

1.5 (D.2.1) Cell and nuclear division

New cells are produced by **division** of existing cells.

A *parent* cell is divided to produce what we call two *daughter* cells.

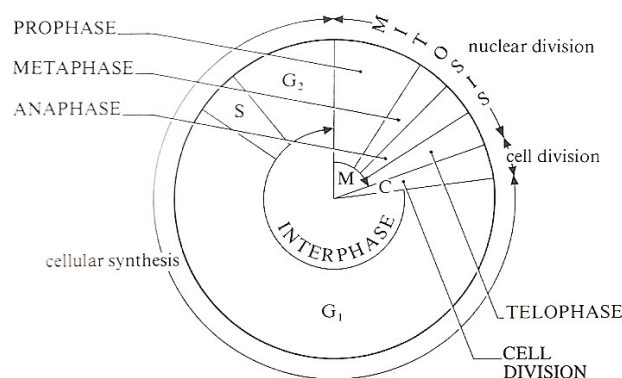
- **Mitosis** is nuclear division resulting in continuity of the chromosome number and genome.
- **Meiosis** is division resulting in reduction of the chromosome number and increased genetic diversity.

Mitosis is a mode of cell division needed for:

- Growth
- Embryonic development
- Tissue repair (cell replacement) when damaged
- Asexual reproduction

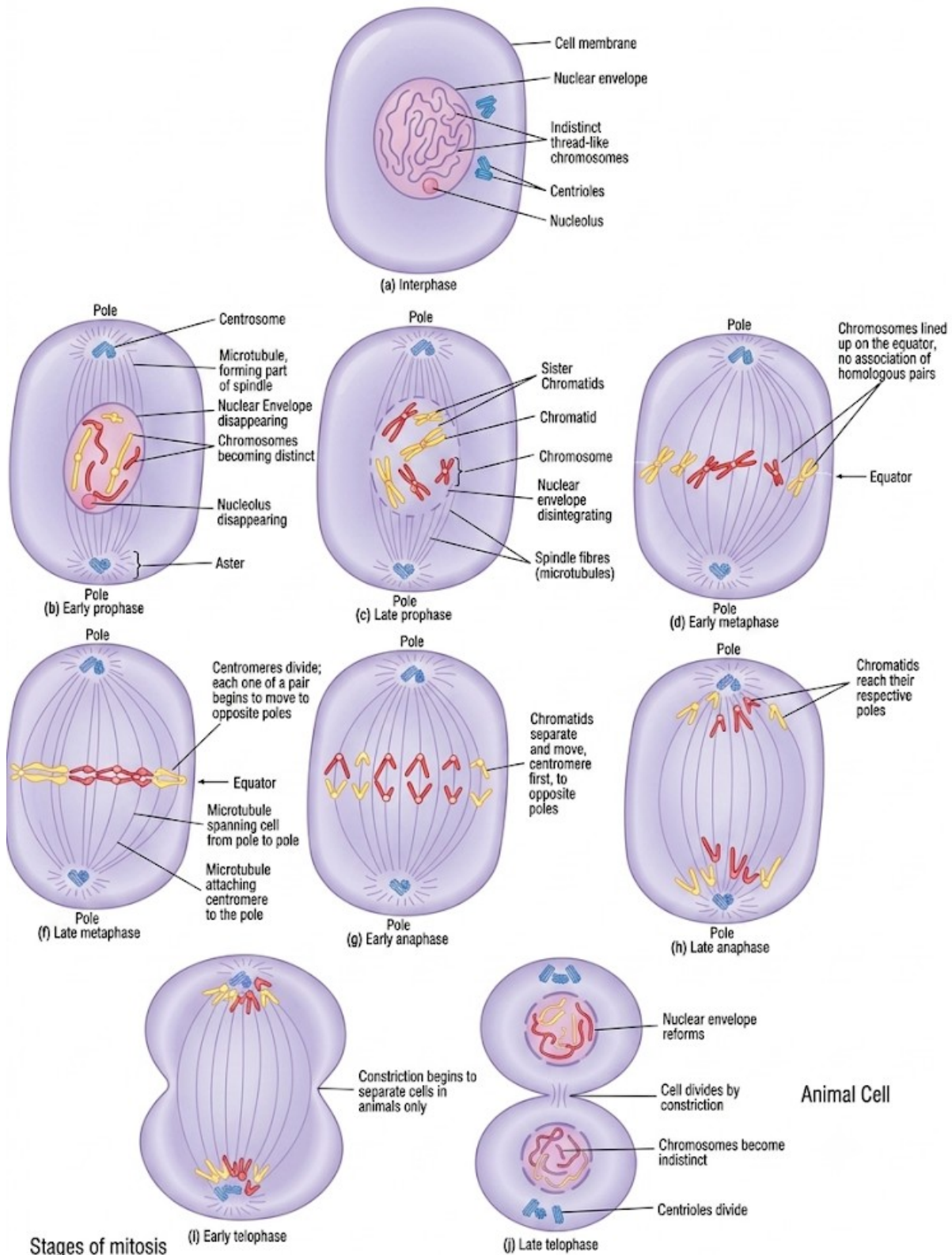
The phases of the cell cycle include:

