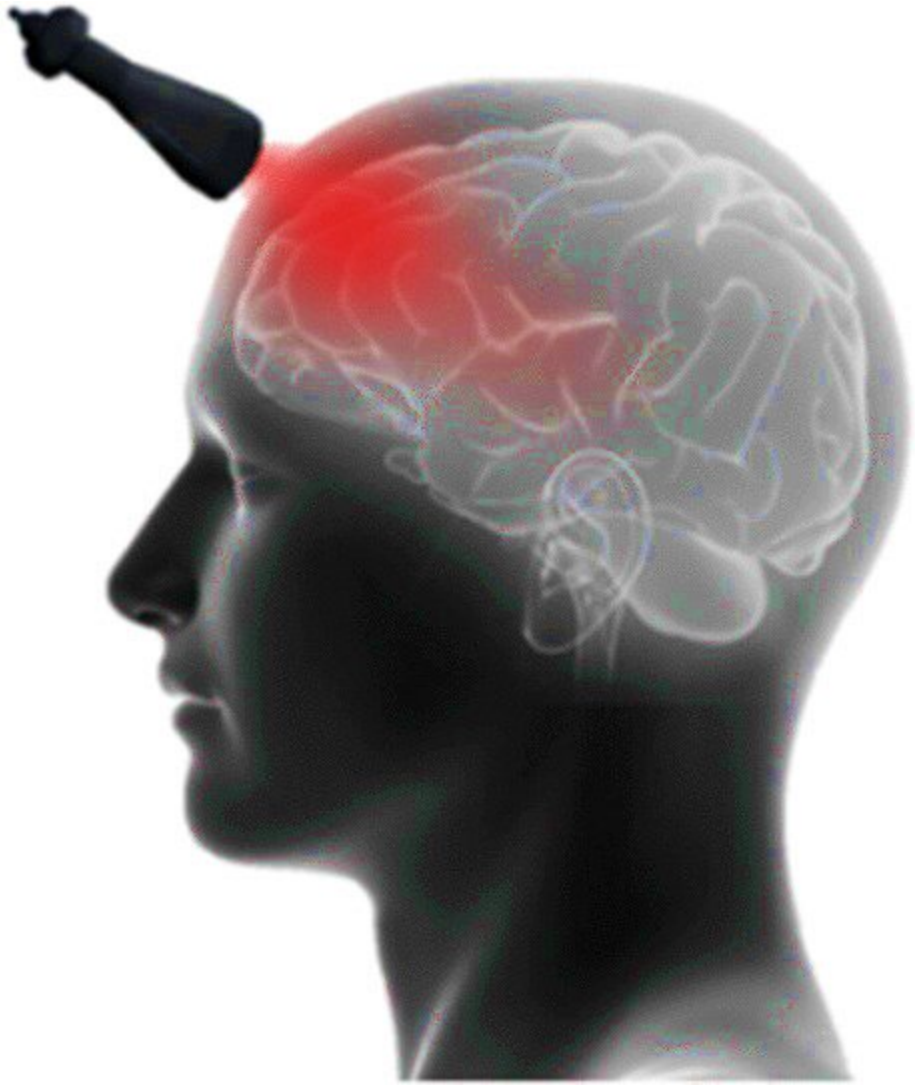


photobiomodulation shapes brain networks and function

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subjects

History of photo
introduction
Cellular Mechanism of PBM
Gated Channels in
Photobiomodulation
Systemic Mechanisms of tPBM
PBM and Brain
Effects of PBM on the Brain
tPBM and Brain deases
tPBM and Ischemic stroke /
traumatic brain injury (TBI)
tPBM and Alzheimer’s Disease
tPBM and Parkinson’s Disease
tPBM and cronic stress
tPBM for Aging
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history

light treatment has roots in ancient Egypt, India, and Greece, as "heliotherapy“

(natural sunlight) for the treatment of skin diseases.



history

Niels Finsen, Danish biologist : the father of modern phototherapy.

He developed the UV light to treat lupus vulgaris.

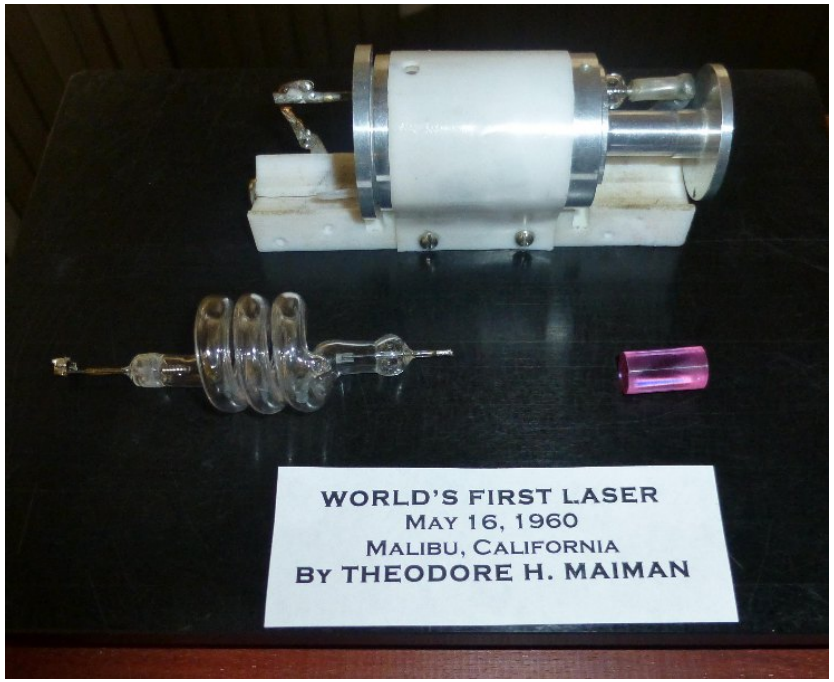
His research was motivated by having Niemann-Pick disease, and noting that his health benefited from going out in the sun

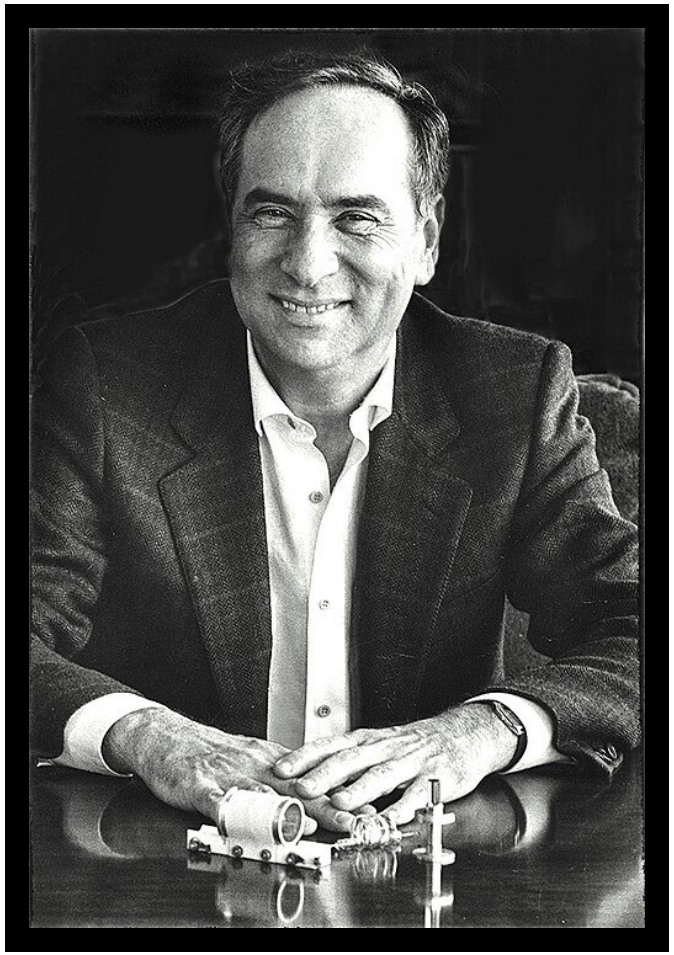
He received the Nobel Prize in Physiology in 1903.



history

Theodore Maiman was able to introduce the laser to the world in 1960.
he went to Stanford University and, defended his doctoral dissertation in physics.





