

# UNIT I

## 0

- Introduction
- Cell theory,
- Whitaker's kingdom classification
- Cell organelles, and their functions
- Homeostasis,
- Replication and cell Division
- Tissue differentiation
- Stem cells and their applications
- Genetic algorithms

# Introduction

# Concept of evolution

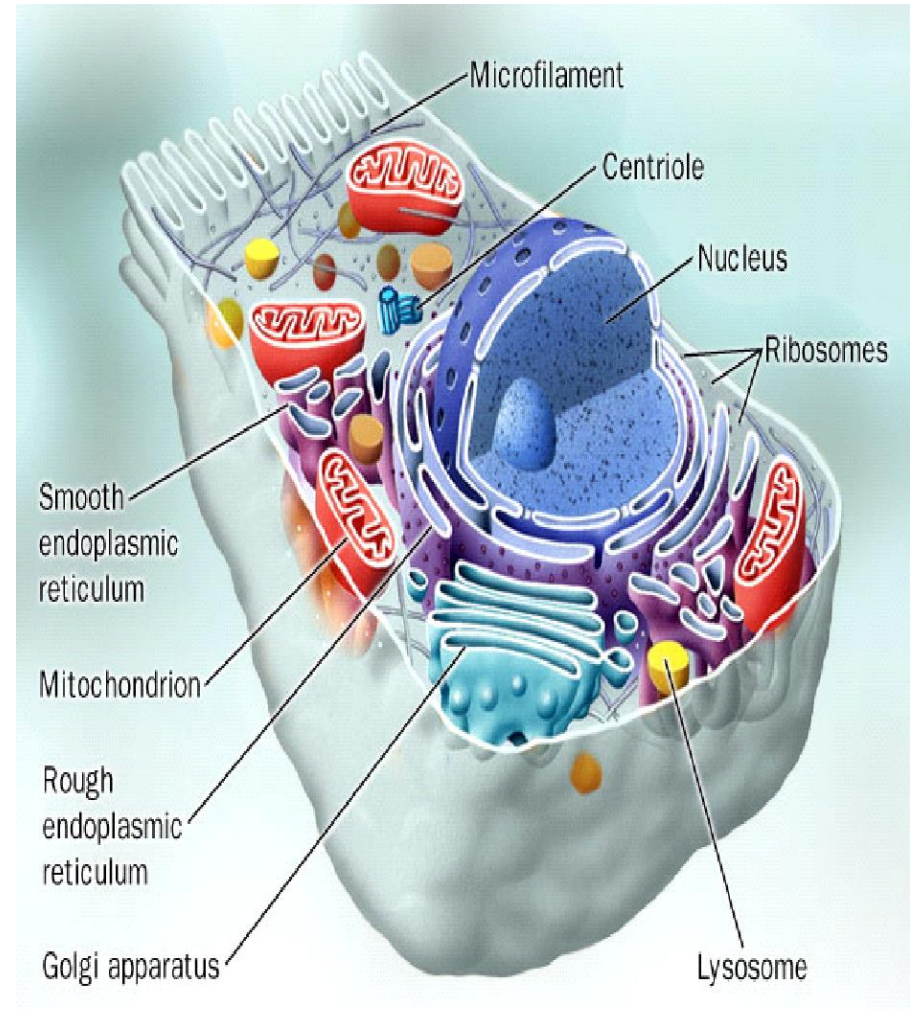
- The process by which different kinds of living organism are believed to have developed from earlier forms during the history of the earth.
- Jean Baptista Lamarck (1801)- spontaneous generation of species according to needs and functionalities of the mutation
- Charles darwin (1859)- Based on survival of the fittest mutations

# 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 repertoire of organelles.
- Whittaker’s Five Kingdom Classification ( 1969)

R.H. Whittaker taxonomist was the first one to propose five kingdom classification.

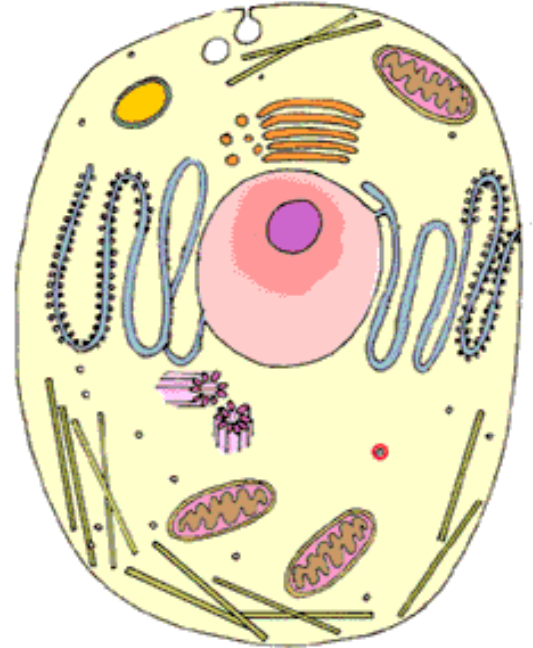
	Monera	Protista	Fungi	Plantae	Animalia
<b>Type</b>	Unicellular Prokaryotes	Unicellular Eukaryotes	Multicellular Non green Eukaryotic	Multicellular, Eukaryotic	Multicellular Eukaryotic
<b>Mode of nutrition</b>	Autotrophic or Heterotrophic	Autotrophic or Heterotrophic	Saprophytic or Parasitic Sometimes Symbiotic	Autotrophic	Heterotrophic
<b>Body</b>	Lack well defined nucleus and cell organelles	Some organisms use pseudopodia or cilia or flagella for movement	Fungus is made up of long filaments called hyphae. The network of hyphae is mycelium	Exhibits high level of tissue differentiation and have specialized body organs.	Exhibits high level of tissue differentiation and have specialized body organs. They have well developed nervous system.
<b>examples</b>	Bacteria, Blue-green Algae 	Amoeba, Paramecium, Euglena 	Yeast, Rhizopus, Mushrooms moulds 	Trees, Plants, Shrubs 	Fish, Insects, Animals Humans, Birds 

# Cell-basic unit of life

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

# CELL THEORY

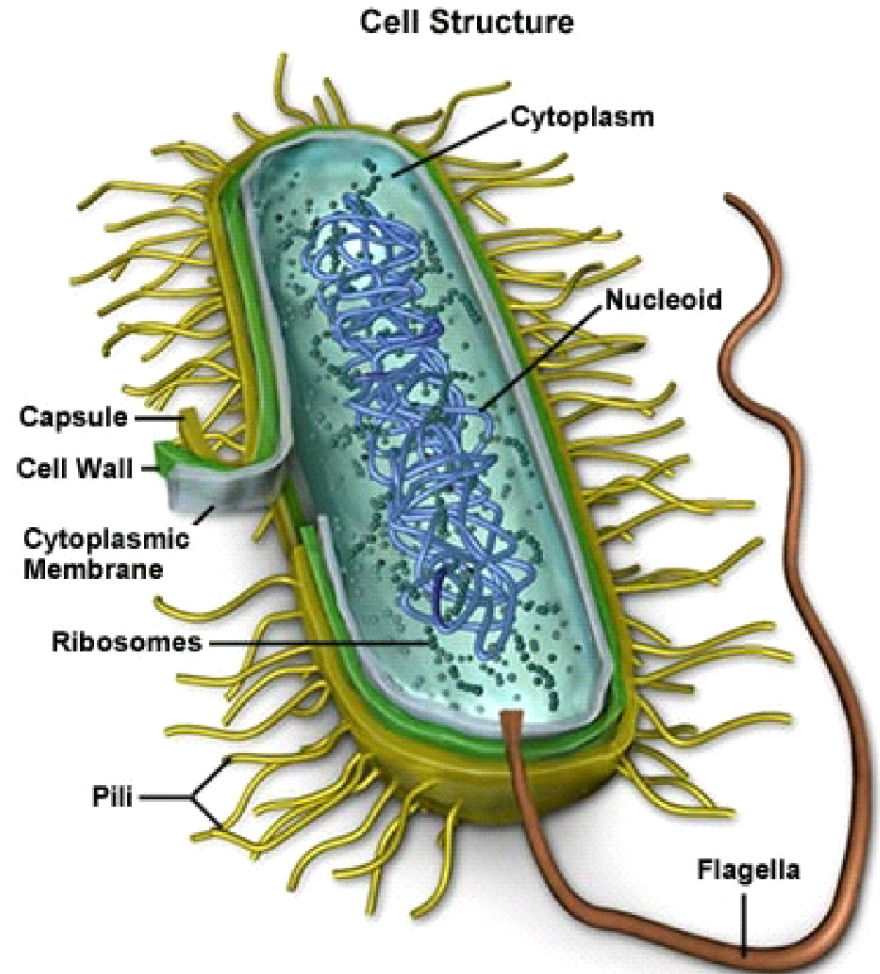
- All living things are made of **cells**
- Cells are the basic unit of **structure and function** in an organism (basic unit of life)
- Cells come from the **reproduction of existing cells** (cell division)





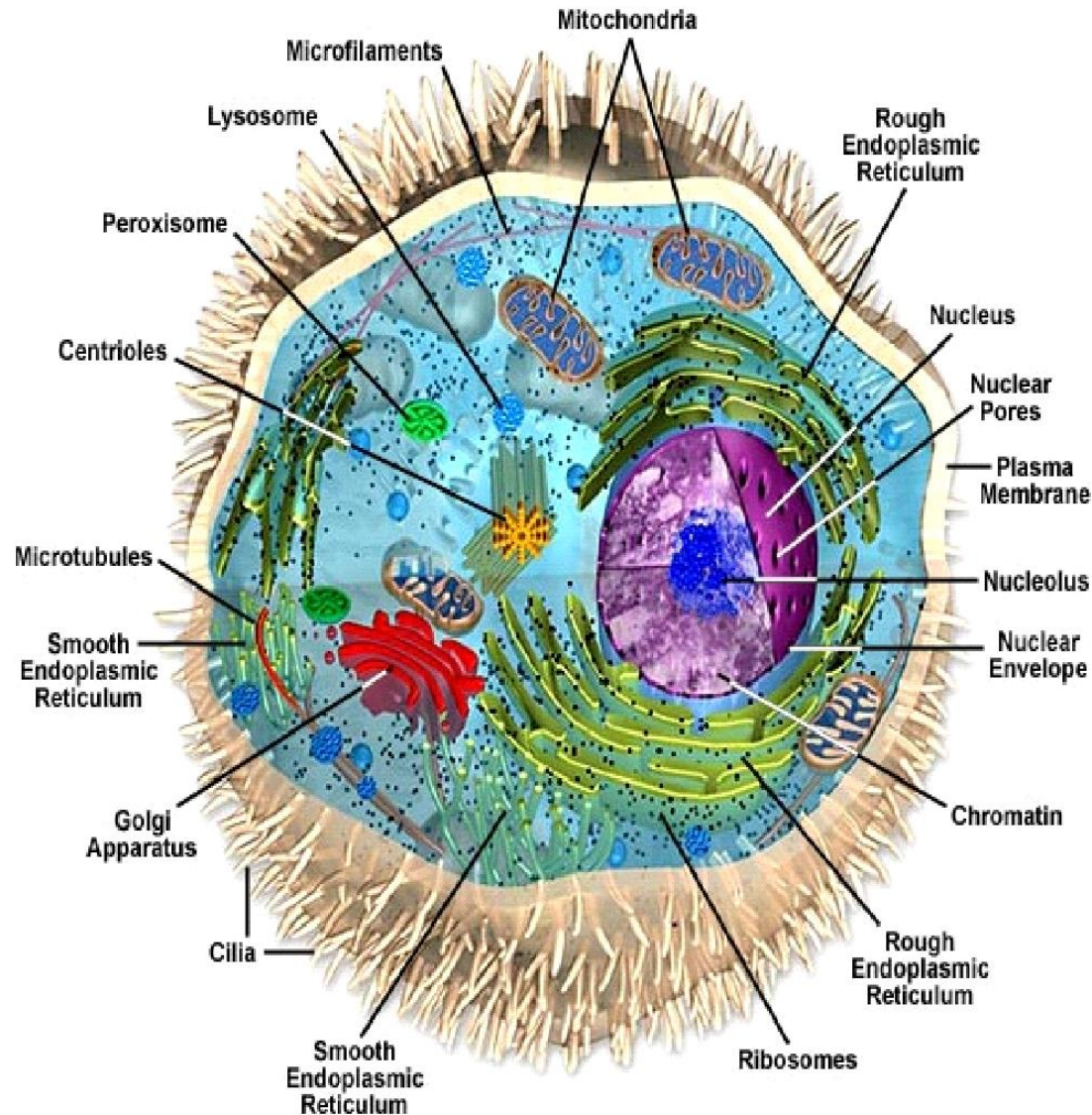
# Prokaryotes

- **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

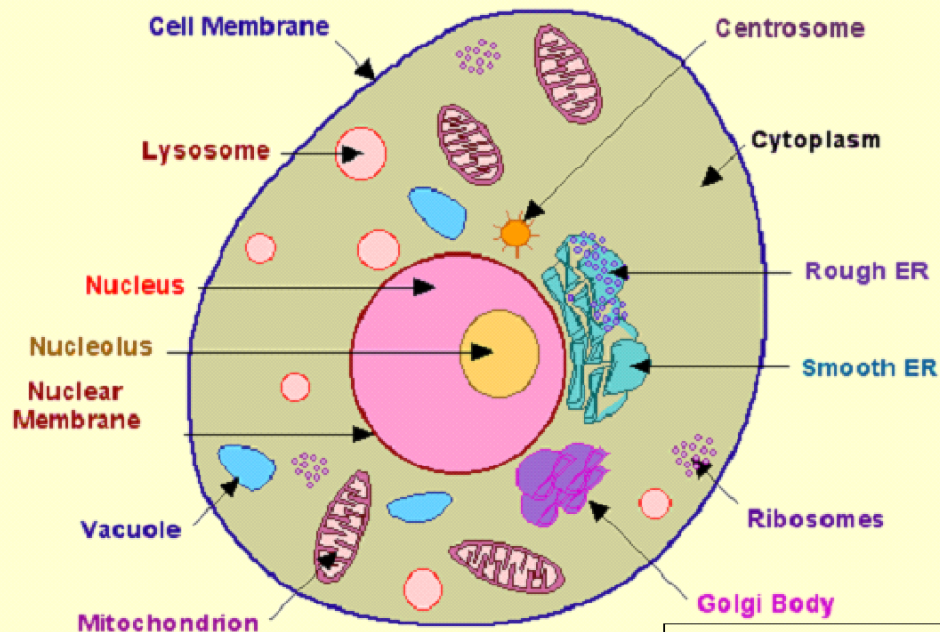


# **Cell Structure and Function**

# Organelles

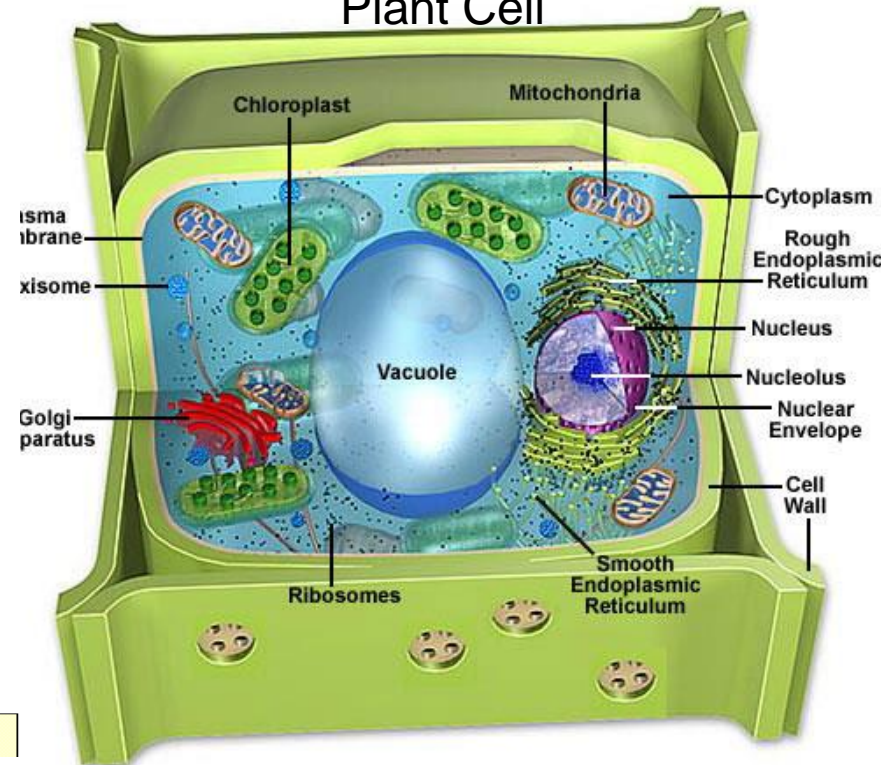
- Very **small** (Microscopic)
- Perform **various functions** for a cell
- Found in the **cytoplasm**
- May or may not be **membrane-bound**

