**Project Title:** Optimization of Microvascular Perfusion

**Participating Labs/Departments:** Microcirculation Laboratory, Center for Ultrasound Molecular Imaging and Therapeutics, University of Pittsburgh

**Location:** University of Pittsburgh Medical Center

**Course Instructors:** John Pacella, MS, MD, Xucai Chen, PhD

**Research Description:** There are a number or research studies in the microcirculation laboratory, mostly geared toward optimization of microvascular perfusion. The student will have the opportunity to observe studies pertaining to the following projects (this is not all inclusive):

1. **Microcirculation:**
   a. Studying microembolization and no reflow, which occurs during coronary stenting. This process involves the iatrogenic release of atherosclerotic debris from the vessel wall downstream into the microcirculation. Many of the parameters mentioned above will be assessed, and in addition, we will investigate endothelial function, flow reserve, and functional capillary density.
   b. Studying the microvascular mechanisms of microbubble facilitated sonothrombolysis. This involves the application of ultrasound to acoustically active bubbles which resonate in the vicinity of blood clot to cause mechanical disruption and clot lysis. The bubbles can be targeted to clot and loaded with drugs to facilitate clot lysis. I am using a one of a kind high speed (25 million frames per second) microscopic camera to study microbubble-clot surface interactions. These studies involved both in vitro and in vivo models.

2. **Vulnerable Plaque:** Developing a system using thermal strain imaging to measure lipid content in the atherosclerotic plaque.

3. **Hemodynamics:** Using venous compliance to estimate filling pressures. We are using ultrasound to assess the compliance of the internal jugular vein as a tool to noninvasively rule out elevated right heart filling pressures.

4. **Interventional cardiology:** Studying angioplasty balloon pressure-volume relation before, during, and after vessel wall contact.

This is a link to the website of the Center for Ultrasound Molecular Imaging and Therapeutics, where this work is being performed.

<http://www.imagingtherapeutics.pitt.edu/>

**Laboratory/Clinical Exposure:** During the course of the semester, the student will have the opportunity to observe a number of research studies. Additionally, the student will gain clinical exposure by shadowing in the catheterization laboratory to observe right heart catheterization, left heart catheterization, percutaneous coronary intervention, insertion of left ventricular assist device, percutaneous aortic valve replacement. This will give the student a chance to see the equipment and
devices used, and how they relate to human anatomy. The student will have the chance to participate during rounds in the coronary care unit, to gain some exposure to clinical decision making and to learn how our technologies relate to people.

**Course Prerequisites:** None.
Project Title: “Probing Acute, Dynamic Disease Processes with Robotics”

Participating Labs/Departments: Engineering Research Accelerator (ERA), formerly Institute for Complex Engineered Systems (ICES)

Locations: Office – Mellon Institute – Molecular Biosensors & Imaging Center (MBIC) – MI292A – phone 8-8638
Laboratory - Mellon Institute – Molecular Biosensors & Imaging Center (MBIC) – MI262

Primary Investigator: Alan Rosenbloom, MD

Research Description: See below

Clinical Exposure: The SURP student will be able to shadow me and my team on rounds in the Intensive Care Unit at a local hospital (within walking distance from CMU) on one or more days, depending on the student’s preference. I will be rounding in an organ transplantation centered ICU for one week per month. On rounds we review each patient’s problems, progress and plan for the day. The team has myself (attending physician), and usually a PharmD (doctor of pharmacology), Respiratory Therapists, Medical Students (not every month), Advance Practice Providers (Nurse Practitioners specialized in ICU care), Interns, Residents, and Critical Care Medicine Fellows (specializing in Critical Care Medicine). Our Fellows come from backgrounds in Internal Medicine and its subspecialties, Emergency Medicine, Anesthesiology, and Surgery. We have one of the oldest and largest Critical Care training programs in the world.

Major/Course/Skill Prerequisites: Students with a background in Chemical Engineering would be a good fit. However, any engineering student with hands-on building skills could also fit in well.

Probing Acute, Dynamic Disease Processes with Robotics

Intensive care units (ICUs) care for seriously ill patients, often during a crisis. This could be after a car wreck, burn, major surgery, cancer chemotherapy, infection, heart attack, stroke or at any time when complex therapy or careful monitoring are needed. ICUs have grown in importance because many people with previously hopeless injuries and illnesses can now be saved. In the future, ICU care will be crucial to achieve revolutionary advances such as stem cell therapies, tissue regeneration, gene editing and many others. Today, in the U.S. alone, ICUs admit about 5.7 million patients per year, playing a role in over 25% of hospital stays, and accounting for almost 50% of total hospital expenses. No modern hospital in the world can function without one or more ICUs.

ICU has the most intense on-going patient monitoring. Even a casual visitor will notice all the monitors beeping and all the devices attached to ICU patients. One would assume that all the vital processes are being tracked. Unfortunately this is not true. ICU monitoring is strangely outmoded and out of touch with basic science. It tracks mostly physiologic indictors that have been measured for decades to centuries (heart rate, blood pressure, body temperature, cardiogram, pulse oximetry etc.). In sharp contrast, basic science advances in understanding disease have primarily been at the molecular level since at least the 1990s. Current ICU lab tests are molecular but almost all of them are years to decades old. Next generation markers of disease a.k.a. “biomarkers” have proliferated in the basic science literature (the term “biomarker(s)” gets about 162 thousand hits in MEDLINE). Despite this huge increase in
published knowledge, biomarkers have been introduced to acute care medicine at a glacial rate - about two (2) per decade. The latest approved biomarker for ICU (Nephrocheck®, introduced in 2014) is measure of acute kidney injury – a common and devastating problem in ICU patients. It took 6 years and over $150 million development cost to reach ICU patients. At this rate, it could take centuries before clinicians will have even rudimentary knowledge of the root processes of acute diseases.

