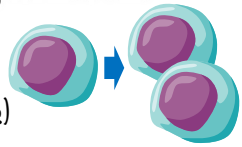
B2.1 Cell & Nuclear Division

Mitosis
Production of two genetically identical cells

Purpose – repair and growth
Result – 2 identical cells
Where – Eukaryotes (somatic cells)



Meiosis (see page 4)
Production of four non-identical cells

Purpose – production of gametes (sex cells)
Result – 4 cells
Where – Eukaryotes (gamete cells - egg/sperm)

Binary Fission (see page 7)
Production of two genetically identical cells

Purpose – reproduction in prokaryotes
Result – 2 identical cells
Where – Prokaryotes

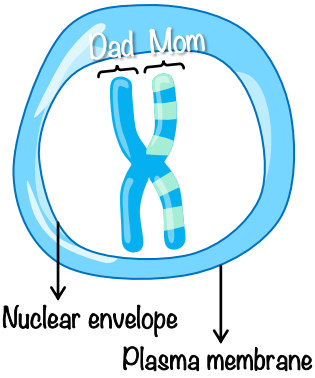
Budding (see page 7)
Production of two genetically identical cells

Purpose – reproduction in yeast
Result – 1 new organism
Where – Eukaryotes (fungi - yeast)

Mitosis – Cells follow a regular (life) cycle called the **cell cycle**, which includes **interphase** for growing and replicating DNA to prepare the cell to divide. The duplicated DNA then divides in two during the process of **mitosis**, and the cytoplasm divides during **cytokinesis**.

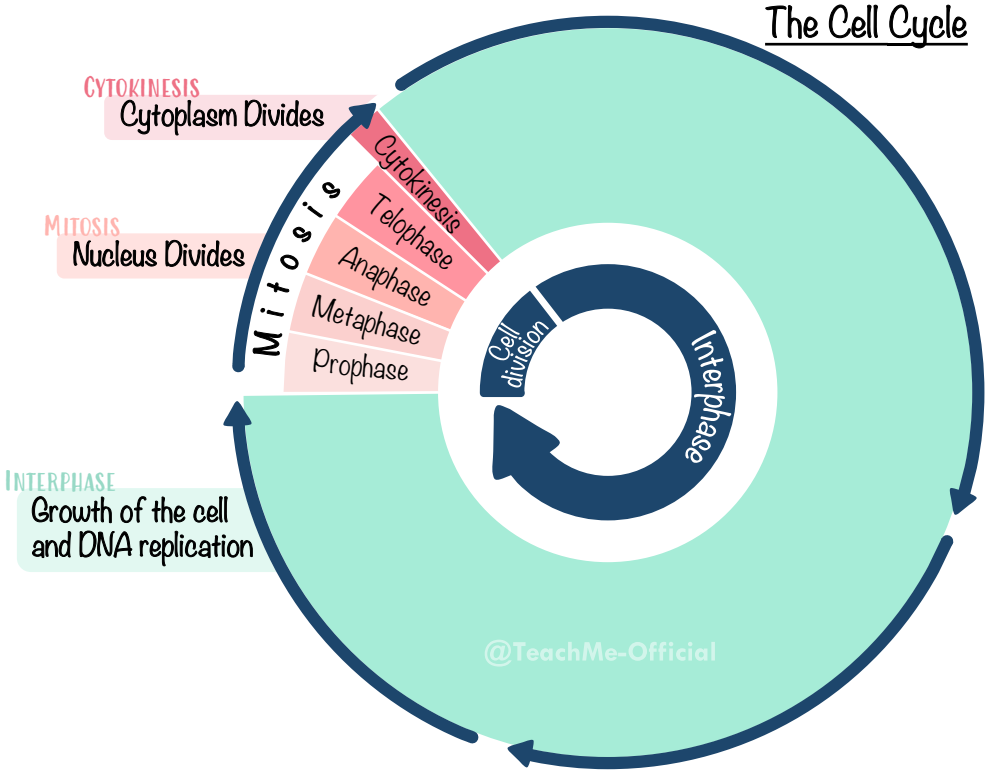
Our Simplified cell

Diploid (2n)

