Bio 13 Student Reference Guide

Prepared for Kingsborough Learning Center

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Contents

Unit 1. Study of Life

Biology is the discipline that studies life. For example, the biology which studies plants is called botany.

Ch.1: Properties of Life

The Eight Characteristics of Life

The living organisms share eight characteristics of life: order, sensitivity or response to stimuli, reproduction, adaptation, growth and development, regulation, homeostasis, and energy processing.

Order

Organisms are organized structures containing one or more cells. Single-celled organisms are complex containing other structures like DNA. Multicellular organisms can be specialized to perform specific functions. These specialized cells form together organs like the heart, liver, or skin

Sensitivity or Response to Stimuli

Organisms respond to different stimuli. For example, plants grow toward the light (phototaxis); bacteria move toward chemicals (positive chemotaxis), or away (negative chemotaxis)

Reproduction

Single-celled organisms reproduce by replicating their DNA (genetic information) and dividing it equally as the cell divides into two cells.

Adaptation

The living organisms exhibit fitness to their environment. This is a result of adaptation due to evolution forced by natural selection. Some bacteria live in high salt environments and are called **extremophiles**. As an environment changes, natural selection over time forces the individuals in a population to change their traits.

Growth and Development

Organisms grow and develop according to genetic information written in genes.

Regulation

All organisms require regulatory mechanisms to manage different internal functions like nutrient transport, response to stimuli, and removing wastes.

Homeostasis

Organisms can maintain stable internal conditions despite environmental changes. For example, regulate body temperature by perspiration (thermoregulation).

Energy Processing

Organisms use energy for their metabolic activities. Plants capture energy from the sun and convert it into chemical energy in glucose.

Fill the blanks:

1. Organisms are able to overcome environmental conditions due to _____
2. As a result of _____ _ _____ ___ _____ bacteria move away of penicillin.
3. Organisms _____to their environment because of evolution.
4. Are viruses living organisms?

Answers:

1. Homeostasis
2. Sensitivity or response to stimuli
3. Adapt
4. No. Viruses are nonliving organisms. So, the eight characteristics of life do not apply to viruses.

Levels of Organization of Life

Atom

It is the smallest unit of matter that consists of a nucleus with protons, neutrons, and electrons around the nucleus; Ex. Na (sodium), Cl (chlorine)

Molecule

Two or more atoms bonded chemically; Ex. NaCl (sodium chloride)

Macromolecules

Large molecules formed from smaller units. Ex. proteins, lipids, carbohydrates, nucleic acids: DNA, RNA

Organelles

Small membrane-enclosed structures inside cells. Ex. ribosomes, mitochondria

Cells

Smallest structures in living organisms. Ex. skin cells

Tissues

Collections of similar cells carrying out the same function. Ex. skin epidermis

Organs

Collections of tissues carrying out a common function. Ex. skin, liver, stomach;

Organ System

Group of organs that work together. Ex. digestive system contains tongue, stomach, intestines;

Organisms

Living individuals. Ex. animal, plant, protist, bacteria

Populations

Individuals of species living in a specified area. Ex. white pine trees in a forest

Communities

All organisms living in a specified area. Ex. bacteria, fungi, plants, animals

Ecosystems

All living organisms and nonliving components in the environment. Ex. animal, plants, soil, water, atmosphere

Biosphere

All life on the Earth

Fill in the blanks:

1. _____ are the membrane-enclosed structures inside a cell.
2. All organisms living in a specific area is a _____ but individuals of species in the area is a _____
3. Lungs and heart working together are an example of an_____
4. The smallest unit of matter is an _____
5. _____are the smallest structure in living organisms

Answers:

1. Organelles
2. Community, population
3. Organ system
4. Atom
5. Cells

Chemical Input to Biology

Life is made up of matter.

Matter

Any substance that occupies space and has mass. Matter exists in many different forms. Rocks, metals, liquids, and animals are examples of matter

Element

Is a form of matter that cannot break down into smaller parts;

Atom

Is the smallest unit of matter that holds an element's chemical property. Ex. one gold atom has properties of gold;

An atom is composed of two regions:

1) **nucleus** – containing **protons** and **neutrons**;
2) **electrons** - surrounding the nucleus;

Subatomic particles:

protons - (+) charge;
neutrons - (0) no charge;
electrons - (-) charge;

Isotopes

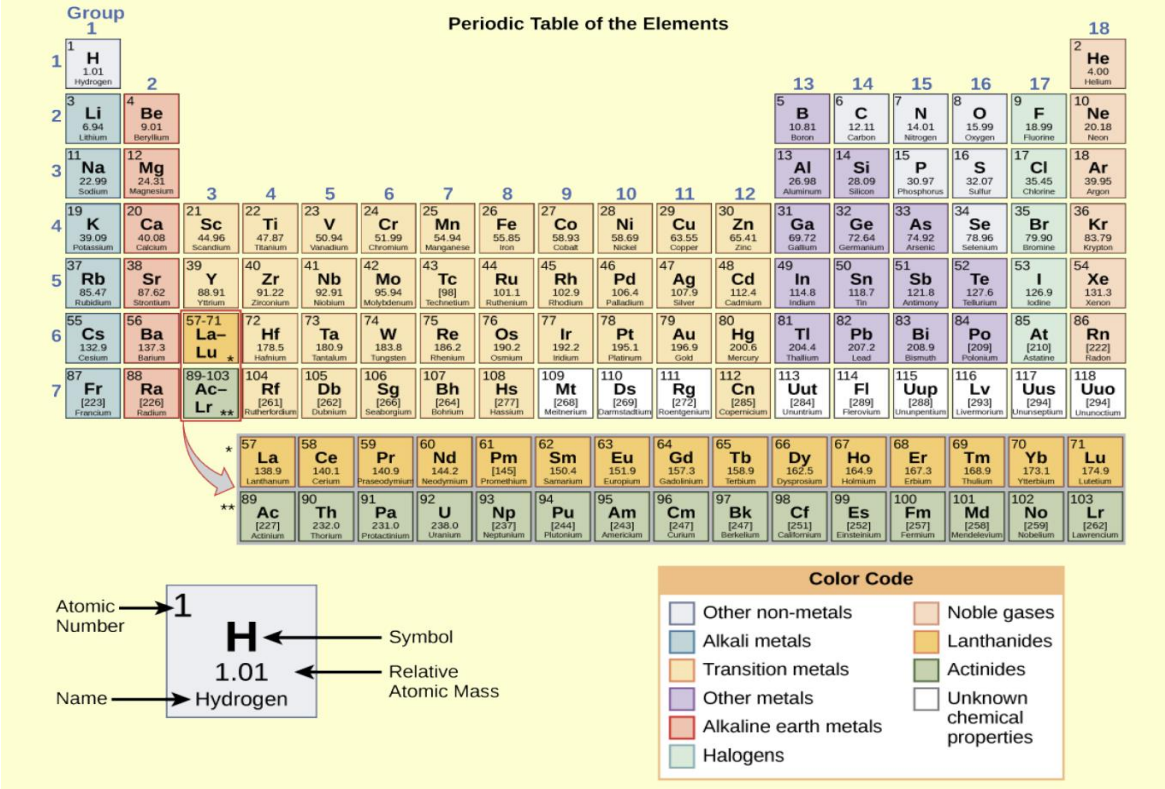
Different forms of an element with the same number of protons but a different number of neutrons are isotopes. Ex. carbon C with the mass 12 amu or 13 amu.

amu - *atomic mass unit*

C-12: 6 protons, 6 electrons, 6 neutrons
C-13: 6 protons, 6 electrons, 7 neutrons

Periodic Table of Elements

Every element in the Periodic Table of Elements is described by a symbol and by two numbers: **Mass number** = protons + neutrons, and **atomic number** = protons = electrons



Subatomic Particles for *an atom*

protons = atomic number
electrons = atomic number
neutrons = mass number – protons

Subatomic Particles for *an ion*

protons = atomic number
electrons = atomic number - positive charge (cation) ***or***
electrons = atomic number + negative charge (anion)
neutrons = mass number - protons

Question: Determine the number of protons, electrons and neutrons for sodium atom Na?

$_{11}Na^{22.990}$

Na - *sodium atom*

- *protons = 11*
- *electrons = 11*
- *neutrons = 23 - 11 = 12*

Losing or gaining negatively charged electrons results in **ions**:

- positive ions **(cations)**
- negative ions **(anions)**

Question: Determine the number of protons, electrons and neutrons for sodium ion Na^+?

$_{11}Na^{22.990}$

Na^+ - *sodium cation*

- *protons = 11*
- *electrons = 11 - 1 = 10*
- *neutrons = 23 - 11 = 12*

Question: Determine the number of protons, electrons and neutrons for calcium ion Ca^{2+}?

$_{20}Ca^{40.078}$

Ca^{2+} - *calcium cation*

- *protons = 20*
- *electrons = 20 - 2 = 18*
- *neutrons = 40 - 20 = 20*

Question: Determine the number of protons, electrons and neutrons for sulfur ion S^{2-}?

$_{16}S^{32.066}$

S^{2-} - *sulfur anion*

- *protons = 16*
- *electrons = 16 + 2 = 18*
- *neutrons = 32 - 16 = 16*

Question: Determine the number of protons, electrons and neutrons for fluorine ion F^-?

