BIOLOGY FOR ENGINEERS

PRIYA.M

ASST.PROFESSOR

BIHER

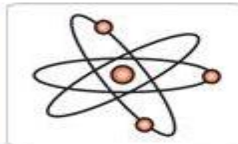
UNIT-1

FROM ATOMS TO ORGANISMS

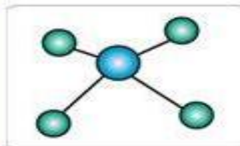
KIT IN USE / ASSEMBLED

SUBATOMIC PARTICLES

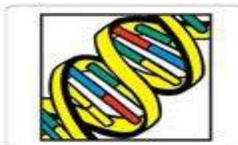
ATOMS



MOLECULES

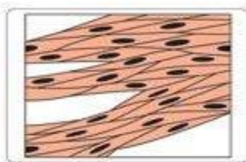


MACRO MOLECULES



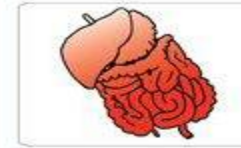
CELLS

TISSUE



ORGANS

ORGAN SYSTEMS



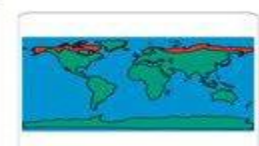
ORGANISM

POPULATION

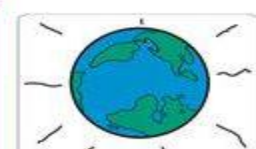
COMMUNITY

ECOSYSTEM

BIOME



BIOSPHERE



The cell: The basic unit of life

What are cells?

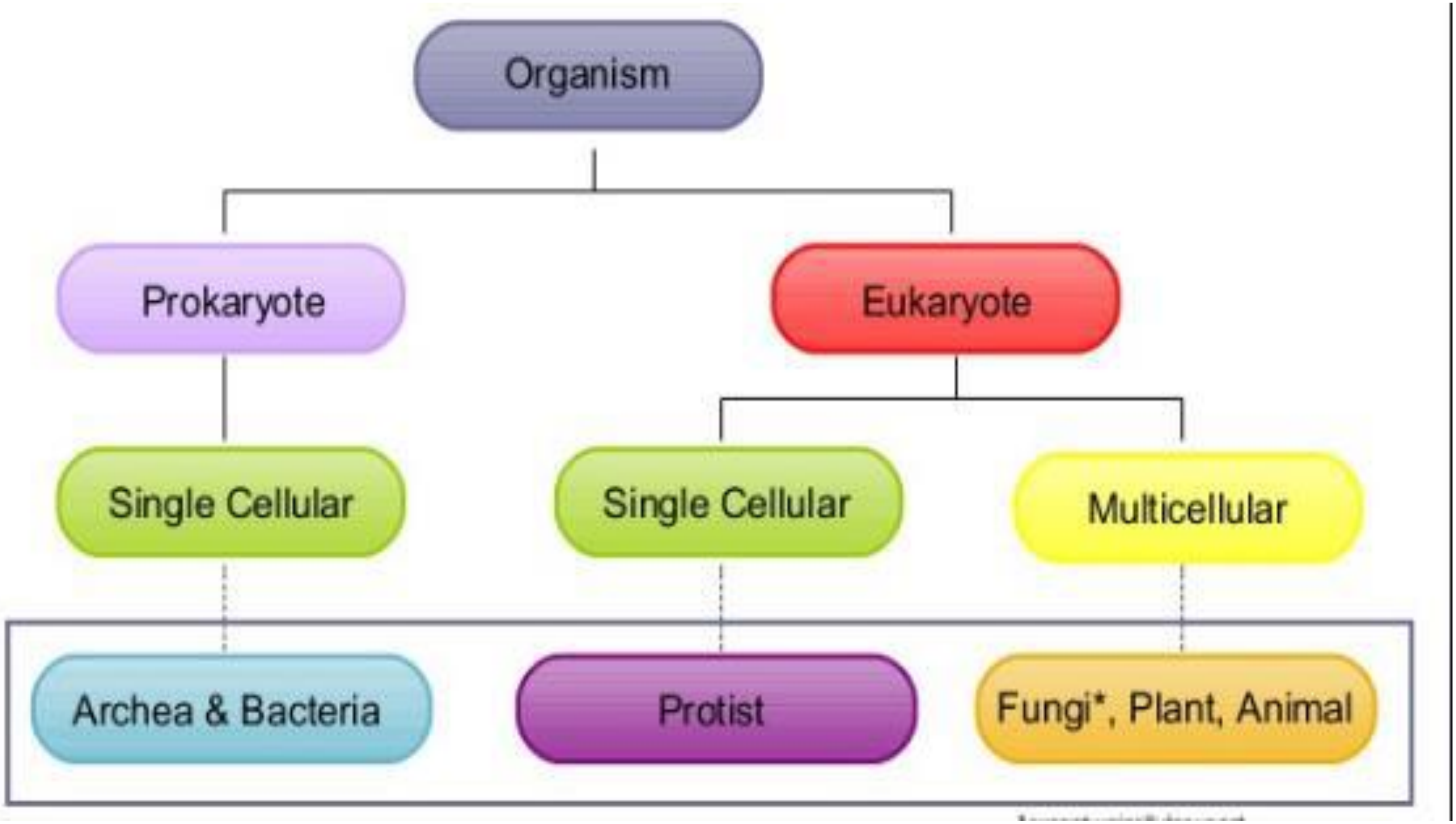
- Cells are the **fundamental structural and functional unit** of all living beings.
- Every cell has its own life.
- Old and week cells in the body continually die and are replaced by new cells.
- All organisms including ourselves, start life as a single cell.
- Cells are so small (microscopic)

CELL THEORY

- Cell theory was eventually formulated in 1838
- Schleiden and Theodor Schwann.
- Cell theory has become the foundation of biology and is the most widely accepted explanation of the function of cells.

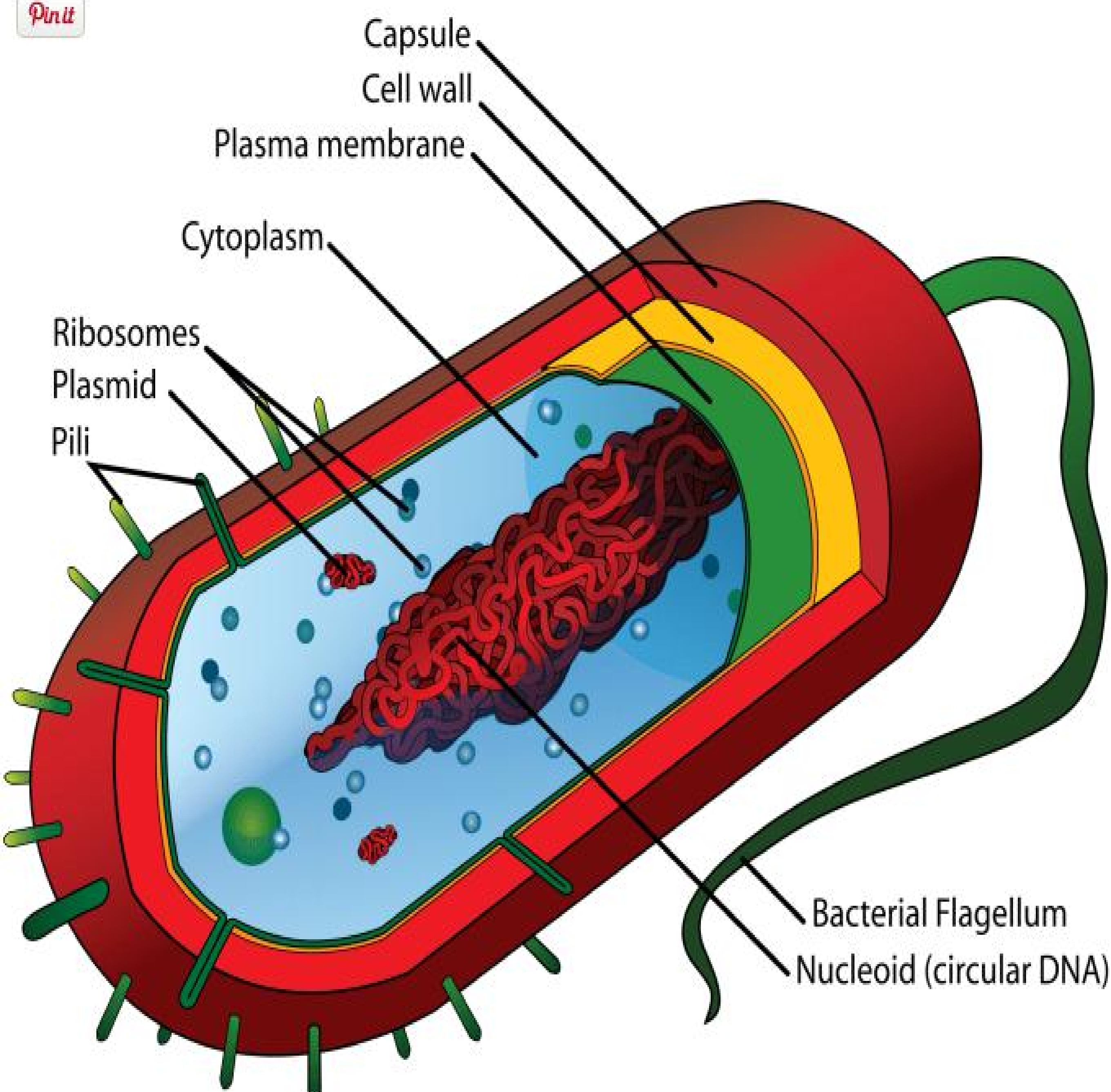
1. All living organisms are composed of one or more cells.
2. The cell is the basic unit of structure and organization in organisms.
3. Cells arise from pre-existing cells.

CLASSIFICATION



PROKARYOTES

- Pro-false   Karyotes – cell
- **lack nucleus** and other membrane bound organelles.
- Prokaryotic cells are placed in two taxonomic domains.
- Bacteria
- Archea bacteria – live in extreme habitats
- Most prokaryotes vary in size from 0.2 µm to 750 µm


Capsule
Cell wall
Plasma membrane
Cytoplasm
Ribosomes
Plasmid
Pili
Bacterial Flagellum
Nucleoid (circular DNA)

PROKARYOTIC CELL STRUCTURE

Capsule: Additional outer covering

- Protects the cell when it is **engulfed** by phagocytes and by viruses
- Retaining moisture

Cell wall: outermost layer, gives shape

- Bacterial cell walls are made of **peptidoglycan layer.**
- Archaea, which do not contain peptidoglycan

Cell membrane: Semipermeable membrane

- regulates the flow of substances in and out of the cell.

Cytoplasm: fluid in nature that fills the cell

- 80% water that also contains enzymes, salts, cell organelles

Ribosomes:

- **Protein synthesis**.

Nucleiod Region:

- contains the bacterial DNA molecule.

Plasmids: Extra piece of chromosomal DNA

- They are double-stranded and circular.

Plasmids are responsible for

1. Virulence factor
2. Antibiotic resistance
3. Conjugation: The process of transferring genetic material from one bacterial cell to another bacterial cell

Pili: hair-like structures on the surface of the cell

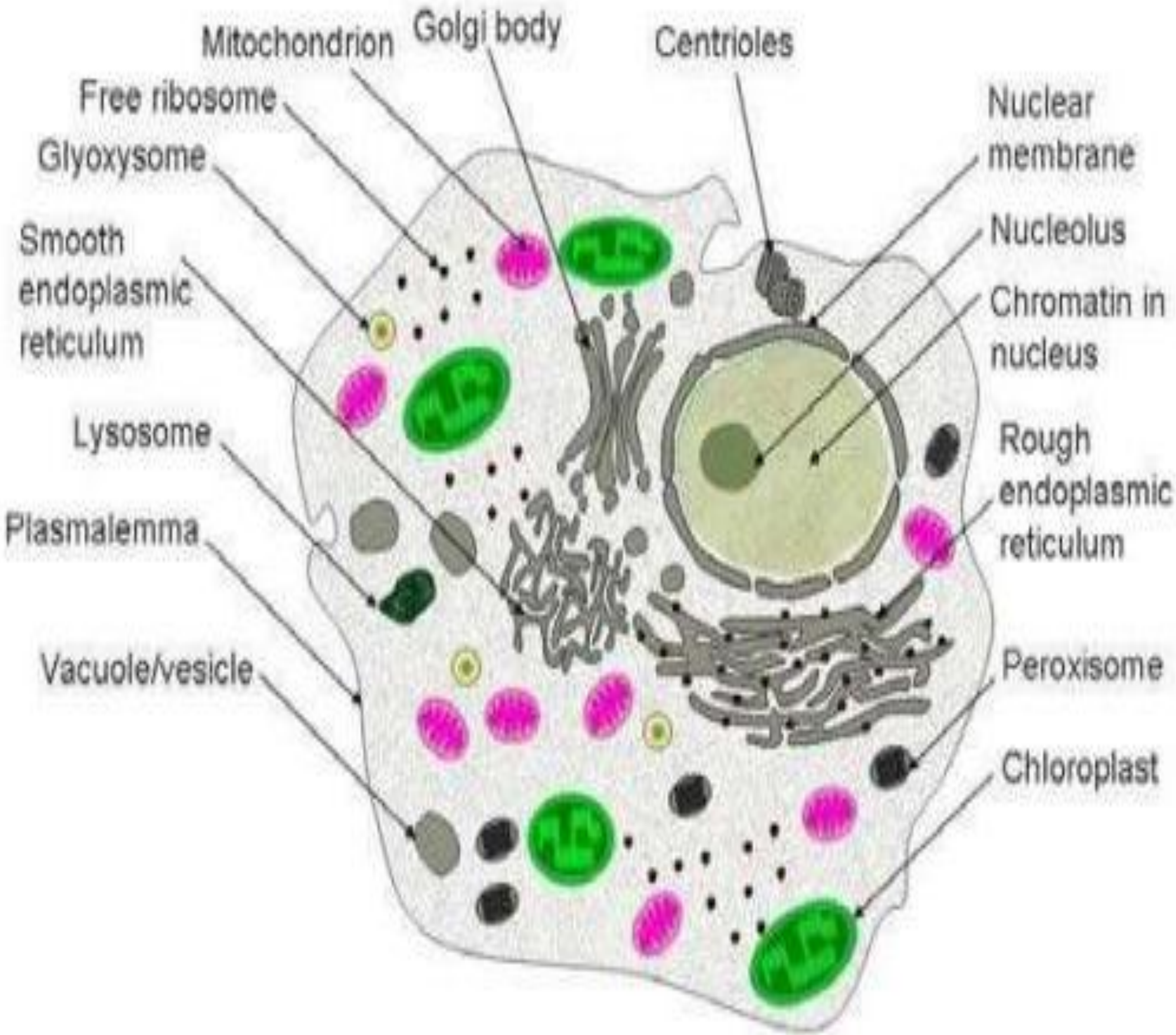
- help attach to other bacterial cells.

Flagella: long, whip-like organelle

- cellular locomotion.
- functions as a sensory organelle, being sensitive to chemicals and temperatures outside the cell.
- Protein flagellin

EUKARYOTIC CELL STRUCTURE AND FUNCTION

- Eu – True   Karyotes – cell
- **Well defined nucleus** and membrane bound organelles
- They belong to the taxa Eukaryota.

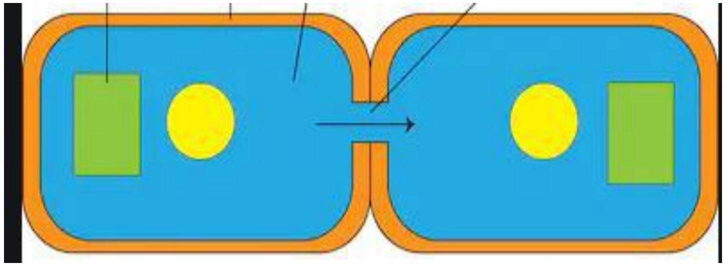

Mitochondrion
Golgi body
Centrioles
Free ribosome
Glyoxysome
Nuclear membrane
Smooth endoplasmic reticulum
Nucleolus
Chromatin in nucleus
Lysosome
Rough endoplasmic reticulum
Plasmalemma
Vacuole/vesicle
Peroxisome
Chloroplast

Cell Wall: Extracellular structure surrounding plasma membrane

- composed of cellulose, hemicellulose, pectin
- it controls turgidity.

Cell membrane : Semipermeable membrane.

Plasmodesmata: Pores in the primary cell wall



Chloroplast/Plastids

- contain **chlorophyll**
- Responsible for photosynthesis.

Mitochondria: spherical to rod-shaped organelles

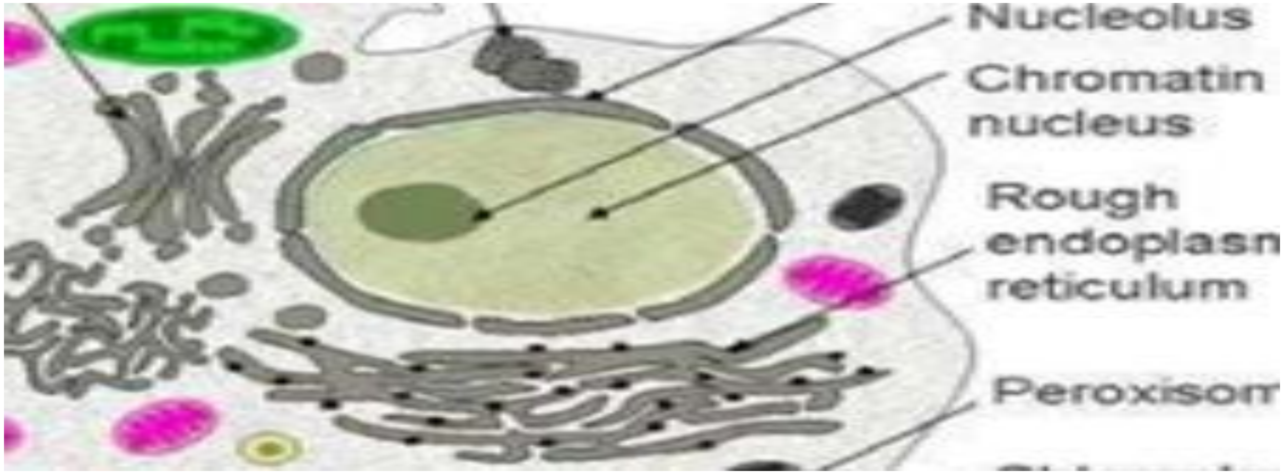
- The mitochondrion converts the energy stored in **glucose into ATP** (adenosine triphosphate)

Nucleus

- Controls **protein synthesis**
- Contains DNA in chromosomes.

Nucleolus:

- Protein synthesis is initiated



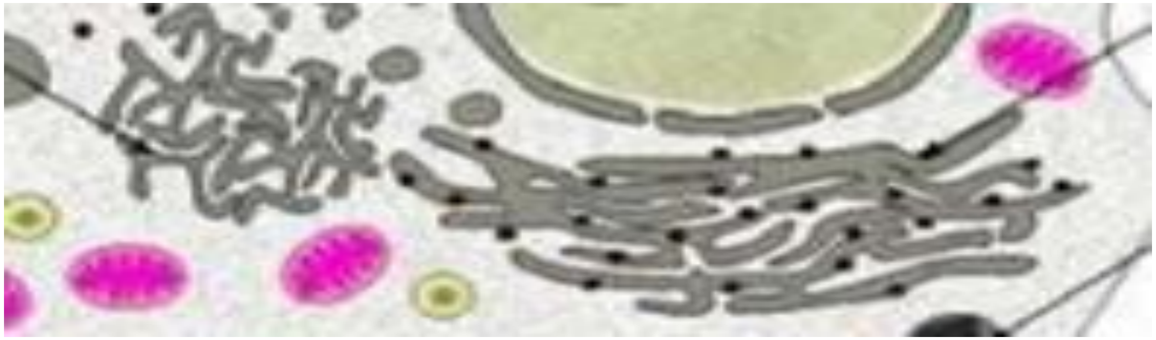
Endoplasmic reticulum

RER – Rough Endoplasmic reticulum

- convoluted sacks
- Contains ribosomes – Protein synthesis

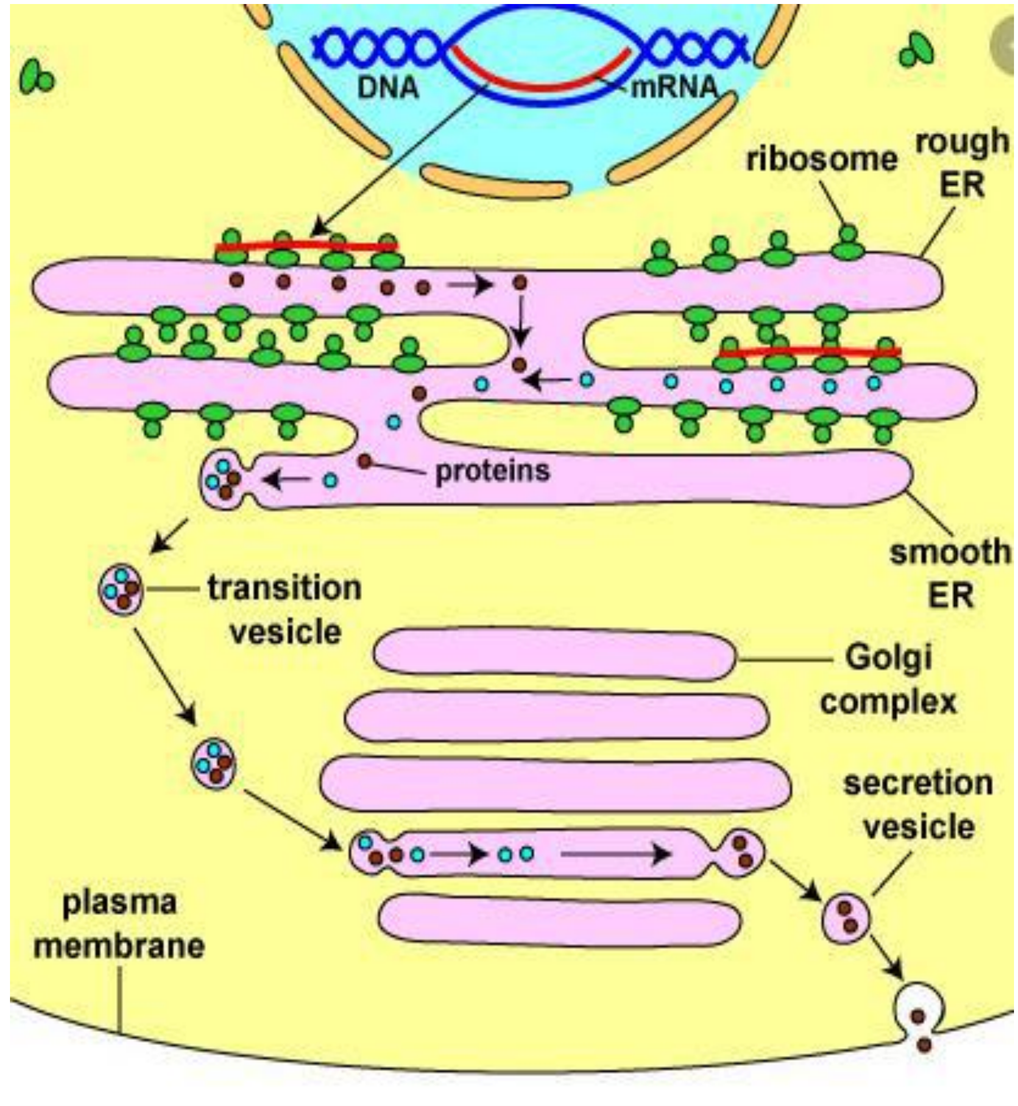
SER - Smooth Endoplasmic reticulum

- convoluted tubes, no ribosomes
- Moves the newly-made proteins to the Golgi body



Golgi apparatus

- flattened, layered, sac-like organelle
- packaging proteins and transport.



Lysosome: stomach of the cell.

- hydrolase enzymes

Peroxisome: breaks down toxic substances like hydrogen peroxide

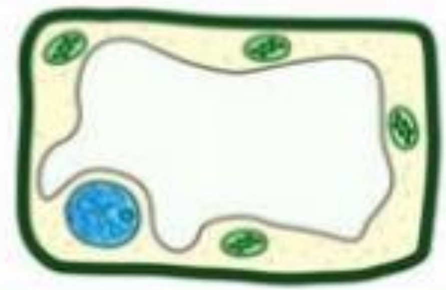
- Oxidase enzymes
- major site of oxygen utilization

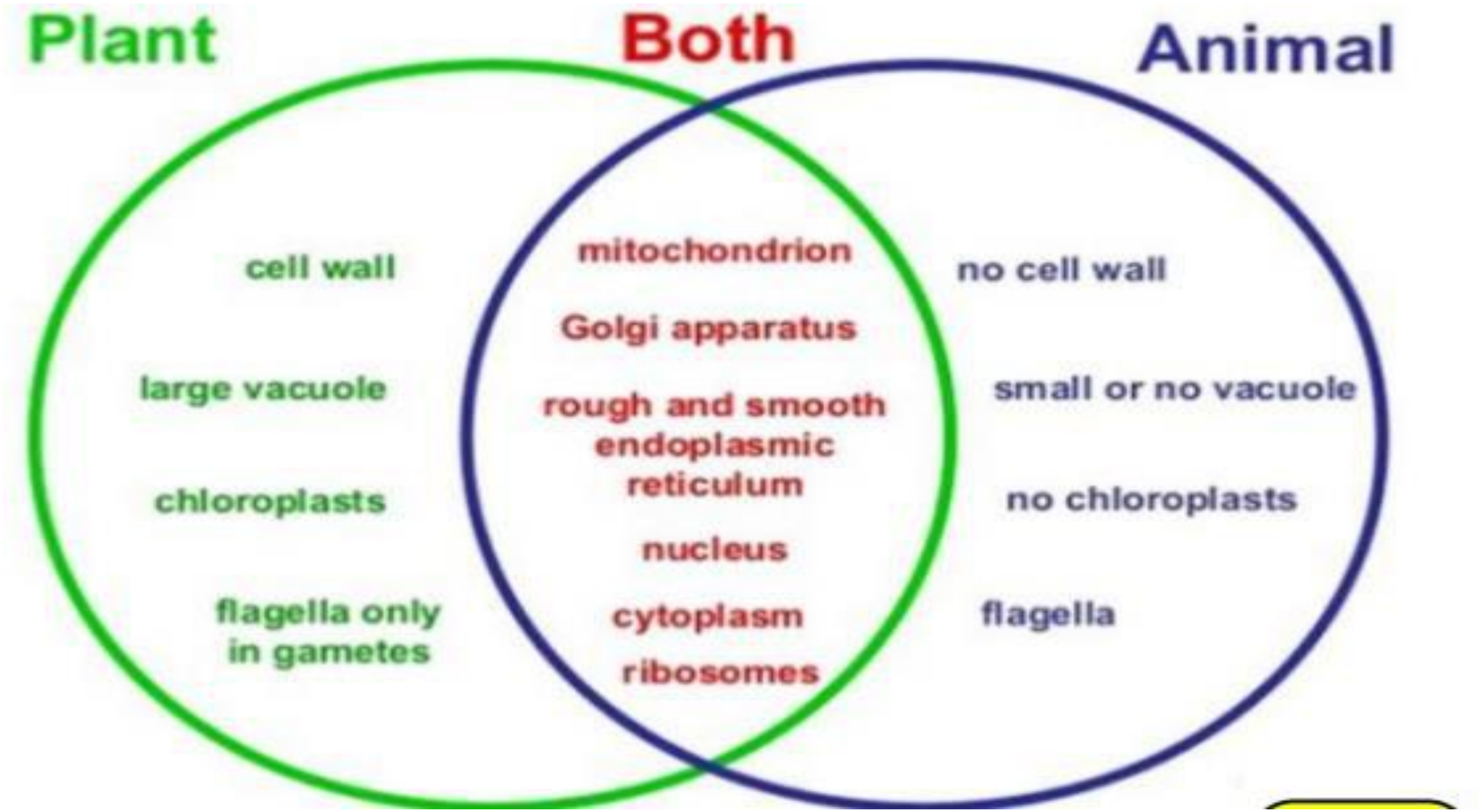
Centrosome: small body located near the nucleus .

- It divides and the two parts move to opposite sides of the dividing cell.

Vacuoles : storage areas

Plant cell vs Animal cell

Type	Animal Cell	Plant Cell
		
Cell wall	Absent	Present (made of cellulose)
Vacuole	Many small temporary vacuoles	One large central vacuole
Chloroplast	Absent	Present
Shape	Variable cell shape	Regular cell shape due to cell wall
Centrioles*	*A pair of centrioles	*No centriole


Plant
Both
Animal
cell wall
large vacuole
chloroplasts
flagella only in gametes
mitochondrion
Golgi apparatus
rough and smooth endoplasmic reticulum
nucleus
cytoplasm
ribosomes
no cell wall
small or no vacuole
no chloroplasts
flagella

Molecular Components of cells

THE MOLECULAR COMPONENTS OF CELL

component	percent of total cell weight
water	70
inorganic ions (sodium, potassium, magnesium, calcium, chloride, etc.)	1
miscellaneous small metabolites	3
proteins	18
RNA	1.1
DNA	0.25
phospholipids and other lipids	5
polysaccharides	2

WATER

- Water is the most abundant molecule in cells, accounting for 70% or more of total cell mass.
- Water is a polar molecule
- Hydrogen atoms have a slight positive charge and Oxygen atoms has a slight negative charge.
- Because of this polar nature, water molecules can form hydrogen bonds with each other or with other polar molecules.
- Interact with positively or negatively charged ions.

