Chapter 2

Cells and Cell Division
ALL Cells are constructed from four classes of large molecules called macromolecules.

- **Carbohydrates** include small sugars and large polymers of sugars
- **Lipids** consist of fats and oils, phospholipids, and steroids.
- **Proteins** are polymers of amino acids and carry out a multitude of functions and activities
- **Nucleic acids** are polymers of nucleotides. They store and transfer genetic information in the cell.
2.1 Cell Structure Reflects Function

- The cell is the basic unit of structure and function in all organisms, including humans.
- Although cells of different tissues (nerve cell vs. muscle cell) differ in their size, shape, function, and life cycle, at the structural level they are all similar.
- All cells have a plasma membrane, cytoplasm, organelles, and a membrane bound nucleus.
- The function of a cell is under genetic control and many genetic disorders are caused by changes in cell function.
Inside the Eukaryotic Cell
The Plasma Membrane

A double-layered plasma membrane separates the cell from the external environment. The membrane controls the movement of molecules into and out of the cell.
Nucleus

- Membrane-bound organelle in eukaryotic cells that contains the chromosomes

Wittman, Bokoch, Waterman-Storer, CIL: 9537
Elements within the Nucleus

**Nucleolus**

- Dense region within the nucleus where ribosomes are synthesized

![Image of nucleus with nucleolus and chromatin highlighted](image)

**Nuclear pores**

(a) Nucleolus

(b) Nuclear pores

(c) Chromatin
Organelles

Endoplasmic reticulum (ER)
• System of cytoplasmic membranes arranged into sheets and channels
• Synthesizes and transports gene products

Ribosomes
• Cytoplasmic particles that aid in the production of proteins
Organelles

Golgi complex
- Membranous organelles composed of a series of flattened sacs
- Sort, modify and package proteins synthesized by the ER

Lysosomes
- Membrane-bound organelles that contain digestive enzymes
Organelles

Proteins travel to the **Golgi complex** and then out of the cell (secreted proteins) or to the **lysosomes** (digestive proteins)
Milk protein being secreted from a cell in the mammary gland of a rat.
Organelles

Mitochondria (singular: mitochondrion)

- Membrane-bound organelles in the cytoplasm of all eukaryotic cells
- Sites of energy production (where ATP is made)
Keep In Mind

- A problem with any one of the organelles just described can cause a genetic disease.
Back to the Nucleus…

- **Chromosomes**
  - Threadlike structures in the nucleus that carry genetic information
  - 46 chromosomes (diploid number, \(2n\)) are present in most human cells

- **Genes**
  - Fundamental units of heredity present on chromosomes
Structures of the Chromosome

- **Sister chromatids**
  - Two chromatids joined by a common centromere
  - Each sister chromatid carries identical genetic information
Structures of the Chromosome

- **Centromere**
  - Region of a chromosome to which microtubule fibers attach during cell division
  - Centromere location gives a chromosome its characteristic shape as we will discuss in Chapter 6
Human Chromosomes

- **Sex chromosomes**
  - Human X and Y chromosomes are involved in sex determination

- **Autosomes**
  - Chromosomes other than the sex chromosomes
  - Human chromosomes 1 through 22 are **autosomes**
2.3 The Cell Cycle

- **Cell cycle**
  - The sequence of events that takes place between cell divisions
  - The proper order of these events is under genetic control
The cell cycle

**INTERPHASE**

- **G1** - Interval of cell growth before DNA replication (chromosomes unduplicated)
- **S** - Interval when DNA replication takes place (chromosomes duplicated)
- **G2** - Interval following DNA replication; cell prepares to divide

**CYTOKINESIS**

- **Telophase**
- **Anaphase**
- **Metaphase**
- **Prophase**

**MITOSIS (M)**

Each daughter cell starts interphase

Cells can leave the cell cycle and enter an inactive state called G0 (G-zero)
Three Phases of the Cell Cycle

1. Interphase
   - G1, S, and G2 phases

2. Mitosis
   - Process where the duplicated chromosomes are segregated into two daughter cells.

3. Cytokinesis
   - Process by which the cytoplasm is divided between the two daughter cells.
Interphase has Three Stages

G1 Phase
Growth takes place after division - the cell doubles in size and replenishes organelles and ribosomes and prepares for chromosome replication.

