General Biology (Biol. 1012)

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Chapter 1: Introduction

- At the end of this chapter you will be able to:
  - ✓ Define the term biology
  - ✓ Explain the scientific methods briefly
  - ✓ Explain the origin and nature of life

The meaning and scope of biology

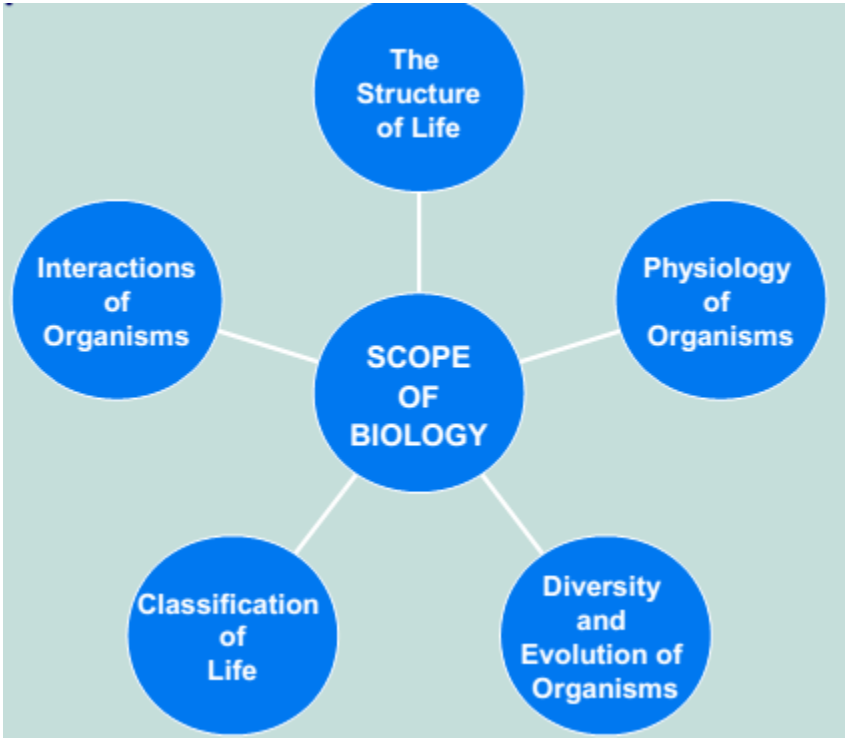
- What is meant by biology/Biological sci.?
- Who coined the term?
- What is the Scope of biology?

1.1 The meaning and scope of biology

- **Biological Sciences** is the study of life and living organisms.
- **Biology (Gk., *bios*, life; *logous*, study) is the study of living beings**
- **Also called *Life Science***
- The term biology was coined by Pierre-Antoine de Monet and Jean-Baptiste de Lamarck in the late 1700s.
- Earlier study of living things was restricted to the **pure Science** like Botany and Zoology that

Scope of biology

- **Biological Sciences** is an extensive study covering the **minute workings of chemical substances** inside living cells to the broad scale concepts of ecosystems and global environmenta



1.2 The origin and nature of life

- **What is life?**
- One of the biggest and most important of emergent phenomena is that of the origin or emergence of life.
- The mystery of life's origin is still **a big debating issue** in science.
- There are a number of theories about the origin of life.

  » ***Special Creationism***

  » ***Spontaneous generation***

1.2 The origin and nature….Cont’d

1. ***Theory of Special Creation***: according to this theory, all the different forms of life that occur today on planet earth have been created by **God, the almighty.**

1.2 The origin and nature of life

1. ***Theory of Spontaneous Generation***:

- this theory assumed that living organisms could arise **suddenly and spontaneously** from any kind of **non-living matter.**
- One of the firm believers in spontaneous generation was **Aristotle**, the Greek philosopher

Aristotle (384-322 BC).

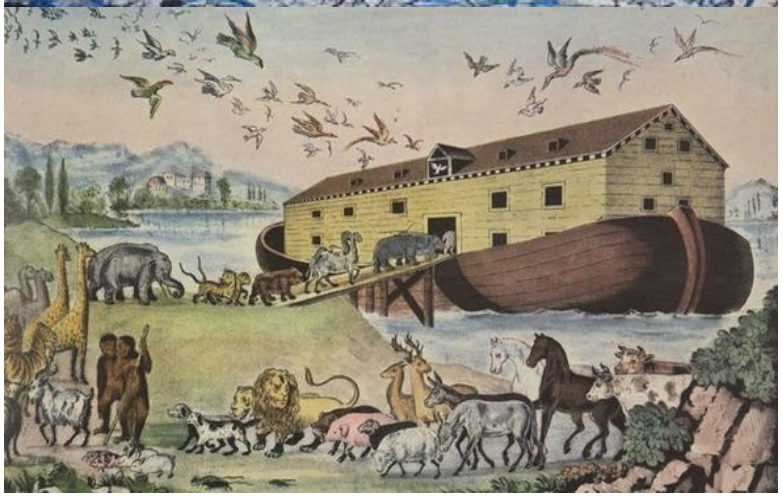
Francesco Redi-1626- 1697

Louis Pasteur 1822- 1895

1.2 The origin and nature….Cont'd

3. *Theory of Catastrophism*:

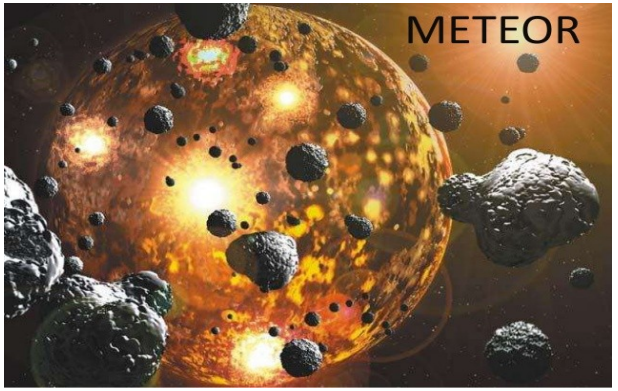
- It is simply a modification of the theory of Special Creation.
- It states that there have been several creations of life by God, each preceded by **a catastrophe** resulting from some kind of geological disturbance.
- Each **catastrophe** completely destroyed the **existing life**, each new creation consisted of life form different from that of previous ones.

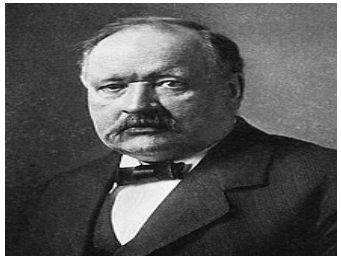


1.2 The origin and nature….Cont'd

4. *Cosmozoic Theory (Theory of Panspermia)*:

- life has reached this planet Earth from other heavenly bodies such as **meteorites**, in the form of highly **resistance spores** of some organisms.
- This idea was proposed by **Richter in 1865** and supported by **Arrhenius (1908)**.
- The theory did not gain any support.
- This theory lacks evidence, hence it was discarded.





Svante Arrhenius-Swedish

Elise Richter-Australia

1.2 The origin and nature….Cont'd

5. Theory of Chemical Evolution:

- Also known as **Materialistic Theory** or **Physico-chemical Theory**.
- Oparin and Haldane theory
- Origin of life on earth is the result of a slow and gradual process of **chemical evolution** that probably occurred about 3.8 billion years ago.
- This theory was proposed independently by two scientists - A. I. **Oparin**, a Russian scientist in 1923 and J.B.S **Haldane**, an English scientist, in 1928.
- The entire process of chemical evolution can be divided in the following steps/ways

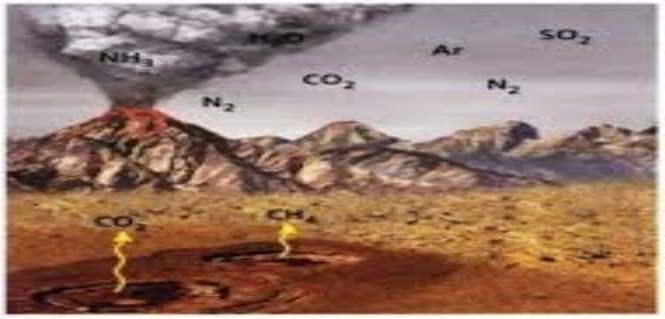


Figure 4 ► Earth's early atmosphere formed as volcanic eruptions released nitrogen, N_2; water vapor, H_2O; ammonia, NH_3; methane, CH_4; argon, Ar; sulfur dioxide, SO_2; and carbon dioxide, CO_2.

Origin of earth and primitive ATM

↓

Formation of NH4, CO2 and H2O vapor

↓

Synthesis of simple OCs

↓

Synthesis of complex OCs

↓

Formation of nucleic acids

↓

Formation of 1st cell

↓

Biological evolution

Nature and characteristics of life

- **Life** is defined as a "condition" that distinguishes animals and plants from **inorganic materials and dead organisms**.
- An individual living creature is called an **organism**. There are many characteristics that living organisms share. They all**:**

A. Irritability: the ability to be excited or detect stimuli and to respond thereto

B. Growth and reproduction: this consists of the power of multiplication and duplication, regeneration and differentiation

Nature and characteristics...Cont'd

C. Adaptability: permitting both change and maintenance of balances (homeostasis)

D. Metabolism: the transformation of energy and the use of materials. These properties, however, can be retained for a while by tissues after death of the organism so there is another mystery of life which we understand only in part.

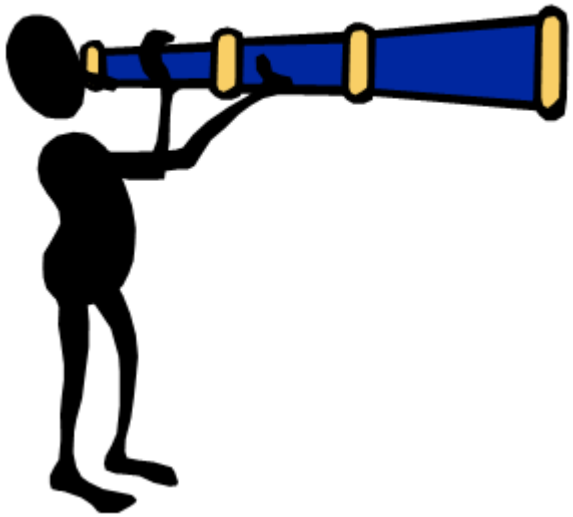
E. Excretion: *the removal from the cell of waste products of metabolism. In plant cells the major excretory products are oxygen from photosynthesis and carbon dioxide from cell respiration.*

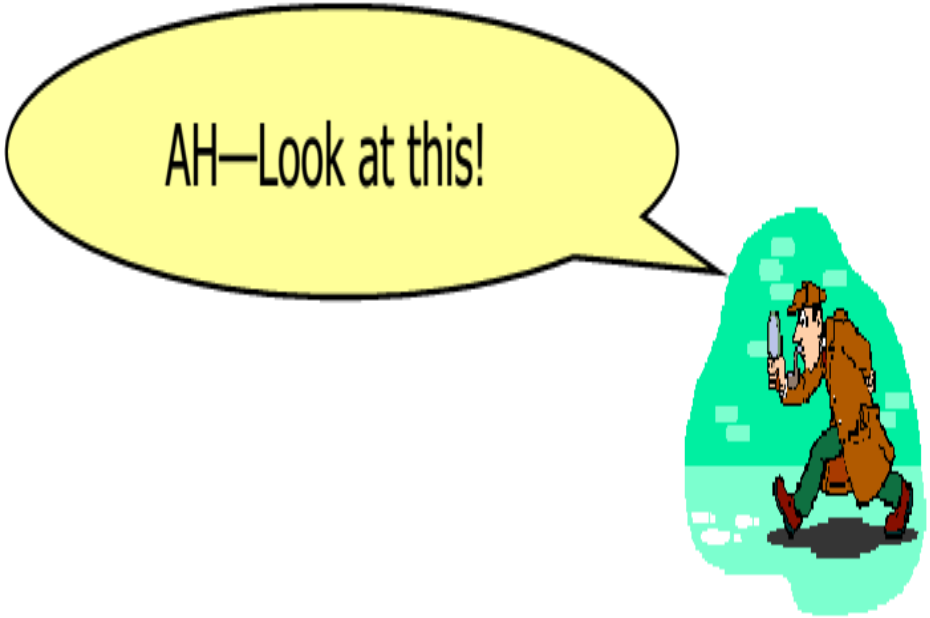
1.3 Scientific Methods

- **What is a scientific method?**
  - It is a process for experimentation that is used to explore observations and answer questions.
  - It is also the technique used in the construction and testing of a **scientific hypothesis.**
- The scientific method has five basic steps, plus one feedback step:
  - **Observation**
  - **Question or problem**
  - **Hypothesis**
  - **Experiment**
  - **Results/conclusions**
  - **Recommendations**

1.3 Scientific Methods…Cont’d

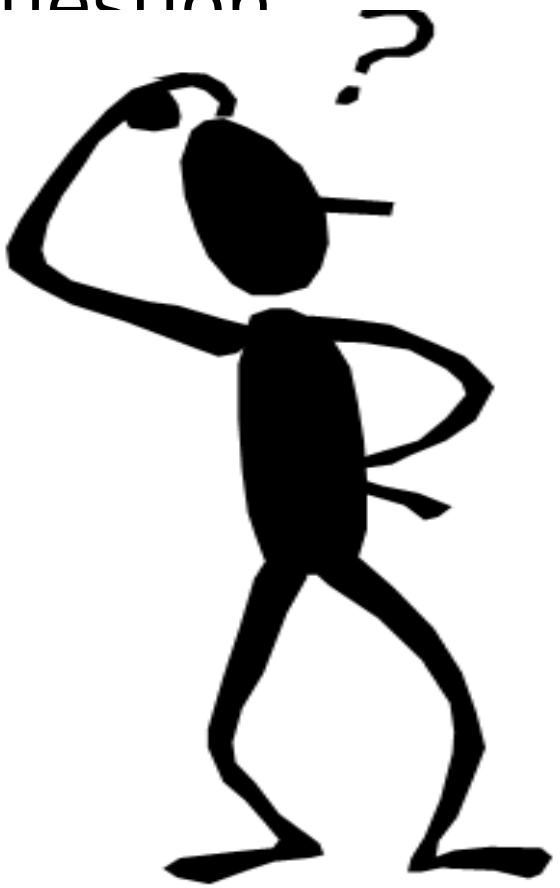
1. Observation- You observe something using your senses. What you see makes you ask a question or state a problem.





1.3 Scientific Methods...Cont'd

2. Problem or Question: You ask a question about what is being observed. State the problem or question

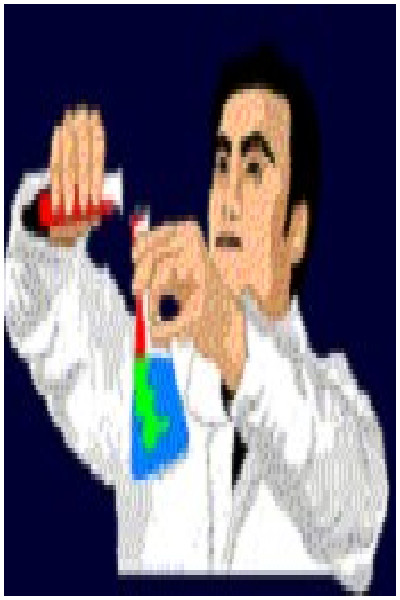


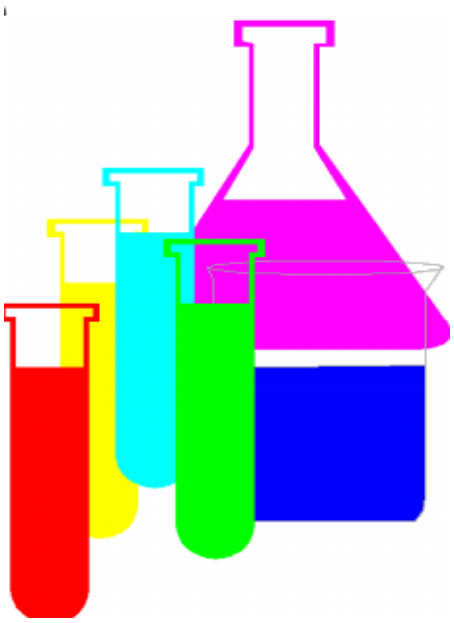
1.3 Scientific Methods...Cont'd

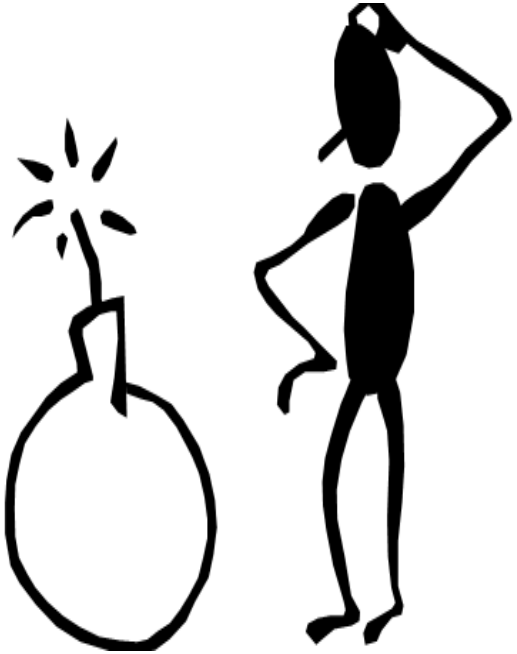
3. Hypothesis-You make an educated guess on what you think the outcome of the experiment, or the answer to your question will be.

1.3 Scientific Methods...Cont'd

4. Experiment- You figure out a way to test whether the **hypothesis is correct**. The outcome must be measurable. **Record** and **analyze** data.







1.3 Scientific Methods...Cont'd

5.Results/Conclusion. You will record the results of your experiment, and repeat the experiment if need be. You will state if your **hypothesis was accepted or not** and try to explain your results.

- ***Rejected Hypothesis*** *- An explanation that has been ruled out through experimentation.*
- ***Accepted Hypothesis*** *- An explanation that has not been ruled out through excessive experimentation and makes verifiable predictions that are true.*

1.3 Scientific Methods...Cont'd

- **Summary of the scientific method**

Step 1: Observe behavior or other phenomena

Step 2: Form a tentative answer or explanation (a hypothesis/guess a reason)

Step 3: Use your hypothesis to generate a testable prediction

Step 4: Make systematic, planned observations (data collection)

Step 5: Results and Discussion Use the observations to evaluate (support, refute, or refine) the original hypothesis

Step 6: Conclusion

Step 7: Recommendation

Exercise

Q1. Which step in the Scientific Method is given here?

1. If I water and feed the plants, then they will grow to be tall and healthy.
2. My hypothesis is accepted. When I watered and fed the plants daily, they grew.
3. Today while walking home, I noticed that the plants in my front yard were starting to die.
4. Why is it that some plants are growing, and other plants are dying? What affects the growth of plants?
5. To answer my questions, I watered and fed the plants daily and recorded my findings.

1. hypothesis

2. Results/Conclusi

3. observation

4. Problem/Questio

5. An experiment

Observe

Question

Hypothesis

Experiment

Results/Conclusion

Chapter two
2. Biomolecules

- **Biological molecules** are the molecules of life (bio-molecules) that are basically found in a living cell and categorized as **organic** and **inorganic** molecules in general.
- Each member of the groups is vital for every single organism on Earth.
- The organic biomolecules are proteins, carbohydrates, **lipids** and **nucleic acids.**
- Without any of these four molecules, a cell and organism would not be able to live**.**

2.1 Carbohydrates

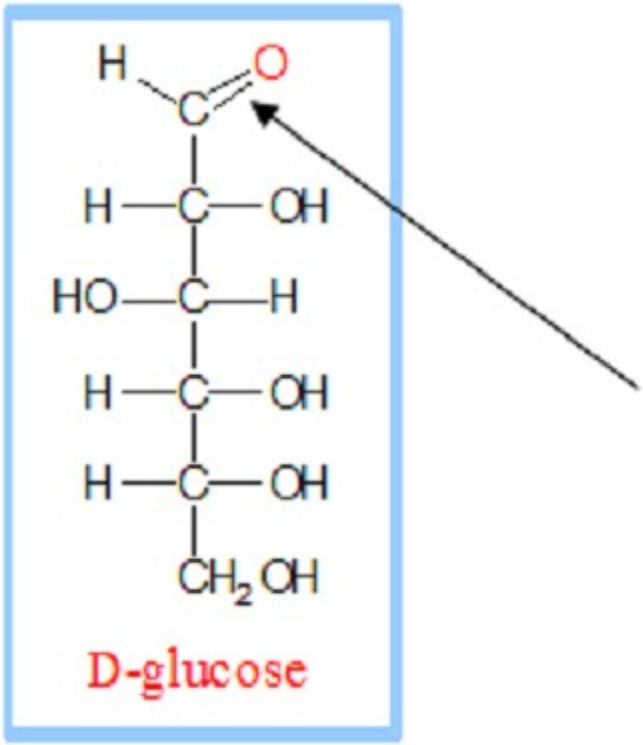
- Carbohydrates are the most abundant macromolecules in nature.
- They are the main source and storage of energy in the body.
- They serve also as structural component of cell membrane.

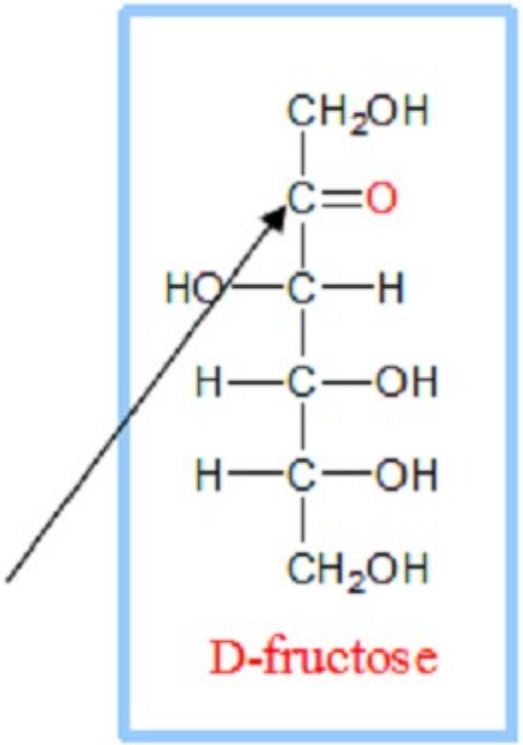
The general molecular formula of carbohydrate is $C_nH_{2n}O_n$ or $(CH_2O)_n$, where $n > 3$.

H and O are in a ratio of 2:1

- Carbohydrates in general are **polyhydroxy aldehydes** or **ketones** or compounds which give these substances on hydrolysis.

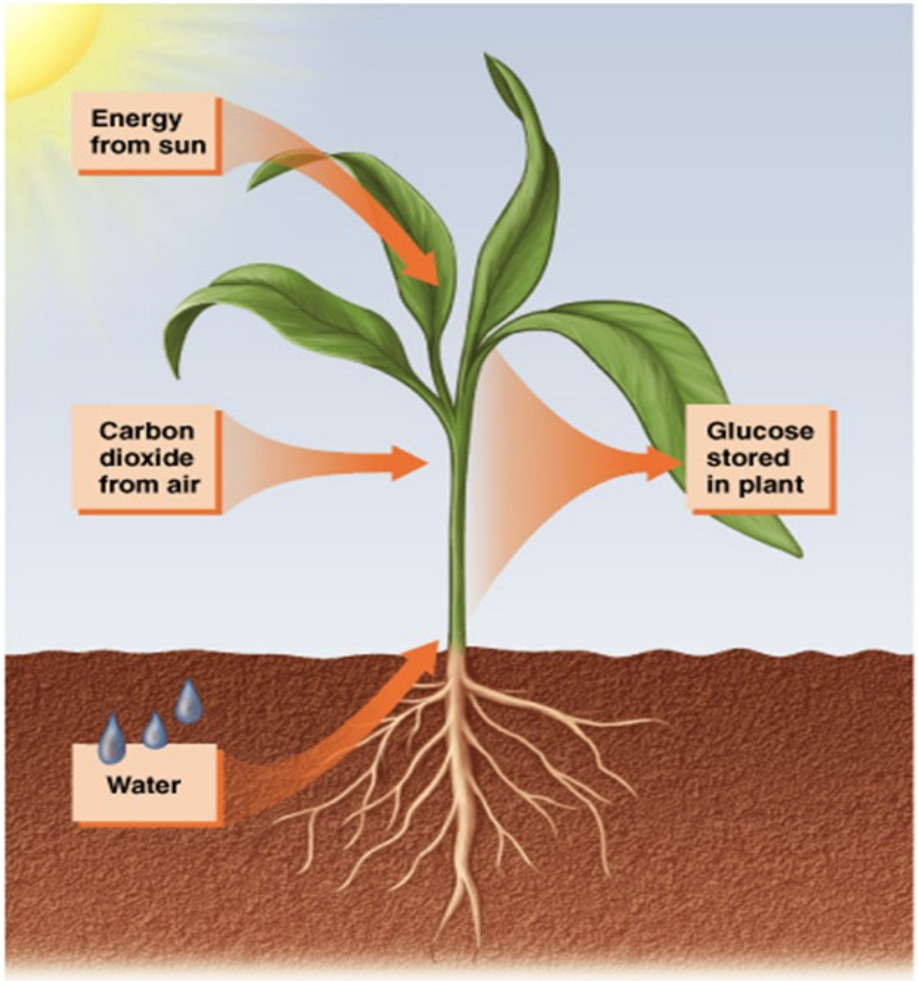
- **Polyhydroxy aldehydes** or ketones are molecules with more than one hydroxyl group (−OH), and a carbonyl group (C=O) either at the terminal carbon atom (aldose) or at the second carbon atom (ketose) are called carbohydrates.
- Glucose is an **aldehyde** while **fructose** is a





Where do Carbohydrates originate?