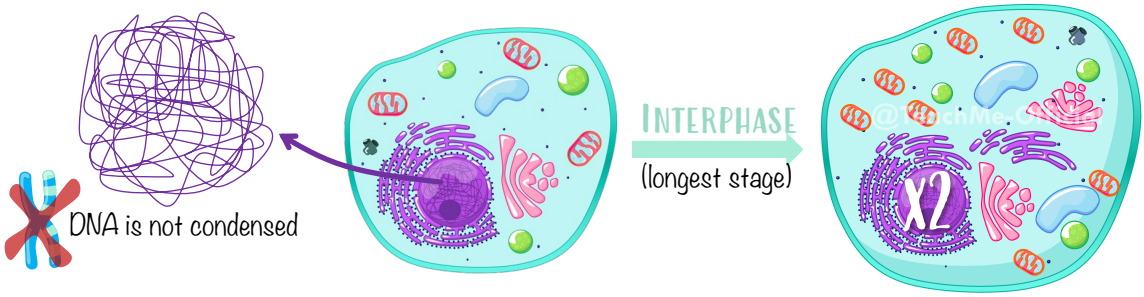


Humans have 23 pairs (46 chromosomes) but we only illustrate one pair for simplicity

The Cell Cycle

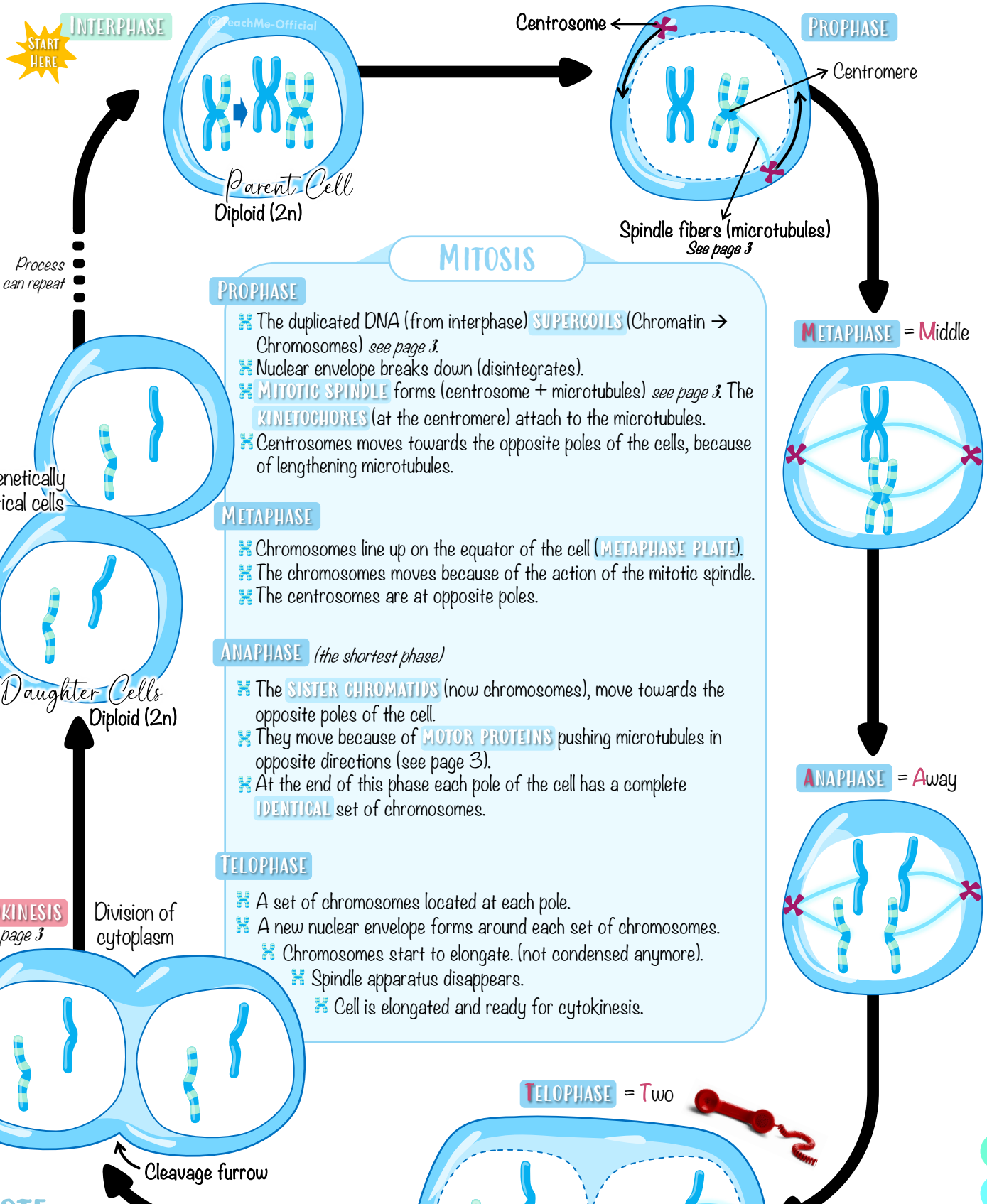


During **interphase**, the cell undergoes growth and replication of organelles such as mitochondria, golgi apparatus etc... To ensure both daughter cells contain everything necessary for them to function. DNA is also replicated to ensure they are both genetically identical. During this phase, DNA is NOT supercoiled; we can only observe chromosomes in prophase.



