Cellular Reproduction
= Cell Division

Passes on Genes from Cells to Cells
Reproduction of Organisms
Genes – DNA – Chromatin fiber – Chromosomes

- Fig. 9.6
- Genes, the segments of DNA, are part of chromatin fiber found in nucleus.
- Chromatin fiber is formed of DNA and Histone proteins.
- Most of the time the chromatin fibers exist as a diffuse network (not visible even under electron microscope).
- However, when the cell starts to divide the chromatin fibers organize into compact threads called Chromosomes.
- Each species has a fixed # of chromosomes – 46 in most human cells.
The Cell Cycle and Mitosis

• Almost all the eukaryotic genes (about 25000 in human genes) are found in the chromosomes. Some genes are present in Mitochondria and Chloroplast.

• DNA associate with 4 kinds of Histones and coil to form Nucleosome. A 5\(^{th}\) histone molecule keep the coils in position. Nucleosomes pack and form thicker and thicker threads. The thickest threads are Chromatids. A chromosome has 1 or 2 chromatids in it.

• A chromosome with 1 chromatid divides to form a chromosome with 2 Chromatids (sister). One chromatid is passed on to each daughter cell.

• Fig 9.3
Cell Cycle

• **Cell Cycle**: Most cells in body divide though at different rates. There are 2 distinct phases that alternate with each other and form a cell-cycle.

• **M-phase**: when a cell is dividing. The daughter cells are half in size.

• **Interphase**: Each daughter cell must grow by making new materials including proteins and DNA. Interphase is divided into 3 sub-phases : G1, S and G2.

• **S-phase** occurs in the middle part of Interphase and DNA replication takes place. DNA and chromosomes are doubled.

• **G1 and G2** are growth phases of cell with synthesis of proteins and ribosome. G1 takes place before S-phase. But G2 occurs after the S-phase.

• Fig 9.2
Mitosis – interphase
The cell division of growth and maintainance

- Mitosis is the division of growth and replacement of lost or damaged cells.
- It is equational division. $2n \rightarrow 2n$ or $1n \rightarrow 1n$
- Fig 8.8 depicts **mitosis** (division of nucleus) and **cytokinesis** (division of cytoplasm).
- **Interphase** near its end has inside cytoplasm 2 centrosomes, each with a pair of centrioles. These initiate the organization of spindle fibers. The chromosomes are double with 2 sister chromatids joined only at centromere but still indistinct.
- Mitosis has 4 distinct phases Prophase, Metaphase, Anaphase and Telophase. *Memory aid: P-MAT*
Mitosis – Prophase

- **Prophase**: is the phase that prepares the cell for mitosis.
- Centrosomes start moving to opposite ends and spindle formation starts.
- Chromosomes coil and pack into thick threads and get distinct.
- In late prophase nuclear envelope degenerates and chromosomes are released in cytoplasm.
- Spindle fibers either join a spindle fiber from the opposite centrosome or connect to the centromere of a chromosome.
Mitosis - Metaphase

• Metaphase: The spindle is fully formed now.
• The chromosome pack further and get most distinct.
• Chromosomes arrange on an imaginary disc = equatorial plate at the middle. The centromereres of chromosomes lie at the plate.
• Each centromere is joined through spindle fibers to both centrosomes.
Mitosis - Anaphase

- Anaphase: is the movement of young chromosomes from the middle towards respective poles (centrosomes).
- It starts suddenly when the centromeres divide. Each chromosome is formed only of 1 chromatid.
- The motor proteins at centromeres move the chromosomes on the microtubules of spindle fibers.
Mitosis
Telophase and Cytokinesis

• **Telophase** begins when the 2 groups of cells reach the poles.
• This phase is the reverse of prophase.
• Chromosomes unpack to diffuse network.
• Nuclear envelope is reorganized from Endoplasmic Reticulum.
• Spindle fibers disappear.
• One nucleus is completely divided into 2 genetically similar daughter nuclei.
Cytokinesis

- **Cytokinesis** takes place along Telophase. [Fig 9.8]
- In an animal cell, cleavage furrow appears at the middle and divides the cytoplasm into 2 equal halves, each with a nucleus.
- In a plant cell, a cell-plate is formed at the middle. Golgi apparatus provides most of the materials packed in vesicles.
- Cell plate starts at the center and proceeds towards parent cell wall.
- Cell plate joins with the parental cell wall to complete the cytokinesis.
- Most plant cells lack centrioles in them and centrosomes organize spindle formation.
Sexual Reproduction in Eukarya

- Fig 10.4
- Most eukaryotes reproduce sexually and asexually
- **Sexual reproduction** has 2 sex cells called **Gametes**.
- **Gametes** may be similar or distinct.
- When distinct Female Gametes are large with lot of cytoplasm and yolk called **Eggs** or Ova (sing. is ovum).
- Male gametes, **Sperms**, are small with a long tail (flagellum).
- **Sex Organs**: In humans a pair of Ovaries produce eggs.
- In humans Testes produce sperms.
- Fertilization: One male gamete (sperm) fuses with one female gamete (egg). The fusion is called Fertilization
Haploid versus Diploid Cells

• Fig 10.1

• Haploid versus Diploid Cells: Each gamete carries one set of chromosomes (genome). Such cells are called Haploid.