- **Interphase**, the longest phase of the cycle, is an active period in the life of a cell when many metabolic reactions occur. It includes protein synthesis, DNA replication and transcription, cell growth and increase in mitochondria and/or chloroplasts.
- **Mitosis** is
- **Cytokinesis** (the end of Mitosis; can be equal or unequal)



Phase	Events within cell
G ₁	Intensive cellular synthesis. Mitochondria, chloroplasts (in plants), ER, lysosomes, Golgi apparatus, vacuoles and vesicles produced. Nucleolus produces rRNA. mRNA and tRNA and ribosomes are synthesised. Cell produces structural and functional proteins. Cell metabolic rate high and controlled by enzymes. Cell growth occurs. Substances produced to inhibit or stimulate onset of next phase.
S	DNA replication occurs. Protein molecules called histones are synthesised and cover each DNA strand. Each chromosome has become two chromatids.
G ₂	Intensive cellular synthesis. Mitochondria and chloroplasts divide. Energy stores increase. Mitotic spindle begins to form.
M	Nuclear division occurs in four phases.
C	Equal distribution of organelles and cytoplasm into each daughter cell.

The stages of mitosis:



Microtubules are hollow cylinders that chromosomes use to move to the opposite poles. **Motor proteins** assemble on the chromosome centromeres and link to the growing microtubules.

Centrosomes are the microtubule-organizing centers.

Phases of mitosis

DNA replication is a prerequisite for both mitosis and meiosis.

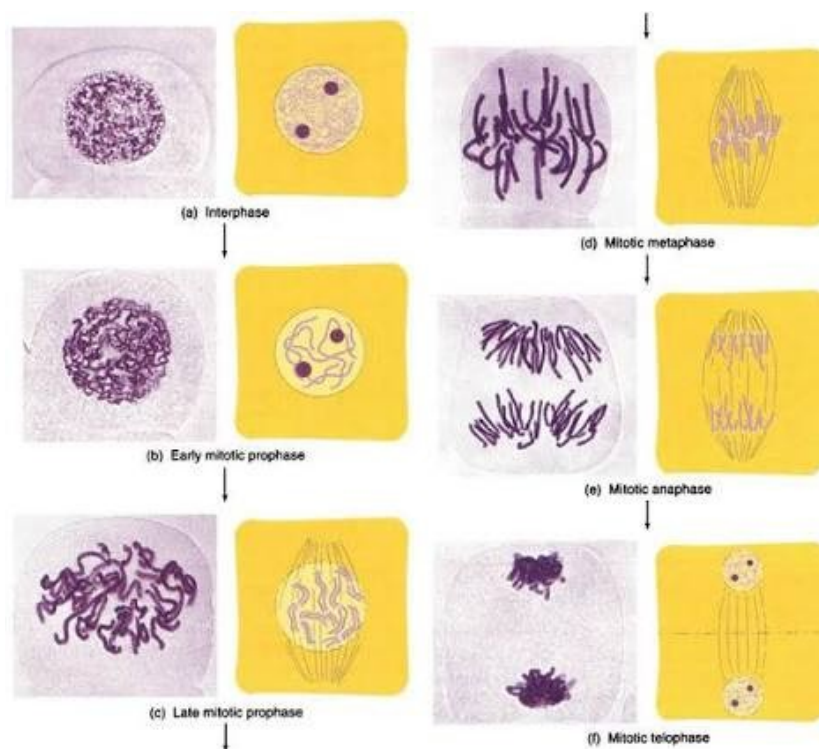
After replication, each chromosome consists of two long DNA molecules (called **sister chromatids**) held together in a **centromere** until anaphase.