**Cross-Section of an Animal Cell**



ER=ENDOPLASMIC RETICULUM

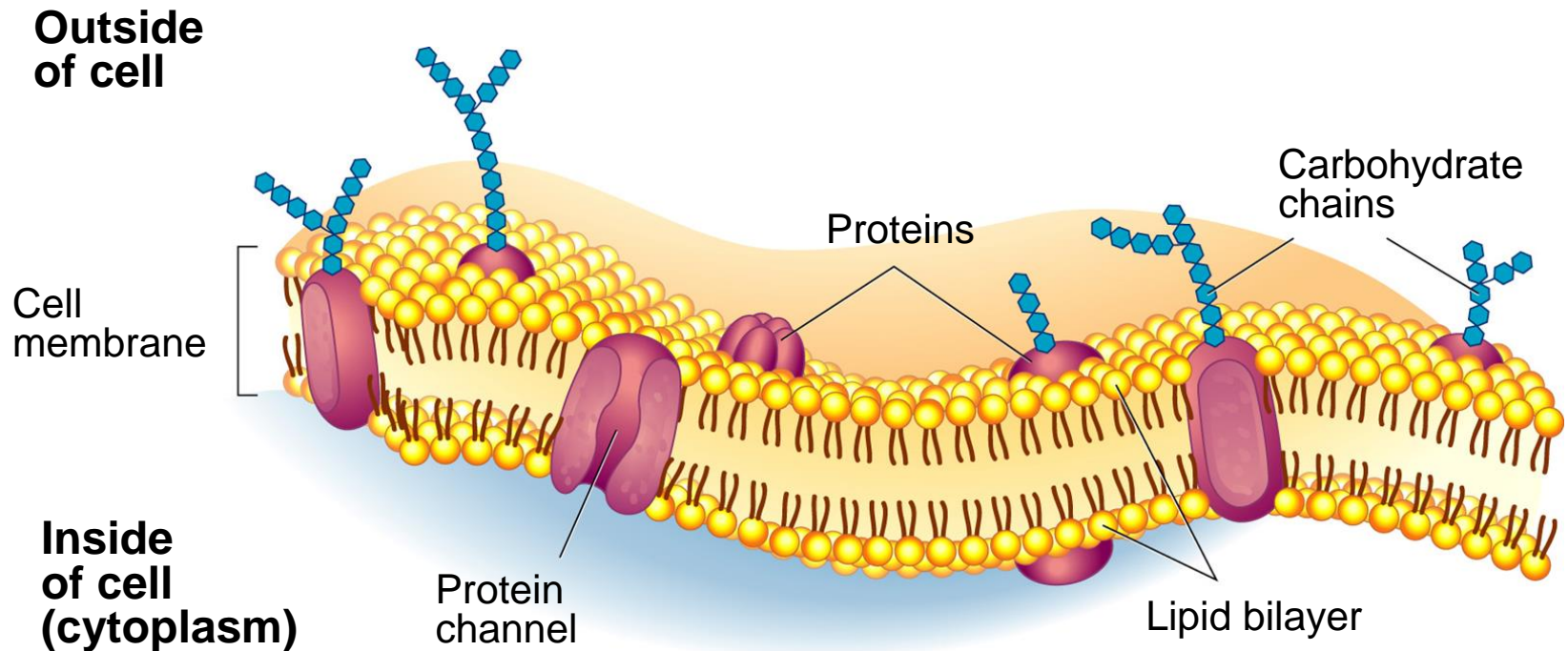
**Plant Cell**





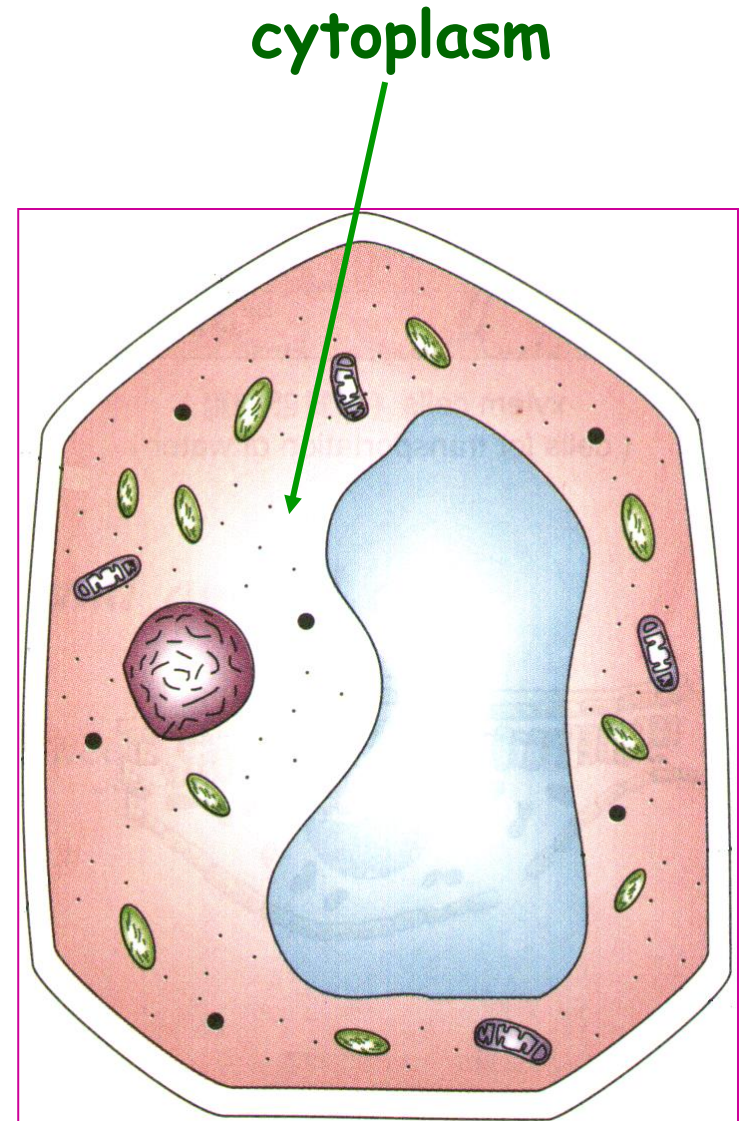
# Cell or Plasma Membrane

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



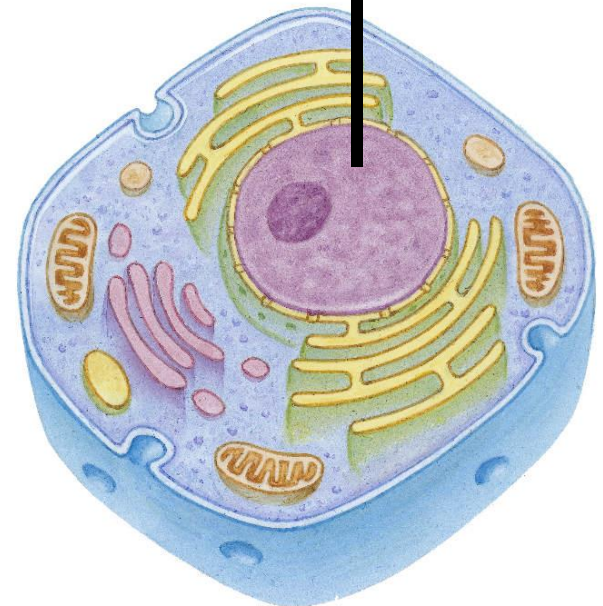
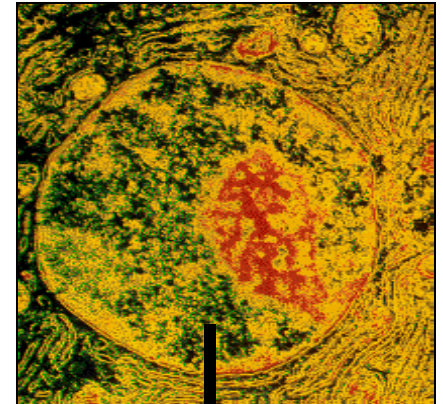
# Cytoplasm of a Cell

- **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



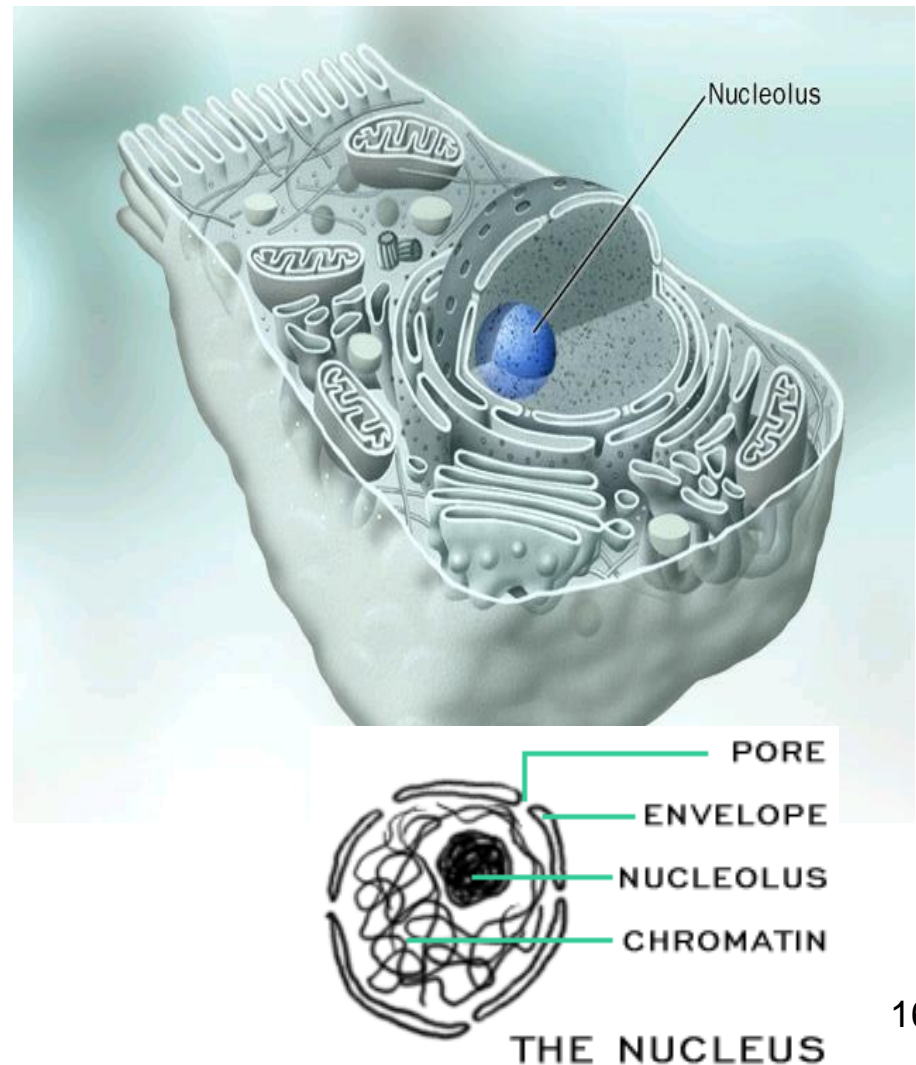
# The Control Organelle - Nucleus

- 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

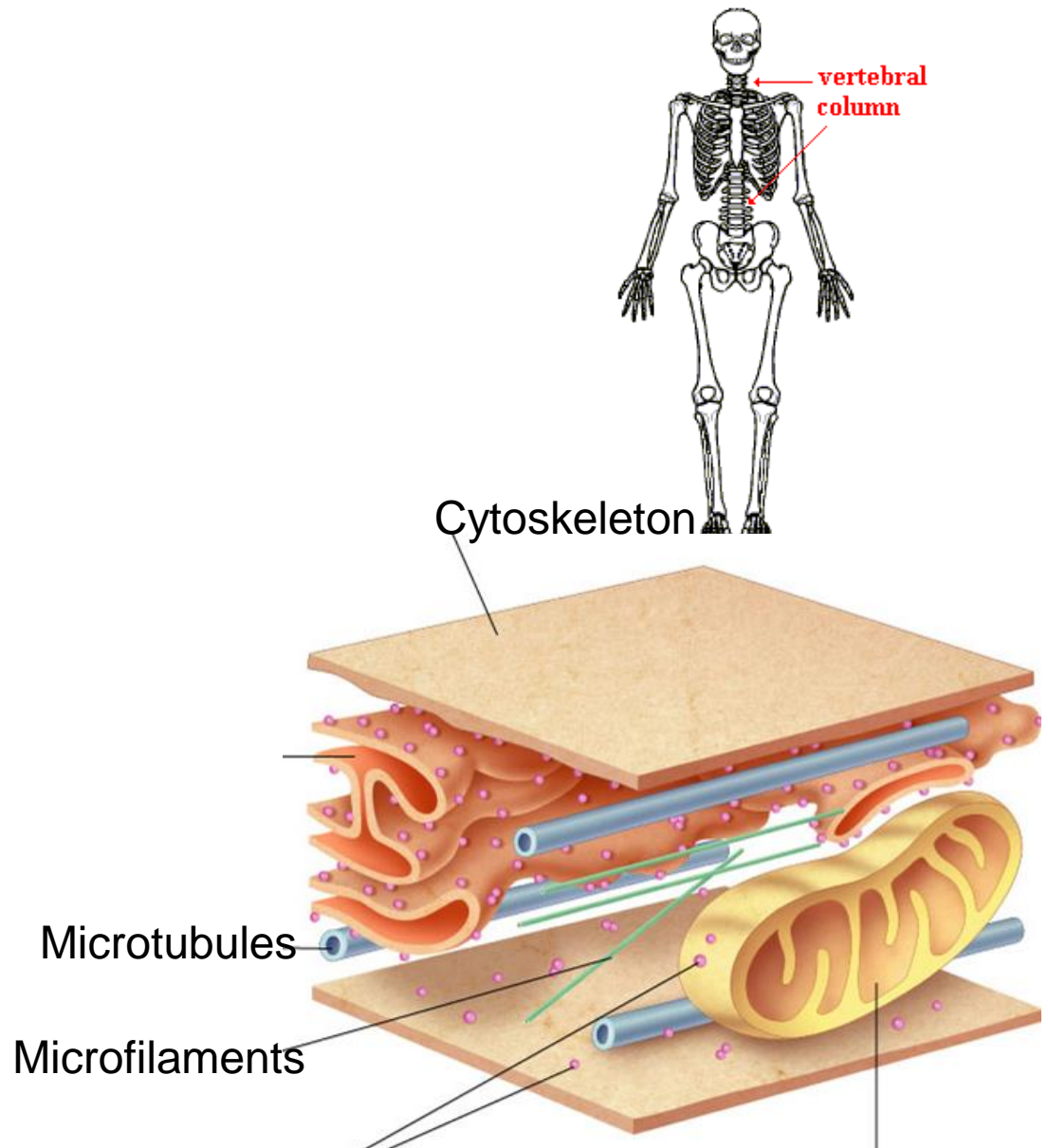
- **Inside nucleus**
- **Cell may have 1 to 3 nucleoli**
- **Disappears** when cell divides
- **Makes ribosomes** that make proteins