$_9F^{18.998}$

F^- - *fluorine anion*

- *protons = 9*
- *electrons = 9 + 1 = 10*
- *neutrons = 19 - 9 = 10*

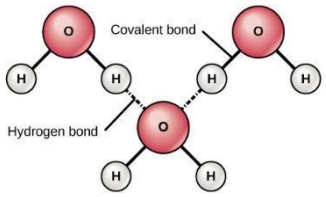
Molecules

The chemical bonds between atoms make molecules.

Chemical Bonds

There are four types of chemical bonds or interactions:

- **ionic bond** - electrons from the less electronegative atom (metal) are transferred to the more electronegative atom (nonmetal). Ex. NaCl
- **covalent bond** - electrons are shared between both nonmetals. Ex. HCl
- **hydrogen bonds** - between H (positive charge δ+) of one molecule and O (negative charge δ–) of another molecule; between H (δ+) of one molecule and N (δ–) of another molecule; between H (δ+) of one molecule and F (δ–) of another molecule. Ex. H_2O---H_2O; NH_3---NH_3; H-F---H-F



- **van der Waals interactions** – electrons accumulate in a different part of a molecule; this is caused by temporary partial charges formed when electrons move around a nucleus.

There are two types of covalent bonds:

- **polar** - there is a difference in electronegativity between the bonding nonmetals, Ex. HCl
- **nonpolar -** the two bonding nonmetals have the same electronegativity, Ex. H-H (H_2) or Cl-Cl (Cl_2)

Ionic and **covalent bonds** are strong bonds. **Hydrogen bonds** and **van der Waals interactions** are weak bonds or interactions.

Questions:

1. Find the mass number and atomic number for the atoms: Ca-40, Na-23
2. Find the number of protons, electrons, and neutrons for the atoms: Fe-56, N-14
3. The ionic bond is formed by _____ of electrons between _____(less electronegative) and _____ (more electronegative)
4. When the _____ of one water molecule makes o weak bond with an _____ of another _____molecule, then the _____bond is formed
5. Electrons _____by both nonmetals is an example of _____ bond.

Answers:

1. Ca-40: mass number = 40.078; atomic number = 20
   Na-23: mass number = 22.990; atomic number = 11

2. $_{26}Fe^{56}$
   protons: 26; electrons: 26; neutrons: 56 - 26 = 30

   $_{7}N^{14}$
   protons: 7; electrons: 7; neutrons: 14 – 7 = 7
3. transfer, metal, nonmetal
4. hydrogen, oxygen, water, hydrogen
5. shared, covalent

Ch.2: Chemistry of Life

Functional Groups

The specific arrangements of chemical elements attached to the carbon and involved in chemical reactions are called functional groups. Examples of functional groups in biological compounds are **hydroxyl (-OH), methyl (-CH_3), carbonyl (-C=O), carboxyl (-COOH), amino (-NH_2), phosphate (-PO_4), and sulfhydryl (-SH)**.

Macromolecules

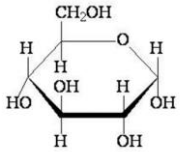
Biological polymers built from monomers are macromolecules. Polymers form by a **dehydration reaction,** that is, the removal of water molecules between monomers. Using water to break down polymers back into monomers is a **hydrolysis reaction**.

There are four types of macromolecules: carbohydrates, lipids, proteins, and nucleic acids.

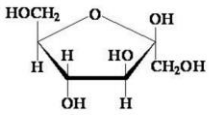
Carbohydrates (sugars)

The general formula presenting all the carbohydrates is: $(CH_2O)n$, where *n - is a multiple of each element*. Ex. *n=6,* $C_6H_{12}O_6$
Carbohydrates are classified as:

- **Monosaccharides** – ("mono" = one), simple sugars, $C_6H_{12}O_6$.
  Examples of monosaccharides:
  - glucose (fruits sugar)
  - fructose (fruits sugar)
  - galactose (milk sugar)



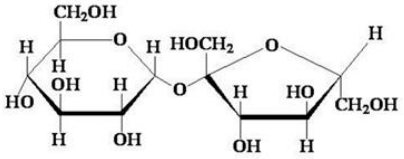
glucose



fructose

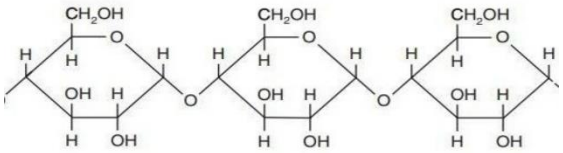
Glucose, fructose, and galactose have the same chemical formula ($C_6H_{12}O_6$) but different arrangements of carbons. They are **isomers**.

- **Disaccharides** – ("di" = two), two monosaccharides connected by **dehydration reaction** (removal of a water molecule). As a result, the **glycosidic linkage** forms between monosaccharides.
  Examples of disaccharides:
  - lactose - milk sugar, composed of glucose + galactose
  - maltose - malt sugar, composed of glucose + glucose
  - sucrose - table sugar, composed of glucose + fructose



Sucrose

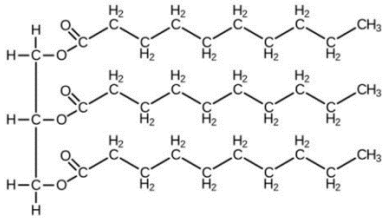
- **Polysaccharides** – (“poly” = many), many monosaccharides connected by glycosidic linkages. Examples of polysaccharides:
  - starch
  - glycogen
  - cellulose
  - chitin



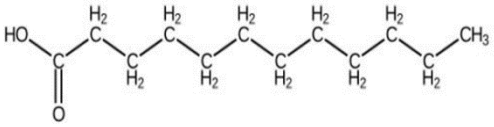
Starch

Lipids (fats, triglycerides)

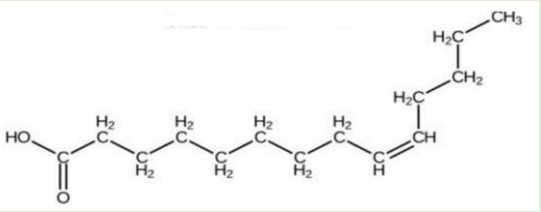
Lipids are macromolecules of **glycerol + three fatty acids** bond together by **ester bonds**. Lipids (fats, triglycerides) are hydrophobic (insoluble in water) and nonpolar molecules, which may contain saturated or unsaturated fatty acids.



- **saturated fatty acid** - contain only single bonds between carbons; solid fats: butter, margarine, lard



- **unsaturated fatty acid** - hold double bond or bonds between carbons; liquid fats: oils



Phospholipid Bilayer

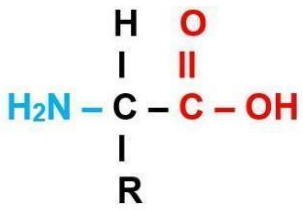
A significant part of the plasma membrane surrounding cells is a phospholipid bilayer, composed of fatty acids bonded to glycerol and a phosphate group.

Phospholipids bilayer has two regions:

- hydrophobic, which “does not interact with water” (fatty acids)
- hydrophilic, which “does interact with water” (phosphate group)

Proteins

Amino acids bonded one to another by a peptide bonds form protein.
Each amino acid has
central carbon -C,
carboxyl -COOH group,
amino -NH_2 group,
side chain -R group,
and hydrogen.



Amino acid

Proteins have different shapes and molecular weights based on the arrangement of the 20 different amino acids. Changes in temperature, pH, and exposure to chemicals may lead to **denaturation** (loss of shape and function of the protein).

There are four levels of protein structure: primary, secondary, tertiary, and quaternary.

- **primary structure** - the unique sequence and number of amino acids in a polypeptide chain;
- **secondary structure** - are alpha (α)-helix and bet\a (β)-pleated sheets held in shape by hydrogen bonds;
- **tertiary structure** - the unique three-dimensional structure of a polypeptide;
- **quaternary structure** - several polypeptides and their interactions.

Nucleic Acids

There are two types of nucleic acids:
- deoxyribonucleic acid (DNA), found in all living organisms
- ribonucleic acid (RNA), which is involved in protein synthesis.

Nucleic acids are polymers made of monomers called nucleotides containing in their structure:

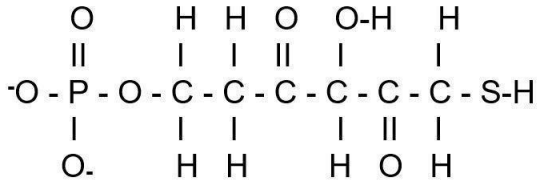
- nitrogenous base
- pentose (five-carbon) sugar
- phosphate group 6

Nitrogenous bases in DNA: Adenine (A) – Thymine (T); Guanine (G) – Cytosine (C)

Nitrogenous bases in RNA: Adenine (A) – Uracil (U); Guanine (G) – Cytosine (C)

Questions:

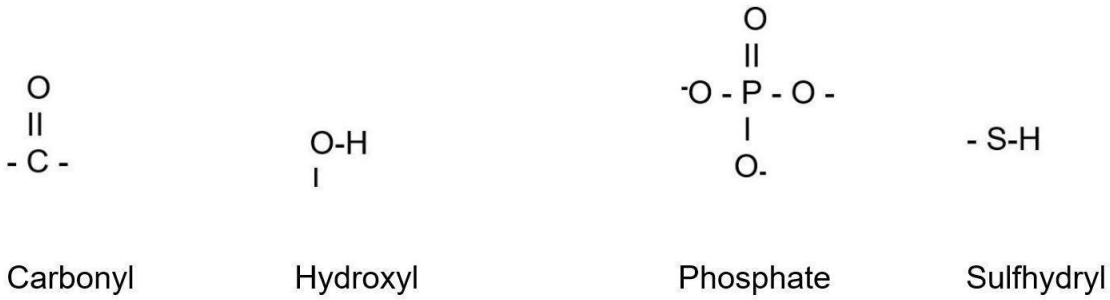
1. List functional groups and their structure:
2. Identify functional groups from the given chemical:



