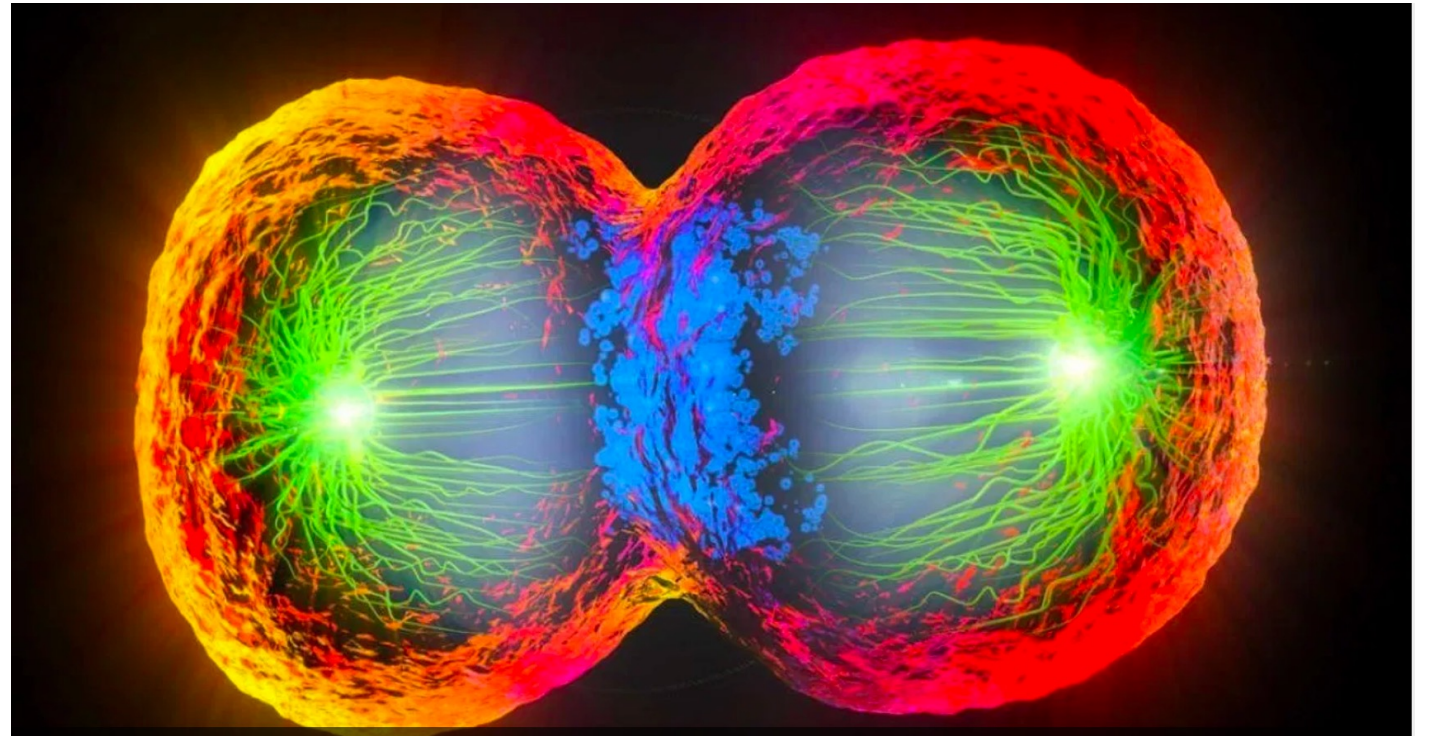


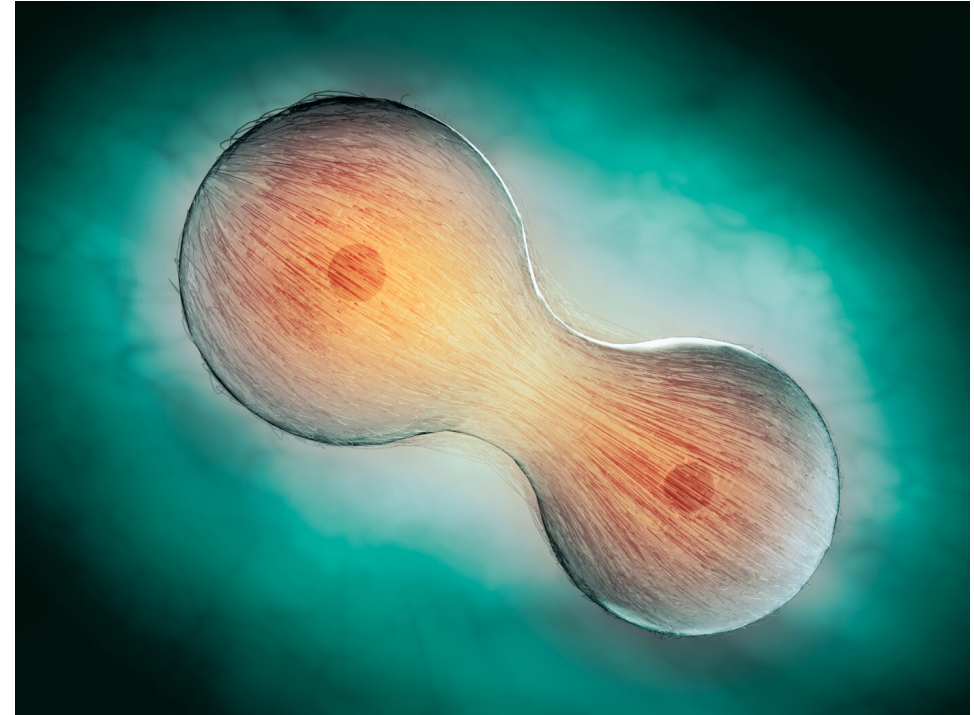
Lesson 8

Cell division



Cell division

- Cells make more cells (copy of themselves)
- Cells make new cells for 3 reasons:
 - Growth → your birth: 1 cell -> 37.2×10^{12} cells
 - Repair → cells surrounding a wound will reproduce themselves to repair the tissue
 - Reproduction → asexual reproduction (typical of single-cell organisms)



Cell division

- **Some cells divide all the time**
 - Surface cells (skin or mucous membranes) are constantly renewed