Histones (proteins) participate in DNA condensation by supercoiling during prophase and throughout.

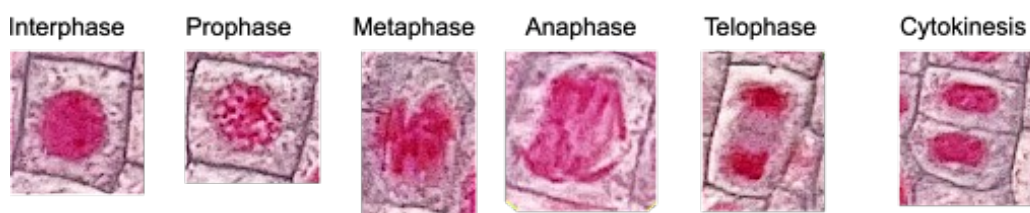
Microtubules and microtubule motors move chromosomes to perform the cell division.

Application of skills: Identify phases of mitosis in diagrams, micrographs, as well as under a microscope.

Animal Cell Mitotic Stages



Plant Cell Mitotic Stages



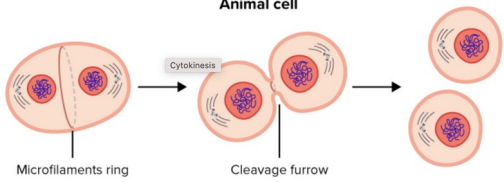
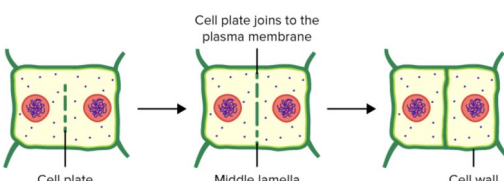
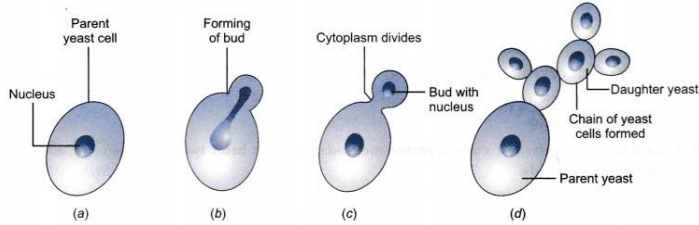
Cytokinesis is the splitting of the cytoplasm in a parent cell to share it between daughter cells.

It is *usually equal*, though not always (see below).

Animal cells: a ring of contractile proteins pinches a cell membrane to split the cytoplasm.

Plant cells: vesicles assemble membrane and cell wall to build new wall and achieve splitting.

Both daughter cells must receive at least one mitochondrion (and any organelle that can only be made by dividing a pre-existing structure, e.g. chloroplast).

Equal Cytokinesis	Unequal Cytokinesis:
(In plant and animal somatic cells) Animal cell  Microfilaments ring Cleavage furrow Plant cell  Cell plate Cell plate joins to the plasma membrane Middle lamella Cell wall	The cytoplasm divides unequally in a) oogenesis during sexual reproduction b) in yeast cells during asexual reproduction (called budding).  (a) (b) (c) (d)

Nuclear division is required prior to whole cell division in order to prevent anucleate cells.

