Third UG – Botany

Fifth Semester

Paper V

Cell Biology, Genetics and Plant Breeding

Dr. A. Sujatha, Department of Botany, MVR
Degree College, Gajuwaka, VSP

Cell Biology

Lesson 1

The cell

DR. A.Sujatha
Department of Botany
M.V.R Degree and PG college
Gajuwaka, Visakhapatnam

The Cell

- **Definition**: The cell is the basic unit of life.

- **Discovery:**
- British scientist Robert Hooke 1665 – Dead cell
- Anton van Leeuwenhoek in Holland – living cell. He was the first person to observe human cells and bacteria.
- Robert Brown (1831) discovered nucleus.

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Cell theory

- Schleiden (1838)and Schwann proposed cell theory.
- Rudolf Virchow (1855) added one more point to the cell theory – known as modern cell theory.
- All living organisms are made up of cells.
- The function of organism is the cumulative function of all the cells.
- All cells arise from pre- existing cells.
- Virchow gave a term - *omnis cellula a cellula*

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Size of the cell

- Smallest cell: Pluro Pneumonia Like Organisms(PPLO)- 0.1micro meters to 0.3 micrometers
- Largest cell: Ostrich egg 175 micro meters X 135 micro meters

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Types of cells

- Based on whether their genes are enclosed by nuclear envelope or not the cells are of 2 types.
- Prokaryotic cells: Bacteria
- Eukaryotic cells: Fungi, Animal cells and plant cells, Protists

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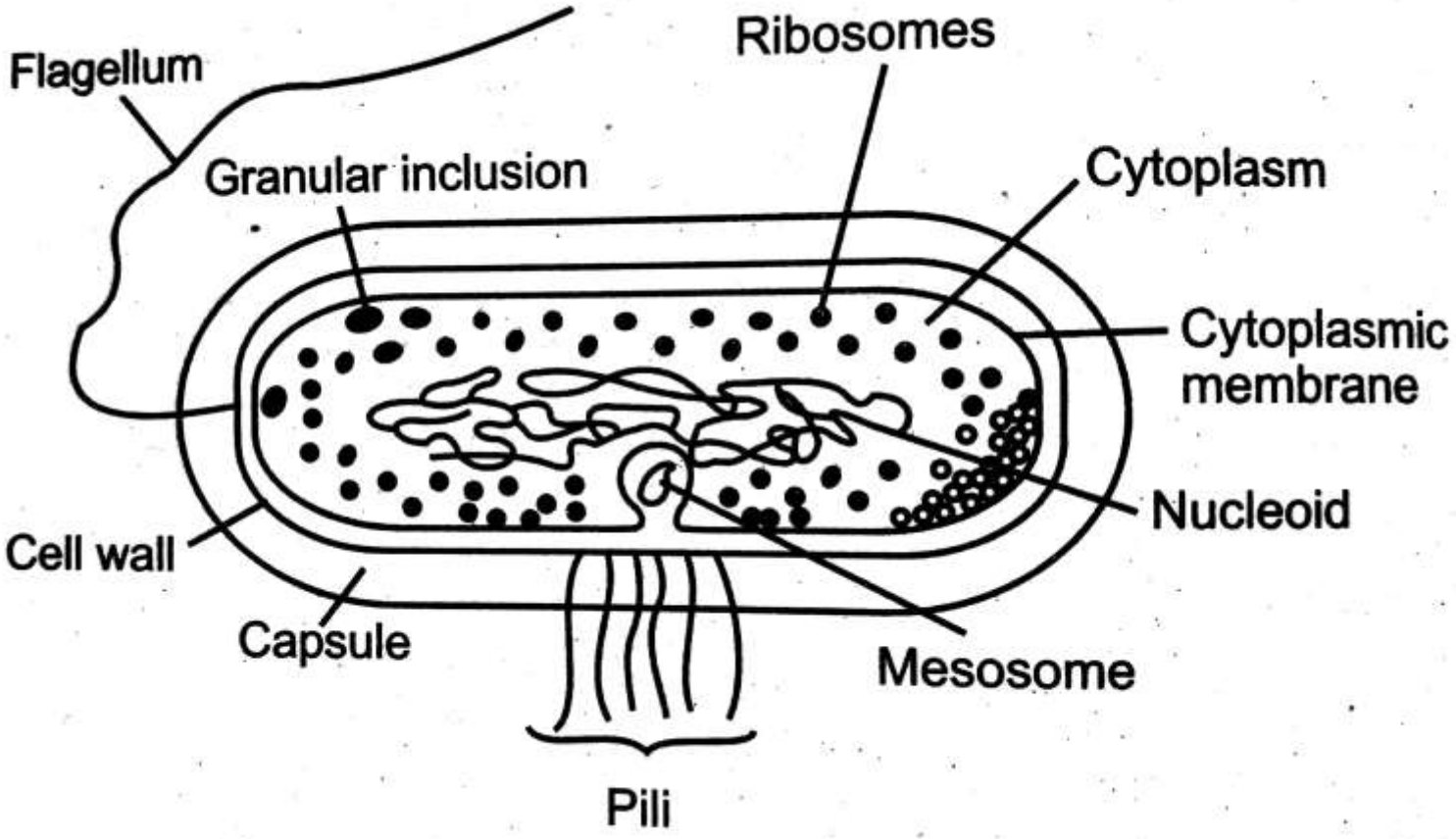
Prokaryotic cell



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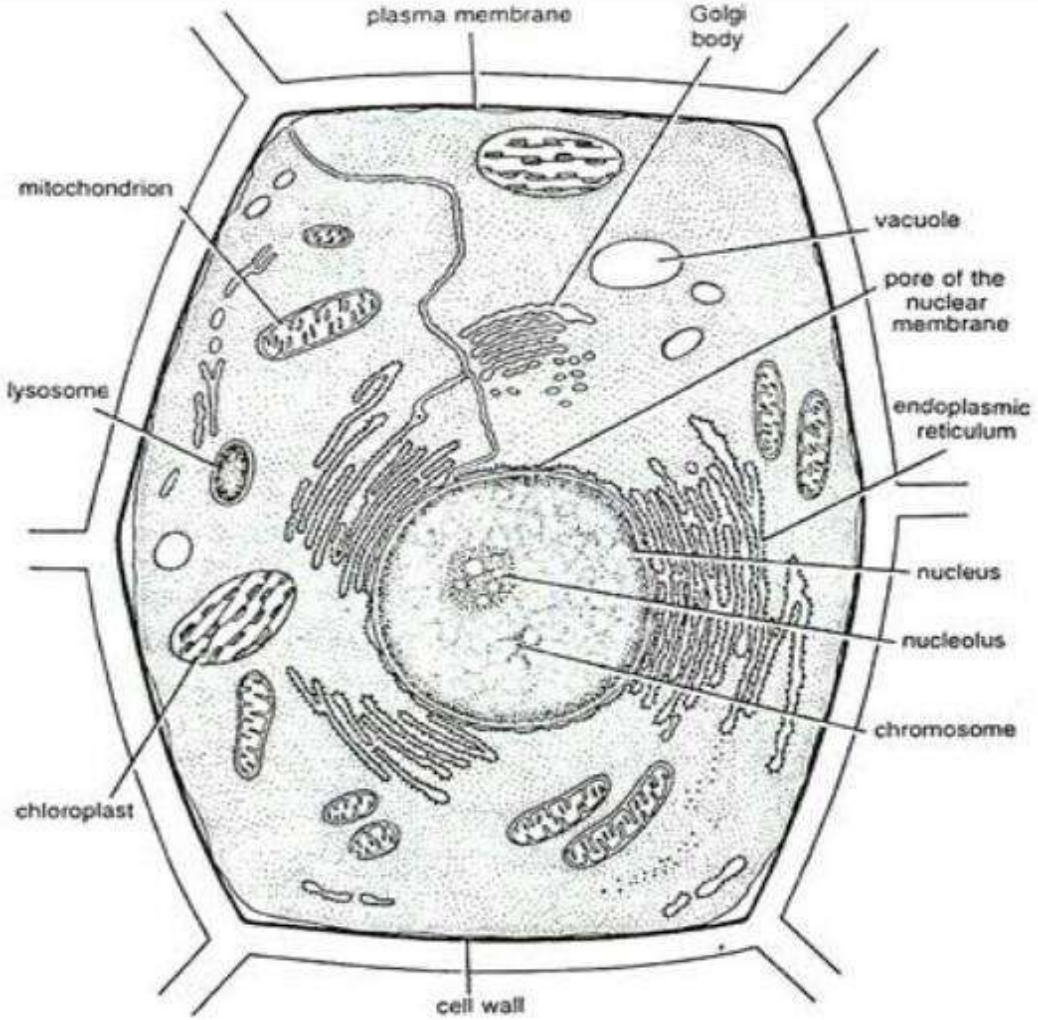
EUKARYOTIC CELL- PLANT CELL



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Difference between Prokaryotic & Eukaryotic cell

Characteristic	Prokaryotic cell	Eukaryotic cell
Size of cell	Typically 0.2-2.0µm in diameter	Typically 10-100 µm in diameter
Example	Bacteria and Archaea	Animals and Plants
Nucleus	Absent	Present
Membrane-enclosed organelles	Absent	Present; examples include lysosomes, Golgi complex, endoplasmic reticulum, mitochondria & chloroplasts
Flagella	Consist of two protein building blocks	Complex; consist of multiple microtubules
Cell wall	Usually present; chemically complex	Only in plant cells and fungi (chemically simpler)
Plasma membrane with steroid	Usually no	Yes
Cytoplasm	No cytosketeton or cytoplasmic streaming	Cytoskeleton; cytoplasmic streaming
Ribosomes	Smaller	Larger
Cell division	Binary fission	Mitosis
Number of chromosomes	One, but not true chromosome	More than one
Sexual reproduction	No meiosis; transfer of DNA fragments only (conjugation)	Involves meiosis

Prokaryotic cells, as well as eukaryotic cells, are covered with the plasma membrane, which is located on top of the cell membrane or mucous capsule. Despite of its relative simplicity, prokaryotes are typically independent cells. Table 4.1 presents the major differences between prokaryotic and eukaryotic cells.

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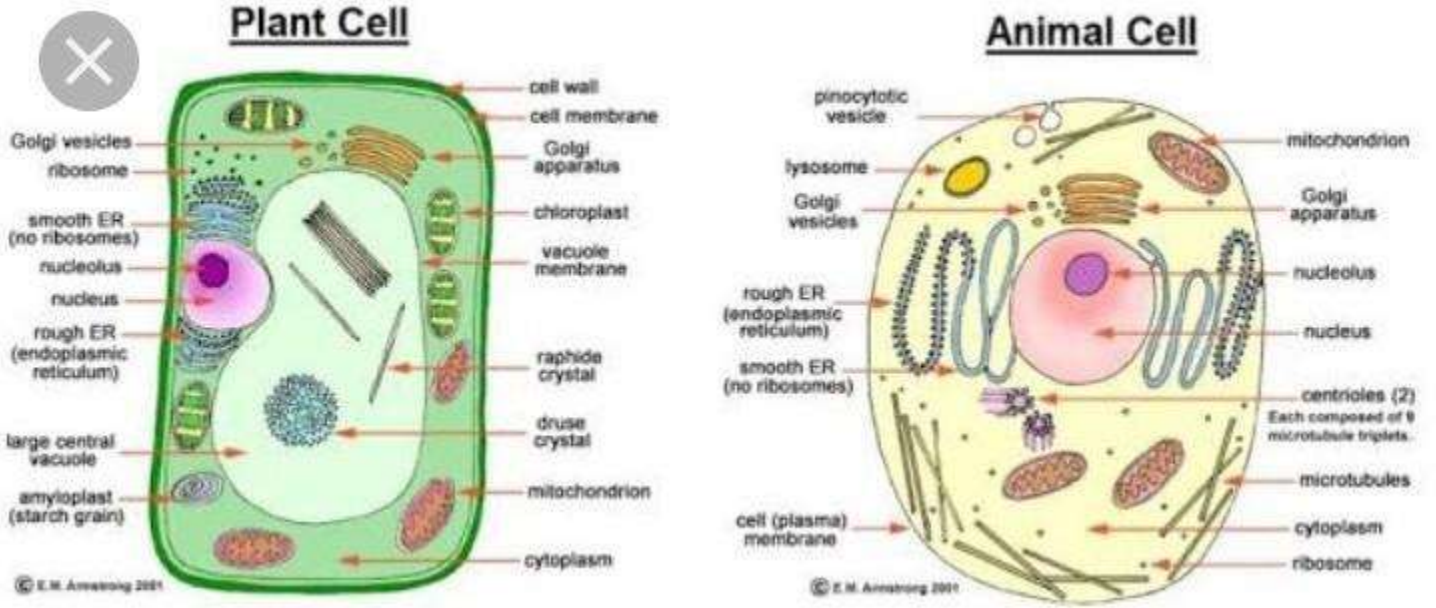
Difference between Plant & Animal cell



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Difference between Plant & Animal cell

S. No	Plant cell	Animal Cell
1	Usually they are larger than animal cells	Usually smaller than plant cells
2	Cell wall present in addition to plasma membrane and consists of middle lamellae, primary and secondary walls	Cell wall absent
3	Plasmodesmata present	Plasmodesmata absent
4	Chloroplast present	Chloroplast absent
5	Vacuole large and permanent	Vacuole small and temporary
6	Tonoplast present around vacuole	Tonoplast absent
7	Centrioles absent except motile cells of lower plants	Centrioles present
8	Nucleus present along the periphery of the cell	Nucleus at the centre of the cell
9	Lysosomes are rare	Lysosomes present
10	Storage material is starch grains	Storage material is a glycogen granules

The end

Thank you

Dr. A. Sujatha, Department of Botany,
MVR Degree College, Gajuwaka, VSP

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Fifth Semester

Paper V

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Unit 1
Cell Biology

Lesson 2
Cell wall

DR. A.Sujatha
Department of Botany
M.V.R Degree and PG college
Gajuwaka, Visakhapatnam

Completed Lesson

Unit 1 - Lesson 1 (The cell)

1. Introduction
2. Prokaryotic and eukaryotic cells
3. Structure of plant cell
4. Nucleus

objectives

1. To learn the structure of plant cell wall.

2. To understand the chemical nature of cell wall.

3. To know the fine structure of cell wall.

4. To learn the function of the cell wall.

Structure of the Lesson

1. Introduction
2. Structure of cell wall
3. Thickness of cell wall
4. Pits
5. Chemical nature of cell wall
6. Fine structure of the cell wall
7. Functions of the cell wall

Introduction

1. One of the characteristic features of the plant cell is the presence of cell wall.

2. It provides rigidity to the plant body.

3. It protects the protoplasm from external injury and prevents the movement of water into the cell.

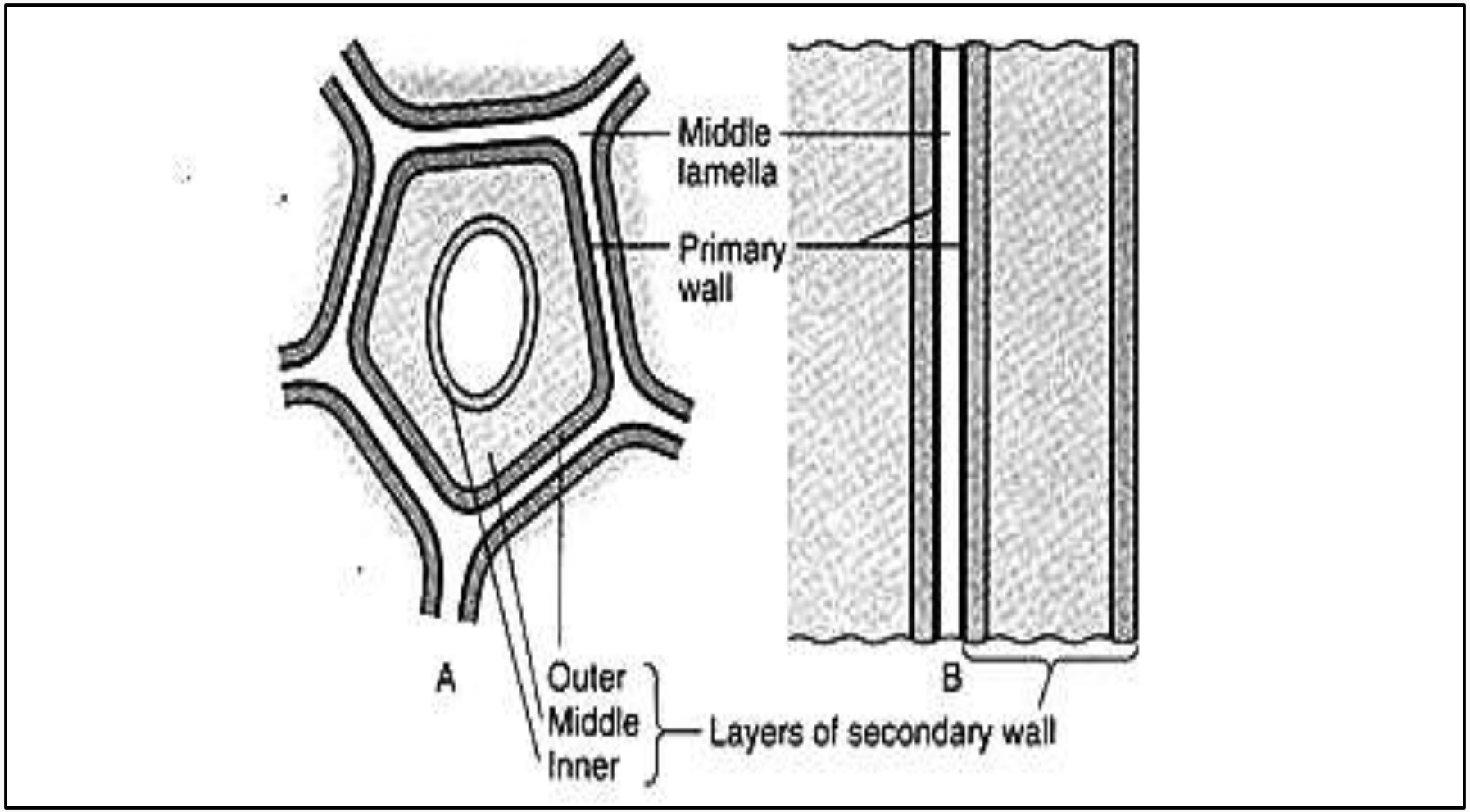
Cell wall structure
cell wall layers

Cell wall layers

In all higher plants the cell wall shows differentiation into the following **four layers -**

1. Middle lamella
2. Primary cell wall
3. Secondary cell wall
4. Tertiary cell wall (occasionally)

Structure



A) Arrangement of various layers of cell wall in a mature plant cell.

B) A portion of enlarged cell wall.

Layer 1: Middle lamella

1. The middle lamella is formed between adjacent cell walls during cell division.
2. It consists of a comparatively thin layer of intercellular material.
3. It is a jelly – like structure and acts as a cementing material between the primary cell walls of adjacent cells.
4. The middle lamella is made up of **pectin, cellulose and calcium.**
5. **Pectin is a hydrophilic** colloidal substance.

Layer 2: Primary Cell Wall

1. The primary cell wall is formed during the early stages of growth and development.

2. It is composed of **cellulose, hemicelluloses, polysaccharides and many other pectic substances.**

3. The primary cell wall is elastic and undergoes extension with the growth of the cell.

4. In many roots, fleshy stems, fruits and leaves, the cells contain only the primary cell wall and the middle lamella .

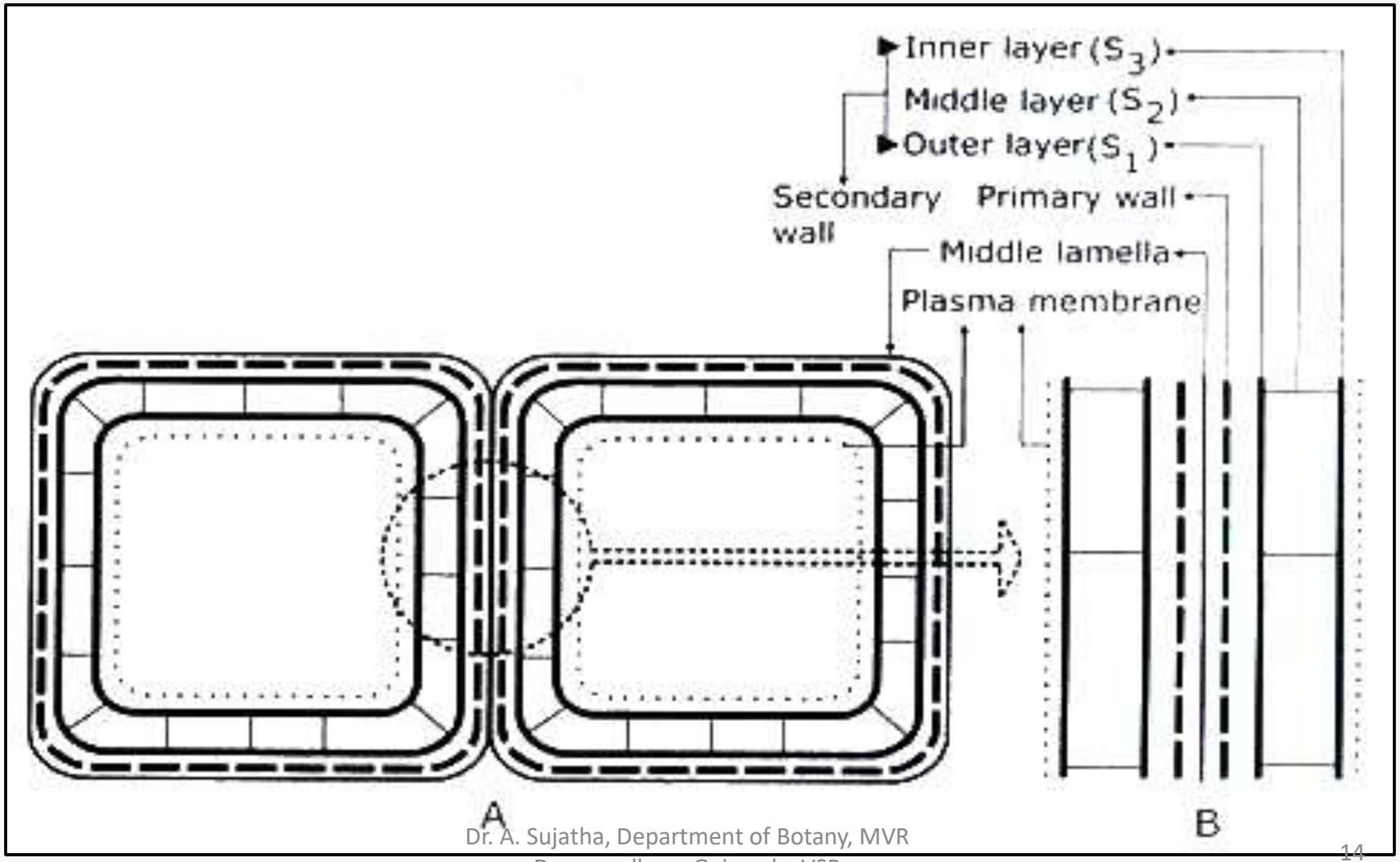
Layer 3: Secondary cell wall

1. It is found only in certain mature and highly specialized cells.
2. Some cells deposit additional layers on the inner surface of the primary wall and this layer is the secondary cell wall.
3. After the formation of secondary cell wall the protoplasm disappears in many cells.
4. The secondary cell wall is usually made up of **cellulose, hemicellulose and polysaccharide.**
5. During maturity, substances like lignin, suberin, waxes, tannins and calcium carbonate are also deposited on the secondary wall.
6. It gives high mechanical strength to the plants.

Sub layers in Secondary cell wall

7. The secondary cell wall commonly has three layers.
    - Outer layer (S1)
    - Middle layer (S2)
    - Inner layer (S3)
8. Among these, the middle layer is usually the thickest.

A) Diagram illustrating the primary and secondary cell walls between adjacent cells
B) A portion of the enlarged cell wall.



Layer 4: Tertiary Cell Wall

1. In some tissues a tertiary cell wall is formed on the inner surface of the secondary cell wall.
2. This layer is very thin and is found in the **xylem, tracheids of Gymnosperms.**
3. It is composed mainly of **xylan, instead of cellulose.**

Thickenings of the Cell Wall

Thickenings of the Cell Wall

1. Generally the wall materials are deposited uniformly throughout the cell.

2. But in some cases (**trachery elements**) they are localized to certain areas on the cell wall and show special patterns.

3. These thickenings provide mechanical support to the cell and usually develop when the cell has attained its full size.

Wall thickening - Types

1. **Annular:** The lignin is deposited in the form of rings on the interior of the primary cell wall.
2. **Spiral:** The thickenings occur in a spiral or spring - like manner.
3. **Scalariform:** The lignin is deposited in a ladder - like manner.
4. **Reticulate:** The lignin is deposited in such a manner that an irregular network is formed.
5. **Pitted:** The wall material is deposited throughout the wall except at some small areas, known as **pits.**

a) Annular, b) Spiral, c) Scalariform, d) Reticulate, e) Pitted (i. Simple, ii. Bordered).

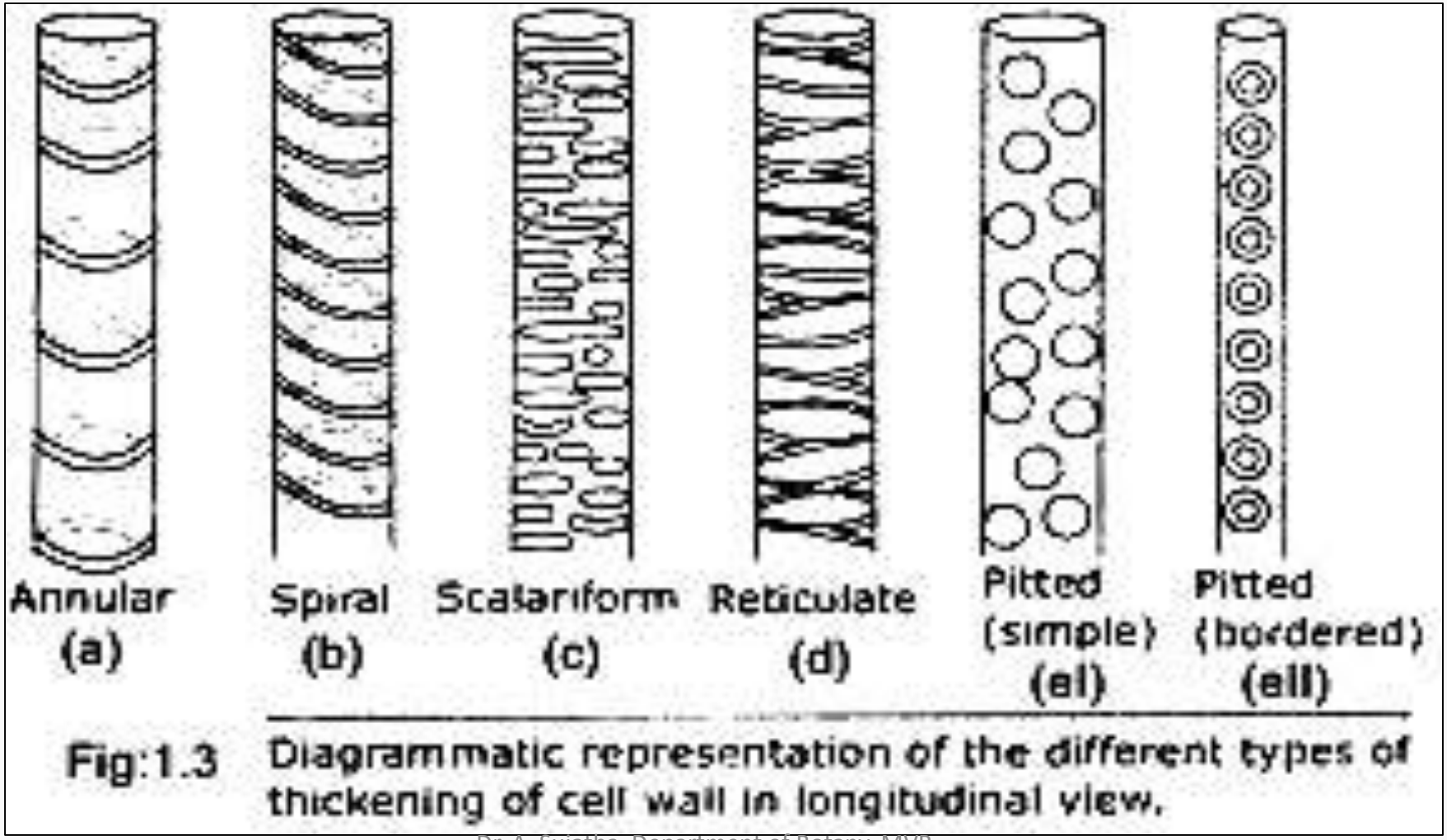


Fig:1.3 Diagrammatic representation of the different types of thickening of cell wall in longitudinal view.

