Ultrastructure of Differently Pigmented *Synechococcus* Cells

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Synechococcus (*Anacystis nidulans, strain L 1402-1*) were grown at +37 °C in an atmosphere of 0.04 vol.% CO_2 using different light conditions. Changing the culture conditions caused alterations in pigment ratios and ultrastructure of *Synechococcus*. In comparison to the low white and red light grown cells under strong white light the number of thylakoids decreased and an accumulation of storage carbohydrates could be observed. The number of the polyhedral bodies also varied with culture conditions. The results are discussed with reference to the pigment composition and the function of the polyhedral bodies.

Numerous cyanobacteria and algae have been used in several investigations to study the influence of different culture conditions (*e. g.* light intensity, temperature, CO_2 and oxygen concentrations) on physiological processes. We observed in differently pigmented cells of *Synechococcus* a change in pattern of $^{14}CO_2$-fixation [1] and in the content of acyllipids [2]. For this reason we investigated the ultrastructure of these differently pigmented cells of *Synechococcus*.

Synechococcus (*strain L 1402-1*) of the Collection of algal cultures, Göttingen was grown in normal atmospheric air at 37 °C. A variation in pigment density and pigment ratio was obtained by using different light conditions: white light of low (0.6×10^3 erg/cm^2 · s) and high intensity (30.8×10^3 erg/cm^2 · s) as well as red light (> 650 nm; 20×10^3 erg/cm^2 · s). For more details see Döhler [1]. The effects of these culture conditions on the absorption spectrum and pigmentation of *Synechococcus* is shown in Fig. 1. The determined chlorophyll a/phycocyanin ratio was for the red light grown cyanobacteria 1:15. In low white light a pigment ratio of 1:6 was found. In white light of high intensity the content of phycocyanin decreased to 1:2,5. For the ultrastructural investigations the *Synechococcus* cells were fixed after the method of Karnovsky [3] and embedded in ERL.

The different conditions in illuminations during growth resulted not only in a shift of pigment ratio together with effects on metabolism but also led to distinct changes in the ultrastructure of *Synechococcus* cells. Cyanobacteria, cultivated in red light, showed between the parallel arranged, well recognizable thylakoid membranes such a dense package of phycobilisomes, that the latter merge to a compact layer (Fig. 2a). This structural result can be explained with the increase of phycocyanin content in red light. The cells, grown in white light of low intensity, showed in comparison to the red light cultures a slight dispersal in the region of phycobili-

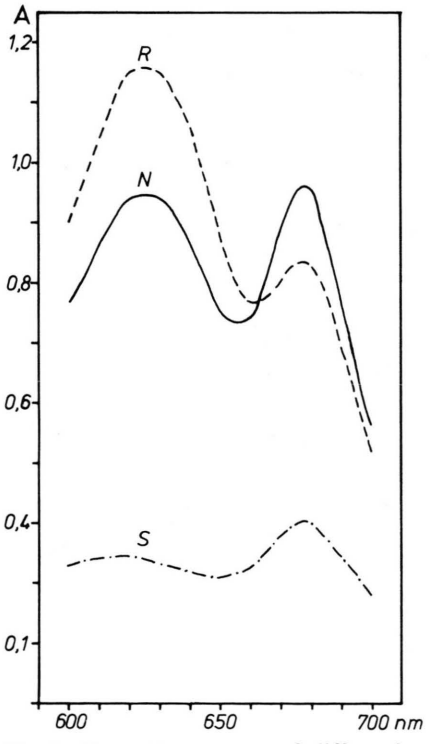

Fig. 1. Absorption spectra of differently pigmented cells of *Synechococcus* (*Anacystis nidulans, strain L 1402-1*): *N* cultivated in white light of low intensity (0.8×10^3 erg/cm^2 · s), *R* cultivated in red light (650 nm, 20×10^3 erg/cm^2 · s), *S* cultivated in white light of high intensity ($30,8 \times 10^3$ erg/cm^2 · s).

Abbreviations: Ph polyhedral body, *PP* polyphosphate granule, *T* thylakoid. Scale bar = 0,5 µm.