History

Endre Mester, M.D. (1903–1984), known as the ‘Father of Photobiomodulation,” discovered the biological effects of low-power lasers and published his findings in 1967.

A tumor that had been surgically implanted into a cancerous lab rat was destroyed by a beam from the newly discovered ruby laser used by McGuff. The laser made for Mester was not as powerful as the laser McGuff had used.

Mester observed that the hair in the exposed areas grew faster than that of the control group. Mester conducted further experiments to investigate whether low-power lasers could also accelerate the healing process of damaged skin.

In animal studies, signs of more rapid wound healing were observed.



introduction

Light is a form of electromagnetic radiation.

This radiation can be described as packets of energy called photons.

A photon is a quantum packet of light energy;

the energy of each photon depends on its frequency.

Wavelength is the distance between two consecutive peaks of a wave.

Frequency is the number of wave oscillations per second, measured in hertz

shorter wavelength, greater radiation energy.

introduction

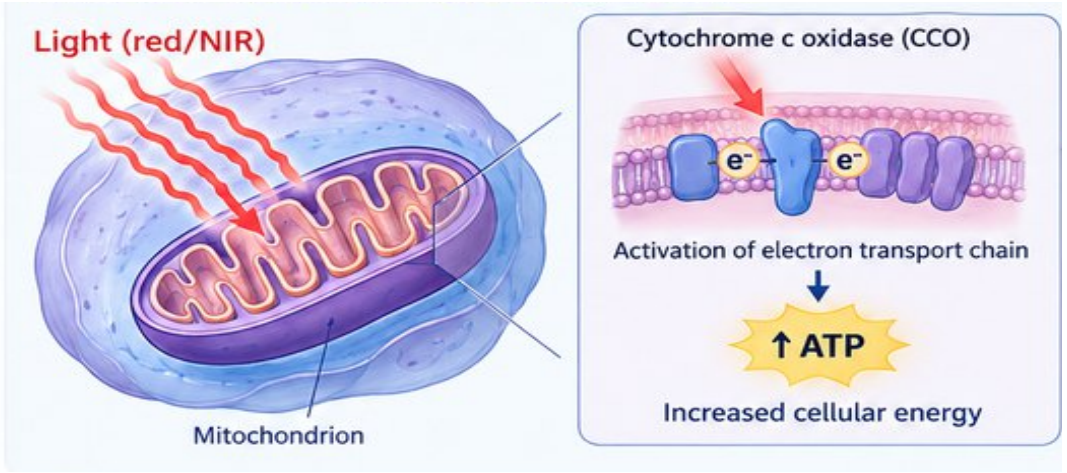
Photobiomodulation (PBM) : use of relatively low-intensity light to induce biological changes in cells and tissues for therapeutic purposes .In older literature, the term "Low-Level Laser Therapy" (LLLT) was also used for this method.

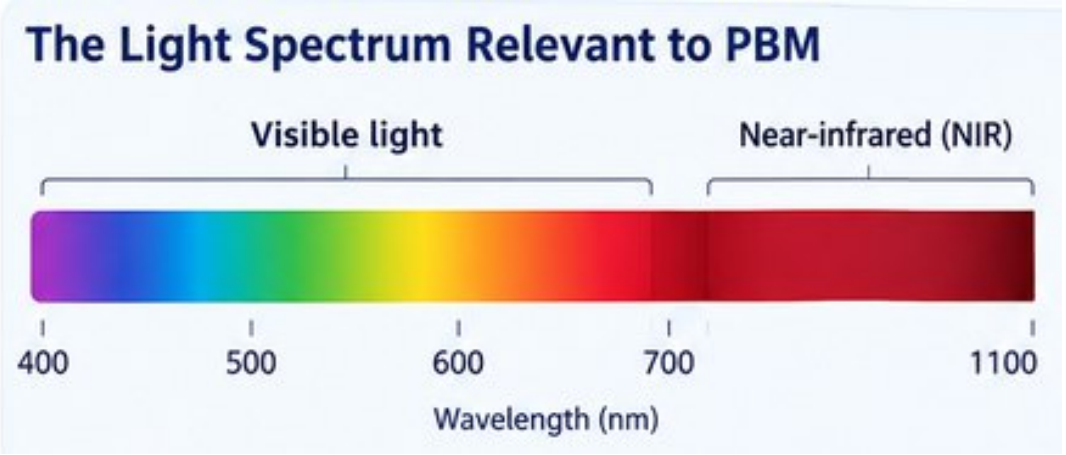
Red light: 600–700 nm

Near-infrared (NIR): 700–1100 nm for deeper tissue

) Longer wavelengths have less scattering.(

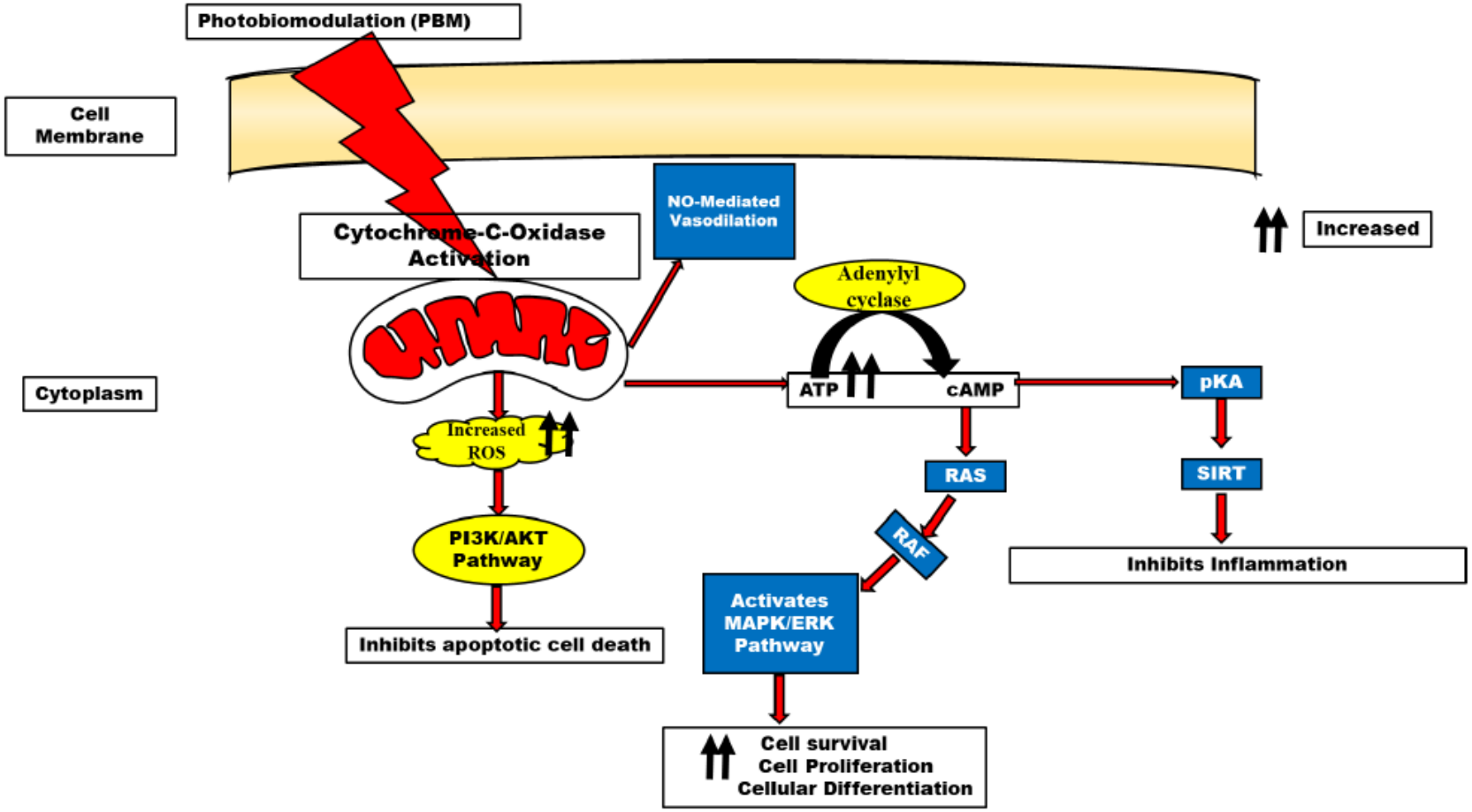
At appropriate parameters, PBM is intended to modulate biological activity without causing destructive tissue damage