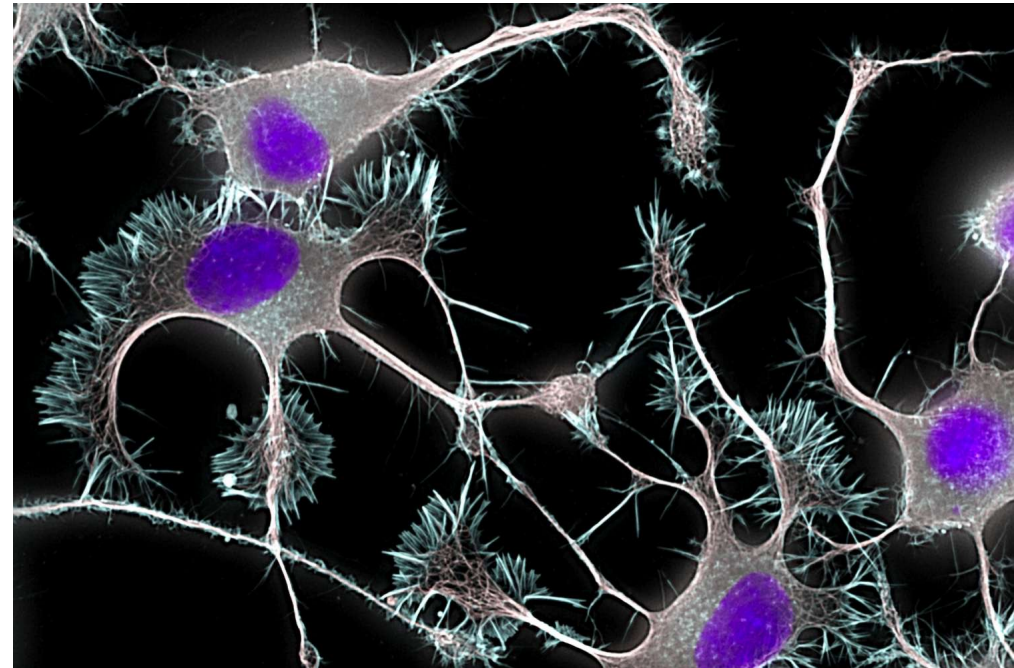
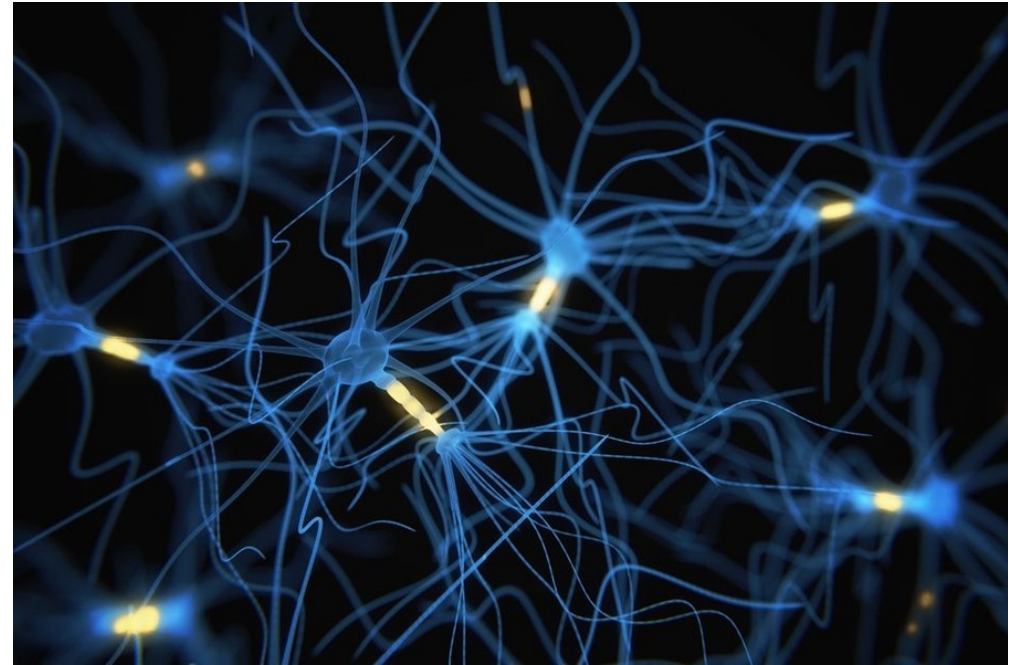
Cell division

- **Some cells divide when signaled to divide**
 - Liver cells do not normally divide but are triggered to divided upon organ damage
- large yellow ovoid, lower right
 - nucleus
- fuzzy blue lines, bottom center
 - RER
- blue lines at left of nucleus
 - SER
- blue lines at upper left
 - Golgi apparatus
- green blobs and spheres
 - mitochondria
- big yellow spheres
 - lysosomes
- fat droplets (pale yellow), glycogen (brown) and plasma membranes (pale green)



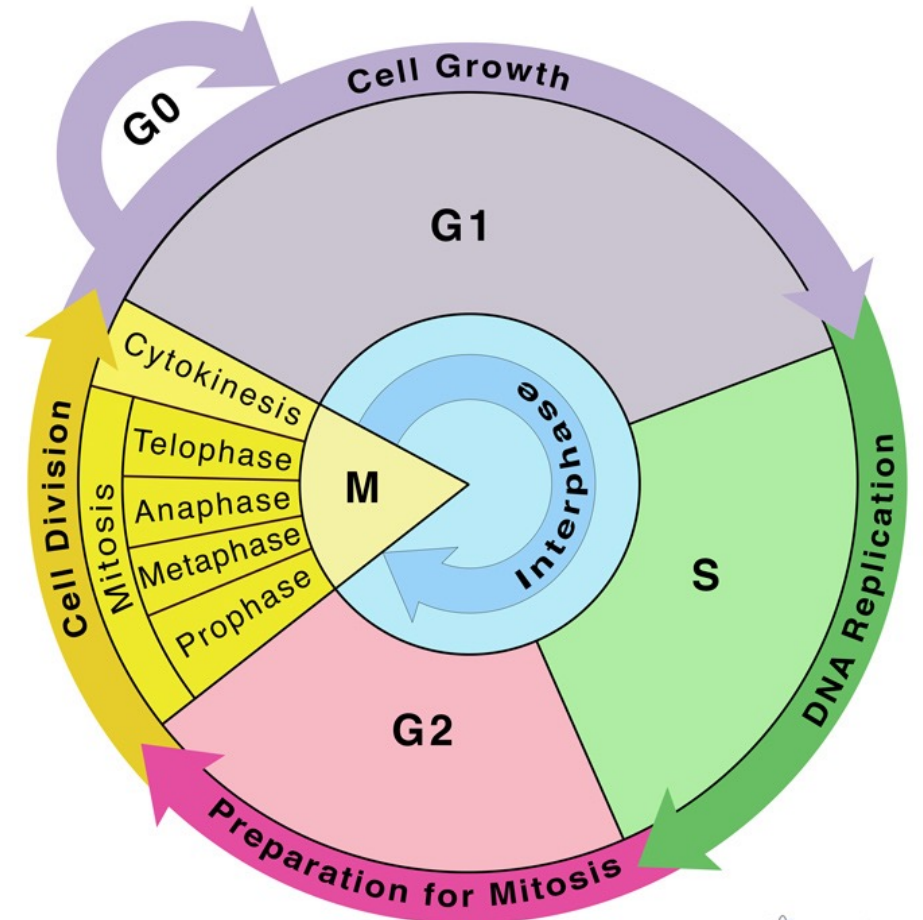
Cell division

- Some cells divide all the time
 - Surface cells (skin or mucous membranes)
- Some cells divide when signaled to divide
 - Liver cells do not normally divide but are triggered to divided upon organ damage
- **Some cells do not divide**
 - Your brain neurons and most cells in the nervous tissue do not divide at all
 - When brain and spine nerves are damaged, they cannot be repaired