3. List macromolecules:
4. What reaction forms polymers?
5. What reaction forms monomers by breaking down polymers?
6. What are isomers?
7. What is the name of the bonds formed between sugar monomers?
8. Give examples of monosaccharides?
9. Give examples of disaccharides?
10. Give examples of polysaccharides?
11. What is the structure of lipids?
12. What is the difference between saturated and unsaturated fatty acids?
13. What is the basic unit of protein?
14. What are the four levels of protein structure?
15. Add complementary DNA bases to the given DNA strand: AAA CCG GAT TTG
16. Add complementary RNA bases to the given DNA strand: AAA CCG GAT TTG

Answers:

1. The functional groups are: **-hydroxyl (-OH), -methyl (-CH_3), -carbonyl (-C=O), -carboxyl (-COOH), -amino (-NH_2), -phosphate (-PO_4), -sulfhydryl (-SH).**
2. The functional groups are as follows:



3. The macromolecules are: **-carbohydrates, -proteins, -lipids, -nucleic acids.**
4. A dehydration reaction forms polymers.
5. Monomers are formed from polymers by **hydrolysis reaction.**
6. **Isomers** are molecules with the same molecular formula but different arrangements of carbons.
7. **Glycosidic linkage** is the name of the bonds formed between sugar monomers.
8. Glucose, fructose, and galactose are simple sugars called **monosaccharides**.
9. Sucrose, lactose, and maltose are **disaccharides.**
10. Starch, glycogen, cellulose, and chitin are **polysaccharides.**
11. The structure of **lipids** is represented by: **glycerol + three fatty acids**
12. **Saturated fatty acids** have only single bonds between carbon atoms;
    unsaturated fatty acids have one or more double bonds between carbon atoms.
13. An **amino acid** is a basic unit of protein.
14. The four levels of protein structure are:48
    - **primary** - sequence of amino acids in the polypeptide chain
    - **secondary** - alpha (α)-helix and beta (β)-pleated sheet
    - **tertiary** - the unique 3-D structure of a polypeptide
    - **quaternary** - several polypeptides and their interactions

15. The complementary DNA bases to the given DNA strand:
    AAA CCG GAT TTG
    CTTAGGCTTACCA

16. The complementary RNA bases to the given DNA strand:
    AAA CCG GAT TTG
    UUUGGCCTAAAC

Metric System and Unit Conversions

The three basic SI units are:

gram (g) – mass
liter (L) – volume
meter (m) – length

Prefixes to be used:

Prefix	Conversion unit **(g); (L) or (m)**
1 pico (p)	1×10^{-12}
1 nano (n)	1×10^{-9}
1 micro (µ)	1×10^{-6}
1 milli (m)	1×10^{-3}
1 centi (c)	1×10^{-2}
1 deci (d)	1×10^{-1}
1 deca (da)	1×10^{1}
1 hecto (h)	1×10^{2}
1 kilo (k)	1×10^{3}
1 mega (M)	1×10^{6}
1 giga (G)	1×10^{9}
1 tera (T)	1×10^{12}

How to convert SI units?

The initially given unit converts first to the basic unit (gram, liter, or meter), depending on what you calculate. Next, follow your shortest way using the above conversions to reach the final answer. Cancel out the same units from the numerator and denominator of the fractions.

Question: Convert the given

- 1.2 nm =? cm (length)

$$1.2\ \text{nm} \times \frac{1\ \text{m}}{1 \times 10^{9}\ \text{nm}} \times \frac{1 \times 10^{2}\ \text{cm}}{1\ \text{m}} = 1.2 \times 10^{-7}\ \text{cm}$$

- 50 mg = ? µg (mass)

$$50\ \text{mg} \times \frac{1\ \text{g}}{1 \times 10^{3}\ \text{mg}} \times \frac{1 \times 10^{6}\ \mu\text{g}}{1\ \text{g}} = 5.0 \times 10^{4}\ \mu\text{g}$$

- 2.0 µL = ? nL (volume)

$$2.0\ \mu L \times \frac{1\ L}{1 \times 10^{6}\ \mu L} \times \frac{1 \times 10^{9}\ nL}{1\ L} = 2.0 \times 10^{3}\ nL$$

- 1.7 pg = ? mg

$$1.7\ pg \times \frac{1\ g}{1 \times 10^{12}\ pg} \times \frac{1 \times 10^{3}\ mg}{1\ g} = 1.7 \times 10^{-9}\ mg$$

- 2.8 mL = ? µL (volume)

$$2.8\ mL \times \frac{1\ L}{1 \times 10^{3}\ mL} \times \frac{1 \times 10^{6}\ \mu L}{1\ L} = 2.8 \times 10^{3}\ \mu L$$

- 7.6 mm = ? cm (length)

$$7.6\ mm \times \frac{1\ m}{1 \times 10^{3}\ mm} \times \frac{1 \times 10^{2}\ cm}{1\ m} = 7.6 \times 10^{-1}\ cm$$

- 1.8 nm = ? mm (length)

$$1.8\ nm \times \frac{1\ m}{1 \times 10^{9}\ nm} \times \frac{1 \times 10^{3}\ mm}{1\ m} = 1.8 \times 10^{-6}\ mm$$

- 3.4 µg = ? mg (mass)

$$3.4\ \mu g \times \frac{1\ g}{1 \times 10^{6}\ \mu g} \times \frac{1 \times 10^{3}\ mg}{1\ g} = 3.4 \times 10^{-3}\ mg$$

- 7.0 mL = ? nL (volume)

$$7.0\ mL \times \frac{1\ L}{1 \times 10^{3}\ mL} \times \frac{1 \times 10^{9}\ nL}{1\ L} = 7.0 \times 10^{6}\ nL$$

- 3.7 mg = ? pg (mass)

$$3.7\ \text{mg} \times \frac{1\text{g}}{1 \times 10^{3}\ \text{mg}} \times \frac{1 \times 10^{12}\ \text{pg}}{1\text{g}} = 3.7 \times 10^{9}\ \text{pg}$$

- 2.8 nL = ? mL (volume)

$$2.8\ \text{nL} \times \frac{1\text{L}}{1 \times 10^{9}\ \text{nL}} \times \frac{1 \times 10^{3}\ \text{mL}}{1\text{L}} = 2.8 \times 10^{-6}\ \text{mL}$$

- 2.6 cm = ? km (length)

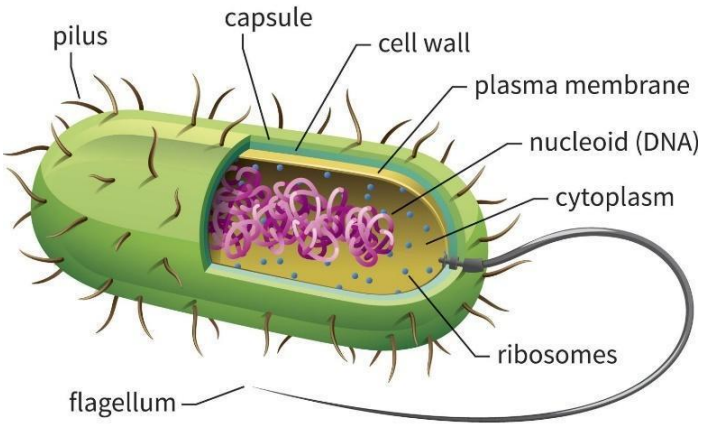
$$2.6\ \text{cm} \times \frac{1\text{m}}{1 \times 10^{2}\ \text{cm}} \times \frac{1\ \text{km}}{1 \times 10^{3}\ \text{m}} = 2.6 \times 10^{-5}\ \text{km}$$

Ch.3: Cell Structure and Function

All organisms are made of cells. The cells fall into two categories: prokaryotic cells and eukaryotic cells.

Prokaryotic Cells

Prokaryotes (pro- = before; -karyon = nucleus) are organisms of the domains of Bacteria and Archaea. Prokaryotic cells share four common structures: 1) a plasma membrane; 2) cytoplasm; 3) DNA; and 4) ribosomes. A prokaryotic cell is a simple, single-celled (unicellular) organism without a nucleus or other membrane-bonded organelles. Prokaryotic DNA is found in the center of the cell, a region called the nucleoid.

