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MITOCHONDRIA DANCE WITH LIGHT: HOW WAVELENGTH CHOREOGRAPHS RESPIRASOMA, NITRIC OXIDE AND OXIDATIVE PHOSPHORYLATION

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The conversion of light energy into chemical energy in chloroplasts and the substrate-dependent oxidation in mitochondria represent the two pillars of eukaryotic bioenergetics, united by an extraordinary architectural homology that reveals their common prokaryotic origin. Although differing in their primary energy input, both organelles exploit a transmembrane proton gradient to drive ATP synthesis via a structurally homologous rotary F_0F_1-ATP synthase. Both share the logic of the electron carrier relay — ubiquinone/-plastoquinone, iron-sulfur proteins, and cytochromes — organized into supercomplexes such as the mitochondria's respirasome (Complexes I, III, and IV) and the photosynthetic PSI–LHCI e PSII–LHCII complex of chloroplasts. The chloroplast is the only eukaryotic compartment in which an ultrafast primary photoreaction occurs. However, a non-stoichiometric photochemical response has been documented in mitochondria, with a non-negligible efficiency of up to 0.2%, compared with 0.5–10% in chloroplasts. In this study, isolated murine liver mitochondria were irradiated at 450, 635, 810, 940, and 1064 nm (0.25–2 W; 1 min; 1 cm^2) and assessed for ATP synthesis rate, O_2 consumption, P/O ratio, Complex I–IV activity, lipid peroxidation, and NOS activity. The results demonstrate that light modulates mitochondrial bioenergetics in a strictly wavelength- and dose-specific manner, with qualitatively distinct response profiles for each wavelength: coupled stimulation, uncoupling, inhibition, and fluence-dependent efficacy windows. The activity of individual complexes reveals distinct photoacceptors along the respiratory chain, with Complex II structurally refractory to photobiomodulation under all conditions. NO production is modulated independently of bioenergetics, with a kinetic dissociation implicating the photostimulation of a putative mitochondrial NOS as an autonomous source of redox signaling. Taken together, the data delineate a complex mitochondrial photobiological landscape in which NO emerges as a photogenerated second messenger that modulates OxPhos through the respirasome.