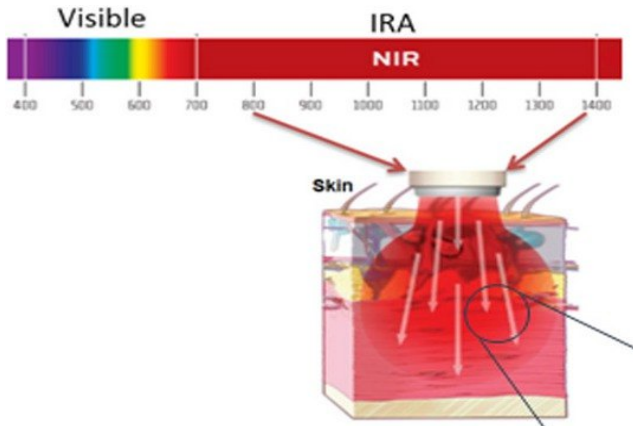




Cellular Mechanism of PBM

side effects.





NIR Light
(800-1400 nm)

Mitochondria

Respiratory chain

NO

PKD

ROS

Redox signaling

ATP

Ca^{2+} Secondary messenger

cAMP

NF-kB

Transcription

AP-1

Jun/Fos

Nucleus

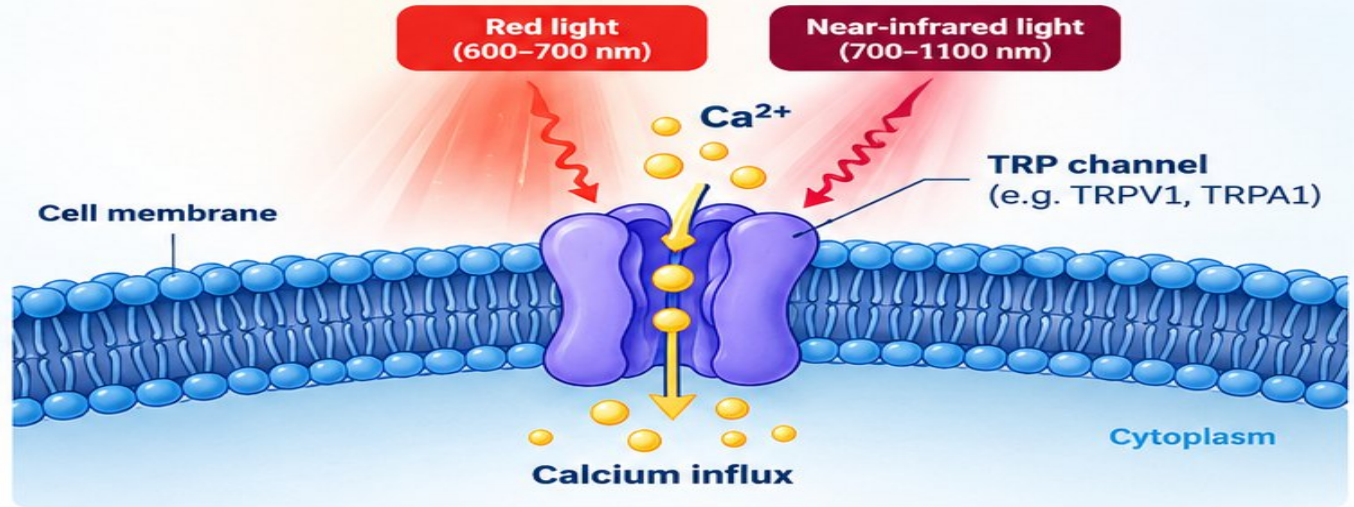
- Growth factor production
- Cell proliferation
- Extra cellular matrix deposition
- Cell mobility/ adhesion
- Cell survival
- Inhibition of apoptosis

The Role of TRP Channels in Photobiomodulation (PBM)

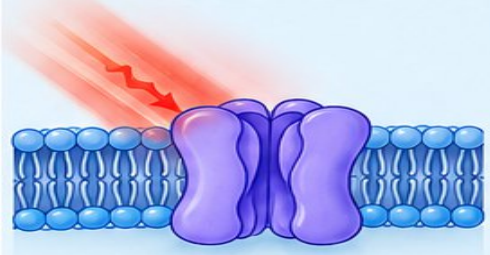
What are TRP channels?

TRP (Transient Receptor Potential) channels are a family of ion channels in cell membranes. They work as sensors for different stimuli, including temperature, chemicals and light.

In PBM, certain TRP channels (especially TRPV1 and TRPA1) can be activated by **red and near-infrared** light, leading to calcium influx and downstream beneficial effects.

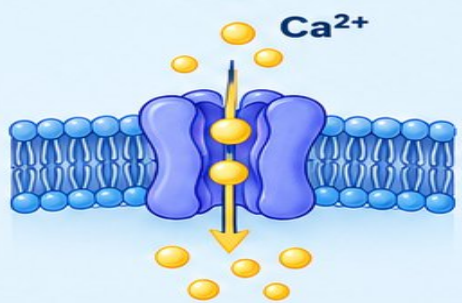


1 Light activates TRP channels



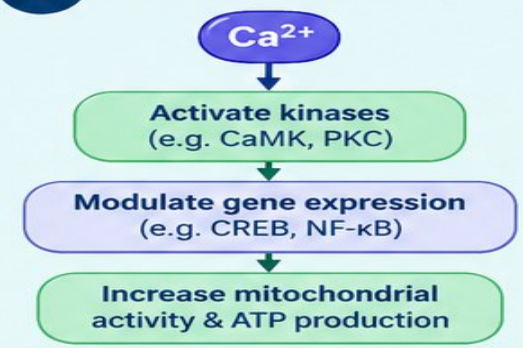
Red or NIR light is absorbed by cellular chromophores and can activate TRP channels (especially TRPV1 and TRPA1) in the membrane.