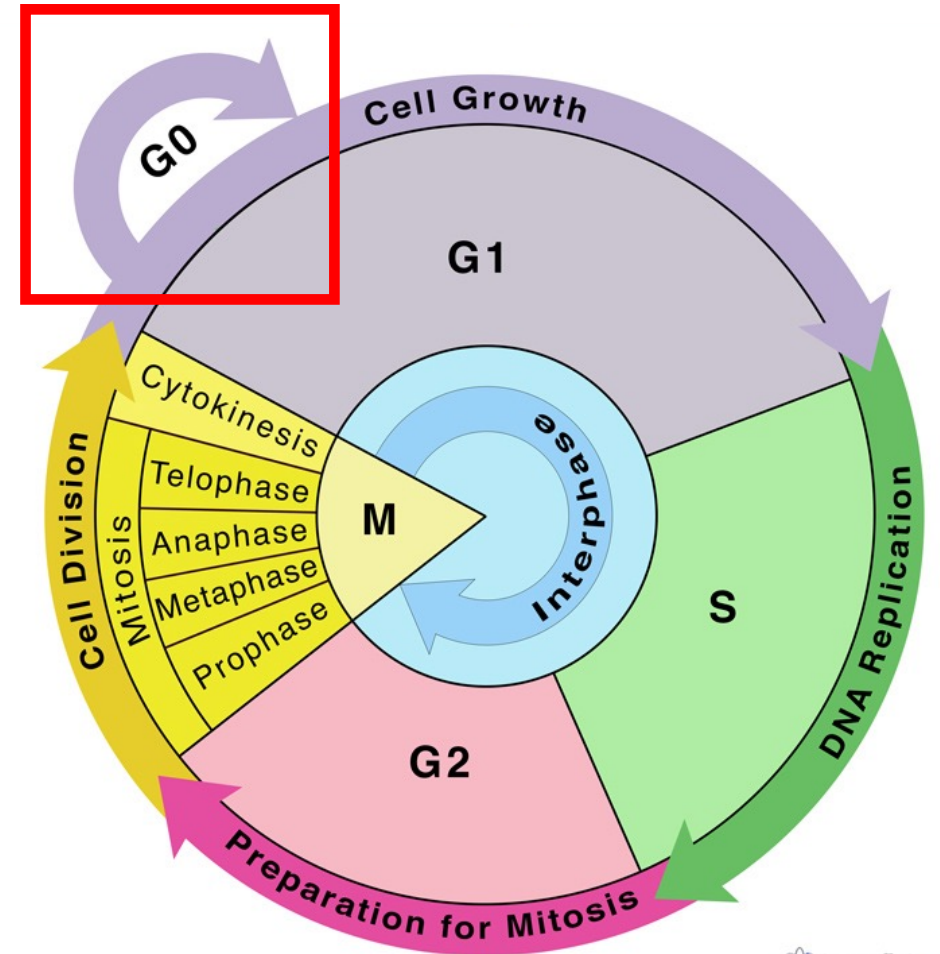
Cell cycle: the cell's traffic light

- **Somatic cells** (all cells except germ cells) divide via **mitosis** (later)
- The non-dividing phase of the cell cycle = **interphase**
 - Three subphases:
 - **G1, S and G2**
- **Cells spend most of their time in G1**
 - The cell factory is in full swing and cells copy all their content except DNA



G0: a cellular state outside the replicative cycle

- Cells were thought to enter G0 primarily due to environmental factors (*e.g.*, starving)
 - limited resources for proliferation
 - was thought of as a resting phase
- **G0 is a normal resident form of non-dividing cells**
 - Neuronal cells (among the most metabolically active cells) reside in a terminal G0 phase as a part of their developmental program



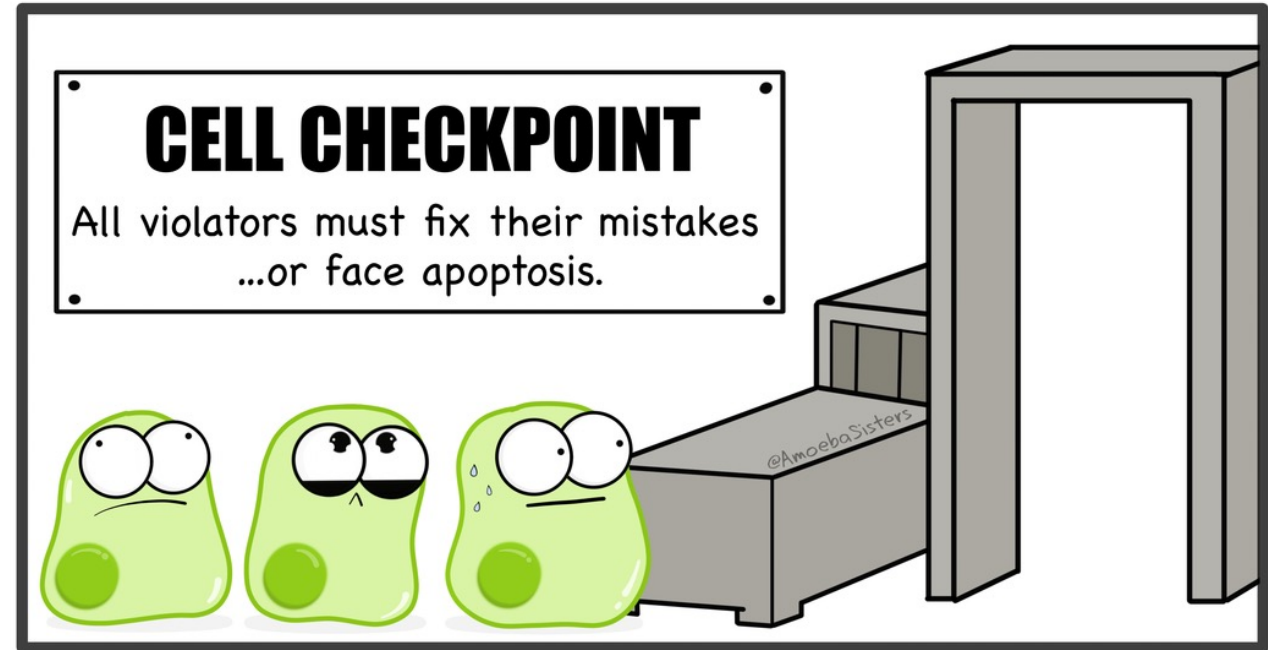
The cell G1 checkpoint

- Before exit G1, dividing cells must pass an integrity test called **checkpoint**
- If checkpoint is negative, repair is attempted
 - **Repair successful** → proceed to next interphase stage (S phase)
 - **Repair unsuccessful** → cell is signaled to commit suicide (**apoptosis = programmed cell death**)



