# Optogenetic Innovations & Opportunities

The labyrinthine structure and underlying processes of the human brain remain among biology's most fascinating enigmas. Springing from the investigations of neurobiologists over the past several decades is the exciting realm of optogenetics, a subfield of synthetic neurobiology. Optogenetics harnesses the power of light to control and monitor specific neurons within living tissue. This is proving a powerful tool, showing promise in a wide spectrum of disease and dysfunction (Deisseroth, 2006) including the amelioration of the symptoms of Leber Congenital Amaurosis and Macular Degeneration. A breakthrough in the application of optogenetics was first demonstrated successfully in 2002 by Boris Zemelman and Gero Miesenböck. Active research is currently focused on optimizing techniques and procedures (Zemelman, 2002). We have joined as a team called the Synthetic Neurobiology Group, or SyNG, to develop new applications for the innovative tools of optogenetics. SyNG has decided to focus upon applications that include screening patients, mapping the brain, and revolutionizing virtual reality for future research.

Optogenetics has evolved into a powerful and versatile tool with potential applications beyond the brain and extending throughout the human body. Our team first investigated a study using optogenetics to determine the cardiac conditions after a heart attack (Ambrosi, 2014). SyNG proposes to further apply this methodology to create a procedure to determine the conditions of various bodily organs, locating damaged tissues throughout the human body. Optogenetics can also be implemented to study interactions of neural networks in the brain with the introduction of a stimulus. Mapping the brain will help uncover the effects of drugs and origins of behavior and psychiatric disorders (Lamballais, 2013). This highly-targeted technique can also be employed to control regions of the brain by allowing for the excitation or inhibition of neurons in a localized region. Specific control can be modified as treatments for stress and psychiatric diseases (Lamballais, 2013). In addition, optogenetics can provide aid to people with memory disorders, facilitating memory recall by directly altering the neurons within their brain. Finally, recent studies into gene therapy using optogenetics have been approved by the FDA, opening a new pathway for treatment of retinal degenerations (Caterina, 2015).  This trailblazing research has inspired SyNG to harness optogenetic gene therapy to create a fully immersive, multi-sensory virtual reality environment. SyNG proposes to embed light-sensitive neurons in the brain and then utilize the controlled firing of neurons to transmit sensory information directly to the brain using microprocessor-controlled bursts of light.

When finalizing the research and development foci, SyNG has considered in its analysis the potential benefit of a given application to humanity and its likelihood of revolutionizing the science field, together with the risk that inevitably accompanies research into new realms.  SyNG has developed a portfolio of proposed applications spanning a spectrum of ratios, from R&D that account for existing limits in optogenetics techniques, to more pioneering applications with vast potential but far greater unknowns. The method of screening patients involving optogenetic tools was deemed to have high potential and practicality in the medical field because it would be a safer means of examining organs. This would facilitate large strides in making diagnosis more accessible and effective. Although this application may not be currently viable, previously mentioned studies have already utilized optogenetics to monitor the heart.

Using optogenetics to map out the brain appears viable with modern technology due to the simplicity of implementing these techniques. Optogenetic brain mapping yields a number of possibilities, as the neurology, psychology and mental therapy fields would see huge benefits and advancements. However, its practicality was questionable, given that the results yielded from these studies would not be nearly as much of a drastic improvement as potentially preventing fatal diseases. Last, applying optogenetic techniques in the field of virtual reality showed the highest potential out of the three options researched, as the nature of the study is boundless. Nevertheless, in terms of viability, more research and time would be needed before optogenetics would be advanced enough to accomplish such a feat, and in terms of practicality, the current state of virtual reality is still largely confined to entertainment purposes.

After deciding upon a set of application areas to pursue, we came up with specific ventures that could be explored in each of those areas of study. Based on an array of previous research, it was found that studies involving use of a ChR2 opsin for cardiac screening may be extremely successful (Ambrosi, 2014). Depending on the screened organ, when a specific opsin is absorbed into the cells of an organ, they can show activation of the regions of the target organ. By comparing the activated regions of the patient to the activated region of a healthy patient, the condition of the organ of the screened patient can be assessed. Further research into the specific type of opsin and the safest form of its introduction to the organ cells would be pertinent in the implementation of the patient screening. Testing of brain mapping will also use the establishment of an opsin that can activate with a light stimulus, and another opsin that can show activated regions of the brain. The functioning of the brain can then be studied by recording the sites of activity using external stressors. This has already been done with MRI imaging, but optogenetics can work backwards to activate brain regions and observe the effects that the excitation of certain neural networks has on the behavior and bodily functioning of the subject. Further research for this application would be studying the various methods to safely and noninvasively introduce the opsin to the targeted area, as well as research into the long term effects of artificial brain stimulation. For the third and final recommendation, testing of the virtual reality simulation will require the light sensitive opsins to be introduced to the sensory regions of the brain. Neurons with the opsins can then be excited by light, creating inputs of information to the specific region of the brain. The brain can then interpret these stimuli as sensations that the person can feel. Further research into the communication of true inputs of information from the eye or ears can be used to model the signals used to communicate the artificial sensations.

Given a vast array of choices for future research and development, team SyNG has determined to focus its efforts upon the applications that appear most likely to yield impactful results: screening patients, mapping the brain, and revolutionizing virtual reality. Furthering the optogenetic techniques used to screen patients will lead to huge strides in disease prevention, less deaths from detectable and treatable illnesses such as heart disease, and ultimately enabling longer and healthier lives. By expanding on the study of the brain with optogenetics, a better understanding of its functionality will be reached, and the possibilities are endless in terms of mental therapy and treatment. With the ability to create fully immersive and sensual worlds, optogenetics-enhanced virtual reality will push the boundaries of this burgeoning technology well beyond what is currently fathomable. Optogenetic tools are among science's promising innovations in recent years. By refining these tools and extending their applications, we hope both to improve understanding of the brain, and develop new diagnostics and treatments of disease and disorder throughout the body.

## Bibliography

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