18BTB101T Biology

UNIT I

- Introduction
- Cell structure and function
- Genetic information, and protein structure
- Cell metabolism
- Homoeostasis
- Cell growth, reproduction, and differentiation

Introduction

Concept of evolution

- Jean Baptistae Lamarak (1801)
- Charles darwin (1859)

Methods of Science

- **The scientific method refers to the model for research developed by Francis Bacon (1561–1626). This model involves the following sequence:**

1. Identifying the problem

2. Collecting data within the problem area (by observations, measurements, etc.)

3. Sifting the data for correlations, meaningful connections, and regularities

4. Formulating a hypothesis (a generalization), which is an educated guess that explains the existing data and suggests further avenues of investigation

5. Testing the hypothesis rigorously by gathering new data

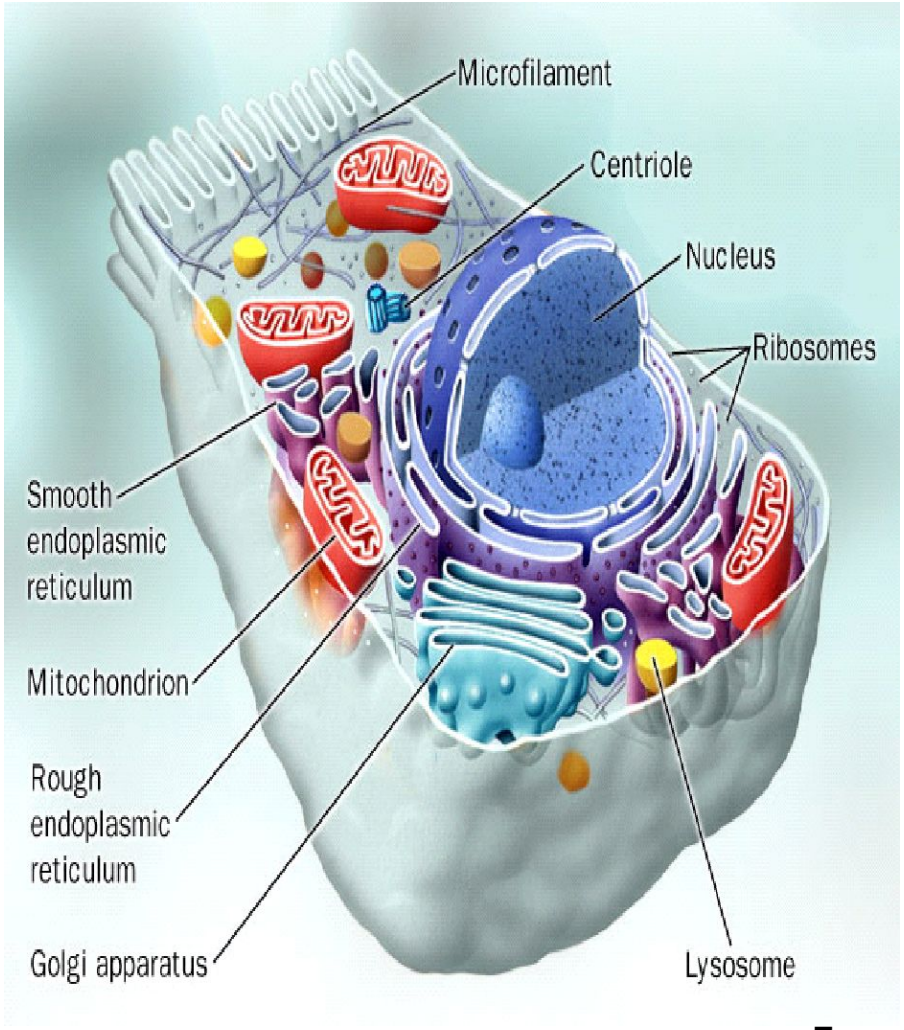
6. Confirming, modifying, or rejecting the hypothesis in light of the new findings

Living Organism

- A living organism may be defined as a complex unit of physicochemical materials that is capable of self-regulation, metabolism, and reproduction.
- Furthermore, a living organism demonstrates the ability to interact with its environment, grow, move, and adapt.

What Are the Main Characteristics of organisms?

1. Made of **CELLS**
2. Require **ENERGY** (food)
3. **REPRODUCE** (species)
4. Maintain **HOMEOSTASIS**
5. **ORGANIZED**
6. **RESPOND** to environment
7. **GROW** and **DEVELOP**
8. **EXCHANGE** materials with surroundings (water, wastes, gases)



Five Kingdoms and their chief characteristics

- **Unicellular organisms that lack a nucleus and many of the specialized cell parts, called organelles. Such organisms are said to be prokaryotic (pro =‘‘before’’; karyotic =‘‘kernel,’’ ‘‘nucleus’’) and consist of bacteria.**

- **All of the other kingdoms consist of eukaryotic (eu = ‘‘true’’) organisms, which have cells that contain a nucleus and a fuller repertory of organelles.**

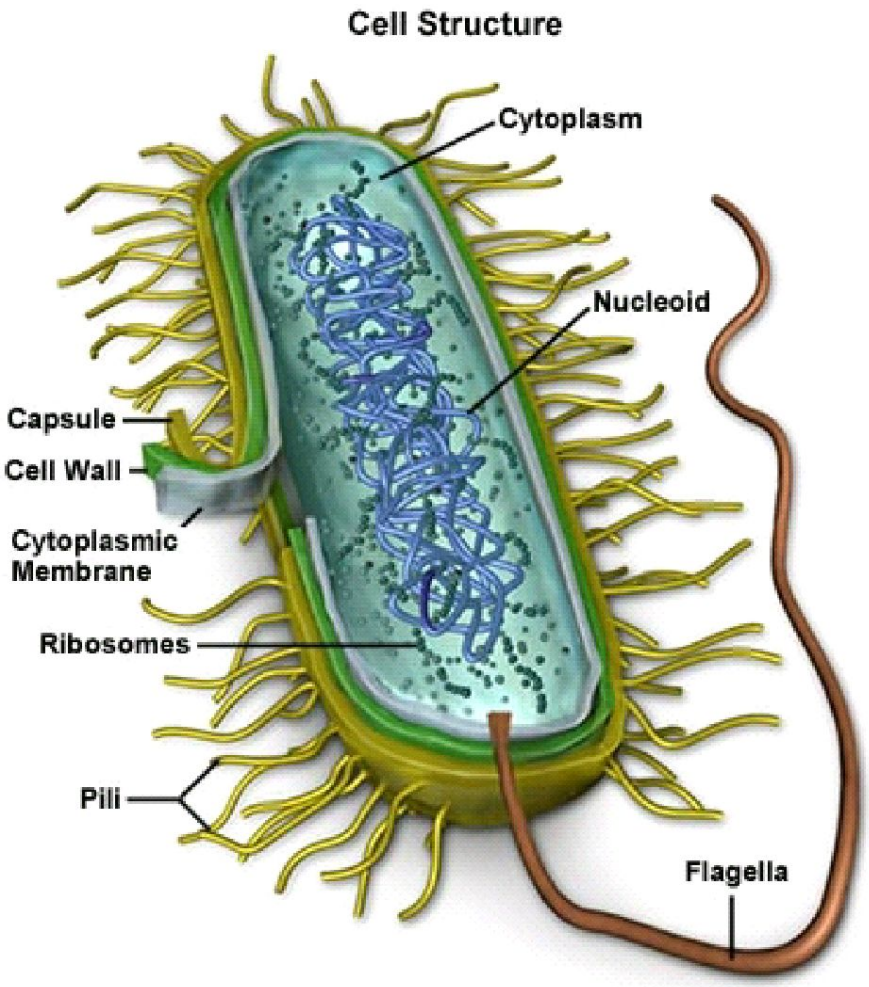
KINGDOM	DISTINGUISHING CHARACTERISTICS	EXAMPLES OF ORGANISMS
1. Monera	Single-celled, *prokaryotic* organisms: cells lack nuclei and certain other specialized parts	Bacteria
2. Protista	Single-celled, *eukaryotic* organisms: cells contain nuclei and many specialized internal structures	Protozoa
3. Plantae	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

Cell-basic unit of life

- Smallest living form
- Inside the cell some structure transport
- Metabolize
- Respire
- Reproduce (Meiosis)
- Multiply (Mitosis)
- Energy producing
- Keep information

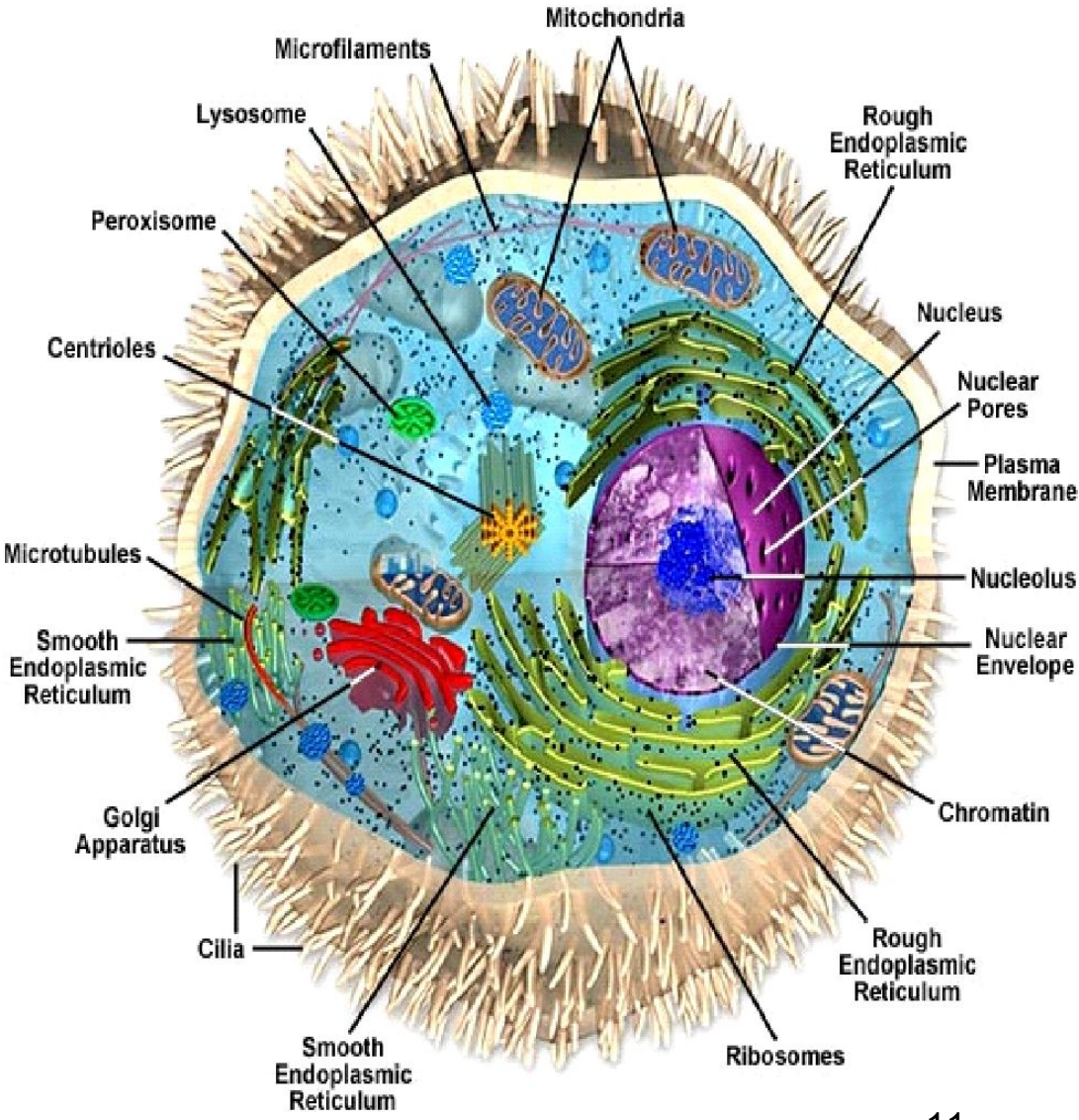
Prokaryotes

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



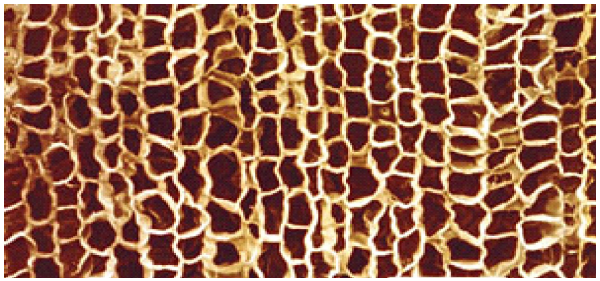
Eukaryotes

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

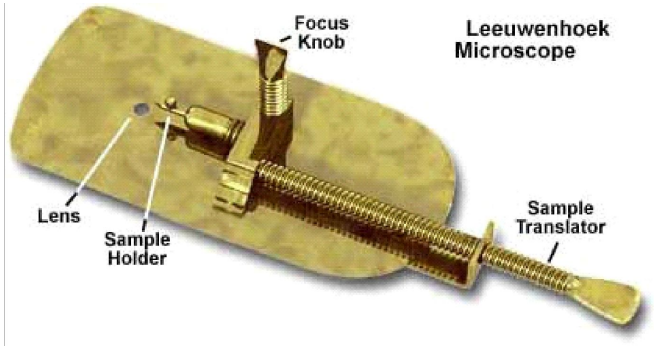


Cells and Cell Theory

- **In 1665, Robert Hooke used a microscope to examine a thin slice of cork (dead plant cell walls). Hooke called them "CELLS" because they looked like the small rooms that monks lived in called "Cells"**



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

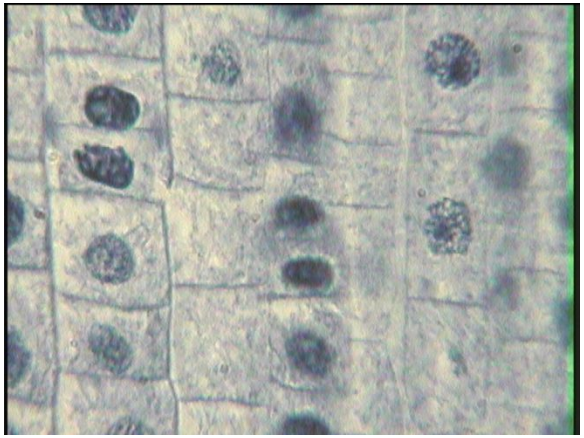


Cell Theory

- **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**

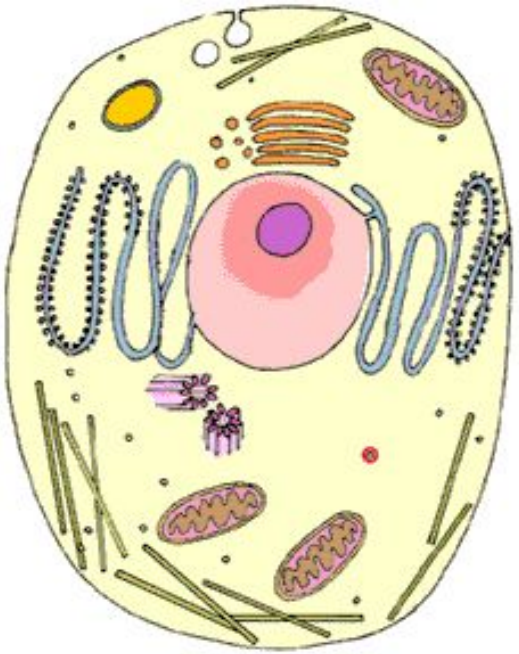
Beginning of the Cell Theory

- 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

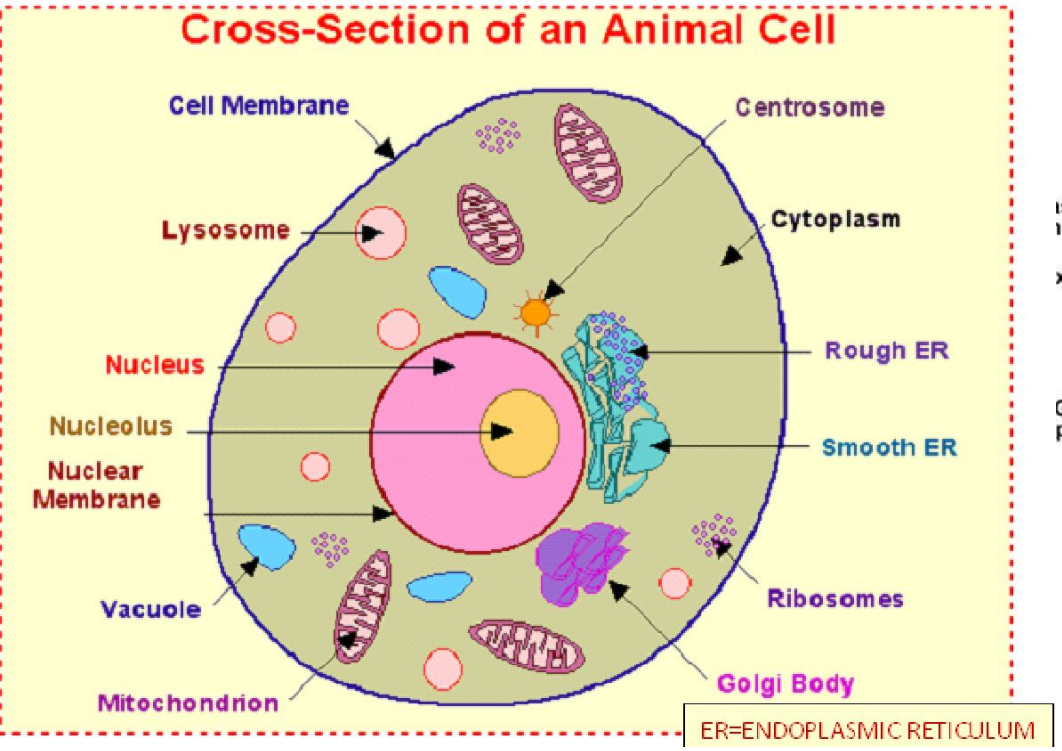
- All living things are made of cells
- Cells are the basic unit of structure and function in an organism (basic unit of life)
- Cells come from the reproduction of existing cells (cell division)

