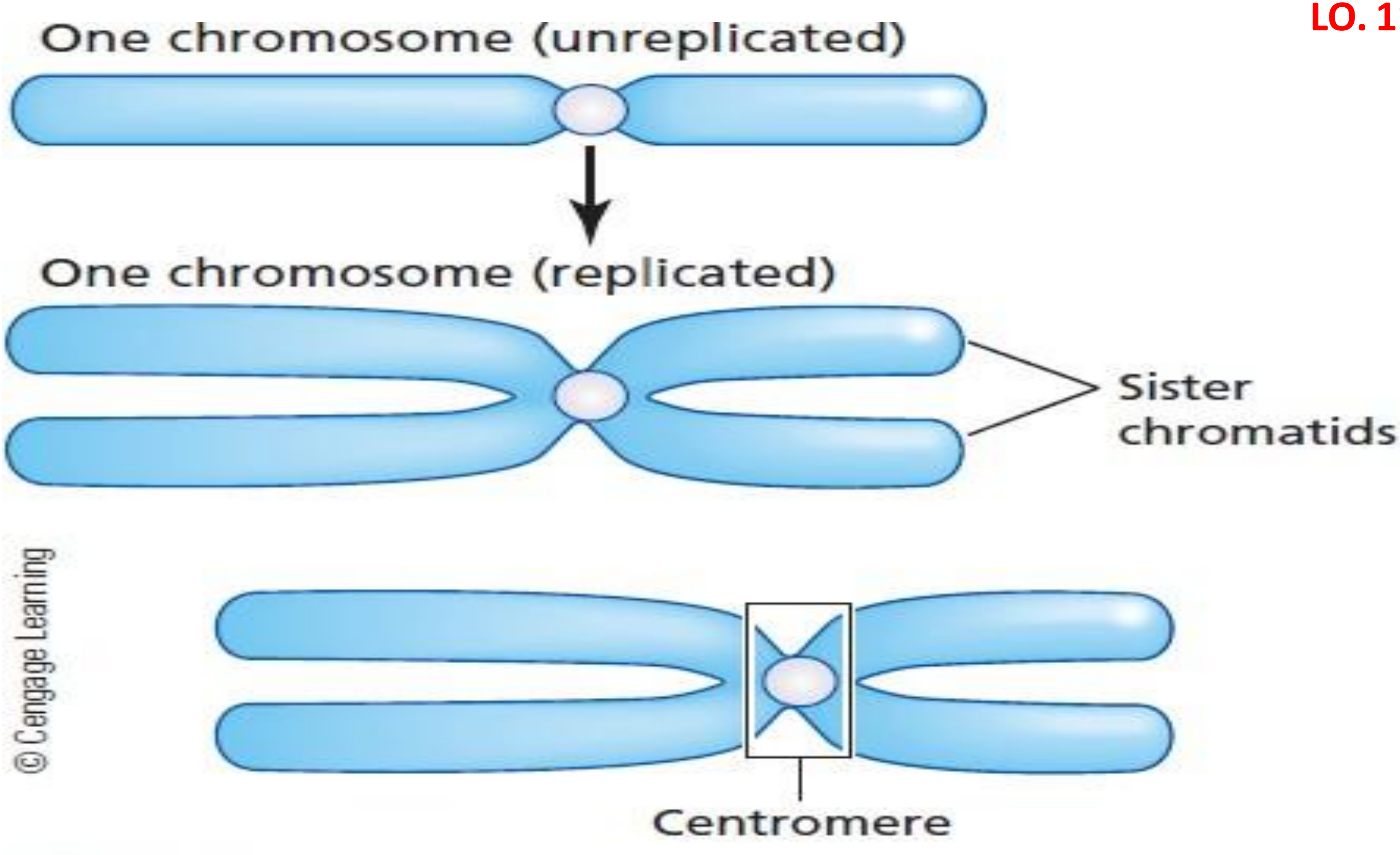
# 1. Interphase: Has three stages:

- **G1 (Gap1) phase:** During this stage, many cytoplasmic components, including organelles, membranes, and ribosomes, are made. This synthetic activity doubles the cell's size.

- **S (Synthesis) phase:** During which a copy of each chromosome is made

- **G2 (Gap2) phase:** (mitochondria are divided, spindles fibers are synthesized) By the end of G2, the cell is ready to divide.

LO. 11.1




**Chromosomes replicate during the S phase.**

**The replicated chromosomes have two sister chromatids**

LO. 11.1

# Phases of cell cycles

| Phase | Characteristics |
|---|---|
| **Interphase** | |
| G1 (Gap 1) | Stage begins immediately after mitosis.<br>RNA, proteins, and organelles are synthesized. |
| S (Synthesis) | DNA is replicated, and chromosomes form sister chromatids. |
| G2 (Gap 2) | Mitochondria divide. Precursors of spindle fibers are synthesized. |
| **Mitosis** | |
| Prophase | Chromosomes condense.<br>Nuclear envelope disappears.<br>Centrioles divide and migrate to opposite poles of the dividing cell.<br>Spindle fibers form and attach to chromosomes. |
| Metaphase | Chromosomes line up on the midline of the dividing cell. |
| Anaphase | Chromosomes begin to separate. |
| Telophase | Chromosomes reach opposite poles.<br>New nuclear envelope forms.<br>Chromosomes decondense. |
| **Cytokinesis** | Cleavage furrow forms and deepens.<br>Cytoplasm divides. |

