Photobiology

Photobiology is the study of the effects of non-ionizing radiation on biological systems. The biological effect varies with the wavelength region of the radiation. The radiation is absorbed by molecules in skin such as DNA, protein or certain drugs. The molecules are changed chemically into products that initiate biochemical responses in the cells.

Biological reaction to light is nothing new, there are numerous examples of light induced photochemical reactions in biological systems. Vitamin D synthesis in our skin is an example of a photochemical reaction. The power density of sunlight is only 105 mW/cm² yet when ultraviolet B (UVB) rays strikes our skin, it converts a universally present form of cholesterol, 7-dehydrocholesterol to vitamin D3. We normally experience this through our eyes which are obviously photosensitive - our vision is based upon light hitting our retinas and creating a chemical reaction that allows us to see. Throughout the course of evolution, photons have played a vital role in photo-chemically energizing certain cells.

Photobiomodulation

Mechanism

The current widely accepted proposal is that low level visible red to near infrared light energy is absorbed by mitochondria and converted into ATP for cellular use. In addition, the process creates mild oxidants (ROS) that leads to gene transcription and then to cellular repair and healing. The process also unclogs the chain that has been clogged by nitric oxide (NO).[1] The nitric oxide is then released back into the system. Nitric oxide is a molecule that our body produces to help its 50 trillion cells communicate with each other by transmitting signals throughout the entire body. Additionally, nitric oxide helps to dilate the blood vessels and improve blood circulation.
At the cellular level, visible red and near infrared light energy stimulates cells to generate more energy and undergo self-repair. Each cell has mitochondria, which perform the function of producing cellular energy called “ATP”. This production process involves the respiratory chain. A mitochondrial enzyme called cytochrome oxidase c then accepts photonic energy when functioning below par.

**Pathways**

- **NO (Nitric Oxide)**
- **ROS (Reactive Oxygen Series)** → PKD (gene) → IkB (Inhibitor κB) + NF-κB (nuclear factor κB) → NF-κB (nuclear factor κB stimulates gene transcription)
- **ATP (Adenosine Triphosphate)** → cAMP (catabolite activator protein) → Jun/Fos (oncogenic transcription factors) → AP-1 (activator protein transcription factor stimulates gene transcription)

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**Section II**

**Parameters**
- The correct wavelength

**Section III**

**Brain Bioenergetics**
- Near-infrared light

**Section IV**

**References**
- [1] – “Biphasic Dose”
for the target cells or chromophores must be employed (633-810 nm). If the wavelength is incorrect, optimum absorption will not occur and as the first law of photobiology states, the Grotthus-Draper law, without absorption there can be no reaction.[2] The photon intensity, i.e., spectral irradiance or power density \( (W/cm^2) \), must be adequate, or once again absorption of the photons will not be sufficient to achieve the desired result. If the intensity is too high, however, the photon energy will be transformed to excessive heat in the target tissue, and that is undesirable.[3] Finally, the dose or fluence must also be adequate \( (J/cm^2) \), but if the power density is too low, then prolonging the irradiation time to achieve the ideal energy density or dose will most likely not give an adequate final result, because the Bunsen-Roscoe law of reciprocity, the 2nd law of photobiology, does not hold true for low incident power densities.[4]

stimulates mitochondrial respiration in neurons by donating photons that are absorbed by cytochrome oxidase, a bioenergetics process called photoneuromodulation in nervous tissue.[5] The absorption of luminous energy by the enzyme results in increased brain cytochrome oxidase enzymatic activity and oxygen consumption. Since the enzymatic reaction catalyzed by cytochrome oxidase is the reduction of oxygen to water, acceleration of cytochrome oxidase catalytic activity directly causes an increase in cellular oxygen consumption.[6] Increased oxygen consumption by nerve cells is coupled to oxidative phosphorylation, ATP production increases as a consequence of the metabolic action of near-infrared light. This type of luminous energy can enter brain mitochondria transcranially, and—indepedently of the electrons derived from food substrates—it can directly photostimulate cytochrome oxidase.

Response in Low Level Light Therapy”; Sulbha K. Sharma (PhD), Ying-Ying Huang (MD), James Carroll, Michael R. Hamblin (PhD)

[2, 3, 4] – “Is light-emitting diode phototherapy (LED-LLLT) really effective?”; Won-Serk Kim (PhD, MD), R Glen Calderhead (PhD)

[5, 6, 7] – “Augmentation of cognitive brain functions with transcranial infrared light”; Francisco Gonzalez-Lima (PhD), Douglas W Barrett (MD)

http://vielight.com/photobiomodulation/
Photobiomodulation

Mechanisms of Brain Photobiomodulation

“Low-energy photon irradiation in the near-IR spectral range with low-energy lasers or LEDs positively modulates various important biological processes in cell culture and animal models. Photobiomodulation is applied clinically in the treatment of soft tissue injuries and accelerated wound healing. The mechanism of photobiomodulation by red to near-IR light at the cellular level has been ascribed by research institutions to the activation of cellular mitochondrial respiratory chain components, resulting in a signaling cascade that promotes cellular proliferation and cytoprotection.

Research indicates that cytochrome c oxidase is a key photo-acceptor of irradiation in the far-red to near-IR spectral range. Cytochrome c oxidase is an integral membrane protein that contains multiple redox active metal centers and has a strong absorbency in the far-red to near-IR spectral range detectable in-vivo by near-IR spectroscopy.

Additionally, photobiomodulation increases the rate of electron transfer in purified cytochrome oxidase, increasing mitochondrial respiration and ATP synthesis in isolated mitochondria, and up-regulating cytochrome oxidase activity in cultured neuronal cells – leading to neuroprotective effects and neuronal function.

In addition to increased oxidative metabolism, red to near-IR light stimulation of mitochondrial electron transfer is known to increase the generation of reactive oxygen species (ROS). ROS functions as signaling molecules, providing communication between mitochondria and the nucleus.”[1]

Photobiomodulation

neuronal stimulation