6.1 What Is Cancer?

- **Tumor**: Unregulated cell division that form a mass of cells with no function
- **Benign tumor**: doesn’t affect surrounding tissues
- **Malignant tumor**: invades surrounding tissues; cancerous
- **Metastasis**: cells break away from a malignant tumor and start a new cancer at another location

Metastatic cells can travel throughout the body via the circulatory system or the lymphatic system.
- Once in either system the cancer cells can travel anywhere in the body

Cancer cells differ from normal cells:
- Divide when they shouldn’t
- Invade surrounding tissues
- Move to other locations in the body

**Risk factors**: increase a person’s risk of developing a disease (Table 6.1)
- Tobacco use: tobacco contains many carcinogens
- Alcohol consumption
- High-fat, low-fiber diet
- Lack of exercise
- Obesity
- Increasing age which weakens the immune system
- Cells that divide frequently such as ovarian cells

6.2 Passing Genes and Chromosomes to Daughter Cells

- **Asexual reproduction**:
  - Only one parent
  - Offspring are genetically identical to parent
- **Sexual reproduction**
  - **Gametes** are combined from two parents
  - Offspring are genetically different from one another and from the parents

Before dividing, cells must copy their DNA

**Gene**: section of DNA that has the instructions for making all proteins

- One molecule of DNA is wrapped around proteins to form a chromosome containing hundreds of genes.
- Different species have different numbers of chromosomes (we have 46).

- Chromosomes are uncondensed before cell division
- Duplicated chromosomes, held together at the centromere, are called sister chromatids
- They are duplicated through DNA replication

- DNA molecule is a double stranded structure similar to a twisted ladder.
- The sides of the ladder are composed of a sugar-phosphate backbone.
- Nucleotides are connected to each other by hydrogen bonding to form the “rungs” of the ladder.
- Adenine (A) pairs with thymine (T)
- Cytosine (C) pairs with Guanine (G)

- DNA molecule is split up the middle of the helix
- Nucleotides are added to each side via hydrogen bonding
- Result is two identical daughter molecules, each with one parental strand and one new strand (semiconservative replication)

- DNA polymerase: the enzyme that replicates DNA
- It moves along the length of the unwound DNA and helps form the new strands

6.3 The Cell Cycle and Mitosis
- Cell cycle has three steps:
  - Interphase: the DNA replicates
  - Mitosis: the copied chromosomes are moved into daughter nuclei
    - Mitosis occurs in somatic or body cells.
  - Cytokinesis: the cell is split into 2 daughter cells

6.3 The Cell Cycle and Mitosis - Interphase
- Interphase has three phases:
  - $G_1$: cell grows, organelles duplicate
  - S: DNA replicates
  - $G_2$: cell makes proteins needed to complete mitosis
- Most of the cell cycle is spent in interphase

6.3 The Cell Cycle and Mitosis - Mitosis
- Mitosis produces genetically identical daughter nuclei
- Mitosis is followed by cytokinesis which splits the two nuclei into two daughter cells
- Four stages:
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase

6.3 The Cell Cycle and Mitosis - Mitosis
- Prophase:
  - Chromosomes condense
  - Nuclear envelope disappears
  - Microtubules pull the chromosomes around during cell division
    - Animal cells: microtubules attached to centrioles at the poles of the cell
6.3 The Cell Cycle and Mitosis - Mitosis
- **Metaphase:**
  - Chromosomes are aligned across the middle of the cell by microtubules
- **Anaphase:**
  - Centromeres split,
  - Sister chromatids are pulled apart toward opposite poles
- **Telophase:**
  - Nuclear envelopes reform around chromosomes
  - Chromosomes revert to uncondensed form

6.3 The Cell Cycle and Mitosis - Cytokinesis
- Cytokinesis is the stage in which two daughter cells are formed from the original one
- After cytokinesis, cells reenter interphase.
- Animals:
  - Proteins pinch the original cell into two new cells
- Cytokinesis in Plants:
  - Starts with vesicles forming the **cell plate**.
  - This results in a new **cell wall** being formed between the cells forming daughter cells.
    - The cell wall is made from **cellulose**

