植物生理
葉綠體
藻類起源與質體
Origins of Algae and their Plastids

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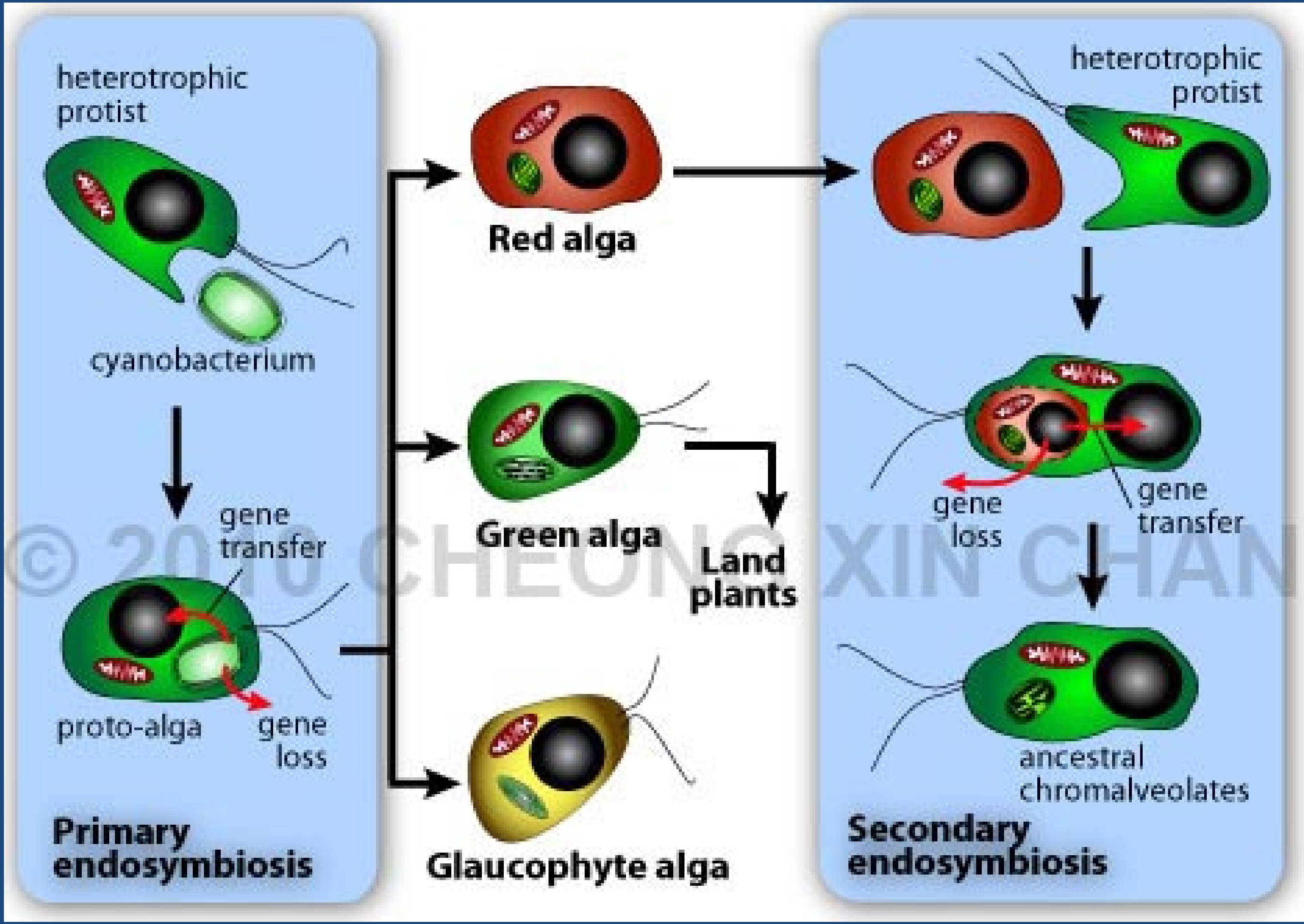
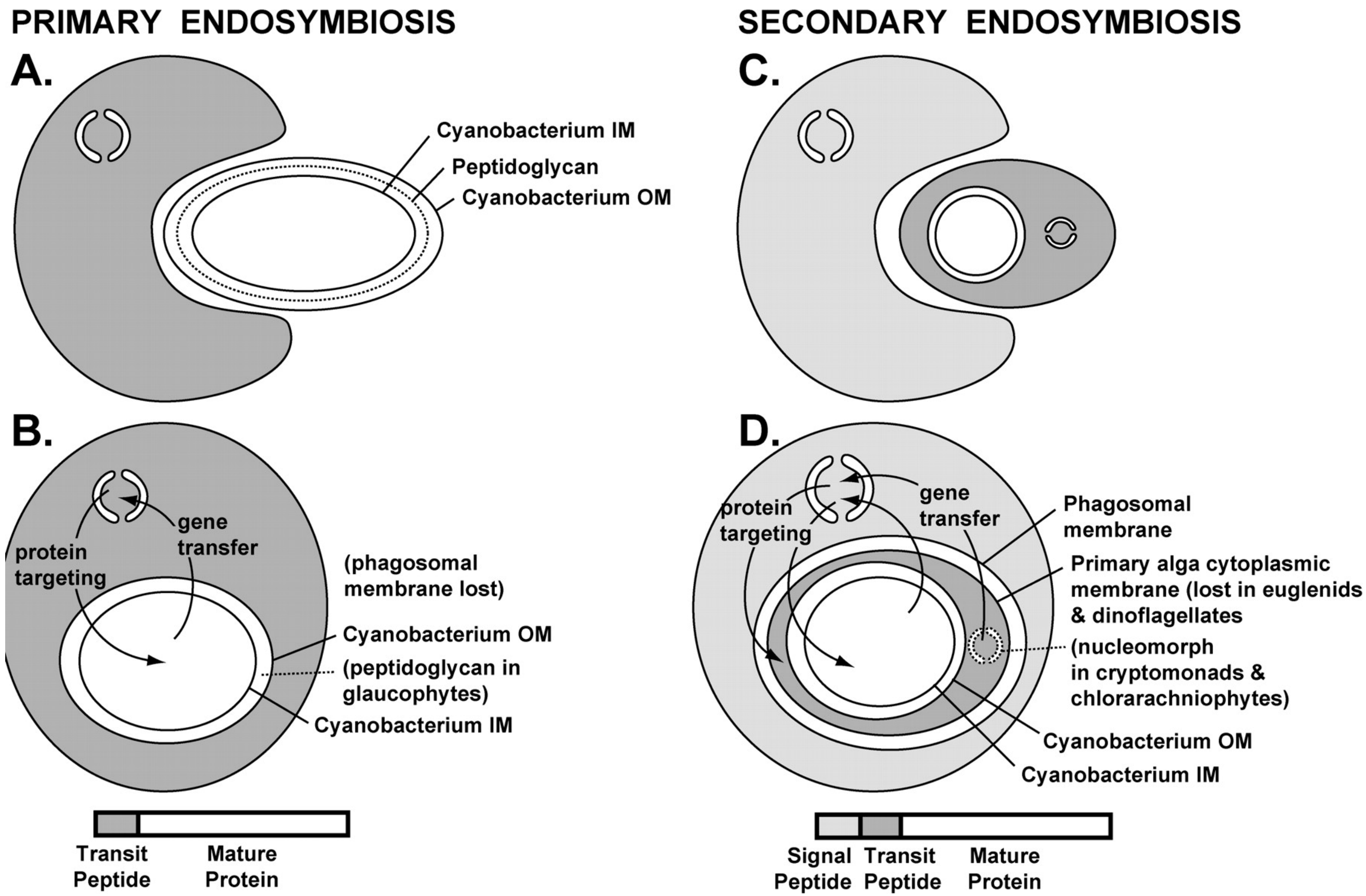
Plastid origin and **algal** evolution



