

Review of Chemistry and Cell



Hierarchy of Physiology Organization



- Atoms → Molecules → Organelles → Cells → Tissues → Organs → Systems

I. Chemistry Review



Table 2.1 Naturally Occurring Elements in the Human Body

Symbol	Element	Atomic Number (see p. 33)	Percentage of Human Body Weight
Elements making up about 96% of human body weight			
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Elements making up about 4% of human body weight			
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.4
S	Sulfur	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1



Goiter is the result of iodine deficiency

Elements making up less than 0.01% of human body weight (trace elements)
 Boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), zinc (Zn)

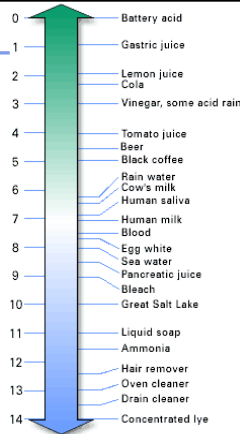
Ions



- Ions are charged atoms
 - Cations are positively charged ions such as Na⁺, K⁺, Mg²⁺, Ca²⁺ and H⁺
 - Anions are negatively charged ions, such as chloride ion (Cl⁻), bicarbonate ion (HCO₃⁻), phosphate ion, protein, sulfate ion, and organic acid
 - Body fluid contains dissolved ions called **electrolytes**.

pH

- pH is symbol for H⁺ concentration of a solution
 - pH scale runs from 0 to 14
- pH = log 1/[H⁺]
 - Neutral: pH = 7
 - Acid : pH < 7
 - Base: pH > 7
- Normal blood pH range is 7.35 – 7.45



http://www.natural-reflux-cure.com/images/ph_scale.gif

Buffers



- Are molecules that slow changes in pH by either combining with or releasing H⁺s
- E.g. the bicarbonate buffer system in blood:



- This buffers pH because reaction can go in either direction depending upon concentration of H⁺s

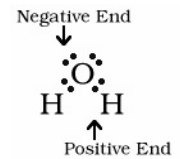
Molecules

- Two or more atoms bond together by chemical bonds form molecules
 - Chemical bonds:
 - ionic
 - covalent
 - Hydrogen
 - Inorganic molecules
 - Organic molecules

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Polarity of Molecules

- Polar molecules
 - Unequal sharing of electrons in covalent bonds
 - Hydrophilic in water
 - Lipophobic in lipid
- Nonpolar molecules
 - H : H



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Biomolecules

- Biomolecules = organic molecules found in living things such as carbohydrates, lipids, proteins and nucleic acids

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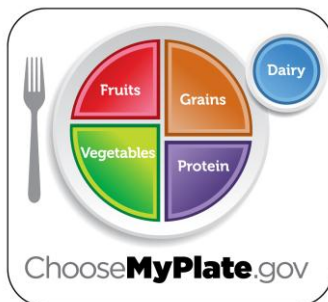
TABLE 2.1 Common Functional Groups Found in Biomolecules

Functional group	Chemical formula	Structure	Chemical property
Hydroxyl	—OH	—O—H	Polar
Sulfhydryl	—SH	—S—H	Polar
Phosphate	—HPO ₄ ⁻	$\begin{array}{c} \text{O} \\ \parallel \\ \text{—O—P—OH} \\ \\ \text{O—} \end{array}$	Polar
Carboxyl	—COOH	$\begin{array}{c} \text{O} \\ \parallel \\ \text{—C} \\ \\ \text{OH} \end{array}$	Acid
Amino	—NH ₂	$\begin{array}{c} \text{H} \\ \\ \text{—N} \\ \\ \text{H} \end{array}$	Base

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Biomolecules from Foods



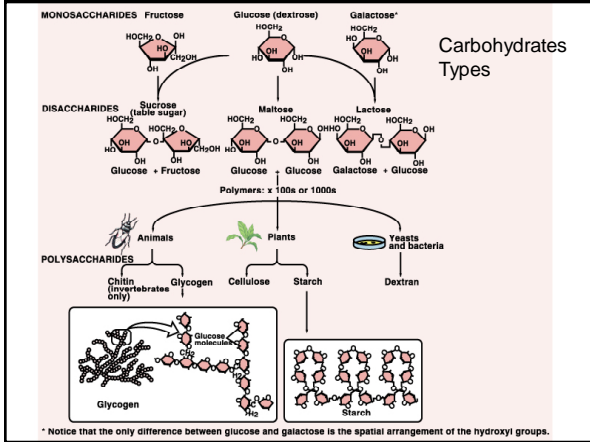
http://www.choosemyplate.gov/global_nav/media_resources.html