- As glucose in plants!
- Glucose
  - Most abundant carbohydrate
  - Produced by plants (& other photosynthetic microorganisms) via photosynthesis
- Simple or



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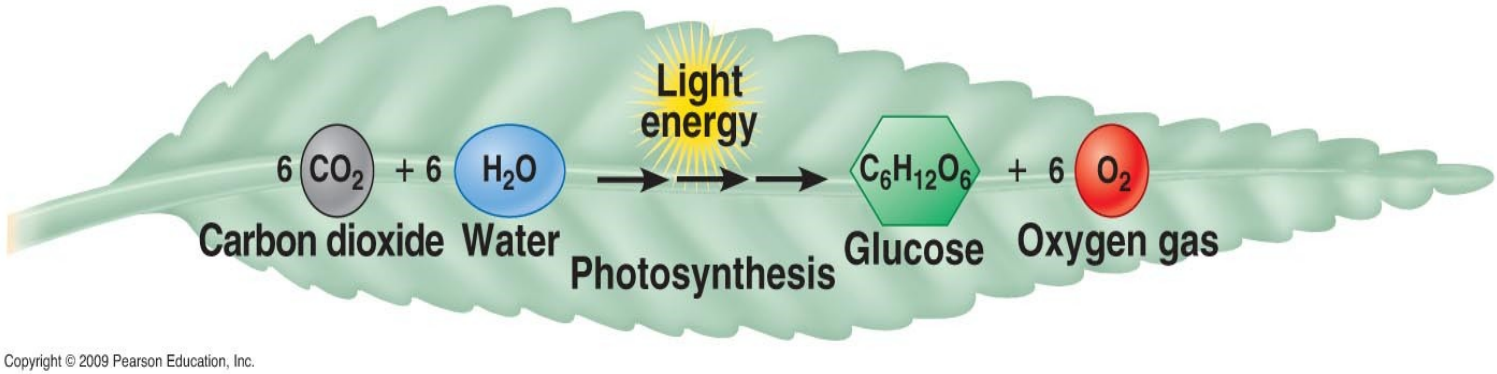

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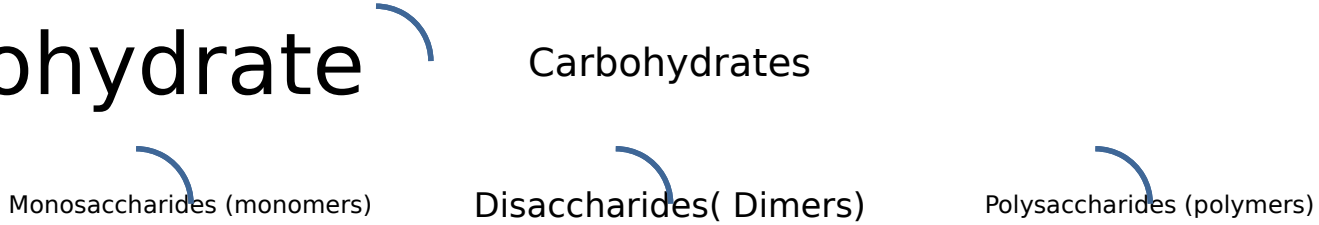
This is the general equation for photosynthesis—the process of capturing sunlight energy and converting it to chemical energy.

Reactions involving carbohydrates

Dehydration synthesis: joining two molecules by removing water

Hydrolysis: splitting two molecules by adding water

Classification and Structure of carbohydrate



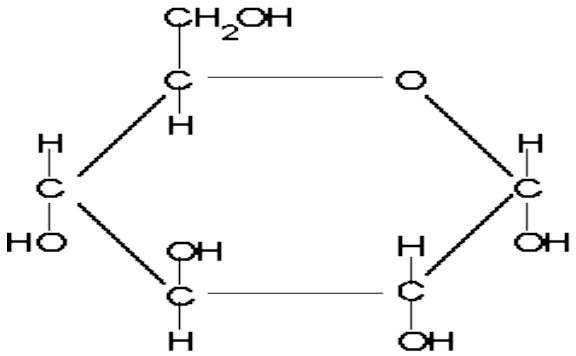
Monosaccharaides

- Monosaccharaides are also called simple sugars.
- They consist of a single polyhydroxy aldehyde or ketone units.
- The most abundant monosaccharaides in nature are the **6-carbon sugars** like glucose and fructose.

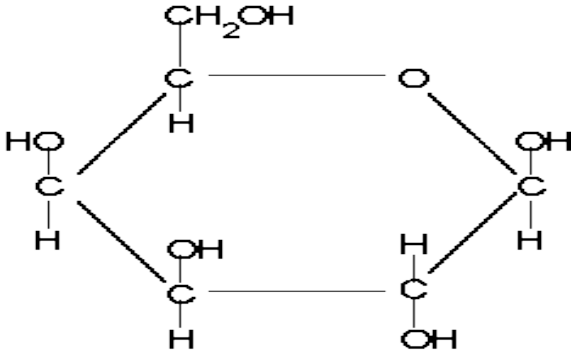
Monosaccharides

$C_6H_{12}O_6$

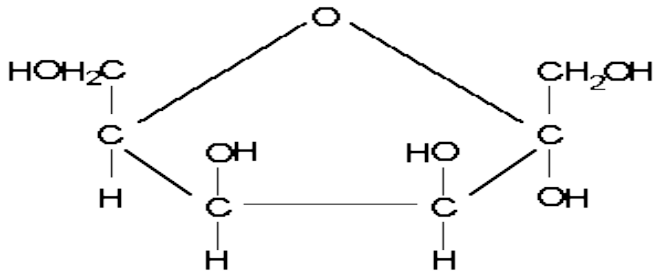
- Fructose: 5 atom ring
- Galactose: 6 atom ring
- Glucose: 6 atom ring



Glucose



Galactose



Fructose

Cont'd...

Glucose

- Glucose is the most important carbohydrate fuel in human cells.
- Its concentration in the blood is about 1 gdm-3.
- The small size and solubility in water of glucose molecules allows them to pass through the cell membrane into the cell.
- Energy is released when the molecules are metabolized.
  - **glucose + glucose = maltose**
- Starch and cellulose are polysaccharides made up of glucose units.

Cont'd...

Galactose

- Galactose molecules look very similar to glucose molecules.
- They can also exist in α and β forms.
  - **Galactose + glucose = Lactose**
- However, glucose and galactose cannot be easily converted into one another.
- Galactose cannot play the same part in respiration as glucose.

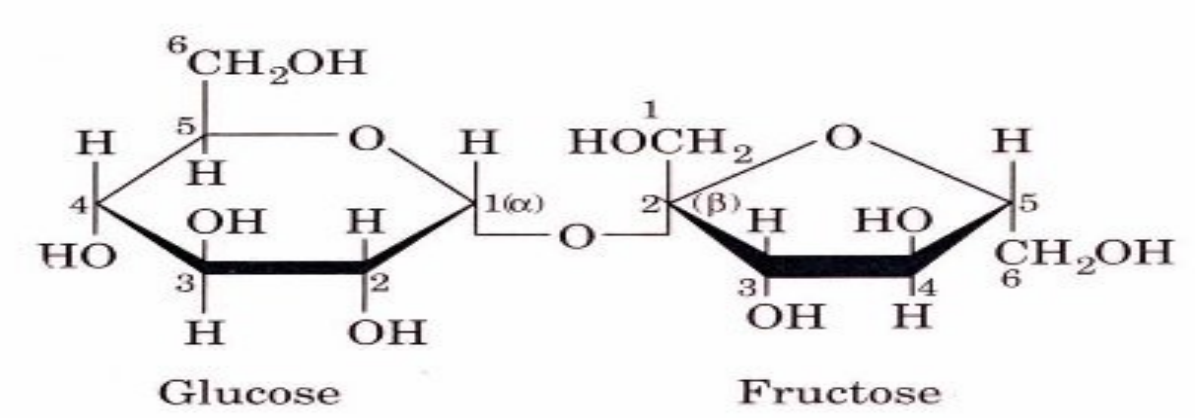
Fructose

- Fructose, glucose and galactose are all hexoses.
- However, whereas glucose and galactose are **aldoses** (**reducing sugars**), **fructose** is a **ketose** (a **non-reducing sugar**).
  - **Fructose + glucose =**

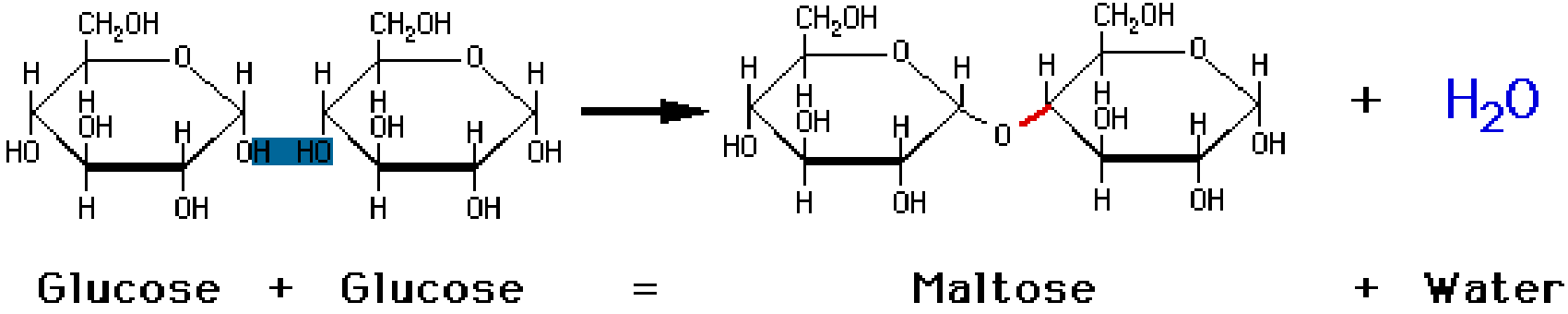
Disaccharides

- Most sugars found in nature are **disaccharides**.
- Disaccharides are soluble in water, but they are too big to pass through the cell membrane by diffusion.
- They are broken down in the small intestine during digestion to give the smaller monosaccharides that pass into the blood and through cell membranes into cells.
- **A condensation reaction** takes place by releasing water and process requires energy.
- A **glycosidic** bond forms and holds the **two** monosaccharide units together.
- The three most important disaccharides are **sucrose**, **lactose** and **maltose**.
- They are formed from the a forms of the appropriate monosaccharides. **Sucrose** is a

- Lactose: glucose + galactose
- Maltose: glucose + glucose
- Sucrose: glucose + fructose



sucrose


Glucose + Glucose = Maltose + Water
Galactose + Glucose = Lactose + Water

Polysaccharides

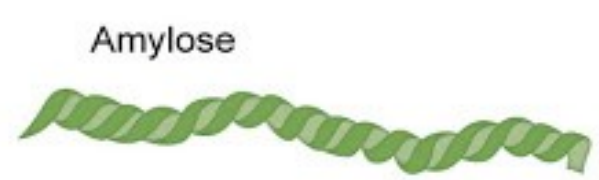
- Monosaccharides can undergo a series of condensation reactions, adding one unit after another to the chain until very large molecules (polysaccharides) are formed.
- This is called **condensation polymerisation**, and the building blocks are called **monomers**.

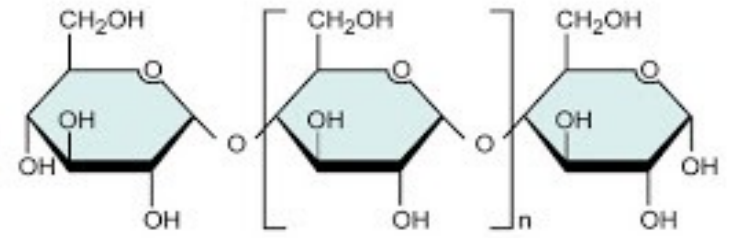
Starch

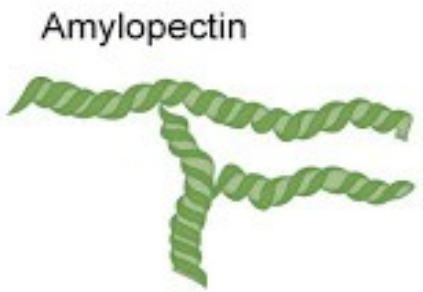
- Starch is often produced in plants as a way of storing energy.

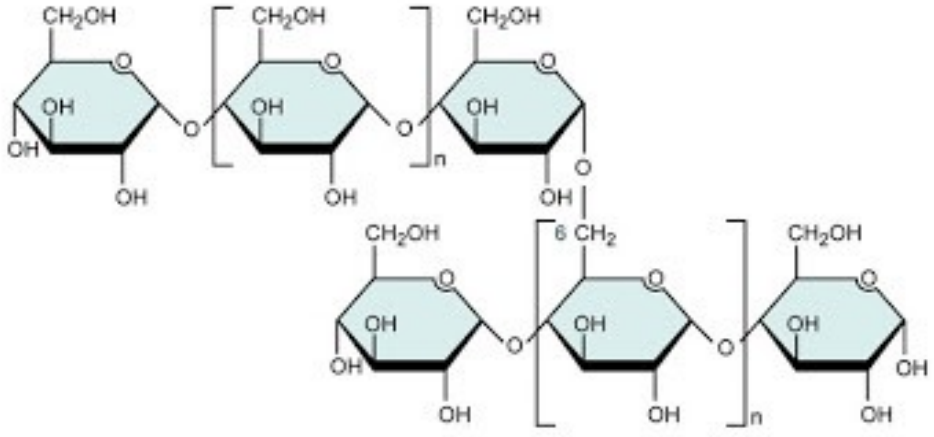
It exists in two forms: **amylose** and **amylopectin**. Both are made from α-glucose.

- **Amylose** is an unbranched polymer of glucose.
- The molecules coil into a helical structure
- **Amylopectin** is a branched polymer of g[illegible] le in w[illegible]









Cellulose

- Cellulose is the most abundant structural polysaccharide in plants. It is fibrous, tough, water insoluble.
- Cellulose is a linear unbranched Homopolysaccharides of 10,000 or more D- glucose units connected by β-(1, 4) glycosidic bonds.
- Humans cannot use cellulose because they lack of enzyme (cellulase) to hydrolyze the β-(1-4) linkages.
- The stomachs of Herbivores contain a specific enzyme called cellulase which enables them to digest cellulose.

Glycogen

- Glycogen is the main storage polysaccharide of animal and fungal cells (Animal starch).
- Like amylopectin glycogen is a branched polysaccharide of D-glucose units in α - (1, 4) linkages, but it is highly branched.
- Glycogen is amylopectin with very short distances between the branching side-chains.
- Starch from plants is hydrolysed in the body to produce glucose.
- Glucose passes into the cell and is used in metabolism.
- Inside the cell, glucose can be polymerised to make glycogen which acts as a carbohydrate energy store.

2.2 Lipids

- Lipids comprise very heterogeneous group of compounds which are **insoluble** in water but **soluble** in non-polar organic solvents such us benzene, chloroform, and ether.
- They are present in all living organisms. The group includes **fats**, **oils**, **waxes** and related compounds**.**
- The primary function of lipids is to store energy

General function of lipids

I. They are efficient energy sources.

II. Serve as thermal insulators.

III.They are structural components of the cell membrane.

IV. Serve as precursors for hormones (steroid hormones).

V. They also dissolve the **vitamins**, which are fat-soluble and assist their digestion

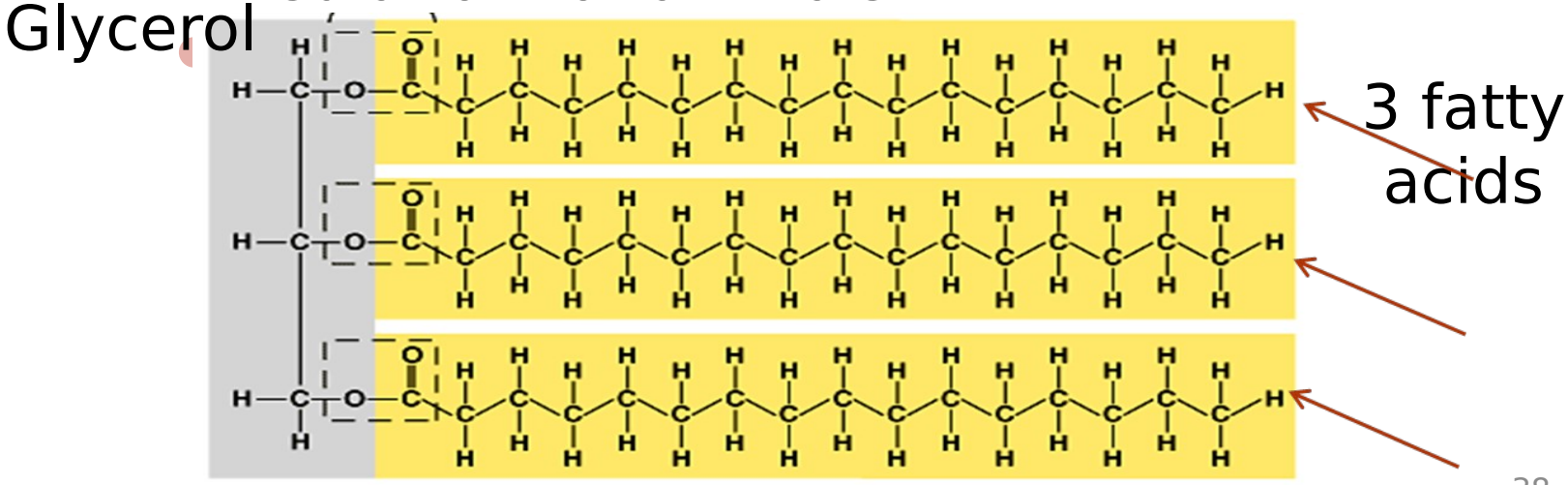
- Lipids are organic molecules essential for life that are composed mostly of C, H, O.

4types of lipids

- **Fats** (triglycerides)
- **Phospholipids**
- **Steroids**
- **Waxes**

Cont'd…

- Storage lipids, e.g., triacylglycerols, make up the **fats** and **oils** used by most organisms as stored forms of energy.
  - **Triglycerol**
  - Fat molecules
    - Structure = 3 fatty acids chains linked to glycerol
    - Functions = long term energy storage and insulation for animals



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- A lipid called a triglyceride is a fat if it is solid at room temperature and an oil if it is liquid at room temperature.
- In addition, triglycerides are stored in the fat cells , also called adipocytes or lipocytes, and are responsible in storing fats and lipids which will facilitate energy store in animal's body.
- Fat cells are categorized in white fat cells and brown fat cells. The different is made from their ways of storing lipids.
- White fat cells store one large lipid drop while brown fat cells store smaller and multiple droplets of lipids spreading in the whole body of the cell.

- Lipids that have tail chains with only single bonds between the carbon atoms are called **saturated fats** because no more hydrogens can bond to the tail
- Lipids that have at least one double bond between carbon atoms in the tail chain can accommodate at least one more hydrogen and are called **unsaturated fats**.
- Fats with more than one double bond in the tail are

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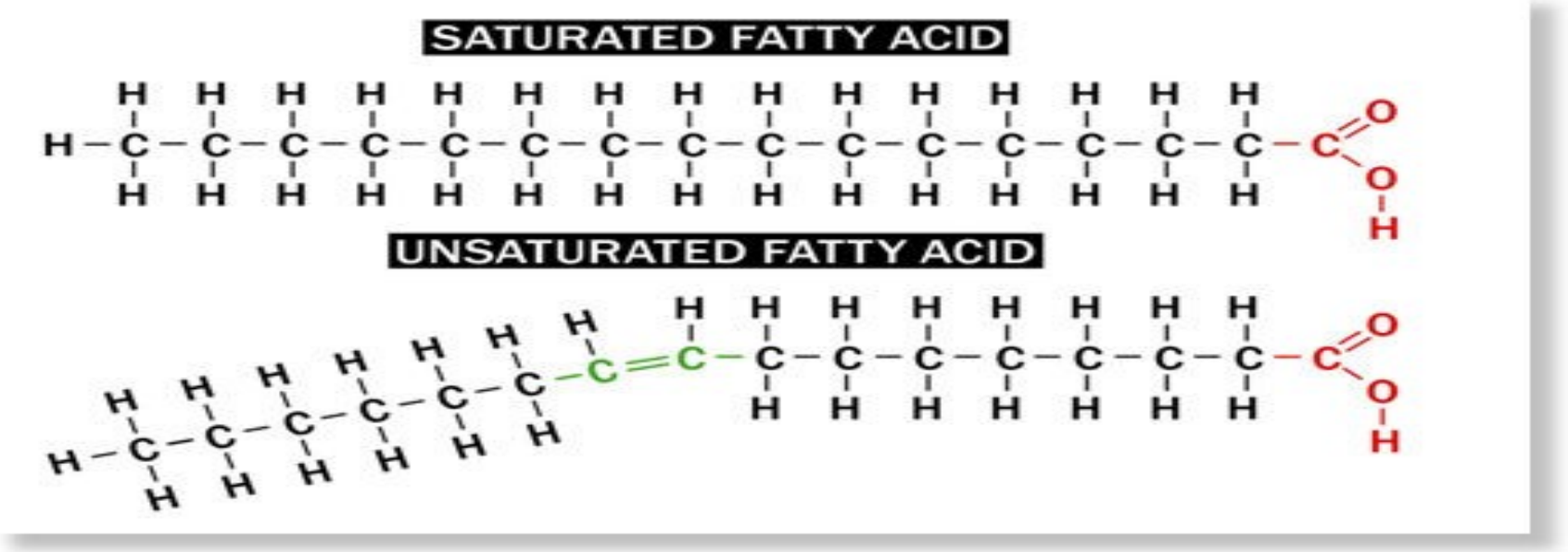
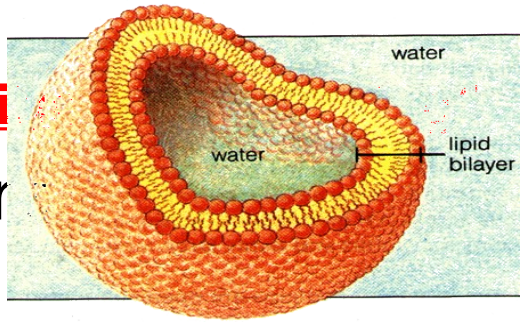
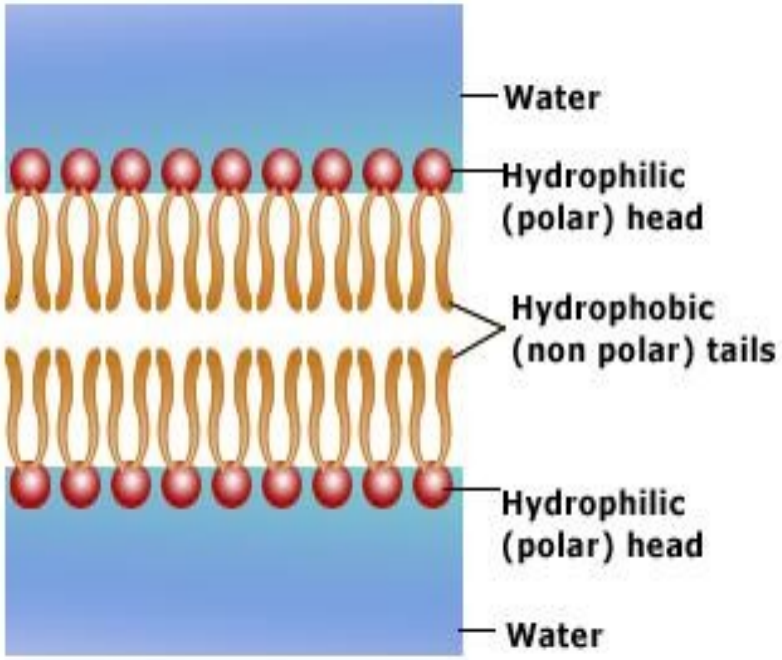
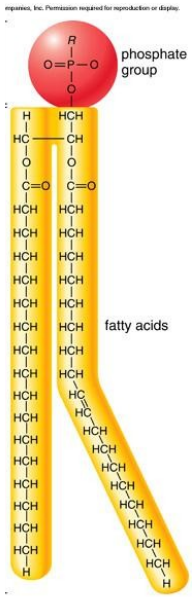


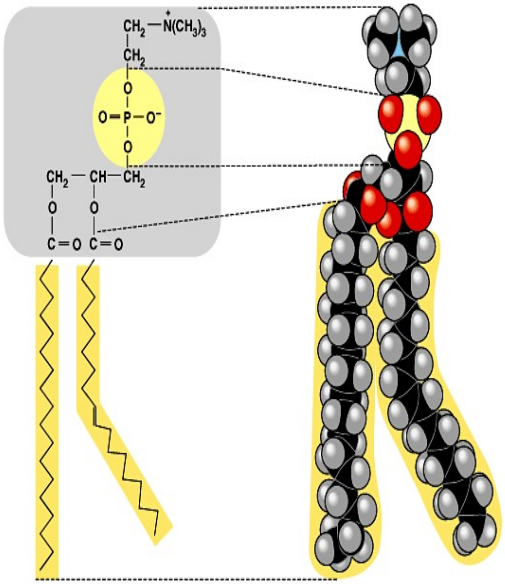
Phospholipids

- Structure: 2 fatty acids chains + phosphate head
  - Fatty acid chains = non-polar = **hydrophobic** "water fearing"
  - Phosphate head = polar = **hydrophi**
- Function: make up cell membr

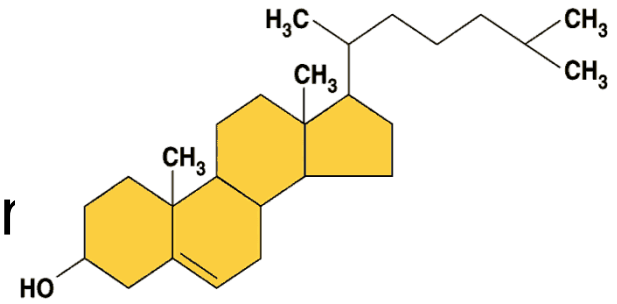




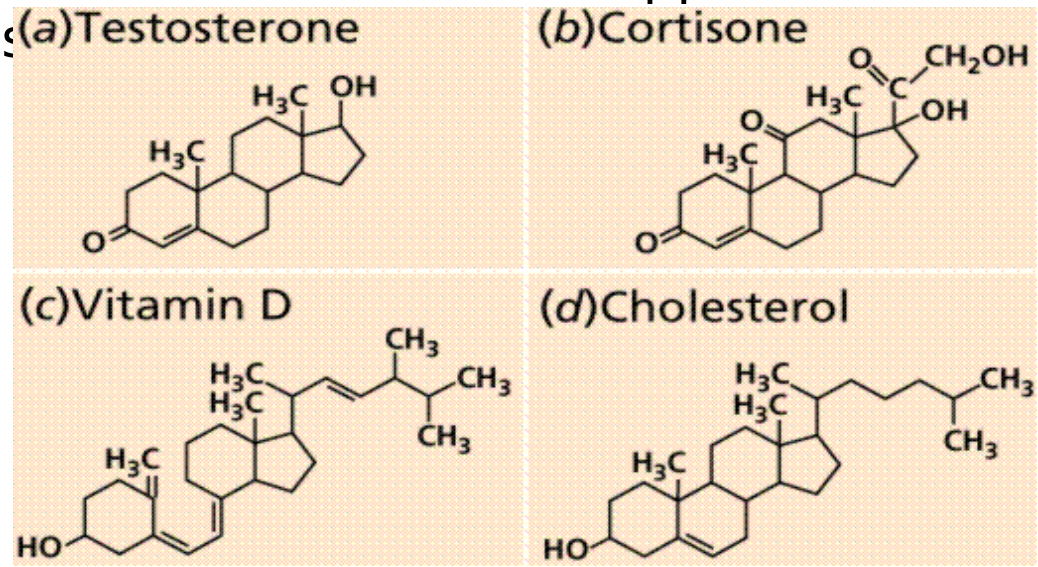




Steroids



- **Structure:** 4 fused Carbon r
- examples:
  - **cholesterol** – Function =control the fluidity of the cell membrane
  - **hormones** – Function = regulate processes in the body (such as pregnancy)
  - **vitamins** (A, B, D) – Function = supports metabolism and cell proces



Waxes

- Solid at room temp
- Insoluble in water
- Function:
  - Protective covering f animals and plants
- Examples:
  - Beeswax
  - Earwax
  - Cuticle of leaf (keeps water in

- A protein is a compound made of small carbon compounds called **amino acids**.
- Amino acids are small compounds that are made of C, N, O, H, and sometimes S.
- All amino acids share the same general structure.
- Amino acids have a central carbon atom like the one shown in Fig. 2.3.
- Proteins are made of different combinations of all 20 different amino acids.
- Several covalent bonds called **peptide bonds** join amino acids together to form proteins.