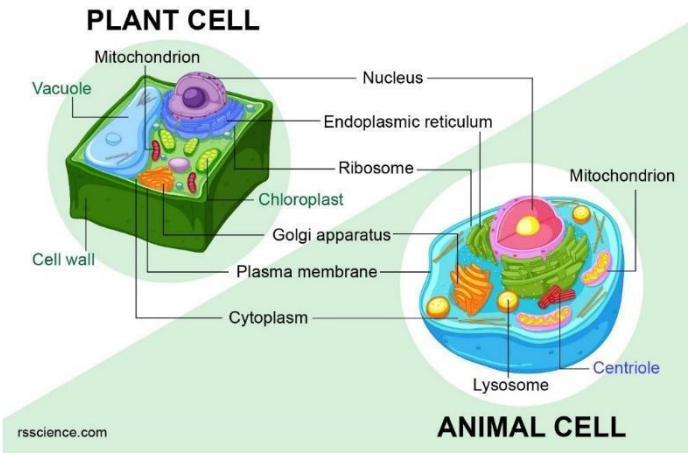


Bacteria are prokaryotes. They have a cell wall made of peptidoglycan (sugar-protein) layer. Some bacteria have a polysaccharide capsule surrounding the cell wall. Other structures are flagella, pili, or fimbriae. Flagella are used for locomotion, pili to exchange genetic material, and fimbriae for attachment. A gel-like substance inside the cell is a cytoplasm, whose main component is a cytosol. The ribosomes are the macromolecular organelles involved in the process of protein synthesis.

Eukaryotic Cells

Eukaryotes (eu- = true; -karyon = nucleus) are multicellular organisms of Animals, Plants, Fungi, and unicellular Protists. Eukaryotes have a membrane-bound nucleus with DNA and other organelles. However, there are differences in the structure and organelles of eukaryotic animal and plant cells.

Fungi are heterotrophic, multicellular organisms of the structure of hyphae, which forms mycelium. The cell wall of fungi consists of a polysaccharide, chitin.



Similarities and Differences in the Structure of Animal and Plant Cells

Organelle	Function
Nucleus	contains genetic material - chromosomes made of DNA and histones proteins
Mitochondria	make energy in the form of ATP from sugar
Ribosomes	proteins synthesis
Golgi Apparatus	proteins package, and distribution
Lysosome	contains digestive enzymes to break down macromolecules
Rough Endoplasmic Reticulum	associated with ribosomes
Smooth Endoplasmic Reticulum	lipids synthesis
Centriole (only animal cell)	cell division
Peroxisomes	oxidation of biomolecules
Additional in Plant cells:	
Chloroplasts	use sunlight to create sugar by photosynthesis
Cell Wall	structure support
Vacuole	water or food storage

Questions:

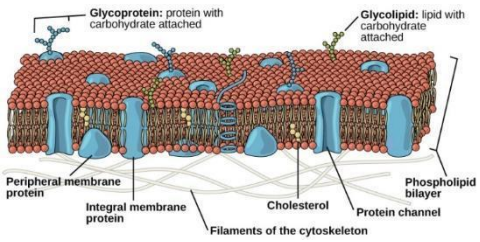
1. Which organelle is common for all types of cells?
2. Which structure is present in prokaryotic and plant cells?
3. Do all bacteria have a capsule covering a cell wall?
4. Which organelle does not match its function?
   a- Ribosomes – protein synthesis
   b- Mitochondria – ATP synthesis
   c- Centriole – cell replication
   d- Golgi apparatus – processes proteins for secretion
   e- All answers are correct
5. What is the difference between pili and fimbriae?

Answers:

1. Ribosomes are common in prokaryotic and eukaryotic cells.
2. Cell wall is present in prokaryotic (bacteria) and plant cells.
3. No, not all bacteria have a capsule.
4. e- All answers are correct.
5. Cells use pili for genetic information exchange but fimbriae for cell attachment.

The Cell Membrane

The plasma membrane components flow and change position, maintaining its fluid mosaic model. The main component of the plasma membrane is a **phospholipid bilayer** containing a phosphate group (hydrophilic, a head) bonded with two fatty acids (hydrophobic, a tail). The **integral channel proteins** move substances into or out of the cell. The **peripheral proteins** from the surface of the membrane serve as recognition sites, enzymes, or attachments for filaments of the cytoskeleton. **Cholesterol** regulates the fluidity of the animal plasma membrane and is ample in the plasma membrane of animals living in low temperatures. **Carbohydrates** are bounded to proteins **(glycoproteins)** or to lipids **(glycolipids)**, which work as cell recognition sites.



Transport Across the Cell Membrane

Plasma membrane is a selectively permeable barrier that allows some substances to enter or leave a cell. Substances may be moved through the cell membrane by passive or active transport.

Passive Transport

Passive transport is the movement of substances through a cell membrane from higher to lower concentrations of the substance without using any energy.

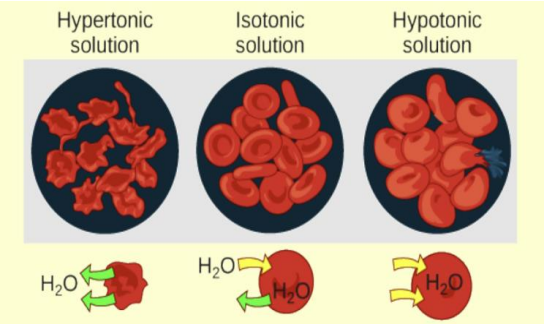
Diffusion - is passive transport. A single substance moves from an area of high to a low concentration until the concentration is equal across the membrane.

Facilitated transport (diffusion) - a substance moves from an area of high to low concentration with the use of transmembrane proteins and without the use of cellular energy.

Osmosis - diffusion of water through a semipermeable membrane from higher to lower concentration of water.

Three types of osmotic solutions:

- **hypotonic -** less solute concentration in the extracellular fluid than inside a cell; water flows from the extracellular fluid into the inside of a cell. As a result, animal cell burst, or lyse
- **isotonic -** equal solute concentration in the extracellular fluid and inside a cell; water flows from the extracellular fluid into a cell and from a cell into the extracellular fluid
- **hypertonic -** more solute concentration in the extracellular fluid than inside a cell; water flows from the inside of the cell into the extracellular fluid. As a result, animal cells shrivel or crenate



Active Transport

uses the cell's energy in the form of adenosine triphosphate (ATP) to move substances through the cell membrane against a concentration gradient, that is, from the low to high concentration of the substance.

Endocytosis – is a type of active transport that moves large particles into a cell

Pinocytosis – is a variation of endocytosis, it is a "cell drinking," where the cell was taking in extracellular fluid

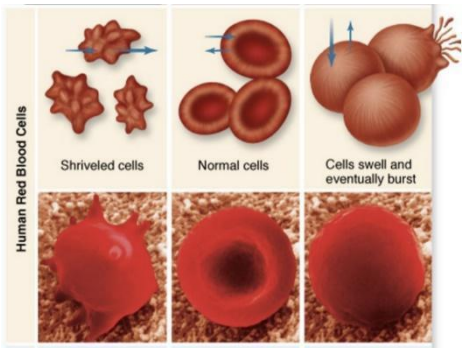
Phagocytosis – is the process by which large particles, such as cells are taken in by a cell

Receptor-mediated endocytosis – is a variation of endocytosis and use of specific binding proteins in the plasma membrane for specific molecules or particles

Exocytosis – is to expel the material from the cell into the extracellular fluid

Questions:

1. Match the given cells with the types of solution



2. The main component of plasma membrane is _____
3. The cell drinking is referred as _____

Answers:

1. Shriveled cells – **hypertonic solution**
   Normal cells – **isotonic solution**
   Cells swell and eventually burst – **hypotonic solution**

2. phospholipid
3. pinocytosis

Ch.4: How do Cells Obtain Energy

Energy and Metabolism

All living cells use energy. Energy is the ability to do work or to create change. Energy in the form of ATP (adenosine triphosphate) may be released (spontaneous reaction) or absorbed (nonspontaneous reaction) when building up polymers (anabolic pathway) or breaking down polymers (catabolic pathway). The chemical reactions which maintain the good condition of the cells are called **metabolism**.

Laws of Thermodynamics

The first law of thermodynamics states that the total amount of energy in the universe is the same, and the energy may be transferred from place to place or transformed into different forms, but it cannot be created or destroyed.

The second law of thermodynamics states that the energy transfer or transformation increases the entropy (disorder) of the universe.

Cellular Respiration

During the process of cellular respiration, the sugar molecule (glucose) is converted into carbon dioxide, water, and energy in the form of ATP (adenosine triphosphate). With the presence of oxygen, the process is aerobic and undergoes:

1) substrate level phosphorylation (glycolysis and Krebs cycle called Citric Acid cycle) and

2) oxidative phosphorylation (electron transport chain and chemiosmosis).

If there is no oxygen present, the anaerobic process called fermentation takes place: glycolysis and lactic acid or ethanol formation with the release of ATP.

The general formula of the cellular respiration (*oxidation-reduction process*):

$C_6H_{12}O_6$	+	$6O_2$	->	$6CO_2$	+	$6H_2O$
glucose		oxygen		carbon dioxide		water

oxidation - losing electrons or hydrogens
reduction - gaining electrons or hydrogens

In the above process:

- glucose is *oxidized* to carbon dioxide
- oxygen is *reduced* to water

Glycolysis

In the cytosol of the cell, six-carbon glucose is converted into two pyruvates (three carbon chain molecules). Four molecules of ATP are produced after two molecules of ATP are consumed. With the presence of O_2 each pyruvate moves into the mitochondrial matrix and is converted first to a two-carbon molecule connected by a bond to coenzyme A, called acetyl CoA.

