Austin J. Baird, PhD

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Education

University of California, Santa Cruz — *Santa Cruz, CA*
BA in Mathematics — *September 2004 - June 2008*
- *Honors Thesis:* Modeling Native California Grassland Populations

University of North Carolina, Chapel Hill — *Chapel Hill, NC*
PhD in Applied Mathematics — *August 2009 - August 2014*
- *Thesis:* Modeling Valveless Pumping Mechanisms, link
- *Advisor:* Dr. Laura Miller, *Committee:* Forest, M. Gregory, Adalsteinsson, David, White, Brian, Mucha, Peter, Kier, William M.

Postgraduate Training

None

Faculty Positions Held

Duke University — *Durham, NC*
Visiting Assistant Professor — *August 2014 - July 2015*

University of Washington — *Seattle, Wa*
Research Assistant Professor — *December 2021 - Present*

Hospital Positions Held

None

Honors

University of North Carolina, Chapel Hill — *Chapel Hill, NC*
Future Faculty Fellow — *June 2012*

University of North Carolina, Chapel Hill — *Chapel Hill, NC*
J. Burton Linker Award in Recognition of Excellence in Teaching — *March 2013*

University of North Carolina, Chapel Hill — *Chapel Hill, NC*
Graduate Assistance in Areas of National Need Fellow — *Fall 2013*

Applied Research Associates, Inc. — *Raleigh, NC*
Above and Beyond the Call of Duty Award — *October 2016*

Department of Defense — *Washington D.C.*
Federal IT Innovations Award — *August 2017*

Applied Research Associates, Inc. — *Raleigh, NC*
Distinguished Member of the Technical Staff — *June 2018*

Applied Research Associates, Inc. — *Raleigh, NC*
Technical Excellence Award — *September 2019*

Board Certifications

None

Current Licenses to Practice

None

Diversity and Equity Inclusion Activities

Graduate Mathematics Association at UNC, Chapel Hill — *Chapel Hill, NC*
Sonia Kovalesky Day Workshop Lead — *May 2012*

Graduate Mathematics Association at UNC, Chapel Hill — *Chapel Hill, NC*
Minority Scientist Mentor — *May 2013*

WISE, NC State University — *Raleigh, NC*
Women in Science and Engineering Speaker — *March 2017*

Affiliations

Society for Simulation in Healthcare
Leadership group on simulation and modeling — *2016 - Present*

IEEE
Engineering in Medicine and Biology — *2018 - Present*

NIH
Inter-agency Modeling and Analysis Group — *2019 - Present*

Teaching Experience

Champion School — *San Jose, CA*
Computer Science, Math, and Physics Middle School Instructor — *August 2008*
- Full course responsibility

University of North Carolina, Chapel Hill, Math 190 — *Chapel Hill, NC*

Chaos and Population Dynamics — *Fall 2012*

- Full course responsibility

University of North Carolina, Chapel Hill, Math 290 — *Chapel Hill, NC*

Applied Mathematical Methods (Computational Lab) — *Spring 2013*

- Full course responsibility
- *Course Materials:* link

Duke University, Math 353 — *Durham, NC*

Introduction to Ordinary and Partial Differential Equations for Engineers — *Fall 2014*

- Full course responsibility

Duke University, Math 353 — *Durham, NC*

Introduction to Ordinary and Partial Differential Equations for Engineers — *Spring 2015*

- Full course responsibility

Mentees — *Raleigh, NC*

Applied Research Associates — *Spring 2016 - October 2021*

- Laura Oelsner
  Dates: May 2018 - August 2019
  Current Position: Becton Dickerson Biomedical Engineer
- Tim Hoer
  Dates: May 2018 - August 2018
  Current Position: Fuel Cell System Engineer
- Rishi Das
  Dates: May 2020 - August 2020
  Current Position: Harvard Medical School Engineering Internship

Raleigh, NC

University of Washington — *Oct 2022 Present*

- Namrata Harish
  Dates: Oct 2022 - Present
  Current Position: BioEngineering Student, University of Washington