Inorganic molecules

- Sodium (Na^+), Potassium (K^+)
- Magnesium, Calcium, Phosphate
- Chloride, bicarbonate
- Constitute 1% of the cell mass.
- These ions are involved in a number of aspects of cell metabolism and function.

Organic molecules

- Unique constituents of cells
- Carbohydrates.
- Lipids
- Proteins
- Nucleic acids

CARBOHYDRATES

- Carbon (C), hydrogen (H) and oxygen (O) atoms, usually with a hydrogen–oxygen atom ratio of 2:1 (as in water)
- empirical formula Cm(H2O)n.
- Their breakdown provides cellular energy.
- Carbohydrates consist of saccharide, a group that includes sugars, starch, and cellulose.
- The saccharides are divided into four chemical groups: Monosaccharides, disaccharides, oligosaccharides, and polysaccharides.

Monosaccharides

- Monosaccharides are the simplest carbohydrates in that they cannot be hydrolyzed to smaller carbohydrates.
- They are aldehydes or ketones with two or more hydroxyl groups.
- Classification
- Monosaccharides with three carbon atoms are called trioses, those with four are called tetroses, five are called pentoses, six are hexoses, and so on.
- Eg: **Glucose, Fructose**

Disaccharides

- Two joined monosaccharides are called a disaccharide .
- two monosaccharide units bound together by a covalent bond known as a glycosidic linkage.
- formed via a dehydration reaction, resulting in the loss of a hydrogen atom from one monosaccharide and a hydroxyl group from the other
- Examples include **sucrose and lactose**

Oligosaccharides

- Three to six units of monosaccharides are joined together to form a oligosaccharide
- Eg: **Raffinose**

Polysaccharides

- A polysaccharide is a large molecule made of many monosaccharides

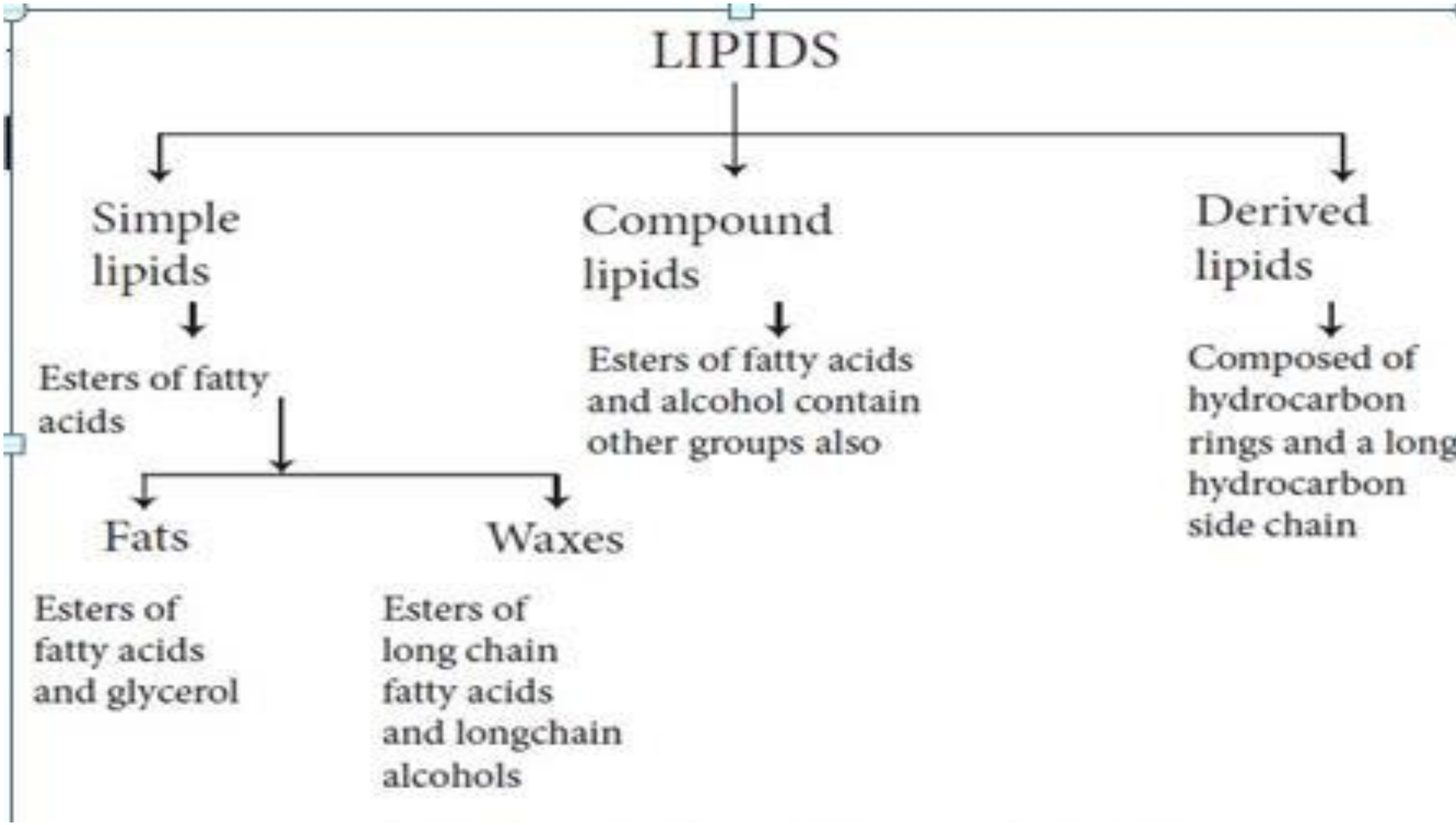
Ex. **Starch, cellulose**.

LIPIDS

- Insoluble organic compounds that consist of fat and oil
- The roles of lipids in cells

1. Energy storage
2. Major component of cell membrane
3. Cell signaling

Classification



Simple Lipids or Homolipids

- Simple lipids are esters of fatty acid linked with various alcohols.
- **Fats and oils (triglycerides, triacylglycerols)**

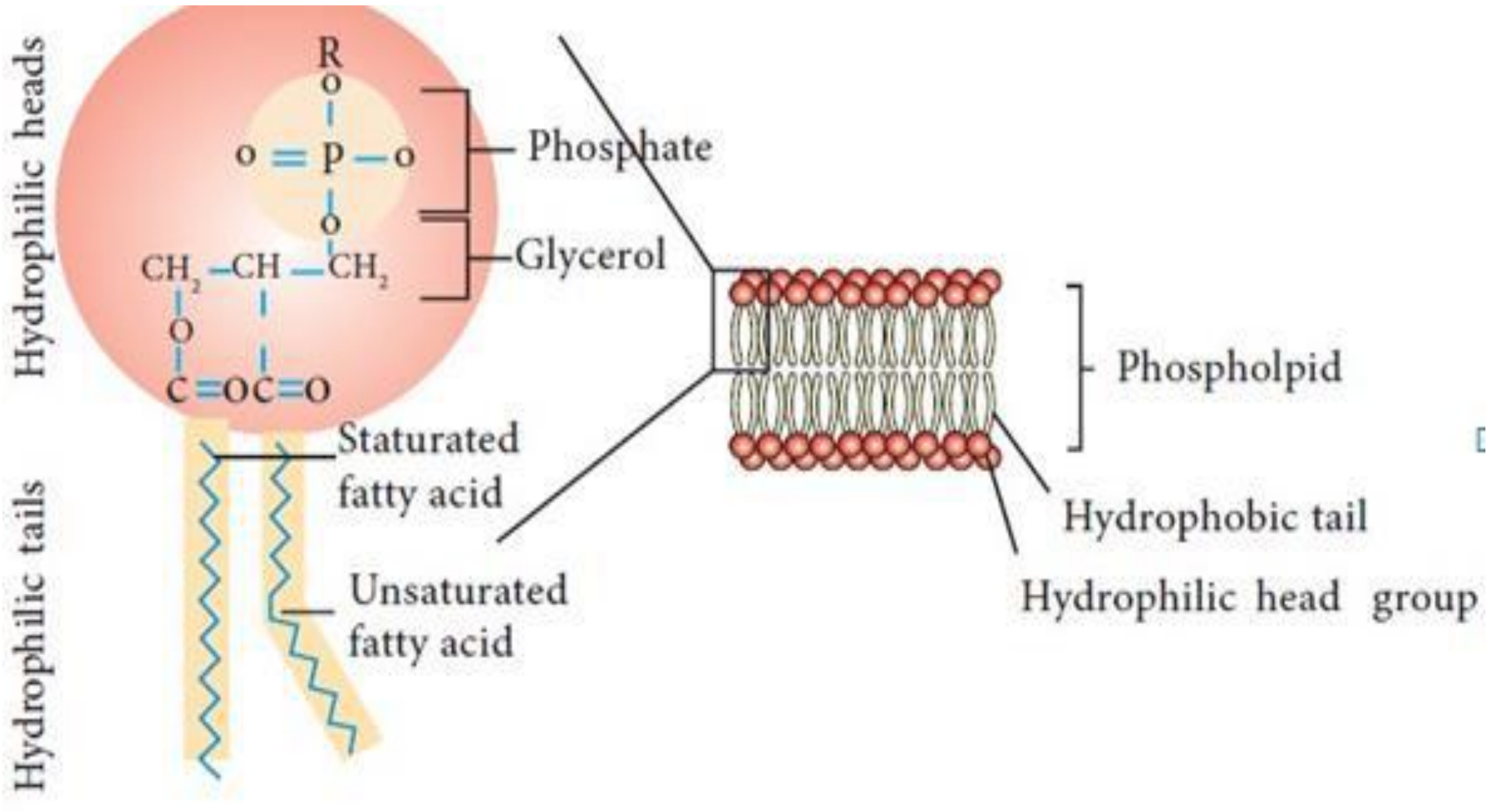
Compound Lipids or Heterolipids

- Heterolipids are fatty acid esters with alcohol and additional groups.
- **Phospholipids**

Derived Lipids

- derived by hydrolysis from compound and simple lipids.
- **Steroids**

Phospholipids



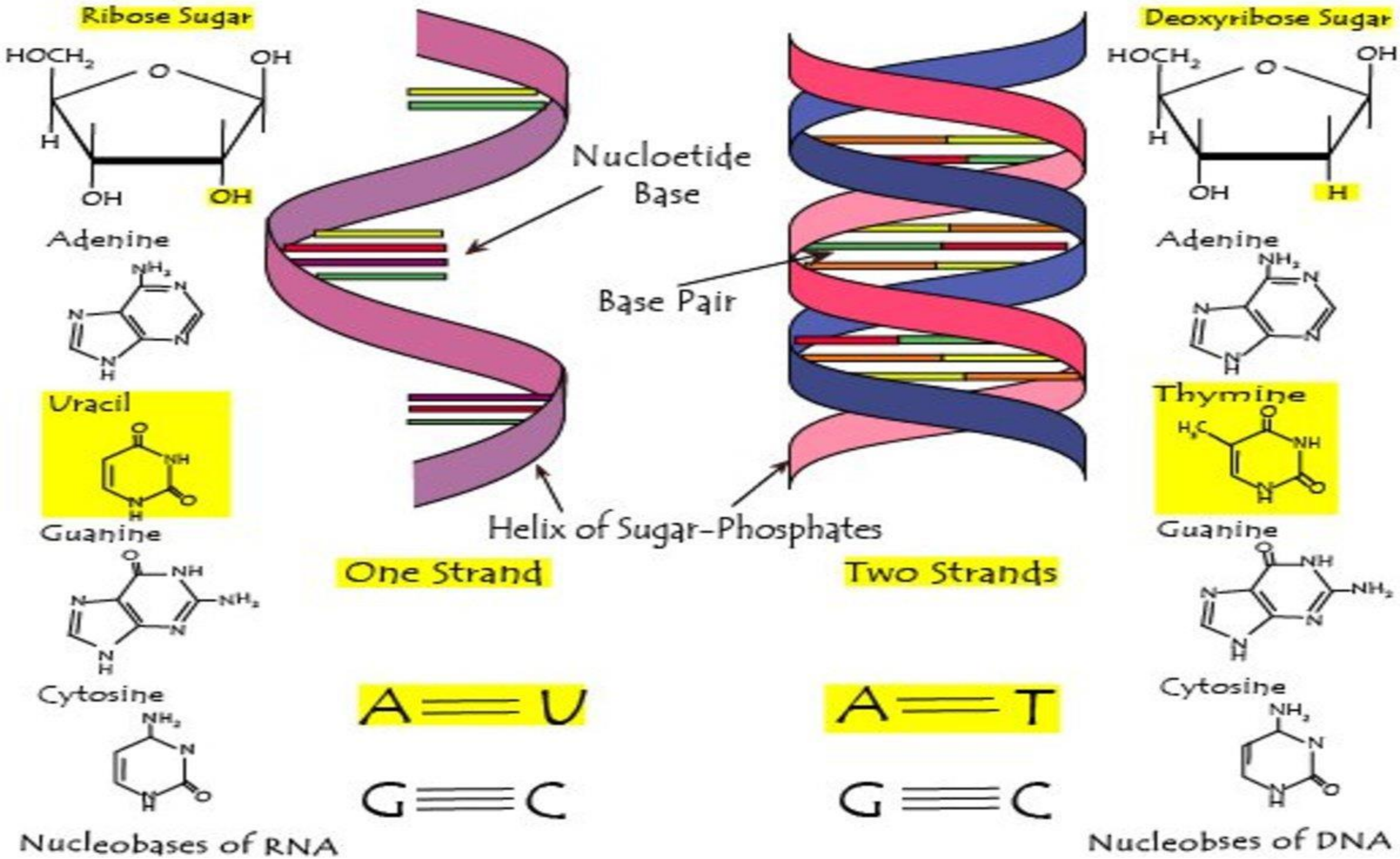
Nucleic acids

- Biopolymers, essential for all known forms of life.
- **DNA -Deoxyribonucleic acid**
- **RNA -Ribonucleic acid**
- Each nucleotide has three components:
- a 5- carbon sugar, a phosphate group, and a nitrogenous base

Difference between DNA and RNA

	DNA	RNA
Found in	Nucleus of the cell	Nucleolus
Function	Genetic information	Protein synthesis
Structure	Double stranded	Single stranded
Sugar group	Deoxyribose	Ribose
Phosphate group	Present	Present
Nitrogenous bases	Adenine (A) Guanine (G) Cytosine (C) Thymine (T)	Adenine (A) Guanine (G) Cytosine (C) Uracil (U)

RNA vs DNA


Ribose Sugar
HOCH2
O
OH
H
OH
OH
Adenine
Uracil
Guanine
Cytosine
Nucleobases of RNA
Nucleotide
Base
Base Pair
Helix of Sugar-Phosphates
One Strand
Two Strands
A═U
G≡C
A═T
G≡C
Deoxyribose Sugar
HOCH2
O
OH
H
OH
H
Adenine
Thymine
Guanine
Cytosine
Nucleobses of DNA

PROTEINS

- While nucleic acids carry the genetic information of the cell, the primary responsibility of proteins is to execute the tasks directed by that information.
- Each cell contains different proteins.
- They perform a wide variety of functions
- Proteins direct virtually all activities of the cell
- Greek word *proteios* means “of the first rank”.

Functions of proteins

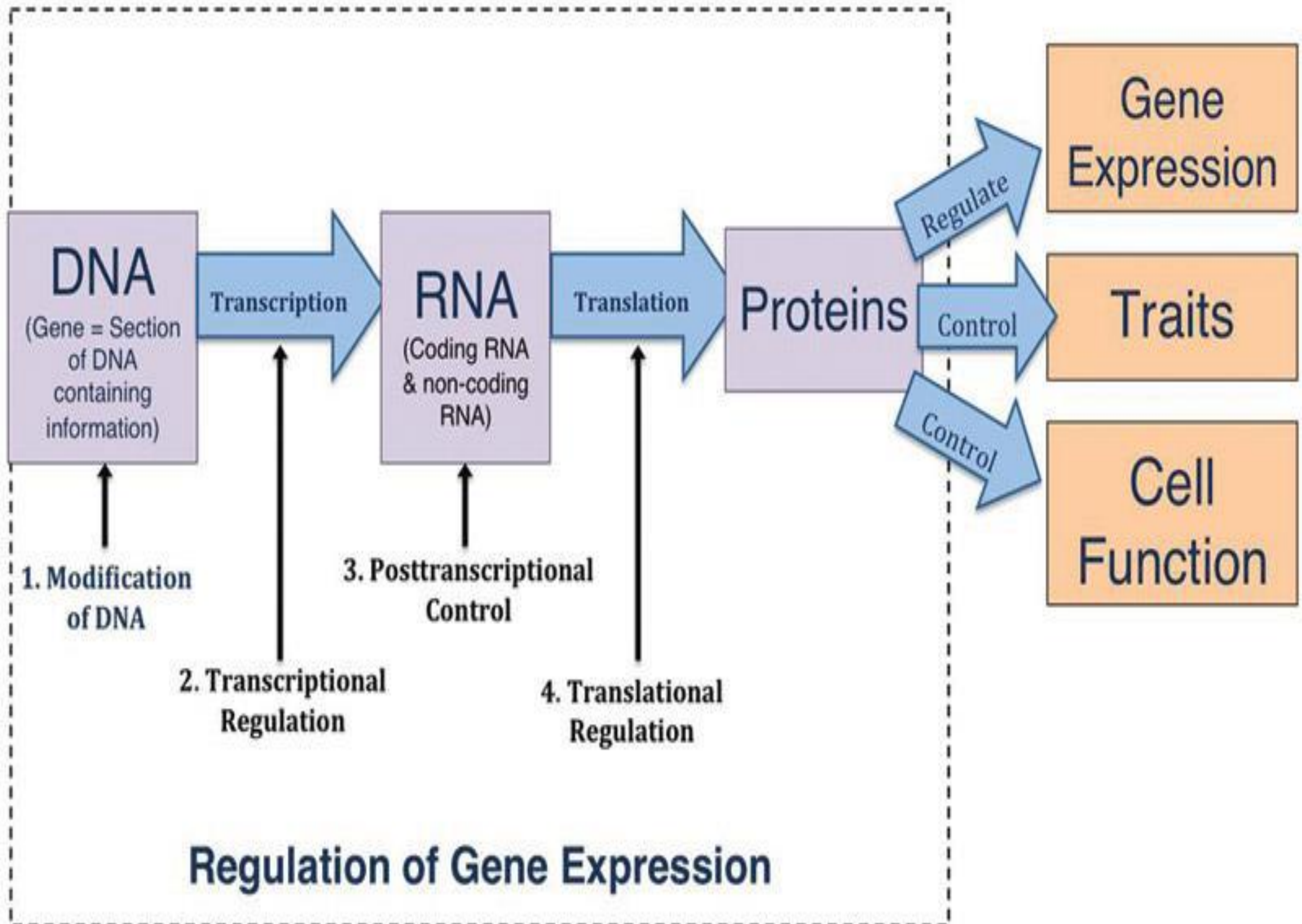
- Serve as structural components of cells and tissues.
- Transport and storage of small molecules
- Transmitting information between cells.
- Providing a defense against infection
- They act as enzymes.
- Catalyze nearly all the chemical reactions in biological systems.

Expression of Genetic Information

Gene expression

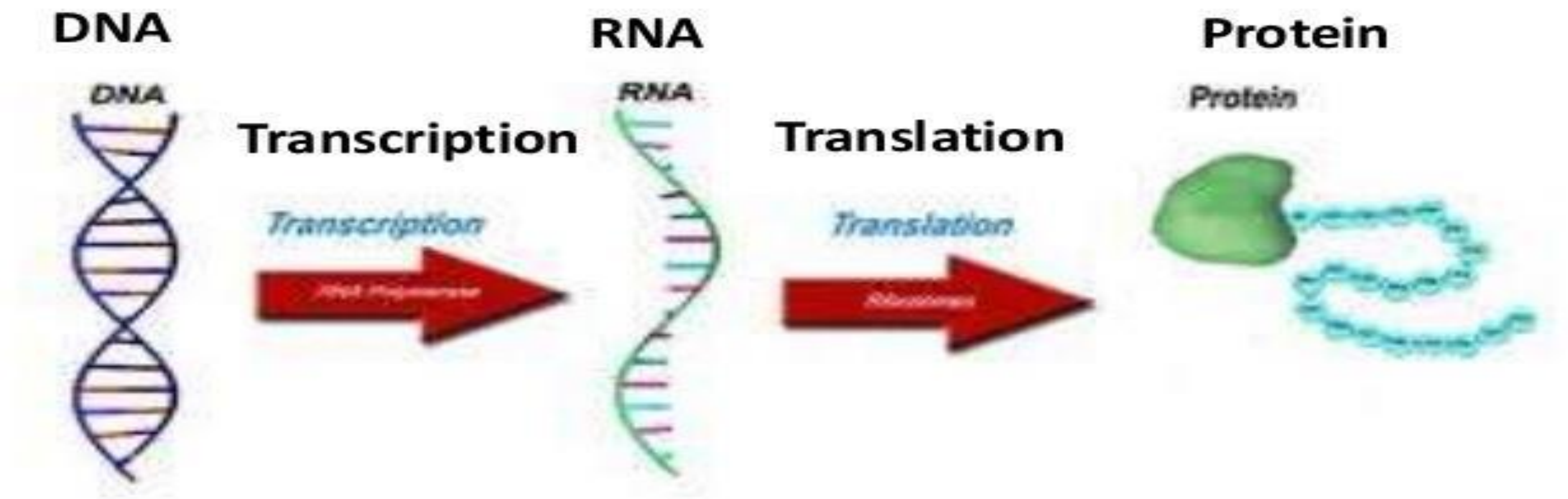
- Gene expression is the process by which the instructions in our **DNA are converted into** a functional product, such as a **protein.**
- It is a regulated process that allows a cell to respond to its changing environment.
- There are two key steps involved in making a protein

1. Transcription
2. Translation.


DNA
(Gene = Section of DNA containing information)
Transcription
RNA
(Coding RNA & non-coding RNA)
Translation
Proteins
Regulate
Control
Control
Gene Expression
Traits
Cell Function
1. Modification of DNA
2. Transcriptional Regulation
3. Posttranscriptional Control
4. Translational Regulation
Regulation of Gene Expression

Central dogma of life

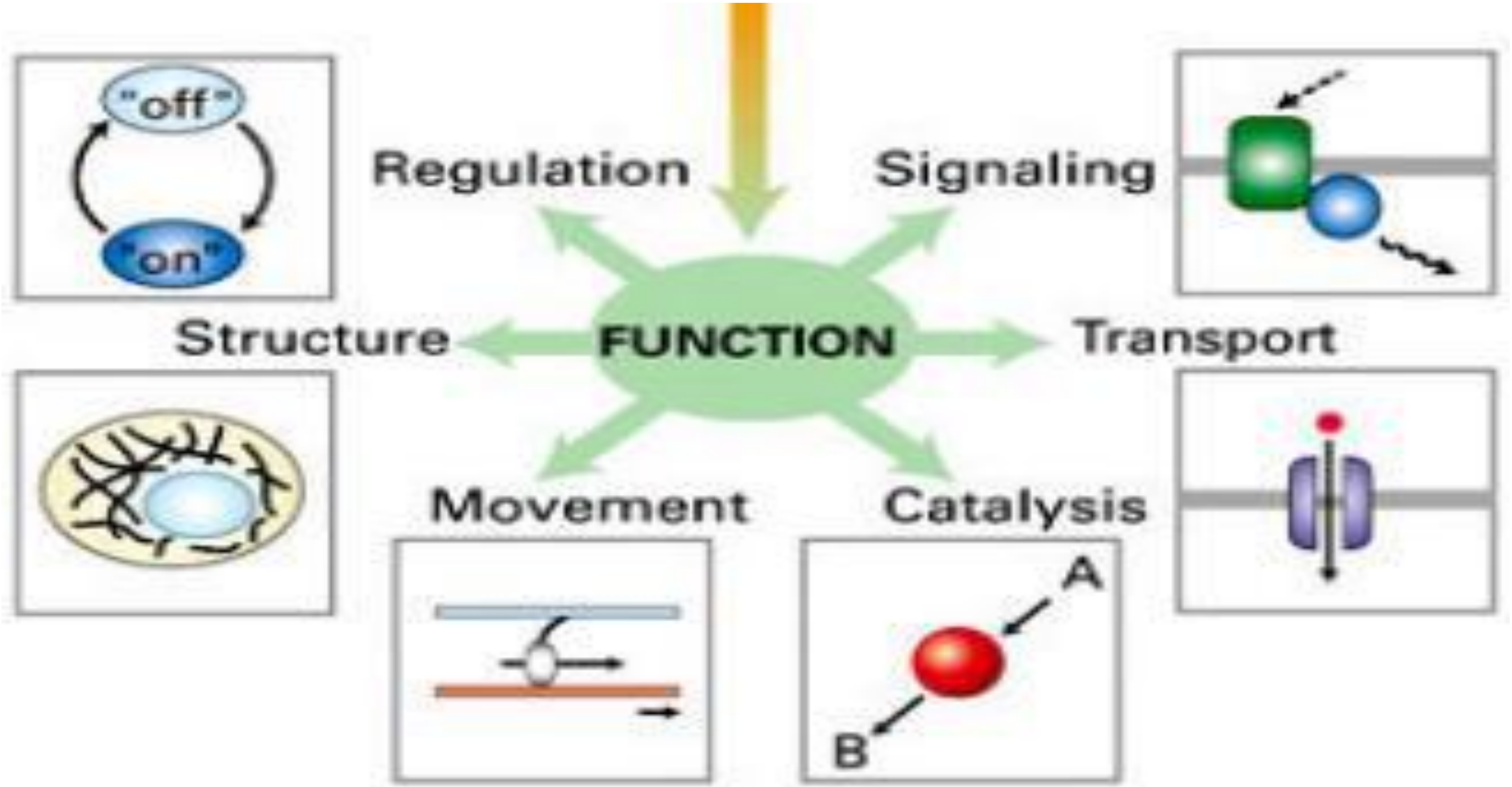
DNA → RNA → Protein



Protein structure and function

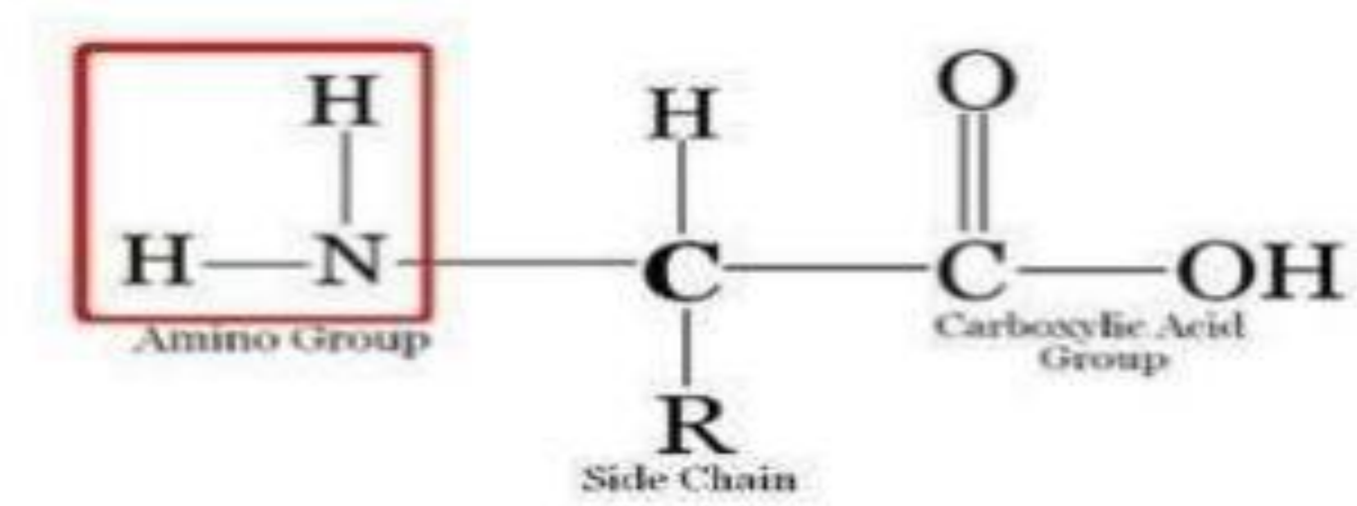
PROTEINS

- Proteins are important for functioning of the cell



AMINO ACIDS

- Proteins are polymers of **amino acids.**
- There are 20 amino acids which are repeatedly found in the structure of proteins.



- Amino acids are group of organic compounds having 2 functional groups

1. (-NH2) amino group
2. (-COOH) carboxylic group.

