15BT101 Biology for Engineers

Chapter I

The Cellular Organization of a living organisms

Introduction

- Biology- broad field of science- study of life
- covers from cell biology to ecosystems

- Cell biology- study of working of cells

- Ecosystem- study of survival of living organisms
- Technological advancements have made this possible

- Examine - cell,cell organelles,genetic information (DNA),cell function, cell metabolism.
- DNA- Deoxyribonucleic acid
- Biology provides clues to lead a life without diseases with better quality.

Biology as one of the fields of science

Any physiochemical component capable of surviving with the external environment is called living organisms

They possess:

self regulatory mechanism/metabolism

reproduction

Evolution- Charles Darwin

ex: Monkeys---------- Humans

Kingdoms and classification

- Classification of organisms – taxonomy
- Prokaryotic – no nucleus and specialized organelles
- ex: bacteria
- Eukaryotic- nucleus and specialized organelles
- Ex: humans/mammalians

KINGDOM	DISTINGUISHING CHARACTERISTICS	EXAMPLES OF ORGANISMS
1. Monera	Single-celled, *prokaryotic* organisms: cells lack nuclei and certain other specialized parts	Bacteria
2. Protista	Single-celled, *eukaryotic* organisms: cells contain nuclei and many specialized internal structures	Protozoa
3. Plantae	Multicellular, eukaryotic organisms that manufacture their food	Ferns, trees
4. Fungi	Eukaryotic, plantlike organisms, either single-celled or multicellular, that obtain their food by absorbing it from the environment	Yeasts, molds
5. Animalia	Eukaryotic, multicellular organisms that must capture their food and digest it internally	Fishes, birds, cows

Methods of Science

- **The scientific method for research developed by Francis Bacon (1561–1626). The sequences are:**

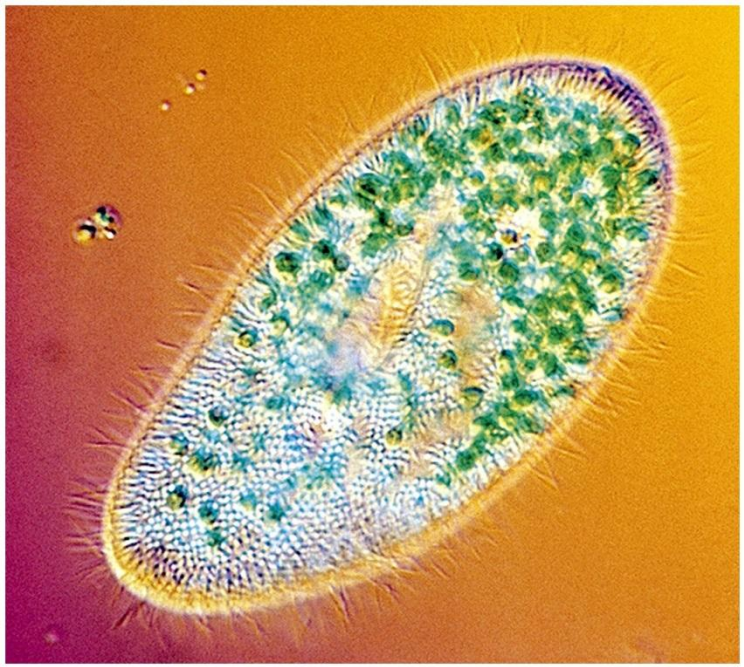
1. **Identifying the problem**
2. **Collecting data through experiments**
3. **Correlations, meaningful connections, and regularities**
4. **Formulating a hypothesis (a generalization)**
5. **Testing the hypothesis rigorously by gathering new data**
6. **Confirming, modifying, or rejecting the hypothesis in light of the new findings**

Main Characteristics of organisms

- Made of **CELLS- basic unit of life- Robert Hooke(1665)**
- Require **ENERGY** (food)
- **REPRODUCE** (species)
- Maintain **HOMEOSTASIS**
- **ORGANIZED**
- **RESPOND** to environment
- **GROW** materials with surroundings (water, wastes, gases) and **DEVELOP**
- **EXCHANGE**

Cells

- Smallest living unit
- Most are microscopic

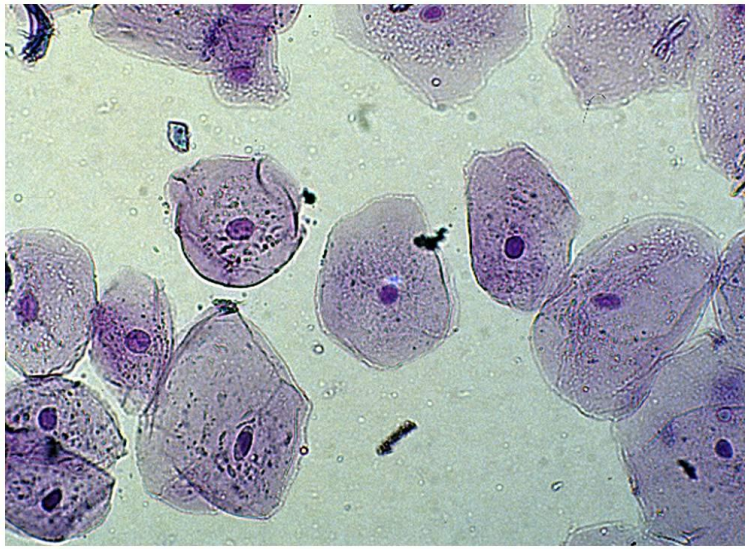


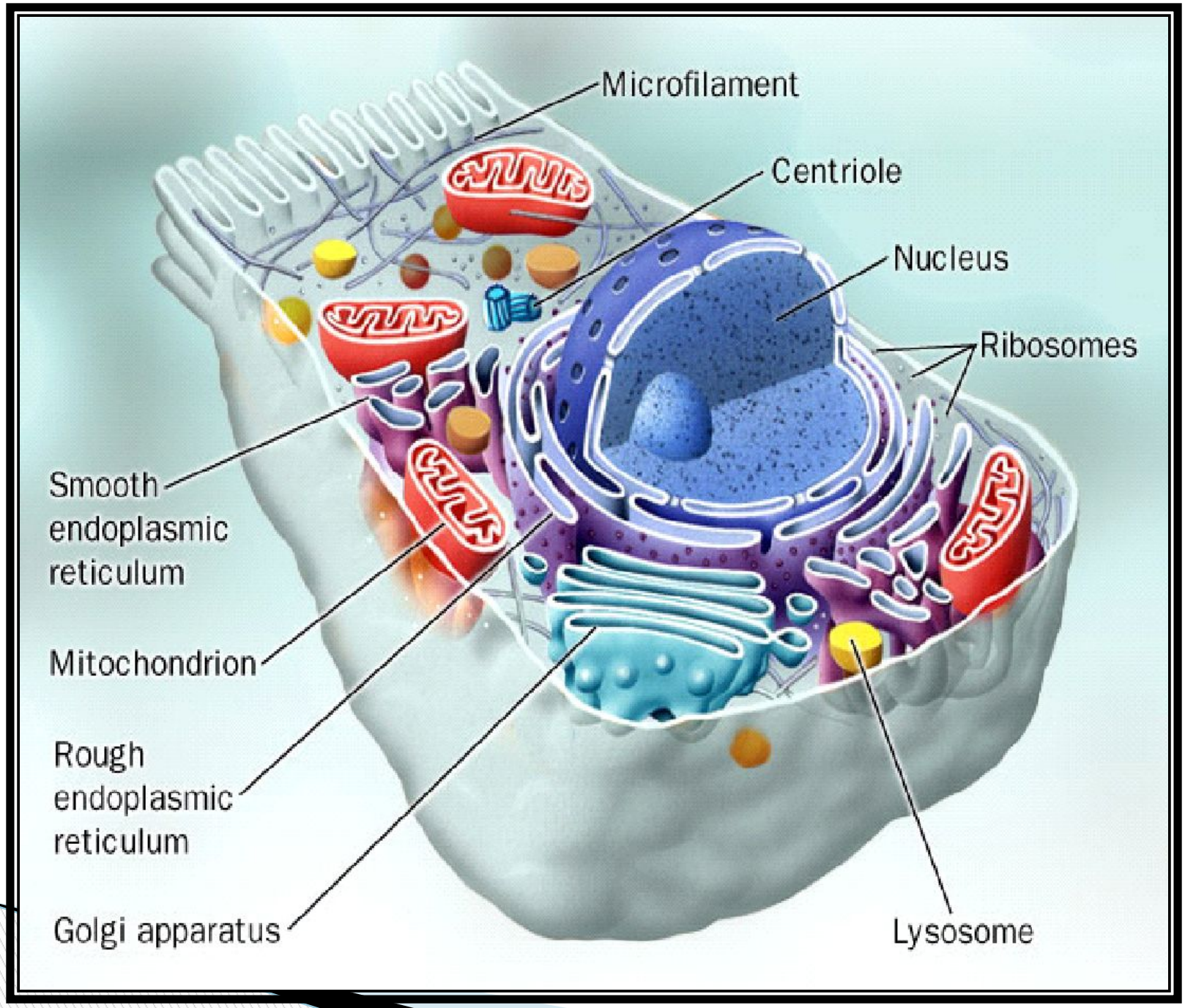
Discovery of Cells

- Robert Hooke (mid-1600s)
  - Observed sliver of cork
  - Saw “row of empty boxes”
  - Coined the term cell

Characteristics of All Cells

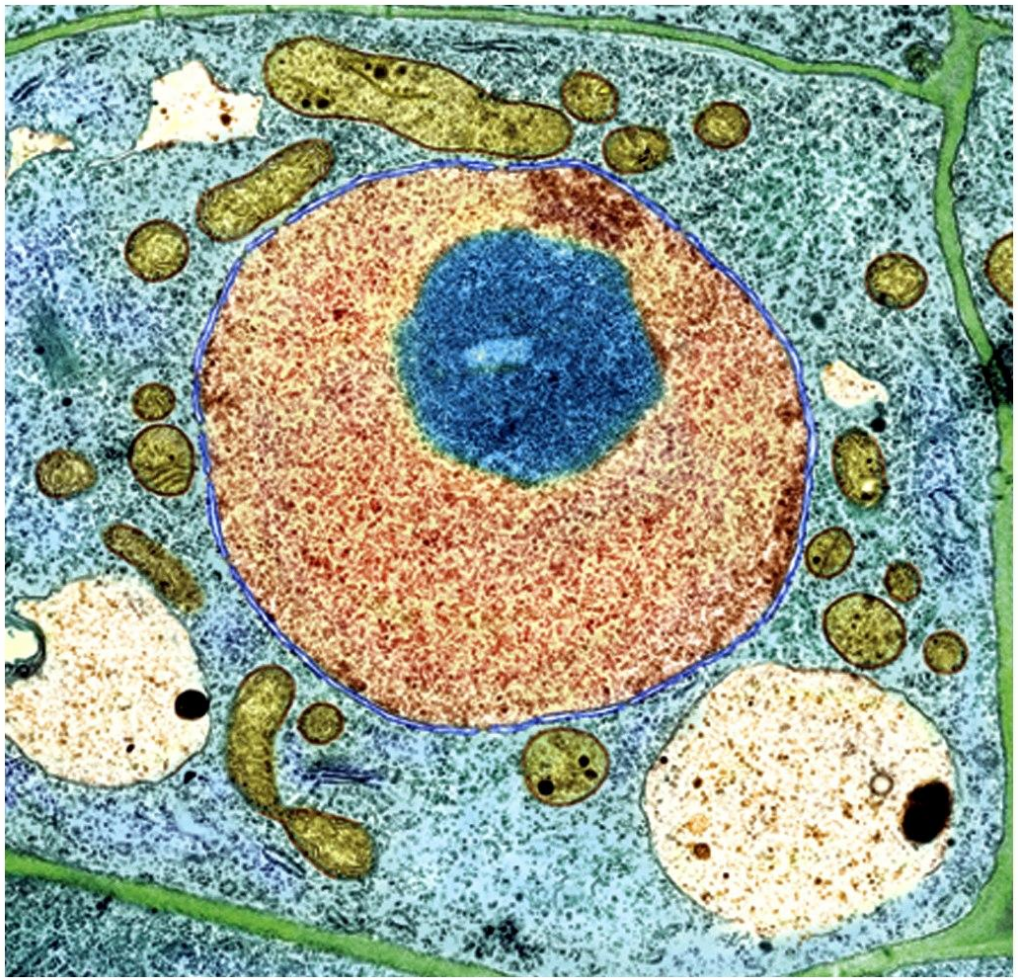
- A surrounding membrane
- Protoplasm – cell contents in thick fluid
- Organelles – structures for cell function
- Control center with DNA




Microfilament
Centriole
Nucleus
Ribosomes
Smooth endoplasmic reticulum
Mitochondrion
Rough endoplasmic reticulum
Golgi apparatus
Lysosome

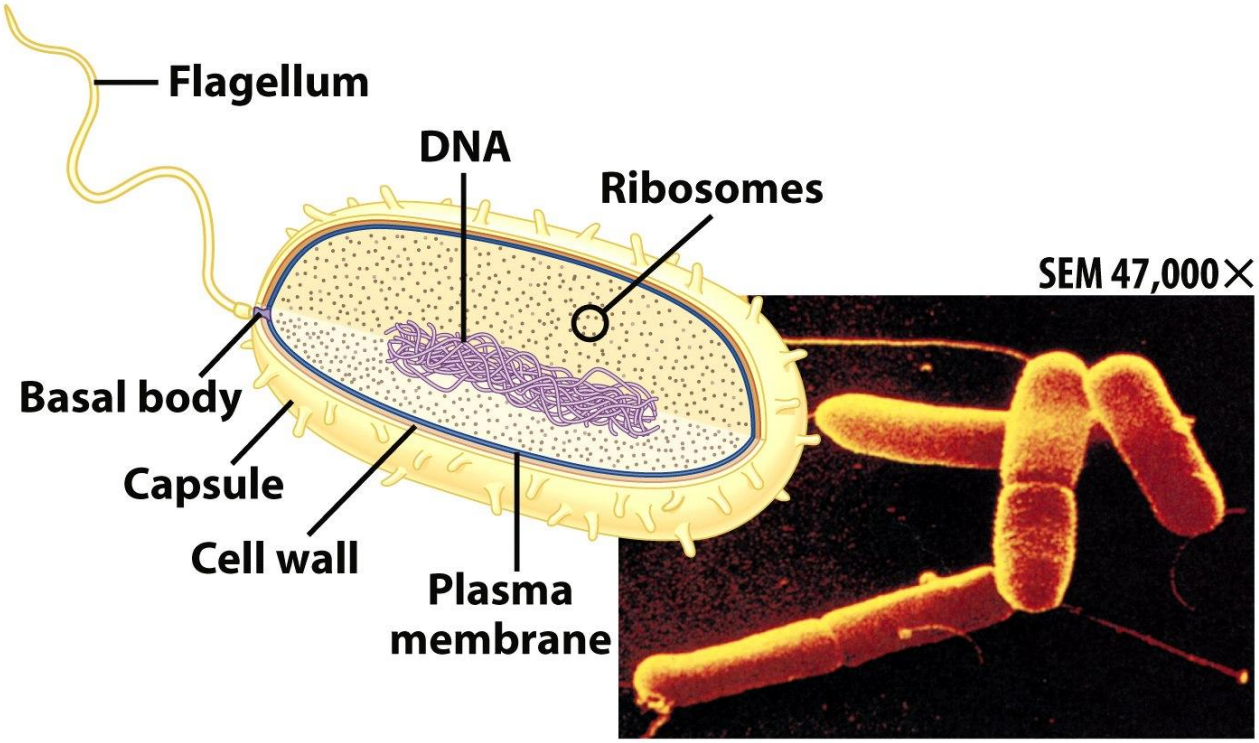
Cell Types

- Prokaryotic
- Eukaryotic



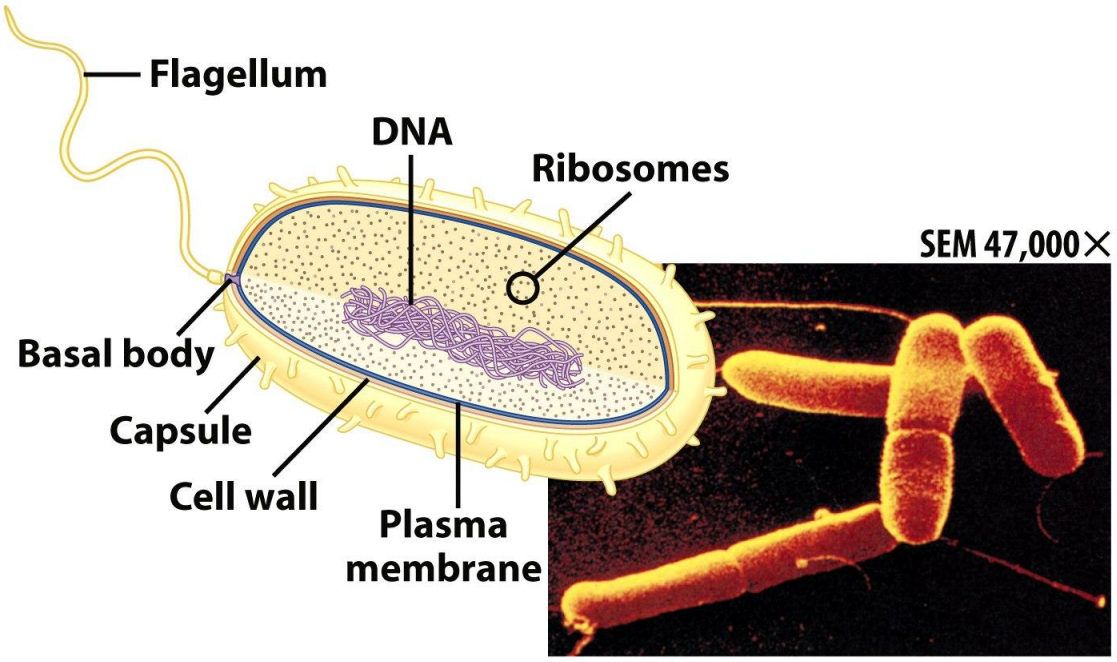
Prokaryotic Cells

- First cell type on earth
- Cell type of Bacteria and Archaea



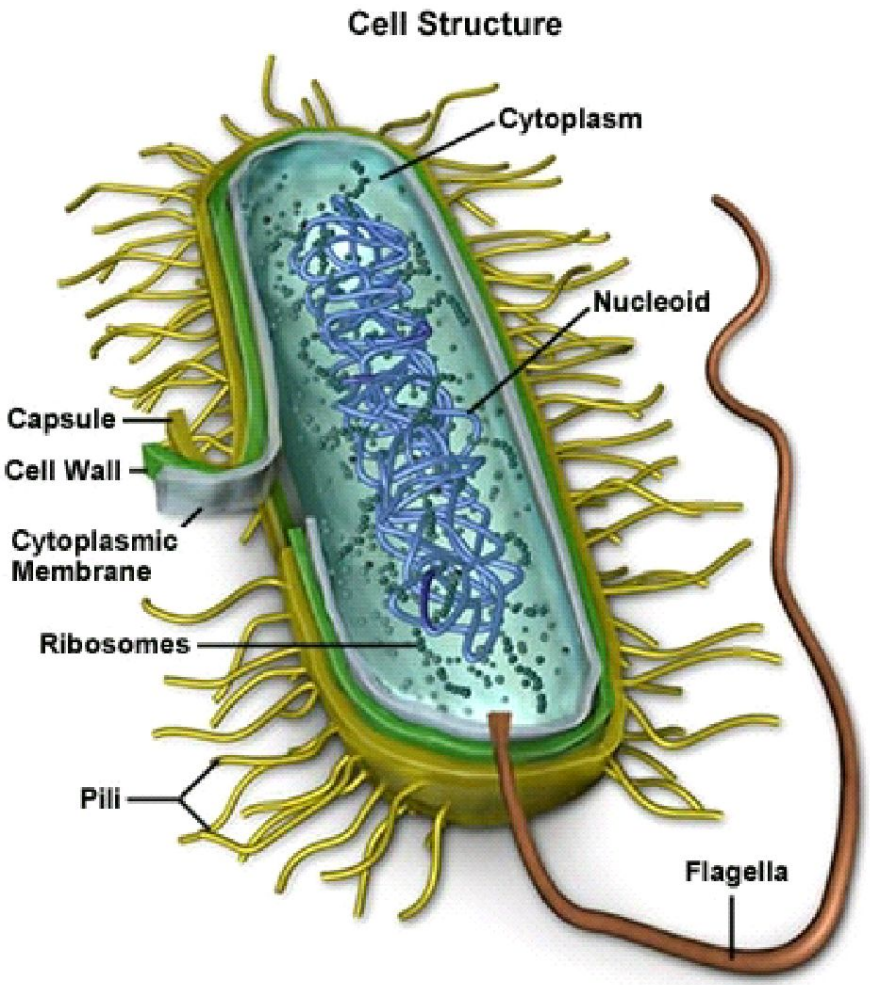
Prokaryotic Cells

- No membrane bound nucleus
- Nucleoid = region of DNA concentration
- Organelles not bound by membranes



