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## BIOGRAPHICAL SKETCH

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NAME: Jonathan F. Wenk

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eRA COMMONS USER NAME: JONATHAN.WENK

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POSITION TITLE: Associate Professor of Mechanical Engineering and Associate Professor of Surgery

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

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INSTITUTION AND LOCATION	DEGREE (if applicable)	Completion Date MM/YYYY	FIELD OF STUDY
Purdue University, West Lafayette, IN	BS (Hons)	05/2003	Mechanical Engineering
University of California, Berkeley, CA	MS	12/2005	Mechanical Engineering
University of California, Berkeley, CA	PhD	12/2008	Mechanical Engineering
University of California, San Francisco, CA	Postdoc	07/2011	Bioengineering/Surgery

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### A. PERSONAL STATEMENT

My long-term research goals focus on the simulation of ventricular and valvular structures in order to evaluate the effects of disease and treatment strategies. With regards to the proposed research, I have worked closely with Co-PI Ken Campbell to develop a computational tool that can be used to test how modifications to specific molecules alter ventricular function. Ultimately, this work might help to optimize patient-specific therapies for men and women with heart failure. Our work will use a multiscale approach that integrates molecular-level mechanisms, which account for alterations due to genetic mutation and targeted drug therapy, with organ-level ventricular pump function. This is possible due to the coupling of Dr. Campbell's molecular/cellular computer code into my finite element framework. This represents the melding our complementary skill sets. In order to extend the capabilities of the modeling technique we have begun collaborating with Dr. Lee, from Michigan State University, to implement growth and remodeling algorithms that will allow the model to predict long-term changes in structure and function. Dr. Yengo, from Penn State University, will provide experimental measurements of myosin-level kinetics, which will help further develop and validate the numerical methods. My background in evaluating functional and structural changes in the left ventricle, due to various disease states, has equipped me with all of the tools that are necessary to carry out the proposed work. In particular, I have developed novel computational techniques that will be used to evaluate the regional mechanics of the heart. I have demonstrated a record of productive research in cardiac mechanics, and my expertise and experience have uniquely prepared me to work on the proposed project.

1. Zhang, X., Haynes, P., Campbell, K. S., and **Wenk, J. F.**, 2015, "Numerical Evaluation of Myofiber Orientation and Transmural Contractile Strength on Left Ventricular Function," *Journal of Biomechanical Engineering*, **137(4)**, 044502. (PMID: 25367232)
2. Nikou, A., Dorsey, S. M., McGarvey, J. R., Gorman III, J. H., Burdick, J. A., Pilla, J. J., Gorman, R. C., and **Wenk, J. F.**, 2015, "Computational Modeling of Healthy Myocardium in Diastole," *Annals of Biomedical Engineering*, **44(4)**, pp. 980-992. (PMCID: PMC4731326)
3. **Wenk, J. F.**, Ge, L. Zhang, Z., Soleimani, M., Potter, D. D., Wallace, A. W., Tseng, E., Ratcliffe, M. B., and Guccione, J. M., 2013, "A Coupled Biventricular Finite Element and Lumped Parameter Circulatory System Model of Heart Failure," *Computer Methods in Biomechanics and Biomedical Engineering*, **16(8)**, pp. 807-818. (PMCID: PMC3367128)

## B. POSITIONS AND HONORS

### Positions and Employment

2008-2009	Research Consultant (on computational modeling) CardioPolymers, Inc., Laguna Hills, CA
2011-2017	Assistant Professor, Department of Mechanical Engineering, Department of Surgery (by joint appointment); University of Kentucky, Lexington, KY
2017-present	Associate Professor, Department of Mechanical Engineering, Department of Surgery (by joint appointment); University of Kentucky, Lexington, KY

### Manuscript Reviewing

Acta Biomaterialia, Computer Methods in Biomechanics and Biomedical Engineering, Cardiovascular Engineering and Technology, Computational Mechanics, Journal of Biomechanical Engineering, Medical & Biological Engineering & Computing, Journal of Biomechanics, Medical Engineering & Physics, Biomechanics and Modeling in Mechanobiology, Computers in Biology and Medicine, Journal of the Royal Society Interface, Circulation, The American Journal of Cardiology.