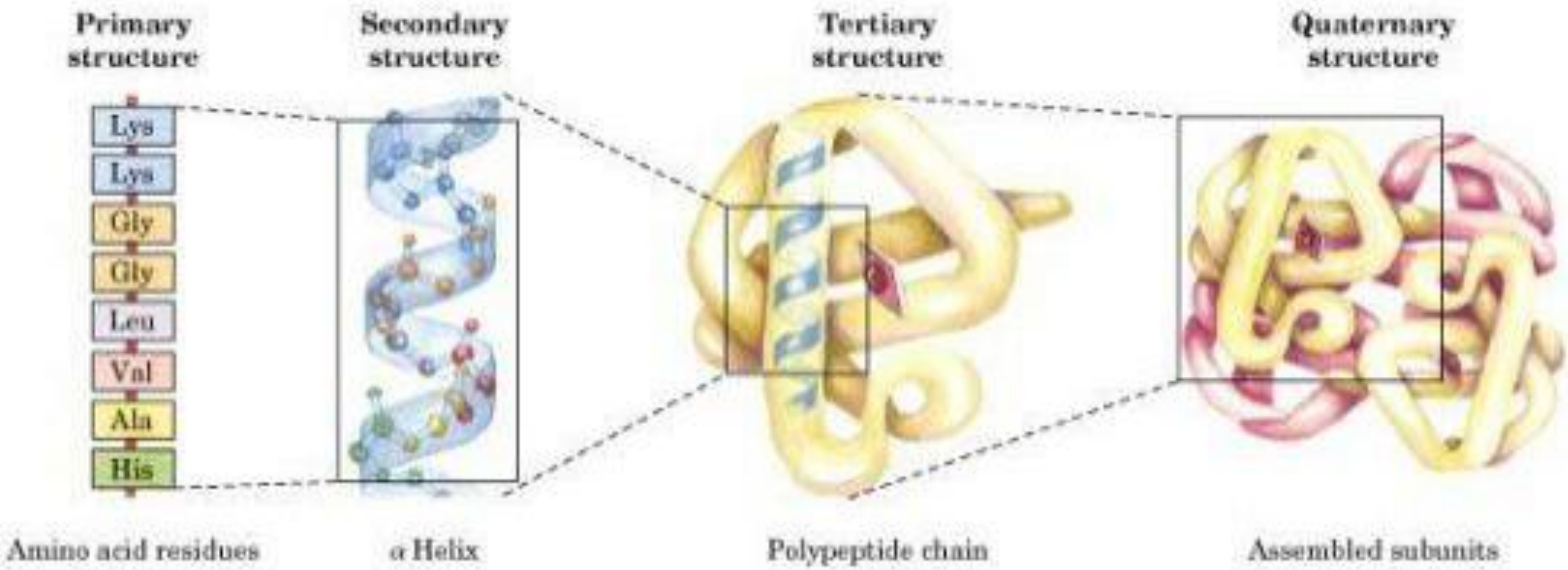
- All amino acids contain carbon, hydrogen, oxygen and nitrogen but additionally some of them contain sulphur

CLASSIFICATION OF AMINO ACIDS

NO	NATURE	AMINO ACIDS
1	NEUTRAL: Amino acids with 1 amino group and 1 carboxyl group	Glycine (Gly), Alanine (Ala), Valine (Val), Leucine (Leu), Isoleucine (Ile)
2	ACIDIC: 1 extra carboxyl group	Aspartic acid (Asp), Asparagine (Asn), Glutamic acid (Glu), Glutamine (Gln)
3	BASIC: 1 extra amino group	Arginine (Arg), Lysine (Lys)
4	S-CONTAINING: Amino acids have sulphur	Cysteine (Cys), Methionine (Met)
5	ALCOHOLIC: Amino acids having –OH group	Serine (Ser), Threonine (Thr), Tyrosine (Tyr)
6	AROMATIC: Amino acids having cyclic structure	Phenylalanine(Phe), Tryptophan (Try)
7	HETEROCYCLIC: Amino acids having nitrogen in ring structure	Histidine (His), Proline (Pro)

- **Essential amino acids:** Histidine (His), Leucine (Leu), Isoleucine (Ile), Lysine (Lys), Methionine (Met), Phenylalanine(Phe), Threonine (Thr), Tryptophan (Try), Valine (Val).
- **Non- essential amino acids:** Glycine (Gly), Alanine (Ala), Aspartic acid (Asp), Asparagine (Asn), Glutamic acid (Glu), Glutamine (Gln), Cysteine (Cys), Proline (Pro), Serine (Ser), Tyrosine (Tyr).

4 levels of protein structure



- Primary – sequence of amino acids
- Secondary – interactions between adjacent amino acids
- Tertiary – 3D folding of the polypeptide
- Quaternary – arrangements of multiple polypeptides

Classification of proteins

Simple proteins

1. Albumin
2. Globulins
3. Histones

Conjugated proteins

1. Phosphoproteins
2. Glycoproteins
3. Chromoproteins
4. Nucleoproteins
5. Metalloproteins

Derived protein

Functions of proteins

ANTIBODIES

- Specialized proteins involved in defending the body from antigens.

CONTRACTILE PROTEINS

- Responsible for movement
- Muscle contraction
- Eg: Actin and Myosin

ENZYMES

- Biochemical reactions
- Often referred to as catalysts.
- Eg: Lactase, Pepsin

HORMONAL PROTEINS

- Messenger proteins
- Help to coordinate body activities
- Eg: Insulin

STRUCTURAL PROTEINS

- Provide support
- Eg: Keratin

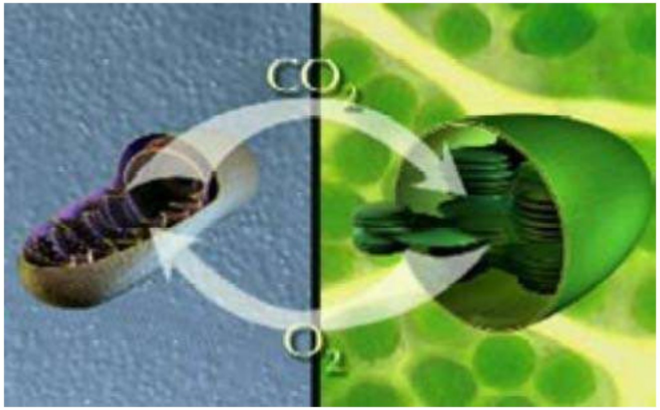
STORAGE PROTEINS

- Stores amino acids
- Eg: Ovalbumin, casein

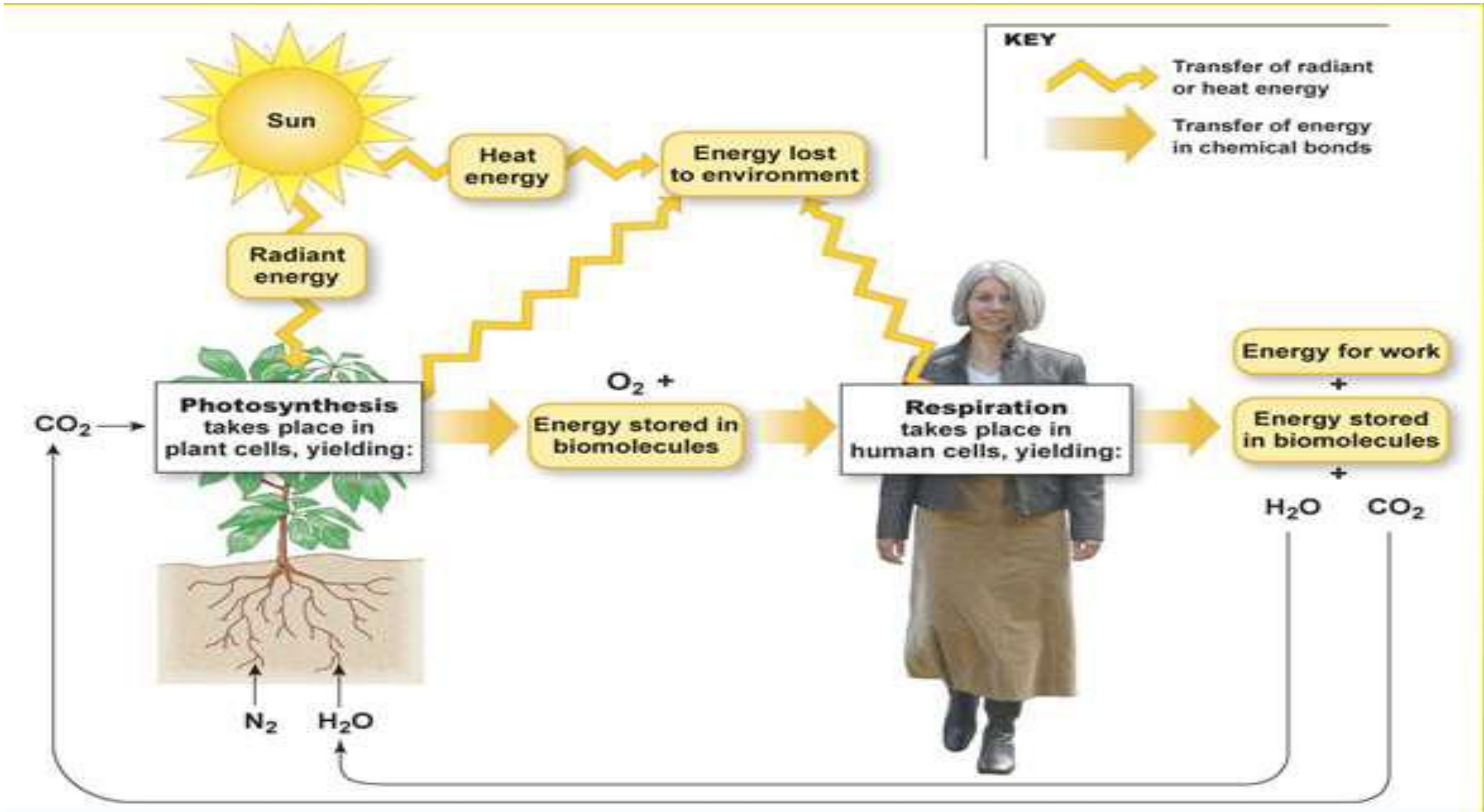
TRANSPORT PROTEINS

- Carrier proteins – move molecules from one place to another place
- Eg: Haemoglobin

CELL METABOLISM



Energy Flow



KEY
Transfer of radiant or heat energy
Transfer of energy in chemical bonds
Sun
Heat energy
Energy lost to environment
Radiant energy
CO_2
Photosynthesis takes place in plant cells, yielding:
O_2 +
Energy stored in biomolecules
Respiration takes place in human cells, yielding:
Energy for work
+
Energy stored in biomolecules
+
H_2O
CO_2
N_2
H_2O

Metabolism

- Metabolism:
  - The sum of all chemical reactions that occur in the body
  - Require the use of enzymes
- General Classification of chemical reactions
  - Anabolic
    - Those that create larger molecules
  - Catabolic
    - Those that breakdown larger molecules into smaller molecules

Metabolism basics

Oxidation – Reduction

A **coupled** reaction in which electrons are transferred from one molecule to another

Oxidation

-Transfers electrons from a molecule to oxygen (removes e^-)

Reduction

– The gain of electrons from a molecule

Dehydration-Hydrolysis

- Uses hydrolase class of enzymes
- Removing water to create larger molecules
- Adding water to split larger molecules into smaller molecules

A**ddition-subtraction-exchange**

- The addition, removal or exchange of chemical groups between molecules
  - Carboxylation – Decarboxylation
  - Phosphorylation – dephosphorylation

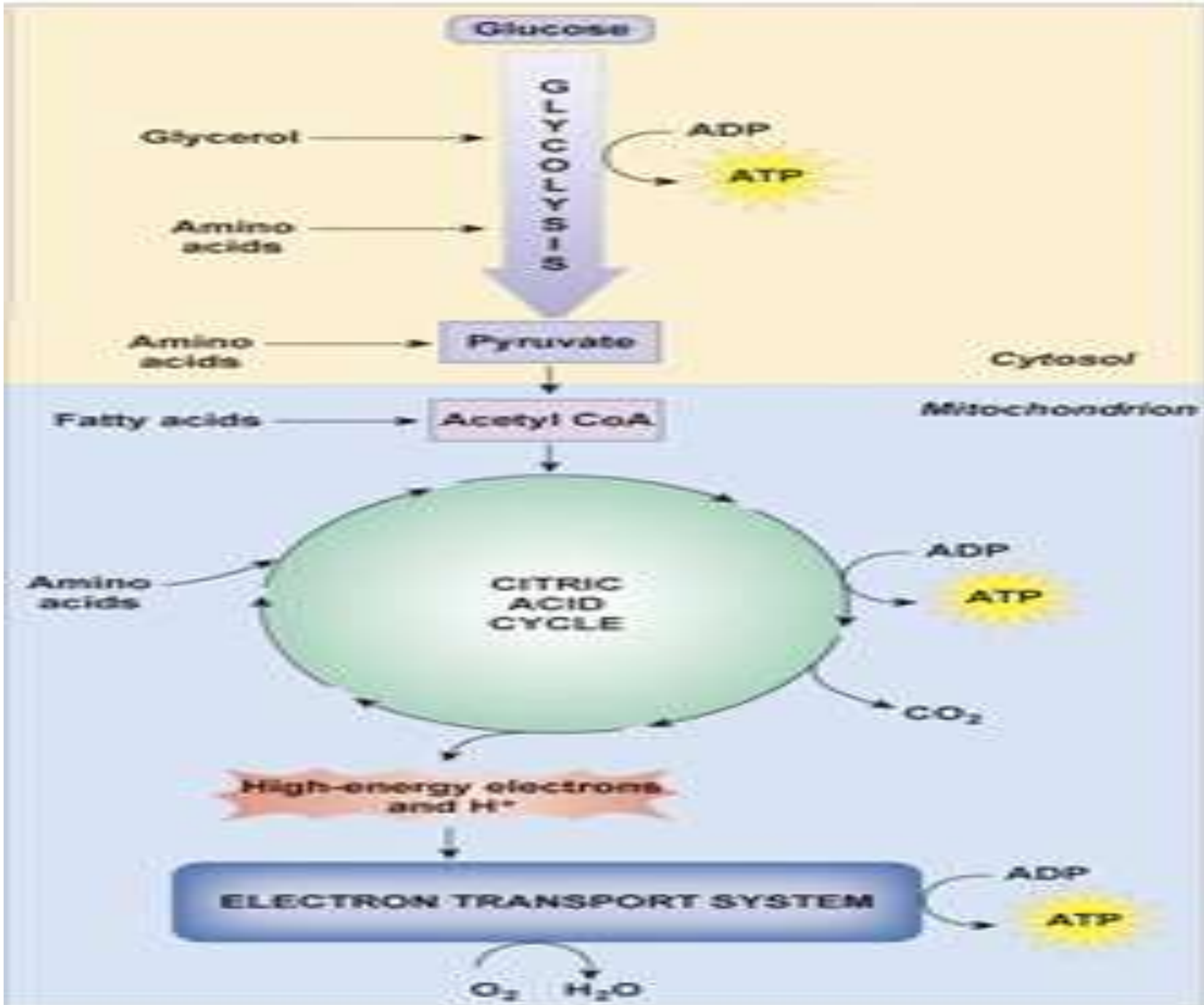
Cell Metabolism/Respiration

- Produces Carbon dioxide, Water, ATP, Heat
- Includes:
- Anaerobic reactions (without O_2) – produce little ATP
- Aerobic reactions (requires O_2) – produce most ATP

- Occurs in a series of reactions
- **Glycolysis**
- **Citric acid cycle (TCA cycle or Kreb's cycle)**
- **Electron transport system**

Production of ATP Overview

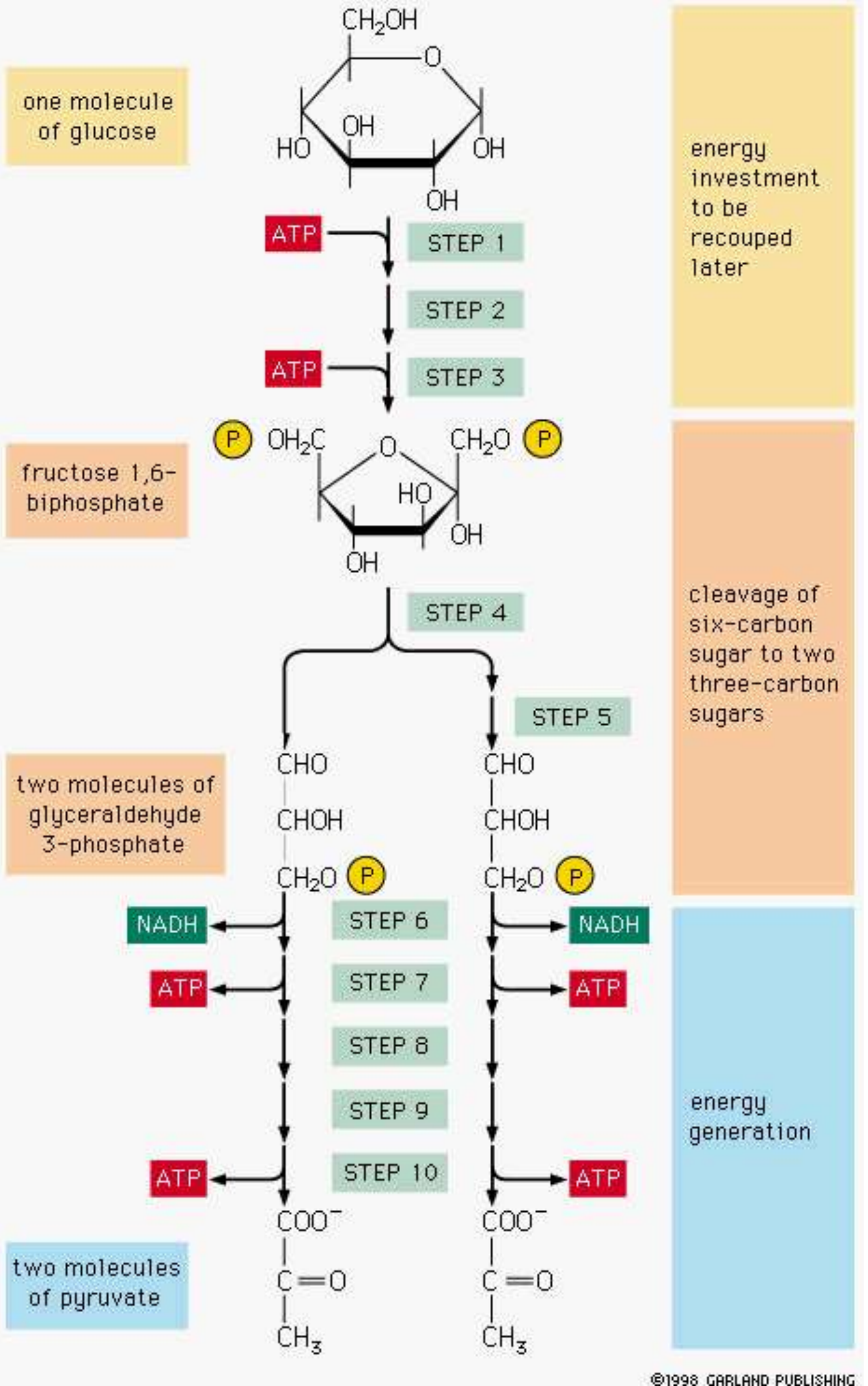
- **Recall the overall equation:**
- $C_6H_{12}0_6 + 6O_2 = 6CO_2 + 6H_2O + 36ATP$
- **Step 1** – Glycolysis
  - formation of two pyruvates
- **Step 2** – Pyruvate oxidative decarboxylation
  - formation of two acetyl CoA
- **Step 3** – Citric Acid Cycle
  - end product (oxaloacetate) combines with acetyl CoA to start, forming the same end product
- **Step 4** – Electron Transport System
  use of high energy protons and electrons (from coenzymes) to power ATP synthesis


Glucose
GLYCOLYSIS
Glycerol
ADP
ATP
Amino acids
Amino acids
Pyruvate
Cytosol
Mitochondrion
Fatty acids
Acetyl CoA
Amino acids
CITRIC ACID CYCLE
ADP
ATP
CO_2
High-energy electrons and H^+
ELECTRON TRANSPORT SYSTEM
ADP
ATP
O_2
H_2O

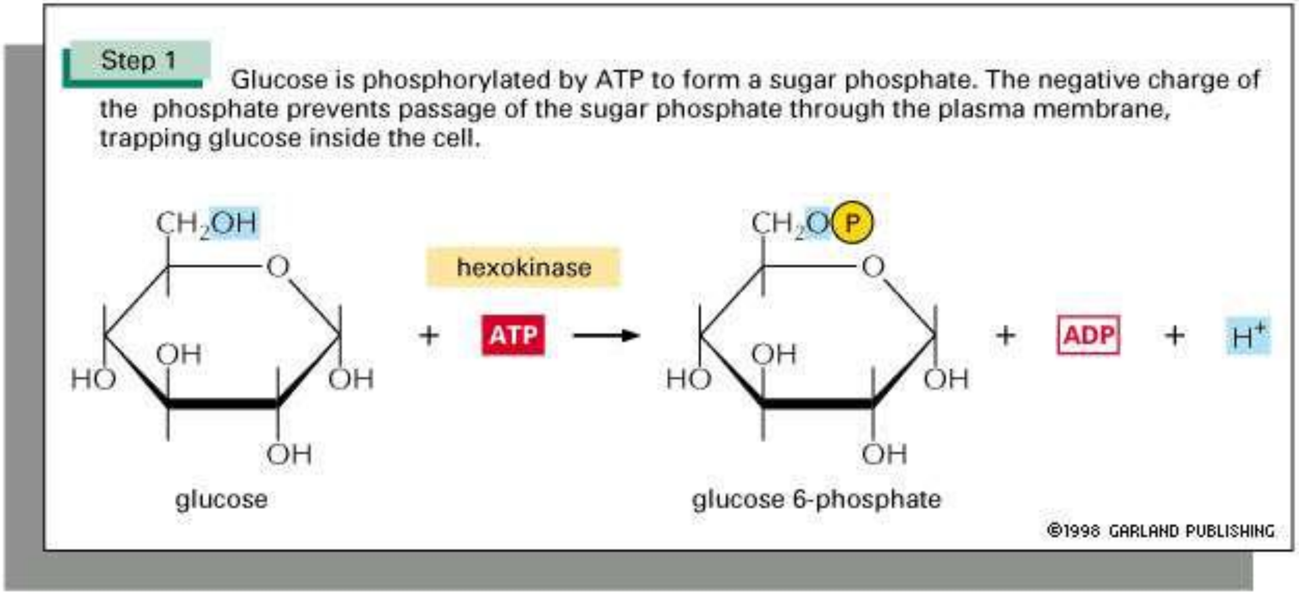
GLYCOLYSIS

- Series of ten reactions
- Breaks down **glucose into 2 pyruvic acid molecules**.
- Occurs in cytosol
- Anaerobic phase of cellular respiration
- Yields two ATP molecules per glucose molecule
- Overall glycolysis yields (net gain) 2 ATP

Overall Process



Glycolysis



Step 1
Glucose is phosphorylated by ATP to form a sugar phosphate. The negative charge of the phosphate prevents passage of the sugar phosphate through the plasma membrane, trapping glucose inside the cell.
hexokinase
ATP
ADP
H+
glucose
glucose 6-phosphate
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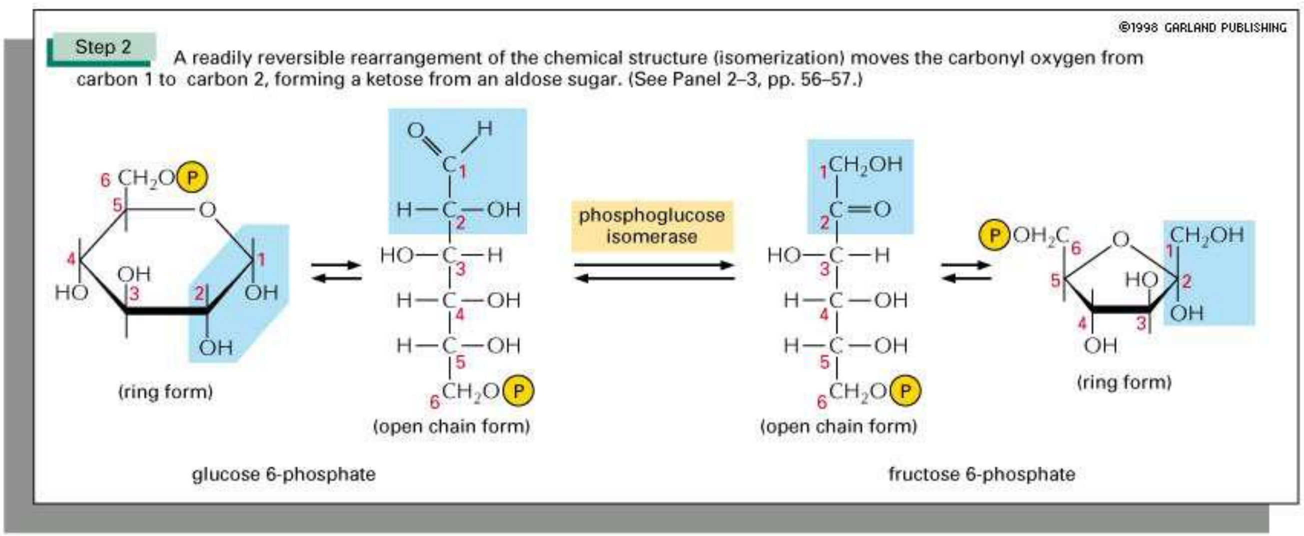

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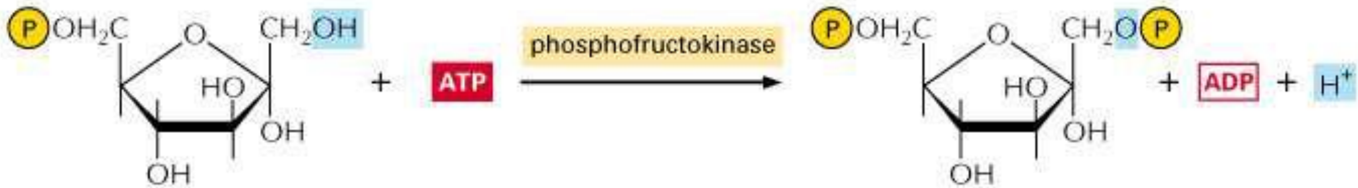
Step 2
A readily reversible rearrangement of the chemical structure (isomerization) moves the carbonyl oxygen from carbon 1 to carbon 2, forming a ketose from an aldose sugar. (See Panel 2–3, pp. 56–57.)
phosphoglucose isomerase
(ring form)
(open chain form)
(open chain form)
(ring form)
glucose 6-phosphate
fructose 6-phosphate

Glycolysis

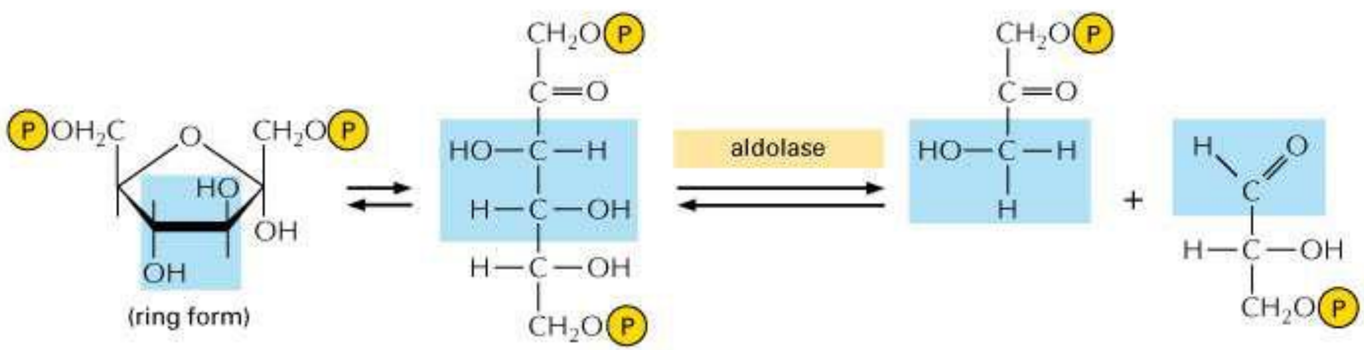
Step 3 The new hydroxyl group on carbon 1 is phosphorylated by ATP, in preparation for the formation of two three-carbon sugar phosphates. The entry of sugars into glycolysis is controlled at this step, through regulation of the enzyme *phosphofructokinase*.



fructose 6-phosphate

fructose 1,6-bisphosphate

Step 4 The six-carbon sugar is cleaved to produce two three-carbon molecules. Only the glyceraldehyde 3-phosphate can proceed immediately through glycolysis.