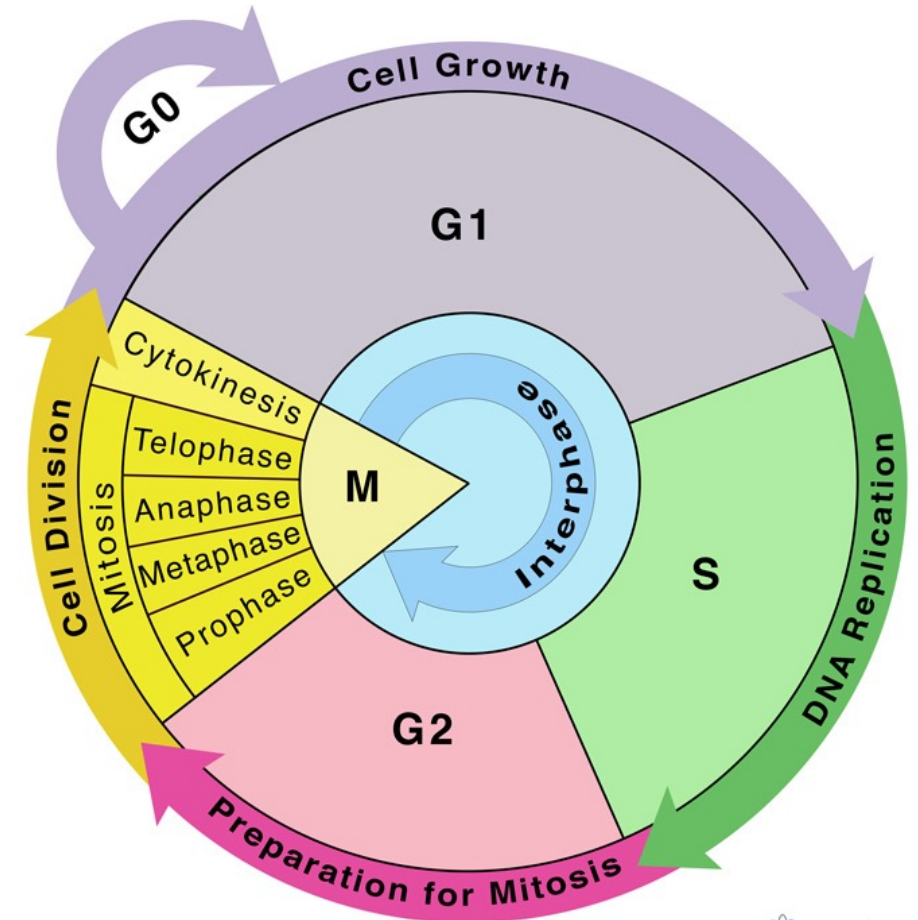
The cell checkpoint

- Criteria for G1 checkpoint pass:
 1. Signals tell cells to divide
 2. Cells must have plenty of nutrients
 3. The DNA must be in optimal conditions
 4. Cells must have the right size and shape to divide



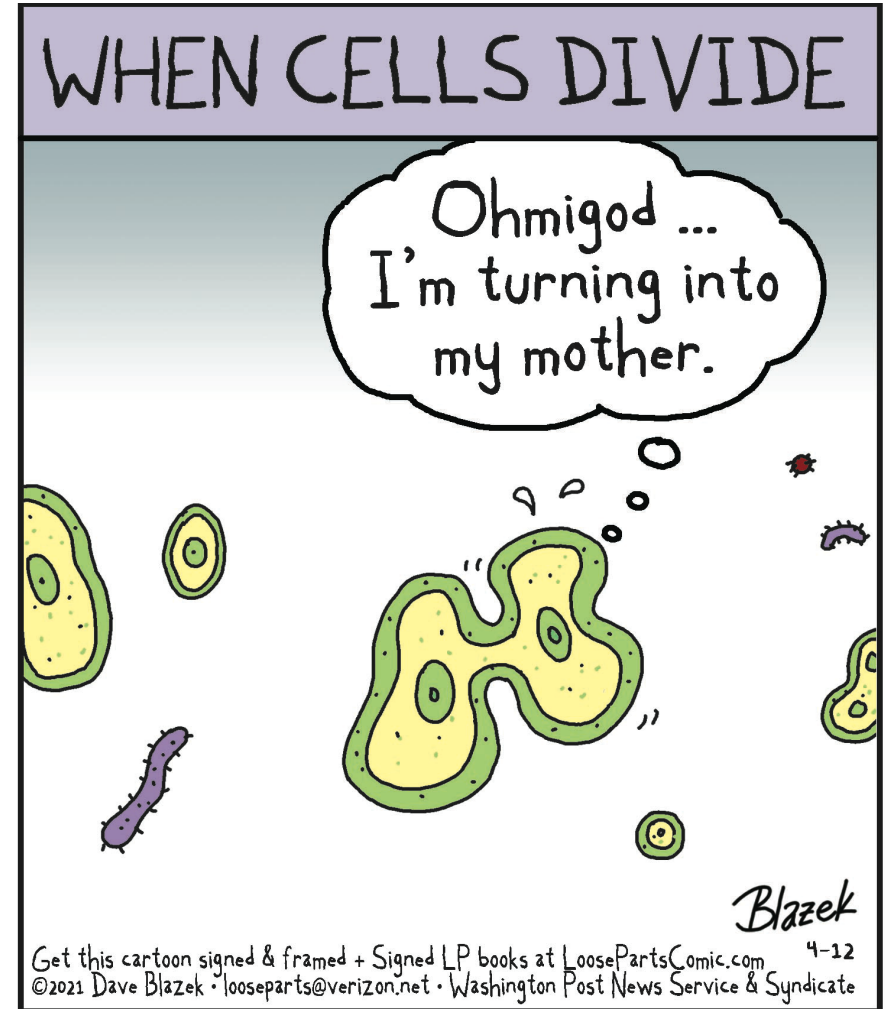
The S phase, G2 and G2 checkpoint

- The **S phase: where DNA is replicated** (later)
 - S stands for synthesis (DNA “synthesis”)
 - Cells are making new DNA
- When DNA replication is over, cells enter **Gap 2 (G2)** stage
 - they undergo another **checkpoint** (G2 checkpoint) to verify DNA replication before entering the last phase (**division**)



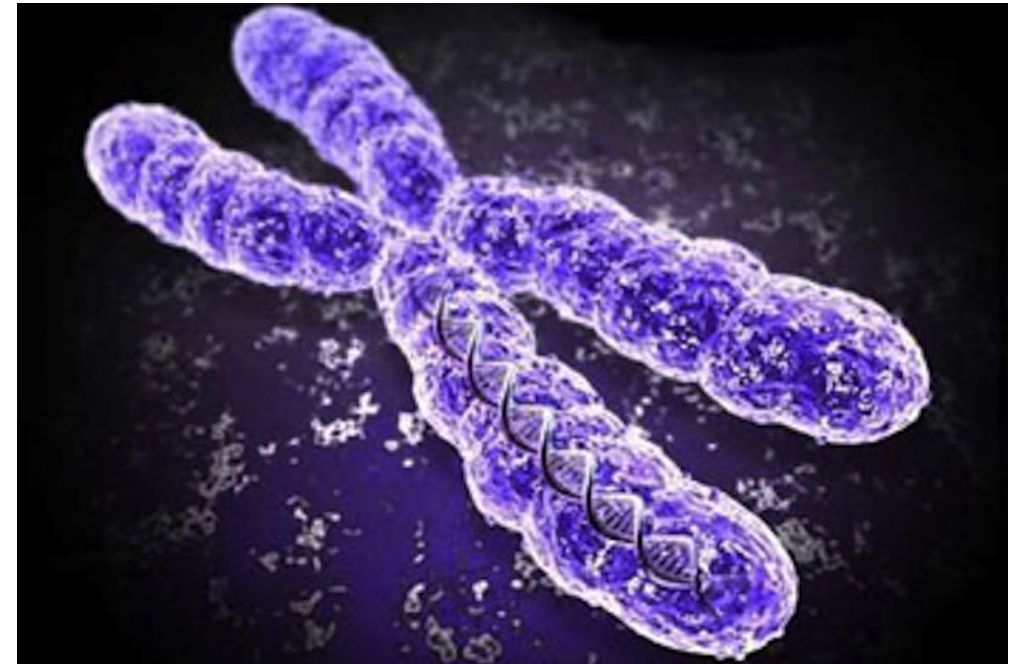
The cell G2 checkpoint

- Criteria for G2 checkpoint pass:
 1. DNA is not damaged
 2. Cells have copied all the chromosomes
 3. Signals tell the cell to proceed into mitosis
- If checkpoint is not successful
 - Cells will be stuck in G2
 - DNA repair is attempted
 - If **successful** → proceed to division
 - If **not successful** → apoptosis