• Zygote the first cell formed by fertilization of gametes has 2 sets of chromosomes (2 genomes). It is called a Diploid Cell.

• Humans have 23 different types of chromosomes. It means in humans 1 chromosome of 23 kinds forms one genome.

• Zygote has 2 genomes and 46 chromosomes. It divides time and again by Mitosis. All cells in human adult (60 trillion) have 46 chromosomes and are Diploid except some millions cells in the ovaries and testes. These cells are haploid.
Fertilization and Meiosis

• If **Fertilization** changes haploid cells (gametes) to diploid cells there must be a process to change diploid cells to haploid cells. (**1n → 2n**). Only then a species can keep the number of its chromosomes constant. For example 46 for humans. Fig 10.1

• **Meiosis**: This is a special type of cell division called Meiosis that changes diploid cells to haploid cells. (**2n → 1n**)

• Meiosis has 2 consecutive cell divisions in it. Meiosis – 1 and Meiosis – 2.

• Meiosis – 1 has 4 phases Prophase -1, Metaphase-1, Anaphase-1 and Telophase-1

• Meiosis – 2 has 4 phases called P-2, M-2, A-2 and T-2.
Meiosis – 1

• **Prophase-1** is very long and divided into 5 subphases. Fig 8.16
  - Just like Prophase of mitosis, it prepares the cell for cell division. Chromosomes coil and pack, nuclear envelope breaks and spindle appears between centrosomes.
  - But it has additional features. Synapse and Crossing Over.
  - **Synapse**: is pairing of similar Chromosomes (Homologous Chromosomes). Each chromosome has 2 sister chromatids joined by a centromere.
  - **Crossing Over** is the exchange of genetic material between non-sister chromatids of a homologous pair. It leads to shuffling of maternal and paternal genes in chromosomes called **Recombination**. Fig 10.5
Meiosis - 1

- Metaphase-1: Homologous chromosome pairs arrange at the imaginary plate. In mitosis single chromosomes arranged at the plate. Complete chromosomes get attached to spindle fibers at centromeres.
- Anaphase-1: No division of centromeres.
- 1 Complete chromosome of each homologous pair, with 2 chromatids, moves towards each pole.
- This results in reducing the number from $2n \rightarrow 1n$.
- Telophase-1 develops nuclear envelopes around one set of chromosomes.
- Cytokinesis divides the cell into 2 daughter cells.
Meiosis – 2

- Meiosis – 2 is needed to separate the 2 chromatids of each chromosome formed during meiosis – 1.
- This time 4 phases are similar to Mitotic phases.
- Prophase-2 prepares the cells to divide.
- Metaphase-2 has the single chromosomes lined up at imaginary plate.
- Anaphase-2: This time centromeres divide and young chromosomes with one chromatid each move towards poles.
- Telophase-2 organizes the daughter nuclei. Spindle disappears.
- Cytokinesis divides the cell into 2 cells.
Non-Disjunction

- **Non-disjunction** is a failure of chromosomes to separate during meiosis. Fig 11.23
- It leads to formation of gametes with 1 chromosome more (24) or less (22) and can form individuals with 45 or 47 chromosomes.
- For example Turner’s syndrome (45) and Klinefelter’s syndrome (47). Fig 10.9 and Fig 10.10 for comparison of mitosis and meiosis.
# Mitosis & Meiosis

## Comparison Fig 10.10

<table>
<thead>
<tr>
<th>Mitosis</th>
<th>Meiosis</th>
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<tbody>
<tr>
<td>• It consists of 1 cell division.</td>
<td>• It consists of 2 divisions, Meiosis-1 and Meiosis-2.</td>
</tr>
<tr>
<td>• 2 haploid or diploid daughter cells produced.</td>
<td>• 4 haploid daughter cells produced.</td>
</tr>
<tr>
<td>• 2 daughter cells are similar to each other and parent cell.</td>
<td>• 4 daughter cells are different from each other and parent cell. (Why?)</td>
</tr>
<tr>
<td>• It is 2n $\rightarrow$ 2n or n $\rightarrow$ n.</td>
<td>• It is always 2n $\rightarrow$ n.</td>
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</tbody>
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Unique Features of Meiosis

- It is a **reductional division**. \(2n \rightarrow n\)
- It makes sexual reproduction possible.
- It is **opposite to** Fertilization. \(n \rightarrow 2n\)
- It consist of two **cell divisions** and produces **4 daughter cells**.
- **Crossing over** in Prophase-1 leads to **Recombination** of genes.
- Recombination is the **largest source of Variations**.
- It operates only in diploid cells. Fig 10.9