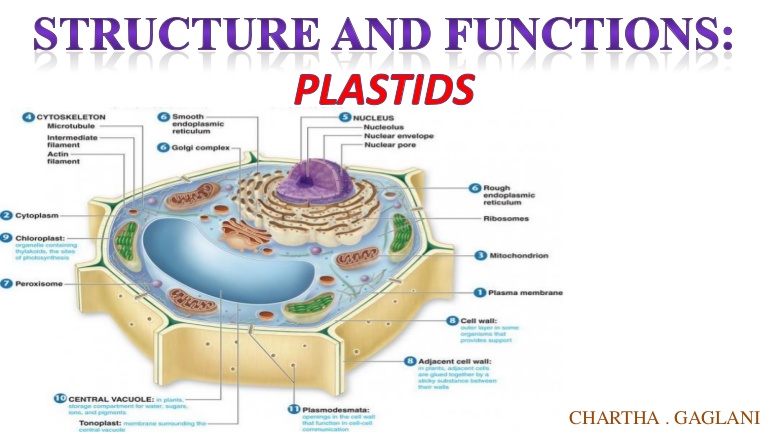
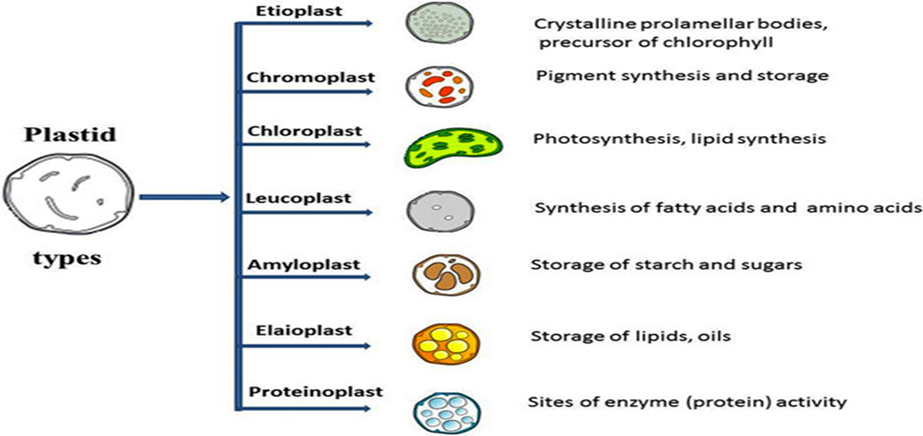
**Topic: PLASTIDS**

**“Plastids are semi-autonomous organelles found, in one form or another, in practically all plant and algal cells, several taxa of marine molluscs and at least one phylum of parasitic protists. The members of the plastid family play pivotal roles in photosynthesis, amino acid and lipid synthesis, starch and oil storage, fruit and flower colouration, gravity sensing, stomatal functioning, and environmental perception.”**

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* Plastids were discovered and named by Ernst Haeckel, but A. F. W. Schimper was the first to provide a clear definition. They are necessary for essential life processes, like photosynthesis and food storage.
* An envelope consisting of two membranes bound each plastid. Internally, the plastid is differentiated into a system of membranes or thylakoids, and a more or less homogeneous matrix, the stroma. The degree of development of the thylakoid system varies among plastid types.
* Plastids arose via an endosymbiotic event in which a protoeukaryotic cell engulfed and retained a photosynthetic bacterium.
* This polyphyletic event occurred multiple times between roughly 1.5 to 1.6 billion years ago.
* Although most of the algal genes were transferred to the nuclear genome, plastids have retained complete protein-synthesizing machinery and enough information to code for about 100 of their approximately 2,500 proteins; all other plastid proteins are coded for by the nuclear genome and imported from the cytoplasm.

**TYPES OF PLASTIDS**



Plastids divide via fission before cytokinesis and are equally apportioned between the two daughter cells, along with the rest of the cytoplasmic contents.

**These are the following types of Plastids:**

1. **Muroplast (Cynoplast or Cyanelle)**
2. **Rhodoplast**
3. **Proplastid (Eoplast)**
4. **Etioplast**
5. **Leucoplasts**
6. **Amyloplast**
7. **Elaioplast**
8. **Proteinoplast**
9. **Chromoplast**
10. **Gerontoplast**
11. **S-Type and P-Type Plastids in Phloem Sieve Elements**
12. **Kleptoplast**
13. **Apicoplast**
14. **Chloroplasts**
15. **Muroplast (Cynoplast):**

**Muroplasts are the photosynthetic organelles of Glaucocystophyte algae and are the only members ofthe so-called “glaucophyte” lineage of plastids.**