Editorial Responsibilities

Frontiers in Physiology: Computational Physiology and Medicine

Review Editor — *June 2022 - Present*

National Responsibilities

Society of Simulation in Healthcare

Chair: Healthcare Systems Modeling Affinity Group — *March 2023 - Present*

Local Responsibilities

None

Funding

Defense Health Agency — *Fredrick, MD*

BioGears Research Award — *August 2013 - August 2018*

- *Role:* Principal Investigator
- *Amount:* $7,800,000
- *Contract(s):* W81XWH-13-2-0068,

Defense Health Agency — *Fredrick, MD*

BioGears Follow-on Research Award — *August 2017 - August 2020*

- *Role:* Principal Investigator
- *Amount:* $1,900,000
- *Contract(s):* W81XWH-17-C-0172

Army Research Labs — *Raleigh, NC*

Fast Computational Simulations of Traumatic Brain Injury — *January 2017 - December 2020*

- *Role:* Principal Investigator
- *Amount:* $353,000
- *Contract(s):* W911NF-17-1-0572

Defense Health Agency — *Orlando, FL*

BurnCare: Virtual Patient Application to Train Thermal Injury — *January 2018 - Dec 2021*

- *Role:* Principal Investigator
- *Amount:* $2,100,000
- *Contract(s):* W911NF-18-C-0037

Defense Health Agency — *Fredrick, MD*

Sustain: Prolonged Field Care Training Framework — *March 2018 - Dec 2021*

- *Role:* Lead Physiology Modeler and Proposal Manager
- *Amount:* $2,200,000
- *Contract(s):* W81XWH-18-C-0169

CyberPatient — *Vancouer, BC*

CyberPatient: Technical Consultations — *Oct 2022 - Jan 2023*

- *Role:* PI
- *Amount:* $23,910

Regis University — *Denver, CO*

Overwatch AI — *March 2023 - Present*

- *Role:* Co-PI
- *Amount:* $68,782.59

Publications

First Section: Peer Reviewed Articles

[1] **Modeling Valveless Pumping Mechanisms**

A. Baird

College of Arts and Sciences, Department of Mathematics (2014)

[2] **Neuromechanical Pumping: Boundary Flexibility and Traveling Depolarization Waves Drive Flow Within Valveless, Tubular Hearts**

A. Baird, L. Waldrop, L. Miller

Japan Journal of Industrial and Applied Mathematics 32.3 (2015) pp. 829–846 Springer

[3] **A Mathematical Model and MATLAB Code for Muscle–Fluid–Structure Simulations**

N. A. Battista, A. J. Baird, L. A. Miller

Integrative and comparative biology 55.5 (2015) pp. 901–911 Oxford University Press

[4] **A Full-Body Model of Burn Pathophysiology and Treatment Using the BioGears Engine**

M. McDaniel, A. Baird

2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) (2019) pp. 261–264 IEEE

[5] **Open Source Pharmacokinetic/Pharmacodynamic Framework: Tutorial on the BioGears Engine**
M. McDaniel, J. Carter, J. M. Keller, S. A. White, A. Baird
CPT: pharmacometrics & systems pharmacology 8.1 (2019) pp. 12–25 Wiley Online Library

[6] **A Whole-Body Mathematical Model of Sepsis Progression and Treatment Designed in the BioGears Physiology Engine**
M. McDaniel, J. Keller, S. White, A. Baird
Frontiers in physiology 10 (2019) p. 1321 Frontiers

[7] **BioGears: A C++ library for whole body physiology simulations**
A. Baird, M. McDaniel, S. A. White, N. Tatum, L. Marin
Journal of Open Source Software 5.56 (2020) p. 2645

[8] **BurnCare tablet trainer to enhance burn injury care and treatment**
A. Baird, M. Serio-Melvin, M. Hackett, M. Clover, M. McDaniel, M. Rowland, A. Williams, B. Wilson
BMC Emergency Medicine 20.1 (2020) pp. 1–10 BioMed Central

[9] **A multiscale computational model of angiogenesis after traumatic brain injury, investigating the role location plays in volumetric recovery**
A. Baird, L. Oelsner, C. Fisher, M. Witte, M. Huynh
Mathematical Biosciences and Engineering 18.4 (2021) pp. 3227–3257

Second Section: Collaborative Authorship

None

Third Section: MedEDPortal

None

Fourth Section: Book Chapter

[1] **Numerical Study of Scaling Effects in Peristalsis and Dynamic Suction Pumping**
A. Baird, T. King, L. Miller
Contemp. Math 628 (2014) pp. 129–148

Fifth Section: Published Books, Videos, Software, ect.