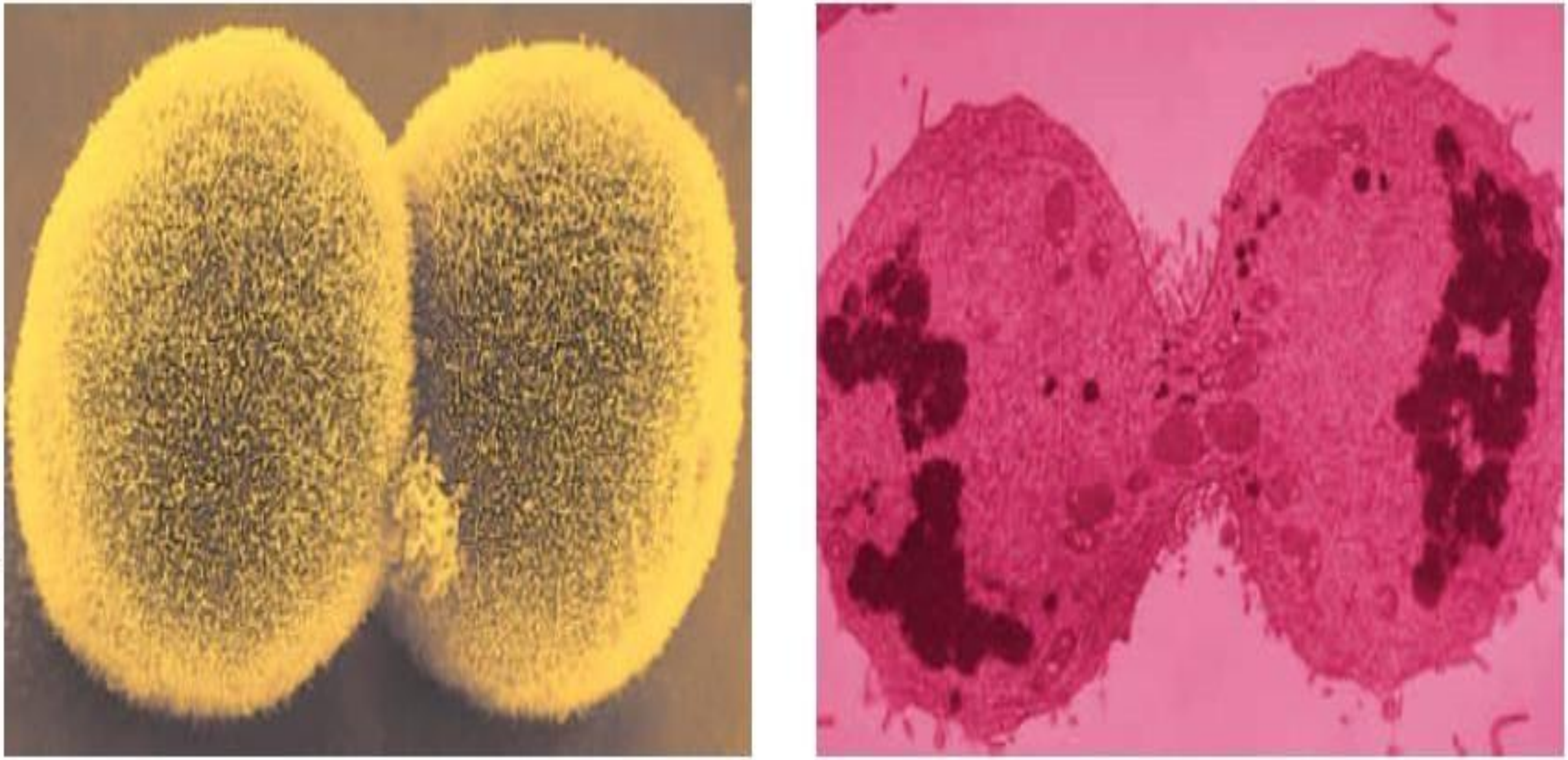
# Cytokinesis

LO. 11.1

- ✓ **Cytokinesis is the formation of a constriction called a cleavage furrow at the equator of the cell.**

- ✓ **The result of mitosis and cytokinesis is a formation two genetically identical cells.**

LO. 11.1



(a) (b)

**Two views of cytokinesis. (a) A scanning electron microscope view of cytokinesis from the outside of the cell. (b) A transmission electron micrograph of cytokinesis in a cross section of a dividing cell.**