Citric Acid Cycle

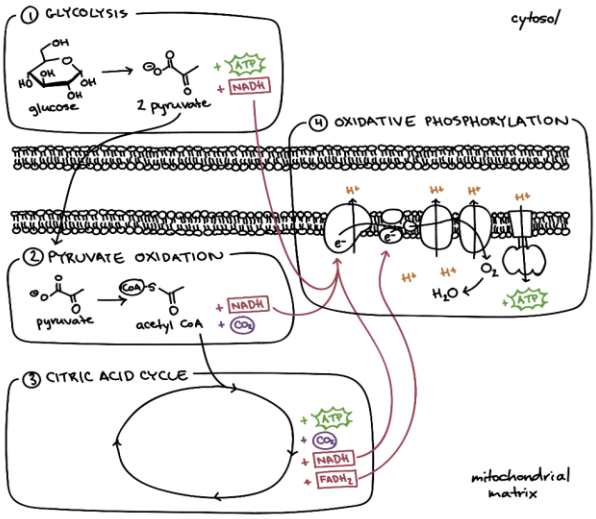
In the mitochondrial matrix, the acetyl CoA combines with a four-carbon starting molecule (oxaloacetate) and goes through a cycle of reactions.

One pyruvate molecule produces: 1 ATP, 3 NADH, 1 FADH2, and 2 CO2.

Oxidative Phosphorylation

In the inner mitochondrial membrane, the NADH and $FADH_2$ produced in the citric acid cycle donate their electrons during the electron transport chain. As electrons move down through the cell membrane in the electron transport chain, protons are pumped out into the intermembrane space, forming a proton gradient. An enzyme ATP synthase in the process called chemiosmosis moves the protons back across the membrane into the mitochondrial matrix. During chemiosmosis, the most cellular energy in the form of ATP is produced. At the end of the electron transport chain, oxygen accepts electrons and protons to form water.

Summary: Steps in Cellular Respiration



Fermentation

In the absence of oxygen-glucose undergoes glycolysis releasing two pyruvates and two ATP. Pyruvates are converted into lactic acid or ethanol.

Ch.5: Photosynthesis

Plants, green algae, or cyanobacteria use sunlight to convert their energy into the chemical energy of sugar. The reaction takes place in leaf cells' chloroplasts. During this process, oxygen is released into the atmosphere as a byproduct. The most effective wavelengths for plants' photosynthesis are red and violet-blue. The reaction takes place in two steps: the Light-Dependent Reaction and the Dark Reaction.

Summary: Steps in Photosynthesis

$$h\Upsilon + CO_2 \rightarrow H_2O + C_6H_{12}O_6 + O_2$$

sunlight — carbon dioxide — water — glucose — oxygen

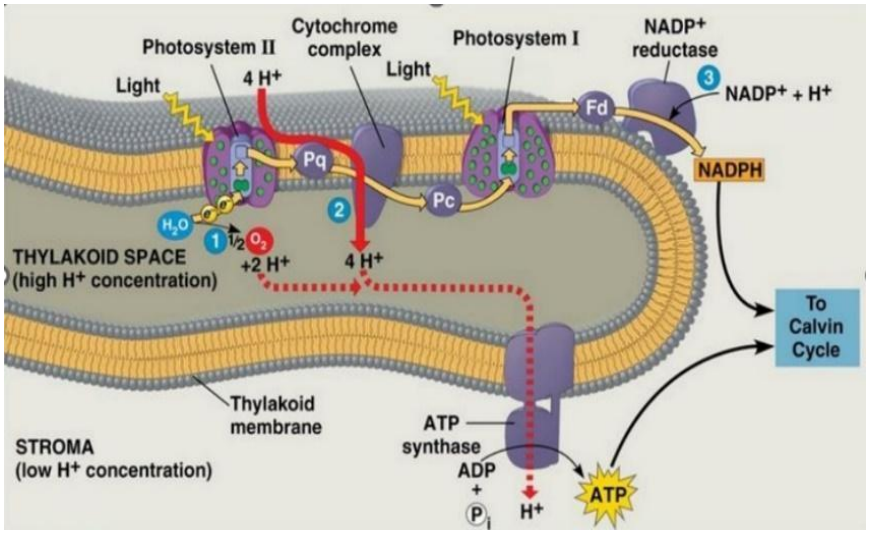
Two steps of photosynthesis:

I – *photo (the Light-Dependent Reaction) releasing NADPH and ATP, H_2O splits into 2 H^+ and ½ O.*

II – *synthesis (the Dark Reaction, Calvin Cycle) producing G3P (sugar)*

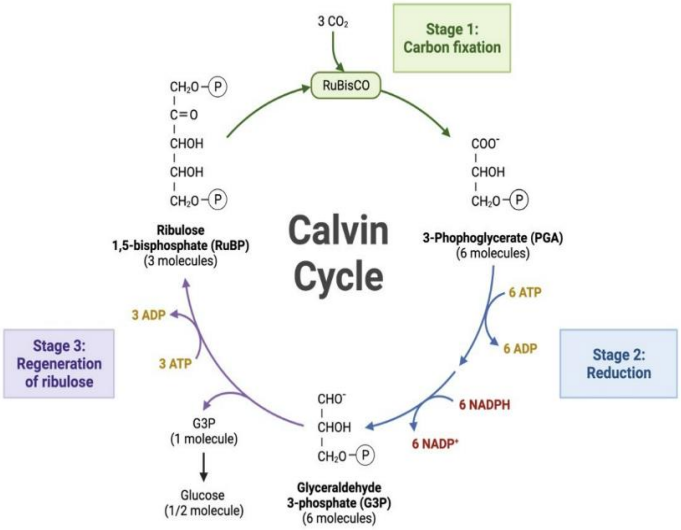
Light-Dependent Reaction

The light-dependent reaction is the *photo* – part of the process of photosynthesis. Light energy is converted into chemical energy in the form of ATP and NADPH. The reaction takes place at the chloroplast's thylakoid membrane starting from photosystem II. The chlorophyll molecules P680 with carbon dioxide and water capture sunlight and release one electron. The excited electron moves by the electron transport chain made up of electron carriers: (plastoquinone (Pq), cytochrome complex, and plastocyanin (Pc)) to photosystem I, which also absorbs a photon from the sunlight. At the same time, a proton gradient forms across the cell's plasma membrane because H_2O is split into $2H^+$ and 1/2 O by photosystem II. The H^+ gradient across the plasma membrane powers ATP synthesis by ADP phosphorylation. Photosystem I contain the chlorophyll molecules P700 which accept an electron from photosystem II. Photosystem I by electron carriers: ferredoxin (Fd) transfers the electrons by another electron transport chain to $NADP^+$ and reduce it with H^+ to NADPH.



Dark Reaction: Calvin Cycle

The Calvin cycle of photosynthesis, takes place in the stroma of the chloroplasts. Carbon dioxide and other products of light-dependent reactions are used for the sugar production. Calvin cycle is performed in a three major steps:



1-**carbon fixation** - RuBisCo (ribulose biphosphate carboxylase) catalyzes the reaction between CO_2 and RuBP (ribulose biphosphate). For one molecule of CO_2 reacting with one molecule of RuBP, two molecules of 3-phosphoglyceric acid (3 – PGA) are produced: CO_2 + RuBP -> 2 (3-PGA)

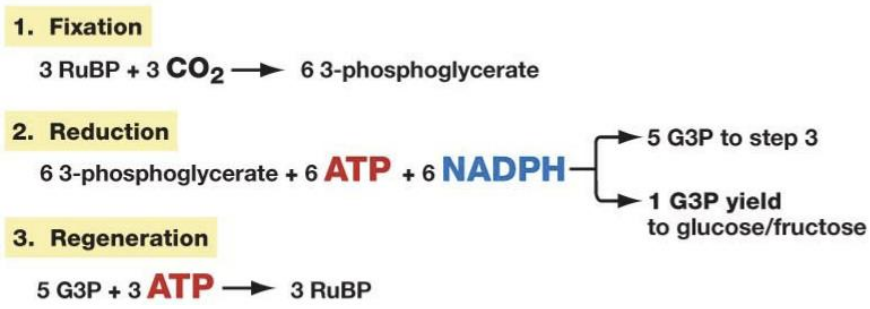
2-**reduction** - APT and NADPH convert 3-PGA into glyceraldehyde 3-phosphate (G3P), which is used to produce sugar and other compounds. In this reaction, 3-PGA receives a phosphate group from ATP and becomes 1,3 – bisphosphoglycerate, which is reduced by electrons donated from NADPH and becomes a G3P (sugar). Both ADP and $NADP^+$ return to the light-dependent reaction and are used again.

3-PGA reduction to G3P:

3 ATP + 6 NADPH + 6 (3-PGA) -> 3 ADP + 6 $NADP^+$ + 6 G3P.

3-**RuBP (ribulose) regeneration** - one of the G3P molecules exit the Calvin cycle and enters the cytoplasm to be used by plants for glucose and other compounds synthesis. The other five G3P molecules produced in three Calvin cycles are used to regenerate RuBP (ribulose) and fix CO_2 . The fixed CO_2 can be used for the Calvin cycle again.

Summary of the Calvin Cycle:



Unit 2. Cell Division and Genetics

Ch.6: The Cell Cycle and Mitosis

Genome

The genetic information of the **eukaryotic cell** is a double-stranded linear DNA called a **genome** located in the nucleus of the cell. A typical human cell's DNA is about 2 meters. The DNA bounded with histone proteins forms **chromosomes**. Human somatic cells (all cells in the human body except sperm and egg) have 46 chromosomes and are 2n-diploid. Human gametes (sperm and egg) have 23 chromosomes and are n-haploid. The functional units of chromosomes are **genes**, which code for specific proteins. In **prokaryotic cells**, the genome is composed of one double-stranded DNA, and it is in the form of a circular plasmid. The location of the genetic information within the prokaryotic cell is called a **nucleoid**.

