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## Contents

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<b>1</b>	<b>Biology</b>	<b>4</b>
1.1	Cell Theory . . . . .	4
1.2	Prokaryote and Eukaryote . . . . .	6
1.3	Organelles . . . . .	7
1.3.1	Cell Membrane . . . . .	7
1.3.2	Cytoplasm . . . . .	7
1.3.3	Nucleus . . . . .	7
1.3.4	Vesicles . . . . .	8
1.3.5	Vacuoles . . . . .	8
1.3.6	Mitochondria . . . . .	9
1.3.7	Lysosomes . . . . .	9
1.3.8	Rough Endoplasmic Reticulum . . . . .	10
1.3.9	Smooth Endoplasmic Reticulum . . . . .	11
1.3.10	Ribosomes . . . . .	11
1.3.11	Golgi Body/Apparatus . . . . .	11
1.3.12	Cytoskeleton . . . . .	11
1.3.13	Chloroplast . . . . .	12
1.4	Animal vs Plant Cells . . . . .	13
1.5	Histology . . . . .	16
1.6	Asexual vs Sexual . . . . .	17
1.6.1	Asexual . . . . .	17
1.6.2	Sexual . . . . .	17
1.7	The Cell Cycle . . . . .	18
1.7.1	Cell Division . . . . .	18
1.7.2	Chromosomes . . . . .	19
1.7.3	Interphase . . . . .	20
1.7.4	Mitosis . . . . .	21
1.7.5	Cytokinesis . . . . .	22
1.8	Cell Cycle Questions . . . . .	23
1.9	Healthy Cell Checkpoints . . . . .	25
1.9.1	$G_1$ Checkpoint . . . . .	26
1.9.2	$G_2$ Checkpoint . . . . .	26

1.9.3 The Spindle Checkpoint . . . . .	26
1.10 Cancer . . . . .	28
1.10.1 Stages of Cancer . . . . .	28
1.10.2 Cancer Prevention . . . . .	29
1.10.3 Cancer Treatment . . . . .	29
1.11 Stem Cells . . . . .	30
1.11.1 Stem Cell Transplant . . . . .	30
1.12 Hierarchy of an Organism . . . . .	32
1.13 Types of Tissues . . . . .	33
1.13.1 Epithelial Tissue . . . . .	33
1.13.2 Connective Tissue . . . . .	33
1.13.3 Muscle Tissue . . . . .	33
1.13.4 Nerve Tissue . . . . .	33
1.14 Stem Cells Case Study Mini-Assignment . . . . .	35
1.15 Digestive System . . . . .	36
1.15.1 Mouth . . . . .	37
1.15.2 Esophagus . . . . .	37
1.15.3 Epiglottis . . . . .	38
1.15.4 Stomach . . . . .	38
1.15.5 Small Intestine . . . . .	38
1.15.6 Large Intestine . . . . .	39
1.15.7 Appendix . . . . .	39
1.15.8 Rectum . . . . .	39
1.15.9 Anus . . . . .	39
1.15.10 Accessory Organs: Liver . . . . .	39
1.15.11 Gall Bladder . . . . .	40
1.15.12 Pancreas . . . . .	40
1.15.13 Diseases of the Digestive System . . . . .	41
1.16 Circulatory System . . . . .	42
1.16.1 Heart . . . . .	42
1.16.2 Blood vessels . . . . .	42
1.16.3 Blood . . . . .	43
1.16.4 Diseases of the Circulatory System . . . . .	44
1.17 Respiratory System . . . . .	46
1.17.1 Nose/Mouth . . . . .	46
1.17.2 Larynx . . . . .	46
1.17.3 Trachea . . . . .	46
1.17.4 Bronchi . . . . .	47
1.17.5 Bronchioles . . . . .	47
1.17.6 In the Lungs: Alveoli . . . . .	47
1.17.7 Pulmonary Arteries and Capillaries . . . . .	48
1.17.8 Pulmonary Veins . . . . .	48
1.17.9 Checkpoint: Pulmonary Fibrosis . . . . .	48
1.17.10 Breathing . . . . .	49
1.17.11 Lung Volume . . . . .	49
1.17.12 Inhalation . . . . .	49
1.17.13 Exhalation . . . . .	49
1.17.14 Respiratory System in Fish . . . . .	50

1.17.15 Diseases of the Respiratory System . . . . .	50
1.18 Musculoskeletal System . . . . .	52
1.18.1 Bone . . . . .	52
1.18.2 Ligament . . . . .	52
1.18.3 Cartilage . . . . .	52
1.18.4 Tendon . . . . .	52
1.18.5 Muscle Types . . . . .	52
1.18.6 Musculoskeletal System in Invertebrates . . . . .	53
1.18.7 Diseases of the Musculoskeletal System . . . . .	53
1.19 Nervous System . . . . .	54
1.19.1 Central Nervous System . . . . .	54
1.19.2 Spinal Cord . . . . .	55
1.19.3 Peripheral Nervous System . . . . .	55
1.19.4 Nerve . . . . .	56
1.19.5 Sensory Receptors . . . . .	56
1.19.6 Reflexes . . . . .	56
1.19.7 Diseases of the Nervous System . . . . .	57
1.19.8 Organ Transplant . . . . .	58
1.19.9 Types of Organ Donors . . . . .	58
1.19.10 Organ Trafficking . . . . .	59

# CHAPTER 1

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## Biology

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### 1.1 Cell Theory

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**Definition 1.1** (Cell Theory). The cell theory states

1. All living things are made of one or more cell.
2. The cell is the simplest unit that can carry out all life processes.
3. All cells come from pre-existing cells.

**Additionally:**

- Cells have not been synthesized in labs yet.
- Appeared 3.8 billion years ago.
- Hydrothermal vents created electrical gradient to form first organic molecules such as amino acids and nucleotides.
- First cell is presumed to be self-replication RNA enclosed by phospholipids.



**Figure 1.1:** Robert Hooke invented the simple microscope to look at thin pieces of cork tree. Classical cell theory was proposed by Schwann, Schleiden, and Virchow.

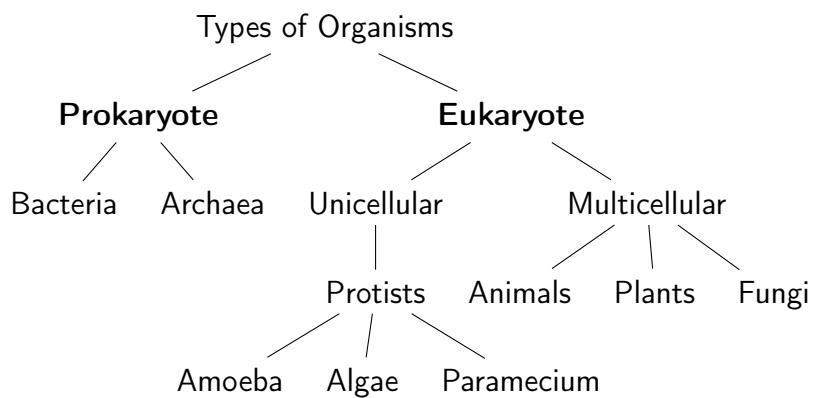
## 1.2 Prokaryote and Eukaryote

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Organisms are divided into two types: prokaryote and eukaryote.

**Definition 1.2 (Prokaryote).** Organisms that have cells which contain **no nucleus**.

**Definition 1.3 (Eukaryote).** Organisms that have cells which contain **a nucleus**. These fit under either **unicellular** or **multicellular**, meaning one nucleus and more than one nucleus, respectively.



## 1.3 Organelles

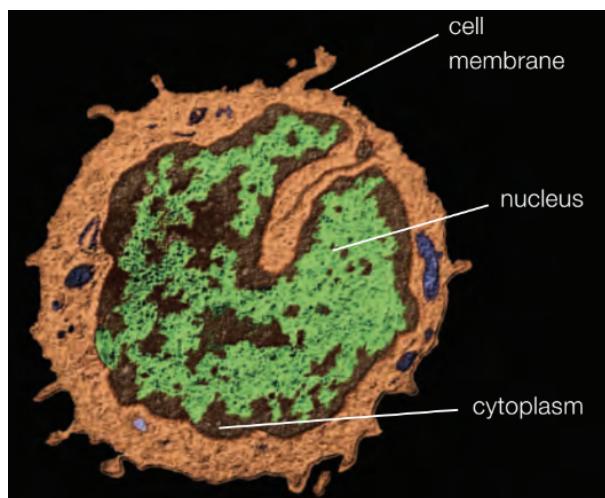
**Definition 1.4 (Organelles).** An organelle is a small structure in a cell that is surrounded by a membrane and has a specific function.

Basically, that organelles act like the organs in your body but instead it is for the cell. There are many different organelles, varying for plants and animals.

### 1.3.1 Cell Membrane

**Definition 1.5 (Cell Membrane).** The cell membrane is like the outer wall of the cell. It is semi-permeable, meaning it allows only certain substances/materials through. See Figure 1.2.

The cell membrane is made of a double layer of lipids. A lipid is a fat-like molecule that does not dissolve in water.



**Figure 1.2:** A cell showing the cell membrane, cytoplasm, and large nucleus.

### 1.3.2 Cytoplasm

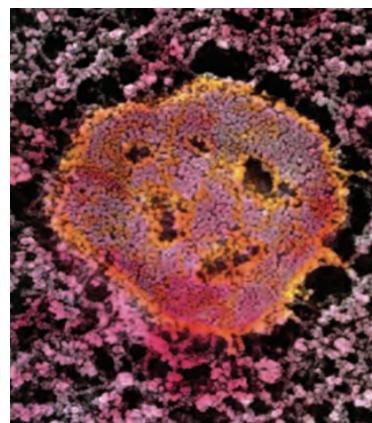
**Definition 1.6 (Cytoplasm).** The cytoplasm is a gel-like substance that fills the cell and surrounds organelles. Cytoplasm contains the nutrients required by the cell to carry on its life purposes. See Figure 1.2.

All organelles are suspended in cytoplasm. The physical nature of the cytoplasm allows the nutrients and organelles to move within the cell.

### 1.3.3 Nucleus

**Definition 1.7 (Nucleus).** The nucleus is the control center of the cell. It controls all activities in the cell, including growth and reproduction. One important thing is that it contains nearly all of the cell's DNA. See Figure 1.3.

**Note:** DNA stands for deoxyribonucleic acid. DNA is very important to the cell because it contains the coded information for making proteins and other molecules. Proteins serve many purposes and are found in various locations of the cell.



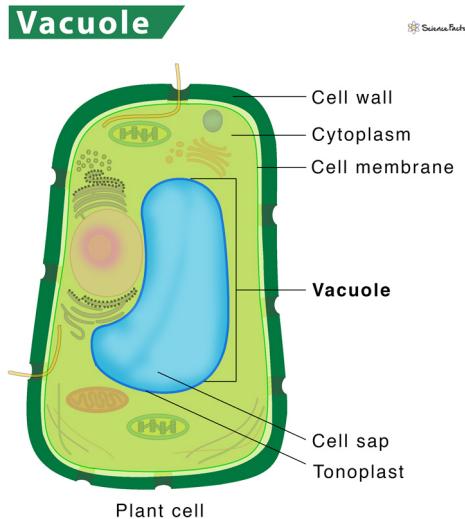
**Figure 1.3:** The nucleus and chromatin in a human cell, as seen through an electron microscope.

#### 1.3.4 Vesicles

**Definition 1.8 (Vesicles).** Vesicles are membrane-bound organelles that store nutrients, waste, and other substances used by the cell. Vesicles can fuse with the cell membrane.

#### 1.3.5 Vacuoles

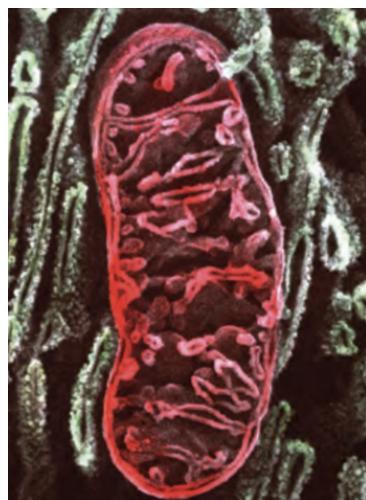
**Definition 1.9 (Vacuoles).** Vacuoles are basically vesicles but bigger and do not fuse with the cell membrane. You can think of them as the storage system. See Figure 1.4./



**Figure 1.4:** A vacuole inside of a plant. You can tell it is inside of a plant because a plant only has ONE large vacuole.

### 1.3.6 Mitochondria

**Definition 1.10 (Mitochondria).** The powerhouse of the cell. The mitochondria supplies the cell with energy by converting the chemical energy within sugar into energy that the cell can use. See Figure 1.5.



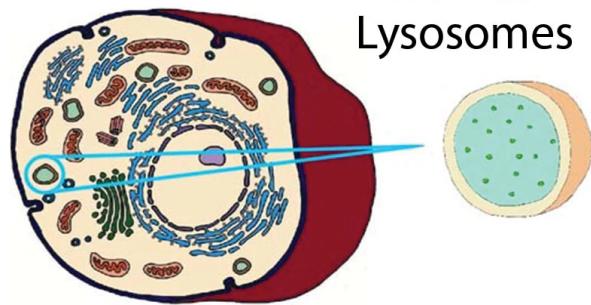
**Figure 1.5:** A mitochondrion, as seen through an electron microscope.