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Carbohydrates

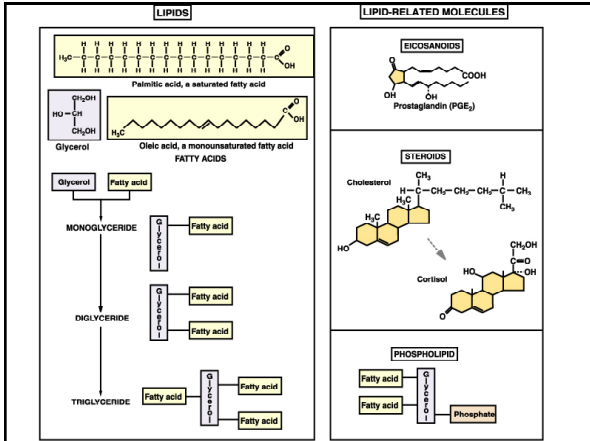
- Carbohydrates: C_n(H₂O)_n polar molecules
- Function
 - Energy source (glucose)
 - Storage of energy (glycogen)
 - Dietary fibers aid elimination (cellulose)
 - Cell membrane components

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Lipids

- Are made of carbon and hydrogen atoms bonded by nonpolar covalent bonds.
- Are hydrophilic
- Functions
 - Energy storage (triglycerides: fat)
 - Hormones (steroids)
 - Cell membrane components (phospholipids, cholesterol)
 - Cell communication (eicosanoids)



Proteins and Amino Acids

- Proteins are polymers of amino acids

Amino group: $\text{H}-\text{N}-\text{H}$

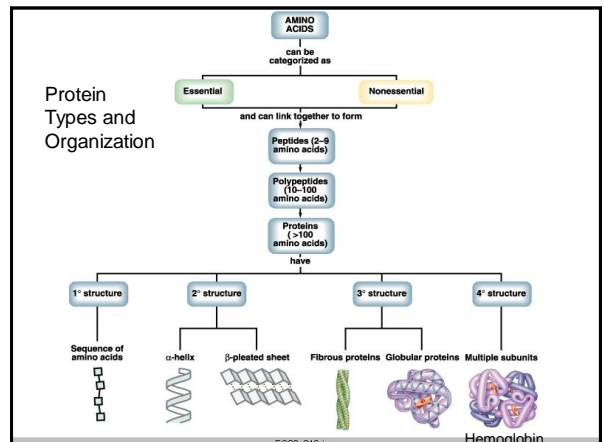
R group: R

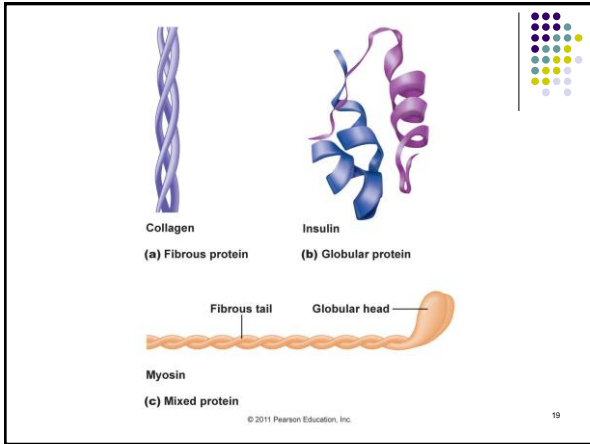
Carboxyl group: $\text{C}=\text{O}$ and $\text{C}-\text{OH}$

(a) Amino acid

Protein Functions

- Enzymes (amylase)
- Cell membrane components
- Structural components (muscle)
- Transporters such as hemoglobin
- Hormones (insulin)
- Antibodies
- Cell recognition (glycoprotein)
- Cell communication (amino acids)

