BIOGRAPHICAL SKETCH

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NAME:	Robert S. MacLeod
eRA COMMONS USER NAME:	rsmacleod
POSITION TITLE:	Professor of Bioengineering

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)

INSTITUTION AND LOCATION	DEGREE (if applicable)	Completion Date MM/YYYY	FIELD OF STUDY
Dalhousie University, Halifax, N.S., Canada	BSc	1979	Engineering Physics
Technische Universität Graz, Graz, Austria	MSc	1985	Electrical Engineering
Dalhousie University, Halifax, N.S., Canada	Ph.D.	1990	Physiology & Biophysics
CVRTI, University of Utah, Salt Lake City, Utah	Postdoctoral	1992	Electrophysiology

A. Personal Statement

I became a University instructor in 1980 and have been a professor with teaching and mentoring responsibilities since 1992. I also have over 30 years of experience as a researcher and in developing software for biomedical simulation, image based modeling, and visualization. I am also a user of such software as it supports my cardiac and neural electrophysiology research, in which I carry out experiments, human studies, and computer simulations. In 1995, I was one of two co-founder of the Scientific Computing and Imaging Institute and have been its associate director ever since (we now include 18 faculty and 175 members). I am also the Co-PI of the NIH funded Center for Integrative Biomedical Computing (CIBC), which has received support since 1999 to create biomedical software. During this time, the CIBC has had a major impact on many biomedical research projects, one of which led to the creation of the Comprehensive Arrhythmia Research and Management (CARMA) Center, where we used image-based analysis to manage patients with cardiac arrhythmias. I continue to pursue synergistic research on all aspects of cardiac electrophysiology and bioelectric fields based on imaged based modeling, simulation, and visualization. Finally, for the past 20 years, I have been the interim co-director and now associate director of the Cardiovascular Research and Training Institute (CVRTI), a center of over 50 people dedicated to cardiac electrophysiology research across all scales. My mentorship approach and my role in this proposal reflect my many years of experience pursuing this research as well as educating students, post doctoral fellows, and junior faculty in the application of experimental, clinical, and computer modeling approaches.

In my time since 1992 as a teacher at the University of Utah, I developed 6 different courses for students in biomedical engineering, many of which are also popular with pre-medical students and graduate students alike. I have developed graduate level Biomedical Engineering tracks in both Computation and Cardiac Electrophysiology & Biophysics and have directed the undergraduate program in Biomedical Engineering and Vice Chair in BME for over 10 years. From 2015-2020, I served as our College of Engineering representative on the MD/PhD program committee, which includes both admissions and mentorship/advising roles. I now serve on our College Equality, Diversity, and Inclusivity Committee. My teaching reviews have placed me in the top 15% of our College of Engineering on several occasions. I am a passionate advocate of novel teaching and advising practices and constantly seek ways to improve the effectiveness of instruction at our institution. For the past 8 months, I have organized biweekly meetings of all the instructors in BME in order to revise and adapt our practices to the challenging constraints of the COVID-19 pandemic. I advise all the students in our undergraduate BME program (90 new admissions per year) and guide them to successful careers in industry, academic research, and medicine. I have also mentored 22 graduate students (as main advisor) to their degrees, 120 more as a member of an advisor committee, and currently sit on 25 advisor committees. I have served as a mentor for an NIH K23 award and been part of the mentoring team on several T32 awards in the School of Medicine.

Relevant recent scientific bibliography :

1. W.G. Good, B. Erem, B. Zenger, J. Coll-Font, J.A. Bergquist, D.H. Brooks, and R.S. MacLeod. Characterizing the Transient Electrocardiographic Signature of Ischemic Stress Using Laplacian Eigenmaps for Dimensionality Reduction. *Comp. in Biol. & Med.*, (in press), 2020.

2. B. Zenger, W.W. Good, J.A. Bergquist, B.M. Burton, J.D. Tate, L. Berkenbile, V. Sharma, and R.S. MacLeod. Novel experimental model for studying the spatiotemporal electrical signature of acute myocardial ischemia: a translational platform. *J. Physiol. Meas.*, 41(1):015002, Feb 2020.