D2.1

Cell & Nuclear Division



MITOSIS

PROPHASE

- The duplicated DNA (from interphase) **SUPERCOILS** (Chromatin → Chromosomes) *see page 3.*
- Nuclear envelope breaks down (disintegrates).
- **MITOTIC SPINDLE** forms (centrosome + microtubules) *see page 3.* The **KINETOCHORES** (at the centromere) attach to the microtubules.
- Centrosomes moves towards the opposite poles of the cells, because of lengthening microtubules.

METAPHASE

- Chromosomes line up on the equator of the cell (**METAPHASE PLATE**).
- The chromosomes moves because of the action of the mitotic spindle.
- The centrosomes are at opposite poles.

ANAPHASE *(the shortest phase)*

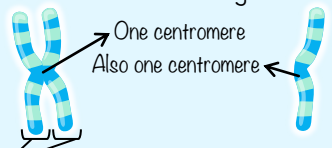
- The **SISTER CHROMATIDS** (now chromosomes), move towards the opposite poles of the cell.
- They move because of **MOTOR PROTEINS** pushing microtubules in opposite directions (see page 3).
- At the end of this phase each pole of the cell has a complete **IDENTICAL** set of chromosomes.

TELOPHASE

- A set of chromosomes located at each pole.
- A new nuclear envelope forms around each set of chromosomes.
- Chromosomes start to elongate. (not condensed anymore).
- Spindle apparatus disappears.
- Cell is elongated and ready for cytokinesis.

NOTE

Chromosome is defined by how many centromeres* it has:



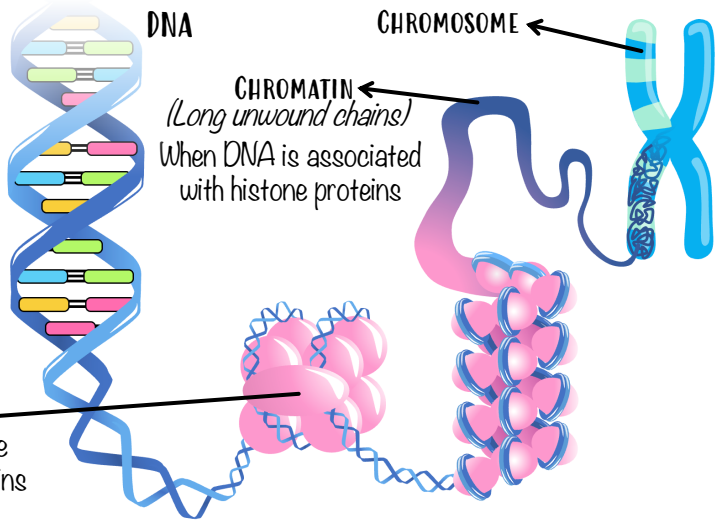
Both are called "chromosome"

*Narrow region in the middle of the chromosome.