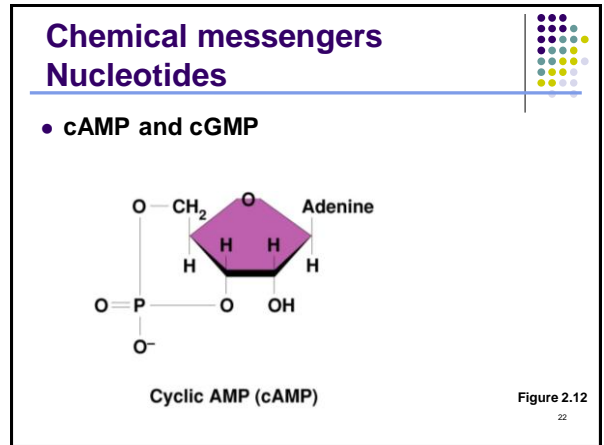
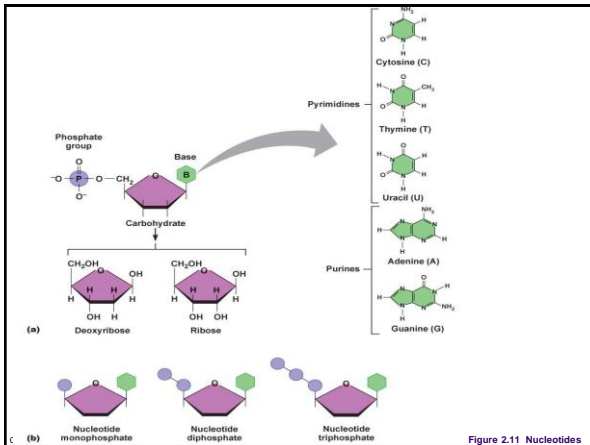




Nucleic Acids and Nucleotides

- Nucleic acids are polymers of nucleotides
- Nucleotides
 - DNA and RNA
 - Cell communication
 - Energy-transferring
- Genetic information (DNA)
- Expression of genetic code (RNA)

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Energy- transferring Nucleotides

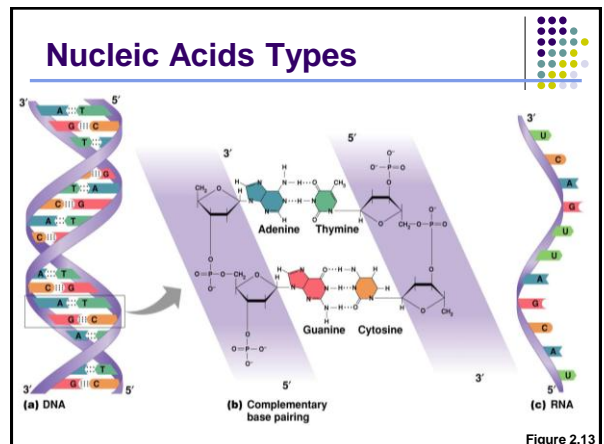
- Adenosine triphosphate (ATP)
- Nicotinamide adenine dinucleotide (NAD)
- Flavin adenine dinucleotide (FAD)

Adenosine

Triphosphate

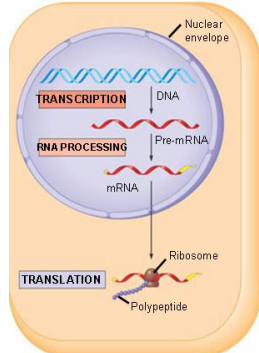
ATP

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From DNA to Protein (Pages 42-48)

- Transcription
 - DNA is transcribed to mRNA in nucleus
- Translation
 - mRNA translated in cytoplasm to proteins



Genes and Diseases

- <http://www.ncbi.nlm.nih.gov/books/NBK22183>
- <http://www.npr.org/blogs/health/2011/06/18/137204964/genome-maps-solve-medical-mystery-for-calif-twins>

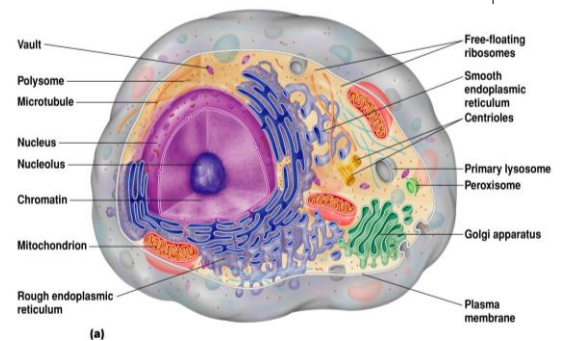
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II. Cell Structures (Table 2.2 page 39)

- A typical cell has
 - Plasma membrane
 - Barrier between cell and external environment
 - Internal compartments of cell
 - Nucleus
 - Cytoplasm
 - Cytosol
 - Organelles
- A mature red blood cell does not have nucleus or many organelles.