My laboratory is focused on using robotics to better understand critical illness at the molecular level by creating tools for clinical researchers to validate biomarkers in ICU patients. Our device is called a DASABA (DAta & SAmple BAnker). The function of the DASABA is to harness molecular data, while preserving the clinical context. This will be done by matching time-stamped biologic samples to the rich clinical data in the Electronic Medical Record (EMR), as well as by creating new data sampling opportunities using Internet of Things (IoT) technology. The uniformity, regularity, reliability and efficiency of data and sample handling that is possible with a robotic device will surpass all currently available systems, and move patient data flow out of the dark ages into the world of data analytics.

Current laboratory work centers on preparing our prototype for initial field testing in an ex vivo organ support system pioneered by a liver transplant surgeon and his team. Up to 20% of human livers harvested for transplantation are not usable. The goal of ex vivo support is to intensely monitor these live human explanted livers while discovering ways to “rehabilitate” them with the goal of bringing them up to par for transplantation into liver failure patients. Our job is to ready the prototype DASABA for the liver support system and for field use in general.

**Clinical Exposure Component:** I am a working Critical Care Medicine physician with nearly 40 years of experience in ICU. I work at a nearby hospital ICU about one week per month throughout the year. Many CMU students have shadowed me and my team on rounds in the ICU. All have found it interesting.

**Laboratory Experience:** The majority of my time is now spent in my lab at CMU – about 3 weeks per month. My lab group is very small and students working summers get highly individualized attention during their stay. There is also a choice of project directions. Perfecting surface chemistry on the sample exposed surfaces in the device is a top priority; thus, students with a Chemical Engineering background would be a good match. Other interesting opportunities include (1) improving the current design of the PCBs, pumps, cooling component, valves and sensors for more rugged field readiness, and (2) building an optical micro-flow sensor – which will involve learning about optics and software image processing. Any engineering student with hands-on (as opposed to only software and modeling experience) could be well suited for accomplishing either or both of these two goals. Note that parts of the system are fabricated with 3D printers. The lab has a medium resolution fused deposition modeling (FDM) printer, which does large parts, and a high resolution stereolithography (SLA) printer which makes small, precise parts.

In conclusion, if you want to see how ICU care is done, and how microfluidic systems work and can interface with ICU care, consider working in my lab for the summer.
Project Title:

**Optical, Non-Invasive Detection of Incipient Pressure Ulcers Based on Capillary Refill Rates**

Participating Labs/Departments:
- Kainerstorfer Lab, BME
- Przybycien Lab, BME/ChemE

Location: Scott Hall
Primary Investigator: Jana Kainerstorfer, Todd Przybycien

Research Description:
The overall goal of the project is to develop an inexpensive, clinical trial-ready, handheld, point-of-care device, based on tissue reflectance spectroscopy (TRS) that can be used to administer a quantitative blanch test for incipient pressure ulcer (PU, or bedsore) detection. Rubitection, Inc., a small CMU start-up company, has developed a simple, first-generation, semi-quantitative prototype device that operates as a tissue reflectance spectrometer which can detect blanching. However, further data analysis on already collected data is required. The student working on the project will be responsible for data analysis and will assist in developing novel modeling approaches. Such will include simplified multilayer models for light transport in the skin that can be run in real time on the device to provide quantitative, physiological descriptors of skin integrity including capillary microvascular bed blanch and refill rates. Furthermore, the student will assist in data collection on healthy volunteers.

Clinical Exposure (Required for SURP in BME at CMU): none
Major/Course/Skill Prerequisites: Basic knowledge of Matlab and signal processing
**Project Title:**
Clinical Immersion for Biomedical Engineers

**Participating Labs/Departments:**
CMU Biomedical Engineering  
The Children’s Institute of Pittsburgh  
Allegheny Health Network

**Location:** Scott Hall and various clinical sites around Pittsburgh

**Primary Investigator:** Conrad Zapanta, Ph.D.

**Research Description:**
The student(s) will define medical problems during a clinical immersion program. This program will occur at various clinical locations at the Allegheny Health Network and the University of Pittsburgh Medical Center. The students will acquire communication skills necessary to interact with clinicians, observe clinical activities, and identify unmet needs that can subsequently be addressed in biomedical design projects. These needs will then be developed into a list of potential design projects for the subsequent Biomedical Engineering (BME) Design course.

**Clinical Exposure (Required for SURP in BME at CMU):**
Clinical immersion experiences at The Children’s Institute of Pittsburgh and various locations within the Allegheny Health Network.

**Major/Course/Skill Prerequisites:**
All BME additional majors welcome. Must have taken 42-202. SolidWorks (or equivalent) experience preferred. Students will have to fulfill specific clinical shadowing requirements, including up-to-date immunization records (Rubella, Rubeola, Varicella and Mumps), a TB test (within the last year), and complete Act 153 Background Clearances (https://www.cmu.edu/child-protection/index.html)