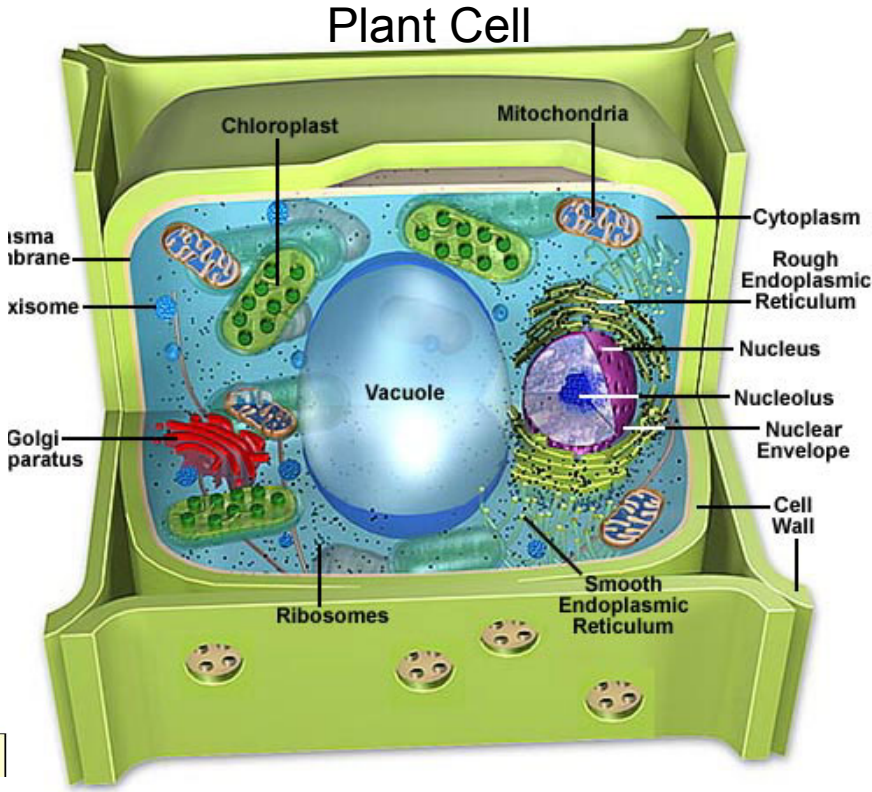


Cell Structure and Function

Organelles

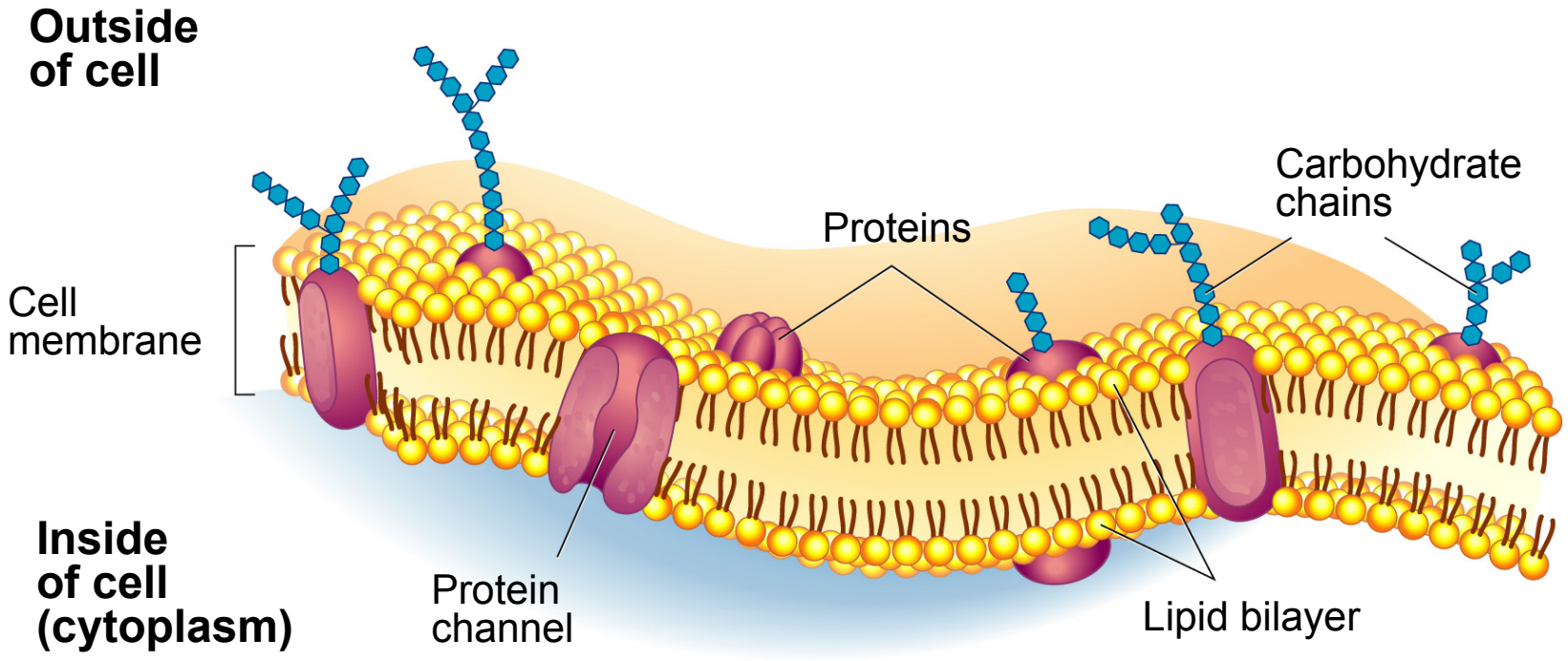
- Very **small** (Microscopic)
- Perform **various functions** for a cell
- Found in the **cytoplasm**
- May or may not be **membrane-bound**





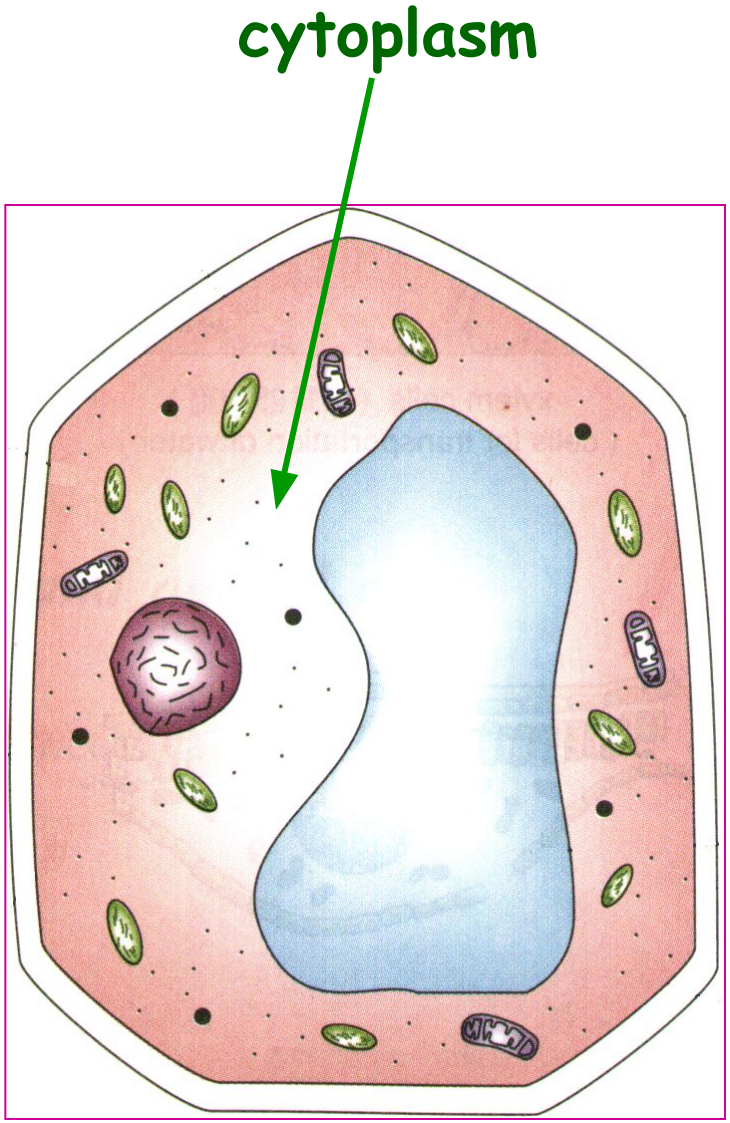
Cell or Plasma Membrane

- Composed of double layer of phospholipids and proteins
- Surrounds outside of ALL cells
- Controls what enters or leaves the cell
- Living layer



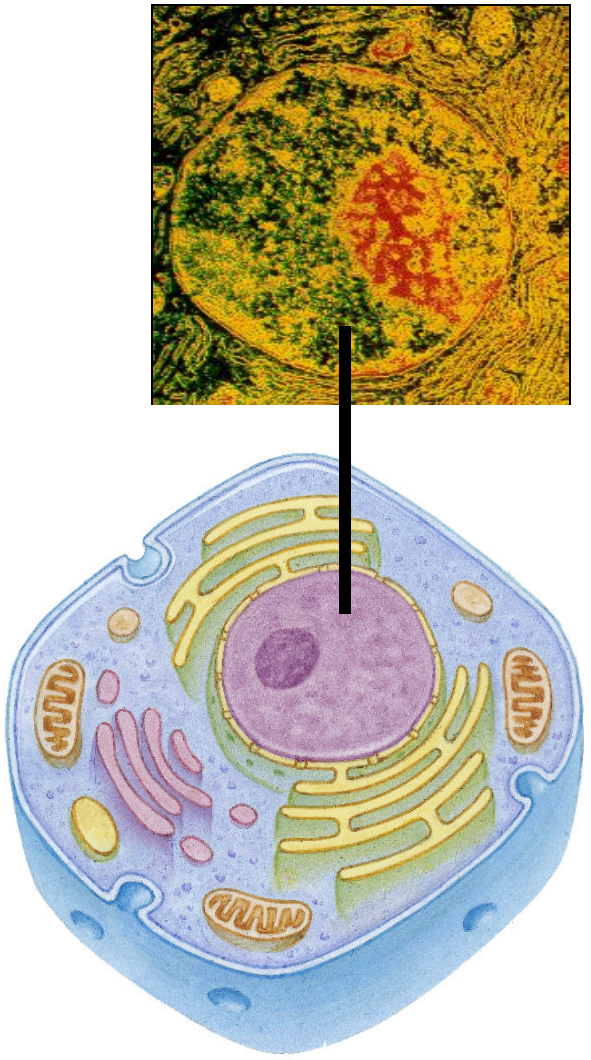
Cytoplasm of a Cell

- **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**



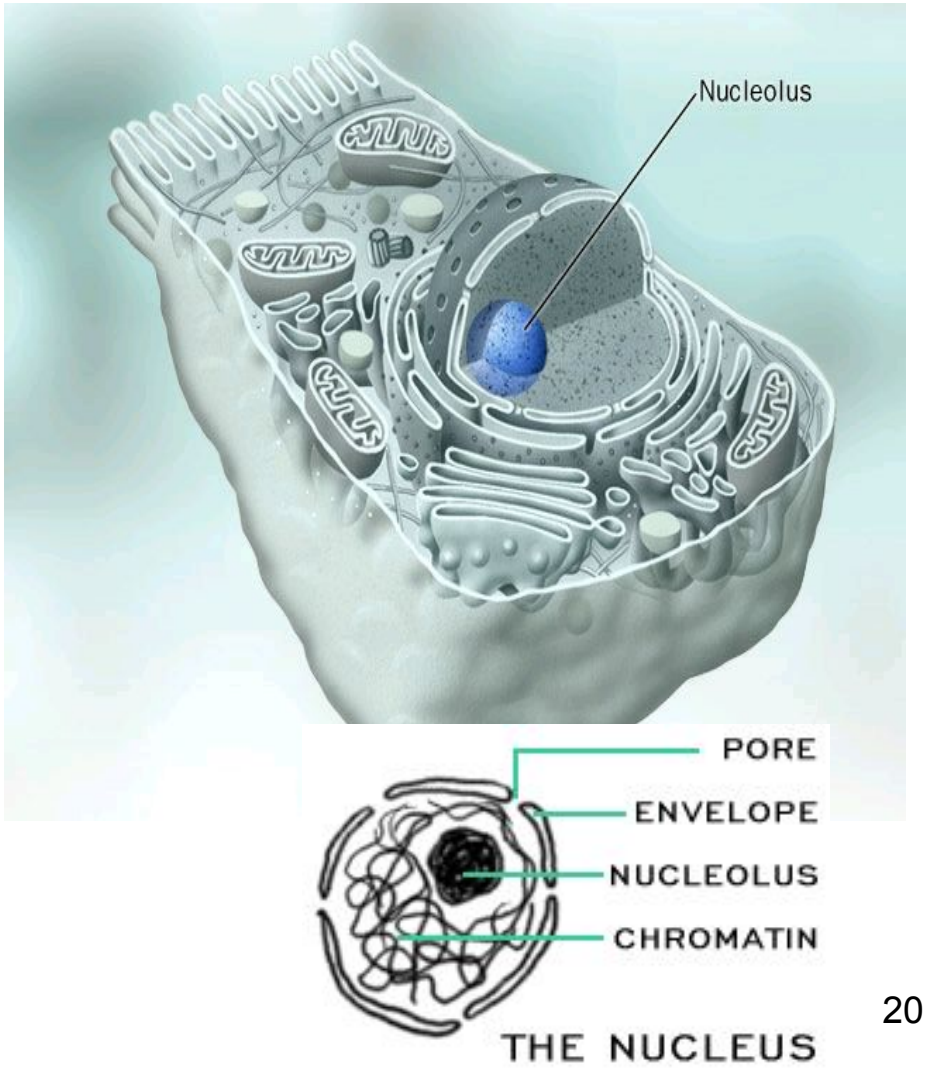
The Control Organelle - Nucleus

- 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



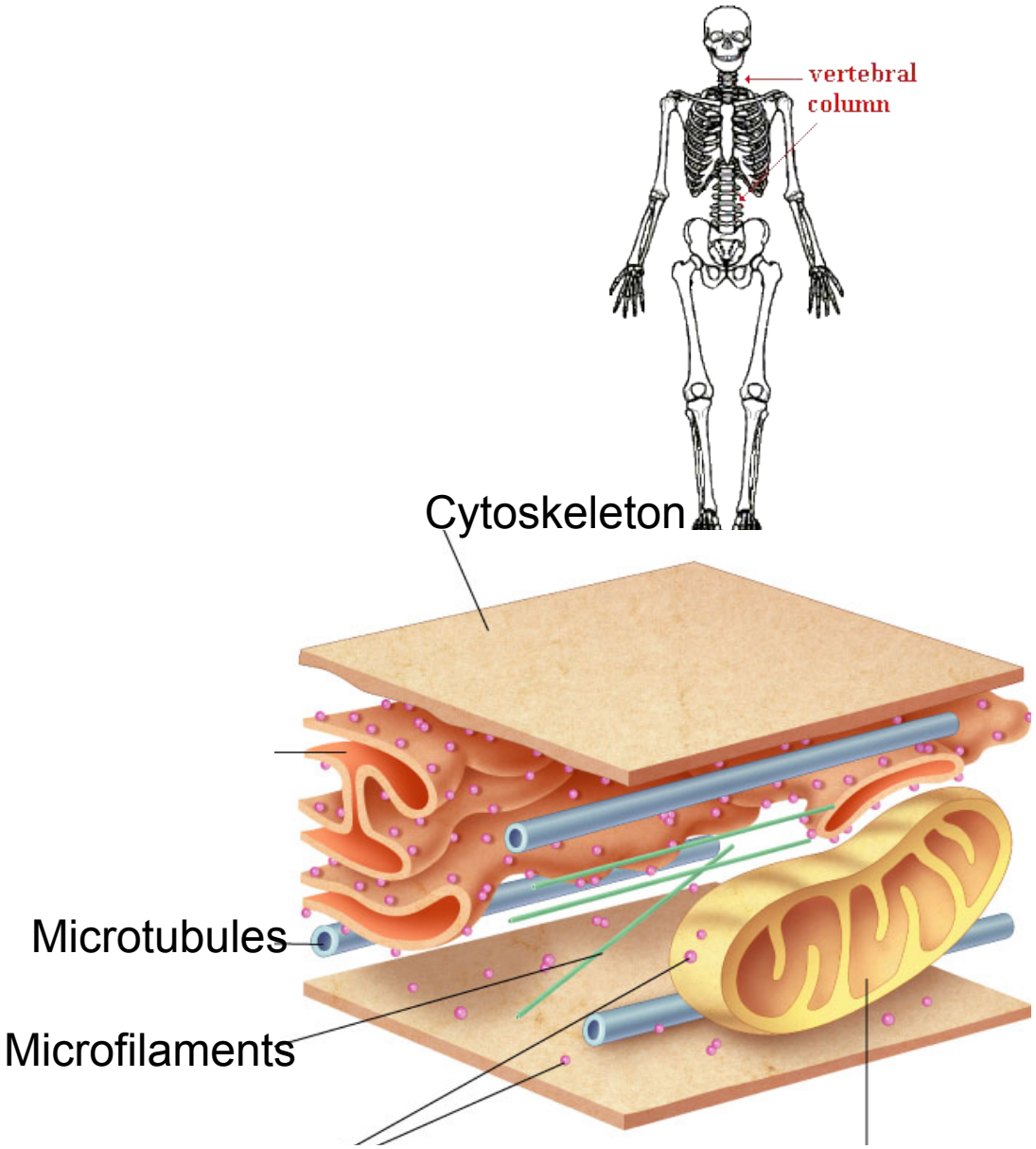
Nucleolus

- Inside nucleus
- Cell may have 1 to 3 nucleoli
- Disappears when cell divides
- Makes ribosomes that make proteins



Cytoskeleton

- Helps cell maintain **cell shape**
- Also help **move organelles** around
- Made of **proteins**
- **Microfilaments** are threadlike & made of ACTIN
- **Microtubules** are tube-like and made of TUBULIN

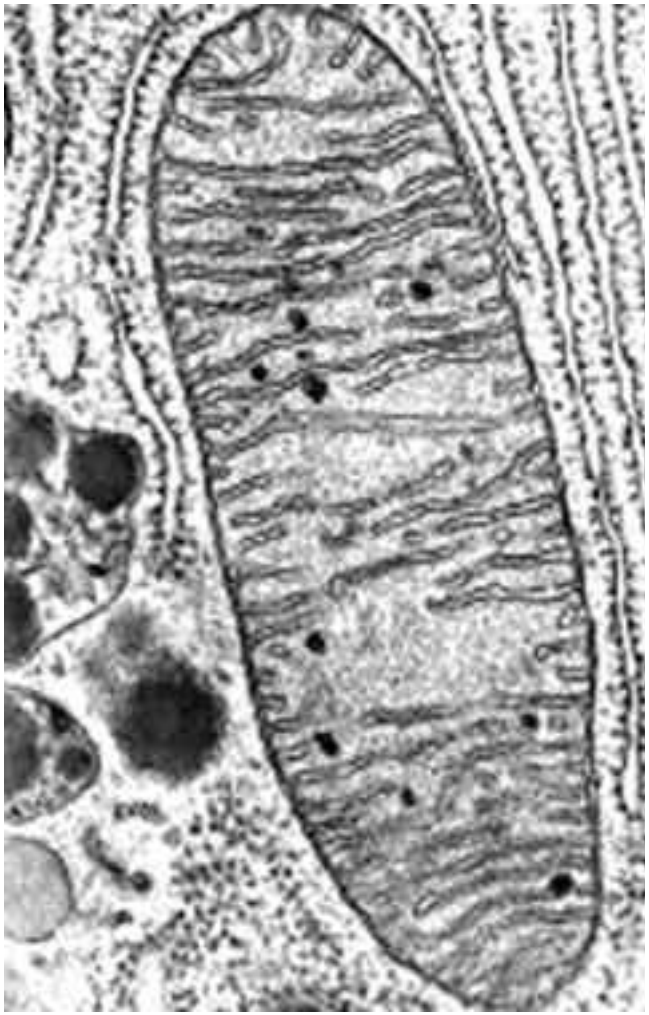


Centrioles

- 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

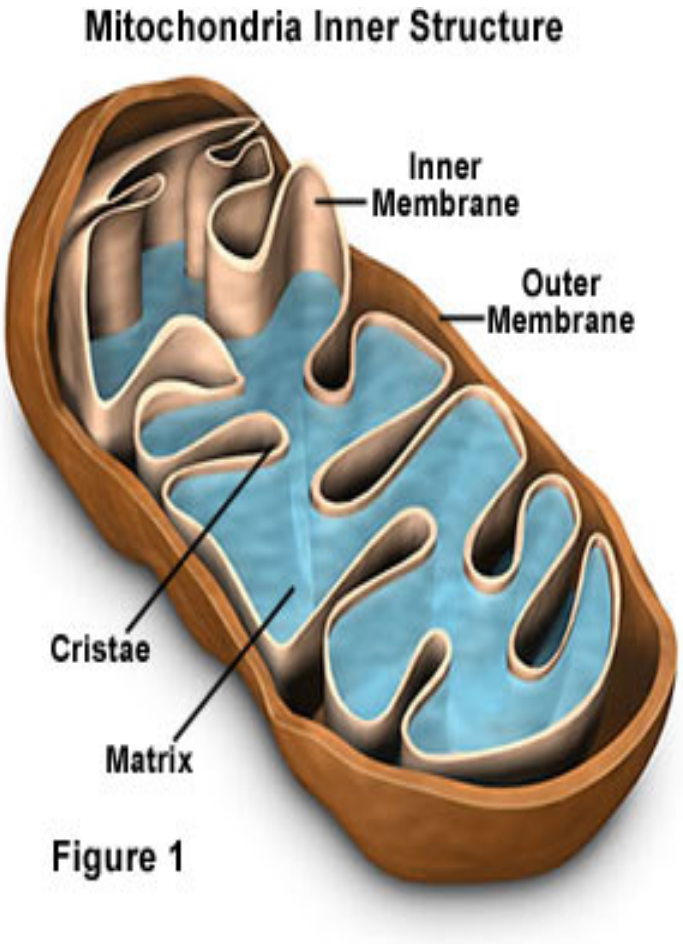
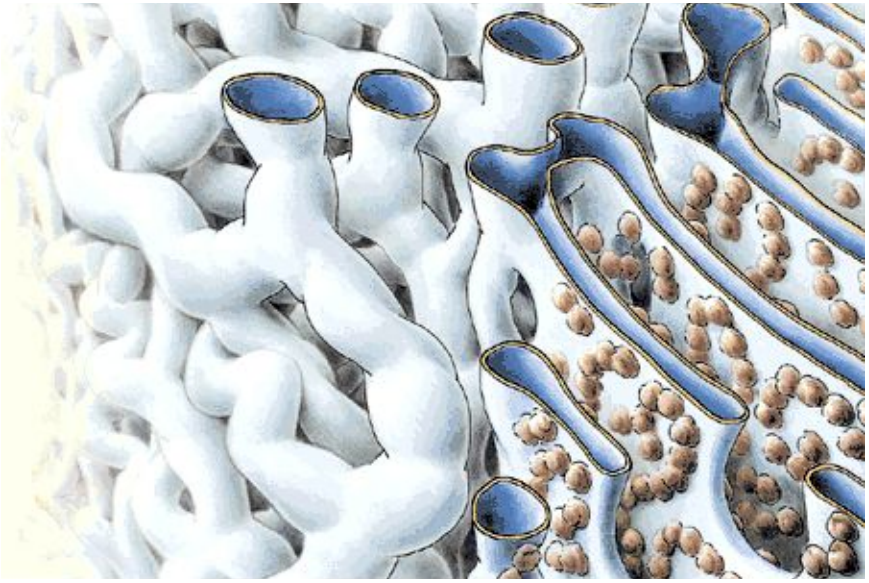