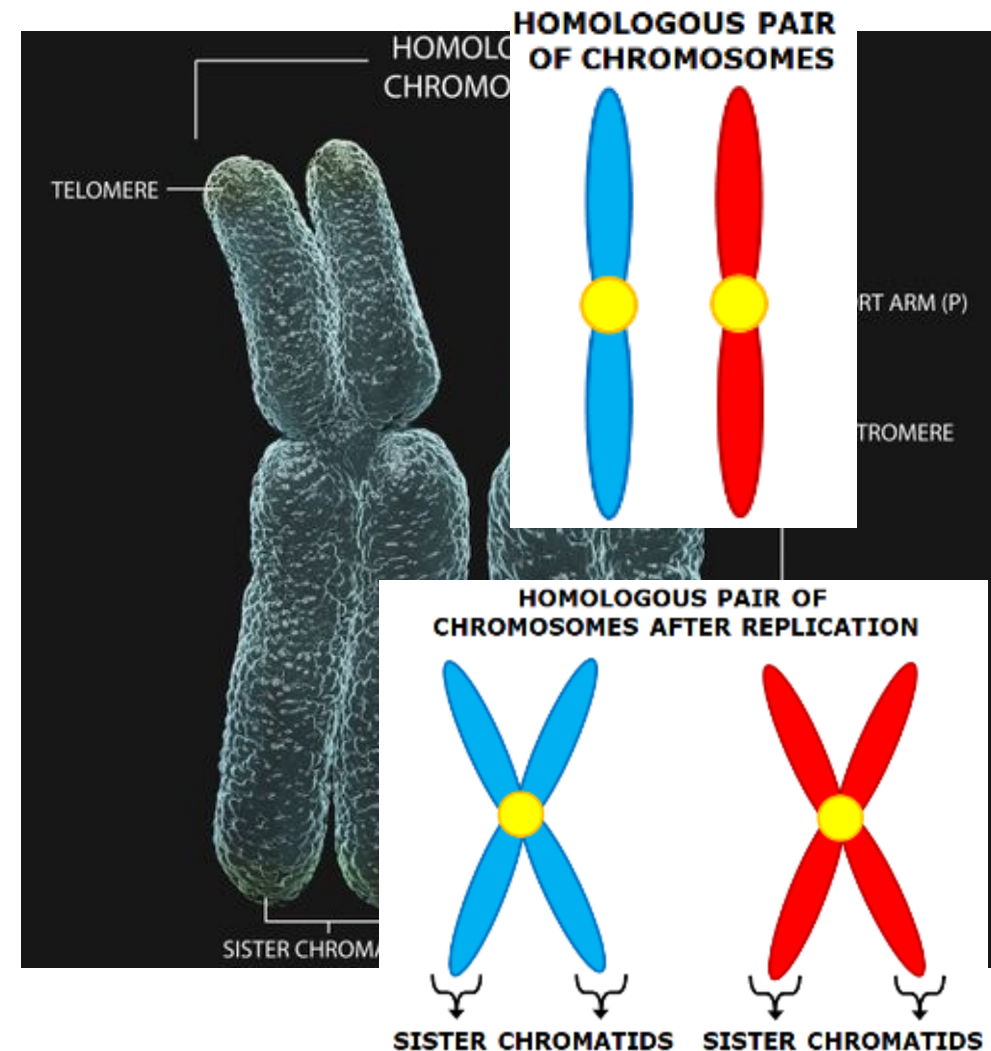
Cell division

1. DNA replication → make two sets of genes (DNA)
 2. DNA partitioning between daughter cells
- Genes (DNA) are organized in chromosomes (chrs)



Cell division

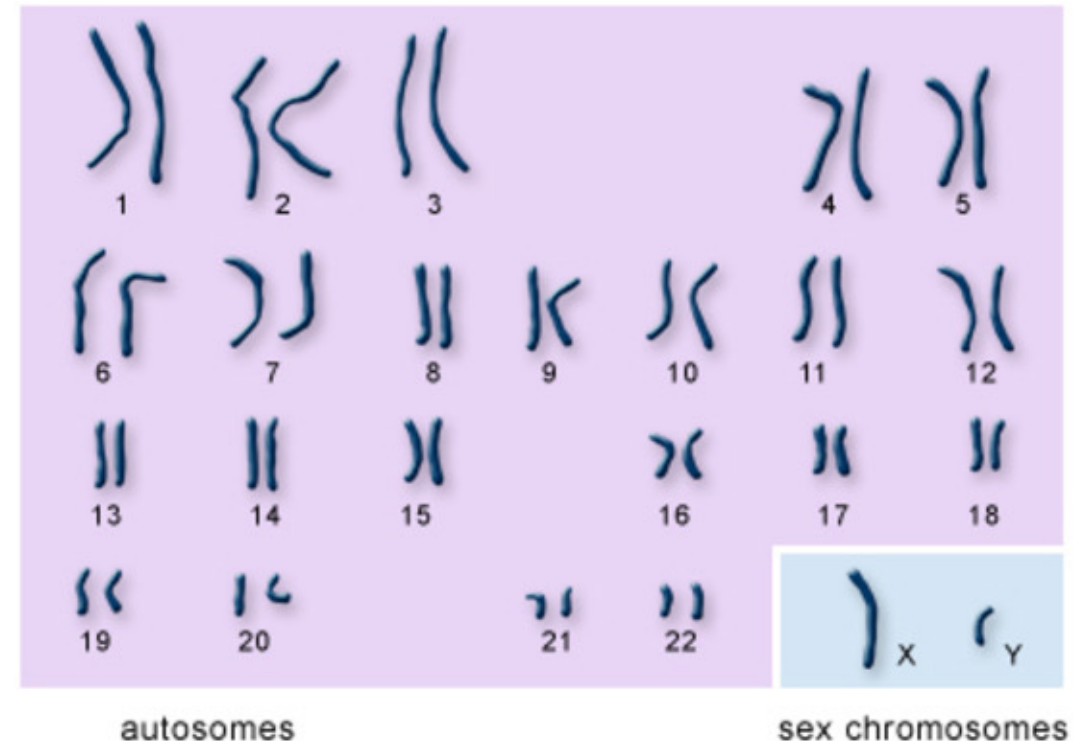
1. DNA replication → make two sets of genes (DNA)
2. DNA partitioning between daughter cells
 - Genes (DNA) are organized in chromosomes (chrs)
 - Body (**somatic**) cells contain 2 of each chr
 - somatic cells are **diploid** (2n)
 - Each matching couple of chrs are called **homologs or homologous chrs**



Cell division

1. DNA replication → make two sets of genes (DNA)
2. DNA partitioning between daughter cells
 - Genes (DNA) are organized in chromosomes (chrs)
 - Body (**somatic**) cells contain 2 of each chr
 - somatic cells are **diploid** (2n)
 - Each matching couple of chrs are called homologs or homologous chrs
- **Normal somatic cells have 23 couples of chrs**
 - That makes **46 chrs in total**
 - One chr couple is the sex chr (**XX or XY**)
 - The remaining 22 couples (aka **autosomes**) look the same in M/F