Cell & Nuclear Division

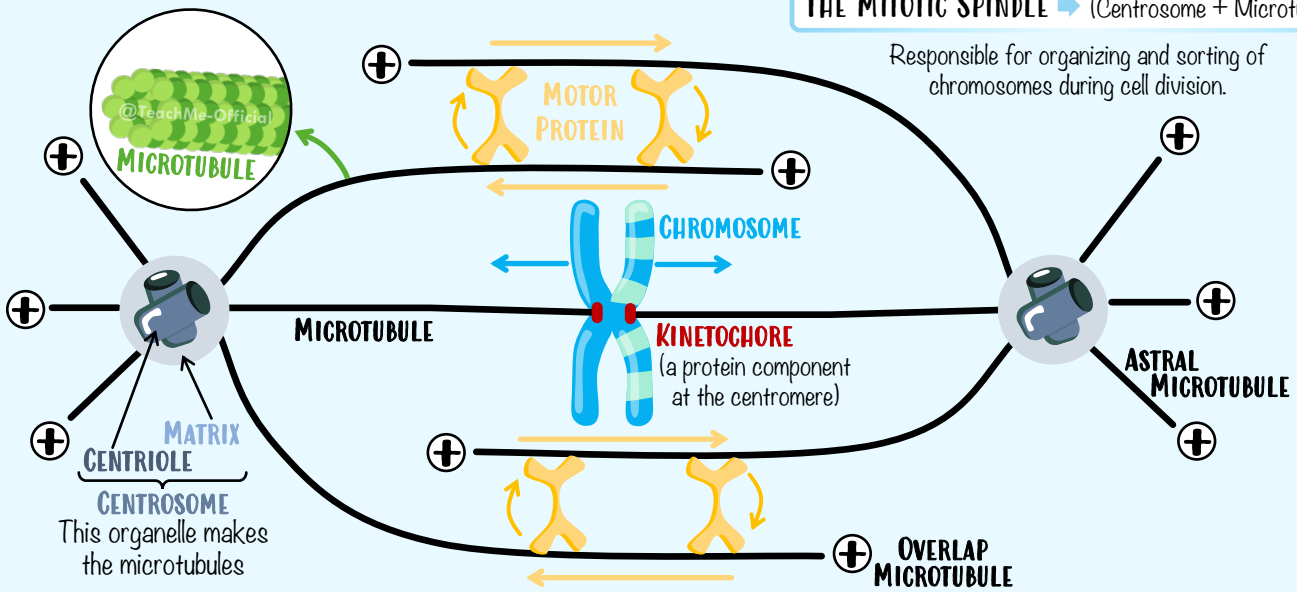
CHROMOSOMES CONDENSE (SUPERCOIL) ➡ during prophase

- In prophase, DNA becomes condensed (supercoiled).
- To not misplace any DNA and to prevent the strands tangling up (like spaghetti) and breaking.
- Transport of DNA is more convenient this way.



THE MITOTIC SPINDLE ➡ (Centrosome + Microtubules)

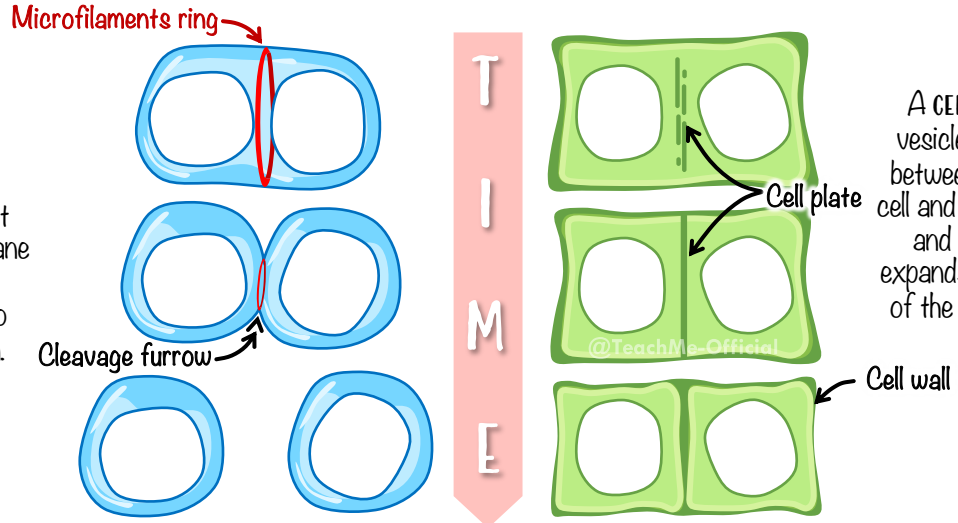
Responsible for organizing and sorting of chromosomes during cell division.



MICROTUBULES [produced by **CENTROSOMES** (specifically centrioles)], extend outward and attach to chromosomes at the **KINETOCHORE**. **MOTOR PROTEINS** move along the **OVERLAPPING MICROTUBULES** by undergoing conformational changes (using ATP), generating the force needed to pull chromosomes apart toward opposite poles of the cell. **ASTRAL MICROTUBULES** help position the spindle apparatus.

CYTOKINESIS – the cytoplasmic division of a cell

Difference between Animal & Plants Cell



ANIMAL CELL

Actin & myosin proteins forms a contractile ring that pinches a cell membrane together (forming cleavage furrow) to split the cytoplasm. Outside To Inside.