### 1.3.7 Lysosomes

**Definition 1.11 (Lysosomes).** Lysosomes are organelles where digestion takes place. They are small organelles that are filled with enzymes. Lysosomes also break down

| invading bacteria and damaged cell organelles. See Figure 1.6.

Essentially, they work as the clean-up system in the cell.

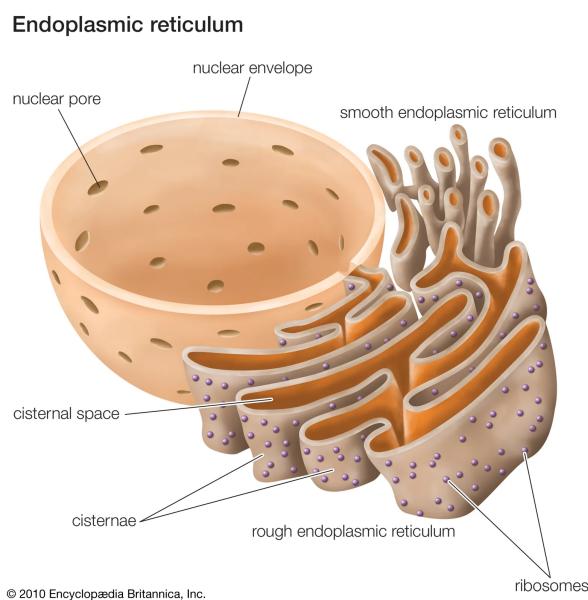


**Figure 1.6:** Lysosomes

**Note (Enzyme):** An enzyme is a protein that can speed up chemical reactions in the cell.

### 1.3.8 Rough Endoplasmic Reticulum

| **Definition 1.12** (Rough Endoplasmic Reticulum). The rough endoplasmic reticulum is like a conveyor belt for proteins and nutrients that are destined for the nucleus. The rough endoplasmic reticulum is studded with ribosomes which allows it to easily transport proteins once they are made. You can think of the rough endoplasmic reticulum as an organelle that synthesizes proteins. See Figure 1.7.



**Figure 1.7:** The rough and smooth endoplasmic reticulums.

### 1.3.9 Smooth Endoplasmic Reticulum

**Definition 1.13** (Smooth Endoplasmic Reticulum). Similar to the smooth endoplasmic reticulum, except that it lacks ribosomes and is involved in lipid metabolism, including the synthesis of phospholipids, steroids, and other lipids. See Figure 1.7.

**Note (Lipid):** Lipid is another word for "fat".

Basically, the rough endoplasmic reticulum is involved in protein synthesis and processing, whereas the smooth endoplasmic reticulum is involved in lipid metabolism and detoxification. The main difference is the presence of ribosomes in both cases.

### 1.3.10 Ribosomes

**Definition 1.14** (Ribosomes). Ribosomes are small, dense-looking organelles that may be attached to the rough endoplasmic reticulum or free in the cytoplasm. Ribosomes are the sites where the proteins are assembled.

### 1.3.11 Golgi Body/Apparatus

**Definition 1.15** (Golgi Body/Apparatus). The golgi body receives proteins from the endoplasmic reticulum and processes them for removal from the cell. They modify, sort, and package these proteins for delivery throughout the cell or outside of the cell. The golgi body looks like a stack of flattened membranes (see Figure 1.8).

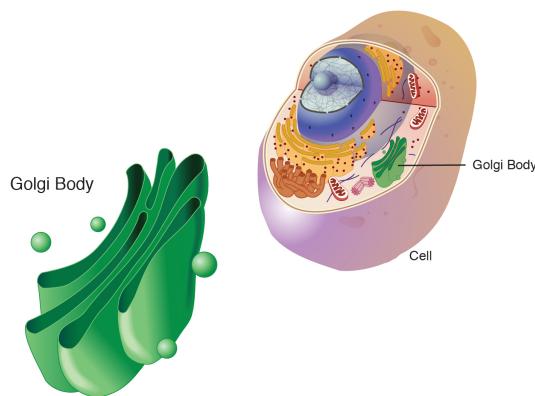


Figure 1.8: Golgi body.

### 1.3.12 Cytoskeleton

**Definition 1.16** (Cytoskeleton). The cytoskeleton gives structure to the cell and is made of protein filaments.

### 1.3.13 Chloroplast

**Definition 1.17** (Chloroplast). Chloroplasts are only found in plants cells and some algae. Contains a pigment called chlorophyll that absorbs light and energy to undergo photosynthesis



**Note (Thylakoids):** Chloroplasts are made of little sacs called **thylakoids**. A stack of thylakoids is called a **grana**. You can think of the thylakoids as solar panels.

## 1.4 Animal vs Plant Cells

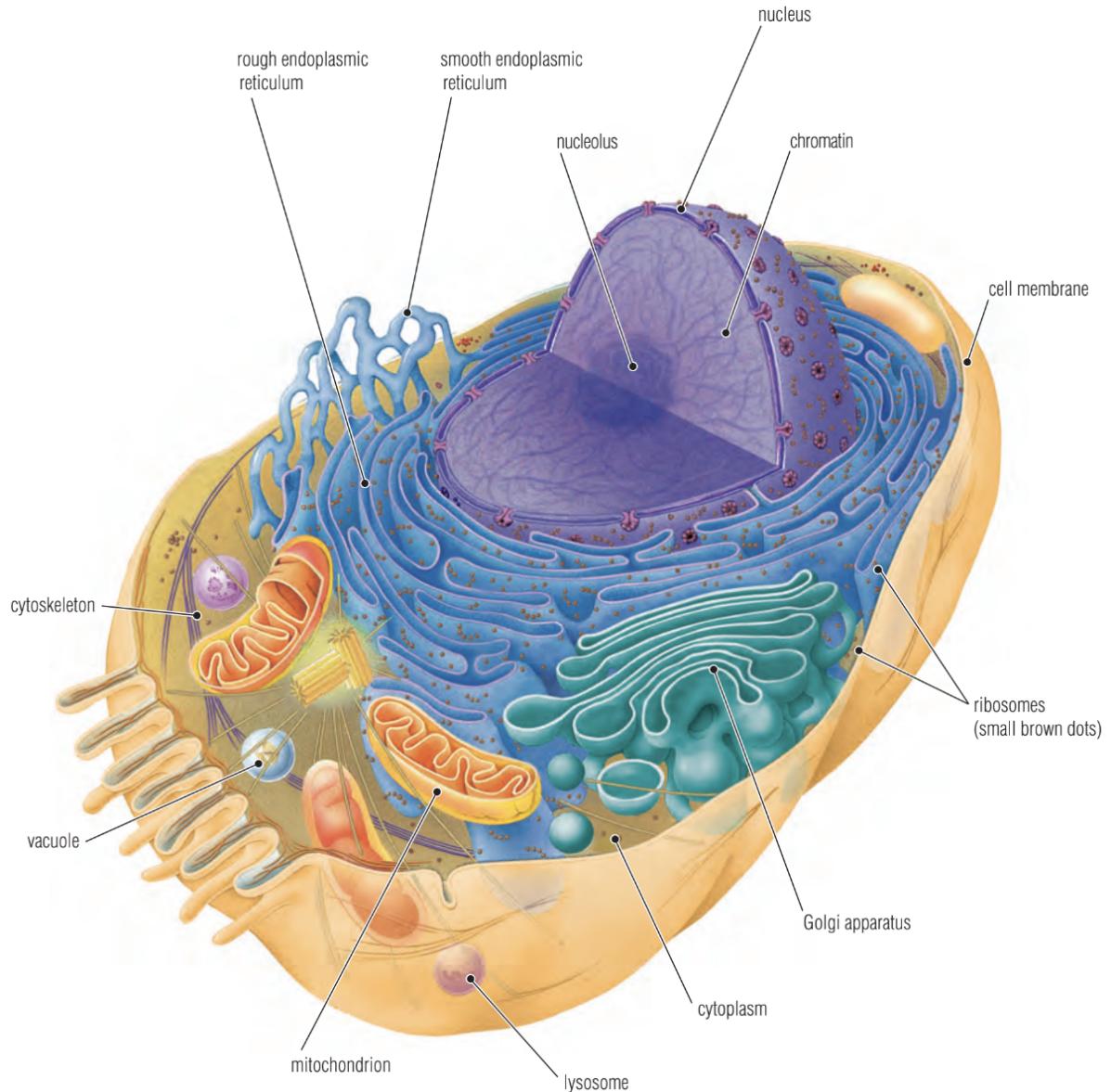
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Plant cells contain all of the organelles contained within animal cells, except for a few extra.  
To contrast

Animal Cell	Plant Cell
<ul style="list-style-type: none"><li>• Nucleus</li><li>• Nuclear membrane</li><li>• Cytoplasm</li><li>• Endoplasmic Reticulum (ER); smooth and rough</li><li>• Ribosomes</li><li>• Golgi apparatus/body</li><li>• Vesicles</li><li>• Vacuoles</li><li>• Mitochondria</li><li>• Cell membrane</li><li>• Lysosomes</li></ul>	<ul style="list-style-type: none"><li>• All of the previously mentioned...</li><li>• Chloroplast</li><li>• Cell wall</li><li>• Large central vacuole</li></ul>

**Table 1.4.1:** Plant cells have an extra **chloroplast, cell wall, and large central vacuole.**

See Figure 1.17 for animal cell and Figure 1.10 for plant cell.



**Figure 1.9:** Animal cell.

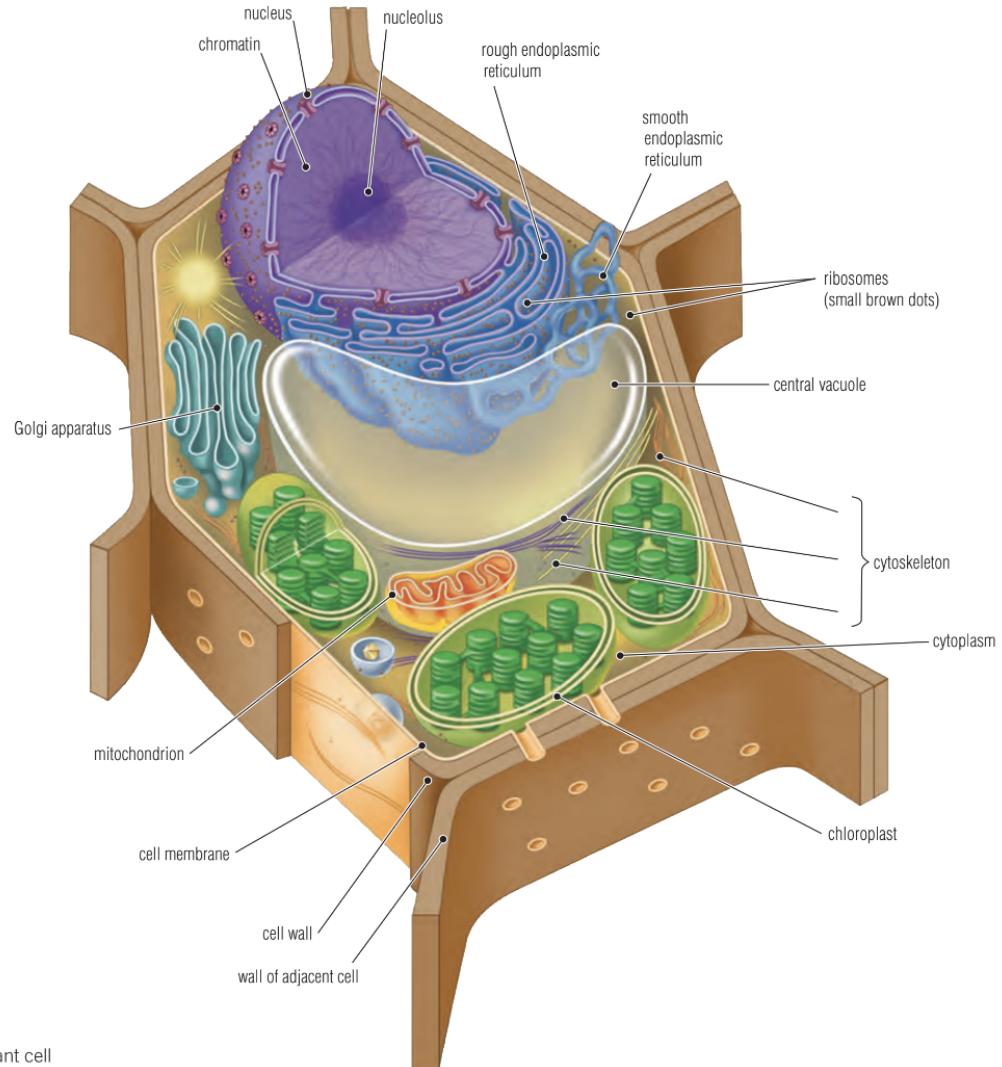


Figure 1.5 A plant cell

**Figure 1.10:** The plant cell contains an extra chloroplast, cell wall, and large central vacuole.

## 1.5 Histology

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**Definition 1.18** (Histology). A branch of study that concerns the study of biological tissues using a microscope.

Thin slices are placed on microscope slides to be visualized underneath a microscope. Specimens stained with various dyes and chemicals to visualize organelles.

## 1.6 Asexual vs Sexual

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### 1.6.1 Asexual

**Definition 1.19** (Asexual). Producing from only one parent. Exact same genes/DNA of the parent cell.

**Advantages:**

- Only need one parent.
- Very efficient; not many resources are required to initiate asexual reproduction.
- Happens very quickly.

**Disadvantages:**

- Decreases overall genetic resilience of the population.
- In turn there will be issues with diseases wiping out the entire population. This is because if there is say ebola, then it will wipe out everyone, since everyone is the same. If it kills one person, it will kill everyone too.