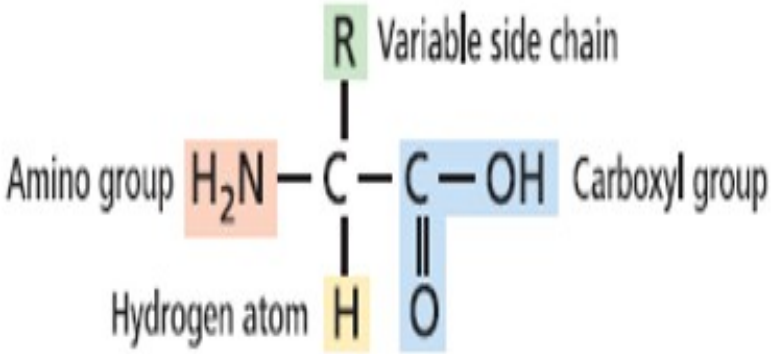


Fig: 2.3. Basic structure of amino acid

2.4 Nucleic acid

- **Nucleic acids** are comp macromolecules that store a transmit genetic information.
- There are two types of nucl acids in living organisms:
  - deoxyribonucleic acid (DNA) and
  - ribonucleic acid (RNA)
- Nucleic acids are made of smaller repeating subunits called **nucleotides**.
- Nucleotides are composed of **C**, **N**, **O**, **P**, and **H** atoms arranged as shown in Fig. 2.5.

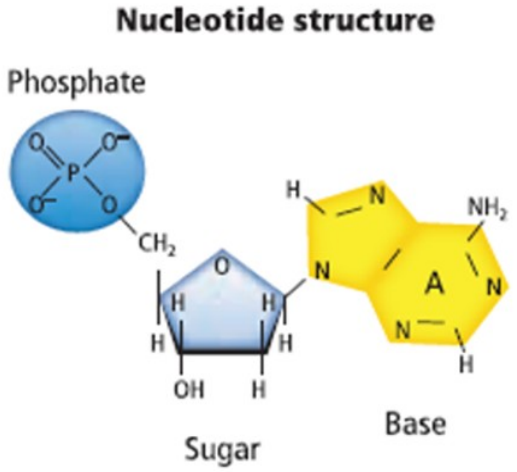


Fig: 2.5. Basic structure of nucleotide

- There are five different bases found in nucleotide subunits that make up DNA and RNA:-
  - **Adenine, Cytosine, Guanine, Thymine and Uracil.**
    - **DNA G, A, C and T; in RNA U is used in place of T**
- Each of these nitrogenous base that sticks out from the chain is available for hydrogen bonding with ot

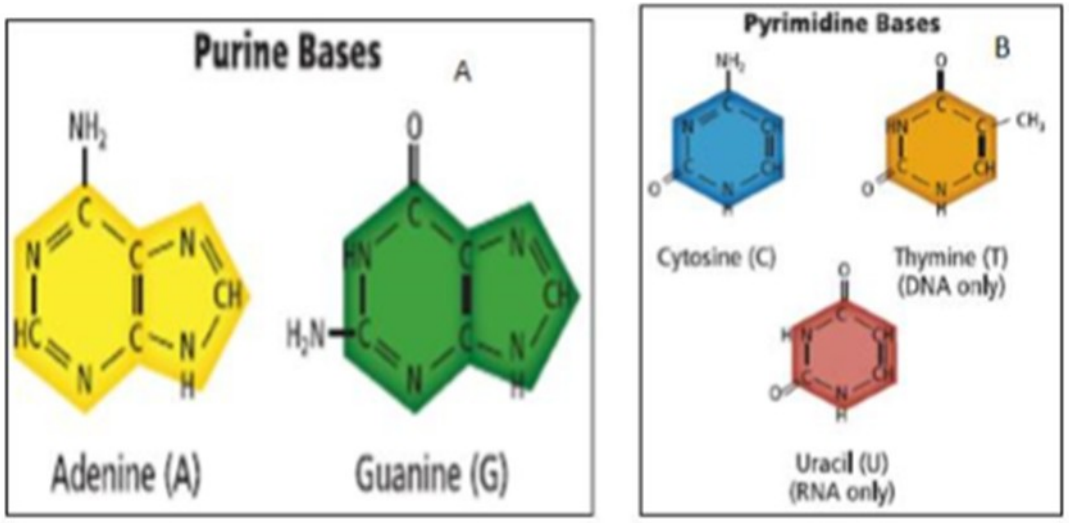


Fig: 2.6. Nitrogenous bases

2.5. Vitamins

- **Vitamins** are organic compounds that are needed in small amounts for metabolic activities.
- **Vitamin D** is made by cells in your skin and Some B vitamins and vitamin K are produced by bacteria living in the large intestine.
- Sufficient quantities of most vitamins cannot be made by the body, but a well-balanced diet can provide the vitamins that are needed.
- Some vitamins that are **fat-soluble** can be stored in small quantities in the liver and fatty tissues of the body.
- Other vitamins are **water-soluble** and cannot be stored in the body. Foods providing an adequate level of these vitamins should be included in a person's diet on a regular basis.

Vitamin A	Beneficial in treating eye disorders, skin infections
Vitamin B9	Reduces risk of neural tube defects during pregnancy
Vitamin B12	Provides relief from symptoms of anemia, kidney and liver disorders
Vitamin C	Helps treat scurvy, cancer and common cold
Vitamin D	Aids in treating arthritis, tooth decay, diabetes and rickets
Vitamin E	Improves blood circulation and slows down aging process
Vitamin K	Reduces risk of menstrual pain and internal bleeding

2.6 Water

- **Water molecules** are formed by covalent bonds that link two hydrogen (H) atoms to one oxygen (O) atom, and each water molecule has the same structure.
- It is one of the most plentiful and essential of compounds, which is a tasteless and odourless, existing in gaseous, liquid, and solid states.

2.7. Minerals

- **Minerals** are inorganic compounds used by the body as building material, and they are involved with metabolic functions.
- For example, the mineral iron is needed to make Hemoglobin and it binds to Hemoglobin in red blood cells and is delivered to body cells as blood circulates in the body.
- **Calcium**, and other minerals, is an important component of bones and is involved with muscle and nerve functions and they serve as cofactors for enzymes.
- **Magnesium** is an important component of the green pigment, chlorophyll, involved in photosynthesis.

Summary

Biomolecules

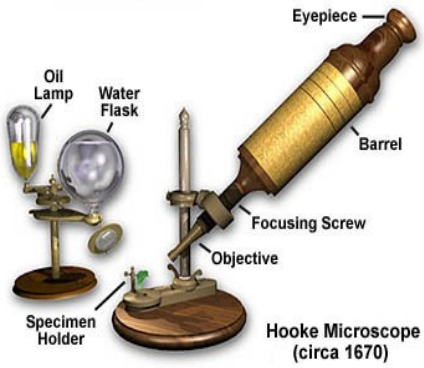
Organic Molecule	Building Block	Functions	Elements	Examples
carbohydrate	monosaccharide	provide energy	C, H, O	starch, glycogen, cellulose
lipid	fatty acids	energy storage protection insulation	C, H, O	fats, oils, waxes, steroids
protein	amino acids	structural components, contracting muscle tissue, transport O_2, immunity, regulates other proteins, chemical reactions	C, H, O, N, S	enzymes
nucleic acid	nucleotides	stores cellular info in the form of a code	C, H, N, P	DNA RNA

What is cell ?

- Cell is fundamental, structural and functional unit of all organisms.
- A cell is the smallest unit that can perform all the functions necessary for life.

- Followed by the development of the microscope

A. In 1665 an English physicist Robert Hooke, discovered cells in a piece of cork, which he examined under his primitive microscope.



- He observed honey combed or porous structures and is the first to gave the name “cells” which means little rooms/small compartments.

B. in 1675 Anton van Leeuwenhoek , a Dutch businessman and a contemporary of Hooke used simple microscope to look at pond water.

- He Observed living cells through a simple microscope or was the first to observe microorganisms in pond water.

C. In 1838, Matthias Schleiden, a German lawyer turned botanist, concluded that, despite differences in the structure of various tissues, plants were made of cells and that the plant embryo arose from a single cell.

c

D. In 1839,Theodor Schwann, a German zoologist and colleague of Schleiden's, published a comprehensive report on the cellular basis of animal life.

- Schwann concluded that the cells of plants and animals are similar structures.

E. By 1855, Rudolf Virchow, a German pathologist, Cells can arise only by division from a preexisting cell.

3.1. The Cell Theory include:

- All known living things are made up of one or more cells.
- The cell is the fundamental unit of structure and function in all living organisms. Or it is the basic unit of life which can perform life processes.
- All living cells arise from pre-existing cells by division.

- **A typical eukaryotic cell has 3 major parts:**
- **plasma membrane: the outer boundary of the cell.**
- **cytoplasm: the intracellular fluid packed with organelles, small structures that perform specific cell functions.**
  - **Organelles** are the structures within the cell that have specific duties to make the cell a functioning unit.

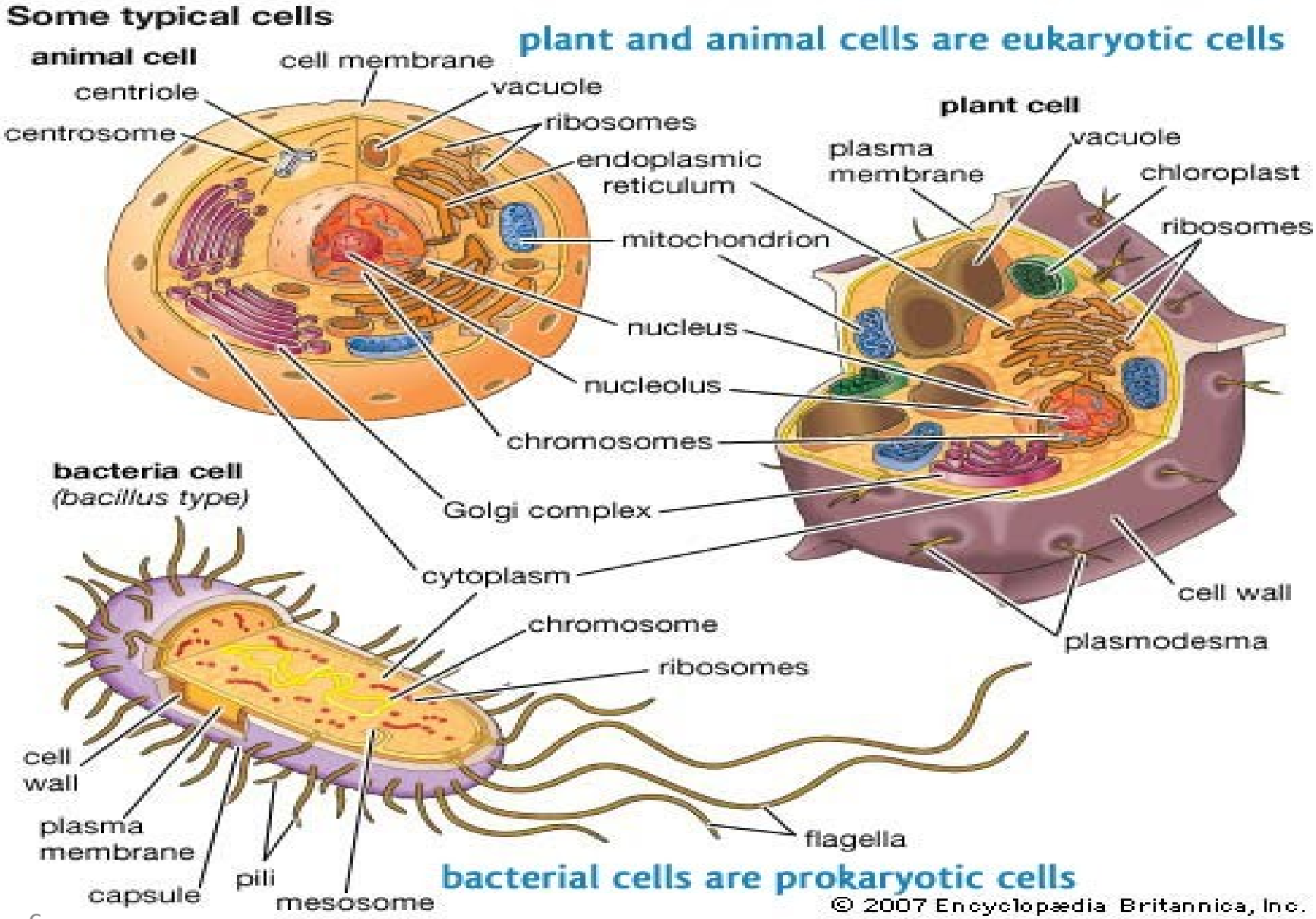
nucleus: an organelle that controls cellular activities. Typically the nucleus resides near the cells center.

3.2. Structure and Function of Organelles

There are two kinds of cell organelles on the basis membrane covering,

- membranous and non membranous organelles.

✔Endoplasmic reticulum (Rough and Smooth), Golgi bodies, mitochondria, chloroplasts, nucleus, lysosomes, peroxisomes and vacuoles are membranous whereas, non-membrane bound cell organelles are ribosomes (70S and 80S), centrosomes, cilia and flagella, microtubules, basal bodies and microfilaments.


Some typical cells
plant and animal cells are eukaryotic cells
animal cell
cell membrane
centriole
vacuole
centrosome
ribosomes
endoplasmic reticulum
mitochondrion
nucleus
nucleolus
chromosomes
Golgi complex
cytoplasm
plant cell
plasma membrane
vacuole
chloroplast
ribosomes
cell wall
plasmodesma
bacteria cell
(bacillus type)
chromosome
ribosomes
cell wall
plasma membrane
capsule
pili
mesosome
flagella
bacterial cells are prokaryotic cells
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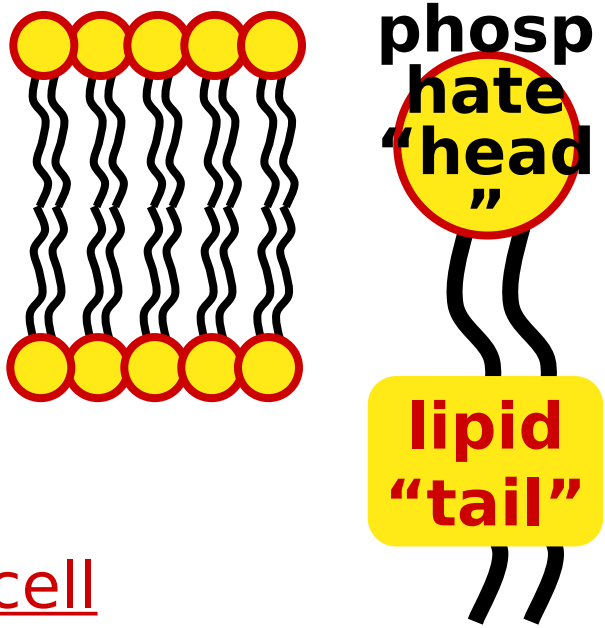
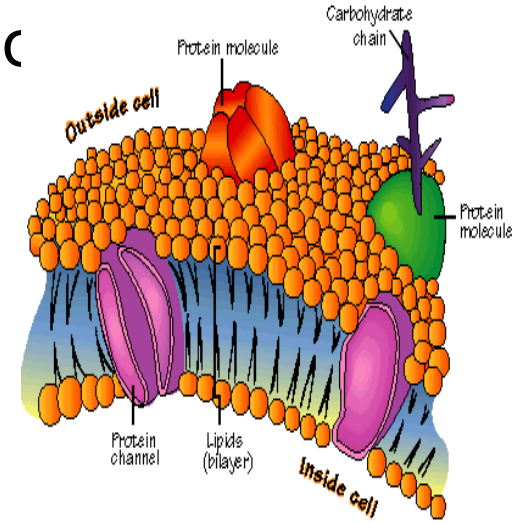
Plasma / Cell membrane: is extremely thin layer of lipids and proteins forming outermost boundary of living cell and enclosing the intracellular fluid (ICF).



- Function
  - separates cell from outside
  - controls what enters or leaves cell
    - O_2, CO_2, food, H_2O, nutrients, waste
  - recognizes signals from other cells
    - allows communication between c
- Structure
  - double layer of fat
    - phospholipid bilayer



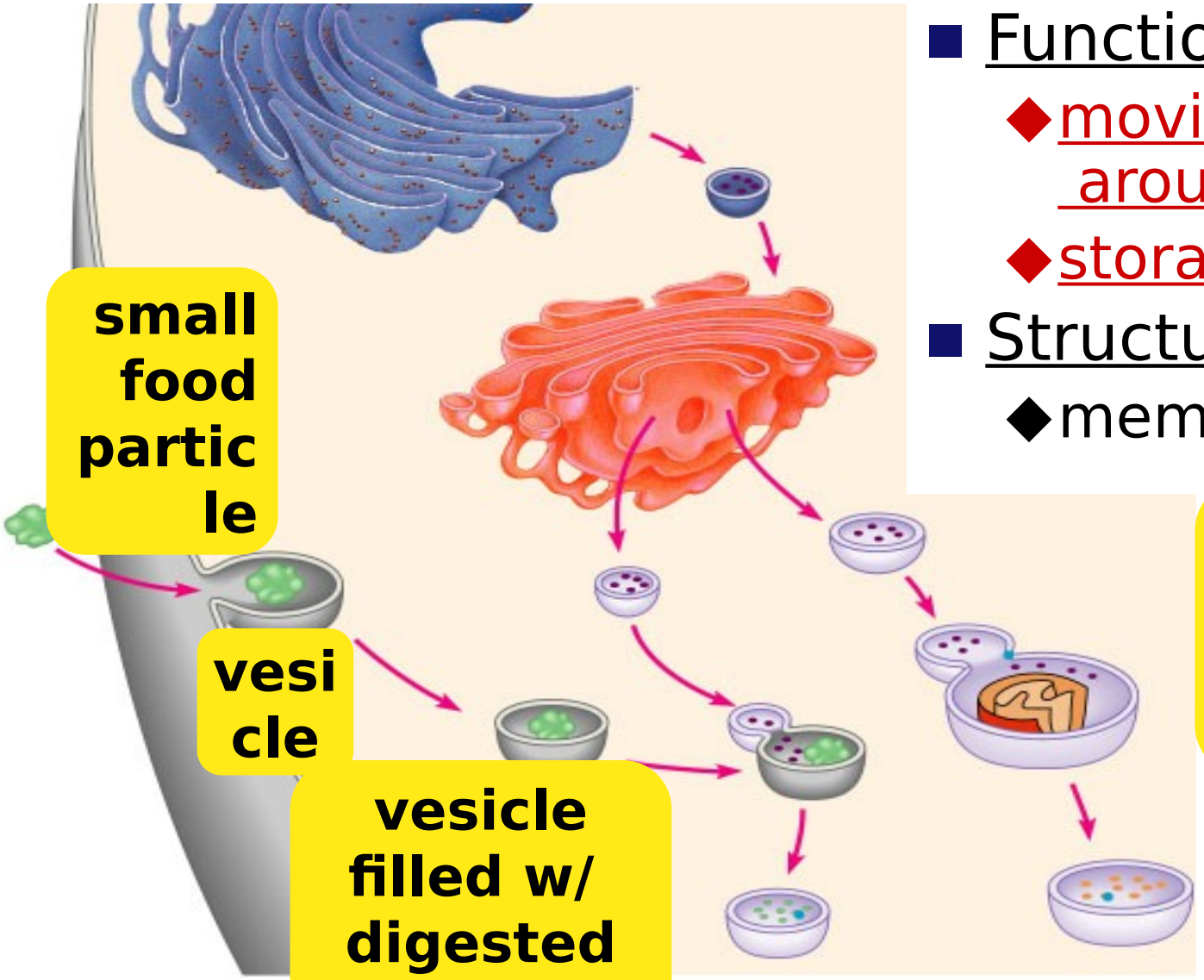
Functions of biological membrane

- Act as carriers for transport of materials
- involved in cell-cell recognition- Glycolipids
- Act as receptors for informational molecules
- Attachment to the cytoskeleton and extracellular matrix (ECM):
- Intercellular joining
- Enzymatic activity
- Antigens: these act as cell identity markers or ''name tag‘
- Energy Transfer
- Cholesterol: acts like a plug, reducing even further the escape or entry of polar molecules through the membrane.

vacuoles

- Vacuoles are membranous sacs similar to, but larger than vesicles.
- Food vacuoles are produced when the cell takes in food particles by phagocytosis.
- Central Vacuole that stores water and dissolved substances.
- Some protists have specialized contractile vacuoles for eliminating excess water.

Vacuoles & vesicles



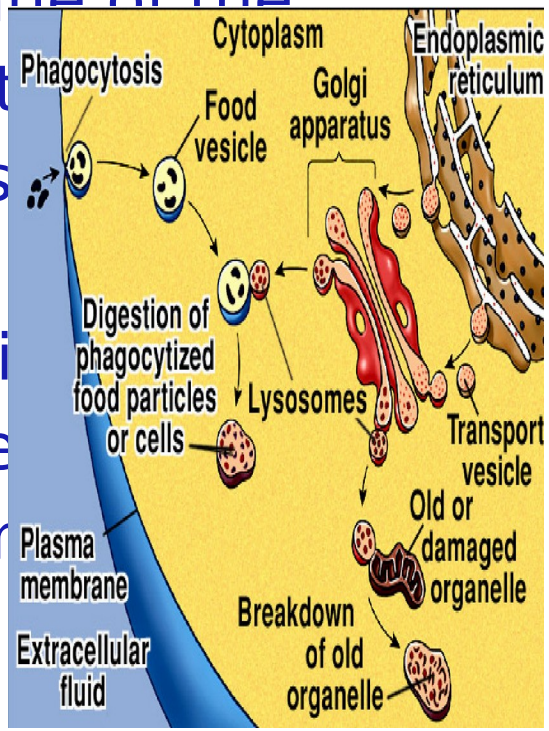
- Function
  - moving material around cell
  - storage
- Structure
  - membrane sac

Lysosomes - vesicles filled with digestive enzymes - used for

intracellular digestion

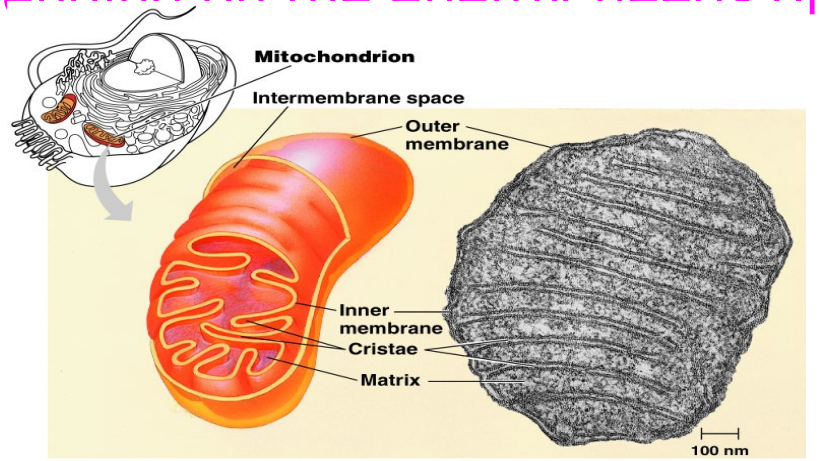
- A lysosome fuses with the membrane of the internalized vesicle and releases it of hydrolytic enzymes into the ves

- These enzymes safely attack the mi other trapped material within the e confines of the vesicle without dam the remainder of the cell.