Pits
Primary pit fields
primary pits
Pit types

Primary pit fields and primary pits

Primary pit fields:

1. Primary pit fields are found in cells which contain only the primary cell wall.
2. In certain areas the primary cell wall is thin and contains a group of pores. These areas are called as the primary pit fields.

Primary pits:

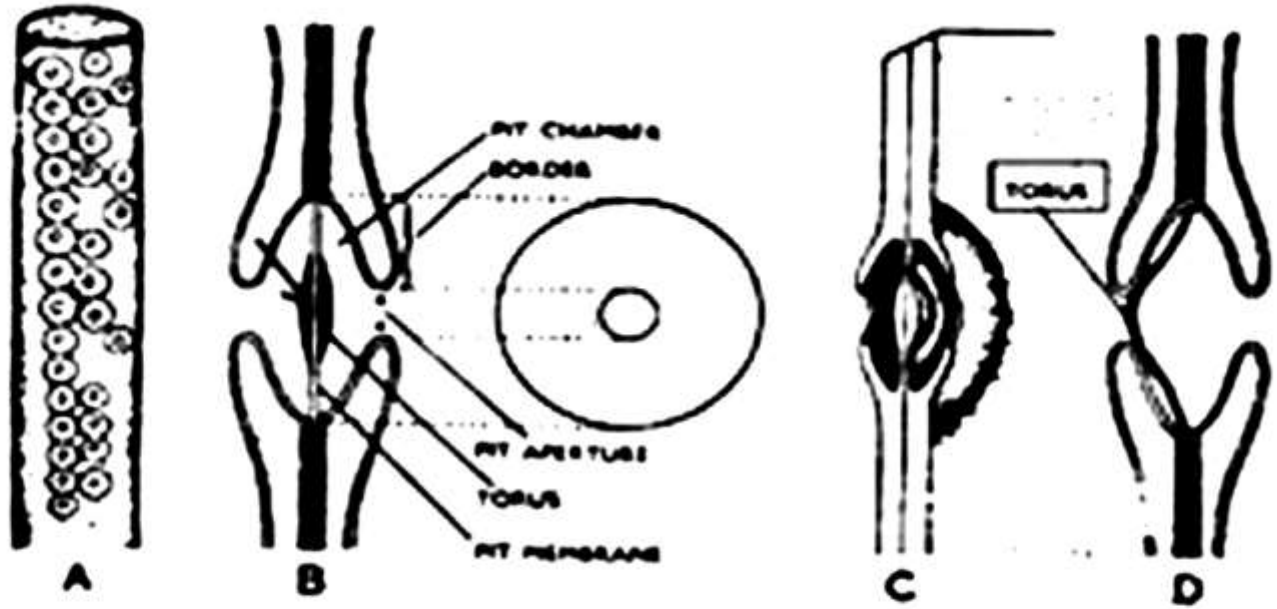
1. Some plants the secondary cell wall has depressions or cavities called pits. Pits are usually found in non-living cells like tracheids and fibres, whose function is conduction and support.
2. Pits are of two types - Simple pits and Bordered pits

Pits types

Pits are of two types - Simple pits and Bordered pits

1. B**ordered pit:** In this type the secondary cell wall projects over the cavity of the pit, enclosing a pit chamber, which opens outside through a pit aperture.
2. **Simple pit** there is no projecting margin.
3. Adjacent pits are separated by the middle lamella and the primary cell wall, which together form the **pit membrane**.
3. The pit membrane may have a thickening called the **torus**, which is formed by circular deposition of microfibrils.
4. The part of the membrane surrounding the torus is called the **margo.**
5. Margo has small openings through which aqueous substances flow from one cell to another.

Diagrammatic representation of a pit with torus



A. A vessel with bordered pit in front view. B. Same in sectional view C. Perspective diagram of the same D. Sectional view of bordered pit with changed position of torus

The pit membrane usually has a thickening called torus.

Origin and growth of the cell wall

Origin and growth of the cell wall

Stages

Stage 1:

New cell wall formation takes place during cell division at the time ofcytokinesis.

Stage 2:

A barrel – shaped body called the **phragmoplast** appears in the region of equatorial plate of the dividing mother cell.

Stage 3:

The microtubules of mitotic spindle pass through the phragmoplast.

Stage 4:

The small vesicles coming from the ER migrate to the equatorial plate and fuse with one another to form a discontinuous membrane called **cell plate**, inside the phragmoplast.

Stage 5:

The cell plate enlarges and soon reaches the side walls of the dividing mother cell. At this stage, the viscosity of the cell plate becomes higher and **on both sides thin lamella** are laid down by the daughter protoplasts.

Growth of cell wall - stages

Stage 6:

These lamella are the precursors of **primary walls** of daughter cells.

Stage 7:

The cell plate gradually undergoes changes to form the **middle lamella.**

Stage 8:

The secondary wall develops later on by the deposition of cellulose, hemicelluloses and pectin beneath the primary cell wall.

Stage 9:

The cell wall increases both in length and thickness.

The growth in length takes place by '**intussusception'** method.

The increase in thickness takes place by the method of '**apposition'.**

Intussusception& apposition growth

1. **Intussusception** is **growth** by deposition of new materials between existing components of cell walls. Cell elongation also occurs through **intussusception**.
2. In apposition, new wall layers are laid and **growth** of wall in new cells occurs.

Chemical composition
(or)
Molecular organization of the cell wall

Chemical composition of the cell wall

The plant cell wall is composed of a variety of polysaccharides, proteins, lignins, hemicelluloses and other compounds including mineral deposits.

1. **Cellulose:**

   a) The main chemical component of the cell wall is cellulose which is one of the substances present in abundance on the earth.

   b) Each cellulose molecule consists of at least 500 glucose molecules.

   c) Cellulose is a polymer of D-glucose Units interlinked by -1, 4 Glycosidic bonds.

   d). It is the simplest polysaccharide which makes up about 50 percent of the total plant material by weight.

2. **Hemicellulose:**

   a) It comprises of a group of n-cellulose polysaccharides.

   b) They include monosaccharide units such as arabinose, xylose, mannose and galactose.

Chemical composition of the cell wall

3. Pectins:

a) Pectins are located in the middle lamella and the outermost layer of the secondary wall.

b) They are the derivatives of polygalacturonic acids.

4. Lignins:

a) Lignins make up about 25 percent of the dry weight of a tree.

b) Lignin is a polysaccharide derivative having a complex structure.

c) It is characterized by having aromatic alcohols of high molecular weight such as hydrophenyl propane.

d)Lignin gives strength to the cell wall. It also resists fungal/pathogen attack.

e).Lignification of cell wall usually begins in the middle lamella and then proceeds to primary and secondary cell walls.

Chemical composition of the cell wall

5. Cutin, wax and suberin:

A variety of lipids are associated with the cell wall for strengthening and to check the evaporation of water from the plant body.

Usually cutin forms a continuous layer, the cuticle.

Cutin and waxes are synthesized and secreted on to the surface by the epidermis.

Suberin occurs in association with cellulose, mostly in the cork cells of the periderm and casparian strips in the walls of the root cells.

Fine structure of the cell wall

Fine structure of the cell wall

- Electron microscopic studies have revealed that cellulose in the cell wall **occurs in the form of fine strands or macrofibrils**, which are arranged in a more or less regular fashion.
- The macrofibrils are about 0.5 in thickness and about 1 long.
- Each macrofibril is composed of approximately **250 microfibrils of 25 nm or 250 A^0 thick.**
- Each microfibril in turn consists of small aggregates which are known as **micelles or elementary fibrils.**
- Each micelle is made up of 100 parallely arranged **cellulose chains**.
- **Each cellulose chain is a polymer of D-Glucose units linked by -1, 4 Glycosidic bonds.**

Fine structure of the cell wall

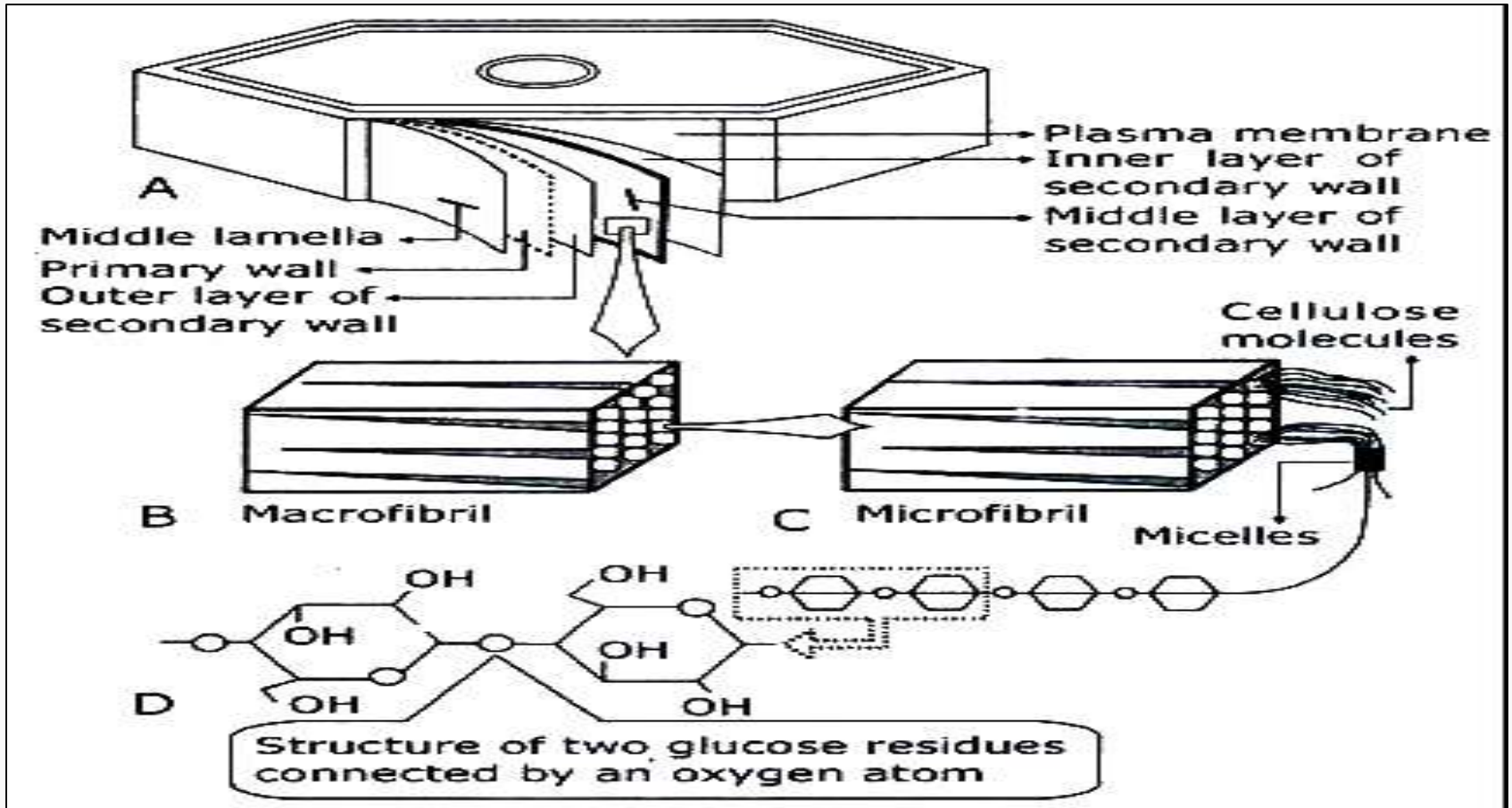


Figure 1.5

Diagram illustrating the structure of cell wall of a fibre. A. Diagrammatic representation of cross section of fibre in three dimensional view showing middle lamella, the primary wall and three layers of secondary wall. B. Macrofibril from a portion of the middle layer of secondary wall. C. Microfibril from a portion of macrofibril

Functions of the cell wall

- The plant cell wall provides definite shape, strength and rigidity.
- It also provides protection against mechanical stress and physical shocks.
- It helps to control cell expansion due to the intake of water.
- Also helps in preventing water loss from the cell.
- It is responsible for transporting substances between and across the cell.
- It acts as a barrier between the interior cellular components and the external environments.
- It acts as a structural skeleton for the plant.

Stay home – Stay safe


THANK YOU

Third UG – Botany

Fifth Semester

Paper V

Cell Biology, Genetics and Plant Breeding

Unit 1
Cell Biology

Lesson 3
Chromosomes

Dr. A.Sujatha, M.Sc, M.Phil, Ph.D
Department of Botany
M.V.R Degree and PG college
Gajuwaka, Visakhapatnam

Completed Lessons

Unit 1: Cell biology

Lesson 3- Chromosomes

3.1 Introduction

3.2 History

3.3 Chromosome number

3.4 Chromosome size

3.5 Types of chromosomes

3.6 Structure of chromosomes

3.7 Karyotype and Idiogram

3.8 Heterochromatin and euchromatin

3.9 Chemical composition of chromosomes.

3.10 Eukaryotic chromosome structure

3.11 Ultra structure of chromosome

Structure of today's Lesson

1. Functions of chromosomes
2. Chromosome Banding
3. Special types of chromosomes

Objectives

1. To understand what are the functions of chromosomes.
2. To learn about chromosome banding.
3. To know about special types of chromosomes.

Introduction

1. Chromosomes are thread-like structures present in the nucleus. They are important because they contain the basic genetic material DNA.
2. These are present inside the nucleus of plants as well as animal cells. Chromosomes were first discovered by Strasburger in 1815 and the term 'chromosome' was first used by Waldeyer in 1888.
3. Human beings have 46 chromosomes in their body. These are arranged into 23 pairs.
4. **"**A Chromosome looks like a thread and is coiled material, made of proteins. Chromosomes are present in the nucleus of all the cells and contain the basic genetic material DNA, which passes from one generation to another".
5. A chromosome has generally 8 parts; Centromere or primary constriction or kinetochore, chromatids, chromatin, secondary constriction, telomere, chromomere, chromonema, and matrix.

Functions of chromosomes

Functions of Chromosomes

1. In 1902 , Sutton and Bover suggested the role of chromosomes in heredity.
2. **Carry the genetic material**: The most important function of chromosomes is to carry the basic genetic material – DNA. DNA provides genetic information for various cellular functions. These functions are essential for growth, survival, and reproduction of the organisms.
3. **Protection the genetic material**: Histones and other proteins cover the Chromosomes**.** These proteins protect it from chemical (e.g., enzymes) and physical forces. Thus, chromosomes also perform the function of protecting the genetic material (DNA) from damage during the process of cell division.

Functions of chromosomes

4. **Cell division**: During cell division, spindle fibers attached to the centromeres contract and perform an important function.

   The contraction of centromeres of chromosomes ensures precise distribution of DNA (genetic material) to the daughter nuclei.

5. **Regulate gene action**: Chromosomes contain histone and non-histone proteins. these proteins regulate gene action.

   Cellular molecules that regulate genes work by activating or deactivating these proteins. This activation and deactivation expand or contract the chromosome.

Chromosome Banding

What is Chromosome banding?

Chromosome banding refers to alternating light and dark regions along the length of a **chromosome**, produced after staining with a dye.

What is a chromosome band?

1. A **band** is defined as the part of a **chromosome** that is clearly distinguishable from its adjacent segments by appearing darker or lighter with the use of one or more **banding** techniques.
2. Bands appear in metaphase chromosomes when they are processed according to a special staining procedure. Then viewed under a microscope.

Chromosome banding - Technique

Technique # 1. C-Bands (specialized Giemsa staining)

Technique # 2. G-Bands (Giemsa stain)

Technique # 3. Q-Bands (Quinacrine stain)

Technique # 4. R-Bands (reverse of the G-band stain)

Technique 1. C-Bands:

1. The technique of C-banding originated after the work of **Pardue and Gall** who reported that constitutive heterochromatin can be stained specifically by **Giemsa-solution**.
2. Each chromosome possesses a different degree of constitutive heterochromatin which enables the identification of individual chromosomes.
3. Constitutive heterochromatin is located near the centromere, at telomeres and in the nucleolar organizer regions (NOR); it is composed of highly repetitive DNA.
4. C-banding represents the constitutive heterochromatin, and the banding is caused by differential staining reactions of the DNA of heterochromatin and euchromatin.

Technique # 2. G-Bands

1. The technique of G-banding involves **Giemsa**(non-flourescent) staining following pretreatment with weak trypsin solution, urea or protease.
2. It provides greater detail than C-banding.
3. It was first used for human chromosomes by Summer et al. in 1971.
4. G-bands may reflect a stronger chromatin condensation.
5. However, this technique is not suitable for plant chromosomes.

Technique # 3. Q-Bands

1. The method of Q-banding was developed by Caspersson et al. in 1968.
2. The chromosomes stained with fluorescent dyes, **Quinacrine or Quinacrine mustard** show bright and dark zones under UV light.
3. Q – banding is found to result from interaction between **quinacrine and region of DNA that are rich in adenine and thymine.** While guanine and cytosine quench fluorescence, so region rich in those bases would present in the unstained inter band.
4. This technique is used to identify human and mice chromosomes.

Technique # 4. R-Bands

1. It is a reverse giemsa banding.
2. **R**-banding is a cytogenetics technique that produces the reverse of the G-**band** stain on chromosomes.
3. Resulting chromosome patterns shows darkly stained **R bands**, the complement to G-**bands**.
4. Darkly colored **R bands** are **guanine-cytosine** rich, and adenine-thymine rich regions are more readily denatured by heat.
5. R-Banding – Results from heat treatment in a phosphate buffer followed by **staining** with Giesma dyes.

Purpose of Chromosome Banding

1. Banding can be used to identify chromosomal abnormalities, such as translocations, because there is a unique pattern of light and dark bands for each chromosome.
2. G-**banding** is useful because the **patterns** of stripes on the chromosomes are unique enough that you should be able to confidently identify each chromosome
3. G-**banding** is a technique used in cytogenetics to produce a visible karyotype by staining condensed **chromosomes**.
4. It is useful for identifying genetic diseases through the photographic representation of the entire **chromosome** complement.
5. Chromosome banding patterns can be used not only for the identification of individual chromosomes of an organism but also to establish evolutionary relationships between different species.

Special types of Chromosomes

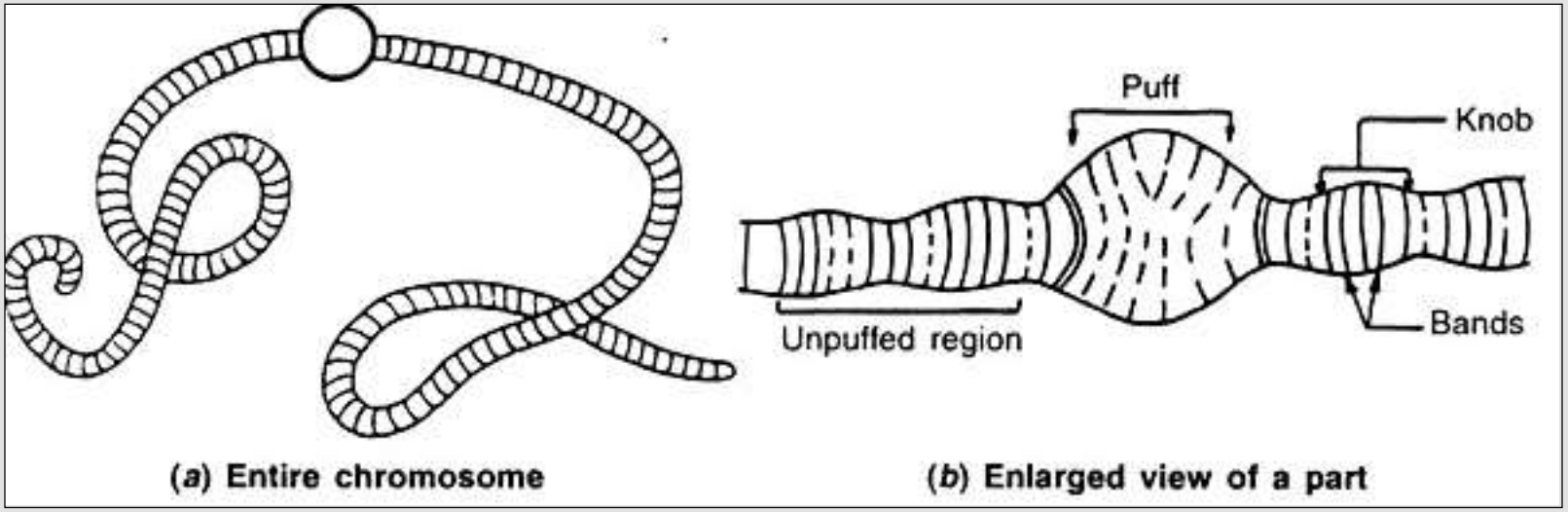
Introduction

1. In Eukaryotic organisms certain chromosomes are found only in certain special tissues and are not seen in other tissues.
2. These chromosomes are larger in size and are called giant chromosomes.
3. In certain plants, they are found in the suspensors of the embryo.
4. There are two types of giant chromosomes - Polytene chromosome and Lampbrush chromosome

Polytene chromosomes

1. Polytene chromosomes were observed by C.G. Balbiani in 1881 in the salivary glands of *Drosophila*.
2. The characteristic feature of polytene chromosome is that along the length of the chromosome there is a series of dark bands alternate with clear zones called inter bands.
3. The polytene chromosome has extremely large puff called **Balbiani ring**. It is also known as chromosomal puff.
4. As this chromosome occurs in the salivary gland it is known as salivary gland chromosome

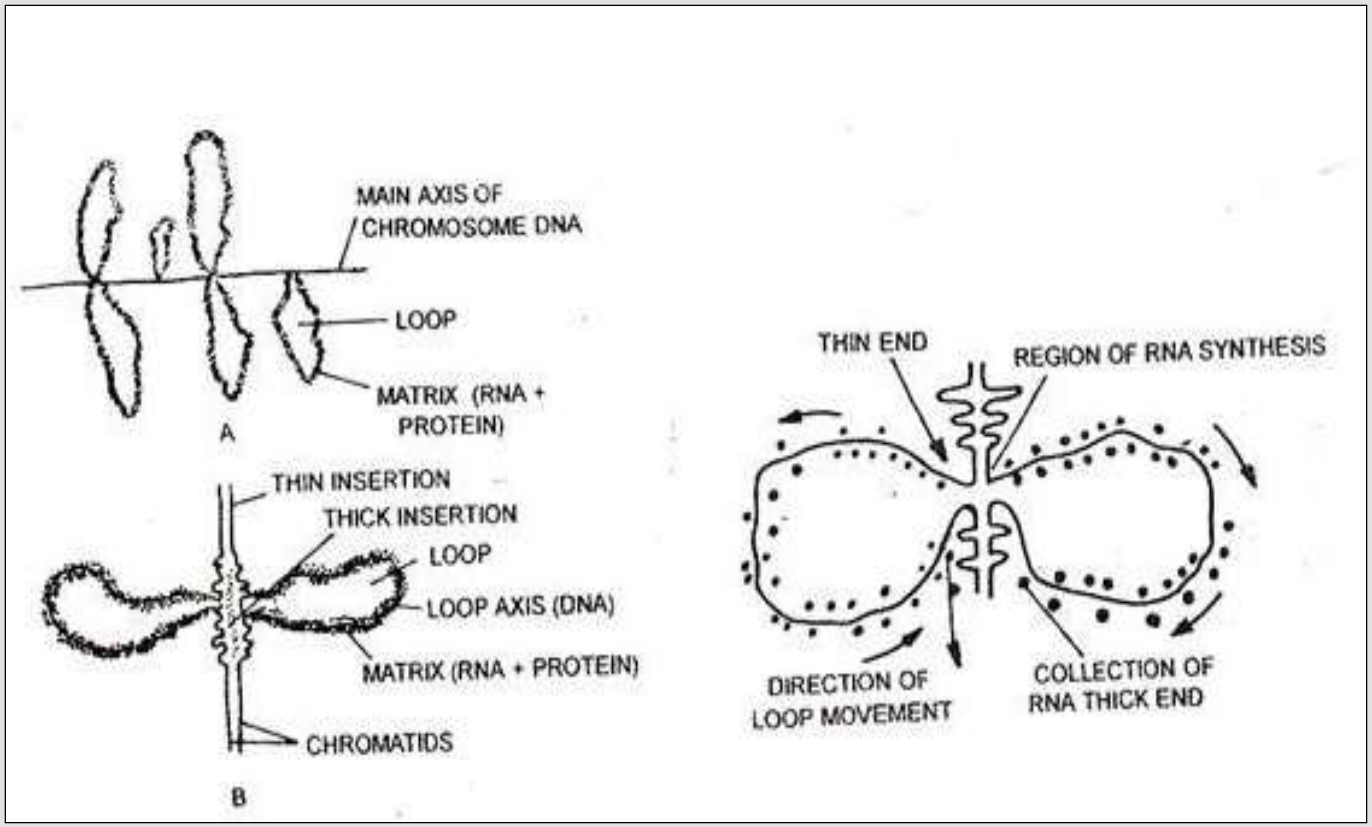
Polytene chromosomes



Lampbrush chromosomes

1. Lamp brush chromosomes were first observed by Flemming in 1882. It look like brushes.
2. They occur at the diplotene stage of meiotic prophase in oocytes of an animal *Salamandor* and in giant nucleus of the unicellular alga *Acetabularia*.
3. The highly condensed chromosome forms the chromosomal axis, from which lateral loops of DNA extend as a result of intense RNA synthesis.

Lampbrush chromosomes



A). Gross structure

B). Enlarged view;

C). Synthesis of RNA in a loop of lampbrush chromosome

B – chromosomes

1. These are also called **supernumerary chromosomes**.
2. Nucleus of some animals and plants possess in addition to the normal chromosomes (autosomes) one or more super numerary chromosomes.
3. Wilson (1905) was the cytologist to observe them in hemipteran insect (*Metapodus*). These are named as B – chromosomes, have normal structure but smaller than the autosomes.
4. They are predominantly heterochromatic in insects and maize or predominantly euchromatic in rye.
5. In maize their number per cell vary from 0 to 30 and affect development and fertility only when they occur in large number.

Next class

Genetic material DNA

Stay home – Stay safe


THANK YOU

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Unit 1
Cell Biology

Lesson 1
The cell

DR. A.Sujatha
Department of Botany
M.V.R Degree and PG college
Gajuwaka, Visakhapatnam

Cytoplasmic organelles

Plastids

Structure:

1. It occurs in plant cells. It is 4µm to 6µm in diameter.

2. It is colourless or coloured.

3. Plastid types:

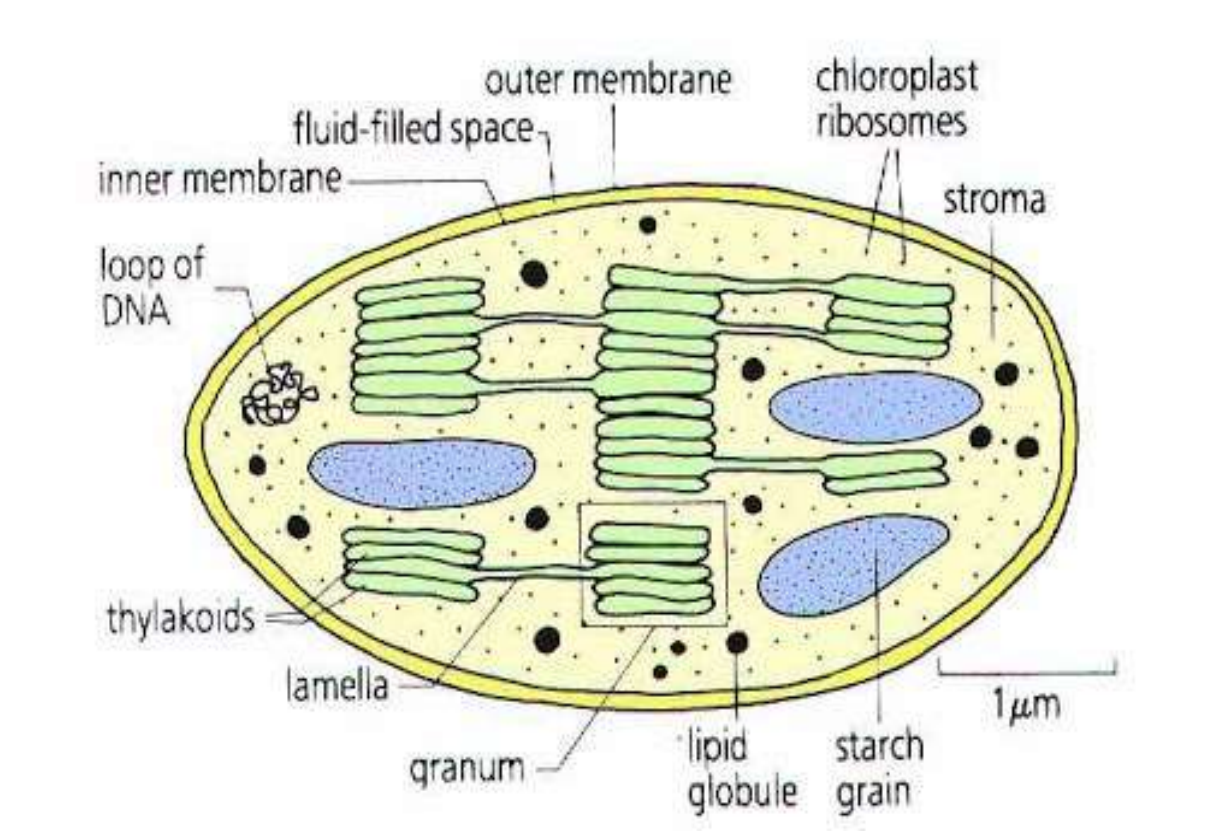
- Colourless – leucoplasts (store starch & lipids)
- Coloured – chromoplasts (Green coloured plastids –Chloroplasts They contain DNA, ribosomes and complete protein synthesis machinery).