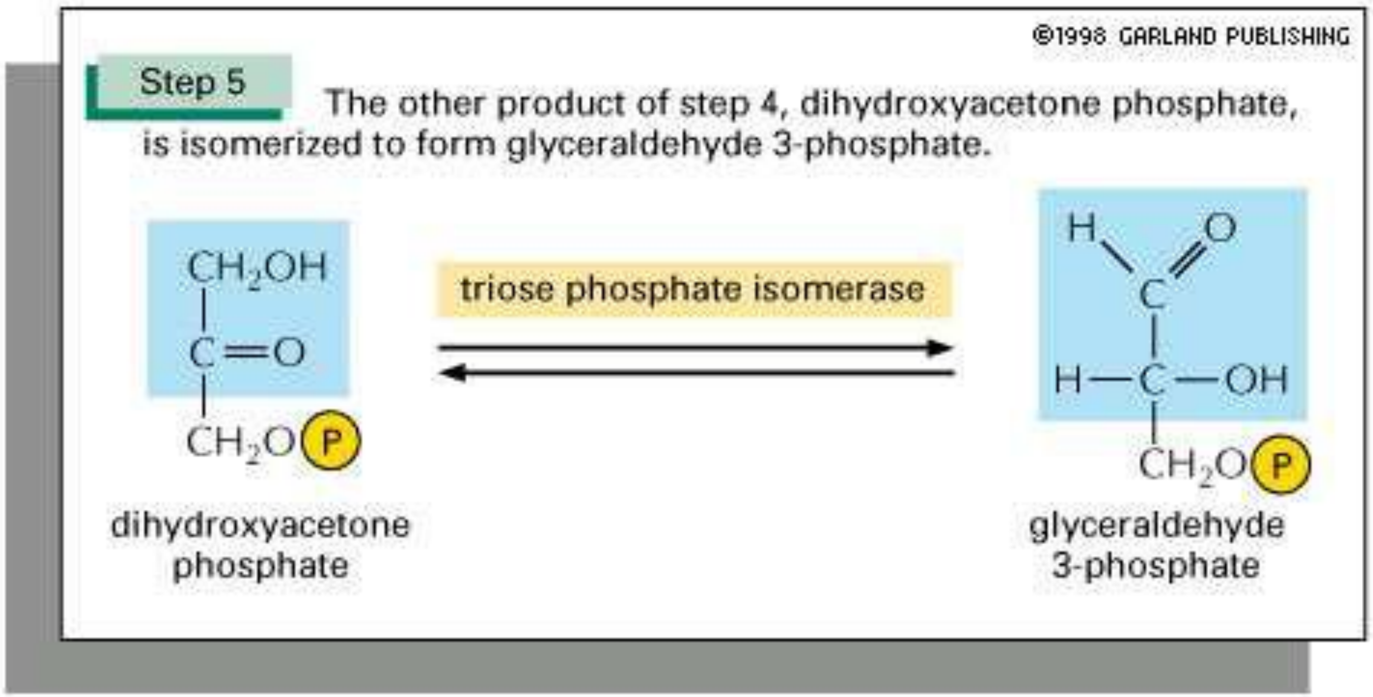
(open chain form)

fructose 1,6-bisphosphate

dihydroxyacetone phosphate

glyceraldehyde 3-phosphate

Glycolysis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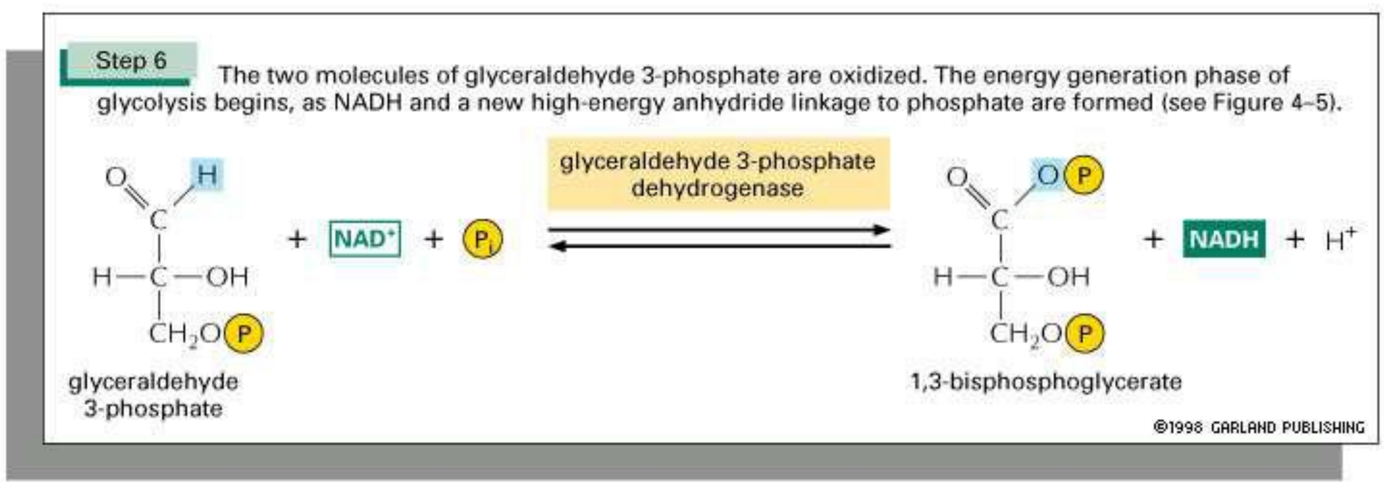
Step 5
The other product of step 4, dihydroxyacetone phosphate, is isomerized to form glyceraldehyde 3-phosphate.
CH2OH
C=O
CH2O P
triose phosphate isomerase
H
O
C
H—C—OH
CH2O P
dihydroxyacetone phosphate
glyceraldehyde 3-phosphate


Step 6
The two molecules of glyceraldehyde 3-phosphate are oxidized. The energy generation phase of glycolysis begins, as NADH and a new high-energy anhydride linkage to phosphate are formed (see Figure 4–5).
glyceraldehyde 3-phosphate dehydrogenase
O
H
C
H—C—OH
CH2O P
+ NAD+ + Pi
O
O P
C
H—C—OH
CH2O P
+ NADH + H+
glyceraldehyde 3-phosphate
1,3-bisphosphoglycerate
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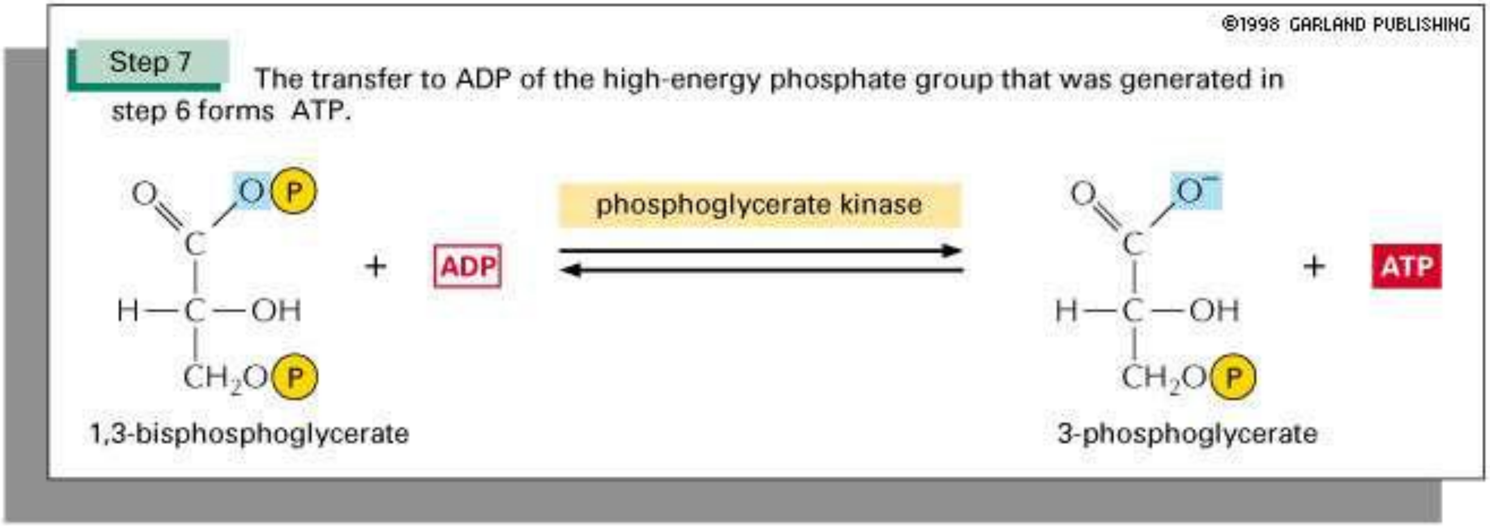
Glycolysis



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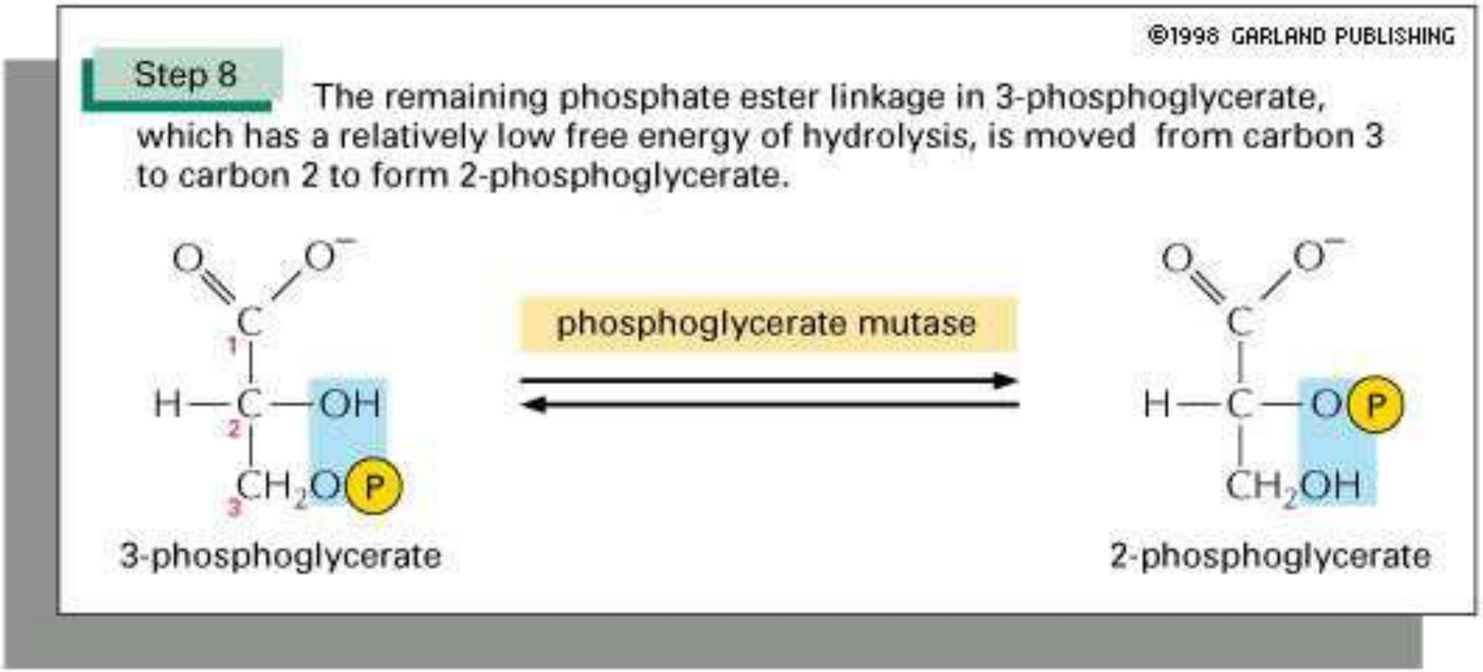
Step 7
The transfer to ADP of the high-energy phosphate group that was generated in step 6 forms ATP.
phosphoglycerate kinase
ADP
ATP
1,3-bisphosphoglycerate
3-phosphoglycerate



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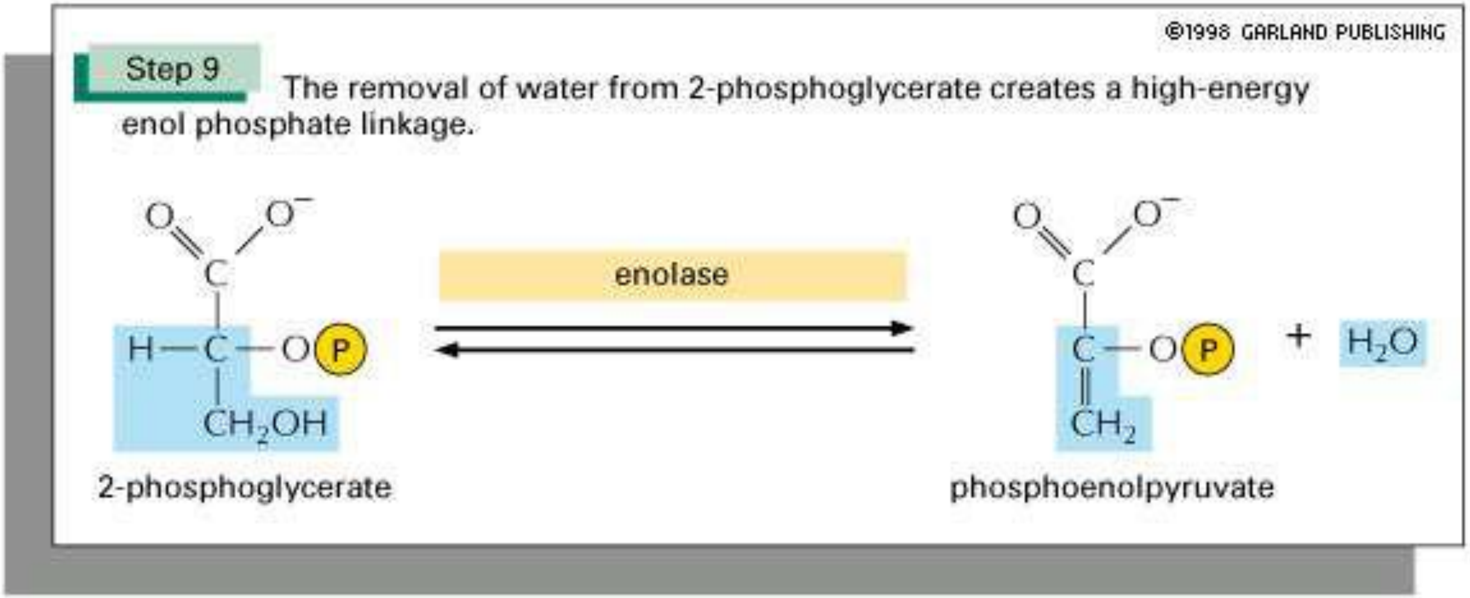
Step 8
The remaining phosphate ester linkage in 3-phosphoglycerate, which has a relatively low free energy of hydrolysis, is moved from carbon 3 to carbon 2 to form 2-phosphoglycerate.
phosphoglycerate mutase
3-phosphoglycerate
2-phosphoglycerate

Glycolysis



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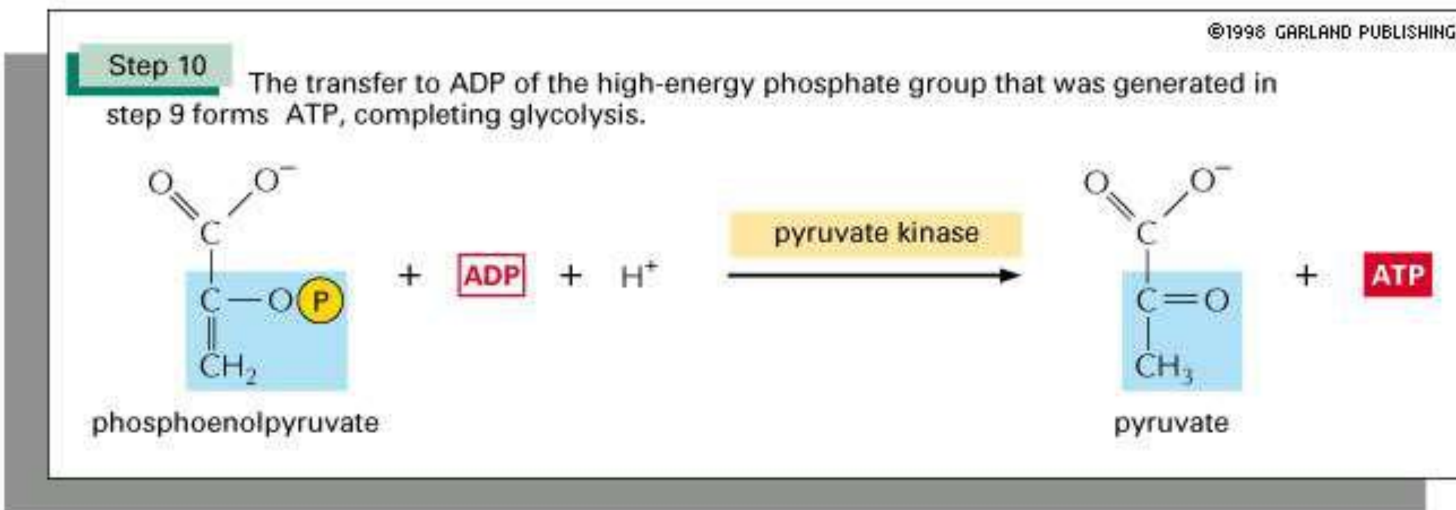
Step 9
The removal of water from 2-phosphoglycerate creates a high-energy enol phosphate linkage.
enolase
P
P
+ H_2O
2-phosphoglycerate
phosphoenolpyruvate



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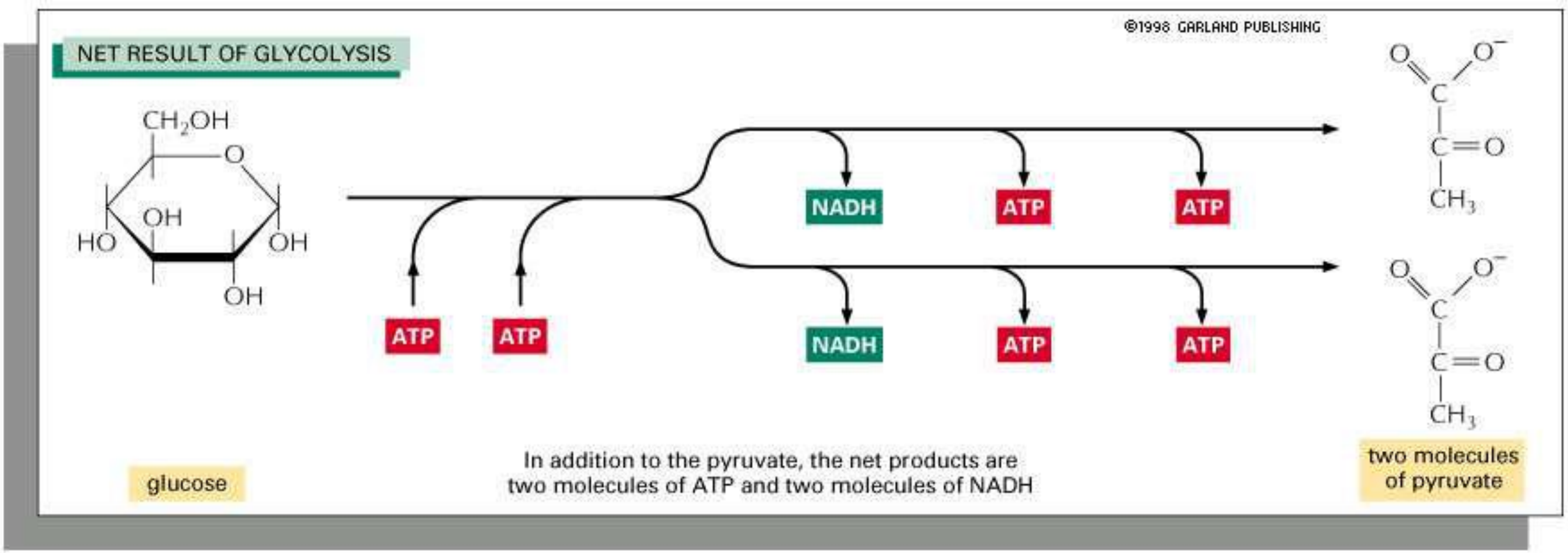
Step 10
The transfer to ADP of the high-energy phosphate group that was generated in step 9 forms ATP, completing glycolysis.
P
+ ADP + H^+
pyruvate kinase
+ ATP
phosphoenolpyruvate
pyruvate

Net Result of Glycolysis

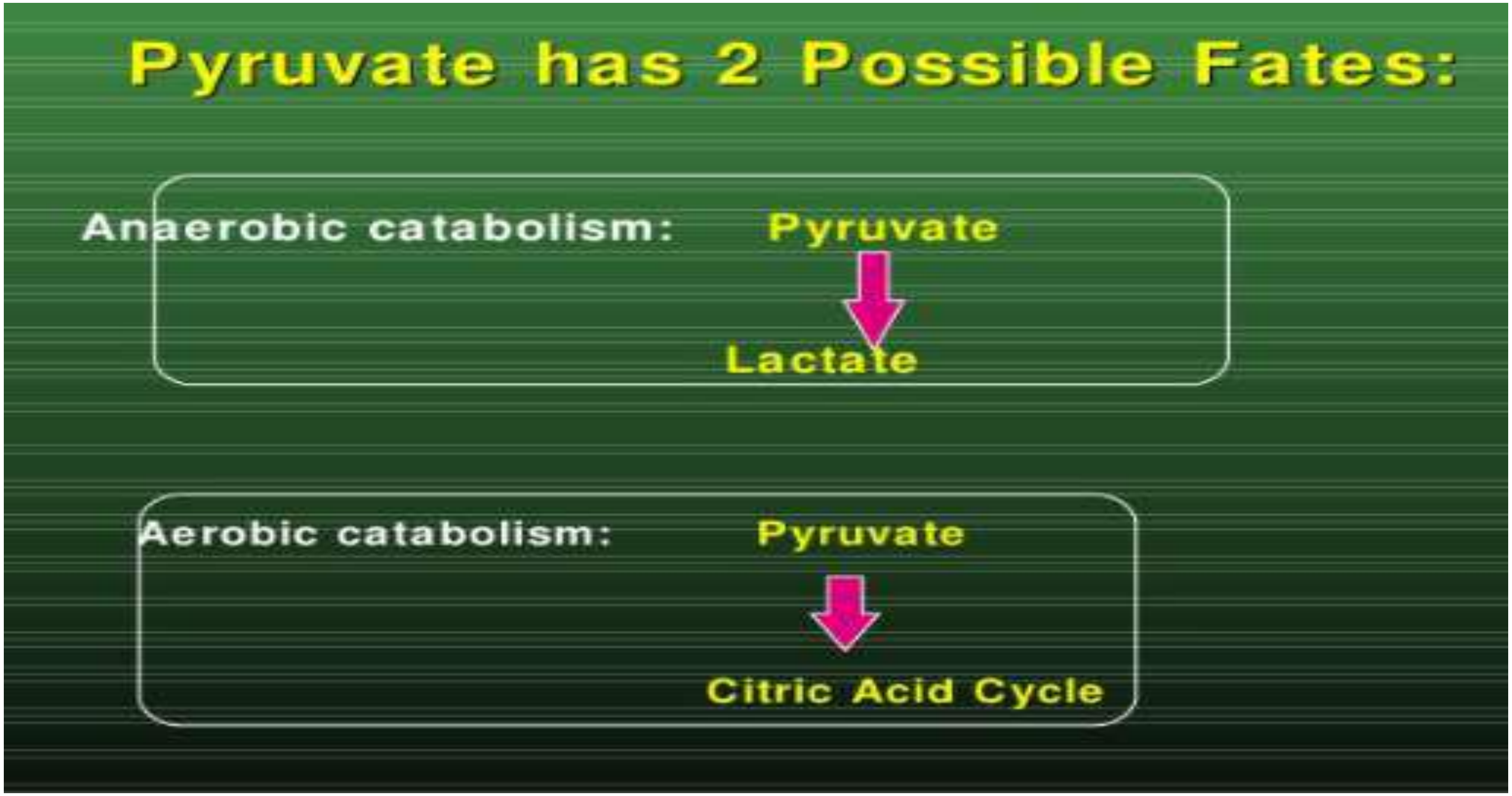
- Glucose + 2 ATP → 2 NADH + 2 ATP + 2 pyruvate
- Net energy outcome 2 NADH and 2 ATP



Steps and Reactions

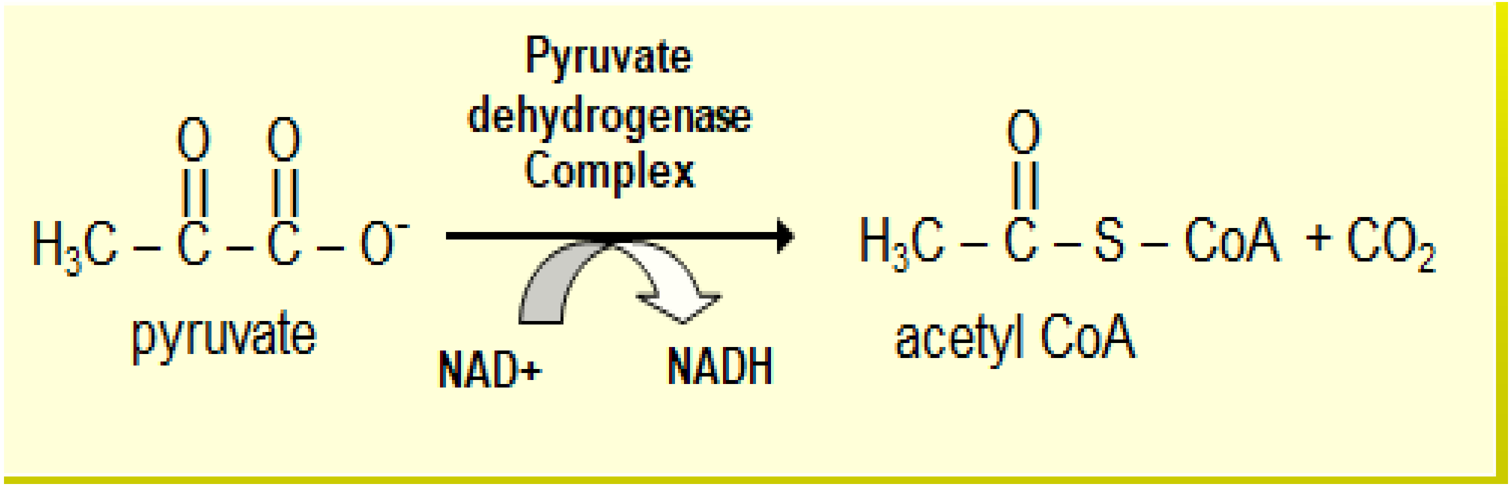
- Step 1 – kinase, phosphate transfer
- Step 2 – isomerase, rearrange atoms
- Step 3 – kinase, phosphate transfer
- Step 4 – cleavage to 2 3-C molecules
- Step 5 – isomerase, rearrange atoms
- Step 6 – dehydrogenase, make NADH
- Step 7 – kinase, phosphate transfer
- Step 8 – isomerase, rearrange atoms
- Step 9 – removal of H_2O
- Step 10 – kinase, phosphate transfer

Fate of Pyruvate



Pyruvate Oxidative Decarboxylation

- This is mediated by a large enzyme complex (pyruvate dehydrogenase) that converts pyruvate to Acetyl CoA
- Occurs within the mitochondria
- NAD^+ is reduced to NADH,
- Carbon dioxide is released
  - This leaves a 2 carbon group (acetyl) to which CoA is attached
- Acetyl CoA is formed



Pyruvate
dehydrogenase
Complex
pyruvate
NAD+
NADH
acetyl CoA

- Pyruvate is moved to the mitochondria
- In the presence of O_2 it is converted to 1 molecule of CO_2 and the remaining 2 C's are attached to Coenzyme A, creating Acetyl CoA using pyruvate dehydrogenase complex
- Also generates a molecule of NADH

