Faculty Research

• Descriptions of faculty research on the BME Department web site (www.wpi.edu/+bme)

• Example general research areas (see WPI Grad Catalog and BME Department web site for detailed descriptions):
  – Bioinstrumentation & Med. Devices (Alatalo, Albrecht, Mensah, Zhang)
  – BioMEMS and Microfluidics (Albrecht, Billiar)
  – Biomaterials and Tissue Engineering (Billiar, Coburn, Mensah, Page, Pins, Rolle, Whittington)
  – Biomechanics (Alatalo, Billiar, Ji, Lammert, Troy)
  – Imaging (Alatalo, Albrecht, Ji, Troy, Zhang)
  – Neuroscience (Albrecht, Lammert)
Billiar: Biomech and Mechanobiology Lab

Soft (0.6 kPa)
Cirka et al., Biophys J, 2016

...stretched

Goldblatt et al., Biophys J, 2019
Musculoskeletal Biomechanics Laboratory – Karen Troy

How does musculoskeletal tissue adapt in response to functional activities?

Focus on human injury detection, prevention, rehabilitation.

Project Examples
• Identifying biomechanical risk factors for metatarsal stress fracture in runners.
• How are bones loaded in the body when we do things?
• Can we predict what exercises might cause bone adaptation or injury?

Techniques:
• Quantitative image analysis
• Finite element modeling
• Clinical collaborations

Identify structures interacting with the bone(s) of interest
Measure kinematics and kinetics
Calculate joint contact forces
Apply forces and constraints to model
What are your opportunities?

• Master’s students – directed research experiences, thesis, projects

• Most projects include quantitative image analysis, computational modeling (sometimes FE), application to musculoskeletal injury and adaptation

• Contact Karen Troy for opportunities – ktroy@wpi.edu
In vitro model systems

1. In vitro tissue models of wound healing
   - Cornwell, Tissue Eng., 10: 3669, 2010
   - Grasman, Tissue Eng., 23, 773, 2017
   - Carnes, Tissue Eng. In prep, 2020

2. Strategic delivery of growth factors and cells
   - Tao, J Tissue Eng Regen Med. 11: 228, 2017
   - Chrobak, ACS Biomaterials 3: 1384, 2017

Cardiac Tissue Engineering

1. Targeted cell (and therapeutic) delivery to the heart
   - Chrobak, ACS Biomaterials 3: 1394, 2017
   - Page, Tissue Eng., 17, 2629, 2011
   - Grasman, Biomater., 72: 49, 2015
   - Carnes, Tissue Eng., 16: 3669, 2010
   - Carnes, Tissue Eng. In prep, 2020

Biopolymer Microthreads

- fibrin, collagen, composites

Microthread organization mimics different tissue architectures

Skeletal Muscle Regeneration

1. Microthread bundles direct functional muscle regeneration for VML
   - Carnes, Bioengineering, 7 (3), 85, 2020
   - Page, Tissue Eng., 17, 2629, 2011
   - Grasman, Biomater., 72: 49, 2015
   - Carnes, Tissue Eng., 16: 3669, 2010
   - Carnes, Tissue Eng. In prep, 2020

Tendon/Ligament Regeneration

1. Braided collagen threads and composite scaffolds to mimic tendon and ligament regeneration
   - Pins, Biophys J., 73: 2164, 1997
   - Makridakis, MS thesis, WPI, 2007

2. Composite patch for myocardial infarct
   - Tao, J Tissue Eng Regen Med. 11: 228, 2017
   - Chrobak, ACS Biomaterials 3: 1384, 2017
Bioinspired Skin Regeneration Matrices (µDERMs)

Engineering the tissue-wound interface: wound healing models harnessing 3D topography to improve outcomes

• Clement, AL, Moutinho, TJ, and Pins, GD. Acta Biomater. 2013 Dec;9(12):9474-84.
• Clement, AL, and Pins, GD. Wound Healing Biomaterials, Oxford Press, 2016