### Grant Reviewing

2012-present	American Heart Association
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### Honors

2005	Outstanding Graduate Student Instructor Award, University of California, Berkeley
2012	ASME Bluegrass Chapter Outstanding Faculty Award, University of Kentucky
2014	STLE Frank P. Bussick Award

### Professional Memberships

2007-present	United States Association for Computational Mechanics
2007-present	International Association for Computational Mechanics
2009-present	American Society of Mechanical Engineers
2009-present	Biomedical Engineering Society
2013-present	American Heart Association

## C. CONTRIBUTIONS TO SCIENCE

Complete list of published work in NCBI My Bibliography

<http://www.ncbi.nlm.nih.gov/myncbi/browse/collection/42789182/?sort=date&direction=descending>

### Inverse calculations of myocardial mechanical properties

Over the past 7 years, I have used a combination of cardiac MRI, finite element modeling, and numerical optimization to estimate the mechanical properties of both passive and active myocardium. This is accomplished by comparing the deformation (strain) calculated from the experimental MRI data with that predicted by the ventricular finite element models. These studies have predicted increased passive stiffness of infarcted tissue, as well as depressed contractility in the border zone myocardium near an infarct. Both of these results have been confirmed with ex vivo experiments.

4. Wang, H., Zhang, X., Dorsey, S. M., McGarvey, J. R., Campbell, K. S., Burdick, J. A., Gorman III, J. H., Pilla, J. J., Gorman, R. C., and **Wenk, J. F.**, 2016, "Computational Investigation of Transmural Differences in Left Ventricular Contractility," *Journal of Biomechanical Engineering*, **138(11)**, 114501. (PMCID: PMC5125313 [Available on 2017-11-01])
5. Mojsejenko, D., McGarvey, J. R., Dorsey, S. M., Gorman III, J. H., Burdick, J. A., Pilla, J. J., Gorman, R. C., and **Wenk, J. F.**, 2015, "Estimating Passive Mechanical Properties in a Myocardial Infarction using MRI and Finite Element Simulations," *Biomechanics and Modeling in Mechanobiology*, **14(3)**, pp. 633-647. (PMCID: PMC4398581)
6. **Wenk, J. F.**, Sun, K., Zhang, Z., Soleimani, M., Ge, L., Saloner, D. A., Wallace, A. W., Ratcliffe, M. B., and Guccione, J. M., 2011, "Regional Left Ventricular Myocardial Contractility and Stress in a Finite Element Model of Posterobasal Myocardial Infarction," *Journal of Biomechanical Engineering*, **133(4)**, 044501. (PMCID: PMC3097530)

### Investigating the effects of myocardial infarction

In order to assess the temporal changes in mechanical properties, I have used finite element modeling and in-vivo data (as described in the previous section) to predict changes in infarct stiffness over a 12 week period (post infarction) in porcine. This work showed the lateral wall infarcts become extremely stiff at 1 week post-infarct and then become progressively less stiff. I have also investigated how myocardial infarction leads to dysfunction in the contractile properties of border zone myocardium near an infarct. The in vivo properties were predicted using computer modeling to assess both sheep and human left ventricles after infarction. The decrease in contraction was confirmed with ex vivo experiments of border zone tissue from sheep with infarction.

7. McGarvey, J. R., Moisejkenko, D., Dorsey, S. M., Nikou, A., Burdick, J. A., Gorman III, J. H., Jackson, B. M., Pilla, J. J., Gorman, R. C., and **Wenk, J. F.**, 2015, "Temporal Changes in Infarct Material Properties: An *In Vivo* Assessment using MRI and Finite Element Simulations," *Annals of Thoracic Surgery*, **100(2)**, pp. 582-589. (PMID: 26095107)
8. Lee, L. C., **Wenk, J. F.**, Klepach, D., Zhang, Z., Saloner, D., Wallace, A. W., Ge, L., Ratcliffe, M. B., and Guccione, J. M., 2011, "A Novel Method for Quantifying In-Vivo Left Ventricular Myocardial Contractility in the Borderzone of a Myocardial Infarction," *Journal of Biomechanical Engineering*, **133(9)**, 094506. (PMCID: PMC3207355)
9. **Wenk, J. F.**, Klepach, D., Lee, L. C., Zhang, Z., Ge, L., Tseng, E., Martin, A., Kozerke, S., Gorman III, J. H., Gorman, R. C., and Guccione, J. M., 2012, "First Evidence of Depressed Contractility in the Borderzone of a Human Myocardial Infarction," *Annals of Thoracic Surgery*, **93(4)**, pp. 118-1194. (PMCID: PMC3314154)
10. Shimkunas, R., Zhang, Z., **Wenk, J. F.**, Soleimani, M., Khalzapour, M., Acevedo-Bolton, G., Wang, G., Saloner, D., Mishra, R., Wallace, A. W., Ge, L., Baker, A., Guccione, J. M., and Ratcliffe, M. B., 2013, "Left ventricular myocardial contractility is depressed in the borderzone after postero-lateral myocardial infarction," *Annals of Thoracic Surgery*, **95(5)**, pp. 1619-1625. (PMCID: PMC3640420)