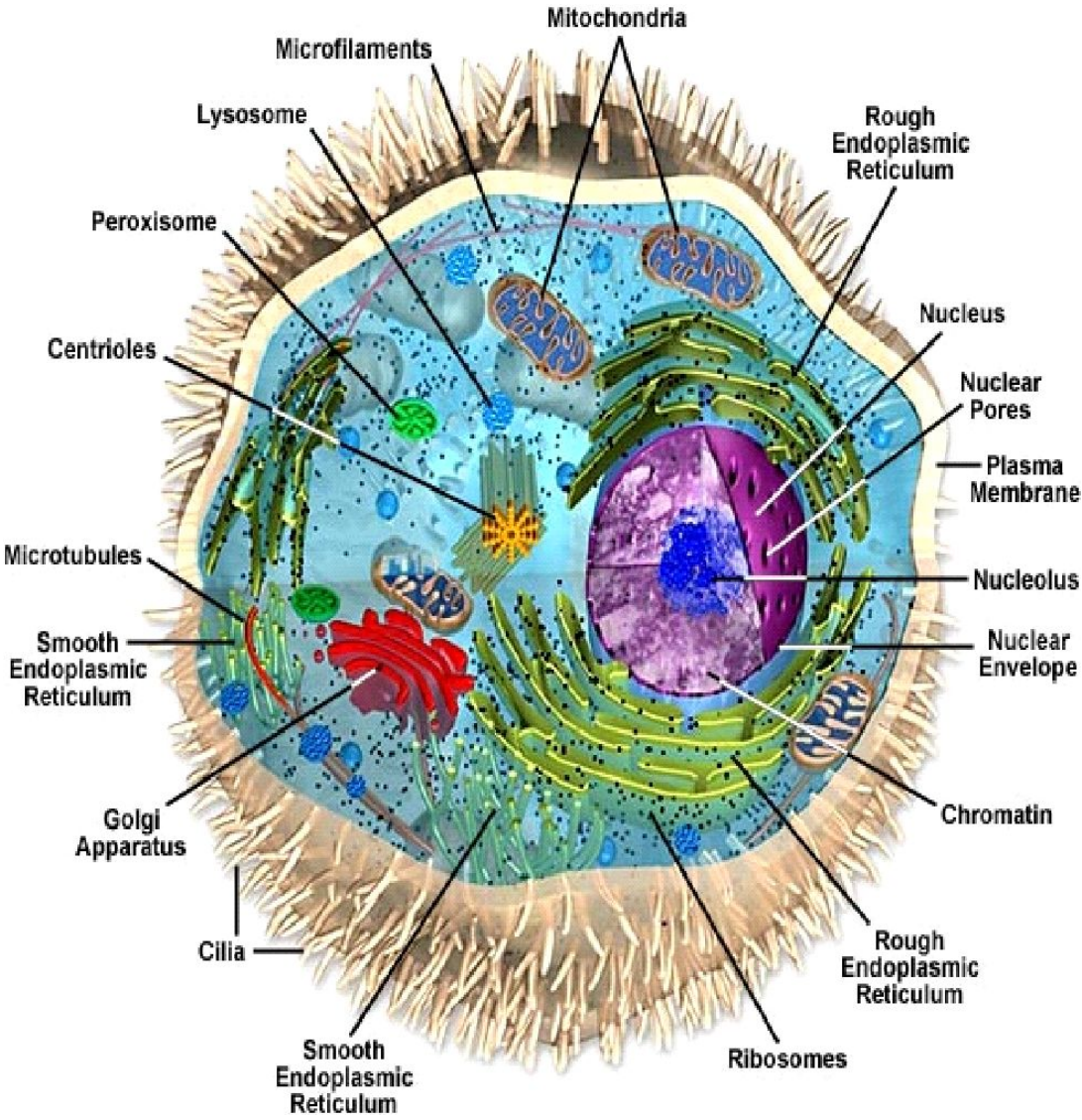
Prokaryotes

- **Nucleoid region** (center) contains the DNA
- **Simple**
- **Surrounded by cell membrane & cell wall (peptidoglycan)**
- **Contain ribosomes** (no membrane) in their cytoplasm to **make proteins**



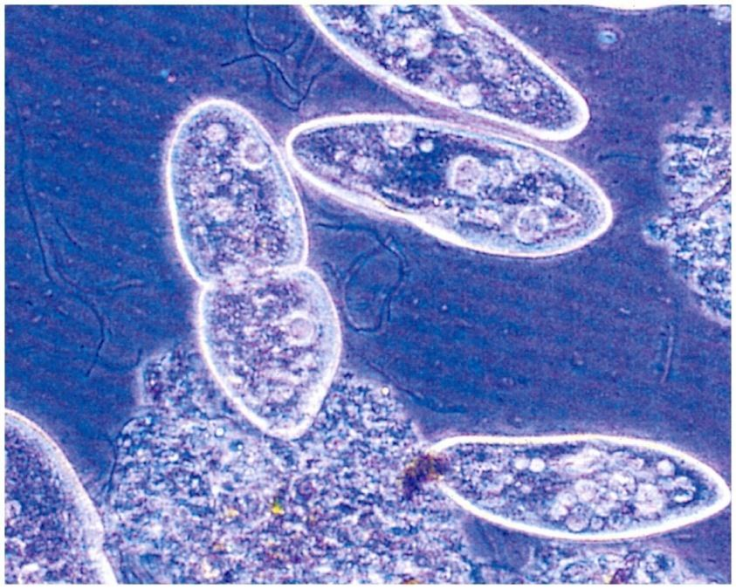
Eukaryotes

- **Cells that HAVE a nucleus and membrane-boun d organelles**
- **Includes protists, fungi, plants, and animals**
- **More complex type of cells**



Eukaryotic Cells

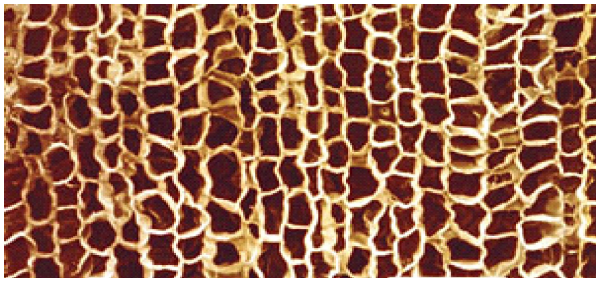
- Nucleus bound by membrane
- Include fungi, protists, plant, and animal cells
- Possess many organelles



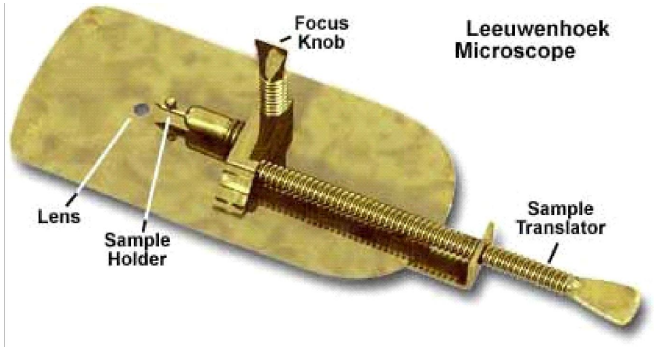
Protozoan

Cells and Cell Theory

- **In 1665, Robert Hooke used a microscope to examine a thin slice of cork (dead plant cell walls).**



- **In 1673, Antony Van Leeuwenhoek (a Dutch microscope maker), was first to view organism (living things)**



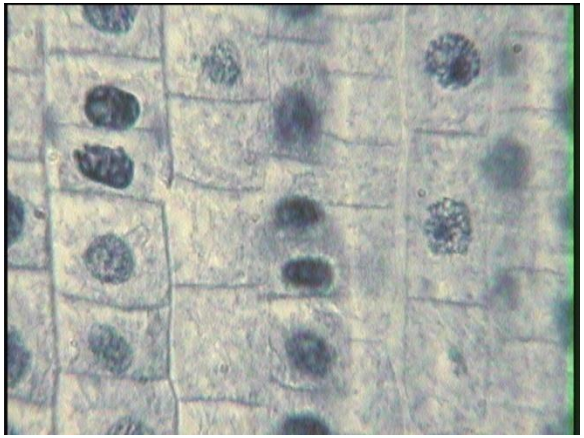
Cell Theory

- **In 1838, a German botanist named Matthias Schleiden concluded that all plants were made of cells**

- **In 1839, a German zoologist named Theodore Schwann concluded that all animals were made of cells**

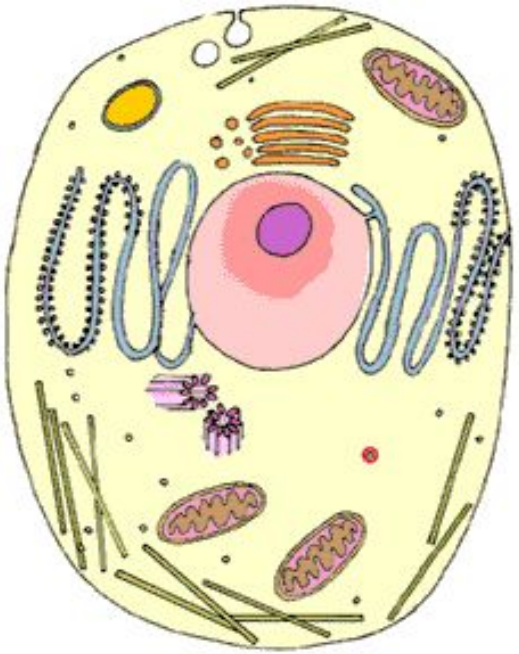
Beginning of the Cell Theory

- **In 1855, a German medical doctor named Rudolph Virchow observed, under the microscope, cells dividing**
- **He reasoned that all cells come from other pre-existing cells by cell division**



Cell Theory

- **All living things are made of cells**
- **Cells are the basic unit of structure and function in an organism (basic unit of life)**
- **Cells come from the reproduction of existing cells (cell division)**
- **Container experiments**



Multicellular organisms possess developing properties

Cells

Tissues

Organs

Every cell contains all genes-genes activation vary from cell to cell

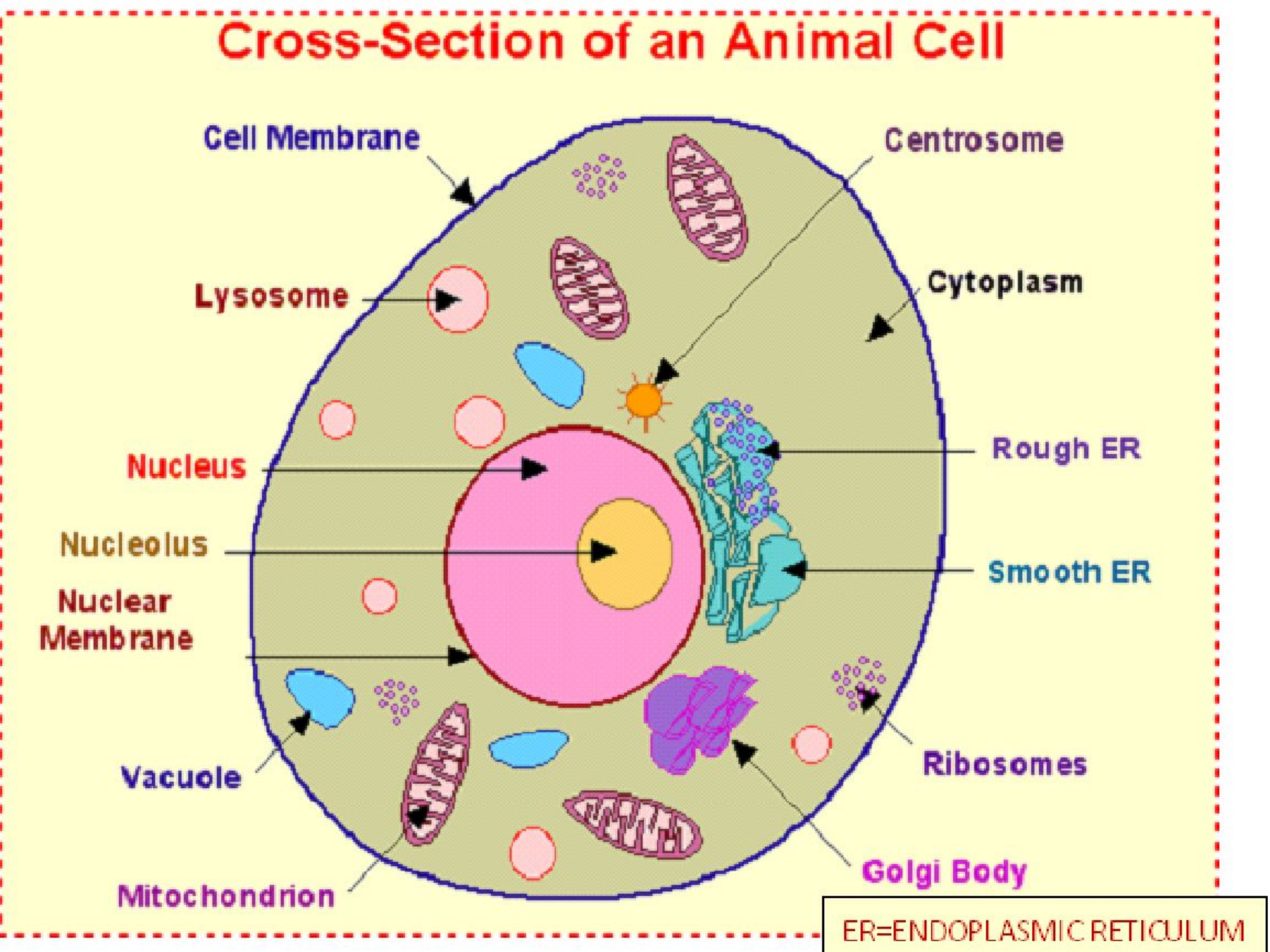
Ex: Keratin genes in hairs and nails, melanin in skin

Cell Structure and Function

Organelles- subcellular structures

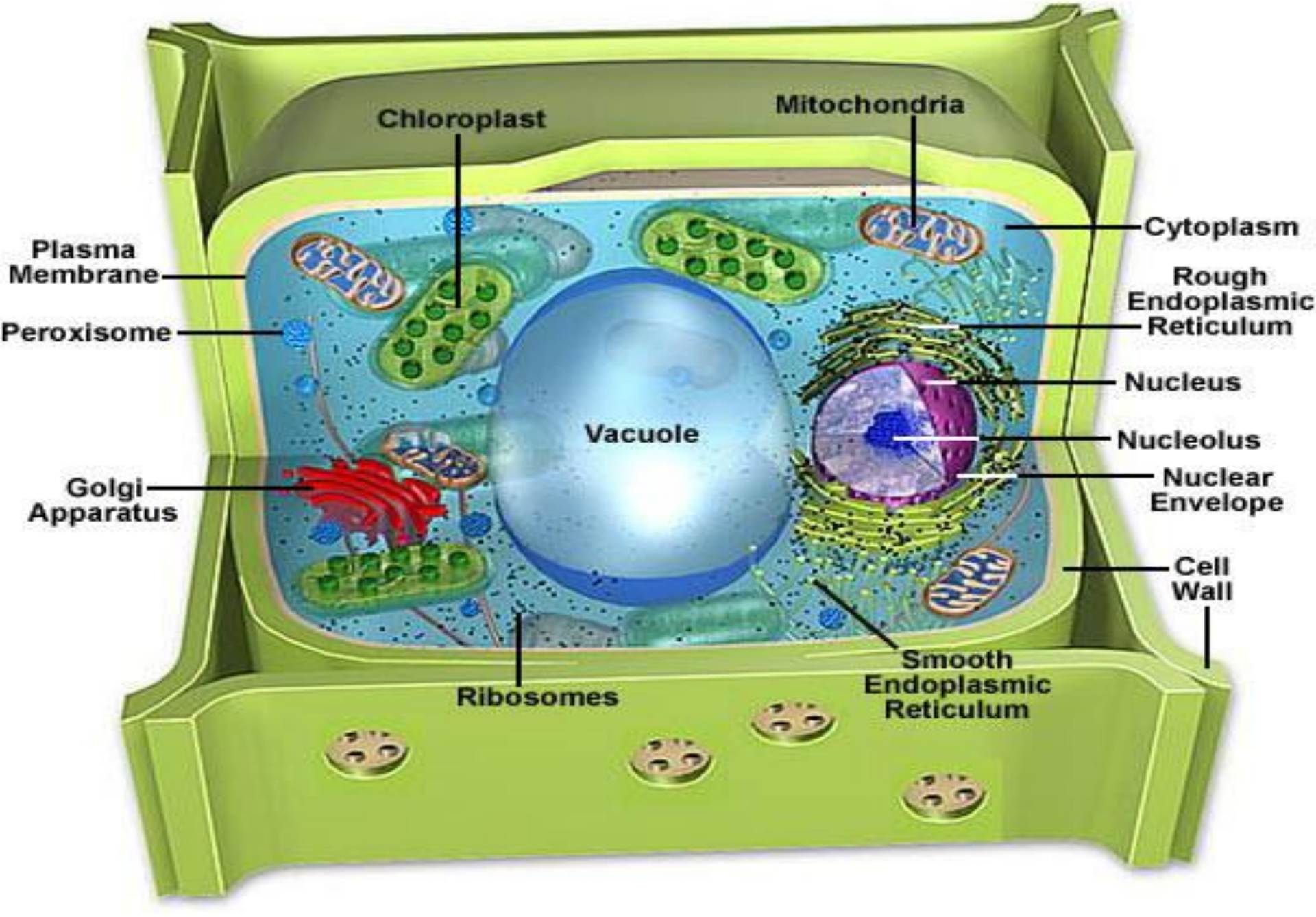
- **Staining of cells and EM(electron microscope)**
- **Very small (Microscopic)**
- **Perform various functions for a cell**
- **Found in the cytoplasm**
- **May or may not be membrane-bound**
- **(ribosomes, flagella,cilia,microtubules,microfilaments)**

Cross-Section of an Animal Cell



ER=ENDOPLASMIC RETICULUM

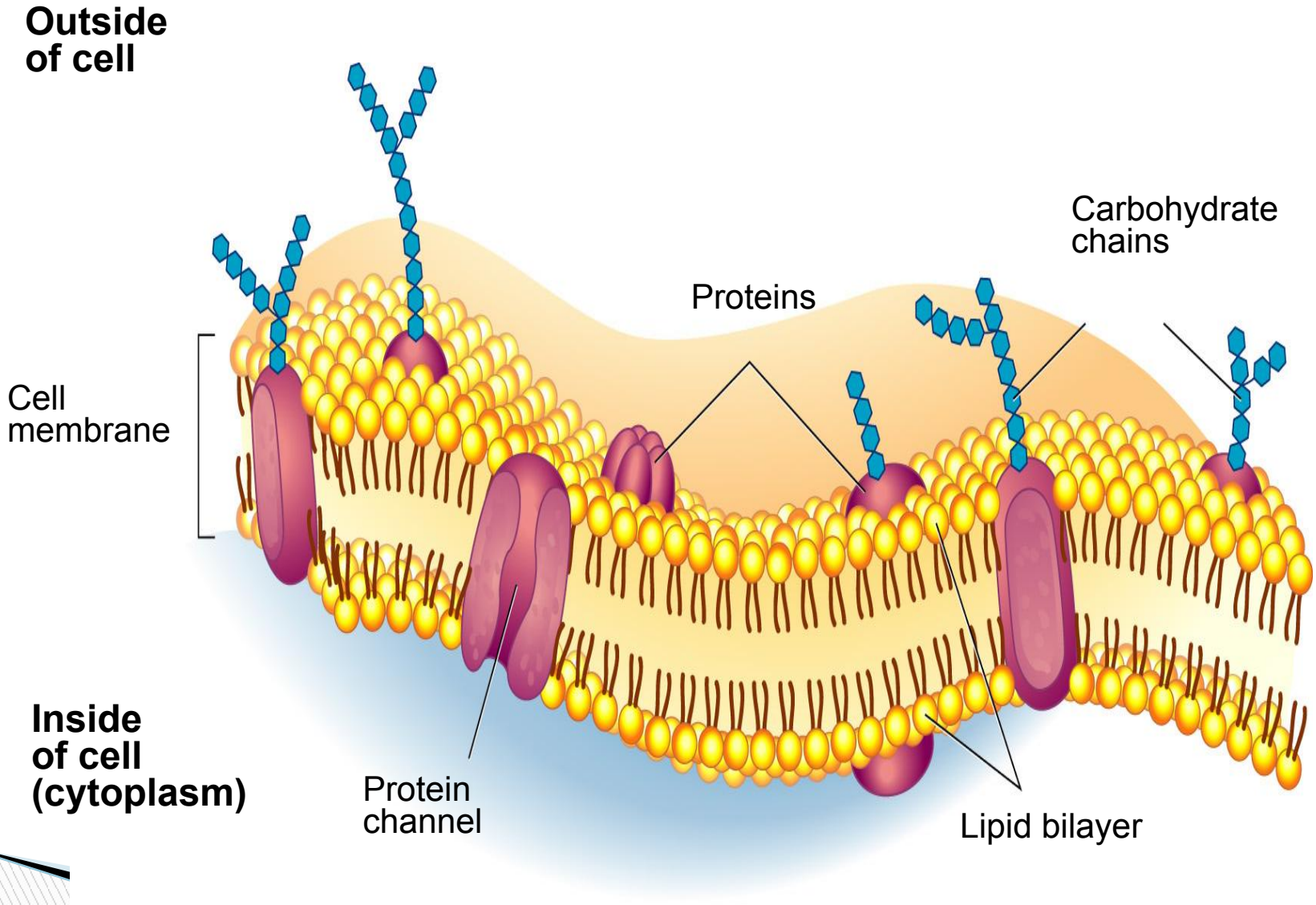
Plant cell


Chloroplast
Mitochondria
Plasma Membrane
Cytoplasm
Rough Endoplasmic Reticulum
Peroxisome
Nucleus
Vacuole
Nucleolus
Golgi Apparatus
Nuclear Envelope
Cell Wall
Ribosomes
Smooth Endoplasmic Reticulum