The Cell Cycle

The cell cycle is a series of stages preparing the cell for division. The cell grows, DNA replicates, and the cell divides into two identical cells. The cell cycle has two major phases:

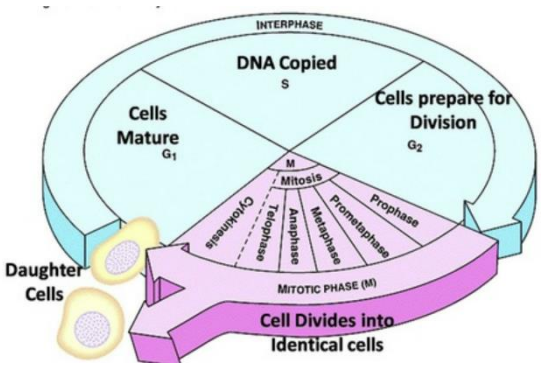
1- **interphase** – prepares the cell to division in 3 steps:

G_1 – cell growth, protein is synthesized for DNA synthesis, and organelles are duplicated

S – DNA and centromeres duplicate

G_2 – cell growth, centrosomes are duplicated

G_0 – zero gaps, cell leaves the cell cycle without dividing



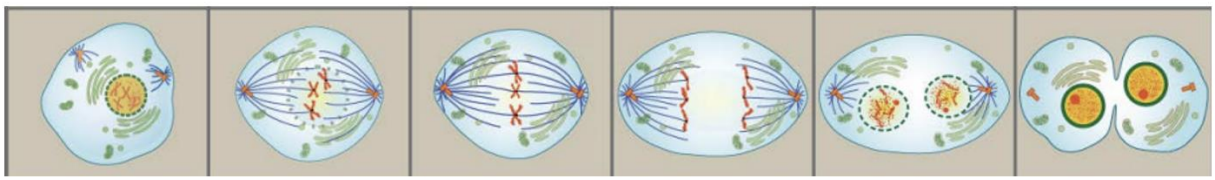
2- **mitosis** – a nuclear division of the cell, where duplicated chromosomes separate into two daughter cells.

Mitosis

The mitotic phase (M phase) is a multi-step process in which duplicated chromosomes align, separate, and move to the two identical daughter cells. Mitosis follows the interphase of the cell cycle.

Subphases of Mitosis:

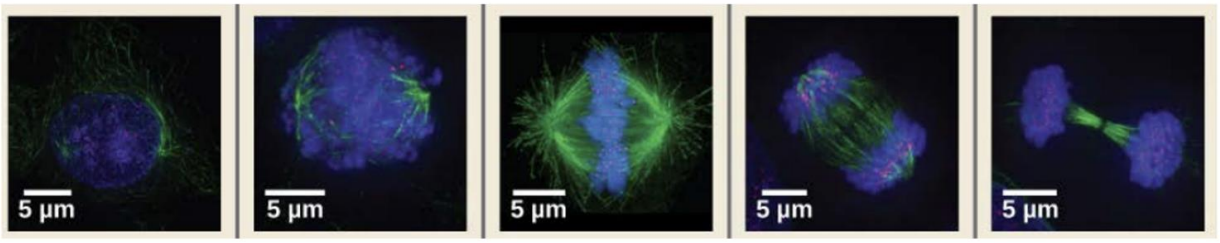
- **prophase** – the envelope around the nucleus breaks down, centrosomes move to the opposite sides of the cell, microtubules extend from centrosomes, chromosomes are visible
- **prometaphase** - chromosomes containing two sister chromatids develop protein (kinetochore), the spindle extends from centrosomes and attach to the chromosomes at the kinetochore
- **metaphase** - the chromosomes align in the equator of the cell (metaphase plate)
- **anaphase** - the sister chromatids separate, and each sister chromatid (now a chromosome) is pulled back by a centrosome
- **telophase** - chromosomes are at the opposite sides of the cell, two daughter nuclei form, an envelope around a nucleus reconstructs
- **cytokinesis** - in *animal cells*: a cleavage furrow forms and the cytoplasm separate into two daughter cells; in *plant cells*: a cell plate forms to separate the two daughter cells



prophase prometaphase metaphase anaphase telophase cytokinesis

Questions:

1. Recognize the stages of mitosis based on the given photographs:



2. Match the event in Mitosis with its description:
Anaphase -
Prophase -
Cytokinesis -
Telophase -
Metaphase -

(A) cytoplasm is divided
(B) mitotic spindle forms
(C) chromosomes line up across the center of the cell
(D) daughter chromosomes move toward opposite sides of the cell
(E) nuclear envelope rebuilds

3. Chromosomes replicate during which phase of the cell cycle?

A - mitosis

B - G1 phase

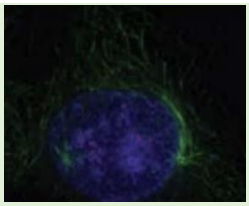
C - G2 phase

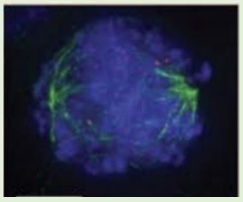
D - S phase

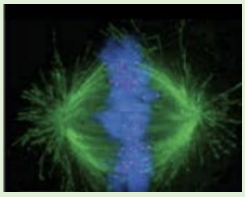
E - all the answers are correct

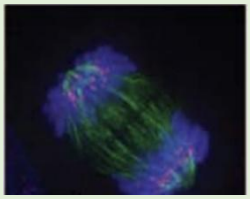
Answers:

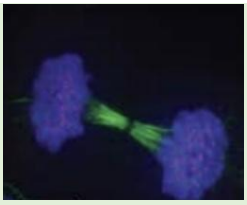
1. Recognize the stages of mitosis based on the given photographs:


prophase


prometaphase


metaphase


anaphase


telophase

2. Match the event in Mitosis with its description:

Anaphase – (D) daughter chromosomes move toward opposite sides of the cell

Prophase – (B) mitotic spindle forms

Cytokinesis – (A) cytoplasm is divided

Telophase – (E) nuclear envelope rebuilds

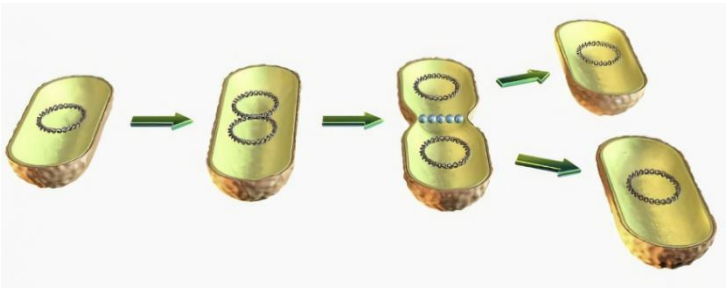
Metaphase – (C) chromosomes line up across the center of the cell

3. Chromosomes replicate during which phase of the cell cycle?

D - S phase

Prokaryotic Cell Division

Prokaryotes (bacteria and archaea) undergo binary fission, meaning a division of the cell in half. Bacterial chromosomes have circular DNA associated with proteins. Cell division begins from bacterial DNA replication and cell elongation. After DNA replication, the bacterial plasma membrane folds inward in the middle of the cell, forming a cell wall. As a result, there are two separate bacterial cells.



Question:

1. What is the correct order of stages in the bacterial cell division:

A) cell elongates, cell wall forms, genetic information duplicates, cell separates into two distinctive cells

B) cell wall forms, the cell divides, DNA duplicates, cell elongates

C) DNA replicates, cell elongates, cell wall forms, cell separates for the two distinctive cells

Answer:

C) DNA replicates, cell elongates, cell wall forms, cell separates for the two distinctive cells

Ch.7: The Cell Cycle and Meiosis

The Cell Cycle - Meiosis

Meiosis is the cell division that produces four haploid cells, each having n=23 chromosomes and called gametes (egg and sperm cells). The process starts from the diploid cell, having 46 chromosomes. In sexual reproduction, the genetic information given to the offspring comes from the union of the female and male gametes. The process takes two rounds, meiosis I and meiosis II, that follow interphase. During interphase, the cell is prepared for division in three steps: G1 - cell growth; S - chromosomes replication; G2 – cell growth

Meiosis I – separates homologous chromosomes

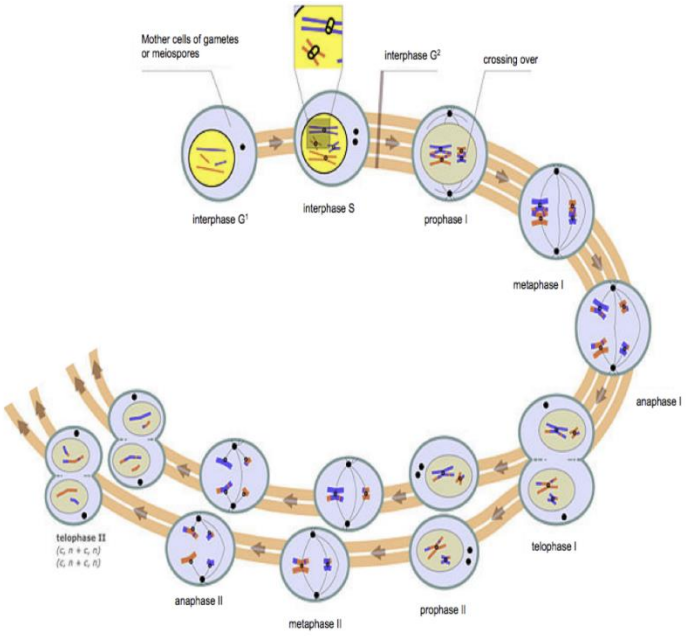
Prophase I – nuclear envelop begins to break down, centrosomes move to the opposite poles of the cell, spindle form, homologous chromosomes, each containing two sister chromatids become connected by a protein called synapsis, the segments of DNA exchange between non-sister chromatids in the process of crossing over, microtubules attach to the kinetochores of the homologous chromosomes