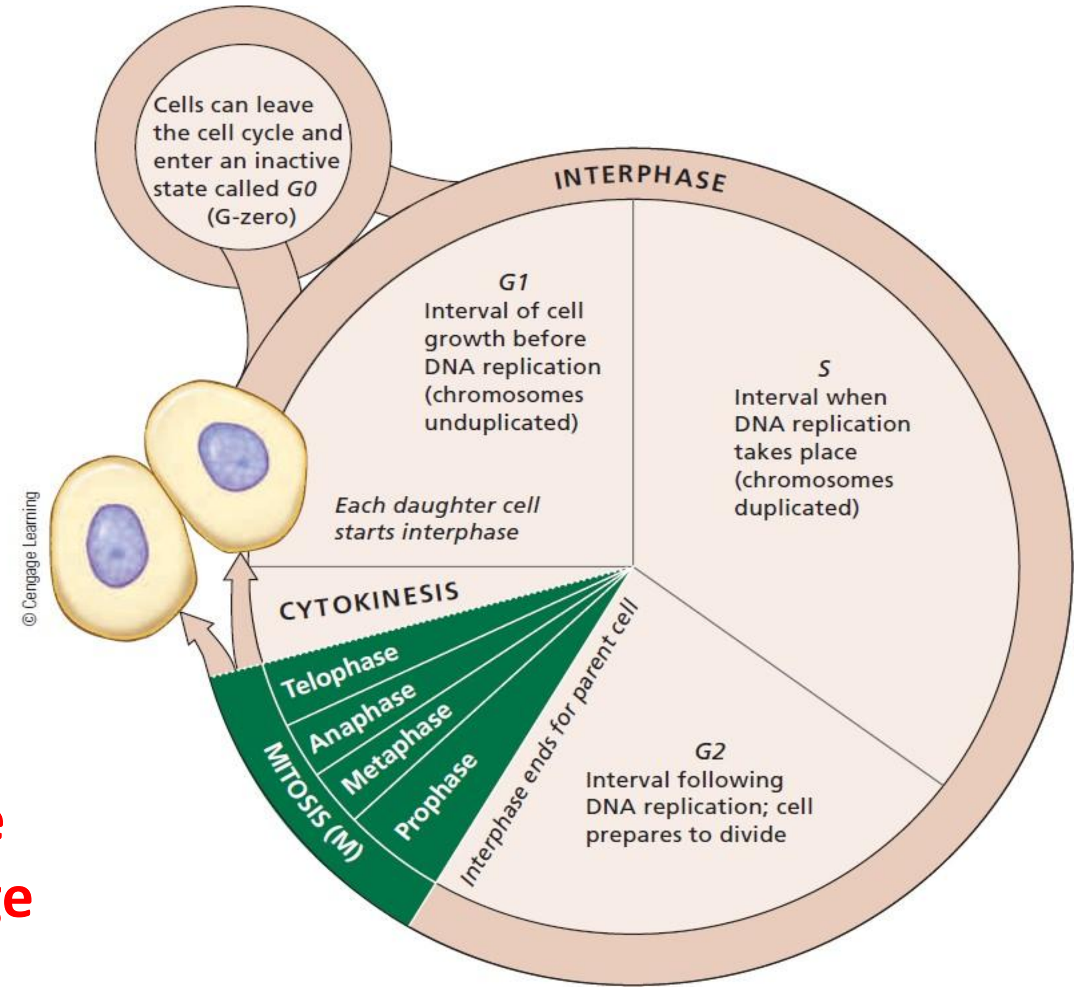
LO. 11.1

**The cell cycle has three stages:**
**1. Interphase 2. Mitosis**
**3.Cytokinesis**

**Interphase has three parts:**
**G1, S and G2**

**Mitosis has four parts:**
**1. Prophase 2. Metaphase**
**3.Anaphase 4. Telophase**

**Some cells can opt out of the cycle and enter a resting stage called G0 ( G Zero).**





GROWTH
CYTOKINESIS
(cytoplasmic
division)
MITOSIS
(nuclear division)

LO. 11.1

# Cell cycle and cell type

- Some cells retain the capacity to divide throughout their life cycle, whereas others do not divide in adulthood.

For example:

- ✓ **Cells in bone marrow** pass through the cell cycle continuously and divide regularly to form blood cells.
- ✓ **Skin cells** constantly divide to replace dead cells that are sloughed off the surface of the body.

- By contrast, other cells, including many cells in the **nervous system**, leave the cell cycle, enter G0, and do not divide in adulthood.

- In between, such as **white blood cells**, that enter G0 but can reenter G1 and divide.

- When cells escape from cell cycle regulation and **grow uncontrollably**, forming cancerous **tumors.**

# Meiosis (Reduction division)

LO. 11.2

**Cells in the testis and ovary called germ cells undergo meiosis and produce gametes (sperm and egg).**

**Cells with two copies of each chromosome are diploid (2n) and have 46 chromosomes.**

**In meiosis: members of a chromosome pair separate from each other, and each daughter cell receives a haploid (n) set of 23 chromosomes.**

**Each gamete contains:**

- ✓ **22 autosome (chromosomes other than the sex chromosomes)**
- ✓ **One sex chromosome (X in ovum and X or Y in sperm).**

**Fusion of two haploid gametes in fertilization restores the chromosome number to the diploid number of 46, providing a full set of genetic information to the fertilized egg.**

# Meiosis

LO. 11.2

**Meiosis includes two rounds of division:**

1. **Meiosis I:** Reduces the chromosome number
2. **Meiosis II:** Begins with haploid cells.

**In meiosis, one diploid cell with 46 chromosomes undergoes one round of chromosome replication and two rounds of division to produce four haploid cells, each of which contains one copy of each chromosome.**

# Meiosis I

LO. 11.2

**Before cells enter meiosis, the chromosomes replicate during interphase.**

**In prophase I:**

**The chromosomes condense.**

**The nuclear envelope disappears.**

**The spindle becomes organized.**

**In metaphase I:**

**Paired homologous chromosomes line up at the equator of the cell.**

**Each chromosome attached to spindle fibers from opposite poles of the cell.**

**Each consists of two sister chromatids joined by a single centromere.**

# Meiosis I (Continue)

LO. 11.2

## In anaphase I:

**Members of each homologous pair separate from each other and move toward opposite sides of the cell.**

## In telophase I

**Nuclear envelope re-form**

## Cytokinesis:

**Occurs after telophase I, producing two haploid cells**

# Meiosis II

LO. 11.2

## In prophase II:

**The unpaired chromosomes consist of two sister chromatids joined by a centromere.**

## At metaphase II:

**The 23 unpaired chromosomes are at the equator of the cell, with spindle fibers from opposite poles of the cell attached to their centromeres.**

# Meiosis II (Continue)

LO. 11.2

## Anaphase II:

**Begins when the centromeres of each chromosome divide. The 46 chromatids become chromosomes and move to opposite poles of the cell.**