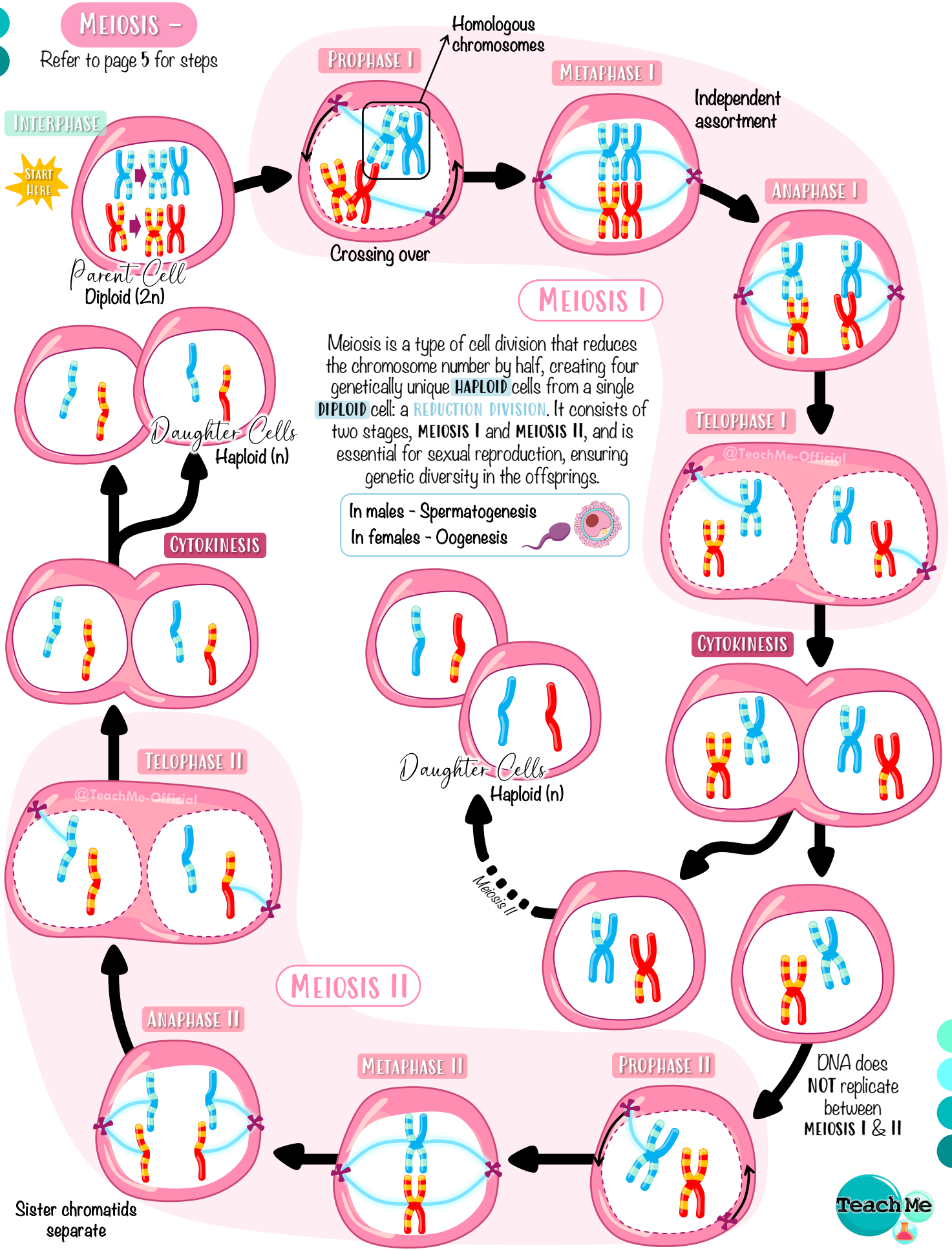
PLANT CELL

A **CELL PLATE** is built up by vesicles that collect midway between the two poles of the cell and lay down cell membrane and cell walls, which then expands outwards to the sides of the cell. Inside To Outside.

Cell & Nuclear Division

MEIOSIS –

Refer to page 5 for steps



Cell & Nuclear Division

Meiosis I

Prophase I

- The duplicated DNA (from interphase) **supercoils** (Chromatin → Chromosomes).
- Nuclear envelope breaks down (**disintegrates**).
- **Mitotic spindle** forms (Centrosome builds new microtubules to pull chromosomes into position). The **kinetochores** attach to the microtubules.
- Centrosome moves towards the opposite poles of the cells, due to lengthening microtubules.
- **Homologous chromosomes** (one pair from mother and one pair from father) pair up.
- **Crossing over** occurs (this promotes variation). This is also known as **recombination** *(see page 6)*.