Karyotype

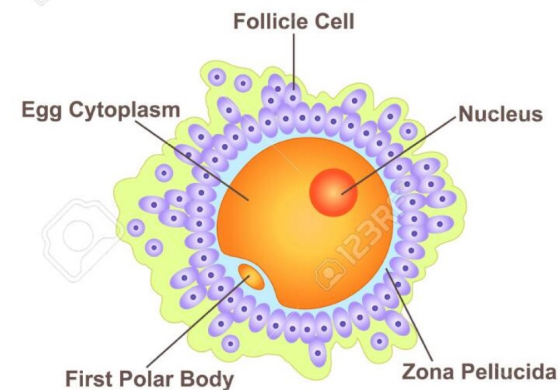


U.S. National Library of Medicine

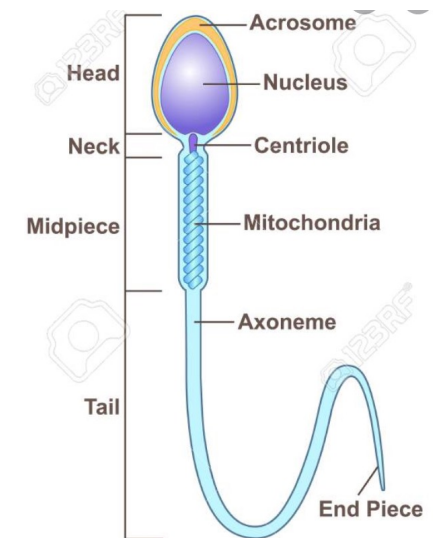
Cell division

1. DNA replication → make two sets of genes (DNA)
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 - Body (**somatic**) cells contain 2 of each chr
 - somatic cells are diploid ($2n$)
 - Each matching couple of chrs are called homologs or homologous chrs
 - Normal somatic cells have 23 couples of chrs
 - That makes 46 chrs in total
 - One chr couple is the sex chr (XX or XY)
 - the remaining 22 couples (aka autosomes) look the same in M/F
 - **Germ** cells ($2n$) generate **gametes** = egg/sperm
 - **Gametes contain 1 of each chr**
 - Gametes are **haploid** (n) cells

Human Germ Cells



Ovum



Spermatozoon

Cell division

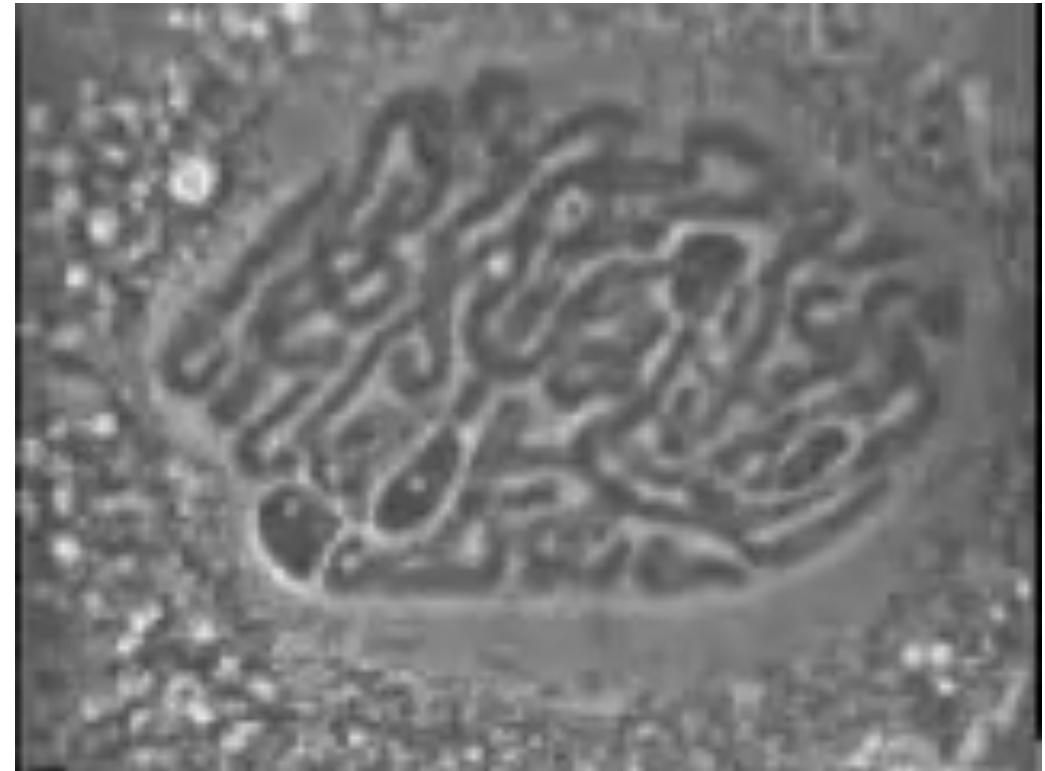
- Two types of cell division
 - **Mitosis**
 - **Meiosis**

Cell division - **MITOSIS**

- **Mitosis** occurs in **somatic** cells
- Outcome = **2** daughter cells **identical** to the parent cell (**2n**)
- The mitotic process in brief:
 - Chrs (DNA) replicate → **sister chromatids**
 - Sister chromatids line up on a special structure called **mitotic spindle**
 - Sister chromatids segregate
 - One copy of each chr is partitioned to each daughter cell (2n)
 - Cell membrane partitions the two daughter cells

Cell division - **MITOSIS**

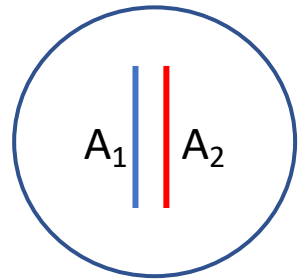
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 - One copy of each chr is partitioned to each daughter cell ($2n$)
 - Cell membrane partitions the two daughter cells
- **1 diploid mother cell ($2n$) → 2 diploid daughter cells ($2n$)**



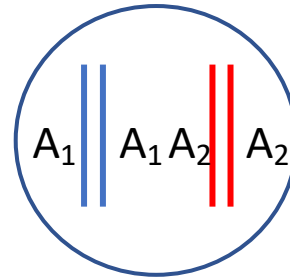
Cell division - MITOSIS

Diploid ($2n$) cell with 1 homolog

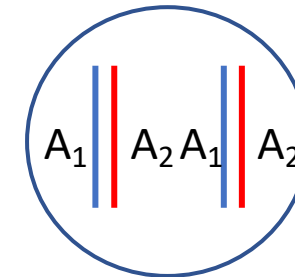
Sister chromatid



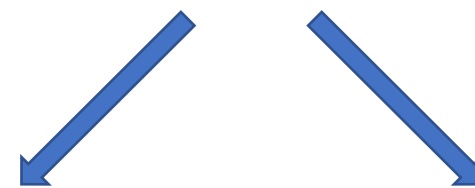
DNA REPLICATION



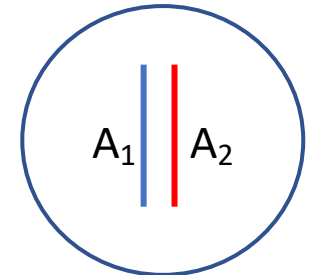
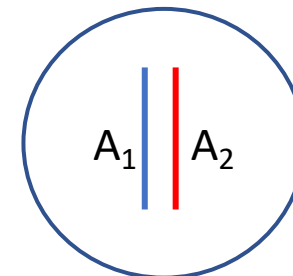
SISTER CHROMATID
SEGREGATION




