Struktur kromosom, siklus sel dan pembelahan sel

RIZKA APRIANI PUTRI, M.SC
rizka_apriani@uny.ac.id
DNA

Genetic information - genome
Packaged into chromosomes
DNA and Chromosomes

An average eukaryotic cell has about 1,000 times more DNA than an average prokaryotic cell.

The DNA in a eukaryotic cell is organized into several linear chromosomes, whose organization is much more complex than the single, circular DNA molecule in a prokaryotic cell.
Chromosomes

All eukaryotic cells store genetic information in chromosomes.

- Most eukaryotes have between 10 and 50 chromosomes in their body cells.
- Human cells have 46 chromosomes.
- 23 nearly-identical pairs
Structure of Chromosomes

Chromosomes are composed of a complex of DNA and protein called chromatin that condenses during cell division.

DNA exists as a single, long, double-stranded fiber extending chromosome’s entire length.

Each unduplicated chromosome contains one DNA molecule, which may be several inches long.
Structure of Chromosomes

- Every 200 nucleotide pairs, the DNA wraps twice around a group of 8 histone proteins to form a nucleosome.

- Higher order coiling and supercoiling also help condense and package the chromatin inside the nucleus:
Chromosomes

Non-homologous chromosomes
- Look different
- Control different traits

Sex chromosomes
- Are distinct from each other in their characteristics
- Are represented as X and Y
- Determine the sex of the individual, XX being female, XY being male

In a diploid cell, the chromosomes occur in pairs. The 2 members of each pair are called homologous chromosomes or homologues.
Chromosomes

A diploid cell has two sets of each of its chromosomes

A human has 46 chromosomes (2n = 46)

In a cell in which DNA synthesis has occurred all the chromosomes are duplicated and thus each consists of two identical sister chromatids

![Diagram of Chromosomes](image)
Homologues

Homologous chromosomes:
- Look the same
- Control the same traits
- May code for different forms of each trait
- Independent origin - each one was inherited from a different parent
In preparation for cell division, DNA is replicated and the chromosomes condense.

Each duplicated chromosome has two sister chromatids, which separate during cell division.

A eukaryotic cell has multiple chromosomes, one of which is represented here. Before duplication, each chromosome has a single DNA molecule.

Once duplicated, a chromosome consists of two sister chromatids connected at the centromere. Each chromatid contains a copy of the DNA molecule.

Mechanical processes separate the sister chromatids into two chromosomes and distribute them to two daughter cells.
Figure 8.11

Pair of homologous chromosomes

Locus

Centromere

Sister chromatids

One duplicated chromosome

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Because of duplication, each condensed chromosome consists of 2 identical chromatids joined by a centromere.

Each duplicated chromosome contains 2 identical DNA molecules (unless a mutation occurred), one in each chromatid:
Structure of Chromosomes

The centromere is a constricted region of the chromosome containing a specific DNA sequence, to which is bound 2 discs of protein called kinetochores.

Kinetochores serve as points of attachment for microtubules that move the chromosomes during cell division:
Structure of Chromosomes

- **Diploid** - A cell possessing two copies of each chromosome (human body cells).
- Homologous chromosomes are made up of sister chromatids joined at the centromere.
- **Haploid** - A cell possessing a single copy of each chromosome (human sex cells).
Phases of the Cell Cycle

Interphase
- $G_1$ - primary growth
- $S$ - genome replicated
- $G_2$ - secondary growth

M - mitosis
C - cytokinesis
Interphase

$G_1$ - Cells undergo majority of growth

$S$ - Each chromosome replicates (Synthesizes) to produce sister chromatids
  ◦ Attached at centromere
  ◦ Contains attachment site (kinetochore)

$G_2$ - Chromosomes condense - Assemble machinery for division such as centrioles
Interphase - $G_1$ Stage

- First growth stage after cell division
- Cells mature by making more cytoplasm & organelles
- Cell carries on its normal metabolic activities
Interphase - S Stage

✓ Synthesis stage
✓ DNA is copied or replicated

Two identical copies of DNA

Original DNA
Interphase – $G_2$ Stage

- 2\textsuperscript{nd} Growth Stage
- Occurs after DNA has been copied
- All cell structures needed for division are made (e.g. centrioles)
- Both organelles & proteins are synthesized
Mitosis

- Some haploid & diploid cells divide by mitosis.
- Each new cell receives one copy of every chromosome that was present in the original cell.
- Produces 2 new cells that are both genetically identical to the original cell.
Mitosis

- Division of the nucleus
- Also called karyokinesis
- Only occurs in eukaryotes
- Has five stages
- Doesn’t occur in some cells such as brain cells
Mitotic Division of an Animal Cell