Metaphase I

- Homologous chromosomes line up on the equator at the centre of the cell (**metaphase plate**).
- The chromosomes move because of the action of the mitotic spindle.
- The centrosomes are at opposite poles.
- Chromosome alignment is random (**independent assortment**), which also promotes variation *(page 6)*.

Anaphase I

- The **homologous chromosomes** separate to the opposite poles of the cell.
- They move because of motor proteins pushing microtubules in opposite directions *(as seen on page 3)*.

Telophase I

- A set of chromosomes located at each pole.
- A new nuclear envelope forms around each set of chromosomes.
- Chromosomes start to elongate (not condensed).
- Spindle apparatus disappears.
- Cell is elongated and ready for cytokinesis.

Meiosis II

Prophase II

- DNA supercoils (Chromatin → Chromosomes).
- Nuclear envelope breaks down (disintegrates).
- Mitotic spindles forms (Centrosome builds new microtubules to pull chromosomes into position).
- The kinetochores attach to the microtubules.
- Centrosome moves towards the opposite poles of the cells, due to lengthening microtubules.

Metaphase II

- Chromosomes line up on the equator at the centre of the cell (metaphase plate).
- The chromosomes move because of the action of the mitotic spindle.
- The centrosomes are at opposite poles.

Anaphase II

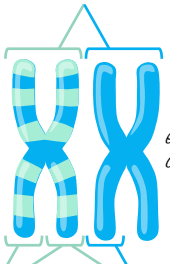
- The **Sister Chromatids** separate to the opposite poles of the cell.
- They move because of motor proteins pushing microtubules in opposite directions *(as seen on page 3)*.

Telophase II

- A set of chromosomes located at each pole.
- A new nuclear envelope forms around each set of chromosomes.
- Chromosomes start to elongate (not condensed).
- Spindle apparatus disappears.
- Cell is elongated and ready for cytokinesis.

Terminology

Homologous chromosomes
(pairs of the same chromosomes)



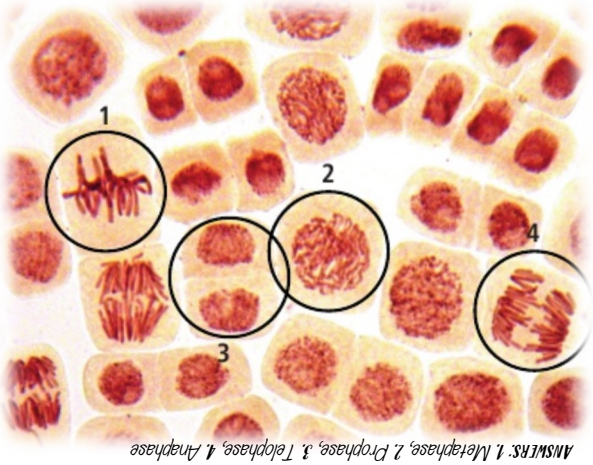
e.g. these are both chromosome 3

Sister chromatids — **Non-Sister chromatids**

two parts of a chromosome attached by a centromere are referred to as "sister chromatids", once they separate into separate cells, they can each be referred to as "chromosome"

Try for yourself

Guess which stage of mitosis each labelled cell is in.



Answers: 1 Metaphase, 2 Prophase, 3 Telophase, 4 Anaphase

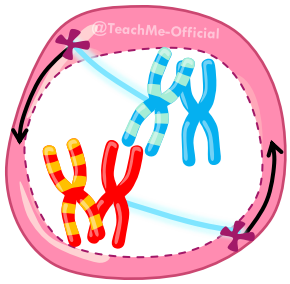
D2.1 Cell & Nuclear Division

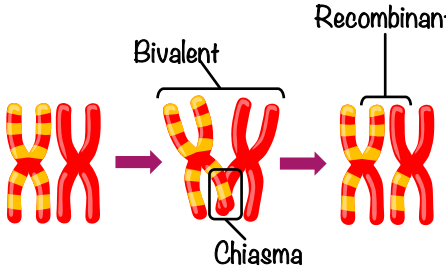
How does the process of meiosis promote genetic variation?

I. CROSSING OVER *During Prophase I*

A process where two non sister chromatids (from a bivalent) exchange (swap) DNA. Allows for mixing of alleles*.