[1] **ajbaird/TBISimulator: Alpha 1.0.1 Windows executable and data**
A. Baird
(Sept. 2020) Zenodo

[2] **BioGears: A C++ library for whole body physiology simulations**
A. Baird, M. McDaniel, S. A. White, N. Tatum, L. Marin
(Dec. 2020) Zenodo

[3] **BurnCare Physiology Data: Burn with Resuscitation**
N. Tatum, A. Baird, S. White, M. Clover, M. Hackett
(June 2021) Zenodo

[4] **BurnCare Physiology Data: Burn with Resuscitation and Escharotomy**
N. Tatum, A. Baird, S. White, M. Clover, M. Hackett
(Aug. 2021) Zenodo

[5] **BurnCare Physiology Data: Burn without Intervention**
N. Tatum, A. Baird, S. White, M. Clover, M. Hackett
(Feb. 2021) Zenodo

Sixth Section: Other PublicationsConference Proceedings

[1] **Electro-Dynamic Suction Pumping at Small Scales**

A. Baird, L. Miller

APS Division of Fluid Dynamics Meeting Abstracts, 2013

Seventh Section: Submitted Manuscripts

Final Section: List of Abstracts

A Full-Body Model of Burn Pathophysiology and Treatment Using the BioGears Engine

- We have created a model of systemic burn pathophysiology by incorporating a mathematical model of acute inflammation within the BioGears Engine. This model produces outputs consistent with burns of varying severities and leverages existing BioGears functionality to simulate the effect of treatment on virtual patient outcome. The model performs well for standard resuscitation scenarios and we thus expect it to be useful for educational and training purposes.

A Whole-Body Mathematical Model of Sepsis Progression and Treatment Designed in the BioGears Physiology Engine

- Sepsis is a debilitating condition associated with a high mortality rate that greatly strains hospital resources. Though advances have been made in improving sepsis diagnosis and treatment, our understanding of the disease is far from complete. Mathematical modeling of sepsis has the potential to explore underlying biological mechanisms and patient phenotypes that contribute to variability in septic patient outcomes. We developed a comprehensive, whole-body mathematical model of sepsis pathophysiology using the BioGears Engine, a robust open-source virtual human modeling project. We describe the development of a sepsis model and the physiologic response within the BioGears framework. We then define and simulate scenarios that compare sepsis treatment regimens. As such, we demonstrate the utility of this model as a tool to augment sepsis research and as a training platform to educate medical staff.

Open Source Pharmacokinetic/Pharmacodynamic Framework: Tutorial on the BioGears Engine

- BioGears is an open-source, lumped parameter, full-body human physiology engine. Its purpose is to provide realistic and comprehensive simulations for medical training, research, and education. BioGears incorporates a physiologically based pharmacokinetic/pharmacodynamic (PK/PD) model that is designed to be applicable to a diversity of drug classes and patients and is extensible to future drugs. In addition, BioGears also supports drug interactions with various patient insults and interventions allowing for a realistic research framework and accurate dose-patient responses. This tutorial will demonstrate how the generic BioGears PK/PD model can be extended to a new substance for prediction of drug administration outcomes.