Metaphase I – pairs of homologous chromosomes line up on the metaphase plate

Anaphase I – homologous chromosome separate, are pooled to the opposite side of the cell

Telophase I – each half of cell has a haploid number of chromosomes containing two sister chromatids;

Cytokinesis I – cytoplasm division and formation of two haploid cells, each containing two sister chromatids



Meiosis II – separates sister chromatids

Prophase II – spindle extend, chromosomes have two sister chromatids move towards metaphase plate

Metaphase II – chromosomes are lined up on metaphase plate

Anaphase II – sister chromatids are separated and move to the opposite sides of the cell

Telophase II – nuclei form and chromosomes decondense

Cytokinesis II – four haploid daughter cells are produced

Errors in Meiosis

During the process of meiosis some abnormalities to the chromosome number or chromosome structural rearrangement can arise. The chromosome chart is the **karyogram that** represents the **karyotype,** which is the number and appearance of chromosomes. The human karyotype has 23 pairs of chromosomes. Each chromosome has two sister chromatids. An individual with 23 pairs of chromosomes is called euploid and has 22 pairs of chromosomes (autosomes) and one pair of sex chromosomes. The sex chromosomes for females are designed as XX and for males XY.

The errors in chromosome number are described as **aneuploidy**:

- monosomy (loss of **one chromosome**, X)
- trisomy (gain of **one chromosome**, XXY).

The errors in an individual with **more than one chromosome set** are called **polyploidy**. For example, an abnormal diploid egg (2n) with a normal haploid sperm (n) result in a **triploid** zygote (3n).

Another error is **nondisjunction** when pairs of homologous chromosomes in Meiosis I or sister chromatids in Meiosis II do not separate properly. In this case, one gamete receives two of the same chromosomes, and another gamete does not receive a copy of the chromosome.

Questions:

Match the phase name to the given description:

Crossing over occurs -

Cytoplasm divides into 2 separate cells -

Homologs line up along the middle of the cell -

Sister chromatids separate -

Not homologous chromosomes line up along the middle of the cell -

Spindle fibers move homologous chromosomes to the opposite sides of the cell -

Answers:

Crossing over occurs – Prophase I

Cytoplasm divides into 2 separate cells – Cytokinesis I

Homologs line up along the middle of the cell – Metaphase I

Sister chromatids separate – Anaphase II

Not homologous chromosomes line up along the middle of the cell – Metaphase II

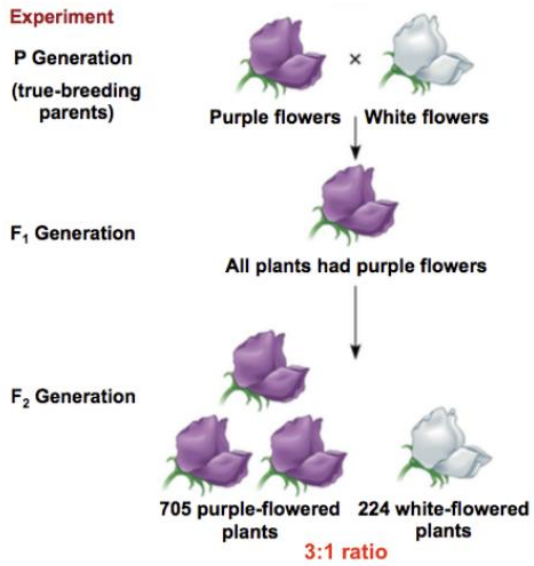
Spindle fibers move homologous chromosomes to the opposite sides of the cell – late Prophase I

Ch.8: Inheritance

Mendel's Experiment

Johann Gregor Mendel (1822-1884) used the garden true-breeding pea plant to study inheritance. The **true-breeding** pea plants are self-pollinated and never pollinated by other plants. Mendel performed hybridization by mating two true-breeding plants that have different traits. P-parental generation was crossed between purple and white flowers. F1 generation produced only purple flowers that self-fertilized, and the F2 generation presented ¾ purple plants and ¼ white (3: 1).

Mendel noticed that other than the plant color, the flowers had identical traits.



After repeating many times, in the same experiment, Mendel expressed the **dominant** traits are inherited and unchanged, but the **recessive** traits disappear over time.

Based on his experiment, Mendel developed **a model of inheritance** pattern 3:1 of inheritance:

1-alternative versions of genes are a reason for variations in inherited character (the gene for different flower color is an **allele**)

2-for each character, an organism inherits two copies of a gene, one from female and another for male

3-if there are two different alleles for a trait than the dominant allele determines the phenotype of the organism

4-two alleles of the trait segregate (separate) from each other and end up in a different gamete during Meiosis

Laws of Inheritance

In meiosis, chromosomes are separated into haploid cells (gametes). During the separation of the homologous chromosomes, only one of the sex chromosomes (X or Y) is passed into the gamete. Female gametes have only X chromosomes. Male gametes have X or Y chromosomes. Offspring develop having a diploid number of chromosomes (46) when the female and male gametes unite, each having a haploid (23) number of chromosomes. The diploid organism has two genetic copies of the same characteristic. For example, it may have a gene for white and a gene for red flower color. The variation of the gene on homologous chromosomes is called **alleles**. Two alleles for a given trait in a diploid organism are expressed by physical appearance and called **phenotype** (red or white color)**.** The genetic make–up for the trait is called **genotype.** The diploid organism that is **homozygous** for a gene has two identical alleles on homologous chromosomes, and their genotype is BB (dominant) or bb (recessive). The diploid **heterozygous** organism has two different alleles on the homologous chromosomes, and its genotype is Bb (one dominant and one recessive).

Genotype	Phenotype
BB Homozygous dominant	
Bb Heterozygous	
bb Homozygous recessive	

Law of dominance states that in a heterozygote (Bb) organism, only the dominant allele (B) will be expressed only the recessive allele (b) will not be expressed, but it will be transmitted to the offspring.

Law of Segregation

This law was developed based on Mendel's pea plant experiment in regard to the only one inherited character (flower color). Mendel noticed the pattern 3:1 (3 red:1 white) flower color for the F2 generation. Even though the F1 generation did not present the red flower color, the trait was passed to the F2 generation. Based on this finding, Mendel concluded that the red color is a *dominant* trait, but the white is *recessive*, masked, and still present in the F1 generation. All the F1 generation was **heterozygous (Bb)** for the one character. This type of cross is called a monohybrid cross. Relating to its discoveries, Mendel concluded **the Law of segregation**: the two alleles (Bb) for the same character (color) segregate during gamete formation.

Law of Independent Assortment

This law was developed based on Mendel's pea plant experiment in regard to two inherited characters (seed color and shape). Mendel crossed two true-breeding pea plants, one dominant for both traits: yellow and round (YYRR), the other one recessive for both traits: green and wrinkled (yyrr). The F1 generation resulted in dihybrid heterozygotes for both traits (YyRr) and produced four gametes: YR (dominant color and shape), Yr (dominant color and recessive shape), yR (recessive color and dominant shape), yr (recessive color and recessive shape). If the four sperm cells fertilize four egg cells, then there are 16 ways to express alleles inherited by offspring in F2 generation in the pattern 9:3:3:1. Based on this experiment, Mendel proposed **the Law of independent assortment,** stating that: alleles for one gene (color or shape) segregate into gametes independently of each other. This law applies only to genes (alleles pairs) on different chromosomes, not homologous chromosomes.

Monohybrid Cross

This type of cross is related to one inherited trait from two heterozygotes parents, each having a (Bb) allele. The two true-breeding parents contribute one out of the two alleles (B or b) to each offspring. The probability of the offspring's genotypic and phenotypic characteristics can be predicted using a **Punnett square**. All the possible combinations of parental alleles are listed on the top of the Punnett square (one parent) and on the side (another parent). The combinations of offspring alleles (diploid cells) are made in the boxes by combining the allele letters, one from the top and one from the side.

Parental generation:

P1 (male) - BB - blue eye color (homozygotes dominant)

P2 (female) - bb - green eye color (homozygotes recessive)

Gametes contributed by parents:

P1: B

P2: b

F1 generation: self-pollinated produces B and b gametes

F2 generation: Punnett square presents contributions of B and b gametes from P1 male and P2 female.

Inside the Punnett square are probabilities of the genotypes/ phenotypes of the offspring.

P1→ P2↓	B	b
B	BB	Bb
b	Bb	bb

The phenotypic ratio: 3 offspring are blue-eyed, and 1 offspring is green eye

The genotypic ratio: **3: 1** or 1: 2: 1

Dihybrid Cross

This type of cross is related to two inherited traits from two parents: one having (YYRR) and another having (yyrr) allele. The two true-breeding parents contribute one out of the two pairs of alleles (YYRR or yyrr) to each offspring. The probability of the offspring's genotypic and phenotypic characteristics can be predicted using a **Punnett square**. All the possible combinations of parental alleles are listed on the top of the Punnett square (male parent) and on the side (female parent). The combinations of offspring alleles are made in the boxes by combining the allele letters, two from the top and two from the side.