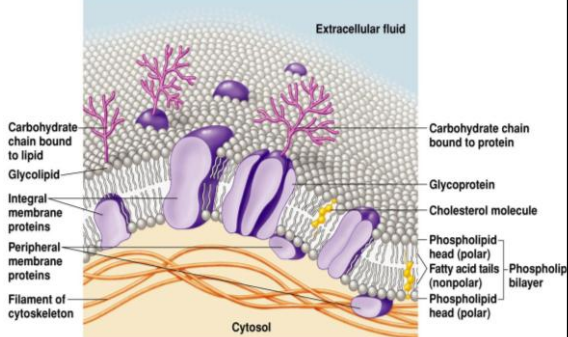
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Structure of a Typical Cell (Table 2.2 Summary)



Plasma Membrane Structure

Fluid mosaic model



Functions of Phospholipids

- Maintain boundary and integrity of cell and its structure
- Barrier to passage of water-soluble substances between ICF and ECF
- Provides fluidity to membrane

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Cholesterol Function in Plasma Membrane

- Adds fluidity to membrane
 - Interferes with hydrophobic interactions between phospholipids
 - Prevents crystallization of phospholipid
- Decreases permeability of membrane to water

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Membrane Proteins

- Integral Membrane Proteins
 - Are embedded within the phospholipid bilayer
 - Some are **transmembrane proteins**
 - Channels
 - Carrier proteins
 - Some are located on one side of membrane
 - Facing cytosol: Enzymes and G proteins
 - Facing extracellular fluid: Enzymes and receptors

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Membrane Proteins

- Peripheral Membrane Proteins
 - Are loosely bound to the membrane by binding with integral proteins or phospholipids
 - Most located on cytosolic side
 - Most function as part of cytoskeleton

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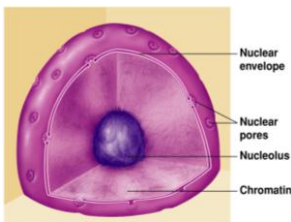
Membrane Carbohydrates

- Carbohydrates covalently bound to membrane lipids or proteins
- Primarily on the extracellular surface
 - Cell recognition for self or none self
 - Glycocalyx
 - Protective layer that also hold cells together

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Structure and Function of the Nucleus

•Structure



• Function

- Nucleolus—site of rRNA synthesis
- Transmission and expression of genetic information
 - Contains DNA (Chromatin)—stores genetic code
 - DNA transcribed to RNA—necessary to express code

(a)

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Cytoplasm

- Consist of cytosol and organelles
- Cytosol
 - Gel-like fluid of the cell
 - Functions of cytosol
 - Location of specific chemical reactions
 - Storage of fat, carbohydrates as inclusions
 - Storage of secretory vesicles

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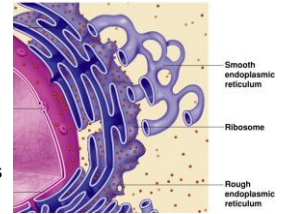
Cytoplasm

- Organelles
 - Membranous organelles
 - Endoplasmic reticulum, Golgi apparatus, mitochondria, lysosomes, peroxisomes
 - Nonmembranous organelles
 - Ribosomes, vaults, centrioles, cytoskeleton

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Endoplasmic Reticulum (ER)

- Rough ER
 - Flattened sacs
 - Granular (ribosome) appearance
- Smooth ER
 - Tubules
 - Smooth appearance
- Lumens of the two ERs are continuous



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Rough Endoplasmic Reticulum

- Functions in synthesis of proteins to be packaged into vesicles
 - Exported out of cell
 - Incorporated into plasma membrane
 - Destined for certain organelles