If cytokinesis (and cell division) occurs without prior nuclear division, one daughter cell may contain the entire nucleus, while the other no nucleus, meaning it will be '*anucleate*'. These cells cannot synthesize proteins, nor grow or maintain themselves leading to a shortened lifespan.

In the case of *erythrocytes* (red blood cells), expelling the nucleus is a deliberate stage in their maturation process to provide more space for hemoglobin to transport oxygen. The short lifespan is a trade-off, but bone marrow renews their supply.

Meiosis is a reduction division used to produce gametes in the human reproductive system.

A **diploid** cell has two complete sets of chromosomes ($2n$), meaning pairs of matched types.

A **haploid** cell has only one single set of chromosomes (n) with no pairs.

The two divisions of meiosis produce **four haploid nuclei from one diploid nucleus**.

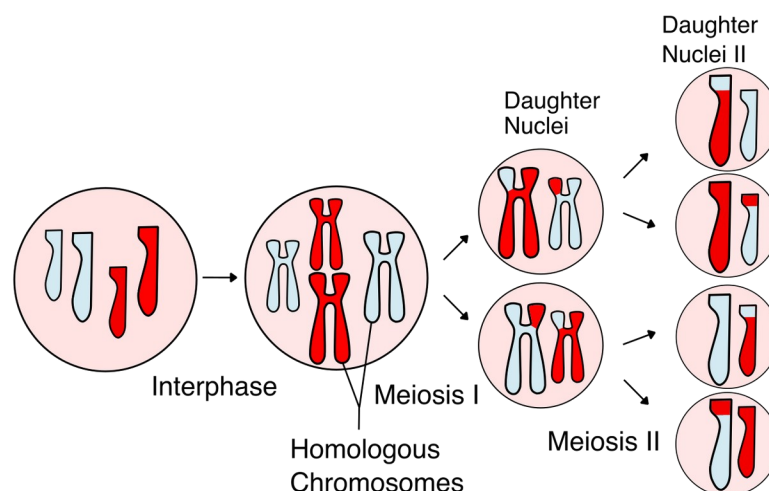


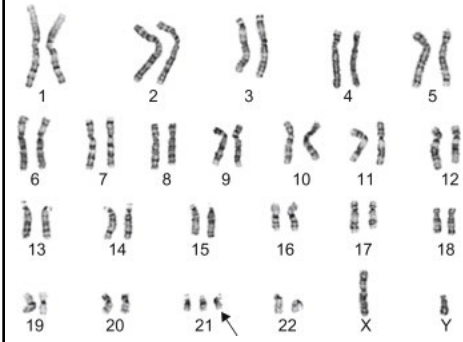
Figure: The two rounds of segregation (= separation) in meiosis.

Down syndrome and non-disjunction during meiosis.

Errors in meiosis can result in the chromosomes not dividing exactly equally. Because many chromosomes contain genes coding for vital life processes, many times a non-disjunction error will result in non-viable gametes.