Pins Lab
INTRODUCTION

Center for Cardiovascular Research and Medical Device Development for Global Health

Solomon A. Mensah
Biomedical Engineering
WPI
Flow Regulated Endothelial Glycocalyx – A Mechanotransducer and Vascular Protector

1. Ebong et al, ATVB 2011
2. Nieuwdorp et al, Curr Opin Lipidol, 2005
Endothelial Glycocalyx and Intercellular Interactions

Primary Tumor

Site of Secondary Tumor

Branching Vessels

Endothelial Cells

Uniform Flow

Disturbed Flow

Endothelial Glycocalyx and Intercellular Interactions

Mensah et al, FASEB, 2020
Current Project-Endothelial Glycocalyx and SARS-Cov-2

A. HS and P-selectin anchor circulating UL VWF in normal blood clot formation

B. ADAMS13 introduced to cleave VWF, activate platelets, and form blood clot
Current Project - Endothelial Glycocalyx and Pneumonectomy

- Cancer
- Lymph nodes
- Lung removed
Current Project- Endothelial Glycocalyx and Endothelin-1

Endothelial Cell

- PI-3-K
- AKT
- eNOS
- L-arg
- L-cit
- Porin
- HSP90
- Dynamin-2
- Caveolin

Vascular Space

- ET_B
- ET_A
- ET-1
- Nitric Oxide Activators
- Shear Stress
- GPCR
- TRPC5
- RTK
- PLC
- IP3
- SR
- PKC
- Ca2+
- Contraction
- Relaxation
- NO
- Smooth Muscle Cell

NO

Guanylyl Cyclase

- cGMP
- PKG
Brain, Behavior & Computation Laboratory

Behavioral Biomarkers of Neurological Disease and Psychological Health

- Facial
- Vocal
- Manual
- Balance, Gait

Biomarker Signal Processing → Machine Learning → Classification

Positive → Clinical Measure

Negative

Major Depressive Disorder, Cognitive Fatigue

Virtual Reality Testing for Phenotyping of Sensorimotor Impairments

Causal Mechanisms

- Visual feedback: 1.3
- Motor feedback: 2.9
- Perceptual feedback: 0.7
- Motor Prediction: 0.2
- Motor Planning: 1.1

Motor Feedback: 1.1

Computational Models of Motor Planning & Adaptation in Healthy & Impaired Speakers

- Impaired - Simple
- Healthy - Complex
- Impaired - Erratic

Structure & Function in Speech Motor Variability Using Real-Time MRI

Cleft Palate, Cancer-Related Glossectomy

Lou Gehrig’s Disease, Speech Motor Disorders

Behaviors Biomarkers of Neurological Disease and Psychological Health

Prof. Adam Lammert (alammert@wpi.edu)
- Neurological disorders affect >100M
- Many involve **altered neural activity within brain circuits**
- We don’t know how this activity is altered, by *trauma, environment, or genetics*
- Toward novel therapeutics

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**QNTL**
quantitative neurotechnology lab

- Our lab engineers new methods to record **living brain function** and identify regulators of neural activity

<table>
<thead>
<tr>
<th>method</th>
<th>experiment</th>
<th>modeling</th>
<th>analysis</th>
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</table>

- **C. elegans**
  - 302 neurons

- **Microfluidics** for precise stimulation

- **Fluorescence microscopy** to record brain activity changes

- Same 2 neurons recorded in 25 living animals

- Regulated neural response!
• Lab tools and topics: what will I learn?