S Phase
DNA synthesis stage. Each chromosome is copied

G2 Phase
Period of preparation for cell division
Mitosis Occurs in Four Stages

Prophase
Chromosomes condense.

Prometaphase
Nuclear envelope breaks down chromosomes attach to microtubules and begin to align at the metaphase plate.
Mitosis Occurs in Four Stages

- **Metaphase**: Chromosomes align at the cell equator, known as the metaphase plate.
- **Anaphase**: Chromosomes separate.
- **Telophase**: Chromosomes continue to move apart and to decondense.

(h) Cytokinesis
2.4 Mitosis is Essential for Growth and Cell Replacement

- Human cells are genetically programmed to divide about 50 times (known as Hayflick limit)

- This limit allows growth to adulthood, and repairs such as wound healing

- Alterations in the limits to cell division can lead to genetic disorders (such as premature aging) or to cancer
Keep In Mind

- Cancer is a disease of the cell cycle—cells lose their ability to stop growing, in a sense, they have found the “fountain of youth”
Spotlight on *Cell Division and Spinal Cord Injuries*

- Many highly differentiated cells, such as those of the nervous system do not divide (They are in the G0 phase.)
- As a result injuries to nervous tissue such as spinal cord do not heal though cell replacement
- New approaches using embryonic tissue suggests that is may be possible to reconnect damages nerve tissue.
- Newly described growth factors also show potential for stimulating the growth and division of cells of the nervous system.
2.4 Cell Division by Meiosis: The Basis of Sex

- **Meiosis**: A form of cell division that produces four haploid cells containing only one copy (paternal or maternal) of each chromosome
  - Meiosis I
  - Meiosis II
Homologous Chromosomes

- **Homologous chromosomes**
  - Have identical gene loci
  - You receive one from mother and one from father
  - Chromosomes that physically pair during meiosis

- **Diploid (2n)**
  - 23 chromosomes from mom, 23 from dad (46 total)

- **Haploid (n)**
  - Each chromosome is represented once, in an unpaired condition
  - The result of meiosis
Meiosis I

prophase I: homologous chromosomes find each other
metaphase I: chromosome pairs align
anaphase I: homologues separate (sister chromatids stay together)
telophase I: cytokinesis
Meiosis II

Interkinesis
There is no DNA replication between the two nuclear divisions.

Interkinesis
No DNA replication

Prophase II
Chromosomes attach to microtubules

Metaphase II
Chromosomes align at the metaphase plate

Anaphase II
Sister chromatids separate

Telophase II
4 haploid cells
Meiosis results in two kinds of haploid, sexual gametes

- Males produce **spermatids** by the process of spermatogenesis
- Females produce **oocytes** by the process of oogenesis
- *Meiosis maintains a constant chromosome number from generation to generation*
Meiosis Produces New Combinations of Genes in Two Ways

1. **Crossing over**: The exchange of chromosome segments of non-sister chromatids of a between homologous pair during prophase I

2. **Independent or random assortment** of maternal and paternal chromosomes in metaphase I. Chromosome pairs line up at random
Crossing over

Gametes

Crossing-over and recombination during meiosis

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Independent (Random) Assortment

Random assortment of chromosomes in meiosis:

(a)

- Dad’s allele: A
- Dad’s allele: B
- Mom’s allele: a
- Mom’s allele: b

In Prophase I, homologous chromosomes physically pair with one another.

(b)

Crossing over takes place between non-sister chromatids.

There is a physical exchange of chromosome segments and the genes they carry.

Crossing over generates new combinations of Mom’s and Dad’s alleles.