Figure 1

- **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**

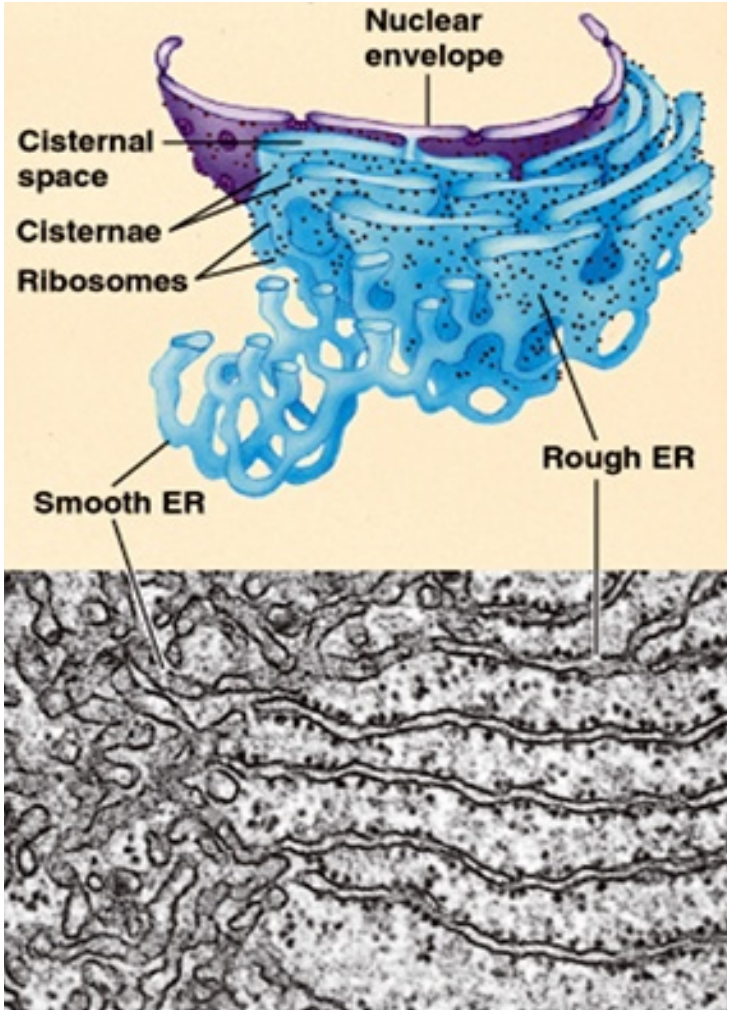
Endoplasmic Reticulum - ER

- Network of hollow membrane tubules
- 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
- Makes membrane proteins and proteins for EXPORT out of cell
- Proteins are made by ribosomes on ER surface
- They are then threaded into the interior of the Rough ER to be modified and transported

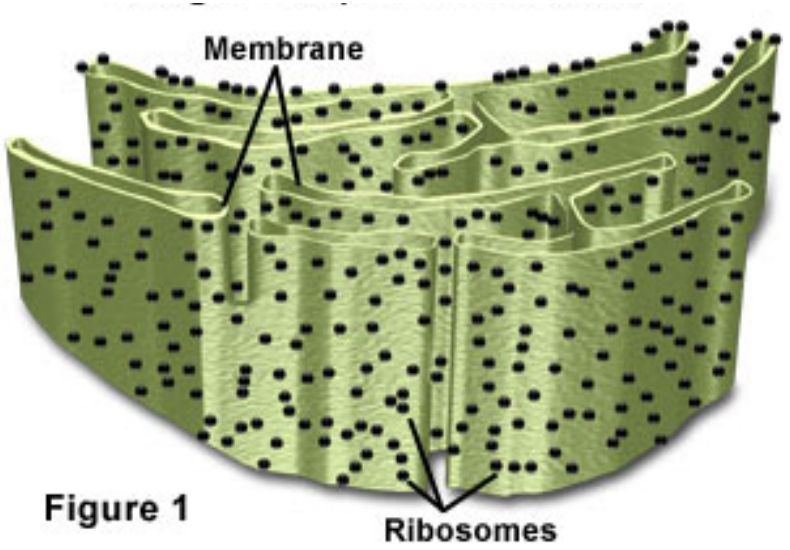
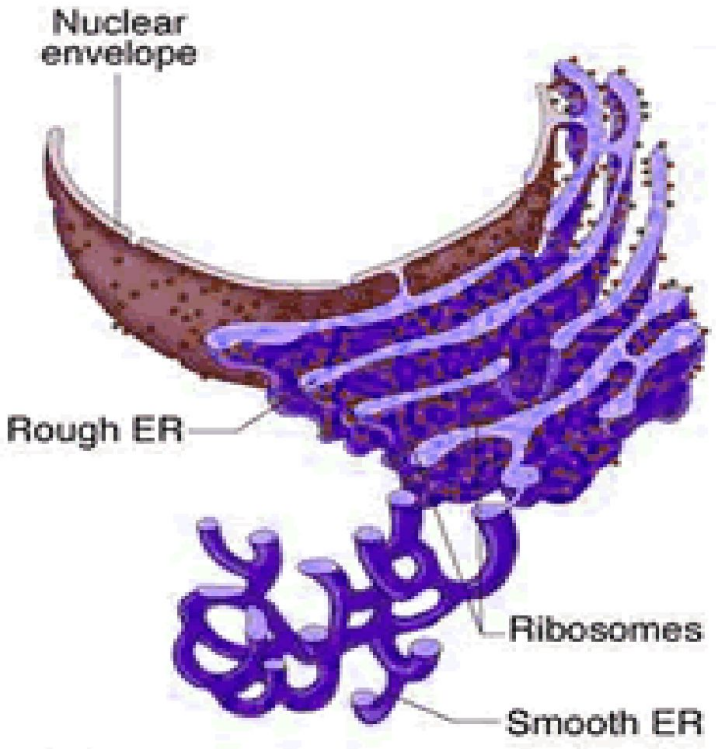


Figure 1

Smooth Endoplasmic Reticulum

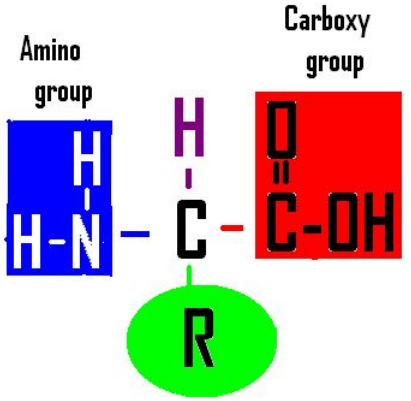
- ***Smooth ER*** **lacks ribosomes on its surface**
- **Is attached to the ends of rough ER**
- **Makes cell products that are USED INSIDE the cell**
- **Makes membrane lipids (steroids)**
- **Regulates calcium (muscle cells)**
- **Destroys toxic substances (Liver)**

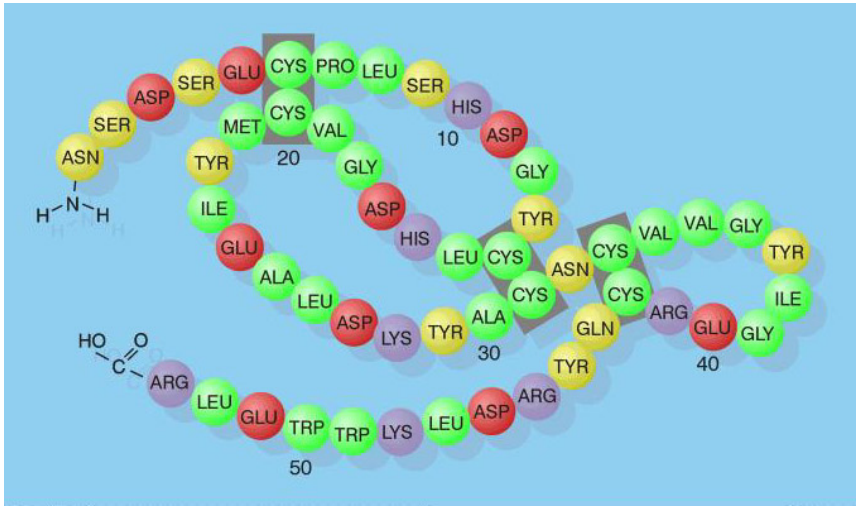


Includes nuclear membrane connected to ER connected to cell membrane (transport)

Ribosomes

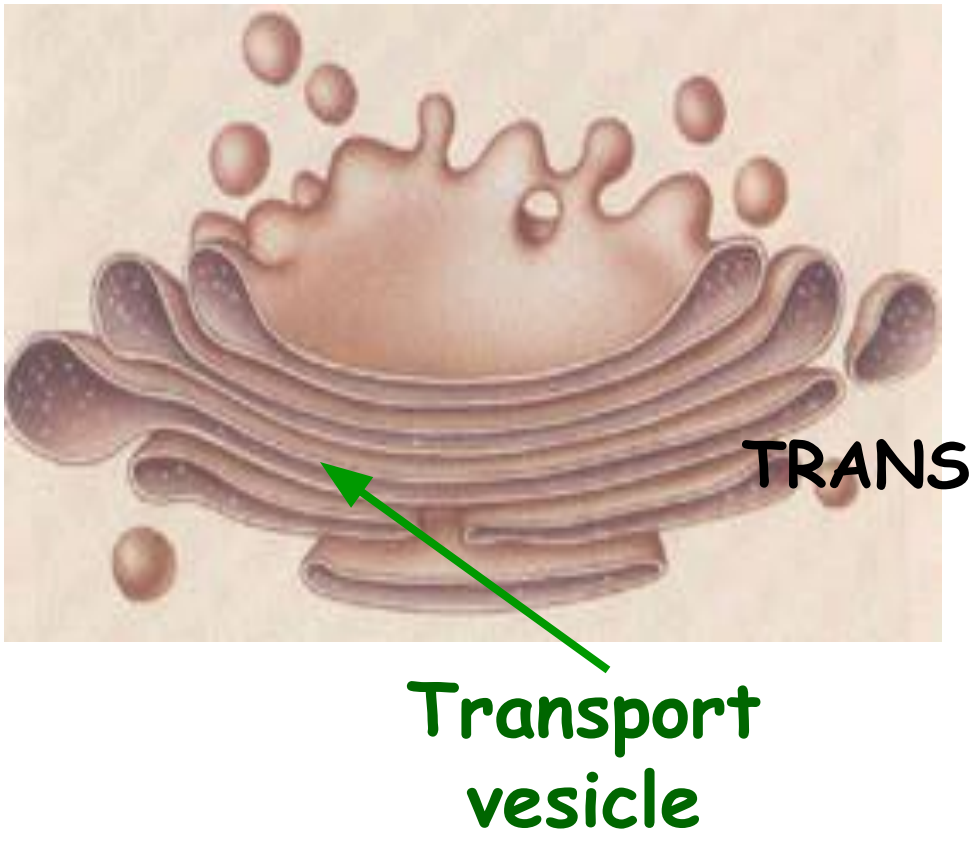
- Made of PROTEINS and rRNA
- "Protein factories" for cell
- Join amino acids to make proteins
- Central Dogma
- Subunits
- Process called protein synthesis
- Can be attached to Rough ER OR Be free (unattached) in the cytoplasm





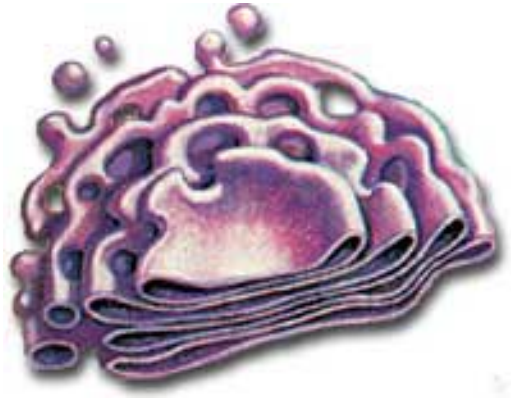
Golgi Bodies

- Stacks of flattened sacs
- Have a shipping side (trans face) and receiving side (cis face)
- Receive proteins made by ER
- Transport vesicles with modified proteins pinch off the ends

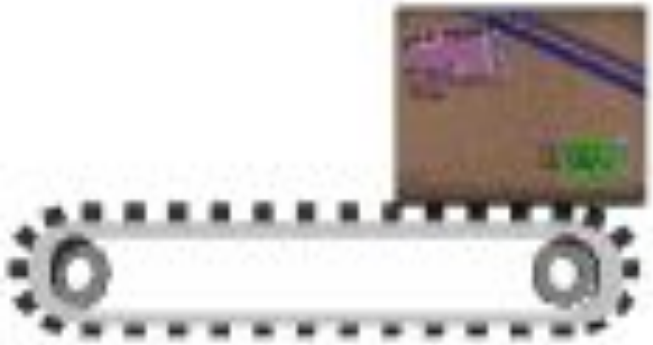


Golgi Bodies

Look like a stack of pancakes

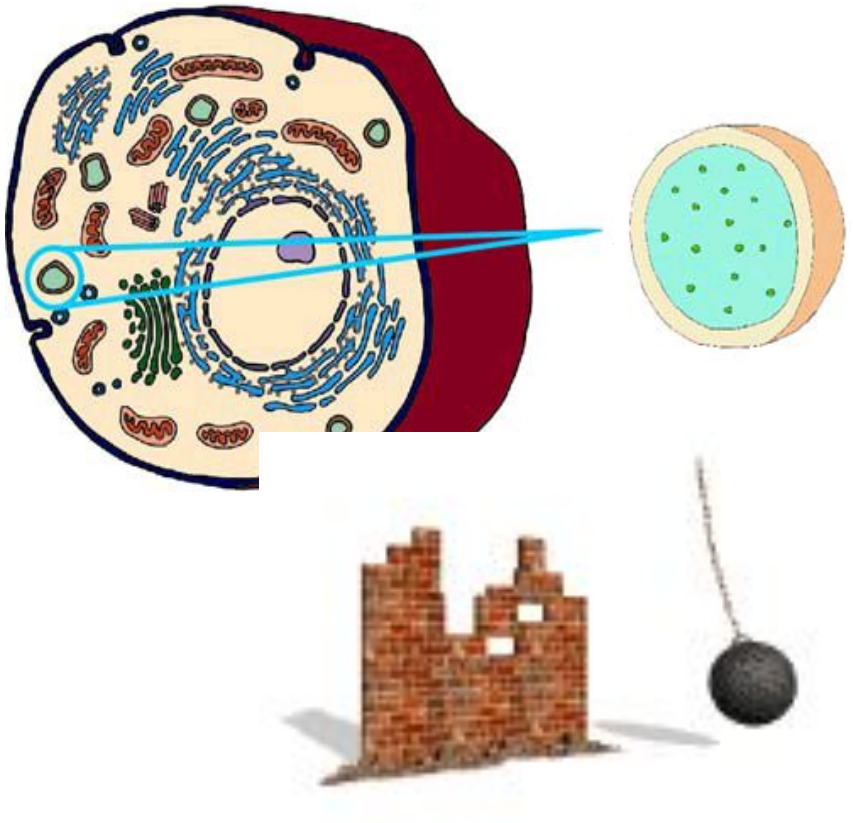


Modify, sort, & package
molecules from ER
for storage OR
transport out of cell



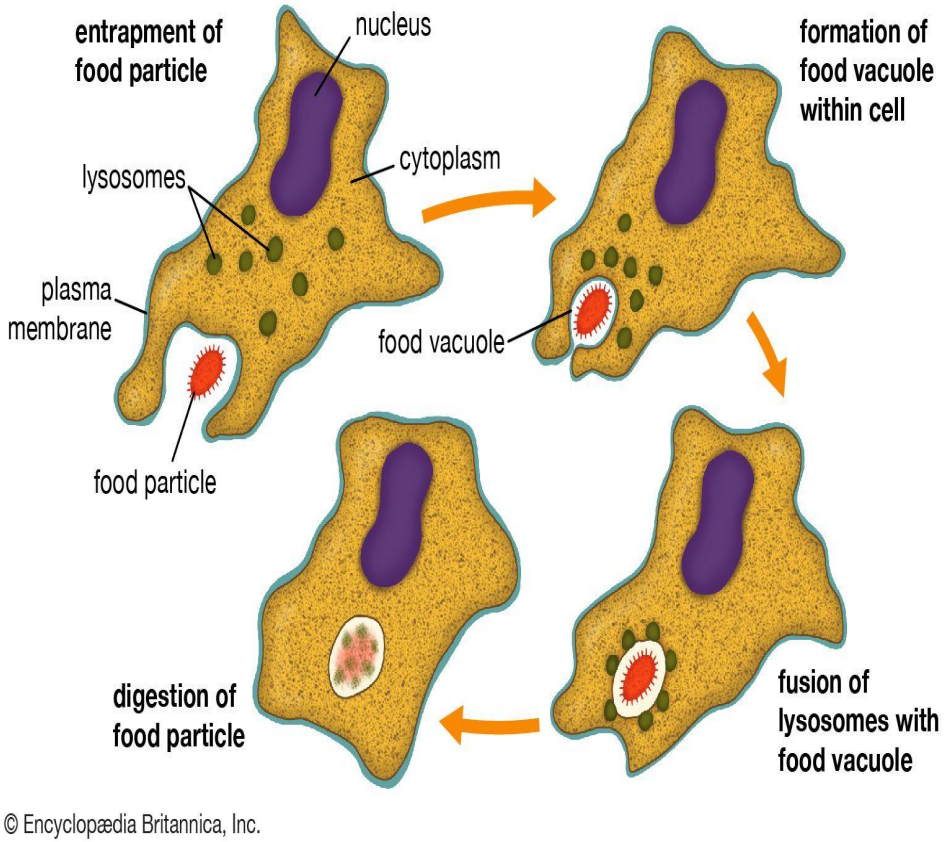
Lysosomes

- 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)