## In telophase II:

**The nuclear envelope re-forms**

## Cytokinesis:

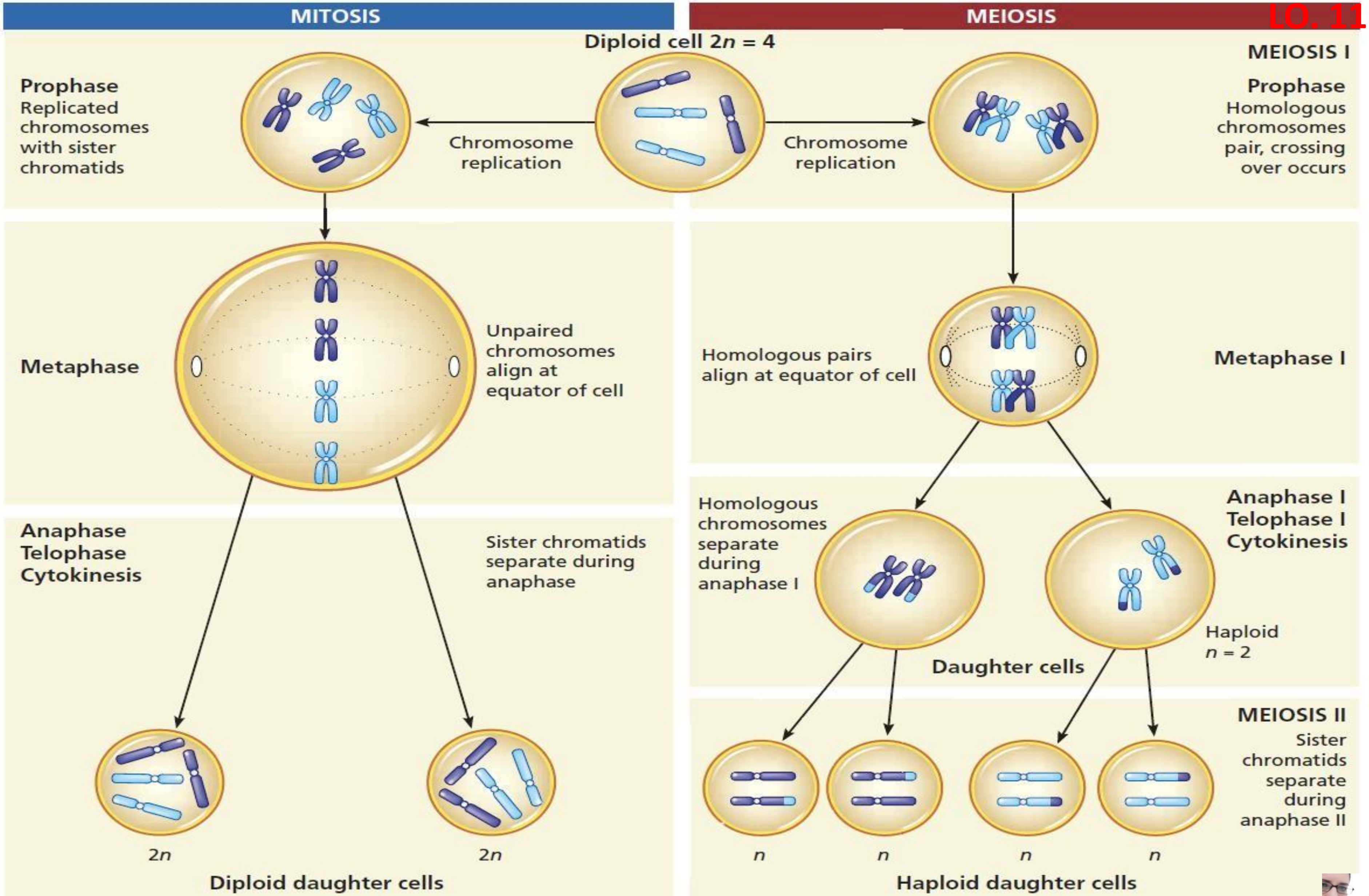
**Then divides the cytoplasm, producing four haploid cells.**

# Summary of Meiosis

LO. 11.2

| Stage | Characteristics |
|---|---|
| Prophase I | Chromosomes become visible, homologous chromosomes pair, and sister chromatids become apparent. Recombination takes place. |
| Metaphase I | Paired chromosomes align at equator of cell. |
| Anaphase I | Paired homologous chromosomes separate. Members of each chromosome pair move to opposite poles. |
| Telophase I | Chromosomes uncoil, become dispersed. |
| Cytokinesis | Cytoplasm divides, forming two cells. |
| Prophase II | Chromosomes re-coil, shorten. |
| Metaphase II | Unpaired chromosomes become aligned at equator of cell. |
| Anaphase II | Centromeres separate. Daughter chromosomes, which were sister chromatids, pull apart. |
| Telophase II | Chromosomes uncoil, nuclear envelope re-forms. Meiosis ends. |
| Cytokinesis | The cytoplasm divides, forming daughter cells. |

LO. 11.2


MITOSIS
MEIOSIS
Diploid cell 2n = 4
MEIOSIS I
Prophase
Replicated chromosomes with sister chromatids
Chromosome replication
Chromosome replication
Prophase
Homologous chromosomes pair, crossing over occurs
Metaphase
Unpaired chromosomes align at equator of cell
Homologous pairs align at equator of cell
Metaphase I
Anaphase
Telophase
Cytokinesis
Sister chromatids separate during anaphase
Homologous chromosomes separate during anaphase I
Anaphase I
Telophase I
Cytokinesis
Haploid
n = 2
Daughter cells
MEIOSIS II
Sister chromatids separate during anaphase II
2n
2n
Diploid daughter cells
n
n
n
n
Haploid daughter cells

LO. 11.2

# Meiosis produces new combinations of genes in two ways:

1. <u>Independent assortment:</u> Random assortment of maternal and paternal chromosomes
2. <u>Crossing over (recombination):</u> This process involves the exchange of parts between non-sister chromatids. This process also called Chiasma (plural Chiasmata).