2 Calcium enters the cell



Activation of TRP channels leads to an influx of Ca^{2+} ions into the cell.

3 Cellular responses



The rise in intracellular Ca^{2+} triggers signaling pathways that affect cell survival, metabolism and inflammation.

4 Therapeutic effects



- More ATP production
- Reduced inflammation
- Enhanced neuroplasticity
- Improved blood flow (in some cases)

These changes can support neuron function and repair, which may contribute to the beneficial effects of PBM in the brain.

In simple words:

TRP channels act like light-sensitive switches on the cell membrane. When red or near-infrared light hits them, they open, calcium enters the cell, and this kick-starts a series of beneficial cellular processes.

Important notes

- Not all TRP channels are involved; TRPV1 and TRPA1 are the most studied.
- The exact mechanisms can vary depending on wavelength, dose and tissue.
- PBM does not just act on TRP channels; it also affects mitochondria, oxidative stress, and other pathways.

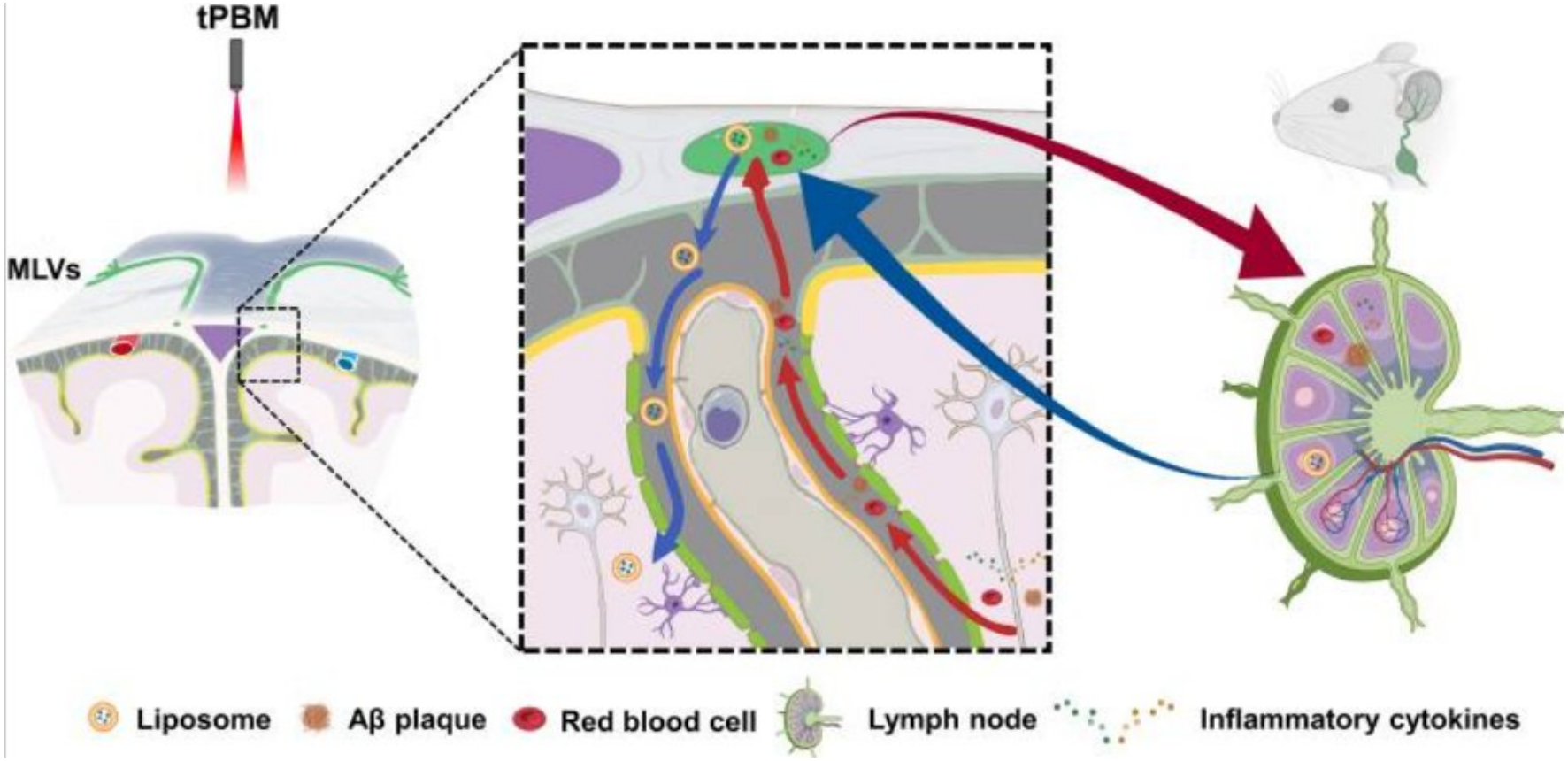
Systemic Mechanisms of tPBM

The brain possesses a waste clearance system (BWRS) that transports waste products and toxins to the cervical lymph nodes via meningeal lymphatic vessels (MLVs). tPBM can enhance the activity of this system.

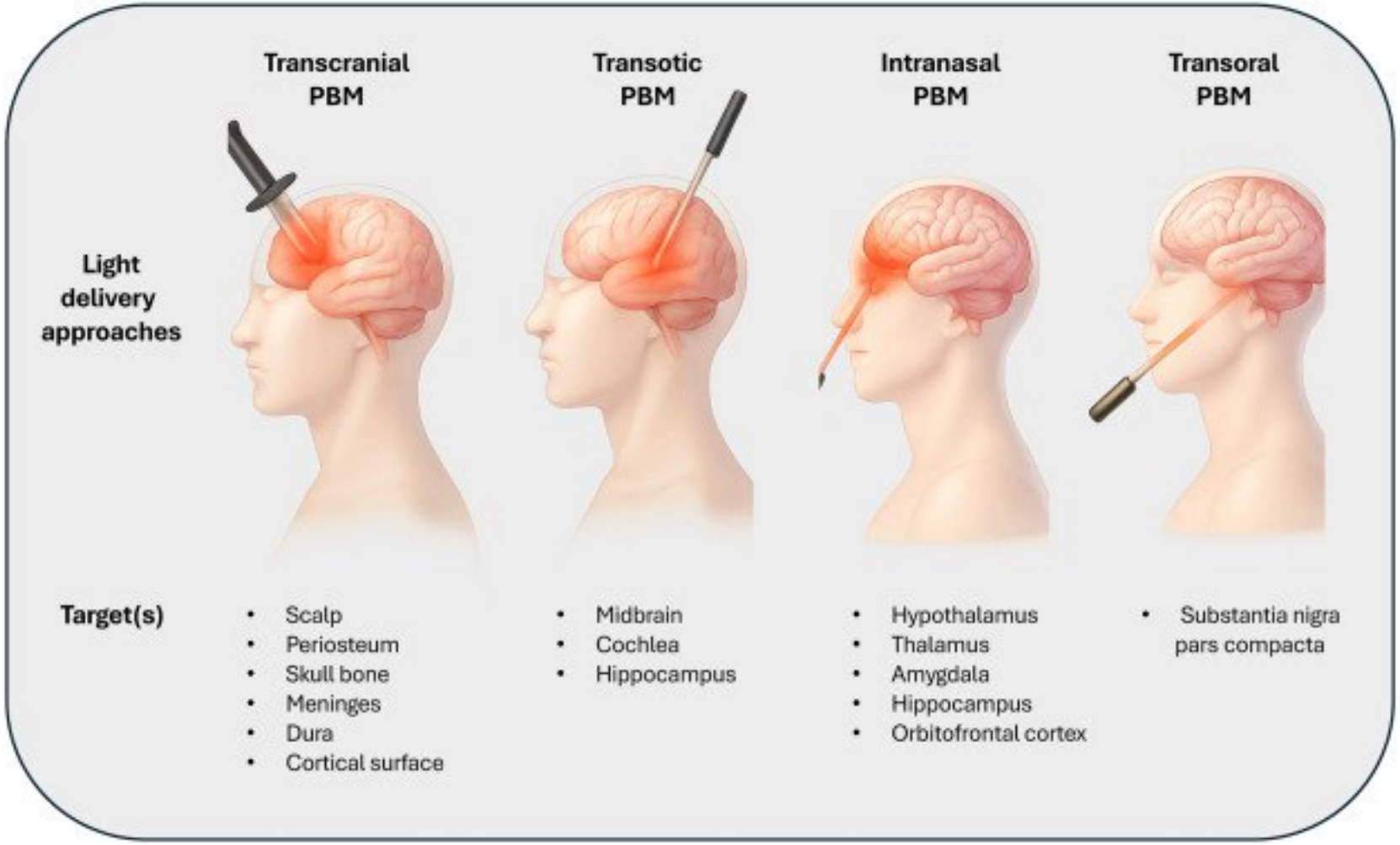
What happens?