Function:

1.Leucoplast : storage of starch and lipids.

2. Chloroplasts - biosynthesis of food – photosynthesis

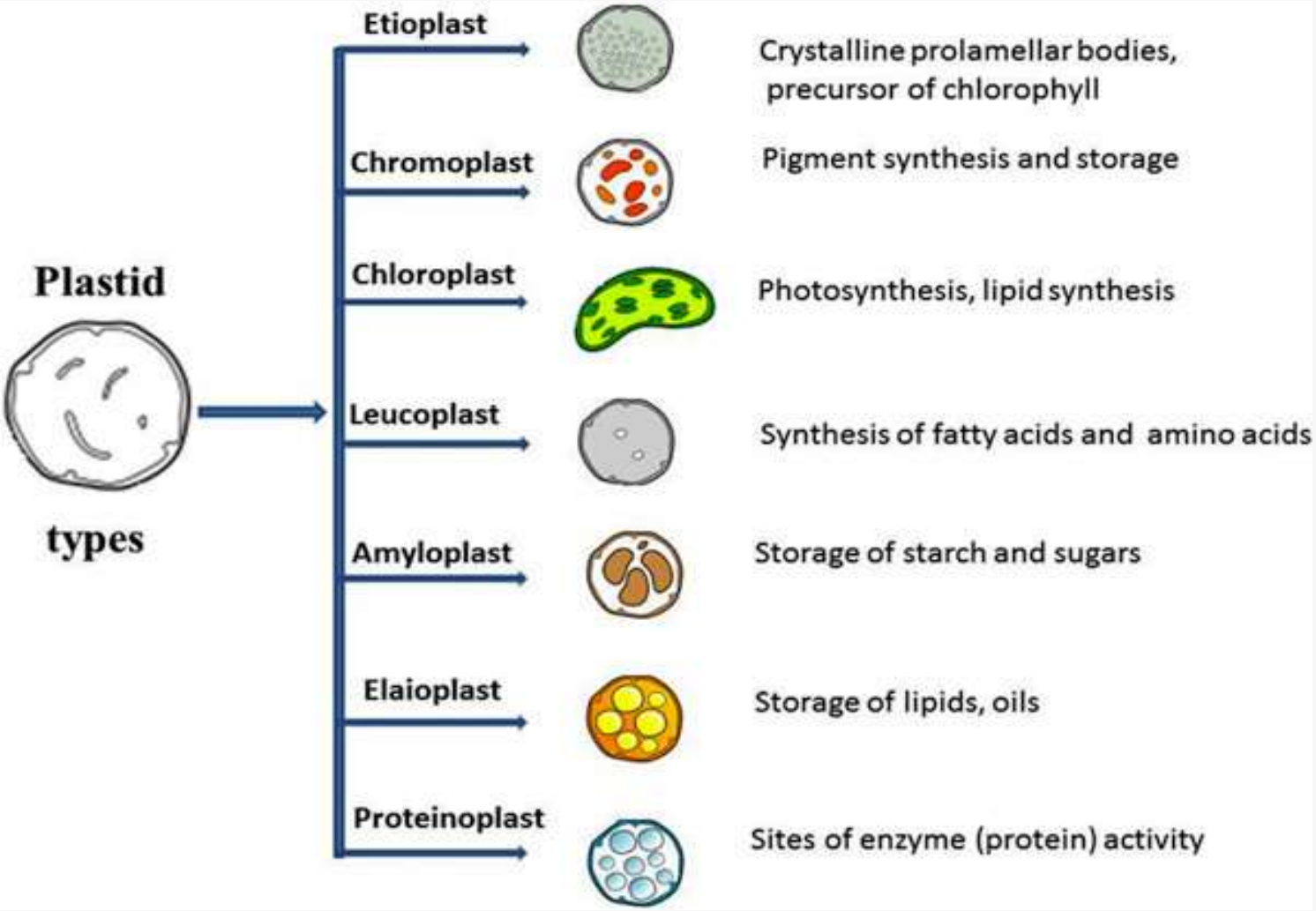
Structure of chloroplast



Polymorphic cell organelle

- Polymorphic cell organelle is an organelle which occurs in different forms and perform different functions.
- Plastids are polymorphic since they occur in different forms and perform different functions

Types of Plastids



Ribosomes

Structure:

1.Size : Small organelles – 140 – 230 A^o

2. Composed of rRNA and proteins.

3. Present free in the cytoplasm or attached to the membrane of RER.

4. Each ribosome is composed of two structural units – a smaller subunit known as 40S subunit & a larger subunit known as 60S subunit.

5. 40S sub units occur on the larger unit and form a cap – like structure.

Function:

Sites of protein synthesis.

Structure of Ribosome

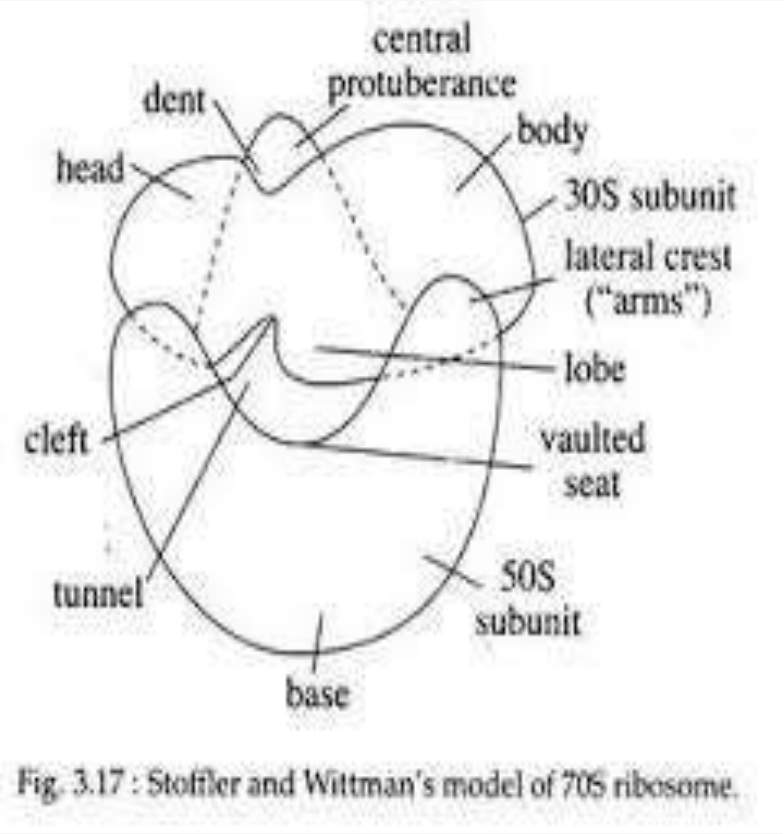


Fig. 3.17 : Stoffler and Wittman's model of 70S ribosome.

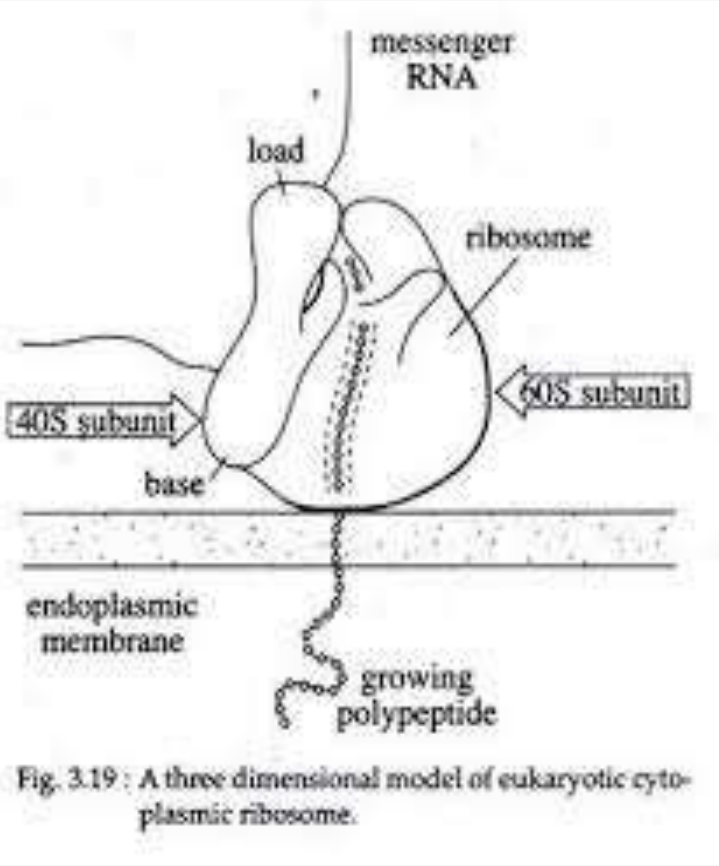


Fig. 3.19 : A three dimensional model of eukaryotic cytoplasmic ribosome.

Microtubules

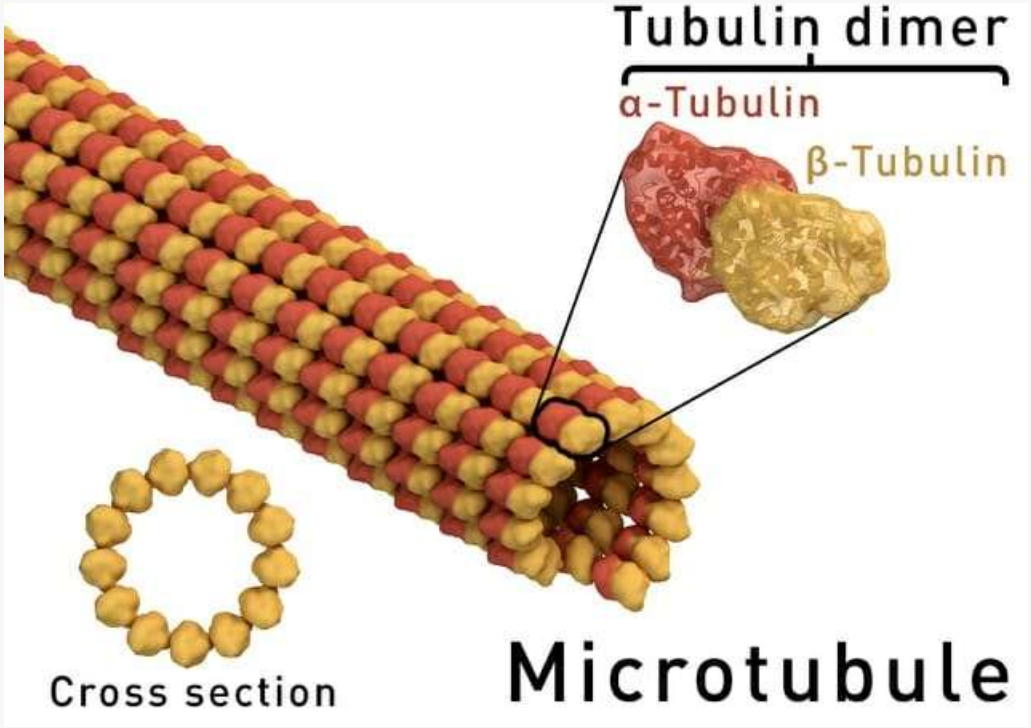
Structure:

1. Seen in both plant and animal cells.
2. The cytoplasm is traversed by numerous ultrafine tubules of *tubulin* proteins – microtubules.
3. Composed of 13 individual protofilaments arranged to form a hollow cylinder.

Function:

1. Play an important role in the formation of spindle fibres during cell division.
2. They form the structural units of the centrioles, basal granules, cilia and flagella.

Structure of microtubules



III Nucleus

1. First discovered by Robert brown in 1831.

2. Number:

a) Uninucleate cells- single nucleus
b) Binucleate cells – two nucleii (eg. tapetal cells of Euphorbiaceae)
c) Syncytial cells – many nucleii (eg. Osteoblasts)
d) Polynunleate cells of plants are called coenocytes (eg. Siphonal alga Vaucheria and certain Fungi mucor

3. Shape:

a) Related to shape of the cell.
b) Spheroid, cuboid or polyhedral cells contain- spheroid nuclei
c) Cylindrical, prismatic or fusiform cells contain – ellipsoid nuclei
d) Squamous epithelium contain discoid nucleii
e) Leucocytes, certain infusoria and glandular cells of some insects contain – irregular shaped nucleii

4. Size:

a) Generally nucleus occupies 10 percent of the total cell volume.
b) It varies in size from 3µm to 25µm in diameter. And depends on cell type

Nucleus - Ultra structure

1. It consists of four structures.
    - Nuclear membrane or karyotheca
    - Nucleoplasm or nuclear sap
    - Chromatin fibres
    - Nucleolus

2. **Nuclear membrane**:

   The nucleus is bounded by two membranes of lipoproteins – called **nuclear membrane. It** form a kind of envelope around the nucleus – nuclear envelope.

3. Nuclear envelope is interrupted by a number of pores.

4. The outer membrane of nuclear envelope remains continuous with the membranes of ER and plasma membrane.

Nucleoplasm

1. The nucleus is filled with a watery substance known as **nucleoplasm or karyolymph or nuclear sap.**
2. Nucleoplasm contains nucleoproteins and inorganic and organic substances like nucleic acids, proteins, enzymes and minerals.
3. In the nucleoplasm events like:

a) Replication of DNA

b) Transcription of RNA

c) Transport of materials

d) Formation of spindle fibres during cell division takes place.

Chromatin Fibres

1. The nucleoplasm contains many thread like , coiled and much elongated structure called **chromatin fibres.** Chromatin fibres are seen in the interphase nucleus.
2. They are distributed either loosely (uncoiled) and called **euchromatin** or dense clumps called **heterochromatin**.
3. During cell division chromatin fibres become thick and ribbon like structures called **chromosomes.**
4. Chromatin contains DNA and proteins. Proteins may be histone and non – histone.

Nucleolus

1. The nucleoplasm contains a conspicuous, darkly stained spherical body known as the **Nucleolus. 1st described by Fontana 1781.**
2. Nucleolus is composed of ribosomal proteins and ribosomal RNA.
3. Nucleolus stores the rRNA molecules which are synthesized by nucleolar organizer (NO) region of DNA.
4. It is not bounded by any limiting membrane.
5. Electron microscopic studies reveal that the nucleolus active in the synthesis of ribosomes exhibits three regions-

    (i). Fibrillar centre

    (ii) Granular region

    (iii) Amorphous matrix

Nucleolus - Functions

1. It is the site for biogenesis of ribosomes.
2. It is one of the main active centres of RNA synthesis.
3. It plays a significant role in cell division.

Morphology of interphase nucleus

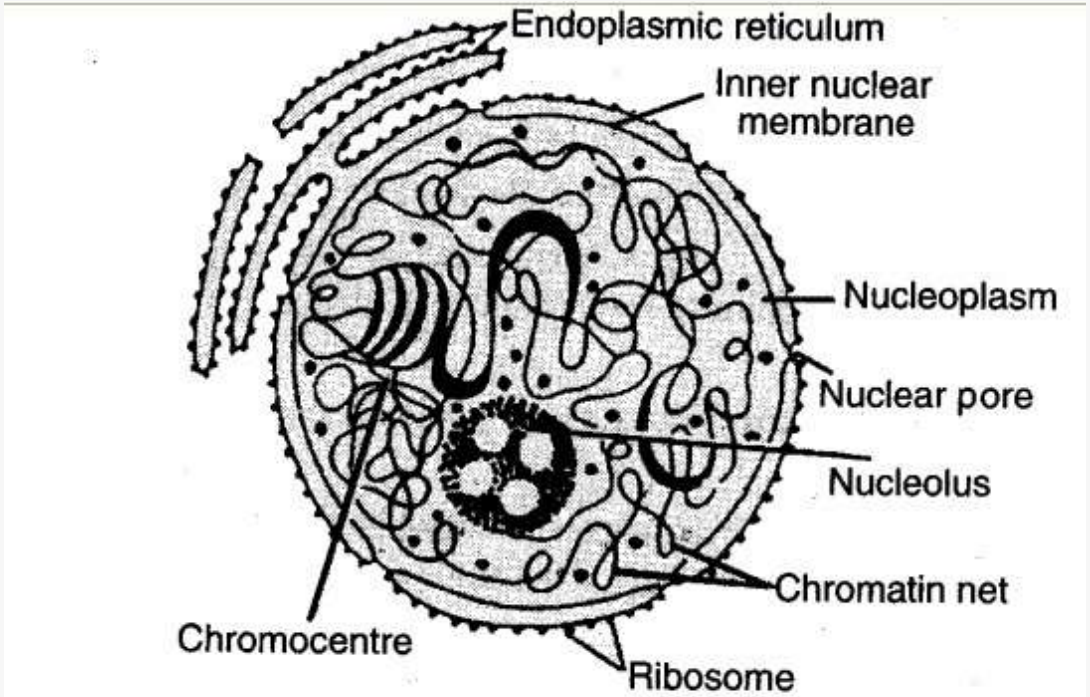


Fig. Eukaryotic nucleus

Functions of Nucleus

1. Metabolism: majority of metabolic activities
2. Heredity
3. RNA synthesis


THANK YOU

Third UG – Botany

Fifth Semester

Paper V

Cell Biology, Genetics and Plant Breeding

Unit II
Genetic material

Lesson 1
DNA as genetic material

Dr. A.Sujatha, M.Sc, M.Phil, Ph.D
Department of Botany
M.V.R Degree and PG college
Gajuwaka, Visakhapatnam

Structure of today's Lesson

1. Introduction
2. DNA as genetic material
3. Transformation

    a) Griffith experiment

    b) Oswald Avery, Colin Macleod and Maclyn McCarty experiment

4. Bacteriophage Infection

    a) Hershy and Chase experiment

Objectives

1. To understand DNA as genetic material.
2. To understand experiments in support of DNA as the genetic material.

Role of DNA in heredity

- It is commonly known that DNA is the genetic material.
- In fact, for many decades, scientists thought that proteins found in chromosomes were the molecules that carry genetic information and did not know that DNA was the heredity material.
- Scientists have carried some experiments to identify the DNA as the carrier of genetic information.

DNA as genetic material

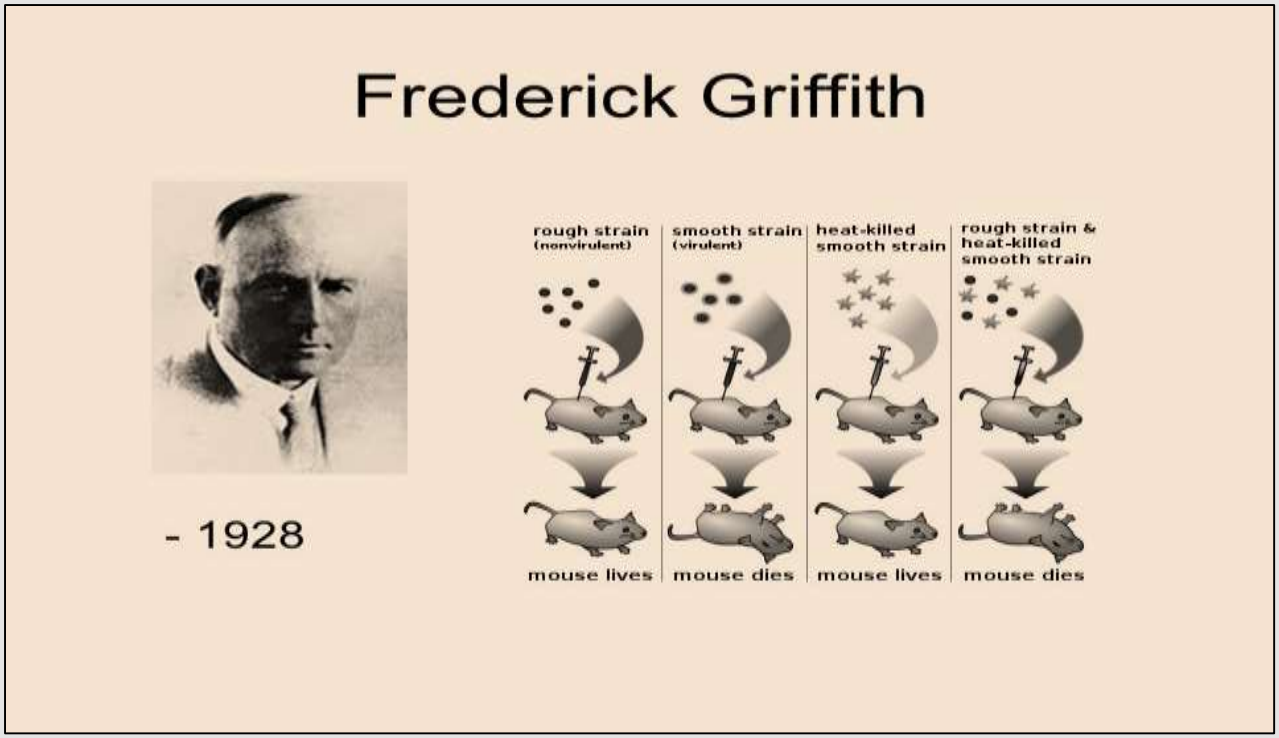
There are some experiment evidences which prove that in most of the organisms DNA is the genetic material and only in some viruses RNA is the genetic material. These experiments include:

- Transformation of bacteria (Griffith)
- Bacteriophage infection (Hershy and Chase convince evidence that DNA is genetic material)
- Transduction
- Biochemical evidences

Transformation

The genetic recombination in which naked DNA from one cell can enter and integrate in another cell is known as genetic transformation.

Griffith expts. of transformation



Griffith systematic experiments with ***Diplococcus pneumonia*** gave a clue that a chemical substance was responsible for genetic transformation.

Frederick Griffith Experiment: Bacterial transformation

- In 1928, British bacteriologist Frederick Griffith conducted a series of experiments using ***Streptococcus pneumoniae*** bacteria and **mice**.
- In his experiments, Griffith used two related strains of bacteria, known as R (rough- without capsule) and S (with a capsule).

Experiment 1: R strain

- **R strain:** When grown in a petri dish, the R bacteria formed colonies, or clumps of related bacteria, that had well-defined edges and a rough appearance (hence the abbreviation "R").
- He selected R_2 strain for his experiments.
- The R bacteria were non – virulent (non – pathogenic), meaning that they **did not cause sickness w**hen injected into a mouse.

Experiment 2: S strain

- S bacteria formed colonies that were rounded and smooth (hence the abbreviation "S").
- The smooth appearance was due to a polysaccharide, or Sugar based, coat produced by the bacteria.
- This coat protected the S bacteria from the mouse immune system, making them virulent (capable of causing disease).
- He selected S3 strain for his experiments.
- Mice injected with live S bacteria **developed pneumonia and died.**

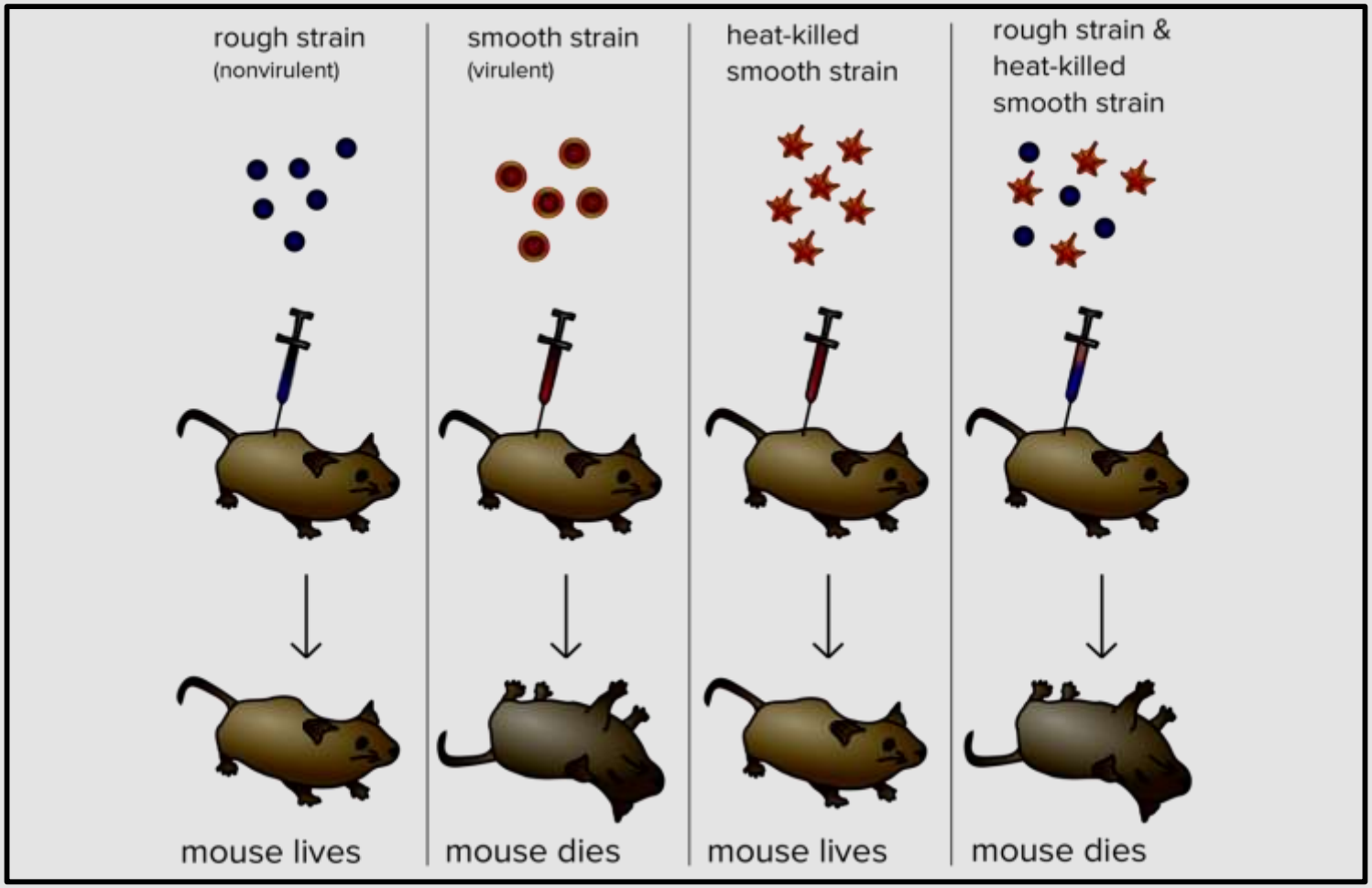
Experiment 3: Heat killed S strain

- As part of his experiments, Griffith tried injecting mice with heat-killed S bacteria (that is, S bacteria that had been heated to high temperatures, causing the cells to die).
- Unsurprisingly, the heat-killed S bacteria did not cause disease in mice.
- The experiments took an unexpected turn .

Experiment 4: Heat killed S strain

- In his 4th expt. harmless R bacteria were combined with harmless heat-killed S bacteria and injected into a mouse.
- He observed that the mouse develop pnenumonia and die.
- When Griffith took a blood sample from the dead mouse, **he found that it contained living S bacteria!**

Griffith experiment



Conclusion of Griffith experiments

- Griffith concluded that the R-strain bacteria must have taken up what he called a "**transforming principle"** from the heat-killed S bacteria, which allowed them to "transform" into smooth-coated bacteria and become virulent.

Draw back of Griffith experiment

- Griffith experiment was a turning point towards the discovery of hereditary material.
- However, it failed to explain the biochemistry of genetic material.
- Hence, a group of scientists, Oswald Avery, Colin MacLeod and Maclyn McCarty continued the Griffith experiment in search of biochemical nature of the hereditary material.

Experiment for Identifying the transforming principle

Avery, McCarty, and MacLeod (1944)

Oswald Avery, Maclyn McCarty & Colin MacLeod Experiment

- In 1944, three Canadian and American researchers, Oswald Avery, Maclyn McCarty, and Colin MacLeod, set out to identify Griffith's "transforming principle."
- They began with large cultures of heat-killed S cells and, through a long series of biochemical steps (determined by careful experimentation), progressively purified the transforming principle by washing away, separating out, or enzymatically destroying the other cellular components.
- By this method, they were able to obtain small amounts of highly purified transforming principle, which they could then analyze through other tests to determine its identity.
- Several lines of evidence suggested to Avery and his colleagues that the transforming principle might be DNA.