3. J. A. Bergquist, W. W. Good, B. Zenger, J. D. Tate, and R. S. MacLeod. GRÖMeR: A Pipeline for Geodesic Refinement of Mesh Registration. In *Lecture Notes in Computer Science*, volume 11504, pages 37–45. Functional Imaging and Model of the Heart (FIMH), Springer Verlag, 2019.

4. J.D. Tate, T.A. Pilcher, K.K. Aras, B.M. Burton, and R.S. MacLeod. Validating Defibrillation Simulation in a Human-Shaped Phantom. *Heart Rhythm J.*, page (epub ahead of print), Nov 2020.

5. B.M. Burton, K.K. Aras, W.W. Good, J.D. Tate, B. Zenger, and R.S. MacLeod. A Framework for Image-Based Modeling of Acute Myocardial Ischemia Using Intramurally Recorded Extracellular Potential. *Annal. Biomed. Eng.*, 46(9):1325–1336, 2018.

B. Positions and Honors

Positions and Employment

1980–86	Research Assistant Professor and Computer System Manager, Institut für Medizinische Physik und Biophysik, Universität Graz, Graz, Austria
1986–90	Graduate Research Assistant, Department of Physiology & Biophysics, Dalhousie University, Halifax, N.S., Canada, Postdoctoral Research Associate, Nora Eccles Harrison Cardiovascular Research and Training Institute, University of Utah School of Medicine, Salt Lake City, Utah, 1990-1992
1992–1998	Research Assistant Professor, Nora Eccles Harrison Cardiovascular Research and Training Institute, University of Utah School of Medicine, Salt Lake City, Utah
1993–1997	Research Assistant Professor, Department of Bioengineering, University of Utah, Salt Lake City, Utah
1998–2003	Assistant Professor, Department of Bioengineering, University of Utah, Salt Lake City, Utah
2003–2012	Tenured Associate Professor, Department of Bioengineering, University of Utah, Salt Lake City, Utah
1999–2003	Acting Co-Director, Cardiovascular Research and Training Institute, University of Utah
2003–present	Associate Director, Cardiovascular Research and Training Institute, University of Utah
2002–present	Associate Director, Scientific Computing and Imaging (SCI) Institute, University of Utah
2006–present	Associate Chair and Head of Undergraduate Studies, Dept. of Bioengineering, U of Utah
2009–2015	Co-founder and Associate Director Comprehensive Arrhythmia Research and Management Center
2012–present	Full Professor, Department of Biomedical Engineering, University of Utah, Salt Lake City, Utah

Other Experience and Professional Memberships

1990–	Member, IEEE Engineering in Medicine and Biology Society (EMBS)
1999–	Member Biomedical Engineering Society (BMES)
1999–	International Society of Electrocardiology (ISE)
2002–	ISE International Council member (since 2016 Executive)
1995–	International Society of Computerized Electrocardiology
1995–	Ad hoc NIH study section member
2005–	Editorial Board, Journal of Electrocardiology
2008–	Member, Heart Rhythm Society (HRS)
2015–	Co-Founder of the Consortium for ECG Imaging
2015–	Board of Computing in Cardiology Society, since 2017 President

Honors

1979	Dalhousie University Medal in Engineering Physics
1980–85	Austrian Student Union Scholarships
1986–90	Izaak Walton Killam Memorial Scholarship
1987–90	Medical Research Council of Canada Studentship
1990–92	Heart and Stroke Foundation of Canada Postdoctoral Fellowship
2016	Fellow of American Institute of Biomedical Engineering (AIMBE)
2017	President of the Computing in Cardiology Society

C. Contribution to Science

Electrocardiographic Inverse Problems: I have spent my entire career exploring novel approaches to electrocardiographic imaging (ECGI) *i.e.,* the estimation of cardiac electrical activity from body-surface ECG. I have pursued a wide variety of approaches and used both computational and experimental methods to develop and validate a range of approaches, and most recently have co-founded a new Consortium for ECGI (www.ecg-imaging.org) to evaluate all aspects of the accuracy and utility of this technique through sharing of validation data and approaches. My lab also hosts a public data base of sample data sets for validation and comparison of inverse solution approaches.