Cell/plasma membrane

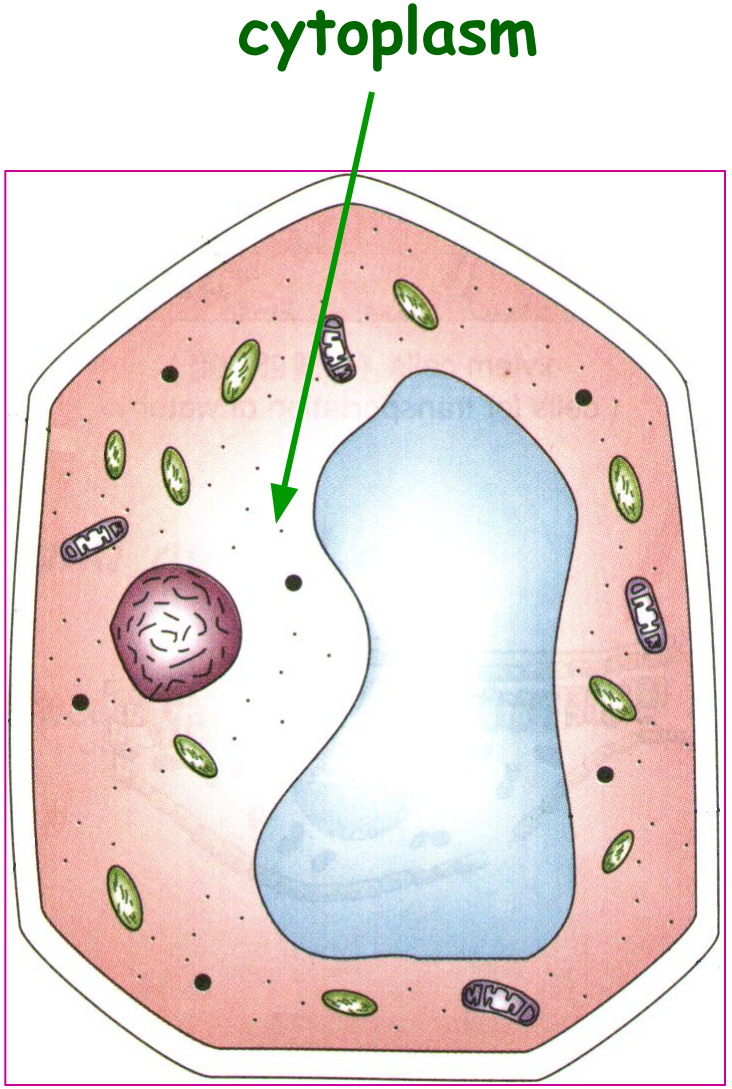
- Outermost layer of the cell
- Structure and shape
- Regulate passage of materials
- Phospholipid bilayer
- Singer and Nicholsan- fluid mosaic model-polar and non polar regions

Cell or Plasma Membrane



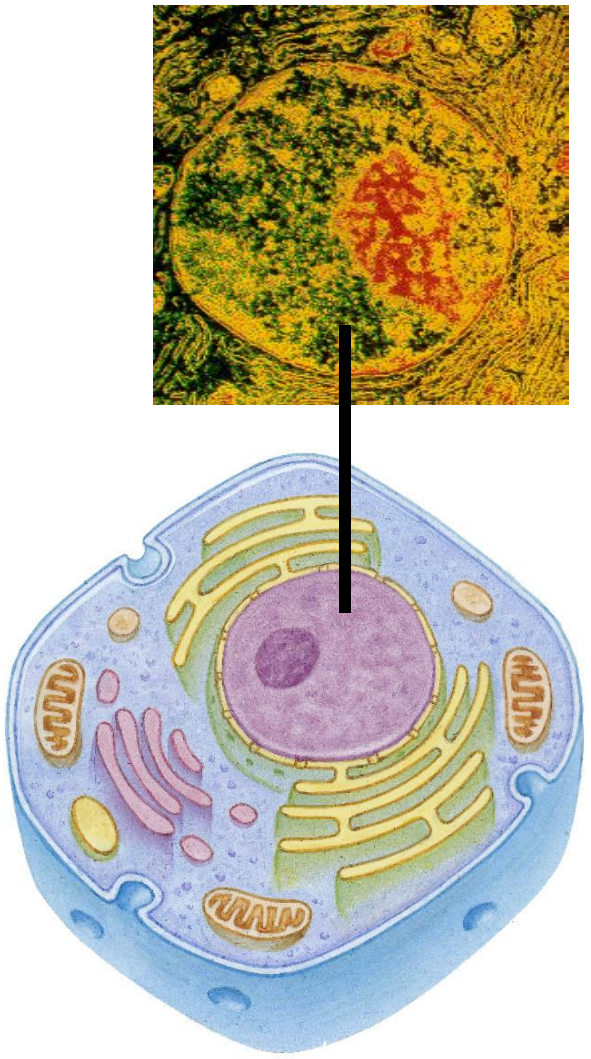
Cytoplasm

- **Jelly-like** substance enclosed by **cell membrane**
- **Provides a medium for chemical reactions to take place**
- Contains **organelles** to carry out specific jobs
- Found in **ALL** cells



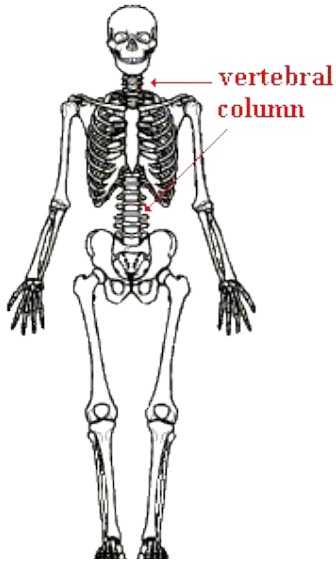
The Control Organelle - Nucleus

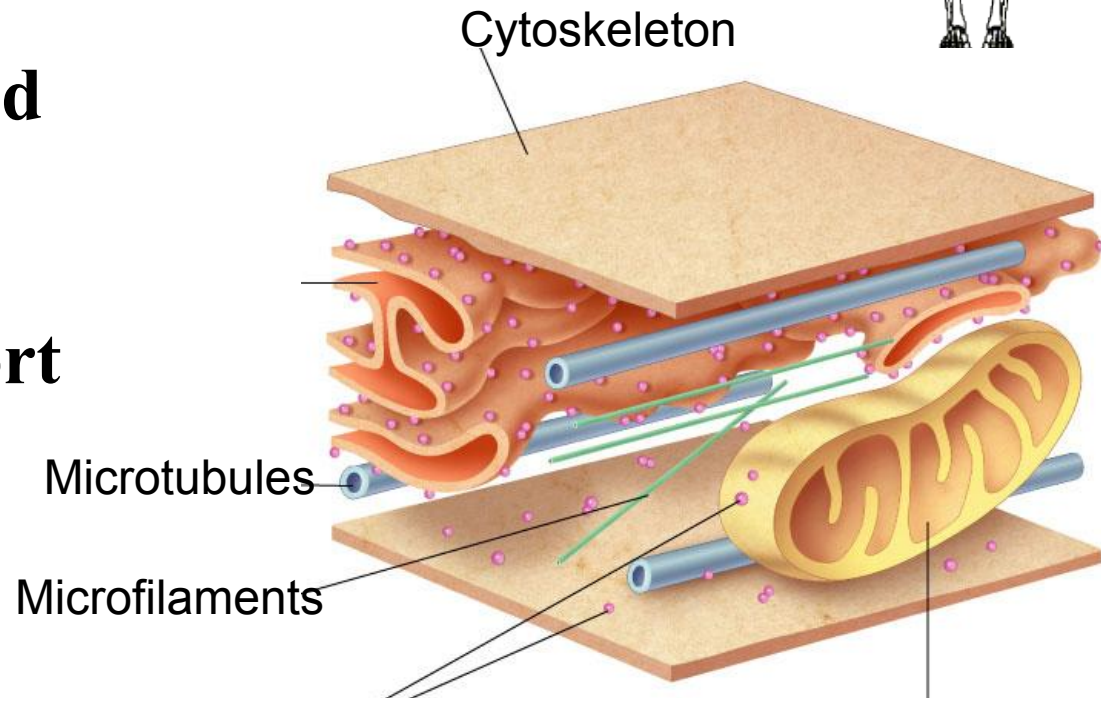
- Controls the normal activities of the cell
- Contains the DNA in chromosomes
- Bounded by a nuclear envelope (membrane) with pores
- Usually the largest organelle
- Each cell has fixed number of chromosomes that carry genes
- Genes control cell characteristic



Cytoskeleton

- **Cellular scaffolding /skeleton**
- **Made of protein**
- **Both prokaryotic and eukaryotic cells**
- **Intracelluar transport and cell division**



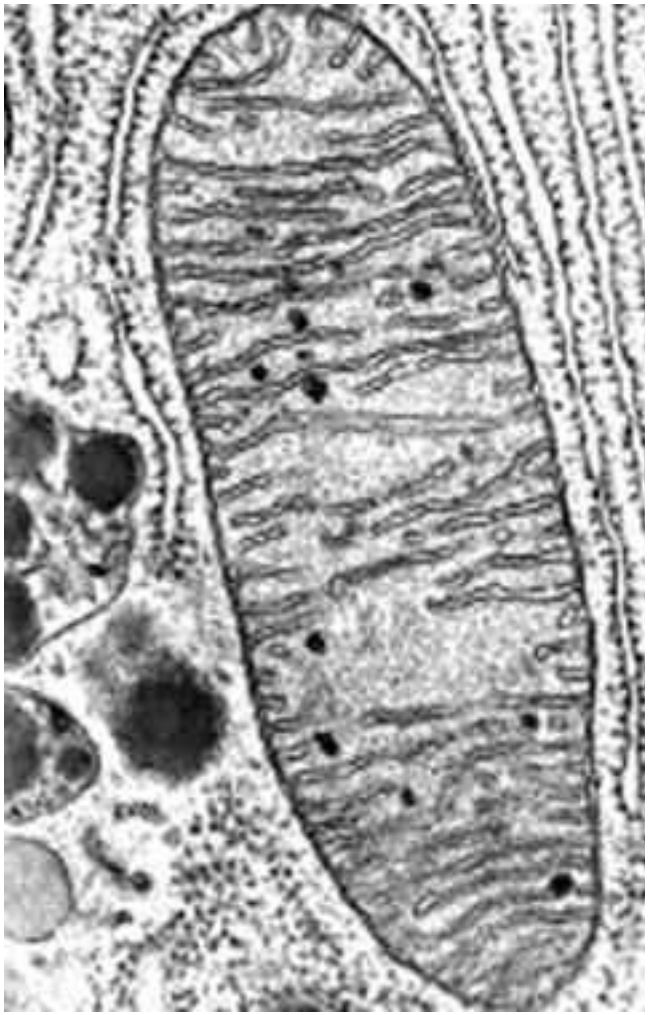


Centrioles

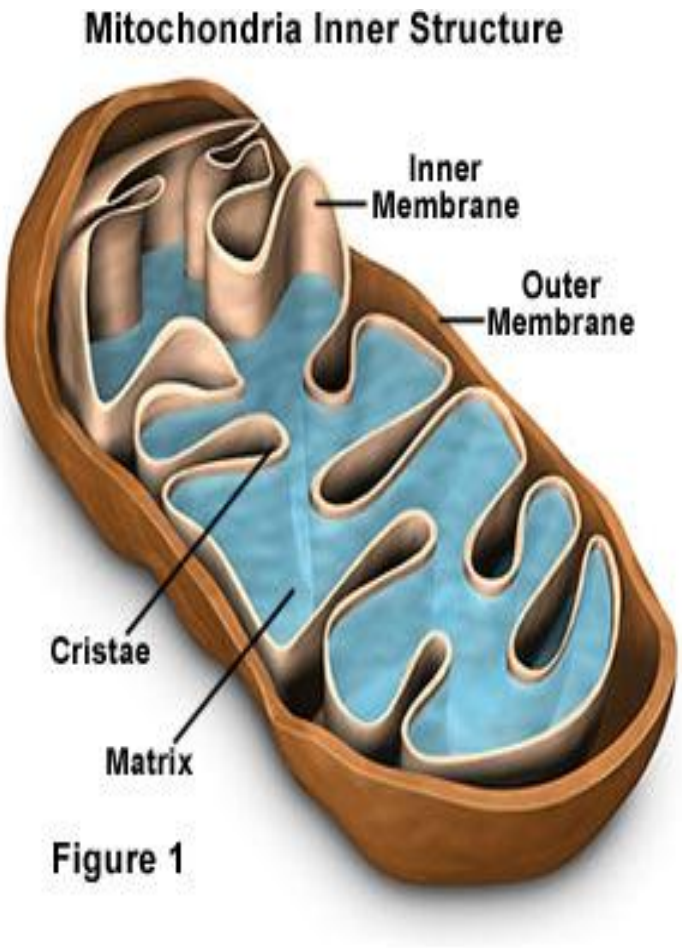
- Found only in **animal** cells
- **Paired** structures near nucleus
- Made of bundle of **microtubules**
- Appear during **cell division** forming **mitotic spindle**
- Help to **pull chromosome pairs apart** to opposite ends of the cell

Mitochondrion (plural = mitochondria)

- **"Powerhouse" of the cell**
- **Generate cellular energy (ATP)**
- **More active cells like muscle cells have MORE mitochondria**
- **Both plants & animal cells have mitochondria**
- **Site of CELLULAR RESPIRATION (burning glucose)**



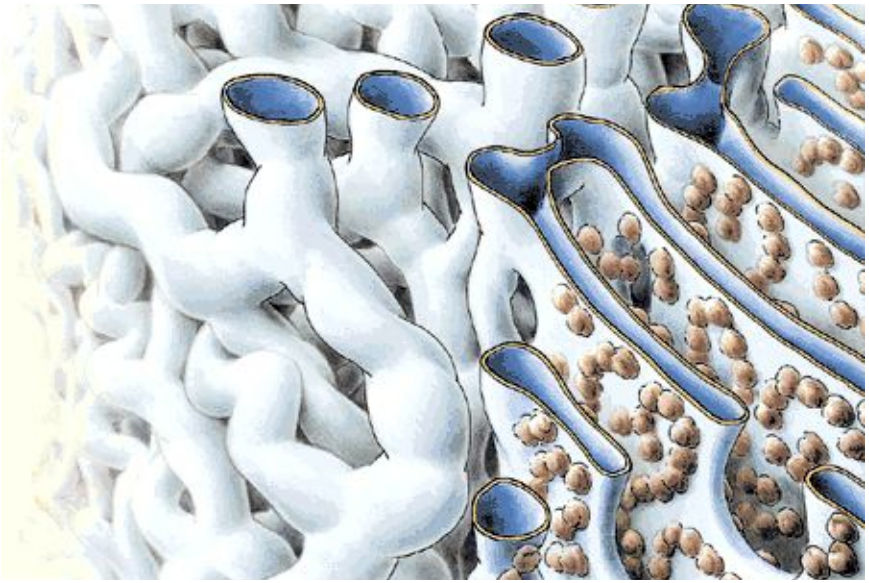
Mitochondria



- **Surrounded by a DOUBLE membrane**
- **Has its own DNA**
  - **Mitochondria come from cytoplasm in the egg cell during fertilization**
  - **Therefore you inherit your mitochondria from your mother!**
- **Folded inner membrane called CRISTAE (increases surface area for more chemical reactions)**
- **Interior called MATRIX**

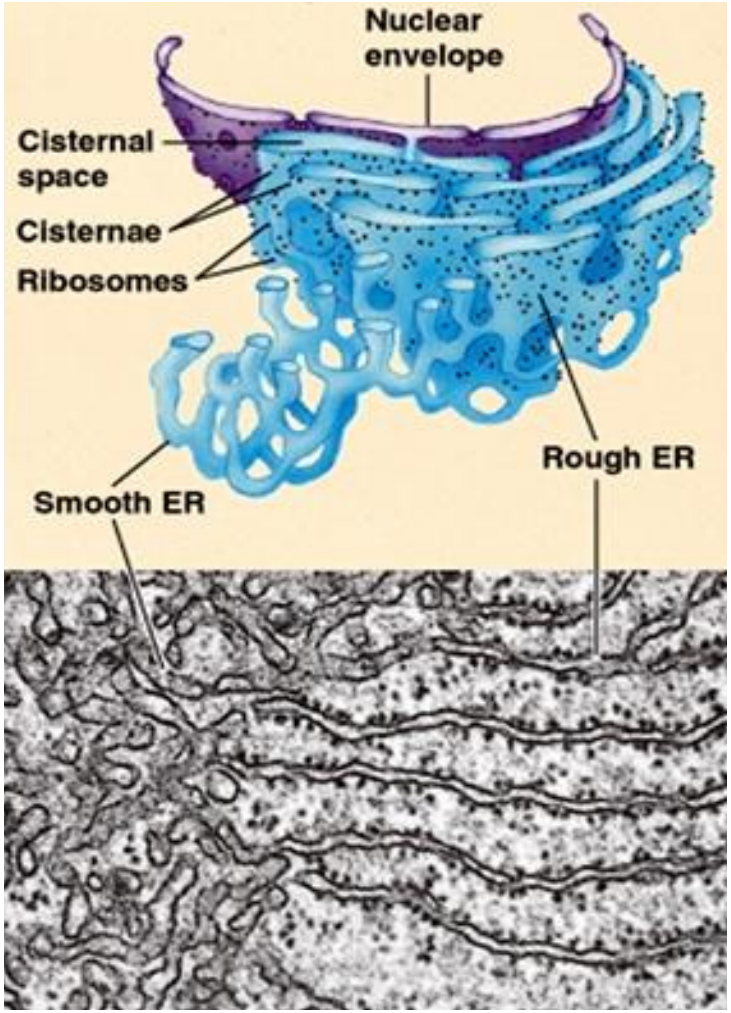
Endoplasmic Reticulum - ER

- Network of **hollow membrane tubules**
- **Sometimes as flattened disks or sacs**
- Connects to **nuclear envelope & cell membrane**
- Functions in **Synthesis** of cell products & **Transport**



Two kinds of ER ---ROUGH & SMOOTH

Rough Endoplasmic Reticulum (Rough ER)



- Has **ribosomes** on its surface
- Produces and process specific proteins
- 2 types of proteins
- Embeddeded in the membrane
- Passes through the membrane