Evidence suggested to Avery the transforming principle might be DNA

- **The purified substance gave a negative result in chemical tests known to detect proteins, but a strongly positive result in a chemical test known to detect DNA**.
- The elemental composition of the purified transforming principle closely resembled DNA in its ratio of nitrogen and phosphorous.
- Protein- and RNA-degrading enzymes (protease and RNAase) had little effect on the transforming principle, but enzymes (DNAase) able to degrade DNA eliminated the transforming activity.
- These results all pointed to DNA as the likely transforming principle.

Interpretation of results

- However, Avery was cautious in interpreting his results. He realized that it was still possible that some contaminating substance present in small amounts, not DNA, was the actual transforming principle.
- Because of this possibility, debate over DNA's role continued until 1952, when Alfred Hershey and Martha Chase used a different approach to conclusively identify DNA as the genetic material.

The Hershey-Chase experiments

The Hershey-Chase experiments

- In 1952 Alfred Hershey and Martha Chase provide convincing evidence that DNA is genetic material.
- They studied **bacteriophage** , or viruses that attack bacteria.
- The phages **T2** they used were simple particles composed of protein and DNA, with the outer structures made of protein and the inner core consisting of DNA.
- The bacteria is ***E. coli***
- .

The Hershey-Chase experiments

- Hershey and Chase knew that the phages attached to the surface of a host bacterial cell and injected some substance (either DNA or protein) into the host.
- This substance gave "instructions" that caused the host bacterium to start making lots and lots of phages—in other words, it was the **phage's genetic material.**
- They developed two phages with ***E.coli*** in two types of media

- To establish whether the phage injected DNA or protein into host bacteria, Hershey and Chase prepared two different batches of phage.
- In each batch, the phage were produced in the presence of a specific radioactive element, which was incorporated into the macromolecules (DNA and protein) that made up the phage.
- In one medium with radioactive sulphur S35 and radioactive phosphorous P32.

- One sample was produced in the presence of a radioactive isotope of sulfur S35. Sulfur is found in many proteins and is absent from DNA, so only phage proteins were radioactively labeled by this treatment.
- The other sample was produced in the presence of a radioactive isotope of phosphorous P32. Phosphorous is found in DNA and not in proteins, so only phage DNA (and not phage proteins) was radioactively labeled by this treatment.

- Each batch of phage was used to infect a different culture of bacteria.
- After infection had taken place, each culture was whirled in a blender, removing any remaining phage and phage parts from the outside of the bacterial cells.
- Finally, the cultures were centrifuged, or spun at high speeds, to separate the bacteria from the phage debris.

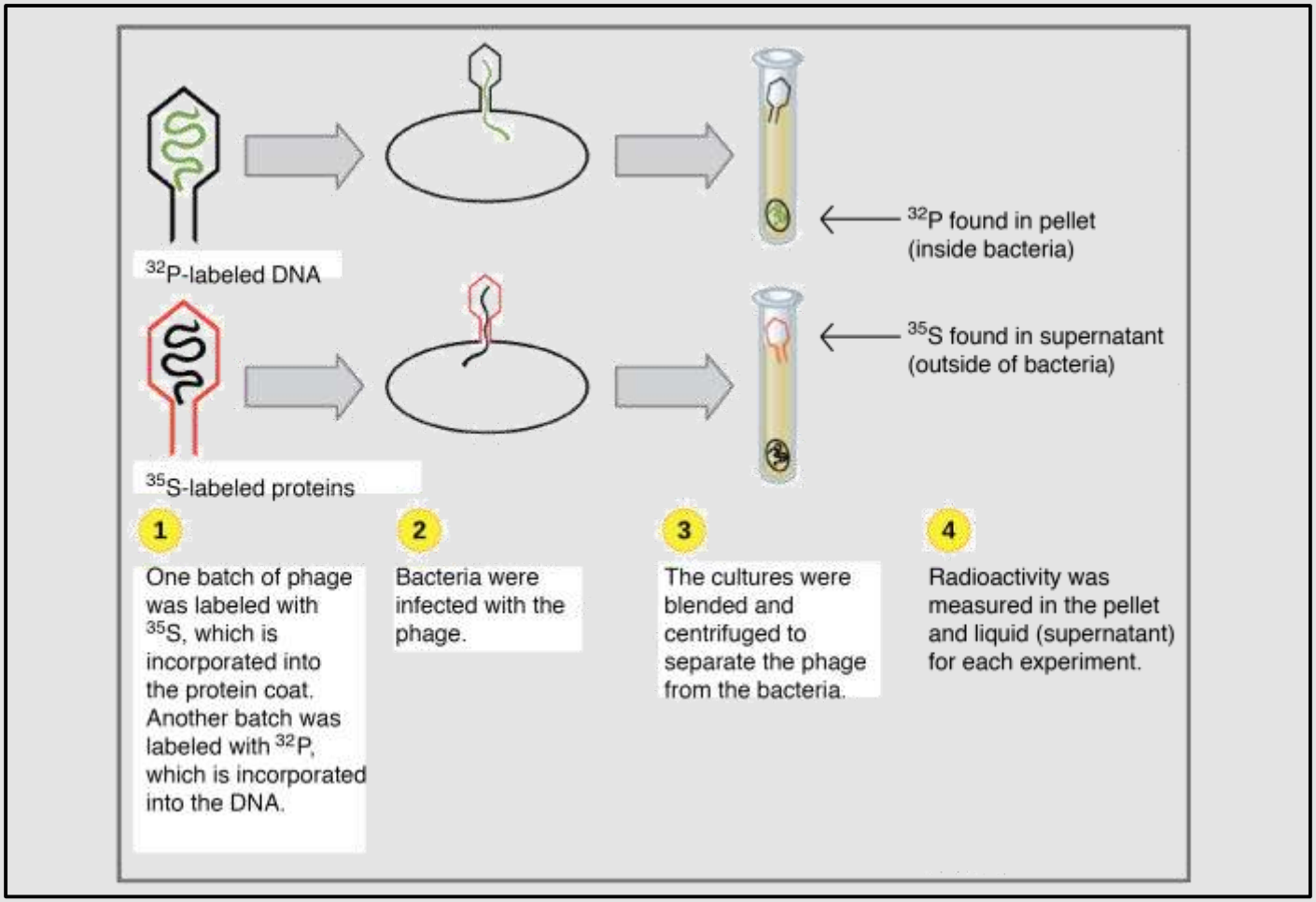
- Centrifugation causes heavier material, such as bacteria, to move to the bottom of the tube and form a lump called a **pellet**.
- Lighter material, such as the medium (broth) used to grow the cultures, along with phage and phage parts, remains near the top of the tube and forms a liquid layer called the **supernatant**.

Conclusion

- When Hershey and Chase measured radioactivity in the pellet and supernatant from both of their experiments, they found that a large amount of P appeared in the pellet, whereas almost all S appeared in the supernatant.
- **Based on this and similar of experiments, Hershey and Chase concluded that DNA, not protein, was injected into host cells and made up the genetic material of the phage.**

Hershey and Chase Experiment

Radioactiove label used32P for DNA & 35S for protein



Transduction

- The genetic recombination in bacteria in which DNA is transferred from one bacteria cell to another via the bacteriophage is known as transduction.
- Bacteriophages attack the bacteria, lyse them and multiply inside the bacteria.
- In this process , some times a small DNA segment of bacteria is contained by the bacteriophage.
- When this attacks another bacteria , the DNA of the previous bacteria from bacteriophage is integrated with the DNA of new bacteria and change some of the features of new bacteria.
- This also suggest that DNA is the genetic material.
- Transduction may be general or specialized.
- Transduction has been reported in several bacteria like *E.coli, Pseudomonas, Salmonella* etc.

Biochemical Evidences

There are several biochemical evidences which also support that Dna is the genetic material.

Next class

Nucleic acids

Stay home – Stay safe


THANK YOU

UG 2 – Semester 4

Paper 4

Plant physiology and metabolism

By

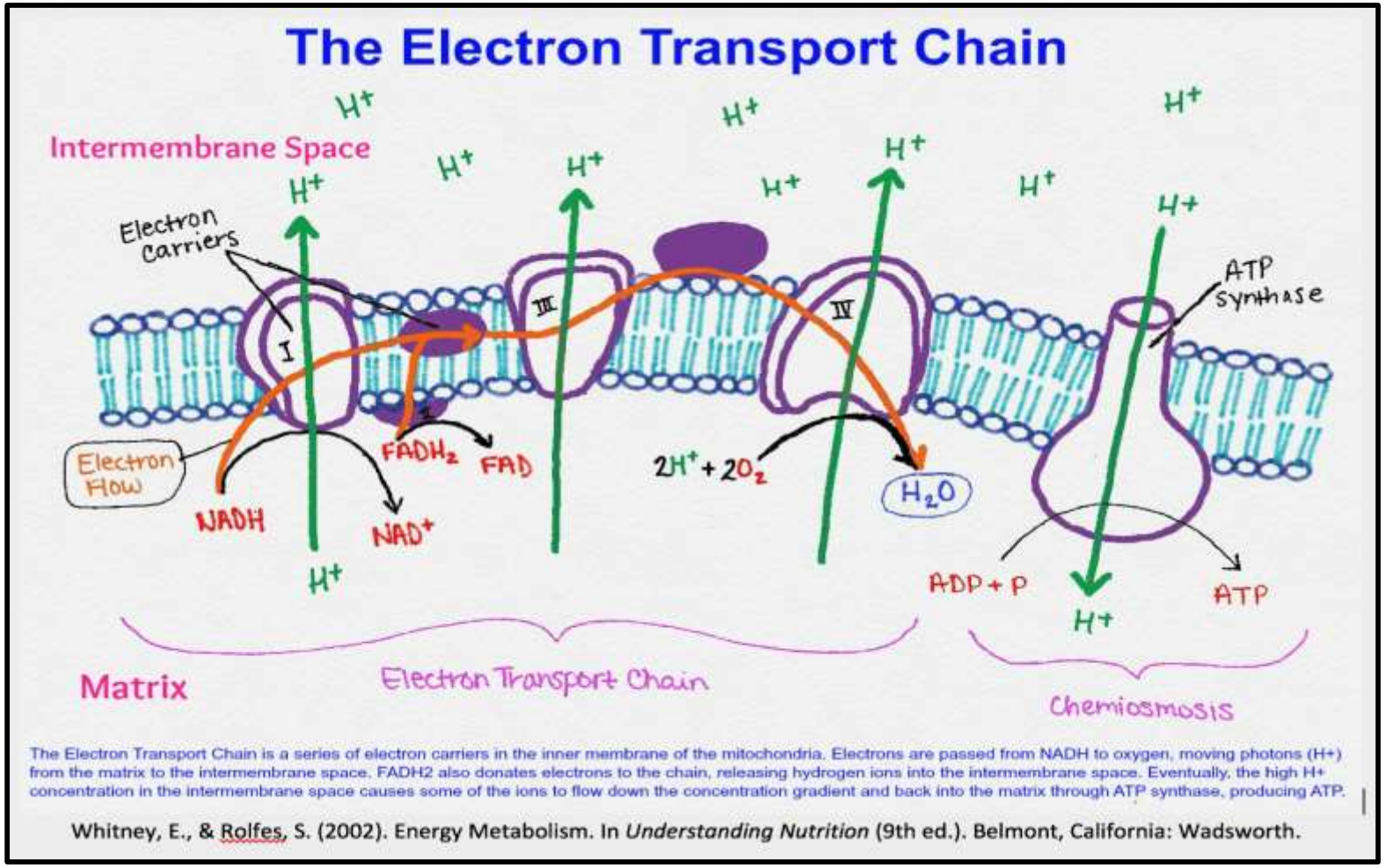
Dr. A.Sujatha, M.Sc, Ph.D

Department of Botany, M.V.R Degree College(UG &PG Courses)

Gajuwaka, Visakhapatnam

Lesson 4

Respiration: Electron transport system, Mechanism of oxidative phosphorylation



Overall stages of respiration

Stage 1. Glycolysis-conversion of glucose into pyruvic acid in cytoplasm of cell.

Stage 2. **Link reaction**-conversion of pyruvic acid into acetyl coenzyme-A in mitochondrial matrix.

Stage 3. **Krebs cycle**-conversion of acetyl coenzyme A into carbon dioxide and water in the mitochondrial matrix.

Stage 4. **Electron transport chain and oxidative phosphorylation** remove hydrogen atoms from the products of glycolysis, link reaction and Krebs cycle release water molecule with energy in the form of ATP in mitochondrial inner membrane (Figure).

Electron transport system (ETS) and oxidative phosphorylation

What is Electron Transport System (ETS)

- By the end of Krebs cycle, glucose molecule oxidise completely but the energy does not release till NADH+ and FADH2 oxidise through ETS (Electron transport System).
- ETS or Electron transport system helps in releasing and utilizing the energy stored in NADH2 and FADH2.
- NADH2 which is formed during glycolysis and the citric acid cycle gets oxidized by an NADH dehydrogenase (Complex I)
- **So the metabolic pathway through which electron passes from one carrier to another is called ETS.**
- ETS is also known as electron transport chain or mitochondrial respiratory chain.
- ETS consists of a series of coenzymes and cytochromes that take part in passage of electrons to its ultimate acceptor namely oxygen.
- ETS is operative in the inner mitochondrial membrane
- ETS in mitochondria consists of **four complexes (oxido reductase complexes) involving transport of electrons and the fifth complex helps in the transport of proton (multiple enzyme complexes)**
- All these are present in mitochondrial membrane

Multiple enzyme complexes

The ETS is carried out by several enzyme complexes.

These 4 multi protein complexes differ from one another in their chemical composition and activity.

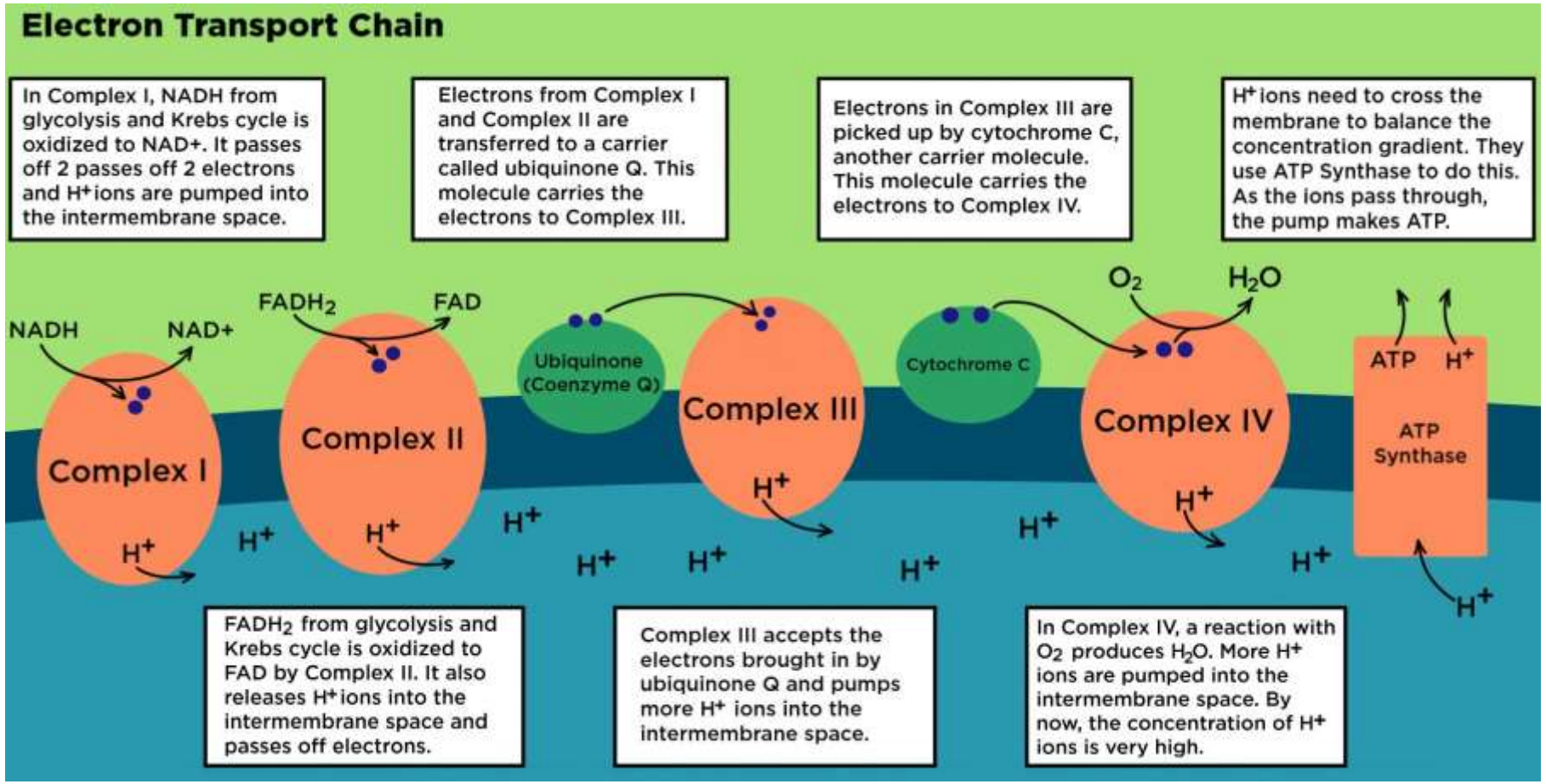
1. **Complex I** : NADH – dehydrogenase or NADH –Q – Reductase or Ubiquinone oxido- reductase. It transfers electrons from NADH to ubiquinone.
2. **Complex II** : Succinate dehydrogenase or succinate Q reductase or ubiquinone oxidoreductase. It transfers electrons from succinate to ubiquinone via Fe- S - centres.
3. **Complex III:** Cytochrome "C" Reductase or Ubiquinol –cyt. C Oxidoreductase or Cyt-b-c complex.
4. **Complex IV:** Cytochrome – C – Oxidase. This transfers electrons to oxygen.
5. **Mobile electron carriers**:

- Lipid Ubiquinone (UQ) or coenzyme Q (CQ)
- Cytochrome "C"

Overall reactions in ETS

- Overall, electrons are transferred from coenzymes NADH or FADH2 onto molecular oxygen which is reduced to water. (formation of water)
- Three of the four oxido reductase complexes(complex I,III & IV) couple their electron transfer reactions with proton translocation across the inner mitochondrial membrane.
- As a result proton gradient is formed which can be used by the ATP SYNTHASE COMPLEX (Complex 5) for the phosphorylation of ADP.
- Cellular respiration is based on a linear ETC (from NADH via complexes I.III AND IV to molecular oxygen

Electron transport – simplified – over view



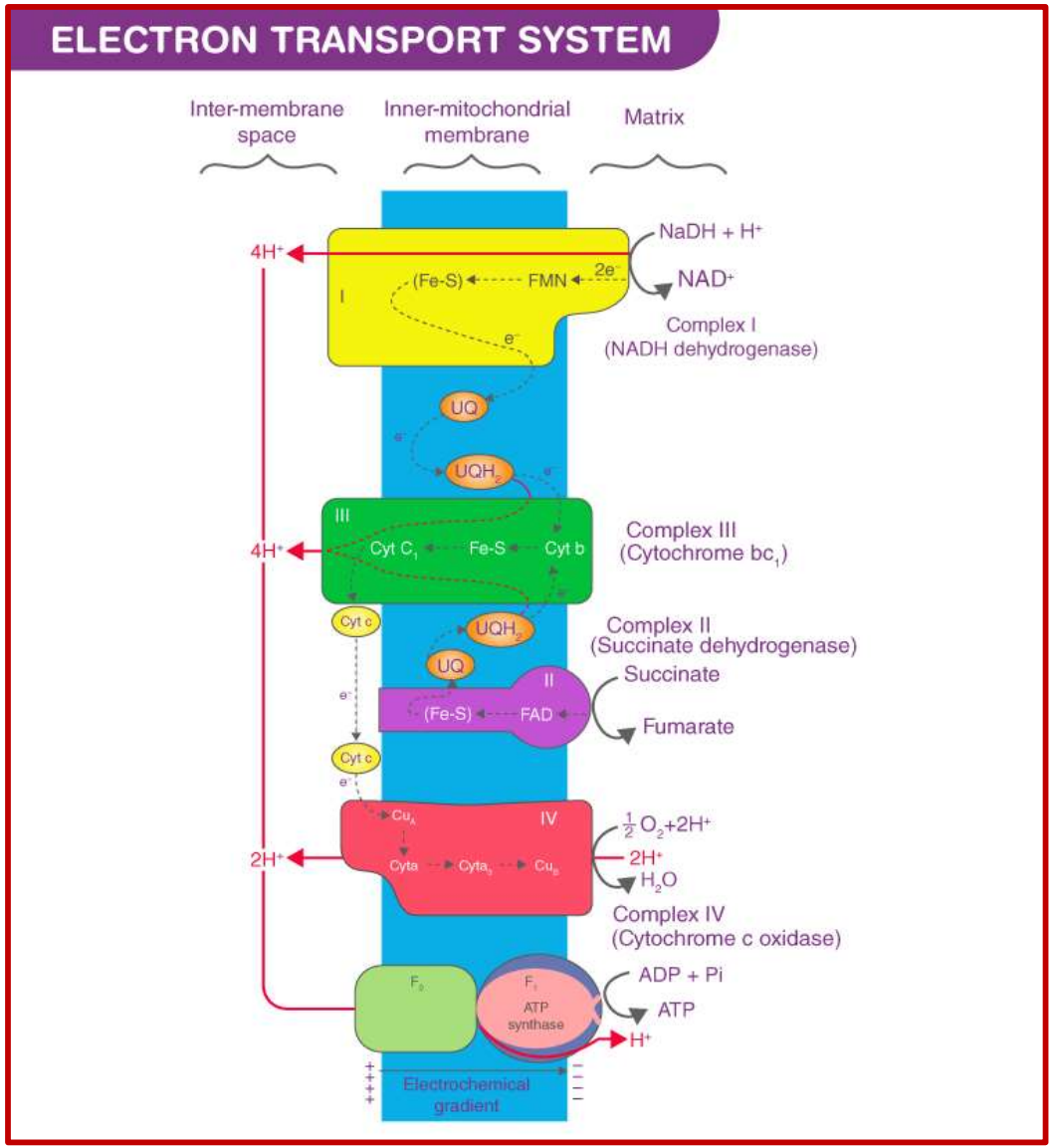
Steps involved in ETS

- Electrons from NADH produced in the mitochondrial matrix during citric acid cycle are oxidised by an NADH dehydrogenase (complex I). And electrons are transferred to ubiquinone located within inner membrane. Ubiquinone also receives reducing equivalents via FADH2 (complex II) that is generated during oxidation of succinate in the citric acid cycle.

Steps in ETS

- The reduced ubiquinone is then oxidised with the transfer of electrons to cytochrome c via cytochrome bc1 complex (complex III).
- Cytochrome c is a small protein attached to the outer surface of the inner membrane and also acts as a mobile carrier for transfer of electrons between complex III and IV.
- Complex IV refers to cytochrome c oxidase complex containing cytochrome a and a2 and 2 copper centres.

Electron Transport System



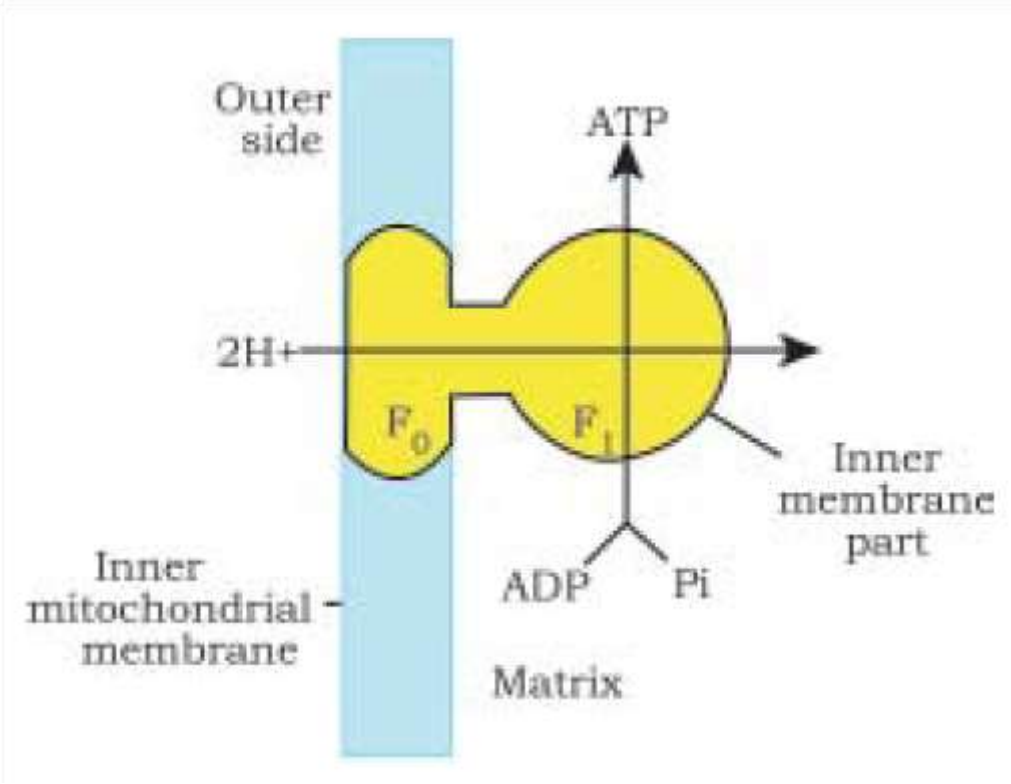
Synthesis of ATP

- When the electrons pass from one carrier to another via complex I to IV in ET chain, they are coupled to ATP synthase (complex V) for the production of ATP from ADP and inorganic phosphate.
- The number of ATP molecules synthesised depends on the nature of electron donor.
- Oxidation of one molecule of NADH gives rise to 3 molecules of ATP, while that of one molecule of FADH2 produces 2 molecules of ATP.
- Although aerobic process of respiration takes place only in the presence of oxygen, the role of oxygen is limited to the terminal stage of the processes. Yet the presence of oxygen is vital, since it drives the whole process by removing hydrogen from the system.
- Oxygen acts as final hydrogen acceptor.
- Since the energy of oxidation – reduction is utilised for the process of production of proton gradient, it is called as oxidative phosphorylation in contrast to photophosphorylation where in light energy is utilized.

Synthesis of ATP

- Energy released during ETS is utilized in synthesising ATP with the help of ATP synthase (Complex V).
- This complex consists of 2 major components, F1 and F2.
- The F1 headpiece is a peripheral membrane protein complex and contains the site for synthesis of ATP from ADP and inorganic phosphate.
- F0 is an integral membrane protein complex that form the channel through which protons cross the inner membrane.
- The passage of protons through the channel is coupled to the catalytic site of the F1 component for the production of ATP.
- For each ATP produced, 4H+ passes through F 0 from the inter membrane space to the matrix down electro chemical proton gradient.