1. L.R. Bear, Y.S. Dogrusoz, W.W. Good, J. Svehlikova, J. Coll-font, E.Van Dam, and R.S. MacLeod. The Impact of Torso Signal Processing on Noninvasive Electrocardiographic Imaging Reconstructions. *IEEE Trans Biomed Eng.* (1-1)2020;(in press).
2. M. Cluitmans, D.H. Brooks, R.S. MacLeod, O. Doessel, M. Guillem, P. Van Dam, J. Svehlikova, B. He, J. Sapp, L. Wang, and L.R. Bear. Consensus on validation and opportunities of electrocardiographic imaging: From technical achievements to clinical applications. *Front. Physiol.* Epub ahead of print, 2018.
3. K.K. Aras, W. Good, J.D. Tate, B.M. Burton, D.H. Brooks, J. Coll-Font, O. Doessel, W. Schulze, D. Patyogaylo, L. Wang, P. Van Dam, and R.S. MacLeod. Experimental Data and Geometric Analysis Repository: EDGAR *J Electrocardiol.* 48(6):975-81, 2015.
4. D.J. Swenson, S.E. Geneser, J.G. Stinstra, R.M. Kirby, and R.S. MacLeod. Cardiac Position Sensitivity Study in the Electrocardiographic Forward Problem Using Stochastic Collocation and BEM. *Ann. Biomed. Eng.*, 39(12):2900–2910, 2011. PMCID: PMC3362042.

Image based biomedical modeling: This research direction stemmed from the recognition of the absence of tools for conducting patient specific, imaged based modeling and simulation of physiology. To extend and make openly available the tools we have developed for the purpose, we have received NIH support since 1999 and now release a complete pipeline of software for image based modeling and simulation. We conduct courses each year (some under separate NIH funding) and have identified over 300 publications from researchers who use our software and techniques for their research.

1. R. Kamali, J. Kump, E. Ghafoori, M. Lange, H. Nan, T.J. Bunch, D.J. Dosdall, R.S. MacLeod, and R. Ranjan. Area Available for Atrial Fibrillation to Propagate is an Important Determinant of Recurrence after Ablation. *JACC Clin. EP* (in press) 2020.
2. J.A. Bergquist, W.W. Good, B. Zenger, J.D. Tate, and R.S. MacLeod. GRÖMeR: A Pipeline for Geodesic Refinement of Mesh Registration. Funct Imaging Model Heart. 11504:37–45, 2019.
3. S. Guler, M Dannhauer, B. Roig-Solvas, A. Gkogkidis, R.S. MacLeod, T.Ball, J.G. Ojemann, and D.H. Brooks. Computationally Optimized ECoG Stimulation with Local Safety Constraints. *NeuroImage* 173:35-48, June 2018.
4. R.S. MacLeod, J.G. Stinstra, S. Lew, R.T. Whitaker, D.J. Swenson, M.J. Cole, J. Kruger, D.H. Brooks, and C.R. Johnson. "Subject-specific, multiscale simulation of electrophysiology: a software pipeline for image-based models and application examples. *Phil. Trans. Royal Soc.* 367(1896):2293–2310, 2009. PMCID: PMC2696107.

Simulation of cardiac arrhythmias and defibrillation: We have conducted, in collaboration with physicians and other simulation researchers, studies based on simulation of both cardiac arrhythmias and the therapeutic management of their extreme forms through defibrillation. Our arrhythmia simulations focus on identifying the role of abnormal tissue substrate in supporting tachycardia and fibrillation. The goals of our defibrillation studies have focused on optimizing electrode and device placement in order to minimize energy needs while achieving successful defibrillation.

1. J.D. Tate, T.A. Pilcher, K.K. Aras, B.M. Burton, and R.S. MacLeod. Validating Defibrillation Simulation in a Human-Shaped Phantom. *Heart Rhythm J* 17(4): 661-668, 2020.
2. A. Prakosa, H.J. Arevalo, D. Deng, P.M. Boyle, P.P. Nikolov, H. Ashikaga, J.E. Blauer, E. Ghafoori, C.J. Park, R.C. Blake III, F.T. Han, R.S. MacLeod, H.R. Halperin, D.J. Callans, R. Ranjan, J. Chrispin, S. Nazarian, and N.A. Trayanova. Personalized Virtual-heart Technology for Guiding the Ablation of Infarct-related Ventricular Tachycardia. *Nature Biomed. Eng.*, 2:732–740, 2019.
3. B.M. Burton, K.K. Aras, W.W. Good, J.D. Tate, B. Zenger, and R.S. MacLeod. A Framework for Image-Based Modeling of Acute Myocardial Ischemia Using Intramurally Recorded Extracellular Potential. *Ann. Biomed. Eng.* 46(9):1325–1336, 2018.

