ORIGIN, ULTRASTRUCTURE & FUNCTIONS OF PLASTIDS

MBOTCC-10
Unit-I

M.Sc. Sem-III
(2018-20)

Introduction:

Plastids constitute a family of cytoplasmic organelles exclusively found in plant cells. One or other of the various kinds of plastid are present in all plant cells except fungi.

The family includes chloroplasts, chromoplasts, amyloplasts and etioplasts.

Schimper (1883) first used the term "plastid" for special cytoplasmic organelles present in eukaryotic plant cells.

Origin of Plastids:

(i) Proplastids are the tiny precursors of all kinds of plastids which are abundant in meristematic cells.

(ii) Population of plastids growing and dividing within the cells of a plant is similar to a population of symbiotic, unicellular microorganisms multiplying in host cells.

(iii) Mereschkowski (1905) suggested that chloroplasts in algae and higher plants evolved from symbiotic blue-green algae (Cyanobacteria).
— Ris and Plaut (1962) revived the above suggestion.

(iv) It is a plausible and attractive hypothesis as there are many similarities between blue-green algae and chloroplasts.
— Thylakoids of blue-green

...Contd. p. 2

algae lie free in the cytoplasm of the cell as they do in the stroma of the chloroplast. — Moreover, they are single and are covered with phycobilisomes as are those of the red algae.

— Blue-green algae carry out an O_2- evolving photosynthesis using essentially the same electron transport and CO_2- fixation pathways as do chloroplasts.

— Ribosomes of blue-green algae are of the same size (70S) as those of chloroplasts.

— The most compelling evidence in favour of the theory lies in the homologies between the primary sequences of certain proteins and nucleic acids in chloroplasts and the corresponding molecules in blue-green algae.

Common Forms of Plastids:

(i) Chloroplasts are the most common plastids which house the photosynthetic apparatus and are usually green.

(ii) Chromoplasts are pigmented yellow to red by carotenoids, but do not photosynthesize.

(iii) Amyloplasts are not pigmented and are specialized for the synthesis and storage of starch grains.

(iv) Etioplasts are normally a transitory stage, and are formed when the development of proplastids into chloroplasts is interrupted by lack of light.

... Contd. p. 3

(v) Leucoplasts refer to all the non-pigmented plastids.

PROPLASTIDS:

(i) They are small, colourless or pale-green, undifferentiated plastids occurring in the meristematic cells of the shoot and the root.

(ii) Roughly ellipsoid or spherical structures; diameter: 1–1.5µm

(iii) They have little internal structure

(iv) Inner membrane of the bounding envelope occasionally extends into the homogenous matrix in the form of invaginations.

(v) There may also be one or two isolated vesicles and thylakoids

(vi) Small starch grains may be present in the proplastids of the root meristem.

(vii) Present to the extent of 7-20% cells in the shoot meristem and 20-40% cells in the root meristem.

CHLOROPLASTS:

(i) In higher plants, chloroplasts are found mainly in the palisade and spongy mesophyll cells of the leaf.

(ii) They are also present in the guard cells of the stomatal apparatus.

(iii) Chloroplasts are found in the cells of all other green tissues.

(iv) Number of chloroplasts per cell varies with the plant species and cell types. 300-400 and 200-300 chloroplasts per cell in the palisade and

... contd. p.4

mesophyll cells of spinach leaf.

(v) All chloroplasts contain the pigment chlorophyll.

~~Internal structure of chloroplast~~

Shape, Size & Number of Chloroplasts

(i) Shape and size of the chloroplast vary in different cells within a species.

– Shape: spheroid, ovoid or discoid; frequently vesicular, with colourless centres; they have deposits of starch granules.

(ii) Average diameter in higher plants: 4 – 6 µm; constant for a given cell type.

(iii) Chloroplasts in polyploid cells are larger than those in the corresponding diploid cells.

(iv) Generally, chloroplasts of plants grown in the shade are larger and contain more chlorophyll than those of plants grown in sunlight.

(v) Number of chloroplasts is relatively constant in different plants.

– In higher plants, there are usually 20 – 40 chloroplasts per cell.

– Leaf of Ricinus communis contains about 400,000 chloroplasts per mm² surface area.

– Number of chloroplasts is increased by division, and reduced by degeneration as per requirement of the cell.

(vi) Changes in shape and volume may be caused by light.

Chloroplast Structure:

(i) Light microscopic studies have shown that chloroplasts are made up of

...Contd. p.5

small granules called grana, which are embedded within a matrix or stroma

(ii) Size of grana: 0.3–1.7 μm

(iii) EM has revealed the true structure of chloroplast, with its three main components: the envelope, the stroma, and the thylakoids.

(iv) Envelope is made up of a double limiting membrane across which molecular interchange with the cytosol occurs. (v) Inner membrane of mature chloroplast is not in continuity with the thylakoids.

(vi) Stroma fills most of the volume of the chloroplasts and is a kind of gel-fluid phase that surrounds the thylakoids

— Stroma contains about 50% of chloroplast proteins, and most of these are soluble. CO_2 fixation occurs here.