Diagramatic presentation of ATP synthesis in mitochondria



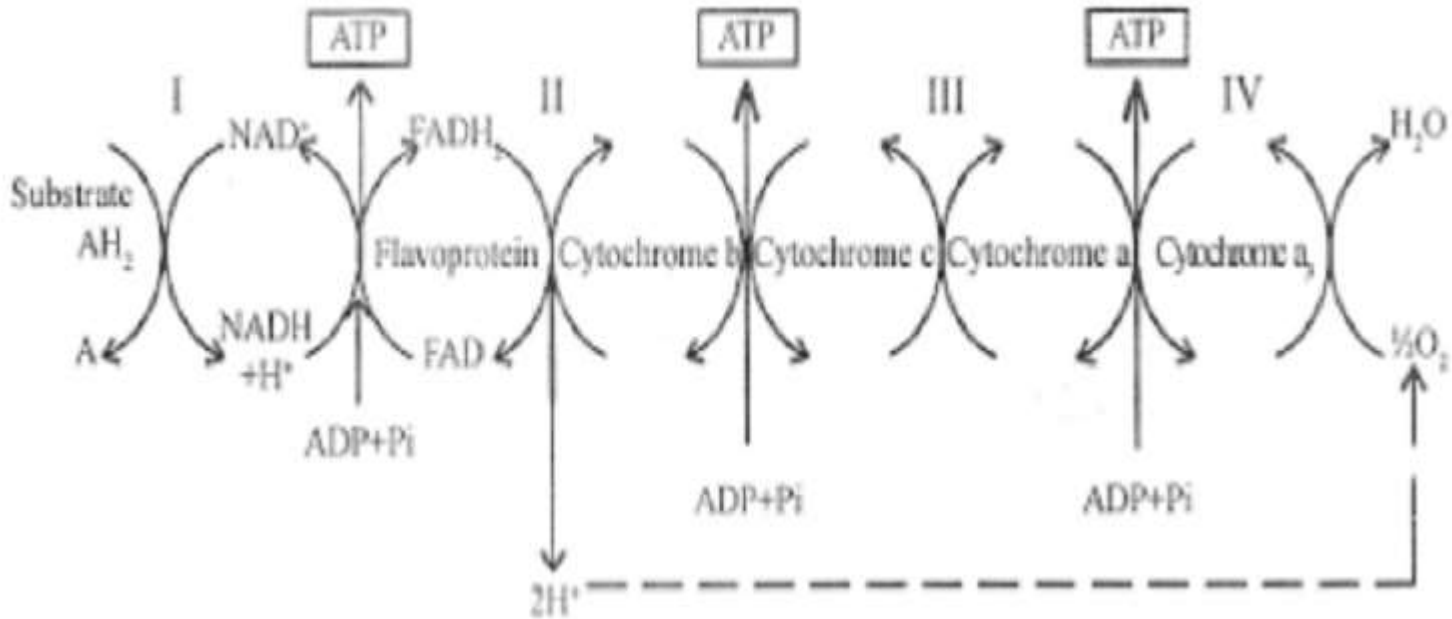


Fig. Electron transport system

Respiratory balance sheet

Respiratory Balance Sheet

Stage of Respiration	Source	Number of ATP Molecules Produced
Glycolysis	Direct 2-molecules of NADH+ H^+ (one molecule of NADH+ H^+ yields 3 molecules of ATP)	2 6
Link reaction	2 molecules of NADH+ H^+	6
Citric acid cycle	6 NADH+ H^+ 2 $FADH_2$ ($FADH_2$ produces only 2 molecules of ATP) Direct	18 4 2

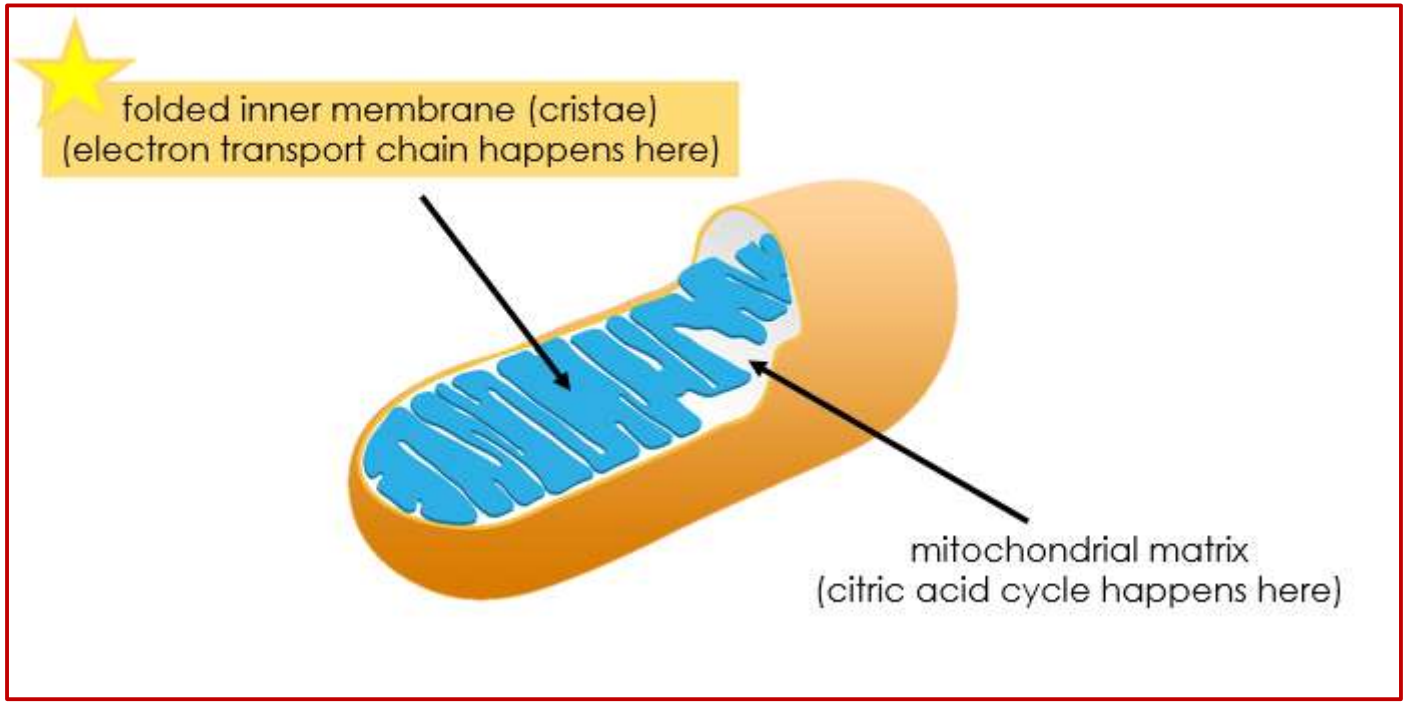
Total : 38 ATP molecules

ETC

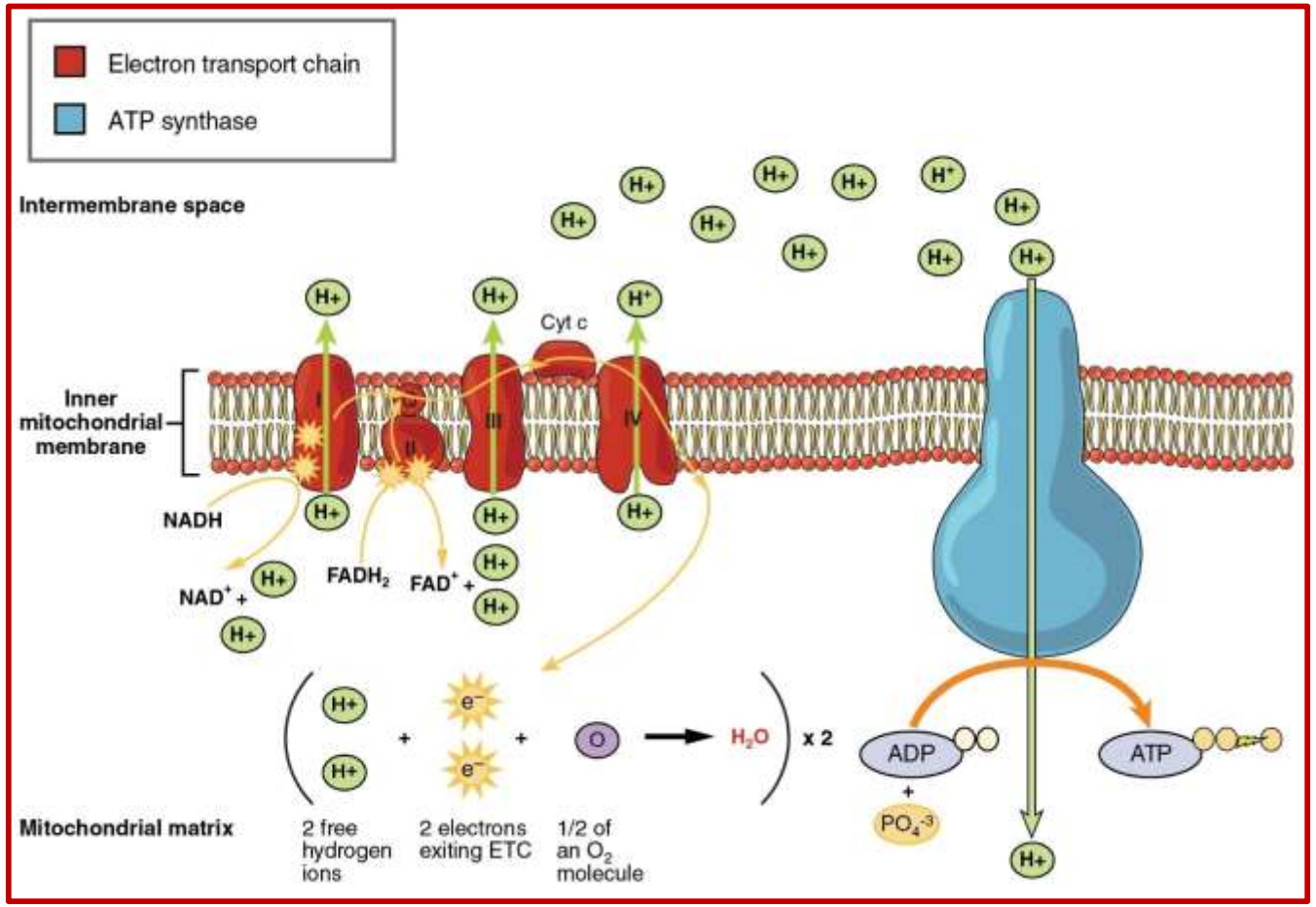
Electron transport chain:

- Occurs in the inner mitochondrial membrane (cristae)
- Requires oxygen (aerobic)
- Produces water and 34 ATP
- Electron carriers drop off electrons and return to citric acid cycle as NAD+ and FADH

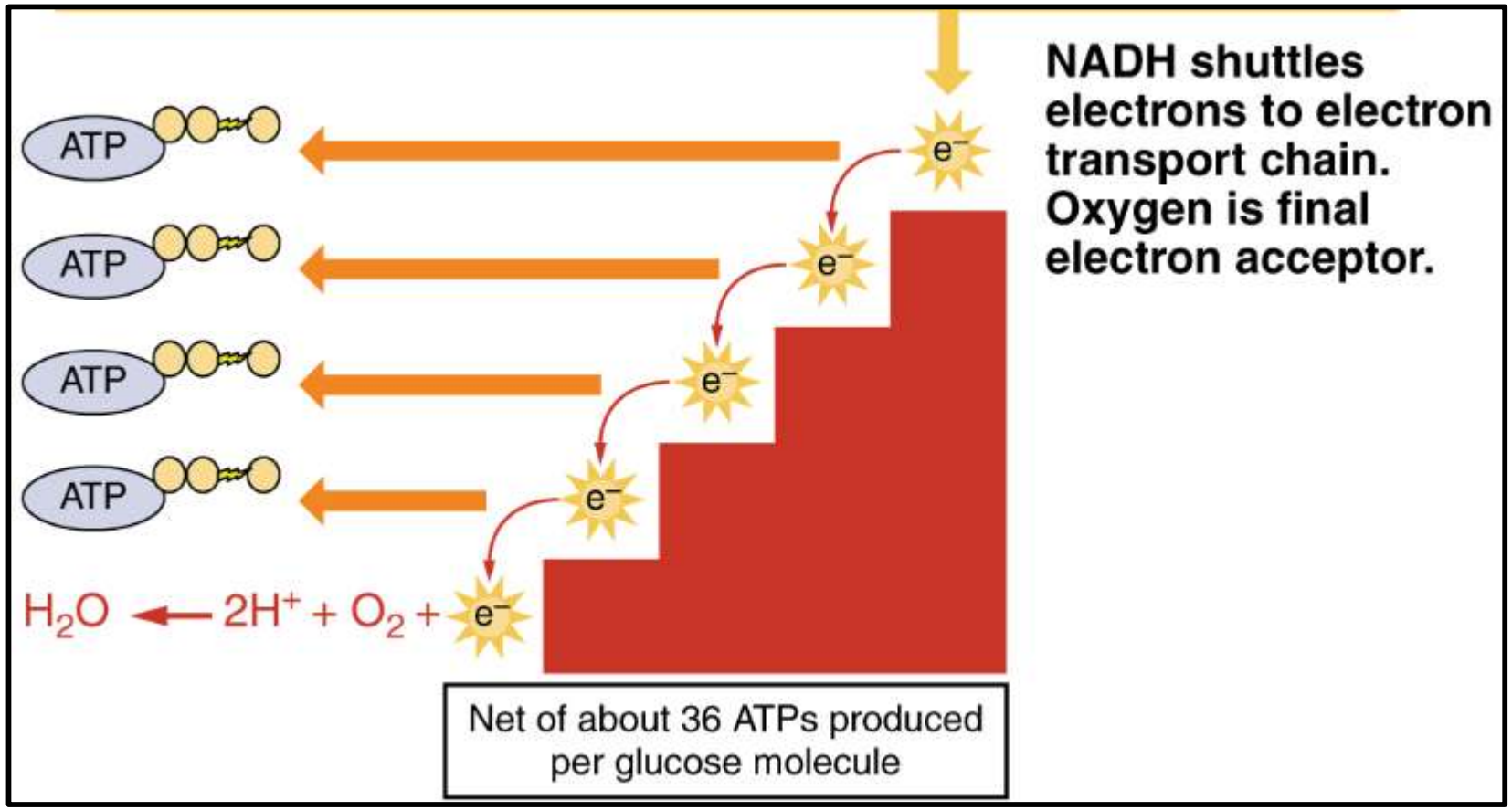
Location of ETS



Over All ET Chain and ATP synthesis



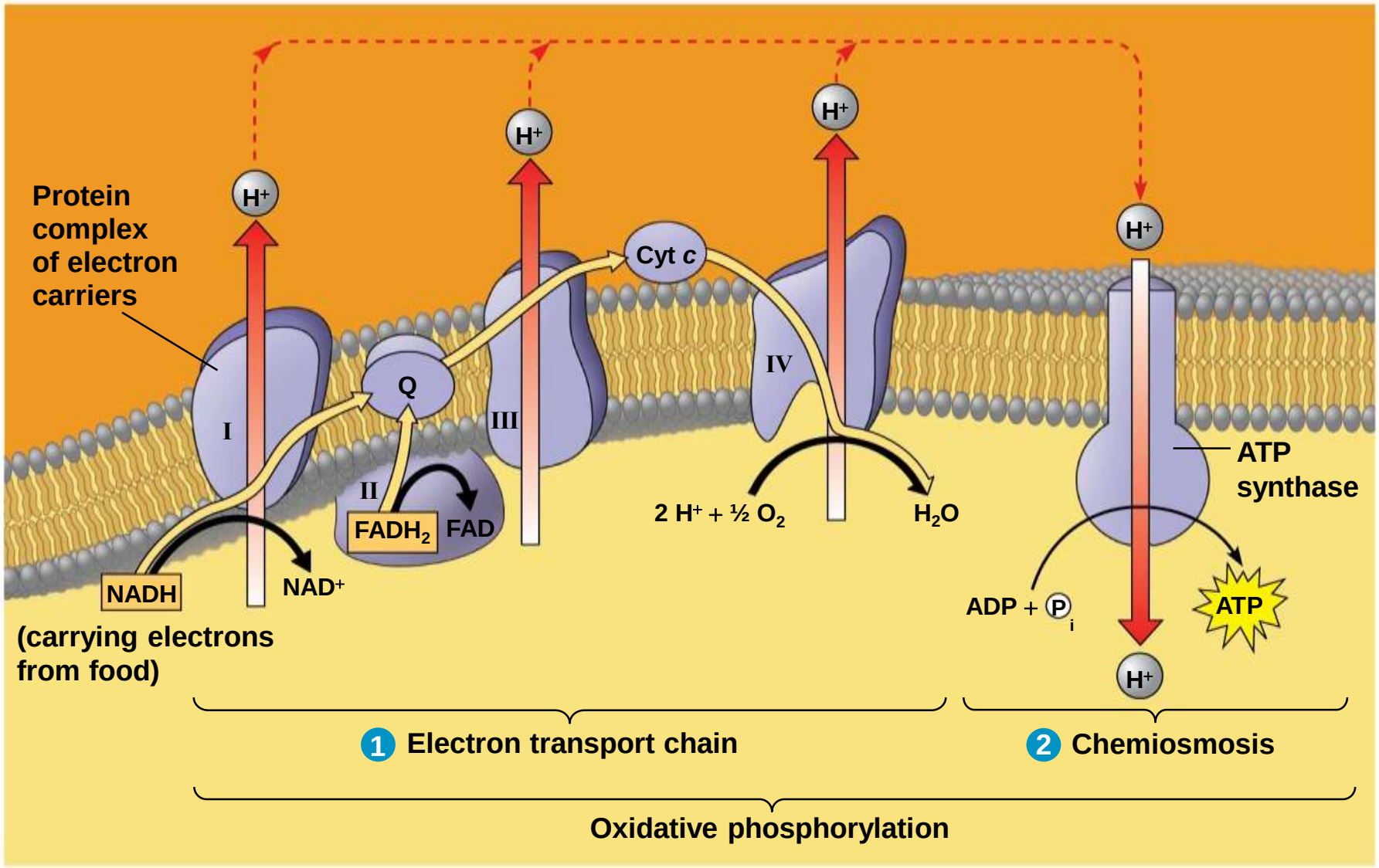
Production of ATP



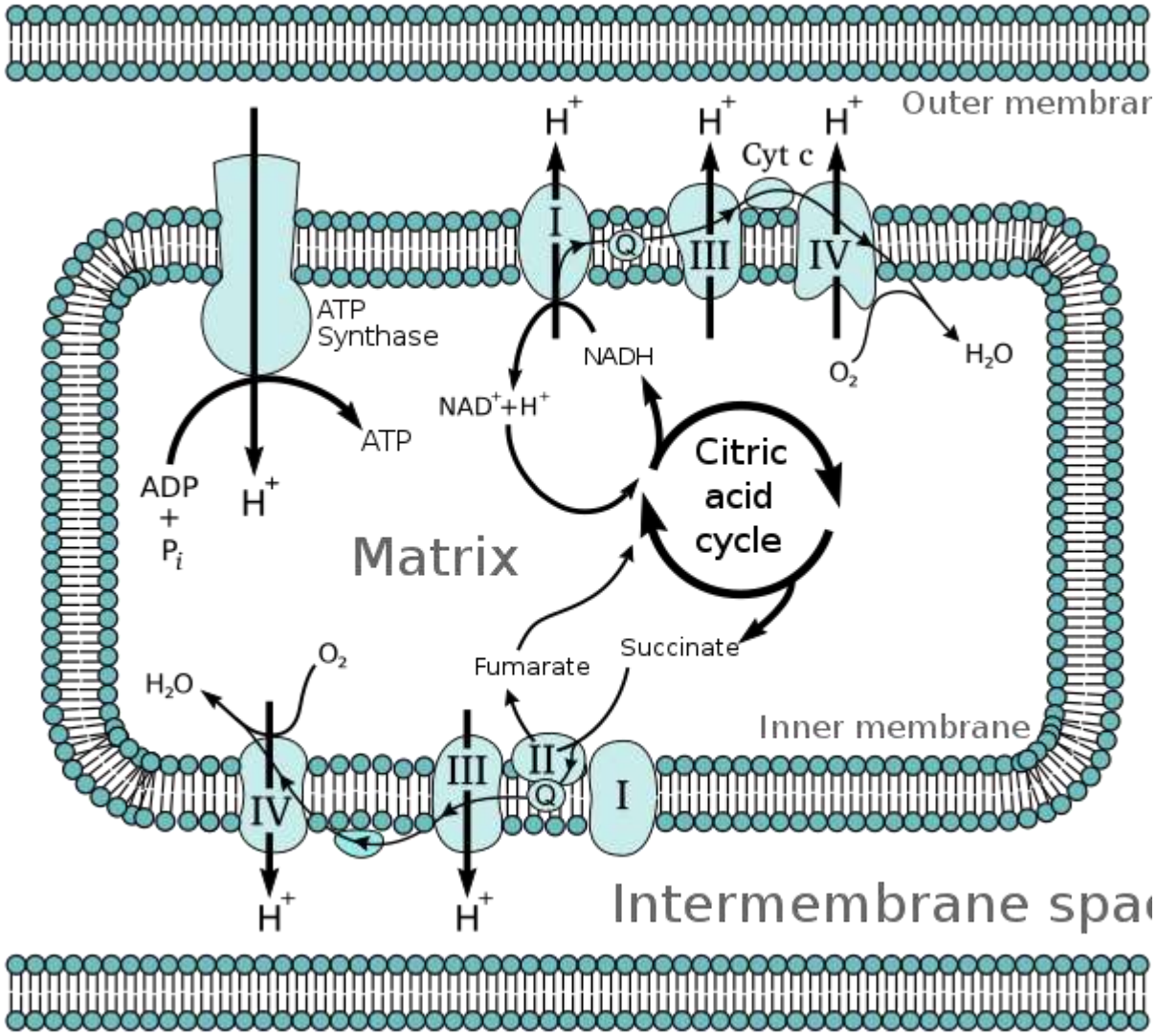
Step 5 : Chemiosmosis

- Oxidative phosphorylation uses the chemical reactions that release energy to drive a chemical reaction that requires energy. These 2 sets of reactions are coupled and interrelated.
- The electrons that flow through electron transport chain is an exergonic process and the synthesis of ATP is an endergonic process.
- These two processes are ingrained within a membrane. As a result, energy will be transmitted from the electron transport chain to ATP synthase by the movement of proteins. This process is termed as chemiosmosis.

Figure 7.14


Protein complex of electron carriers
H+
H+
H+
H+
Cyt c
Q
I
II
III
IV
FADH2
FAD
NADH
NAD+
2 H+ + ½ O2
H2O
ATP synthase
ADP + Pi
ATP
(carrying electrons from food)
1 Electron transport chain
2 Chemiosmosis
Oxidative phosphorylation

Thank you


Outer membrar
H+
H+
H+
Cyt c
I
Q
III
IV
ATP
Synthase
NADH
NAD+ + H+
O2
H2O
ATP
ADP
+
Pi
H+
Citric
acid
cycle
Matrix
Fumarate
Succinate
O2
H2O
Inner membrane
IV
III
II
Q
I
H+
H+
Intermembrane spa

2 UG – Botany

Fourth Semester

Paper V

Cell Biology, Genetics and Plant Breeding

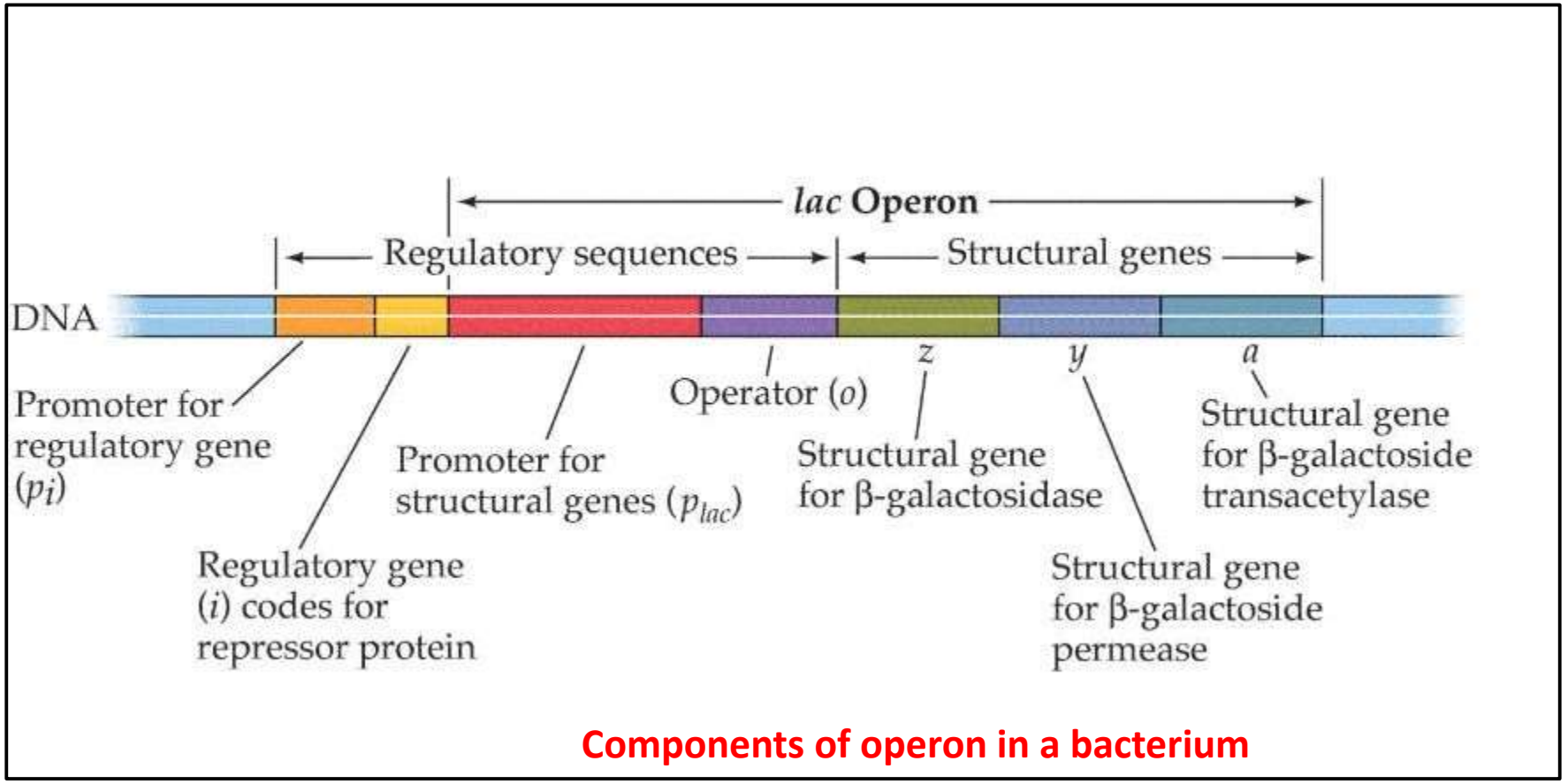
Unit IV : **STRUCTURE AND FUNCTIONS OF DNA**

Lesson 3

Regulation of gene expression in prokaryotes – Lac Operon

Dr. A.Sujatha, M.Sc, M.Phil, Ph.D
Department of Botany
M.V.R Degree college (UG &PG courses)
Gajuwaka, Visakhapatnam

Gene Expression: Lac Operon



Components of operon in a bacterium

Lesson structure

- 1. Introduction
- 2. Methods of regulation of gene expression
- 3. Components of Bacterial operon
- 4. The lac operon- an inducible operon
- 5. Conclusions

What is gene expression?

- Gene expression is the process by which a gene gets turned on in a cell to make RNA and proteins.
- Gene expression may be measured by looking at the RNA, or the protein made from the RNA, or what the protein does in a cell.

What is regulation of gene expression?

- Regulation of gene expression process is **a tightly coordinated process which allows a cell to respond to its changing environment**. During gene expression, genetic codes from the DNA code are converted into a protein with the help of translation and transcription.
- For example, bacteria live in dynamic environmental conditions ranging fro human intestine to polluted rivers, ponds, etc. where they exposed to different metabolites and molecules.
- In such a wide range of ecological conditions, bacteria have to adapt radidly and correctly, which is an indispensable phenomenon for their survival.
- This is possible because of their ability to '**switch on'** and '**switch off'** the expression of specific sets of gene in response to the specific demand of the environment.

Studies in *E.Coli*

- The mechanism was studied well in *E.coli,* having a single circular DNA molecule. When *E.coli* is grown in a culture medium containing lactose, it produces the enzyme beta galactosidase in adundance. This enzyme hydrolyses lactose into glucose and galactose.
- However, very little enzyme is produced in the absence of lactose.
- The protein synthesizing machinery of the cell consumes considerable energy in the form of ATP. It is highly essential for organisms for the optimal use of the available energy by switching off the expression of genes when their products are not required.

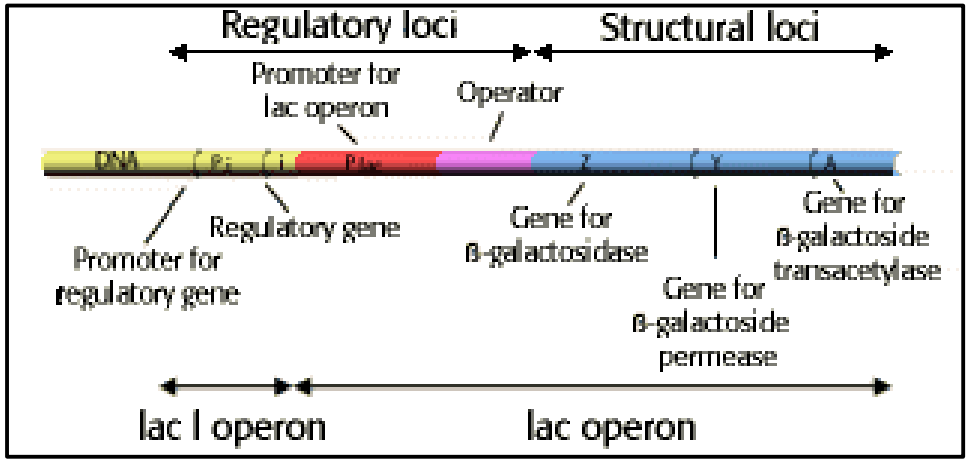
Methods of regulation of gene expression

Various steps of gene expression which includes the following:

- **Replication level** – Any error in copying the DNA may result in an altered expression.
- **Transcriptional level** – During transcription, any error in the polymerization may again lead to a change in expression of the gene.
- **Post-transcriptional level** – During the post-transcriptional modification i.e., RNA splicing, there may be some changes.
- **Translational level** – During translation, if there is an error in the attachment of mRNA to the tRNA molecules, there may arise some changes.
- **Post translational control**. Here proteins made are hydrolysed. Deleterious and unuseful proteins are removed from the cell by proteolysis, for cell growth to succeed.
- Inhibit the production of protein.