* The name comes from the Latin “mura” meaning “wall” and was coined by Schenk (1994) to highlight a key feature of muroplasts; namely, they are bound by a vestige of a peptidoglycan prokaryotic cell wall.
* “Muroplast” will be used in this re view to recognize this unique feature. Originally called “cyanelles”, the abandonment of that term has been ad vocated because, strictly defined, “cyanelle” should be limited to endosymbiotic cyanobacteria and not applied to a fully evolved cellular organelle, such as the modern-day muroplast.
* The glaucophyte line of chloroplasts is represented by the muroplasts, primitive walled chloroplasts found in the glaucocystophytic algae
* In short, although muroplasts clearly had an endosymbiotic origin and retain manyprimitive fea tures, they have evolved to be totally dependent on the algal host cell and should thus be referred to as muro plasts, not cyanelles.
* “Cyanoplast” is also in common usage, but muroplast is preferred because the former term could also apply to the plastids in any “cyano-” organism such as the red alga Cyanidium, which clearly contains rhodoplasts not cyanoplasts. In practice, however, many au thors continue to use “cyanelle” or “cyanoplast” for historic or other pur poses [To further muddy the nomenclaturic waters, “cyanoplast” (or “antho cyanoplast”) has also been used to describe pigmented, anthocyanin-containing, non-membrane-bound, lipid globules found in the vacuoles of some species such as sweet potato (Nozue et al., 1997). Anthocyanin containing cyanoplasts bear no relationship to the photosynthetic cyanoplasts/cyanelles/muroplasts found in the glaucophytes and with whom they share a name.

1. **Rhodoplast:**

Rhodoplasts are the photosynthetic plastids found in the red algae (Phylum Rhodopyhta) and represent the “red lineage” of plastids.

* Technically, chloroplasts, because they do contain chlorophyll a, rhodoplasts are red to purple, depending on the water depth, which influences the light environment and phy cocyanin or phycoerythrin pigment composition.
* Rhodoplast morphology varies from stellate to cup shaped to ovoid and rhodoplasts may or may not con tain a pyrenoid (Broadwater and Scott, 1994). They are bound by a double membrane and contain unstacked thylakoids studded with phycobilisomes.
* Phycobilisomes are super molecular aggregates of pigmented phycobiliproteins and linker proteins.
* Phycobilisomes funnel the majority of their absorbed light energy to PSII whereas PSI is served by Chl a and zeaxanthin-containing light harvesting complexes.
* The Rhodophyta do not contain chlorophylls b (as is found in the Chlorophyta) or c (as found in the Chromophyte).
* The Rhodophyta Rubisco holoenzyme is the typical “Form 1” type (i.e. it has eight large and eight small subunits, L8S8, as is found in the Chlorophytes) but it differs from the Rubisco of green lineage plastids in that both subunits are encoded by the plastid genome.

1. **Proplastids:**

**All the three types of plastids arise from small, colourless, pale green, undifferentiated plastids called proplastids present in meristematic (dividing cells) of roots and shoots.**

* They are the precursors of more highly differentiated plastids such as chic:roplasts, chromoplasts or amyloplasts (leucoplasts that store starch grains). Initially, the proplastid contains few or no internal membranes.
* As the proplastid differentiates into a chloroplast, flattened vesicles develop from the inner membrane of the plastid envelope and eventually align themselves into grana and stroma thylakoids. The thylakoid system of mature chloroplast appears discontinuous with the envelope.
* Proplastids may also develop into chromoplasts and leucoplasts. The chromoplasts may also be formed from chloroplasts or amyloplasts.
* All proplastids have a similar, simple structure (which is the basis for their common name) but the specificity of the term “proplastid” has not been well defined in the literature. As a consequence, it may encompass several different plastid types with significantly different functions. Thompson and Whatley (1980) referred to proplastids in meristematic tissues as “eoplasts”, but the name has not been widely adopted and the use of “proplastids” persists. For purposes of this review, two types of proplastids will be considered, germinal proplastids (Thompson and Whatley’s “eoplast”) and nodule proplastids.
* Germinal proplastids are found in meristematic and embryonic tissues and cells in tissue culture and they are the developmental precursors to all other plastid types.
* Initially, they were originally thought to be metabolically unimportant and to merely serve as a source for plastid production through fission.
* However, recent studies have indicated they may contribute directly to the metabolism of meristematic tissues. The identification of this key role for proplastids in meristematic tissues suggests they play a larger part in tissue development that was once envisioned.
* Nodule proplastids have a similar appearance in the electron microscope to germinal proplastids, but have been linked to a vital role in the biochemistry of nitrogen fixation. In biological nitrogen fixation, N2 is reduced to ammonia by symbiotic bacteria found in root nodules.
* The resulting ammonia (which is highly toxic and must be removed) is incorporated into glutamine in the cytosol of the nodule cell.