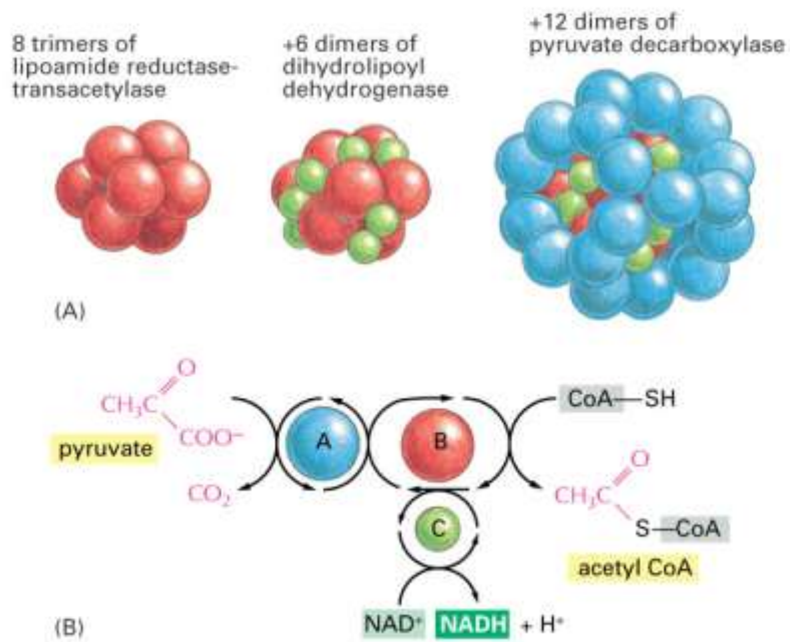


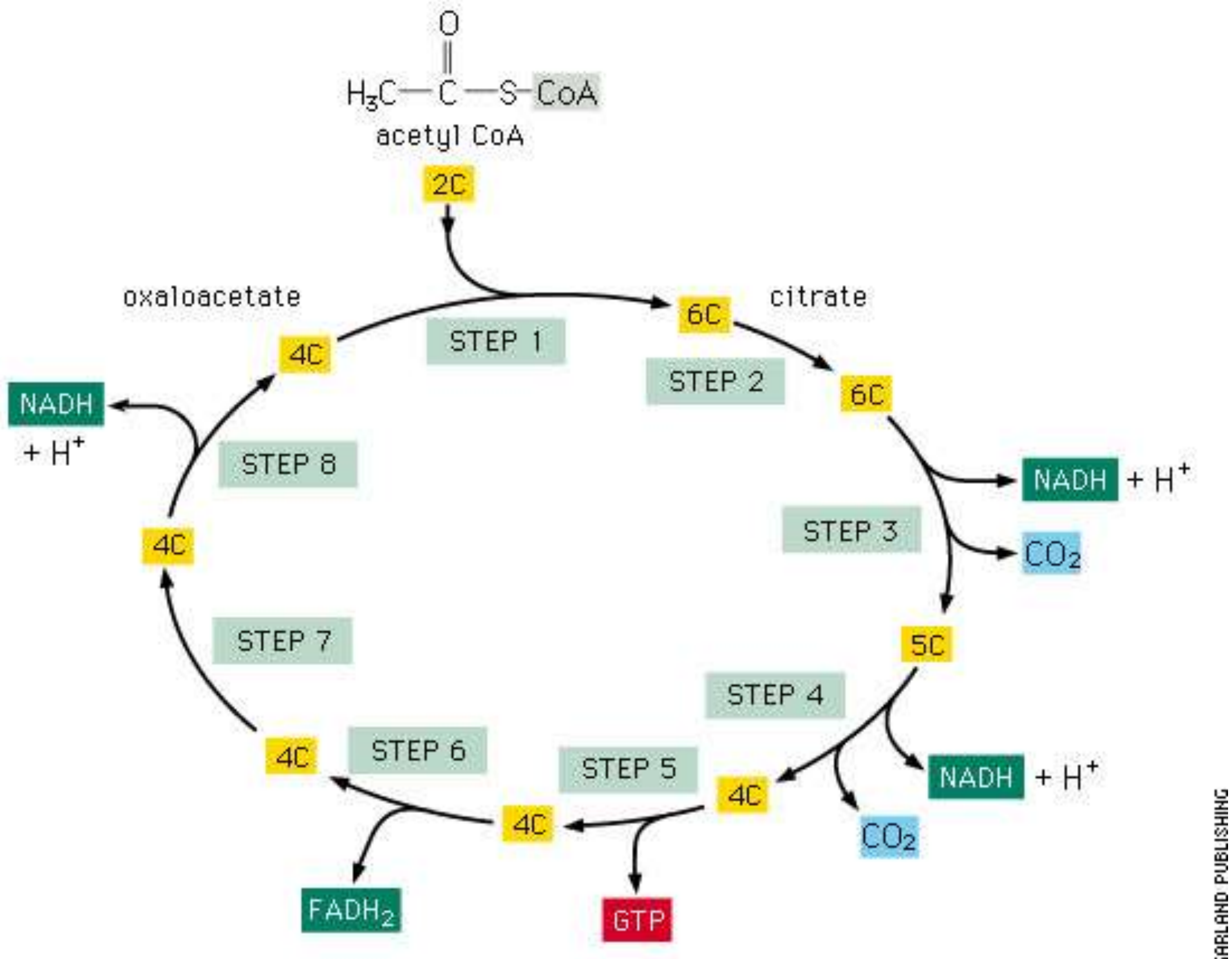
Figure 13-8 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Citric Acid Cycle

- Through a series of oxidation/reduction, addition/subtraction and ligand reactions oxidize pyruvate to carbon dioxide and water.
- Make an end product (oxaloacetate) that can start the cycle again
- Produce GTP (which phosphorylates ADP to ATP)
- Reduce NAD+ and FAD coenzymes which are to be used in the **Electron Transport System**

- By end of cycle, all the C of glucose is released as CO_2,

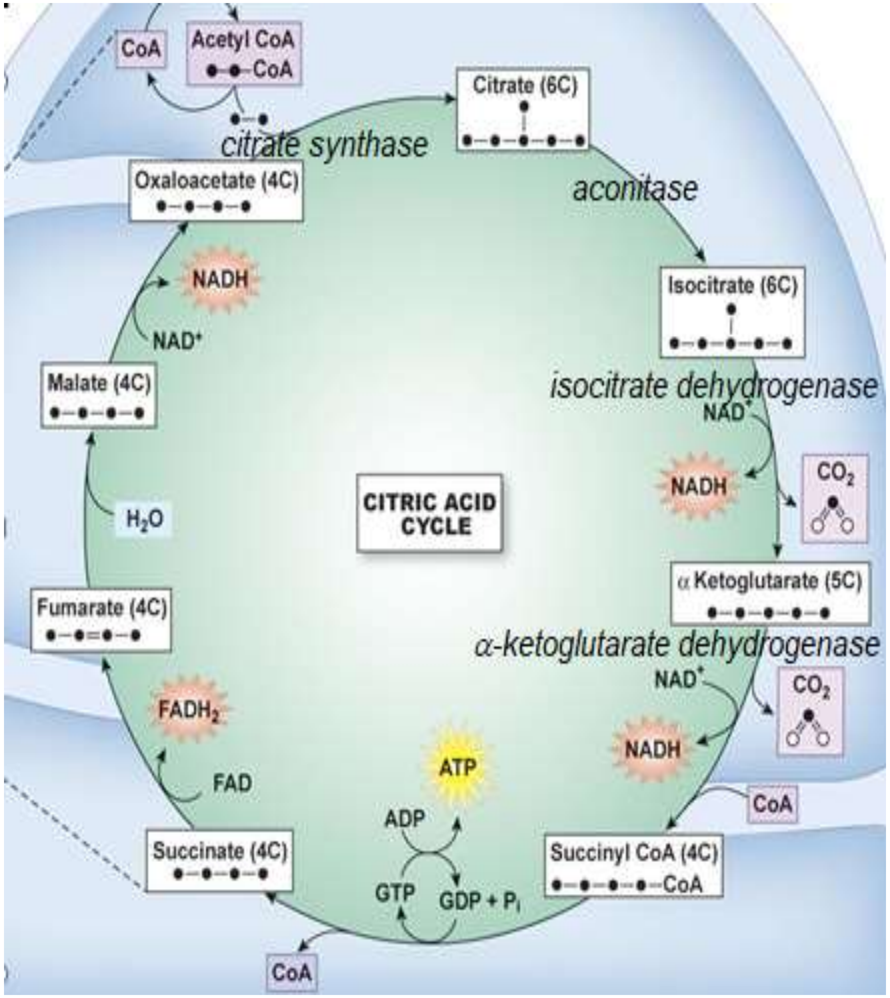
Citric Acid Cycle
(TCA Cycle, Kreb's Cycle)



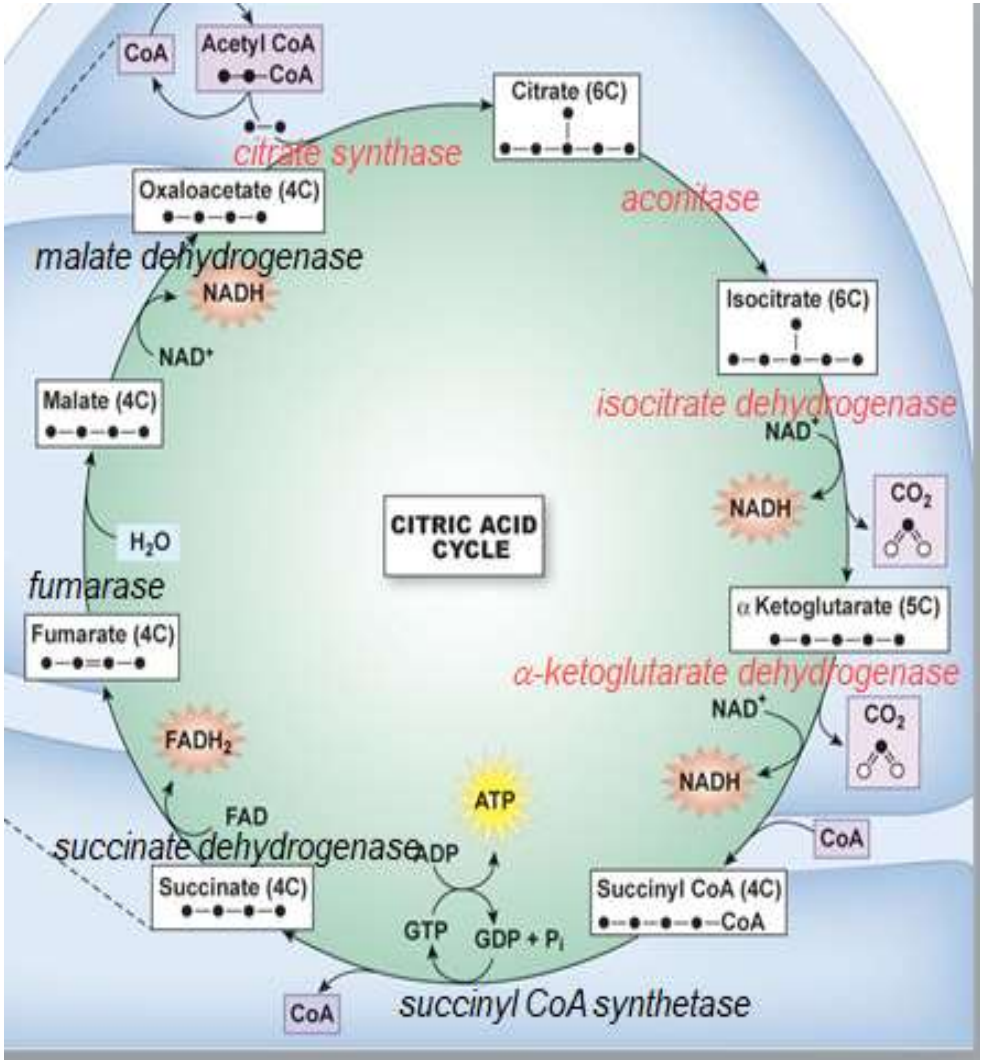
***NET RESULT: ONE TURN OF THE CYCLE PRODUCES THREE NADH, ONE GTP, AND ONE FADH$_2$, AND RELEASES TWO MOLECULES OF CO_2

Steps

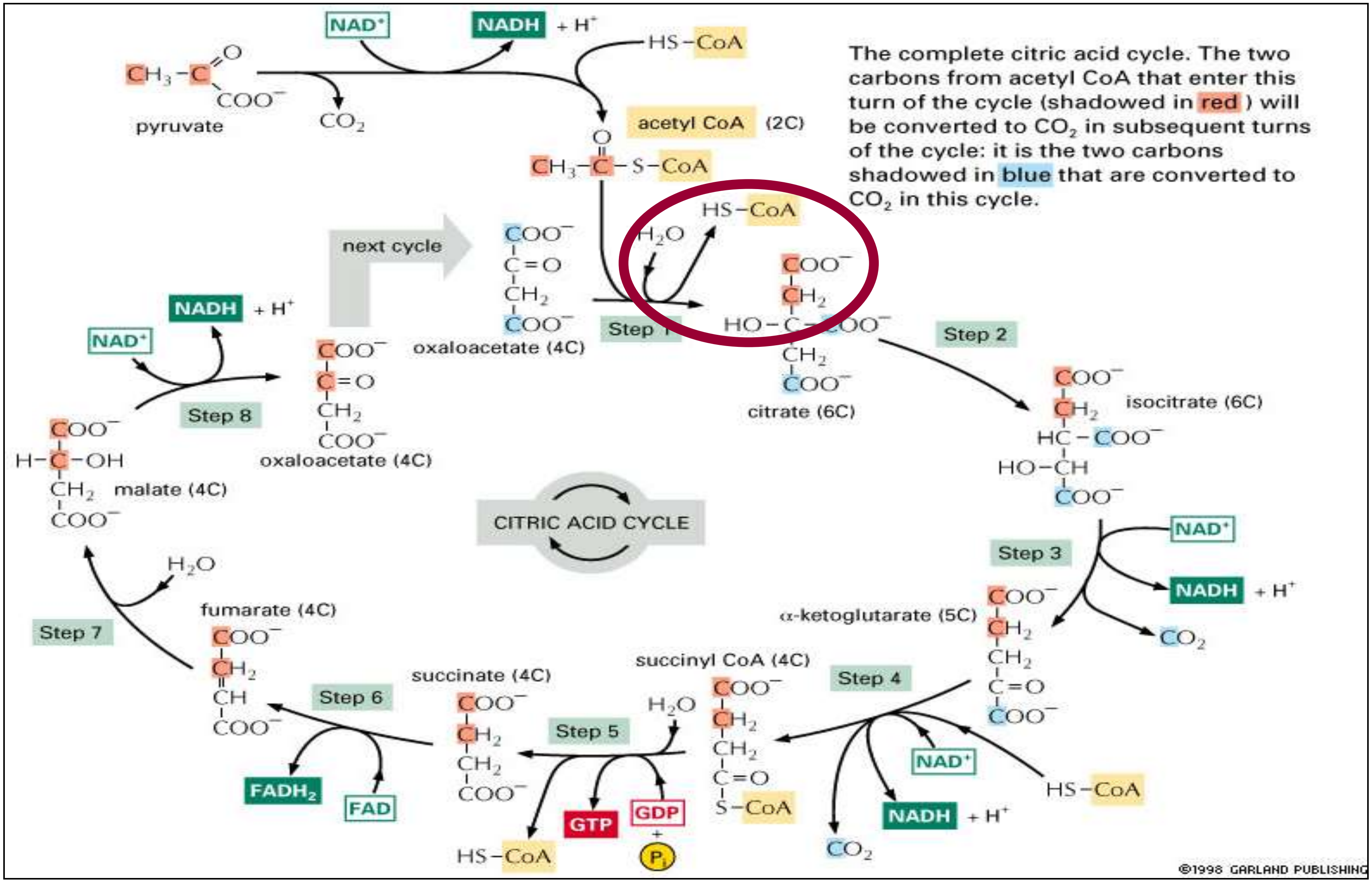
1. Acetyl CoA combines with oxaloacetate to form Citrate using ***citrate synthase***
2. Citrate is converted to Isocitrate by ***aconitase***
3. Isocitrate is oxidized and decarboxylated by ***isocitrate*** *dehydrogenase* to form α-ketoglutarate
4. α-ketoglutarate is converted into succinyl CoA by ***α-ketoglutarate dehydrogenase***



5. Succinyl CoA is converted into Succinate as CoA is subtracted and GDP is phosphorylated by ***succinyl CoA synthetase***
6. Succinate is oxidized to Fumarate by ***succinate dehydrogenase***, reducing FAD in the process
7. Fumarate is converted to Malate by ***fumarase,*** adding water in the process
8. Malate is converted back to oxaloacetate by ***malate dehydrogenase*** and is further oxidized, and NAD^+ is reduced.



- Requires O_2 but as H_2O (red circle)
- Some of the steps products can leave mitochondria and used in the cytosol to make precursors like amino acids

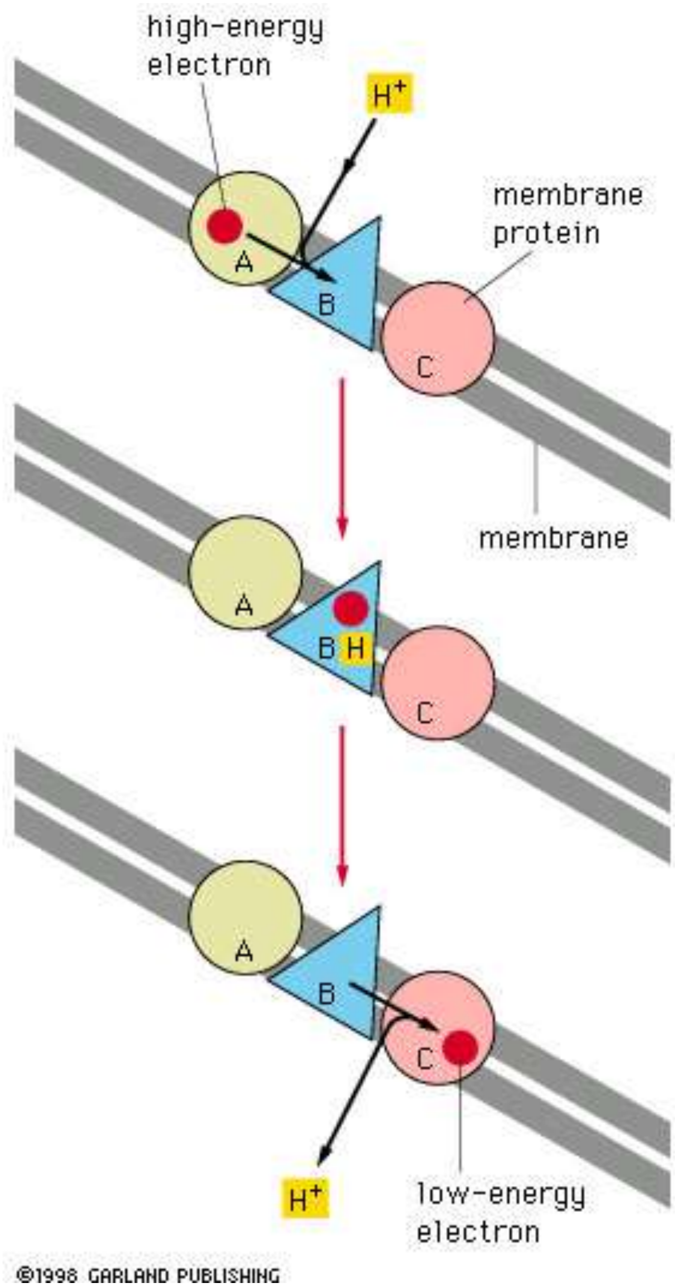


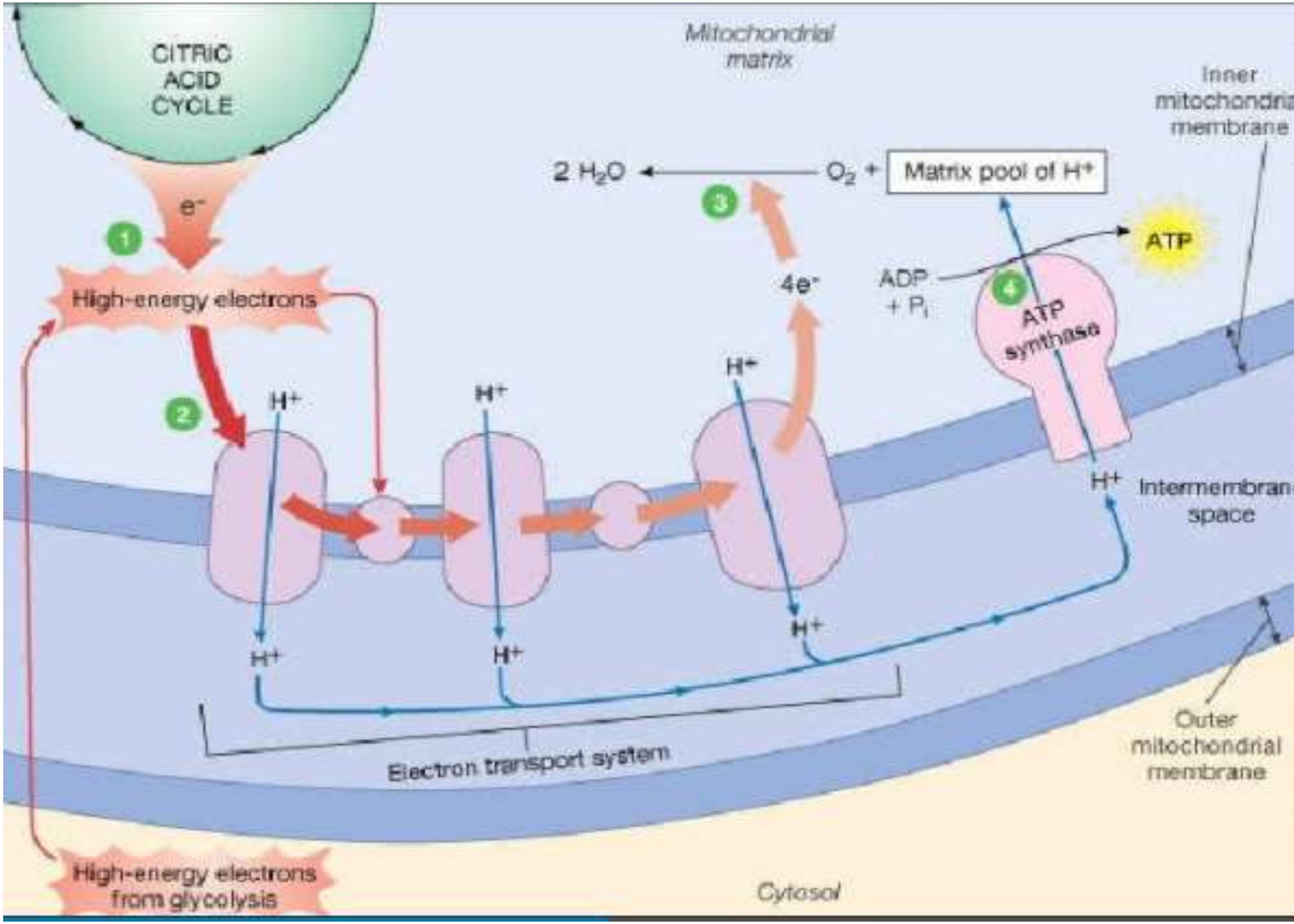
Energy produced

- Energy produced from citric acid cycle (per cycle)
- 1 ATP
- 3 NADH
- 1 $FADH_2$
- Waste - 2 CO_2

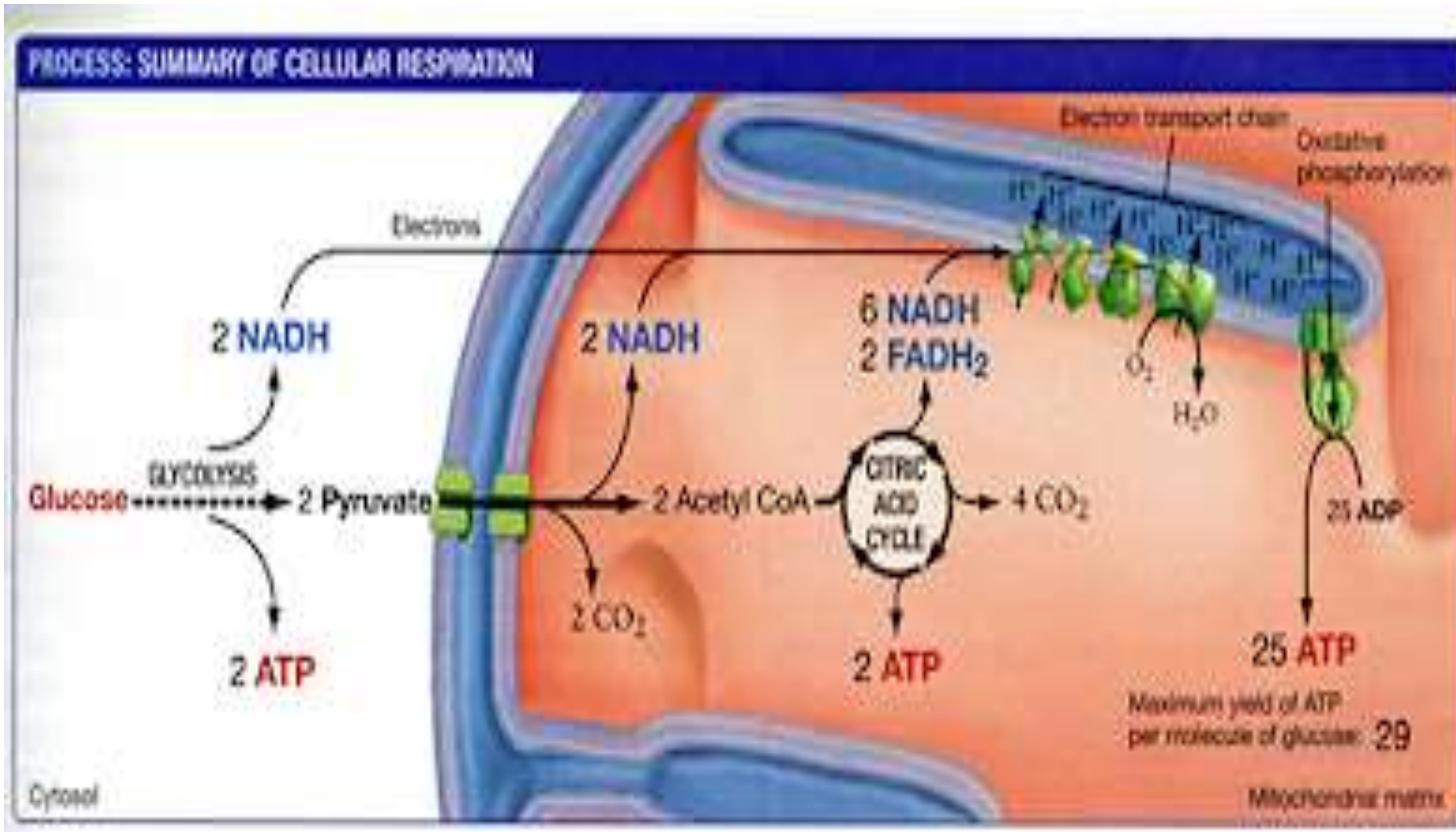
Electron-Transport Chain

- Final step in energy generation – most energy released here
- e^- of NADH and $FADH_2$ move through the chain, moving to lower energy level
- Occurs in the inner membrane of the mitochondria
- Specialized molecules accept and donate e^- as they move down chain
- Create an electrochemical gradient
  - As e^- move down chain, H^+ move across the membrane, altering the concentration of H^+ on either side = gradient
  - Gradient used to generate ATP




CITRIC
ACID
CYCLE
Mitochondrial
matrix
Inner
mitochondrial
membrane
2 H_2O
O_2 +
Matrix pool of H^+
e⁻
1
3
ATP
High-energy electrons
4e⁻
ADP
+ P_i
4
ATP
synthase
2
H^+
Intermembrane
space
Electron transport system
Outer
mitochondrial
membrane
High-energy electrons
from glycolysis
Cytosol

- Energy released by movement of electrons through transport system is stored temporarily in H^+ gradient.
- NADH produces a maximum of 2.5 ATP
- $FADH_2$ produces a maximum of 1.5 ATP
- 1 ATP formed per $3H^+$ shuttled through ATP synthase.

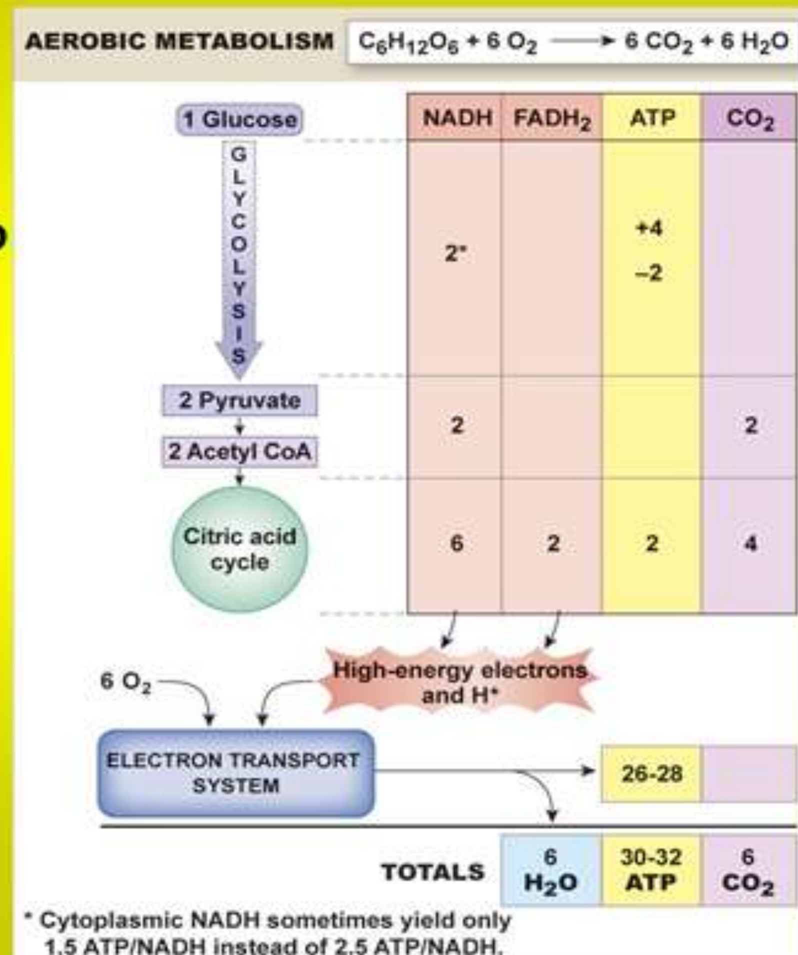


PROCESS: SUMMARY OF CELLULAR RESPIRATION
Electron transport chain
Oxidative phosphorylation
Electrons
2 NADH
2 NADH
6 NADH
2 FADH2
O2
H2O
Glucose
GLYCOLYSIS
2 Pyruvate
2 Acetyl CoA
CITRIC ACID CYCLE
4 CO2
25 ADP
2 CO2
2 ATP
2 ATP
25 ATP
Maximum yield of ATP per molecule of glucose: 29
Cytosol
Mitochondrial matrix

End Result of Aerobic Cellular Respiration

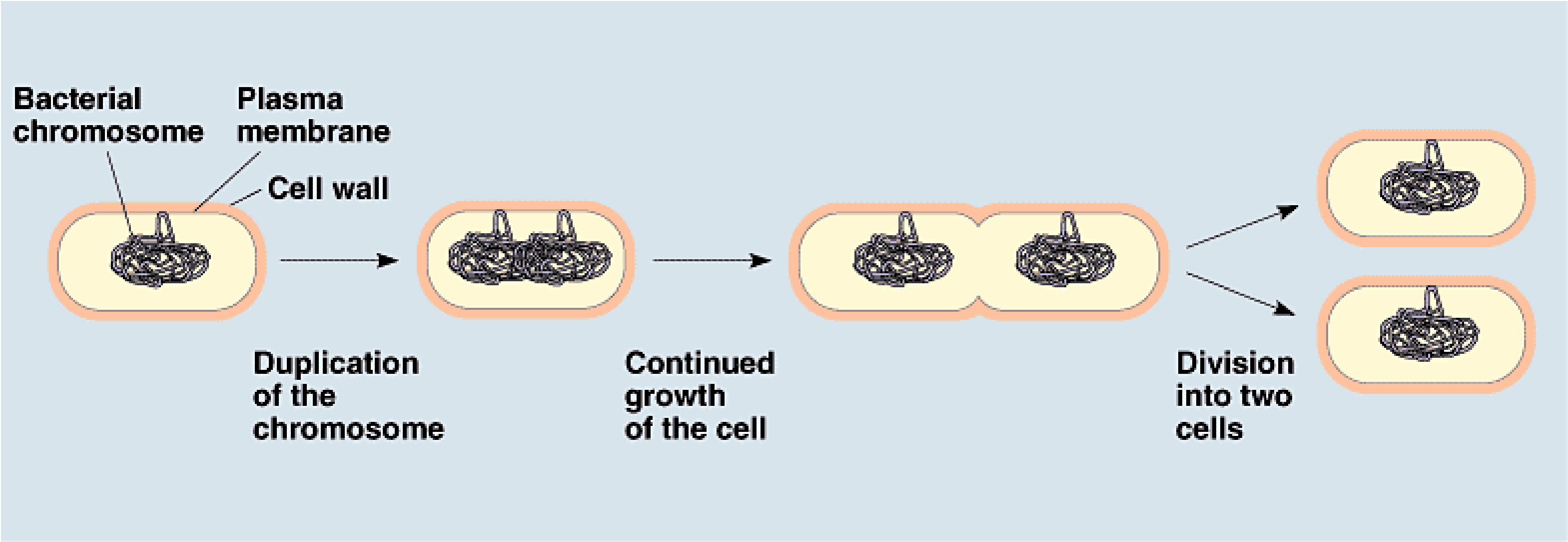
- ATP numbers…
- 8 NADH = 20 ATP
- 2 NADH = 3 ATP
- 2 FADH = 3 ATP
- Glyc/Kreb 4 ATP

30 ATP



CELLS GROW AND REPRODUCE

Prokaryotic cell reproduction
<u>Binary Fission</u>



Binary fission

- *“Binary fission is a form of asexual reproduction in which an organism divides into two, each part carrying one copy of genetic material.”*

- **Asexual reproduction**
- typically observed in prokaryotes and few single-celled eukaryotes.
- In this method of asexual reproduction, there is a separation of the parent cell into two new daughter cells..