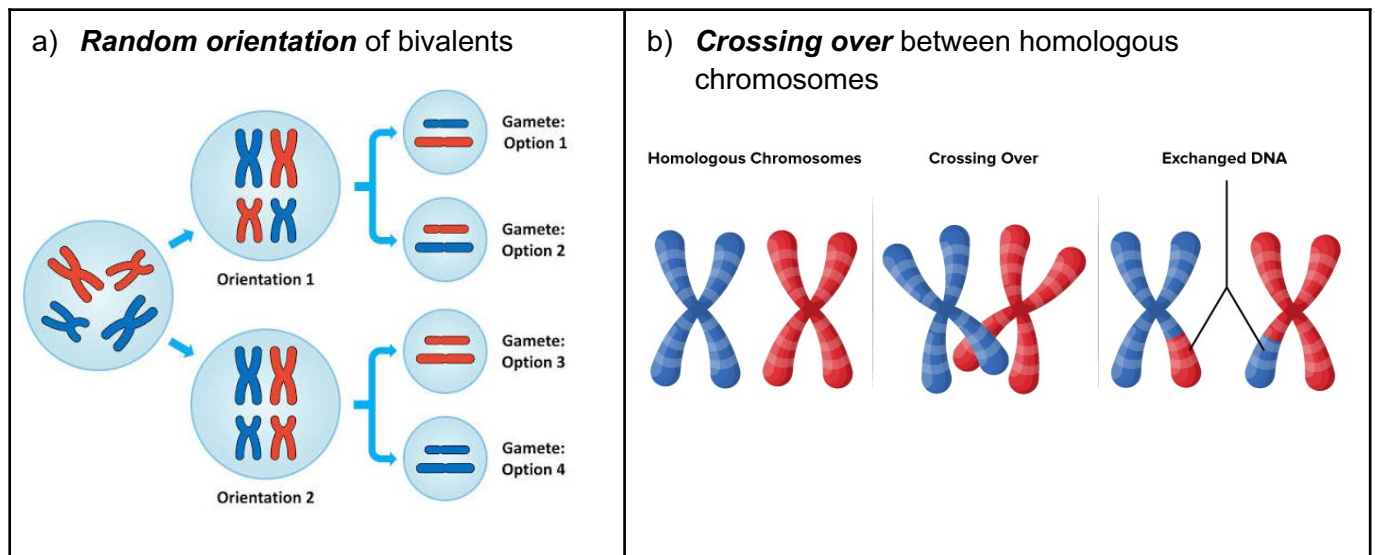
However, there is an example of a viable zygote containing an extra chromosome at number 21 (see *karyogram* on the right).

This is the cause for what we know as **Down syndrome**.



Meiosis is a source of genetic variation.

Meiosis generates genetic diversity through two processes that happen prior to meiosis I and II:



Higher Level

Cell proliferation is the rapid increase in the number of cells. In animals, growth plates near the end of bones are active in childhood, with cell divisions contributing to bone growth. Another example is tissue repair to replace damaged cells (wounds). In plants, cell proliferation is confined to regions called meristems found at the tips of stems and roots.

Cyclins are proteins involved in the control of the cell cycle. They ensure tasks are performed at the correct time and that the cell only moves to the next stage of the cycle when appropriate. How? A threshold level of a specific cyclin required to pass each checkpoint in the cycle.

Uncontrolled cell division causes **tumours (cancer)** that can occur in any organ or tissue.

Mutagens include:

Chemicals, Nitrosamines in tobacco, mustard gas used as a chemical weapon, the solvent benzene.

High energy radiation, X-rays, short or medium wave UV, gamma rays, and alpha particles from radioactive isotopes. In the nuclear accident at Chernobyl (1986) and the nuclear bombing of Hiroshima (1945), radioactive isotopes were released, exposing people to dangerous levels of radiation.

Proto-oncogenes are genes that can become cancer-causing after mutating and are involved in the development of primary tumours (**benign** tumours). **Metastasis** is the movement of cells from a primary tumour to set up secondary tumours in other parts of the body (**malignant** tumours). Benign tumours are non-cancerous, grow slowly, and do not spread to other body parts. Malignant tumours are cancerous, grow fast, and can invade nearby tissues or spread to distant organs through the bloodstream or lymphatic system. **Tumor suppressor genes** prevent cell proliferation and function (as brakes) at checkpoints in the cell cycle to correct possible errors during DNA replication.

The mitotic index is the ratio between the number of cells in mitosis in a tissue and the total number of observed cells. It can be calculated using this equation:

$$\text{Mitotic Index} = \frac{\text{Cells } \in \text{ mitosis}}{\text{Total cells } \in \text{ field of view}}$$

It is an important *prognostic tool* for predicting the response of cancer cells to chemotherapy.

Application of skills: Students should observe populations of cells to determine the mitotic index.