A multiscale computational model of angiogenesis after traumatic brain injury, investigating the role location plays in volumetric recovery

- Vascular endothelial growth factor (VEGF) is a key protein involved in the process of angiogenesis. VEGF is of particular interest after a traumatic brain injury (TBI), as it re-establishes the cerebral vascular network in effort to allow for proper cerebral blood flow and thereby oxygenation of damaged brain tissue. For this reason, angiogenesis is critical in the progression and recovery of TBI patients in the days and weeks post injury. Although well established experimental work has led to advances in our understanding of TBI and the progression of angiogenisis, many constraints still exist with existing methods, especially when considering patient progression in the days following injury. To better understand the healing process on the proposed time scales, we develop a computational model that quickly simulates vessel growth and recovery by coupling VEGF and its interactions with its associated receptors to a physiologically inspired fractal model of the microvascular re-growth. We use this model to clarify the role that diffusivity, receptor kinetics and location of the TBI play in overall blood volume restoration in the weeks post injury and show that proper therapeutic angiogenesis, or vasculogenic therapies, could speed recovery of the patient as a function of the location of injury.

BioGears: A C++ library for whole body physiology simulations

- BioGears is an open source, extensible human physiology computational engine that is designed to enhance medical education, research, and training technologies. BioGears is primarily written in C++ and uses an electric circuit analog to characterize the fluid dynamics of the cardiopulmonary system. As medical training requirements become more complex, there is a need to supplement traditional simulators with physiology simulations. To this end, BioGears provides an extensive number of validated injury models and related interventions that may be applied to the simulated patient. In addition, BioGears compiled libraries may be used for computational medical research to construct in-silico clinical trials related to patient treatment and outcomes. Variable patient inputs support diversity and specification in a given application. The engine can be used standalone or integrated with simulators, sensor interfaces, and models of all fidelities. The Library, and all associated projects, are published under the Apache 2.0 license and are made available through the public GitHub repository. BioGears aims to lower the barrier to create complex physiological simulations for a variety of uses and requirements

BurnCare tablet trainer to enhance burn injury care and treatment

- Applied Research Associates (ARA) and the United States Army Institute of Surgical Research (USAISR) have been developing a tablet-based simulation environment for burn wound assessment and burn shock resuscitation. This application aims to supplement the current gold standard in burn care education, the Advanced Burn Life Support (ABLS) curriculum. Subject matter experts validate total body surface area (TBSA) identification and analysis and show that the visual fidelity of the tablet virtual patients is consistent with real life thermal injuries. We show this by noting that the error between their burn mapping and the actual patient burns was sufficiently less than that of a random sample population. Statistical analysis is used to confirm this hypothesis. In addition a full body physiology model developed for this project is detailed. Physiological results, and responses to standard care treatment, are detailed and validated. Future updates will include training modules that leverage this model. We have created an accurate, whole-body model of burn TBSA training experience in Unreal 4 on a mobile platform, provided for free to the medical community. We hope to provide learners with more a realistic experience and with rapid feedback as they practice patient assessment, intervention, and reassessment.

Whole Body PBPK Model of Nasal Naloxone Administration to Measure Repeat Dosing

- Opioid use in the United States and abroad is an endemic part of culture with yearly increases in overdose rates and deaths. As rates of overdose incidence increases, the use of the safe and effective reversal agent, Naloxone, in the form of a nasal rescue spray is being fielded and used by emergency medical technicians (EMTs) at a greater and greater rate. Despite advances in deployment of these rescue products, deaths are continuing to increase. There is evidence that repeated dosing of a Naloxone nasal spray (such as Narcan) is becoming more common due to the amount and type of opiate being abused. Although there is strong evidence of the benefits of Naloxone related to opioid reversals there are still not repeated dosing guidelines, as a function of opiate and amount the patient has taken. Goal directed dosing is promising, where respiratory markers are being used as an indication of the patient recovery but require time and understanding by the EMT. We construct a whole-body model of the pharmacokinetics and dynamics of opiates (Morphine and Fentanyl) on respiratory depression. We then construct a model of nasal deposition and administration of naloxone to investigate repeat dosing requirements for large overdoses and analyze how the two opiates may influence these requirements. We show that naloxone is highly effective at reversing respiratory symptoms of the patient and recommend dosing requirements as a function of opiate and amount administered. By designing the model to include circulation and respiration we investigate physiological markers that may be used in goal directed therapy rescue treatments.