### 1.6.2 Sexual

**Definition 1.20** (Sexual). Producing offspring by fusion of two gametes (egg and sperm). Offspring will have genetic material from both parents and newer cells will be created through mitosis.

**Advantages:**

- Genetic variability of the population will be high.
- As a result, the population will be more resilient in the face of pathogens.
- For example, some people weren't affected at all by the bubonic plague because they had a slight variance in their genetics that made them immune to the disease.

**Disadvantages:**

- Two parents are required; slower than asexual reproduction.
- Time and energy are required to find a suitable mate for reproduction.
- Not every individual in the population gets to reproduce. Example: fat and obese people have a lower chance to reproduce than muscular people.
- Genetically heritable conditions can be passed down. Example: diabetes.

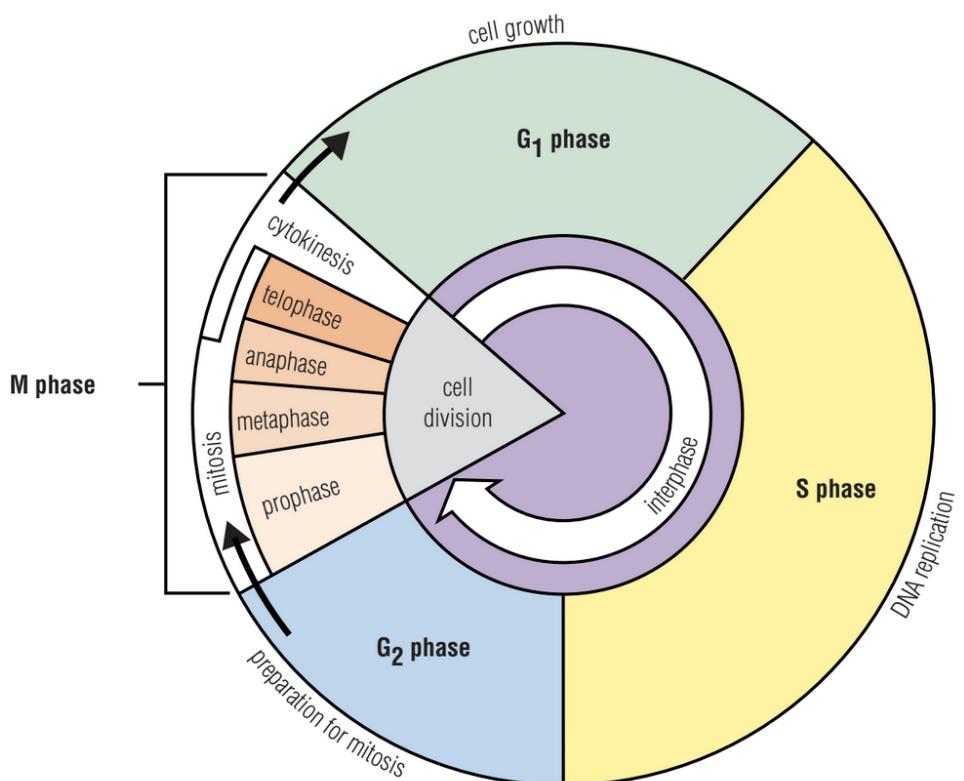
## 1.7 The Cell Cycle

**Definition 1.21 (Cell Cycle).** In your body, cells are constantly dying and being replenished. During much of the cell cycle, the cell prepares for **cell division**. The three stages are:

1. Interphase
2. Mitosis
3. Cytokinesis

See Figure 1.11.

Cell division occurs for the purpose of reproduction. There are two types, namely **asexual** and **sexual**.



**Figure 1.11:** The cell cycle has four phases. During most of the cell cycle, the cell is growing, replicating its DNA, and preparing for cell division.

### 1.7.1 Cell Division

**Definition 1.22 (Cell Division).** Cell division is the process by which a single cell divides into two or more daughter cells. This process is essential for the growth and maintenance of all living organisms.

One method of cell division is known as **mitosis** (see Section 1.7.4).

Cell division allows organisms to **grow**.

- Nutrients move through diffusion (high concentration to low concentration).
- Water enters and leaves the cell through osmosis (high concentration to low concentration).
- Cells need to divide to ensure a high surface area to maximize diffusion of nutrients/waste and osmosis of water.
- We need lots of cells that will cover a greater surface area because it speeds up the process of diffusion.

Cell division allows organisms to **repair**.

- Organisms need to repair cells from damage or old age.

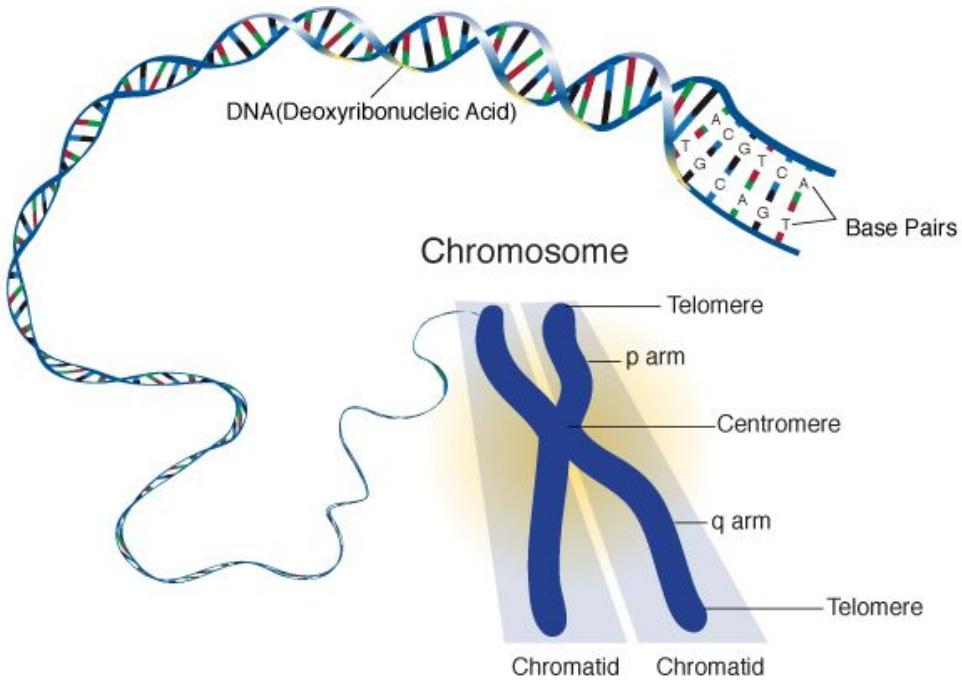
Repair Rate for Cells

Cell Type	Turnover Time
Stomache	2-4 days
Skin	10-30 days
Red blood cells	4 months
Liver cells	6-12 months
Brain cells	Life time

- Stages of skin regeneration:
  - New skin cells.
  - Coming to surface.
  - Degeneration process.
  - Dead skin cells.

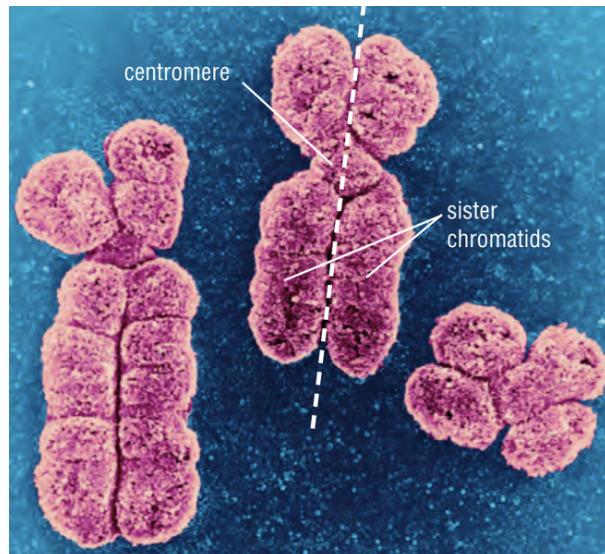
## 1.7.2 Chromosomes

**Definition 1.23 (Chromosomes).** Each chromosome is a long piece of DNA and protein. They carry genetic information in the form of genes. The number of chromosomes between each organism varies. Chromosomes are only visible when the cell is dividing. See Figure 1.12.



**Figure 1.12:** Chromosomes.

Before cell division can occur, each chromosome is copied, as shown in Figure 1.13. The chromosome consists of two identical copies, can **sister chromatids**. When the cell divides, one chromatid goes to each of the new cells.



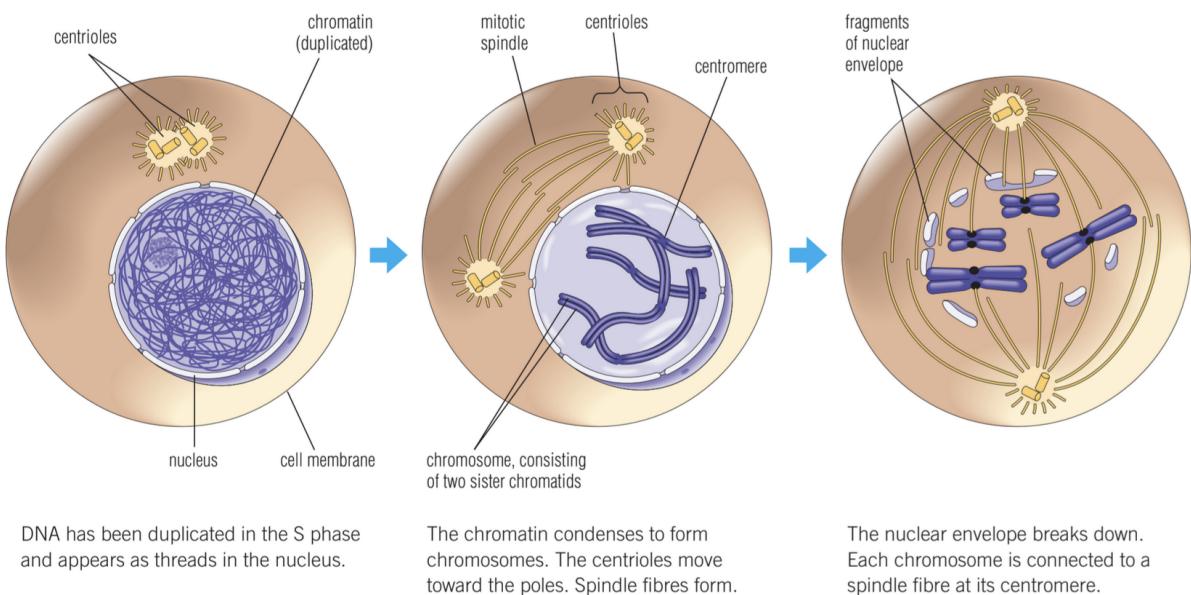
**Figure 1.13:** Each chromosome consists of two identical sister chromatids. The **centromere** is where the sister chromatids attach.

### 1.7.3 Interphase

**Definition 1.24** (Interphase). The cell spends the most time in interphase. This phase refers to a period where the cell carries out its regular cell functions. This stage prepares

the cell for **mitosis**. There are three phases (in the particular order):

1. **G1 Phase:** the cell grows in size and carries out normal metabolic processes.
2. **S Phase:** DNA replication, resulting in the formation of two identical copies of the cell's genetic material.
3. **G2 Phase:** organelles are duplicated. The cell undergoes further growth and prepares for division by synthesizing proteins necessary for mitosis. See Figure 1.14.



**Figure 1.14: S phase and G2 phase.**

**Note:** The cell grows until it reaches a certain size, at which it is healthier for the cell to undergo cell division.

#### 1.7.4 Mitosis

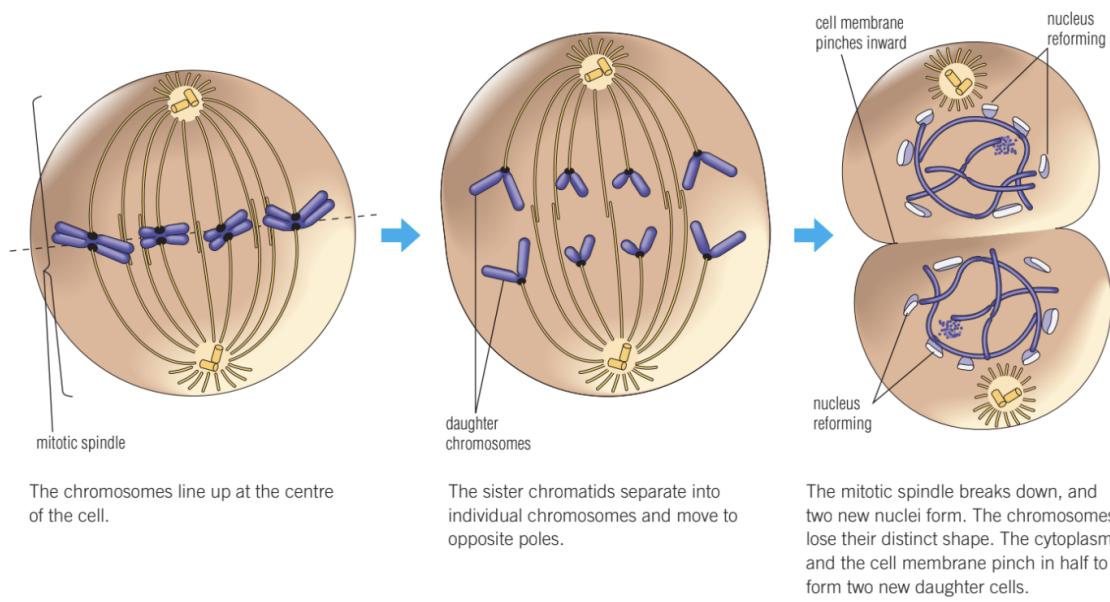
**Definition 1.25 (Mitosis).** Mitosis is the stage in which DNA in the nucleus is divided. There are 4 stages of mitosis:

1. **Prophase:** the chromosomes shorten and thicken.
2. **Metaphase:** chromosomes line up in the middle of the cell.
3. **Anaphase:** chromatids break apart at the centromere and move to opposite poles.
4. **Telophase:** two nuclei formed after nuclear envelopes reform around each group of chromosomes.

| See Figure 1.15.

