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Light gradients in photosynthetic systems of spherical symmetry: theory and experiment

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A theory of light intensity distribution in photosynthetic membrane systems of spherical symmetry is given. An approach based on the use of polar coordinates was adapted for a theoretical description of such vesicles. Examples of the calculated light gradient and created photovoltage as a function of sphere radii and light wavelength are presented. Light-gradient photovoltage measurements were performed on EDTA-treated thylakoids and on smotically swollen thylakoids (blebs), both of spherical symmetry but of different size. In the case of EDTA-vesicles, the negative polarity (due to normal light gradient) was observed in the blue range of the absorption spectrum, while the positive polarity, corresponding to the inverse light gradient was observed at λ=530 and λ=682 nm. The sign of the photovoltage polarity in large blebs (swollen thylakoids) is the same as that obtained for whole chloroplasts, although differences in the amplitudes are observed. Fits to the photovoltage amplitudes measured as a function of light wavelength, enabled a derivation of the values of the dielectric constant of the protein, ε_s=3, and the refractive index of the photosynthetic membrane for light propagating perpendicular and parallel to the membrane surface, n_t=1.42 and n_v=1.60, respectively. The latter two values determine the birefringence of the biological membrane $\Delta n=n_v-n_t=0.18$.