LO. 11.2

# Key points of meiosis

- Begins with diploid cell
- Only produces gametes: genetically different haploid cells
- Has two cell division stages: meiosis I and meiosis II
- Meiosis I produces two haploid cells each containing one chromosome from the homologous pairs
- Meiosis II separates sister chromatids to produce four haploid gametes

LO. 11.2

# Key points of meiosis

**Prophase I**

- Synapsis: pairing of homologous chromosomes
- Tetrad: 4 sister chromatids of paired homologous chromosome
- Result of crossing over – genetic variety in gametes
- All gametes are haploid

LO. 11.2

# Formation of Gametes

**In males: The production of sperm, known as Spermatogenesis, occurs in the testes.**

**Spermatocytes, undergo meiosis, and the four haploid cells that result are called sperm.**

# Formation of Gametes

LO. 11.2

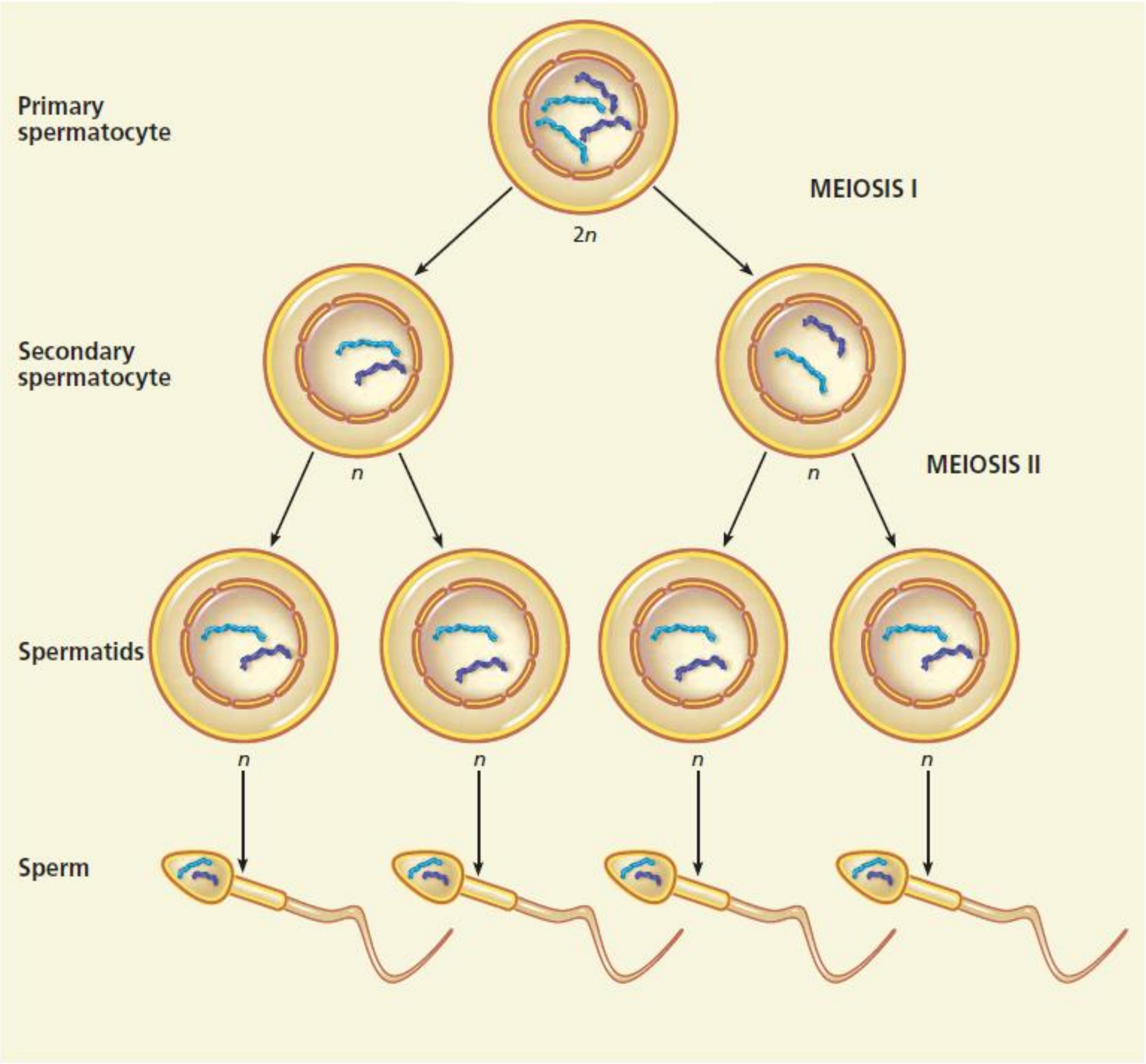
**In females: the production of gametes is called oogenesis and takes place in the ovaries.**

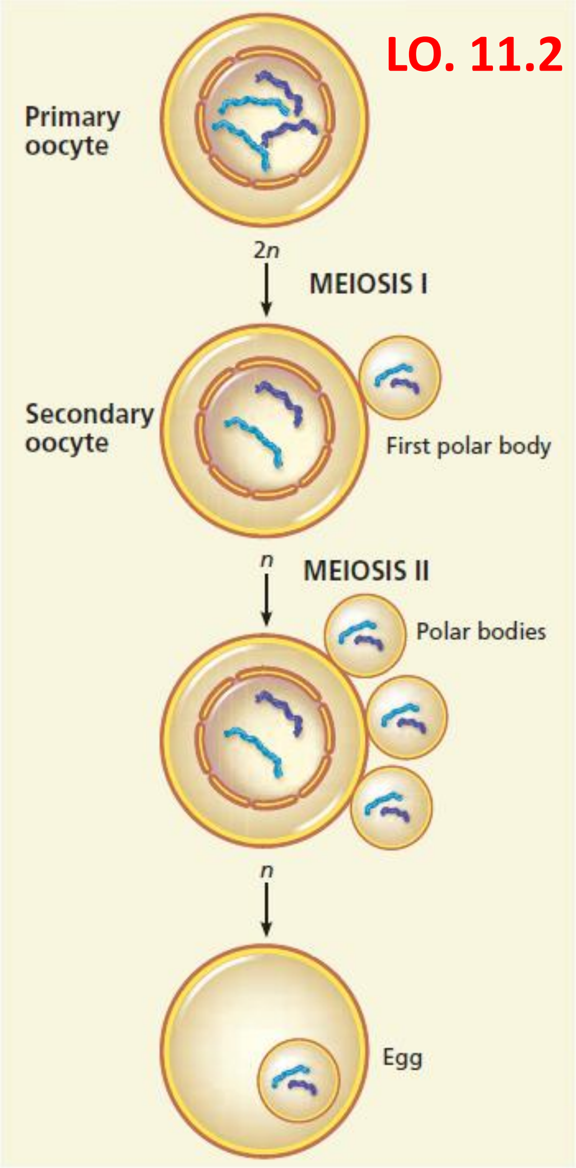
**One primary oocyte which begin meiosis per month but the cytokinesis does not produce cells of equal size.**