4. K.S. McDowell, S.S. Zahid, F. Vadakkumpadan, J. Blauer, R.S. MacLeod, and N.A. Trayanova. Virtual Electrophysiological Study of Atrial Fibrillation in Fibrotic Remodeling, *PLoS ONE*,10(2), 2015. PMCID: PMC4333565.

Electrocardiology of acute ischemia: Myocardial ischemia remains a leading cause of mortality and morbidity and has been a physiological focus of my research career. We have applied inverse electrocardiography (ECG Imaging) and other signal analysis approaches to identify and localize ischemia in humans; we have carried out animal research studies to characterize the electrical changes induced by ischemia at the tissue and whole heart scale; we have proposed novel concepts of the location of acute ischemia and its evolution over time that contradict long held beliefs.

1. W.G. Good, B. Erem, B. Zenger, J. Coll-Font, J.A. Bergquist, D.H. Brooks, and R.S. MacLeod. Characterizing the transient electrocardiographic signature of ischemic stress using Laplacian Eigenmaps for dimensionality reduction. *Comp. in Biol. & Med.*, (in press), 2020.
2. B. Zenger, W.G. Good, J.A. Bergquist, B.M. Burton, J.D. Tate, L. Berkenbile, V. Sharma, and R.S. MacLeod. Novel experimental model for studying the spatiotemporal electrical signature of acute myocardial ischemia: a translational platform. *Physiol Meas.* 41(1):0015002, 2020.
3. K.K. Aras, D.J. Swenson, B.M. Burton, and R.S. MacLeod. Spatial Organization of Acute Myocardial Ischemia. *J Electrocardiol.* 49(3):689-692, 2016.
4. K. Aras, B. Burton, D. Swenson, and R. MacLeod, Sensitivity of epicardial electrical markers to acute ischemia detection. *J. Electrocardiol.* 47(6): 836-41, 2014. PMCID: PMC4252649.

Image analysis for cardiac arrhythmias: MRI imaging approaches have made enormous progress in evaluating the substrate changes that arise in patients suffering from cardiac arrhythmias. We have developed novel approaches to analyze cardiac MRI in patients with atrial fibrillation, including the ability to predict treatment outcome and thus guide clinical management of this very common arrhythmia. Ongoing studies are expanding these capabilities to evaluate the effectiveness of ablation strategies and determine the mechanistic relationships between tissue pathology and the nature of the resulting arrhythmias.

1. R. Kamali, J. Schroeder, E. DiBella, B. Steinberg, F. Han, D.J. Dosdall, R.S. Macleod, and R. Ranjan. Reproducibility of clinical late gadolinium enhancement magnetic resonance imaging in detecting left atrial scar after atrial fibrillation ablation. *J Cardiovasc Electrophysiol.* (epub ahead of print), 2020.
2. K. Yamashita, R. Kamali, E. Kwan, R.S. MacLeod, D.J. Dosdall, and R. Ranjan. Effective Ablation Settings That Predict Chronic Scar After Left Atrial Ablation. *JACC Clin Electrophysiol.* Feb;6(2):143-152, 2020
3. K. Yamashita, E. Kwan, R. Kamali, E. Ghafoori, B.A. Steinberg, R.S. MacLeod, D.J. Dosdall, and R. Ranjan. Blanking period after radiofrequency ablation for atrial fibrillation guided by ablation lesion maturation based on serial MR imaging. *J Cardiovasc. Electrophysiol.* 31(2):450–456, 2020.
4. J. Cates, E. Bieging, A. Morris, G. Gardner, N. Akoum, E. Kholmovski, N. Marrouche, C. McGann, R.S. MacLeod. Computational Shape Models Characterize Shape Change of the Left Atrium in Atrial Fibrillation. *Clin. Med. Insights Cardiol.*, 8(S1):11–99, doi: 10.4137/CMC.S15710, 2015.