Components of bacterial operon

- An operon consists of two categories of genes.
- 1. **Control genes** that include **regulator, promoter and operator genes**. These genes control the structural genes.
- 2. **Structural genes** that transcribe to form polycistronic mRNA which on translation synthesize enzymes.



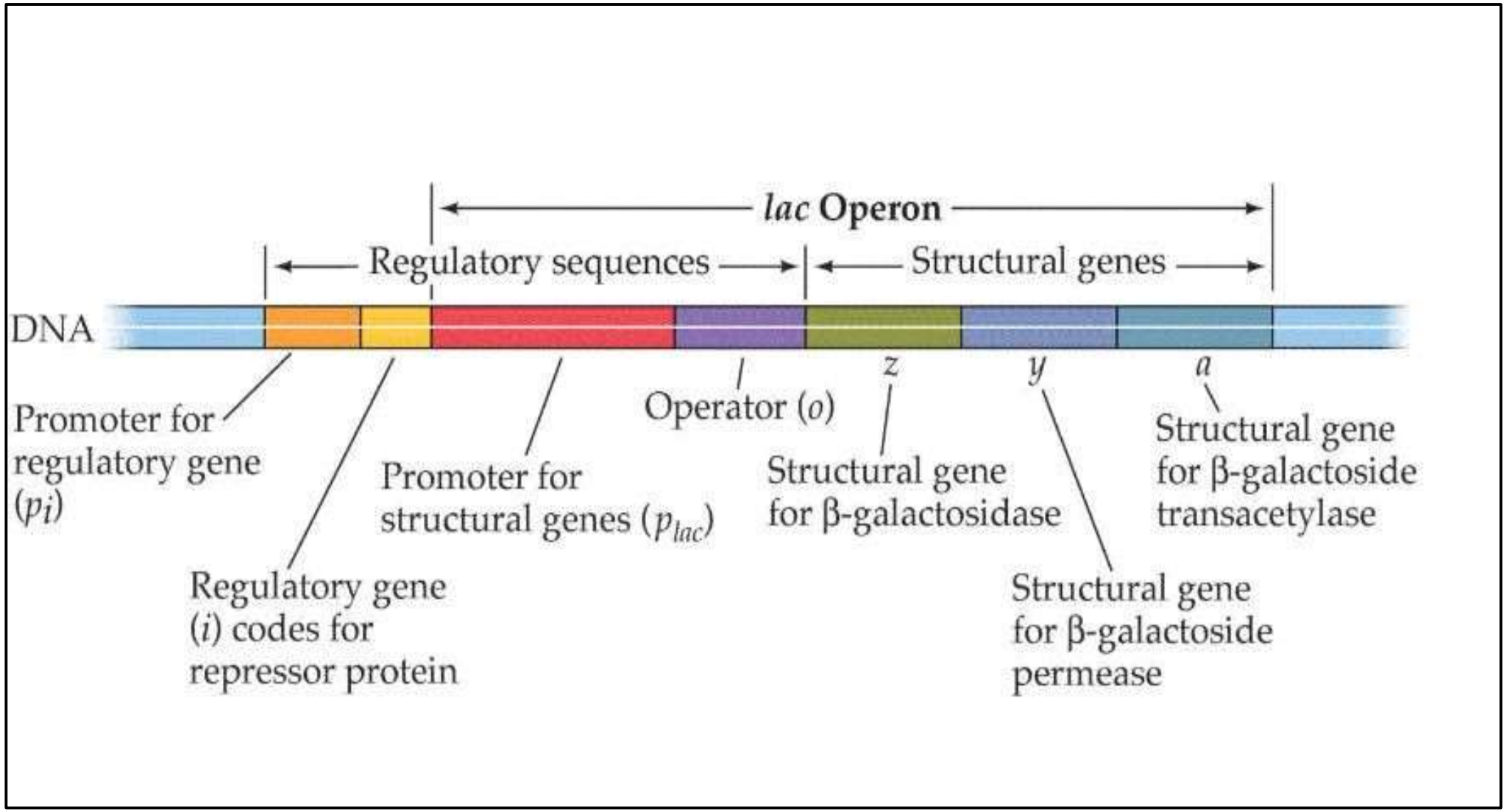
What is The lac operon ?

- “Lac operon is an operon or a group of genes with a single promoter that encode genes for the transport and metabolism of lactose in *E.coli* and other bacteria.”

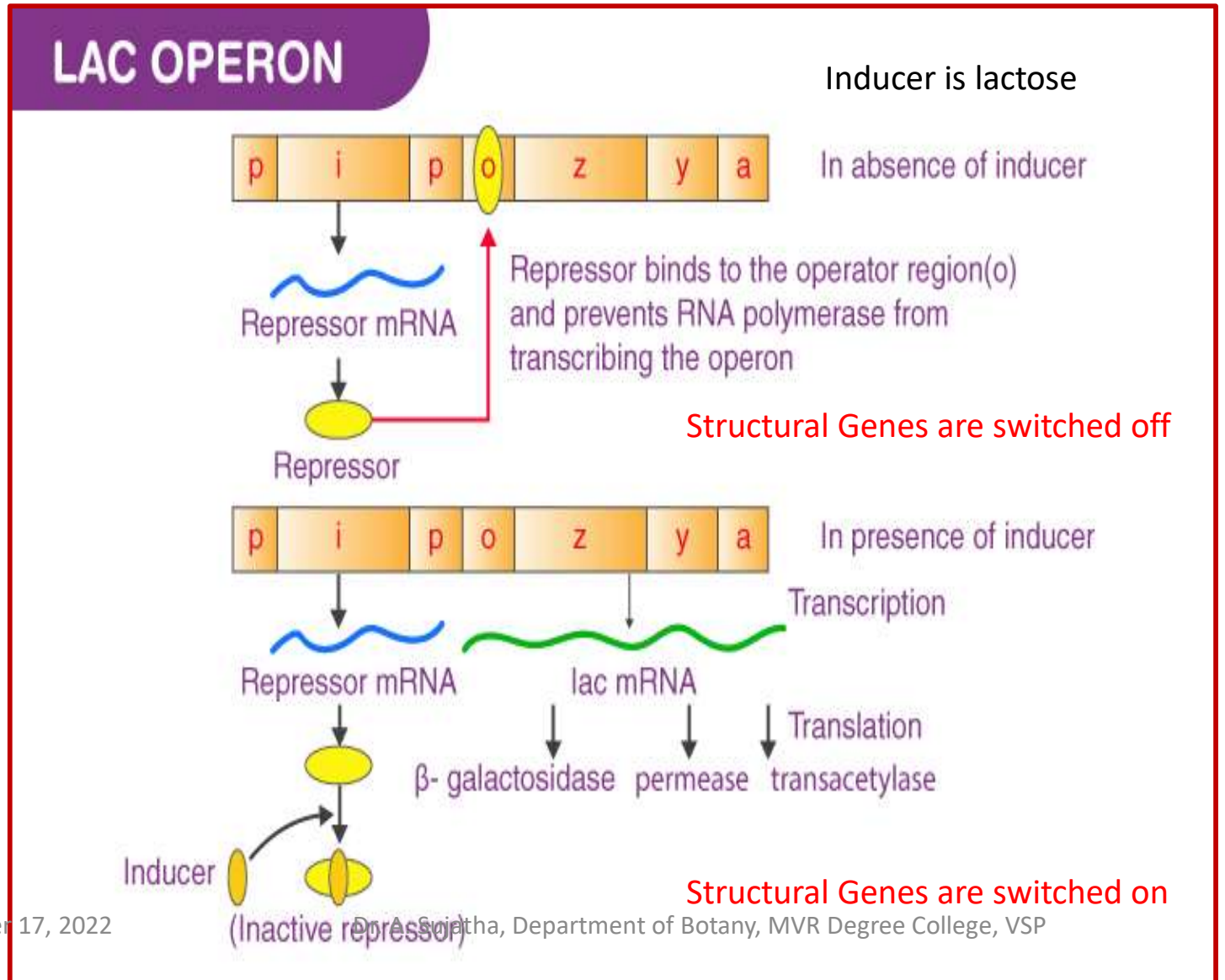
The lac operon – An inducible operon

- Gene regulation in prokaryotes can be explained with the help of the Lac Operon model.
- Here the alteration in physiological and environmental conditions can be observed leading to an alteration in expression in prokaryotes. It was observed by Jacob and Monod.
- The lac operon consists of:
- **Regulatory gene *i*** – It codes for the repressor protein.
- ***z* gene** – It codes for beta-galactosidase which catalyzes the hydrolysis of lactose into glucose and galactose.
- ***y* gene** – It codes for permease which regulates the lactose permeability in the cell.
- ***a* gene** – It codes for transacetylase which assists the enzyme beta-galactosidase.
- Hence, all these genes help in lactose metabolism.
- In lac operon, lactose acts as an inducer. If lactose is provided in the medium for the bacteria, the regulatory gene is activated. The inducer will bind to the repressor protein and render it inactive which allows transcription of the operon. Thus, the lac operon is negatively regulated in this case.

Lac operon components



Lac operon concept



Gene Regulation in Eukaryotes

- Gene regulation in eukaryotes is regulated by transcriptional activators and repressors.
- The repressors bind to specific DNA sequences and inhibit transcription.
- In eukaryotes, transcription involves several steps.
- It occurs in both, nucleus (transcription) and cytoplasm (translation).

Conclusion

- Lac operon contains genes involved in metabolism.
- The genes are expressed only when lactose is present and glucose is absent.
- The operon is turned on and off in response to the glucose and lactose levels: catabolite activator protein and lac repressor.
- The lac repressor blocks the transcription of the operon. In the presence of lactose, it stops acting as a repressor.
- catabolite activator protein activates the transcription of the operon, only when glucose levels are low.

Thank you

Second UG – Botany

Fourth Semester

Paper V

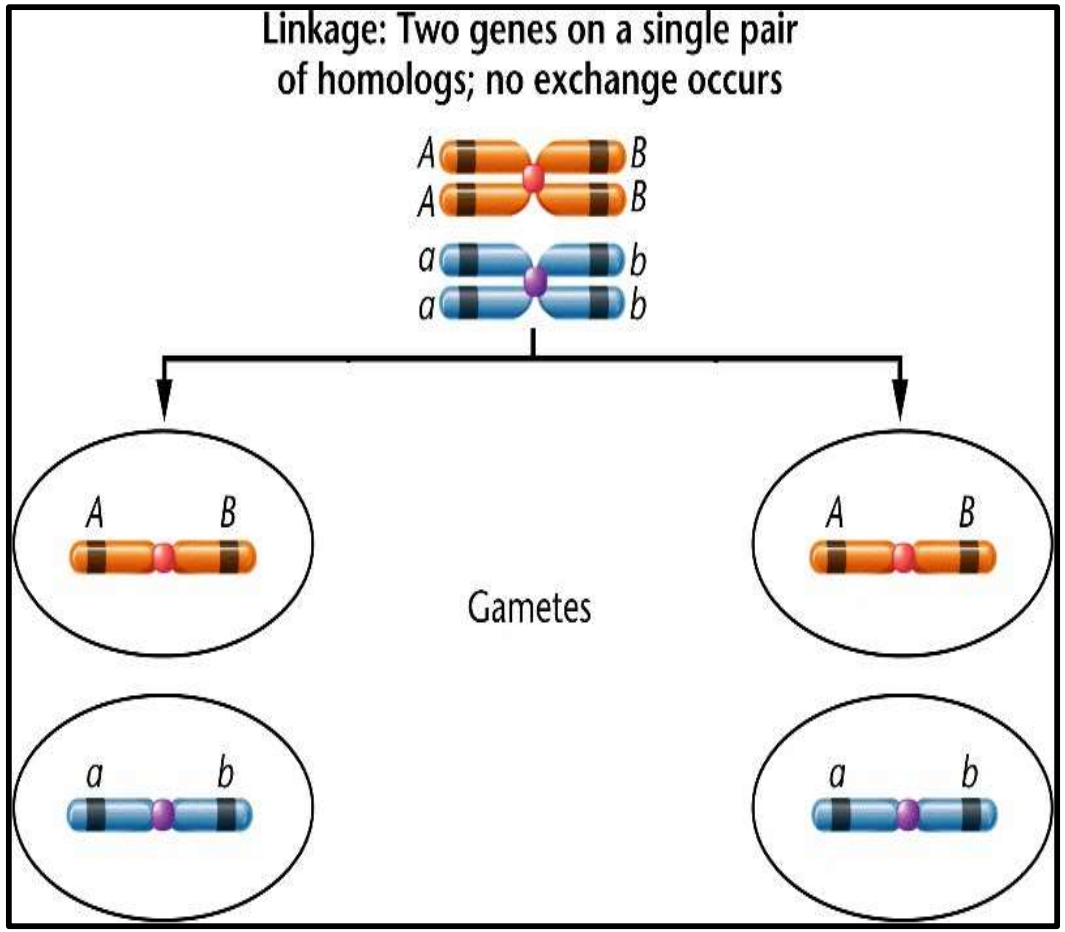
Cell Biology, Genetics and Plant Breeding

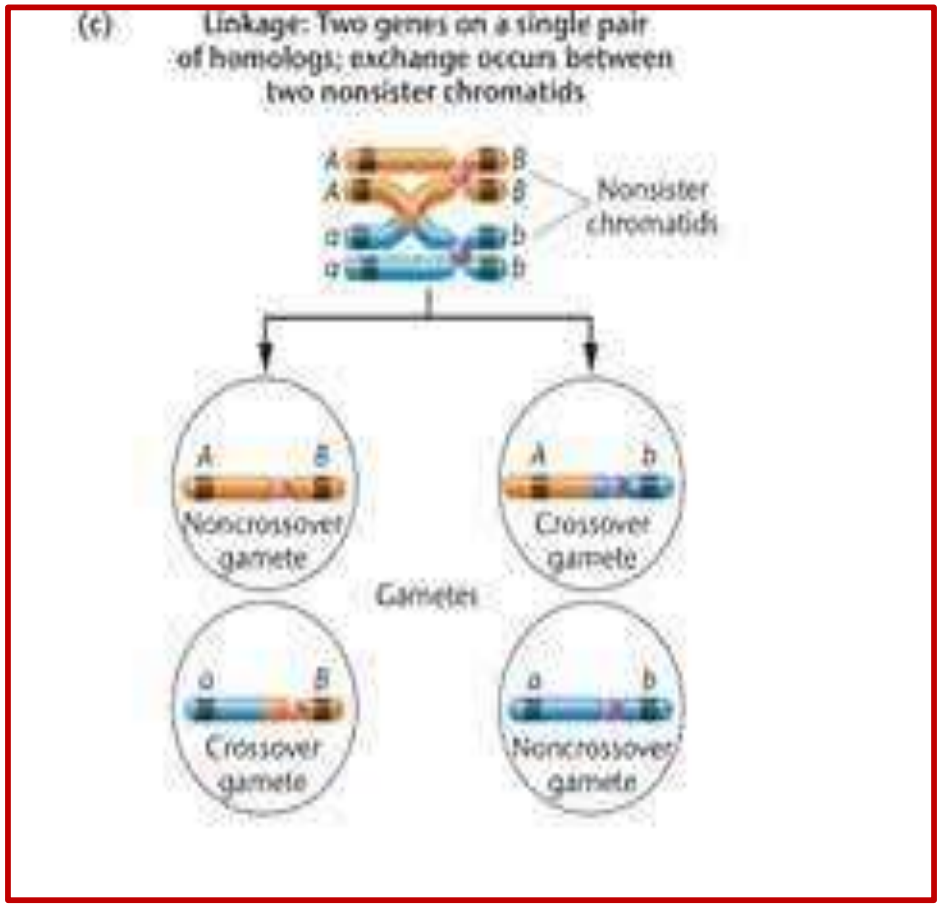
Unit 3: Mendelian and Non- Mendelian Genetics

Lesson - 3

A brief account of linkage and crossing over, Chromosomal mapping, 2-point and 3- point test cross

Dr. A.Sujatha
Department of Botany
M.V.R Degree College (UG & PG Courses)
Gajuwaka, Visakhapatnam


Linkage: Two genes on a single pair of homologs; no exchange occurs
A B
A B
a b
a b
A B
A B
Gametes
a b
a b


(c) Linkage: Two genes on a single pair of homologs; exchange occurs between two nonsister chromatids
Nonsister chromatids
Noncrossover gamete
Crossover gamete
Gametes
Crossover gamete
Noncrossover gamete

Linkage

Introduction

- The genes are located on chromosomes.
- The genes located on the same chromosome are being inherited together and are known as **linked genes**.
- The characters linked by these genes are called **linked characters**.
- The tendency of two or more genes to stay together during inheritance is known as **linkage**.
- Genes located on different chromosomes assort independently.
- But linked genes on the same chromosome **do not assort independently**.
- The linked genes which remain together during the process of inheritance show **complete linkage.**
- Sometimes they may be separated during gametogenesis and show **incomplete linkage**.
- Incomplete linkage takes place due to crossing over.
- Due to crossing over new recombination appear, which lead to the evolution of species.
- They are also helpful for **construction of chromosome maps.**

Discovery of Linkage

- The theory of linkage was proposed by T.H.Morgan in 1911.
- Its existence was described under different names

1. Sutton hypothesis: Sutton 1903
2. Coupling and repulsion hypothesis Bateson and Punnet 1906
3. Morgans concept of linkage: T.H .Morgan 1910
4. Chromosomal theory of linkage: Morgan and Castle 1911
5. Linkage groups

1.Sutton hypothesis or Chromosome theory of inheritance

- Sutton (1903) formulated chromosome theory of inheritance.
- This theory suggested that each chromosome bears more than one gene and all the genes are situated in one chromosome are inherited together in the offspring.
- This theory provides a physical basis of heredity.

2. Coupling and Repulsion hypothesis

- Bateson and Punnet (1906) formulated this hypothesis to explain the unexpected results of dihybrid test cross in pea plants. They formulated the hypothesis of coupling and repulsion.
- **Coupling hypothesis**: It is defined as the tendency of alleles either dominant or recessive coming from the same parent to enter the same gametes in higher proportion and get inherited together. As a result of this the gametes with parental alleles are produced in more number.
- **Repulsion hypothesis:** It is defined as the tendency of alleles dominant or recessive coming from different parents to repel and enter into different gametes and get inherited separately.

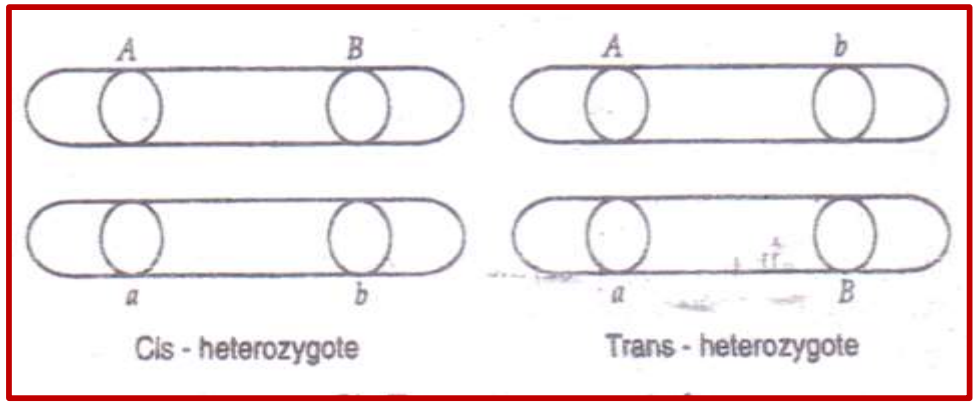
3. Morgan's concept of linkage

- While working on *Drosophila* T.H .Morgan (1910) found that coupling and repulsion was not complete.
- He suggested that the two genes found in coupling phase on the same chromosome.
- In repulsion phase the genes are found on different homologous chromosomes.
- Such type of genes are called linked genes and this phenomenon of inheritance is called linkage by Morgan.
- He also stated that the strength of linkage depends upon the distance between the linked genes in the chromosome.
- This helped the cytogeneticists in the construction of genetic or linkage maps of chromosomes.

4. Chromosome theory of linkage

- Morgan and Castle (1911) formulated this theory.
- According to this theory closely related genes show strong linkage and widely located genes show weak linkage.
- Arrangement of linked genes is of two types, in the heterozygous individuals.
- **Cis – arrangement:**
- In a pair of homologous chromosomes, A and B dominant genes are located on one member of chromosome and recessive genes a and b are located on the other chromosome. This arrangement is known as Cis-arrangement and the genes are in coupling phase.
- **Trans-arrangement:**
- In a pair of homologous chromosomes, the dominant gene A and the recessive gene b are located on one chromosome. The dominant gene B and the recessive gene a are located on another chromosome. This arrangement is known as trans-arrangement and in this case the genes are in repulsion phase.

Cis- Trans arrangement of genes



5. Linkage groups

- All the genes which are located on the same chromosome constitute a linkage group. The number of linkage groups of a species is equal to the haploid chromosome number of that species.
- Example:
- *Drosophila* has 4 pairs of chromosomes and show 4 linkage groups
- *Zea mays* has ten pairs of chromosomes and show 10 linkage groups

Kinds of linkage

Kinds of linkage

- Linkage is of two types:

1. Incomplete linkage
2. Complete linkage

Incomplete linkage

- It is common in almost all the organisms.
- In this exchange of genetic material takes place between two non-sister chromatids of two homologous chromosomes by process of crossing over.
- This leads to the formation of new combinations and less number of parents in the test cross progeny.
- **Example:** In maize the cross between coloured and normally filled seeds and colourless shrunken seeds.

Complete linkage

- In this case the linked genes are closely associated and do not separate.
- As a result of this only parental character combinations are recovered in test cross progeny.
- Complete linkage is a very rare phenomenon.
- Example: Male *Drosophila*

Factors affecting the strength of Linkage

- The following physiological and environmental factors affect the strength of linkage.
- **Distance :** Closely related genes show strong linkage while the genes widely located show weak linkage.
- **Age**: With the increase in age the strength of linkage increases.
- **Temperature**: Increase in temperature decreases the strength of linkage.
- **X-rays**: Exposure to X-rays reduces the strength of linkage.

Significance of Linkage

- It reduces the possibility of variations in gametes.
- It increases the possibility of increase in parental combinations.

Crossing over

Occurrence of crossing over

- The term crossing over is coined by T. H Morgan.
- The concept of crossing over was first proposed by Morgan and Castle.
- **Crossing over may be defined as the exchange of genetic material between the two non- sister chromatids of two homologous chromosomes.**
- Crossing over is not seen in male *Drosophila* and female silk worm.

Salient features of Crossing over

- It is an alternative to linkage
- It separates the linked genes on the same chromosome
- It depends upon the distance between the genes
- If distance is more changes of crossing over will be more
- It takes place between two non-sister chromatids of two homologous chromosomes.
- Occurrence of recombination of genes
- Genetic variations in populations are mostly due to crossing over

Frequency of Crossing over

- Frequency of crossing over depends upon the distance between the genes and length of the chromosome.
- The frequency with which the crossing over occurs between two genes is expressed in terms of percentage of crossing over.
- If the distance between the genes is more the chances of crossing over and chiasmata formation are more .
- The percentage of crossing over is the expression of the number of recombinations in percentage to the total number of offsprings.
- Frequency of crossing over (%) =

$$\frac{\text{No. of recombinant individuals from a test cross}}{\text{Total number of progeny in the test cross}} \times 100$$

Factors controlling the frequency of Crossing over

- Besides the distance between the linked genes the following physiological, environmental and genetical factors also influence it.
- High and low temperature increase the frequency of Crossing over.
- X-rays increase the frequency of Crossing over.
- Centromeres tend to suppress the recombinant.
- Inversion of chromosomes suppresses the chances of crossing over.
- Increase in age decreases the frequency of crossing over.

Examples of Crossing over

- **Recombination in Maize:**
- A heterozygous Maize plant with coloured and normally filled seeds is test crossed with double recessive plant with colourless shrunken seeds. The following varieties of F2 plants are obtained.

Mechanism of Crossing over

- Crossing over occurs during sporogenesis and gametogenesis in which meiotic cell division takes place.
- In zygotene stage of prophase - I of meiosis I bivalents are formed due to synapsis. In pachytene stage tetrads are formed.
- Each tetrad consists of 4 chromatids of two homologous chromosomes.
- The non-sister chromatide of two homologous chromosomes twist over each other.
- These points of contact between non-sister chromatids produce cross like figure and are called chiasmata.
- In the presence of endonuclease enzyme the chromatids break at the region of chiasmata.
- The broken segments of chromatid fuse in the presence of ligase enzyme.
- After the completion of crossing over the two non-sister chromatids repel each other.
- During diplotene stage desynapsis takes place.
- The chiasma moves towards the ends of the chromosome. This movement of chiasma is known as terminalisation. In diakinesis the chromatids become thick and shorter.
- Each event of crossing over produces two recombinant chromatids called cross over chromatids and two original chromatids called non-crossover chromatids.

Theories explaining the mechanism of crossing over

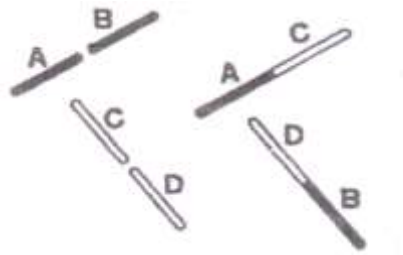
- The following theories have been proposed to explain the mechanism of crossing over.

1. Duplication theory
2. Copy – choice hypothesis
3. Break and exchange theory

Theories explaining the mechanism of crossing over

- Even though the breakage and reunion theory is the most widely accepted theory, there is a lot of controversy about the breakage and exchange of chromatids.
- Following theories have been proposed to explain the breakage of chromatids.
- **Serebrovsky's contact first theory:**
- The non-sister chromatids of homologous pairs first touch and twist over each other. At the point of contact the chromatids break and broken segments then rejoin to form new combinations.
- **The breakage first theory of Muller:**
- The chromosomes first break into two or more segments. The broken segments of non-sister chromatids then rejoin with an exchange forming chiasma.

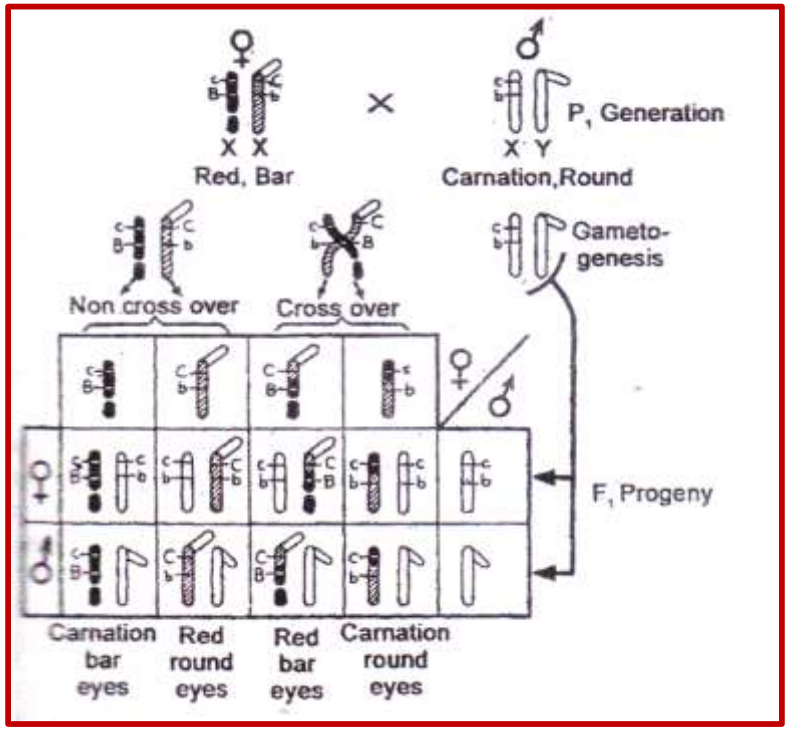
Breakage first theory of chiasmata formation



Cytological evidences of crossing over

- One of the x-chromosomes carrying both the recessive alleles come from the male fly. It is normal type.
- The other X-chromosome in 4 types of female flies is found to be with different morphology.
- Carnation bar – CB Parental.
- Carnation round – cb – recombinant.
- Red Bar – CB Recombinant type (L-shape).
- Red round Cb Parental –(L-shape).
- The appearance of new X-chromosome is the result of recombination.
- The above cytological observations provided a strong evidence

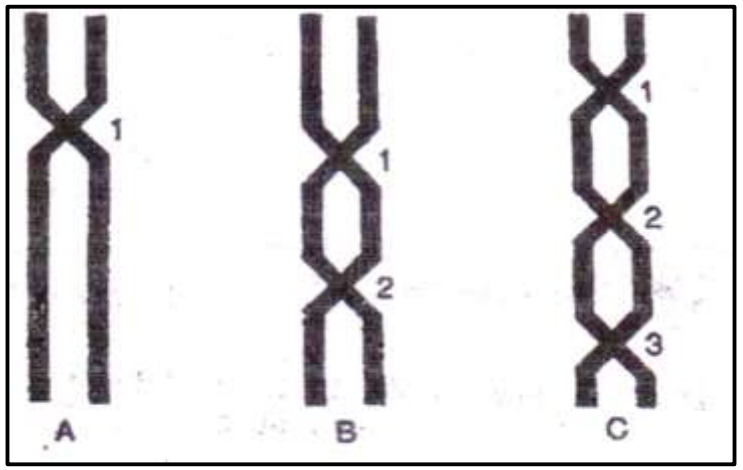
Cytological demonstration of crossing over in *Drosophila*



Kinds of crossing over

- On the basis of number of chiasmata formed the following are the different types of crossing over.
- Single crossover:
- Only one chiasma is formed all along the length of the chromosome. It is common type.
- **Double crossover**:
- Two chiasmata are formed at two points. It's occurrence is rare.
- Multiple crossover:
- It occurs rarely . More than two chiasmata are formed on the same chromosome pair.