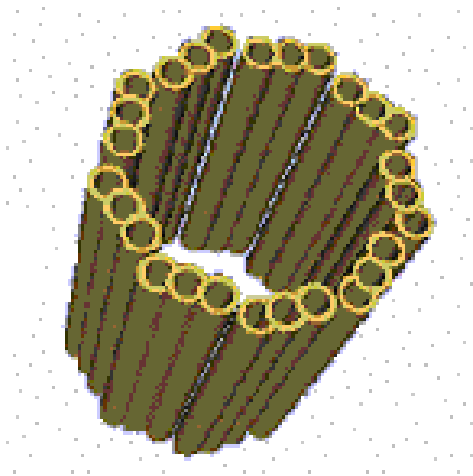


# Cytoskeleton

- 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



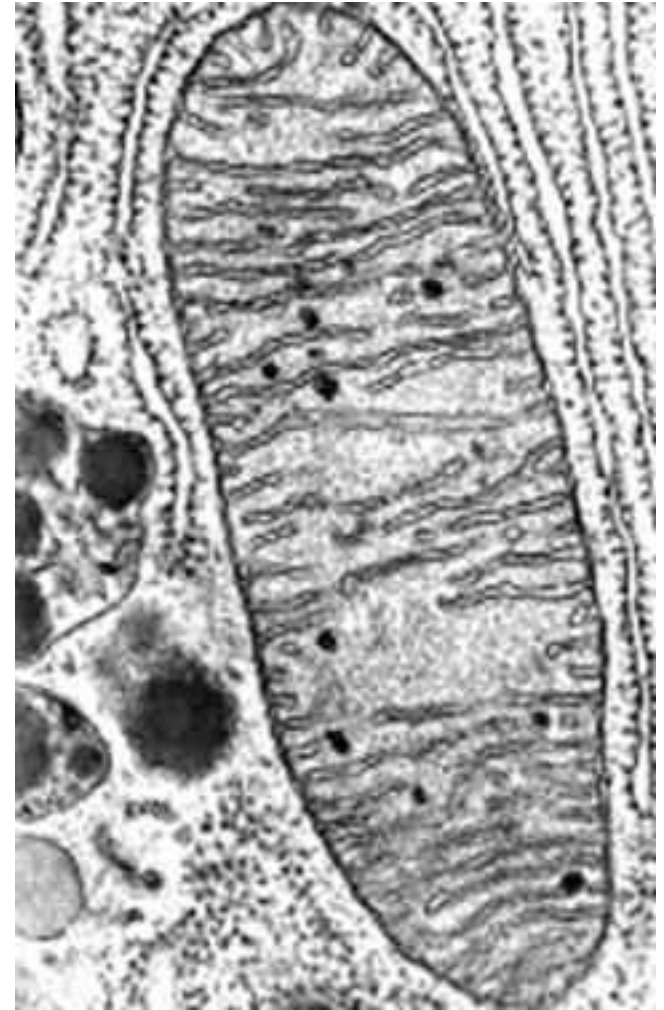
# Centrioles



- 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

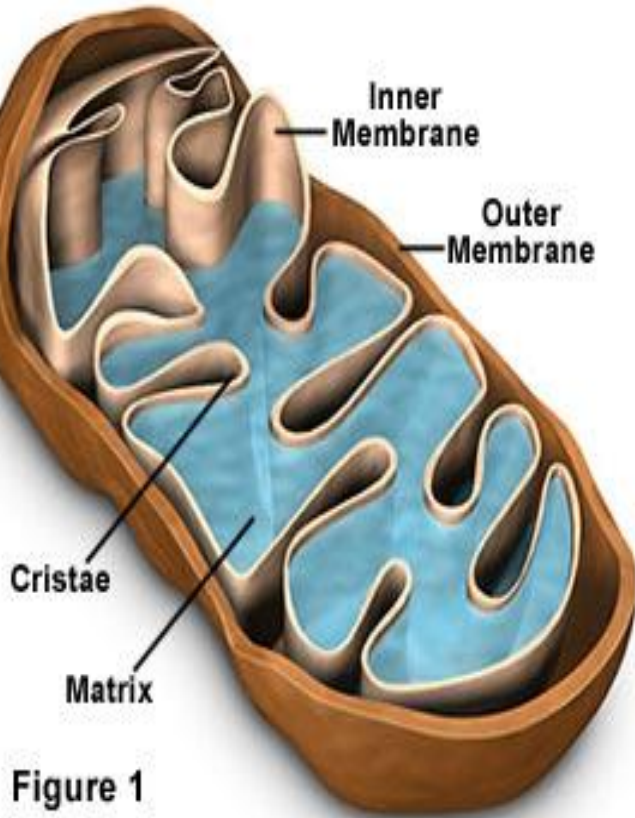
# Mitochondrion (plural = mitochondria)

- “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

Mitochondria Inner Structure

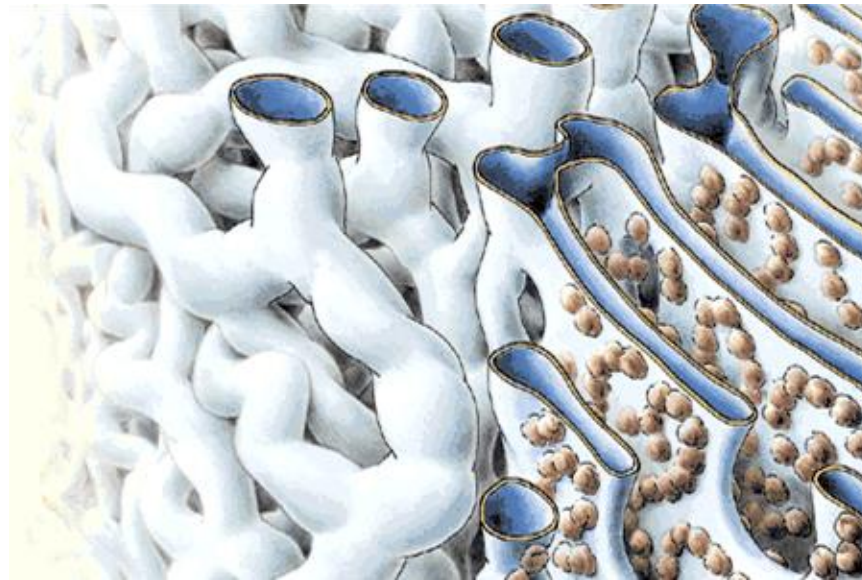


- **Surrounded by a DOUBLE membrane**
- **Has its own DNA**
  - Mitochondria come from cytoplasm in the egg cell during fertilization
  - **Therefore** you inherit your mitochondria from your mother!
- **Folded inner membrane called CRISTAE (increases surface area for more chemical reactions)**
- **Interior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



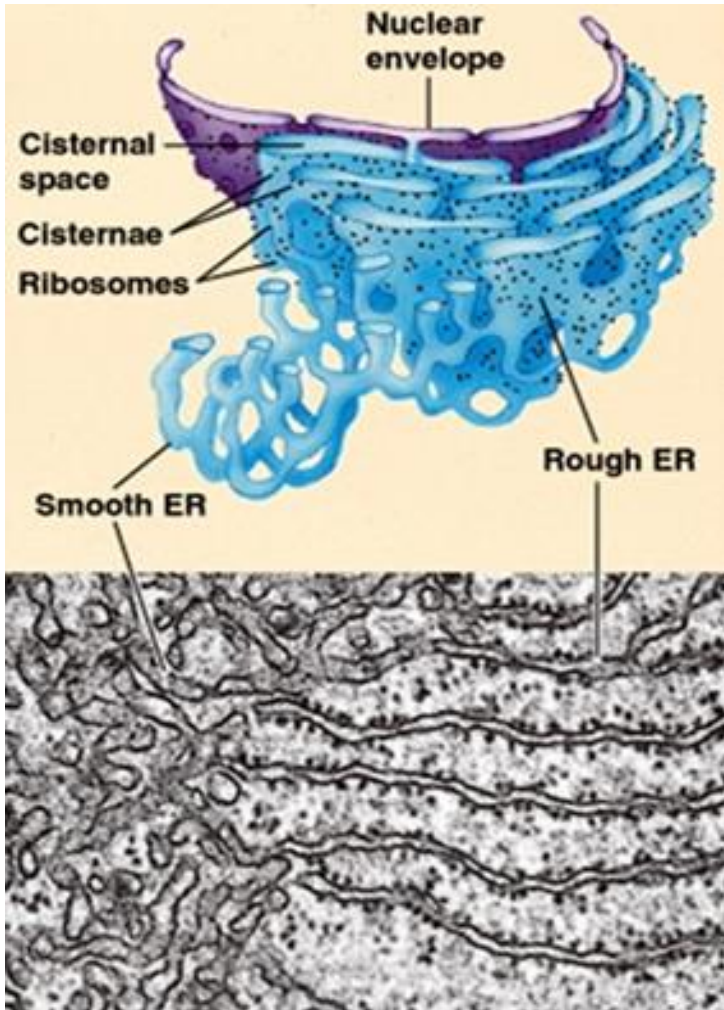
# Endoplasmic Reticulum - ER

- 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

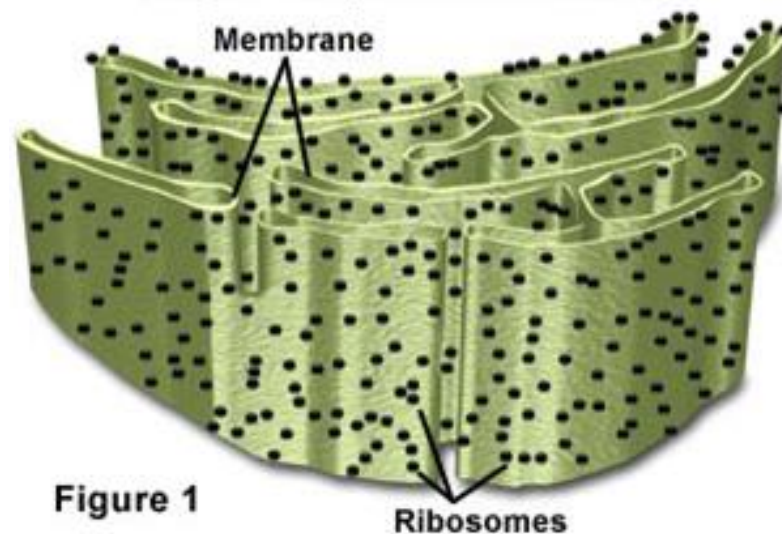
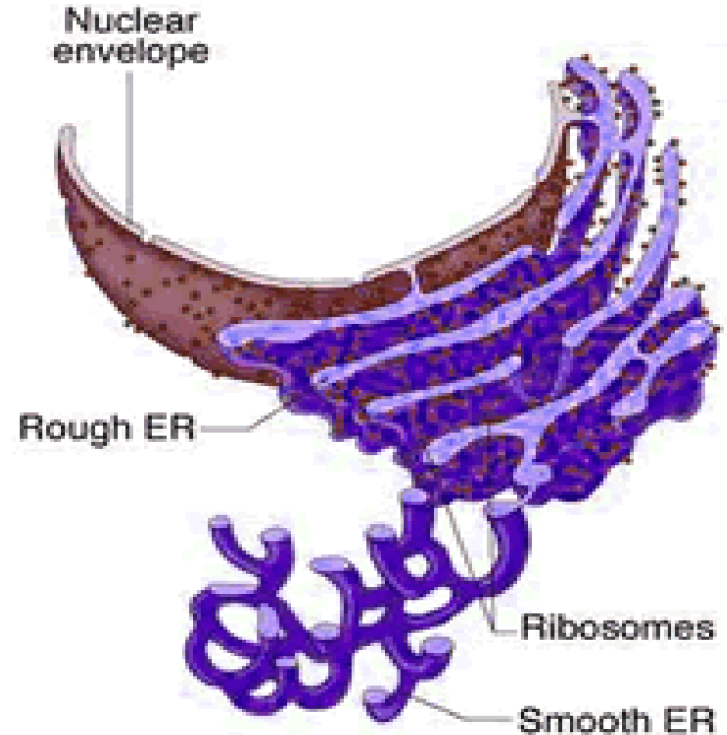


Figure 1

# Smooth Endoplasmic Reticulum

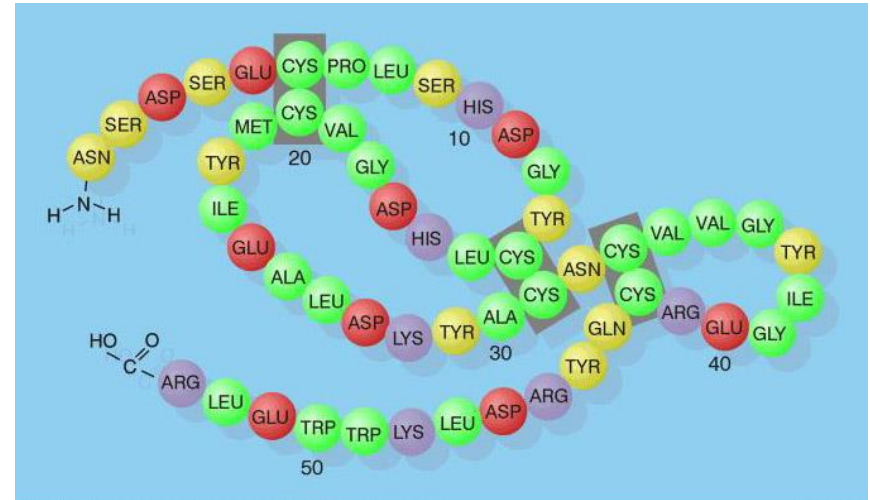
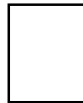
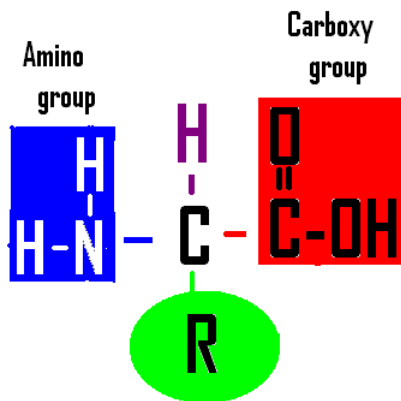
- *Smooth ER* lacks ribosomes on its surface
- Is **attached to the ends** of rough ER
- Makes cell products that are **USED INSIDE the cell**
- Makes membrane lipids (**steroids**)
- **Regulates calcium** (muscle cells)
- **Destroys toxic** substances (Liver)



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

# Ribosomes

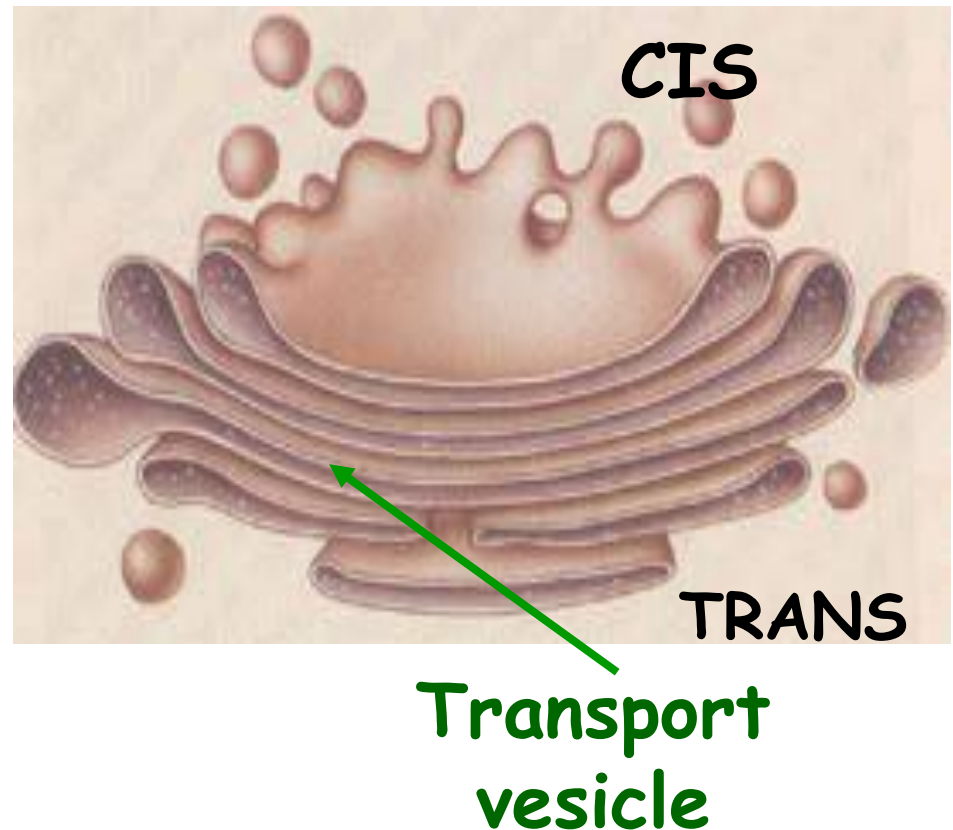
- Made of **PROTEINS** and **rRNA**
- “Protein factories” for cell
- Join **amino acids** to make proteins
- Process called **protein synthesis**
- Can be attached to Rough ER OR Be free (unattached) in the **cytoplasm**





