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Nature's Marvel: Human Eyes Harness the Power of Photosynthesis

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INTRODUCTION

For centuries, photosynthesis has been regarded as a remarkable ability found only in plants, algae, and a few microorganisms. It is the natural process through which sunlight is converted into chemical energy, sustaining almost all life on Earth. But what if a small part of this extraordinary plant machinery could be borrowed to help heal damaged human tissues? This fascinating idea is no longer limited to science fiction. Researchers at the National University of Singapore (NUS) have developed an innovative technology that allows mammalian eye cells to temporarily use plant-derived photosynthetic components to repair damaged tissues. Instead of making animals capable of producing their own food like plants, scientists extracted tiny photosynthetic structures from spinach leaves and delivered them into injured corneal cells. Once exposed to ordinary visible light, these miniature "solar engines" generate energy-rich molecules that help damaged cells fight oxidative stress and accelerate healing (Shi et al., 2025).

The discovery offers a completely new way of treating eye diseases. Disorders such as severe dry eye disease and corneal injuries are often driven by excessive production of reactive oxygen species (ROS), which damage cellular proteins, lipids, and DNA. As oxidative stress increases, the natural antioxidant defenses of the eye become exhausted, inflammation worsens, and tissue repair slows dramatically. Existing therapies, including artificial tears, anti-inflammatory drugs, and corticosteroids, mainly reduce symptoms without addressing the underlying energy shortage within damaged cells. The newly developed LEAF (Light-reaction Enriched thylakoid NADPH-Foundry) system takes a different approach by supplying therapeutic energy directly where it is needed, using nothing more than ordinary ambient light (Shi et al., 2025; Craig et al., 2017).

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How Photosynthesis Helps Human Eye Cells

The LEAF technology is inspired by one of nature's most efficient energy-producing systems the photosynthetic thylakoid membranes found inside spinach chloroplasts. These membranes contain the molecular machinery responsible for capturing sunlight and converting it into usable cellular energy. Scientists carefully isolated intact thylakoid structures from fresh spinach leaves while removing the components responsible for sugar production. As a result, the engineered particles retain only the light-dependent reactions of photosynthesis, making them suitable for medical applications rather than food production (Shi et al., 2025).

The purified thylakoids are then enclosed within transparent nanoparticles measuring about 400 nanometres in diameter. Their extremely small size enables them to penetrate the corneal surface efficiently after being administered as simple eye drops. Once inside corneal epithelial cells, these nanoparticles behave like temporary "neo-organelles", functioning alongside the cell's natural components without disrupting normal cellular activities. When the treated eye is exposed to normal indoor lighting or sunlight, chlorophyll molecules within the transplanted thylakoids absorb light energy and initiate the first stage of photosynthesis. During this process, electrons move through Photosystem II, the cytochrome b6f complex, and Photosystem I, leading to the production of two essential molecules ATP, which serves as the cell's energy currency, and NADPH, a powerful reducing molecule that protects cells against oxidative damage (Nelson & Yocum, 2006).

The newly generated NADPH immediately strengthens the antioxidant defense system of corneal cells by neutralizing harmful reactive oxygen species, including hydrogen peroxide. Experimental studies showed that the LEAF nanoparticles eliminated more than 95% of intracellular oxidants, thereby preventing damage to proteins, lipids, and DNA that would otherwise impair cell survival. As oxidative stress declines, inflammatory signalling pathways are also suppressed. The treatment reduces the production of pro-inflammatory cytokines while encouraging immune cells in the cornea to adopt a tissue-repairing rather than tissue-damaging role. This shift creates an environment that supports rapid healing and restoration of normal ocular function.