**G₂ of Interphase**
- Centrosomes (with centriole pairs)
- Chromatin (duplicated)
- Nucleolus
- Nuclear envelope
- Plasma membrane

**Prophase**
- Early mitotic spindle
- Aster
- Centromere
- Chromosome, consisting of two sister chromatids

**Prometaphase**
- Fragments of nuclear envelope
- Kinetochore
- Nonkinetochore microtubules
- Kinetochore microtubule
Prophase

- The chromatin fibers become more tightly coiled, condensing into discrete chromosomes observable with a light microscope.
- The nucleoli disappear.
- Each duplicated chromosome appears as two identical sister chromatids joined together.
- The mitotic spindle begins to form. It is composed of the centrosomes and the microtubules that extend from them. The radial arrays of shorter microtubules that extend from the centrosomes are called asters (“stars”).
- The centrosomes move away from each other, apparently propelled by the lengthening microtubules between them.
Metaphase

- Metaphase is the longest stage of mitosis, lasting about 20 minutes.
- The centrosomes are now at opposite ends of the cell.
- The chromosomes convene on the metaphase plate, an imaginary plane that is equidistant between the spindle’s two poles. The chromosomes’ centromeres lie on the metaphase plate.
- For each chromosome, the kinetochores of the sister chromatids are attached to kinetochore microtubules coming from opposite poles.
- The entire apparatus of microtubules is called the spindle because of its shape.
Mitotic Division of an Animal Cell

**METAPHASE**
- Metaphase plate
- Spindle
- Centrosome at one spindle pole
- Daughter chromosomes

**ANAPHASE**
- Cleavage furrow

**TELOPHASE AND CYTOKINESIS**
- Nucleolus forming
- Nuclear envelope forming
Anaphase

• Anaphase is the shortest stage of mitosis, lasting only a few minutes.
• Anaphase begins when the two sister chromatids of each pair suddenly part. Each chromatid thus becomes a full-fledged chromosome.
• The two liberated chromosomes begin moving toward opposite ends of the cell, as their kinetochore microtubules shorten. Because these microtubules are attached at the centromere region, the chromosomes move centromere first (at about 1 µm/min).
• The cell elongates as the nonkinetochore microtubules lengthen.
• By the end of anaphase, the two ends of the cell have equivalent—and complete—collections of chromosomes.
Telophase

- Two daughter nuclei begin to form in the cell.
- Nuclear envelopes arise from the fragments of the parent cell’s nuclear envelope and other portions of the endomembrane system.
- The chromosomes become less condensed.
- Mitosis, the division of one nucleus into two genetically identical nuclei, is now complete.
Mitosis in a plant cell

Prophase. The chromatin is condensing. The nucleolus is beginning to disappear. Although not yet visible in the micrograph, the mitotic spindle is starting to form.

Prometaphase. We now see discrete chromosomes; each consists of two identical sister chromatids. Later in prometaphase, the nuclear envelope will fragment.

Metaphase. The spindle is complete, and the chromosomes, attached to microtubules at their kinetochores, are all at the metaphase plate.

Anaphase. The chromatids of each chromosome have separated, and the daughter chromosomes are moving to the ends of the cell as their kinetochore microtubules shorten.

Telophase. Daughter nuclei are forming. Meanwhile, cytokinesis has started: The cell plate, which will divide the cytoplasm in two, is growing toward the perimeter of the parent cell.
Daughter Cells prepare for Division into Identical cells.

Daughter Cells

Interphase

DNA Copied

Cells Mature

G1

Cells prepare for Division

G2

Mitosis

Prophase

Prometaphase

Metaphase

Anaphase

Telophase

Mitotic phase (M)

Cell Divides into Identical cells

RIZKA_APRIANI@UNY.AC.ID
Functions of Cell Division

(a) **Reproduction.** An amoeba, a single-celled eukaryote, is dividing into two cells. Each new cell will be an individual organism (LM).

(b) **Growth and development.** This micrograph shows a sand dollar embryo shortly after the fertilized egg divided, forming two cells (LM).

(c) **Tissue renewal.** These dividing bone marrow cells (arrow) will give rise to new blood cells (LM).
Cytokinesis

- Cleavage of cell into two halves
  - Animal cells
    - Constriction belt of actin filaments
  - Plant cells
    - Cell plate
  - Fungi and protists
    - Mitosis occurs within the nucleus
Cytokinesis In Animal And Plant Cells

(a) Cleavage of an animal cell (SEM)

(b) Cell plate formation in a plant cell (SEM)