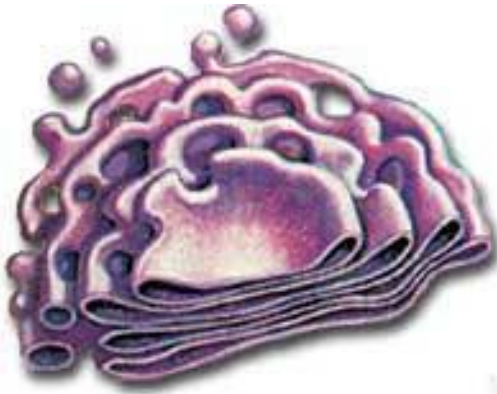
# Golgi Bodies

- 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

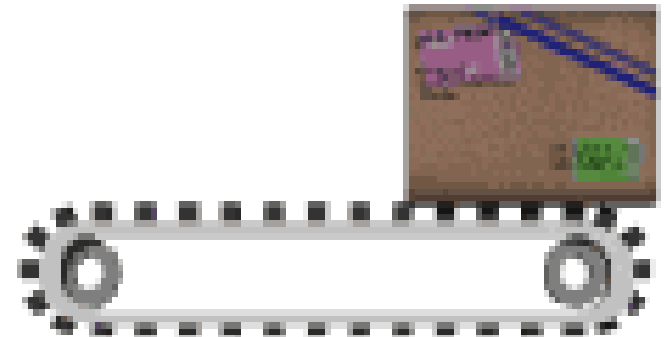


# Golgi Bodies

Look like a stack of pancakes

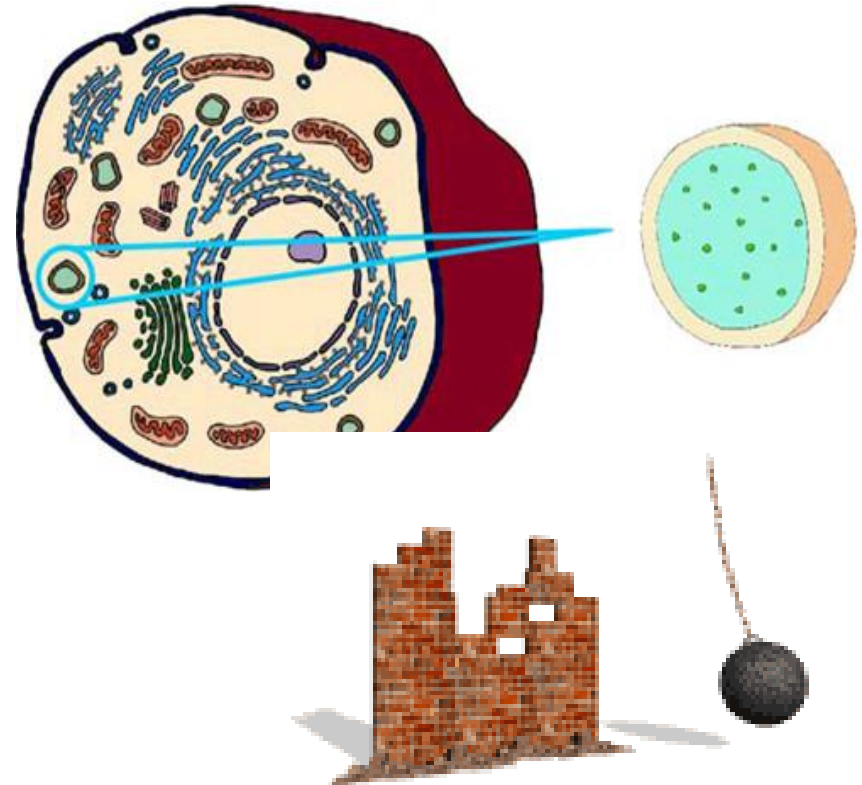


**Modify, sort, & package**  
molecules from ER  
for **storage** OR  
**transport** out of cell



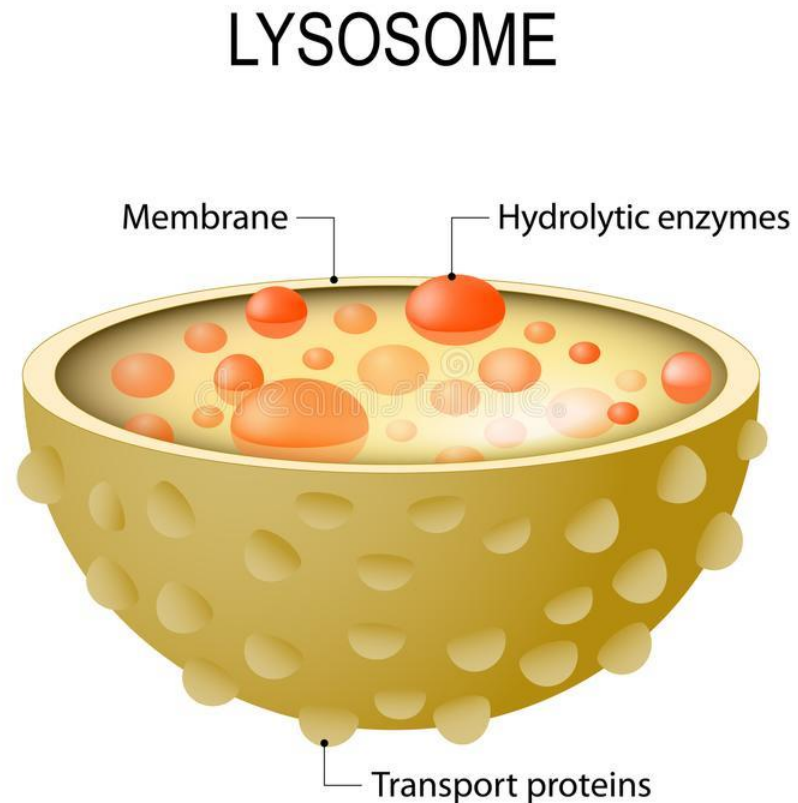
# Lysosomes

- 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)



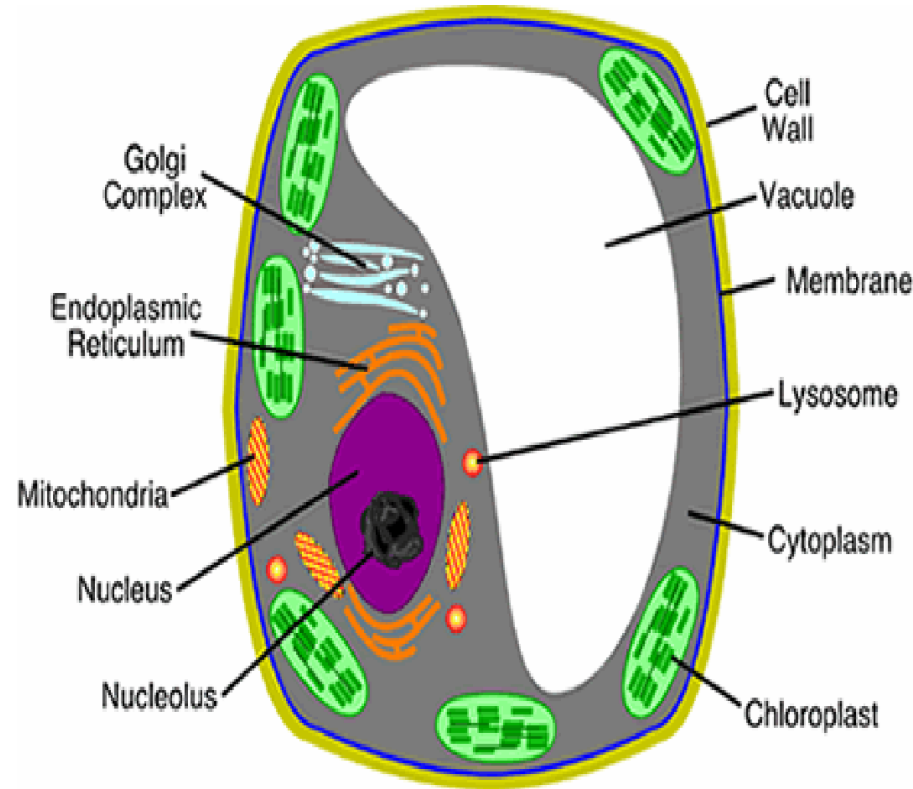
# Lysosome Digestion

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



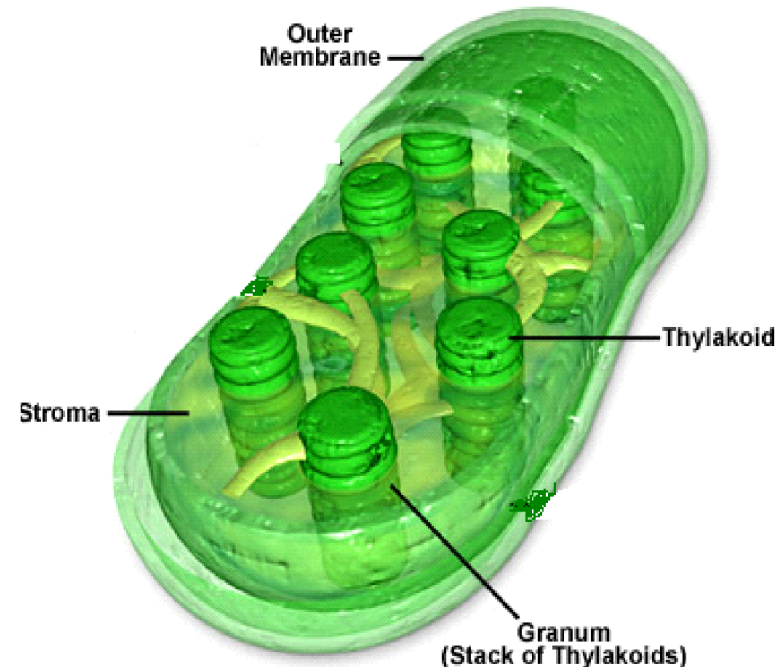
# Vacuoles

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



# Chloroplasts

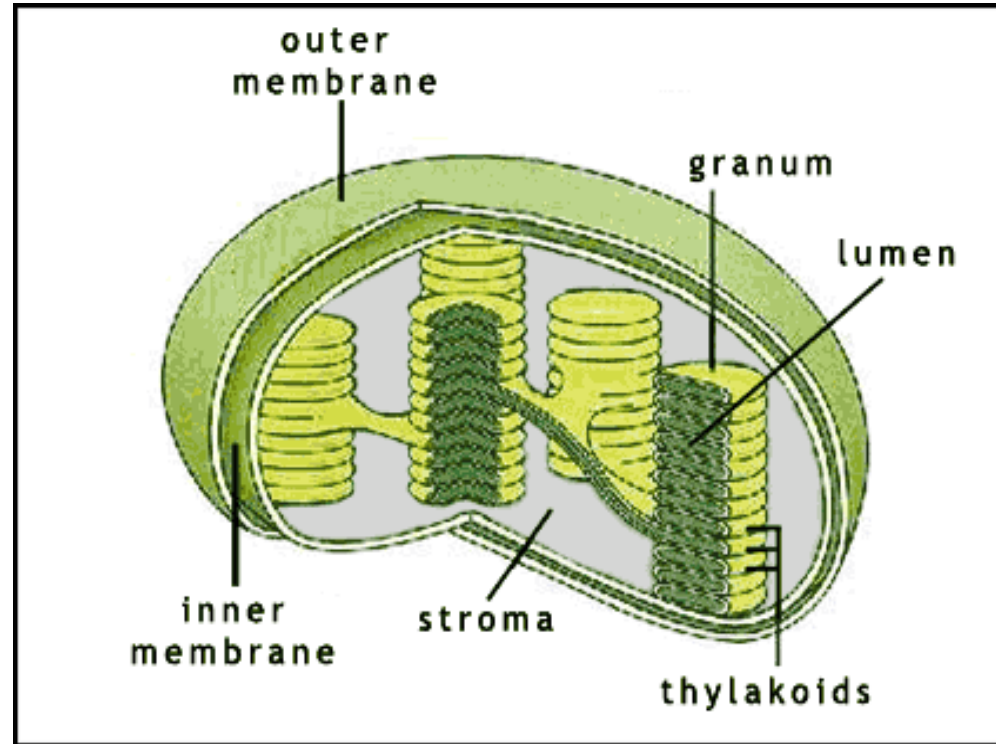
- Found only in **producers** (organisms containing **chlorophyll**)
  - Use **energy from sunlight** to make own **food (glucose)**
  - Energy from sun stored in the **Chemical Bonds of Sugars**
- 
- ❖ Surrounded by **DOUBLE** membrane
  - ❖ **Outer** membrane **smooth**
  - ❖ **Inner** membrane modified 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



# Homeostasis



# Homeostasis

Definition : Maintenance of the relative stability of the physical and chemical aspects of the internal environment within a range compatible with cellular function.

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.

# Homeostatic Control System

Is a functionally interconnected network of body components that operate to maintain a given physical or chemical factor in the internal environment relatively constant around an optimal level.

Can be classified as:

- Intrinsic (local controls) are inherent compensatory responses of an organ to a change
- Extrinsic controls are responses of an organ that are triggered by factors external to the organ , namely, by the nervous and endocrine systems

# Extrinsic homeostatic systems

## • Nervous System

The nervous system maintains homeostasis by controlling and regulating the other parts of the body.

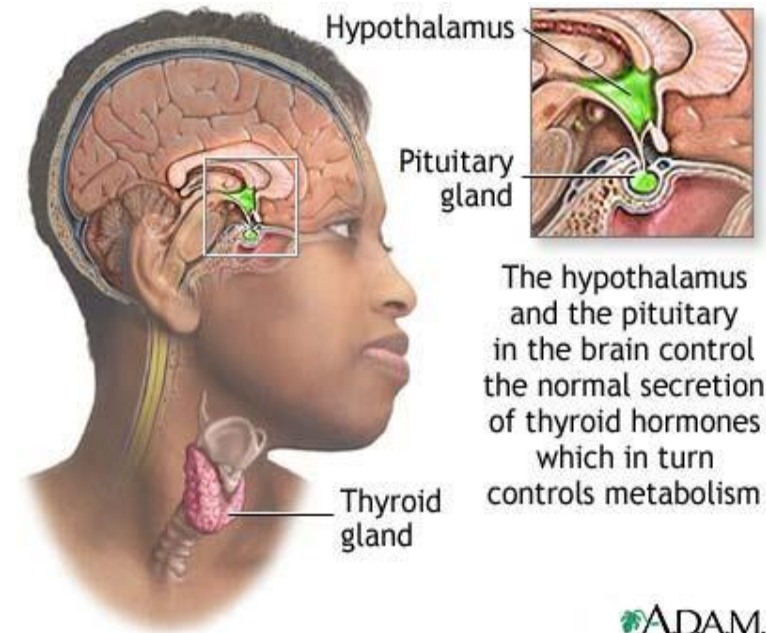
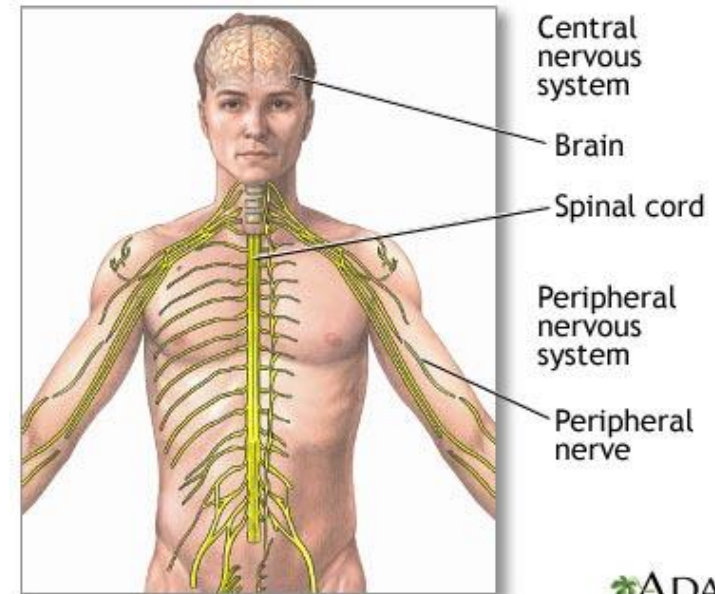
- A deviation from a normal set point acts as a stimulus to a receptor, which sends nerve impulses to a regulating center in the brain. The brain directs an effector to act in such a way that an adaptive response takes place.

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.