### 1.7.5 Cytokinesis

**Definition 1.26 (Cytokinesis).** Cytokinesis is the final stage of the cell cycle, where the cytoplasm is split and two daughter cells are formed. In an animal cell, this is done through the pinching of the membrane (cleavage furrow). In a plant cell, this is done through the formation of a cell plate.



**Figure 1.15:** Prophase then metaphase, anaphase, and telophase then cytokinesis.

## 1.8 Cell Cycle Questions

---

1. What is the purpose of the cell cycle?

**Solution.**

- Sustain the processes for cell division to occur.
- Cell growth; duplication of DNA and duplication of organelles.
- Maintain regular cell function.

2. Define the term “interphase” and describe its purpose.

**Solution.** It refers to the period of time in which the cell carries out its regular cell functions. The purpose of interphase is to get the cell ready to divide (growth of the cell, duplication of the cell, duplication of DNA, duplication of organelles).

3. (a) What is mitosis?

**Solution.** This is when a single parent cell divides into two new daughter cells. The parent cells and daughter cells have the same DNA.

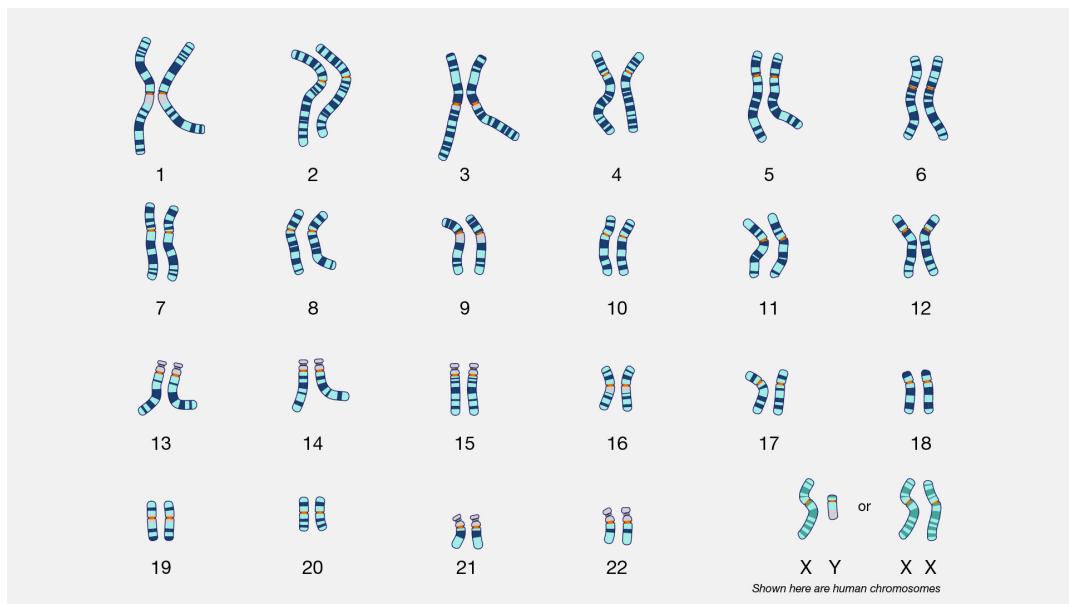
(b) Why is mitosis important to the cell?

**Solution.** **Cell reproduction;** making new cells. **Growth;** optimization of cell surface area to cell volume ratio. High surface area to volume ratio is important. A high surface area to volume ratio maintains that nutrients can enter the cell efficiently and that waste can leave the cell efficiently.

4. Define and distinguish between the following terms: chromosomes, centromere, and sister chromatids.

**Solution.**

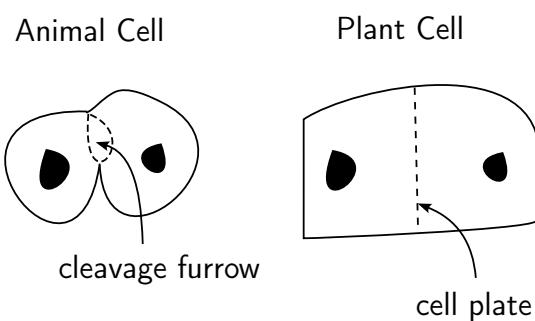
- **Chromosome:**
  - Genetic material.
  - Coiled version of cellular DNA called chromatin)
  - Comprised of sister chromatids.
- **Sister chromatids:**
  - Identical copies of DNA which are part of the chromosomes.
  - Attached at the center with a centromere during prophase and metaphase.
  - The sister chromatids are separated in mitosis during anaphase.
- **Centromere:**
  - Holds the sister chromatids together during prophase and metaphase.
  - 2 sister chromatids attached by a centromere from the chromosome.



**Figure 1.16:** Karyotypes. In the bottom right, we see that there is XY or XX. The reason for this is because the one on the right (XY chromosome) is the male chromosome, and the one on the left (XX chromosome) is the female chromosome.

5. Explain the meaning of cytokinesis.

**Solution.** Happens after telophase. Is defined as the splitting/division of the cytoplasm. In an animal cell, this is done through the pinching of the membrane (we call this a cleavage furrow). In a plant cell, this is done through the formation of the cell plate.



**Figure 1.17:** Animal Cell vs Plant Cell

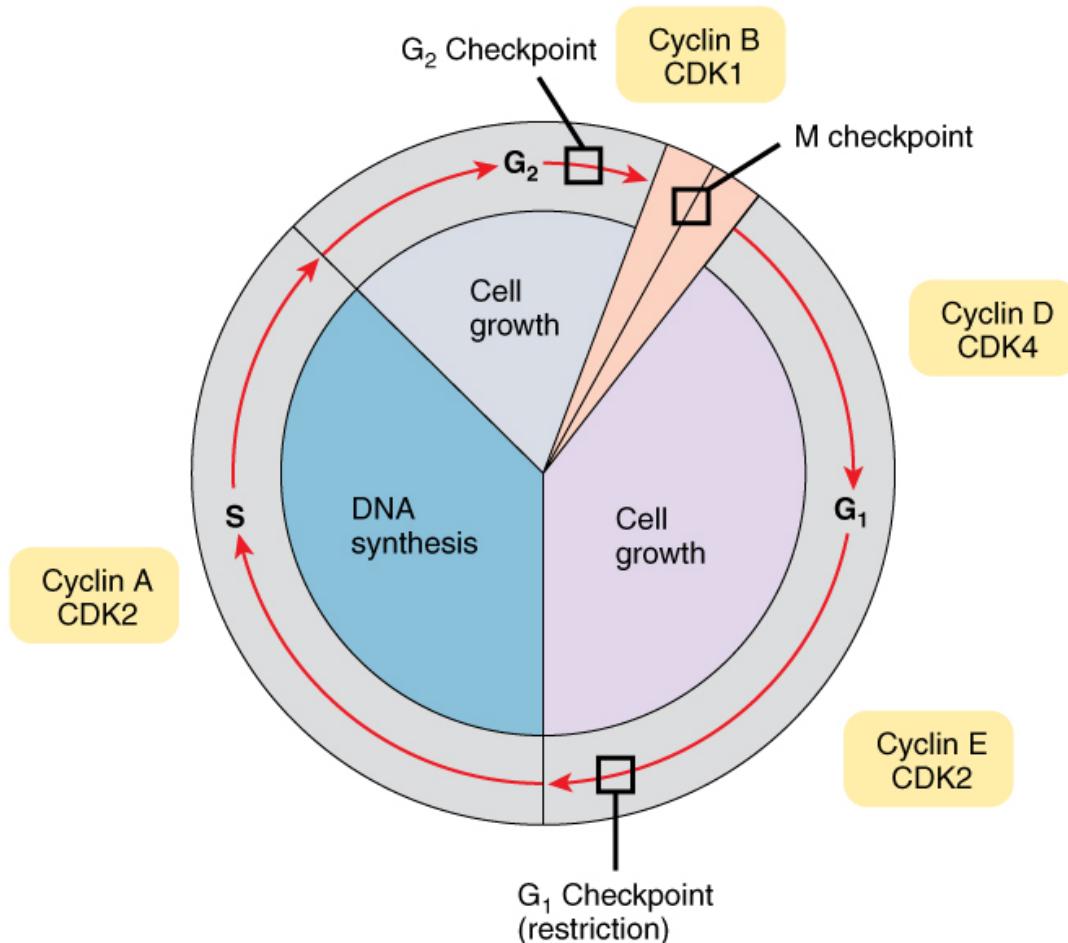
## 1.9 Healthy Cell Checkpoints

**Definition 1.27 (Healthy Cell Checkpoints).** A cell will not divide if

- Signals from surrounding cells tell the cell not to divide.
- Not enough nutrients for cell growth.
- DNA has not been replicated.
- DNA is damaged.

Cell can undergo programmed cell death (apoptosis). See Figure 1.18.

For more information, visit <https://www.khanacademy.org/science/ap-biology/cell-communication-and-cell-cycle/regulation-of-cell-cycle/a/cell-cycle-checkpoints>



**Figure 1.18:** If a cell doesn't get the go-ahead cues it needs at the G<sub>1</sub> checkpoint, it may leave the cell cycle and enter a resting state called the G<sub>0</sub> phase. Some cells stay permanently in G<sub>0</sub>, while others resume dividing if conditions improve.

git clone –recursive <https://github.com/ahrm/sioyek>

### 1.9.1 $G_1$ Checkpoint

**Definition 1.28 ( $G_1$  Checkpoint).** The main decision point for a cell; that is, the primary point at which it must choose whether or not to divide. Once the cell passes the  $G_1$  checkpoint and enters S phase, it becomes irreversibly committed to division. See Figure ??.

### 1.9.2 $G_2$ Checkpoint

**Definition 1.29 ( $G_2$  Checkpoint).** At this stage, the cell will check:

- **DNA integrity:** is any of the DNA damaged?
- **DNA replication:** was the DNA completely copied during S phase? If there is damage, the cell will stall at the  $G_2$  phase to repair. If the damage is unrepairable, the cell will undergo apoptosis (self destruction). See Figure ??.

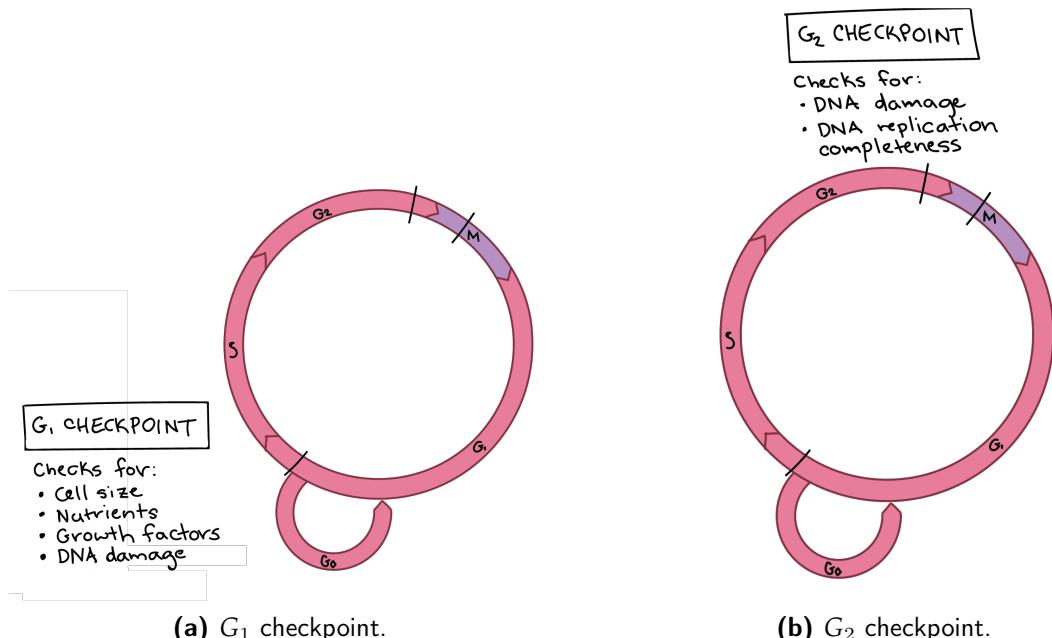
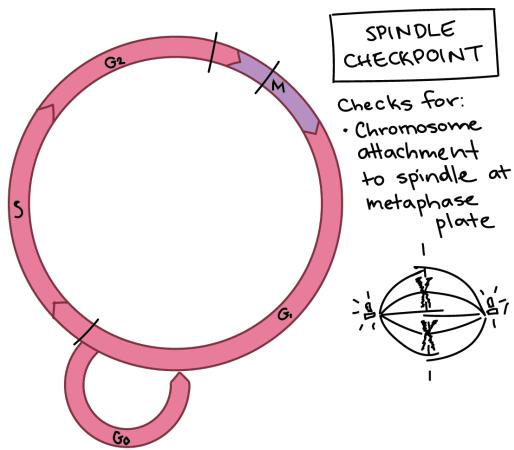


Figure 1.19: The  $G_1$  and  $G_2$  checkpoints.