6.4 Cell Cycle Control and Mutation
- Cell division is a tightly controlled process
- Normal cells halt at **checkpoints**
- Proteins survey the condition of the cell
- Cell must pass the survey to proceed with cell division
- 3 checkpoints: G1, G2, and metaphase
- **Growth factors** stimulate cells to divide
- Growth factors bind to **receptors** to trigger a response from a cell
- **Mutation**: a change in the sequence of DNA
  - Changes to DNA can change the structure and function of the protein coded by the DNA
  - Mutations may be inherited or caused by carcinogens

6.4 Cell Cycle Control and Mutation
- **Proto-oncogenes**: genes that code for the cell cycle control proteins
- When proto-oncogenes mutate, they become **oncogenes**
  - Their proteins no longer properly regulate cell division
  - They usually overstimulate cell division
- **Tumor suppressor genes**: genes for proteins that stop cell division if conditions are not favorable
  - When mutated, can allow cells to override checkpoints
- Depending on the number of mutations and whether the tumor suppressor protein is functional will determine whether it is a benign or malignant tumor that is formed.
6.4 Cancer Development Requires Many Mutations
- Progression from benign tumor to cancer requires many mutations.
- **Angiogenesis**: tumor gets its own blood supply
- Loss of **contact inhibition**: cells will now pile up on each other
- Loss of **anchorage dependence**: enables a cancer cell to move to another location
- **Immortalized**: cells no longer have a fixed number of cell divisions due to an enzyme called **telomerase**

6.4 Cell Cycle Control and Mutation – Multiple Hit Model
- **Multiple hit model**: process of cancer development requires multiple mutations
- Some mutations may be inherited (familial risk)
- Most are probably acquired during a person’s lifetime

6.5 Cancer Detection and Treatment
- Early detection increases odds of survival
- There are different detection methods for different cancers
- Some cancers produce increased amount of a characteristic protein
- **Biopsy**: surgical removal of cells or fluid for analysis
  - **Needle biopsy**: removal is made using a needle
  - **Laparascope**: surgical instrument with a light, camera, and small scalpel

6.5 Cancer Detection and Treatment - Treatment Methods
- **Chemotherapy**: drugs that selectively kill dividing cells
  - Combination of different drugs used (“cocktail”)
  - Interrupt cell division in different ways
  - Helps prevent resistance to the drugs from arising
  - Normal dividing cells are also killed (hair follicles, bone marrow, stomach lining)

- **Radiation therapy**: use of high-energy particles to destroy cancer cells
  - Damages their DNA so they can’t continue to divide or grow
  - Usually used on cancers close to the surface
  - Typically performed after surgical removal of tumor
- If a person remains cancer free after treatment for 5 years they are in **remission** and after 10 years they are cured.

6.6 Meiosis
- Specialized form of cell division in **gonads** to produce **gametes**
- Reduces number of chromosomes in each cell by one-half
  - Chromosomes come in **homologous pairs**
  - Gamete gets one of each pair

- Chromosomes can be visualized using a **karyotype**.
  - Human **somatic cells** have 22 pairs of **autosomes** and one pair of **sex**
chromosomes

- Gametes are **haploid** or have 1 set of 23 chromosomes
- When the egg and sperm nuclei fuse it forms a zygote which is **diploid**
- Somatic or body cells are also **diploid**

- Starts with interphase – DNA is duplicated
- Meiosis takes place in two stages:
  - **Meiosis I**
    - Separating out the homologous pairs into 2 separate cells
  - **Meiosis II**
    - Separating out the sister chromatids in each cell to produce 4 haploid cells.

- **Crossing over**: exchange of equivalent portions of chromosomes between members of a homologous pair
  - Results in new types of gametes being formed
  - **Linked genes** typically cross over together
- **Random alignment**: the way in which different pairs of chromosomes align and get separated during meiosis I is random
  - Results in different types of games being formed

**6.6 Meiosis - Mistakes in Meiosis**

- **Nondisjunction**: failure of homologues to separate normally during meiosis
- Results in a gamete having one too many chromosomes (**trisomy**) or one too few chromosomes (**monosomy**)
- Most embryos that result from such gametes will die before birth
- Several chromosome abnormalities are known in humans (Table 6.2)

- For cancer mutations to be passed on to offspring, they must take place in cells that give rise to gametes.
- Mutations caused by environmental exposures are not passed on unless the mutation occurs in the gametes.
  - Mutations in somatic cells (e.g., skin cancer from UV ray exposure) are not heritable.