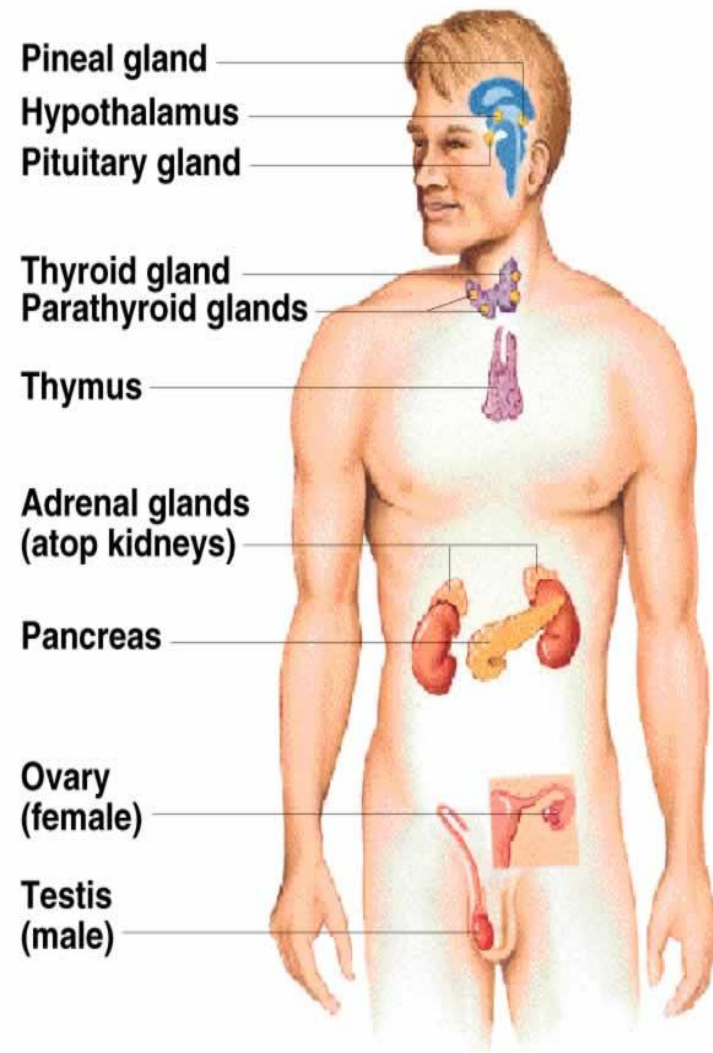
- The hypothalamus is a portion of the brain particularly concerned with homeostasis; it influences the action of the medulla oblongata, a lower part of the brain, the autonomic nervous system, and the pituitary gland.

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.



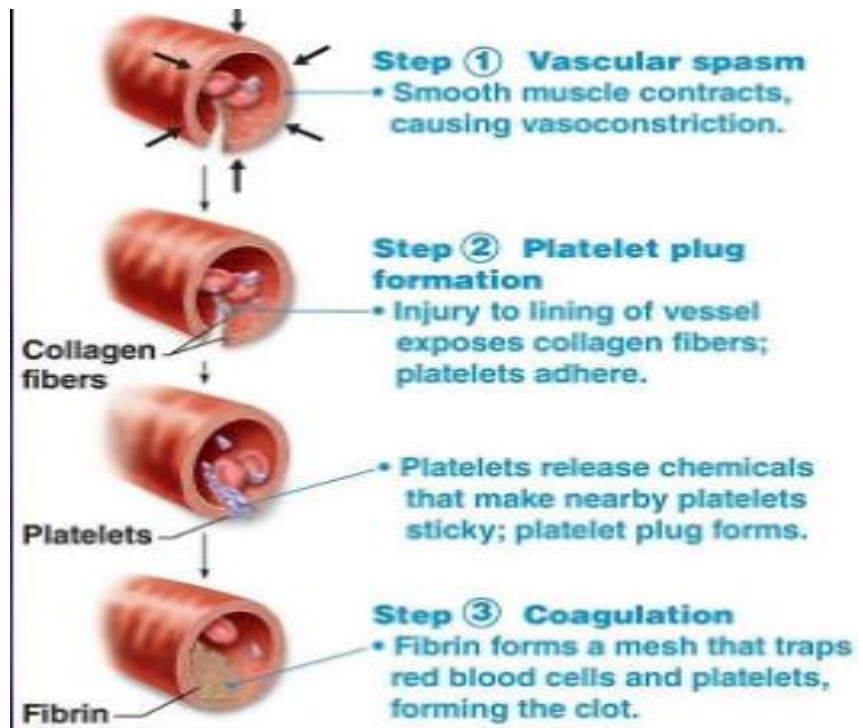
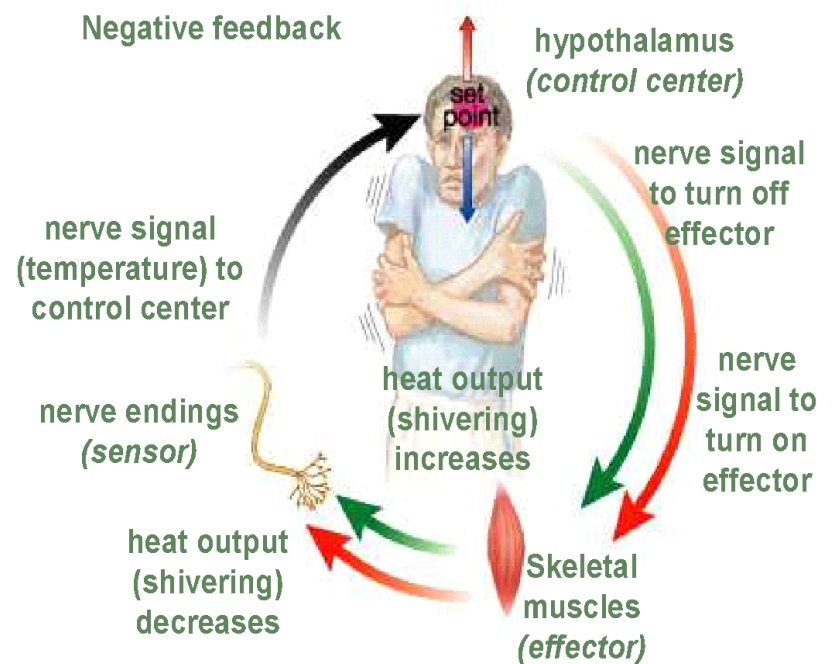
## • **Endocrine System**

- The endocrine system consists of glands which secrete special compounds called **hormones** 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.



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- 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.

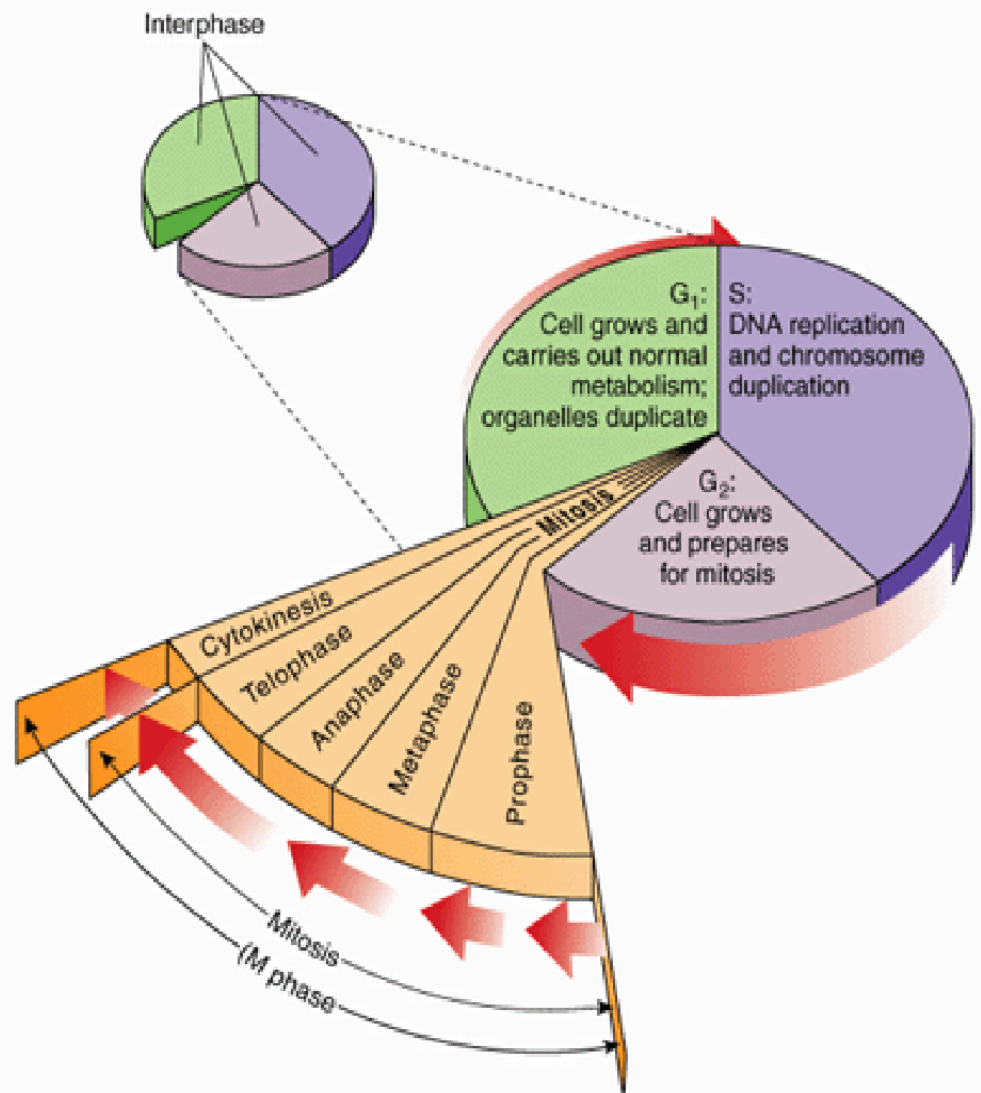


# **Cell growth, reproduction, and differentiation**



# The Cell Cycle

- Mitosis and meiosis are single steps in cell cycle
- G<sub>1</sub>, S, G<sub>2</sub>, and M phases
  - Cells not in process of dividing are in G<sub>0</sub> phase
  - Chromosomes are duplicated in preparation for the next round of division during interphase



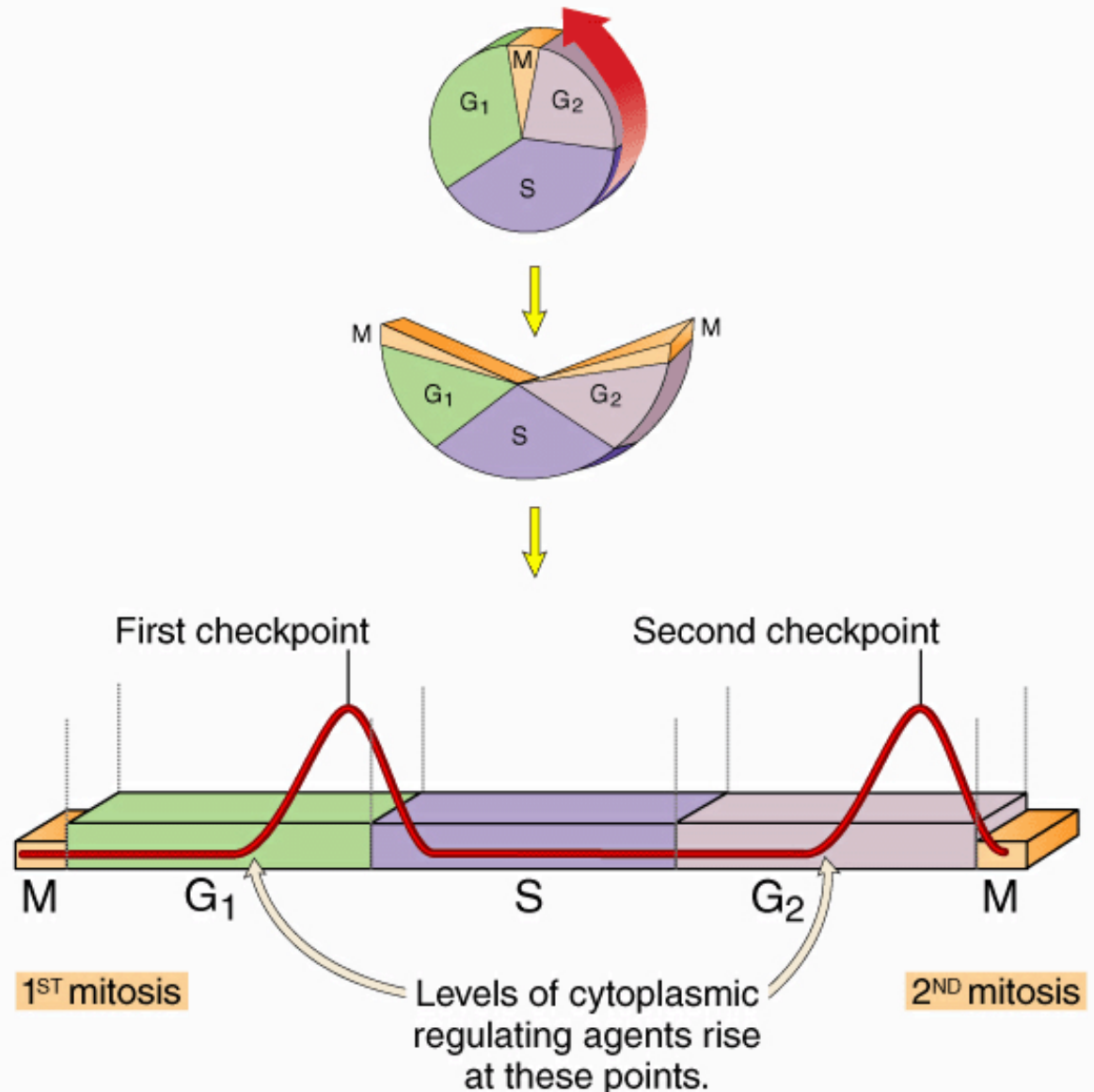
# **Control of the Cell Cycle**

- **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**



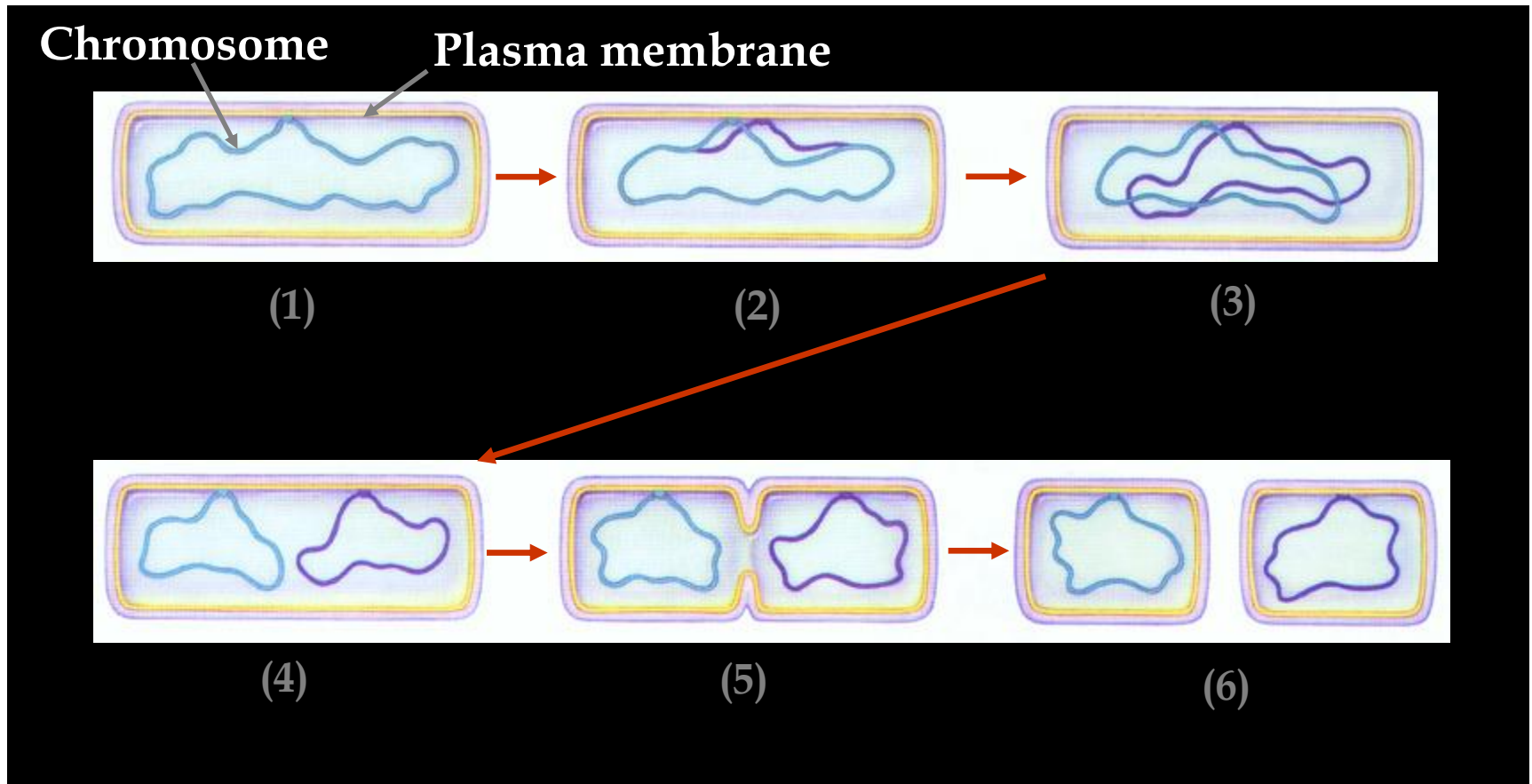
# Control of the Cell Cycle

- Cell cycle control is focused at 3 places:
- G1 checkpoint
- G2 checkpoint
- M checkpoint
  - Before S phase (DNA synthesis)
  - At transition between G<sub>2</sub> and M phase