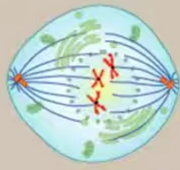
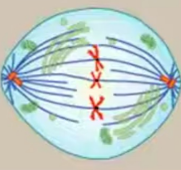
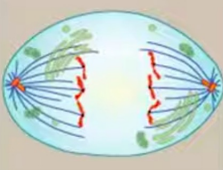
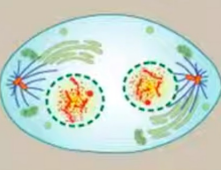
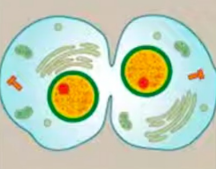
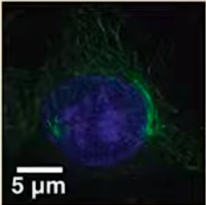
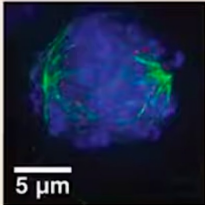
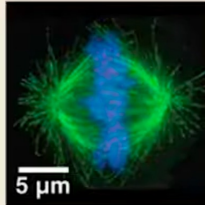
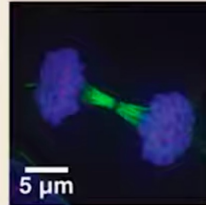
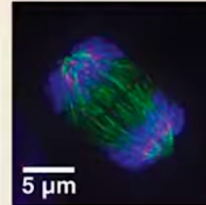
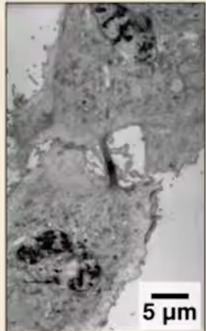
Homologs partitioning into
daughter cells



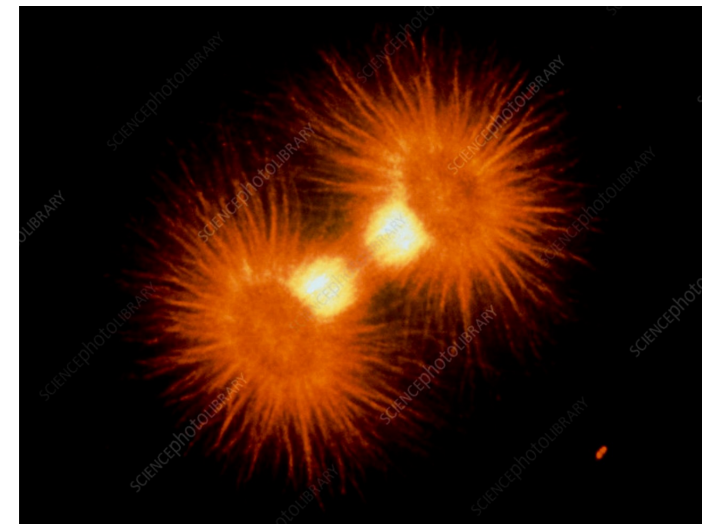
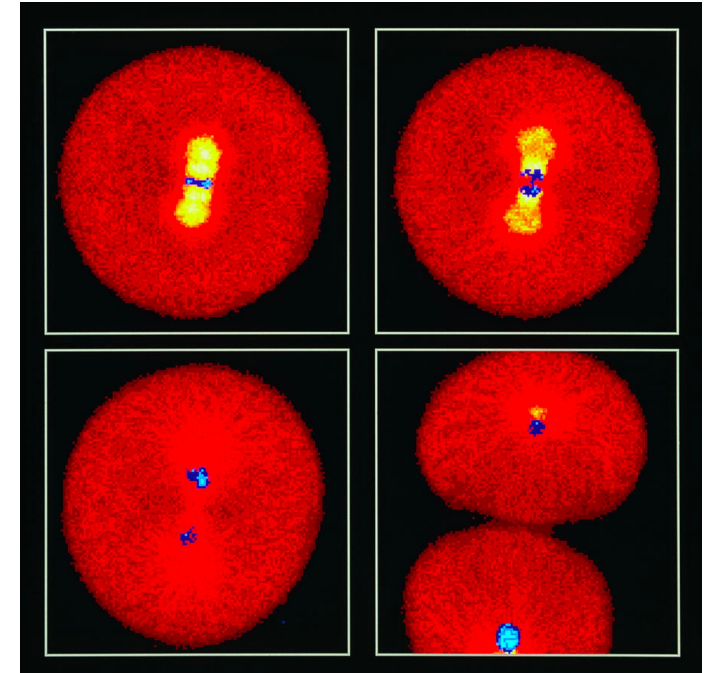
Two diploid ($2n$) daughter cells identical to the
parent cell



Cell division - MITOSIS

Prophase	Prometaphase	Metaphase	Anaphase	Telophase	Cytokinesis
					
<ul style="list-style-type: none"> Chromosomes condense and become visible Spindle fibers emerge from the centrosomes Nuclear envelope breaks down Centrosomes move toward opposite poles 	<ul style="list-style-type: none"> Chromosomes continue to condense Kinetochores appear at the centromeres Mitotic spindle microtubules attach to kinetochores 	<ul style="list-style-type: none"> Chromosomes are lined up at the metaphase plate Each sister chromatid is attached to a spindle fiber originating from opposite poles 	<ul style="list-style-type: none"> Centromeres split in two Sister chromatids (now called chromosomes) are pulled toward opposite poles Certain spindle fibers begin to elongate the cell 	<ul style="list-style-type: none"> Chromosomes arrive at opposite poles and begin to decondense Nuclear envelope material surrounds each set of chromosomes The mitotic spindle breaks down Spindle fibers continue to push poles apart 	<ul style="list-style-type: none"> Animal cells: a cleavage furrow separates the daughter cells Plant cells: a cell plate, the precursor to a new cell wall, separates the daughter cells
					
5 μm	5 μm	5 μm	5 μm	5 μm	5 μm

MITOSIS

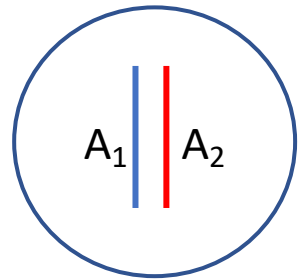


Cell division - **MEIOSIS**

- Goal of meiosis: production of gametes (egg/sperm, **haploid**) from **diploid germ cells**
- Outcome:
 - **4** cells
 - **non-identical to the parent**
 - each daughter cell (egg/sperm) is **haploid** → $n = 1$ copy of each chr
- The meiotic process in brief:
 - Chrs (DNA) replicate → **sister chromatids**
 - Sister chromatids come close one another and exchange DNA segments (**chiasma, crossing-over**)
 - Ensures individual genetic variability
 - Meiosis 1
 - Each replicated homologous chr pair goes to daughter cells
 - Output is two diploid cells
 - Meiosis 2
 - The two daughter cells divide again
 - Single homolog goes to each new daughter cell
 - Output is 4 haploid cells

Cell division - MEIOSIS

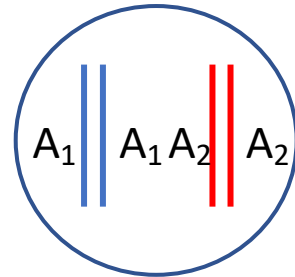
Diploid ($2n$) cell with 1 homolog



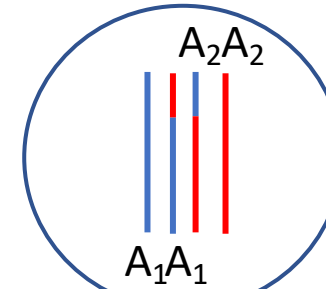
DNA REPLICATION



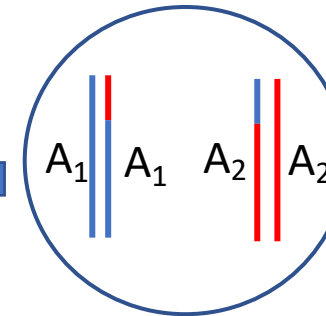
Sister chromatid



CHIASMA
CROSSING OVER



SISTER CHROMATID
SEGREGATION

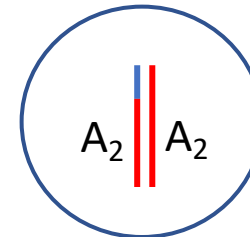
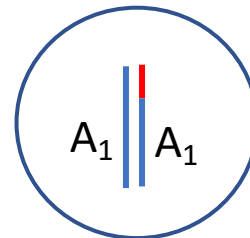