Steps involved

Step 1- Replication of DNA

- The bacterium uncoils and replicates its **chromosome**, essentially doubling its content.

Step 2- Growth of a Cell

- After copying the chromosome, the bacterium starts to grow larger
- It is followed by an increase in cytoplasmic content.

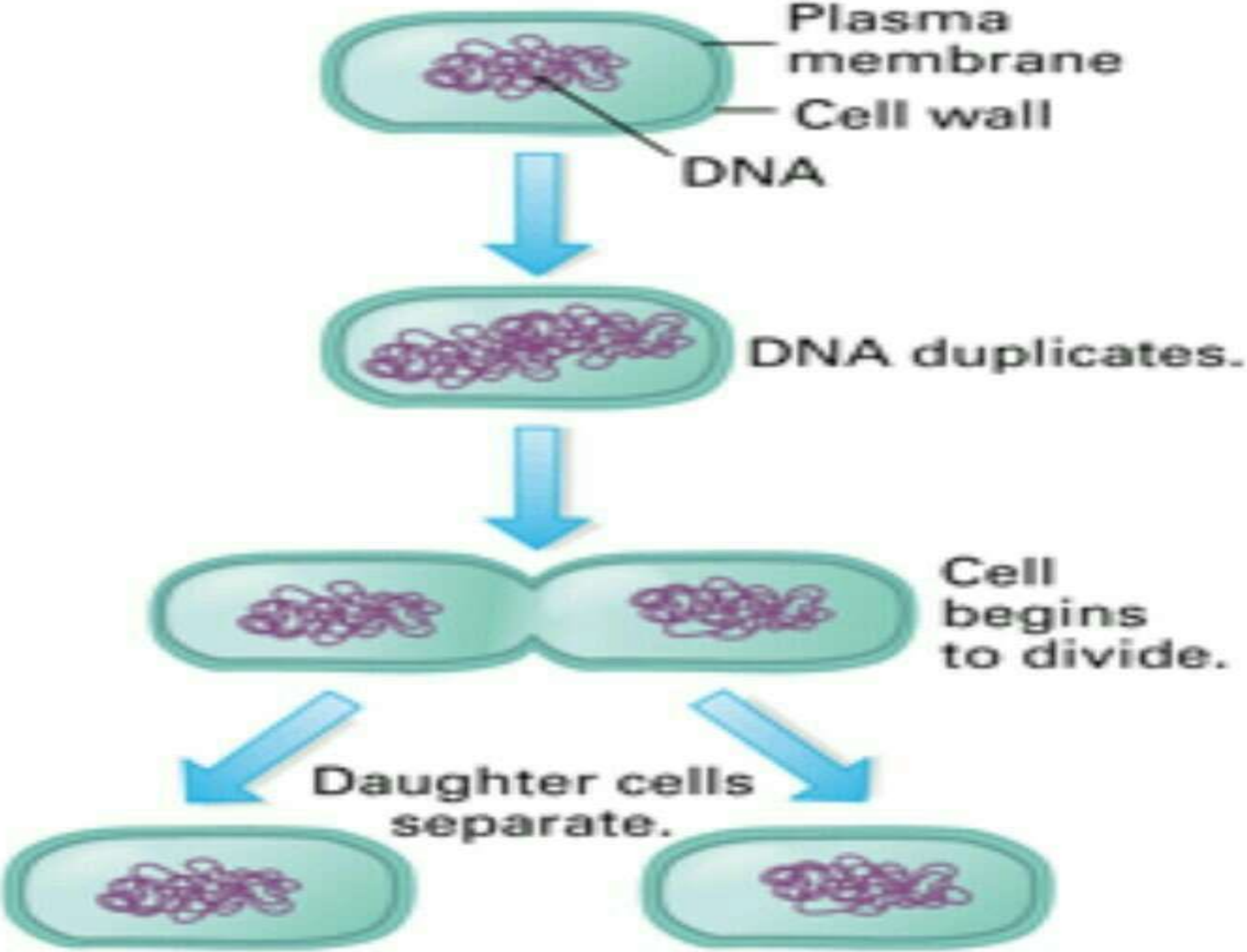
Step 3-Segregation of DNA

- The cell elongates with a septum forming at the middle.
- The two chromosomes are also separated in this phase.

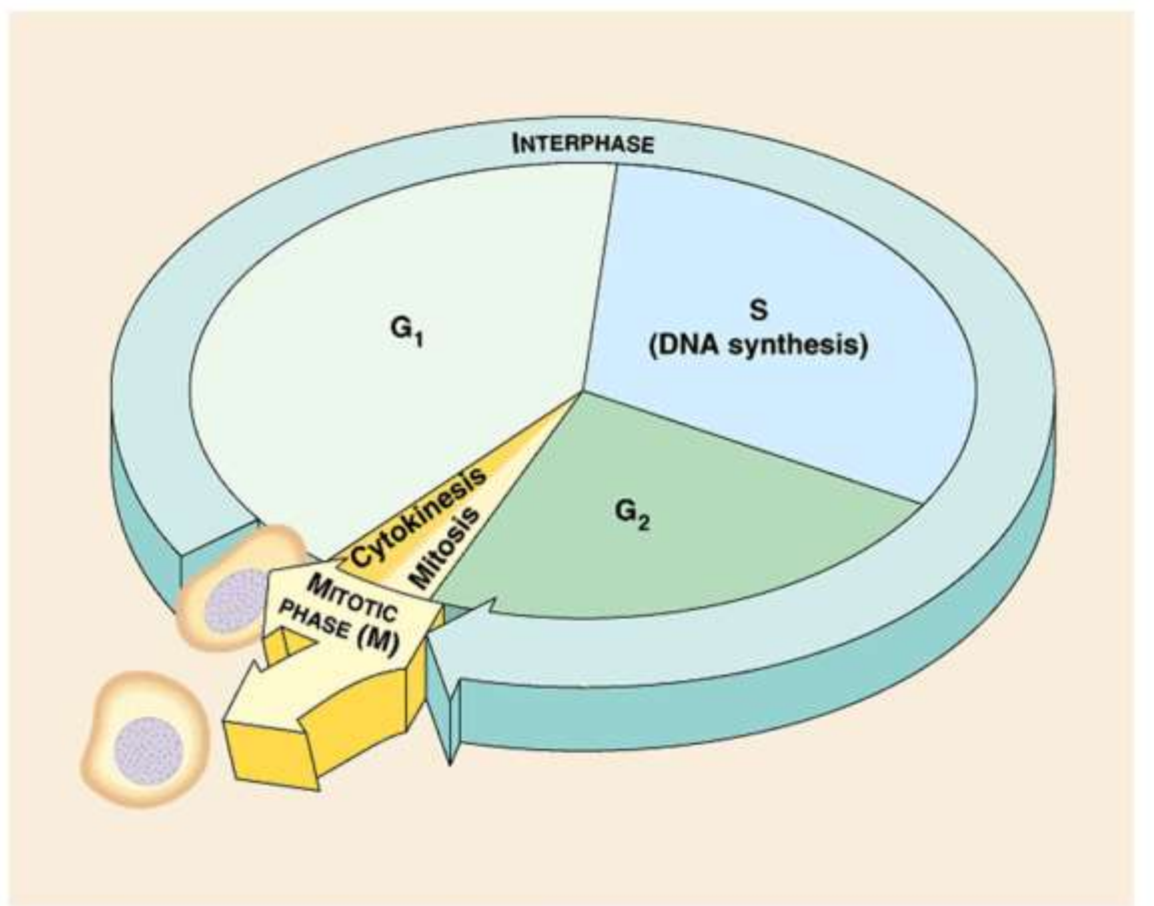
Step 4- Splitting of Cells

- A new cell wall is formed at this phase, and the cell splits at the centre, dividing the parent cell into two new daughter cells.

Binary Fission



Eukaryotic Cell Cycle



Cell Cycle

- A cell cycle is a series of events that takes place in a cell as it grows and divides.
- Actively dividing eukaryote cells pass through a series of stages known collectively as the **cell cycle**

Phases of cell cycle

- Two gap phases (G1 and G2)
- S (for synthesis) phase, in which the genetic material is duplicated
- M phase, in which mitosis partitions the genetic material and the cell divides.
- After completing the cycle, the cell either starts the process again from G1 or exits the cycle through G0.

Interphase

- The stages in the cell cycle between one mitosis and the next, which include G1, S and G2, are known collectively as the **interphase**.

G1 phase

- First gap phase
- Cell increases in size
- Cellular contents duplicated

S phase

- DNA replication

the cell synthesizes a complete copy of the DNA in its nucleus.

G2 phase

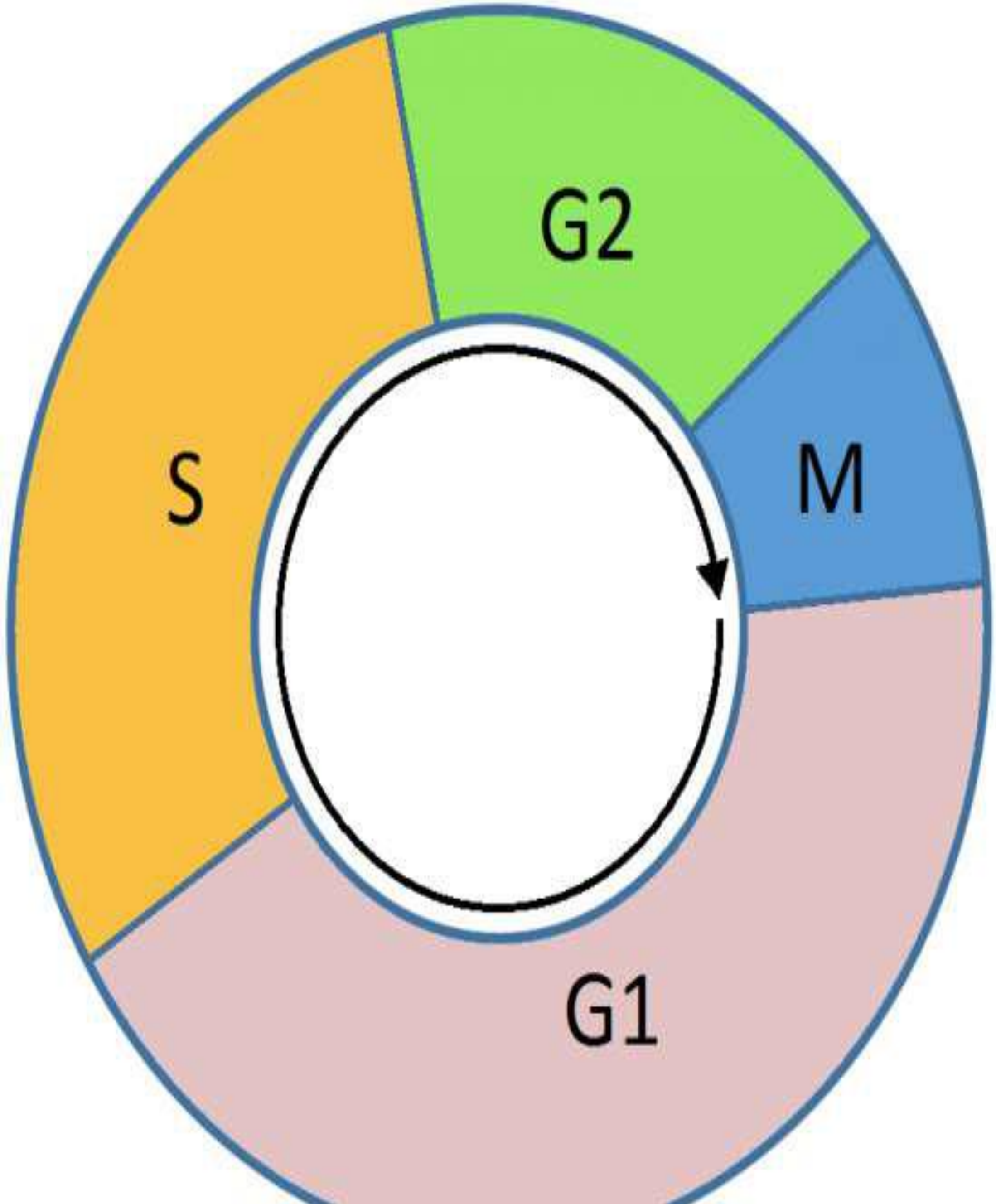
- Second gap phase
- Cell grows more
- Organelles and proteins develop in preparation for cell division

M phase

- Mitosis followed by cytokinesis (cell separation)
- Formation of two identical daughter cells

G0 phase

- While some cells are constantly dividing, some cell types are at rest.
- These cells may exit G1 and enter a resting state called G0.
- In G0, a cell is performing its function without actively preparing to divide.



G1 - Growth

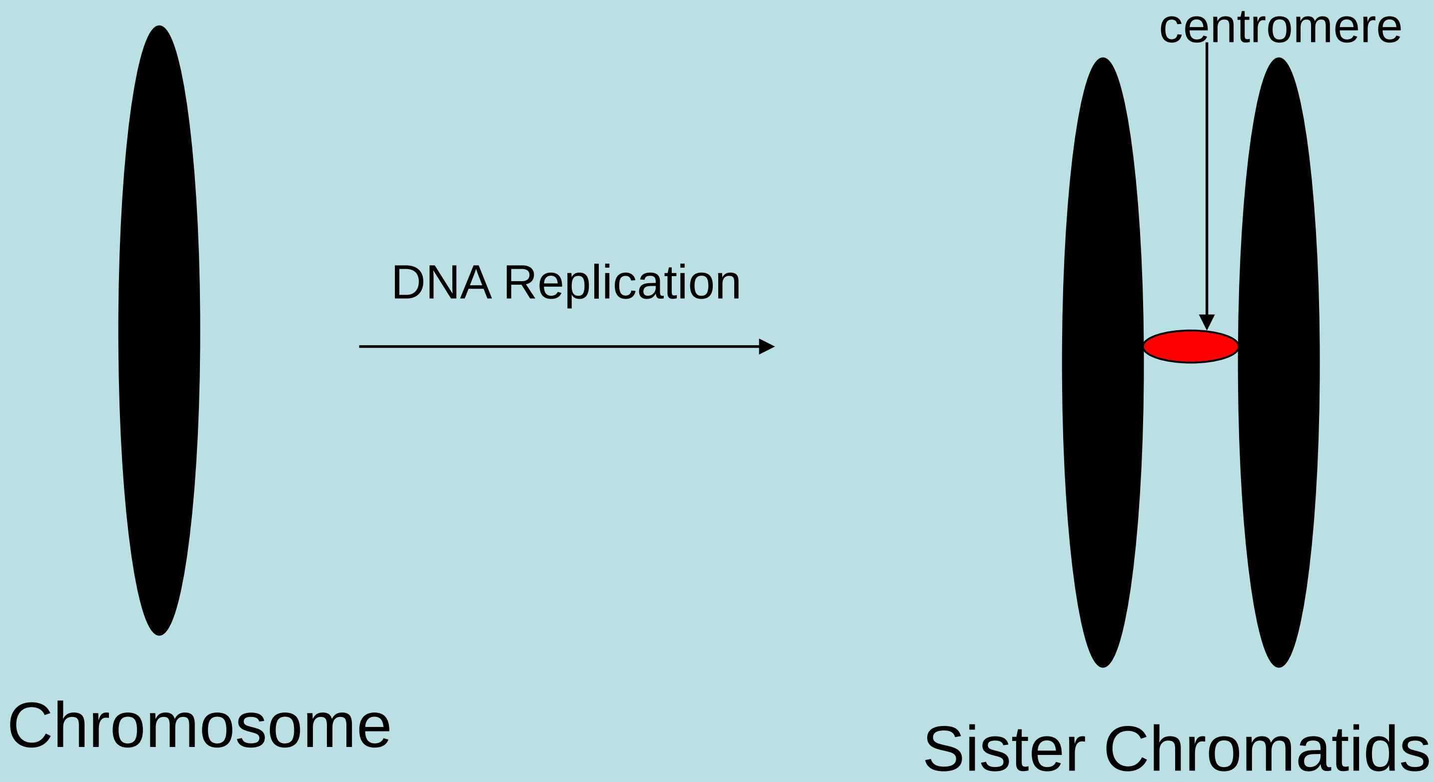
S - DNA synthesis

G2 - Growth and preparation for mitosis

M - Mitosis (cell division)

STATE	PHASE	SYMBOL	DESCRIPTION
RESTING	Gap 0	G_0	A phase where the cell has left the cycle and has stopped dividing.
INTER PHASE	Gap 1	G_1	Cells increase in size in Gap 1. The G_1 checkpoint control mechanism ensures that everything is ready for DNA synthesis. It takes about 8 hours.
	Synthesis	S	DNA replication occurs during this phase. It takes about 7 to 8 hours.
	Gap 2	G_2	During the gap between DNA synthesis and mitosis, the cell will continue to grow. The G_2 checkpoint control mechanism ensures that everything is ready to enter the M (mitosis) phase and divide. It takes about 4 hours.
CELL DIVISION	Mitosis	M	Cell growth stops at this stage and cellular energy is focused on the orderly division into two daughter cells. A checkpoint in the middle of mitosis (Metaphase Checkpoint) ensures that the cell is ready to complete cell division. It takes about 1 hour.

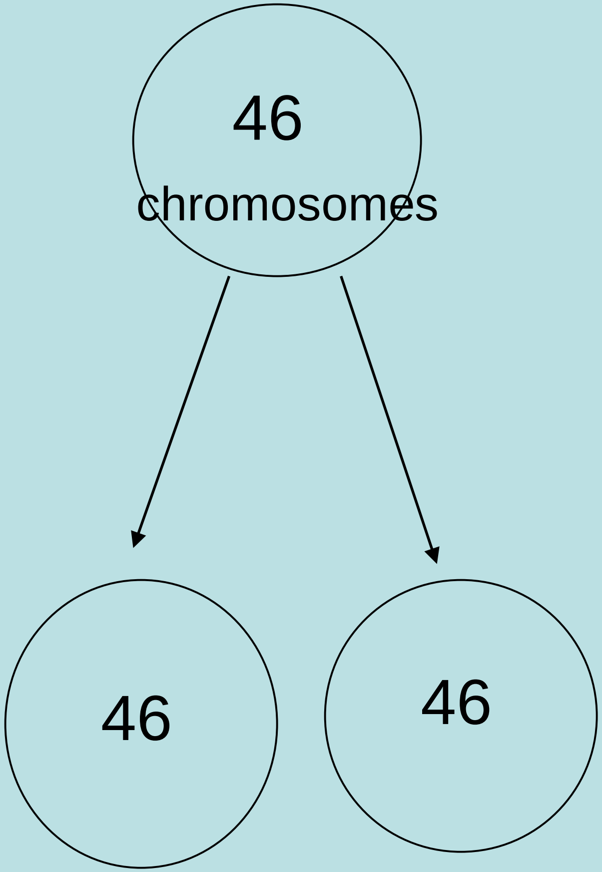
Sister Chromatids



MITOSIS

- During the **mitotic phase** (*including mitosis and cytokinesis*), the replicated chromosomes and cytoplasm separate into two new daughter cells.
- Mitosis: cell reproduction for growth and replacement of cells.

•



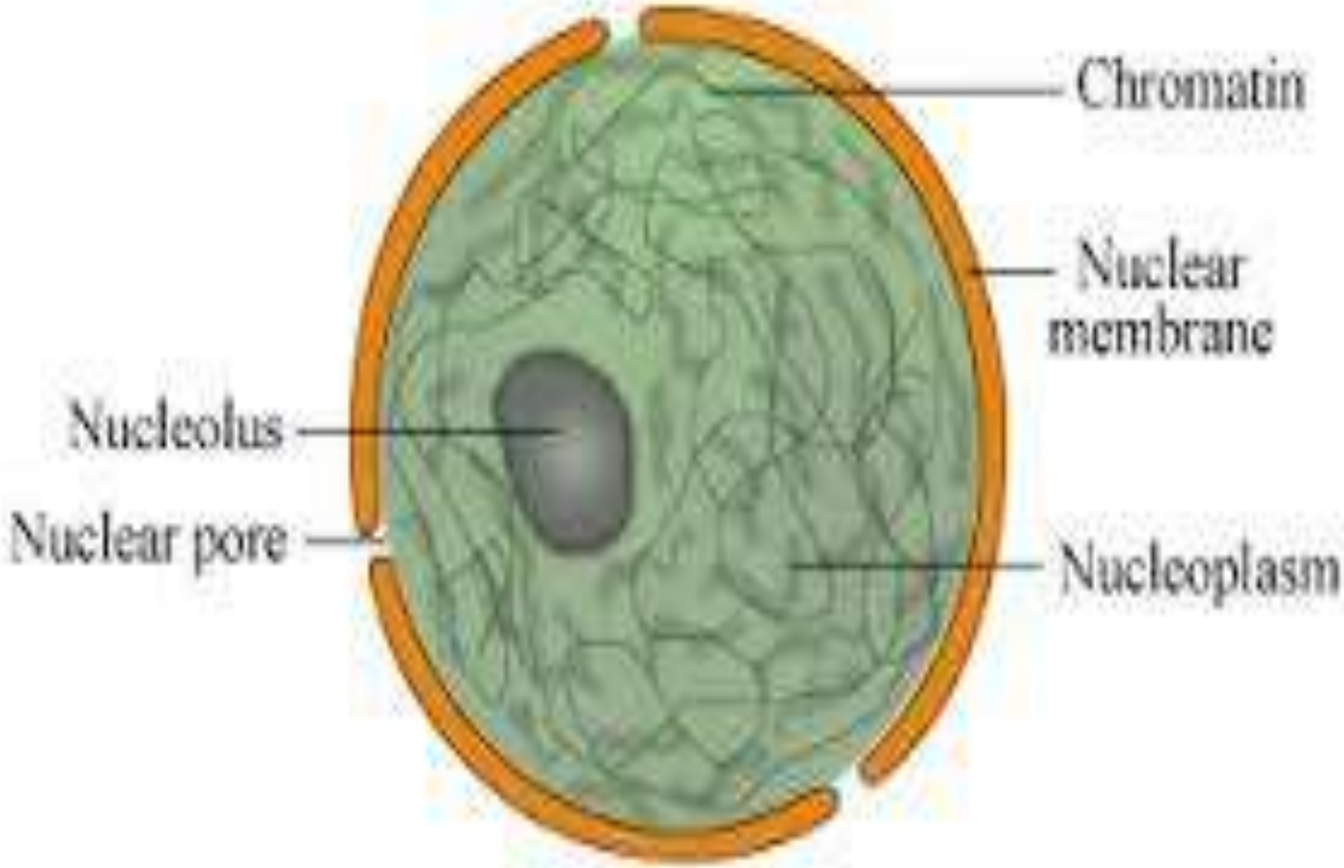
Mitosis
One division

Mitosis

- Mitosis is the process by which a eukaryotic cell separates the chromosomes in its cell nucleus into two identical sets in two nuclei
- It is a relatively short period of the cell cycle and is complex and highly regulated.
- Errors in mitosis can result in cell death through apoptosis or cause mutations that may lead to cancer.

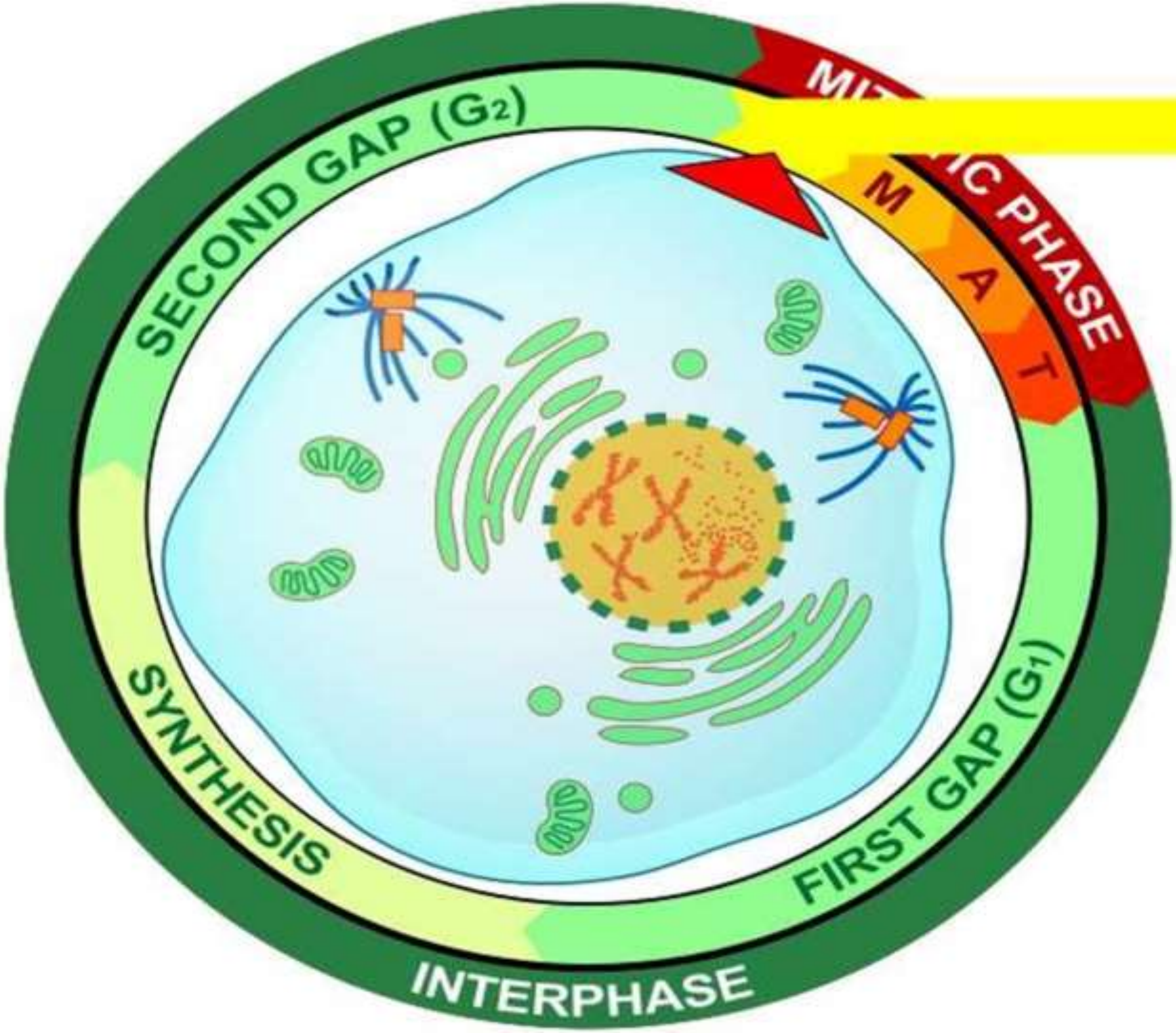
Phases in Mitosis

- Prophase: chromosomes thicken, nucleus disappears
- Metaphase: chromosomes line up at center
- Anaphase: centromeres split, sister chromatids separate
- Telophase: cytokinesis, division of the cytoplasm


Chromatin
Nuclear membrane
Nucleolus
Nuclear pore
Nucleoplasm

PROPHASE

- The **nuclear envelope is broken down**
- long strands of chromatin condense to form shorter more visible strands called chromosomes
- the **nucleolus disappears**,
- microtubules attach to the chromosomes at the kinetochores present in the centromere.



