der Auwera *et al.*[9] have done a combined analysis of small- and large-subunit ribosomal RNAs. Their results are important because — unlike the poorly resolved trees based on small-subunit rRNAs that are sometimes cited as evidence against plastid monophyly — their 'rate-calibrated' tree finds strong support for the green/red clade, albeit with limited sampling of the major groups of eukaryotes (and no glaucophytes). A four-gene study by S. L. Baldauf *et al.* (personal communication) features more impressive sampling of eukaryotes and reveals, although with low support, a monophyletic assemblage of all three primary-plastid-containing groups.

How far are we, then, from being able to write with textbook-like certainty of a single cyanobacterial origin of all plastids? We need more information from both mitochondrial and nuclear genes of glaucophytes. Fortunately, sequencing of the mitochondrial genome of the glaucophyte *Cyanophora paradoxa* is nearing completion. Preliminary analyses (F. Lang, personal communication) place it, with modest support, as the sister group to the strongly supported green algal/red algal clade defined by previous analysis of mitochondrial genomes[4].

For most relevant sets of data from nuclear and mitochondrial genes, sampling within eukaryotes is rather poor, and in most plastid data sets the cyanobacteria are poorly represented. This increases the chances that phylogenetic artefacts may have led to spurious placements of taxa in these poorly sampled trees. As Moreira *et al.*[6] point out, sampling is a particular problem for their multigene analyses, which include just one lineage (animals plus fungi) from which many eukaryotes were studied, and only six or seven groups from which just one eukaryote was sampled. A particular concern is whether the strong support for the green algal/red algal clade obtained in the 13-protein analysis arises largely from inclusion of elongation factor-2 — the only molecule that on its own provided strong support for this group. One wonders what a 12-protein analysis (that is, excluding elongation factor-2) would show.

These caveats aside, it is nonetheless impressive that so many phylogenies constructed from analysis of all three genomes — as well as derived commonalities of plastid targeting, gene content and arrangement, and the composition of light-harvesting pigments[1–3,10] — are painting the same picture. That is, the primary plastids in red and green algae and glaucophytes all arose from a single, ancient symbiosis between a cyanobacterium and a eukaryote. We are rapidly approaching the almost untestable proposition that two or more symbiotic events could have taken place only if they occurred in a relatively short period and only if they involved closely related groups of eukaryotic hosts and cyanobacterial guests, both presumably well adapted for their respective roles.

As Cavalier-Smith has argued[7], among the implications of a single origin of primary plastids is a single origin of the complex machinery by which plastids import proteins made in the main body of the cell. In support of this idea, transit peptides from red algae and glaucophytes direct efficient import of proteins into plastids of land plants, and vice versa (for glaucophytes at least)[1]. A second implication is that the variety of light-responsive pigments of primary (and secondary) plastids probably reflects differential loss of one or more such pigments and associated proteins from a cyanobacterial ancestor that was fully equipped with all of these compounds[11].

When did the breakthrough symbiosis occur? Cavalier-Smith[7] speculates that it was as recent as 600 million years ago, but this seems increasingly unlikely given the evidence for red algal fossils of 1.2 billion years in age[12]. Fossils of controversially algal origin date to 2.1 billion years[13], and the first cyanobacteria date back at least 2.7 billion years[14]. What did this cyanobacterial ancestor look like, and did it possess any of the gene arrangements and types of light-harvesting complex that are thought to be defining features of (monophyletic) plastid evolution[1–3,10]? Sadly, phylogenetic analyses have been unable to identify specific relatives of plastids among living cyanobacteria, making this problem hard to tackle.

A single origin of primary plastids now seems certain. But the number of secondary symbioses (that is, ingestion by a host cell of a eukaryotic cell that already contains plastids) is controversial. Estimates range from as few as two[7] to as many as seven[1]. Answering this question will require not only — as with primary symbiosis — an improved understanding of phylogeny, but also a search for symbiotically derived genes in eukaryotes postulated[7] to have lost plastids of secondary origin. ■

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1. Palmer, J. D. & Delwiche, C. F. *Plant Syst. Evol.* **11** (suppl.), 53–86 (1997).
2. Stoebe, B. & Kowallik, K. V. *Trends Genet.* **15,** 344–347 (1999).
3. Turmel, M., Otis, C. & Lemieux, C. *Proc. Natl Acad. Sci. USA* **96,** 10248–10253 (1999).
4. Burger, G., Saint-Louis, D., Gray, M. W. & Lang, B. F. *Plant Cell* **11,** 1675–1694 (1999).
5. Stiller, J. W. & Hall, B. D. *Proc. Natl Acad. Sci. USA* **94,** 4520–4525 (1997).
6. Moreira, D., Le Guyader, H. & Philippe, H. *Nature* **405,** 69–72 (2000).
7. Cavalier-Smith, T. *Trends Plant Sci.* **5,** 174–182 (2000).
8. Martin, W. *et al. Nature* **393,** 162–165 (1998).
9. Van der Auwera, G., Hofmann, C. J. B., De Rijk, P. & De Wacher, R. *Mol. Phylogenet. Evol.* **19,** 333–342 (1998).
10. Durnford, D. J. *J. Mol. Evol.* **48,** 59–68 (1999).
11. Tomitani, A. *et al. Nature* **400,** 159–162 (1999).
12. Butterfield, N. J. *Palaeobiologica* (in the press).
13. Han, T. M. & Runnegar, B. *Science* **257,** 232–235 (1992).
14. Brock, J. J., Logan, G. A., Buick, R. & Summons, R. E. *Science* **285,** 1033–1036 (1999).

Daedalus

A flicker of interest

The human eye is sensitive to change above all else. Hence the flashing indicator for cars, the blink comparator and the flicker photometer, and the blinking cursor on the computer screen. Indeed, says Daedalus, hence the strange and terrible authority of the computer screen itself, and of the TV and cinema screen as well. The subliminal flicker of these hypnotic displays rivets the attention and subverts the mind.

So Daedalus wants to give printed text and pictures, and indeed objects in the real world, the eye-appeal of constant flicker. What is needed is a dye whose reflectivity is not steady, but oscillates about a mean value. Ordinary phosphors absorb light and emit it later. The photon energy is stored in the crystal structure as excited unpaired electrons. So Daedalus is inventing an oscillating phosphor.

He recalls that unpaired electrons are paramagnetic. An excited state should therefore induce a local magnetic field; and the rate at which it decays should depend on the local field. DREADCO solid-state physicists are therefore growing tiny phosphor crystals each containing a two-state magnetic inclusion. The idea is that the phosphor will absorb light until its growing field 'flips' the magnetic element. This will trigger the rapid re-emission of light; the field will decay and the magnetic inclusion will flip back. The result will be an unsteady, oscillating phosphor, driven by the energy of the light falling on it. It will brighten and darken endlessly about its mean reflectivity.

Artists and ad-men will rush to exploit the new products. DREADCO's 'Wink' inks and paints will flicker beckoningly from posters, magazines and the more garish of fashion clothes and accessories. Warning signs, safety regulations, identifying marks and disclaimers in contracts will signal their importance in unmissable Wink. High-frequency Winks, compelling subliminal attention without it being obvious why, will revolutionize the cosmetics industry. Its customers, without seeming garish or blatant, will now be able to call subtle attention to their most charming features. Long-period Winks will alleviate the visual boredom of institutions and offices; they will even vary in frequency with the ambient illumination. In theatres and clubs, strobe lighting on Winked decor will induce amazing interference effects. Sadly, patrons may be at risk of epileptic fits. **David Jones**

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