1. **Etioplast:**

Etioplasts are plastids in shoot tissues that have been developmentally arrested during the proplastid to chloroplast transition due to absence of light or to extremely low light conditions.

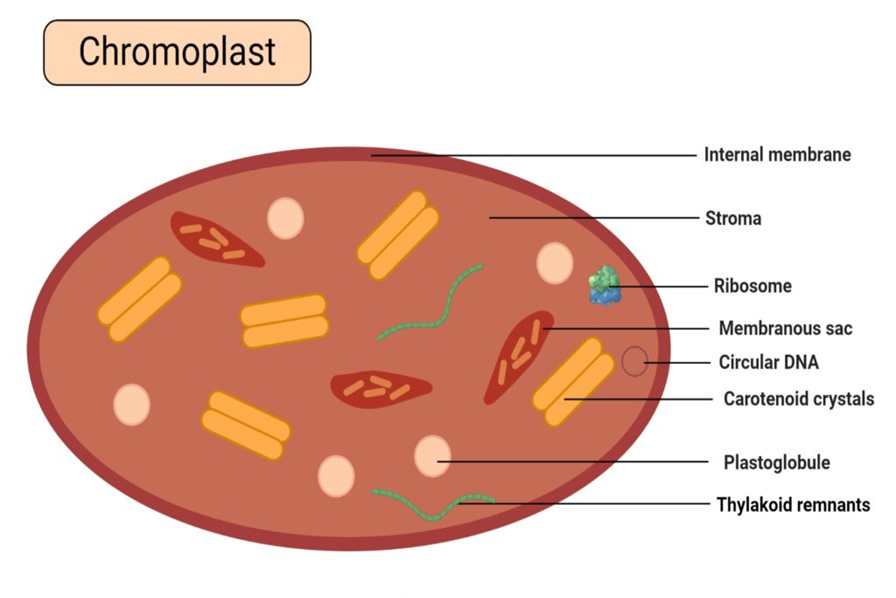
* The term “etiolated” comes from the French etioler ´ (meaning straw) and was coined by Erasmus Darwin in 1791 to describe the white color and straw-like appearance of celery grown in the dark. Kirk and Tilney-Bassett (1967) first applied the etio prefix to etioplasts to distinguish them from their developmental precursors, the undifferentiated germinal proplastids.
* Etioplasts, therefore, are the plastids found in white, light-deprived stem and leaf tissue (but not roots; etioplasts do not form in dark-grown root cells Newcomb, 1967).

1. **Leucoplast:**

* **Leucoplast (sometimes spelled “leukoplast”, e.g. Negm et al., 1995) is the term used to categorize color less, non-pigment-containing plastids; “leuco” mean ing white.**
* There are three generally recognized types; starch storing (amyloplasts), oil and lipid storing (elaio plasts) and protein storing (proteinoplast). The struc ture and function of amyloplasts and elaioplasts are well understood. Proteinoplasts are less well defined.
* Leucoplasts are unpigmented plastids that have neither chiorophyll nor lipid pigments carotenoids). These are least differentiated structurally and lack an elaborate membrane system. The leucoplasts are involved in synthesis of many types of fats and lipids which are transported to other organelles and inserted into their membranes, and proteins. Some leucoplasts known as amyloplasts synthesize starch.
* Leucoplasts are the non-pigmented organelles.
* They are found in the non-photosynthetic parts of the plant, such as the roots.
* Depending on what the plant needs, they may become essentially just storage sheds for starches, lipids, and proteins.
* They are more readily used for synthesizing amino acids and fatty acids.
* A leucoplast may be an **amyloplast** that stores starch, an **elaioplast** that stores fat, or **a proteinoplast** that stores proteins.

1. **Chromoplast:**

**Chromoplasts are units where pigments are stored and synthesized in the plant. These are found in flowering plants, fruits, and aging leaves. The chloroplasts actually convert over to chromoplasts.**

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* The carotenoid pigments allow for the different colors seen in fruits and the fall leaves. One of the main reasons for these structures and the colors is to attract pollinators.
* Chromoplasts are pigmented plastids of variable shape. These lack chlorophyll but synthesize carotenoid pigments and are often responsible for the yellow, orange or red colour of many flowers, old leaves, some fruits and some roots such as carrots.
* Chromoplasts contain an extensive membrane system but grana are absent. The pigments may be prese either as part of the membrane or discrete droplets, plastoglobuli (sing: plastoglobulus). fruits ripen, chloroplasts often synthesize large amounts of lipid pigments, altern thylakoids and convert to chromoplasts.
* In ripening fruit, chromoplasts most often develop from chloroplasts although they may arise directly from proplastids in other tissues In the fruit of at least one arum, the developmental pathway is from amyloplast to chloroplast to chromoplast. Chromoplasts can also de-differentiate and revert back to chloroplasts under the proper storage and lighting conditions.