Prophase

*Nucleolus disappears

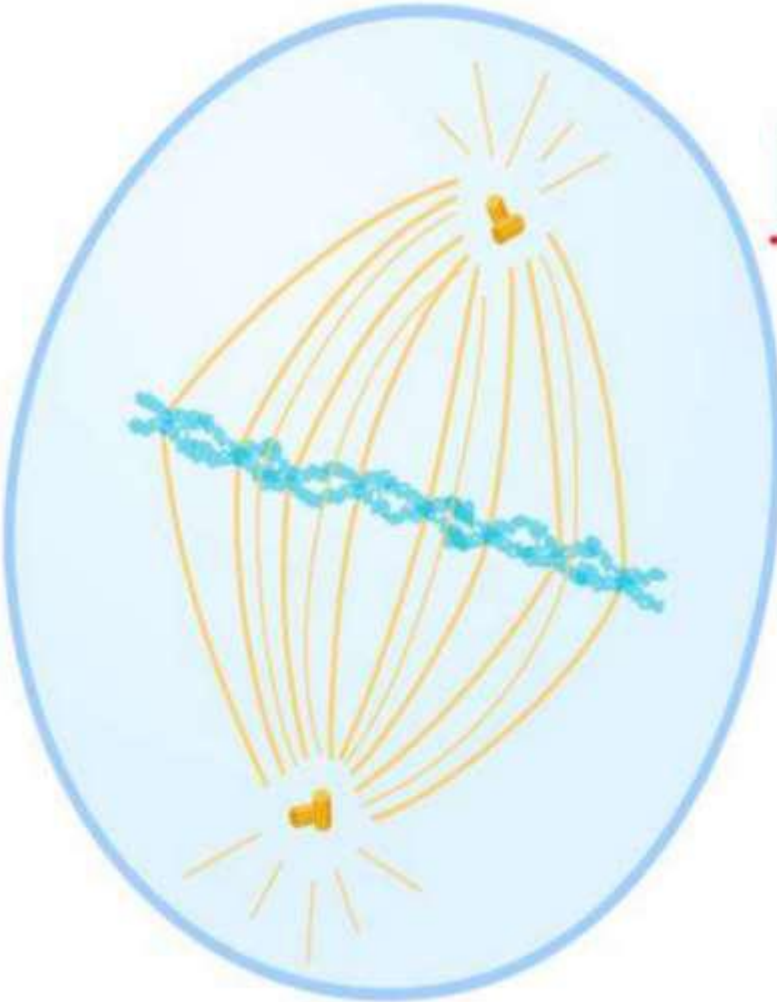
*Chromatin condenses into chromosomes

*Separation of centrosomes

*Formation of the mitotic spindle

METAPHASE

- In metaphase, the centromeres of the chromosomes convene themselves on the metaphase plate (*or equatorial plate*), an imaginary line
- Chromosomes line up in the middle of the cell by microtubule organizing centers pushing and pulling on centromeres of both chromatids thereby causing the chromosome to move to the center.



Metaphase

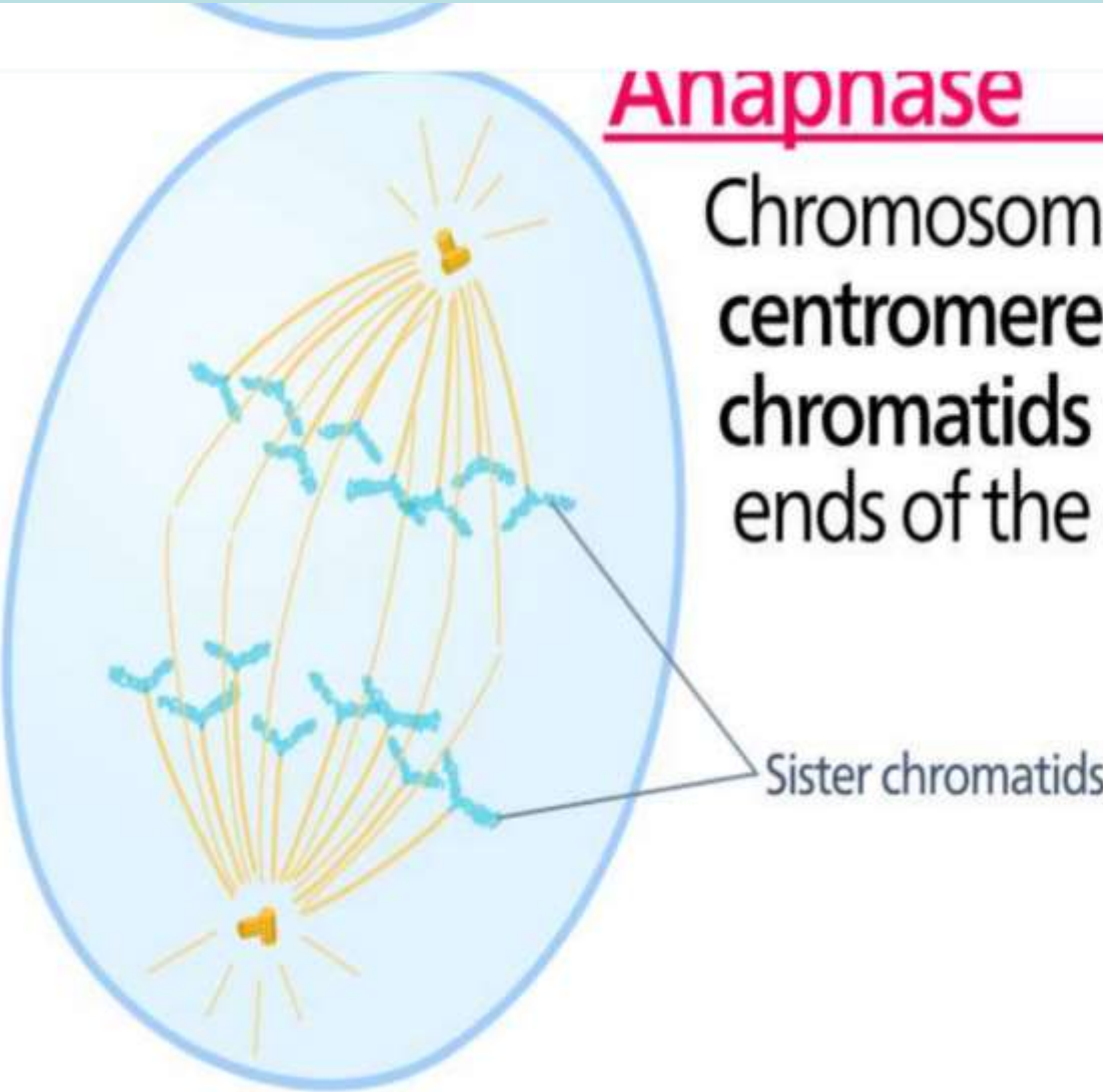
Chromosomes line up along **metaphase plate** (imaginary plane)

ANAPHASE

- After the chromosomes line up in the middle of the cell,
- the spindle fibers will pull them apart and chromosomes are split apart as the sister chromatids move to opposite sides of the cell

Anaphase

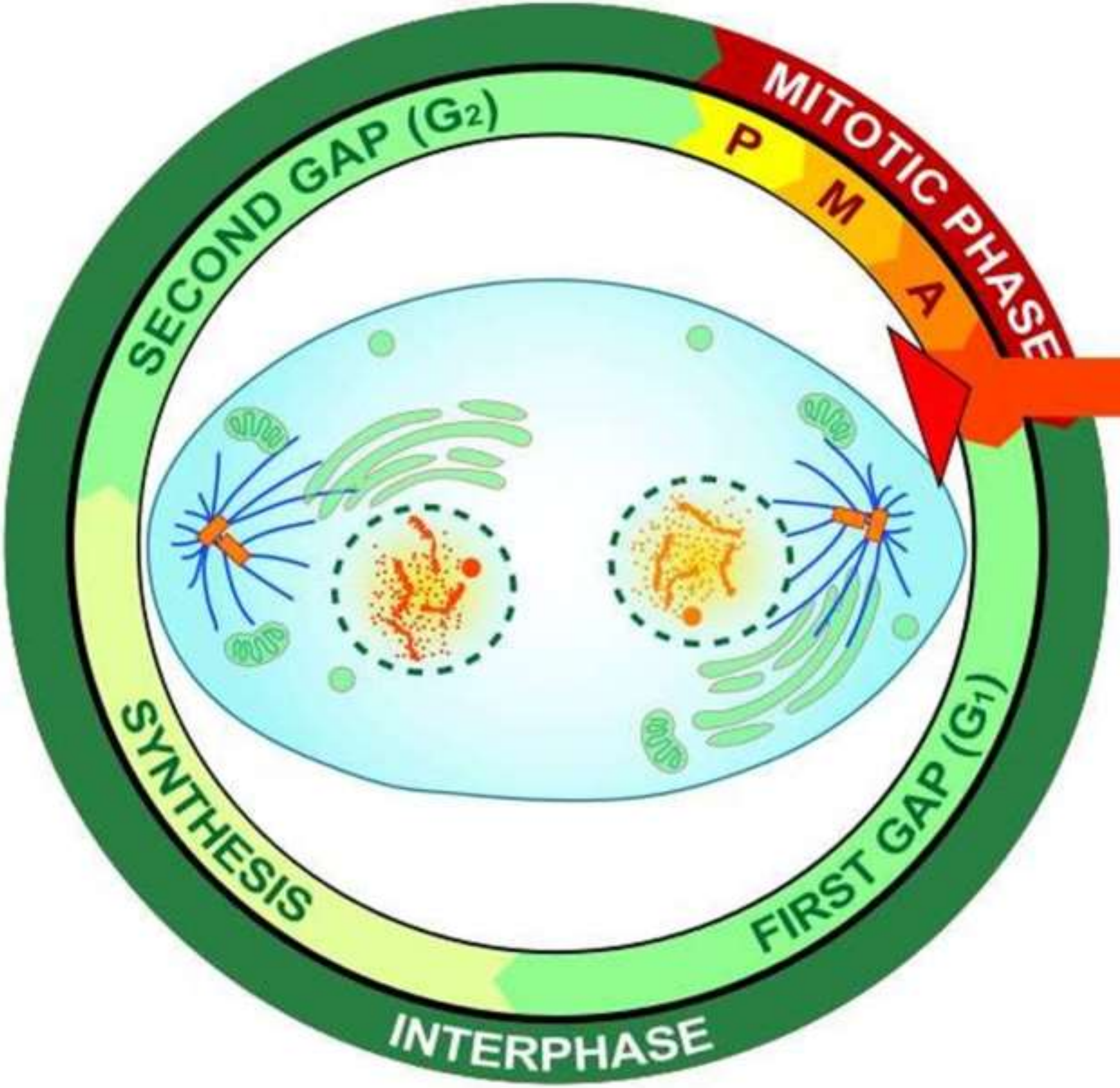
Chromosomes break at **centromeres**, and **sister chromatids** move to opposite ends of the cell



TELOPHASE

- Telophase is the last stage of the cell cycle in which a cleavage furrow splits the cells

- This occurs through the synthesis of a new nuclear envelopes
- reformation of the nucleolus as the chromosomes decondense



Telophase

*New nuclear envelope forms

*Chromosomes unfold back into chromatin

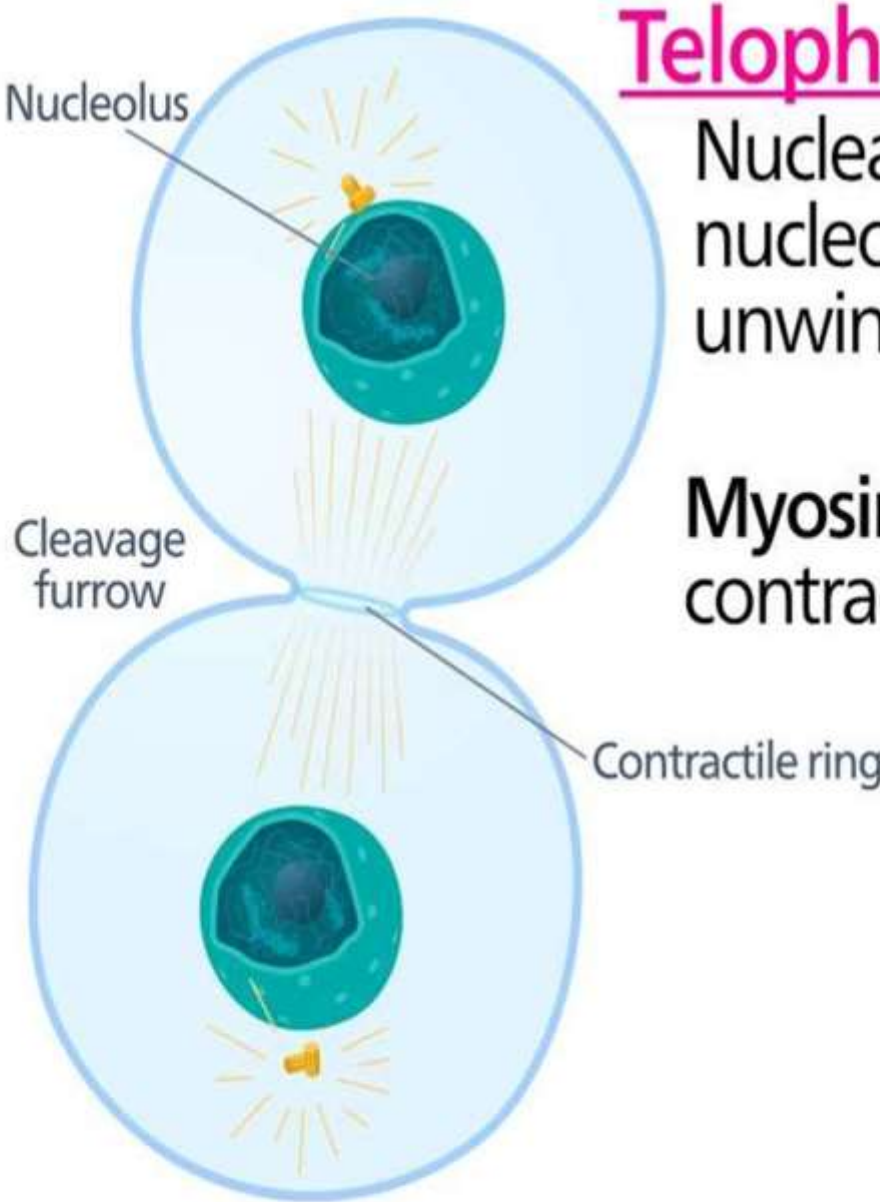
*Nucleoli reapear

*Cell continues to enlogate

CYTOKINESIS PHASE

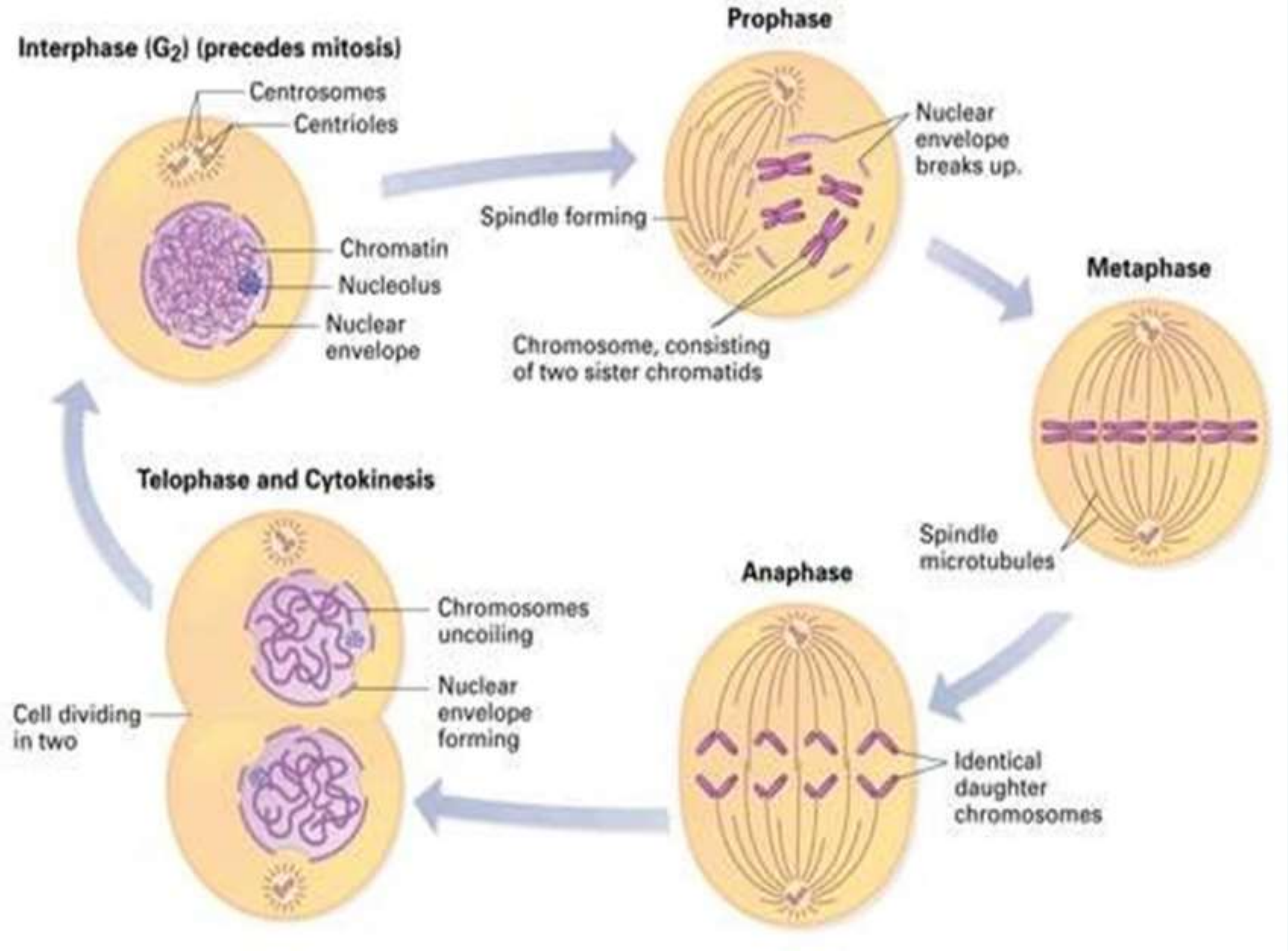
- Mitosis is immediately followed by cytokinesis, which divides the nuclei, cytoplasm, organelles and cell membrane into two cells containing roughly equal shares of these cellular components.
- Mitosis and cytokinesis together define the division of the mother cell into two daughter cells, genetically identical to each other and to their parent cell.

Telophase and Cytokinesis



Nuclear membrane reforms, nucleoli reappear, chromosomes unwind into chromatin

Myosin II and **actin** filament ring contract to cleave cell in two


Interphase (G_2) (precedes mitosis)
Centrosomes
Centrioles
Chromatin
Nucleolus
Nuclear envelope
Prophase
Nuclear envelope breaks up.
Spindle forming
Chromosome, consisting of two sister chromatids
Metaphase
Spindle microtubules
Anaphase
Identical daughter chromosomes
Telophase and Cytokinesis
Chromosomes uncoiling
Nuclear envelope forming
Cell dividing in two

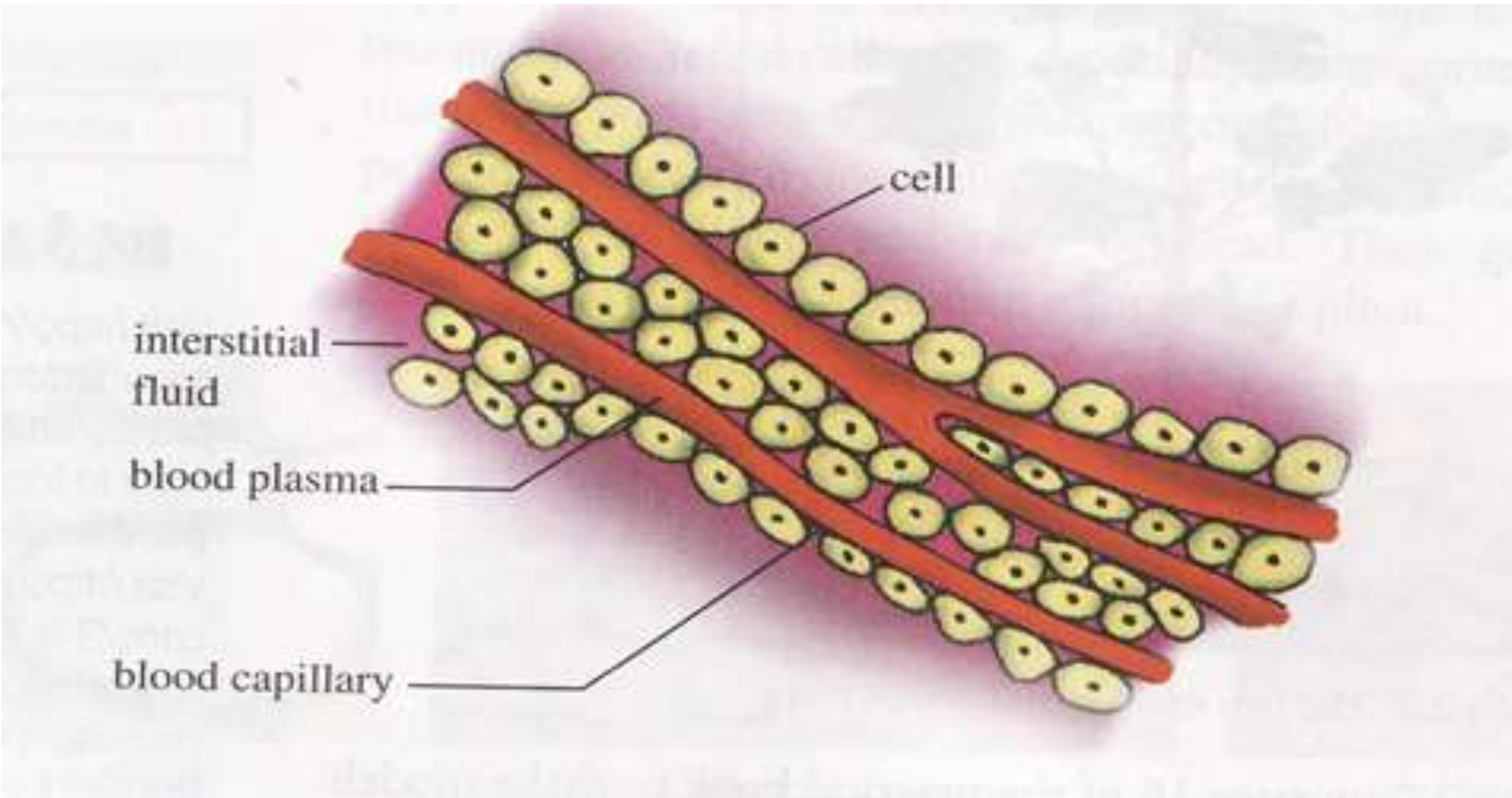
Course Name: Biology for Engineers
Course Code: U20BTBT01
Topics: Cells maintain their internal environment
Cell respond to their external environment

Lecture Delivered By
Ms. M. Priya
Assistant Professor
Department of IBT
Bharath Institute of Higher Education and Research
Chennai-600073

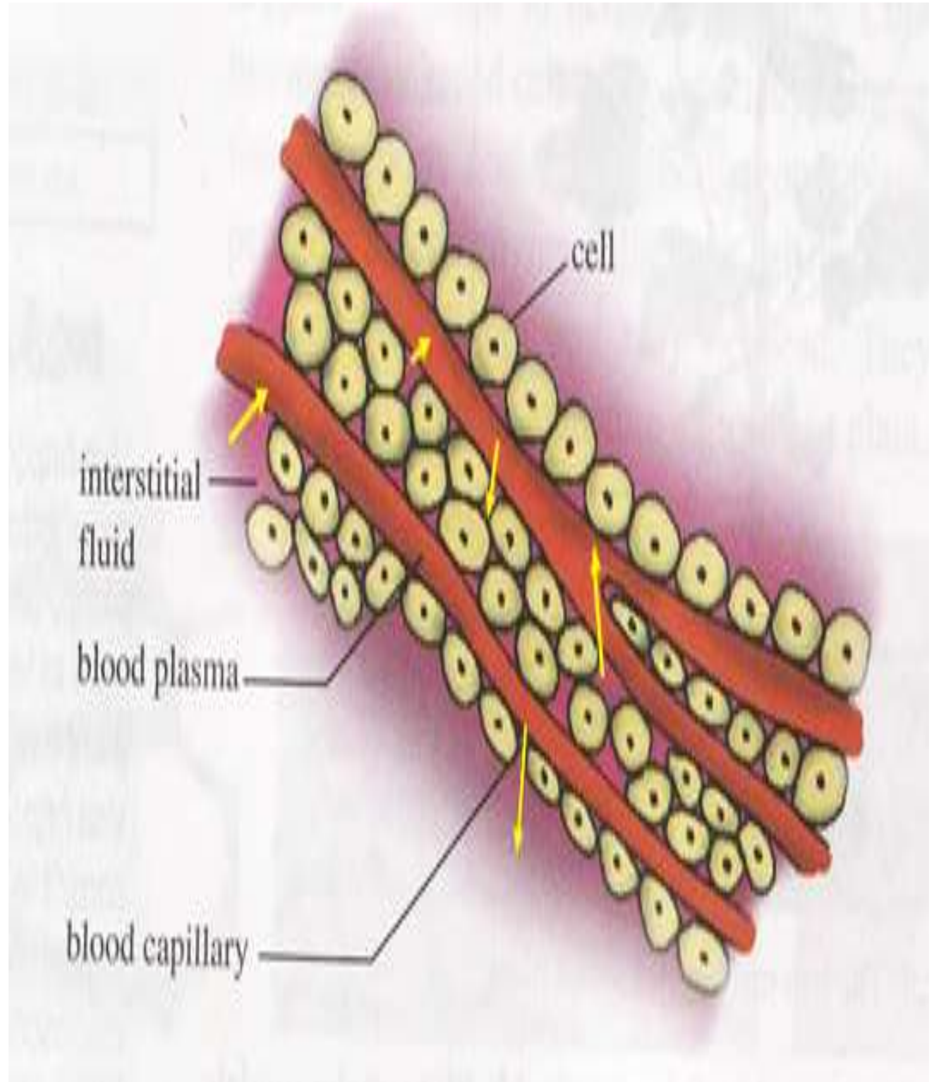
Internal environment

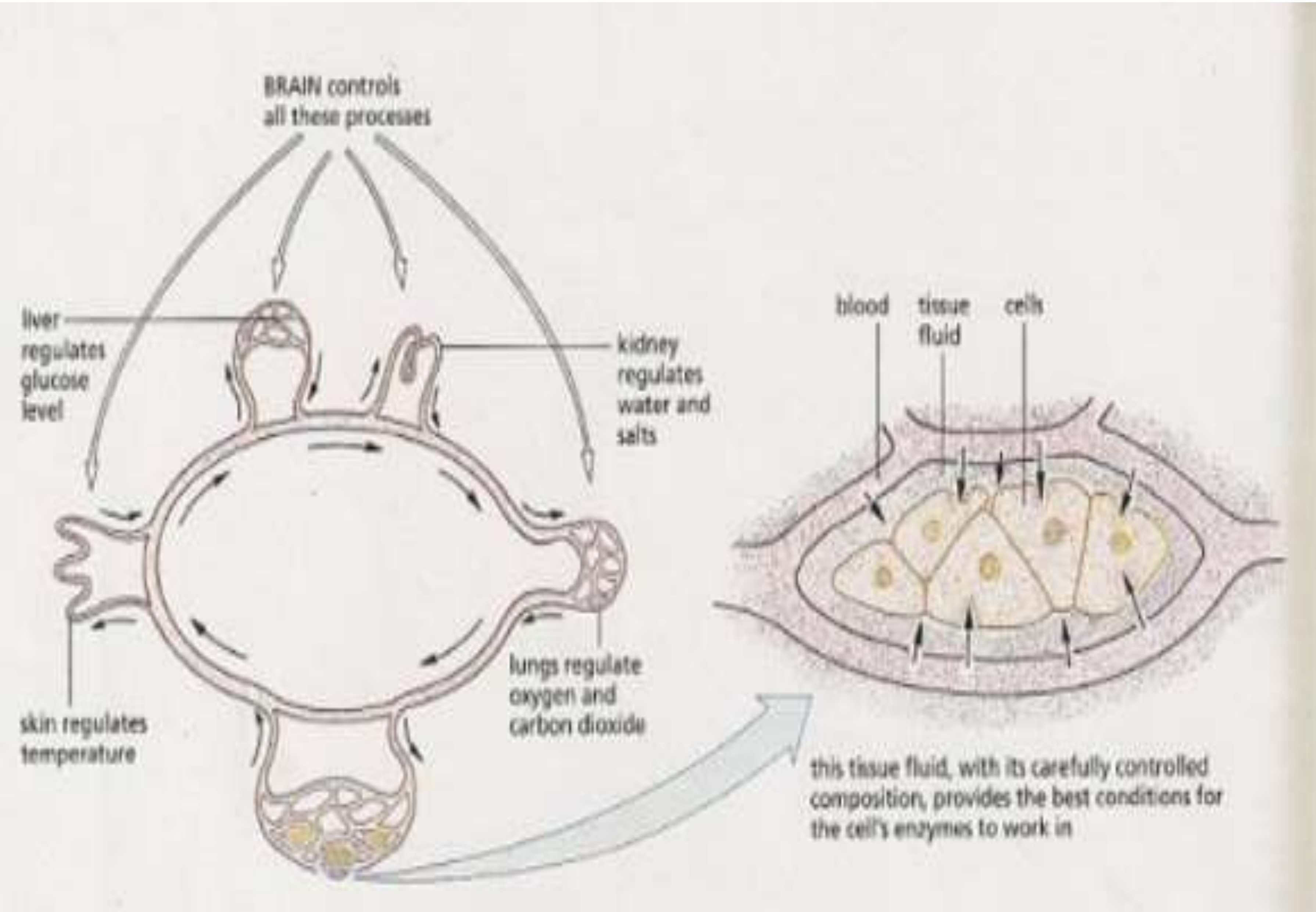
- The environment inside an organism.
- Plant- filled with air
- Animal- filled with liquid (interstitial fluid)

- Internal environment of a multicellular organisms consist of
  - **interstitial fluid**- fills the spaces between the cells and constantly bathes the cells and keeps the cells functioning
  - **blood plasma**


cell
interstitial
fluid
blood plasma
blood capillary

- Nutrient and waste substances are exchanged between the interstitial fluid and the blood plasma contained in the blood capillaries.