1. Relaxation of the endothelium in meningeal and mesenteric lymphatic vessels
2. PBM reduces tight junction (TJ) proteins.
3. Lymphatic vessels function like a pump. The NO generated by PBM improves this pumping action.

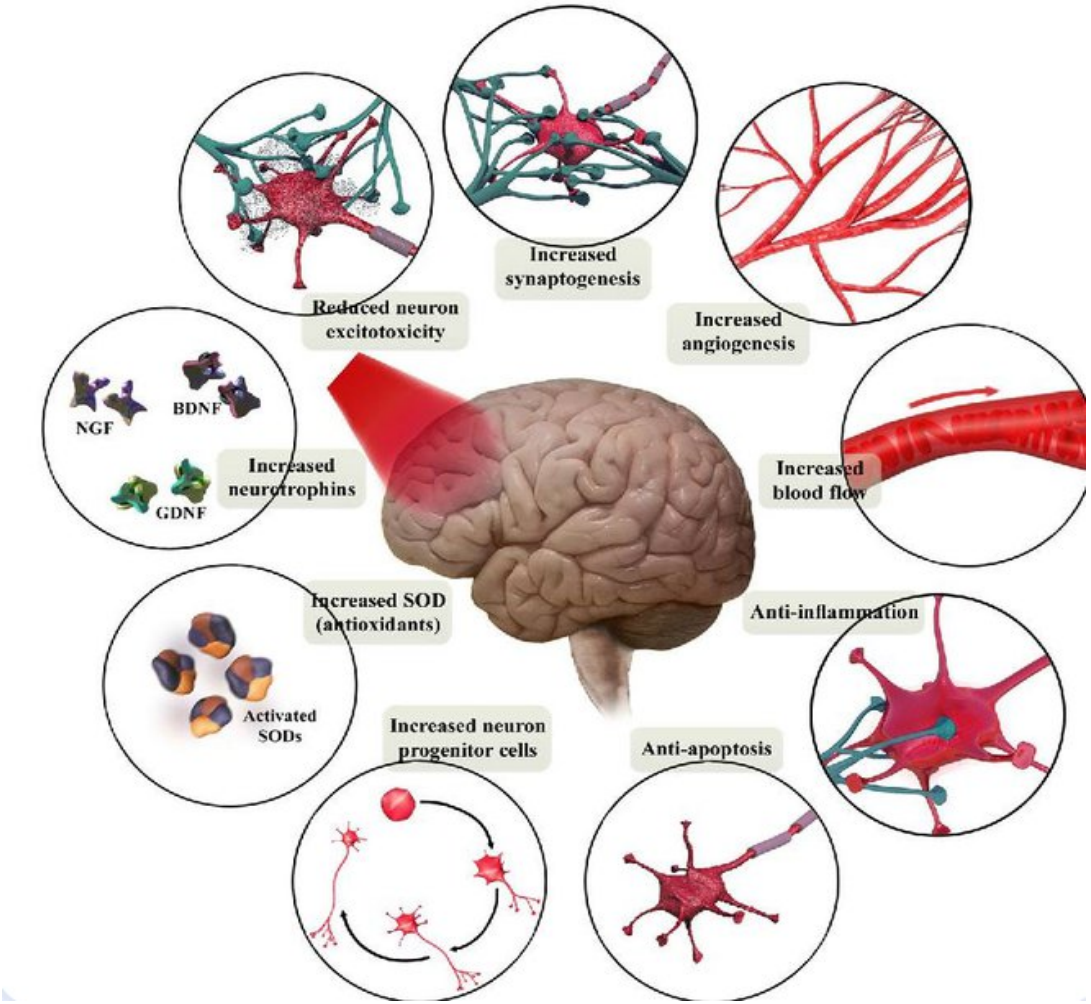
Systemic Mechanisms of tPBM



PBM and Brain



Effects of pbm on the Brain



tPBM and Brain deases

stroke

traumatic brain injury (TBI)

Alzheimer's disease (AD)

Parkinson's disease

Depression , anxiety, PTSD

Cognitive enhancement

Hypoxic-Ischemic

Intracerebral Hemorrhage

Multiple Sclerosis (MS)

Aging

Epilepsy

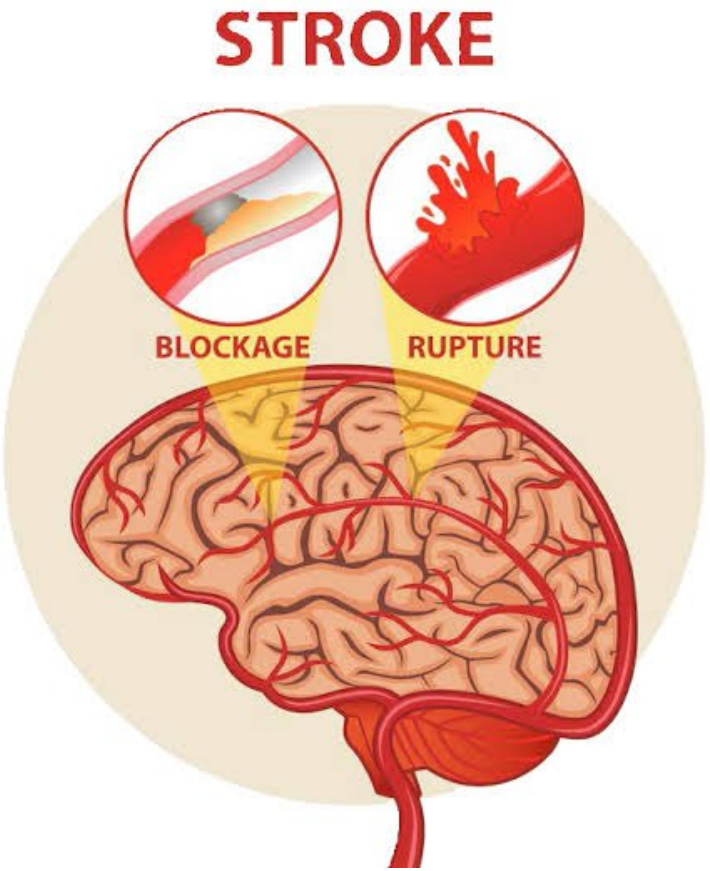
tPBM and Ischemic stroke / traumatic brain injury (TBI)

mitochondria are damaged during ischemia and trauma.