**The larger cell (secondary oocyte) becomes the functional gamete (ovum) and the nonfunctional, smaller cells are known as polar bodies.**

**Result of meiosis in female is ovum with 3 polar bodies**

LO. 11.2


Primary spermatocyte
MEIOSIS I
2n
Secondary spermatocyte
n
n
MEIOSIS II
Spermatids
n
n
n
n
Sperm


Primary oocyte
2n
MEIOSIS I
Secondary oocyte
First polar body
n
MEIOSIS II
Polar bodies
n
Egg

# Genotype verses Phenotype

LO. 11.3

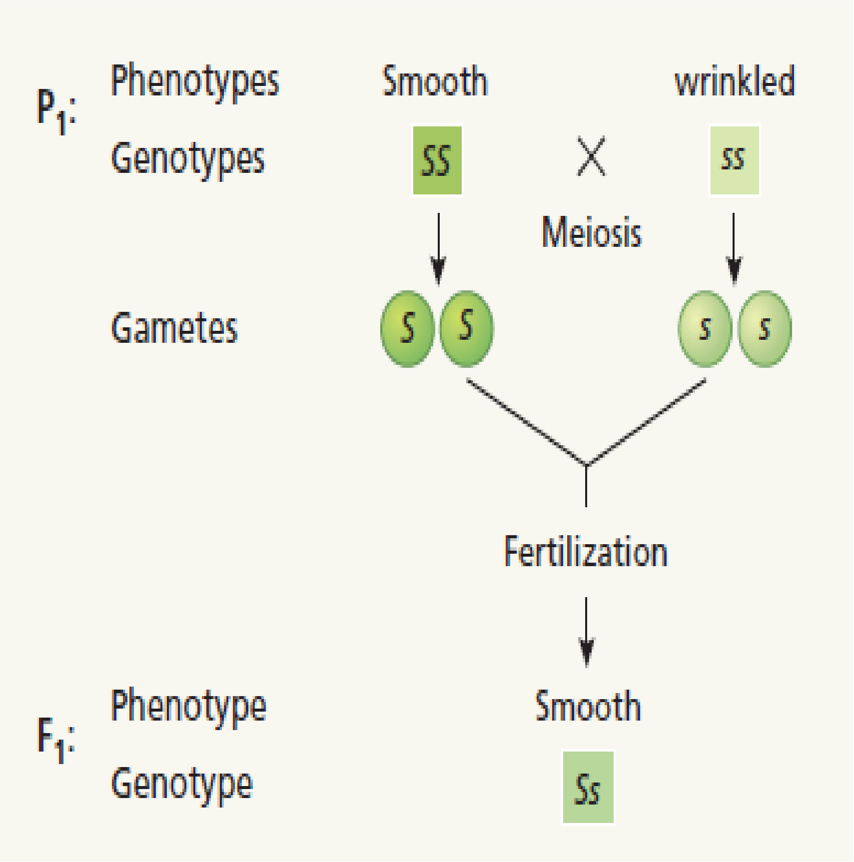
- **Genotype** describes the genetic makeup of an organism.
- **Phenotype** describes the appearance of an organism.

# Genotype verses phenotype

LO. 11.3

**Cross plants with smooth peas to plants with wrinkled peas, all the F1 peas will be smooth.**

**The P1 and F1 plants with smooth peas have identical phenotypes but different genotypes.**




The phenotypes and genotypes of the parents (P1) and the offspring (F1) in a cross involving seed shape.