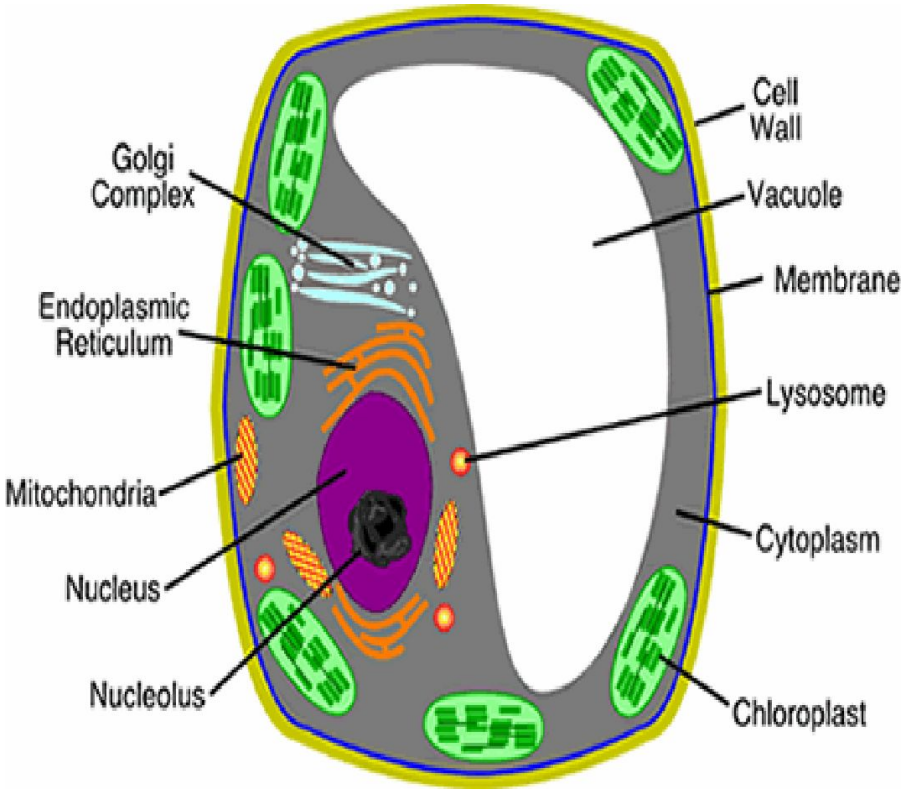
Lysosome Digestion

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



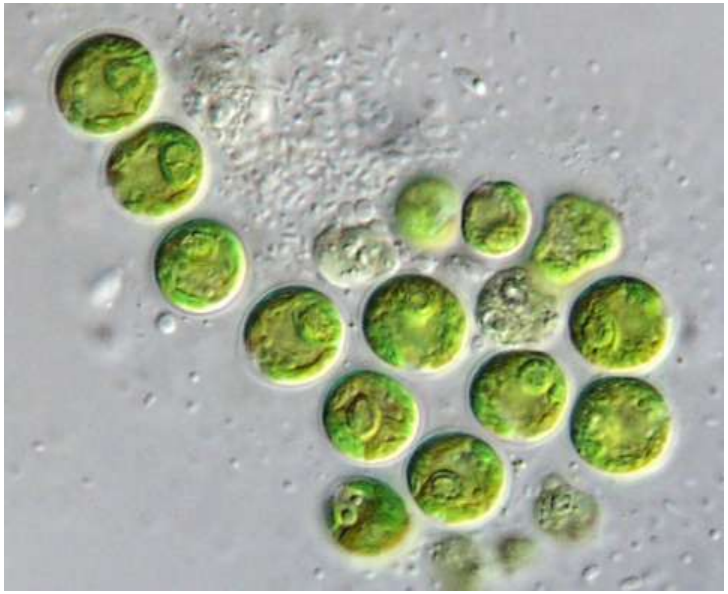
Vacuoles

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

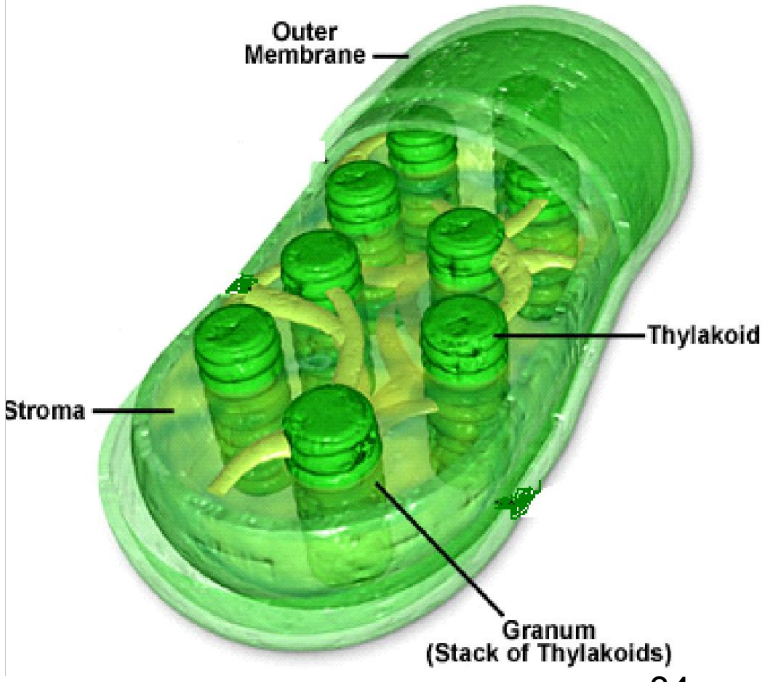


Chloroplasts

- 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

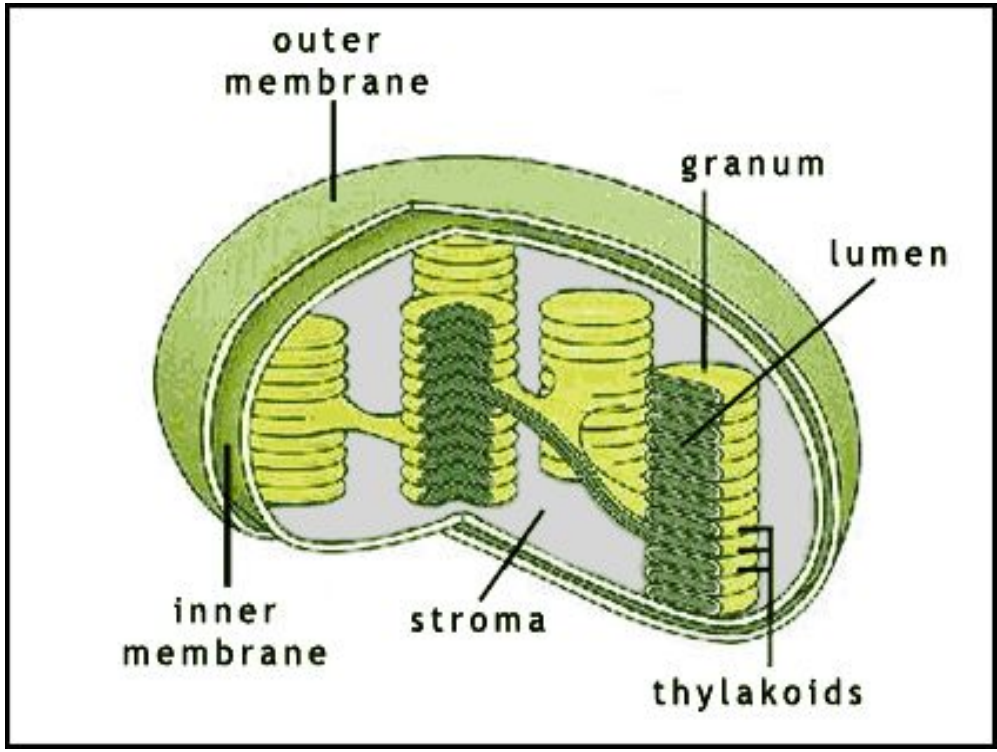


- Surrounded by DOUBLE membrane
- Outer membrane smooth
- Inner membrane modified into sacs called Thylakoids
- Thylakoids in stacks called Grana & interconnected
- Stroma – gel like material surrounding thylakoids



Chloroplasts

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

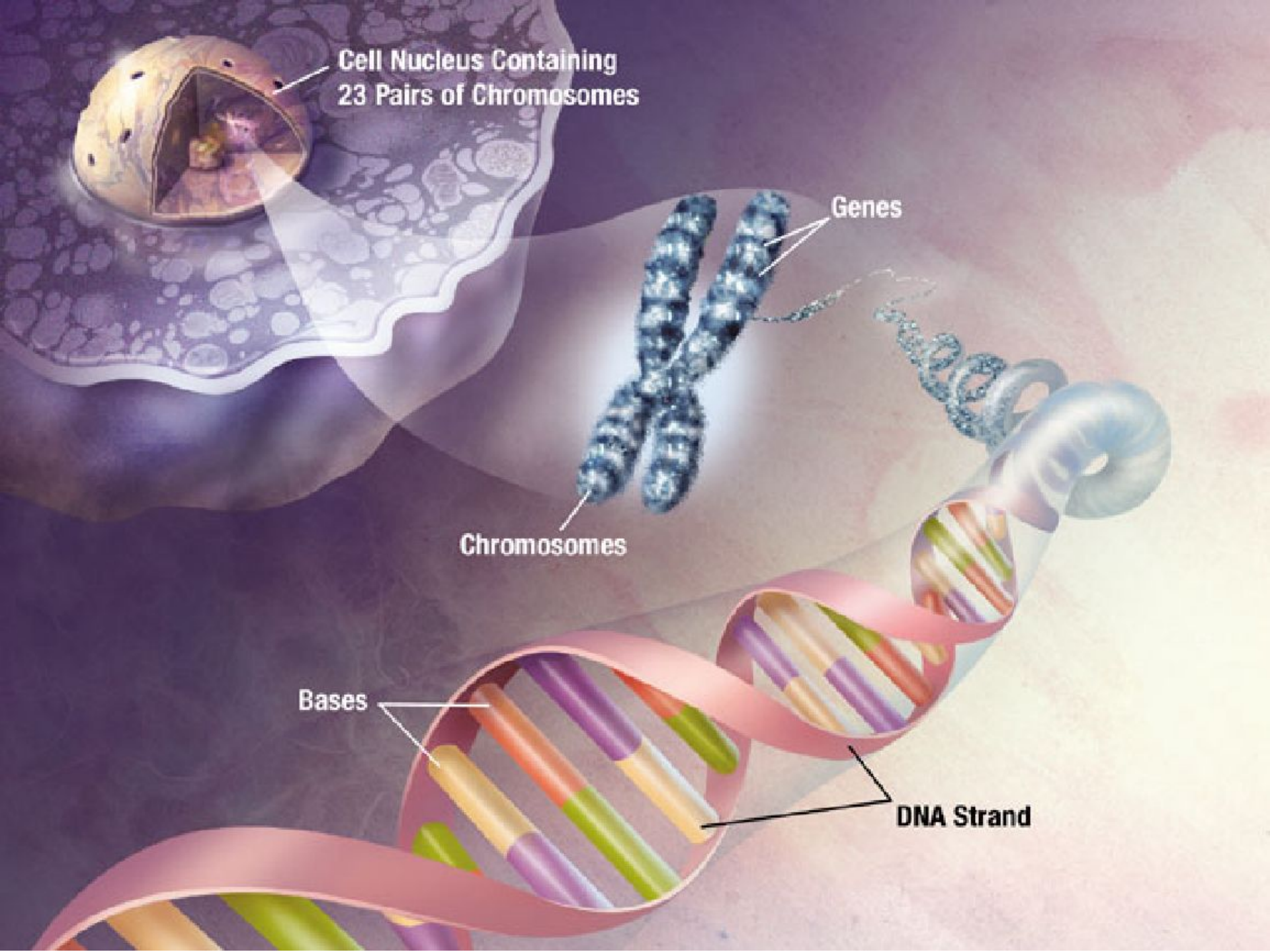


Genetic information and protein structure

Genetic information

- Genetic information is in the chromosomes found in the nucleus.
  - necessary for reproduction of species and therefore, its propagation on earth.
  - It is coded along the length of a polymeric molecule composed of four types of monomeric units. This polymeric molecule is deoxyribonucleic acid (DNA).
  - It is the chemical basis of heredity which is organised into **genes,** the fundamental units of genetic information. Genes control the synthesis of various types of ribonucleic acid (RNA).

- Nucleic acid is a polynucleotide consisting of nucleotides as the repeating subunits. Each nucleotide is made up of three components are, (i) pentosugar, (ii) nitrogenous base and (iii) phosphate.
- This linkages repeated many times to build up large structures containing hundreds to millions of nucleotides within a single giant molecule.
  - **Pentosugar:** It is a type of cyclic 5 carbon sugar, which connects two phosphate groups The type of sugar molecule in DNA is deoxyribose, where as in RNA is ribose.
  - **Nitrogenous base:** Nucleic acids contains 5 major heterocyclic bases, adenine (A), guanine (G), cytosine (C), thymine (T) and uracil (U). First four bases are common in DNA, in case of RNA thymine is replaced with uracil
  - **Phosphate:** A phosphate group is attached to the 5' carbon of the sugar by a phosphodiester linkage. This phosphate group is solely responsible for the strong negative charge of the nucleic acids.


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

Proteins

- **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		

Valine	Leucine	Isoleucine
Threonine	Methionine	Phenylalanine
Tryptophan	Lysine	Histidine

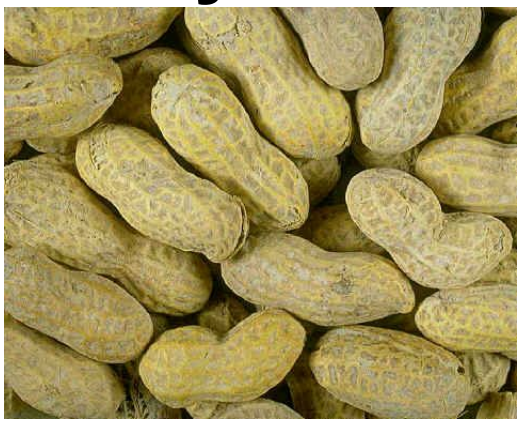
Arginine

Essential Amino Acids

Protein Functions in the Body

- **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**

Storage

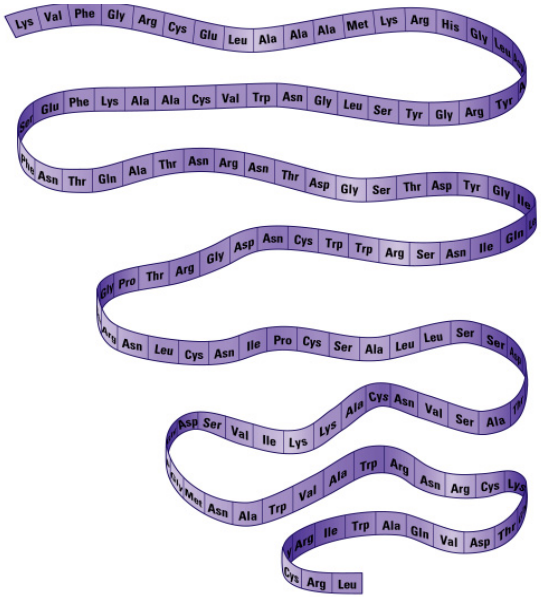


Structural

Transport

Primary Protein Structure

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



- Amino acids have in common a central carbon C atom to which are attached a hydrogen atom (H), amino group (NH2), and carboxyl group (COOH)

- Joined by peptide bond where carboxyl group of one amino acid condenses with an amino group of next to eliminate water

Secondary structure

The conformation of the polypeptide by twisting or folding is referred to as secondary structure.

Alpha helix

- Residues per turn with a hydrogen bond between C=O of n^{th} amino acid and NH of residue $n+4^{th}$ amino acid
- In globular proteins, alpha helix vary considerably in length ranging from four or five amino acids to every forty residues
- The average length is around ten residues corresponding to three turns
- The rise per residue of an alpha helix is 1.5A along the helical axis which corresponds to about 15A from one end to the other of an average alpha helix
- The width of the alpha helix is around 4A.
- Almost all observed alpha helix is right-handed helix in a protein
- Alanine, glutamine leucine, and methionine are strong helix-forming amino acids
- Proline, Glycine, Tyrosine, and serine occur in the helix rarely.

Beta sheet

- Build up from different regions of the polypeptide chain
- Beta strands are 5 to 10 aa residues and interact in parallel or antiparallel to form pleated sheets.
- Beta sheets can also combine into mixed beta sheets with some beta strands pairs parrel and some anti-parallell.

Tertiary structure

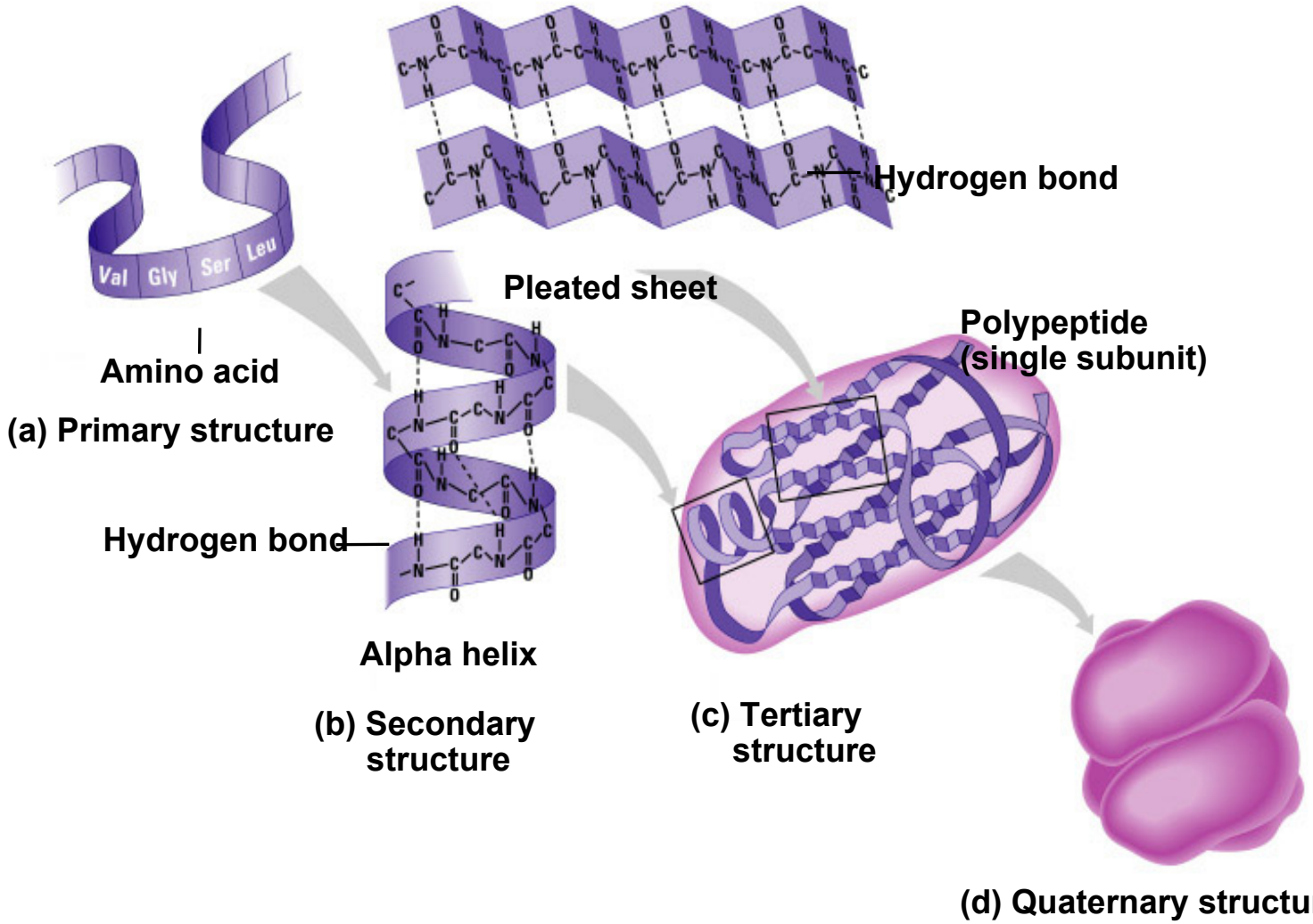
- Alpha helix and beta sheets fold up compact into super secondary structures or domains called tertiary structure
- One important tertiary interaction is the di sulphide bond. Di sulphide bond is formed between the sulphur atoms of cysteine residues.
- Disulphide provides mechanical strength to the protein and also determines the chemical properties by stabilizing the correct active conformation.
- Major stabilizing factor in the tertiary structure of the protein is
    - Hydrophobic interaction
    - Polar and non polar amino acid interaction
    - Salt bridges between oppositely charged amino acids.
    - Hydrogen bonding in the interior of the protein

Quaternary structure

- Protein in its active form exists as an aggregate of more than one folded polypeptide. The macromolecular structure so build-up is called the quaternary structure

- Non covalent interactions and disulphide bridges are responsible for quaternary structure

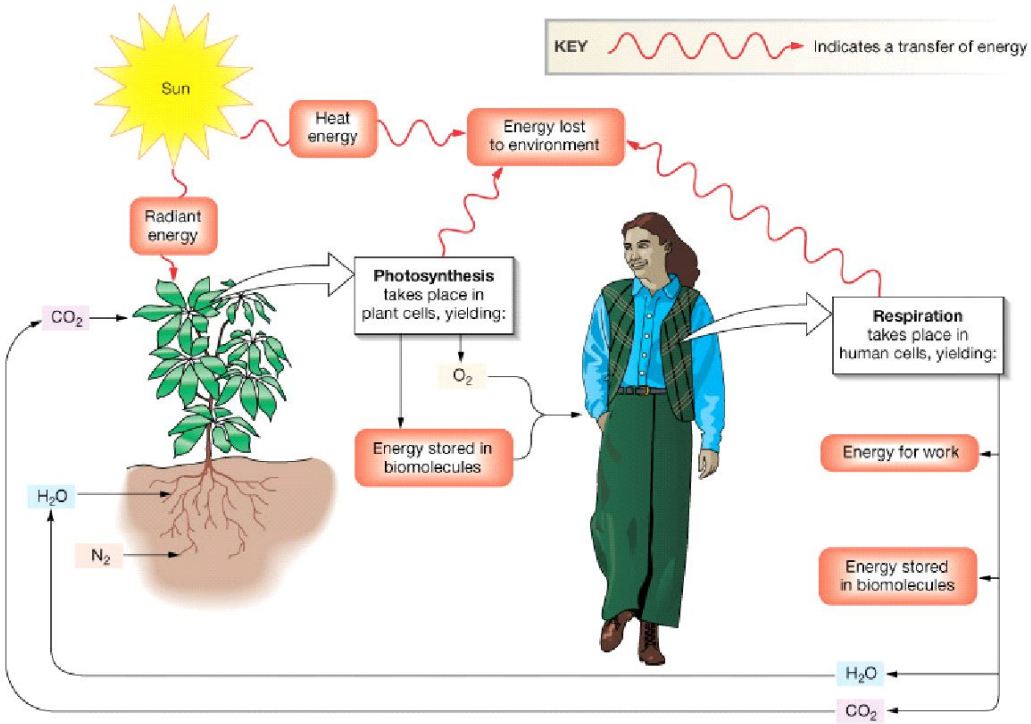
Protein Structures or CONFORMATIONS



Cell metabolism

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.