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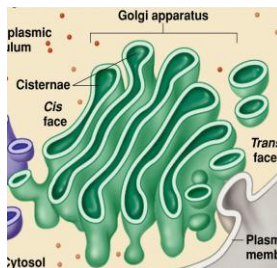
Smooth Endoplasmic Reticulum

- Functions in lipid synthesis, including triglycerides and steroids
- Stores calcium
- Specialized in some cell
 - For example: Smooth ER in liver contains detoxification enzymes that break down toxic materials in the blood

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Golgi Apparatus

•Structure



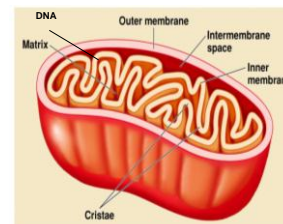
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• Functions

- Post-translational processing of proteins
- Packaging of proteins (and other molecules) into vesicles and directing them to target

Mitochondria

•Structure



(a)

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• Functions

- “Power house” of the cell (generates ATP)

Mitochondrial Cytopathies

- A new subspecialty of medicine that deals with mitochondrial and metabolic conditions.
- Include more than 40 different identified diseases that have different genetic features.
 - Mitochondria are unable to completely burn food and oxygen in order to generate energy.

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Lysosomes

- Structure
 - Enzyme containing membrane sac
- Function
 - Contain enzymes that degrade cellular or extracellular debris
 - To degrade extracellular debris
 - Endocytosis
 - Phagocytosis

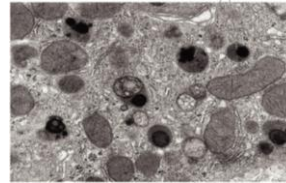


Figure 2.21

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Peroxisomes

- Small membrane sac
- Function
 - Degrade certain waste molecules
 - Amino acids
 - Fatty acids
 - Toxic foreign substances
- By-product of degradation = H_2O_2
 - Contain catalase to break down H_2O_2
$$2H_2O_2 \rightarrow 2H_2O + O_2$$

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Ribosomes

- Are made of RNA and proteins
 - Fixed ones are attached to endoplasmic reticulum
 - Free ones are loose in cytosol
- Function in protein synthesis

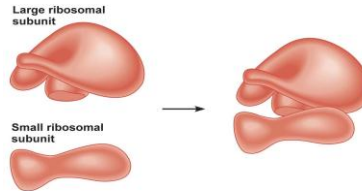


Figure 2.22

Vaults

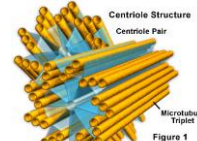
- Barrel-shaped organelle made of vault RNA (vRNA) and proteins
- May function
 - in transport of molecules between nucleus and cytoplasm
 - Provide chemical signal for cell survival



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Centrioles

- Paired cylindrical structures
- Perpendicular to each other
- Function in development of mitotic spindle which helps cell division



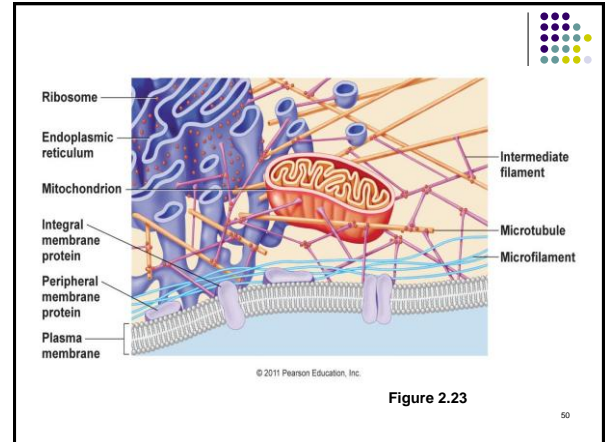
<http://micro.magnet.fsu.edu/cells/centrioles/centrioles.html>

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Cytoskeleton

- Lattice of fibrous proteins also called filaments
- Functions
 - Mechanical support and structure
 - Intracellular transport of materials
 - Suspension of organelles
 - Formation of adhesions with other cells
 - Contraction
 - Movement