*Allele – Version of a gene





Promotes genetic variation

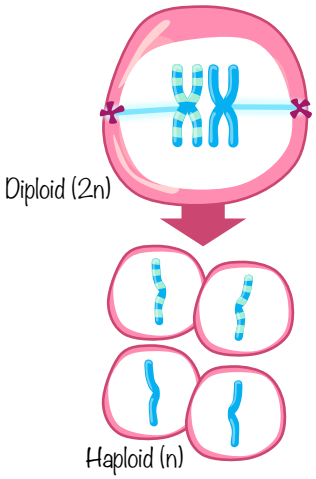
"forming chromosomes that are subtly different from both parents"

II. INDEPENDENT ASSORTMENT *During Metaphase I*

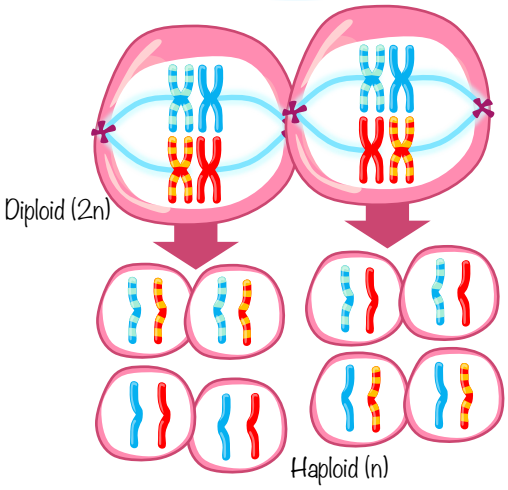
At the metaphase plate in metaphase I, the homologous chromosomes line up in a random fashion (in a random orientation) which allows them to be sorted into separate cells randomly, allowing for a multitude of possible combinations.

Example (if crossing over does not occur)

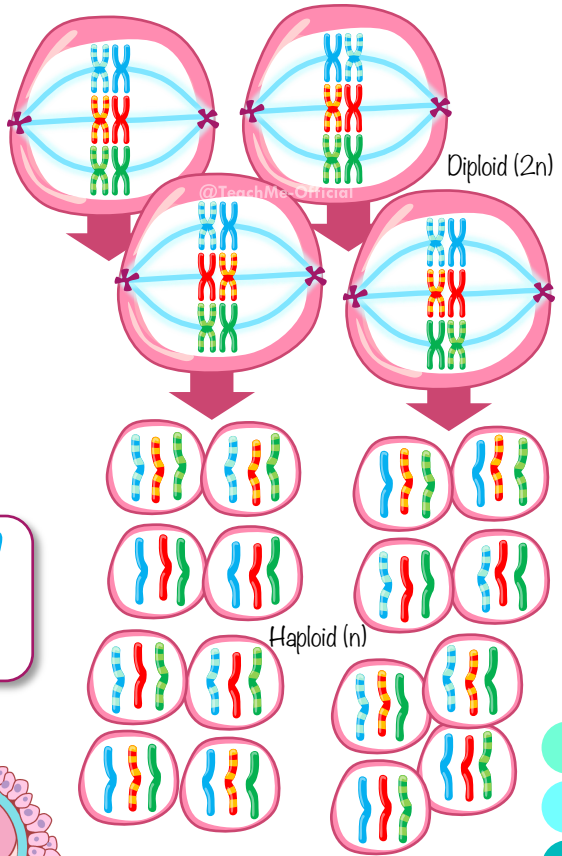
1 homologous chromosomes can yield **2** genetically unique gametes