Hedges, S. Blair et al. (2004) "A molecular timescale of eukaryote evolution and the rise of complex multicellular life" BMC Evolutionary Biology 4:2

Fig. 2. Primary and secondary endosymbiosis.

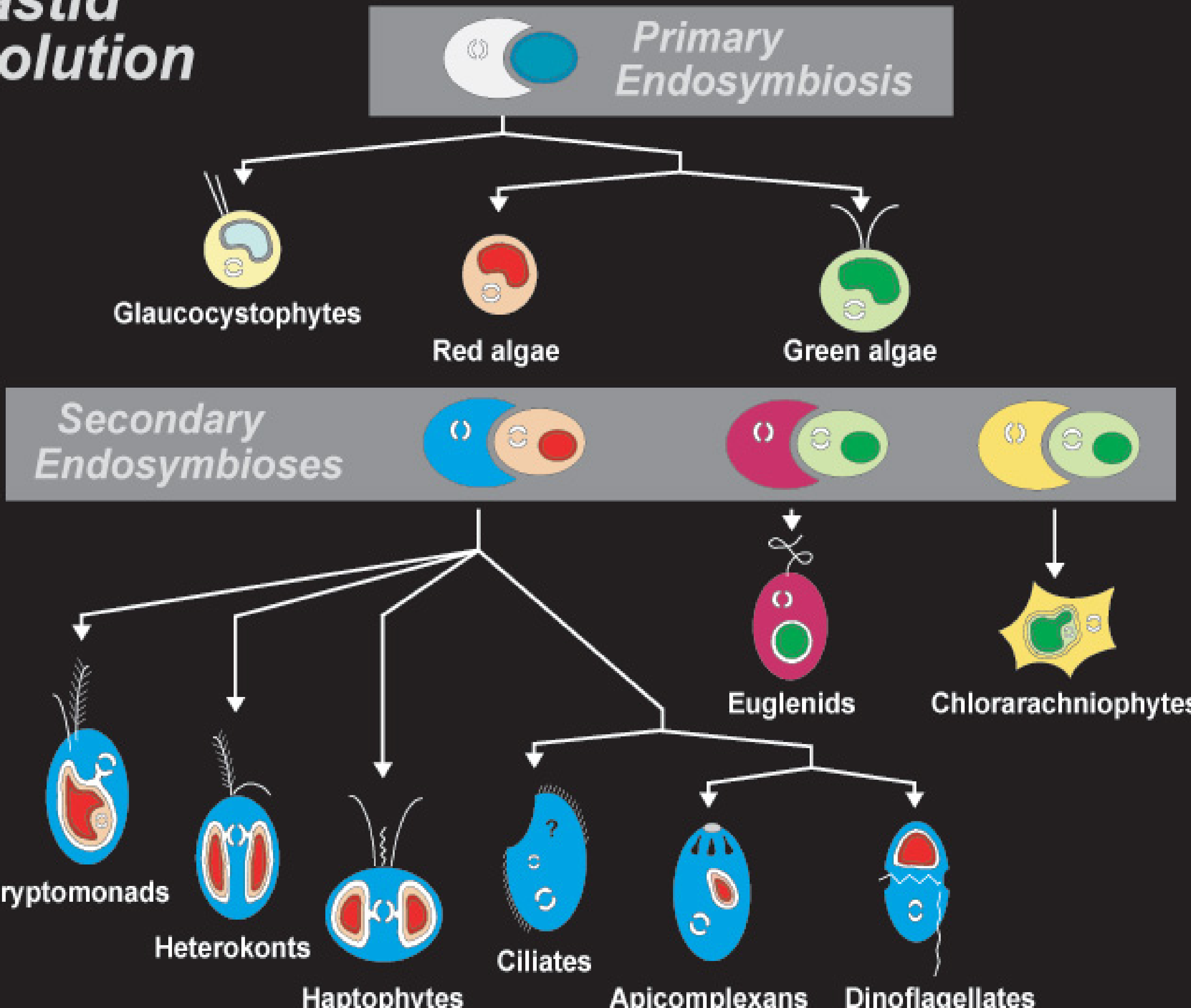


Keeling P J Am. J. Bot. 2004;91:1481-1493

Primary endosymbiosis refers to the original uptake and retention of a cyanobacterium by a eukaryote

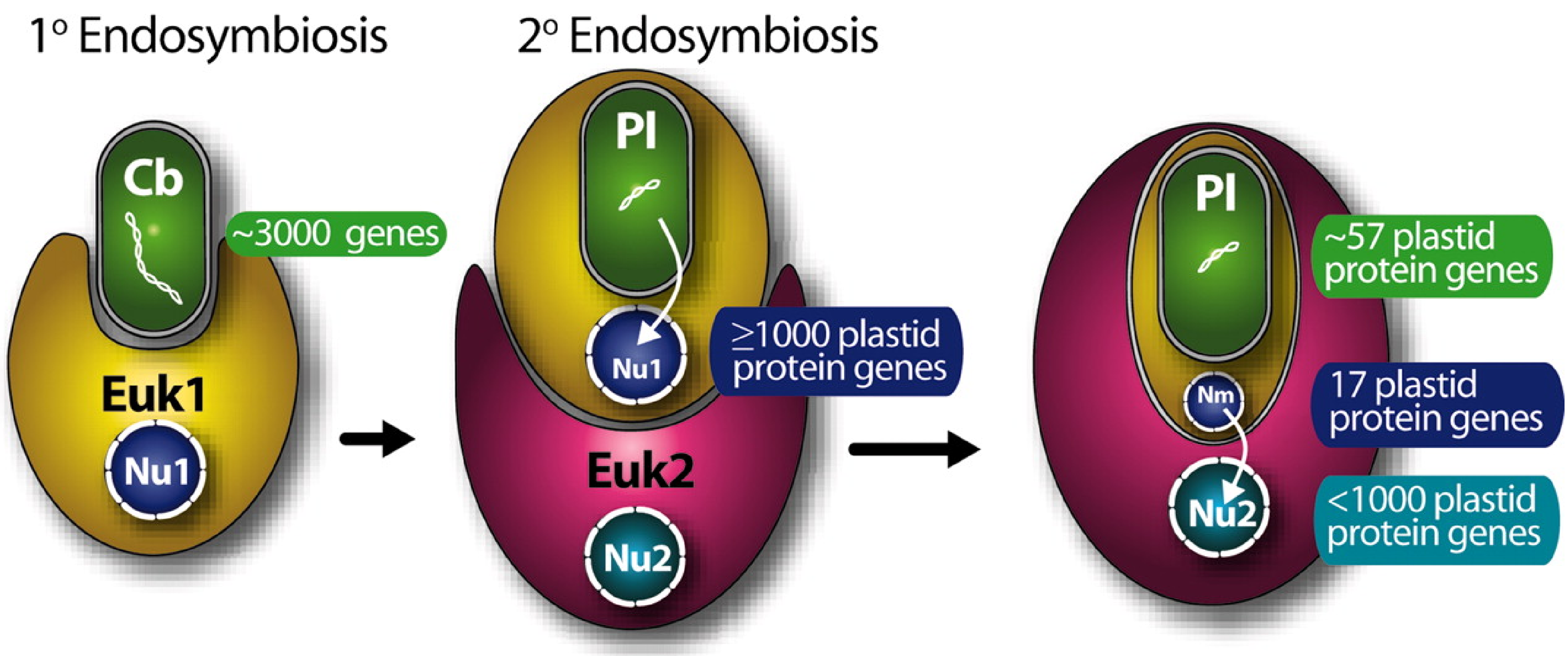
- The protein products of most of these nuclear genes continue to function in the plastid, and they are post-translationally targeted there by means of an N-terminal leader called a transit peptide.
- Transit peptides are recognized by protein complexes in the inner and outer membranes of the plastid (called TICs and TOCs) that direct the translocation of proteins across the membranes (McFadden, 1999⇓).
- Primary plastids are found in three major lineages: glaucophytes, red algae, and green algae (including plants).