Tpbm → cellular energy can be restored . → neurons at risk of death can be saved

In a mouse model of TBI, 810-nm irradiation increased BDNF levels

in the dentate gyrus and was associated with synaptogenesis.



tPBM and Alzheimer’s Disease

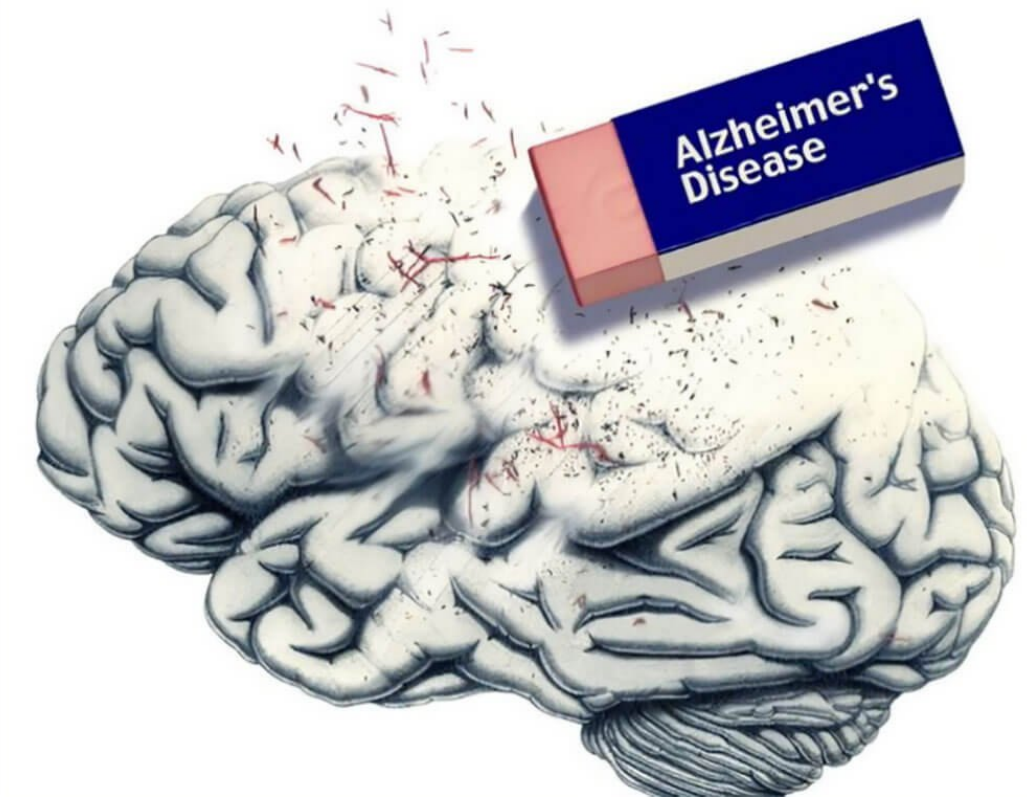
The amyloid cascade and A peptide in the brain is a central event in disease pathology,

-tPBM (1267 nm),especially during deep sleep → lymphatic removal significant reduction of Aβ plaques in the hippocampus CA1 region

-tPBM (633 nm) shifted the amyloid precursor protein (APP) processing toward the nonamyloidogenic pathway by activating **Sirtuin 1 protein**

-In clinical trials,the application of tPBM (1060 to 1080 nm)

for 28 consecutive days improved cognitive and memory ability in AD patients



tPBM and Parkinson's Disease

It is characterized by the loss of dopaminergic neurons in the substantia nigra.

mitochondrial dysfunction, oxidative stress, and protein mishandling have a central role

numerous studies demonstrated that tPBM (670 and 810 nm) effectively alleviated PD pathology in PD mouse model.

In clinical. found that tPBM (635 nm plus 810 nm LEDs) could safely and meaningfully improve individual motor signs of PD.

importance the effectiveness of treating the abdomen and the brain with PBM (gut/brain axis) in PD.

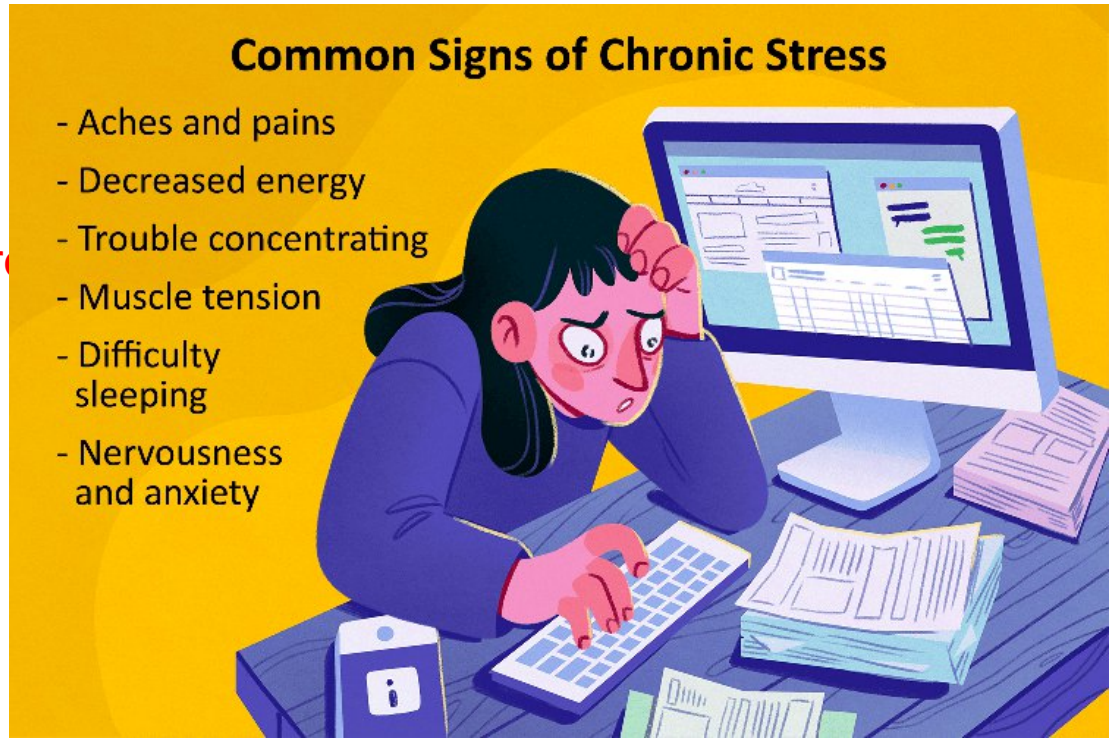
Other light delivery strategies :such as neck and intranasal PBM, were also used in combination with tPBM for clinical PD treatment

tPBM and cronic stress

Cronic stress leads to the continuous secretion **of cortisol** (keeping the HPA axis ac → Stressed mitochondria produce free radicals (ROS) this state is known as **oxidative stress** damage neurons and activate → oglia **neuroinfla → ation** .

disrupt : serotonin, dopamine, and noradrenaline →

1. weakening the hippocampus (memory) and
2. the prefrontal cortex (decision-making and emotional contr



tPBM and cronic stress

Under stress, the NO molecule binds to CCO and slows it down, Light detaches this NO, so ATP produces again and releasing released NO improving blood flow.

