Project: Can Tissue Oxygen Metabolism be Measured with only five wavelengths?

Supervisors:
Mamadou Diop, Schulich School of Medicine & Dentistry, Western University

Location of Study:
Lab: MSB 416; Office Kresge 101

Project Description:
Cytochrome c oxidase (CCO) is the final electron acceptor in the mitochondrial electron transport chain and is a very sensitive marker for cellular oxidative metabolism. CCO features four redox centers: two heme groups and two copper sites. One of these copper sites, known as the Cu-Cu dimer copper A (CuA), has a broad absorption spectrum in the near-infrared region, with a strong peak in its oxidized form typically centered around 830 to 840 nm in mammalian cells.

Due to the relatively low *in vivo* concentration of CCO—approximately 10% that of hemoglobin—and its broad absorption spectrum, measurements usually require dozens of wavelengths to accurately estimate its concentration in tissue. This makes it difficult to develop low-cost, frugal NIRS devices that are appropriate for continuous neuromonitoring in low-resource settings.

Interestingly, a recent publication suggests that CCO concentration can be reliably determined using only five wavelengths, potentially simplifying the instrumentation and expanding applications.

The objective of this project is to replicate these findings. We will generate data using NIRFAST, a software package designed for simulating light propagation in tissue. We will compare the CCO concentration estimates obtained from the traditional method utilizing dozens of wavelengths against the five-wavelength approach to evaluate any discrepancies.

Skills and Experience Necessary:
Required: Matlab, good writing skills

The student will gain a solid understanding of light-tissue interaction and learn how to simulate light propagation within tissue. Additionally, the student will develop MATLAB scripts for data analysis and visualization. The student will also be trained in scientific communication, focusing on both oral presentations and scientific writing.

Project: Tissue Mimicking phantoms for validating point-of-care NIRS devices

Supervisors:
Mamadou Diop, Schulich School of Medicine & Dentistry, Western University

Location of Study:
Lab: MSB 416, Office Kresge 101

Project Description:
Continuous-wave hyperspectral near-infrared spectroscopy (cw-hNIRS) is a low-cost, frugal, and noninvasive technology that can measure tissue blood oxygenation, flow, and oxygen metabolism at the point-of-care. The technique measures light attenuation at dozens of wavelengths and applies spectral derivatives to improve accuracy. Further, cw-hNIRS has the potential to assess the redox state of cytochrome-c-oxidase (oxCCO), which a sensitive biomarker of cellular oxidative metabolism. However, there are ongoing controversies regarding the ability of cw-hNIRS to detect such a small signal amidst the much stronger hemoglobin signal. In this project, we will rigorously assess the capability of cw-hNIRS to measure oxCCO using tissue-mimicking phantoms. The phantoms will consist of Intralipid to replicate the light scattering properties of tissue, along with swine blood and baker's yeast; the latter metabolizes oxygen in a manner similar to human cells.

Skills and Experience Necessary:
Required: Safe lab practices, Matlab, good writing skills.

The student will acquire good understanding of light-tissue interaction and the use of cw-hNIRS to measure cellular oxygen metabolism. Further, the student will learn to develop Matlab scripts for data analysis and visualization. Scientific communication, including oral presentation and scientific writing will be an integral part of the training.

Project: Measuring Optical Pathlength in Tissue: Toward the Development of a Frugal Tissue Oximeter

Supervisors:
Mamadou Diop, Schulich School of Medicine & Dentistry, Western University

Location of Study:
Lab: MSB 416; Office Kresge 101

Project Description:
Near-infrared spectroscopy (NIRS) is a low-cost, noninvasive technique capable of measuring key physiological parameters, including tissue blood oxygenation, flow, and metabolism, at the point of care. Continuous-wave NIRS (cw-NIRS) is the simplest form of NIRS and serves as the basis for most commercial NIRS devices. However, cw-NIRS can only measure relative changes in these parameters and cannot provide absolute values, as it is unable to estimate the optical pathlength within the tissue. The objective of this project is to utilize a low-coherence continuous-wave light source and interferometry to accurately measure the optical pathlength in tissue. This technique will be tested using tissue-mimicking phantoms, and the results will be compared to measurements obtained using state-of-the-art time-resolved NIRS, which is currently the gold standard for measuring optical pathlength in tissue.

This study will lay the foundation for developing an affordable cw-NIRS device for point-of-care monitoring in remote and low-resource settings.

Skills and Experience Necessary:
Required: Matlab, good writing skills

The student will gain a solid understanding of light-tissue interaction and how to measure light path in highly scattering media such as tissue. Additionally, the student will be trained in scientific communication, focusing on both oral presentations and scientific writing.

Project: Affordable Near-Infrared Spectroscopy (NIRS)

Supervisors:
Keith St Lawrence, Department of Medical Biophysics, Western University
Daniel Milej, Department of Medical Biophysics, Western University

Location of Study:
Lawson Research Institute, St Joseph Hospital, F0-102

Project Description:

This project aims to create a miniaturized, affordable Near-Infrared Spectroscopy (NIRS) device that uses a white light source for non-invasive tissue analysis. Traditional NIRS systems are often expensive and complex, making them inaccessible in low-resource settings such as remote areas in sub-Saharan Africa or Northern Canada. Our goal is to build a simple, cost-effective device that can bring advanced diagnostic capabilities to places with limited healthcare infrastructure.

The device will use a white LED light source, which covers a broad spectrum of wavelengths, allowing the measurement of various tissue components, including oxyhemoglobin, deoxyhemoglobin, and water content. A compact diffraction grating and basic lens system will separate the light into individual wavelengths. At the same time, a photodiode array will detect the signals, providing the necessary data without relying on expensive sensors.