Plastid Evolution



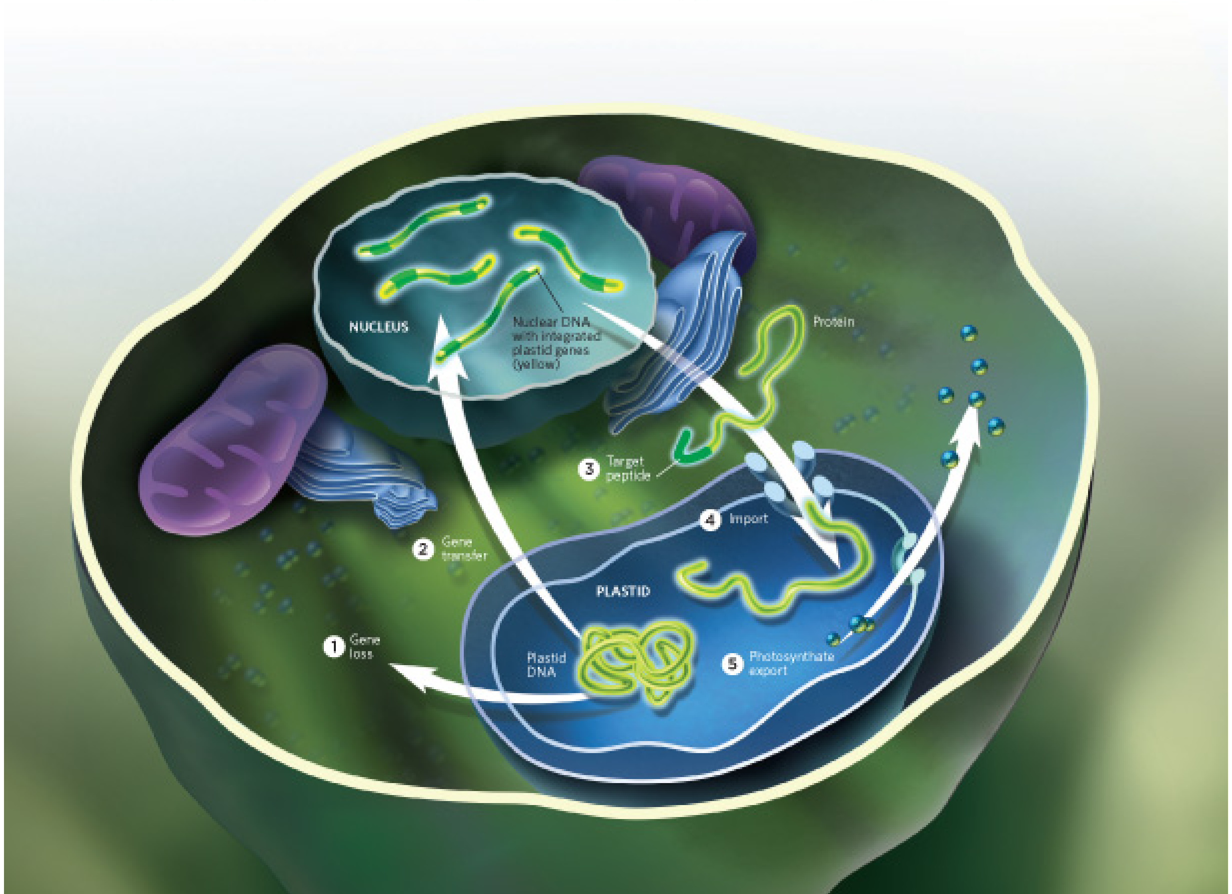
Archibald & Keeling, 2003.