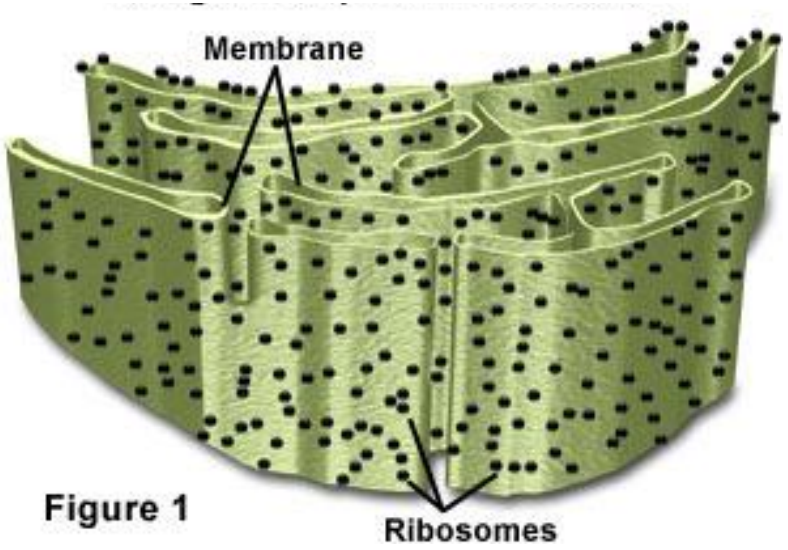
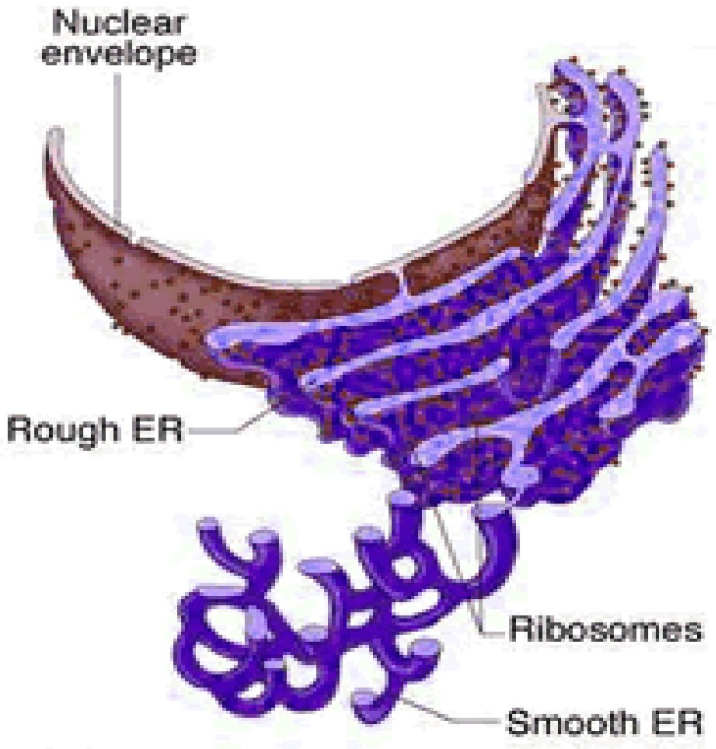


Figure 1

Smooth Endoplasmic Reticulum

- ***Smooth ER*** **lacks ribosomes on its surface**
- **Is attached to the ends of rough ER**
- **Makes cell products that are USED INSIDE the cell**
- **Makes membrane lipids (steroids)**
- **Regulates calcium (muscle cells)**
- **Destroys toxic substances (Liver)**



Includes nuclear membrane connected to ER connected to cell membrane (transport)

Ribosomes- protein factories

Makes protein from amino acids

mRNA ⟹ Protein

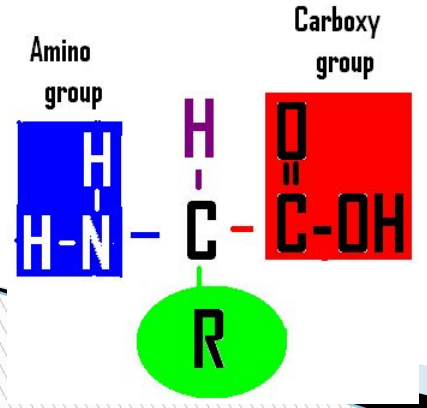
DNA ⟹ mRNA ⟹ Protein(central dogma of biology)

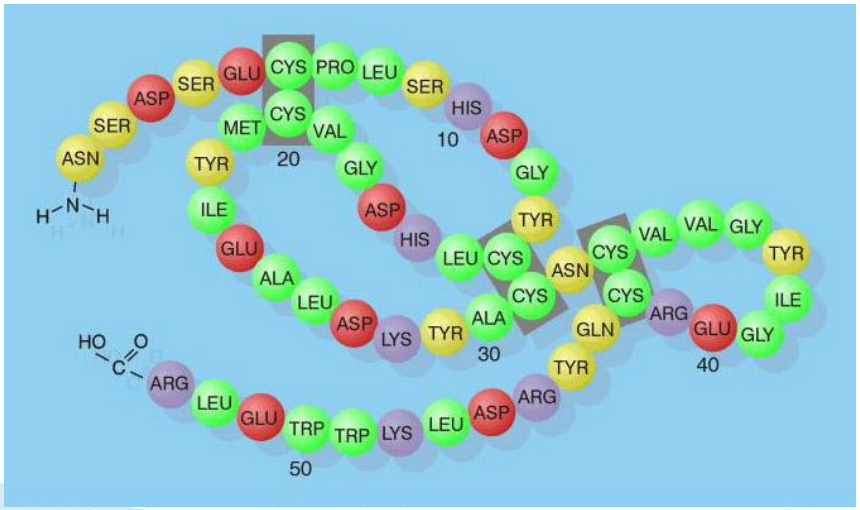
a.a+tRNA ⟹ ribosomes+mRNA ⟹ Proteins

Divided into two subunit-large and small

Large binds with tRNA and amino acids

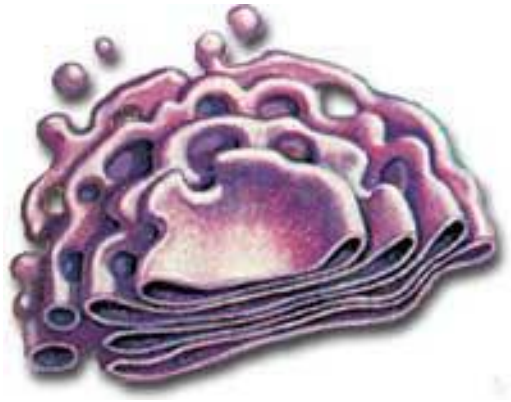
Small binds with mRNA





Golgi Bodies

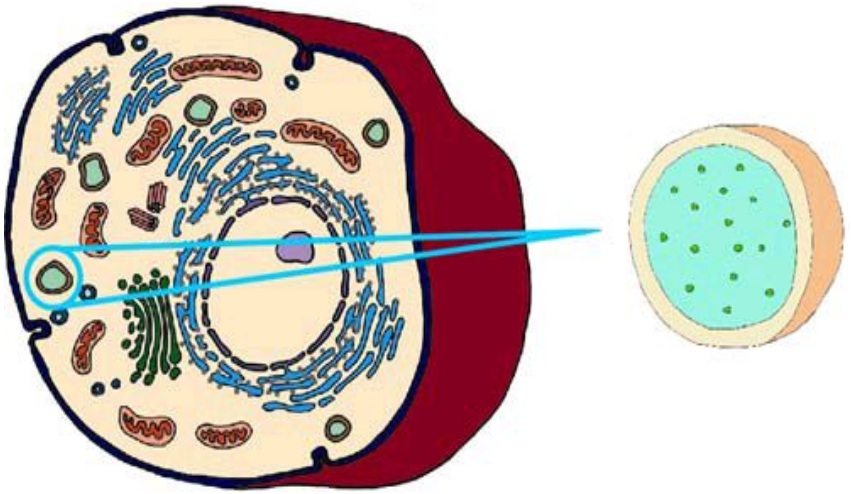
Look like a stack of pancakes



Modify, sort, & package
molecules from ER
for storage OR
transport out of cell

Lysosomes

- Contain **digestive enzymes**
- Break down **food, bacteria,** and **worn out cell parts** for cells
- Programmed for **cell death (AUTOLYSIS)**
- Lyse (break open) & **release enzymes** to break down & recycle cell parts)

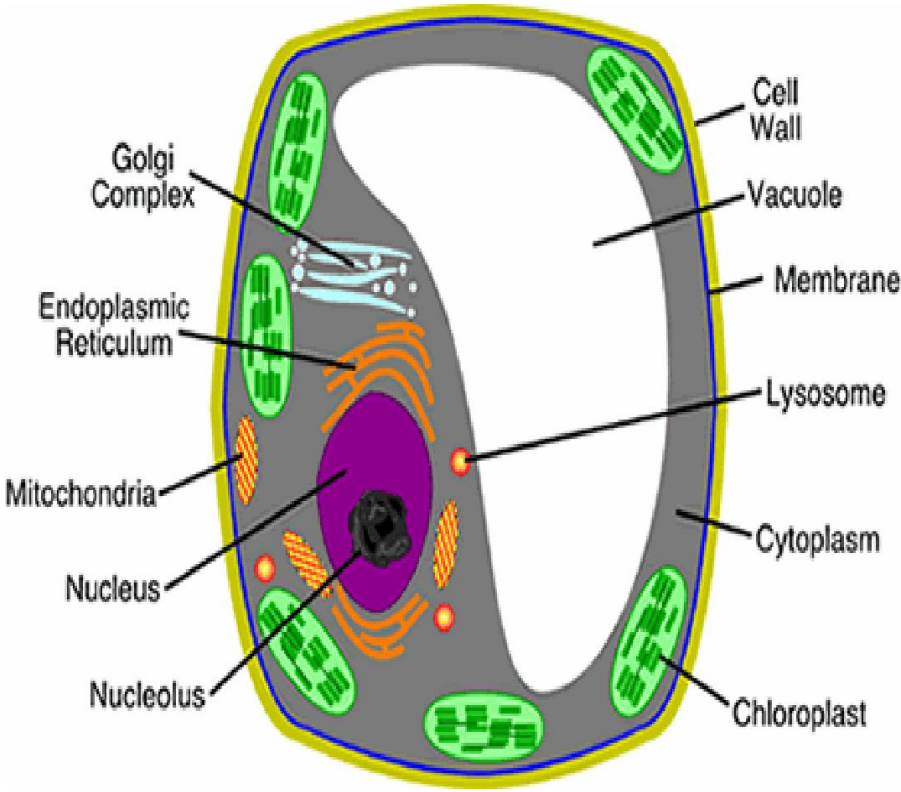


Lysosome Digestion

- **Cells take in food by phagocytosis**
- **Lysosomes digest the food & get rid of wastes**

Vacuoles

- **Fluid filled** sacks for **storage**
- **Small or absent** in ***animal*** cells
- ***Plant*** cells have a **large Central Vacuole**
- **No vacuoles** in ***bacterial*** cells
- In plants, they store **Cell Sap**
- Includes storage of **sugars, proteins, minerals, lipids, wastes, salts, water, and enzymes**



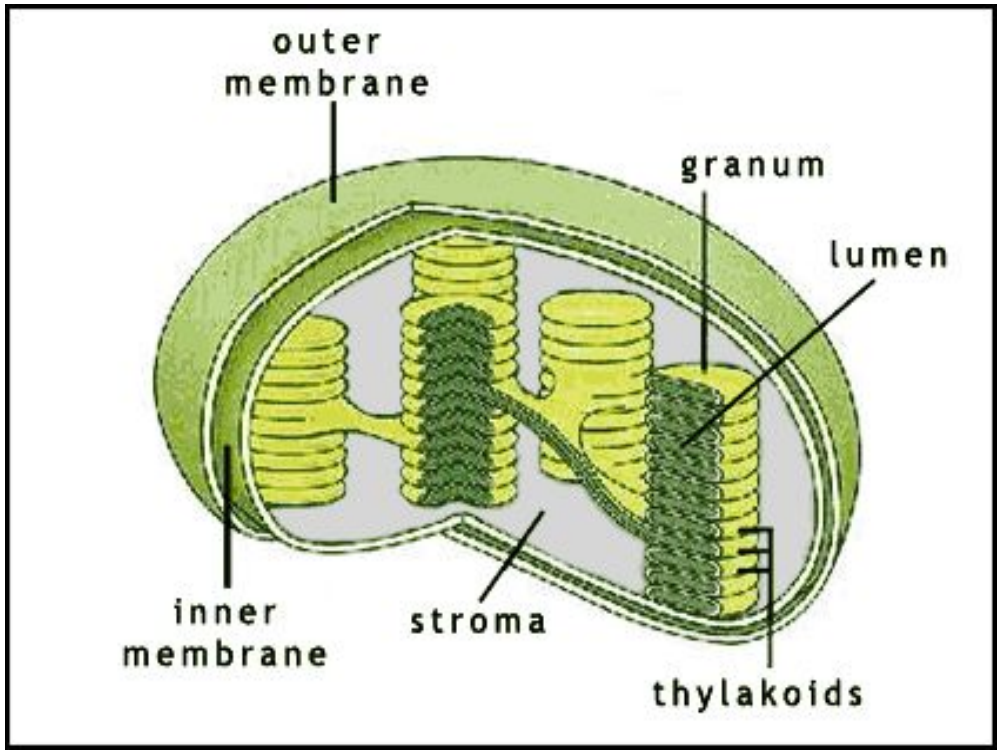
Chloroplasts

- Found only in producers (organisms containing chlorophyll)
- Use energy from sunlight to make own food (glucose)
- Energy from sun stored in the Chemical Bonds of Sugars

- Surrounded by DOUBLE membrane
- Outer membrane smooth
- Inner membrane modified into sacs called Thylakoids
- Thylakoids in stacks called Grana & interconnected
- Stroma – gel like material surrounding thylakoids

Chloroplasts

- Contains its own DNA
- Contains enzymes & pigments for Photosynthesis
- Never in animal or bacterial cells
- Photosynthesis – food making process



Genetic information, protein synthesis, and protein structure

DNA

- Hereditary material
- Chromosomes
  - DNA
  - Protiens
  - Form for cell division
- Chromatin

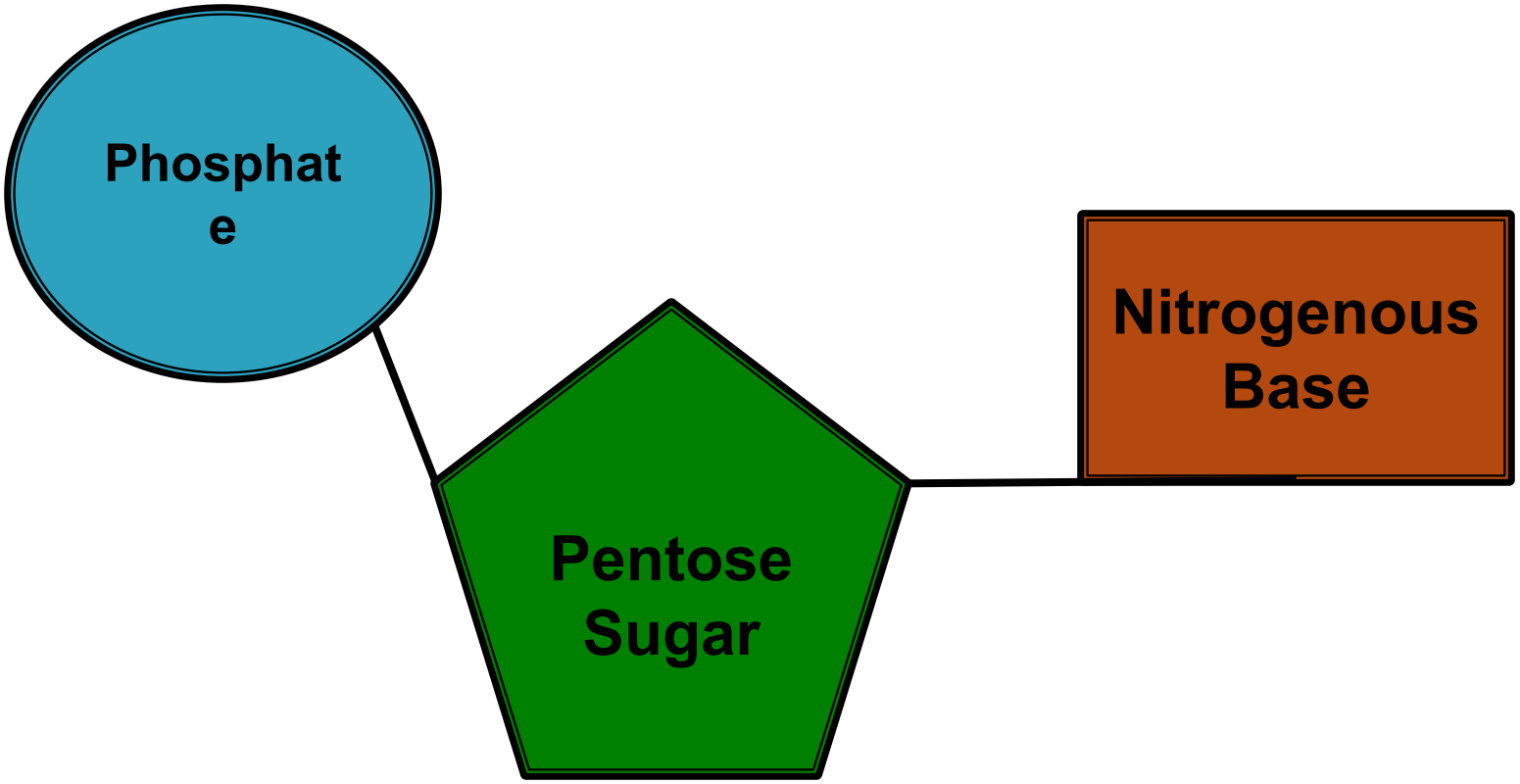
DNA Structure

- DNA consists of two molecules that are arranged into a ladder-like structure called a Double Helix.

- A molecule of DNA is made up of millions of tiny subunits called Nucleotides.

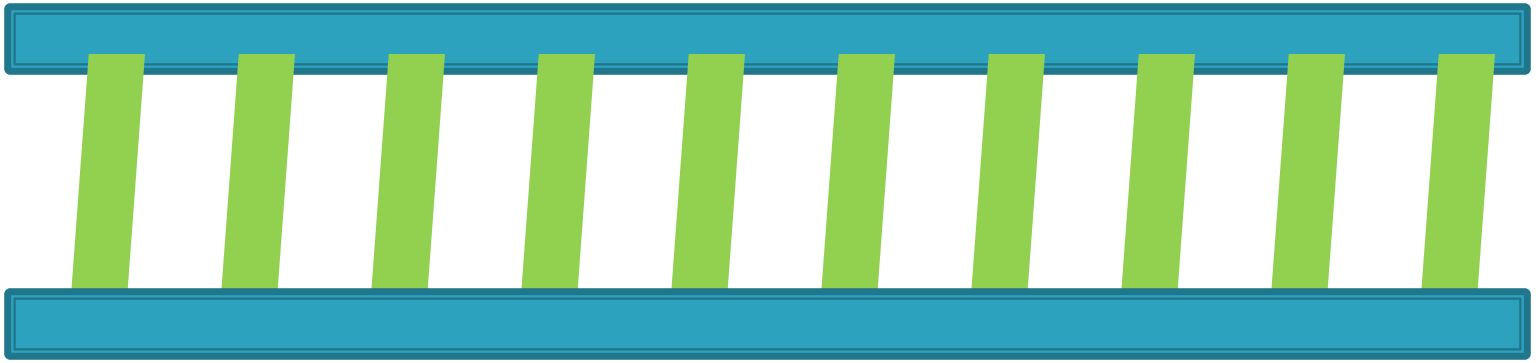
- Each nucleotide consists of:
  1. Phosphate group
  2. Pentose sugar
  3. Nitrogenous base

Nucleotides



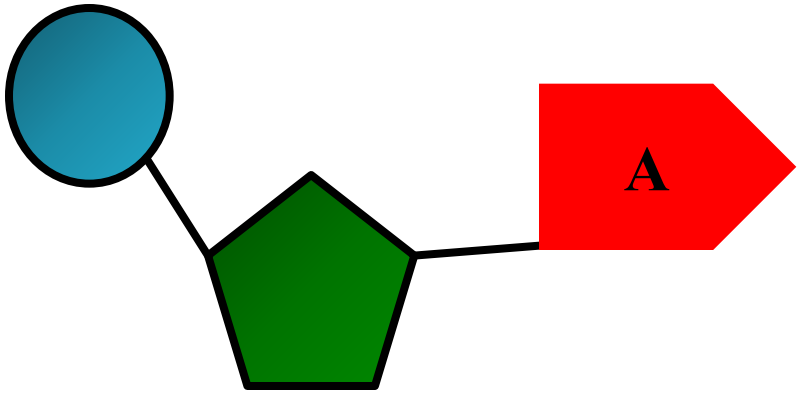
Nucleotides

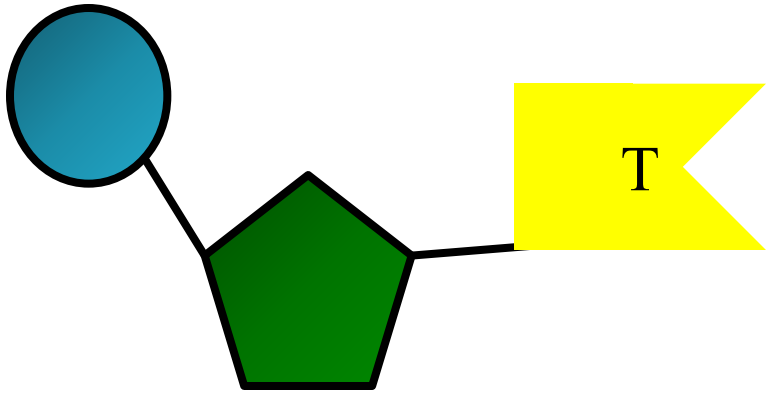
- The phosphate and sugar form the backbone of the DNA molecule, whereas the bases form the “rungs”.