2 homologous chromosomes can yield **4** genetically unique gametes



4 homologous chromosomes can yield **8** genetically unique gametes



Promotes genetic variation

Number of chromosomes

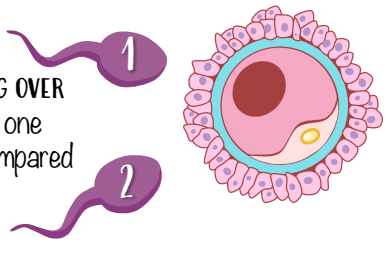
2^N = unique gametes

Humans have 23 chromosomes

2^{23} = 8,388,608 unique gametes

III. FERTILIZATION

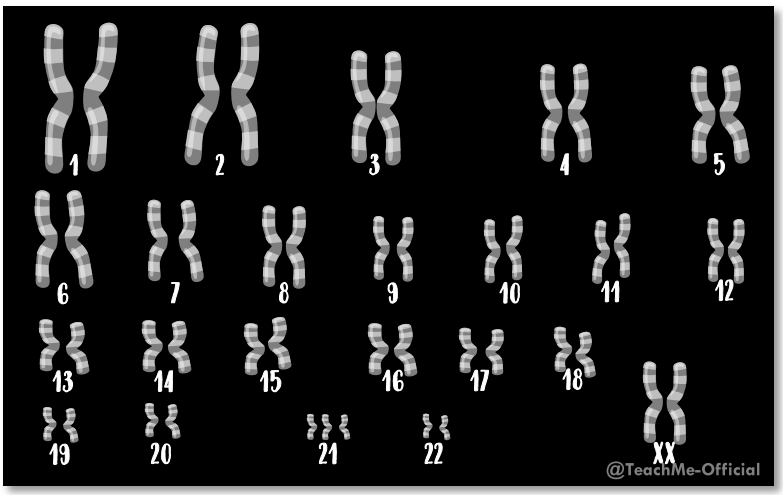
Each **EGG** and **SPERM** is highly variable due to **CROSSING OVER** and **INDEPENDENT ASSORTMENT**. The outcome of sperm one fertilizing with the egg will be genetically different compared to the outcome of sperm two fertilizing with the egg.



Imagine combining crossing over, independent assortment and fertilization how many different combinations of genetic material we can get?

Cell & Nuclear Division

Non-Disjunction A disorder where there is improper separation of chromosomes during meiosis, ultimately resulting in a gamete (sex cell) with an abnormal chromosome number. If the disorder happens on chromosome 21 (trisomy 21) we call it down syndrome.

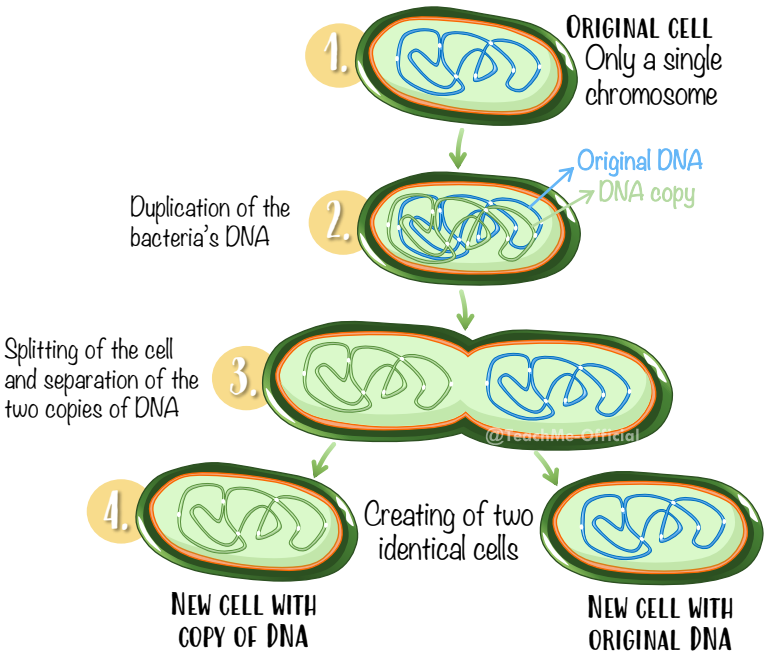


A karyogram would reveal the third copy of chromosome 21

Typical features of trisomy 21

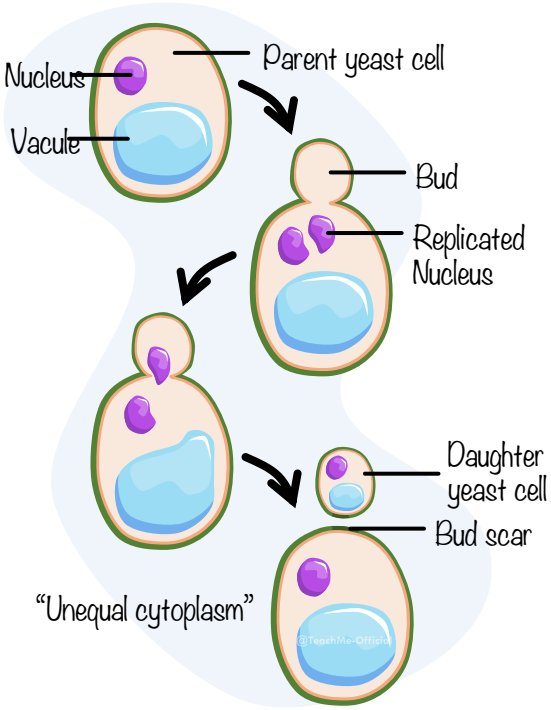
Binary Fission –

Cell division in prokaryotic cells, important for reproduction.



Budding –

Cell division in fungi (yeast), important for reproduction.



notes