Gene exchange and loss



THE PLASTID GENE SHUFFLE

Early in plastid evolution, many endosymbiont-derived genes were lost ❶ and others migrated to the host nuclear genome ❷ through a process called endosymbiont gene transfer. Plastid-harboring eukaryotes then had to devise a system to target the protein products of these transferred endosymbiont genes back to the plastid. Their solution was to attach plastid-targeting peptides to the N-terminus of these proteins ❸, which direct them from the cytoplasm to the plastid and across its outer and inner membranes. This plastid-protein targeting system also involved the evolution of complex multiprotein translocon import channels within the plastid membranes that recognize targeting peptides ❹. Finally, the host cell has devised ways to export the riches of photosynthesis and other plastid-derived molecules from the plastid into the cytosol ❺, where they act as the substrate for the synthesis of other important organic molecules, such as glucose.



http://www.the-scientist.com/?articles.view/articleNo/33711/title/Steal-My-Sunshine/

plastid

- Chloroplast
- Chromoplast
- Proplastid
- Leuoplast, amyloplast

- Chloroplast R.R.
- Pyrenoid: RuBisco+stores

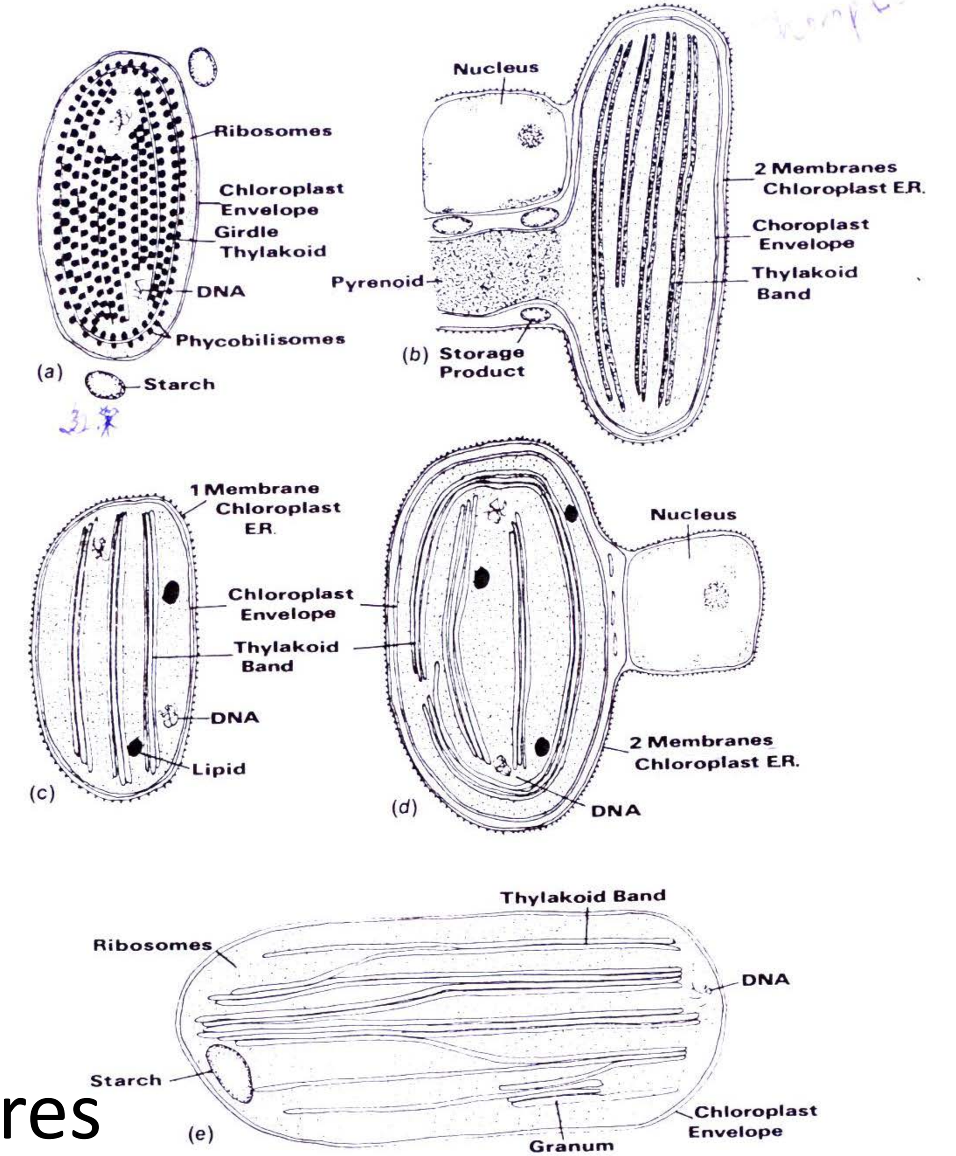
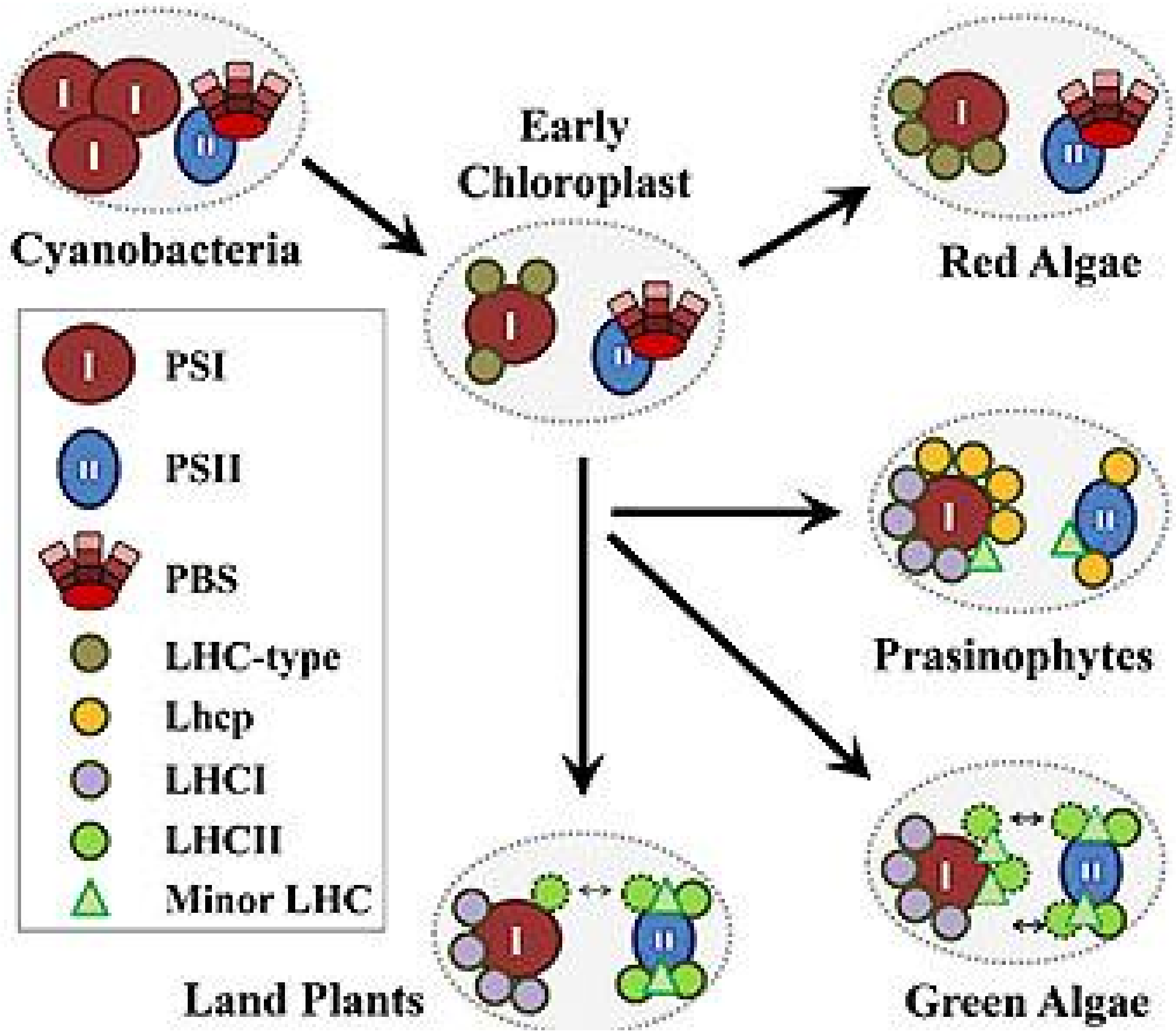