To keep the design simple, we will integrate the optical components into a small, custom-built PCB, which will be powered by a microcontroller (such as the ESP32). This will handle data collection, processing, and wireless communication to a mobile app for real-time analysis. The app will allow healthcare workers to view results instantly and make decisions quickly, even in settings with limited access to medical equipment.

This frugal spectrometer can be used for applications like anemia screening, hydration monitoring, and checking vascular health. This project aims to improve healthcare access and diagnostic accuracy in underserved areas by keeping costs low and the design user-friendly.

Skills and Experience Necessary:

- Potential student should have experience designing simple analog and digital circuits, particularly for signal amplification and processing. In addition, some proficiency in programming microcontrollers (e.g., ESP32, Arduino) for data acquisition and control of optical components and the ability to design and fabricate a custom PCB (Printed Circuit Board) for integrating the components is required.

Project: Prototype Optimization for Non-Invasive Blood Cell Determination by Image Capture

Supervisors:

Dr. Michael Rieder, Robarts Research Institute, UWO
Dr. Ehsan Kamrani, Department of Engineering, University of Waterloo

Location of Study:

BioNext Hub, Robarts Research Institute

Project Description:

This internship is to work on prototype optimization for non-invasive blood cell determination by image capture of directed light across the capillary nailbed. The hypothesis is that using single cell imaging and image analysis a blood count can be determined that obviates the need for bloodwork and laboratory analysis, facilitating care in rural, remote and resource-constrained environments. The research and development team includes clinicians, clinician investigators, biomedical engineers and software developers. The project is based in the BioNext Medical Innovations Hub at Robarts, a technology incubator with a strong biomedical engineering core and numerous graduate and summer students and with key core facilities including robust 3-D printing capacity. The student will be involved in the fabrication of prototype devices and in working with the research and development team to create and then validate prototype devices as well as in optimizing hardware-software integration for image analysis and blood count determination. The student will also work with the clinical team to facilitate real world validation of the prototypes developed in a series of health care settings and to explore the possibility of remote and continuous data capture.

Skills and Experience Necessary:

- Skills in biomedical engineering including prototype fabrication and software/hardware integration
- Skills/experience in image capture and photoimaging

Project: Low-Cost Smart Toothbrush for Children Living with Neuro-developmental Challenges in Low-Resource Settings

Supervisor:

James Lacefield
Faculty of Engineering and Schulich School of Medicine & Dentistry

Location of Study:

Building, Office or Lab room number: Robarts Research Institute

This project was suggested by our partners in the Department of Dental Sciences at the University of Nairobi, Kenya. Studies in high-income nations demonstrate that using a smart toothbrush to guide brushing technique and promote brushing habits can improve the oral health of people facing neurodevelopmental challenges, but sophisticated commercial toothbrushes are unaffordable even for upper-middle-class families in sub-Saharan African nations. The goals of this project are to design a device that provides capabilities comparable to a commercial smart toothbrush at < 25% of the cost, and is effective when used by children under the supervision of their caregivers with minimal coaching from dental care professionals.

The current prototype employs inertial measurement units (IMUs) to track the position and orientation of the brush-head and a Hall effect pressure sensor to measure the contact pressure at the tooth surface. An Arduino Nano BLE Sense microcomputer in the brush handle analyzes the user's brushing performance. Brushing performance metrics are transmitted via Bluetooth to a second Arduino within the brush's charging stand and presented to the user by a child-friendly color LED display. A student joining this project will complete the design and fabrication of a mechanical assembly to rotate the brush-head and will develop an AI algorithm to identify the mouth section currently being brushed using the IMU data. A research ethics protocol for a pilot patient study of usability will also be devised with guidance from faculty members in the Schulich School of Dentistry.

Skills and Experience Necessary:

- Experience with computer-aided design and 3D printing of small mechanical components. Experience with, or strong interest in learning, tiny machine learning (also known as edge AI) methods to implement AI algorithms efficiently on a microcomputer processor.
- Whereas this project is an ongoing activity of the Western Engineering Biomedical Club (WEBMC), preference will be given to applicants who are active members of the WEBMC Design Team.

Project: Ultra-Miniature Optical Instrumentation: qPCR Systems

Supervisors:
David Holdsworth, Schulich School of Medicine & Dentistry
Tamie Poepping, Physics & Astronomy, Faculty of Science

Location of Study:
Robarts Research Institute, Centre for Medical Imaging Technology & Physics & Astronomy Building, PAB 136

Project Description:
Analytic instrumentation for biomedical research is typically too expensive for low-resource settings, limiting research capacity. However, recent developments in ultra-miniature optical instrumentation provide the opportunity to re-think some types of lab equipment, such as quantitative PCR (qPCR) systems. Like many lab instruments, qPCR depends on accurate measurement of weak fluorescent signals, and a new generation of low-cost, low-power miniature spectrometers may provide a solution for epi-fluorescent acquisition during qPCR thermal cycling.

The selected student will be expected to participate in:

- investigating the performance of a 14-channel spectrometer (AS7343, Osram) as a candidate for a data acquisition module in a low-cost qPCR system using a programmable microcontroller (Raspberry Pi Pico);
- developing and testing a multi-well configuration;
- testing spectrometer performance and compatibility with a thermal cycler.

Skills and Experience Necessary:

- Basic knowledge of electric circuitry is required.
- Programming experience (C/C++, python) would be an asset but not required.