# DNA replication-Binary fission

**Daughter cells are identical copies**



**Neither mitosis nor meiosis occurs in prokaryotes**

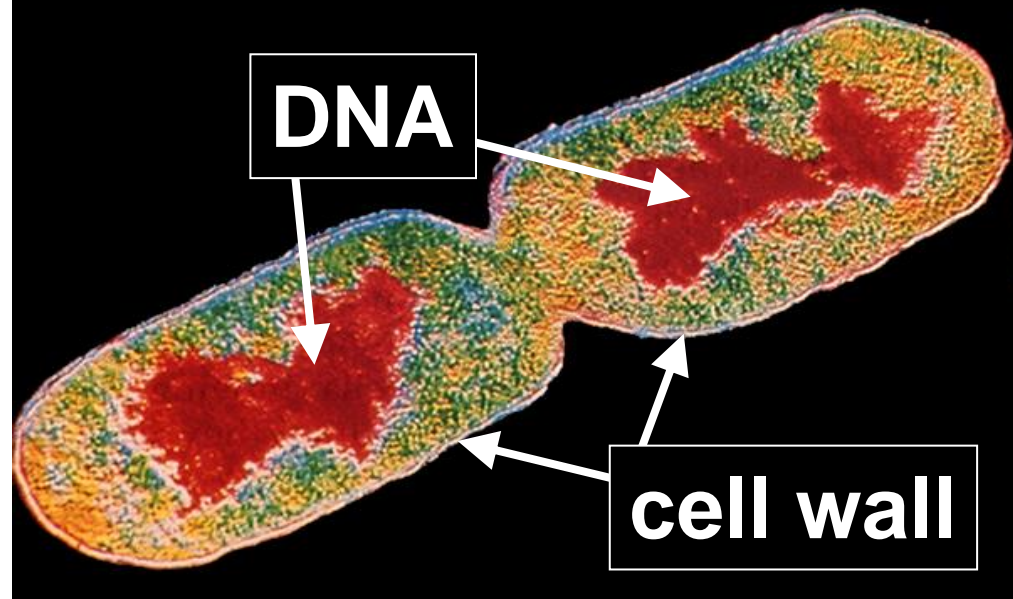
# Bacteria

## 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

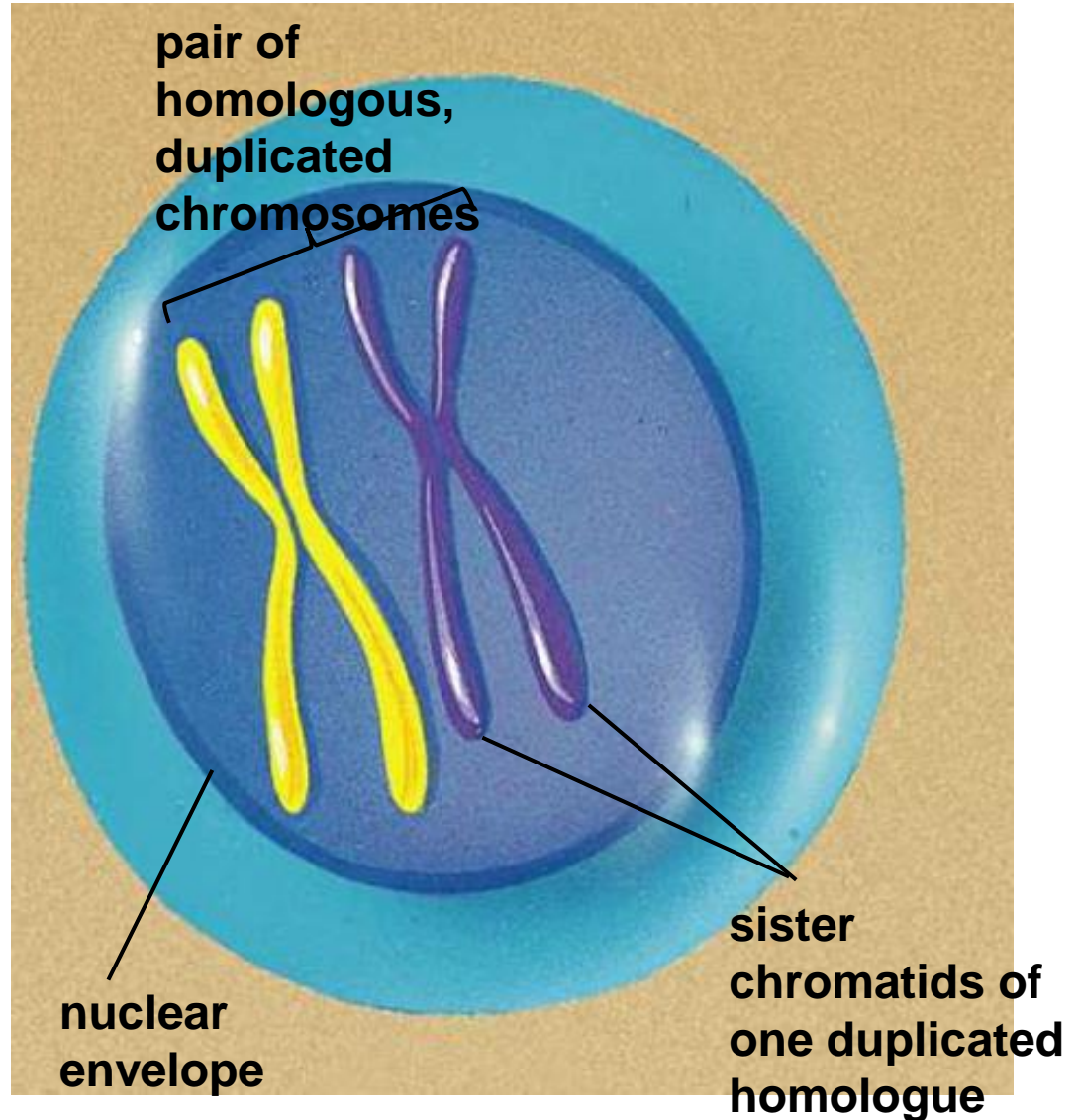
**Transduction** → Transfer of genetic material between prokaryotes by viruses

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

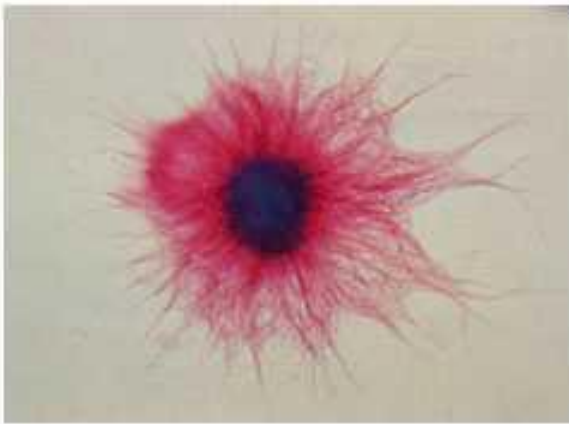
# Mitosis

- **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



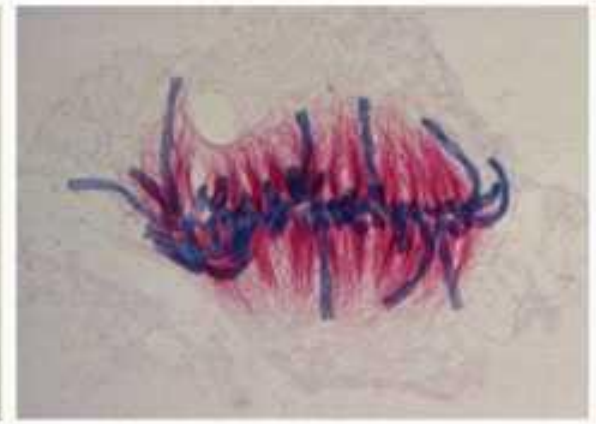




**(a) Interphase in a seed cell:** The chromosomes (blue) are in the thin, extended state and appear as a mass in the center of the cell. The spindle microtubules (red) extend outward from the nucleus to all parts of the cell.



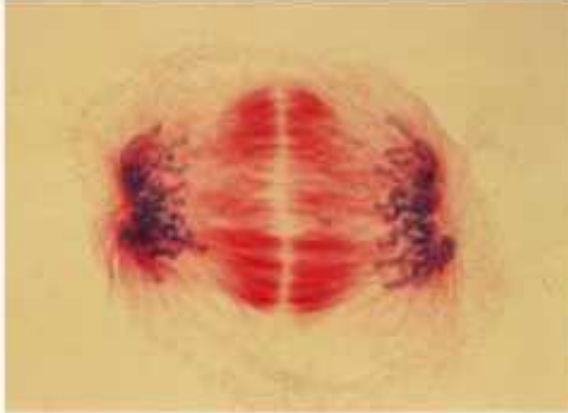
**(b) Late prophase:** The chromosomes (blue) have condensed and attached to the spindle microtubules (red).



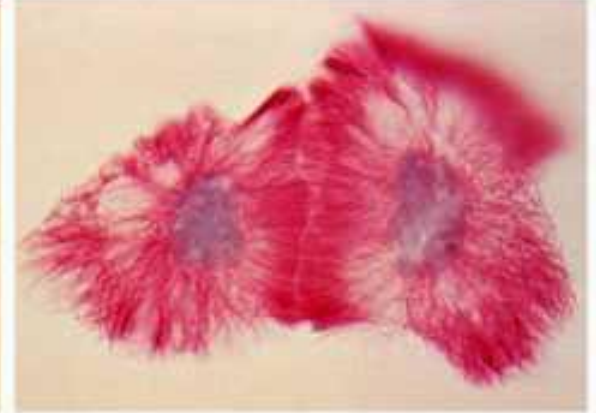
**(c) Metaphase:** The chromosomes have moved to the equator of the cell.



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



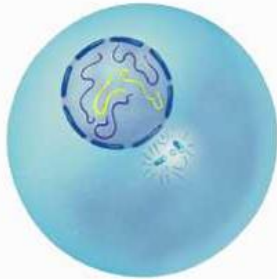
**(e) Telophase:** The chromosomes have gathered into two clusters, one at the site of each future nucleus.



**(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



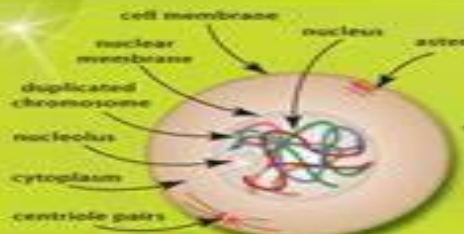


# CELL DIVISION

## Mitosis or somatic cell division

A cell divides producing two genetically identical daughter cells.

- new cells are produced for growth or repair of aging or damaged tissues.
- for asexual reproduction.



### Interphase:

The stage between two successive cell divisions.

- Prior to mitosis, thin strands of DNA in a cell thicken into chromosomes, which then duplicate.



1

### Early Prophase:

- The centrioles divide and, with the asters, move apart.
- The nuclear membrane begins to disintegrate.



2

### Late Prophase:

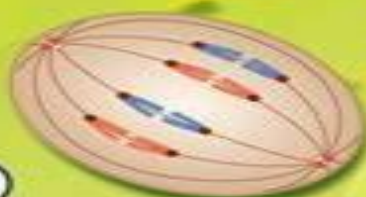
- The centrioles and asters are pushed to the opposite poles of the cell.
- Spindle fibres extend between the poles.
- The nuclear membrane and nucleolus have almost disappeared.



3

### Metaphase:

- The nuclear membrane disappears completely.
- The double chromosomes, their centromeres attached to the spindle fibres, align at the metaphase plate, the midline of the cell.



4

### Early Anaphase:

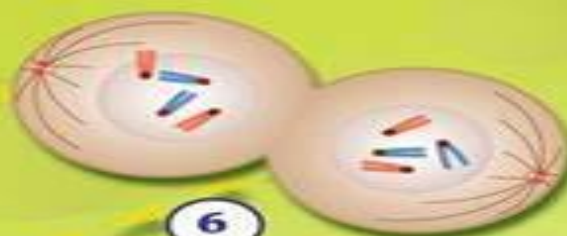
- The centromeres split, half moving to one pole and half to the other pole.



5

### Late Anaphase:

- The chromosomes have almost reached their respective poles.
- The cell membrane begins to contract at the midline.



6

### Telophase:

- The cell membrane completes contraction, closing over to split the cell in two.
- Nuclear membranes form around the chromatin masses within each new daughter cell.



### Mitosis completed:

- There are now two cells, with structures and chromosomes identical to each other and to the original cell.





# **Meiosis**

## **Characteristics of meiosis**

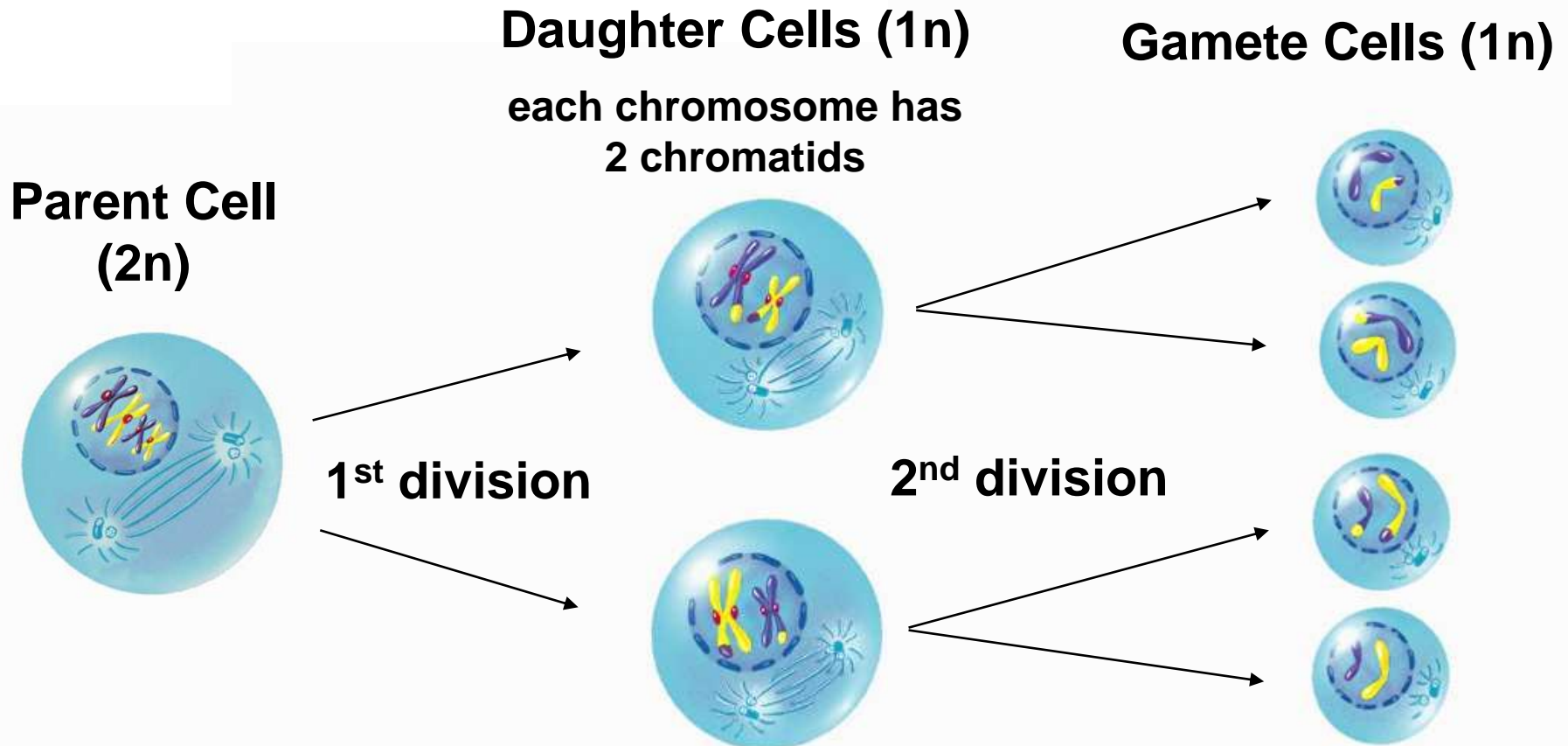
- **1. Occurs in sex cells (germ cells) and produces gametes**
- **2. A reductional division resulting in haploid cells**
- **3. Involves two sequential divisions resulting in four cells**
- **4. Produces cells that are genetically different because of genetic recombination (crossing-over).**