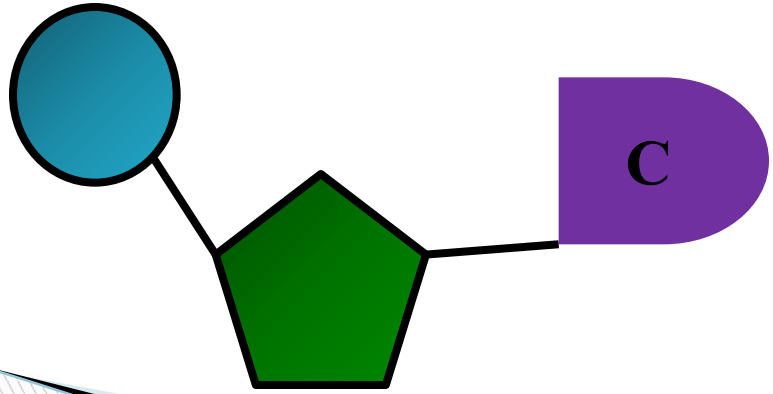


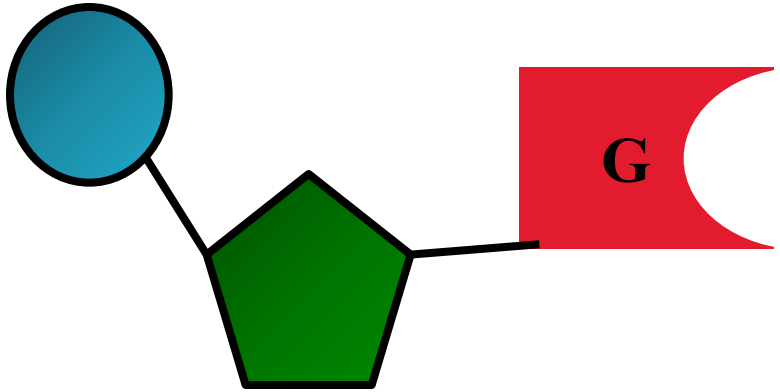
- There are four types of nitrogenous bases.

Nucleotides









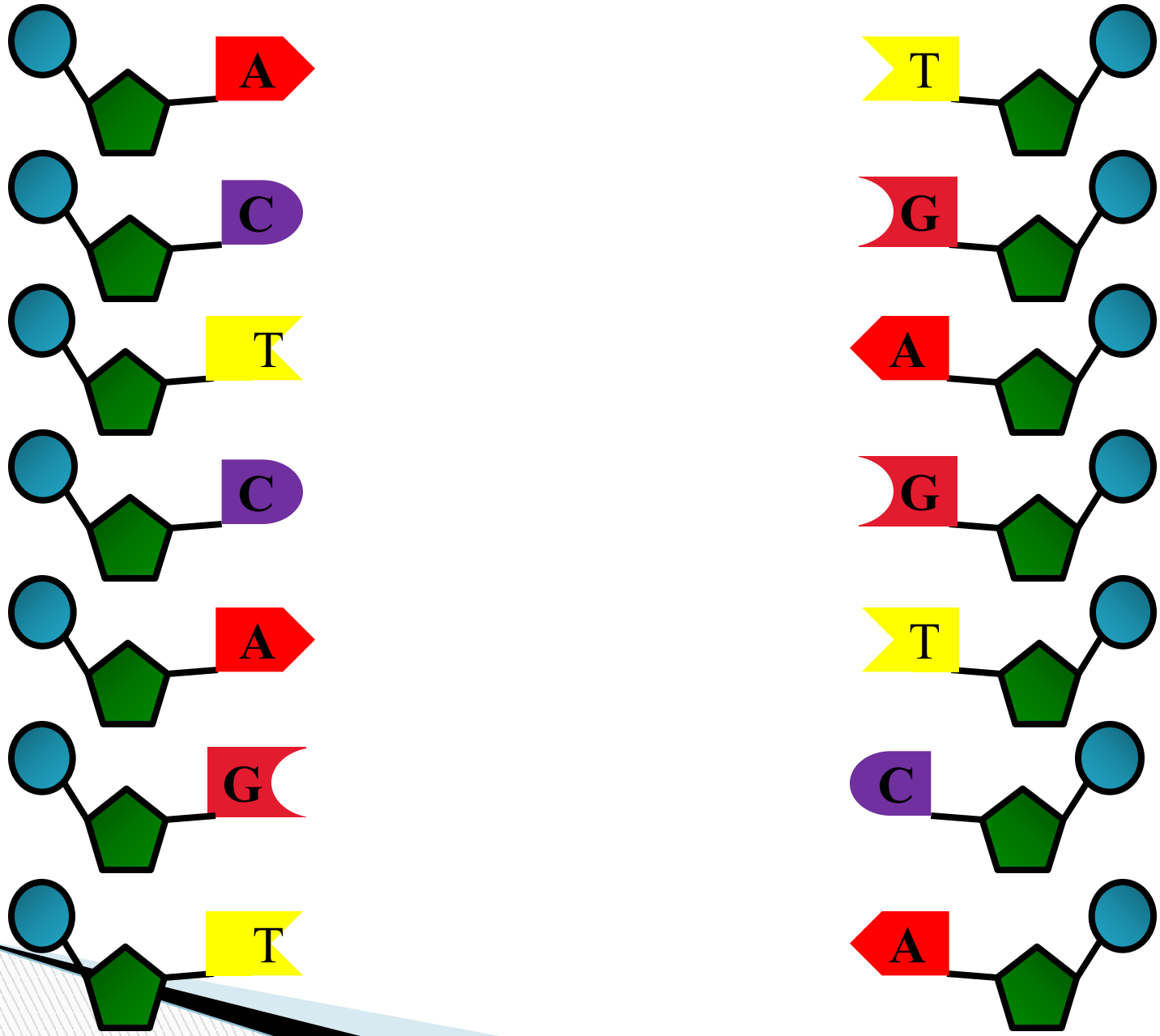
Nucleotides

- Each base will only bond with one other specific base.
  - Adenine (A)
  - Thymine (T)

  } Form a base pair.

  - Cytosine (C)
  - Guanine (G)

  } Form a base pair.


A
C
T
C
A
G
T
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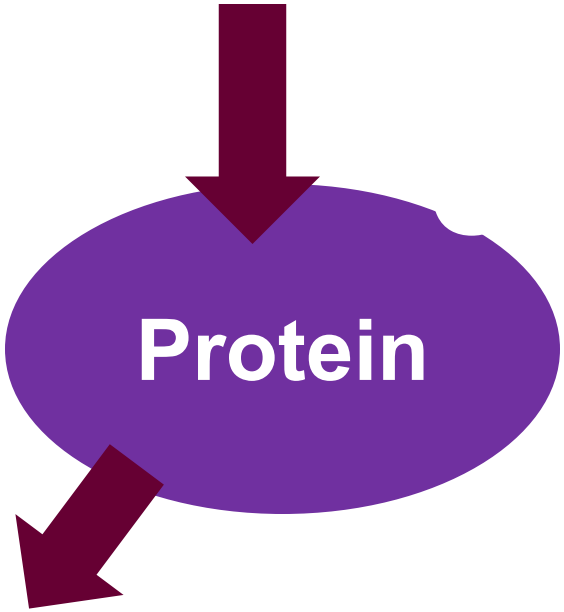
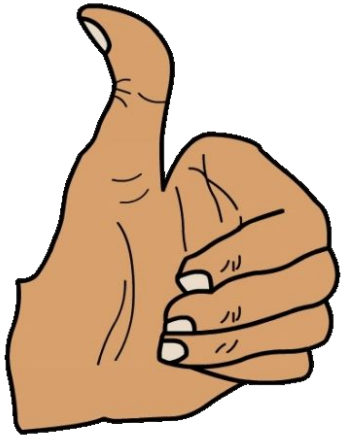
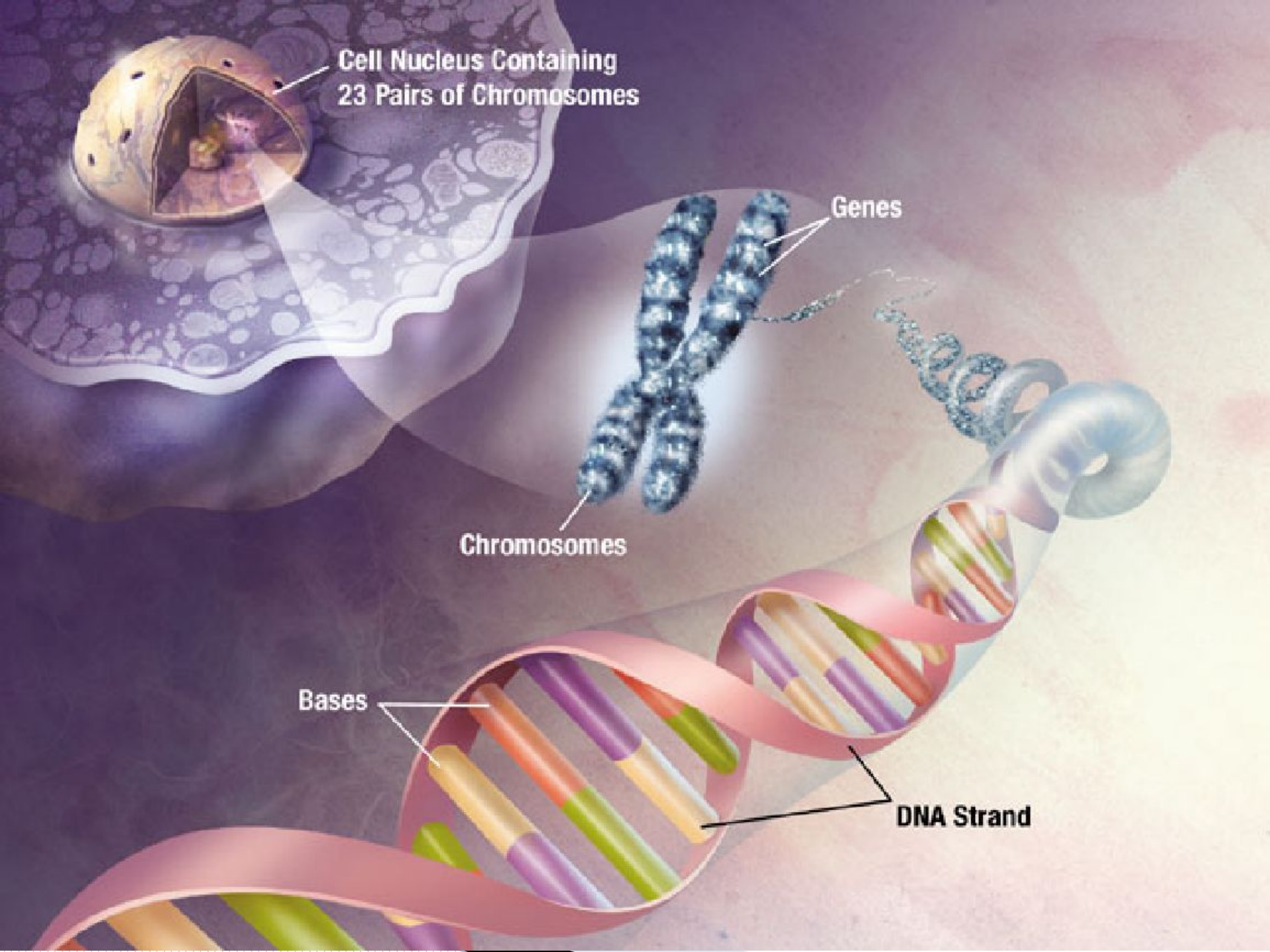
G
A
G
T
C
A


Protein




Cell Nucleus Containing
23 Pairs of Chromosomes
Genes
Chromosomes
Bases
DNA Strand

Proteins-organic molecule(50%)

- **Proteins are polymers (macromolecules) made of monomers called amino acids**
- **All proteins are made of 20 different amino acids linked in different orders**
- **Proteins are used to build cells, act as hormones & enzymes, and do much of the work in a cell**

Essential *versus* Non-essential Amino Acid

Humans need ALL 20 amino acids to be able to make proteins.

Glycine	Alanine	Serine
Cysteine	Proline	Tyrosine
Aspartic Acid	Asparagine	Glutamic Acid
Glutamine	Arginine	

Valine	Leucine	Isoleucine
Threonine	Methionine	Phenylalanine
Tryptophan	Lysine	Histidine

Arginine

Essential Amino Acids

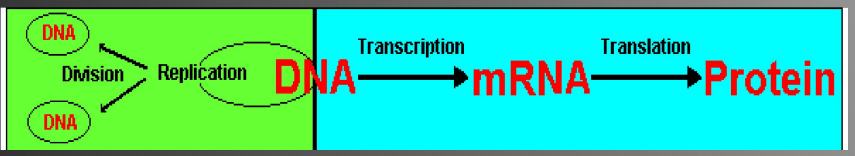
Essential and Non-essential Amino Acids

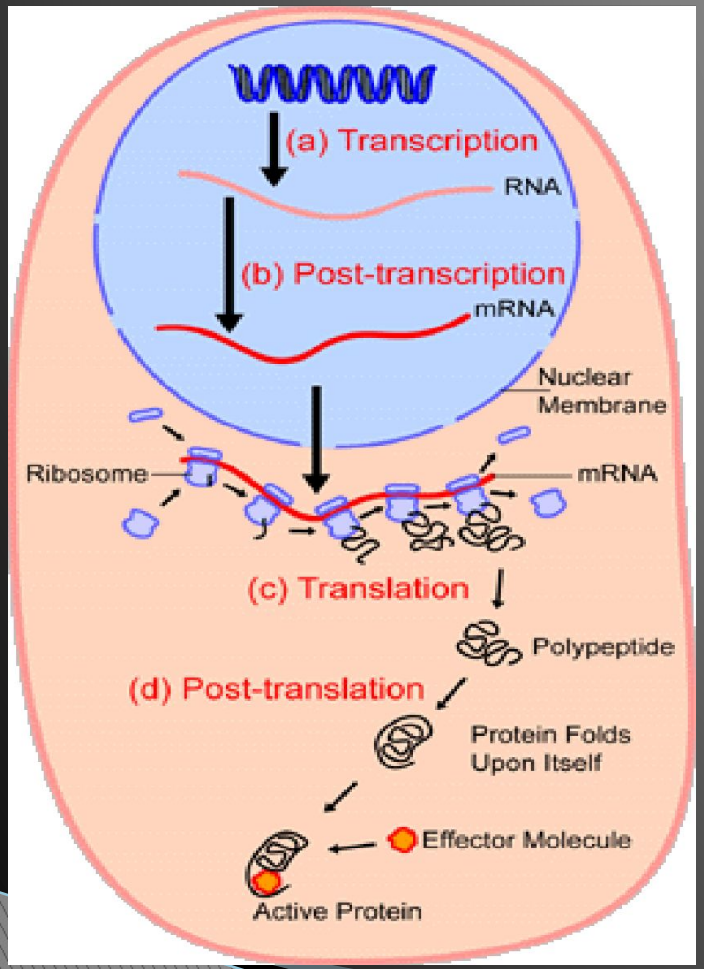
- Essential (10)
  - Arginine
  - Histidine
  - Isoleucine
  - Leucine
  - Lysine
  - Methionine
  - Phenylalanine
  - Threonine
  - Tryptophan
  - Valine
- Non-essential
  - Alanine
  - Asparagine
  - Aspartate
  - Cysteine
  - Glutamate
  - Glutamine
  - Glycine
  - Proline
  - Serine
  - Tyrosine

Factors influencing protein structure

- Hydrogen bonds
- Hydrophobic interactions
- Electrostatic interactions
- Van der Waals interactions

Protein Synthesis





1. DNA unwinds
2. mRNA copy is made of one of the DNA strands.
3. mRNA copy moves out of nucleus into cytoplasm.
4. tRNA molecules are activated as their complementary amino acids are attached to them.
5. mRNA copy attaches to the small subunit of the ribosomes in cytoplasm. 6 of the bases in the mRNA are exposed in the ribosome.
6. A tRNA bonds complementarily with the mRNA via its anticodon.
7. A second tRNA bonds with the next three bases of the mRNA, the amino acid joins onto the amino acid of the first tRNA via a peptide bond.
8. The ribosome moves along. The first tRNA leaves the ribosome.
9. A third tRNA brings a third amino acid
10. Eventually a stop codon is reached on the mRNA. The newly synthesised polypeptide leaves the ribosome.

Protein Functions in the Body

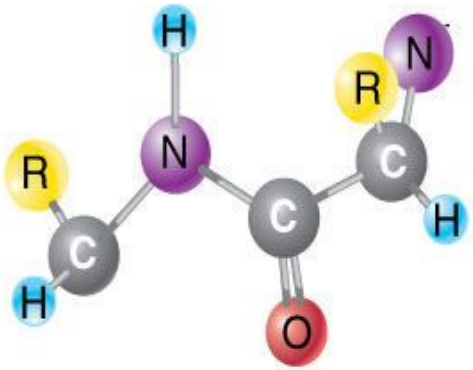
Structural

- **There are many different proteins in your body, and they perform different functions. Proteins functions include:**
  - **Contributing to enzyme activity that promotes chemical reactions in the body**
  - **Signaling cells what to do and when to do it**
  - **Transporting substances around the body**
  - **Keeping fluids and pH balanced in the body**
  - **Serving as building blocks for hormone production**
  - **Helping blood clot**
  - **Promoting antibody activity that controls immune and allergy functions**
  - **Serving as structural components that give our body parts their shapes**

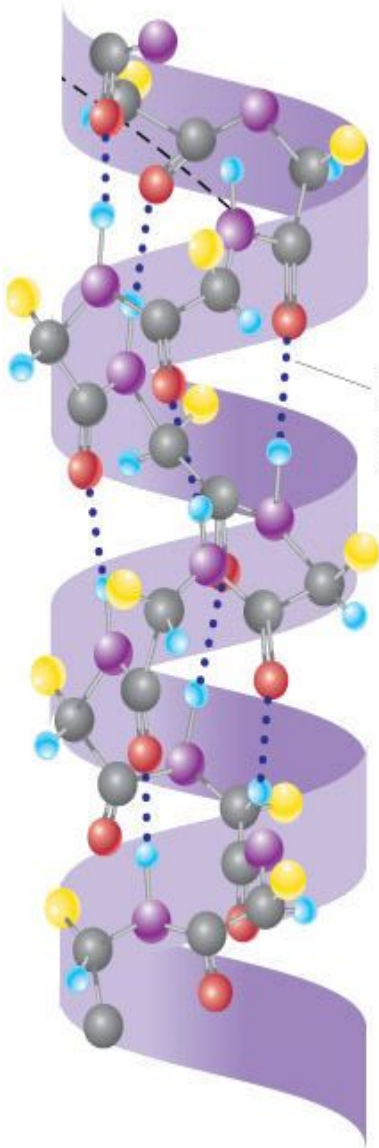
dynamic

Functions of proteins

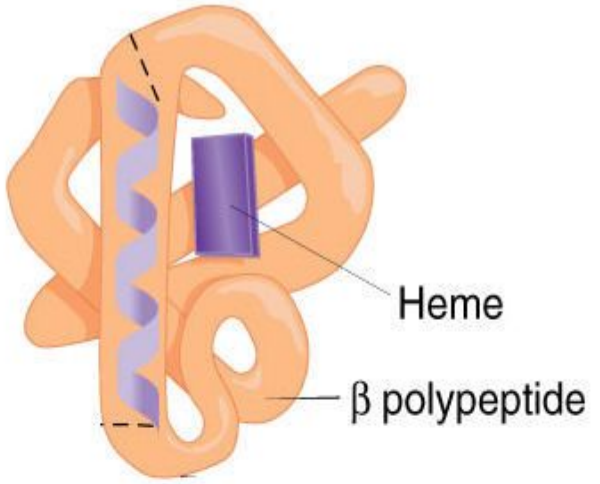
- Structural functions:
- act as bricks-structure and strength-collagen in bone,keratin in skin
- Dynamic functions:
- enzymes,harmones,immunoglobulins,storage protein
- Woking horses of a cell



