

Letter from the Editors

The key event in the history of life on our planet was the enslavement of a cyanobacterium by a eukaryotic host cell. This process, known as the primary endosymbiosis, resulted in the first plastids [1]. Primary plastids have two envelope membranes and occur in the three following eukaryotic lineages: glaucophytes, red algae and green plants, the latter including green algae and land plants. According to the modern systematics, all the primary plastid-containing groups constitute the supergroup Archaeplastida (formerly Plantae), which, in contrast to other supergroups such as Excavata, the SAR clade and Opisthokonta, was created by endosymbiotic event [2].

The current issue of Acta Societatis Botanicorum Poloniae (ASBP) contains nineteen papers: fourteen reviews and five original articles. The series of these invited papers has a special purpose. Last year, we had celebrated 90th anniversary of our journal and this was acknowledged on the covers of the subsequent four issues. This year, 2014, opens the last decade leading to the even more noble anniversary – to the journal's centennial. Editors of ASBP would like to celebrate this special occasion by publishing a few issues dedicated to the hottest topics in plant science in the next decade. This issue is meant to be the first. Its leading theme is the Evolution of Plant Cells, the subject often neglected in the textbooks on Plant Cell Biology, which deal mainly with the properties of a cell of a higher plant, often forgetting its long and complicated evolutionary history.

In the first paper, Mackiewicz and Gagat [3] discuss the monophyly of Archaeplastida from the perspective of phylogenies of plastid and host genes. An updated view on the origin of primary plastids, is provided by Ku et al. [4]. In this review, the authors discuss such important topics as the cyanobacterial source of primary plastids, the physiological context of their establishment, and the current controversies surrounding interpretations of the trees for primary plastid origin. According to one of the recent hypotheses, the cyanobacterial ancestor of primary plastids received some help during its initial evolution from a concomitant chlamydial endosymbiont [5]. This hot topic is critically discussed by Deschamps [6].

The next three papers deal with distinct aspects of plant cell evolution. By using bioinformatics methods, Petrželková and Eliáš [7] demonstrate drastic reduction in the number of Rab GTPase genes in red algae. The absence of Rab5 suggests a significant modification or degradation of the endocytotic pathway in these algae. In turn, Sanchez-Puerta [8] presents available data on the participation of mitochondrial, plastid, and nuclear genomes in horizontal gene transfer between distinct plant species with a special emphasis on mitochondrial genomes. The paper by Krenz et al. [9] is devoted to

stromules, the peculiar extensions of the envelope of primary plastids. They critically review current data on the topic and include new GFP-based results on the induction of stromules by plant viruses.

According to the traditional view, all primary plastids, i.e. those of glaucophytes, red algae, and green plants, have prokaryotic origin. An alternative evolutionary scenario is discussed by Kim and Maruyama [10]. They argue that the plastids of green plants evolved from eukaryotic algae (glaucophytes or red algae) via secondary endosymbiosis. Eukaryotic alga-derived plastids are characteristic for several other protist lineages such as Euglenophyceae, chlorarachniophytes, dinoflagellates, cryptophytes, Ochrophyta, and haptophytes [2].

Multicellularity evolved on multiple occasions within Archaeplastida [11]. Niklas et al. [12] propose a new look at the quantification of complexity in multicellular organisms, including representatives of green plants. In their study they show how the number of possible cell phenotypes increase over evolutionary time, producing significantly more complexity in the structure and function of multicellular plant organism.

In addition to primary endosymbiosis, the second key event in the evolution of Eukaryotic life on the Earth (which also involved archaeplastid representatives), was the invasion of land by one of the green algal lineages. The new environment provided significant challenges for these new inhabitants, such as water stress, UV radiation and lack of mechanical support, resulting in the evolution of interesting adaptations. From this perspective, Banasiak [13] describes evolution of the main components of the cell wall in land plant cells. In turn, Wang et al. [14] review the examples of the impact of horizontal gene transfer on land plant evolution, which include among others, the synthesis of flavonoids and lignins, the origin of vascular tissues, and the evolution of C_4 photosynthesis in Poaceae.