1. **Gerontoplast:**

**The gerontoplast (“γερoντ” is Greek for “old man”) is a biochemically and metabolically distinct plastid variant that develops from a chloroplast during the senescence of foliar tissue.**

* Gerontoplast formation and fate are extensively reviewed in this volume by Krupinska and as such will only be briefly discussed here.
* Ultrastructurally, gerontoplast development is seen primarily as a progressive unstacking of grana, a loss of thylakoid membranes and a massive accumulation of plastoglobuli.
* The plastoglobuli are thought to contain the lipid-soluble degradation products from the thylakoid membranes. Other lipid-protein inclusions are often seen in and being exuded from the stroma.
* The **function** of the gerontoplast, in association with other organelles in an aging cell, is clearly to affect a controlled dismantling of the photosynthetic apparatus during senescence.

1. **S-Type and P-Type Plastids:**

**Phloem tissue is responsible for the transport of photosynthate from source tissues (leaves or other photo synthetic organs) to sink tissues (roots, stem and developing seeds and fruit).**

* Phloem tissue contains four distinct cell types: phloem fibers, phloem parenchyma, phloem companion cells and phloem sieve elements.
* Long distance transport occurs in the phloem sieve elements while the other phloem cells are involved in support and protection (fibers) or loading and unloading of photosynthate from the sieve elements (parenchyma and companions’ cells).
* The function of sieve element plastids is not fully understood but they may play a role in the response of phloem to injury, particularly the p-type plastids.
* Upon mechanical damage, the sieve plates of phloem sieve elements become occluded with protein and cellular debris, thus halting all transport. This would play a large role in a successful defense against a phloem-feeding insect or to prevent the spread of pathogenic bacteria, fungi or virus particles.
* The severity of the damage influences the severity of the response. A mild stimulus (penetration with a 0.1 μm diameter electrode tip for instance) results in a rapid expansion of the p-protein crystalloids, which then plug the sieve plates.

1. **Kleptoplast:**

**Coined in 1990 by Clark and colleagues, the term “kleptoplast” refers to chloroplasts that have been stolen from algal cells and taken up by cells of a host animal (“κλεπτo” from the Greek for “thief”) and describes a relationship between animals and al gae that was recognized as early as 1904.**

* Kleptoplasty is fairly common in ciliates, foraminifera and sacoglossan mollusks with the relationship between kleptoplasts and the sacoglossan sea slug Elysia chlorotica (phylum Mollusca, subclass Opisthobranchia) being the most advanced and the most studied. In this latter case, the sea slugs feed on algae (usually Vaucheria litorea), digest the algal cells and retain only the chloroplasts within the cytoplasm of cells lining the digestive tract.
* The animals turn bright green and look remarkably like a healthy plant leaf. Kleptoplasts retain their outer and inner boundary.
* Kleptoplasts in Elysia chlorotica have been shown to retain their photosynthetic capacity after ingestion, in some instances for up to several months.
* Animals bearing a full complement of kleptoplasts can survive in the light with no external food source for their entire nine-month life span and successfully reproduce whereas animals left in the dark soon die.

1. **Apicoplast:**

**Apicoplasts are plastids found in small, parasitic worms of the Apicomplexan family (taxonomy), most notably Plasmodium falciparum, the malarial parasite.**

* They were initially described as small cytoplasmic bodies, based on their appearance in the electron microscope.
* It was not until sequencing of the Apicomplexan genome that genes of certain plastid origin were found and later localized to the apicoplast.
* The apicoplast genome contains evidence of both red and green algal ancestry, and the story of its origin(s) is continuing to unfold today.