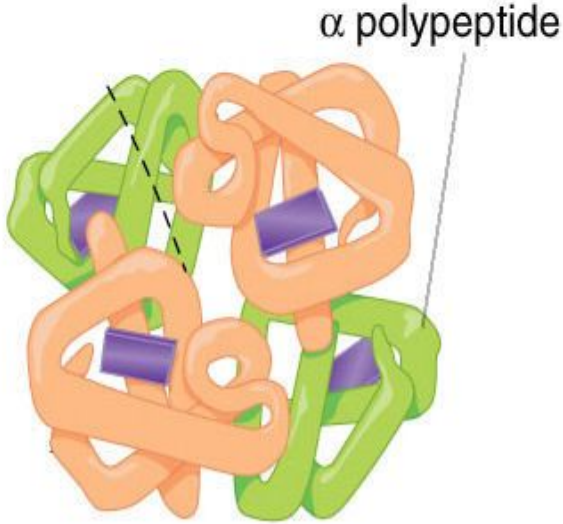
(a) Primary structure



(b) Secondary structure



c) Tertiary structure

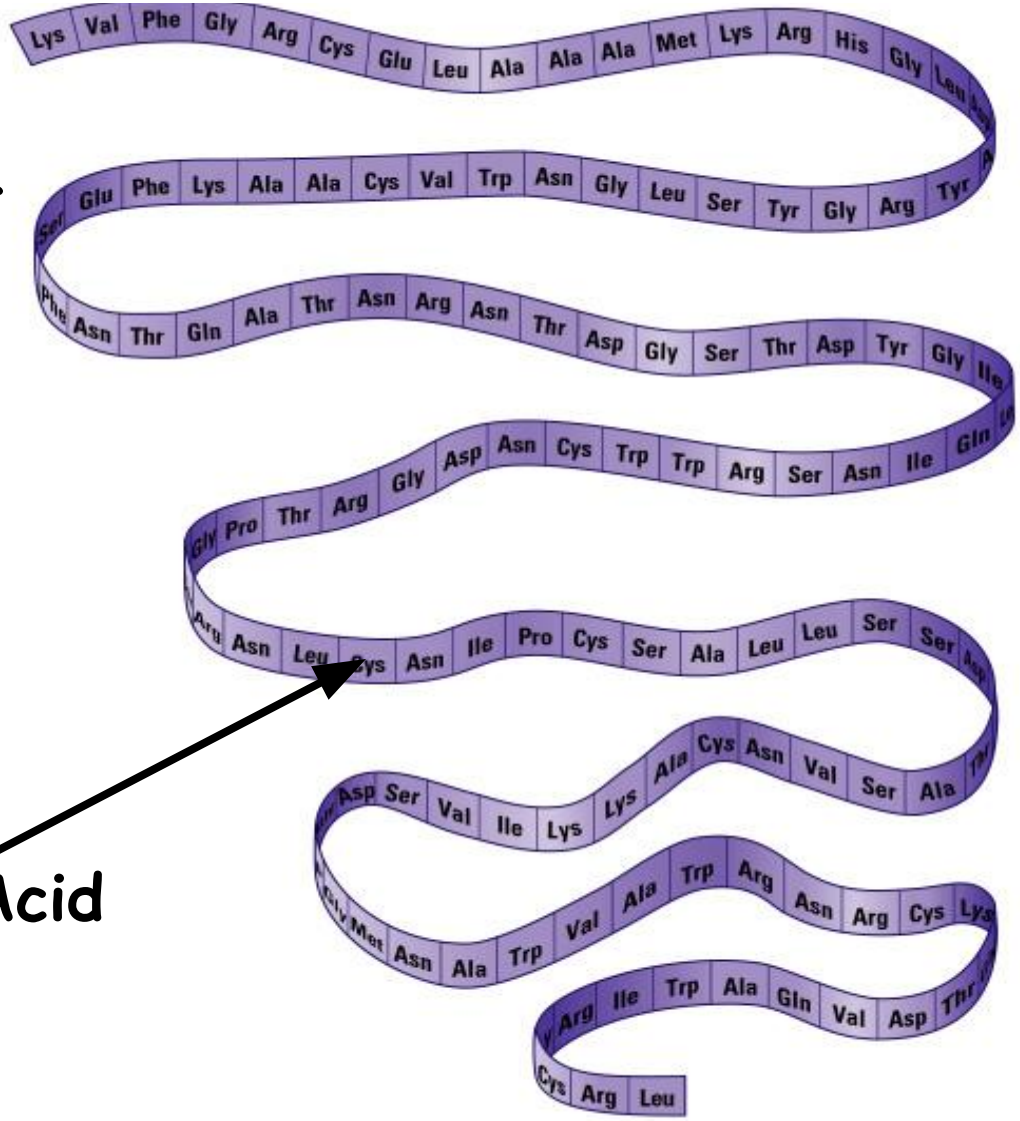


(d) Quaternary structure

Primary Protein Structure

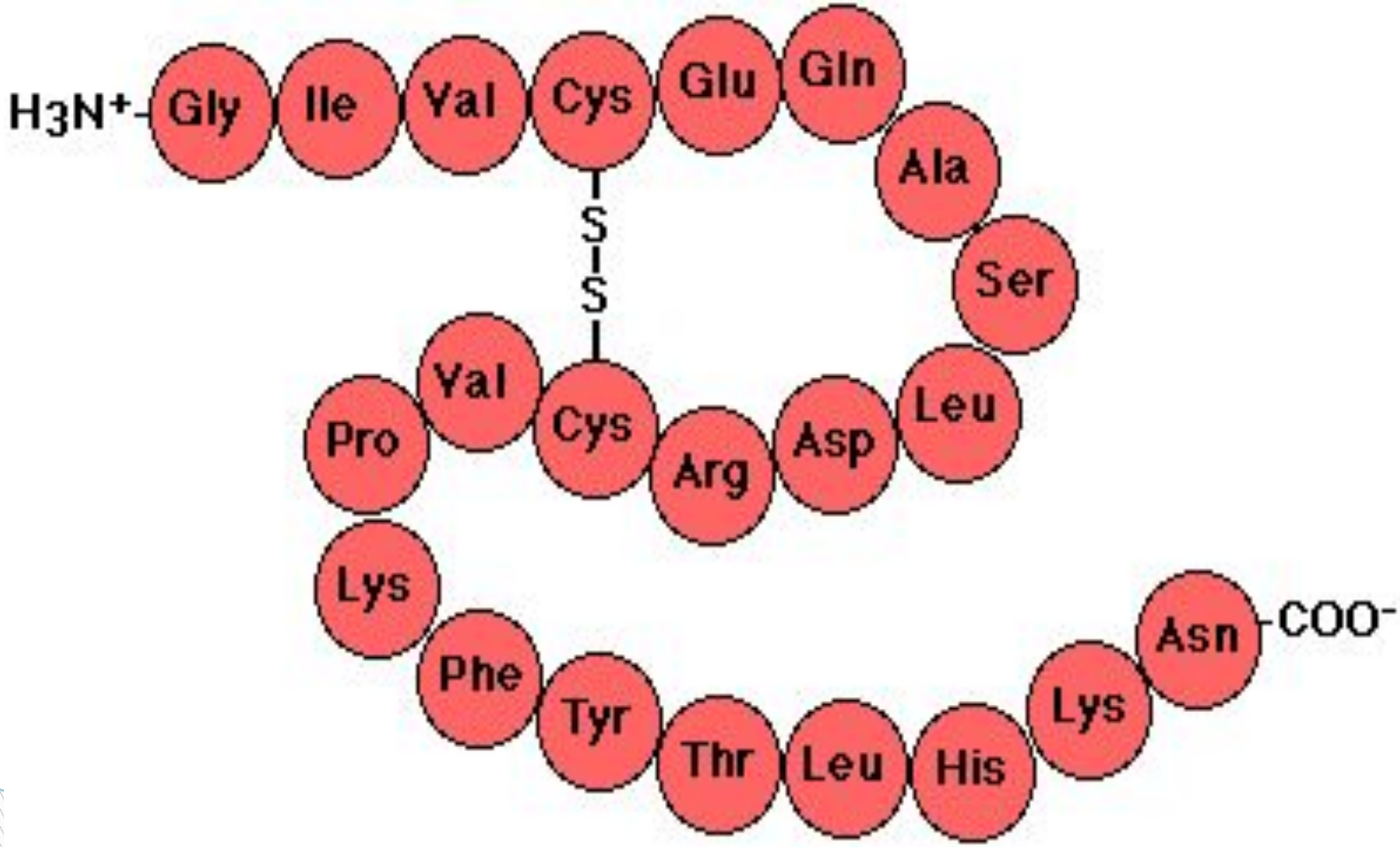
The primary structure is the specific sequence of amino acids in a protein

called polypeptide



Amino acids

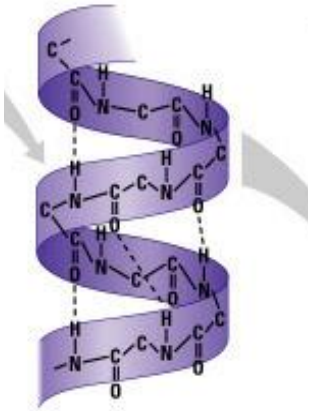
- Central carbon atom
- Hydrogen atom
- Amino group
- Carboxyl group


H3N+
Gly
Ile
Val
Cys
Glu
Gln
Ala
Ser
Leu
Asp
Arg
Cys
Val
Pro
Lys
Phe
Tyr
Thr
Leu
His
Lys
Asn
COO-
S
S

Secondary Structure in Proteins(alpha helix and beta sheet)

- In general proteins fold/twist into two broad classes of structure termed,
- globular proteins
- fibrous proteins.
- Globular proteins are compactly folded
- fibrous proteins are more filamentous or elongated.

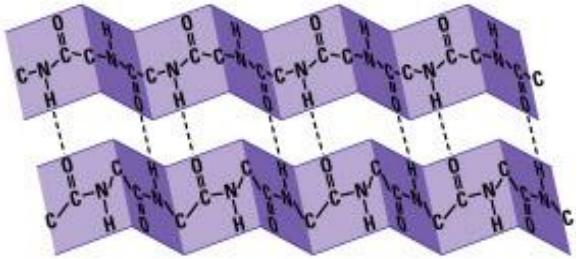
Alpha helix



- 3.6 residues per turn
- Hydrogen bond
- Polar in nature
- Length vary from 4-5 a.a to forty a.a
- 1.5 Å length
- Width 4 Å (armstrong)

Beta sheet

- Parallel
- Antiparallel
- mixed –both strands
- 5 to 10 residues long
- Two terminals :amino terminal
- carboxy terminal
- Hydrogen bond



Tertiary Structure of Proteins

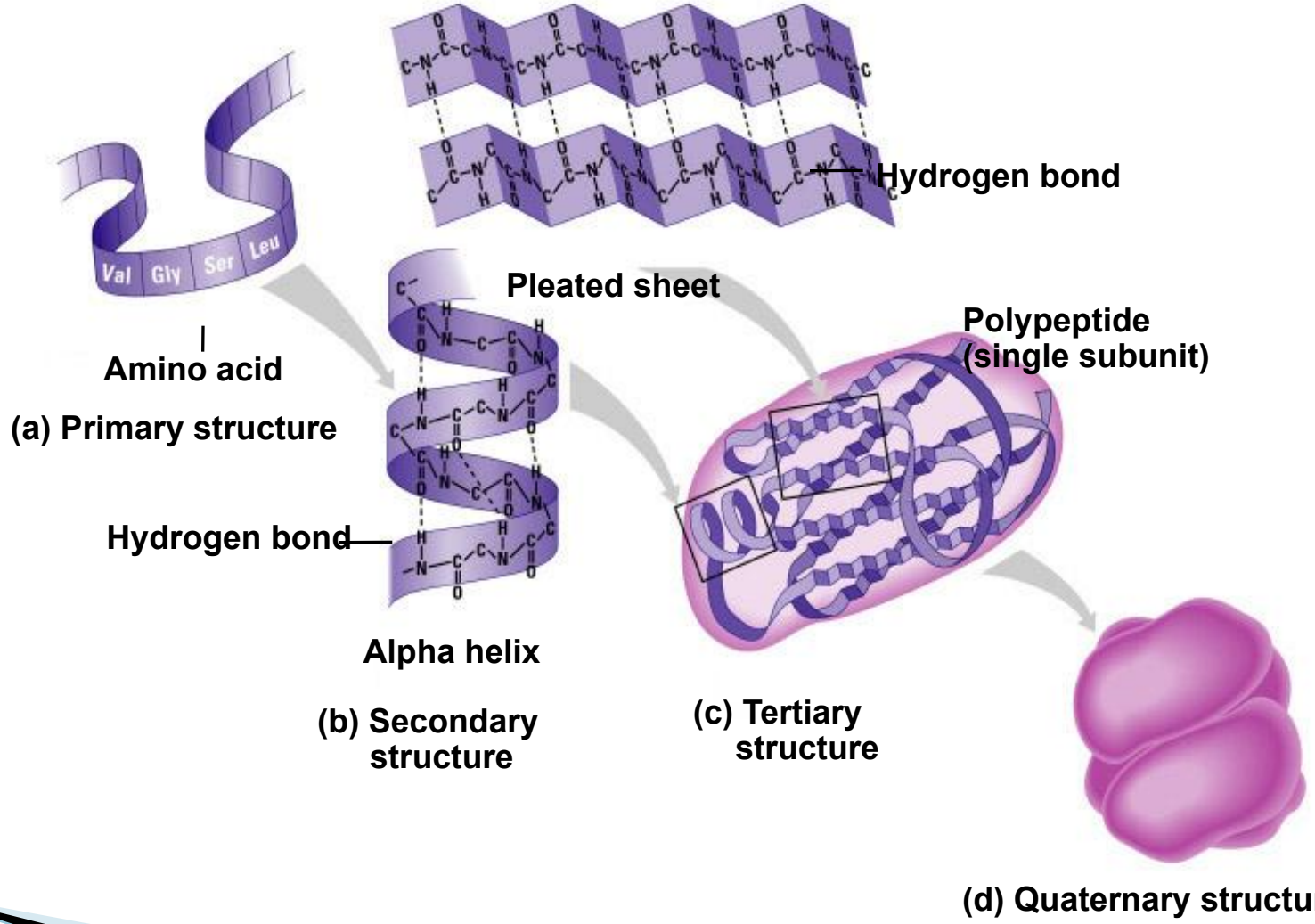
- Formed by packing structural elements to compact globular units called domains/super secondary structural units
- **Disulphide bond(sulphur atoms)**
- **Polar and non polar (oil drop)**
- **Salt bridges**
- **Strong columbic interactions**

Quaternary Structure

- Many proteins contain 2 or more different polypeptide chains that are held in association by the same non-covalent forces that stabilize the tertiary structures of proteins.
- Haemoglobin-tetrameric protein(hexa,octa)

- Rotation axes-2,4,5,6 and 8 fold axes
- Glyceraldehyde-3-phosphate dehydrogenase etc..

Protein Structures or CONFORMATIONS



Cell metabolism

- Living organisms –energy and carbon source-synthesize cellular material

Energy- phototrophs and chemotrophs

Phototrophs

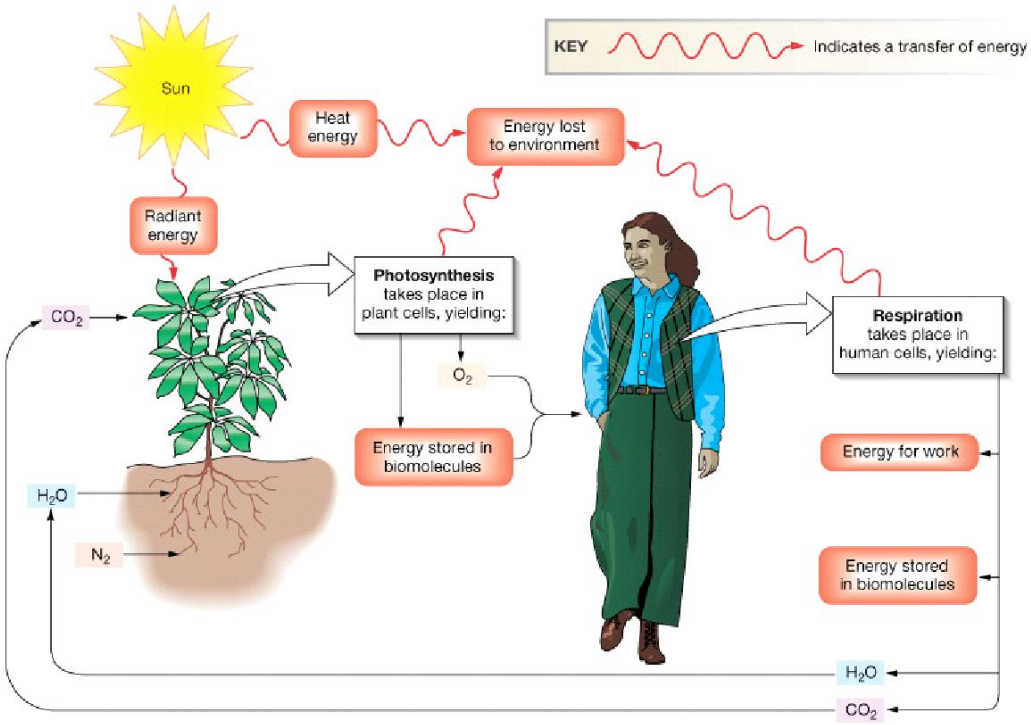
1. autotrophs
2. heterotrophs

Chemotrophs

1. lithotrops
2. organotrophs

Cell metabolism

- ***Energy*** **is the ability to do work.**
- **Living things need to acquire energy; this is a characteristic of life.**
- **Cells use acquired energy to:**
  - **Maintain their organization**
- **Carry out reactions that allow cells to develop, grow, and reproduce**



ATP: Energy for Cells

- ATP (*adenosine triphosphate*) is the energy currency of cells.

- ATP is constantly regenerated from ADP (*adenosine diphosphate*) after energy is expended by the cell.

- Use of ATP by the cell has advantages:

  1) It can be used in many types of reactions.

  2) When ATP → ADP + P, energy released is sufficient for cellular needs and little energy is wasted.