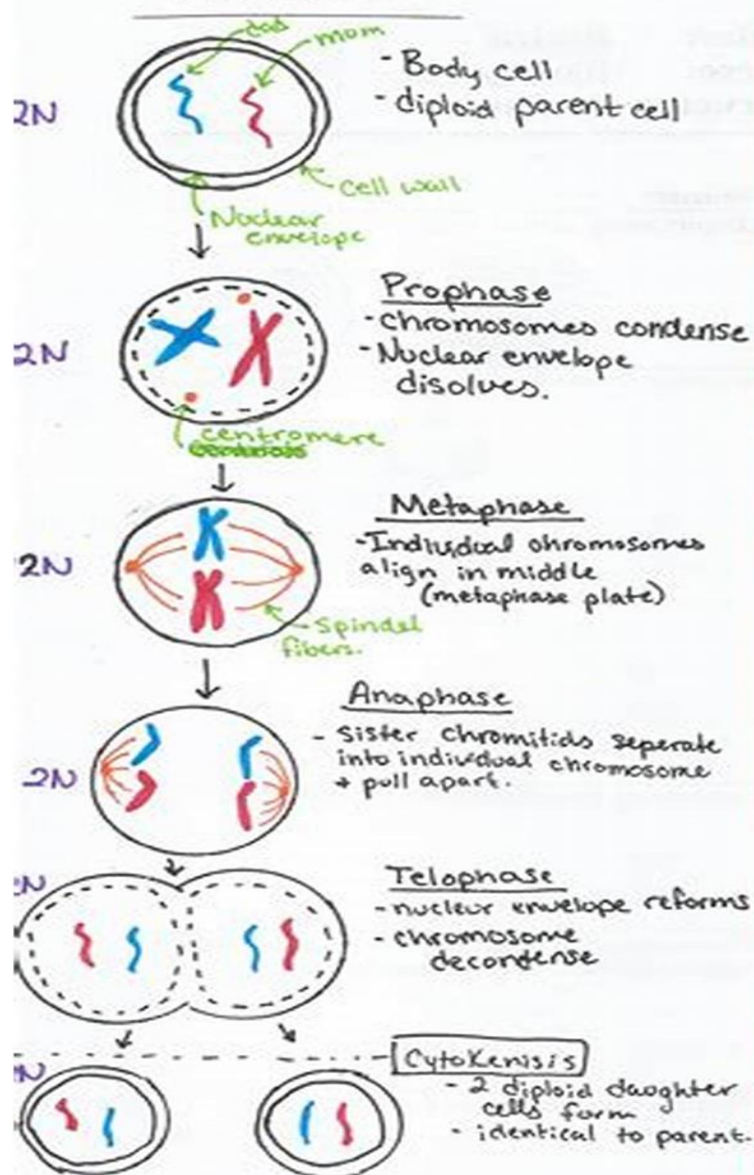
# **Meiosis produces gametes for sexual reproduction**

- **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**

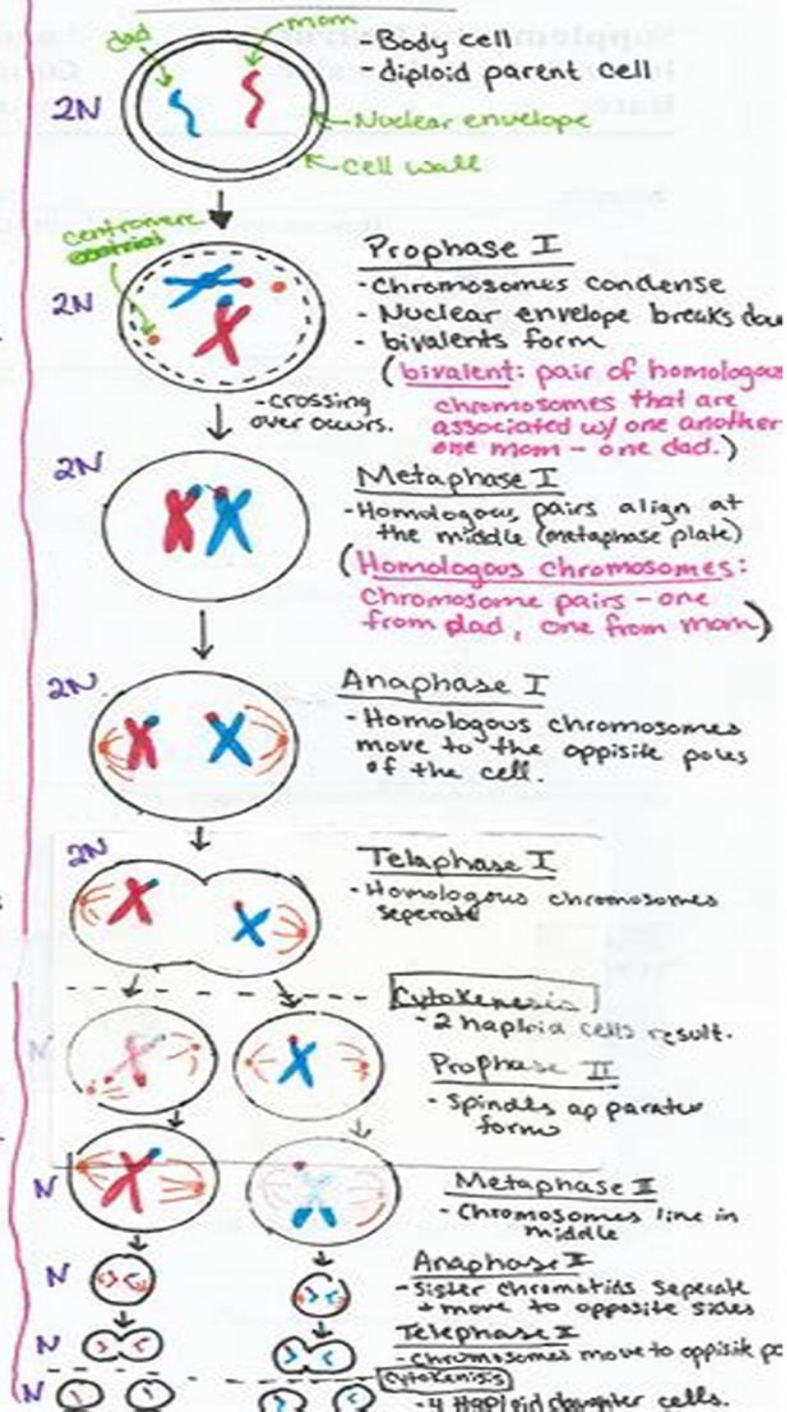
# Meiosis



# Mitosis

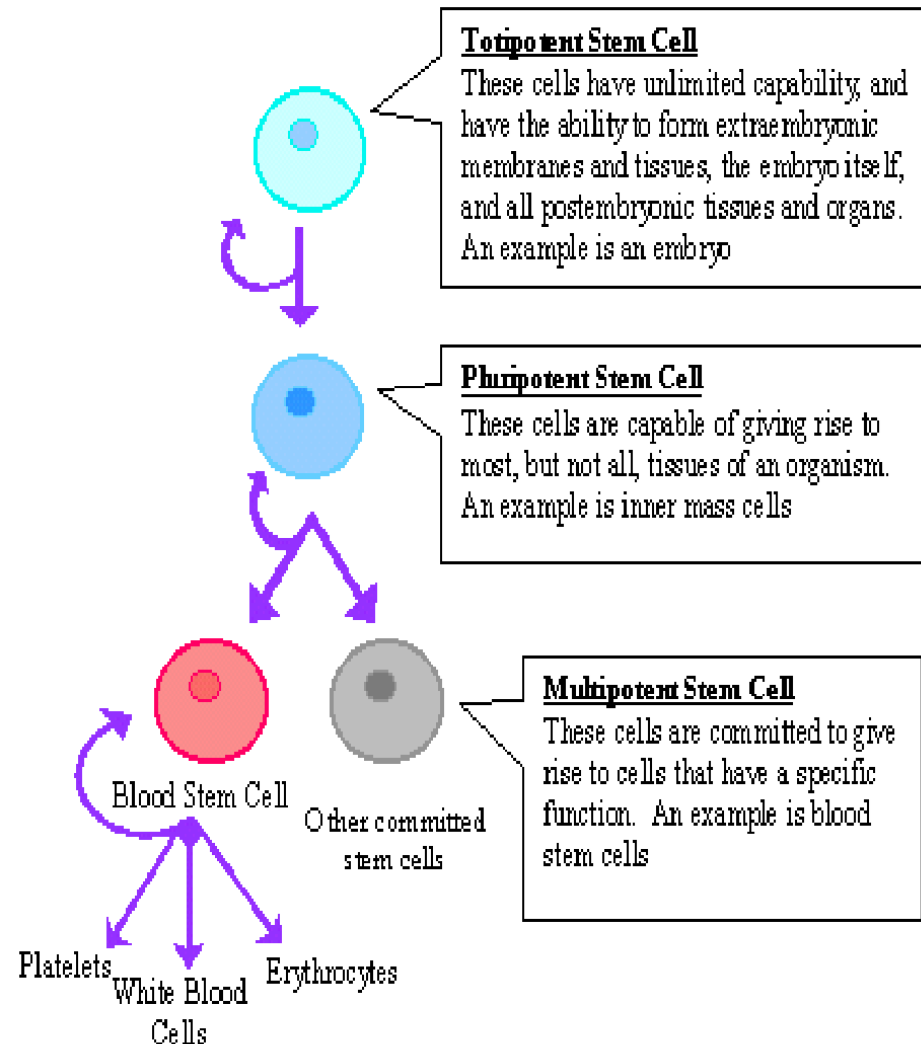


# Meiosis

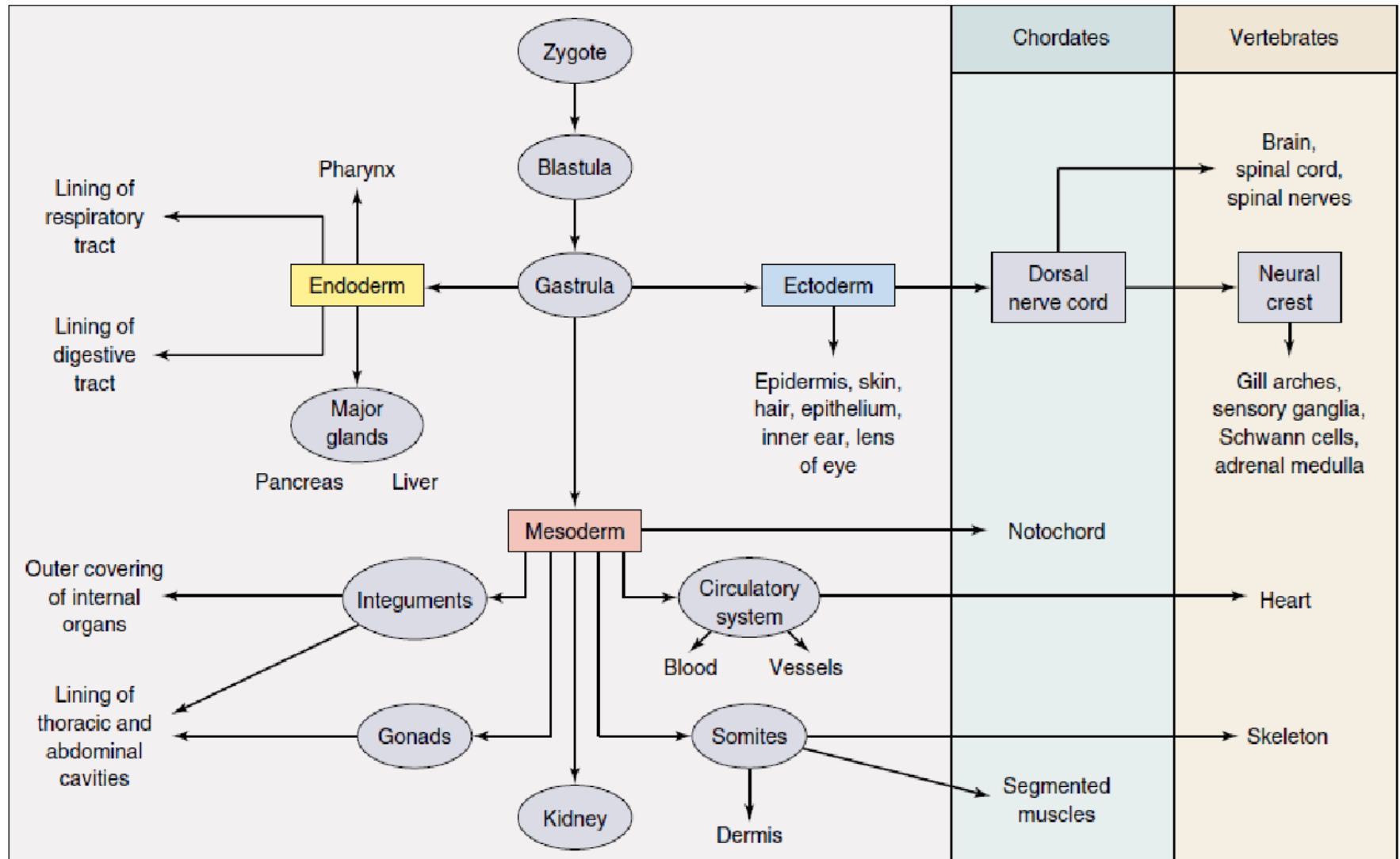


# Cell Differentiation

- 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

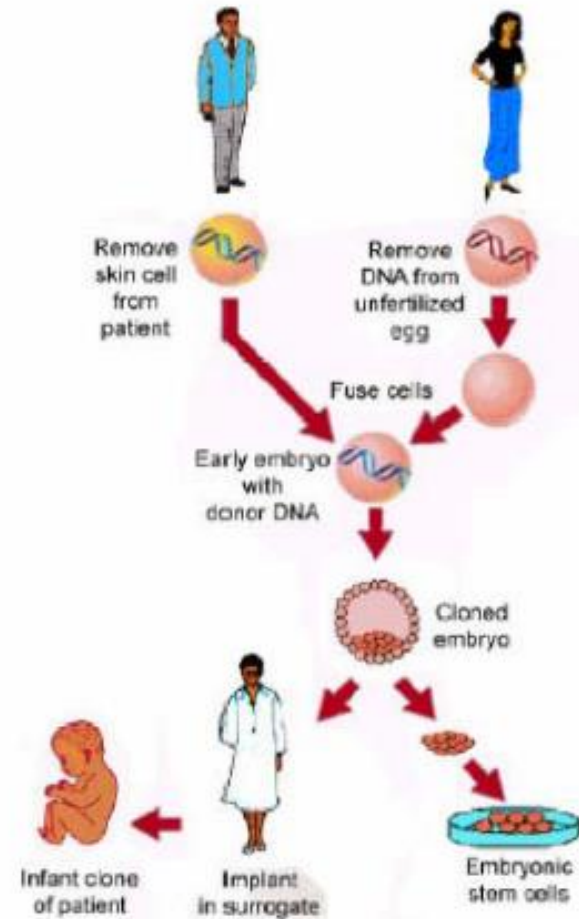
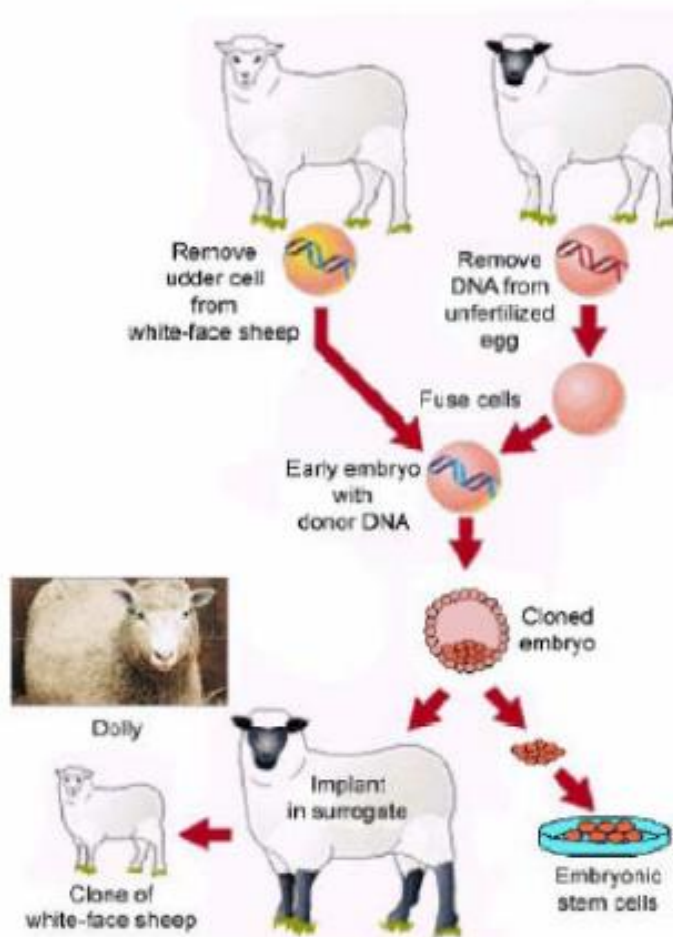


# Stem cells and tissue engineering

**Stem cell (SC)**- Stem Cells are the cells which has the ability to divide for indefinite periods and which can give rise to specialized cells of various tissues of body.