Single, double and multiple cross-overs

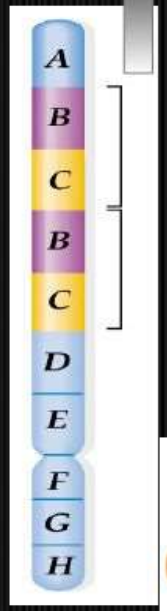


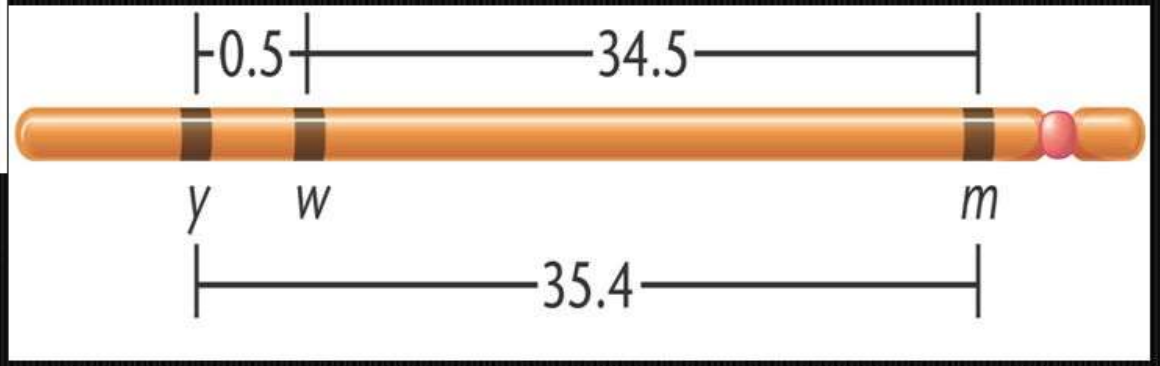
Significance of crossing over

- It is a direct evidence for the linear arrangement of genes on the chromosome
- The frequency of crossing over helps in the construction of chromosome maps
- It is useful to study the nature and functional mechanism of genes
- As a result of crossing over new gene recombinations are produced. These variations lead to evolution of species.

THANK YOU

For having a link to linkage





Second UG – Botany

Fourth Semester

Paper V

Cell Biology, Genetics and Plant Breeding

Unit 3: Mendelian and Non- Mendelian Genetics

Lesson 4

Concept of maternal inheritance

(Correns experiment on *Mirabilis jalapa*)

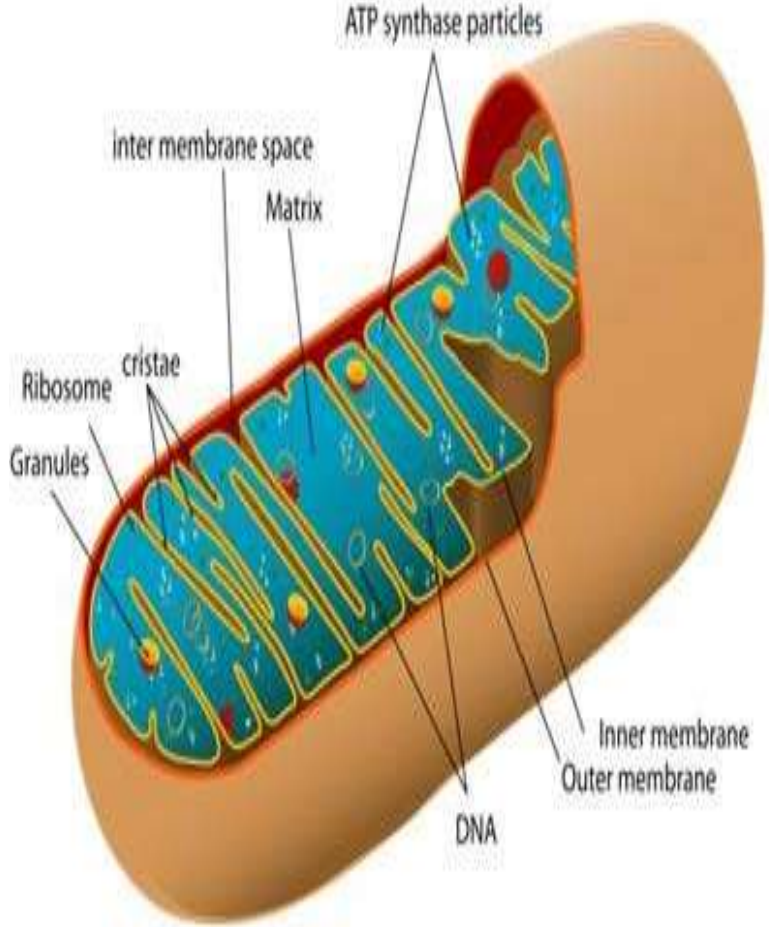
Dr. A.Sujatha
Department of Botany
M.V.R Degree College (UG & PG Courses)
Gajuwaka, Visakhapatnam

Introduction

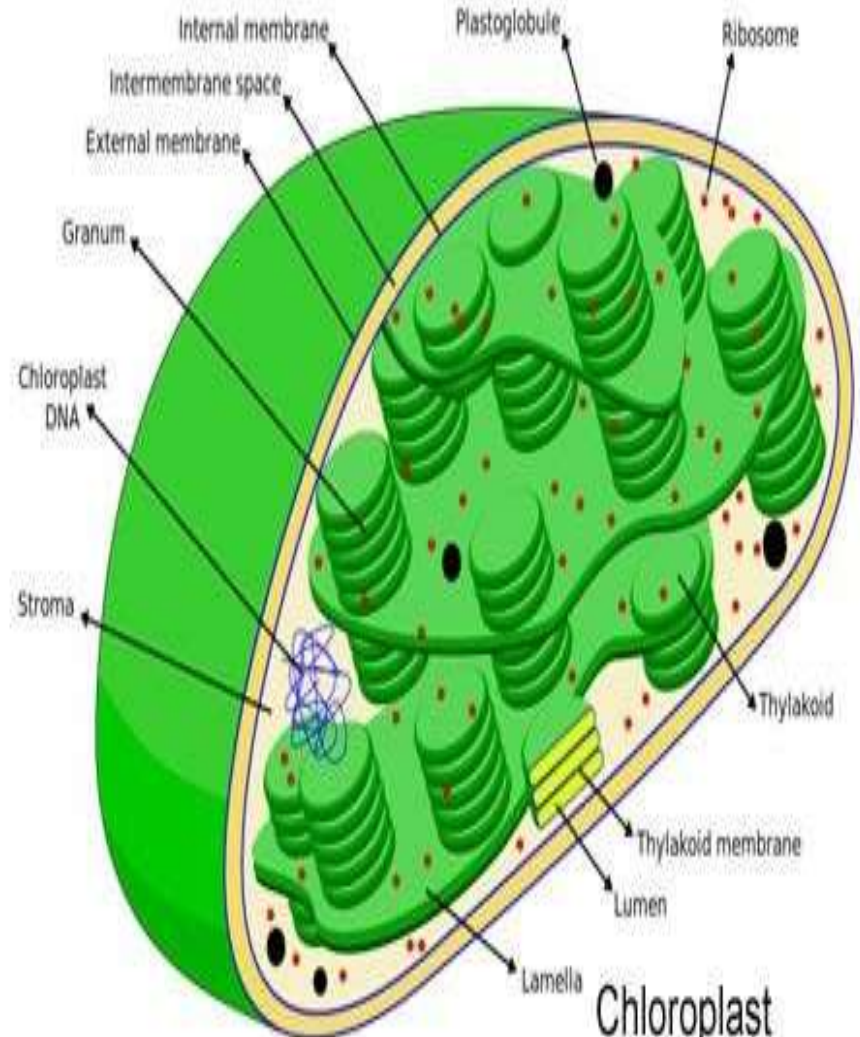
- 1. Maternal inheritance is considered as one of the types of cytoplasmic inheritance.
- 2. The transmission of characters from parents to offspring through cytoplasmic genes is called cytoplasmic inheritance.
- 3. It is also called as extra chromosomal inheritance or non- Mendelian inheritance or Non nuclear gene inheritance.

Concept of maternal inheritance

- Cytoplasmic inheritance is governed by genes found in chloroplasts and mitochondria (autonomous organelles) which are present in cytosol. These have their own DNA material. So maternal inheritance may be through plastid or mitochondria.
- Maternal inheritance where in traits of the offspring are maternal in origin due to expression of extra nuclear gene or DNA present in the ovum (in animals) or egg cell (in plants) during fertilization.
- In maternal inheritance the traits inherited by the offspring are exclusively linked to the genetic material transmitted by the mother or female parent to their offspring.
- Extra nuclear gene in the cytoplasm that are present either in mitochondria or plastids of ovum or egg cell are transferred from mother or maternal parent.
- It is also called uni parental inheritance or maternal effect.
- The first case of maternal inheritance was first reported by C.E. Correns, a German Botanist in four o'clock plant called *Mirabilis jalapa*



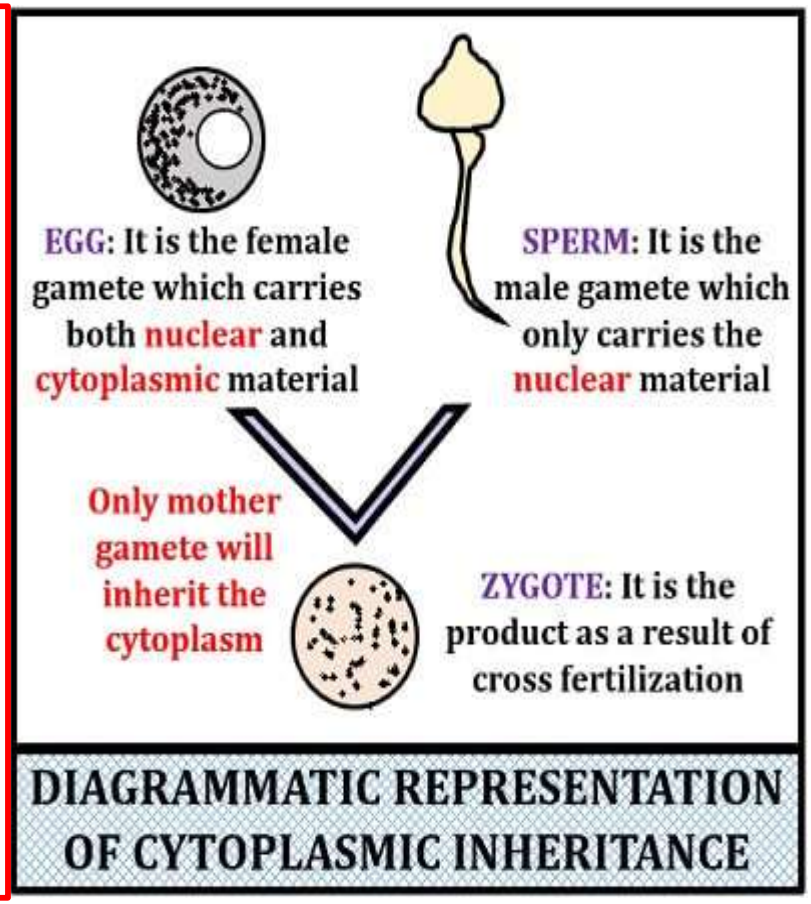
Mitochondria



Chloroplast

Concept of Cytoplasmic /Maternal inheritance

1. During fertilization , Cytoplasm in zygote is contributed by egg only.
2. Egg has cytoplasm and Nucleus.
3. Sperm brings only nuclear material.
4. Cytoplasmic inheritance is from female /maternal.
5. Plastids and mitochondria present in cytoplasm are autonomous (have their own DNA) and play an important role in cytoplasm inheritance.
6. Plastids are present in plants only whereas mitochondria are seen both in plants and animals.
7. Plastid inheritance in Mirabilis jalapa was studied by Correns



DIAGRAMMATIC REPRESENTATION OF CYTOPLASMIC INHERITANCE

Plastid Inheritance in Mirabilis:

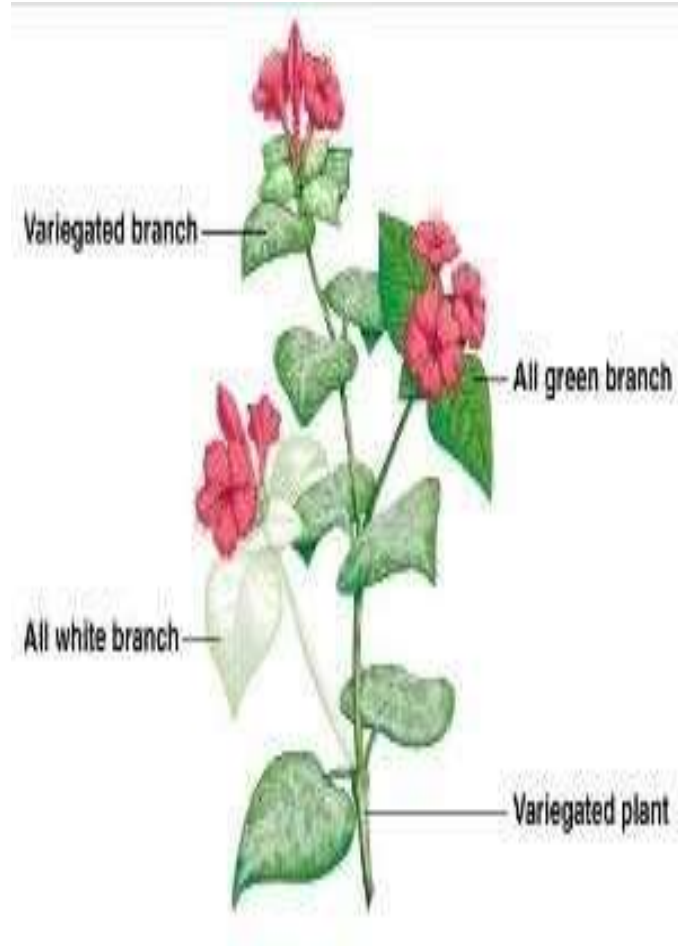
- Plastid inheritance means the inheritance of plastid characteristics due to plasma genes located in plastids.
- Plastid inheritance was first described by C. Corens (1909) in the four o'clock plant, *Mirabilis jalapa*.
- Leaves of Mirabilis jalapa may be green, white or variegated and some branches may have only green, only white or only variegated leaves. Varie- gation means the presence of white or yellow spots of variable size on the green background of leaves.

Variegation may be produced by:

(a) Some environmental factors,

(b) Some nuclear genes,

(c) Plasma-genes in some cases.



Correns experiments

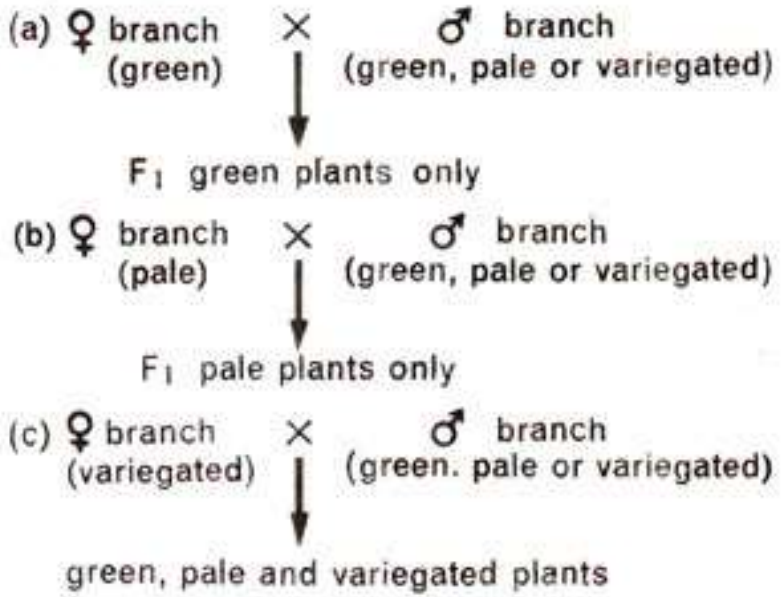
- The classic study of maternal inheritance was performed by Correns on the four o'clock plant in 1909 in *Mirabilis jalapa.*
- This plant can have either green, variegated (white and green) or white leaves.
- Flower structures can develop at different locations on the plant and the flower color corresponds to the leaf color.
- Correns conducted three types of crosses between female and male parental flowers of Mirabilis jalapa.

.

Table 22.1: Plastid Inheritance in Variegated four O'clock Plant

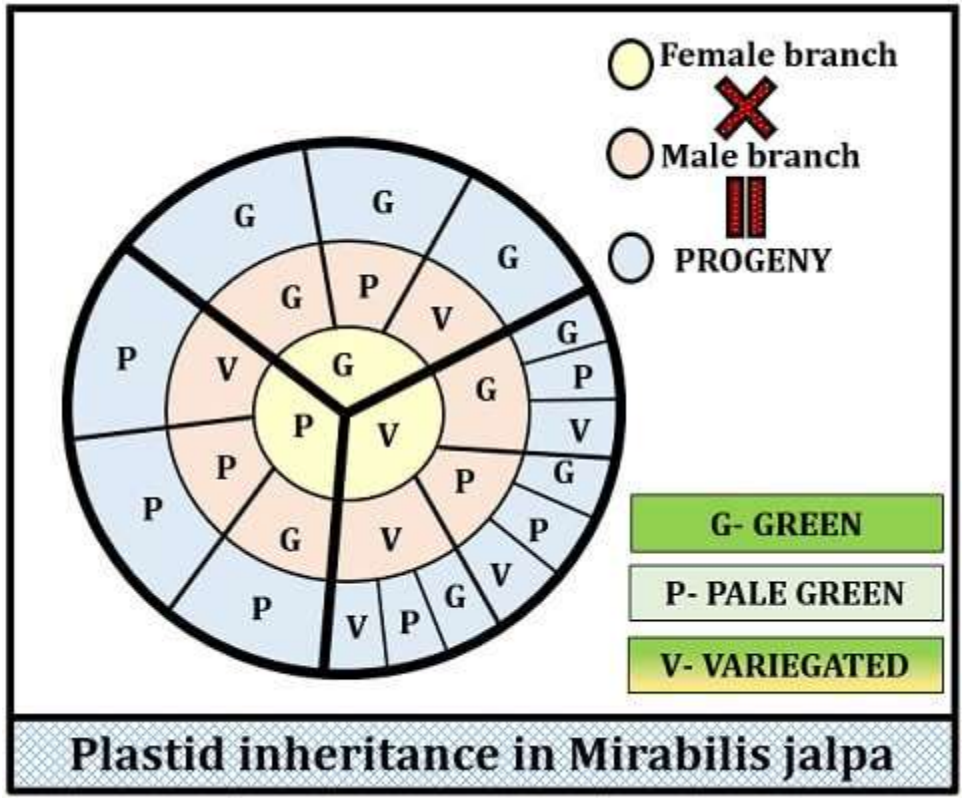
Leaf phenotype of branch used as male plant	Leaf phenotype of branch used as female plant	Leaf phenotype of the progeny (F_1)
Green	Green	Green
	White or yellow	White or Colourless
	Variegated	Green, White or Colourless, Variegated
White or Colourless	Green	Green
	White or Colourless	White or Colourless
	Variegated	Green, White or Colourless, Variegated
Variegated	Green	Green
	White or Colourless	White or Colourless
	Variegated	Green, White or Colourless, Variegated

3 Experiments of Correns on Mirabilis jalapa



From various crosses of leaf phenotypes of *Mirabilis jalapa*, clearly indicates that leaf phenotype of the progeny is the same as that of the female parent. The phenotype of male parent did not contribute anything to the progeny.

Plastid inheritance in ***Mirabilis jalapa***



Correns observations

- The color of the egg cell-donating branch (female parent) determined the color of the offspring.
- Female parent branches that were pure green or pure white produced only pure green or pure white offspring, respectively.
- Female parent branches that were variegated could produce all three types of offspring, but not in any predictable ratios.

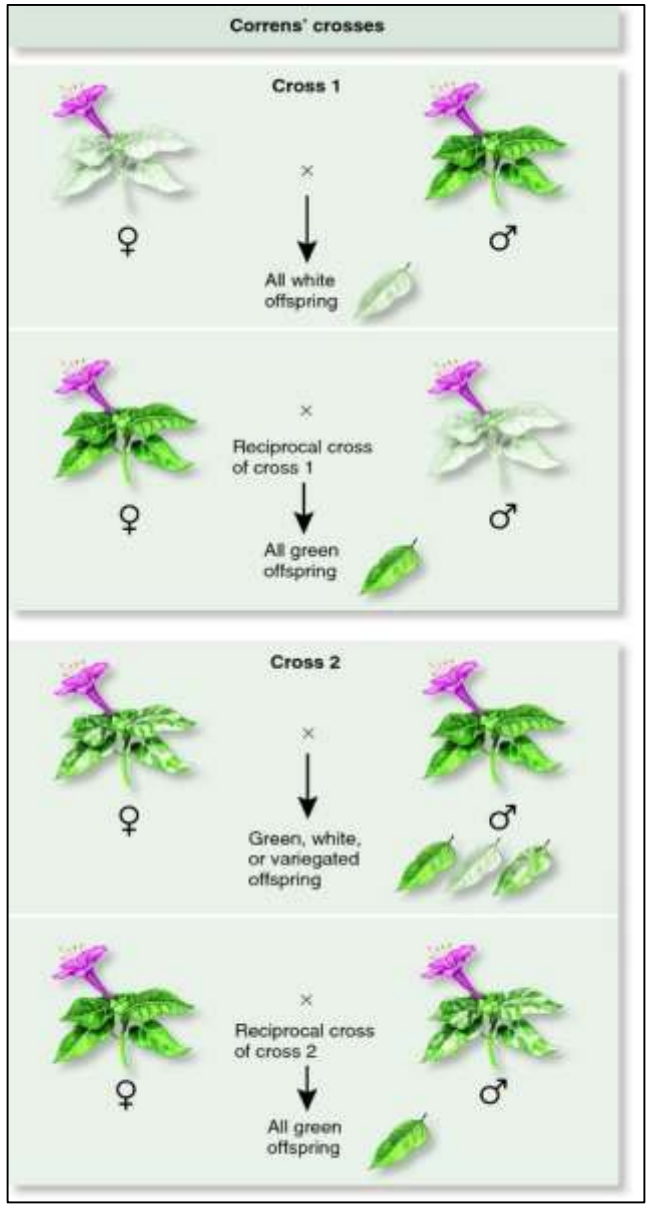
Correns speculations

- Correns speculated that some factor in the cytoplasm of the egg cell must determine the color of the offspring.
- The leaf colour inheritance is totally through the non-nuclear cytoplasmic genes, located in the plastids of egg cell of female parental plant
- According to Correns the leaf colour inheritance in the experimental crosses in mirabilis jalapa is a non-Mendelian maternal inheritance.

Correns Conclusions

- 1. In *Mirabilis jalapa* maternal inheritance is governed by chloroplast which are originated from proplastids.
- 2. If proplastid is normal , they develop normal chloroplasts. And if proplastids are mutants they will produce white chloroplasts.
- 3. It reveals that green leaf branches have green chloroplasts white branches will have mutant non chlorophyllous plastids and variegated branches have a mixture of both green and whit chloroplasts.
- 4. Female parent is the main contributor of cytoplasm to the zygote and through this cytoplasmic plastids are also transferred to the zygote from female parental plant. Hence phenotype of F1 progeny is after female parent reflecting maternal inheritance.

Thank You


Correns' crosses
Cross 1
All white offspring
Reciprocal cross of cross 1
All green offspring
Cross 2
Green, white, or variegated offspring
Reciprocal cross of cross 2
All green offspring

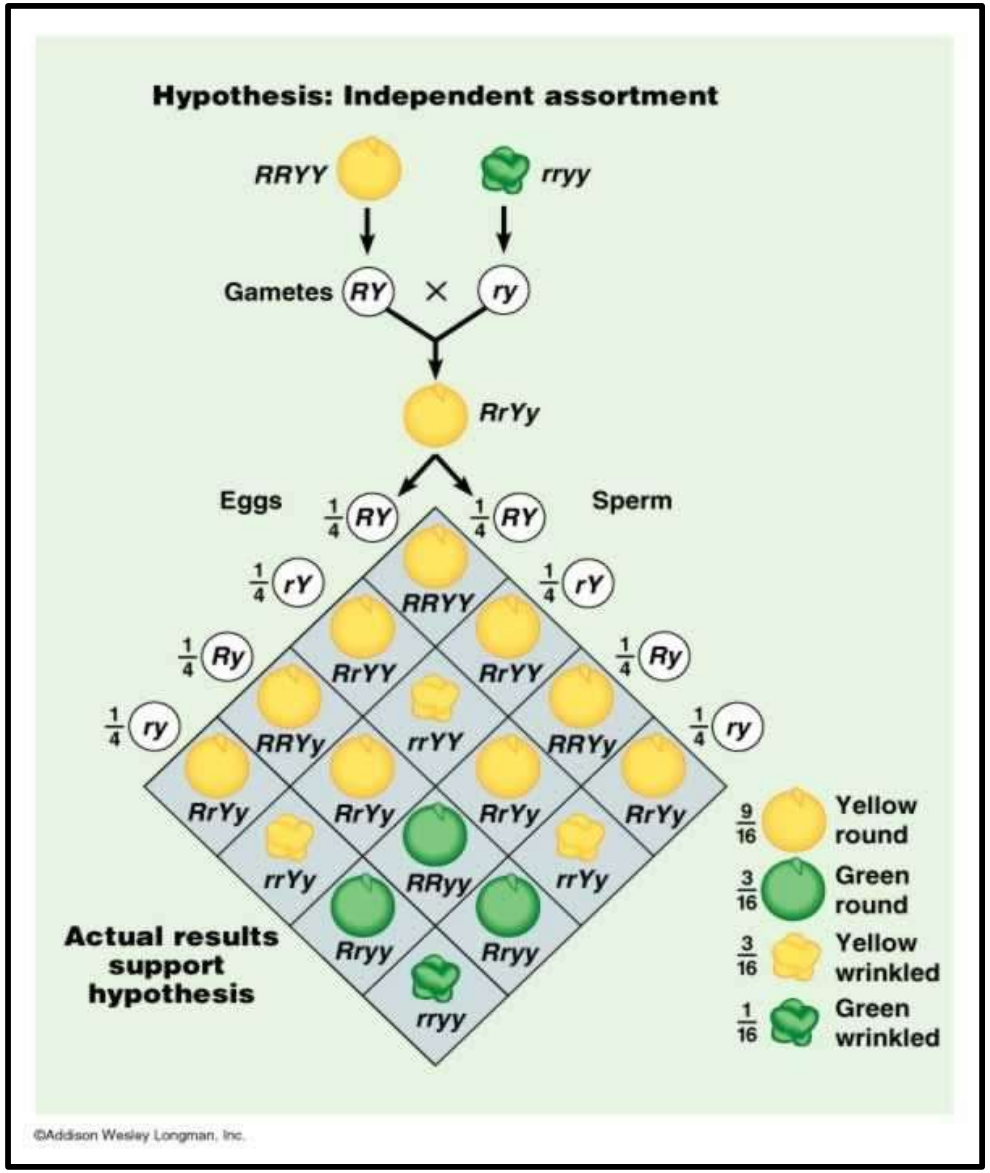
Second UG – Botany

Fourth Semester

Paper V

Cell Biology, Genetics and Plant Breeding

Genetics


Hypothesis: Independent assortment
RRYY
rryy
Gametes RY × ry
RrYy
Eggs
Sperm
¼ RY
¼ rY
¼ Ry
¼ ry
RRYY
RrYY
RRYy
rrYY
RrYy
rrYy
RRyy
Rryy
rryy
Actual results support hypothesis
9/16 Yellow round
3/16 Green round
3/16 Yellow wrinkled
1/16 Green wrinkled
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Unit 3: Mendelian and Non- Mendelian Genetics

Lesson 1

Mendel's Laws of inheritance

Dr. A.Sujatha
Department of Botany
M.V.R Degree College (UG & PG Courses)
Gajuwaka, Visakhapatnam

Monohybrid crosses

- A cross between two parents differing in a single pair of contrasting characters is known as monohybrid cross.