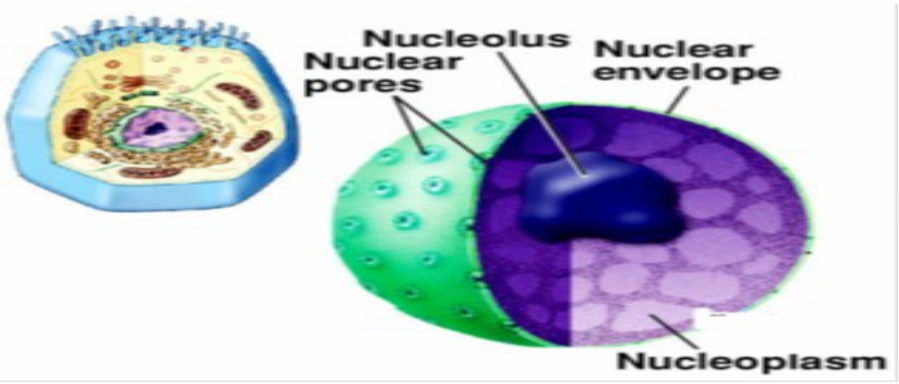
- Mitochondria - cellular powerhouses - the site of much of the energy harvest by cells
- Have double membrane structure-a smooth outer that surrounds the mitochondria, and inner membrane folded into inward projections called cristae
- Two spaces within the mitochondrion - the matrix and the intermembrane space

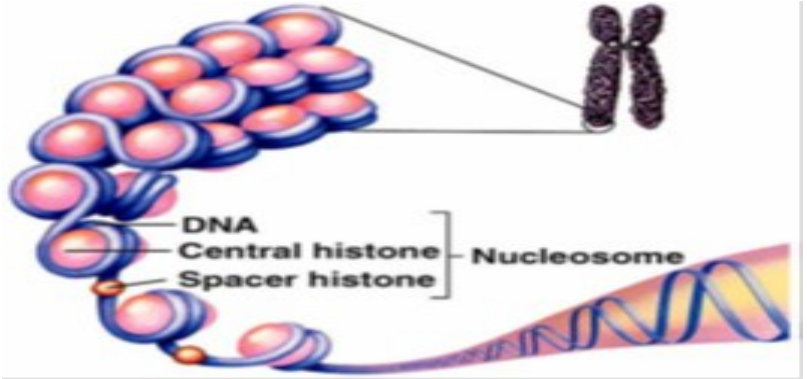
Their number varies depending on the energy needs of each particular cell types.



Nucleus - the largest and most obvious membrane bound compartment - controls cell activities and serves as the cell‟s master

- contains the nucleolus - a darkened region where ribosomal RNA is synthesized
- contains chromosomes - consist of DNA wrapped around proteins
- Nucleus is surrounded by the nuclear envelope - a double membrane
- Nuclear membrane has nuclear pores that control entry and exit of





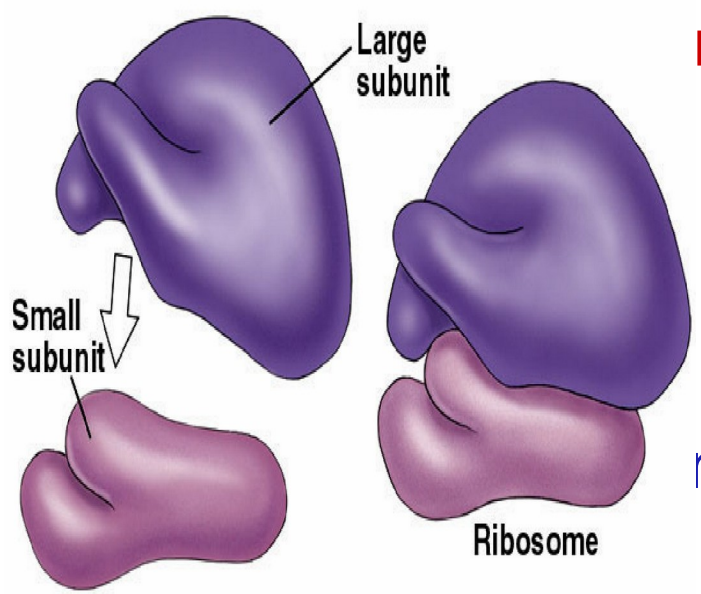
Nucleus may be:

- rounded e.g. in hepatocytes.
- indented (segmented) e.g. in neutrophils.
- binucleated e.g. in parietal cells, cardiac muscle cells.
- multinucleated e.g. in osteoclasts, skeletal muscle cells.
- very large (many DNA) e.g. in megakaryocytes.
- absent e.g. in mature erythrocytes, blood platelets.

The nucleus is surrounded by a nuclear envelope

Ribosomes – protein

ry



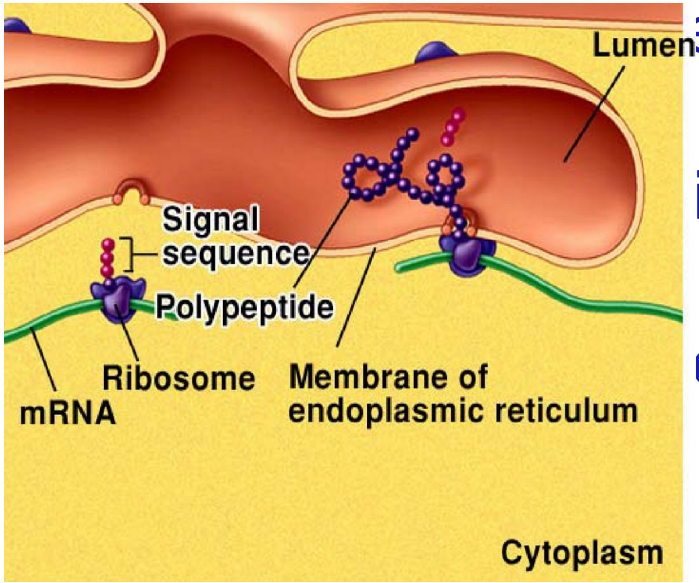
- two subunits - large

made of

mal RNA (rRNA)

- subunits

ey are



ins

- protein synthesis

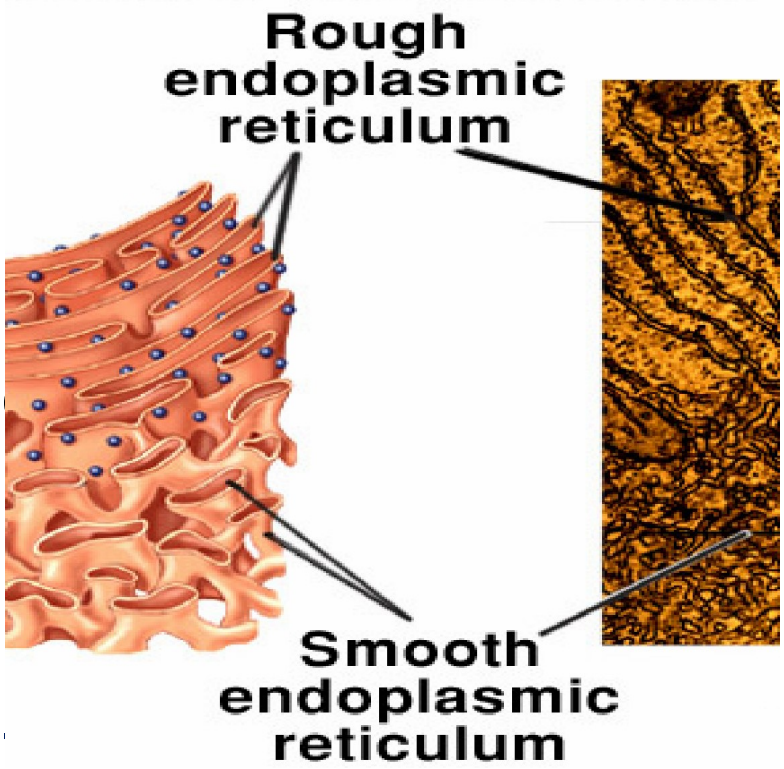
e

that are

cytoplasm

and on ribosomes

Endoplasmic reticulum (ER) - a web-like series of membranes within the cytoplasm in the form of flattened sheets, sacs, tubes, creates many membrane enclosed spaces - spreads throughout the cytoplasm - has connections with the outer membrane of the nucleus and the plasma membrane.

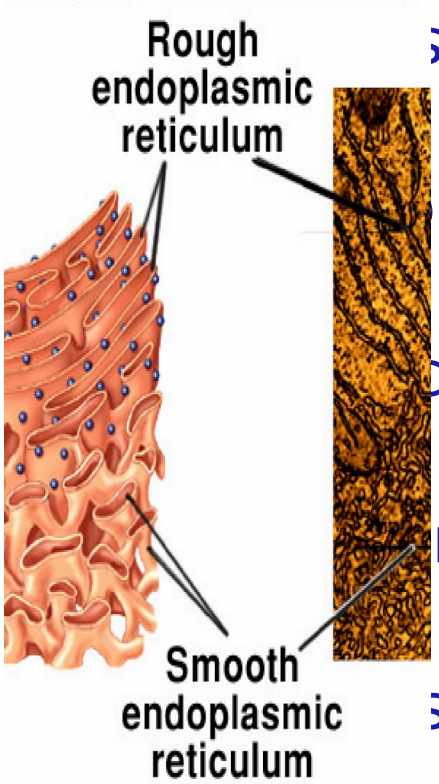


-breakdown of

-storage of

-synthesis of

Two types of ER - rough and smooth



rough ER - studded with

s

- site of synthesis

roteins

- all ribosomes on

ctively

involved in

nthesis –

smooth ER - site for synthesis

s and other lipid,

Ca++ storage in

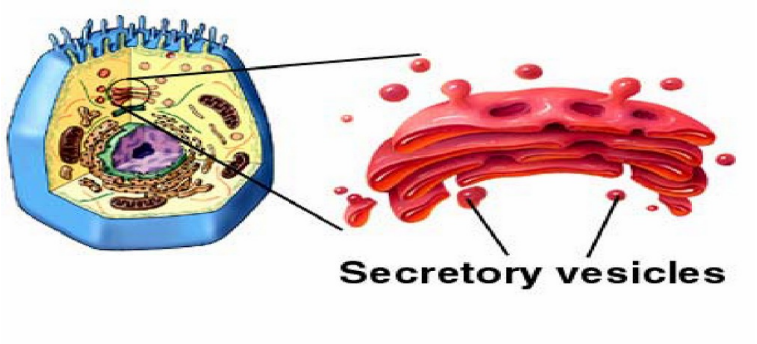
muscles, detoxification

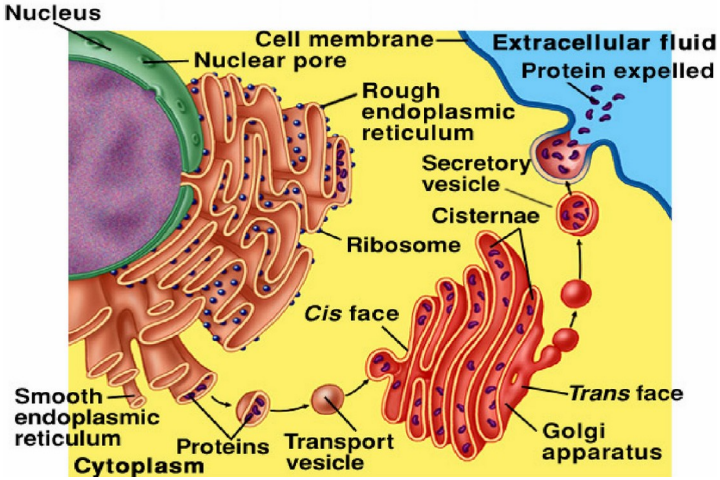
of drugs, toxins,

alcohol (especially in liver cell)

The highly convoluted

Golgi Apparatus - The Golgi complex is elaborately associated with the ER and contains sets of flattened, curved, membrane- enclosed sacs, or cisternae, stacked in layers.





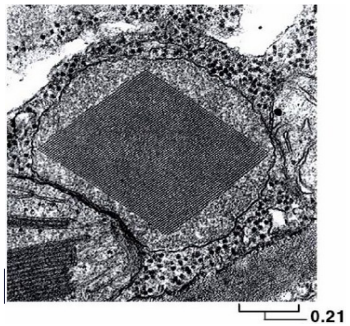
Function

- Processing the raw material into finished product
- Sorting and directing finished product to their final destination.

Structure

- membrane sacs

The Golgi is functionally associated with the ER



Peroxisomes - Is membrane-enclosed sacs co

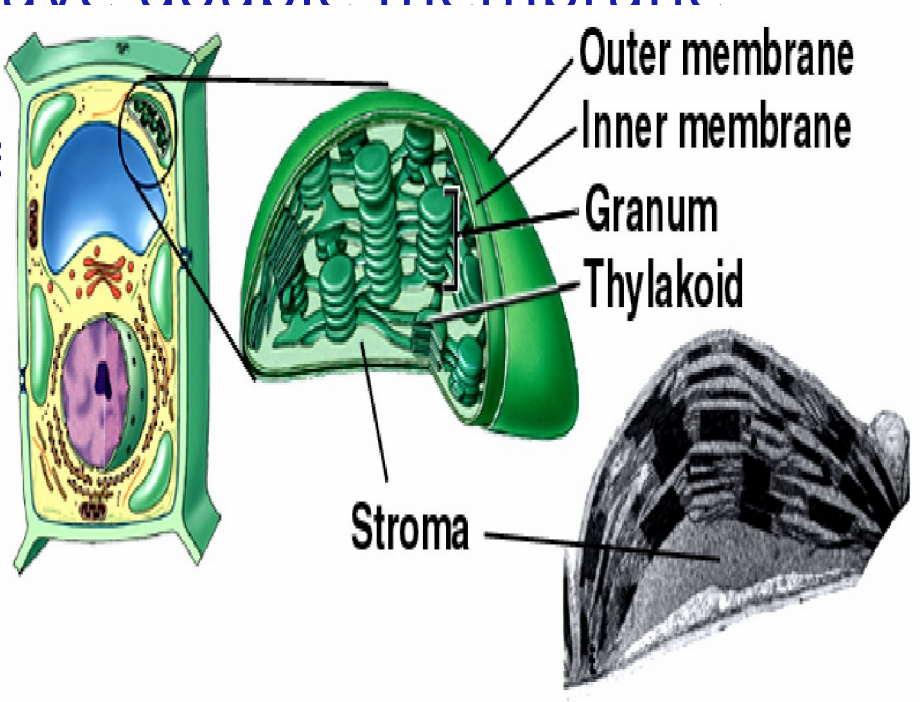
oxidative enzymes and catalase that detoxify various wastes.

- are found both in plant and animal cells
- used for removing reactive compounds from the cytoplasm - create H_2O_2 as a byproduct and decompose it with the enzyme catalase into harmless water and oxygen

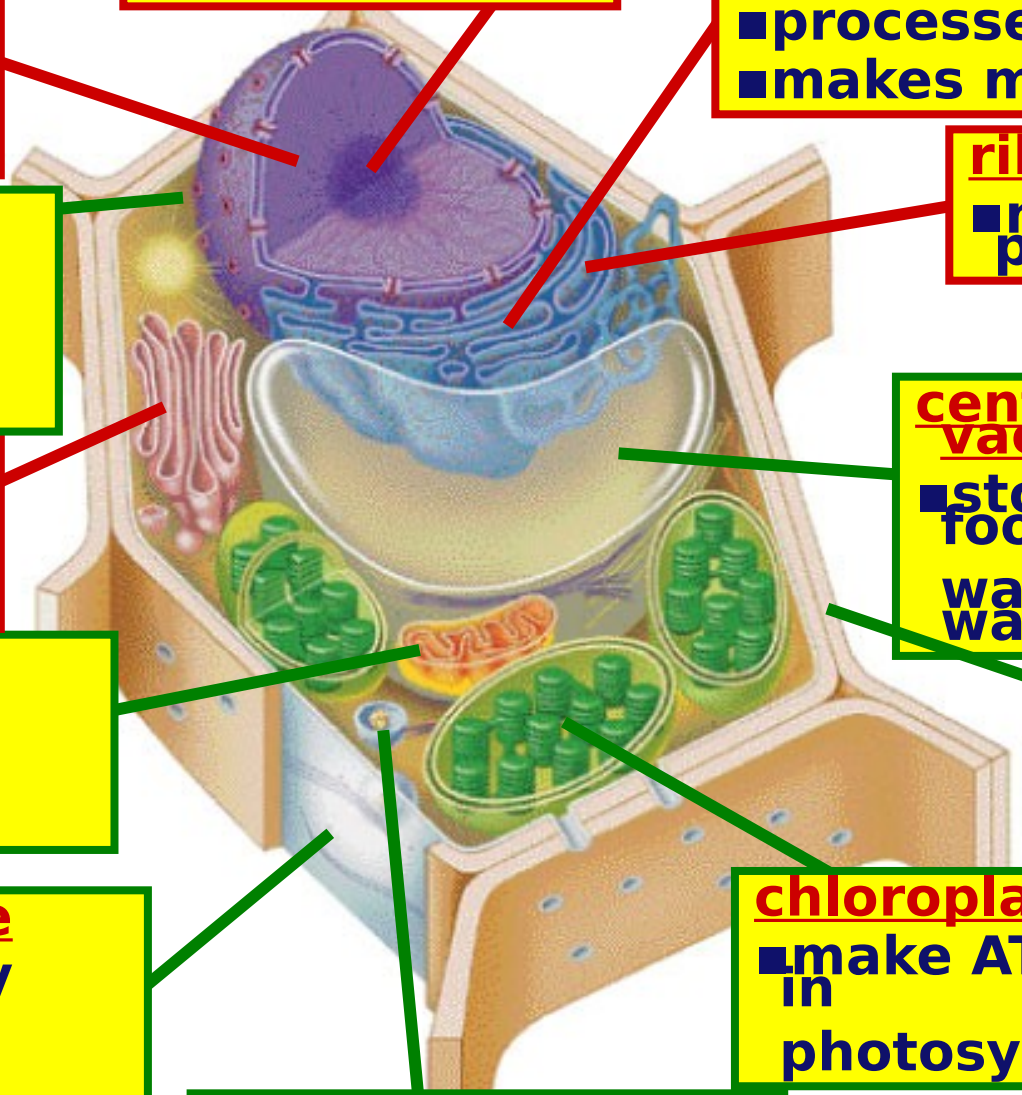
Chloroplasts - sites of photosynthesis - in nearly all plants and some protists trap light energy and convert it into chemical energy have double membrane structure

- inner space is the stroma

Within the stroma have a series of stacks of flattened membrane structures called thylakoids - the stacks are called grana



The light energy trapping molecules of photosynthesis are found in the membranes of the thylakoids.



nucleolus
- make ribosomes

endoplasmic reticulum
- processes proteins
- makes membranes

nucleus
- control cell
- protects DNA

ribosomes
- make proteins

cytoplasm
- jelly-like material around organelles

Golgi apparatus
- finish & ship proteins

central vacuole
- storage: food, water or waste

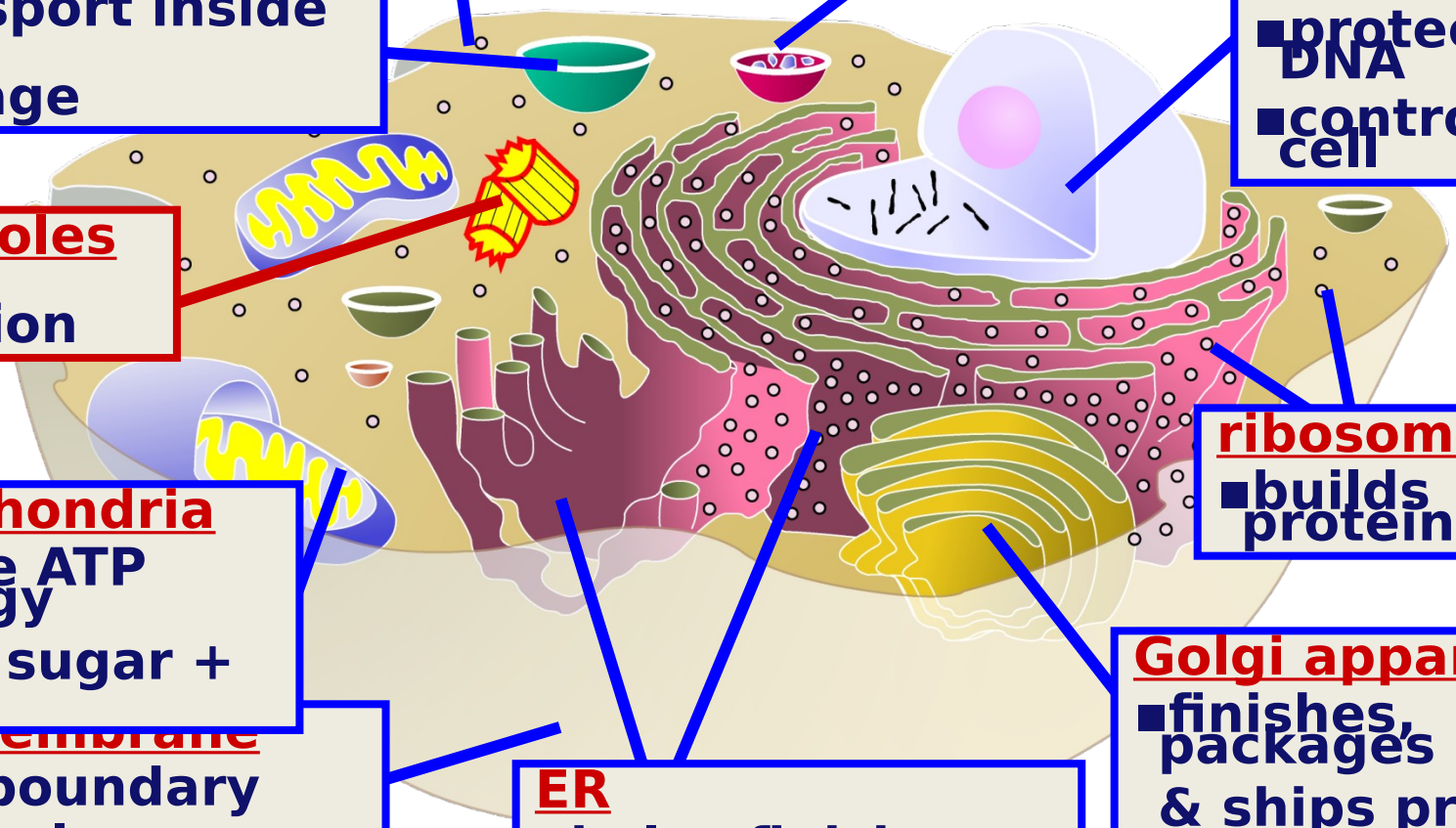
mitochondria
- make ATP in cellular respiration

cell wall
- support

cell membrane
- cell boundary
- controls movement of materials in & out
- recognizes signals

chloroplast
- make ATP & sugars in photosynthesis

lysosome
- digestion & clean up



cytoplasm
- jelly-like material holding organelles in place

lysosome
- food digestion
- garbage disposal & recycling

vacuole & vesicles
- transport inside cells
- storage

nucleus
- protects DNA
- controls cell

centrioles
- cell division

ribosomes
- builds proteins

mitochondria
- make ATP energy from sugar + O_2

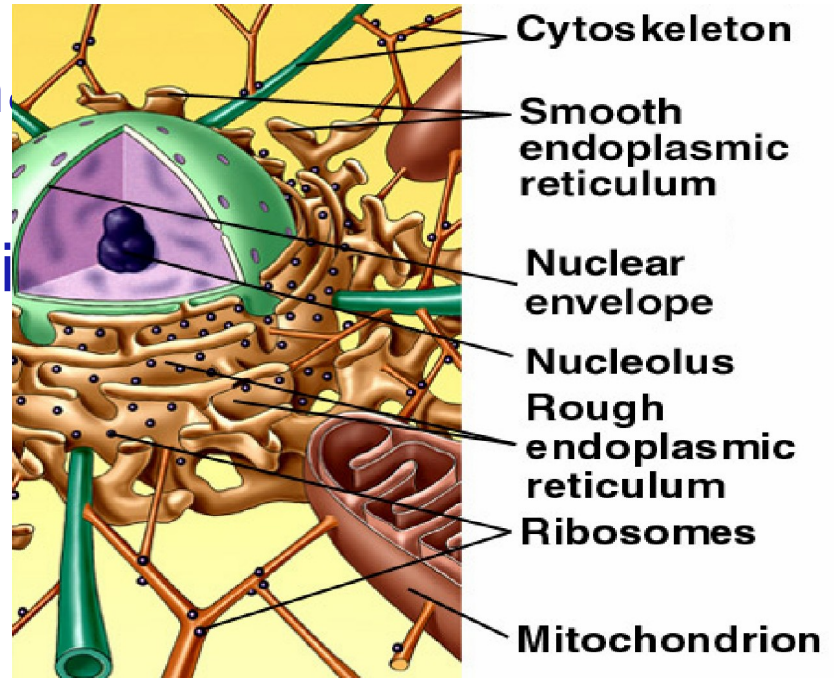
Golgi apparatus
- finishes, packages & ships proteins

cell membrane
- cell boundary
- controls movement of materials in & out
- recognizes

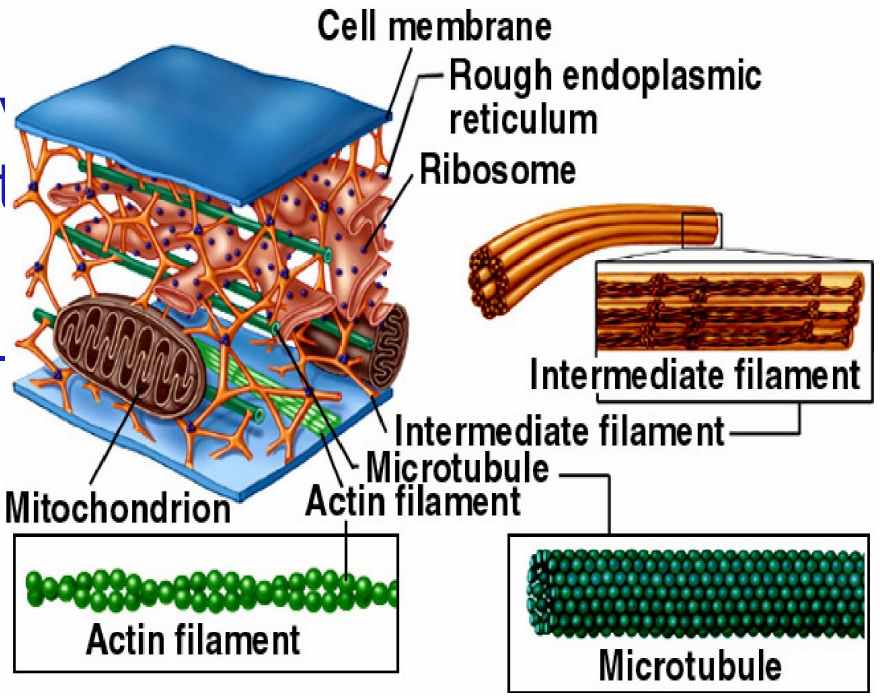
ER
- helps finish proteins
- makes membranes

Cytoskeleton - scaffolding of proteins that transport materials, position and move organelles, maintain and change cell shape, and organize enzymes into functional associations.