  AMP+PPi → ATP

Function of ATP

- Cells make use of ATP for:
- *Chemical work* – ATP supplies energy to synthesize macromolecules, and therefore the organism
- *Transport work* – ATP supplies energy needed to pump substances across the plasma membrane
- *Mechanical work* – ATP supplies energy for cellular movements

Two types of metabolic reactions

Anabolism

- larger molecules are made
- requires energy

Dehydration synthesis

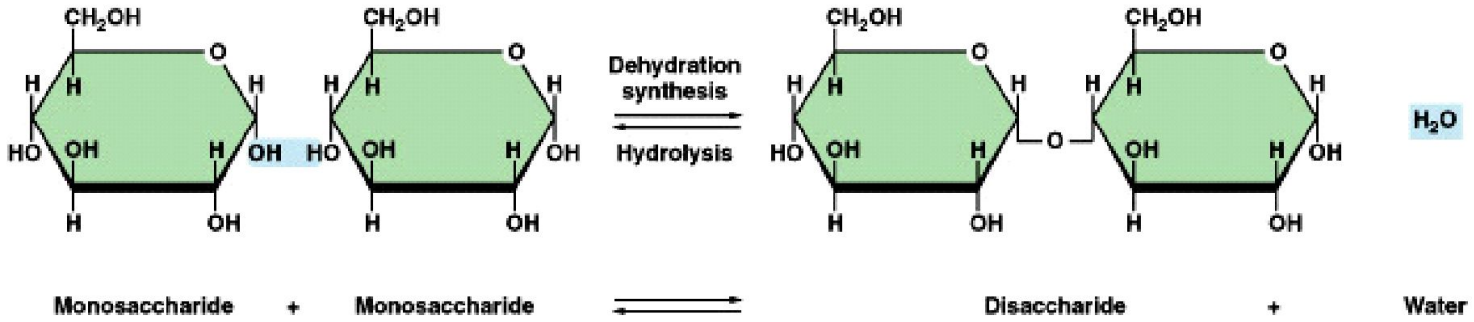
- type of anabolic process
- used to make polysaccharides, triglycerides, and proteins
- produces water

Catabolism

- larger molecules are broken down
- releases energy

Hydrolysis

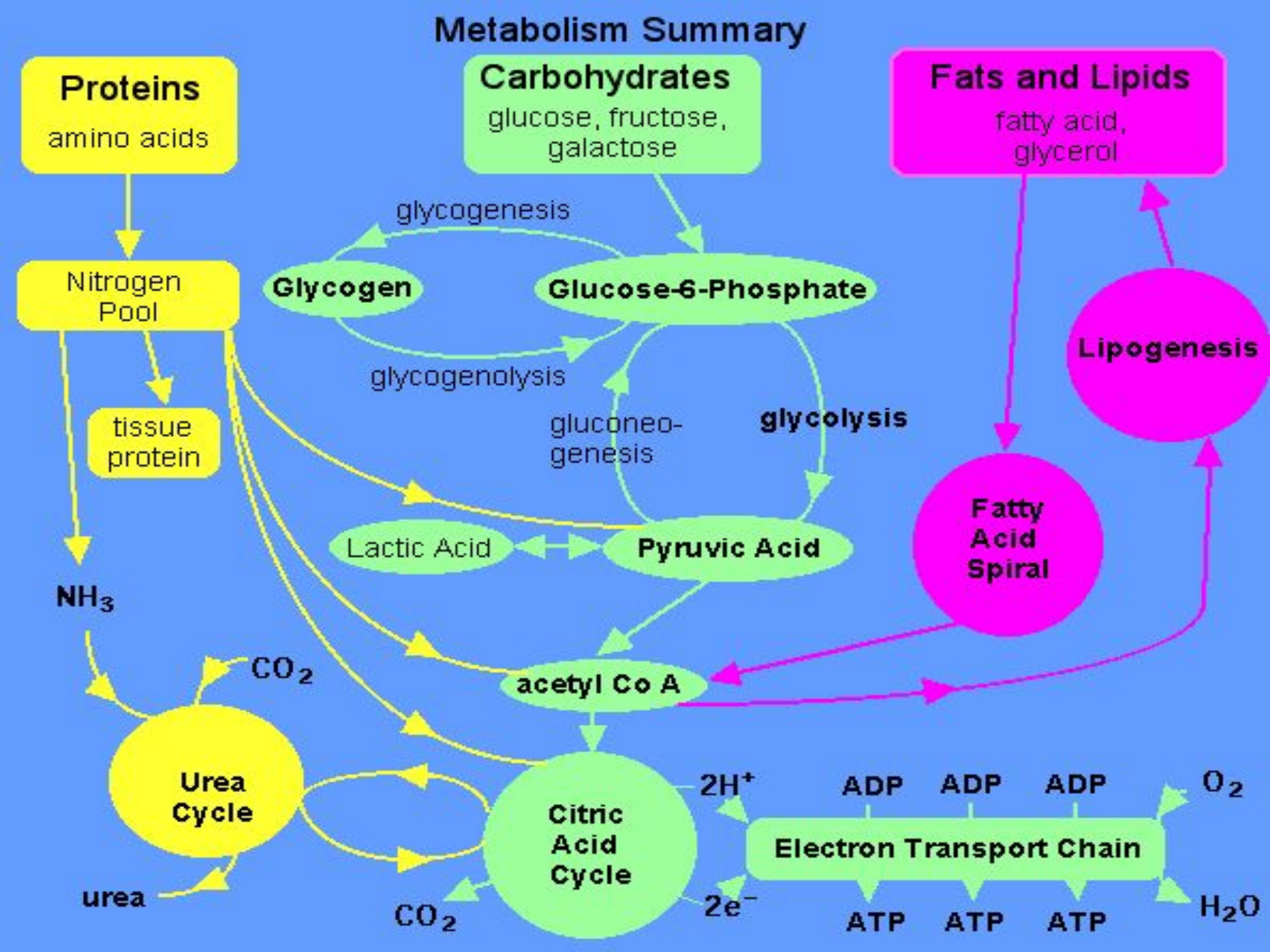
- a catabolic process
- used to decompose carbohydrates, lipids, and proteins
- water is used
- reverse of dehydration synthesis

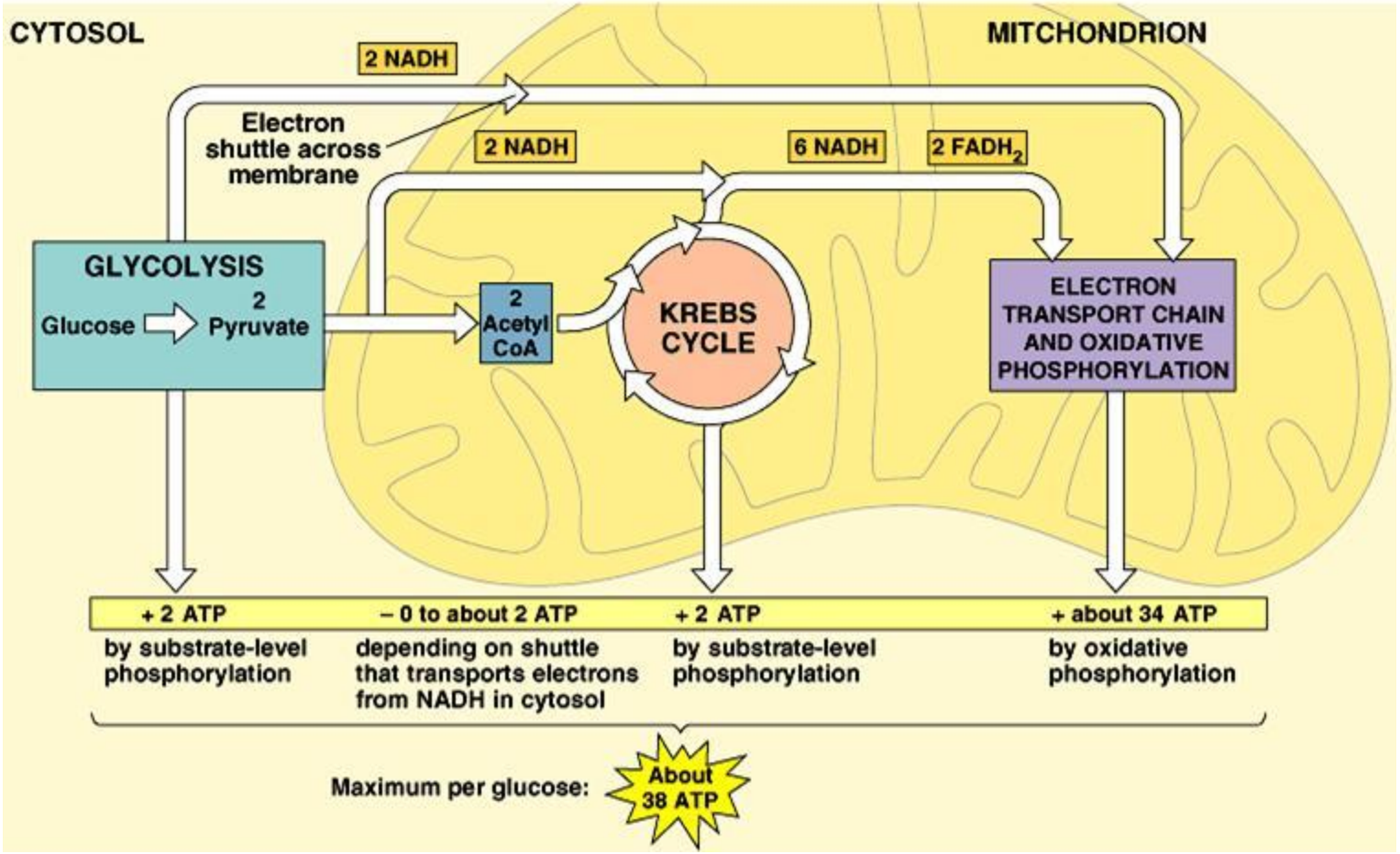


- **Amino acid**: building blocks of protein-important constituent of plasma membrane
- **Fatty acids**: building blocks of phospholipids and glycolipids-plasma membrane
- **Carbohydrate:**plasma membrane.

Metabolic pathways

- Carbohydrate-tricarboxylic acid cycle/ kreb cycle/citric acid cycle, glycolysis
- Glycolysis:splitting of glycogen
- ETC and oxidative phosphorylation:ATP produced using ATP synthase(mitochondria)

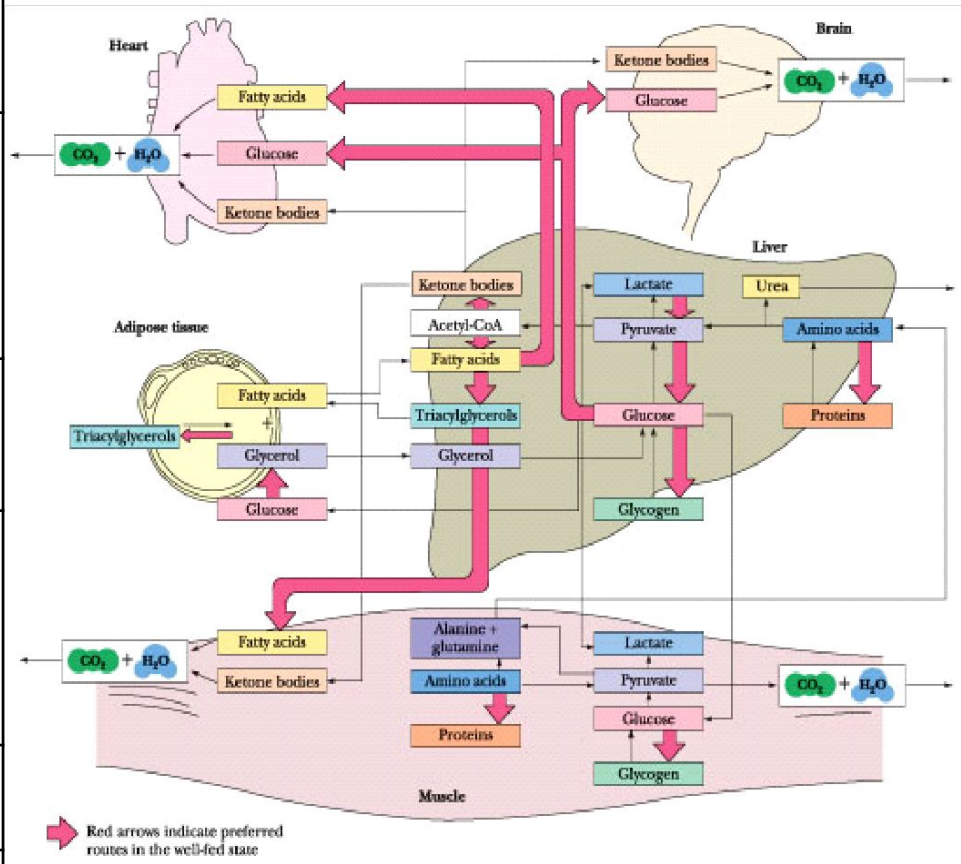

Metabolism Summary
Proteins
amino acids
Carbohydrates
glucose, fructose, galactose
Fats and Lipids
fatty acid, glycerol
glycogenesis
Nitrogen Pool
Glycogen
Glucose-6-Phosphate
Lipogenesis
glycogenolysis
tissue protein
gluconeo-genesis
glycolysis
Fatty Acid Spiral
Lactic Acid
Pyruvic Acid
NH3
CO2
acetyl Co A
Urea Cycle
Citric Acid Cycle
2H+
ADP ADP ADP
O2
Electron Transport Chain
urea
CO2
2e−
ATP ATP ATP
H2O



- **Prokaryotic cells** need not carry out ATP/ADP exchange.
- Thus, bacteria have the potential to produce approximately 38 ATP per glucose.

Metabolic relationships among the major human organs: brain, muscle, heart, adipose tissue, and liver

Organ	Energy Reservoir	Preferred Substrate	Energy Sources Exported
Brain	None	Glucose (ketone bodies during starvation)	None
Skeletal muscle (resting)	Glycogen	Fatty acids	None
Skeletal muscle (prolonged exercise)	None	Glucose	Lactate
Heart muscle	Glycogen	Fatty acids	None
Adipose tissue	Triacylglycerol	Fatty acids	Fatty acids, glycerol
Liver	Glycogen, triacylglycerol	Amino acids, glucose, fatty acids	Fatty acids,glucose, ketone bodies



Homeostasis

What is Homeostasis?

- Body cells work best if they have the correct
  - Temperature
  - Water levels
  - Glucose concentration

- Your body has mechanisms to keep the cells in a constant environment.

What is Homeostasis?

The maintenance of a constant environment in the body is called Homeostasis

Bleeding -homeostasis

- Primary homeostasis- formation of **platelet**
- Secondary-formation of **fibrin**
- Tertiary-formation of **plasma**

- **Homeostatic Regulation:**
- **receptor**:changes in environment
- **control centre**: information from receptor
- **effectors**- responds to command

Pathways that alter homeostasis

Extrinsic homeostatic system

Intrinsic **homeostatic system**

Endocrine system

Nervous system

Nervous system:

1.Peripheral Nervous System –spinal nerves

2.Autonomic Nervous System-control internal organs

2 divisions-symphathetic (emergency) and parasympathetic system(everyday existence)

- Skin-sensory organ-receive stimuli-transmit message to spinal cord/brain

Endocrine system

Endocrine system:

PTH(parathyroid hormone)-released to blood --blood calcium level is low.

- TSH
- Sex harmones and mammary glands.
- Muscle cells

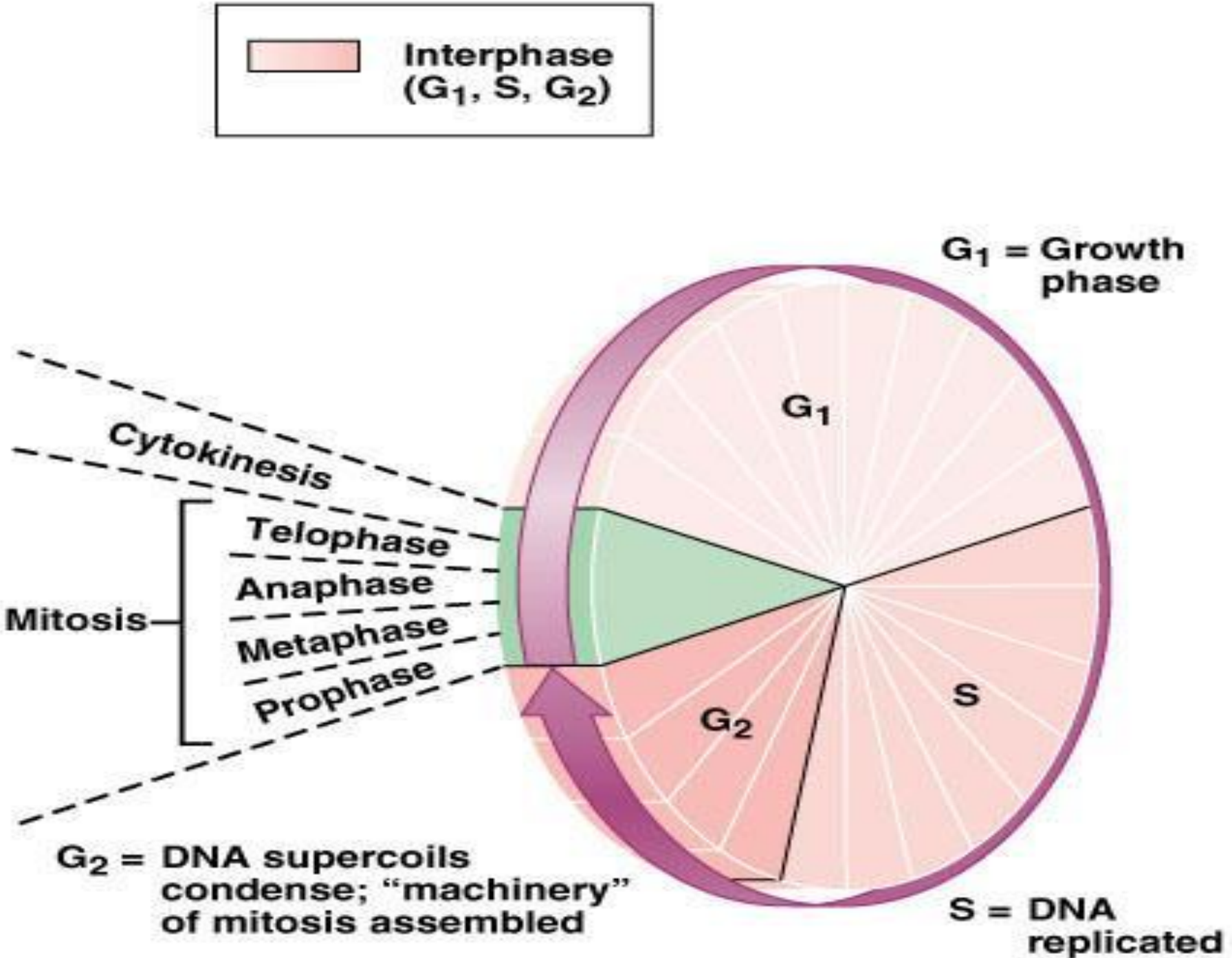
Cell growth, reproduction, and differentiation

Cell cycle

- Controlled cycle of duplication and cell division

Events:

- Reproductive signal to activate reproduction
- Duplication of genetic material
- Segregation
- cytokinesis


Interphase
(G1, S, G2)
G1 = Growth
phase
G1
Cytokinesis
Telophase
Anaphase
Mitosis
Metaphase
Prophase
G2
S
G2 = DNA supercoils
condense; "machinery"
of mitosis assembled
S = DNA
replicated

Five Phases of the Cell Cycle

- G_1 - primary growth phase
- S – synthesis; DNA replicated
- G_2 - secondary growth phase

collectively these 3 stages are called interphase

- M - mitosis
- C - cytokinesis

Mitosis and Meiosis

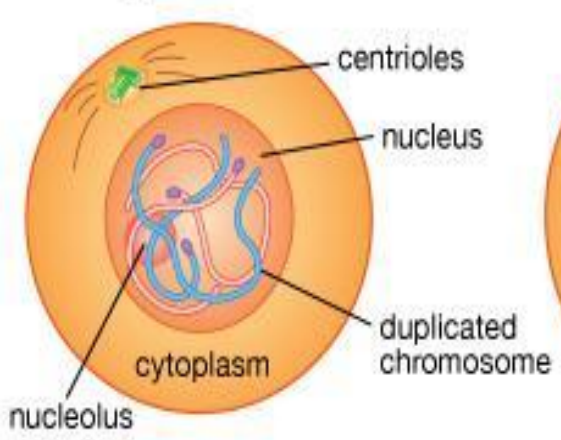
- **Mitosis:**
  -division of **somatic** (body) cells

- **Meiosis**
  -division of gametes (sex cells)

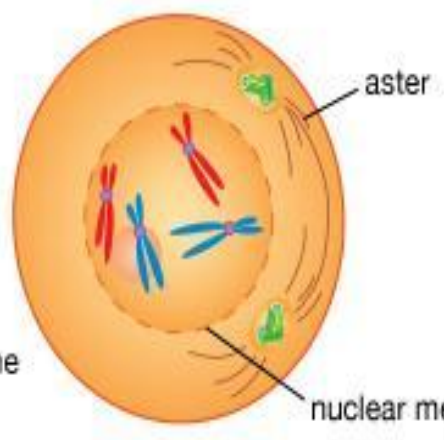
Mitosis

- Interphase
- Prophase
- Metaphase
- Anaphase
- Telophase

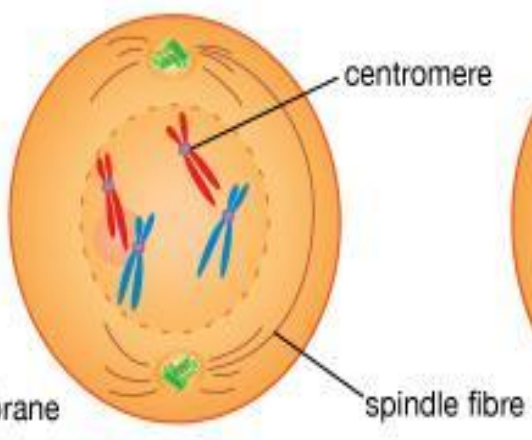
Mitosis, or somatic cell division



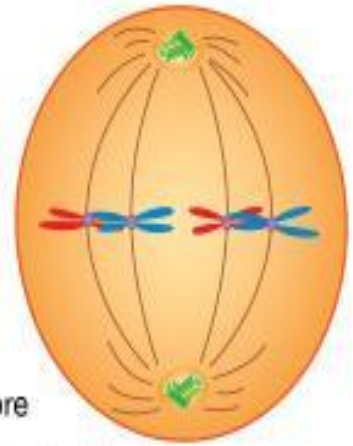
Prior to mitosis, each chromosome makes an exact duplicate of itself. The chromosomes then thicken and coil.