### 1.9.3 The Spindle Checkpoint

**Definition 1.30 (The Spindle Checkpoint).** The M checkpoint is known as the “spindle checkpoint”. Here, the cell examines whether all the sister chromatids are correctly attached to the spindle microtubules. See Figure 1.20.

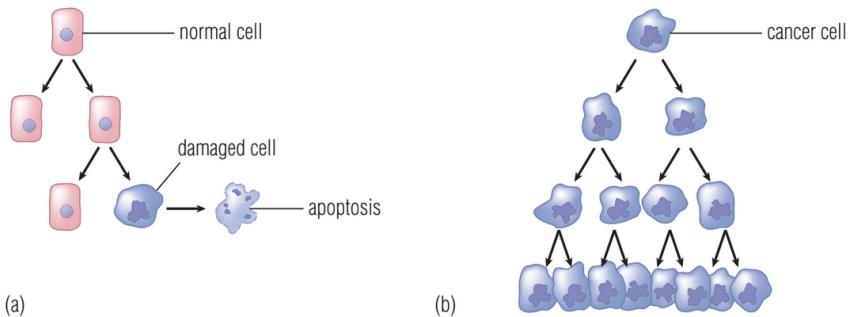


**Figure 1.20:** The spindle checkpoint (M checkpoint).

## 1.10 Cancer

**Definition 1.31 (Cancer).** This is a group of diseases in which cells grow and divides uncontrollably. See Figure 1.21 and Table 1.10.1.

This is caused by mutations to the DNA within cells which can allow rapid growth, fail to stop uncontrolled cell growth, or make errors when correcting DNA. Mutations are inherited or caused by environmental factors (i.e. radiation, viruses, carcinogens, etc.).



**Figure 1.21:** (a) Cell division and cell death in normal cells. (b) Cell division in cancer cells.

### 1.10.1 Stages of Cancer

**Stage 0:** cancer cells remain in place to form a mass called a tumour.

**Stage 1:** small tumour has not grown deeply into nearby tissues and has not spread to lymph nodes.

**Stage 2 & 3:** larger tumours have grown deeply into nearby tissue and may have spread to lymph nodes.

**Stage 4:** cancer has spread to other organs or parts of the body (metastasis).

Colorectal Cancer 5 year survival rates

Stage	Survival Rate
I	94%
II	82%
III	67%
IV	11%

Normal Cells	Cancer Cells
Make exact copies of themselves through mitosis.	Make exact copies of themselves through mitosis.
Reproduces for about 50-60 cell divisions.	Does not stop reproducing.
Stick together to form masses of cells as appropriate.	Does not stick to other cells. Behaves independently.
Self-destruct (apoptosis) when too old or damaged.	May move to another location of the body.

**Table 1.10.1:** Comparing normal cells with cancer cells.

### 1.10.2 Cancer Prevention

**Healthy choices:**

- Live smoke-free.
- Wear sunscreen and sun protection.
- Maintain a healthy body.
- Get vaccinated.
- Check your family history.
- Get screened regularly.

### 1.10.3 Cancer Treatment

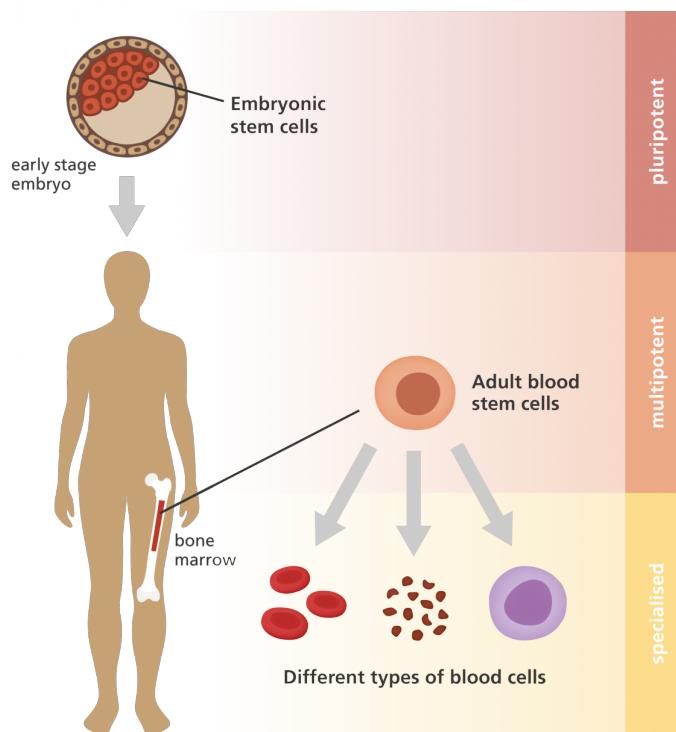
- **Surgery** to physically remove the tumour.
- **Chemotherapy** uses chemicals and drugs to kill cancer cells; taken orally to intravenously.
- **Radiation therapy** uses focused beams of radiation to target cancer cells.

## 1.11 Stem Cells

**Definition 1.32 (Stem Cells).** Cells that can self-renew and differentiate into many different types of cells in the body. Two types:

1. **Embryonic stem cells** are derived from embryos and can differentiate into any cells.
2. **Adult stem cells** are found in the body and can differentiate into a limited number of cell types.

See Figure 1.22.



**Figure 1.22:** Stem Cells

**Note:** Embryonic stem cells are right after fertilization.

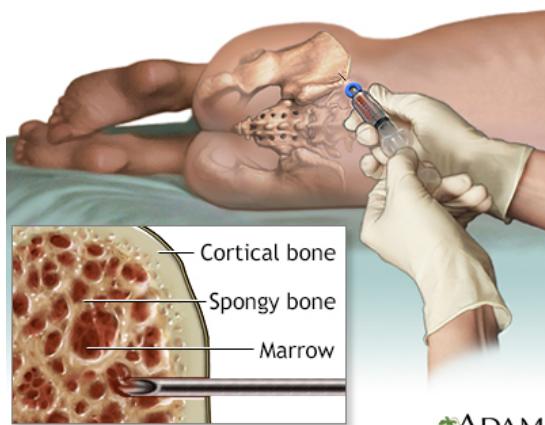
### 1.11.1 Stem Cell Transplant

**Definition 1.33 (Stem Cell Transplant).** Stem Cell Transplant replaces stem cells from

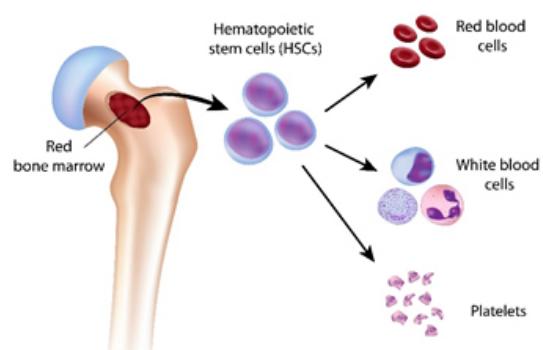
a donor and is performed when a patient's stem cells or bone marrow have been damaged by disease, Chemotherapy, or radiation therapy.

Stem cells can be collected from the:

- Bone marrow
- Peripheral blood
- Umbilical cord



(a) Bone marrow biopsy



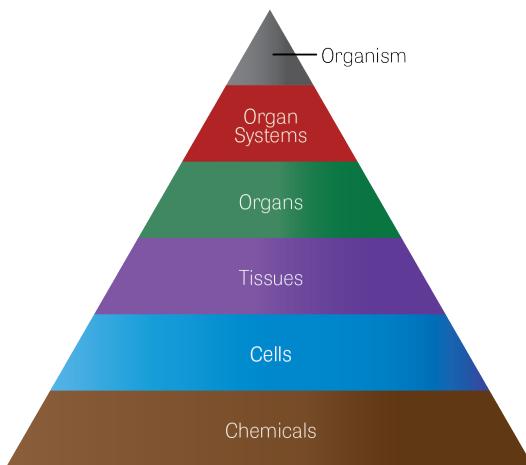
(b) Bone marrow stem cells

## 1.12 Hierarchy of an Organism

**Definition 1.34** (Hierarchy of an Organism). The hierarchy is

cell → tissue → organ → system → organism

See Figure 1.23.



**Figure 1.23:** Hierarchy of an Organism

1. Cellular level heart muscle cell.
  2. Tissue level heart muscle tissue.
  3. Organ level heart.
  4. Organ system level circulatory system.
  5. Organism level deer.
- 
- **Cell:** the smallest function unit of an organism.
  - **Tissue:** a group of cells that perform a similar limited function.
    - Four main types: epithelial, connective, muscle, and nerve tissue
  - **Organ:** a structure composed of different tissues to perform a complex function.
  - **Organ system:** a system of one or more organs that work together to perform a vital body function.

## 1.13 Types of Tissues

---

### 1.13.1 Epithelial Tissue

**Definition 1.35** (Epithelial Tissue). A thin sheet that covers body surfaces and lining the internal organs.

- Skin and lining of the digestive system.
- Protection from hydration.
- Low friction surfaces.

### 1.13.2 Connective Tissue

**Definition 1.36** (Connective Tissue). Connective tissue are various types of cells and fibres held together by a liquid, solid, or a gel, known as a matrix.

- Bones, tendons, and blood.
- Provides support and insulation.

### 1.13.3 Muscle Tissue

**Definition 1.37** (Muscle Tissue). Muscle tissue contains proteins like actin and myosin that can contract and move.

- Muscles that make bones move.
  - Muscles surrounding the digestive tract.
  - Heart.
- 
- Bundles of long cells called muscle fibres that contain specialized proteins capable of shortening or contracting.
- 
- Movement.

### 1.13.4 Nerve Tissue

**Definition 1.38** (Nerve Tissue). Nerve tissue conducts electrical signals from one part of the body to another.

- Brain.
  - Nerves in sensory organs.
- 
- Long, thin cells with fine branches at the ends capable of conducting eleectrical im-pulses.
- 
- Sensory.
  - Communication within the body.
  - Coordination of body functions.

## 1.14 Stem Cells Case Study Mini-Assignment

---

1. What is the difference between embryonic stem cells and adult stem cells?

**Solution.** Embryonic stem cells:

- Embryonic stem cells exist only right after the fertilization of an egg.
- Embryonic stem cells can specialize into any kind of body cell, be it epithelial cell, a red blood cell, nerve cell, bone cell, etc.
- Adults don't have embryonic stem cells.

Adult stem cells:

- Adult blood stem cells are located in the bone marrow AND in the peripheral blood.
- Adult blood stem cells can only differentiate into either red blood cells, white blood cells, or platelets.

2. Based on the article, how would you describe what cancer is?

**Solution.** As a result of some kind of mutation in the cellular DNA, this causes healthy cell checkpoints to become dysfunctional and causes uncontrollable cell growth/division. This uncontrollable growth eventually materializes as a tumor in the healthy tissue

3. Conduct some research on the following cancer treatments: chemotherapy, radiation therapy, and surgery. Do you think that differentiation therapy has any benefits over these known treatments? Explain your reasoning.

**Solution.**

- Chemotherapy is targeted to kill cancer cells, but in the administration of chemotherapy, the drugs are targeting the healthy cells as well. Though chemotherapy may be effective in killing the cancer cells, it also damages healthy cells, which can lead to adverse effects such as nausea, hair loss, and decreasing in immune function.
- Radiation therapy, unless specifically localized, can also have adverse effects on surrounding healthy tissue.
- Differentiation therapy is much more targeted towards turning cancer cells back into normal cells, so the use of toxic chemicals is not necessary. This can decrease the number of adverse effects as well as results of this treatment.

With this new kind of treatment, it could open many doors to groundbreaking cancer research and therapy; possibly high mobilization of this particular kind of research (can lead to scientific discoveries).

## 1.15 Digestive System

**Definition 1.39 (Digestive System).** The digestive system is the organ system responsible for breaking up and digesting food, and secreting waste. The digestive tract is lined with epithelial tissue, goblet cells that release mucus, connective tissue, muscles, and nerves. See Figure 1.24.