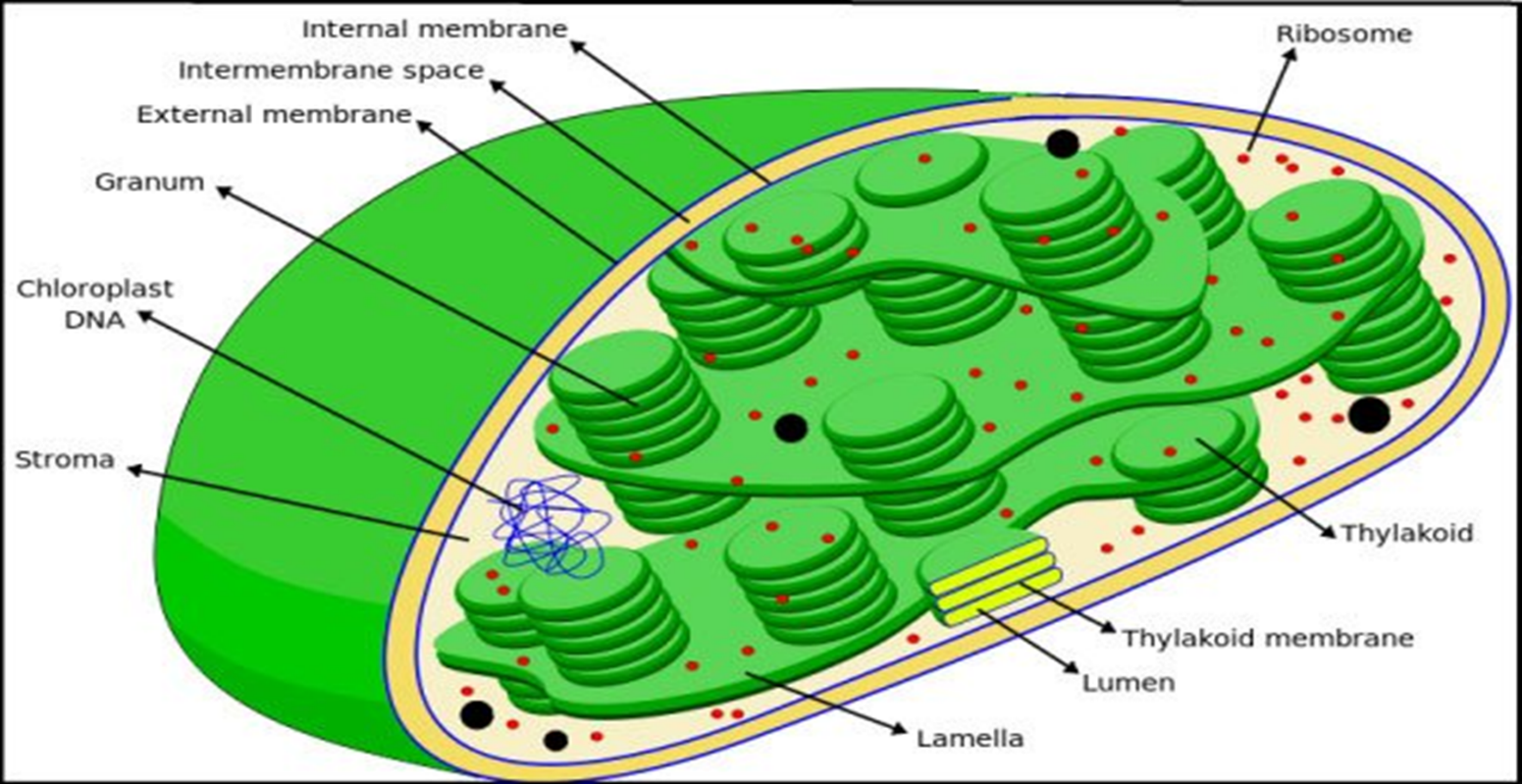
1. **Chloroplasts:**

**Chloroplasts are green, disc-shaped plastids that contain chlorophyl laments. The green colour of the chloroplasts is because of chlorophyll. The pigments are receptors for light energy necessary for photosynthesis, therefore act as sites of photosynthesis.**

* Two membranes, outer membrane and an inner surround the chloroplast. Both these membranes are separated by a intermembrane space. The inner membrane encloses a fluid known as stroma.
* **Thalakoids:** Membrane becomes extensively folded to form membranous sheets called thylakoide project into the matrix. In certain regions the thylakoids form small bag-like vesicles.
* **Grana:** Sicles (grana thylakoids) that become stacked together. The stack of vesicles is called a granum grana). Thus, the inner membrane divides the interior of chloroplast into two compartment the thylakoid space and the stroma.
* Chlorophylls and carotenoid pigments are embedded in the thylakoid membranes. These pigments are responsible for capturing light that drives photosynthesis. The DNA of the chloroplast exists in circular form and is not associated with histones
* The ability to form chloroplasts and the pigments involves the contribution of nuclear and plastid DNA. Some chloroplast proteins are encoded by plastid DNA and synthesizer within the chloroplast itself. Most of the chloroplast proteins, however, are encoded by nuclear DNA, synthesized in the cytosol, and then imported into the chloroplast.