BRAIN controls
all these processes
liver
regulates
glucose
level
kidney
regulates
water and
salts
skin regulates
temperature
lungs regulate
oxygen and
carbon dioxide
blood
tissue
fluid
cells
this tissue fluid, with its carefully controlled
composition, provides the best conditions for
the cell's enzymes to work in

Factors affecting internal environment

- <u>**Physical factors:**</u>
- Temperature
- Osmotic pressure
- Concentration of oxygen and carbon dioxide in the bloodstream
- <u>**Chemical factors:**</u>
- Salt level
- Glucose level
- pH

- In order for cells of the body to function optimally, the physical factors and the chemical factors within the internal environment must be maintained at a relatively constant level
- Eg: Temperature

- For human, the internal environment need to be maintain around 37°C.
- At this temperature, the enzymes give the optimal enzyme activity.
- If the temperature too high, enzymes denatured- so lose ability to function.
- If the temperature too low, enzymes become inactive.

What is the mechanism which regulates the physical and chemical factors in the internal environment?

HOMEOSTASIS

- **Homeostasis is a process that regulates the chemical and physical parameters in the internal environment so that the conditions are always suitable to meet the needs of cells**

Homeostatic control system

- 3 functional components
- Receptor
- Control center
- Effector

1. Receptor

detect a change (stimuli)

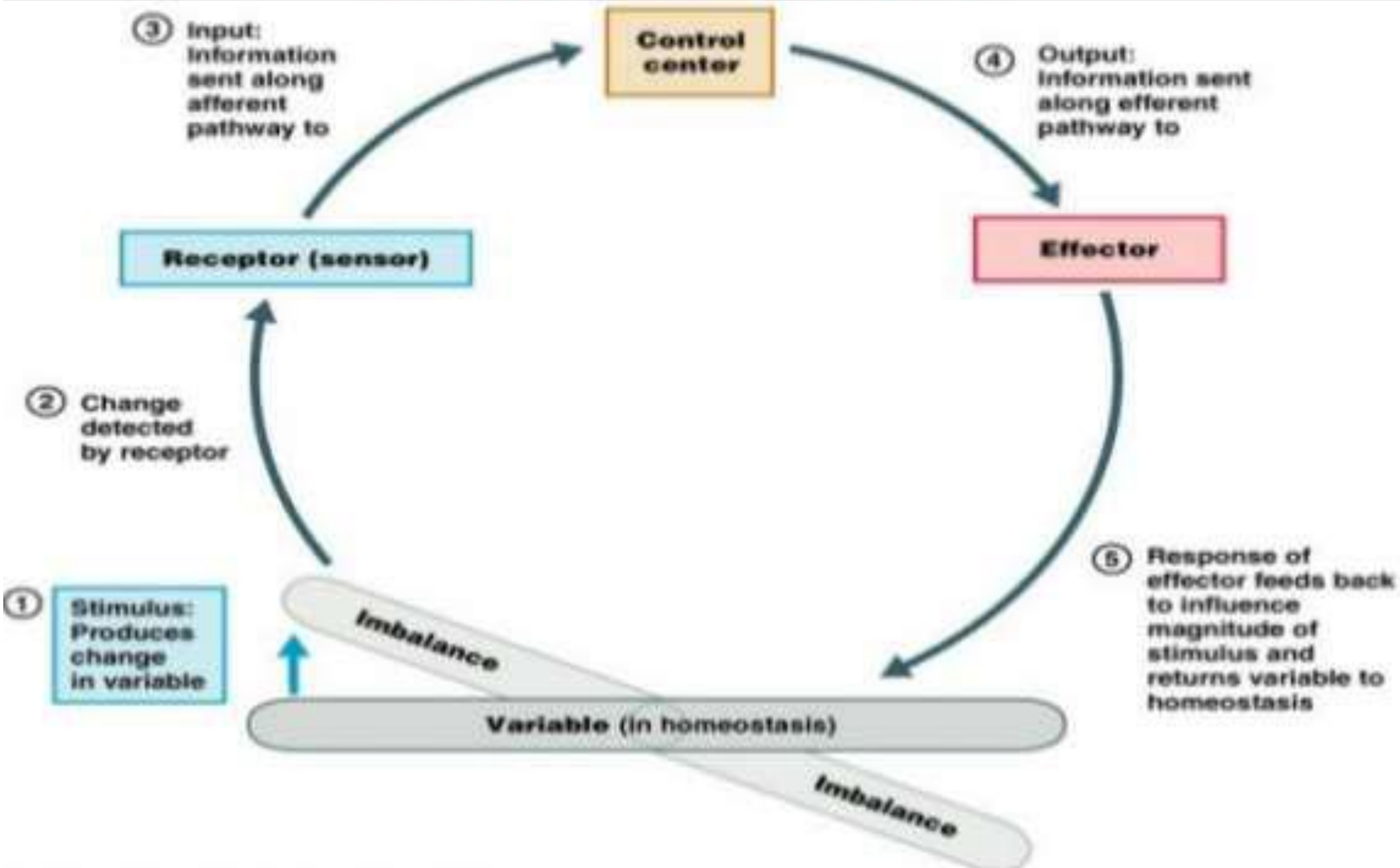
2. Control center

receive message from receptors and process the information

3. Effector

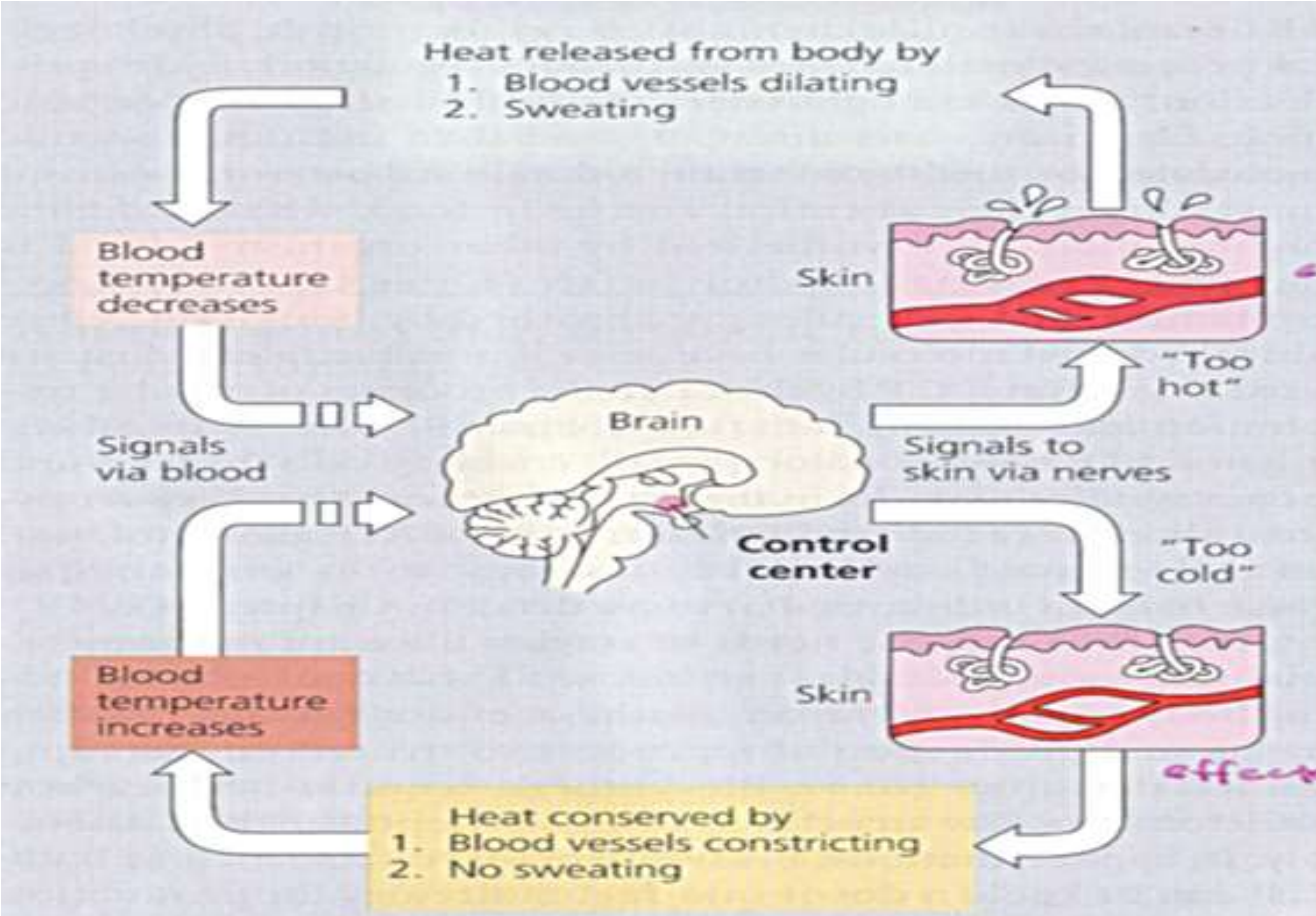
receive message from control center and carry out the appropriate response.

A FEEDBACK LOOP



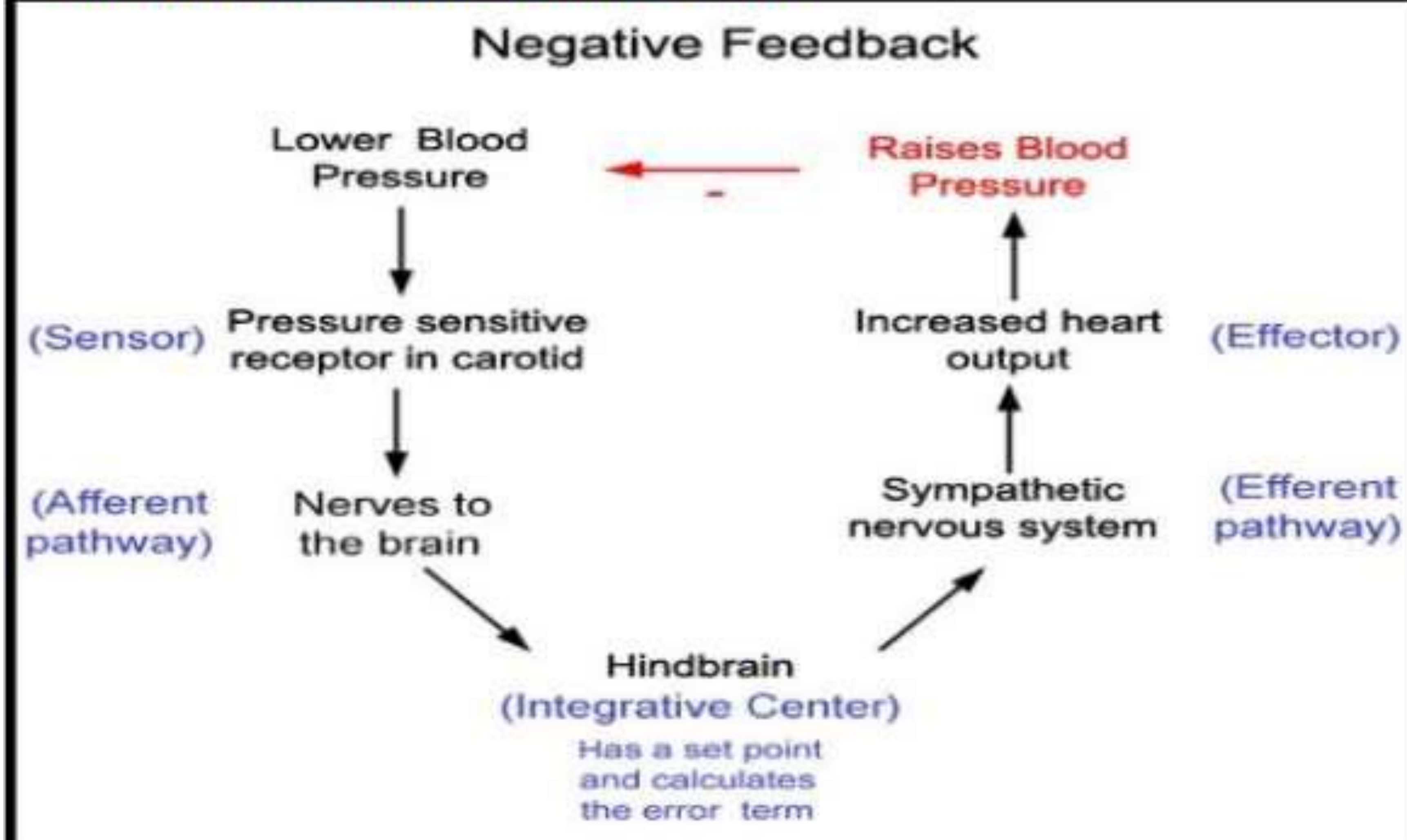
Negative feedback

- Mechanism that maintain the factor at some mean value
- **Reverse a change**
- Restore abnormal values to normal



Heat released from body by
1. Blood vessels dilating
2. Sweating
Blood temperature decreases
Skin
"Too hot"
Brain
Signals via blood
Signals to skin via nerves
Control center
"Too cold"
Skin
Blood temperature increases
effecto
Heat conserved by
1. Blood vessels constricting
2. No sweating

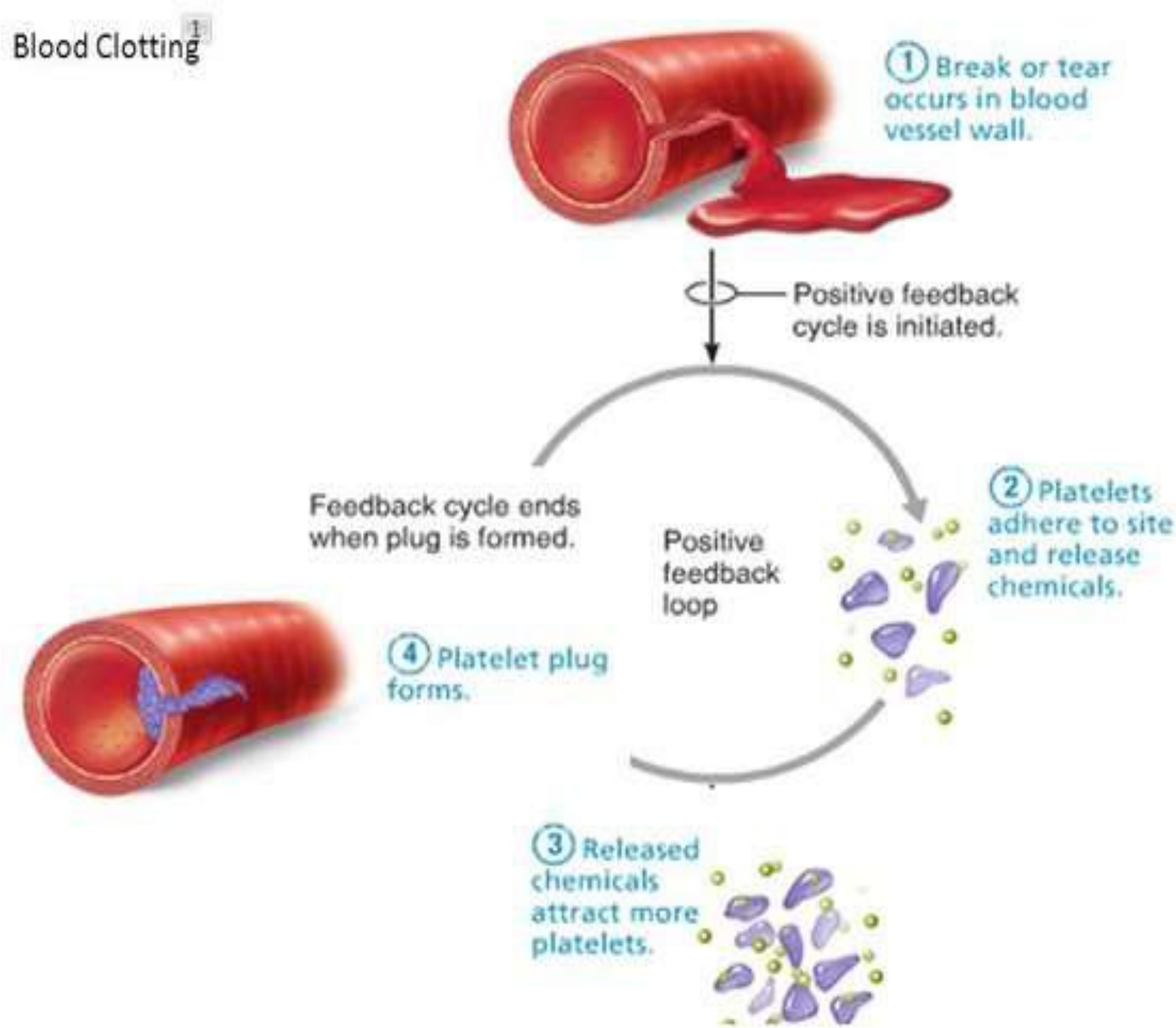
EXAMPLE: NEGATIVE FEEDBACK
BLOOD PRESSURE REGULATION



Positive feedback

- Strengthen a change
- Makes abnormal

values more abnormal



Cells respond to their external environment

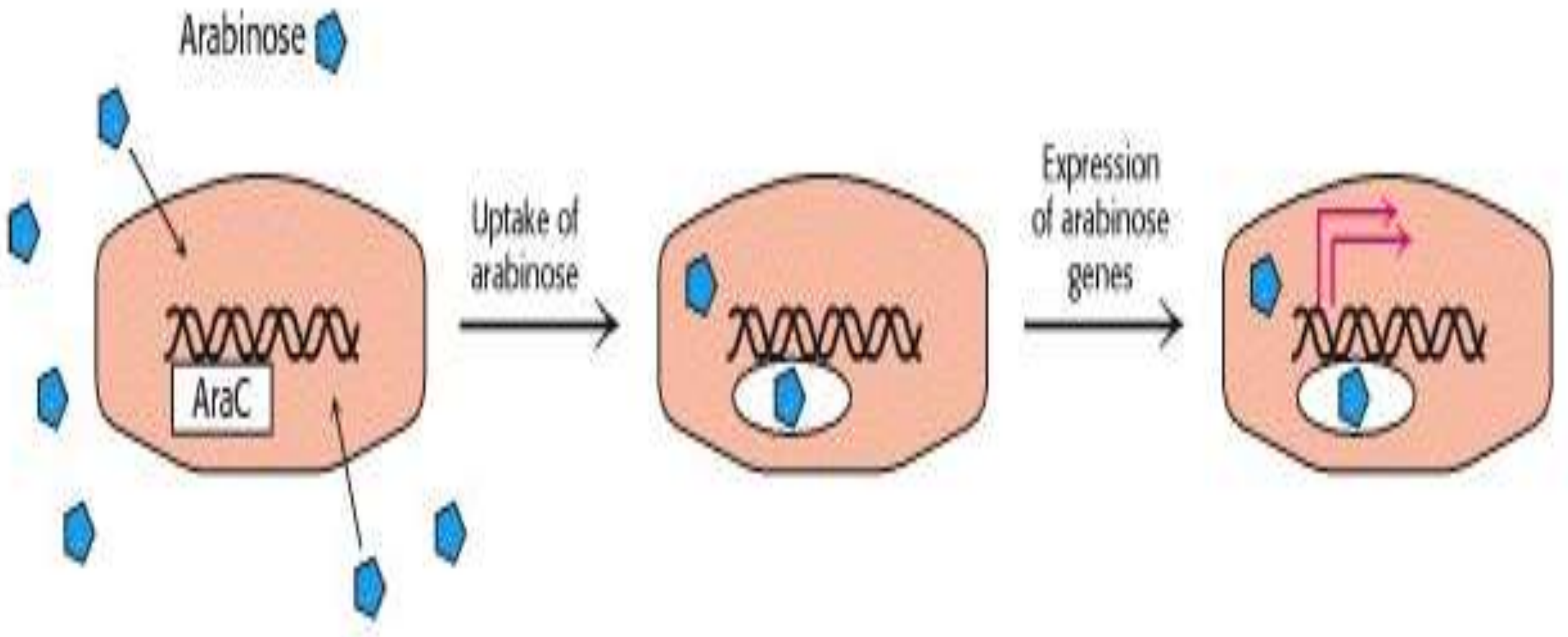
External environment

- The environments in which cells grow often change rapidly
- There are some mechanisms for adjusting their environmental change.
- The adjustments can take many forms,
- changes in the activities of **preexisting enzyme molecules**
- changes in the rates of synthesis of **new enzyme molecules**
- changes in **membrane-transport processes**.

Chemicals

- the detection of environmental signals will occur inside the cells.
- Chemicals could pass into cells
- **diffusion** through the cell membrane
- action of **transport proteins**.
- Chemicals will bind directly to proteins present inside the cell and modulate their activities.

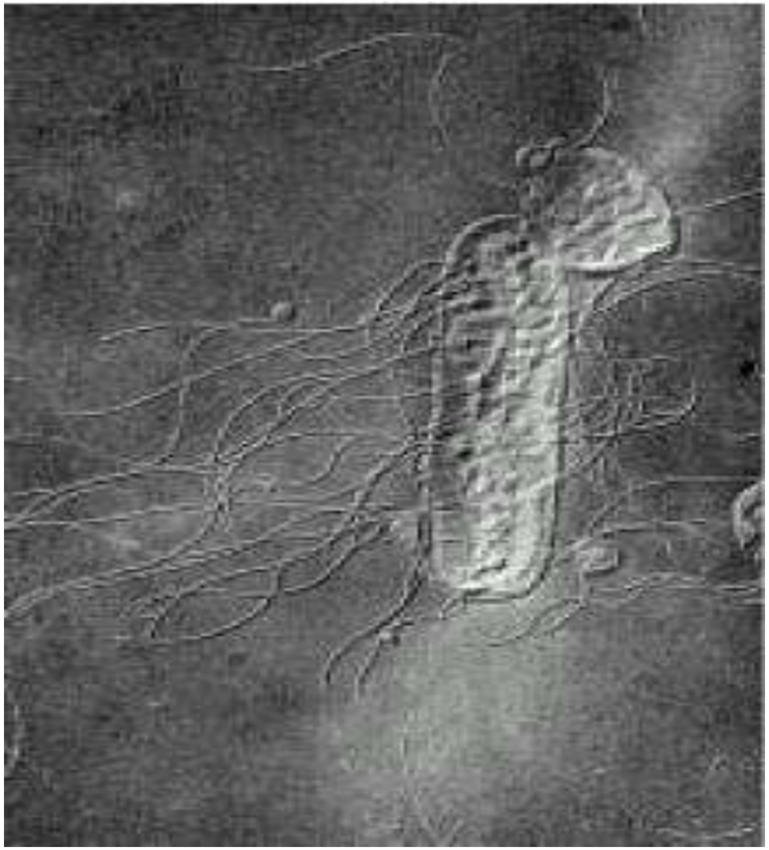
- An example is the use of the sugar arabinose by the bacterium *Escherichia coli*



Movement

- The development of the ability to move was another important stage of cells
- capable of adapting to a changing environment.
- Bacteria swim through the use of filamentous structures termed ***flagella***

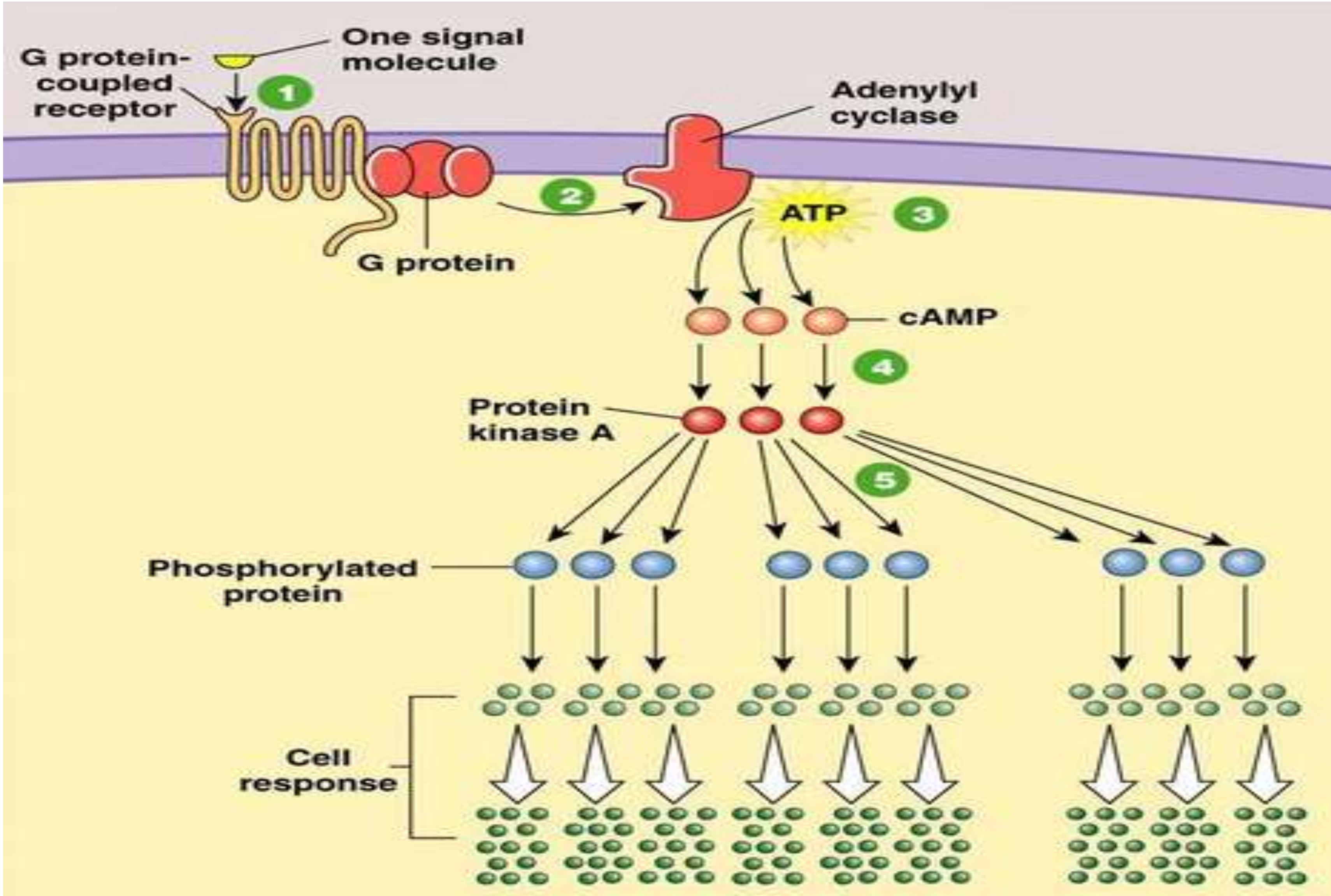
- Each bacterial cell has several flagella, which, under appropriate conditions, form rotating bundles that efficiently propel the cell through the water.
- At the base of each flagellum are assemblies of proteins that act as motors to drive its rotation.



Signals

- Mechanisms appeared for detecting signals at the cell surface.
- Cells could thus respond to signaling molecules even if those molecules did not pass into the cell.
- **Receptor proteins** , embedded in the membrane, could bind chemicals present in the cellular environment

- Binding , produces changes in the protein structure that could be detected at the inside surface of the cell membrane.
- By this means, chemicals outside the cell could influence events inside the cell.


One signal molecule
G protein-coupled receptor
1
Adenylyl cyclase
2
G protein
ATP
3
cAMP
4
Protein kinase A
5
Phosphorylated protein
Cell response

Epinephrine-stimulated cAMP synthesis