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

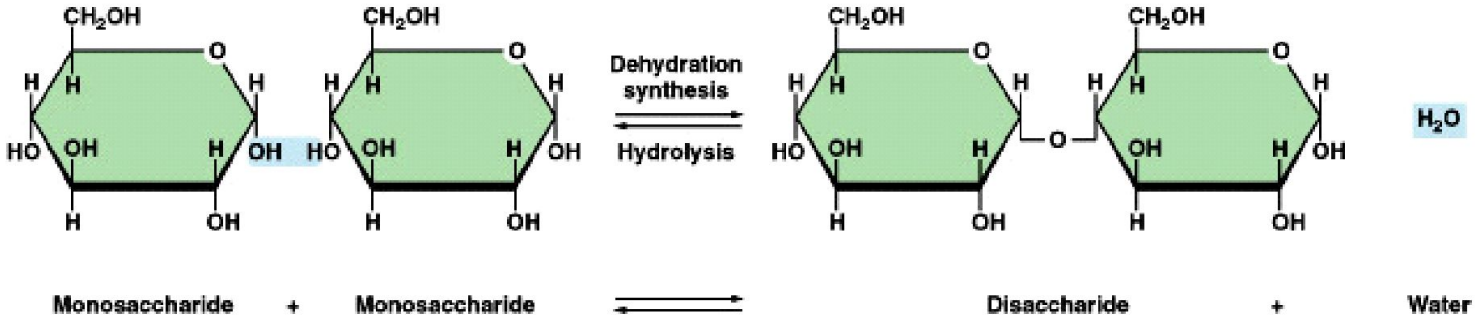
- type of anabolic process
- used to make polysaccharides, triglycerides, and proteins
- produces water

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



Carbohydrate metabolism

- **Carbohydrate metabolism** is a fundamental biochemical process that ensures a constant energy supply to living cells.
- During digestion, carbohydrates are broken down into simple, soluble sugar glucose that can be transported across the intestinal wall into the circulatory system to be transported throughout the body and absorbed into the cell
- Once the absorbed glucose is transported to the tissues, **cellular respiration** begins
- on glycolysis, a process where glucose is oxidized, releasing the energy stored in its bonds to produce ATP. The last step in glycolysis produces the product **pyruvate**
- The pyruvate molecules generated during glycolysis are transported across the mitochondrial membrane into the inner mitochondrial matrix, where they are metabolized by enzymes in a pathway called the **Krebs cycle**
- Oxidative phosphorylation
- During the Krebs cycle, high-energy molecules, including ATP, NADH, and FADH2, are created. NADH and FADH2 then pass electrons through the electron transport chain in the mitochondria to generate more ATP molecules
- important pathways in carbohydrate metabolism
  - pentose phosphate pathway conversion of hexose sugars into pentoses,
  - glycogenesis -conversion of excess glucose into glycogen, stimulated by insulin,
  - glycogenolysis conversion of glycogen polymers into glucose, stimulated by glucagon
  - gluconeogenesis *de novo* glucose synthesis

Amino acid Metabolism

Amino acid biosynthesis

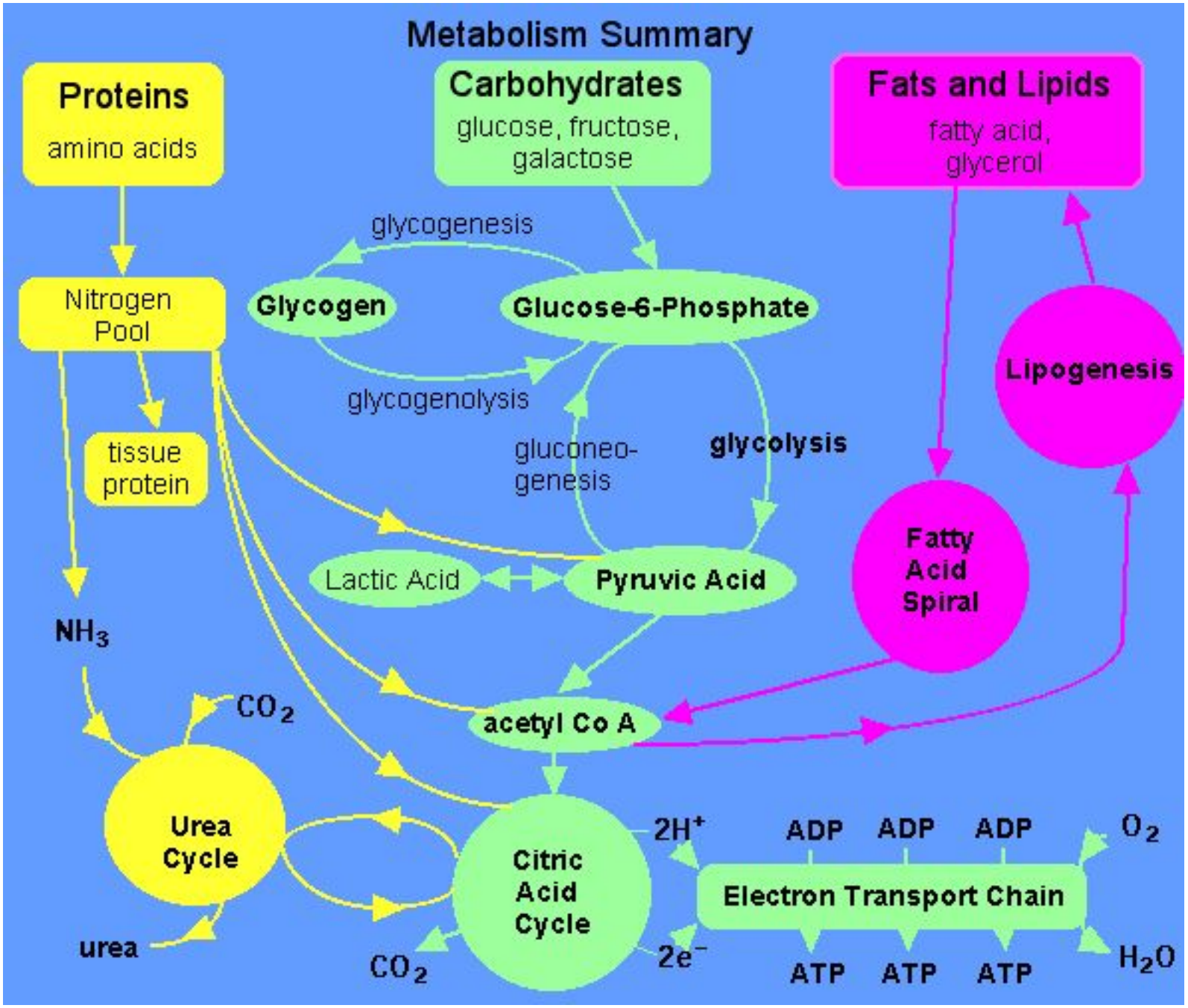
- Amino acids derive mainly through intermediate of glycolysis and citric acid cycle or pentose phosphate pathway.

Amino acid Catabolism

- Removal or exchange of functional groups
- Involves transamination, deamination, and decarboxylation
- Releases excess nitrogen in the form of ammonium (**NH_4^+**), which then enters the urea cycle), which then enters the urea cycle, is converted into urea, and excreted through the urine
- Catabolism of the remaining carbon skeleton
- In general, all 20 AAs can be broken down into 1 of 6 intermediates: pyruvateIn general, all 20 AAs can be broken down into 1 of 6 intermediates: pyruvate, acetyl-CoAIn general, all 20 AAs can be broken down into 1 of 6 intermediates: pyruvate, acetyl-CoA, oxaloacetateIn general, all 20 AAs can be broken down into 1 of 6 intermediates: pyruvate, acetyl-CoA, oxaloacetate, alpha-ketoglutarate, succinyl-CoAIn general, all 20 AAs can be broken down into 1 of 6 intermediates: pyruvate, acetyl-CoA, oxaloacetate, alpha-ketoglutarate, succinyl-CoA, and fumarate.
- Ketogenic AAs metabolize to acetyl-CoAKetogenic AAs metabolize to acetyl-CoA, later used in the citric acid cycleKetogenic AAs metabolize to acetyl-CoA, later used in the citric acid cycle, ketogenesisKetogenic AAs metabolize to acetyl-CoA, later

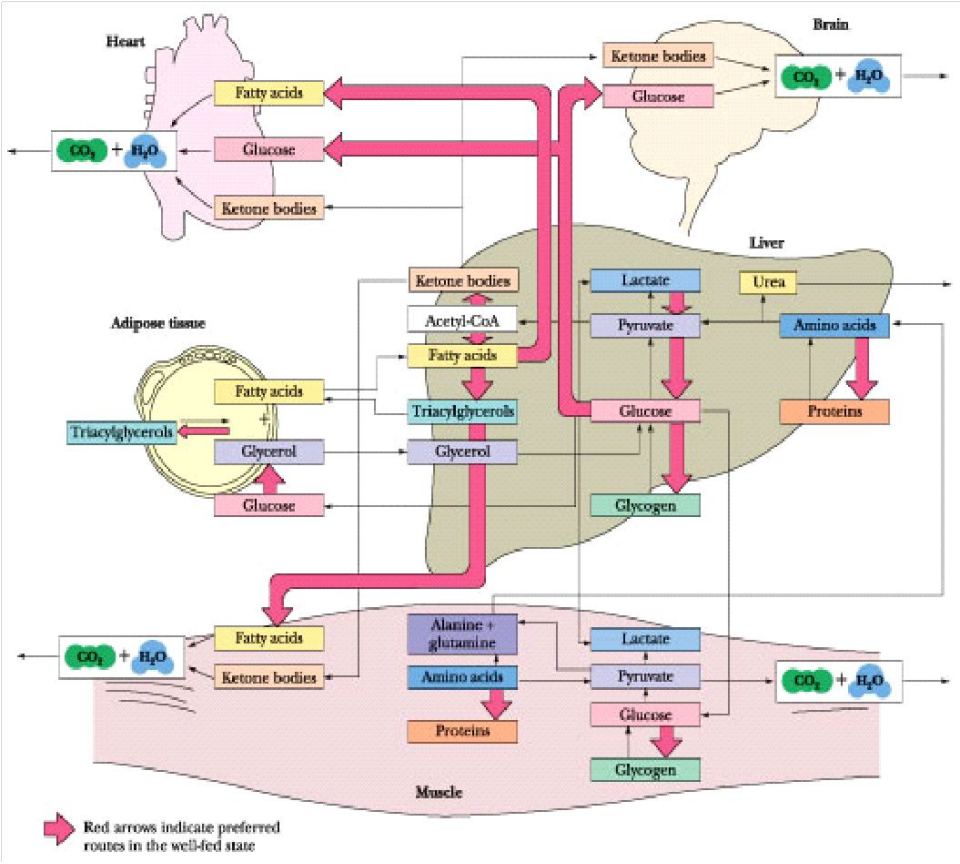
• Fatty Acid Metabolism

- Hydrocarbon chain with terminal carboxylate group.
- Process of degradation converts a fatty acid in to activated acetyl units which are later processed by citric acid cycle.
- Activated fatty acid gets oxidized double bond is formed hydration & addition of oxygen
- 4C fragment is cleaved by co enzyme A acetyl CoA & fatty acid with two carbon less than the parent fatty acid
- Fatty acid with even number of carbon atoms : process repeats until the fatty acid is completely converted in to acetyl CoA
- Fatty acid with odd number of carbon atoms: results in formation of citric acid cycle intermediates.


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

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



Homoeostasis

Homoeostasis

Definition : Condition in which internal environment of the body remains constant despite change in external environment.

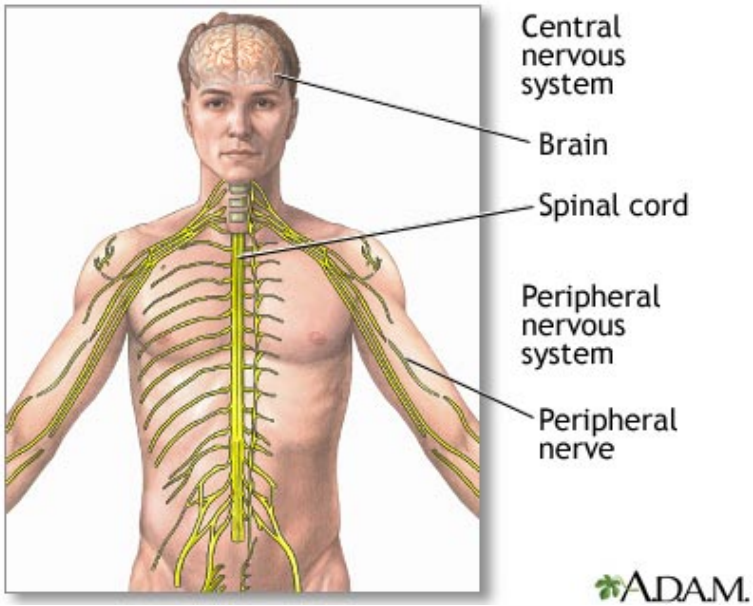
Maintaining a constant internal environment with all that the cells need to survive (O_2, glucose, minerals, ions, and waste removal) is necessary for individual cells. The processes by which the body regulates its internal environment are referred to as *homeostasis*.

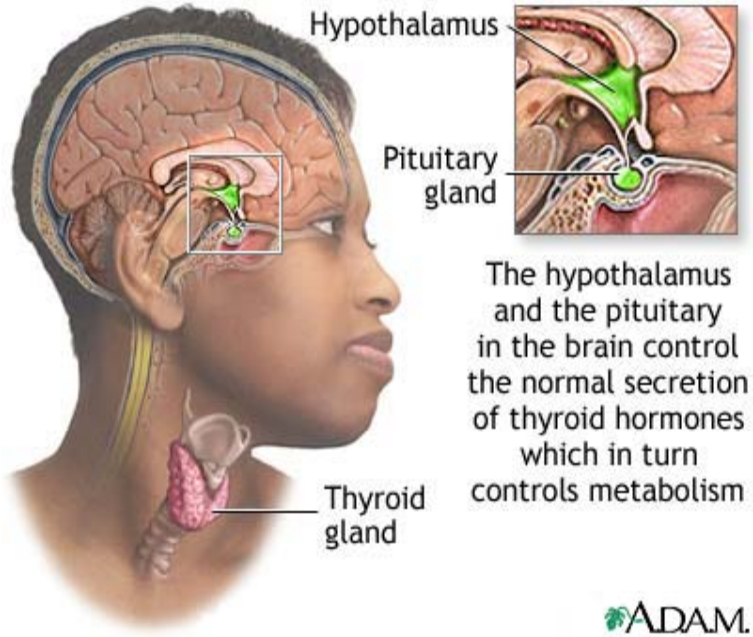
Components : 1) sensor
2) afferent pathway
3) integration center or comparator
4) efferent pathway
5) effector organ(s)

- Physiological control systems are the nervous system, endocrine system, and immune system through feedback mechanisms.

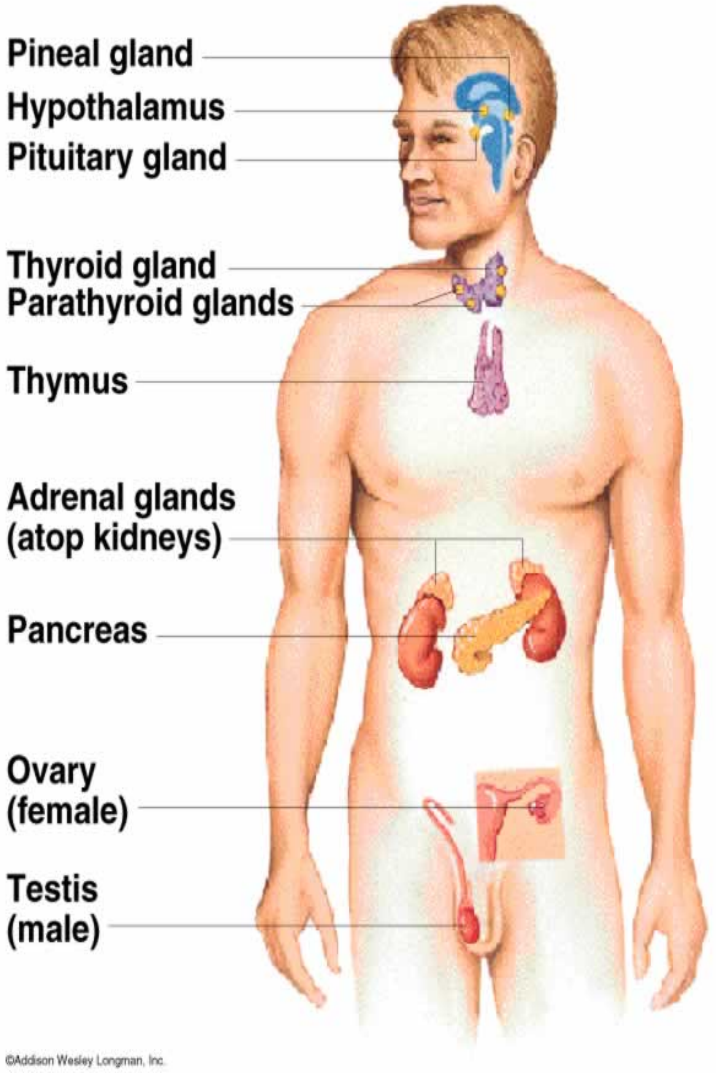
Intrinsic homeostatic systems

- **Nervous System**
- The nervous system maintains homeostasis by controlling and regulating the other parts of the body.
  - A deviation from a normal set point acts as a stimulus to a receptor, which sends nerve impulses to a regulating center in the brain. The brain directs an effector to act in such a way that an adaptive response takes place.
- The nervous system has two major portions: the **central nervous system** and the **peripheral nervous system**.
- Regulating centers are located in the central nervous system, consisting of the brain and spinal cord.
  - The hypothalamus is a portion of the brain particularly concerned with homeostasis; it influences the action of the medulla oblongata, a lower part of the brain, the autonomic nervous system, and the pituitary gland.
- The peripheral nervous system consists of the spinal nerves. The **autonomic nervous system** is a part of peripheral nervous system and contains motor neurons that control internal organs. It has two divisions, the **sympathetic** and **parasympathetic** systems.