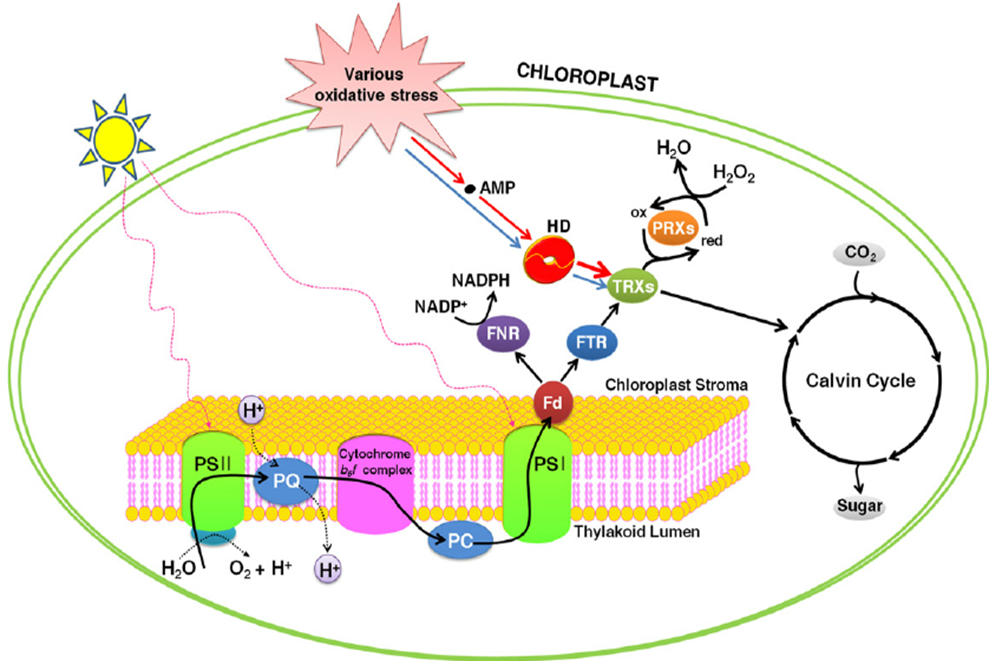
**Structure of Plastids**

Chloroplasts may be spherical, ovoid or discoid in higher plants and stellate, cup-shaped or spiral as in some algae. They are usu­ally 4-6 µm in diameter and 20 to 40 in number in each cell of higher plants, evenly distributed throughout the cytoplasm. The chloroplast is bounded by two lipoprotein membranes, an outer and an inner membrane, with an intermembrane space between them. The inner membrane encloses a matrix, the stroma which contains small cylindri­cal structures called grana. Most chloroplasts con­tain 10-100 grana.



**The Grana and Thylakoids:**

* Each granum has a number of disc-shaped membranous sacs called grana lamellae or thylakoids (80-120Å across) piled one over the other.
* The grana are intercon­nected by a network of anastomosing tubules called inter-grana or stroma lamellae.
* Single thylakoids, called stroma thylakoids, are also found in chloroplasts.
* Electron dense bodies, osmophilic granules along with ribosomes (70S), circular DNA, RNA and soluble enzymes of Calvin cycles are also present in the matrix of the stroma.
* Chloroplasts thus have three different mem­branes, the outer, the inner and the thylakoid membrane.
* The thylakoid membrane consists of lipoprotein with a greater amount of lipids which are galactolipids, sulpholipids, phospholipids.
* The inner surface of the thylakoid membrane is gra­nular in the organization due to small spheroidal quantosomes.The quantosomes are the photosynthetic units, and consist of two structurally distinct photosystems, PS I and PS II, containing about 250 chlorophyll molecules. Each photosystem has antenna chlorophyll com­plexes and one reaction center in which energy conversion takes place. In higher plants, the pig­ments present are chlorophyll-a, chlorophyll-b, carotene, and xanthophyll.
* The two photosystems and the components of the electron transport chain are asymmetrically distributed across the thylakoid membrane. Electron acceptors of both PS I and PS II are on the outer (stroma) surface of the thylakoid membrane. Electron donors of PS I are on the inner (thylakoid space) surface.