- 3 components - actin filaments, microtubules, and intermediate filaments
- all are polymers of sm
  protein subunits -
  lengthen through addi
  of polymer subunits,



- actin filaments - involved in cell movements and in membrane deformations - smallest components of the cytoskeleton
- microtubules - hollow tubes made of proteins called tubulins responsible for cell movements and movements of organelles within the cytoplasm, mo during cell division - larges cytoskeleton
- intermediate filaments - 8 stranded protein Fibers - play a role in cell structure, anchoring organelles and in transport of materials



3.4. Cellular diversity

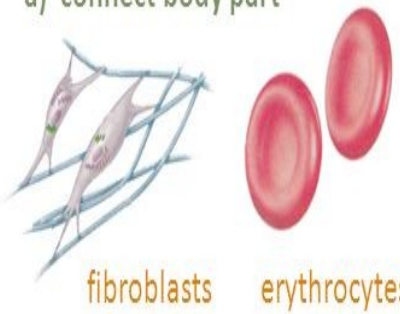
- It is well known that differentiated cells can have many sizes, forms, and shapes.
- The size and shape of the cell is determined by their functions
- Cell morphology in animal tissues is diverse, enormously diverse! It can range from rounded to star-like, from multi-lobed to fili form.
- Plant cells also show a wide diversity of forms, which is determined by the cell wall, being cuboidal and columnar shapes the most common shapes.

c

Cell Diversity

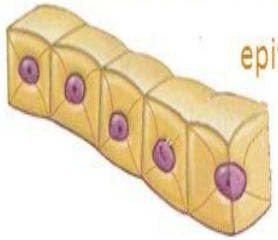
Cells that ...

a) connect body part



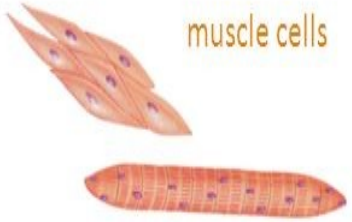
fibroblasts erythrocytes

b) cover and line body organs



epithelial cells

c) move organs and body parts



muscle cells

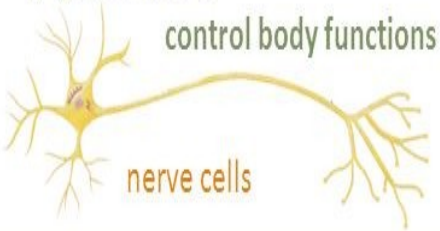
d) store nutrients

fat cells

e) fight disease

macrophage

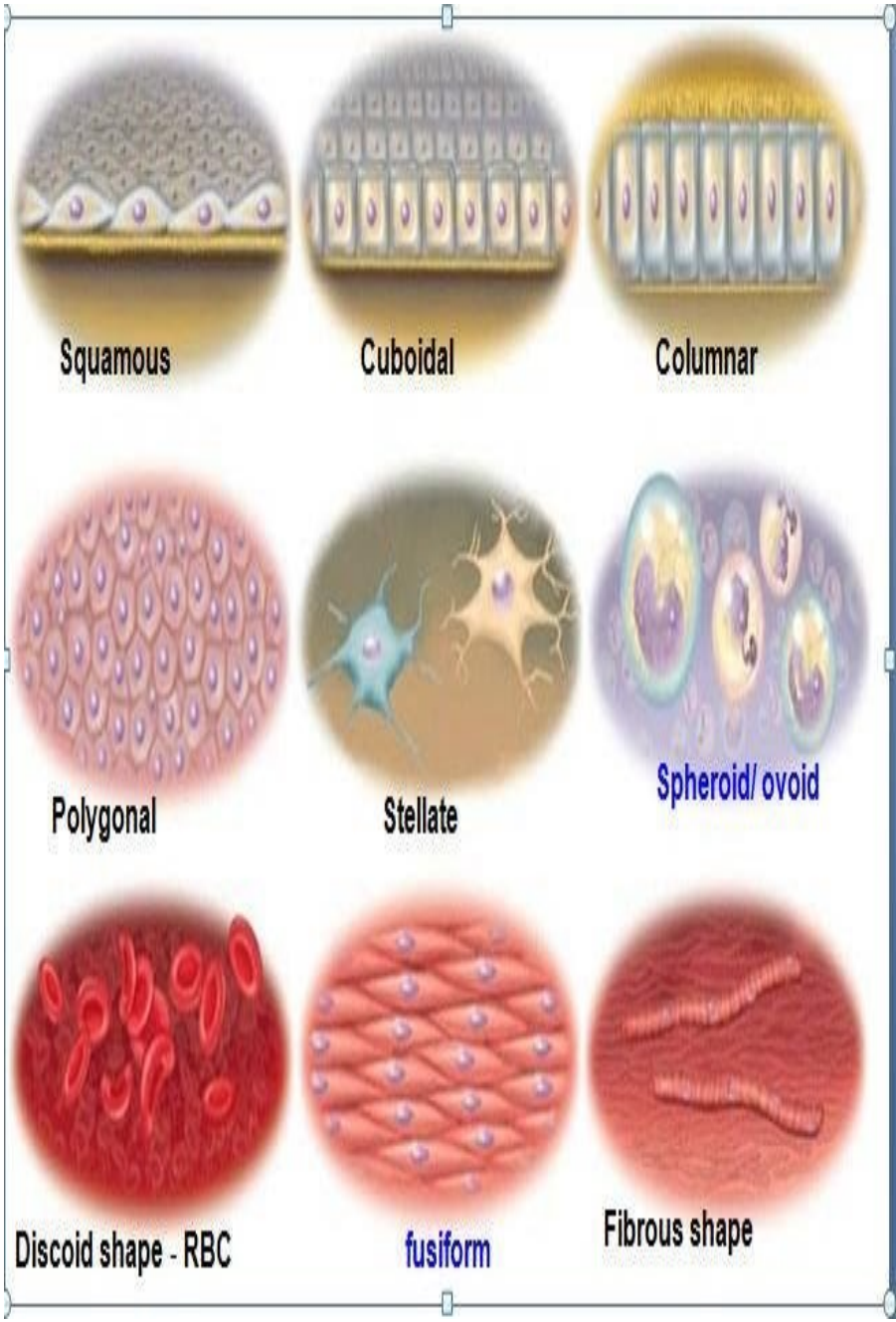
f) gather info & control body functions



nerve cells

g) involve in reproduction

sperm

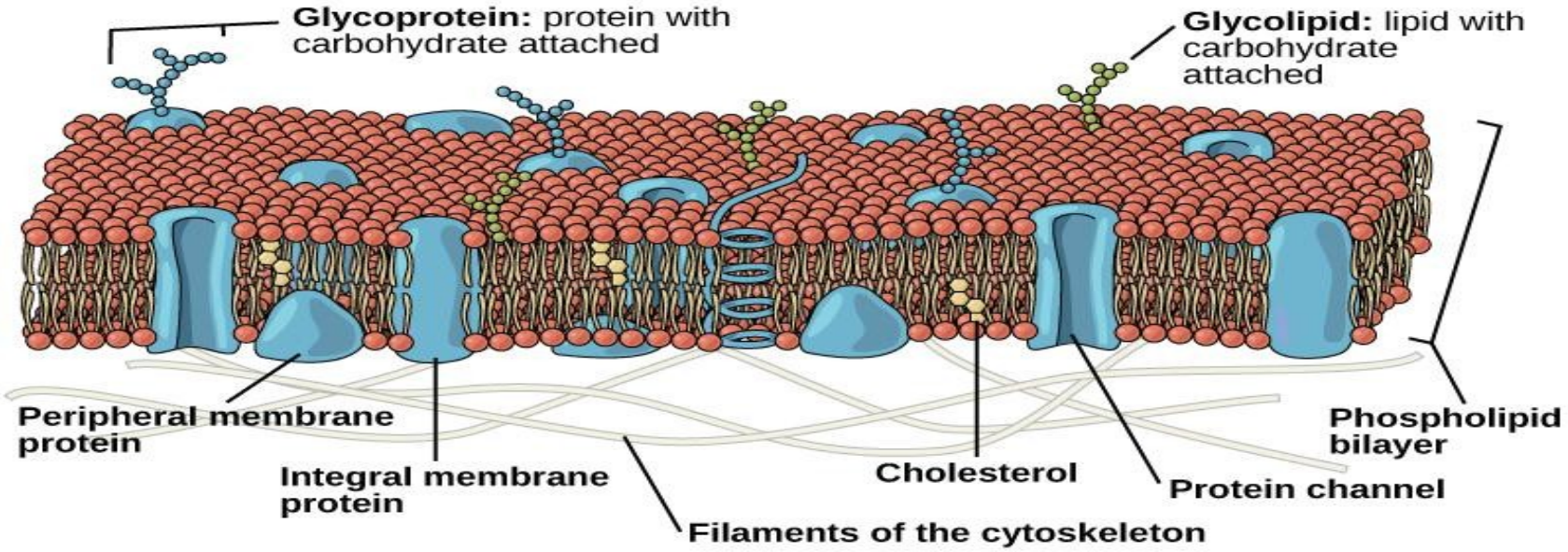


Various types of animal cells (shape)

3.5. Transport in cells

3.5.1. Nature and structure of biological membranes

All membrane lipids are amphipathic-that is, they contain both a hydrophilic and hydrophobic regions.



3.5.2. Membrane permeability and material transport

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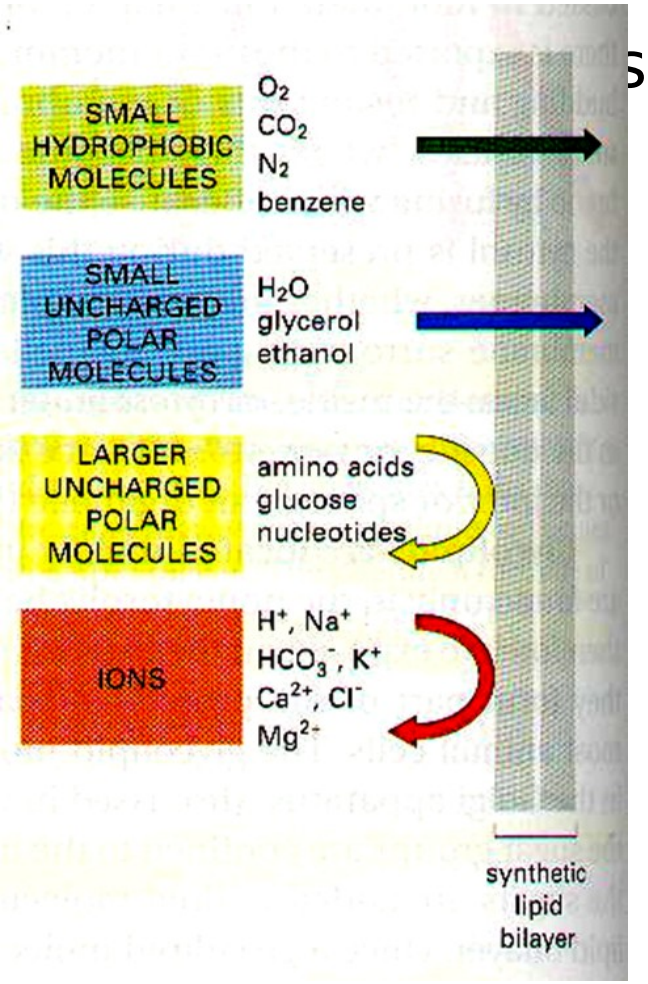
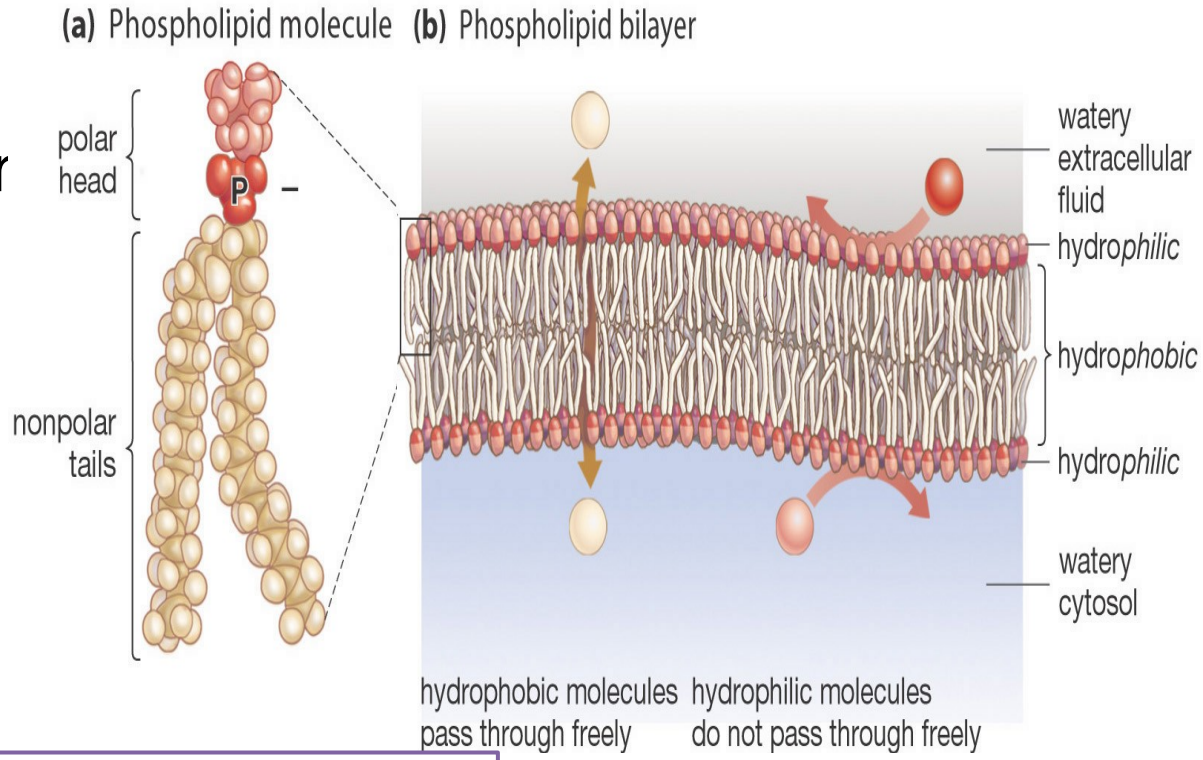




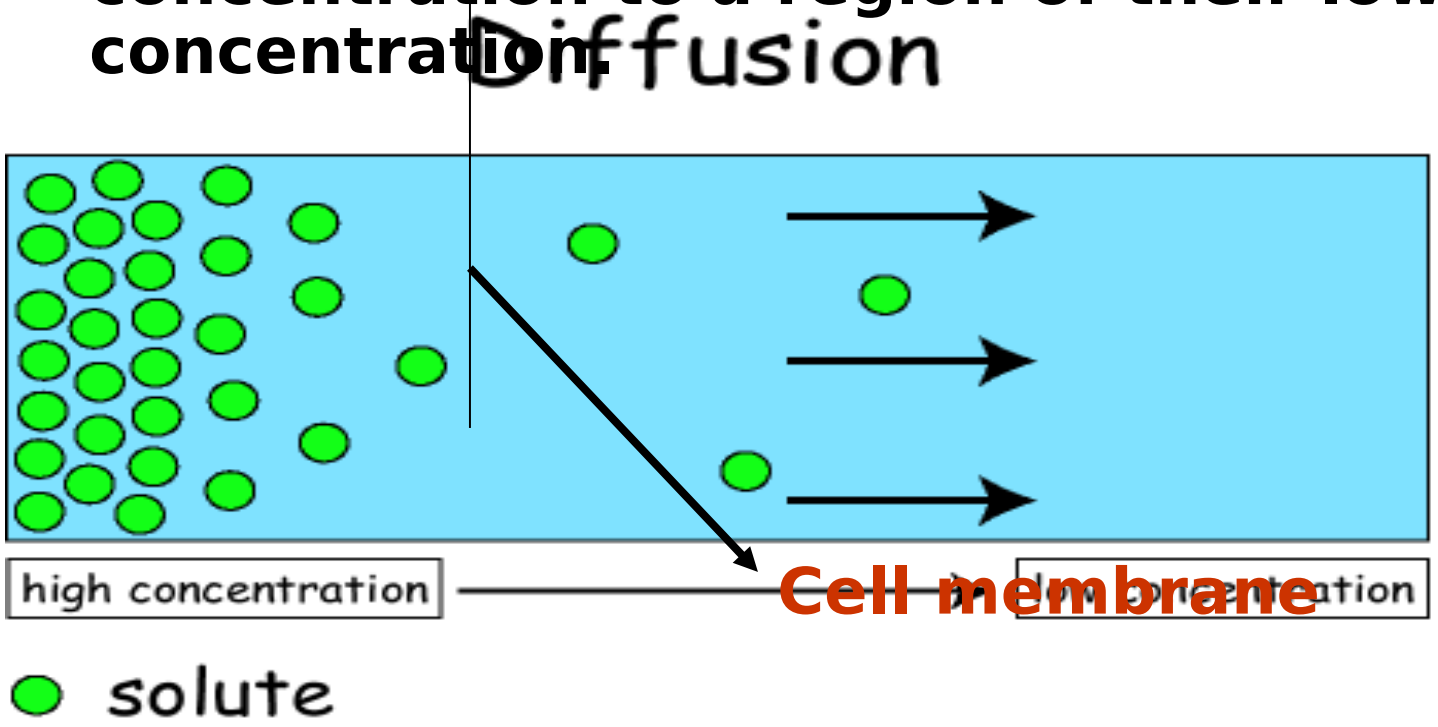
The cell membrane is made of 2 layers of

Hydrophobic molecules pass easily; hydrophilic DO

3.5.3. Types of transport in cells

Diffusion through a Membrane

Diffusion is the net movement of molecules from a region of their high concentration to a region of their lower concentration.



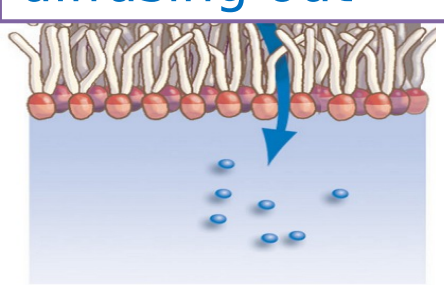
Solute moves DOWN concentration gradient (HIGH to LOW)

1. Simple diffusion-

❖**Doesn’t require energy**

- Movement across higher

to lower concentration gradient.
Example: Oxygen or water diffusing into a cell and carbon dioxide diffusing out



Materials move down their concentration gradient through the phospholipid bilayer.

2. Facilitated diffusion-

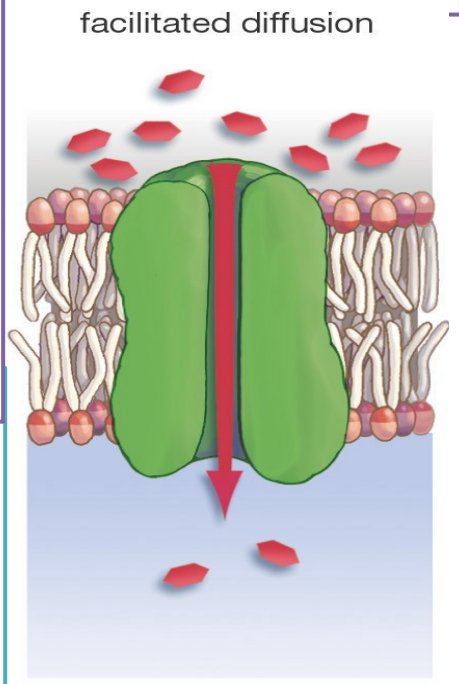
❖ **Doesn’t require energy**

❖ **Uses transport proteins to move high to low concentration**. Examples: Glucose or amino acids moving from blood

Carrier- Mediated Transport displays three characteristics:
1. Specificity 2. Saturation 3. Competition

diffusion across a membrane are:

1. permeability of the membrane
2. surface area of the membrane
3. molecular weight of the substance (lighter one diffuses rapidly)
4. distance through which

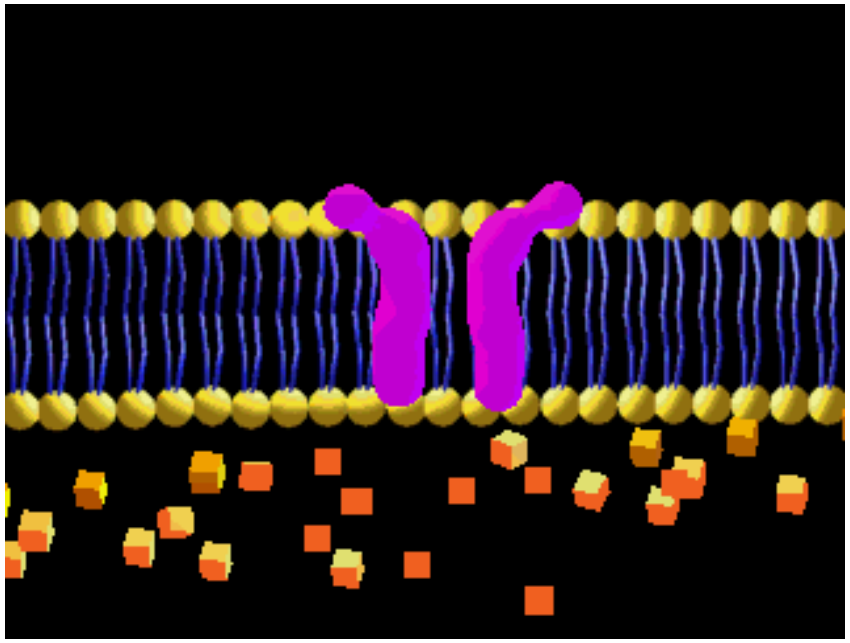


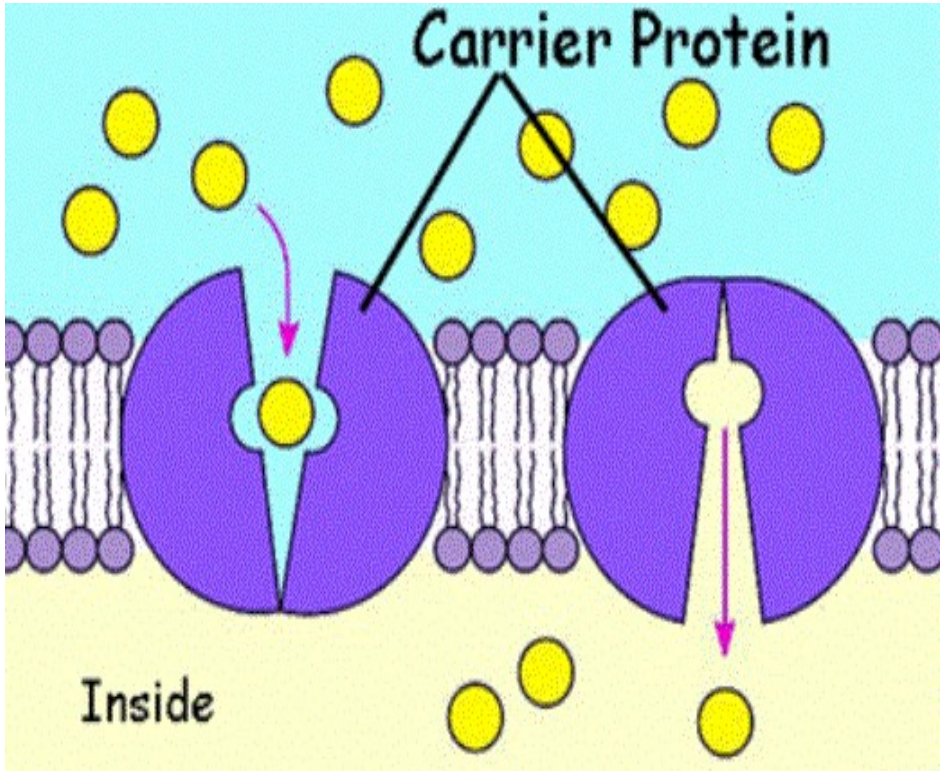
The passage of materials is aided both by a concentration gradient and by a transport protein.

Types of Transport Proteins

2. **Carrier proteins** can change shape to move material from one side of the membrane to the other

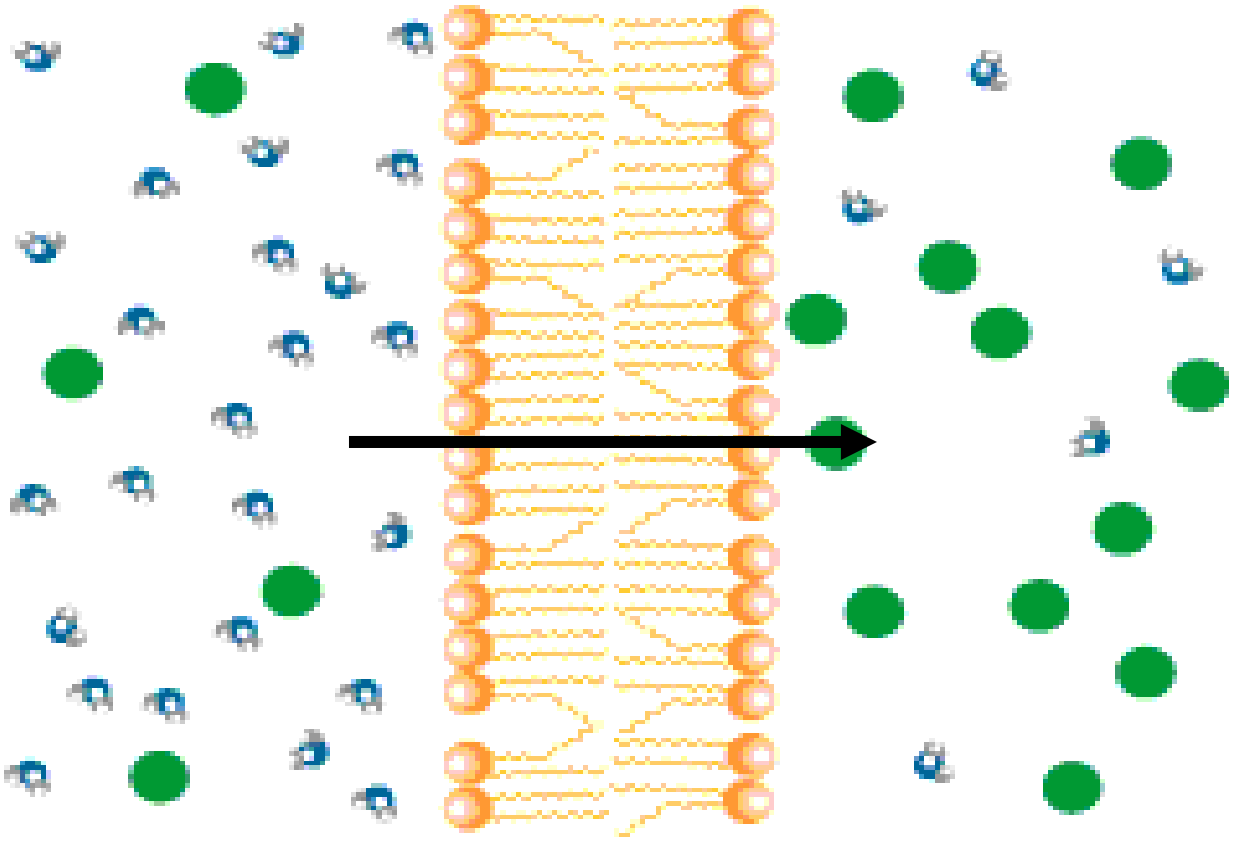
1. **Channel proteins** are emb
the cell membrane & have a pore for materials to cross





Osmosis is the net diffusion of water down its own concentration gradient.