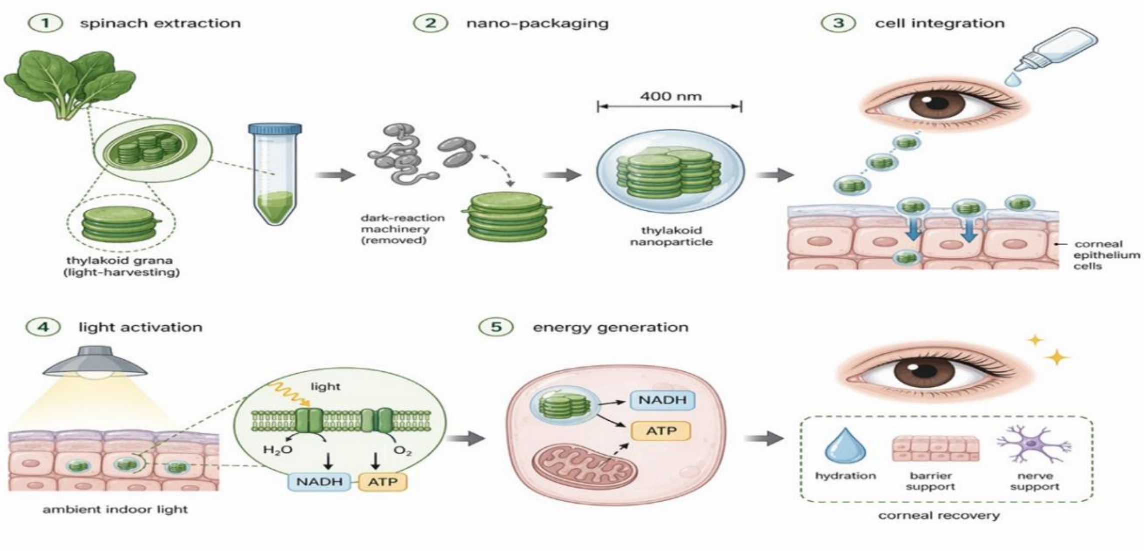

Fig 1. Mechanism of "LEAF" Nanoparticle System, Source: AI generate

The effectiveness of the technology was demonstrated in preclinical studies using mice with severe dry eye disease. Animals treated with LEAF eye drops showed significant improvement within just five days. Tear production recovered to near-normal levels, inflammation decreased markedly, and damaged corneal tissues regenerated without any detectable signs of toxicity (Shi et al., 2025). It is important to note that this technology does not make animals capable of performing complete photosynthesis. The transplanted plant components remain confined to the treated tissue and generate only ATP and NADPH for local cellular repair. They do not produce glucose or replace the need for normal nutrition, meaning the treated animals still rely entirely on conventional food for survival (Shi et al., 2025).

Potential Applications

Although the LEAF system was originally designed to treat diseases of the eye, its potential applications may extend far beyond ophthalmology. Since oxidative stress and chronic inflammation contribute too many degenerative disorders, researchers believe this light-powered technology could eventually become a versatile platform for regenerative medicine.

The most immediate application is the treatment of corneal diseases, including severe dry eye syndrome, corneal ulcers, chemical burns, and ocular surface injuries. By restoring intracellular ATP and NADPH levels, LEAF nanoparticles can accelerate tissue repair while reducing inflammation and oxidative damage. Researchers also envision adapting the technology for retinal disorders, such as age-related macular degeneration (AMD) and inherited retinal diseases. Because oxidative stress plays a central role in retinal degeneration, localized photosynthetic bioenergetics may one day help protect retinal neurons and preserve vision, provided efficient light delivery and targeted nanoparticle transport can be achieved (Beatty et al., 2000; Shi et al., 2025).

Beyond ophthalmology, the technology may prove valuable in skin wound healing. Chronic wounds, diabetic ulcers, burns, and ultraviolet-induced skin damage all involve elevated oxidative stress and impaired cellular metabolism. By generating ATP and NADPH directly within damaged tissues, LEAF nanoparticles could accelerate tissue regeneration, stimulate collagen production, and improve the overall wound-healing process (Sen, 2009; Shi et al., 2025). Another promising application involves skeletal muscle regeneration. Local injection of photosynthetic nanoparticles into injured muscles could reduce oxidative damage following trauma, surgery, or intense physical exercise while supplying additional energy required for tissue repair (Shi et al., 2025).

More broadly, the LEAF platform introduces an entirely new concept in cross kingdom synthetic biology, where biological components from plants are temporarily integrated into animal cells to enhance their natural healing capacity. In the future, similar biohybrid systems could be developed to treat neurological disorders, cardiovascular diseases, or other conditions in which oxidative stress limits tissue regeneration (Shi et al., 2025).

CONCLUSION

The LEAF nanoparticle system marks an exciting milestone in synthetic biology, nano medicine, and regenerative medicine. By borrowing one of nature's most efficient energy-conversion systems from spinach, scientists have shown that ordinary visible light can be transformed into a therapeutic tool for repairing damaged eye tissues. Instead of simply relieving symptoms, this technology directly restores the cellular energy and antioxidant capacity needed for healing. Despite dramatic headlines suggesting that animals can now "photosynthesize," the reality is far more practical and scientifically exciting. The technology does not allow mammals to survive on sunlight or produce their own food. Rather, it provides localized, light driven bioenergetic support that helps damaged cells recover more efficiently. Although further clinical studies are needed before this approach reaches patients, the remarkable success observed in preclinical models suggests that plant-inspired bioengineering may open an entirely new chapter in the treatment of eye diseases and many other oxidative stress-related disorders (Shi et al., 2025).

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