**Live Neural Activity, image processing**

**Neural Disorders, Genetics, Behavior (e.g. Sleep, Learning)**

2D/3D Microscopy, Optogenetics

- Microfabrication/fluidics
- Automated experiments, instrumentation
- Biomaterials
BME-MicroFabrication Lab (MFL)

- Also, we run a microfabrication cleanroom, available for all grad students to use after training.

wp.wpi.edu/qntl

- Spin-coat, Photolithography, Etching, Stereomicroscopy, Profilometry, Plasma

BME555: BioMEMS and Tissue Microengineering, Spring ('23 next)

- Also: 3D printing, rapid-prototyping microfluidics, etc.
Lab Questions & Projects:

- How does brain activity (excitability) change after:
  - traumatic brain injury (TBI)
  - deep-brain stimulation (DBS)?
- And during learning, sleep, & aging?
- Organism models of human neuropsychiatric disorders (CRISPR, RNAi) for high-throughput screening (HTS)

Available Master’s / Rotation projects, Fall 2022:

**Functional HTS for compounds that alter neural communication *in vivo***

- focus on targeting gap junctions and chemical synapses
- genetic engineering & automation

**New methods to study neuropeptide communication, and multisensory attention!**

- behavior recording
- hardware / software / microscopy

- other related ideas? let’s chat!
Brenton Faber
Professor
BME & HUA

Social dynamics of health & medicine
Scientific communication

Practicing paramedic
- 911 and ED@Home

Lab works with a local free health clinic:
- Describe and model social factors that influence access to care and care efficacy

- Cardiovascular disease and stroke risk assessment and prevention

- Technology adoption in low resource settings (ultrasound, EKG)

Member UMMS “Humanities Lab”
Modeling Physiological Phenomena

Non-invasive in vivo Health Monitoring

Point-of-care Devices
The JI lab at WPI – Prof. Songbai Ji

• Concussion Biomechanics
• Surgical image-guidance
Concussion biomechanics: better detection

- Computational modeling
- Medical imaging
- Data science, machine learning and deep learning
- Lots of opportunities to collaborate with other institutions (VT, UBC, Stanford, UU, etc.)
- Work with industry (helmet, mouthguard, etc.)
Surgical image-guidance: improve patient outcome

• Help improve surgical accuracy
• Work with lots of medical image data
• Data science techniques
• New collaboration with colleagues at UMASS medical school
• Work with device companies
Scaffold Design for Tissue Engineering and Disease Modeling

Materials for drug delivery

Decellularized plant cell materials for tissue engineering and drug delivery

Potential MS theses or projects:
- Chondroitin sulfate drug delivery systems
- Hydrogel development for nerve regeneration
- Scaffold design for in vitro cancer modeling

Timing – let’s discuss

Dr. Jeannine M. Coburn, jmcoburn@wpi.edu
INCREASE understanding of disease progression and regenerative processes

IMPROVE predictive power of preclinical models

ENHANCE successful reintegration of function tissue
Fibrosis-mediated transformation in pancreatic cancer risk factors in vitro (focus on obesity)

**Pancreatic cancer exosomes:**
- Transforms stromal cells (e.g., fibroblasts)
- Alters metabolism in adipose cells

**Adipose-derived exosomes:**
- **Obesity:** Secretion affected by pro-inflammatory cargo; Affects inflammation in other cells
- **Cancer:** Promotes migration, invasion of stromal cells; Suppresses proliferation

**Project 1:** Determine how stiffening of the extracellular matrix (ECM) regulates exosome secretion in pancreatic cells and/or adipose cells.

**Project 2:** Determine how stiffening of the extracellular matrix (ECM) contributes to early malignant transformation of pancreatic cells with KRAS and/or p53 mutations.

**Project 3:** Determine how stiffening of the extracellular matrix (ECM) regulates pancreatic-adipose crosstalk and sensitivity to paracrine signals.
Using photopolymerizable collagen matrices to investigate how progressive stiffening alters lymphatic trafficking in PDAC

Project 1: Determine how stiffening of the extracellular matrix (ECM) regulates expression of adhesion and chemotaxis markers in lymphatic endothelial cells (LEC).

Project 2: Determine how stiffening of the extracellular matrix (ECM) regulates cell-cell adhesion between pancreatic tumor cells and lymphatic endothelial cells (LEC).

