

# On the Discovery of Two Light Reactions and Two Pigment Systems in Photosynthesis: The Emerson Enhancement Effect—Commentary

**Emerson R, Rabinowitch E** (1960) Red drop and role of auxiliary pigments in photosynthesis. *Plant Physiol* **35**: 477–485

I nominate an article of Robert Emerson and Eugene Rabinowitch for inclusion in the “Classics Collection,” as the phenomena described in this article form part of the basis for the “Z-scheme” model of the photosynthetic light reactions. All of us today are familiar with the Z-scheme, the Hill and Bendall scheme of electron transfer from water to NADP<sup>+</sup> in oxygenic photosynthesis. In this article, Emerson’s long-time colleague Eugene Rabinowitch presents the basic background and the first understanding of Emerson’s discoveries of the anomalous “red drop” (Emerson and Lewis, 1943) and of the “Emerson enhancement effect” (Emerson et al., 1957) in photosynthesis, which is the forebear of the concept of two light reactions and two photosystems in photosynthesis. Red drop is the drop-off in photochemical efficiency at wavelengths greater than 680 nm, while the Emerson enhancement effect is that when far-red and red light are combined, the rate of photosynthesis obtained is greater than the sum of rates of photosynthesis at far-red and red light. These together, with the finding that red and far-red light have antagonistic effects on the oxidation and reduction of cytochromes, formed the experimental basis for the proposal of the two sequentially ordered photosystems of the Z-scheme. The first published action spectra of the Emerson effect in four different organisms (a red alga, a green alga, a diatom, and a cyanobacterium), as well as

an understanding and discussion of the phenomenon as known then, are also given. Emerson’s original concepts, of “short-wave” and “long-wave” photosystems, were presented at the 1958 annual meeting of the Phycological Society of America, held at Bloomington, Indiana, and are included only in its News Bulletin (Emerson and Chalmers, 1958). The Emerson and Rabinowitch article was the backdrop that led to many discoveries, including the existence of chlorophyll *a* in the short-wave photosystem (now PSII) of Emerson (Govindjee and Rabinowitch, 1960) and the discovery of the two-light effect and two photosystems through the discovery of the Emerson effect in the NADP Hill reaction, showing that the effect is in photosynthesis, not respiration (Govindjee et al., 1964). This article was published posthumously in 1960, as Emerson had died on February 4, 1959; it was submitted in November 1959.

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