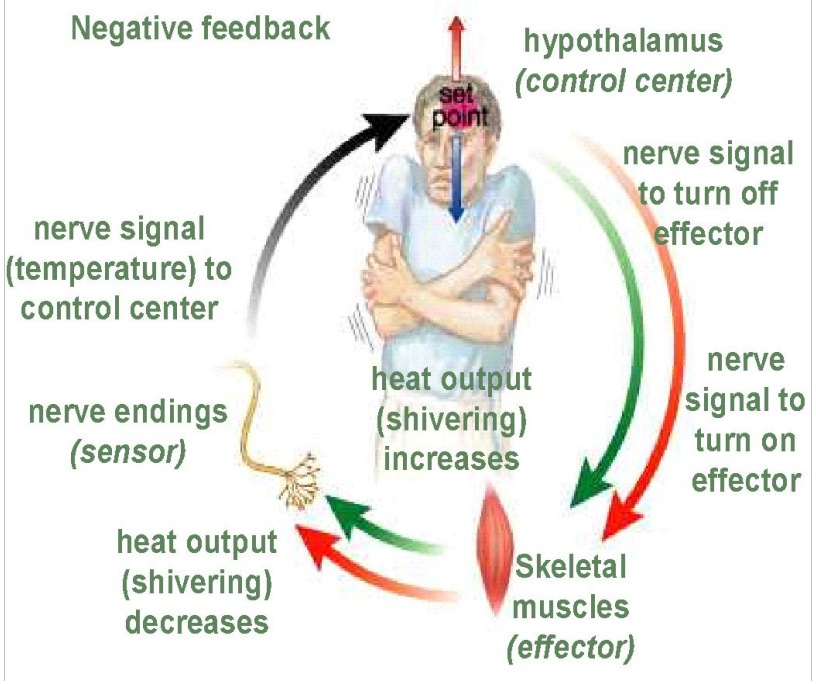


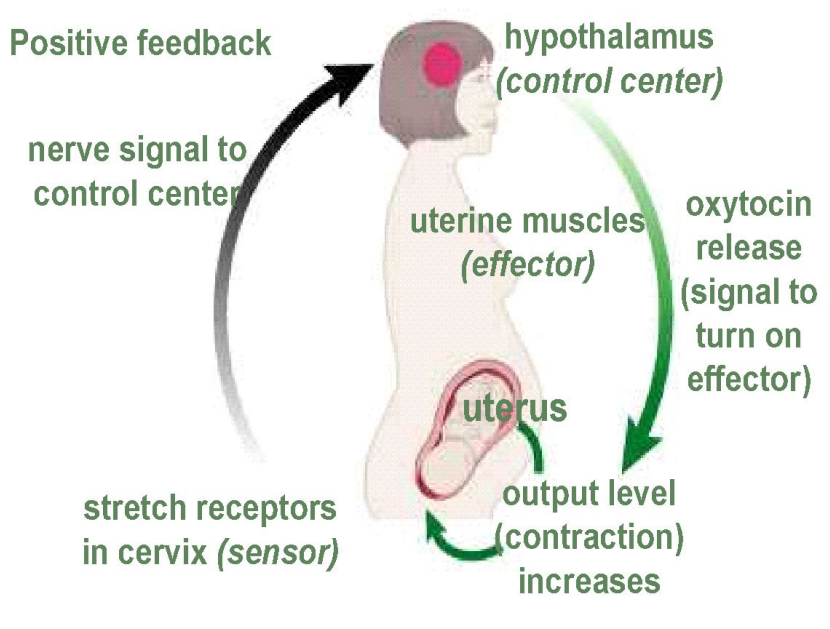
- **Endocrine System**
- The endocrine system consists of glands which secrete special compounds called **hormone**s into the bloodstream.
- Each hormone has an effect on one or more target tissues. In this way the endocrine system regulates the metabolism and development of most body cells and body systems.
- For e.g. the endocrine system has sex hormones that can activate sebaceous glands, development of mammary glands, alter dermal blood flow, and release lipids from adipocytes etc besides governing reproduction.
- In the muscular system, hormones adjust muscle metabolism, energy production, and growth.
- In the nervous system, hormones affect neural metabolism, regulate fluid/electrolyte balance and help with reproductive hormones that influence CNS (central nervous system), development and behaviours.
- In the cardiovascular system, hormones regulate heart rate and blood pressure.
- Hormones also have anti-inflammatory effects and control the lymphatic system.



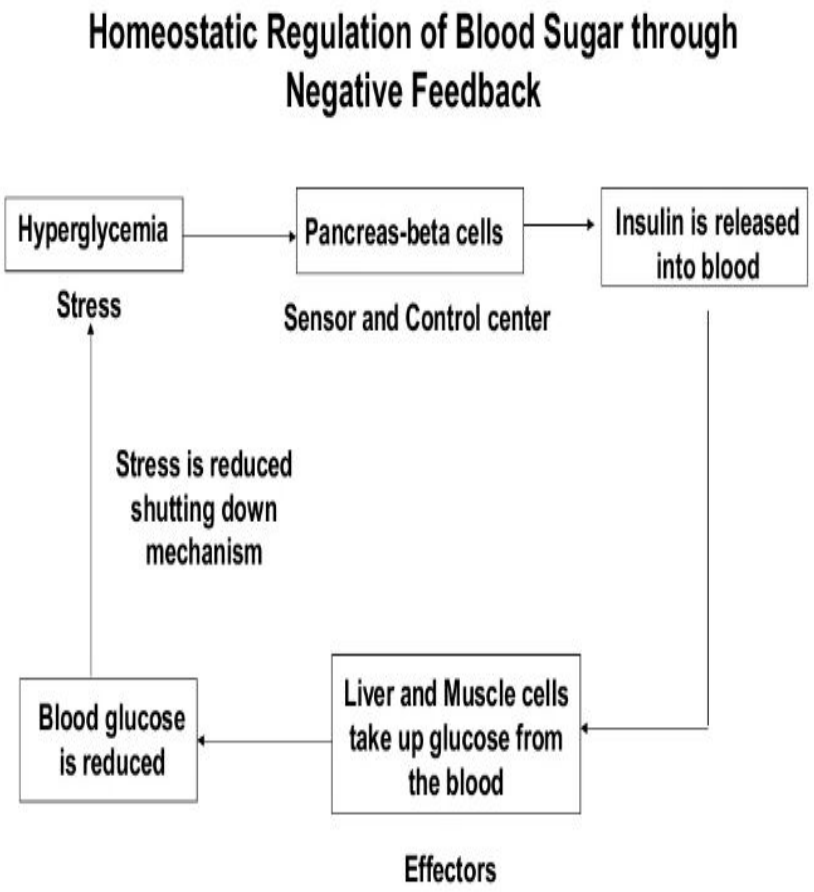
- Negative feedback : a control system that causes the value of a physiological measurement to change in the direction **opposite** to the initial deviation from set point.

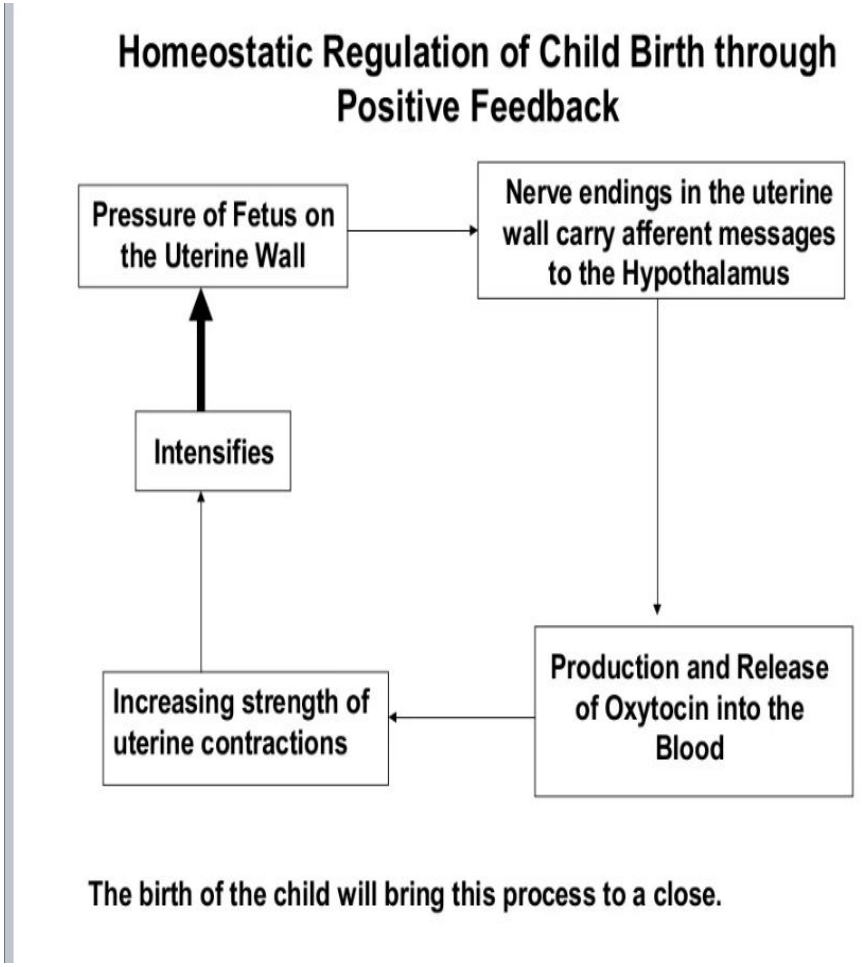
- Positive feedback : a control system that causes the value of a physiological measurement to change in the **same** direction as the initial deviation from set point.





Homoeostasis





Cell growth, reproduction, and differentiation

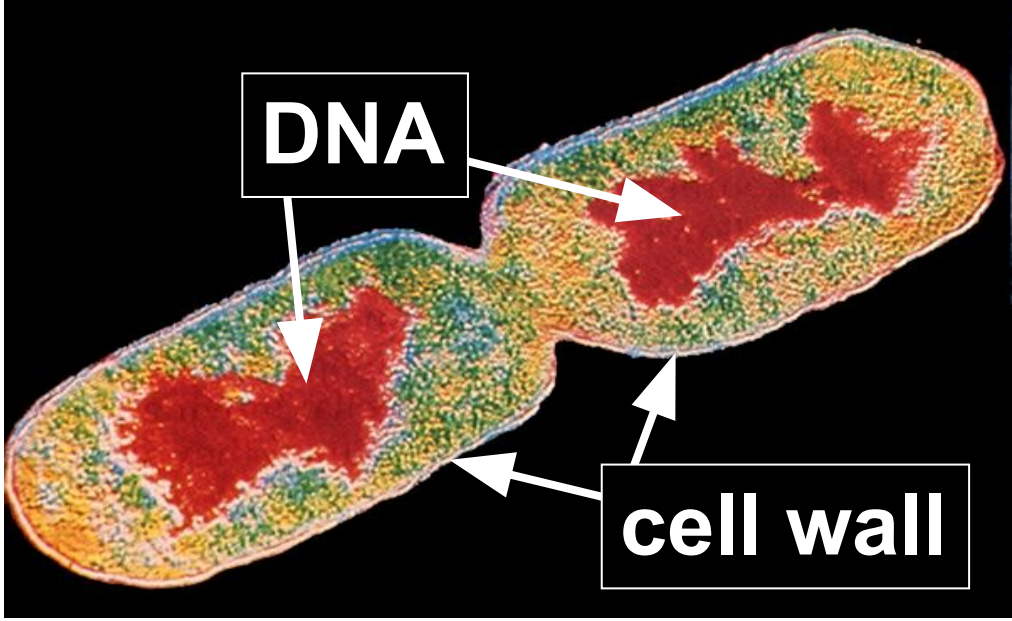
Bacteria

Reproduction

Asexual, through binary fission

No true sexual reproduction, since neither mitosis nor meiosis exist in prokaryotes

Horizontal transfer of genetic material



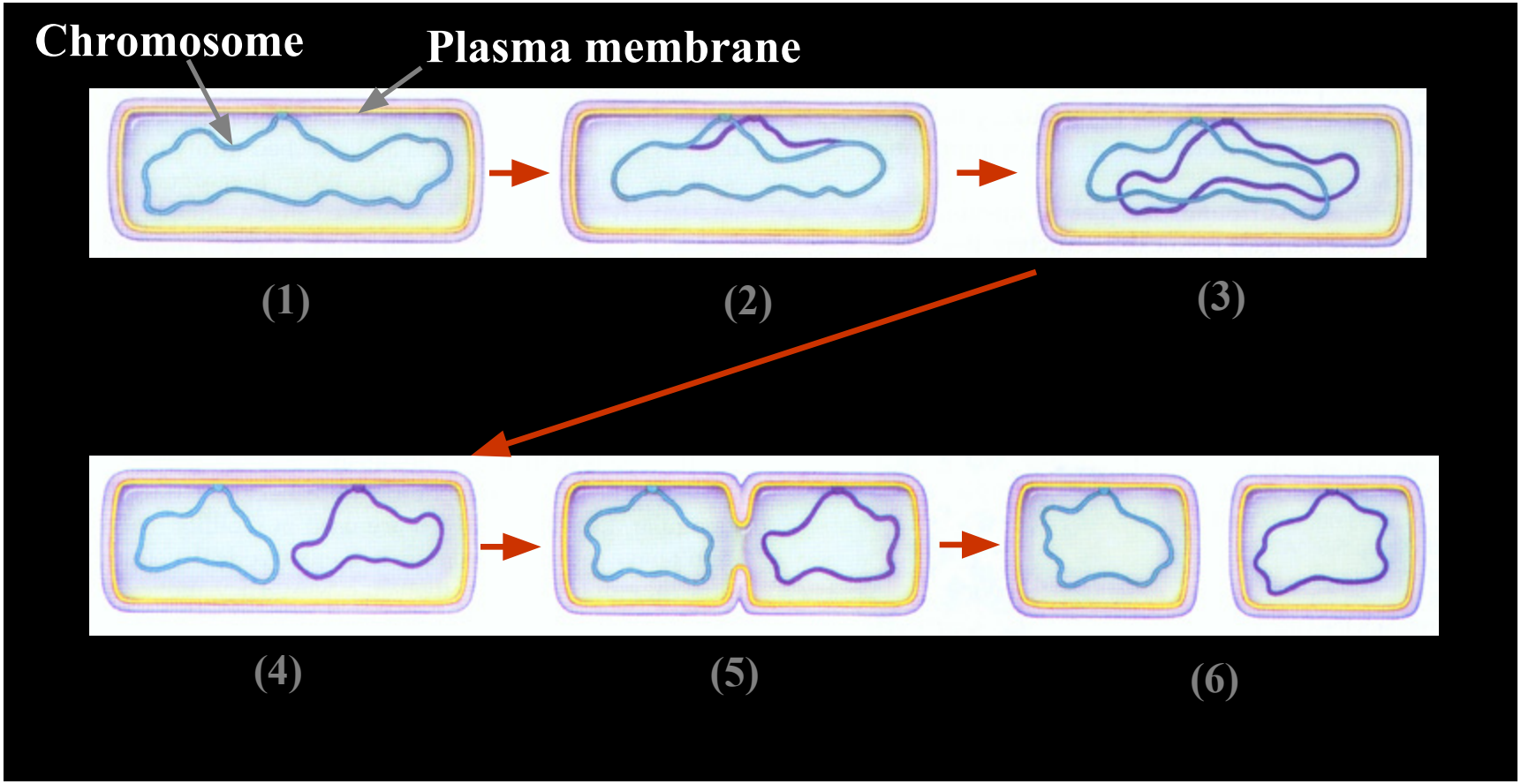
Transformation → **Uptake of genetic material from the environment**

Transduction → **Transfer of genetic material between prokaryotes by viruses**

Conjugation → **Direct transfer of genetic material from one prokaryote to another**

Binary fission

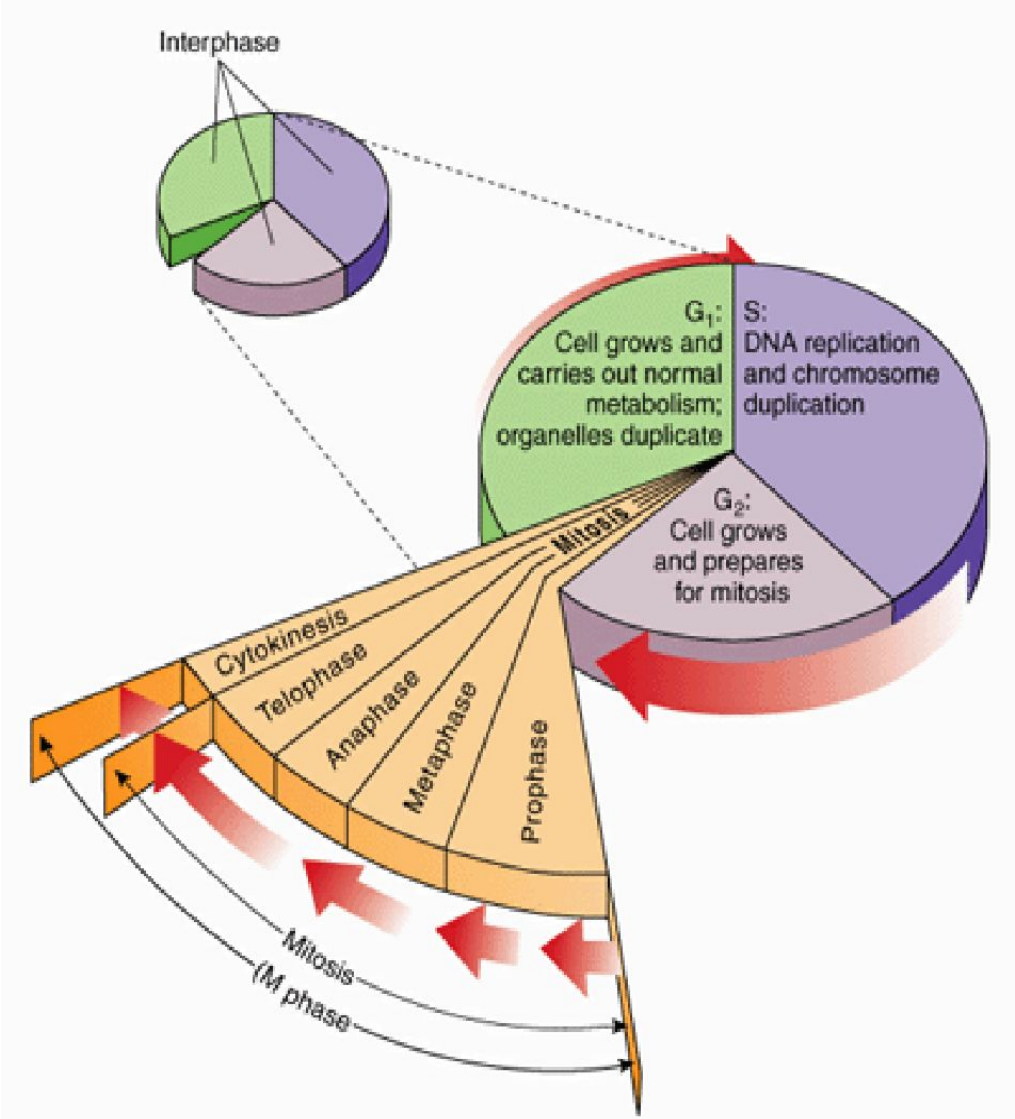
Daughter cells are identical copies



Neither mitosis nor meiosis occurs in prokaryotes

The Cell Cycle

- **Mitosis and meiosis are single steps in cell cycle**
- **G1, S, G2, and M phases**
  - **Cells not in process of dividing are in G0 phase**
  - **Chromosomes are duplicated in preparation for the next round of division during interphase**
  - **G1, S & G2 pahse comes under interphase**



Control of the Cell Cycle

- **The stimuli for entering the cell cycle is in the form of growth factors and cytokines that are capable of inducing mitotic divisions**

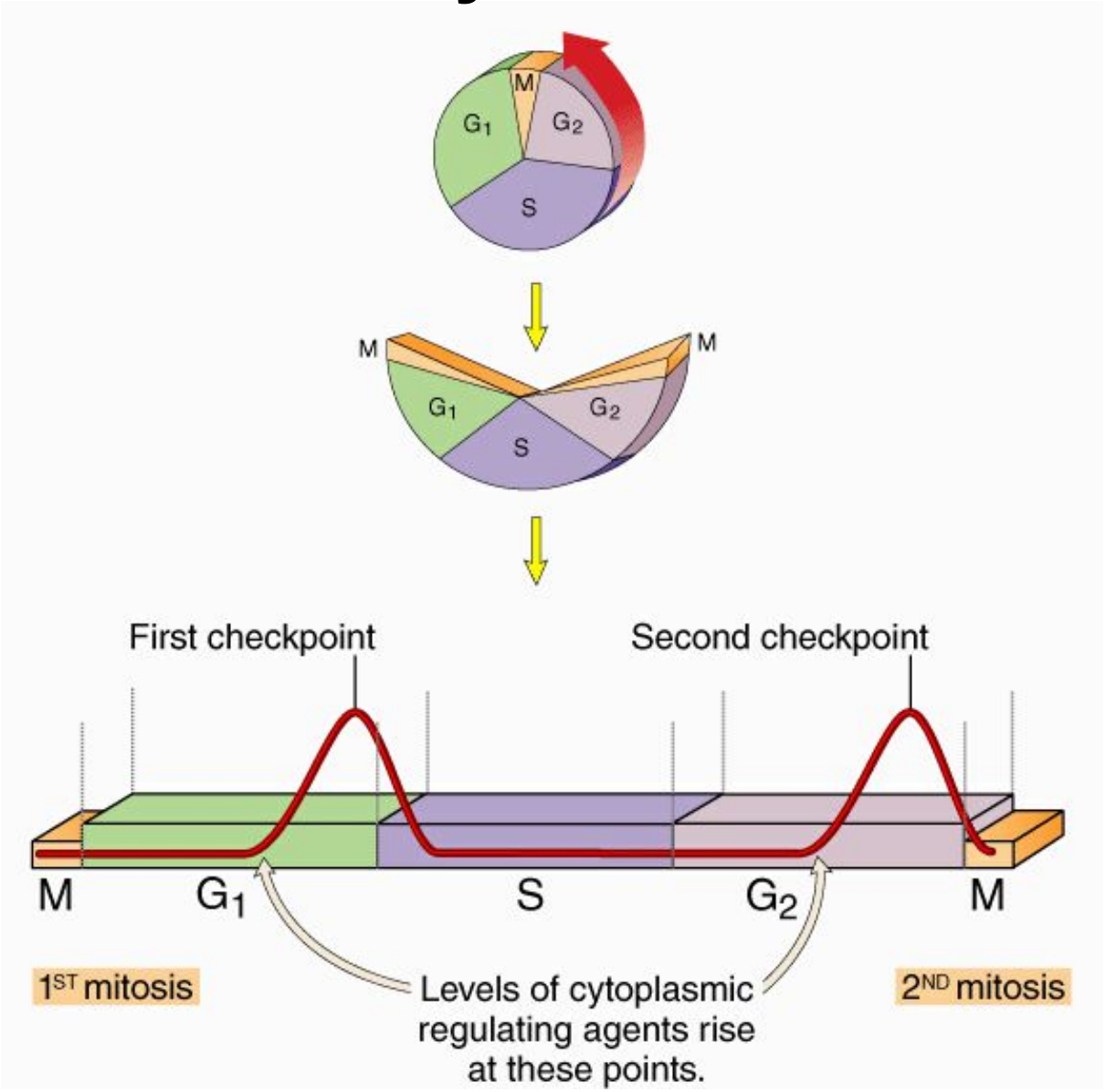
- **The cell cycle is highly regulated**
  - **Proteins whose concentrations rise & fall in a controlled manner**
    - **Cyclin and cyclin-dependent kinases (cdk)**
    - **p53 and pRb**
    - **Inhibitors of cdk**

