REPPERGER RESEARCH INTERN PROGRAM

RESEARCH PROJECT #: AFRL-RHB-21-08

STUDIES ON QUANTUM DYNAMICS OF ELECTRON TRANSFER IN MITOCHONDRIA

PROJECT DESCRIPTION: The 711th Human Performance Wing (711 HPW), headquartered at Wright-Patterson Air Force Base in Ohio, is the first human-centric warfare wing to consolidate human performance research, education and consultation under a single organization. 711 HPW conduct state of the art research advancing human performance in air, space, cyberspace and supports the most critical Air Force resource – the Airman of our operational military forces. The research projects connect to a wide range of disciplines and collaborators across government labs, academia, industry, and military operators in order to generate the most innovative and effective solutions

Objectives:

1. Design and program biologically-conjugated nanomaterials (NMs) that can increase the rate of electron transfer and ATP production in mitochondria to combat stress induced premature fatigue and enhance airmen readiness.
2. Regulate the electron transfer rate by photoexciting NMs that can donate electrons into the electron transport chain (ETC) thereby modulate production of ATP in mitochondria

Mitochondrial health is a critical indicator of medical attributes and is capable of measuring an individual's physiological condition. Human health, performance, and endurance are dependent upon the health of the cell's mitochondria. The exposure to operational stress factors is linked to critical medical attributes that impact Airmen performance. During intense exercise or physical activity, the body's consumption of ATP rises, but the ETC and ATP synthase cannot keep up with the increasing demand for ATP, leading to premature fatigue. Stress induced oxidative stress is known to decrease mitochondrial activity by depleting ATP levels, photobiomodulation (PBM) has been studied as a potential prevention, where the cell absorbs light to increase ATP production. However, the practical application of PBM is controversial and photothermal effect can be detrimental to the cell. Therefore, it is important to control and understand the dynamics of electron transfer and the proton gradient to enhance ATP production. Nanomaterials (NMs) can be programed to couple to the ETC through attaching a bio-molecule that binds to a protein in the ETC and regulate ATP production. By designing the NM's optical properties such that it acts as an electron donor, the NM can be excited with light and transfer an electron into the ETC. By pumping electrons into the ETC in this manner, the electron transport rate should increase, increasing the proton gradient and therefore production of ATP to delay the onset of fatigue and injury induced trauma. In view of the importance of mitochondria, this project addresses fundamental questions regarding the understanding of the quantum dynamics of electron transfer in mitochondria and their regulation by photoactivated NMs.

ACADEMIC LEVEL: Bachelors, Masters, PhD

DISCIPLINE NEEDED:

- Life Health and Medical Sciences
    - Biochemistry
    - Biophysics
    - Cellular and Molecular Biology

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- Nanotechnology
    - Nanotechnology

RESEARCH LOCATION: Wright-Patterson AFB Dayton, OH

RESEARCH ADVISER: Dr. Saber Hussain, PhD
Biology, Indian Institute of Chemical Technology, India, 1991

Dr. Saber Hussain, Senior Scientist, Core Research Area Lead, Applied Biotechnology Branch, Bioengineering Division, 711HPW/RH, Wright-Patterson Air Force Base, Ohio. He is full affiliated Professor of Pharmacology and Toxicology, Wright State School of Medicine, Dayton, OH. Dr. Hussain began (1987) his scientific career as a toxicology research fellow at the highly regarded Indian Institute of Chemical Technology (IICT) and received his doctorate degree in 1991. Here, his novel exploration of heavy metal biotransfer between different proteins in complex biological environment led to a series of prestigious research fellowships in Italy, Switzerland, and the U.S. Dr. Hussain joined the Air Force Research Laboratory at Wright-Patterson AFB in 1999, where his research interests transitioned into elucidating fundamental interaction of operationally relevant stressors with biological system with reference to critical medical attributes that impact Airmen performance. The focus to addresses fundamental questions regarding the understanding of the quantum dynamics of electron transfer in mitochondria and their regulation.

His research resulted in author/co-authorship of 150 peer-reviewed publications, several book chapters, and above 200 technical abstracts. He is currently an Associate Editor of Toxicological Sciences and serves as an editorial member of several other toxicology journals including Nanotoxicology Journal. He is a Fellow of the Academy of Toxicological Sciences and Fellow of U.S. Air Force Research Laboratory. He serves as an expert reviewer for several government and private organizations.