# Importance



## Properties

- Two defining property-Ability to **differentiate** into other cells, ability to **self regenerate**
- It can be maintained in the *in vitro* conditions for extended period using artificial medium
- Its karyotype remains stable even after many division
- It can produce any type of adult cells of the organisms.

# Classification of stem cells

**Unipotent** - cell which can make exact copies of itself indefinitely, can differentiate, and produce same type of cells eg. Adult muscle stem cell

**Totipotent**- can become any cell type  
eg: Morula stage of Embryos

**Pluripotent**- almost any kind of cell except placenta  
eg: Embryonic SC

**Multipotent**- Produces limited range of cell types  
Adult SC: nerve cells, blood cells, muscle cells, bone and skin cells.

# Sources of stem cells

## 1. EMBRYONIC STEM CELLS

- Isolated from blastocyst stage of embryos
- Pluripotent (capable of developing into almost all the cell types of the body) in nature

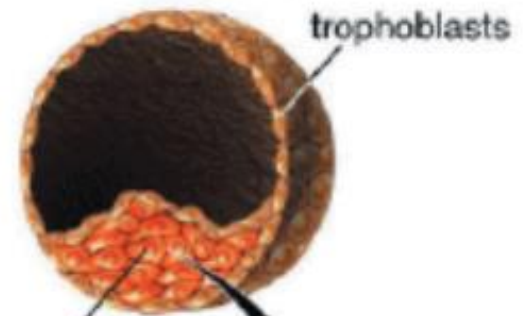
## 2. ADULT STEM CELLS

- It is present in all the organs, but very little amount
- They are multipotent (ability of a single stem cell to develop into more than one cell type but with ability to differentiate into a closely related family of cells).

# Culture of embryonic stem cells

- Collection of embryos from IVF centres
- Isolation of ICM (inner cell mass) from the blastocyst stage
- Transfer ICM to the center of culture plate containing feeder cells and growth medium
- It can be differentiated to any cells by adding specific medium

**Blastocyst**  
(64 to 200 cell stage,  
cross-section)



*Propagation  
in Culture*

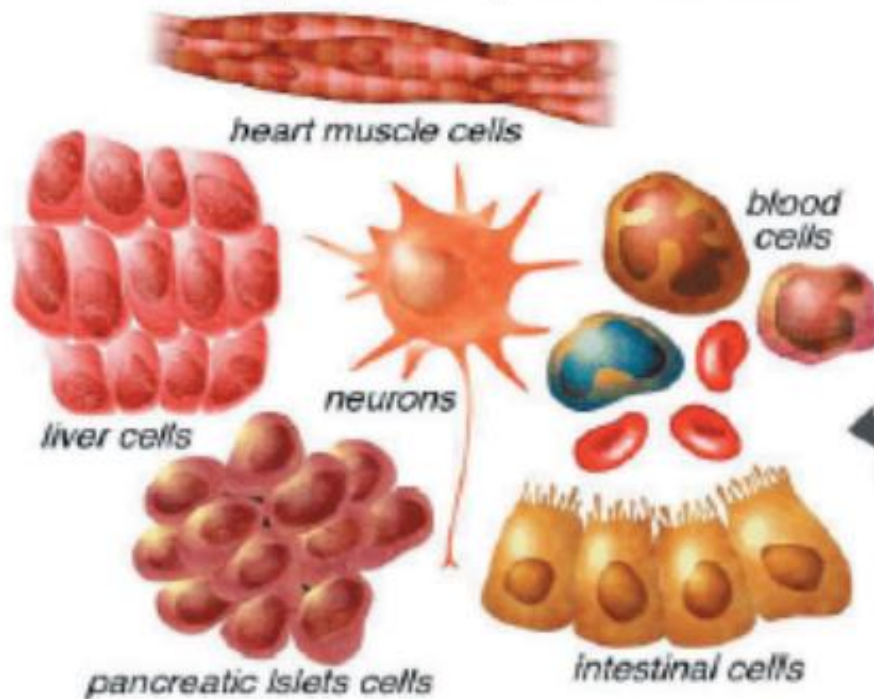
Inner cell mass



**Pluripotent  
embryonic  
stem cells**

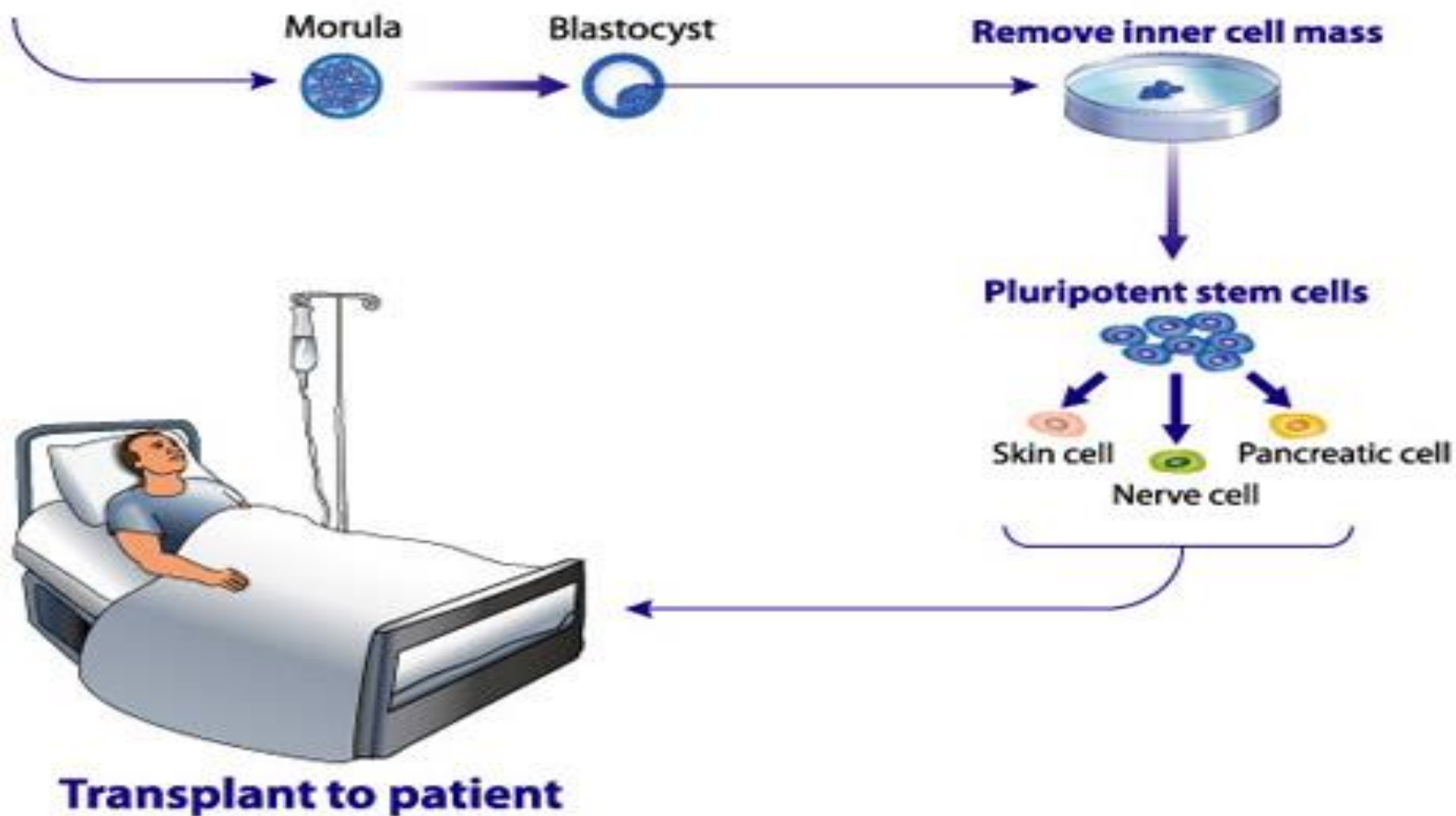
*Differentiation*

**Development of specialized cells**





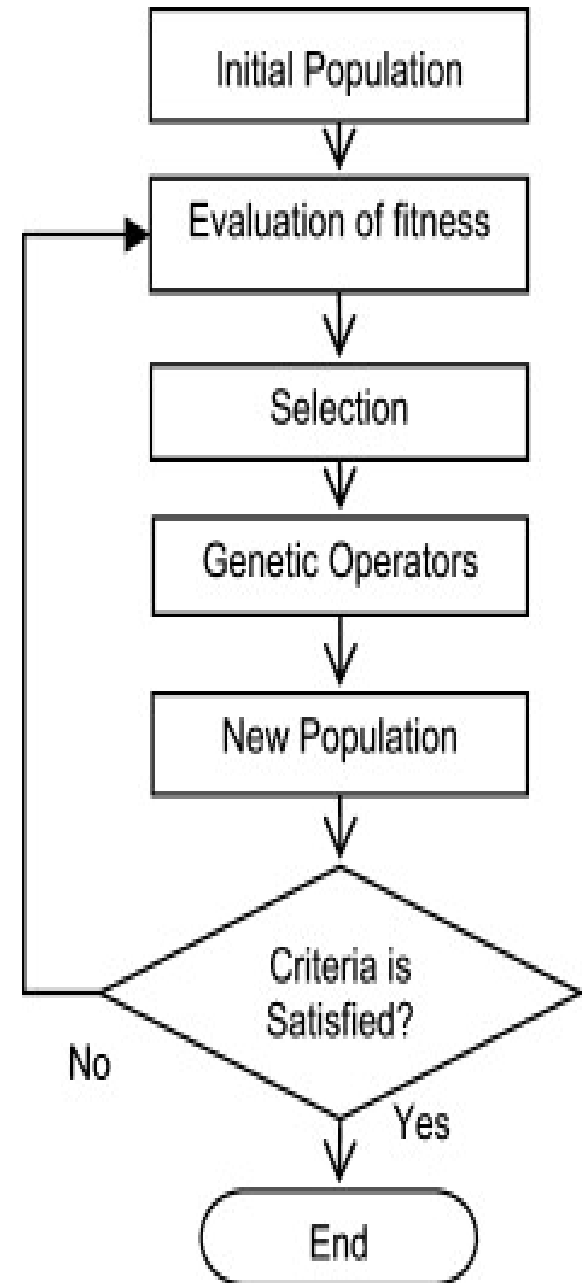
## In vitro fertilization



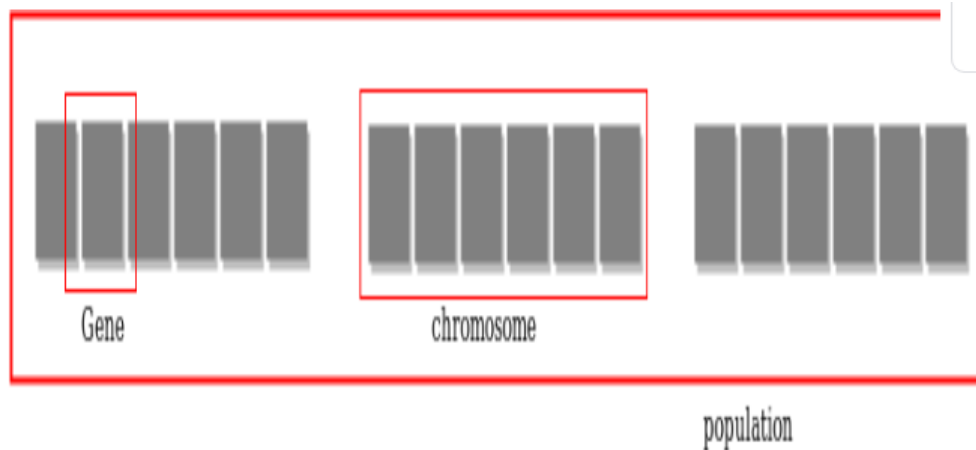
# Genetic Algorithms

- **Genetic algorithms (GA) in programming, simulate the process of natural selection** which means those species who can adapt to changes in their environment are able to survive and reproduce and go to next generation. In simple words, they simulate “survival of the fittest” among individual of consecutive generation for solving a problem.

- Genetic algorithms are based on an analogy with genetic structure and behaviour of chromosomes of the population.
- Following is the foundation of GAs based on this analogy –
  1. Individual in population compete for resources and mate
  2. Those individuals who are successful (fittest) then mate to create more offspring than others
  3. Genes from “fittest” parent propagate throughout the generation, that is sometimes parents create offspring which is better than either parent.
  4. Thus each successive generation is more suited for their environment.



## Components of a search space in Genetic algorithm



- Gene represents a single solution to a problem
- chromosome (individual) is composed of several genes or multiple similar solutions.
- population of individuals are maintained within search space - all solutions to the problem

**The whole algorithm can be summarized as –**

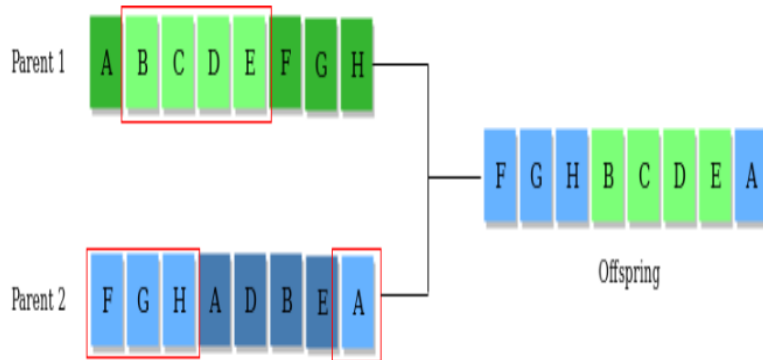
- 1) Randomly initialize n populations
- 2) Determine fitness of population
- 3) Until convergence repeat:
  - a) Select parents from population
  - b) Crossover and generate new population
  - c) Perform mutation on new population
  - d) Calculate fitness for new population

# The Fitness score

- The GAs maintains the population of  $n$  individuals (chromosome/solutions) along with their fitness scores.
- The individuals having better fitness scores are given more chance to reproduce than others.
- The individuals with better fitness scores are selected who mate and produce **better offspring** by combining chromosomes of parents.
- Always the new generation of solutions will have better fitness than the parent population.



# Operators for GA



**Crossover**



**Mutation**

- The Algorithm uses certain biological concepts as operators to find better solutions
- **CrossOver**
- **Mutation**
- **Selection** ( best fitness score in previous generation)

# Uses of GA

**Genetic Algorithms are primarily used in optimization problems of various kinds, but they are frequently used in other application areas**

- **Optimization** – Genetic Algorithms are most commonly used in optimization problems wherein we have to maximize or minimize a given objective function value under a given set of constraints
- **DNA Analysis** – GAs have been used to determine the structure of DNA using spectrometric data about the sample.
- **Neural Networks** – GAs are also used to train neural networks, particularly recurrent neural networks.
- **Parallelization** – GAs also have very good parallel capabilities, and prove to be very effective means in solving certain problems, and also provide a good area for research.

# Advantages-disadvantages of GA

- Does not require any derivative information (which may not be available for many real-world problems).
- Is faster and more efficient as compared to the traditional methods.
- Provides a list of “good” solutions and not just a single solution.
- GAs are not suited for all problems, especially problems which are simple and for which derivative information is available.
- Fitness value is calculated repeatedly which might be computationally expensive
- Being stochastic, there are no guarantees on the optimality or the quality of the solution.

**Thank you**