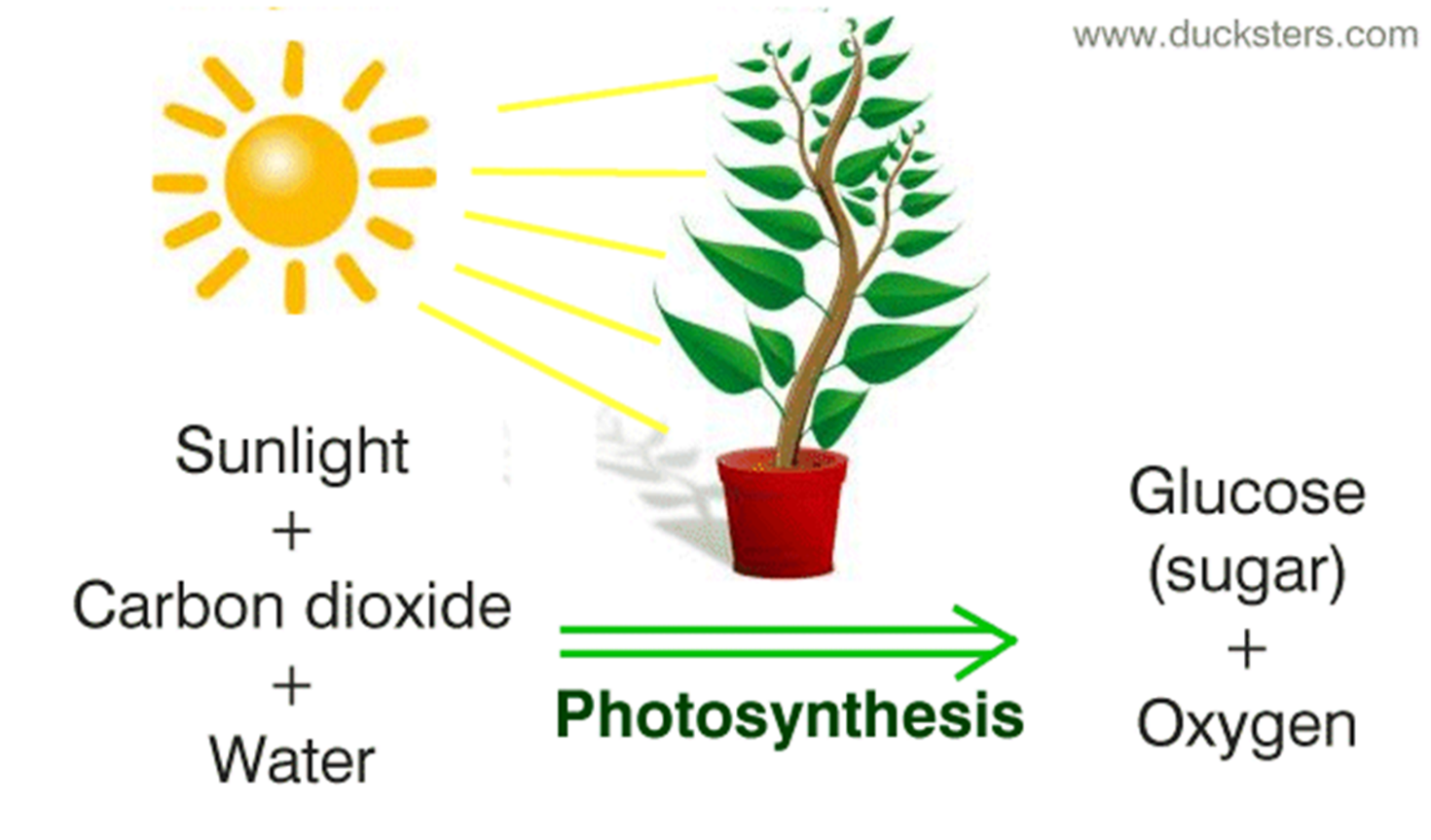
* A common misconception seen in most biology texts is that the double-membrane envelope of the chloroplast is similar to the double-membrane of the mitochondrion. This is conceptually incorrect. It is true that the outer mitochondrial membrane and the outer chloroplast envelope membrane are analogous in that both are rather minimal barriers between the cytoplasm and the organellar interior However, the inner mitochondrial membrane and the inner chloroplast envelope membrane are very different in structure and function. The inner mitochondrial membrane is the site of oxidative phosphorylation,
* Chloroplasts from spinach (Spinacea oleracea), a C3 plant. 10a. A transmission electron micrograph of an entire choloroplast in thin section showing grana (G) and starch grains (S). Scale bar = 1.0 μm. 10b. High magnification view of a sin gle granum in thin section showing the stroma (St) and a stromal thylakoid (StT). The two membranes of the chloroplast envelope (CE) are also visible. Scale bar = 0.1μm. A low voltage, high resolution scan ning electron micrograph of a pea (Pisum sativum) chloro plast containing several starch grains (S). Also visible are mi tochondria (M), the tonoplast (To) and a cell wall (CW). Scale bar = 1.0 μm. 10d. High magnification view of a several grana (G) and stromal thylakoids (StT). Scale bar = 0.1 μm.