Parental generation:
P1 (male) - YYRR – yellow and round (homozygotes dominant for both traits)
P2 (female) - yyrr - green and wrinkled (homozygotes recessive for both traits)

Gametes contributed by parents:
P1: YR
P2: yr

F1 generation: dihybrid, heterozygotes for both traits YyRr, self-pollinated produces: YR, Yr, yR, yr gametes

F2 generation: Punnett square represents the contribution of YR, Yr, yR, yr gametes from F1 generation

Inside the Punnett square are listed probabilities of the genotypes/ phenotypes of offspring.

P→ P2 ↓	YR	Yr	yR	yr
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

The phenotypic ratio:

- 9 yellow and round
- 3 yellow and wrinkled
- 3 green and round
- 1 green and wrinkled

The genotypic ratio: **9: 3: 3: 1**

Sex-linked Disorder

Sex chromosomes are designed as X or Y. An egg cell carries an X chromosome. A sperm cells carry X or Y chromosomes. If an egg is fertilized by a sperm carrying an X chromosome, then the zygote develops into a female XX. If an egg is fertilized by a sperm carrying a Y chromosome, then the zygote develops into a male XY.

The gene located on either sex chromosome is called a sex-linked gene. Fathers carrying either X or Y chromosomes pass X-linked alleles to all their daughters but none to their sons. Mothers can pass the X-linked alleles to both sons and daughters.

If X-linked disease is caused by a recessive allele, then the female will express the phenotype only if she is homozygous for that allele. A male receiving a recessive allele from his mother will express the trait.

Questions:

1.Fill the blanks

Fathers carrying _____ or _____ chromosomes pass X - linked diseases to all of their _____but not to their _____. Mothers can pass the X-linked disorders to _____ and _____.

2. Predict genotype and phenotype monohybrid cross for the F2 generation. Father is heterozygous for a blonde hair color (Bb), and the mother is homozygous recessive for brown hair color (bb).

3. A homozygous tall plant (TT) is crossed with a heterozygous plant (Tt). What is the genotype in the F1 generation?

4. Match the definitions with the terms:

A. homozygous; B. heterozygous; C. alleles;

__1. Different forms of genes for the same trait

__2. Genotypes of two different alleles

__3. Genotypes of two the same alleles

Answers:

1. Fill the blanks

Fathers carrying __X___ or __Y___ chromosomes pass X - linked diseases to all of their _____daughters_____but not to their ___sons_____. Mothers can pass the X-linked disorders to __sons_____ and _____daughters_.

2. Predict genotype and phenotype monohybrid cross for the F2 generation. Father is homozygous dominant for a blonde hair color (BB), and the mother is homozygous recessive for brown hair color (bb).

P1 (male) - BB – blond hair color (homozygotes dominant)

P2 (female) - bb – brown hair color (homozygotes recessive)

Gametes contributed by parents:

P1 (male): B

P2 (female): b

F1 generations: self-pollinated produces B and b gametes

P1→ P2↓	B	b
B	BB	Bb
b	Bb	bb

***The phenotype*: 3 blonde and 1 brown hair color**

***The genotype*: 3: 1 or 1: 2: 1**

3. A homozygous tall plant (TT) is crossed with a heterozygous plant (Tt). What is the phenotype in the F1 generation?

P1→ P2↓	T	T
T	TT	TT
t	Tt	Tt

The phenotype: all plants are tall

4. Match the definitions with the terms:

A. homozygous; B. heterozygous; C. alleles;

_C_1. Different forms of genes for the same trait

_B_2. Genotypes of two different alleles

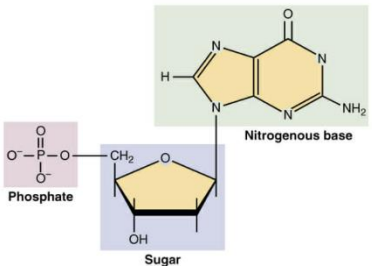
_A_3. Genotypes of two the same alleles

Unit 3. Molecular Biology

Ch. 9: Molecular Bases of Life

DNA

The building blocks of deoxyribonucleic acid (DNA) are nucleotides made up of a 5-carbon sugar (deoxyribose), a phosphate group, and a nitrogenous base.

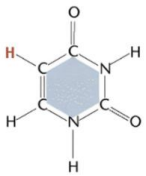


There are four nitrogenous bases: *2 purines*: Adenine (A) and Guanine (G), and *2 pyrimidines*: Thymine (T) and Cytosine (C).

The DNA structure was determined by James Watson and Francis Crick in the 1950s. The double helix is formed by two complementary strands. The two strands are formed from nucleotides combined by hydrogen bonds according to the rule: A --- T, G --- C.

RNA

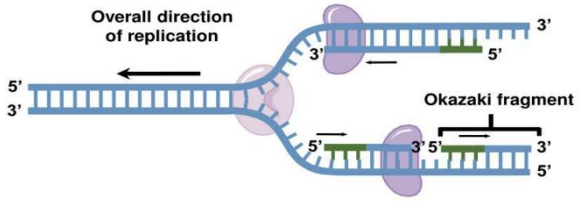
The building units of ribonucleic acid (RNA) are nucleotides made up of a 5-carbon sugar (ribose), a phosphate group, and a nitrogenous base. The four nitrogenous bases are: A --- U, G --- C. RNA is a single strand. There are known a few kinds of RNA acids involved in protein production: mRNA (messenger RNA), rRNA (ribosomal RNA), and tRNA (transfer RNA).



Uracil
U

DNA Replication

In the S phase of the cell cycle, before the process of mitosis or meiosis, the DNA is replicated. Adenine (A) always pairs with Thymine (T) and Guanine (G) with Cytosine (C). This is the complementary nature of the two strands.



The first step in DNA replication is the separation of the complementary strands with helicase. One strand became a Lagging, and another a Leading strand. DNA primase creates RNA primer. DNA polymerase adds nucleotides one by one to the complementary strand in the direction of 5' to 3' of the new, growing strand. Single strand binding proteins prevent the strands from coming back together. Topoisomerase relieves the tension from unwinding the DNA. DNA polymerase adds Okazaki fragments to the Lagging strand in the direction of 5' to 3' of the new strand. DNA ligase sticks the Okazaki fragments together.

Transcription

It takes place in the nucleus of the eukaryotic cell. The process starts from a characteristic sequence promoter TATA box. RNA polymerase adds RNA nucleotides to the template DNA strand according to the pattern (A – U, G – C). A cap joints the 5' end and Poly-A-Tail joints the 3' end of the new RNA strand. The noncoding introns are removed from the pre-mRNA, and coding exons are combined. The mature mRNA leaves the nucleus in the direction of 5'cap to a 3' Poly-A-Tail.

Translation

The process is called protein synthesis. It involves decoding mRNA into protein by tRNA. Different tRNA molecules translate mRNA codons into amino acids. Each tRNA carries a triplet nucleotide sequence (anticodon) which matches to codons carried by mRNA. The 5' mRNA end enters the cell's ribosome. Since the mRNA moves through the ribosome, the tRNA-s recognize the mRNA codons and attach to each with complementary anticodon while adding its amino acids into the growing polypeptide chain.

There are starting and stopping codons. For example, AUG translates into amino acid (Met, Methionine), or it is a starting codon. Repeated UAA, UAG, or UGA codons stop the process of translation.

First base	Second base: U	Second base: C	Second base: A	Second base: G	Third base
U	UUU, UUC: PHE; UUA, UUG: LEU	UCU, UCC, UCA, UCG: SER	UAU, UAC: TYR; UAA, UAG: STOP	UGU, UGC: CYS; UGA: STOP; UGG: TRP	U C A G
C	CUU, CUC, CUA, CUG: LEU	CCU, CCC, CCA, CCG: PRO	CAU, CAC: HIS; CAA, CAG: GLN	CGU, CGC, CGA, CGG: ARG	U C A G
A	AUU, AUC, AUA: ILE; AUG: MET or START	ACU, ACC, ACA, ACG: THR	AAU, AAC: ASN; AAA, AAG: LYS	AGU, AGC: SER; AGA, AGG: ARG	U C A G
G	GUU, GUC, GUA, GUG: VAL	GCU, GCC, GCA, GCG: ALA	GAU, GAC: ASP; GAA, GAG: GLU	GGU, GGC, GGA, GGG: GLY	U C A G

Questions:

1. Add complementary mRNA strand to the template strand:

3’-AAAACGCGGTTTACG- 5’

2. Add complementary DNA strand to the template strand:

3’-AAAACGCGGTTTACG- 5’

3. List the amino acids polypeptide chain coded by the sequence:

GUGGUUGCGGAACCUUGU

Answers:

1.Add complementary mRNA strand to the template strand:

3’-AAAACGCGGTTTACG- 5’

5’-UUUUGCGCCAAAUGC- 3’

2. Add complementary DNA strand to the template strand:

3’-AAAACGCGGTTTACG- 5’

5’-TTTTGCGCCAAATGC- 3’

3. List the amino acids polypeptide chain coded by the sequence:

GUGGUUGCGGAACCUUGU

Val-Val-Ala-Glu-Pro