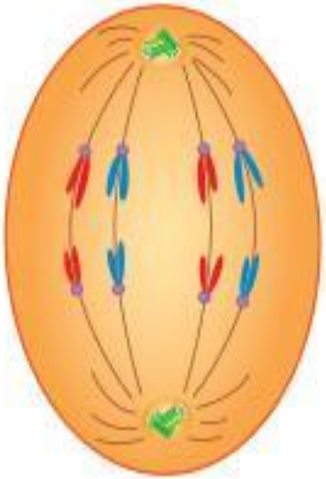
In early prophase, the centrioles, which have divided, form asters and move apart. The nuclear membrane begins to disintegrate.



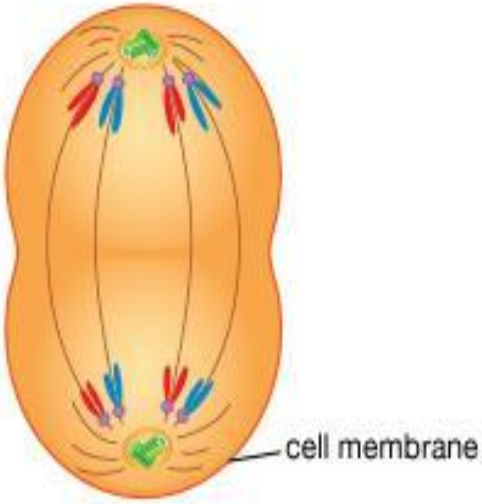
In late prophase, the centrioles and asters are at opposite poles. The nucleolus and nuclear membrane have almost disappeared.



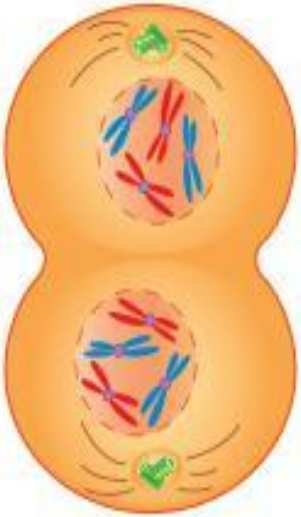
The doubled chromosomes—their centromeres attached to th spindle fibres—line up at mid-ce in the metaphase.



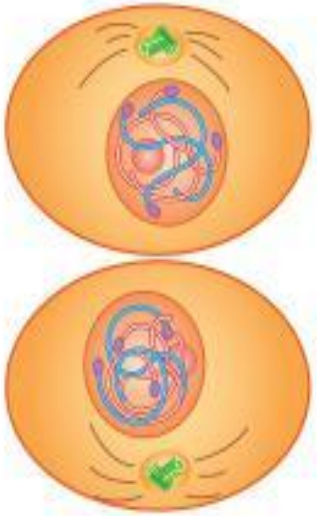
In early anaphase, the centromeres split. Half the chromosomes move to one pole, half to the other pole.



In late anaphase, the chromosomes have almost reached their respective poles. The cell membrane begins to pinch at the centre.



The cell membrane completes constriction in telophase. Nuclear membranes form around the separated chromosomes.



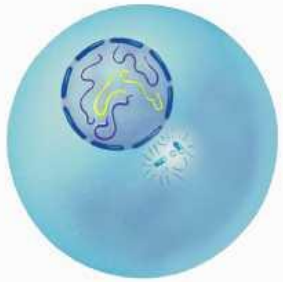
Mitosis completed, there are two cells with the same structures an number of chromosomes as the parent cell.

Meiosis

Meiosis I	Meiosis II
Prophase I (leptotene,zygotene,pachytene, Diplotene and diakinesis)	Prophase II
Metaphase I	Metaphase II
Anaphase I	Anaphase II
Telophase I	Telophase II

Each new nucleus is genetically identical to the parent nucleus

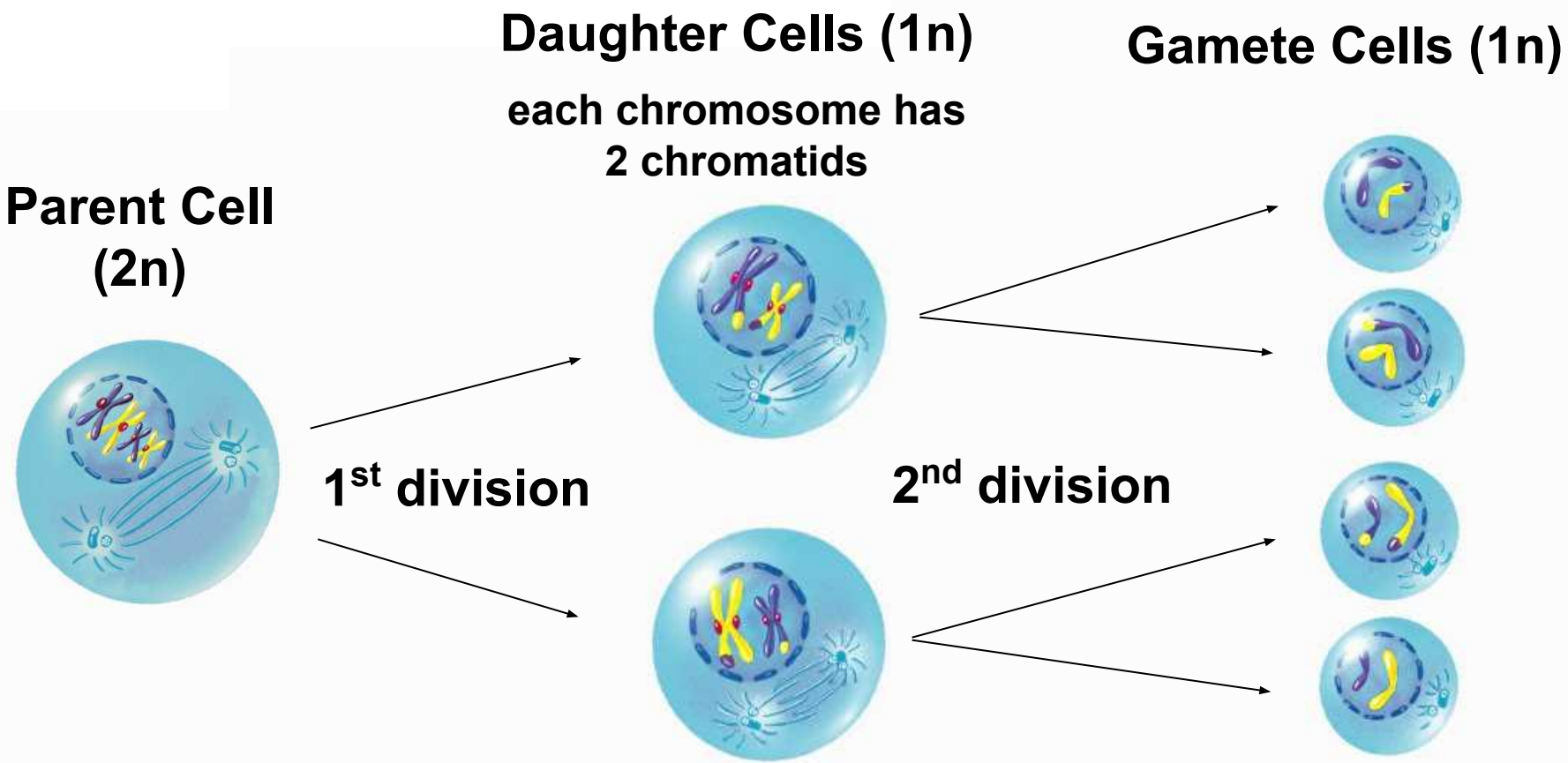
Parent Cell
Chromosomes have been replicated



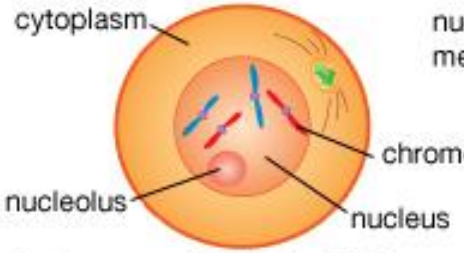
Mitosis

Daughter Cells
Each cell has the same genetic makeup as the parent cell

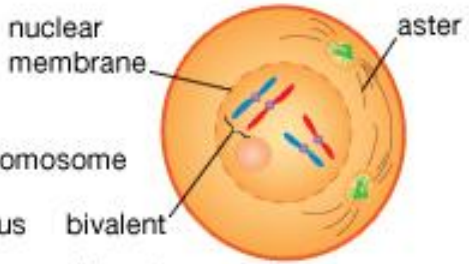
Meiosis


Daughter Cells (1n)
each chromosome has 2 chromatids
Gamete Cells (1n)
Parent Cell (2n)
1st division
2nd division

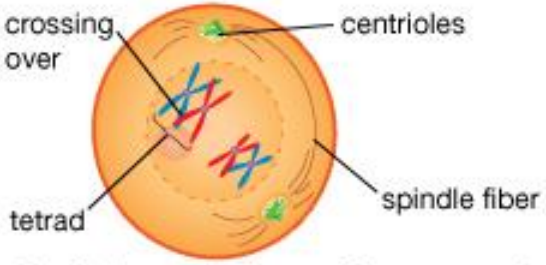
Meiosis, or sex cell division



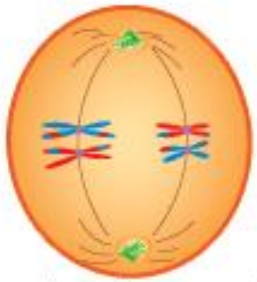
At the onset of meiosis, DNA strands thicken into chromosomes. Homologous, or like, chromosomes begin to approach each other.



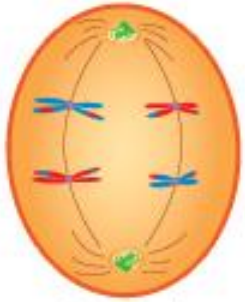
Homologous chromosomes pair to form bivalents. The centrioles divide and move to opposite poles of the cell.



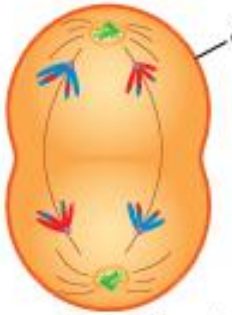
The bivalents duplicate to form tetrads, or four-chromatid groups. The nuclear membrane disintegrates. Crossing over (recombination) occurs.



In metaphase I, the tetrads, attached to spindle fibers at their centromeres, line up at mid-cell.

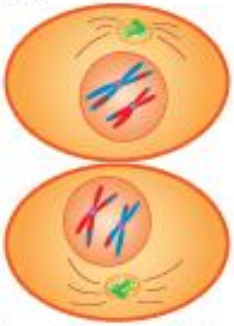


In early anaphase I, the tetrads separate, and the paired chromatids move along the spindle to their respective centrioles.

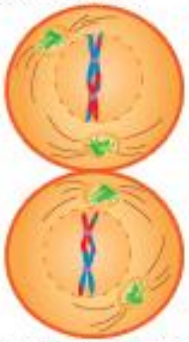


In late anaphase I, the chromatids have almost reached the spindle poles. The cell membrane begins to constrict.

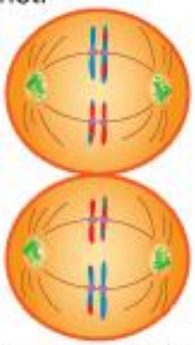
In telophase I, nuclear membranes enclose the separated chromatids. The cell membrane completes its constriction.



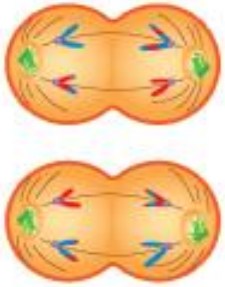
The first meiotic division ends. There are now two cells, each with the same number of chromatids as the parent cell.



Prophase II begins. In the second meiotic division, homologous chromatids do not duplicate but merely separate.



In metaphase II, the chromatids line up at mid-cell. The centrioles and asters are at the poles. A spindle has formed.



In anaphase II, the now-separated chromatids approach their respective poles. The cell membrane begins to constrict.

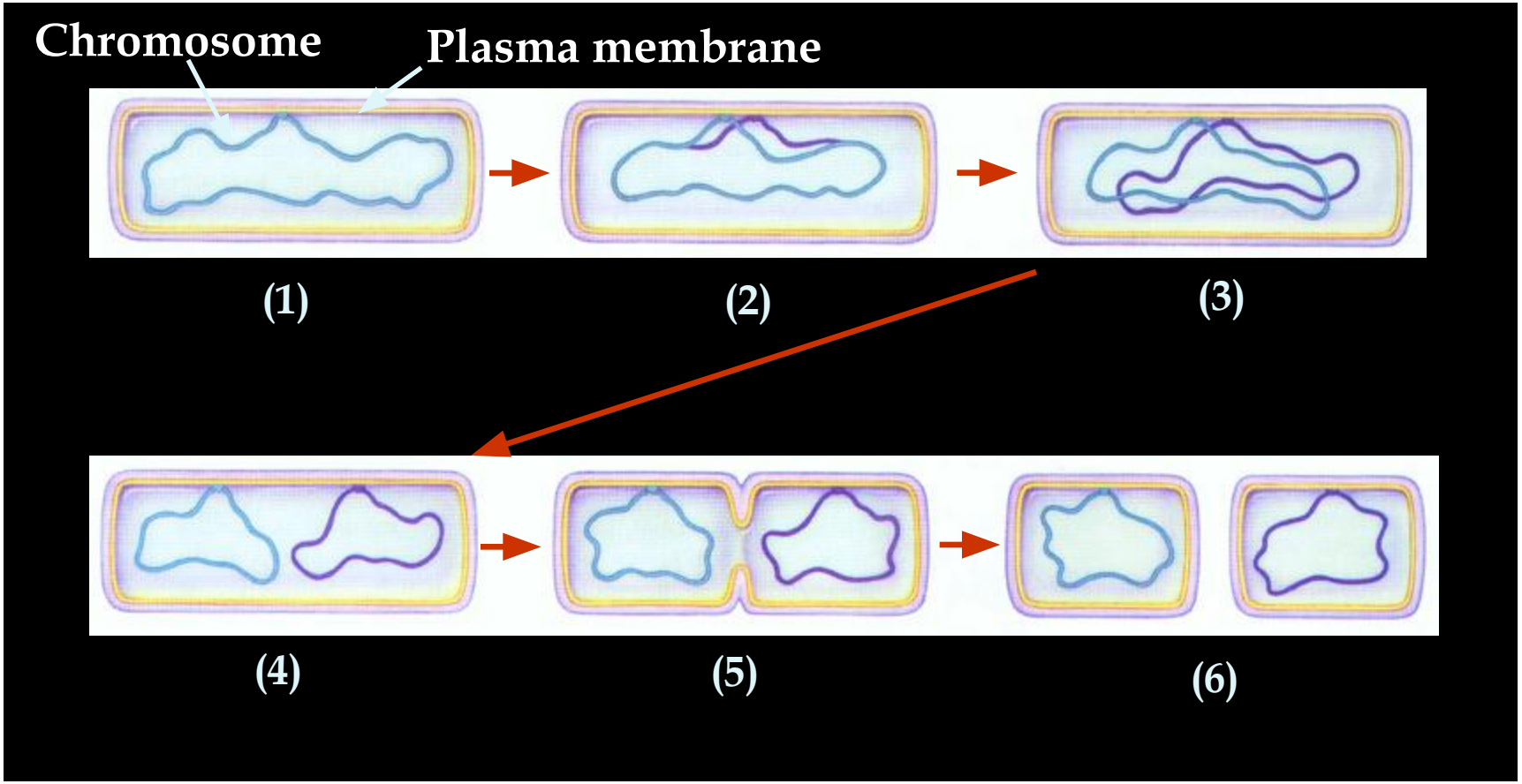
Telophase II has been completed. There are now four cells, each with half the number of chromosomes of the parent cell.

Comparison of Divisions

	Mitosis	Meiosis
Number of divisions	1	2
Number of daughter cells	2	4
Genetically identical?	Yes	No
Chromosome #	Same as parent	Half of parent
Where	Somatic cells	Germ cells
When	Throughout life	At sexual maturity
Role	Growth and repair	Sexual reproduction

Binary fission

Daughter cells are identical copies



Neither mitosis nor meiosis occurs in prokaryotes

Cell differentiation

- Unspecialized cells acquiring properties of specialized cell is defined as cell differentiation.
- During differentiation part of the DNA are turned off and only specific part are expressed.
- Differentiated cells are different from one another from their protein products to morphology.

Cell types

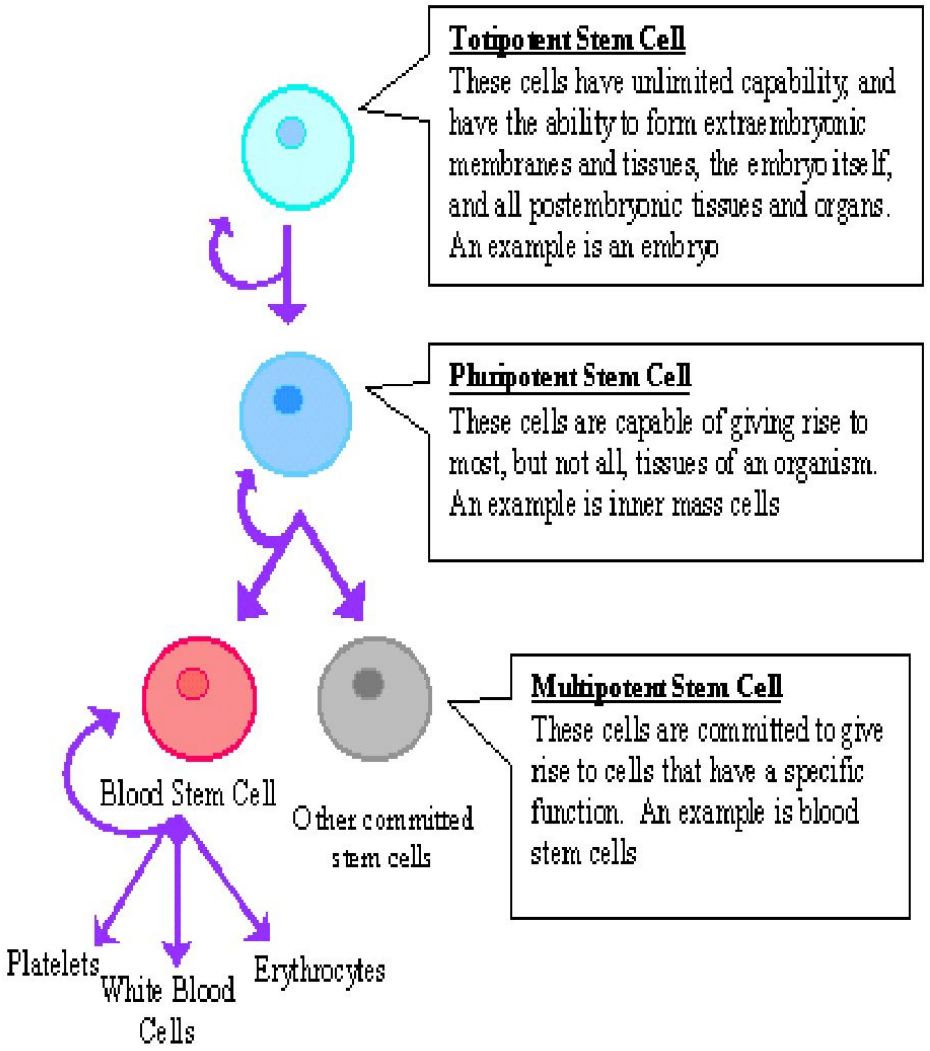
- Totipotent
- Pluripotent
- Multipotent

What is the difference between totipotent, pluripotent, and multipotent?

- Totipotent cells can form all the cell types in a body, plus the extraembryonic, or placental, cells
- Pluripotent cells can give rise to all of the cell types that make up the body except placental cells. ex:embryonic stem cells
- Multipotent cells can develop into more than one cell type, but are more limited than pluripotent cells
- ex: haematopoeitic stem cells

Cell Differentiation

- The process of altering the pattern of gene expression and thus becoming a cell of a particular type is called cell differentiation.
- Presence of chemicals (or other influences) starts altering the decisions as to which genes will be turned on or off.
- The zygote is a totipotent cell - its daughter cells can become any cell type. As the development proceeds, some of the cells become pluripotent - they can become many, but not all cell types.
- Later on, the specificity narrows down further and a particular stem cell can turn into only a very limited number of cell types, e.g., a few types of blood cells, but not bone or brain cells or anything else. That is why embryonic stem cell research is much more promising than the adult stem cell research



Differentiation of different tissues and organs