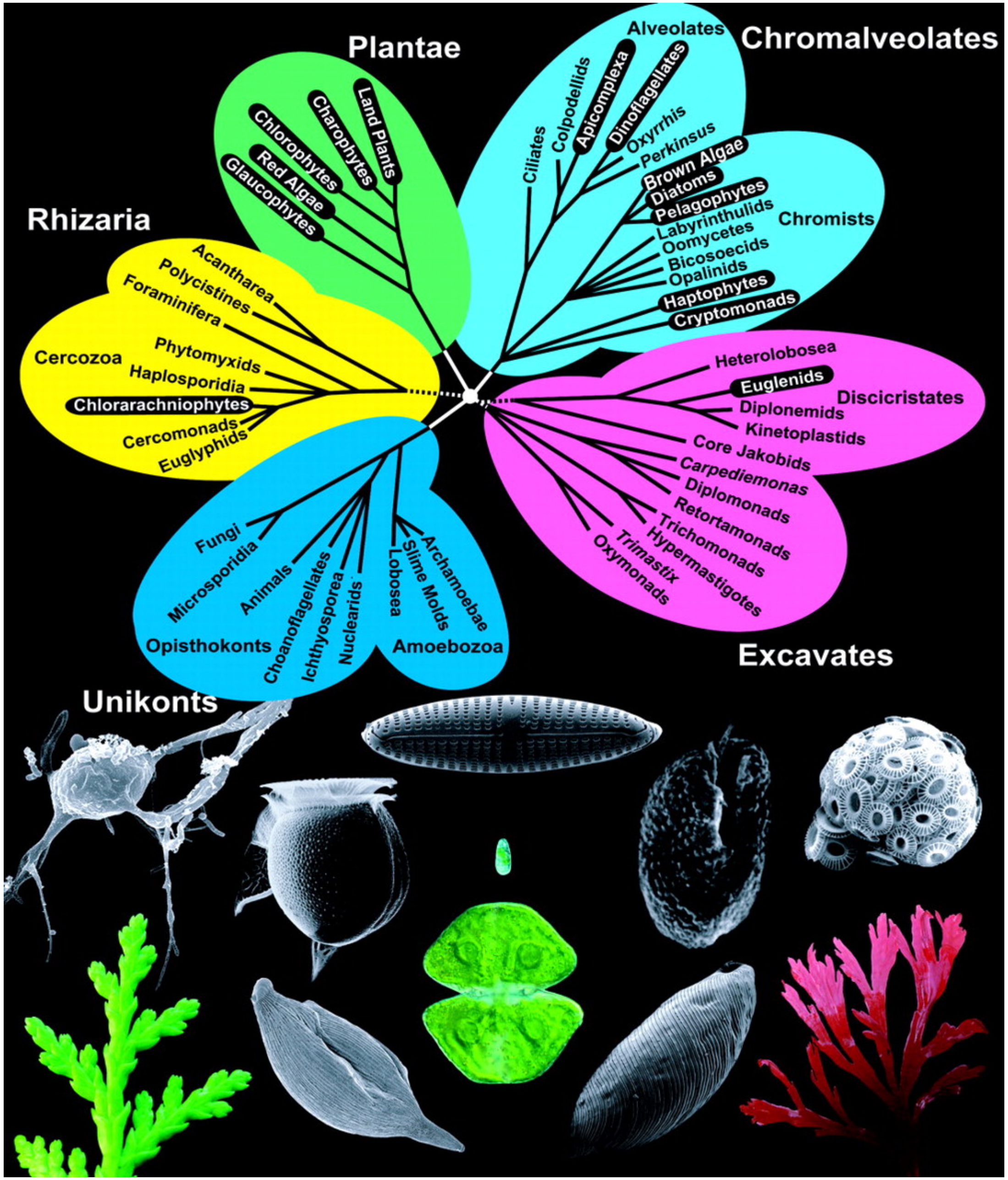
Fig. 1-8. Types of chloroplast structure in eucaryotic algae. (*a*) One thylakoid per band, no chloroplast endoplasmic reticulum (Rhodophyta). (*b*) Two thylakoids per band, two membranes of chloroplast E.R. (Cryptophyta). (*c*) Three thylakoids per band, one membrane of chloroplast E.R. (Dinophyta, Euglenophyta). (*d*) Three thylakoids per band, two membranes of chloroplast E.R. (Chrysophyta, Prymnesiophyta, Bacillariophyta, Raphidophyta, Xanthophyta, Eustigmatophyta, Phaeophyta). (*e*) Two to six thylakoids per band, no chloroplast E.R. (Chlorophyta).