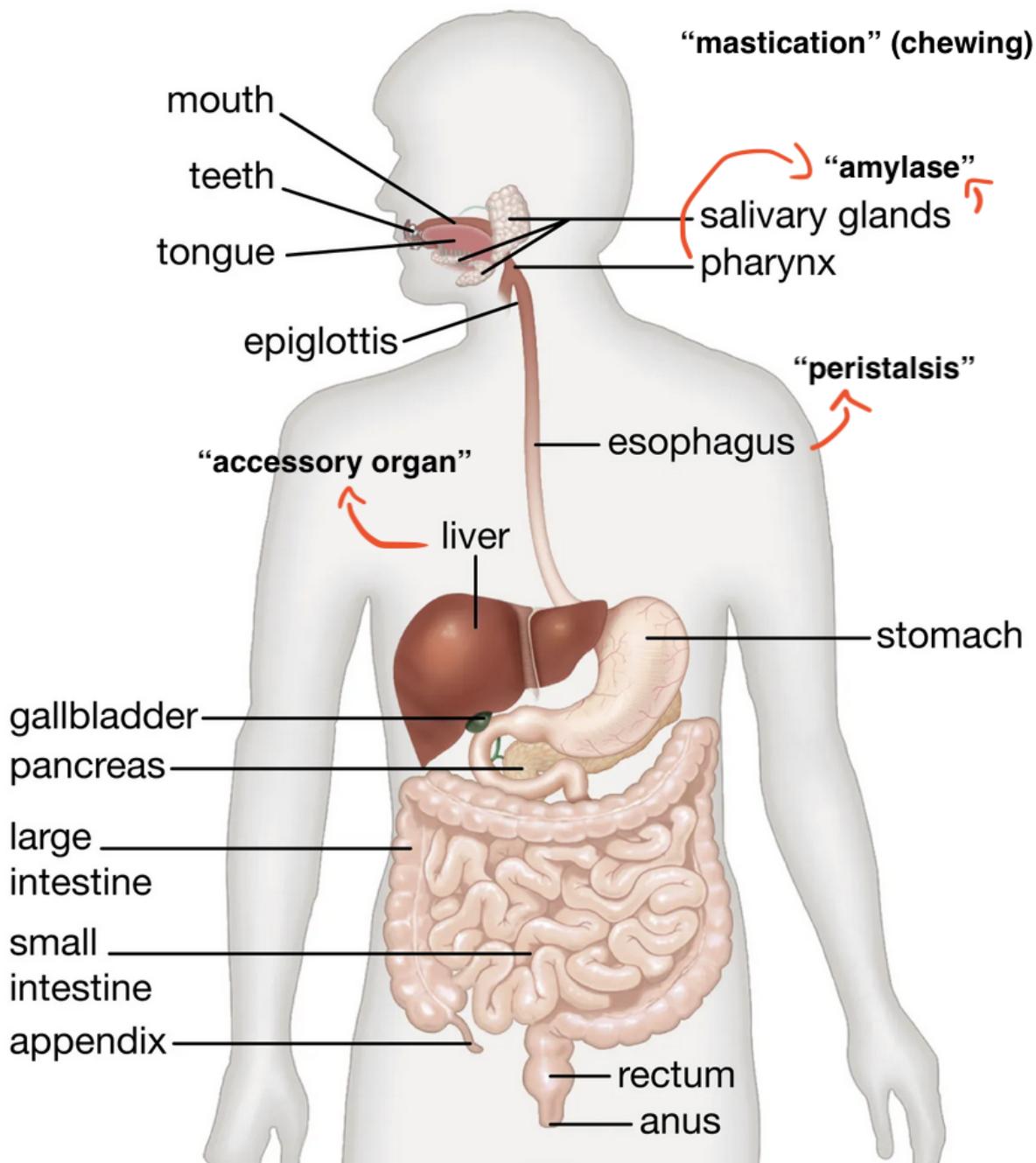


Figure 1.24: The digestive system.

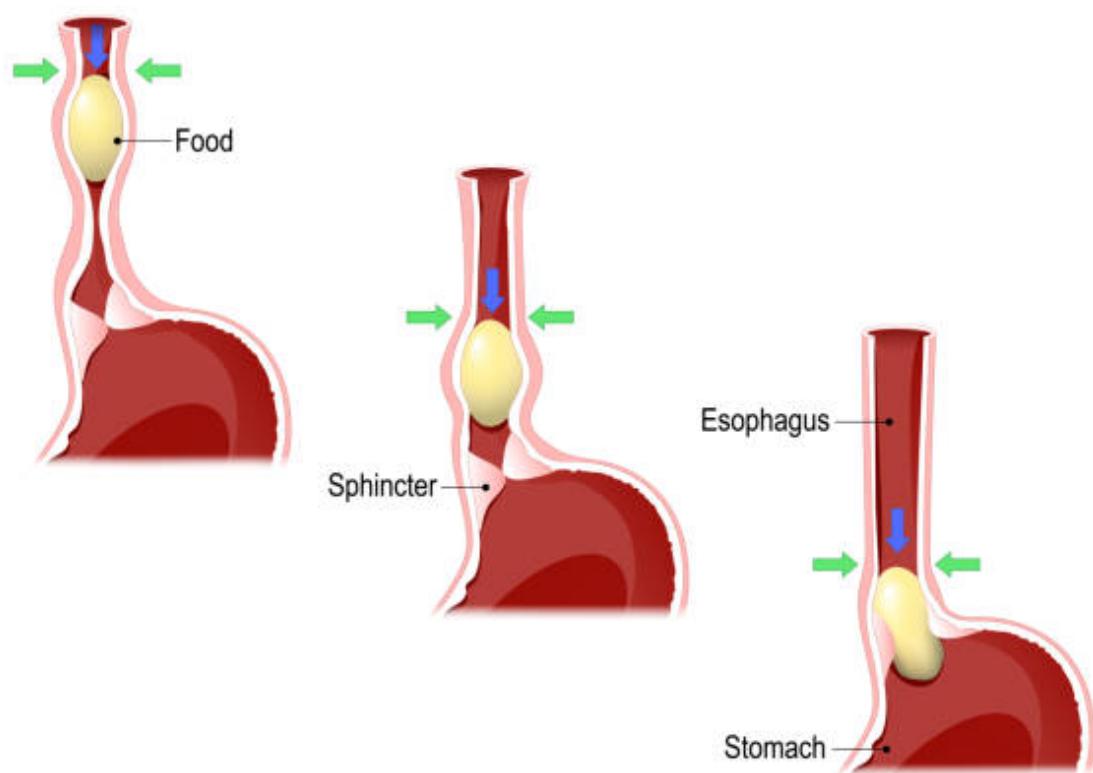
### 1.15.1 Mouth

**Definition 1.40 (Mouth).** The mouth is where food enters and undergoes mechanical breakdown (**mastication**) and chemical breakdown through the saliva to form a **bolus**. The bolus is a ball-like mixture of food and saliva.

### 1.15.2 Esophagus

**Definition 1.41 (Esophagus).** A muscular tube that contracts through **peristalsis** to move the bolus to the stomach. See Figure 1.25.

## PERISTALSIS



**Figure 1.25:** Peristalsis the **smooth muscles** create a pinch that pushes the bolus down into the stomach..

### 1.15.3 Epiglottis

**Definition 1.42 (Epiglottis).** Is a flap that seals off the trachea during swallowing to direct the bolus to the esophagus.

### 1.15.4 Stomach

**Definition 1.43 (Stomach).** A J-shaped organ that holds, churns, and adds acids and enzymes to turn the bolus into **chyme**. Chyme is the partially digested food that contains acids and enzymes. See Figure 1.26.

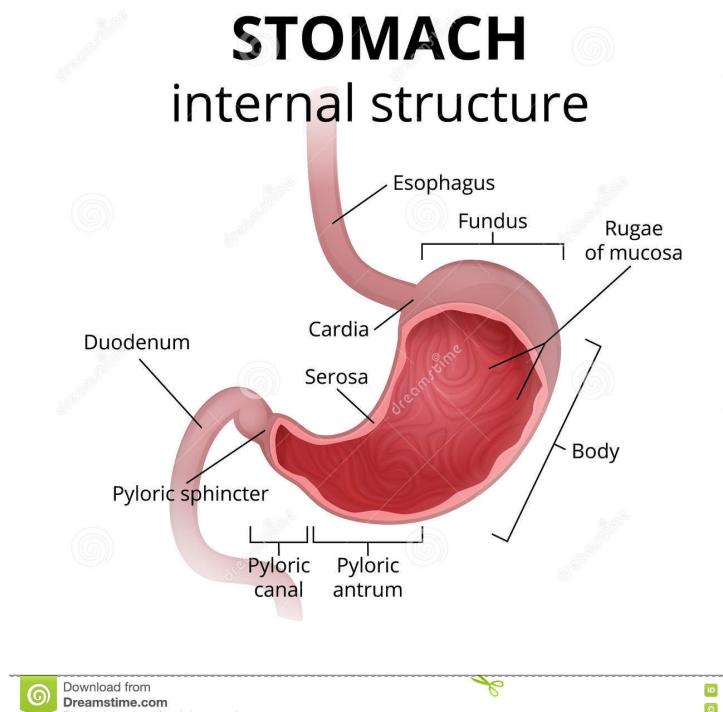
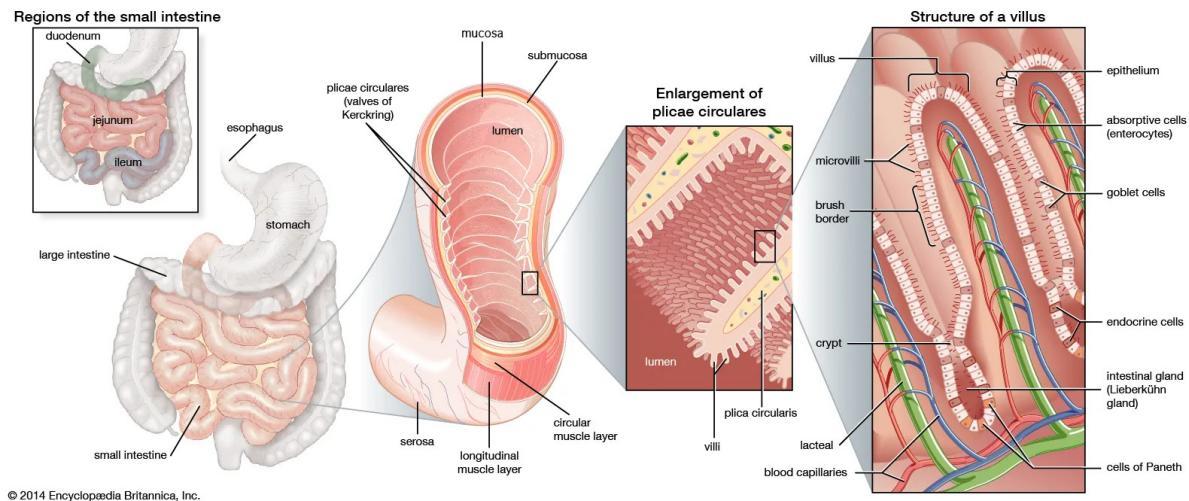


Figure 1.26: The stomach.

### 1.15.5 Small Intestine

**Definition 1.44 (Small Intestine).** The small intestine continues to digest and is the main site of absorption of nutrients. Consists of **villi** and **microvilli** to increase surface area for absorption. See Figure 1.27.



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**Figure 1.27:** The small intestine have small villi and further microvilli which ensures that you obtain all the nutrients from the food.

### 1.15.6 Large Intestine

**Definition 1.45** (Large Intestine). A probiotic environment that mainly absorbs water and minerals.

### 1.15.7 Appendix

**Definition 1.46** (Appendix). May house beneficial gut bacteria.

### 1.15.8 Rectum

**Definition 1.47** (Rectum). The end of the large intestine that temporarily stores feces.

### 1.15.9 Anus

**Definition 1.48** (Anus). An opening where feces is excreted.

### 1.15.10 Accessory Organs: Liver

**Definition 1.49** (Liver). Produces **digestive enzymes** and **bile**; also removes toxins from the blood. See Figure 1.28.

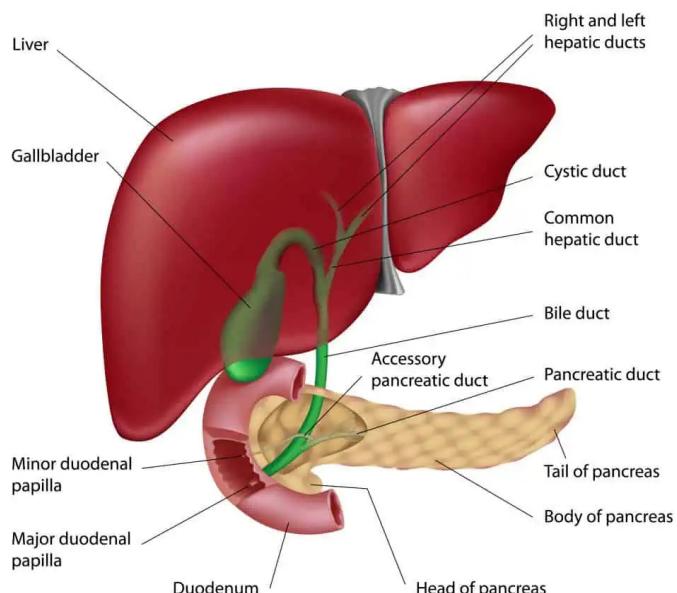
### 1.15.11 Gall Bladder

**Definition 1.50** (Gall Bladder). Stores the **bile**, which is used to emulsify fats. See Figure 1.28.

### 1.15.12 Pancreas

**Definition 1.51** (Pancreas). Produces insulin, which is a hormone that regulates blood glucose concentration after a meal. See Figure 1.28.

Liver, Gallbladder, Pancreas and Bile Passage



**Figure 1.28:** The accessory organs: the liver, gall bladder, and pancreas.

### 1.15.13 Diseases of the Digestive System

	Gastroesophageal Reflux Disease (GERD)
Description	Irritation of the esophageal lining due to acid from the stomach.
Symptoms	Heartburn, chest pain, bitter taste
Causes	Weakening or abnormalities of the esophageal sphincter
Treatment	Antacids, drugs to reduce acid production, surgery

**Table 1.15.1:** Gastroesophageal Reflux Disease (GERD)

	Gastric Ulcer
Description	Open sores that develop in the stomach lining
Symptoms	Stomach pain, vomiting blood, dark blood in stool
Causes	Helicobacter pylori infection NSAIDS (i.e. ibuprofen)
Treatment	Antibiotics if H. pylori infection, alternative medication

**Table 1.15.2:** Gastric Ulcer disease.

## 1.16 Circulatory System

---

**Definition 1.52** (Circulatory System). The organ system responsible for the

- Delivery of nutrients and gases.
- Regulation of body temperature.
- Defense against invading organisms.