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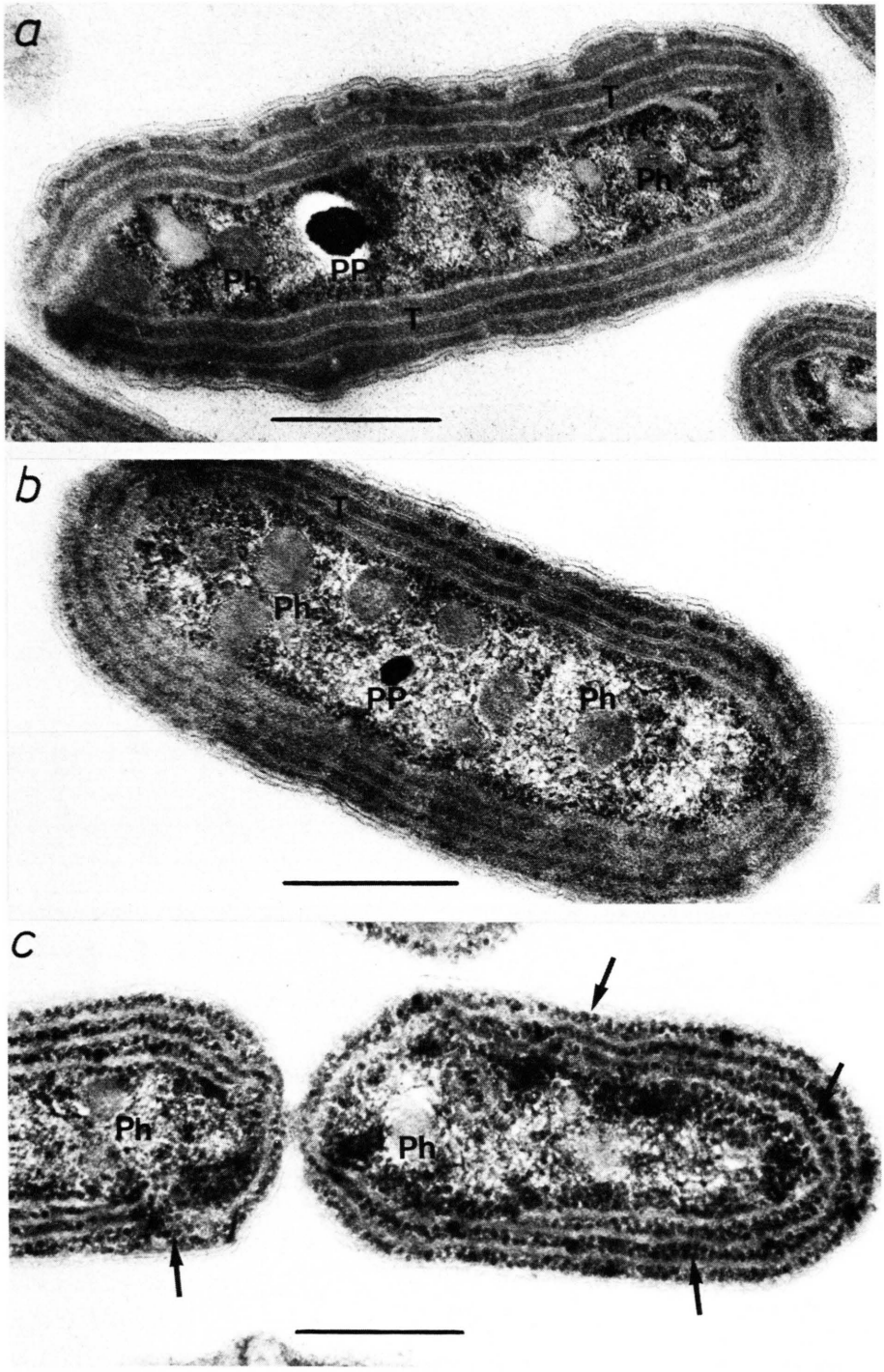

Fig. 2. Electron micrographs of a thin section of *Synechococcus*. *a* grown in red light, × 46000; *b* in white light of low intensity, × 48000 and *c* in white light of high intensity, × 45000. The space between the thylakoids is filled up by granules of storage carbohydrates (arrows).

somes, but in other respects we didn't find any further remarkable difference (Fig. 2b).

In *Synechococcus* cells, grown in high white light, certain differences to red and low white light cultures could be observed. The number of thylakoids running parallel to the cell wall goes down from 3 or 4 to 2 rarely 3 in strong light cultures. The space between the photosynthetic lamellae is filled up by densely packed granules of storage carbohydrates. Obviously the number of phycobilisomes has strongly decreased (Fig. 2c). The low content of phycocyanin in strong light is therefore also remarkable in the cell structure. An accumulation of storage carbohydrates could be expected from the investigations of Döhler [1], who observed a high level of sugar phosphates under strong white light conditions in contrast to the low white and red light *Synechococcus* cultures. With regard to the thylakoids our results agree with the results of Peat and Whitton [4]. They described a decrease in amount and a dispersed arrangement of thylakoids of *Chlorogloea fritschii* after cultivation in white light of high intensity.

Besides the phosphate bodies the polyhedral bodies attract attention. In *Synechococcus* cells, grown in red light and in white light of low intensity, usually 3–5 polyhedral bodies occurred and in the cyanobacteria, grown in high white light, only 1–2 polyhedral bodies were found. Between the number of polyhedral bodies and the measured activity of ribulose-1,5-bisphosphate carboxylase [1] a correlation can be recognized: small number of polyhedral bodies and relatively high RubP carboxylase activity. Codd and Stewart [5] could prove, according to enzyme kinetic investigations and quantitative precipitation of the enzyme, a distinct accumulation of RubP carboxylase in the polyhedral bodies. Shively [6], who investigated the possible function of polyhedral bodies, suggested the name of carboxysomes. Heterocysts of *Anabaena*, which are nearly unable for photosynthetic CO_2 fixation, do not contain carboxysomes [7]. On the other hand, carboxysomes were also noticed in acinetes of cyanobacteria, which cannot carry out photosynthetic CO_2 fixation [7, 8]. This proves a storage function of carboxysomes.

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