SISTER CHROMATID
PARTITIONING
INTO DAUGHTER CELLS



MEIOSIS 1

Two diploid ($2n$) daughter cells
non-identical to the parent cell

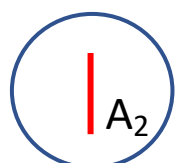
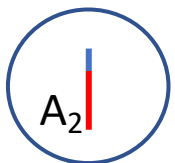
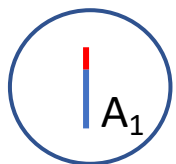
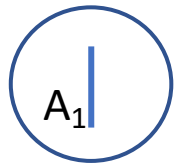


SISTER CHROMATID
PARTITIONING
INTO DAUGHTER CELLS



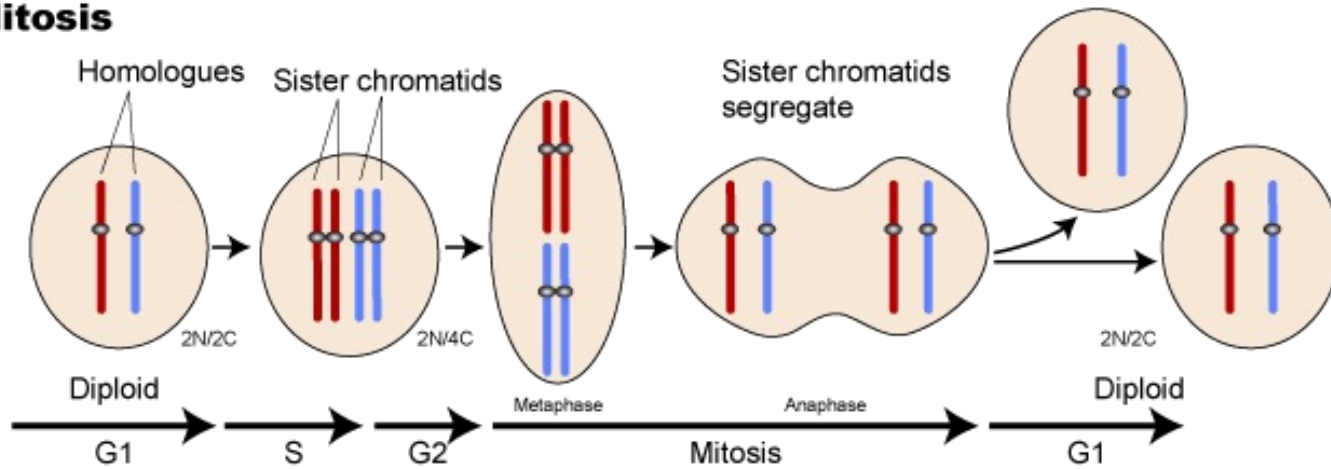
MEIOSIS 2

Four haploid (n) daughter cells
non-identical to the parent cell

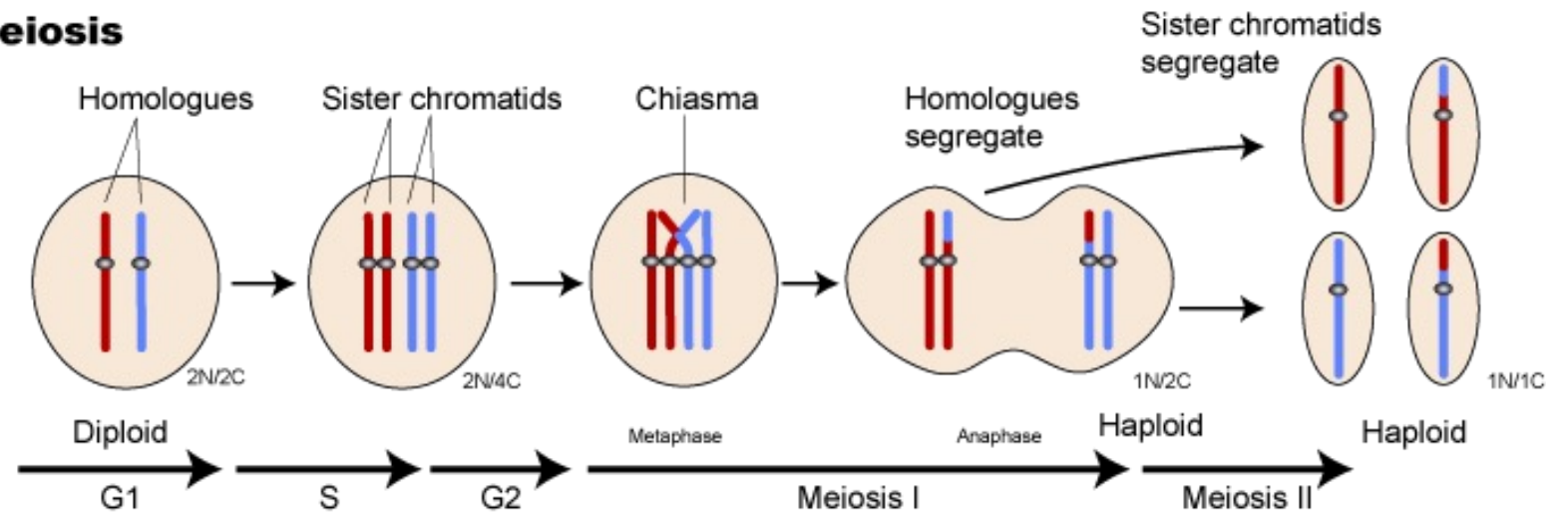


Cell division – Mitosis vs. Meiosis

Mitosis



Meiosis



A big mistake- Nondisjunction

- Meiosis must sort the chromosomes very carefully to ensure each gamete gets a complete set of chrs (via many checkpoints)
- Sometimes, chrs fail to separate and travel together = **nondisjunction**
- If this happens during meiosis I and then meiosis II proceeds regularly
 - Output = two gametes having an extra copy of one of the chrs and two gametes missing one of the chrs
- If this happens during meiosis II
 - Output = two normal gametes, one gamete having an extra copy of one chr and one gamete missing one of the chr
- When a gamete with an abnormal number of chrs is fertilized, the result is an aneuploid individual
 - A person who has the wrong number of chrs in her/his cells

When more is less – Trisomy 21 (or Dawn Syndrome)

- In humans, very few aneuploid events are compatible with life
- One of these is also the most common chromosomal defect among humans (1/733 births)
- Originates from the aneuploidy condition of having 3 copies of chromosome 21 and normal gametes
- Problems of Trisomy 21
 - Increased risk of heart diseases
 - Alzheimer's disease
 - Childhood leukemia
 - Impaired respiratory and thyroid conditions
 - Mild to moderate mental impairment
- Trisomy 21 risk increases with mother age (rises quickly after age 35)
- Current research is focused on discovery the gene(s) leading to DS and to correct these faulty genes with gene therapy