D. Research Support

Ongoing Research Support

NIH/NIGMS R24GM136986 (MacLeod, Johnson, Whitaker) Date: 5/1/2020–4/30/2023
Center for Integrative Biomedical Computing Legacy Transition
Role: Co-PI
The goal of this plan is to complete, with the assistance of the software engineers at Kitware Inc, the conversion of all the technical products achieved over the lifetime of the CIBC into well crafted, validated computer code with all the necessary support for both users and future maintainers of the code base.

NIH/NIBIB U24EB029012 (MacLeod) Date: 9/3/2019–6/30/2022
Integration of Uncertainty Quantification with SCIRun Bioelectric Field Simulation Pipeline
Role: PI
This project harnesses mature and modern techniques for uncertainty quantification (UQ) from the computational science and mathematics communities and incorporates them into the established biomedical simulation software framework SCIRun.

NIH/NHLBI RO1 (Ranjan) Date: 7/1/2018–6/30/2023
Myocardial Substrate Driven Mechanistic Insights into Atrial Fibrillation
Role: Co-Investigator
The goal of this project is to use a combination of serial electrical mapping at different resolutions and high resolution *in vivo* and *ex vivo* MRI proposed to develop a mechanistic approach to catheter-based ablation.

P41 RR12553 (Johnson, MacLeod, Whitaker) Date: 9/1/15–4/30/2021
NIH/NCRR Center for Integrated Biomedical Computation
Role: Co-PI
This Center is national research resource (P-41) that has existed since 1999. The goals of the current edition are to address biomedical research problems in bioelectric fields, imaged-based anatomy, multi-scale tissue modeling and simulation, and scientific visualization. We will accomplish these goals by creating state-of-the- art computational techniques and innovative, well-engineered software, which, in combination with and freely distributed to the science community, will significantly advance biomedical computing research.

No ID Number (MacLeod) Date: 7/1/17–6/30/21
Nora Eccles Treadwell Foundation
Electrocardiographic Characterization of Myocardial Ischemia
Role: PI
The overarching goal of this research is to recognize and diagnose all forms of myocardial ischemia using the ECG. We seek, through measurements, experiments, and simulations to achieve the most complete understanding possible of the full spectrum of ischemia in terms of its bioelectric source, its electrical interaction with surrounding tissues, and its reflection on the body surface.

Recently Completed Research Support

NSF (Ojemann, MacLeod, Brooks, and Ball) Date 9/1/2015–8/31/2019
Collaborative Research: US-German Research Proposal: Optimization of Human Cortical Stimulation
Role: Subcontact PI
In this Collaborative US-German project, we seek to apply experimental and simulation approaches to improve cortical stimulation of the brain. 1. Optimization of electrode design for delivery to deeper cortical layers including cortex in the sulci. 2. Validation of electrode models in animal studies of microstimulation. 3. Confirmation of modeling in human studies.
British Heart Foundation PG/15/8/31130 (Aslanidi) Date: 5/1/2015–12/30/2018
Dissecting multifactorial mechanisms of atrial fibrillation: Predictive modelling framework for evaluating medical treatments
Role: Co-Investigator

R25GM107009-01 (MacLeod, Weiss, Whitaker) Date: 7/1/2013–6/30/2018
Image Based Modeling, Simulation, and Visualization Summer Course for Biomedical Researchers
The goal of this program was to expand the scope of current Center for Integrative Biomedical Computing (CIBC) and Muskuloskeletal Research Lab (MRL) training to create a dedicated two-week course in the area of image based modeling and simulation applied to bioelectricity and biomechanics. Role: Co-PI

DP1HL123271 (Trayanova) Date: 8/1/2015-7/31/2017
Virtual Electrophysiology Laboratory
Role: Subcontract PI
The goal of this subcontract is to serve as the clinical testing site for the use of image based simulation to identify arrhythmogenic substrate in patients suffering from post myocardial infarction ventricular tachycardia.

2 P41 RR12553 (Johnson) Date: 9/1/1999–8/30/2015
NIH/NCRR Center for Integrated Biomedical Computation
Role: Co-Investigator and Center Co-director

No ID Number (MacLeod) Date: 7/1/05–6/30/17
Nora Eccles Treadwell Foundation
Electrocardiographic Characterization of Myocardial Ischemia
Role: PI