請看文章7.9. 補充資料 PSII PSI 演化假說

Major LhcII 是可以移動到PSI =state 2
綠藻保有此類的能力較高等植物大，綠藻 Minor LhcI 也會移動

Fig. 1. Tree of eukaryotes and diversity of plastid-bearing eukaryotes.



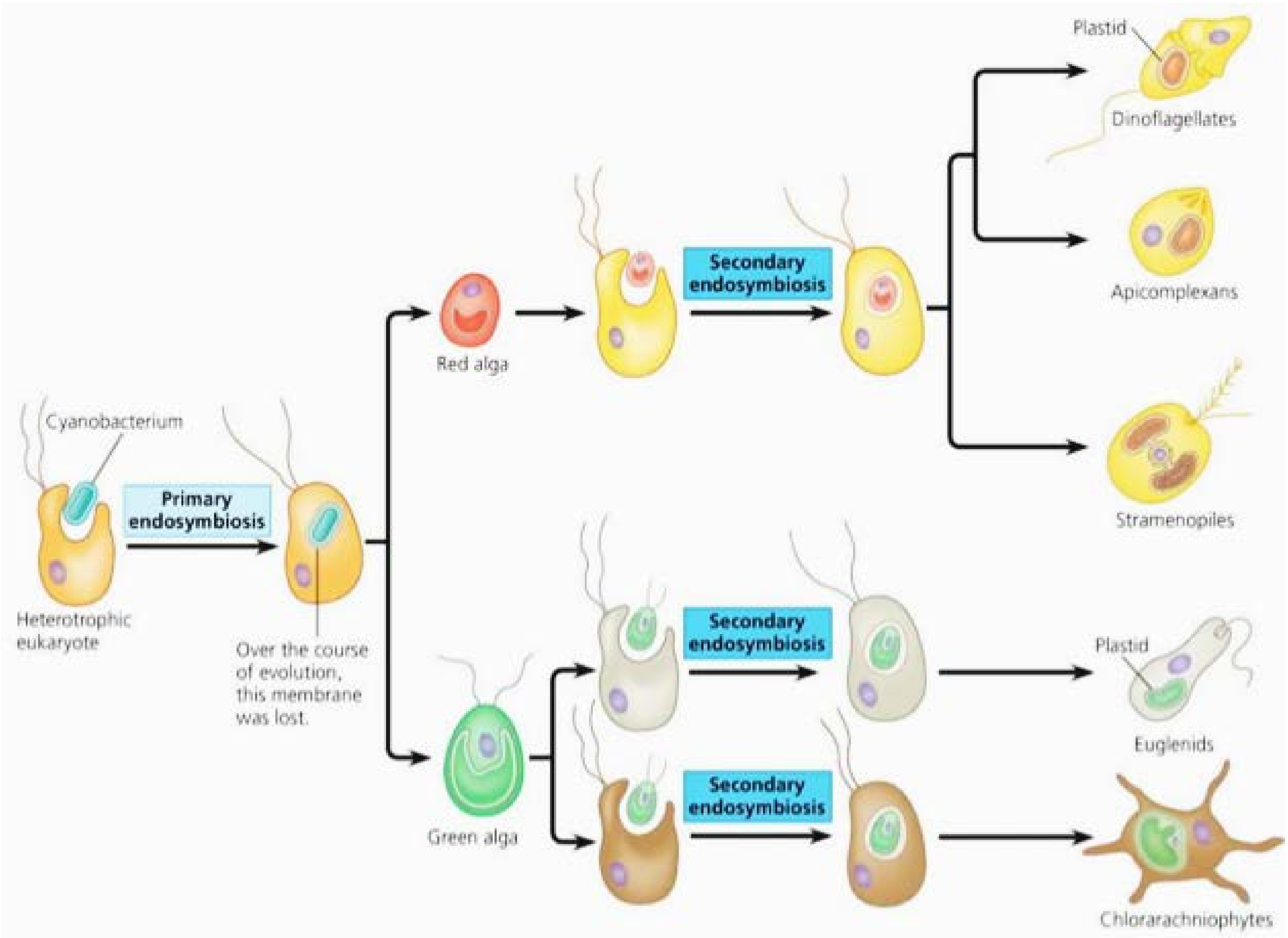
This was perhaps most obvious in the **euglenids**, whose plastids were quickly recognized to share a number of characteristics with green algae, whereas their flagellar apparatus was more akin to that found in the parasitic and nonphotosynthetic kinetoplastid protozoa (Leedale, 1967; Kivic and Walne, 1984). Molecular systematics further reinforced these contradictions by demonstrating that euglenids and trypanosomes were closely related at the nuclear level to the exclusion of green algae (Sogin et al., 1986).

PRIMARY PLASTIDS

- Primary endosymbiosis

Primary endosymbiosis refers to the original uptake and retention of a cyanobacterium by a eukaryote

- These plastids are bound by two membranes, which are derived from the inner and outer membranes of the Gram-negative cyanobacterium (Jarvis and Soll, 2001⇓).
- The once free-living prokaryote was reduced and transformed into the organelles we see today, partly by the loss of much of its genome and the transfer of most of the remaining genes to the nucleus of its host.


Plastid
Dinoflagellates
Apicomplexans
Stramenopiles
Red alga
Secondary endosymbiosis
Cyanobacterium
Primary endosymbiosis
Heterotrophic eukaryote
Over the course of evolution, this membrane was lost.
Secondary endosymbiosis
Plastid
Euglenids
Secondary endosymbiosis
Green alga
Chlorarachniophytes

- **Glaucophytes** (glaucocystophytes) are a small group of microscopic algae found in freshwater environments. There are only about 13 species of glaucophytes, and although not particularly common in nature they are important because they occupy a pivotal position in the evolution of photosynthesis in eukaryotes (see later). They also represent an intermediate in the transition from endosymbiont to plastid in that they are unique among plastids in retaining the prokaryotic peptidoglycan layer between their two membranes. Glaucophyte plastids contain photosynthetic pigments chlorophyll *a,* phycobilins, and phycobilisomes, small particles organized on the outer face of thylakoid membranes that are also found in cyanobacteria. (For a review on glaucophytes, see Bhattacharya and Schmidt, 1997⇓; Steiner and Loffelhardt, 2002⇓.)

- **Red algae** are a very large and diverse group of microscopic algae and macroalgae that are present in freshwater and common in marine environments. Red algal plastids contain chlorophyll *a,* phycobilins, and phycobilisomes. For a review of red algae, see Saunders and Hommersand (2004) in this issue.

- **Green algae** are another large and diverse group of predominantly freshwater algae whose plastids harbor chlorophylls *a* and *b.* Green algae are roughly divided into chlorophytes and charophytes. Charophytes are the ancestors of **land plants**, which share a great number of similarities to charophytes and green algae as a whole. For a review of green algae, see Lewis and McCourt (2004) in this issue.

Chan, C. X. & Bhattacharya, D. (2010) The Origin of Plastids. Nature Education 3(9):84

http://www.nature.com/scitable/topicpage/the-origin-of-plastids-14125758