The Archaeplastida persist not only as autotrophs, but also as numerous parasitic forms. Parasites have been found in land plants (e.g. *Cuscuta*, *Epifagus*, *Striga*), green algae (e.g. *Helicosporidium*), and red algae (e.g. *Choreocolax*, *Gracilariophyla*). Salomaki and Lane [15] describe the peculiar cellular strategies used by parasitic red algae during infection of their host cells. All parasitic archaeplastid species contain permanent non-photosynthetic plastids but adelphoparasitic red algae, which are closely related to their hosts, borrow host plastids. A genomic perspective on the transition to parasitism in *Helicosporidium* is offered by Sun and Pombert [16]. The studies on parasitic red and green algae are very important because they offer novel perspectives on the evolution of apicomplexan parasites, which cause such

burdensome diseases as malaria and toxoplasmosis. These parasites contain a non-photosynthetic plastid, known as the apicoplast [17], and it is hypothesized that they have evolved from a *Chromera*-like photosynthetic ancestor [18].

It is still believed that the transformation of endosymbionts into cell organelles is extremely rare. Consequently, the cyanobacterial primary endosymbiosis in the ancestor of Archaeplastida is regarded as a unique organelle birth in the history of life on our planet. A new challenge to this view comes from the thecate amoeba *Paulinella chromatophora*. This protist harbors two cyanobacterium-derived photosynthetic bodies, termed chromatophores, which were acquired independently of primary plastids [19]. It was recently demonstrated that *Paulinella* chromatophores import nuclear-encoded proteins, thus they represent true cell organelles ([20], see also [21]). Taking into account these and other data, Nowack [22] critically reviews the *Paulinella* endosymbiosis in the broader context of the evolution of cell organelles of prokaryotic origin. In further support of the organellar nature of *Paulinella* chromatophores, Gagat and Mackiewicz [23] show that the two distinct strains of *P. chromatophora*, which probably represent separate species, contain the same complement of Tic-like proteins. They also identify, for the first time, the homolog of Tic62 in both *Paulinella* strains. In their review, Nakayama and Inagaki [24] focus on the genome evolution in the N₂-fixing cyanobacterial endosymbionts of diatoms. These endosymbioses are very interesting from the perspective of the primary endosymbiosis in Archaeplastida because the first driving force for the establishment of the engulfed cyanobacterium as the permanent endosymbiont, and then the true cell organelle, could be N₂ fixation [4]. Moreover, it is possible that some of these endosymbionts with highly reduced genomes, such as the cyanobacterial UCYN-A phylotype [24], import proteins encoded by the host nucleus and thus extend the list of cell organelles.

Photosynthetic eukaryotes contain not only plastids but also kleptoplastids [25]. The latter structures are temporary photosynthetic bodies, which are regularly ingested by their hosts, either as the whole cells or as sequestered plastids from their donors. Kleptoplastids occur in numerous protists (true experts in their acquisition are dinoflagellates [25]), but they have also been found in animals such as sea slugs of the genus *Elysia* (see the issue cover). They make of these animals the peculiar plant-like organisms. In their review, de Vries et al. [26] encourage us to look at plastid evolution through the lens of the sea slug's kleptoplastid system.

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Interesting implications of the Archaeplastida world can be found in the last three papers. Olmos and Kargul [27] review applications of artificial photosynthesis in solving the energy problems in our world. In her discussion on RNA world evolution, Szweykowska-Kulińska [28] convinces us that we live, in fact, in a New RNA World, which is visible in archaeplastid cells. In the last paper, which is focused on the future of life on our planet, Mautner [29] regards it as a unique phenomenon and proposes exporting life into space via directed panspermia. If we actually decide to do so in the future, good candidates for such expeditions would be the red algae Cyanidiales, which are well known for dwelling in extreme environments [30].

In the end of this briefing on the content of this issue, we would especially like to thank all the authors who enthusiastically responded to our call and joined the project of showing the plant cell's past, present and perspectives. We are also very grateful to our numerous reviewers who helped us to elevate the quality of submitted papers. The outcome is now to be read and evaluated by the readers.

As for the future, we would welcome both scientific letters on all the topics discussed in the current issue of ASBP and new submissions of papers on plant cell evolution to our journal. One such publication can already be announced: a comprehensive review on glaucophyte algae will appear in one of the next issues of ASBP.

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