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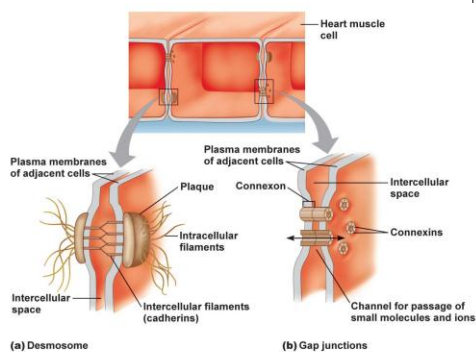
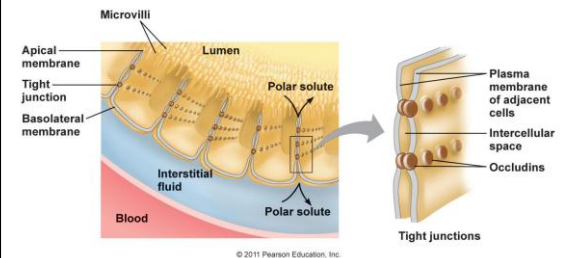
III. Cell-to-Cell Adhesions

- Cell adhesion molecules
 - Tight junctions
 - Regulate transepithelial transport
 - Desmosomes
 - Binds cells together for strength
 - Found in tissue subject to mechanical stress (the heart, skin and uterus)
 - Gap junctions
 - Communication is direct (the heart and smooth muscle)

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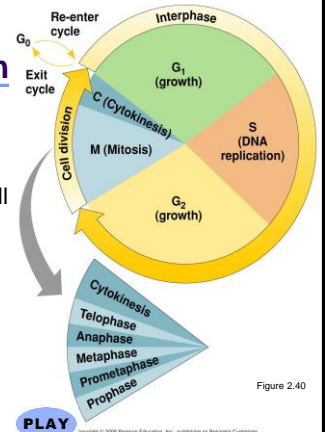
Tight Junctions

- Found in epithelium ()



IV. Cell Division

- The cell cycle is the series of events that include cell growth, DNA replication and cell division
 - Interphase
 - G_0 , G_1 , S, and G_2
 - Cell division
 - M (mitosis) is the division of the nucleus
 - C (cytokinesis) is the division of the cytoplasm



Mitosis

- Mitosis
 - Is the separation of sister chromatids
 - Produces genetically identical cells.
 - Functions in repair and growth in humans.
 - DNA replicated once
 - Cells undergo division once
- The new daughter cells have the same chromosome number as the parental cells.
- Uncontrollable cell division = cancer



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Meiosis

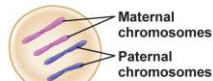
- Forms reproductive sex cells such as sperm (spermatogenesis) and egg cells (oogenesis).
 - These reproductive cells have half of the chromosomes as their parental cells.
 - They are also genetically different from their parental cells.
 - DNA replicated once
 - Cells undergo division twice



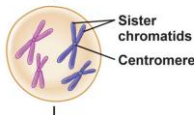
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Meiosis

① Diploid germ cell ($2n$ chromosomes)



② DNA is replicated ($2n \times 2$ chromosomes)



③ Homologous chromosomes group together in pairs



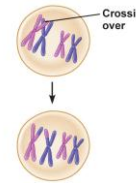
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Figure 22.1 (1 of 5)

Meiosis

④ Crossing over occurs



Exchange of DNA segments occurs = crossing over

⑤ New chromosomes containing mixtures of maternal and paternal genes are created

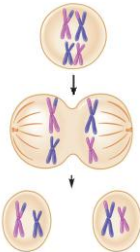
New chromosomes with mixed source of genes

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Figure 22.1 (3 of 5)

Meiosis

⑥ Independent assortment occurs



Random alignment of sister chromatids at midline = independent assortment

⑦ Meiosis I

First meiotic division
2 cells with $2n$ chromosomes

($n \times 2$ chromosomes)

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Figure 22.1 (4 of 5)

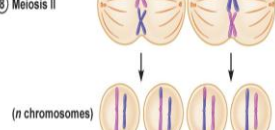
Meiosis

($n \times 2$ chromosomes)



2nd meiotic division occurs

⑧ Meiosis II



4 cells with n chromosomes

(n chromosomes)

Haploid daughter cells

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Figure 22.1 (5 of 5)