Mendel's Procedure for monohybrid cross

1. Mendel observed one trait at a time. (For example, he crossed tall and dwarf pea plants to study the inheritance of one gene).
2. He hybridized plants with alternate forms of a single trait (monohybrid cross). The seeds produced by this cross were grown to develop into plants of Fillial$_1$ progeny or F_1-generation (F_1-plants).
3. He then self-pollinated the tall F_1 -plants to produce plants of Fillial$_2$ progeny or F2-generation.

Mendel's Observations

(i) In F_1generation, Mendel found that all pea plants were tall and none was dwarf.

(ii) He also observed other pair of traits and found that F_1 always resembled either one of its parents and the traits of other parent were not found in this generation.

(iii) In F_2-generation, he found that some of the offsprings were 'dwarf, i.e., the character which were not seen in F_1-generation was expressed in F_2.

(iv) These contrasting traits (tall/dwarf) did not show any mixing either in F_1 or in F_2-generation.

(v) Similar results were obtained with the other traits that he studied. Only one of the parental traits was expressed in F_1-generation, while at F_2 stage, both the traits were expressed in the ratio of 3:1. (Fig.).

(vi). Three fourth of the plants were tall and one fourth were dwarf.

Out of 1064 F2 plants, 787 were tall and 277 were dwarf.

So, a ratio of 3; 1 can be noticed.

It means, F_2 generations consist of three types of plants:

i). Tall homozygous (pure) – 25%(TT).

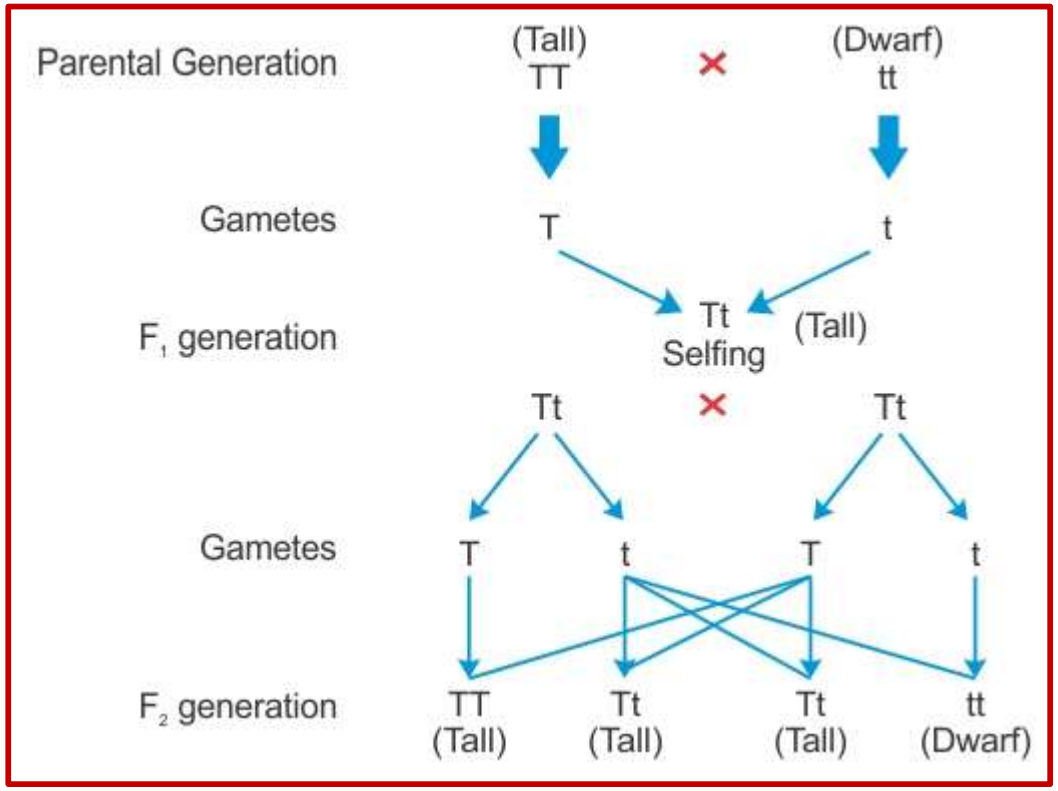
ii). Tall heterozygous (hybrid) – 50% (TT).

iii). Dwarf homozygous (pure) – 25% (tt).

From this observations Mendel concluded that F_2 ratio is more accurately considered as 1:2:1 and not 3:1.

This ratio is known as monohybrid genotypic ratio.

Mendel cross can be schematically represented as follows:



Results obtained from monohybrid crosses for the remaining six characters were identical with those for plant height

Mendel's Inferences

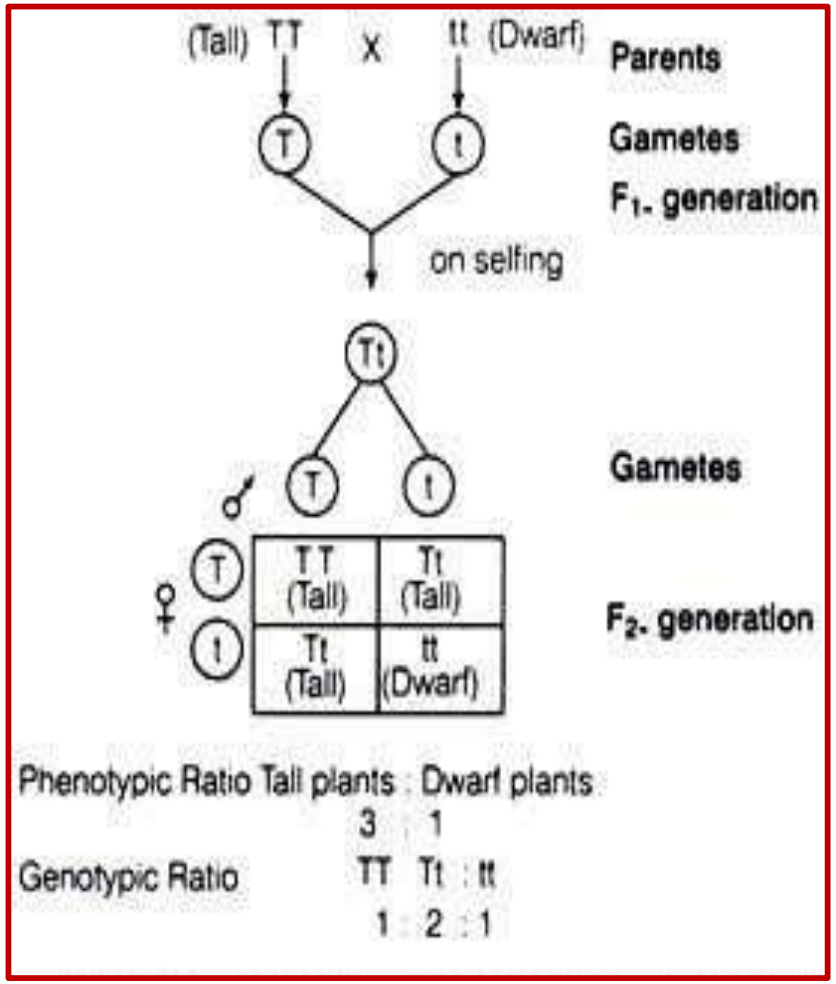
- Following inferences were made by Mendel based on his observations:
  - He proposed that some factors pass down from parent to offsprings through the gametes. Now-a-days these factors are known as genes: (a) Genes are hence, the units of inheritance. (b) Genes which code for a pair of contrasting traits are known as alleles, i.e., they are slightly different forms of the same gene.
  - Genes occur in pairs in which, one dominates the other called dominant factor and expresses itself, while the other remains hidden and is recessive. Such pairs of contrasting traits are called allelomorphs and the genes controlling them are called allels (T or t).
  - Allele can be similar in case of homozygote TT or tt and dissimilar in case of heterozygote Tt.
  - In a true-breeding tall or dwarf pea variety, the allelic pair of genes for height are identical or homozygous.
  - TT and tt are called genotype of the plant, while the term tall and dwarf are the phenotype.
  - When the tall and the dwarf plant produce gametes by the process of meiosis, the alleles of the parental pair segregate and only one of the allele gets transmitted to a gamete.
  - Thus, there is only a 50% chance of a gamete containing either allele, as the segregation is a random process.
  - During fertilization, the two alleles, T from one parent and t from other parent are united to produce zygote, that has one T and one t allele or the hybrids have Tt.
  - Since, these hybrids contain alleles which express contrasting traits, the plants are heterozygous.

Summary of F2 data obtained by Mendel for different monohybrid crosses in peas

Character	Dominant character	No. obtained	Recessive character	No. obtained	Total plants	Phenotypic percentage and ratio
1.Form of seed	Round	5474	Wrinkled	1850	7324	74.75:25.25 2.96:1
2.Colour of cotyledon	Yellow	6022	Green	2001	8023	75.00:25.00 3.00:1
3.Colour of seed coat	Coloured	705	white	224	929	76.00:24.00 3.15:1
4.Form of pod	Simply	882	Constricted	299	1181	74.75:25.25 2.95:1
5.Color of the pod	Green	428	yellow	152	580	73.75:26.25 2.82:1
6. Position of flower	Axial	651	Terminal	207	858	75.75:24.25 3.41:1
7.Height of plant	Tall	787	Dwarf	277	1064	74.00:26.00 2.84:1
Total		14949		5010	19959	75.00:25.00 3.00:1

Punnett Square

1. The four boxes or squares given to indicate progeny in the F2 generation are known as Punnett square (more popularly known as checker board) after Reginald C. Punnett who first developed this approach.
2. All possible combinations or unions of the different male and female gametes during fertilization are represented by this Punnett square.
3. The genotypes and phenotypes of all potential offspring can be known by reading the entries in the boxes.
4. F2 generation phenotypic ratio = 3;1 (3 tall : 1 dwarf)
5. F2 generation genotypic ratio = 1:2:1 (1 TT : 2 Tt : 1 tt)



Law of segregation

- Based on the results obtained from the monohybrid cross, Mendel postulated the first law, the" **Law of segregation or Law of purity of gametes** '.
- It states that the two alleles of a gene when present together in a heterozygous state, do not fuse or blend in any way, but remain distinct and segregate during meiosis or in the formation of gametes so that each meiotic product or gamete will carry only one of them.
- Segregation of genes is a universal phenomenon in all organisms reproducing by normal sexual method.

Dihybrid crosses

- A cross between 2 parents differing in two pairs of contrasting characters is known as dihybrid cross.
- The progeny of such cross are called dihybrids.

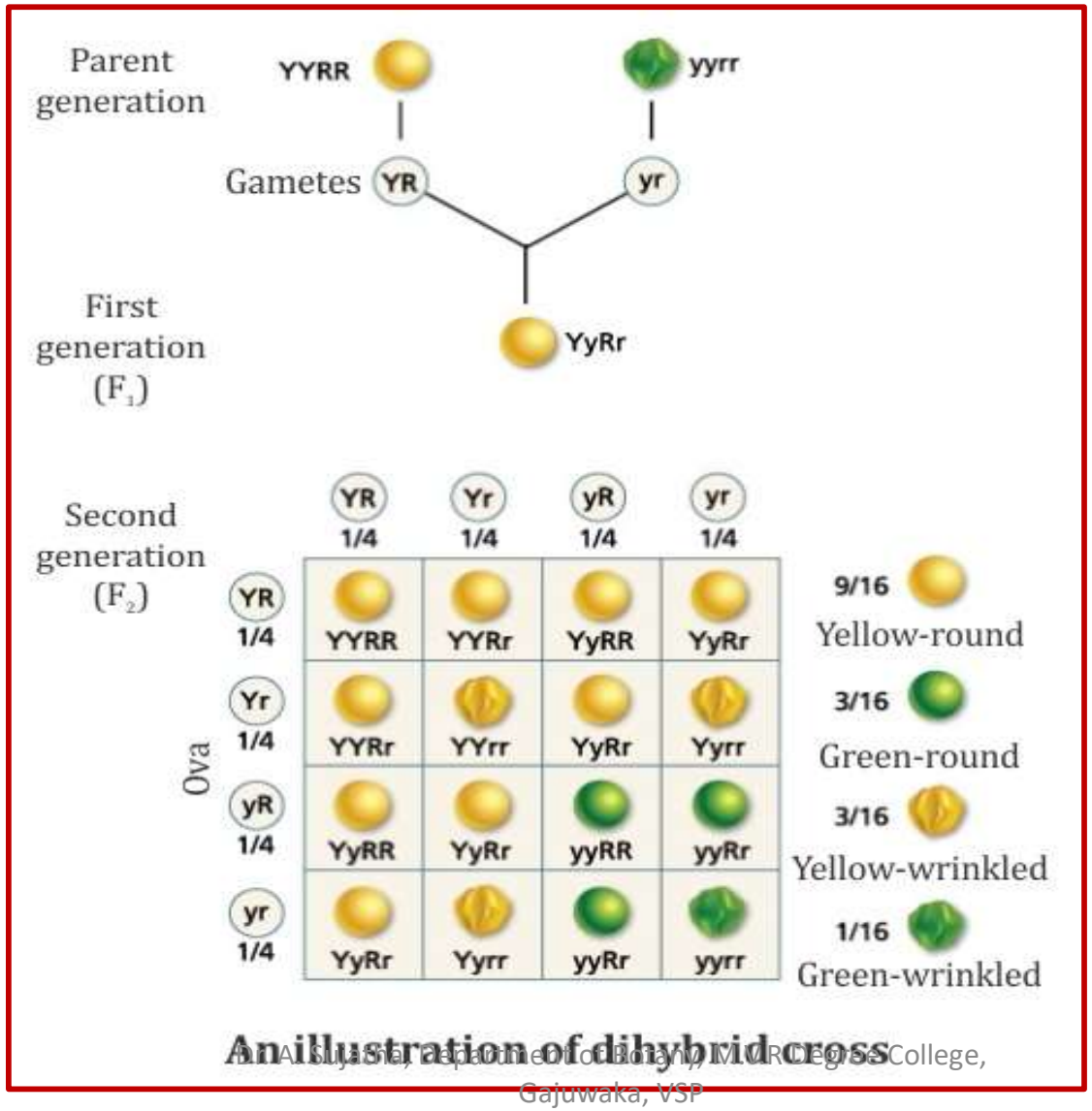
Mendel's Procedure

- In another experiment Mendel crossed a homozygous pea plant having yellow round seeds (YYRR) with a homozygous pea plant having green wrinkled seeds (yyrr). All the F1 hybrids were found to have yellow round seeds. Such a cross involving two parental plants differing in two characters is called a dihybrid cross.
- When F1 hybrids were allowed to undergo self pollination, the F2 generation progeny was showing four kinds of phenotypes in a definite pattern.

Mendel's Observations

- From a total of 556 seed obtained, 315 were yellow and round, 101 were yellow and wrinkled, 108 were green and round, 32 were green and wrinkled.
- These results were found to fit very nearly a phenotypic ratio of 9:3:3:1, nine plants with round, yellow seeds, three plants with round, green seeds, three plants with wrinkled, yellow seeds and one plant with wrinkled, green seeds. This ratio is called Di-hybrid ratio .
- From his experiment, Mendel observed that the pairs of traits in the parental generation sorted independently from one another, from one generation to the next.
- The genotypic ratio of 1:2:2:4:1:2:1:2:1. When second generation progeny is raised from the first generation, the genes combine independently irrespective of their association.
- The F2 progeny showed not only the parental combination i.e. yellow round and green wrinkled phenotypes, but also the new combination i.e. yellow wrinkled and green round phenotypes.
- These new combinations are produced due to genetic recombination among the factors by independent assortment.
- This recombination is called Mendelian Recombination.

The results of dihybrid cross can be shown graphically as follows:



An illustration of dihybrid cross

Mendel's Inferences

From the results of dihybrid experiment Mendel concluded the following points:

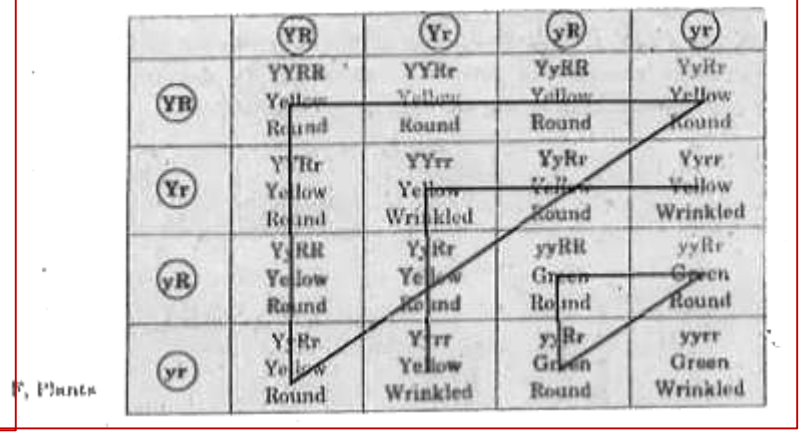
- 1. The members of two sets of alleles segregated in F_2 generation.
- 2. The alleles of one set behaved independently with respect to those of the other set at the time of combination, i.e., they are independently assorted, as for example, round character appeared in combination with green and wrinkled appeared with yellow in the above cross.
- The above two points are read in Mendel's second principle called **Law of Independent Assortment.**

Law of independent assortment

Now the mode of inheritance in the dihybrid cross can be explained in the following way.

After fertilization, the possible combinations will be 4 x 4 = 16. Mendel represented round character of seed by R and wrinkled by r.

Similarly, he represented the yellow character by Y and green by y.



F, Plants	YR	Yr	yR	yr
YR	YYRR Yellow Round	YYRr Yellow Round	YyRR Yellow Round	YyRr Yellow Round
Yr	YYRr Yellow Round	YYrr Yellow Wrinkled	YyRr Yellow Round	Yyrr Yellow Wrinkled
yR	YyRR Yellow Round	YyRr Yellow Round	yyRR Green Round	yyRr Green Round
yr	YyRr Yellow Round	Yyrr Yellow Wrinkled	yyRr Green Round	yyrr Green Wrinkled

Law of Independent Assortment or the Law of freedom Recombination:

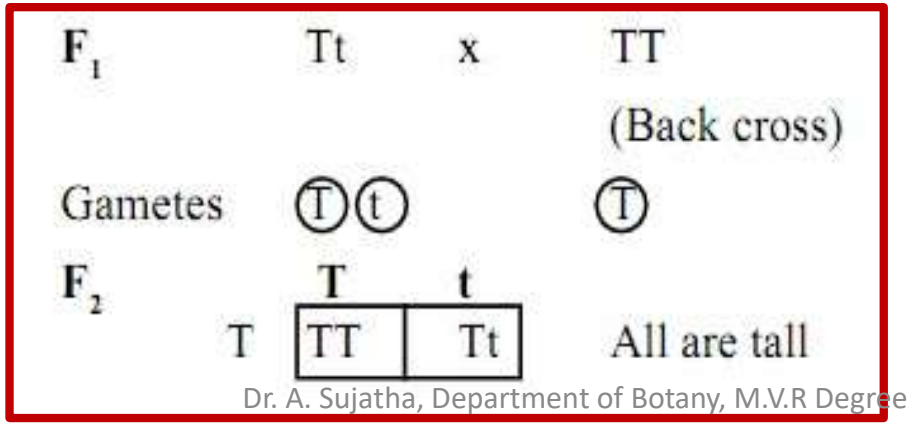
- Based on the results of the dihybrid crosses in pea plant, Mendel postulated his second law known as the " Law of independent assortment" which states that " when plants differ from each other in two or more pairs of contrasting characters or factors, then the inheritance of one pair of factors is independent to that of the other pair of factors.

Trihybrid cross

- In a trihybrid cross the parents differ through three characters. Mendel crossed homozygous tall, round and yellow (TT RRYY) with dwarf, wrinkled and green (ttrryy). All the F_1 plants were tall round and yellow (TtRrYy).
- **On self fertilization these hybrid plants produced:**
- (i) 27 tall, round and yellow
- (ii) 9 tall, round and green
- (iii) 9 tall, wrinkled, yellow
- (iv) 9 dwarf, round, yellow
- (v) 3 tall, wrinkled, green
- (vi) 3 dwarf, round, yellow
- (viii) 3 dwarf, wrinkled, yellow
- (viii) 1 dwarf, wrinkled, green.

Back cross

- When the F_1 individuals are crossed with any one of its parents or organisms that are phenotypically and genotypically similar to the parents, it is called Back cross.
- If the F_1 hybrid is crossed with the parent having dominant traits no recessive individual are obtained in the progeny.



Test Cross : Monohybrid test cross

When the F1 individuals are crossed with the recessive parent or organism similar in phenotype and genotype to the recessive parent, it is called test cross. It is used to test whether an individual is homozygous (pure) or heterozygous (hybrid). A monohybrid test cross gives a phenotypic ratio 1: 1

Tall
Tt

Dwarf
tt

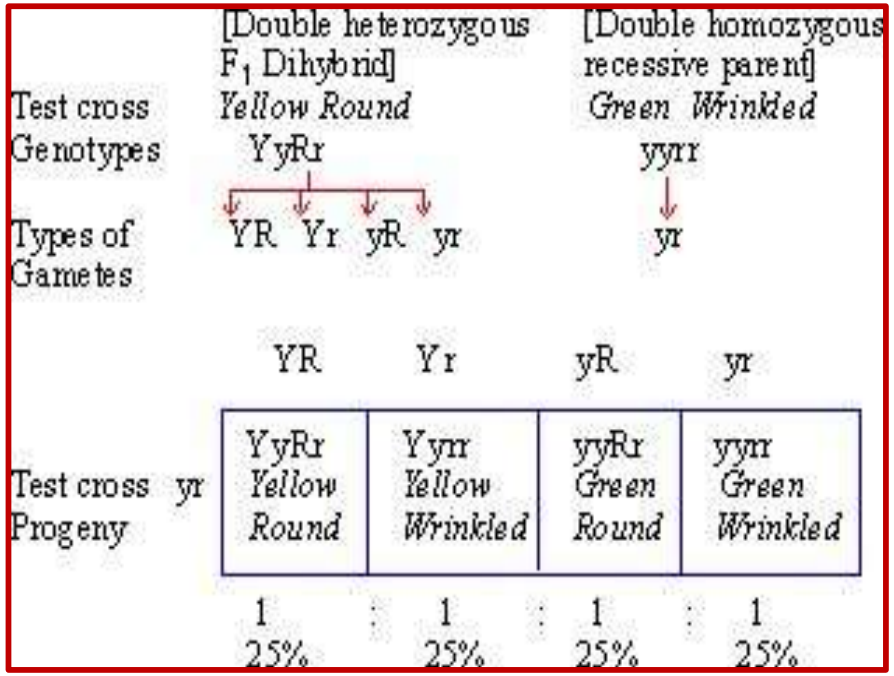
	t	t
T	Tt Tall	Tt Tall
t	tt Dwarf	tt Dwarf

Tall (Tt) - 50% dominant **Dwarf - (tt) - 50% recessive**

Phenotypic ratio - 2 tall : 2 dwarf - 1:1
Genotypic ration - 2Tt :2tt - 1:1

Test Cross: Dihybrid test cross

A dihybrid test cross gives a ratio of 1:1:1:1




Thank you…

Second UG – Botany

Fourth Semester

Paper V

Cell Biology, Genetics and Plant Breeding

Unit 3: Mendelian and Non- Mendelian Genetics

Lesson 4

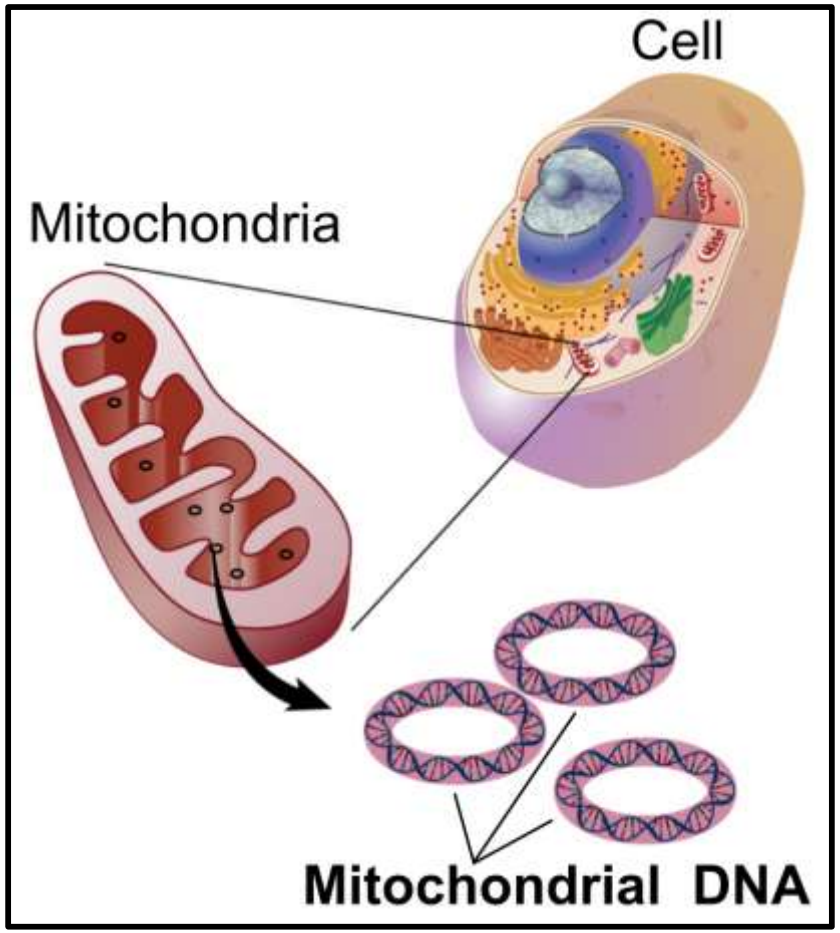
MITOCHONDRIAL DNA

Dr. A.Sujatha
Department of Botany
M.V.R Degree College (UG & PG Courses)
Gajuwaka, Visakhapatnam

Introduction

1. In eukaryotes the nucleus is the primary organelle for storing the genetic information of the cell.
2. However, certain organelles of the cell other than nucleus also contain their own genome.
3. These organelles are mitochondria and chloroplasts present in the cytoplasm.
4. They play an important role in cytoplasmic inheritance of characters.
5. The genes located in the chromosomes are called nuclear genes oe simply genes.
6. All other types of genes found outside the nucleus are reffered to as the **extra nuclear genome.**

Mitochondrial DNA (mt DNA)



Mitochondrial DNA (mt DNA)

1. Mitochondria are structures within cells that convert the energy from food into a form that cells can use.
2. They are called as power house since they produce ATP energy.
3. They are dispersed in cytosol.
4. With in the mitochondrial matrix small ribosomes and circular DNA molecules are present.
5. The mitochondrial DNA is represented as mt DNA.
6. It was discovered in 1960. The complete nucleotide sequences of mt DNA have now been determined.

Mitochondrial DNA (mt DNA)

7. mt DNA is a circular molecule and varies from n 16.5 kb (mammals) to 100kb or more (higher plants) in length.

8. The G+C content of mt DNA shows considerable variations from one species to another ie 18% in yeast to 47% in higher plants.

9. The mt DNA encodes all the RNA copies and some proteins needed for mitochondrial function.

10. The genes are transcribed and translated within the mitochondria.

11. But several proteins are contributed by nuclear DNA

Yeast mitochondrial Genome

- 1. Mitochondrial genome of yeast and several other fungi is about 78kb long.
- 2. It has both split and uninterrupted genes.
- 3. Mt DNA encodes for two ribosomal RNA molecules, complete range of t RNA molecules and m RNA for the synthesis of nine proteins.
- 4. the genes for two Rrna molecules are situated on separate portions of the genome.
- 5. Mitochondria alone cannot carry out all its genetic activity and other functions.
- 6. Most of its key function are controlled by nucleus DNA.
- 7. Most of its key function are controlled by nuclear DNA.
- 8. The polymerase for the synthesis of mitochondria DNA and RNA and nearly all the mitochondrial ribosomal proteins are encoded by nuclear genes and synthesised in cytoplasmic region.
- 9. Genes for the synthesis of enzymes for Kreb's cycle and electron transport chain are encoded by nuclear genes.
- 10. All these proteins are made in the cytoplasm and are transported later.
- 11. The mt DNA encoded for 24 t RNA's.
- 12. These genes have organised in operon fashion.
- 13. The genetic code for mitochondria from that of the nucleus in several respects.

Thank You