- **Internal checkpoints & guardians monitor cell health**

- **Errors in this process can lead to uncontrollable growth and cancer**

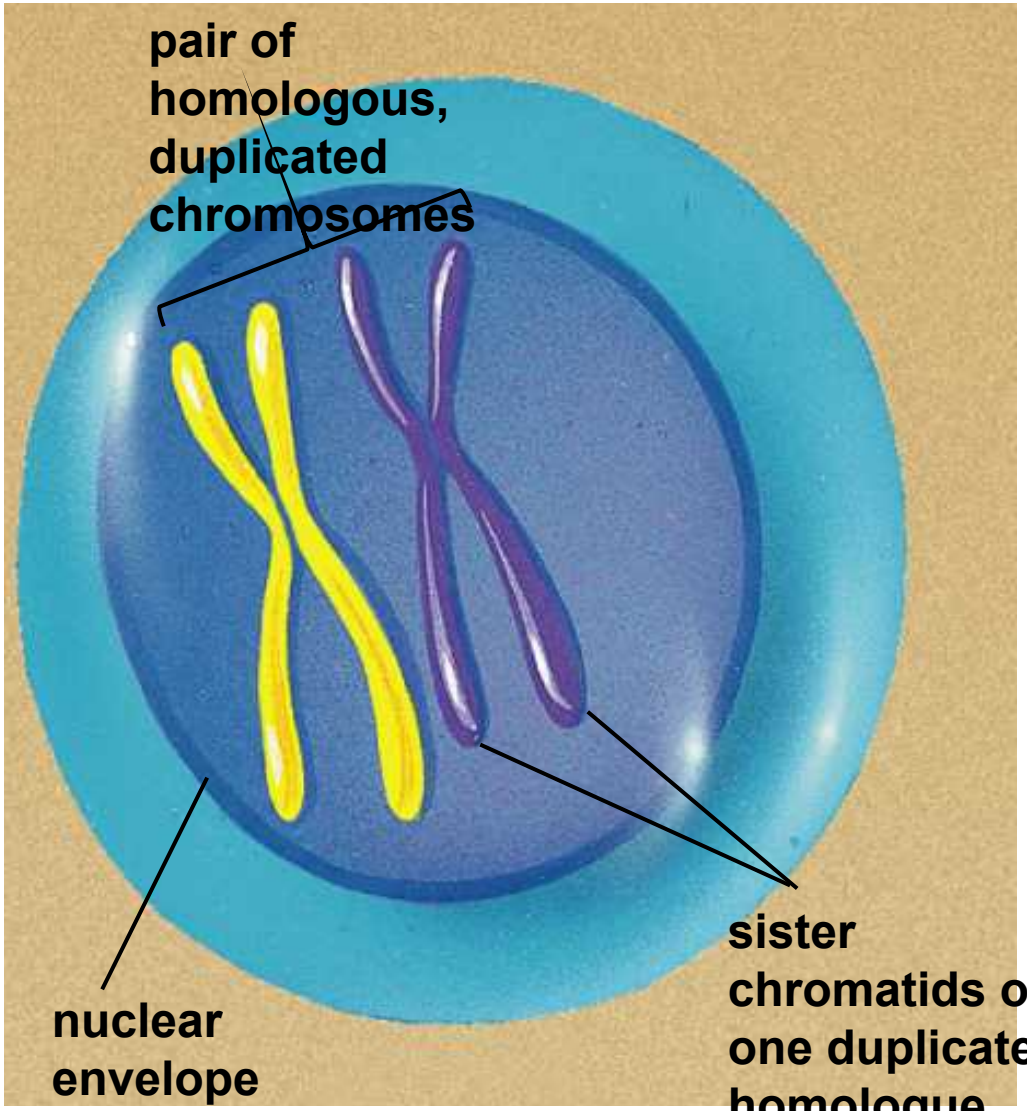
Control of the Cell Cycle

- Cell cycle control is focused at 3 places:
- G1 checkpoint
- G2 checkpoint
- M checkpoint
  - Before S phase (DNA synthesis)
  - At transition between G_2 and M phase



Mitosis

- **Four phases**
  - **1. Prophase: chromosomes condense, spindle apparatus forms, nuclear envelope breaks down**
  - **2. Metaphase: chromosomes line up at equator of cell**
  - **3. Anaphase: sister chromatids separate**
  - **4. Telophase: new nuclear envelopes form, chromosomes unwind**



Stages of Mitosis

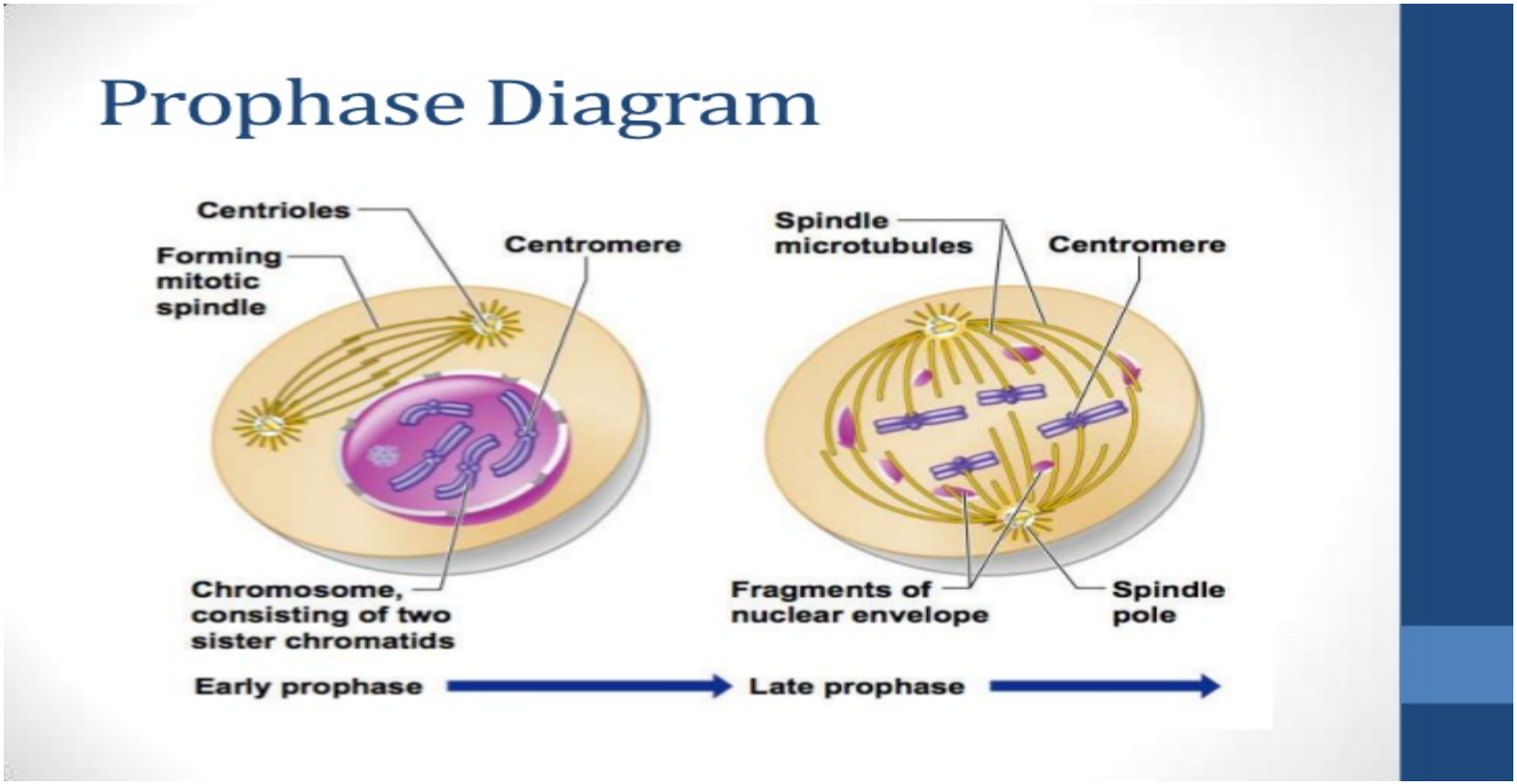
Prophase

•Condensation of genetic material to form compact chromosomes composed of two chromatids attached to centromere.

• Chromosome condensation prevents DNA breakage.

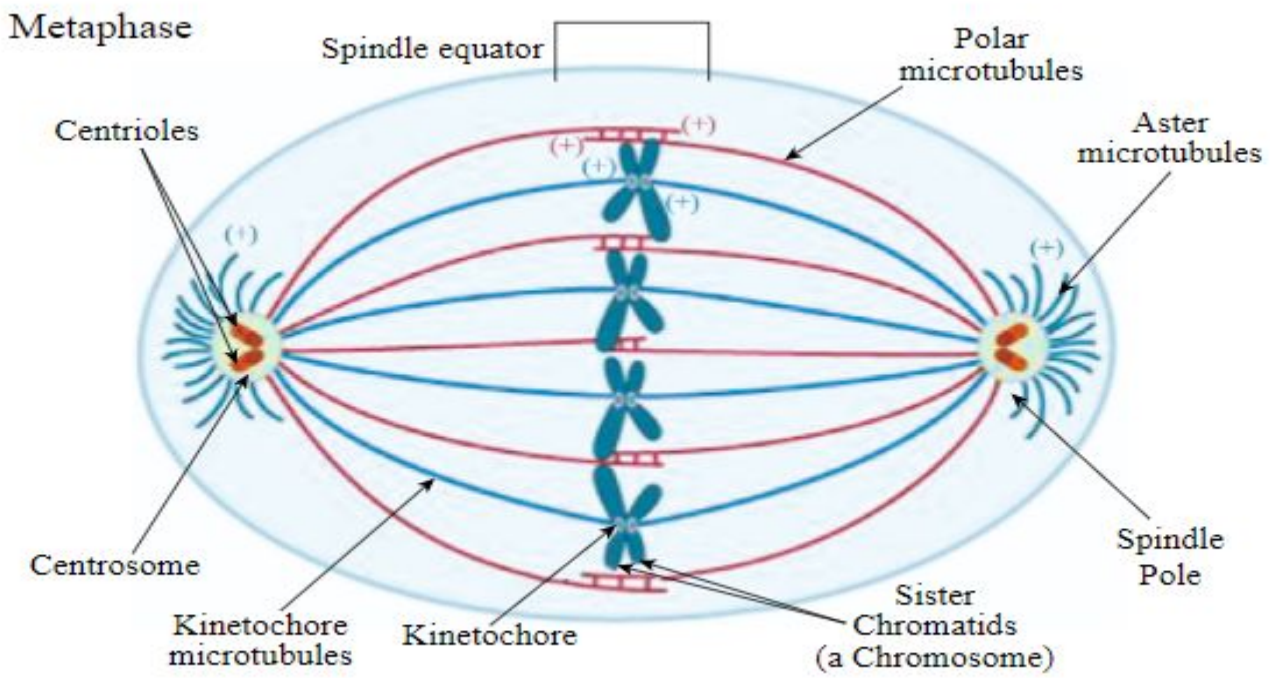
•Nuclear envelope starts disintegrating

•Initiation of mitotic spindle (structure tat separates two chromosomes) formation



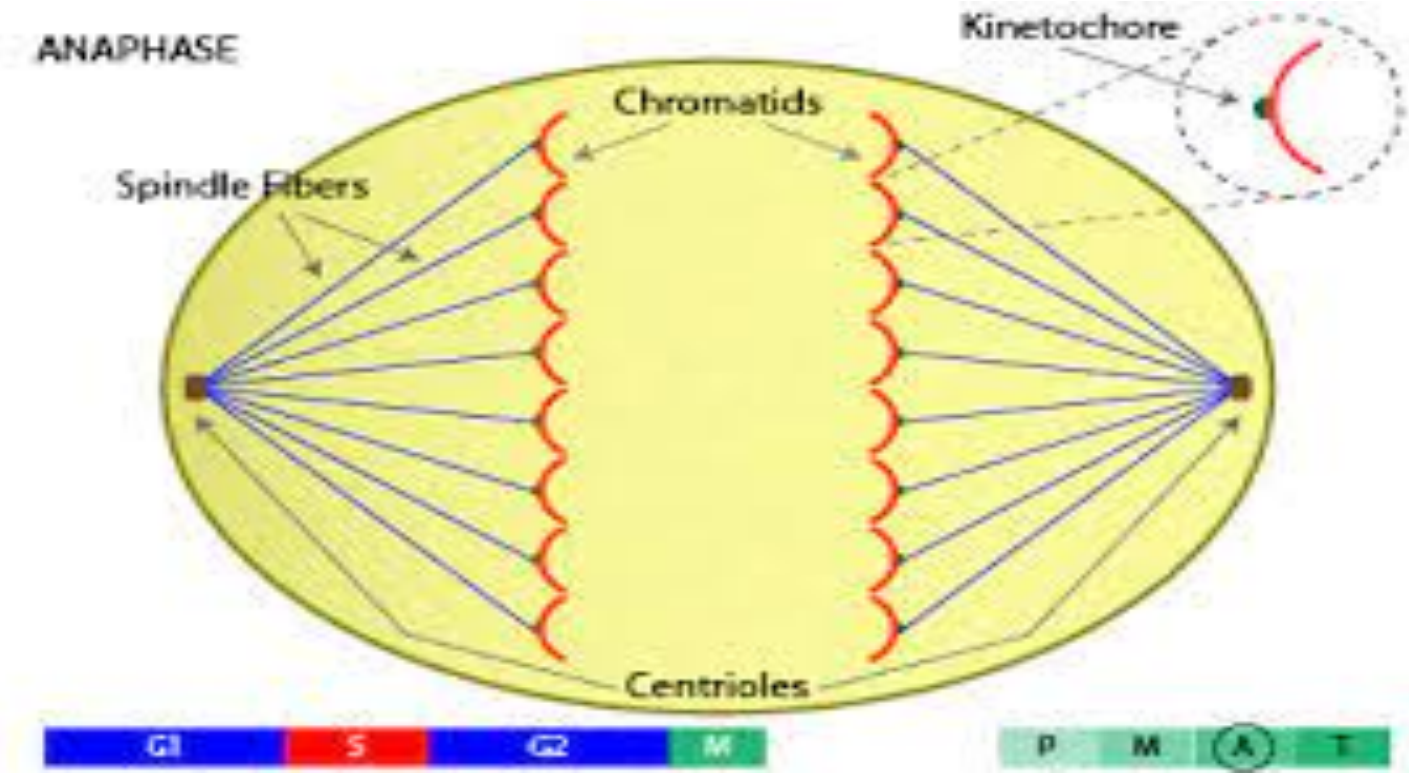
Metaphase

- The microtubules start pulling the chromosomes with equal force and the chromosome ends up in the middle of the cell. This region is known as the metaphase plate.
- Mitotic spindles are fully developed
- Centrosomes are at opposite poles of the cell
- Chromosomes : lined up at metaphase plate
- Centrosome: organelle near nucleus , involved in the formation of mitotic spindle



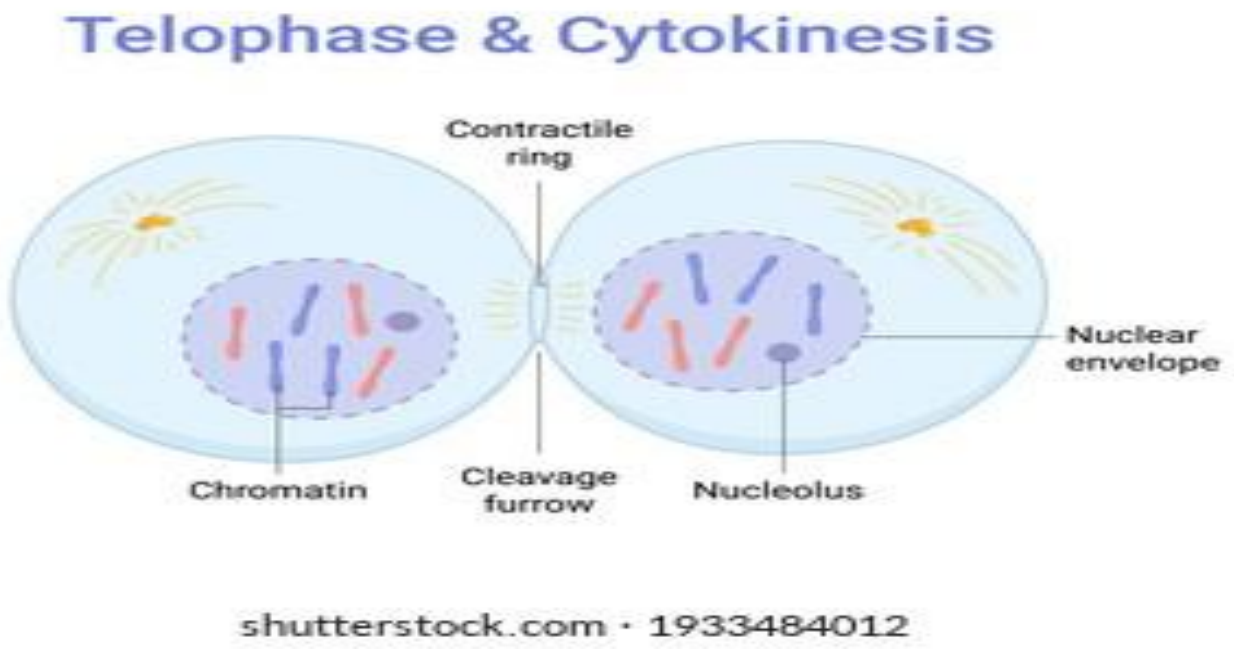
Anaphase

- The splitting of the sister chromatids marks the onset of anaphase.
- These sister chromatids become the chromosome of the daughter nuclei.
- The chromosomes are then pulled towards the pole by the fibres attached to the kinetochores of each chromosome.
- The centromere of each chromosome leads at the edge while the arms trail behind it.
- Each chromatid consists of 1 double stranded DNA & referred as daughter chromosome.
- Kinteochore has protein : molecular motors (cytoplasmic dynein).
- ATP □ ADP + Pi : contributes to energy required for the movement of chromosomes to two poles



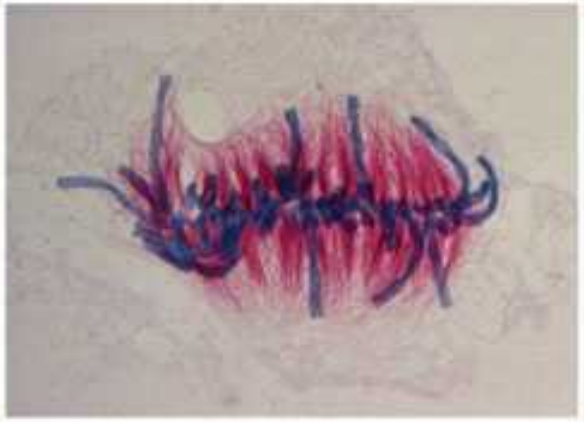
Telophase

- The chromosomes that cluster at the two poles start coalescing into an undifferentiated mass, as the nuclear envelope starts forming around it.
- The nucleolus, Golgi bodies and ER complex, which had disappeared after prophase start to reappear.
- Each progeny nucleus contains one complete genome from father & one complete genome from mother.
- At the end of telophase the daughter nuclei enter interphase
- Two nuclei, identical to each other
- Cytokinesis : Division of cytoplasm.