— It has ribosomes (70S) and DNA also, both of which are involved in the synthesis of some of the structural proteins of the chloroplast.

— synthesis of sugars, starch, fatty acids, and some proteins occurs in the stroma.

(vii) Thylakoids consist of flattened vesicles arranged as a membranous network. — Outer surface of the thylakoid is in contact with the stroma, and its inner surface encloses an intra-thylakoid space.

— Thylakoids may be stacked like a pile of coins, forming the grana, or they may be unstacked (stroma thylakoids) forming a system of

... Contd. p. 6

anastomosing tubules that are joined to the granal thylakoids.

— Number of thylakoids per granum may vary from a few to 50 or more.

— Thylakoids contain about 50% of the protein and all other components involved in the essential steps of photosynthesis.

Molecular Organization of Thylakoids

(i) Lipids represent about 50% of the thylakoid membrane.

(ii) Chlorophylls, carotenoids, and plastoquinones are directly involved in photosynthesis.

— Structural lipids, such as glycolipids, sulpholipids, and few phospholipids are also present.

(iii) In higher plants, there are two types of chlorophyll — a and b.

— Small amounts of pigments absorbing light at a wavelengths of 700 nm and 680 nm respectively are also present which are represented as P700 and P680. ~~respectively~~

— Carotenoids are masked by the green chlorophyll.

— Amount of chlorophyll decreases in autumn and other pigments, viz., carotenes and xanthophylls become apparent.

(iv) Protein components of the thylakoid membrane are represented by 30-50 polypeptides disposed as the following five major supramolecular complexes:

(a) PS I — Reactive centre P700 + β-carotene + several polypeptides

— lower Chl a/b ratio

(b) PS II — Reaction centre P680 with two intrinsic proteins + β-carotene

... Contd. p.7

- High chl a/b ratio
- Acts as light trap in photosynthesis

(c) Cytochrome b/f — contains one cytochrome f + two cytochromes of b563 + one FeS Centre + a polypeptide
- Uniformly distributed in the grana.

(d) ATP-synthetase — CF_0 hydrophobic portion + a proteolipid that makes a proton channel + CF_1 or Coupling factor which synthesizes ATP from ADP and Pi, using the proton gradient provided by the electron transport

(e) Light-Harvesting Complex (LHC) — Two main polypeptides + Chl. a & b
- Main function is to capture solar energy

Mainly localized in the stacked thylakoids and lacks photochemical activity.

Detailed information about the macromolecular organization of the thylakoid membrane has been obtained by using freeze-fracturing technique.

CHROMOPLASTS:

(i) They are carotenoid-containing plastids which impart orange, yellow or red colours to many fruits, flower petals and some roots (eg. carrot).

(ii) They usually develop from chloroplasts, and so have the same shape and size as chloroplasts.
- Most structural features are of the chloroplast. However, photosynthetic membrane system has been replaced by structures rich in carotenoids.
- Five different types of Chromo

...Contd. p.8

plasts have been recognized on the basis of their internal structure. They are:

(a) Globular type – Simplest type possessing only homogenous plastoglobuli containing carotenoids – Found in most flower petals.

(b) Membranous type – It has up to 25 sets of concentric membranes which contain carotenoids – Found in daffodil petals.

(c) Tubulous type – It possesses many fibres which are supposed to contain caroteno-protein complexes – Found in the fruit of Capsicum annuum.

(d) Reticulo-tubular type – It contains a ramifying network of branched, non-parallel tubules. – Found in the spadix of Typhonium divaricatum.

(e) Crystalline type – Contains carotenoid in the form of crystals. – β-carotene and lycopene are commonly present. e.g., Tomato fruits

(iii) No physiological function is known for chromoplasts.

AMYLOPLASTS:

(i) Mature plastids almost completely filled with starch grains.

(ii) Found in storage tissues such as cotyledons or endosperm of seeds and tubers.

(iii) Also found in the root cap cells

(iv) Starch grains are embedded in the stroma which also contains DNA and a few ribosomes.

(v) Function of amyloplasts in storage tissues is to synthesize starch from imported sucrose produced in the photosynthetic tissues.

... Contd. p. 9

ETIOPLASTS :

(i) Formed naturally in the primary leaves or cotyledons of germinating seedlings before they emerge from the soil into the light.

— Also found in differentiating meristems at the base of leaves in Poaceae members where the coleoptile or the older leaves cut out most of the light.

(ii) Nomenclature indicates a plastid characteristic of an etiolated leaf (a leaf of a plant grown in the dark).

(iii) Shape — Irregularly ellipsoidal with a long diameter of about 3 µm.

(iv) Double-membrane envelope contains a proteinaceous stroma in which are embedded 1–4 prolamellar bodies.

(v) These are large quasicrystalline structures composed of interconnected membranous tubules called prolamellar bodies.