1. **Ameboid Plastids:**

**Amoeboid plastids have been defined as any plastid that has protrusions of the envelope.**

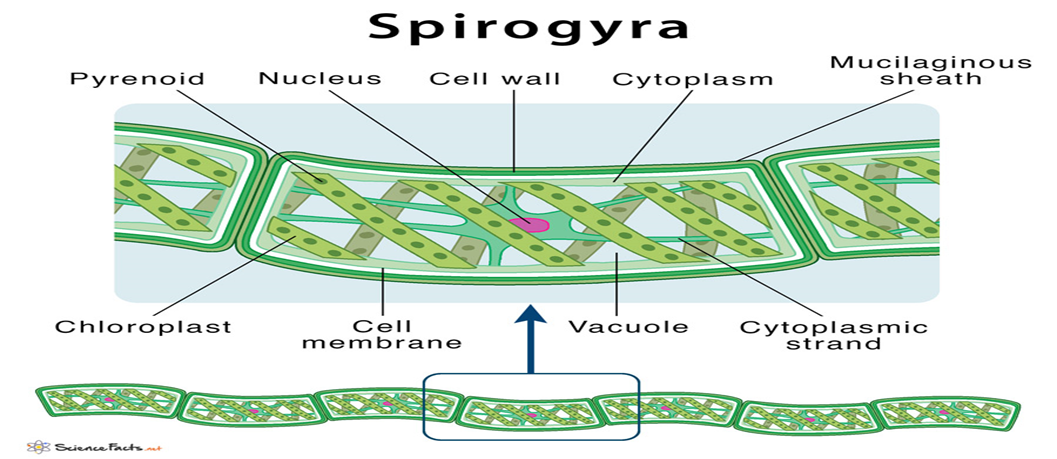
* They were first recognized by early light microscopists but their exact function, or if indeed their unique shape represents any specific function, is not clear.
* Electron microscopical studies have found amoeboid plastids in developing leaves and roots and in leaves and tepals of members of the Amaryllidaceae. They are also common in the leaves of chilling stressed tissues.

**Functions:**

* All plant cells contain plastids in some shape or form. This roll-call indicates their functional diversity and demonstrates that plastids lie at the very core of plant cellular function.
* Plastids are the site of manufacture and storage of important chemical compounds used by the cells of autotrophic eukaryotes.
* The thylakoid membrane contains all the enzymatic components required for photosyn­thesis. Interaction between chlorophyll, electron carriers, coupling factors, and other components takes place within the thylakoid membrane. Thus, the thylakoid membrane is a specialized struc­ture that plays a key role in the capture of light and electron transport. Thus, chloroplasts are the centers of synthesis and metabolism of carbohydrates.
* They are not only of crucial importance in photosynthesis but also in the storage of primary foodstuffs, particularly starch.
* Its function largely depends on the presence of pigments. A plastid involved in food synthesis typically contains pigments, which are also the ones responsible for the color of a plant structure (e.g. green leaf, red flower, yellow fruit, etc.). Like mitochondria, plastids have their own DNA and ribosomes. Hence, they may be used in phylogenetic studies.

**Questions:**

1. **Which of the following common feature of plastids and mitochondria?**
2. Both double stranded
3. Both contains 70S ribosome
4. Both are double membrane
5. All of the above (Answer)
6. **Which of the following are colourless plastids?**
7. Amyloplast
8. Elaioplast
9. Proteinoplast
10. All of the above (Answer)
11. **Plastids are present in:**
12. Fungi
13. Blue-green Algae
14. Bacteria
15. Euglenoids (Answer)



1. **Which of the following type of plastid help in pollination?**
2. Leucoplast (Answer)
3. S-Type and P-Type Plastids
4. Ameboid
5. None
6. **The bright colour of ripe fruits are due to:**
7. Leucoplast
8. Chloroplast
9. Amyloplasts
10. Chromoplast (Answer)
11. **The structure of chromoplast is:**
12. Globular
13. Fibrillar
14. Membranous
15. All of the above (Answer)
16. **Numbers of Thalakoids in Granum:**
17. 12-40 (Answer)
18. 10-22
19. 20-40
20. None
21. **The fluids that surrounds the thalakoids:**
22. Grana
23. Stroma (Answer)
24. Intergranum
25. None of these
26. **The protein storing plastid is called:**
27. Amyloplast
28. Leticoplast
29. Lipoplast
30. None (Answer)
31. **The starch storing leucoplast are called:**
32. Amyloplast (Answer)
33. Lipoplast
34. Both a and b
35. None

….END….