Increased energy and reduced oxidative :

1. Microglia become calmer, and inflammation decreases.
2. Levels of serotonin and other neurotransmitters improve.
3. Cortisol levels decrease(according to some studies.)

The 10 Hz pulsed infrared laser was as effective as the drug citalopram

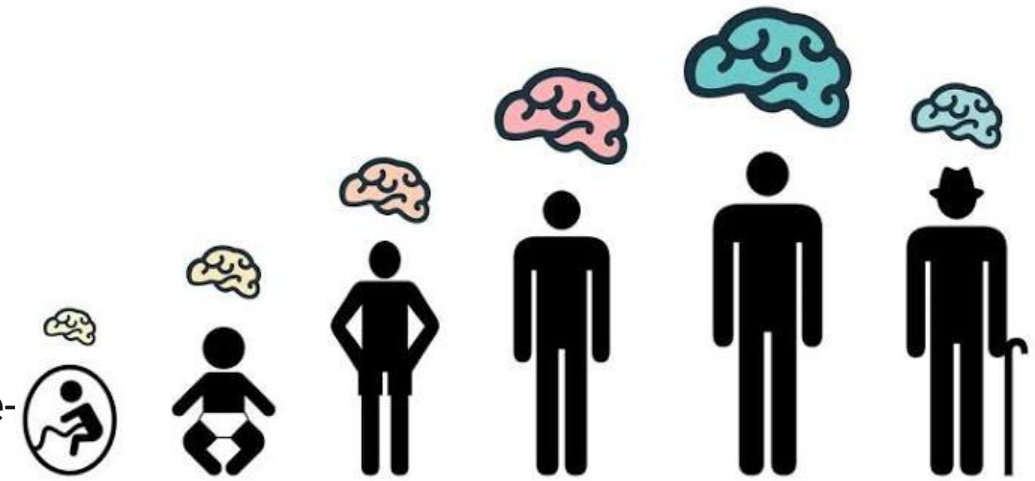
The mice received light exposure on both their heads and abdomens . → gut microbiome also affects the brain.

tPBM for Aging

important factors associated with aging :

Oxidative stress and **mitochondrial dysfunction**

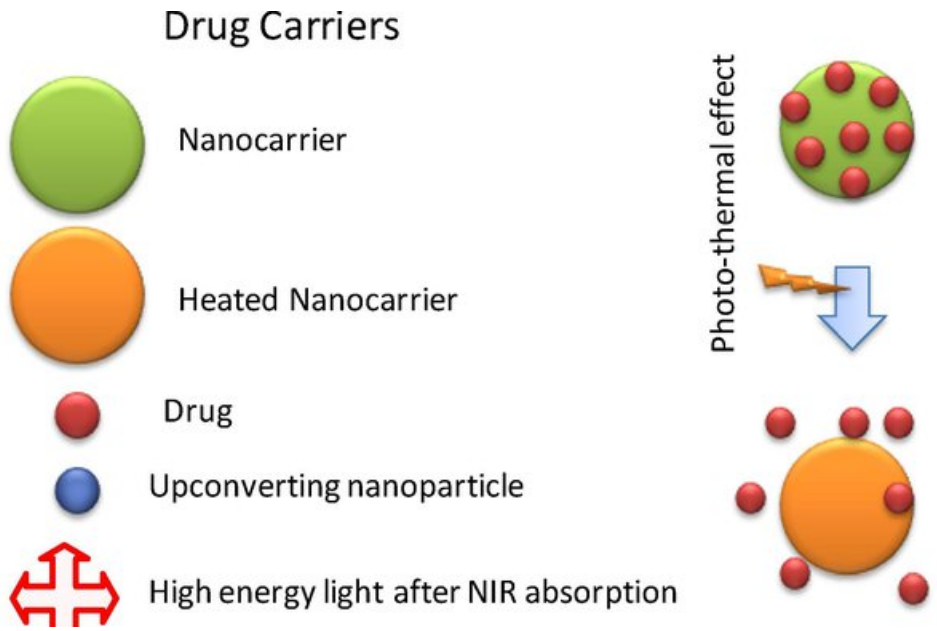
1. transcranial red (660 nm) and NIR (810 nm) light treatment alleviated memory and cognitive decline, mitochondrial dysfunction, oxidative stress, and cell apoptosis in the aging mouse model.
2. tPBM (670 nm) had beneficial effects on the inhibition of age-related glial cell (e.g., astrocyte and microglia) proliferation.
3. aging :decrease of regional brain CCO activity . observed that tPBM mitigated the inflammatory response, vascular function, cell survival, and glucose metabolism in the aged brain



tPBM and nano technology

The idea is that the nanoparticle should not merely act as a drug carrier; rather, it should absorb light and, in response, release the drug or alter the cell.

1. Controlling the timing of drug release
2. using lightAbility to tune light absorption at a specific wavelengt
3. Improved targeting of specific cells or regions
4. Combining drug delivery with a light-responsive mechanism



What are the side effects of tPBM?