**Components:**

- Heart.
- Blood vessels.
- Blood.

**Note (Veins vs Arteries):** Veins carry blood TO the heart, and arteries carry blood AWAY from the heart.

### 1.16.1 Heart

**Definition 1.53** (Heart). A pump that distributes nutrients and gases to every cell in the body. The heart is composed of three kinds of tissues:

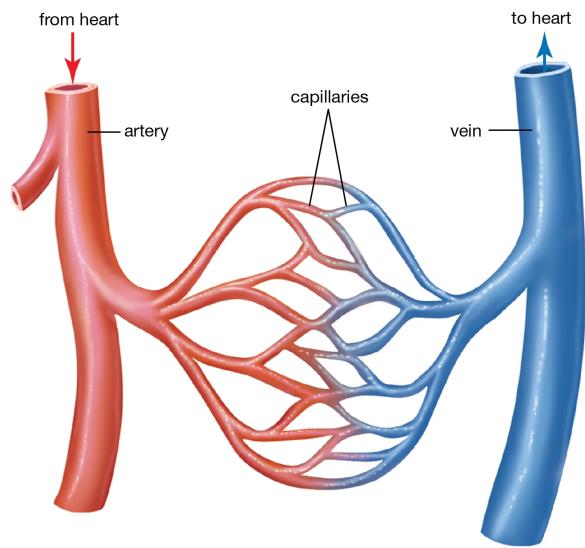
- **Cardiac muscle tissue** contracts synergistically (at the same time) to pump blood throughout the body.
- **Nerve tissue** is responsible for the heart rate and can respond to stress, temperature, and physical activity.
- **Epithelial tissue** lines the inner surface of the heart to allow blood to flow freely; smooth layer of epithelial tissue on the outside reduces friction and protects the heart from damage.

### 1.16.2 Blood vessels

**Definition 1.54** (Blood vessels). There are three kinds of blood vessels:

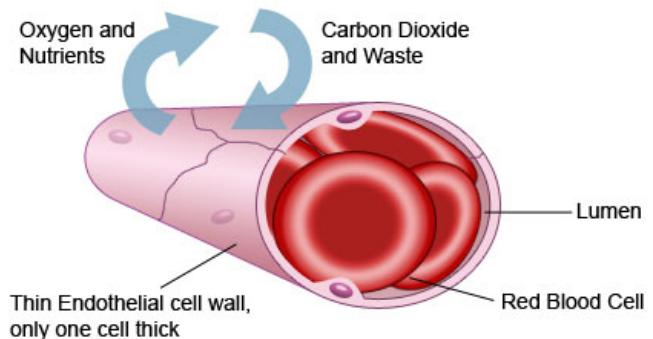
- **Artery** carries blood away from the heart; have thick, muscular walls to withstand high blood pressure. See Figure 1.29.
- **Vein** carries blood through the heart; have thinner walls with valves to pump blood back to the heart. See Figure 1.29.

- **Capillary** connects arteries to veins; have one-cell thick walls to maximize diffusion of substance between blood and tissues. See Figure 1.30.



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**Figure 1.29:** The artery (red) and the vein (blue). The connect part are referred as the capillaries.



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**Figure 1.30:** The cappilary.

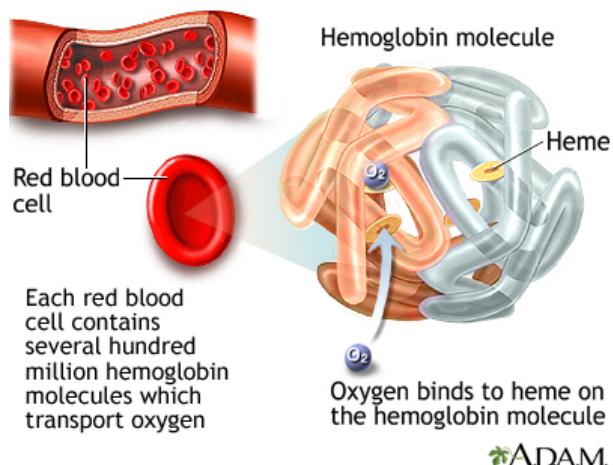
### 1.16.3 Blood

**Definition 1.55 (Blood).** A connective tissue that consists of the following main cells:

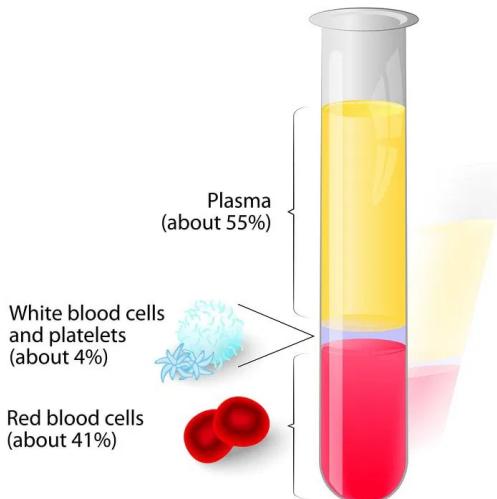
- **Erythrocytes** are red blood cells that are biconcave in shape and contain hemoglobin that attaches to oxygen and carbon dioxide.
- **Leukocytes** are white blood cells that are defending the body against pathogens.
- **Platelets** help in blood clotting.

- **Plasma** is protein rich liquid that suspends the cells.

See Figure 1.31 and Figure 1.32.



**Figure 1.31:** Hemoglobin.



**Figure 1.32:** A centrifuge for separating blood plasma. This is known as **hematocrit**.

**Note:** Blood keeps your body warm by flowing through your veins.

#### 1.16.4 Diseases of the Circulatory System

	Varicose Veins
Description	Swollen or twisted veins underneath the skin.
Symptoms	Bulging, bluish veins. Swelling, aching and cramps in the legs.
Causes	Weak or damaged vein walls and valves from blood pressure increase.
Treatment	Compression therapy. Surgery to remove veins or close them

**Table 1.16.1:** Varicose Veins

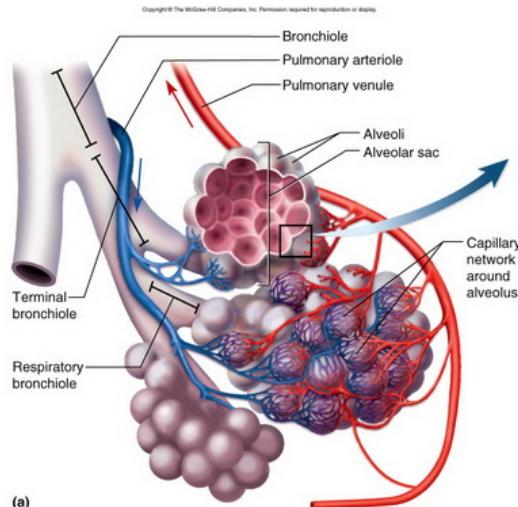
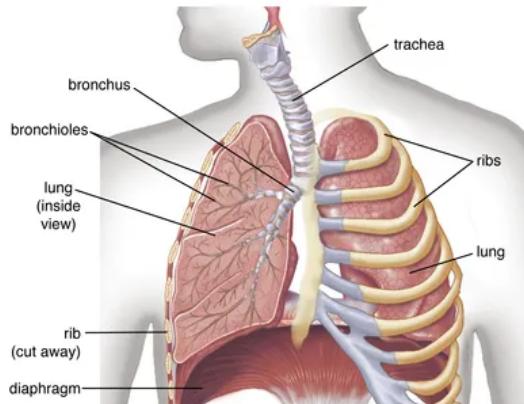
	Artherosclerosis
Description	Plaque (fat, cholesterol, calcium) buildup in the arteries.
Symptoms	Numbness. Pain.
Causes	Damaged arteries. Smoking. High amounts of fat/cholesterol in blood.
Treatment	Angioplasty. Bypass grafting.

**Table 1.16.2:** Artherosclerosis

## 1.17 Respiratory System

Monday  
April 3 2023

**Definition 1.56 (Respiratory System).** Responsible for providing oxygen to the body and removing carbon dioxide from the body. See Figure 1.33 (a).



(a) The lungs are protected by ribs. (b) The alveoli are in the lungs (search chatGPT for what this does).

**Figure 1.33:** The respiratory system.

### 1.17.1 Nose/Mouth

**Definition 1.57 (Nose/Mouth).** Where air enters and passes through the pharynx (throat).

- Mucous and hairs trap small particulates.
- Capillaries in the nose warm the air.

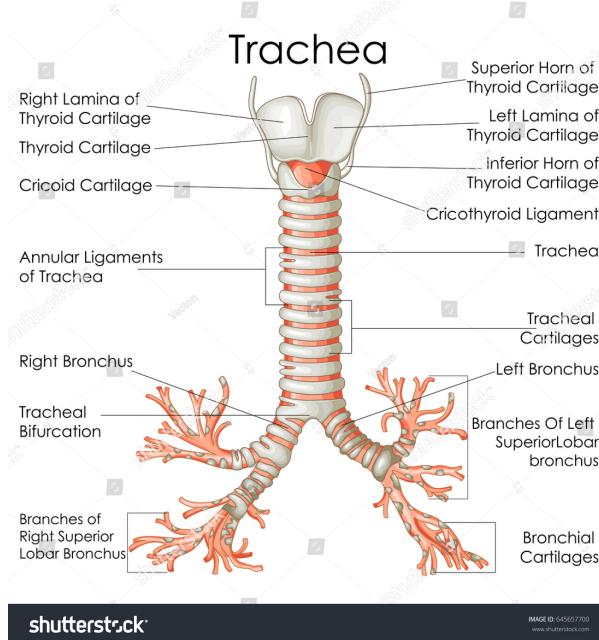
### 1.17.2 Larynx

**Definition 1.58 (Larynx).** For sound production and also functions to protect the lower airways by closing or coughing.

### 1.17.3 Trachea

**Definition 1.59 (Trachea).** The windpipe that is surrounded by cartilage rings to prevent collapse. The very top is the voice box, and it branches off into the bronchi, which

eventually branches off into the lungs. See Figure 1.34.



**Figure 1.34:** The trachea branches off into the lungs.

#### 1.17.4 Bronchi

**Definition 1.60 (Bronchi).** Where the trachea splits into the left and right bronchus.

- Contains goblet cells in the epithelial lining to produce mucus.
- Lined with cilia (hair-like projections) to sweep materials out of the lower airway.

#### 1.17.5 Bronchioles

**Definition 1.61 (Bronchioles).** Where the bronchi splits into smaller tubes.

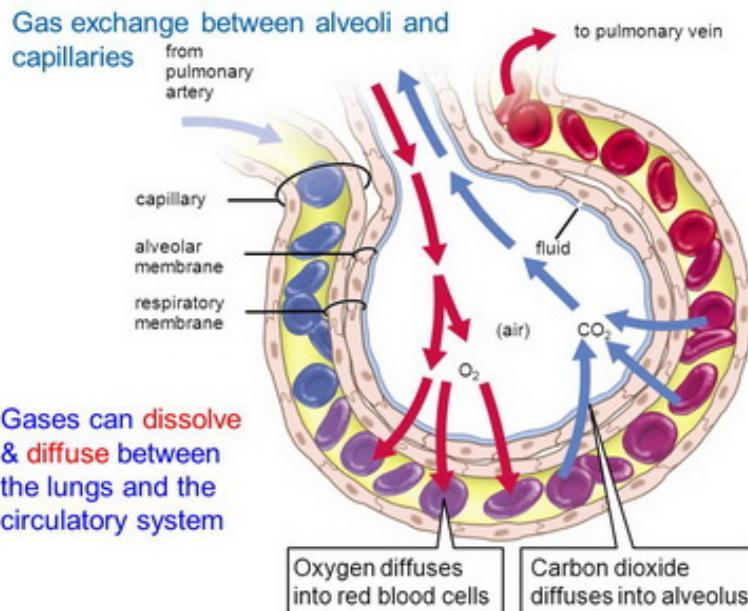
#### 1.17.6 In the Lungs: Alveoli

**Definition 1.62 (In the Lungs: Alveoli).** Tiny, capillary-bound sacs where gas exchange occurs between air and blood. See Figure 1.33 (b) and Figure 1.35.

- Membranes are thin to maximize diffusion.

A better way to put it, from Figure 1.35, you can see that the alveoli and capillary are

actually separated. How it works is that oxygen from the bronchioles → alveoli gets diffused across and turns into carbon dioxide. Similarly, oxygen from the capillary itself gets diffused across and becomes deoxygenated as well.



**Figure 1.35:** The oxygen diffuses (from blue to purple to red) and carbon dioxide is diffused out.

### 1.17.7 Pulmonary Arties and Capillaries

**Definition 1.63** (Pulmonary Arties and Capillaries). Provides a large supply of deoxygenated blood to alveoli.

### 1.17.8 Pulmonary Veins

**Definition 1.64** (Pulmonary Veins). Brings oxygenated blood back to the heart to be distributed to the rest of the blood.

### 1.17.9 Checkpoint: Pulmonary Fibrosis

Pulmonary Fibrosis is when the tissue around the alveoli thickens and scars. How will this affect gas exchange?

**Solution:** The scar tissue will make gas exchange less efficient; this will result in a slowing down of the gas exchange, and will mean that the body's cells won't get rid of waste or get a delivery of oxygen as quickly as normal.