Invited Presentations

Integrative and Mechanical Physiology Group — *Chapel Hill, NC*
Pumping Mechanisms and their Scaling Effects in Tubular Hearts — *September 2012*

Society of Integrative and Comparative Biology — *San Francisco, CA*
Scaling and Pumping in Tubular Hearts — *January 2013*

Integrative and Mechanical Physiology Group — *Chapel Hill, NC*
Modeling Neurons — *March 2013*

Society of Mathematical Biology — *Osaka, Japan*
Electro-Dynamic Suction Pumping at Small Scales — *August 2014*

Duke Interdisciplinary Discussion Course — *Durham, NC*
Moving Fluid in Tubes — *October, 2014*

Experimental Biology — *Boston, MA*
Implications of Increase Renal Venous Pressure for Renal Hemodynamic and Reabsorptive Function Studied by a Mathematical Model of the Kidney — *March 2015*

Chemical and Biological Defense Science and Technology Conference — *Long Beach, CA*
BioGears: Simulating Whole-Body Response to Chemical Exposure — *November 2017*

International Meeting on Simulation in Healthcare — *Los Angeles, CA*
An In-Silico Whole-Body Framework to Simulate Kinetics and Dynamics of Pharmaceuticals and Associated Reversal Agents — *January 2018*

Virtual Physiological Human Conference — *Zaragoza, Spain*
An In-Silico Whole-Body Framework to Simulate Kinetics and Dynamics of Pharmaceuticals and Associated Reversal Agents — *September 2018*

Department of Defense Working Group on Computational Modeling of Human Lethality, Injury, and Impairment from Blast-Related Threats — *Arlington, VA*
BioGears Human Physiology Engine — *February 2019*

American College of Surgeons Simulation Summit — *Chicago, IL*
BioGears: A Framework for Multiscale Physiology Modeling — *March 2019*

Society for Simulation in Healthcare — *Raleigh, NC*
BioGears Model to Simulate Patient Responses to Sepsis — *March 2019*

BioGears Conference — *Raleigh, NC*
"BioGears Drug Modeling Overview" — *March 2020*
- *Conference Talks:* link

University of Arizona Modeling and Computation Seminar — *Tucson, AZ*
"A Whole-Body Physiological Model of Sepsis and Associated Treatments, Designed in the BioGears Engine" — *March 2021*

University of Arizona Modeling and Computation Seminar — *Tucson, AZ*
"A Whole-Body Physiological Model of Sepsis and Associated Treatments, Designed in the BioGears Engine" — *March 2021*

CyberPatient Technical Interest Meeting — *Virtual*
"BioGears: Physiological Modeling and Engine Construction for High Fidelity Simulation Training" — *Jan 2022*

University of Washington Biological Engineering Design Seminar — *Seattle, WA*
"Engineering Design with Biological Purpose" — *April 2022*

University of Washington Biological Engineering Seminar — *Seattle, WA*
"BioGears: Whole-Body Physiological Model to Support Healthcare Simulation, Research and Training" — *April 2022*

Society of Industrial and Applied Mathematics: Life Sciences Conference — *Pittsburgh, PA*
"Modeling the whole-body response to infection and associated acute inflammation, investigating clinical treatments and outcomes" — *July 2022*

Other Employment

Applied Research Associates, Inc. — *Raleigh, NC*
Biomedical Modeling Group Leader (Senior Engineer, Distinguished Member of the Technical Staff) — *February 2016 - October 2021*

- Lead a multidisciplinary team across 4 different projects
- In charge of agile development processes, product roadmap, delivery scheduling, and direct communication with government customers
- Led and won multiple research and development funds through Defense Health Agency and Army Research Lab grants
- Principal investigator of the BioGears, BurnCare training application, and the traumatic brain injury angiogensis projects
- Organized teaming across three research hospitals and multiple small businesses
- Communicate research progress through multiple conferences and peer reviewed publications, including the BioGears 2020 conference
- Oversaw implementation of all models associated with BioGears releases 7.0-7.5