In human tPBM studies, reported adverse effects have generally been mild:-

Headache

Sensation of warmth

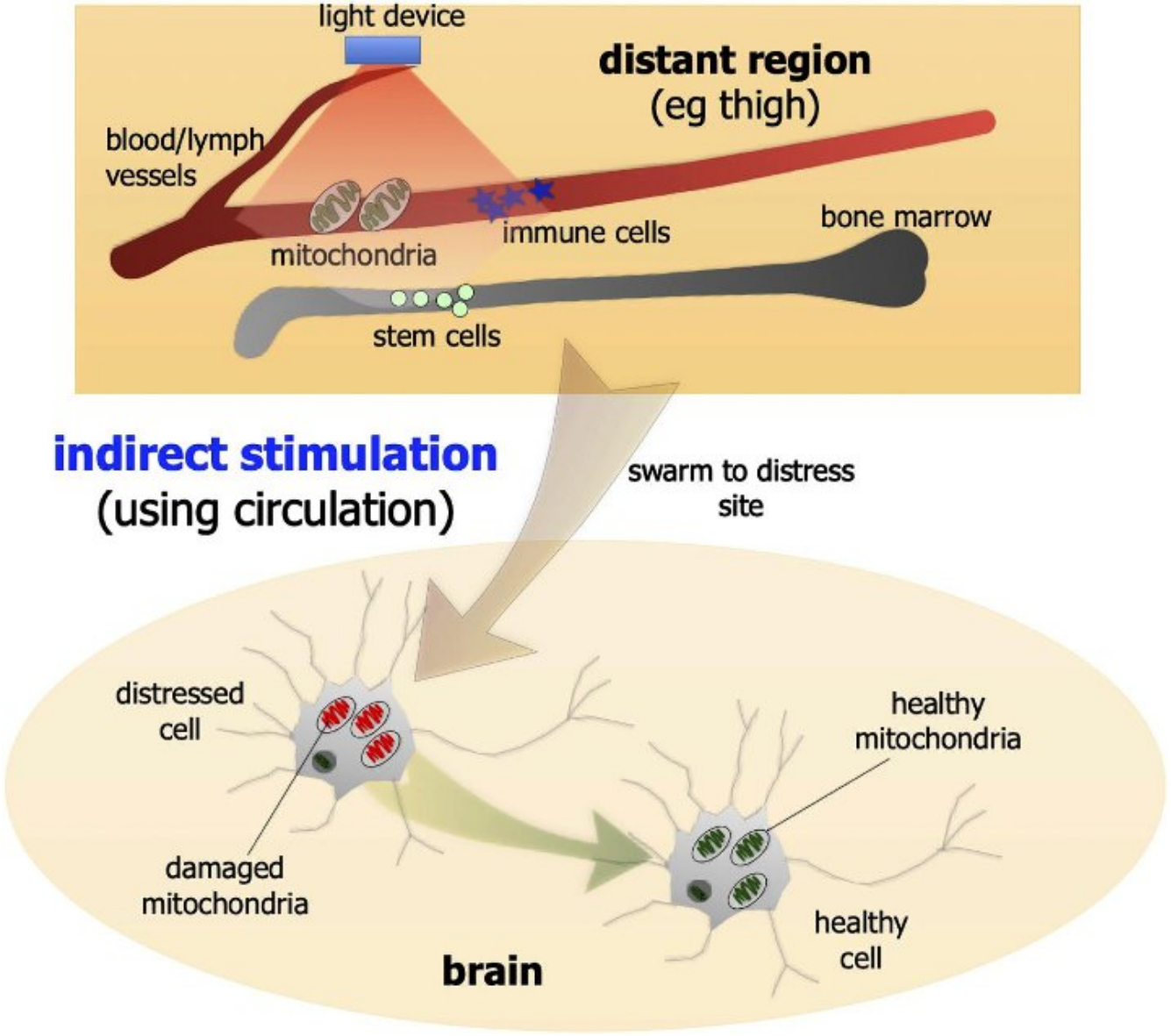
Fatigue

Sleep disturbances

Irritability or mood changes

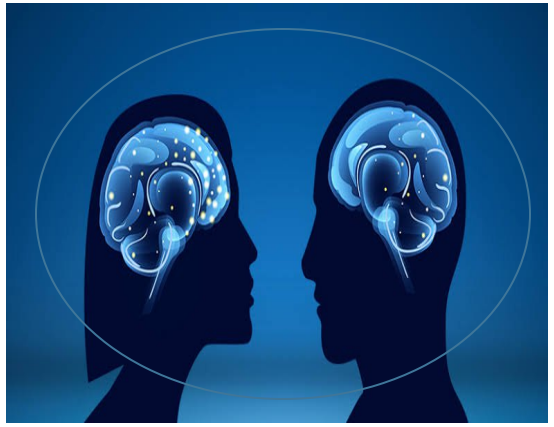
Tinnitus or seeing unusual colors

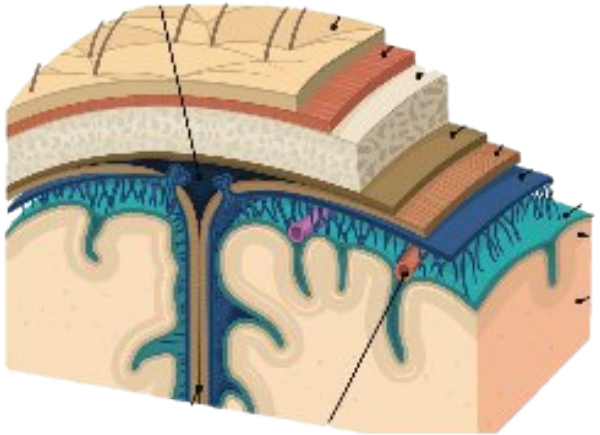
Remote/Systemic PBM

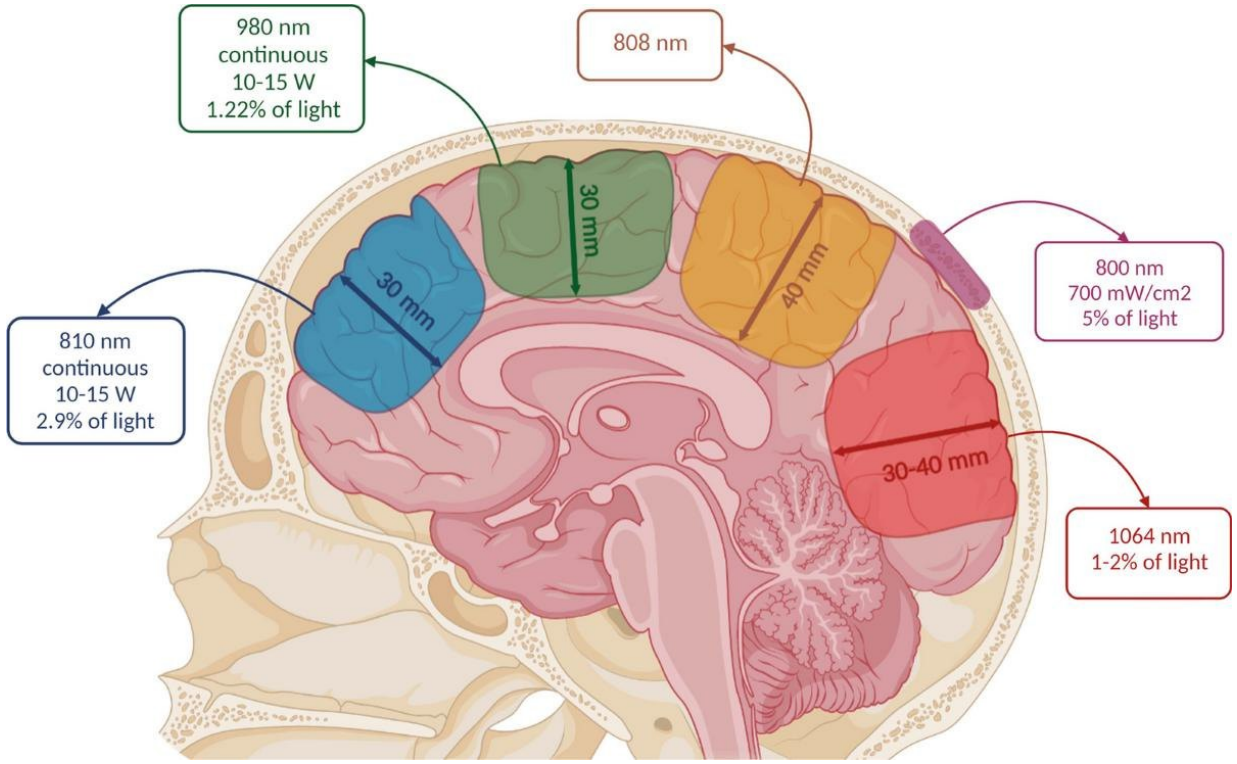


Chalenges

1. Limited light penetration through the scalp and skull
2. Uncertainty regarding the optimal dose (dosimetry)
3. Individual and Anatomical Differences
4. The difficulty of targeting deep brain regions
5. Differences Between Devices
6. measuring actual light penetration in the brain







Physical parameters in pbm

Wavelength (nm)

Optical power (W or mW)

Irradiance (W/cm² or mW/cm²)

Fluence / radiant exposure (J/cm²) =Irradiance (W/cm2)×Time (s)

Spot size and illuminated area

Exposure time

Continuous-wave vs pulsed light

Pulse frequency and duty cycle

Number of sessions and interval between sessions

Target site and tissue penetration

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Thanks!