## 1.17.10 Breathing

**Definition 1.65** (Breathing). The process of breathing is caused by pressure differences between the atmosphere and the inside of the lungs.

Air moves from an area of high pressure to low pressure.

- Pressure can be changed by changing volume.
  - Volume increases, pressure decreases. For example, imagine a balloon.
  - Volume decreases, pressure increases.

The equation is  $V \propto \frac{1}{p}$ .

## 1.17.11 Lung Volume

**Definition 1.66** (Lung Volume). Lung volume can be changed by:

- Contraction or relaxion of muscles in the rib cage.
- Contraction or relaxion of the **diaphragm**, which is a dome-shaped muscle underneath the lungs.

In other words, when you inhale, the diaphragm compresses, and your lungs expand. When you exhale, this is when the diaphragm “relaxes”, and is when it gets back into its normal shape, casugint he lungs to get smaller and greater air pressure within the lungs.

Tuesday  
April 4 2023

## 1.17.12 Inhalation

**Definition 1.67** (Inhalation).

- Rib cage expands.
- Diaphragm contracts and flattens.
- Lung volume increases.
- Lung pressure decreases.

Air moves in.

## 1.17.13 Exhalation

**Definition 1.68** (Exhalation).

- Rib cage contracts.
- Diaphragm relaxes and arches.
- Lung volume decreases.
- Lung pressure increases.

Air moves out.

#### 1.17.14 Respiratory System in Fish

**Definition 1.69** (Respiratory System in Fish).

- Gas exchange occurs in the **gills**, which is a highly folded structure to maximize surface area.
- Undergoes countercurrent exchange to maximize oxygen uptake from water.
- Gills are surrounded by capillaries to bring blood close to the water.

#### 1.17.15 Diseases of the Respiratory System

	Tuberculosis
Description	Bacterial infection that mainly affects the lungs but can spread to other parts of the body.
Symptoms	Coughing for 3 or more weeks. Coughing up blood or mucous. Chest pain.
Causes	<i>Mycobacterium tuberculosis</i> is a bacterium that attacks the lungs.
Treatment	Antibiotics

**Table 1.17.1:** Tuberculosis

**Note (Pneumonia on lungs):** When someone is experiencing pneumonia as a result of COVID-19, the lungs in an x-ray won't be dark.

	Pneumonia
Description	Inflammation of the alveoli; alveoli may be filled with fluid or pus.
Symptoms	Coughing, chest pain, fever.
Causes	Bacterial, viral, or fungal infection.
Treatment	

**Table 1.17.2:** Pneumonia

	COVID-19
Description	A respiratory illness caused by the coronavirus called SARS-CoV-2
Symptoms	Fever, cough, difficult breathing.
Causes	SARS-CoV-2 virus
Treatment	

**Table 1.17.3:** COVID-19

## 1.18 Musculoskeletal System

---

**Definition 1.70** (Musculoskeletal System). The organ system that consists of muscles and bones. Function:

- Supports the body.
- Protects delicate organs.
- Movement.

### 1.18.1 Bone

**Definition 1.71** (Bone). A hard and dense tissue that consists of bone cells within a matrix of minerals like calcium and phosphorus. Canals inside in the bones contain nerves and blood vessels.

### 1.18.2 Ligament

**Definition 1.72** (Ligament). A tough, elastic tissue that holds bones together at the joints.

### 1.18.3 Cartilage

**Definition 1.73** (Cartilage). A dense tissue that provides strong, low-friction support for bones.

### 1.18.4 Tendon

**Definition 1.74** (Tendon). A connective tissue that connects muscles to bones.

### 1.18.5 Muscle Types

**Definition 1.75** (Muscle Types). Muscle consists of long bundles of muscle fibres that contain protein like actin and myosin for contraction. Types:

- **Skeletal Muscle** (voluntary).
- **Smooth Muscle** (involuntary).

- Cardiac Muscle (heart).

### 1.18.6 Musculoskeletal System in Invertebrates

**Definition 1.76** (Musculoskeletal System in Invertebrates). All vertebrates have Musculoskeletal systems. Invertebrates have other adaptations for structure and support:

- Jellyfish rely on water to provide structural support.
- Worms have muscles that work against body fluids.
- Insects and arthropods have exoskeleton.

### 1.18.7 Diseases of the Musculoskeletal System

	Osteoporosis
Description	A disease that causes bones to become weak and brittle because the creation of new bones does not keep up with loss of old bone.
Symptoms	Back pain, loss of height over time, stooped posture.
Causes	Age, hormones, poor diet.
Treatment	Drugs like bisphosphonates, hormone-related therapy.

**Table 1.18.1: Osteoporosis**

Wednesday  
April 5  
2023

## 1.19 Nervous System

**Definition 1.77 (Nervous System).** The organ system that senses the environment and coordinates appropriate responses.

- **Central nervous system (CNS)** consists of the brain and spinal cord. The brain is protected by the skull and the spinal cord is protected by the spine.
- **Peripheral nervous system (PNS)** consists of the nerves in the rest of the body.

See Figure 1.36.

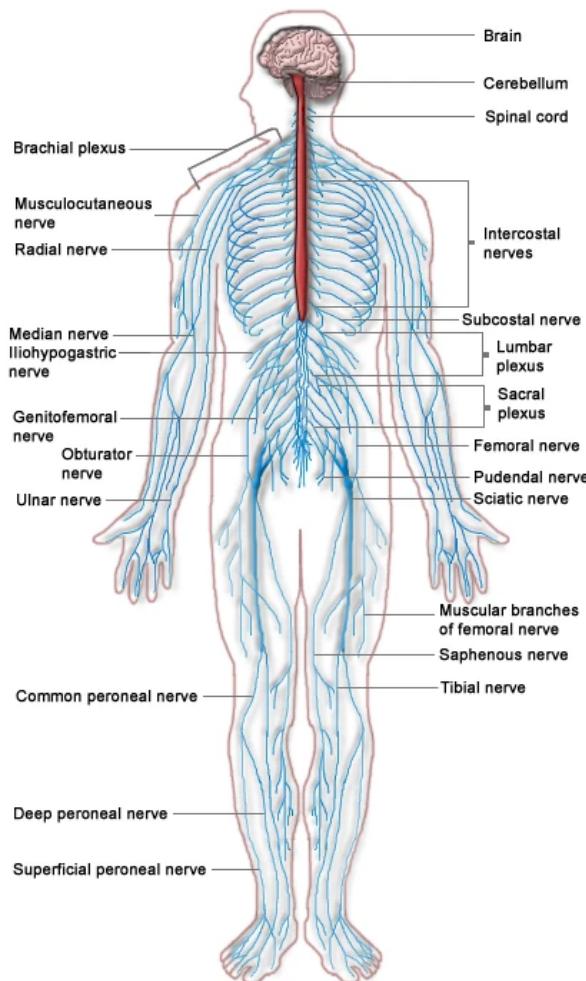
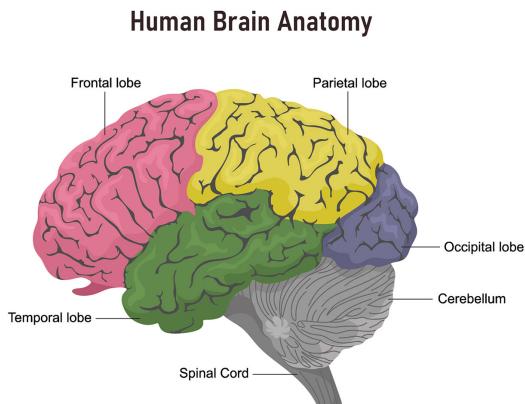


Figure 1.36: The nervous system.

### 1.19.1 Central Nervous System

**Definition 1.78 (Central Nervous System).** The brain consists of over billions of neurons and synapses.

- Protected by the skull and cerebrospinal fluid.

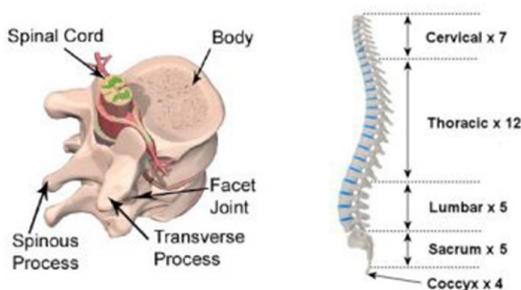


**Figure 1.37:** The brain is like tofu. In the tofu, there is some water that protects the tofu. The cerebrospinal fluid acts like that water in the tofu.

### 1.19.2 Spinal Cord

**Definition 1.79** (Spinal Cord). A long, fragile tube of nerves that carries signals between the brain and body.

- The spinal cord is protected by the spine.



**Figure 1.38:** The spinal cord (on the left) and the spine (on the right).

### 1.19.3 Peripheral Nervous System

**Definition 1.80** (Peripheral Nervous System).

- The **neuron** is a nerve cell that sends electrical impulses to the target cell.

- **Myelin sheath** is a fatty material that covers the axon; acts as insulation to allow for electricla impulses to travel quickly tand from to the wrong neuron.

#### 1.19.4 Nerve

**Definition 1.81** (Nerve). A bundle of neurons. Types of nerves:

- Nerves for voluntary muscles.
- Nerve for involuntary functions.
- Nerves for sensory organs.

#### 1.19.5 Sensory Receptors

**Definition 1.82** (Sensory Receptors). Receive information from the external environment to be processed by the brain.

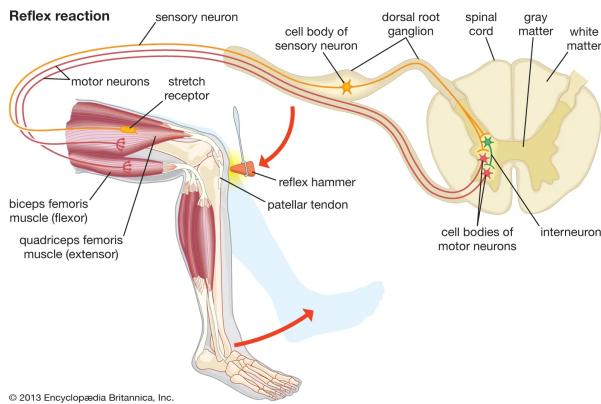
- Receptors sense sight, touch, temperature, taste, smell, sound, pressure, pain, balance, stretch, position.

#### 1.19.6 Reflexes

**Definition 1.83** (Reflexes). Actions that do not require the brain and occur without conscious thought through a reflex arc in the spinal cord.

- Reflexes are intended to prevent injury and protect us from danger.
- Types:
  - Deep-tendon reflex.
  - Withdrawal reflex.
  - Startle reflex.
  - Blink reflex.
  - Gag reflex.

See Figure 1.39.

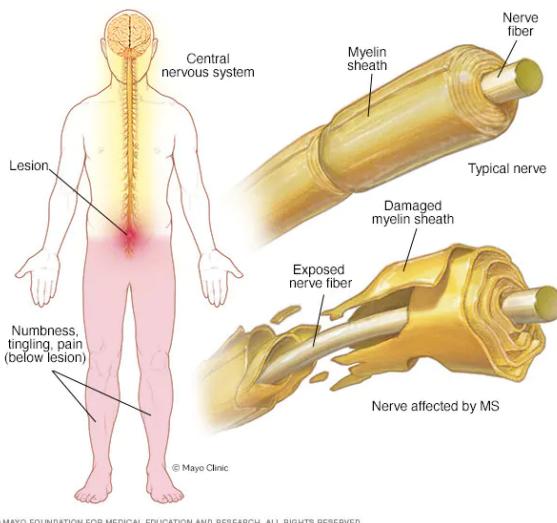


**Figure 1.39:** The doctor will hit your knee, and usually you will kick. If you do not kick, something is wrong.

### 1.19.7 Diseases of the Nervous System

	Multiple Sclerosis
Description	Myelin sheaths in the central nervous system deteriorates leading to nerve damage.
Symptoms	Numbness or weakness in one or more limbs. Electric-shock sensations. Tremor, lack of coordinate.
Causes	Autoimmune diseases; the body is attacking its own mechanism.
Treatment	No cure. Drugs to reduce nerve inflammation. Drugs to modify progression.

**Table 1.19.1:** Multiple Sclerosis



**Figure 1.40: Multiple sclerosis; damaged myelin sheath.**

	Concussion
Description	Brain injury that affects brain function.
Symptoms	Headache, ringing in the ears, nausea and vomiting, amnesia.
Causes	Trauma to the head from a fall or sports. Violent shaking of upper body.
Treatment	Physical and mental rest. Pain relief medication.

**Table 1.19.2: Concussion**

Thursday  
April 6  
2023

## 1.19.8 Organ Transplant

**Definition 1.84 (Organ Transplant).** Surgery where the organ or tissue of the donor is given to the recipient to replace a damaged organ or tissue. Organ transplants have been performed since the early 1800s when blood transfusions were explored.

## 1.19.9 Types of Organ Donors

**Definition 1.85 (Types of Organ Donors).**

- **Invis donor organs** are organs that come from a living person - usually a family member with similar genetic traits to avoid rejection by the immune system. Ex: kidney, lobe of lungs, part of the liver.
- **Deceased donor organs** are organs that come from a dead person.

- **Xenotransplantation** is the transplanting of body parts from one species of another. Ex: heart valves from pigs.

### 1.19.10 Organ Trafficking

**Definition 1.86** (Organ Trafficking). The practice of stealing or buying organs through exploitation, coercion, or fraud. Low supply of organs but a high demand for organ transplants lead to a black market. Most common trafficking organs are kidneys.