Project 3: Determine how stiffening of the extracellular matrix (ECM) regulates motility of pancreatic tumor cells across a lymphatic endothelial cells (LEC) monolayer.

Project 4: Determine how stiffening of the extracellular matrix (ECM) regulates barrier integrity of lymphatic endothelial cells (LEC) and transendothelial migration of pancreatic tumor cells.

Image: Bokas, A., Cancers 2020, 12, 432.
Introduction

Haichong (Kai) Zhang (hzhang10@wpi.edu)
Assistant Professor
Biomedical Engineering
Robotics Engineering
Computer Science (Affiliate)

Background:
B.S./M.S. – Kyoto University, Japan
M.S./Ph.D. – Johns Hopkins University

Teaching
- BME 4201 Biomedical Imaging
- BME 3014 Signal Processing Laboratory
- BME/RBE 595 Medical Imaging and Robotic Instrumentation

Lab:
50 Prescott 4th floor, Medical FUSION Laboratory
Medical FUSION (Frontier Ultrasound Imaging and Robotic Instrumentation) Lab
- Focuses on interface of medical robotics, sensing, and imaging to create future healthcare.
  1. Robotic assisted imaging systems: How can a robot revolutionize medical imaging?
  2. Ultrasound and photoacoustic image-guided therapy: How can advanced imaging revolutionize image guided therapy?

Biological Sensing / Imaging
- Brain recording
- Cancer detection

Medical Robotics
- Co-robotic imaging system
- Robot-assisted intervention
- Point-of-care system

Enabling Technologies
- Image reconstruction
- Advanced signal processing
- Machine learning
- Hand-eye calibration
- Enabling low-cost system
Thrust 1: Robotic Assisted Imaging Systems

Robotic Ultrasound Scanning
- Point-of-care lung ultrasound is a lung diagnostic imaging method to triage COVID-19 patients.
- To counter the shortage of healthcare staffs in rural areas, we develop an autonomous robot-assisted diagnostic platform.

Robot-Assisted Autonomous Lung Ultrasound Scanning
X. Ma, et al., IEEE IROS, 2021

Sponsor: NIH Common Fund Administrative Supplement (DP5OD028162)
Thrust 2: Ultrasound and Photoacoustic Image-Guided Therapy

Detection: Where should be treated?
Avoidance: Where should not be treated?
Monitoring: When to stop treatment?

Molecular Photoacoustic Imaging of Prostate Cancer
- Photoacoustic (PA) imaging is capable of image targeted molecular contrast agents in vivo.
- We develop an image-guided interventional platform for targeted cancer treatment.

In vivo photoacoustic imaging of PSMA targeted tumor
H. K. Zhang, et al., J. Biophotonics, 2018

Sponsor: NIH OD028162, CA134675
Thrust 2: Ultrasound and Photoacoustic Image-Guided Therapy

**Detection:** Where should be treated?  
**Avoidance:** Where should not be treated?  
**Monitoring:** When to stop treatment?

Photoacoustic Necrotic Tissue Visualization for Ablation Monitoring
- We extend the use of photoacoustic imaging for highlighting ablated tissue with respect to the non-ablated counter part.

![Ultrasound](image1.png) ![Photoacoustic necrotic map](image2.png)

**Photoacoustic Ablation Monitoring**
*Ablated tissue, highlighted in red.*

S. Gao, et al., IEEE IUS, 2021
Medical FUSION (Frontier Ultrasound Imaging and Robotic Instrumentation) Lab focuses on:

- Interface of medical robotics, sensing, and imaging.

1. Robotic assisted imaging systems: How can a robot revolutionize medical imaging?
2. Ultrasound and photoacoustic image-guided therapy: How can advanced imaging revolutionize image guided therapy?

Contact: Haichong (Kai) Zhang
hzhang10@wpi.edu