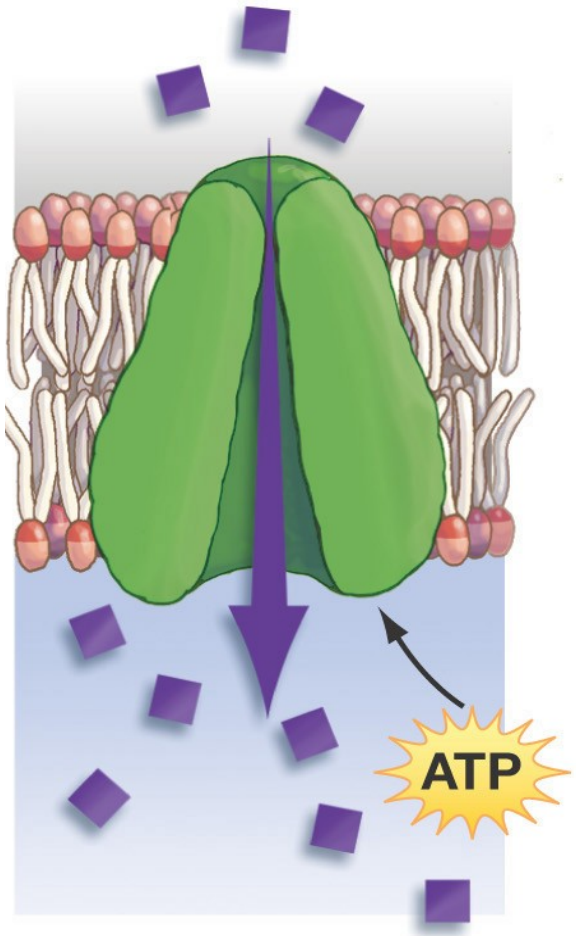
Diffusion of H_2O Across A Membrane



High H_2O potential
Low solute

Low H_2O potential
High solute concentration

Active Transport



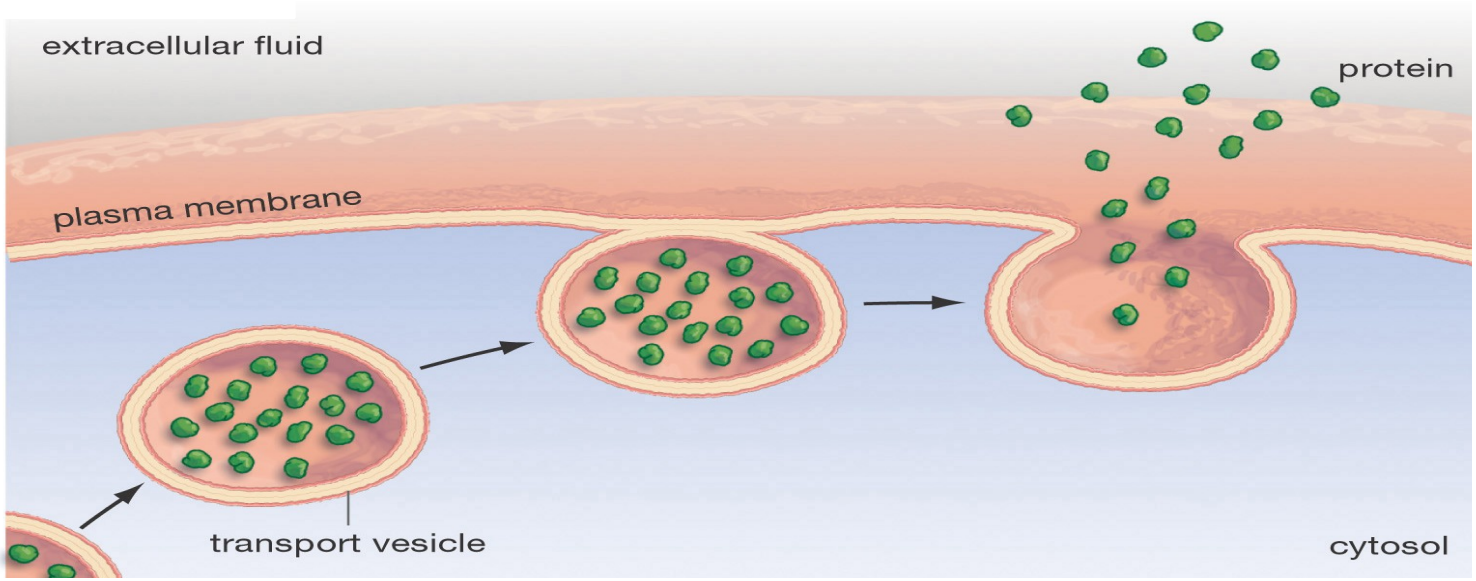
Molecules again move through a transport protein, but now energy must be expended to move them against their concentration gradient.

- Requires energy or ATP
- Moves materials from LOW to HIGH concentration
- AGAINST concentration gradient

- Examples: Pumping Na^+ (sodium ions) out and K^+ (potassium ions) in against strong concentration gradients.
- Called Na+-K+ Pump

Moving the “Big Stuff”

Exocytosis- moving

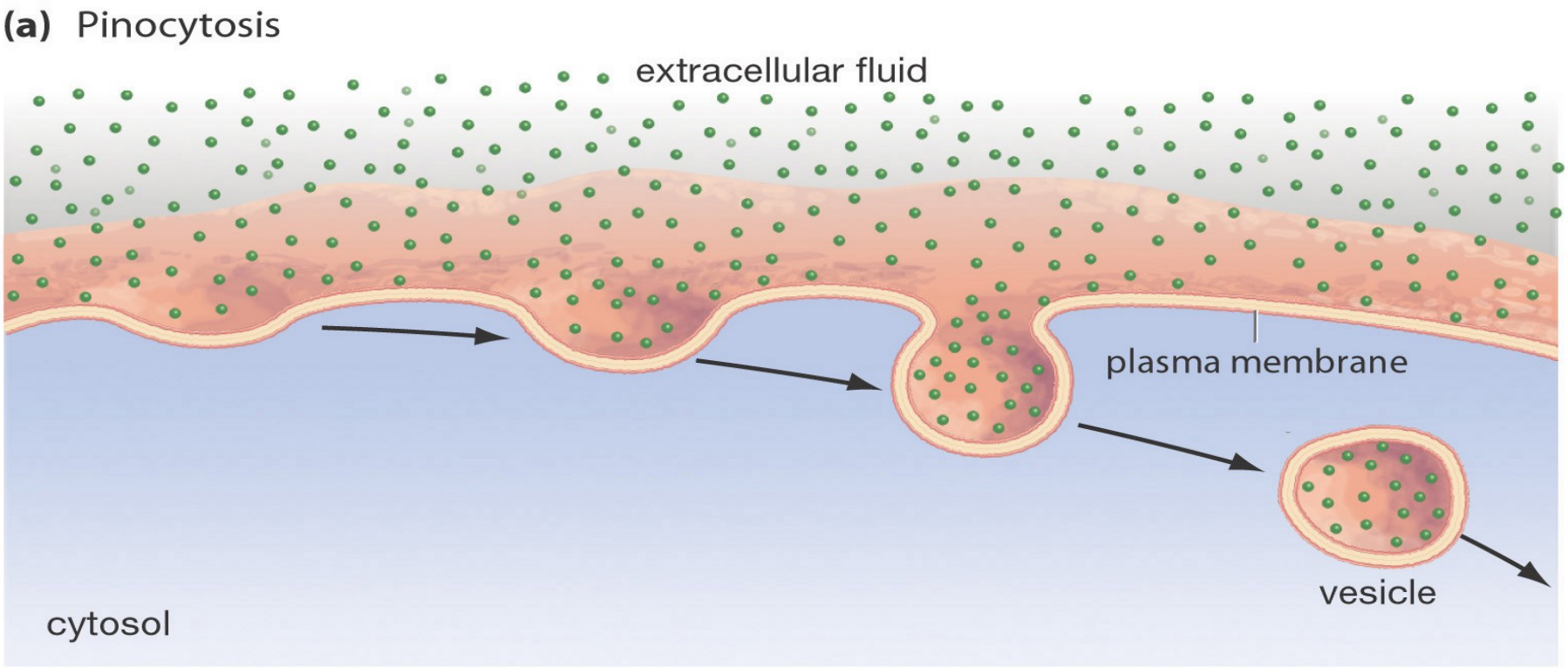


Molecules are moved out of the cell by vesicles that fuse with the plasma membrane.

This is how many hormones are secreted and how nerve cells communicate with one another.

Large molecules move materials into the cell by one of three forms of endocytosis.

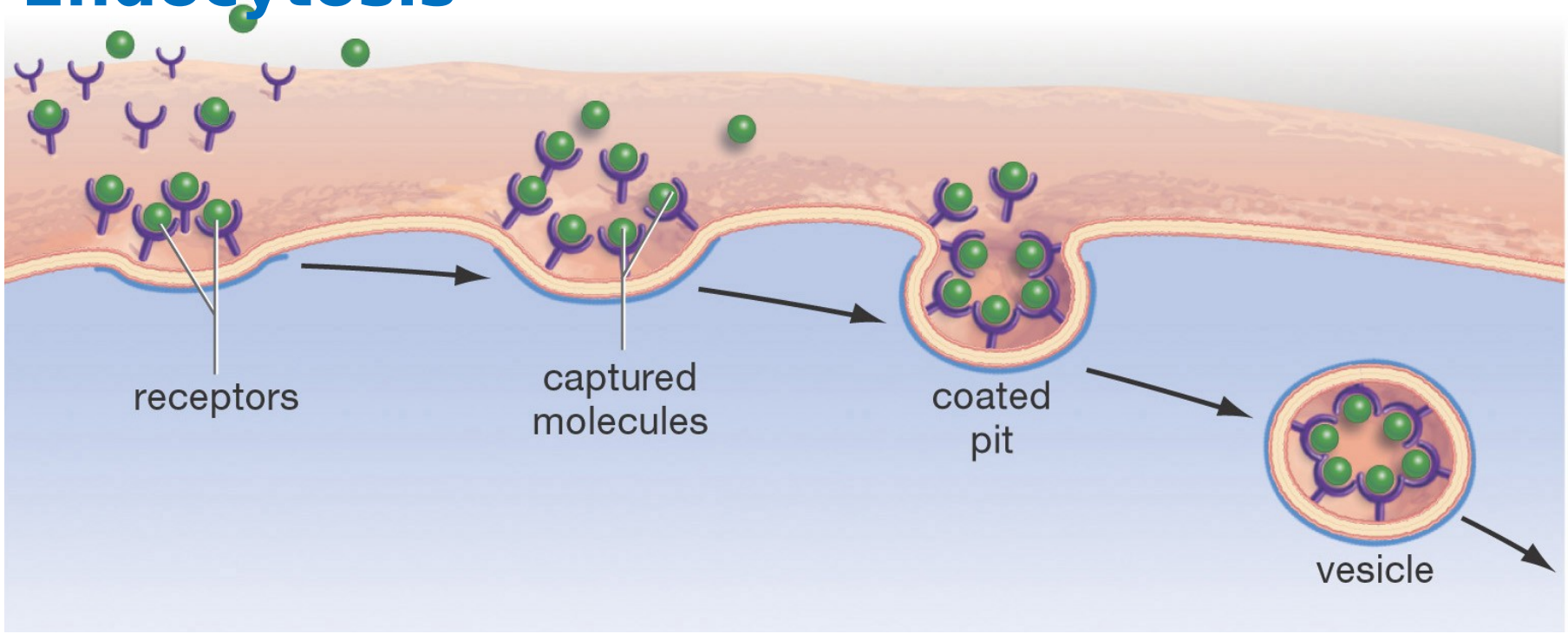
1. Pinocytosis (Cell Drinking)



Most common form of endocytosis.

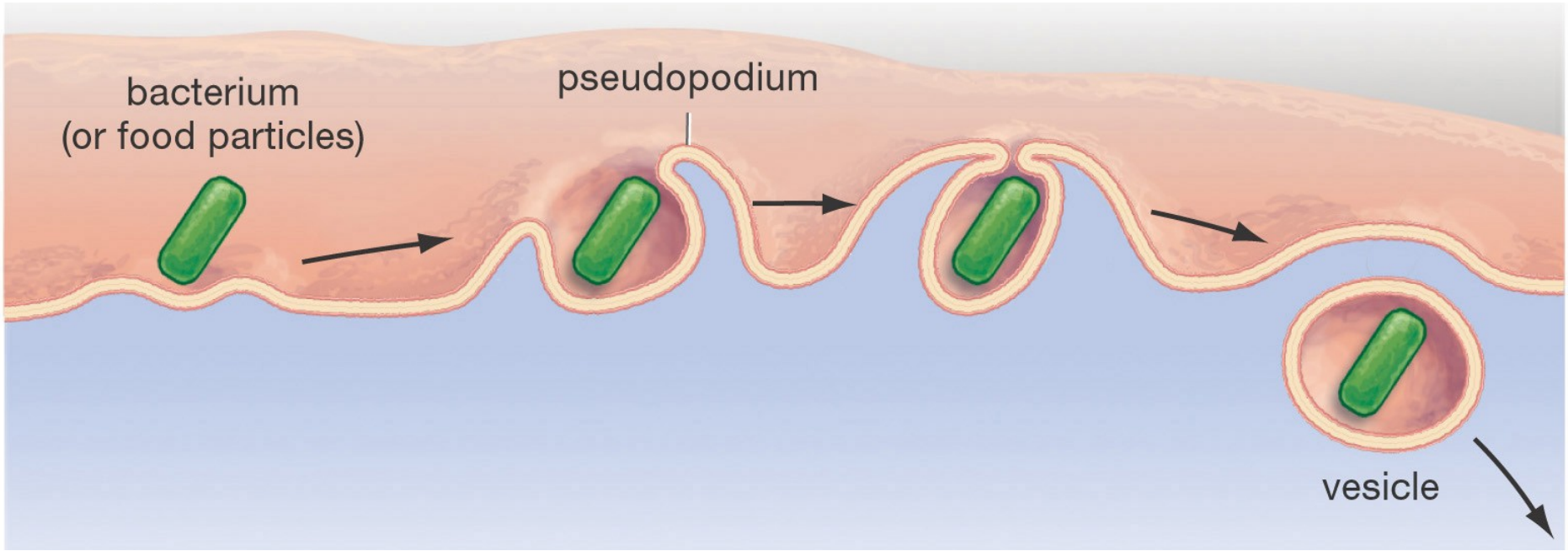
Takes in dissolved molecules as a vesicle.

2. Receptor-Mediated Endocytosis



Some integral proteins have receptors on their surface to recognize & take in hormones, cholesterol, etc.

3. Phagocytosis



Used to engulf large particles such as food, bacteria, etc. into vesicles

Capture of a Yeast Cell (yellow) by Membrane Extensions of an Immune System Cell (blue)

CHAPTER 4

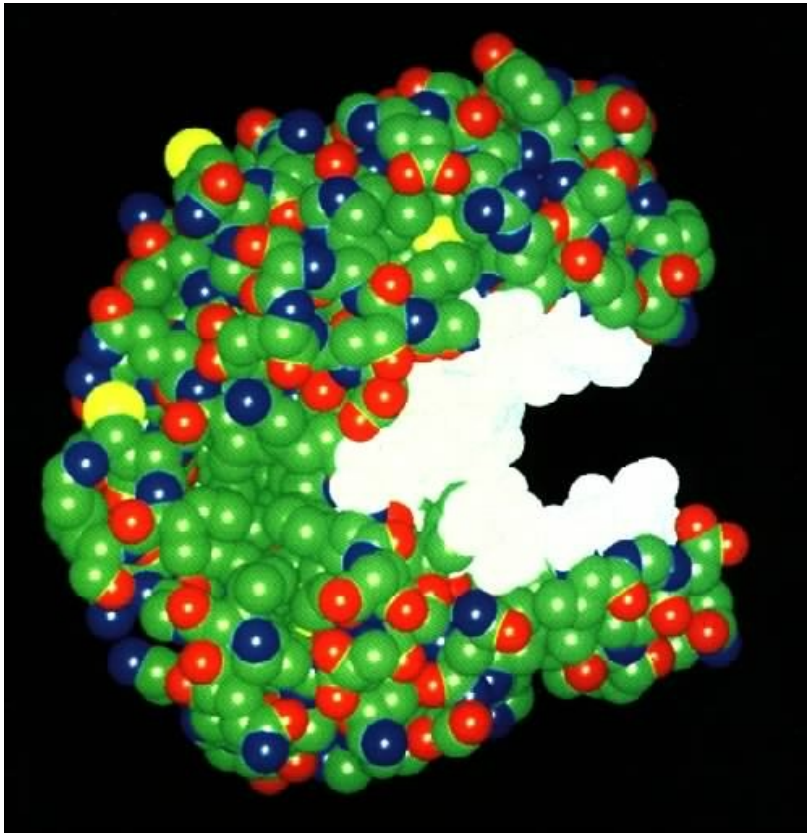
Cellular Metabolism and Metabolic Disorders

- Metabolism is thus the sum of chemical reactions that takes place within each cell of a living organism and that provides energy for vital processes and synthesizing of new organic materials.
- Broadly, these reactions can be divided into catabolic reactions that convert nutrients to energy and anabolic reactions that lead to the synthesis of larger biomolecules.

4.2. Enzymes and their role in metabolism

What Are Enzymes?

- **Most enzymes are Proteins (tertiary and quaternary structures)**
- **Act as Biological Catalyst to accelerates a reaction**
- **Not permanently changed in the process**



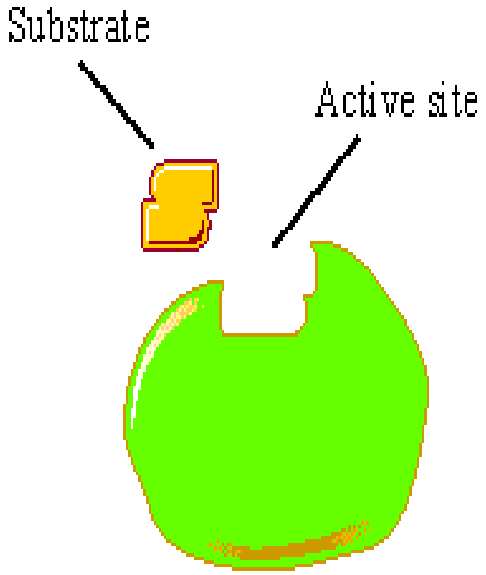
ENZYMES…

- **Are specific for what they will catalyze**
- **Are Reusable**
- **End in –*ase***

  -Sucrase

  -Lactase

  -Maltase



- Most enzymes are protein in nature.
- Depending on the presence and absence of a **non protein** component with the enzyme, enzymes can exist as, simple enzyme or holoenzyme

Cont'd...

1. **Simple enzyme**: It is made up of only protein molecules not bound to any non proteins. Example: **Pancreatic Ribonuclease.**

2. **Holo enzyme** is made up on protein groups and non-protein component.

- The protein component of this holo enzymes is called **apoenzyme** and the non-protein component of the holo enzyme is called a **cofactor**.
- If this cofactor is an organic compound it is called a **coenzyme** and if it is an inorganic groups it is called a**ctivator**. (Fe 2+, Mn 2+, or Zn 2+ ions). If the cofactor is bound so tightly to the apoenzyme and is difficult to remove without damaging the enzyme it is sometimes called a prosthetic group.

Cont'd...

COENZYMES-

- Coenzymes are derivatives of **vitamins** without which the enzyme cannot exhibit any reaction.
- One molecule of coenzyme is able to convert a large number of substrate molecules with the help of enzyme.
- Coenzyme accepts a particular group removed from the substrate or donates a particular group to the substrate
- Coenzymes are called co substrate because the changes that take place in substrates are complimentary to the changes in coenzymes.
- The coenzyme may participate in forming an intermediate enzyme-substrate complex
- Example: NAD, FAD, Coenzyme A

Cont'd...

Metal ions in enzymes

- Many enzymes require metal ions like

  ca^{2+}, K^{+}, Mg^{2+}, Fe^{2+}, Cu^{2+}, Zn^{2+}, Mn^{2+} and Co^{2+}

  for their activity.
- Metal-activated enzymes-form only loose and easily dissociable complexes with the metal and can easily release the metal without denaturation.
- Metalloenzymes hold the metal tightly on the molecule and do not release it even during extensive purification.

Properties of Enzymes

Active site: the active site binds the substrate, forming an enzyme-substrate (ES) complex. ES is converted to enzyme-product (EP); which subsequently dissociates to enzyme and product.

Enzyme turnover number :refers to the amount of substrate converted per unit time

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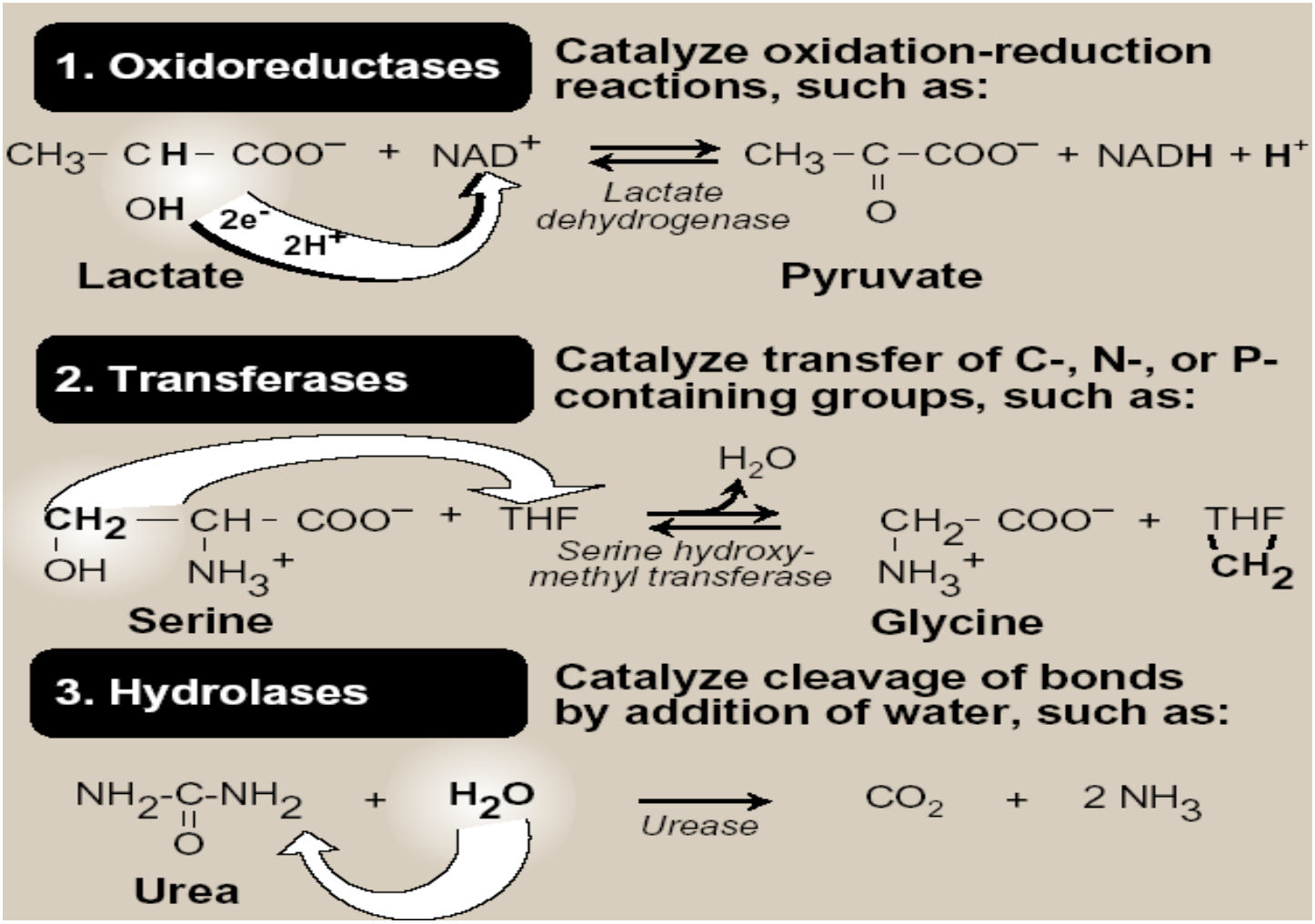
Classification of Enzymes on the basis of the reactions they catalyze



