REPPERGER RESEARCH INTERN PROGRAM

RESEARCH PROJECT #: AFRL-RHB-25-11

Electrochemical Array Sensing Platform for Detection of Human Performance Biomarkers

PROJECT DESCRIPTION: Deployed personnel perform long missions in challenging environments with few resources, which can in turn negatively affect their ability to complete their duties. Current commercial sensors can track an individual's physiological parameters (heart rate and skin temperature) or measure blood electrolytes and some biomarkers (lactate, glucose, urea, creatinine, hemoglobin, hematocrit). While these metrics provide some information on the physical and health status of an individual, evaluating fatigue and stress-related biomarkers would provide more detailed insights into cognitive performance. Additionally, further insights into the status of personnel will be achieved by measuring a combination of biomarkers in parallel and then relating the unique outputs to determine the performance status of personnel.

The goal of this project is to develop an electrochemical device that will detect and monitor the concentrations of multiple biomarkers in various biological fluids for human performance applications. Previously developed biological sensing elements (BSE), such as regulatory proteins – allosteric transcription factors (TFs) will be used to trigger the cell-free transcription of unique RNA sequences. In the absence of a TF-binding analyte of interest, transcription is blocked, while addition of the sample containing the analyte leads to the efficient transcription of the corresponding RNA output strands. When expressed, the reporter RNAs will interact with complementary redox-labeled single stranded DNA (ssDNA) that has been integrated onto a micropatterned electrochemical array. With an applied current, the redox label on the flexible DNA strand will transfer electrons to the electrode surface, resulting in an electrochemical signal. Upon binding of the reporter RNA the redox label is shifted away from the electrode surface, inhibiting electron transfer and reducing the signal output. Each electrode in the multiplexed sensor will have superior selectivity to the target TF, since the capture ssDNA will be designed as the unique complimentary sequence. Therefore, specific biochemical signals related to the physiological and cognitive status of the Airman/Guardian will be characterized.

LEARNING OBJECTIVE: Participants will learn about and engage with research topics in allosteric transcription factors, RNA reporters, cell-free transcription, human performance biomarkers, electrochemical detection, and electrochemical array.

ACADEMIC LEVEL: Undergraduate; Masters; Doctoral

DISCIPLINE NEEDED:

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering

RESEARCH LOCATION: Wright-Patterson Air Force Base, Dayton, Ohio

The material was CLEARED on 29 Sep 2023; Case Number: AFRL-2023-4845.

RESEARCH MENTOR: Svetlana Harbaugh, Ph. D
Chemistry/Biochemistry, Moscow State Lomonosov University, Russia, 1999

Dr. Svetlana Harbaugh is a Research Scientist and a Technical Lead for the Biological Sensors for Airmen and Guardians Augmentation Line of Effort (LoE) in the Health and Performance Sensing and Assessment Core Research Area (HPSA), at the 711th Human Performance Wing (711HPW) in the Air Force Research Laboratory. As part of the Air Force mission, this LoE focuses on developing capabilities and providing biotechnology solutions to sense and augment human performance. Dr. Harbaugh obtained her Master's degree in Chemistry and PhD in Biochemistry from Moscow State Lomonosov University, Russia (1999). Her current research is focused on the development of cell-based and cell-free biosensors for detection and monitoring of performance biomarkers in biological fluids and the development of intervention strategies for augmentation of human performance.

RESEARCH MENTOR: Trevor Tilly, Ph. D
Environmental Engineering, University of Florida, 2020

Dr. Trevor Tilly is an aerosol scientist and Research Engineer in the Health and Performance Sensing and Assessment Core Research Area (HPSA), at the 711th Human Performance Wing, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio. Dr. Tilly was a recipient of the Science, Math, and Research for Transformation (SMART) Scholarship, and is currently focused on advancing electrochemical aptamer-based sensors to wearables and field-deployable health and human performance monitors.

The material was CLEARED on 29 Sep 2023; Case Number: AFRL-2023-4845.