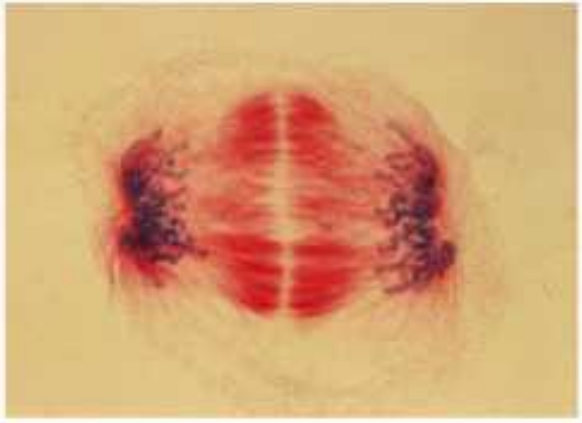
(a) Interphase in a seed cell: The chromosomes (blue) are in the thin, extended state and appear as a mass in the center of the cell. The spindle microtubules (red) extend outward from the nucleus to all parts of the cell.

(b) Late prophase: The chromosomes (blue) have condensed and attached to the spindle microtubules (red).

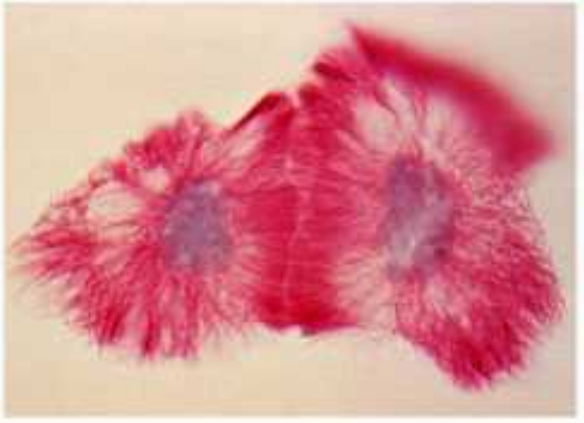


(c) Metaphase: The chromosomes have moved to the equator of the cell.

(d) Anaphase: Sister chromatids
have separated, and one set has moved toward each pole.



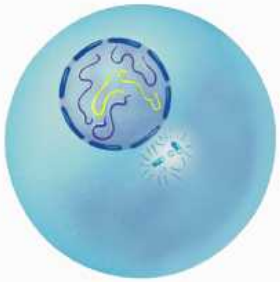
(e) Telophase: The chromosomes have gathered into two clusters, one at the site of each future nucleus.



(f) Resumption of interphase: The chromosomes are relaxing again into their extended state. The spindle microtubules are disappearing, and the microtubules of the two daughter cells are rearranging into the interphase pattern.

Each new nucleus is genetically identical to the parent nucleus

Parent Cell
Chromosomes have been replicated



Mitosis

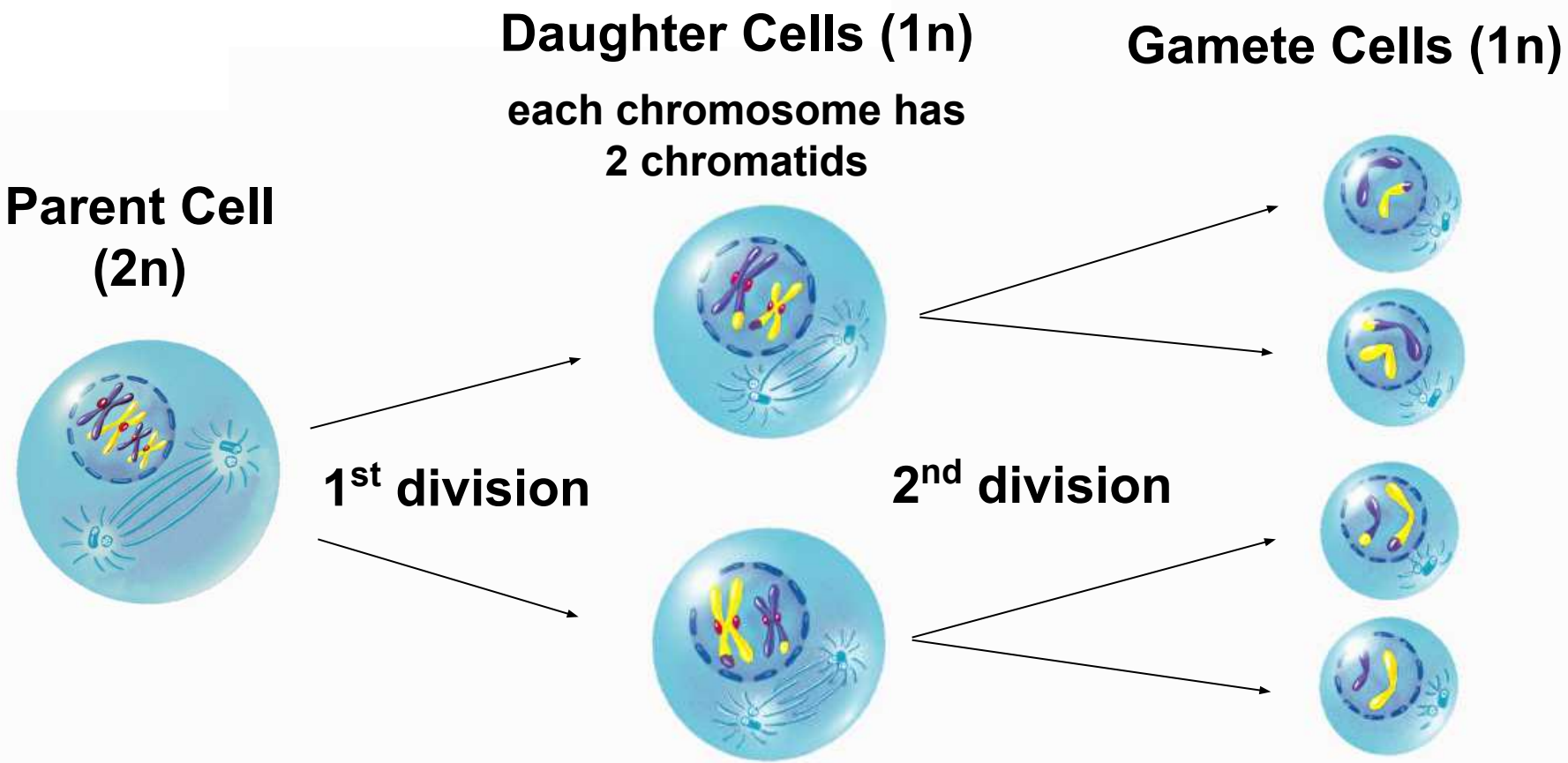
Daughter Cells
Each cell has the same genetic makeup as the parent cell

Meiosis

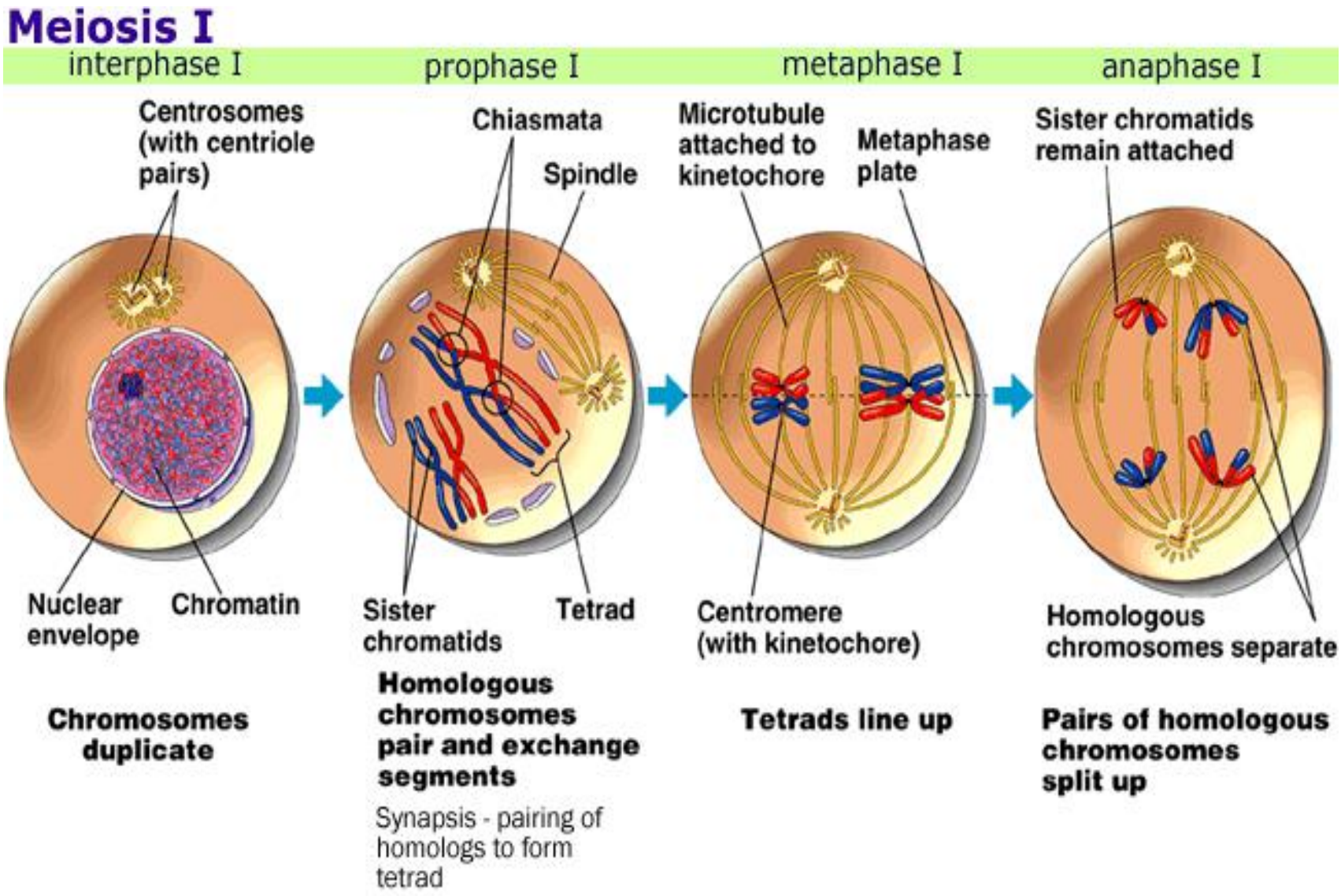
Characteristics of meiosis

- **1. Occurs in sex cells (germ cells) and produces gametes**
- **2. A reductional division resulting in haploid cells**
- **3. Involves two sequential divisions resulting in four cells**
- **4. Produces cells that are genetically different because of genetic recombination (crossing-over).**

Meiosis


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

Meiosis - I


Meiosis I
interphase I
prophase I
metaphase I
anaphase I
Centrosomes (with centriole pairs)
Nuclear envelope
Chromatin
Chromosomes duplicate
Chiasmata
Spindle
Sister chromatids
Tetrad
Homologous chromosomes pair and exchange segments
Synapsis - pairing of homologs to form tetrad
Microtubule attached to kinetochore
Metaphase plate
Centromere (with kinetochore)
Tetrads line up
Sister chromatids remain attached
Homologous chromosomes separate
Pairs of homologous chromosomes split up

Process of Meiosis

Meiosis begins with a parent cell that is diploid results in four daughter cells that are haploid

Meiosis I

Prophase I.

- chromatin condenses to form chromosomes and they remain joined at a central point called the centromere.
- A large structure called the meiotic spindle also forms from long proteins called microtubules on each side, or pole, of the cell.

Metaphase I

- The pairs of homologous chromosome form tetrads. Within the tetrad, any pair of chromatid arms can overlap and fuse in a process called crossing-over or recombination.
- The homologous pairs of chromosomes align on either side of the equatorial plate.

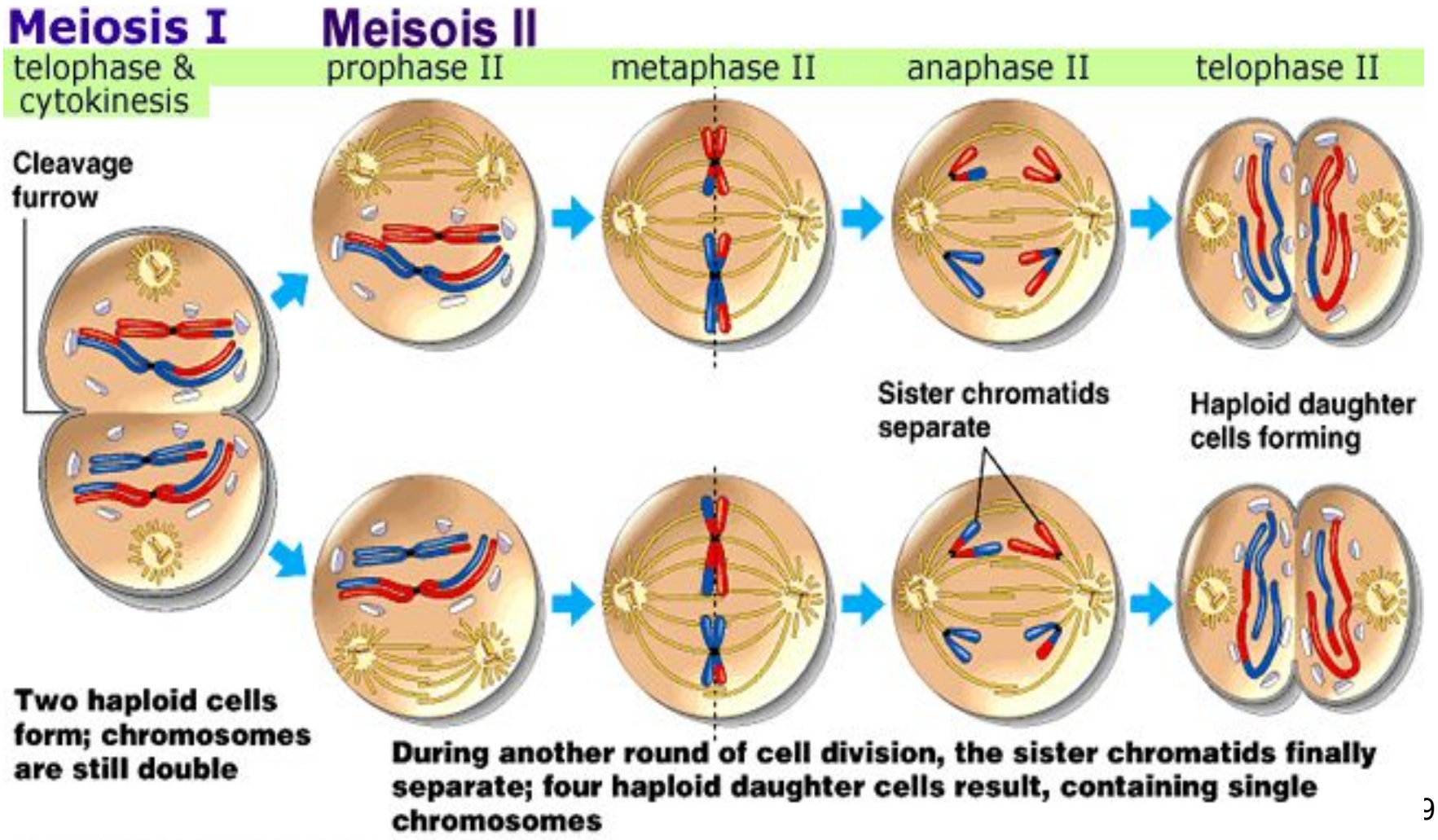
Anaphase I

The spindle fibers contract and pull the homologous pairs, each with two chromatids, away from each other and toward each pole of the cell.

Telophase I

The chromosomes are enclosed in nuclei. The cell now undergoes a process called cytokinesis that divides the cytoplasm of the original cell into two daughter cells. Each daughter cell is haploid and has only one set of chromosomes, or half the total number of chromosomes of the original cell.

Meiosis II



Meiosis II

Mitotic division of each of the haploid cells produced in meiosis I.

Prophase II

- The chromosomes condense, and a new set of spindle fibers forms. The chromosomes begin moving toward the equator of the cell.

Metaphase II

- The centromeres of the paired chromatids align along the equatorial plate in both cells.

Anaphase II

- The chromosomes separate at the centromeres. The spindle fibers pull the separated chromosomes toward each pole of the cell.

Telophase II

- The chromosomes are enclosed in nuclear membranes. Cytokinesis follows, dividing the cytoplasm of the two cells. At the conclusion of meiosis, there are four haploid daughter cells

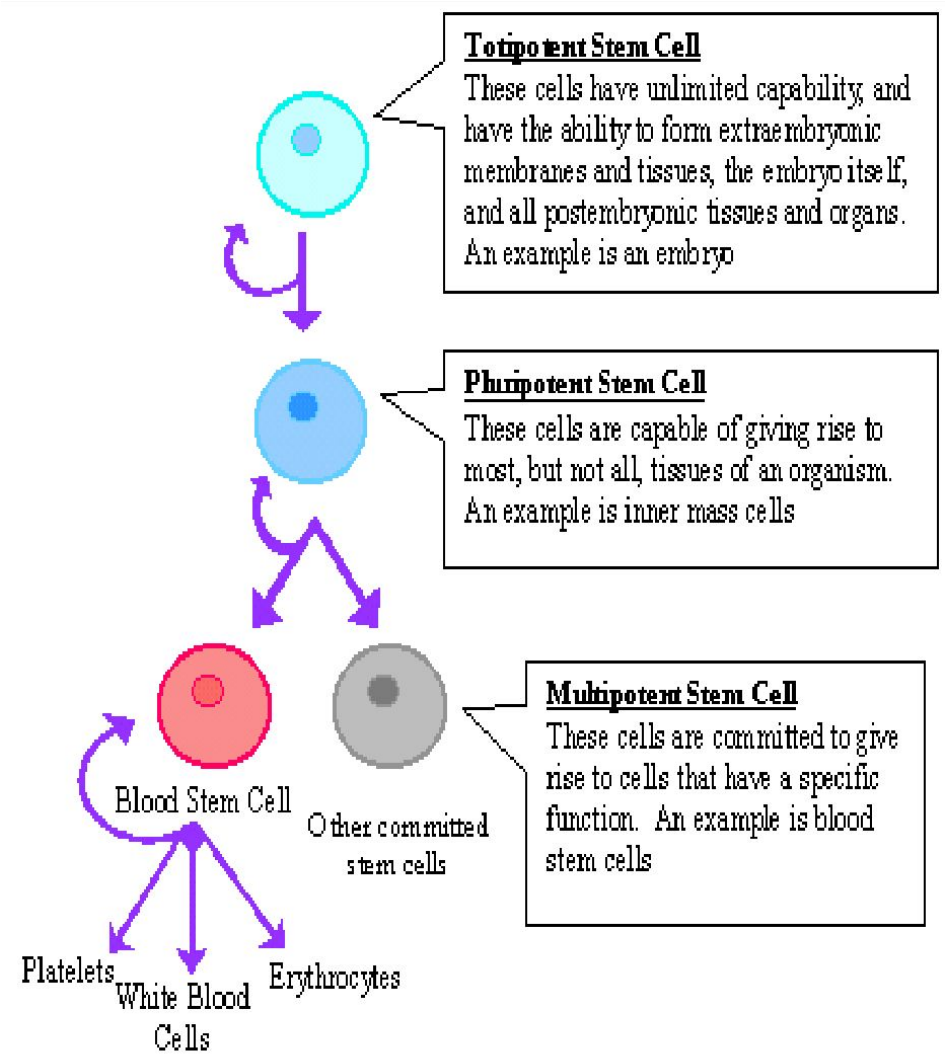
Meiosis produces gametes for sexual reproduction

- **Multiplies number of cells but also reduces chromosome number in each daughter cell to exactly half the number present before meiosis**
- **Daughter cells get 1 member of each homologous pair, i.e. 1 allele for each gene**
- **Mitosis produces 2 daughter cells**
- **Meiosis produces 4 daughter cells**
- **All body cells in humans are diploid, *except* gametes**
- **Cells with 1 member of each homologous pair are haploid**

Cell Differentiation

- The process during which young, immature (unspecialized) cells take on individual characteristics and reach their mature (specialized) form and function.
- The original mass of cells, which have not undergone differentiation, are known as *stem cells*.
- Stem cells which can differentiate into entire organisms are known as embryonic stem cell and are said to be totipotent.
- 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