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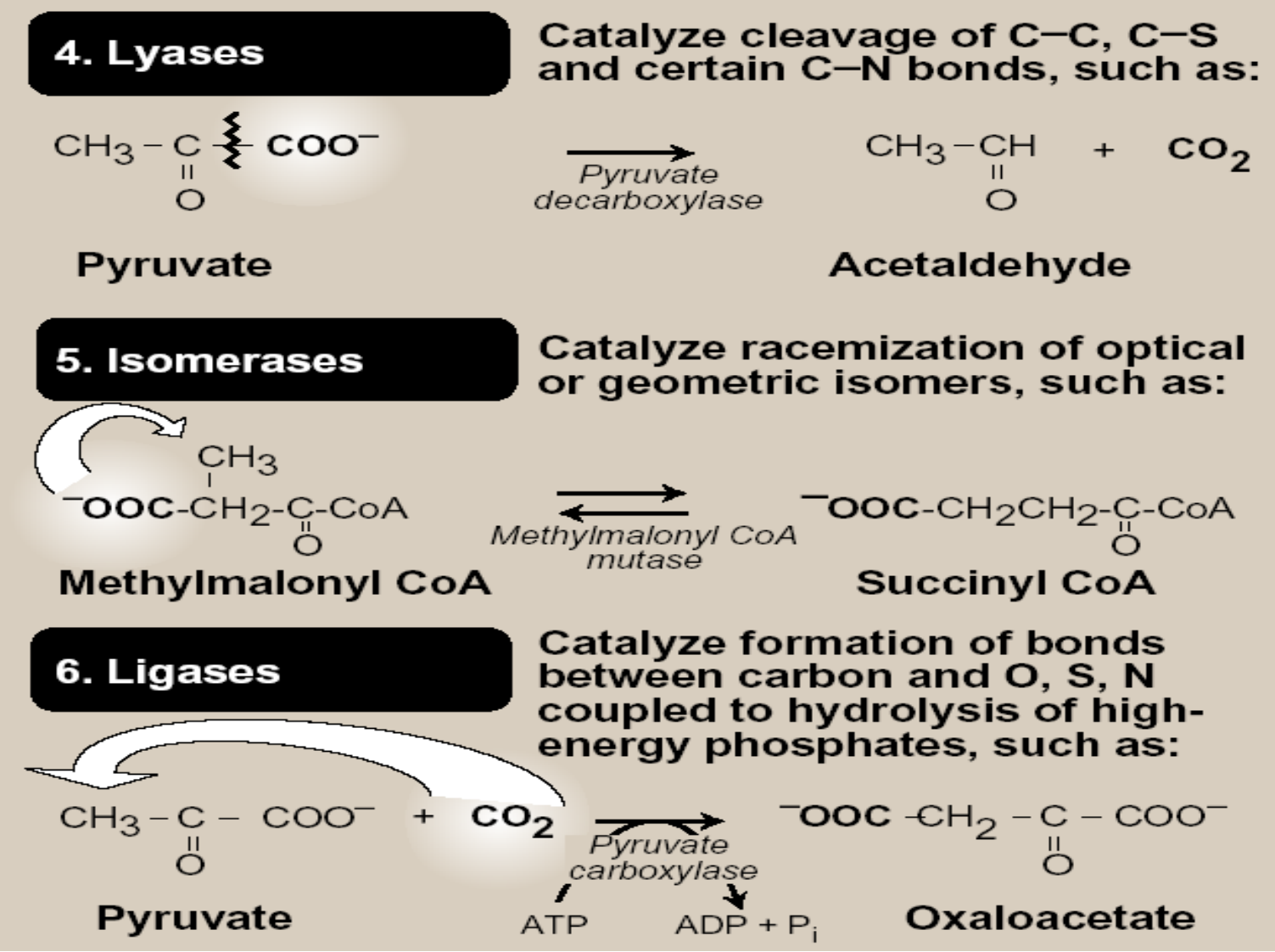
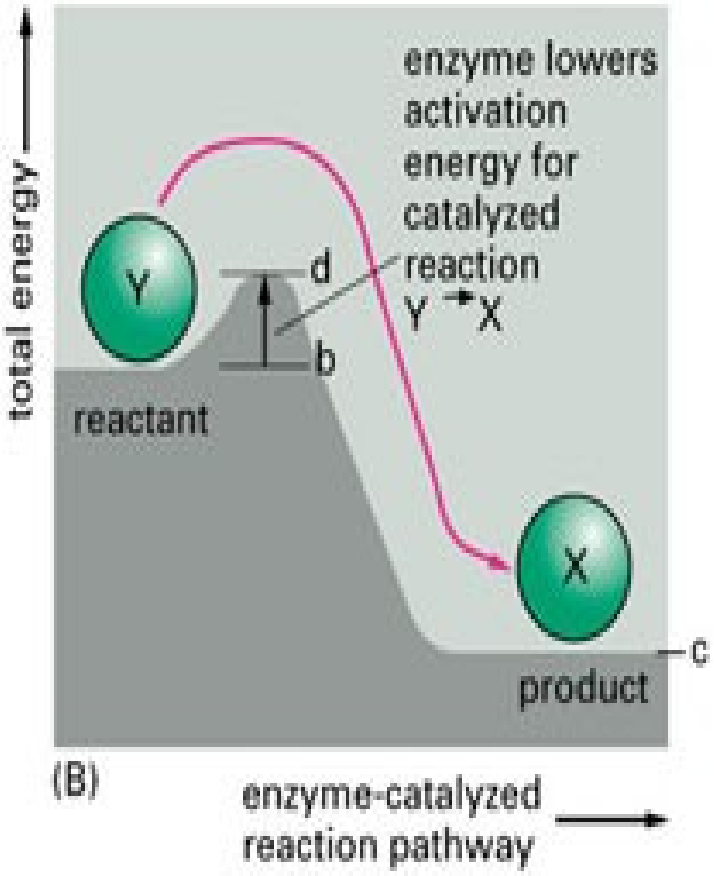

4. Lyases
Catalyze cleavage of C–C, C–S and certain C–N bonds, such as:
Pyruvate
Pyruvate decarboxylase
Acetaldehyde
5. Isomerases
Catalyze racemization of optical or geometric isomers, such as:
Methylmalonyl CoA
Methylmalonyl CoA mutase
Succinyl CoA
6. Ligases
Catalyze formation of bonds between carbon and O, S, N coupled to hydrolysis of high-energy phosphates, such as:
Pyruvate
Pyruvate carboxylase
ATP
ADP + Pi
Oxaloacetate

Cont'd...

How do enzymes Work?

Enzymes work by weakening bonds which lowers activation energy

- **Activation Energy** is needed to convert **potential energy** into **kinetic energy**.



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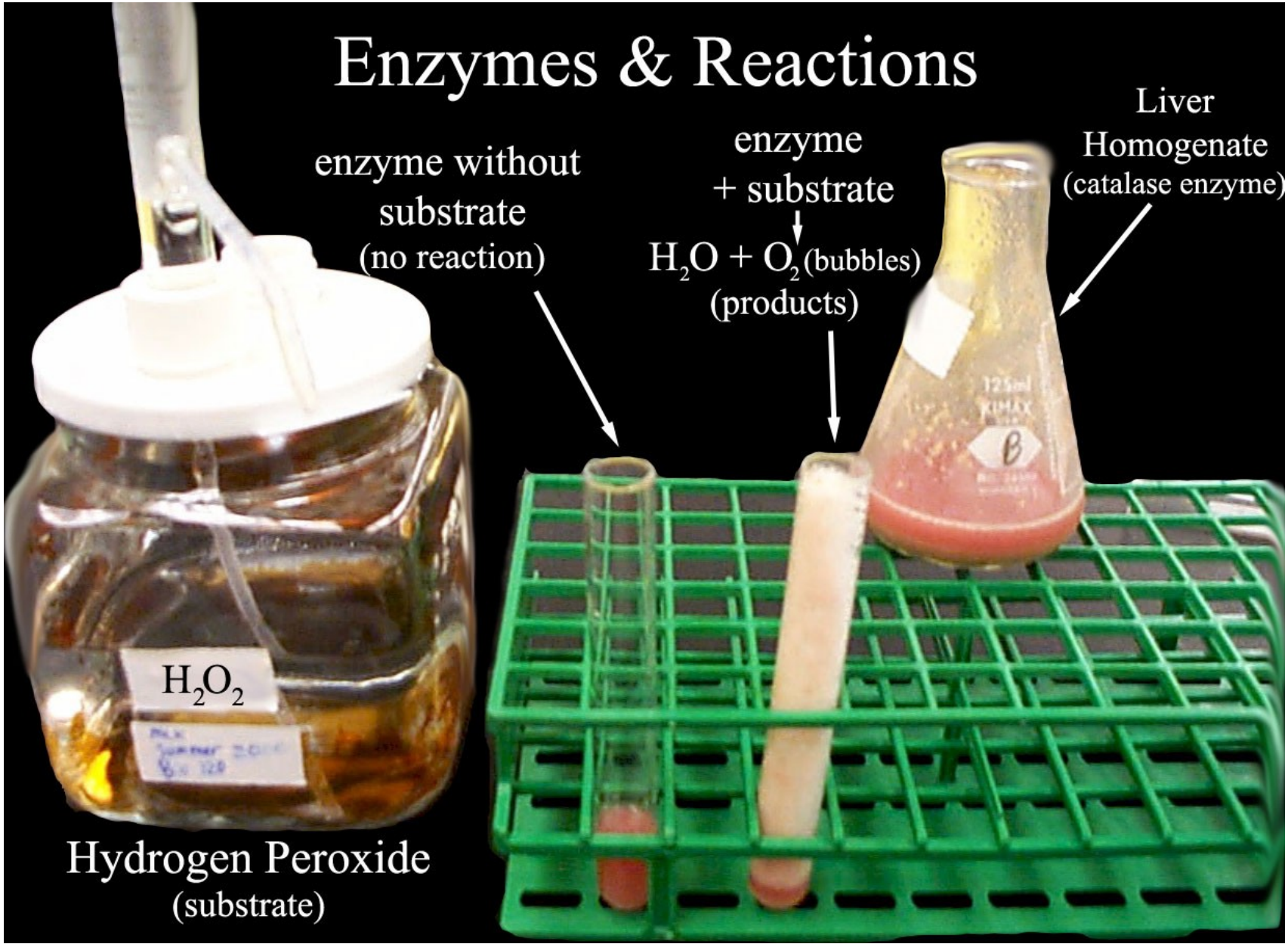
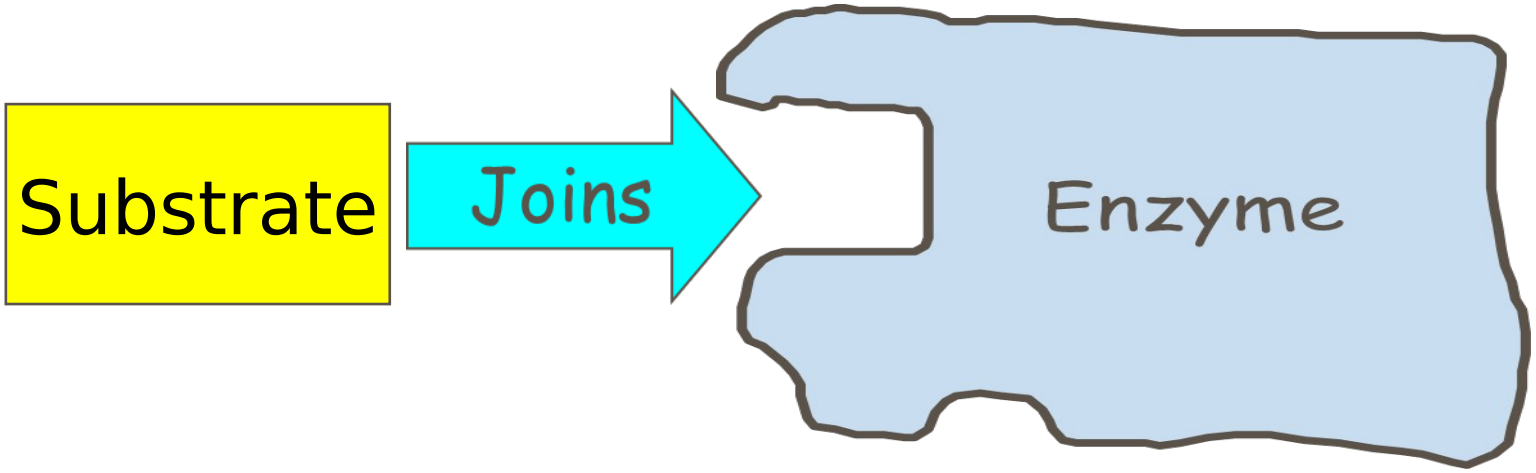

Enzymes & Reactions
enzyme without substrate (no reaction)
enzyme + substrate
$H_2O + O_2$ (bubbles)
(products)
Liver Homogenate (catalase enzyme)
H_2O_2
Hydrogen Peroxide
(substrate)

Enzyme-Substrate Complex

- The **substance** (reactant) an **enzyme** acts on is the **substrate**



Active Site

- A **restricted region** of an **enzyme** molecule which **binds** to the **substrate**.

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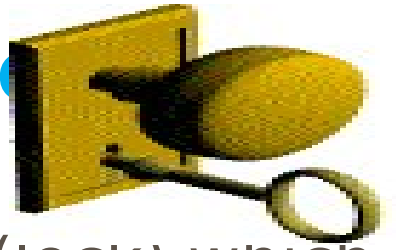
Models of How Enzymes W



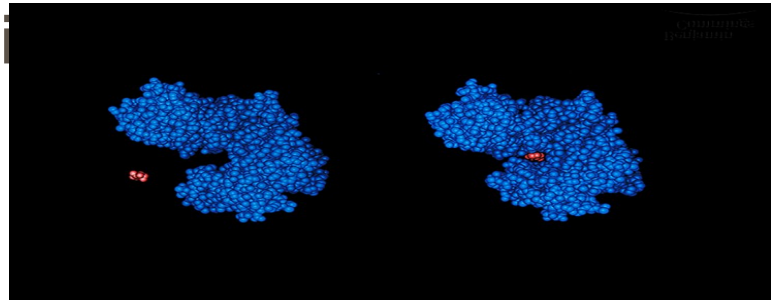
1. **Lock and Key model**

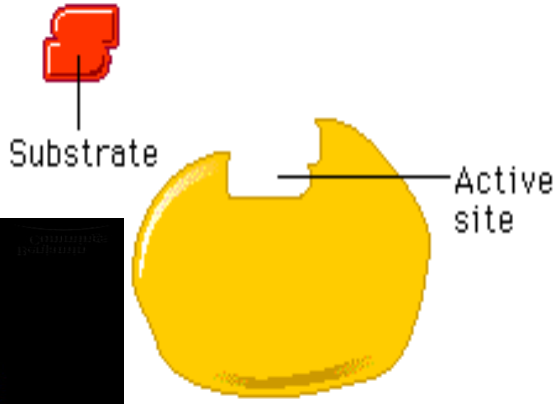
- Substrate (key) fits to the active site (lock) which provides a microenvironment for the specific reaction.

2. **Induced Fit model**

- **A change in the shape of an enzyme's active site**
- **Induced by the substrate**

Substrate "almost" fits into the active site, causing a strain on the chemical bonds, allowi reaction.





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Factors that Affect Enzymes

- **Environment (Temperature & pH)**
- **Cofactors**
- **Coenzymes**
- **Inhibitors**
- **Allosteric Sites**

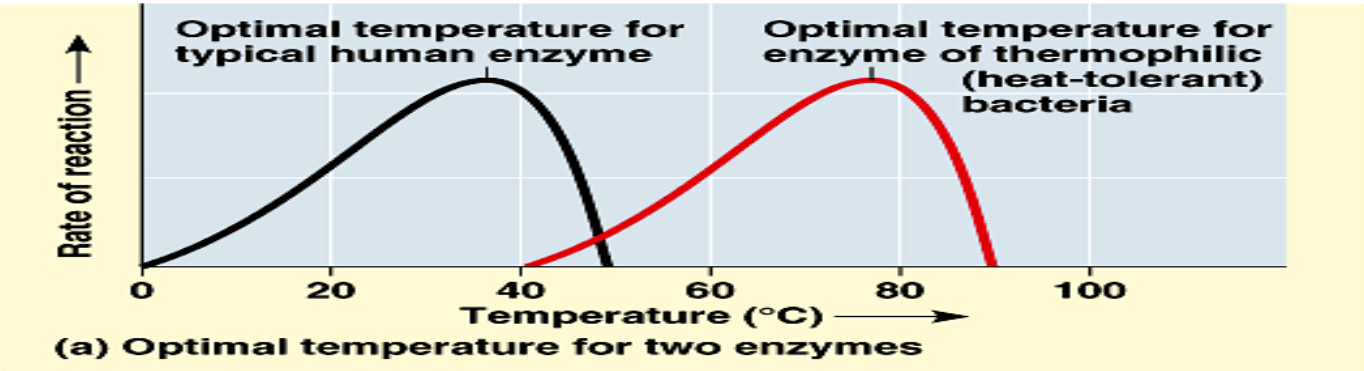
Environment

- Factors that change protein structure will affect an enzyme.
- Examples:
  - pH shifts
  - temperature
  - salt concentrations

Cont'd...

Temperature & pH

- **High temperatures denature enzymes (Most enzymes like normal body temperatures)**
- **Most enzymes function near neutral pH (6 to 8)**



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Cofactors

- Inorganic substances (zinc, iron, copper) are sometimes need for proper enzymatic activity.
- Non-protein helpers can bond to the active site of enzymes to help in reactions
- **Example:**

  Iron must be present in the **quaternary structure of hemoglobin** in order for it to pick up oxygen.

Coenzymes

- Organic molecules that act as cofactors which help enzymes.
- Examples:
  - vitamins

Cont'd...

Two examples of Enzyme Inhibitors

a. **Competitive inhibitors:** are chemicals that resemble an enzyme's normal substrate and compete with it for the active site.

b. **Noncompetitive inhibitors:**

Inhibitors that do not enter the active site, but bind to another part of the enzyme causing the enzyme to change its shape, which in turn alters the active site.

Control of Metabolism

- Is necessary if life is to function.
- Controlled by switching enzyme activity "off" or "on" or separating the enzymes in time or

Cont'd...

Types of Control

1. Switching on or off the genes that encode for specific enzyme production
2. Allosteric sites
3. Feedback inhibition
4. cooperativity

Allosteric Regulation

- The control of an enzyme complex by the binding of a regulatory molecule.
- Regulatory molecule may stimulate or inhibit the enzyme complex.
- Allosteric site is a specific receptor site on some part of the enzyme molecule away from the active site
- When activated, this site changes the shape of the enzyme to inhibit it or to stimulate it

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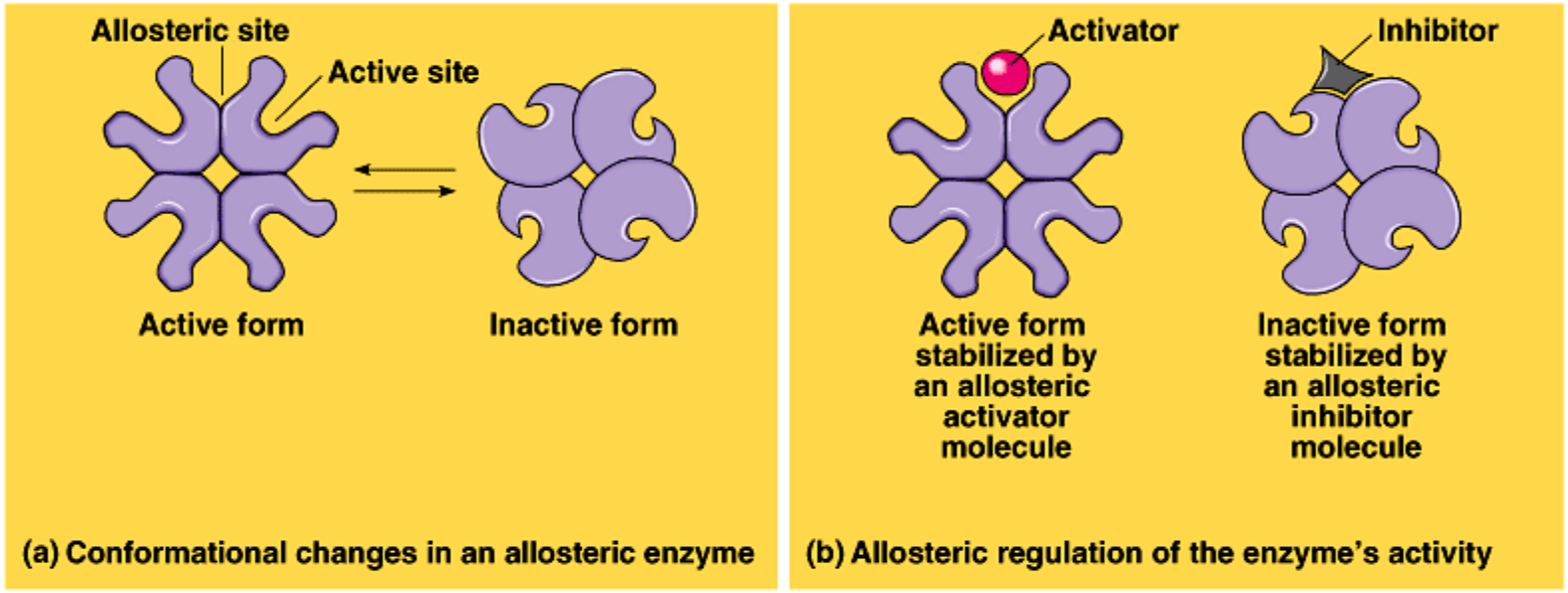

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Feedback Inhibition

- When a metabolic pathway is switched off by its end-product.
- End-product usually inhibits an enzyme earlier in the pathway.
- Prevents the cell from wasting chemical resources

4.3 Bioenergetics and biosynthesis

4.3.1. Cellular respiration

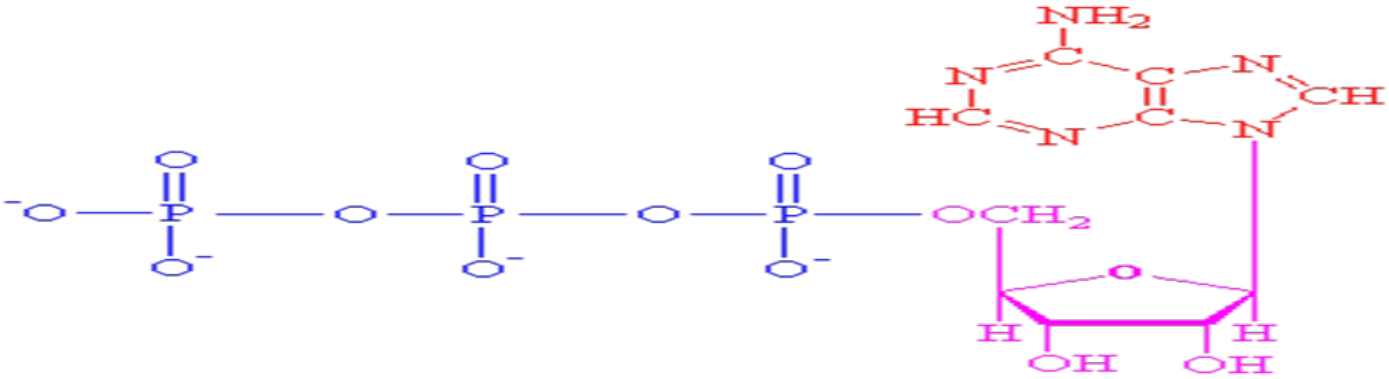
- Most living organisms obtain energy by breaking down organic molecules (catabolism) during cellular respiration.
- This catabolic process can be divided into 3 phases.
- Phase I - Breakdown of large complex biomolecules like polysaccharides, proteins and lipids into their respective building blocks (hydrolysis). The chemical reactions occurring during this stage do not release much energy.
- Phase II - These building blocks are usually oxidized to a common intermediate, acetyl - CoA. Additionally, pyruvate or other citric acid cycle intermediates may also be formed (in glycolysis and other pathways).
- Phase III – This consists of the citric acid cycle (i.e. oxidation of acetyl - CoA to CO_2, formation of NADH and $FADH_2$) followed by electron transport and oxidative phosphorylation. Energy released by electron transport to O_2 is coupled to ATP synthesis. This cycle is responsible for the release of much energy (TCA cycle and ETC)

Molecular structure of ATP

- Adenosine triphosphate (ATP) is a nucleoside triphosphate used in cells as a coenzyme.
- It is often called the "molecular unit of currency" of intracellular energy transfer.
- ATP transports chemical energy within cells for metabolism.
- It is one of the end products of photophosphorylation, cellular respiration, and fermentation and used by enzymes and structural proteins in many cellular processes, including biosynthetic reactions, motility, and cell division.

- Substrate level phosphorylation, oxidative phosphorylation in cellular respiration, and photophosphorylation in photosynthesis are three major mechanisms of ATP biosynthesis.
- Metabolic processes that use ATP as an energy source convert it back into its precursors.
- ATP is therefore continuously recycled in organisms.

- One molecule of ATP contains three phosphate groups, and it is produced by a wide variety of enzymes, including ATP synthase, from adenosine diphosphate (ADP) or adenosine monophosphate (AMP) and various phosphate group donors.



ATP consists of a base, in this case adenine (red), a ribose (magenta) and a phosphate chain (blue).

4.3.1.1 Anaerobic respiration

- Anaerobic respiration is a form of respiration using electron acceptors other than oxygen.
- Anaerobic metabolic processes do not require oxygen.

Glycolysis

- Glycolysis (from glycose, an older term for glucose + -lysis degradation) is the metabolic pathway that converts glucose $C_6H_{12}O_6$, into pyruvate, $CH_3COCOO^- + H^+$.
- The free energy released in this process is used to form the high-energy compounds ATP (adenosine triphosphate) and NADH (reduced nicotinamide adenine dinucleotide).

- Glycolysis does not require or consume oxygen.
- The terms "aerobic glycolysis" and "anaerobic glycolysis" refer to glycolysis in the presence or absence of oxygen, respectively.
- Glycolysis occurs, with variations, in nearly all organisms, both aerobic and anaerobic.
- The wide occurrence of glycolysis indicates that it is one of the most ancient known metabolic pathways.
- It occurs in the cytosol of the cell.

The entire glycolysis pathway can be separated into two phases:

1. The Preparatory Phase – in which ATP is consumed and is hence also known as the investment phase

- The first five steps are regarded as the preparatory (or investment) phase, since they consume energy to convert the glucose into two three-carbon sugar phosphates (G3P).