(vi) When etiolated leaves are exposed to light, etioplasts are rapidly converted into chloroplasts, and prolamellar bodies are transformed into the thylakoid membrane system.

INTERCONVERSION OF PLASTIDS :

(i) Chloroplasts, etioplasts, chromoplasts and amyloplasts can all develop directly from proplastids.

(ii) Etioplasts develop into chloroplasts in the light.

— Amyloplasts are commonly formed as intermediate stages in the development of etioplasts and chloroplasts.

(iii) Chromoplasts can be formed from chloroplasts or even the vice versa.

...Contd. p.10

DIVISION OF PLASTIDS:

(i) In meristems, division of proplastids matches cell division, but this is not seen elsewhere.

(ii) Many extrinsic and intrinsic factors influence the division of plastids.

(iii) Division of proplastids and chloroplasts is well known, but little is known about the division of other plastid types.

—— X ——

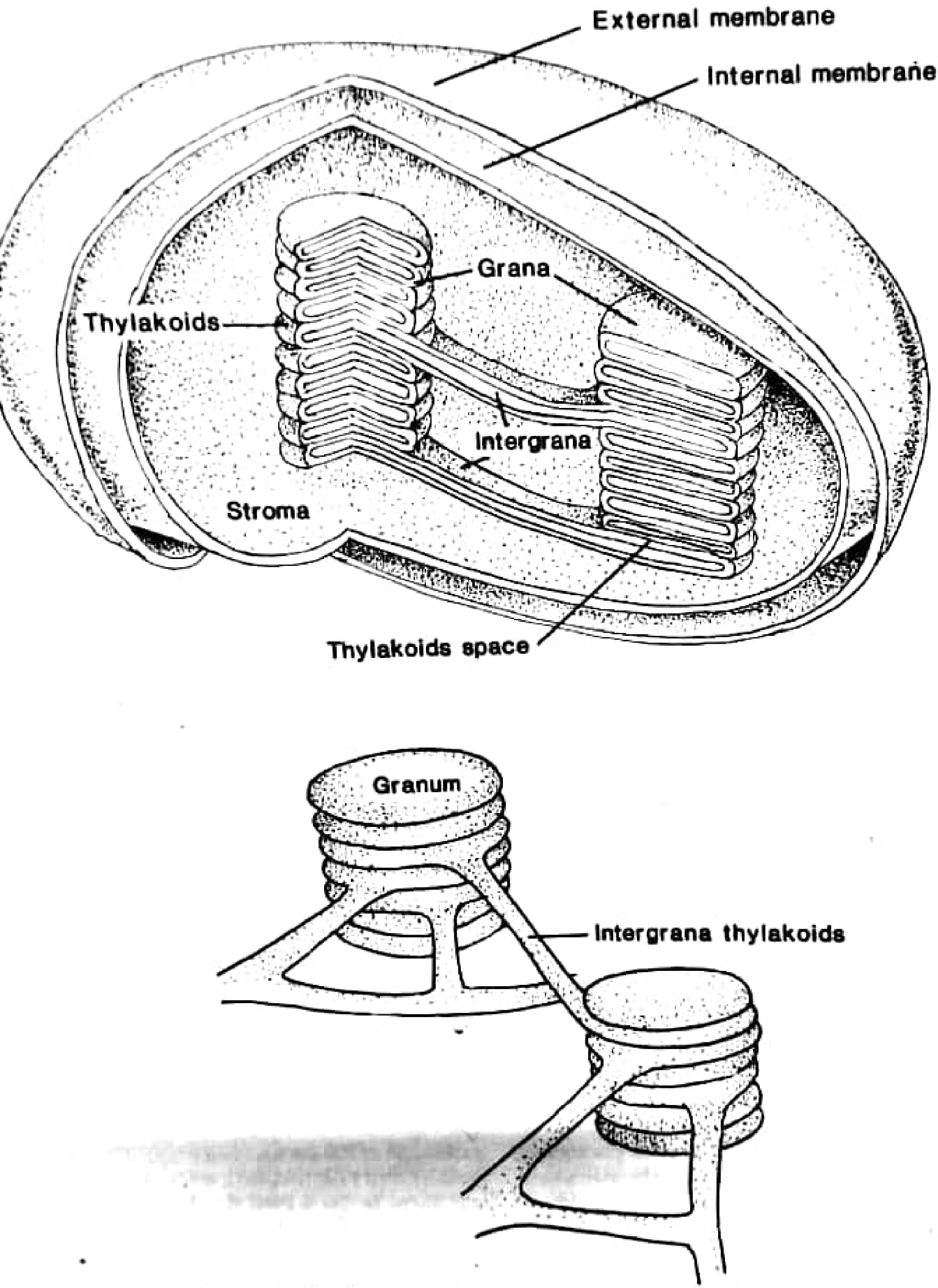

Fig. 12–6. *Top,* diagram of a chloroplast showing the main structural components. *Bottom,* three-dimensional diagram of two grana with the stacked thylakoids and the unstacked ones that cross through the stroma of the chloroplast.