# Dominant verses Recessive trait

LO. 11.4

**Genes determine traits and can be present but not expressed.**

**The trait is expressed called dominant trait.**

**The trait is not expressed called recessive trait.**

# Dominant verses recessive trait

LO. 11.4

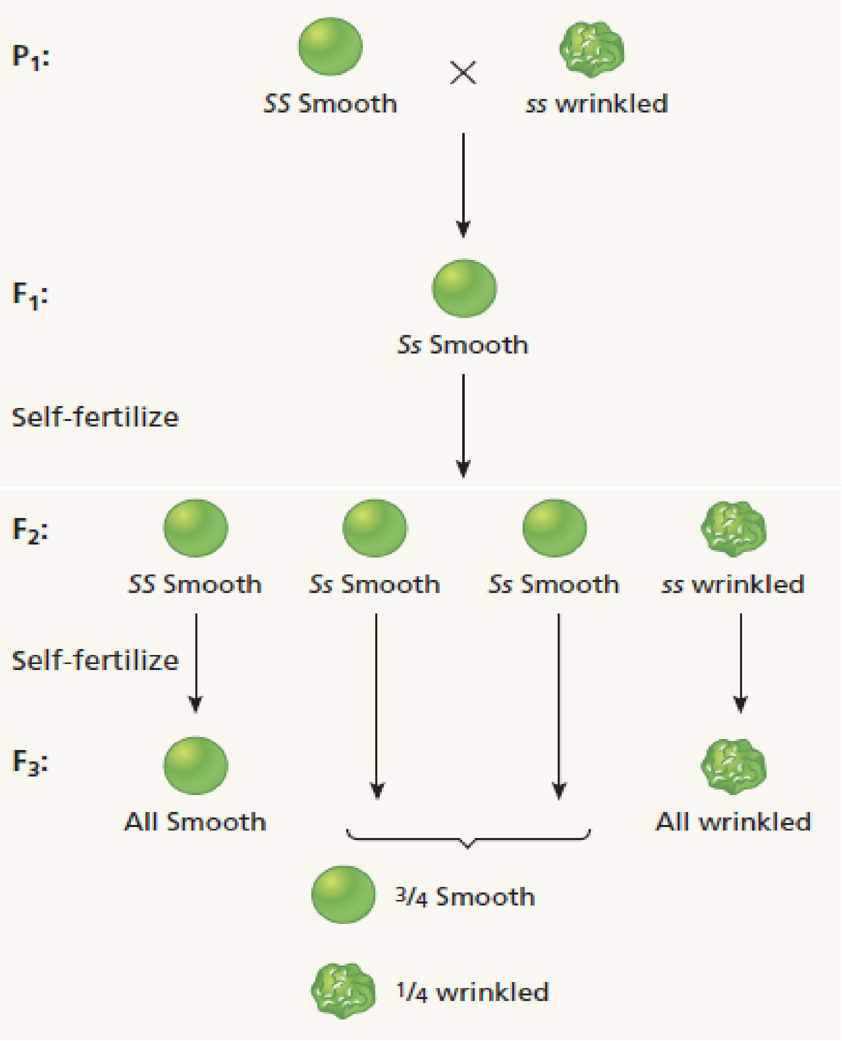
Cross plants with smooth peas to plants with wrinkled peas, all the F1 peas will be smooth.

When these peas are planted and the mature plants are self-fertilized, the next generation of plants (F2) will have some wrinkled peas.

This means that the peas from the F1 plants must carry a gene for wrinkled that was present but not expressed.

The trait expressed in F1 plants a **dominant trait**.

The trait not expressed in the F1 but expressed in some F2 plants a **recessive trait**.



# Gene verses Allele

LO. 11.5

**Allele is the alternative forms (version) of gene; each individual has two alleles for every gene, which can either be the same or different.**

**The gene for pea shape (S) has two alleles: smooth (S) and wrinkled (s).**

**Individuals that carry identical alleles of a given gene (SS or ss) are homozygous for this gene.**

**When two different alleles are present in a gene pair (Ss), the individual has a heterozygous genotype.**

**Hemizygous: having only one copy of a gene (and therefore one allele), which denote the genes on X chromosome in male.**

# Albinos

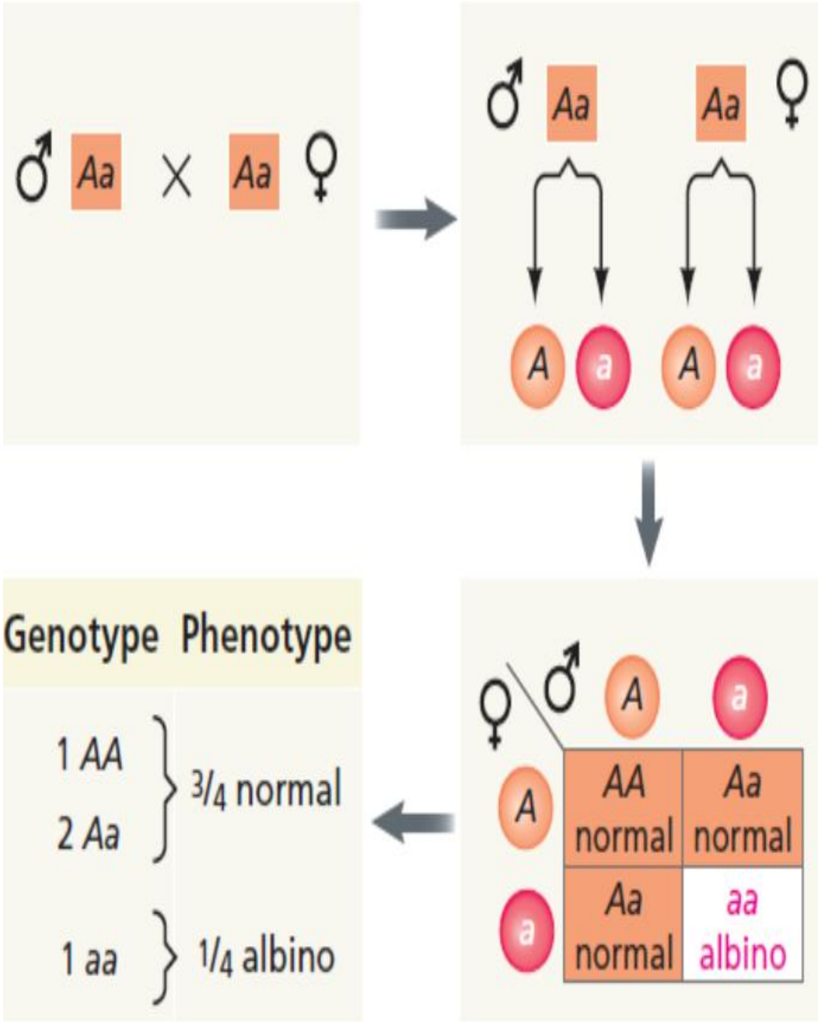
LO. 11.5

Homozygotes (aa) cannot make a pigment called melanin, which is the principal pigment in skin, hair, and eye color.
As a result, albinos have very pale white skin, white hair, and colorless eyes.
Anyone carrying at least one dominant allele (A) can make enough pigment to have skin, hair, and eye color that is normal.