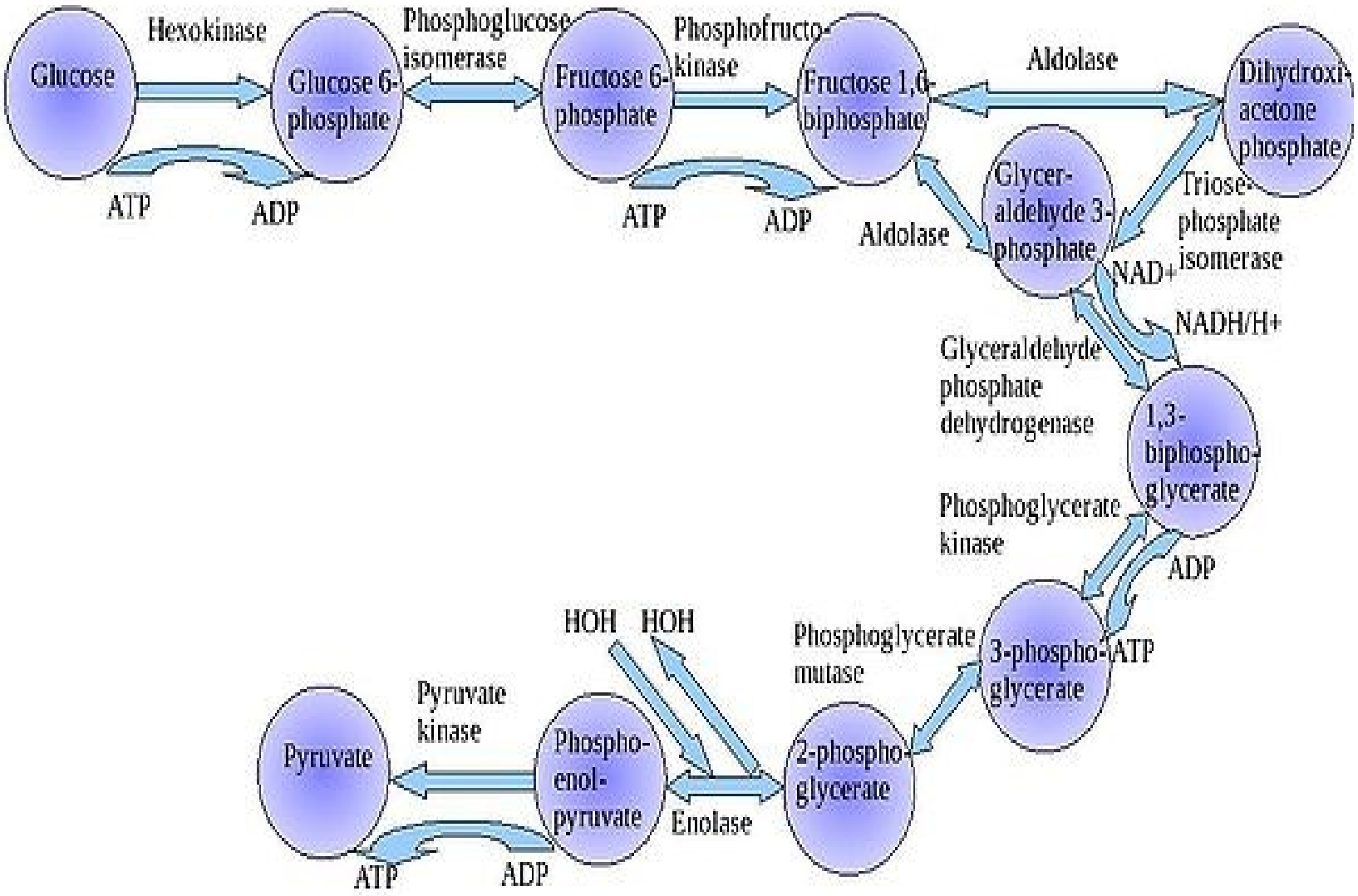
2. The Pay Off Phase – in which ATP is produced.

- Characterized by a net gain of the energy-rich molecules ATP and NADH.
- This yields 2 NADH molecules and 4 ATP molecules, leading to a net gain of 2 NADH molecules and 2 ATP molecules from the glycolytic pathway per glucose.
- Substrate-level phosphorylation is the mechanism to produce ATP during glycolysis.

Biochemical logic for the presence of regulatory steps

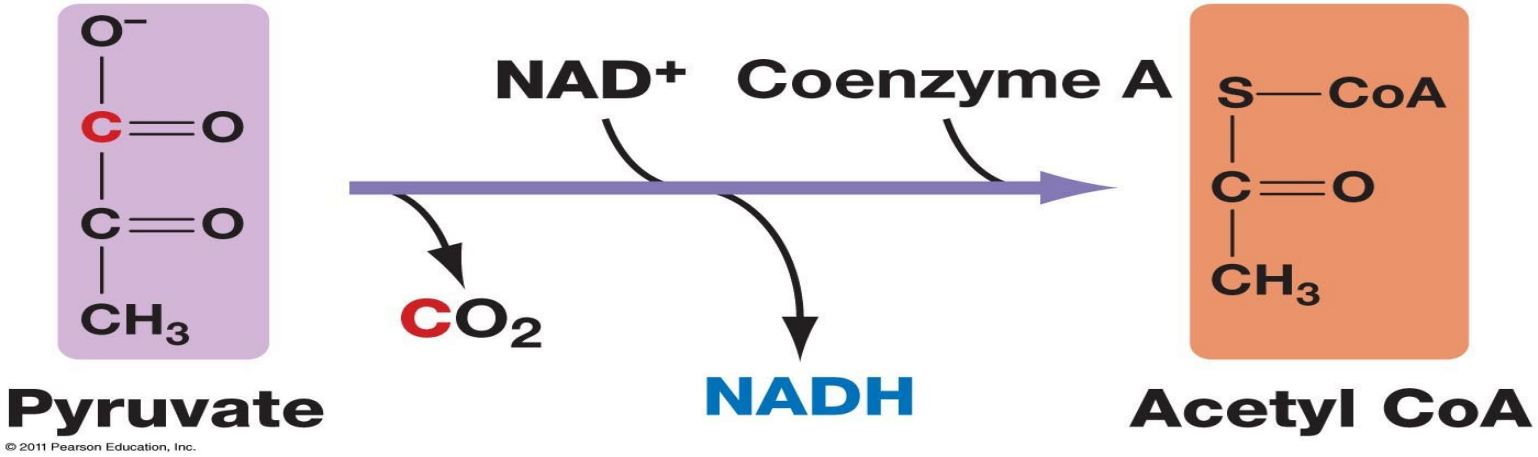
- The existence of more than one point of regulation indicates that intermediates between those points enter and leave the glycolysis pathway by other processes.
- For example, in the first regulated step, hexokinase converts glucose into glucose-6-phosphate. Instead of continuing through the glycolysis pathway, this intermediate can be converted into glucose storage molecules, such as glycogen or starch.

Glycolysis involves ten enzymatic reactions as described below



4.3.1.2 TCA(Tricarboxylic Acid) cycle and ETC(Electron Transport Chain): Aerobic respiration

- One fate of pyruvate is that it enters to TCA cycle for complete oxidation. But there are intermediate processes: **The Oxidation of Pyruvate to form Acetyl CoA for Entry Into the Krebs Cycle**
- 2 NADH's are generated (1 per pyruvate)
- 2 CO_2 are released (1 per pyruvate)



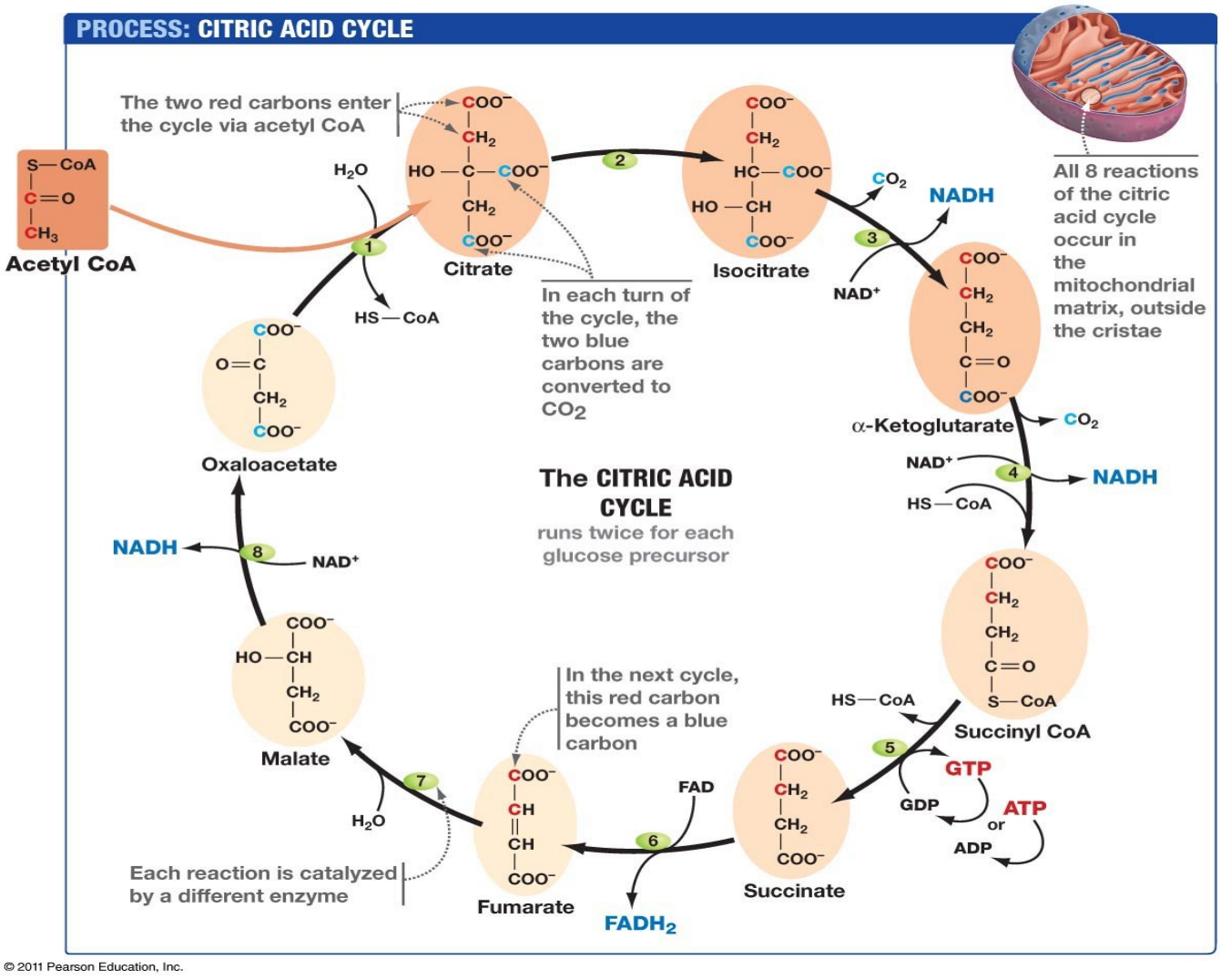
- **The Krebs Cycle (citric acid cycle, TCA cycle)**

- is considered as central pathway of aerobic metabolism, as it serves two purposes- bioenergetics and biosynthesis

1. **Bioenergetics:** The cycle carries out complex degradation of acetyl group in acetyl - CoA to CO_2, resulting in release of energy (ATP or GTP) and reducing power (NADH and $FADH_2$).
2. **Biosynthesis:** It supplies precursors for several biosynthetic pathways of amino acids, pyrimidines, purines etc

Example:- α-ketoglutarate and oxaloacetate are used for synthesis of a number of amino acids like glutamic acid, asparatic acid etc

- Acetyl - CoA is the starting material for fatty acid biosynthesis.



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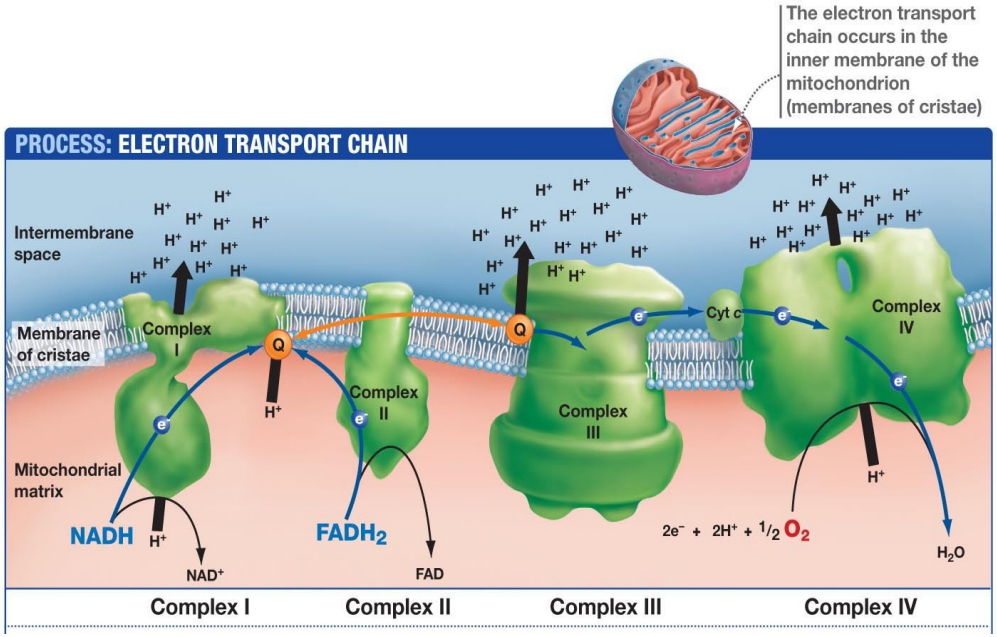
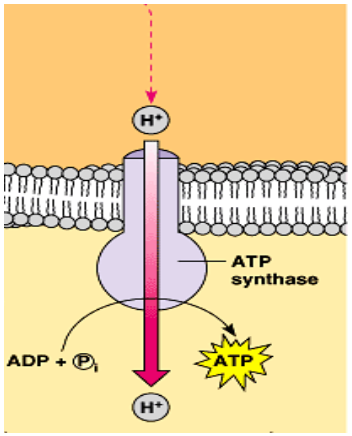
- 6 NADH's are generated (3 per Acetyl CoA that enters)
- 2 FADH2 is generated (1 per Acetyl CoA that enters)
- 2 ATP are generated (1 per Acetyl CoA that enters)

Therefore, the total numbers of molecules generated in the Oxidation of Pyruvate and the Krebs Cycle is: 8 NADH, 2 FADH2, 2 ATP and 6 CO2

7.3.2 Electron transport chain

- In aerobic respiration, electron transport is the final step in the break-down of glucose.
- It also is the point at which most of the ATP is produced. High-energy electrons and hydrogen ions from NADH and FADH2 produced in the Krebs cycle are used to convert ADP to ATP.





The maximum net Energy Production from Aerobic Respiration is 36-38.

Biosynthesis

- **Biosynthesis** is a multi-step, enzyme-catalyzed process where substrates are converted into more complex products in living organisms.
- In biosynthesis, simple compounds are modified, converted into other compounds, or joined together to form macromolecules.
- This process often consists of metabolic pathways.
- Some of these biosynthetic pathways are located within a single cellular organelle, while others involve enzymes that are located within multiple cellular organelles.
- Examples of these biosynthetic pathways include the **production of lipid membrane components** and **nucleotide**.

Cont’d…

- The prerequisite elements for biosynthesis include: precursor compounds, chemical energy (e.g. ATP), and catalytic enzymes which may require coenzymes (e.g.NADH, NADPH).
- These elements create monomers, the building blocks for macromolecules.
- Some important biological macromolecules include: **proteins**, which are composed of amino acid monomers joined via peptide bonds, and
- **DNA** molecules, which are composed of nucleotides joined via phosphodiester bonds.

Requirements of Biosynthesis

I. Photosynthesis

- Energy is transformed all around us every day.
- Batteries convert chemical energy into electric energy, and radios convert electric energy into the energy carried by sound waves.
- Similarly, some **autotrophs** convert light energy into chemical energy through **photosynthesis.**

The importance of photosynthesis

- The processes of all organisms, from **bacteria** to **humans** require energy and to get this energy, many organisms access stored energy by eating food.
- Carnivores eat other animals and herbivores eat plants. **But where does the stored energy in food originate?**

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- All of this energy can be traced back to the process of **photosynthesis** and **light energy** from the sun.
- Photosynthesis is essential to all life on earth.
- It is the only biological process that captures energy from outer space (sunlight) and converts it into chemical energy in the form of **Glyceraldehyde3-phosphate** (G3P), which in turn can be made into sugars and other organic compounds such as **proteins**, **lipids**, and **nucleic acids**.
- **Plants** use these compounds in all of their metabolic processes.
- Unlike plants, **animals** need to consume other organisms to consume the molecules they need for their metabolic processes.

The process of photosynthesis

- During photosynthesis, molecules in leaves capture sunlight and energize electrons, which are then stored in the covalent bonds of carbohydrate molecules.
- That energy within those covalent bonds will be released when they are broken during cell respiration.
- **How long lasting and stable are those covalent bonds?**
- The energy extracted today by the burning of coal and petroleum products represents sunlight energy captured and stored by **photosynthesis** almost 200 million years ago.

➢ **Photoautotrophs**

✓ Are organisms(plants, algae, and some bacteria) which have a capability of performing photosynthesis and they use light to manufacture their own food.

Cont'd…

- **Heterotrophs**: are organisms, such as animals, fungi, and most other bacteria, they must rely on the **sugars** produced by photosynthetic organisms for their energy needs.
- **Chemoautotrophs**: are very interesting group **of bacteria** synthesize sugars, not by using sunlight's energy, but by extracting energy from inorganic chemical compounds.
- The importance of photosynthesis is not just that it can capture sunlight's energy.
- A lizard sunning itself on a cold day can use the sun's energy to warm up.
- Photosynthesis is vital because it evolved as a way to store the energy in solar radiation (the photo part) as high energy electrons in the carbon-carbon bonds of carbohydrate molecules (the ''synthesis'' part).

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Other variant of photosynthesis

- Commonly known photosynthetic processes is the one known as **oxygenic photosynthesis**.
- The other type is termed as **anoxygenic photosynthesis**.
- The general principles of anoxygenic and oxygenic photosynthesis are very similar,
- But oxygenic photosynthesis is the most common and is seen in **plants, algae** and **cyanobacteria**.
- During **oxygenic photosynthesis**, light energy transfers electrons from water (H2O) to carbon dioxide (CO2), to produce carbohydrates.
- In this transfer, the CO2 is "reduced," or receives electrons, and the water becomes "oxidized," or loses electrons. Ultimately, oxygen is produced along with carbohydrates.

Cont'd…

- On the other hand, anoxygenic photosynthesis uses electron donors other than **water**.
- The process typically occurs in bacteria such as **purple bacteria** and **green sulfur bacteria**, which are primarily found in various aquatic habitats.

The photosynthetic apparatus

- **Plastids**
  - Photosynthetic eukaryotic organisms contain organelles called **plastids** in their cytoplasm.
  - Plastids generally contain pigments or can store nutrients.
  - Colorless and nonpigmented **leucoplasts** store fats and starch, while **chromoplasts** contain

Cont'd…

- Photosynthesis occurs in the chloroplasts; specifically, in the **grana** and **stroma** regions.
- The **grana** is the innermost portion of the organelle; a collection of disc-shaped membranes, stacked into columns like plates.
- The individual discs are called **thylakoids**. It is here that the transfer of electrons takes place.
- Chloroplasts are similar to mitochondria, the energy centers of cells, in that they have their own genome, or collection of genes, contained within circular DNA

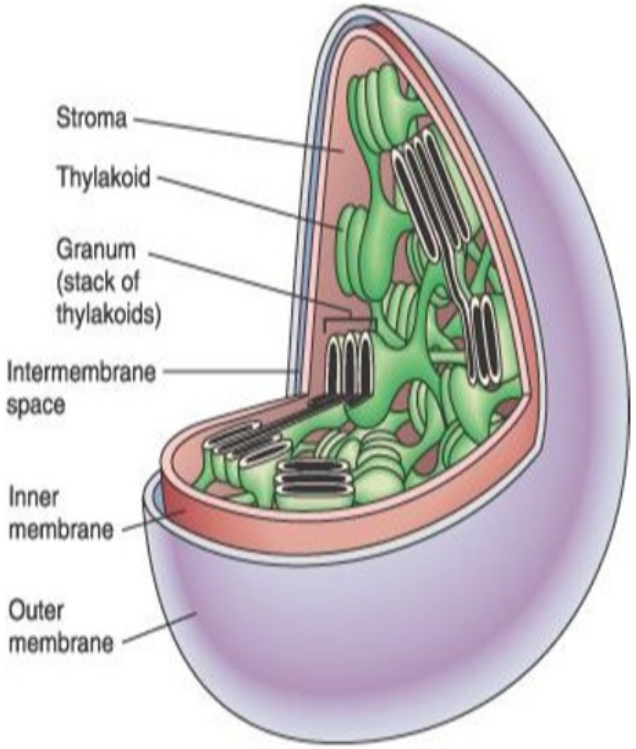

Fig: 4.4. structure of chloroplast

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Pigments

- **Pigments** are molecules that bestow color on plants, algae and bacteria, but they are also responsible for effectively trapping sunlight.
- Pigments of different colors absorb different wavelengths of light. There are 3 main group of pigments.

1. Chlorophylls

- These green-colored pigments are capable of trapping blue and red light.
- Chlorophylls have three subtypes, **dubbed chlorophyll a**, **chlorophyll b** and **chlorophyll c**.
- There is also a bacterial variant aptly named bacteriochlorophyll, which absorbs infrared light.
- This pigment is mainly seen in purple and green bacteria, which perform anoxygenic photosynthesis.

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2.Carotenoids: these red, orange or yellow-coloured pigments absorb bluish-green light. Examples of carotenoids are **xanthophyll (yellow)** and **carotene** (orange) from which carrots get their color**.**

3.Phycobilins: these red or blue pigments absorb wavelengths of light that are not as well absorbed by chlorophylls and carotenoids. They are seen in **cyanobacteria** and **red algae.**

Antennae

- Pigment molecules are associated with **proteins**, which allow them the flexibility to move toward light and toward one another.
- A large collection of 100 to 5,000 pigment molecules constitutes antennae. These structures effectively capture light energy from the sun, in the form of photons.

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Reaction centers: the pigments and proteins, which convert light energy to chemical energy and begin the process of electron transfer, are known as **reaction centers**.

The photosynthetic process

- The reactions of plant photosynthesis are divided into those that require the presence of sunlight and those that do not.
- Both types of reactions take place in **chloroplasts**: light dependent reactions in the thylakoid and light-independent reactions in the stroma**.**
- **Light-dependent reactions :**When a photon of light hits the reaction center, a pigment molecule such as chlorophyll releases an electron.
- The released electron manages to escape by traveling through an electron transport chain, which generates the energy needed to produce **ATP** (adenosine triphosphate, a source of chemical energy for cells) and **NADPH**.
- The "electron hole" in the original chlorophyll pigment is filled by taking an electron from water. As a result, oxygen is released into the atmosphere.

Cont'd...

- **light-independent reactions** (also called dark reactions and known as the **Calvin cycle**): Light reactions produce ATP and NADPH, which are the rich energy sources that drive dark reactions.
- Although **NADPH** and **ATP** provide cells with large amounts of energy, these molecules are not stable enough to store chemical energy for long periods of time.
- Thus, there is a second phase of photosynthesis called the Calvin cycle in which energy is stored in organic molecules such as glucose.

Three chemical reaction steps make up the Calvin cycle:

- **Carbon fixation**,
- **Reduction** and
- **Regeneration**.

Cont’d…

- These reactions use **water and catalysts**.
- The carbon atoms from carbon dioxide are ''fixed,'' when they are built into organic molecules that ultimately form three-carbon sugars. These sugars are then used to make glucose or are recycled to initiate the Calvin cycle again.

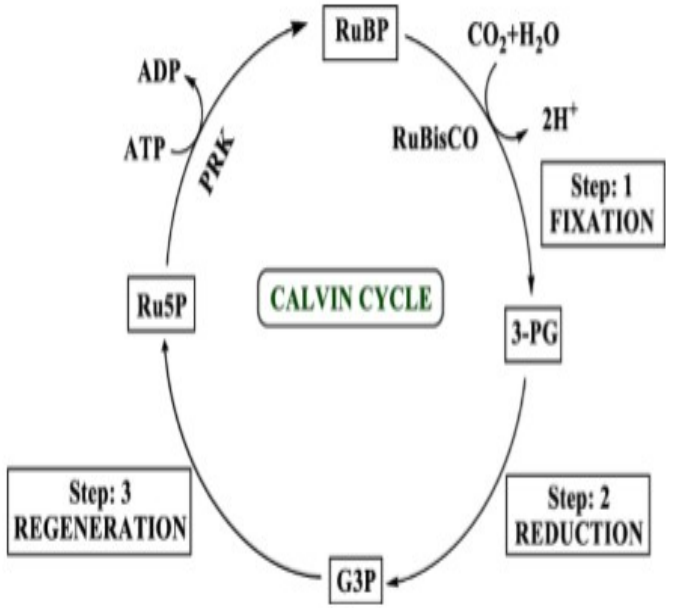

Fig:4.6. Calvin cycle

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Alternative Pathways

- The environment in which an organism lives can impact the organism's ability to carry out **photosynthesis**.
- Environments in which the amount of **water** or **carbon dioxide** available is insufficient can decrease the ability of a photosynthetic organism to convert **light energy** into **chemical energy**.
- For example, plants in hot, dry environments are subject to excessive water loss that can lead to decreased photosynthesis.
- Many plants in extreme climates have altered native photosynthesis pathways to **maximize energy conversion**.

Cont'd...

- C4 plants one adaptive pathway that helps plants maintain photosynthesis While minimizing water loss is called the C4 pathway.
- **The C4 pathway** occurs in plants such as sugar cane and corn and these plants are called C4 plants because **they fix carbon dioxide into four-carbon compounds instead of three-carbon molecules during the Calvin cycle**.
- C4 plants also have significant structural modifications in the arrangement of cells in the leaves.
- In general, C4 plants keep their stomata closed during hot days, while the four carbon compounds are transferred to special cells where CO2 enters the Calvin cycle.
- This allows for sufficient carbon dioxide uptake, while simultaneously minimizing water loss.

Cont'd…

- CAM plants Another adaptive pathway used by some plants to maximize photosynthetic activity is called crassulacean acid metabolism (CAM photosynthesis).
- **The CAM pathway** occurs in water conserving plants that live in deserts, salt marshes, and other environments where access to water is limited.
- CAM plants, such as **cacti**, **orchids**, and **the pineapple** allow carbon dioxide to enter The leaves only at night, when the atmosphere is cooler and more humid.
- At night, these plants fix **carbon dioxide** into **organic compounds.**
- During the day, carbon dioxide is released from these compounds and enters the Calvin cycle.
- This pathway Also allows for sufficient carbon dioxide uptake, while minimizing water loss.

CHAPTER 5

GENETICS AND EVOLUTION