# Albinos

LO. 11.5

If the parents are heterozygotes here are four possible combinations of gametes at fertilization.
The predicted phenotypic ratio of 3 pigmented: 1 albino offspring and a genotypic ratio of 1AA : 2Aa : 1aa.
It does mean, each child has a 25% chance of being albino and a 75% chance of having normal pigmentation.



# Gene verses Allele

LO. 11.5

**Codominant alleles:** Both alleles are fully expressed in heterozygotes.

**Incomplete dominance alleles:** Expression of a phenotype that is intermediate to those of the parents

Any individual can carry only two alleles of a gene, but a population can carry many different alleles of a gene.

# Blood groups

LO. 11.5

**There is one gene (I) for the ABO blood types, and it has three alleles, $I^A$ , $I^B$, and i.**

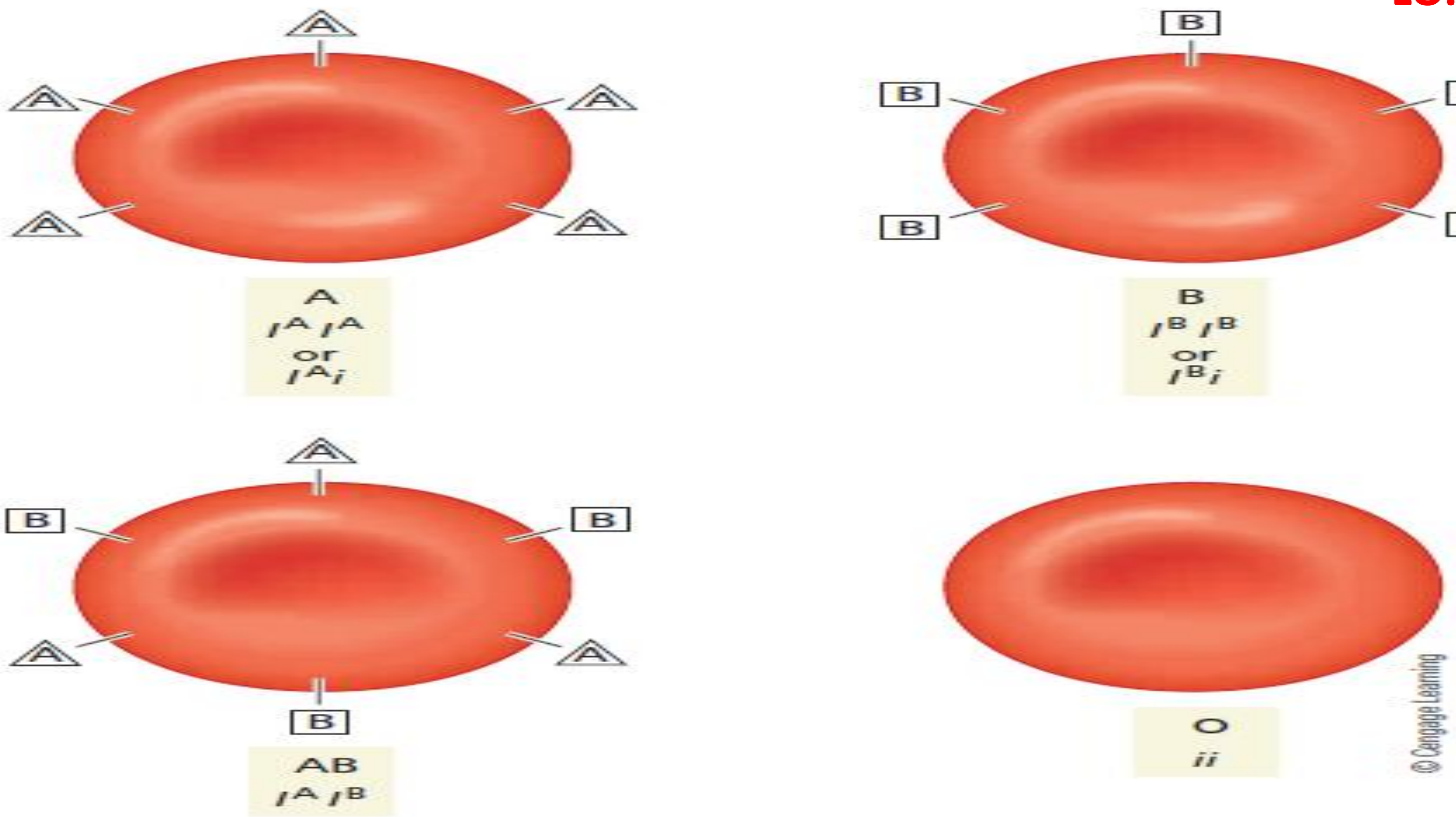
**If there are homozygous for the A allele ($I^A$ $I^A$) or are heterozygous for the A allele ($I^A$ i ), that carry the A antigen on cells and have blood type A.**

**If there are homozygous for the B allele ($I^BI^B$ ) or are heterozygous for the B allele ($I^B$i), you carry the B antigen and are type B.**

**The third allele (i) does not make any antigen, and individuals homozygous for this allele carry no encoded antigen on their cells. The A and B alleles are codominant, so those who are heterozygous ($I^A$ $I^B$) have the AB blood type.**

**The allele for the O blood type is recessive to both the A and B alleles.**

LO. 11.5




Each allele of codominant genes is fully expressed in heterozygotes. Type A blood has A antigens on the cell surface, and type B has B antigens on the surface. In type AB blood, both the A and the B antigen are present on the cell surface. Thus, the A and the B alleles of the *I* gene are codominant. In type O blood, no antigen is present. The *i* allele is recessive to both the A and the B alleles.

# ABO Blood Types

LO. 11.5

| Genotypes | Phenotypes |
|---|---|
| $I^A I^A$, $I^A i$ | Type A |
| $I^B I^B$, $I^B i$ | Type B |
| $I^A I^B$ | Type AB |
| $ii$ | Type O |


Thank you