### Growth and remodeling of ventricular myocardium

Over that last several years, I have worked with Dr. Lee (Co-I) to develop finite element models that use growth and remodeling algorithms to alter the geometry of the ventricle due to changes in pressure loading. Patient-specific MRI data was used to assess growth and remodeling before and after surgical ventricular restoration surgery. It was found that the surgery does not prevent adverse remodeling, which is consistent with clinical observations. Another study used a growth and remodeling algorithm that was coupled to an electromechanical model to investigate the effects of infarct stiffness on ventricular function. It was found that stiffer infarcts reduce the amount of adverse remodeling in both the remote and border zone myocardium.

11. Klepach, D., Lee, L. C., **Wenk, J. F.**, Ratcliffe, M. B., Zohdi, T. I., Navia, J. L., Kassab, G. S., Kuhl, E., and Guccione, J. M., 2012, "Growth and remodeling of the left ventricle: A case study of myocardial infarction and surgical ventricular restoration," *Mechanics Research Communications*, **42**, pp. 134-141. (PMCID: PMC3390946)
12. Lee, L. C., **Wenk, J. F.**, Klepach, D., Zhang, Z., Zhong, L., Ge, L., Ratcliffe, M. B., Navia, J. L., Kassab, G. S., and Guccione, J. M., 2013, "Physics-based Analysis of Patient-specific Surgical Ventricular Restoration – Importance of an Ellipsoid Left Ventricular Geometry for Diastolic and Systolic Function," *Journal of Applied Physiology*, **115(1)**, pp. 136-144. (PMCID: PMC3727014)
13. Lee, L. C., Sundnes, J., Genet, M., **Wenk, J. F.**, and Wall, S. T., 2016, "An Integrated Electromechanical-Reversible Growth Heart Model for Simulating Cardiac Therapies," *Biomechanics and Modeling in Mechanobiology*, **15(4)**, pp.791-803. (PMID: 26376641)
14. Nikou, A., Dorsey, S. M., McGarvey, J. R., Gorman III, J. H., Burdick, J. A., Pilla, J. J., Gorman, R. C., and **Wenk, J. F.**, 2016, "Effects of Using the Unloaded Configuration in Predicting the In Vivo Diastolic Properties of the Heart," *Computer Methods in Biomechanics and Biomedical Engineering*, **19(16)**, pp.1714-1720. (PMCID: PMC5278778 [Available on 2017-12-01])

### Investigating the effects of medical devices and treatment

I have investigated the effects of injecting biomaterials (such as alginate and hydrogel) into myocardium and infarcted tissue, as a means of improving long-term ventricular function. It was found that injections reduce stress in the myocardium, as well as alter the mechanical stiffness of the tissue. By tuning the properties of the injectate material, this could have a long-term benefit to pump function. In addition, studies were conducted to evaluate the effects of the CorCap cardiac support device. While the myocardial wall stress was found to decrease, pump function was also found to decrease (acutely) and the pre-tension in the device had a significant effect on pump function.

15. Dorsey, S. M., McGarvey, J. R., Wang, H., Nikou, A., Arama, L., Koomalsingh, K. J., Kondo, N., Gorman III, J. H., Pilla, J. J., Gorman, R. C., **Wenk, J. F.**, and Burdick, J. A., 2015, "MRI Evaluation of Injectable Hyaluronic Acid Hydrogel Therapy to Limit Ventricular Remodeling after Myocardial Infarction," *Biomaterials*, **69**, pp. 65-75. (PMCID: PMC4556569)
16. **Wenk, J. F.**, Wall, S. T., Peterson, R. C., Helgerson, S. L., Sabbah, H. N., Burger, M., Stander, N., Ratcliffe, M. B., and Guccione, J. M., 2009, "A Method for Automatically Optimizing Medical Devices for Treating Heart Failure: Designing Polymeric Injection Patterns," *Journal of Biomechanical Engineering*, **131(12)**, 121011. (PMID: 20524734)
17. Kichula, E. T., Wang, H., Dorsey, S. M., Szczesny, S. E., Elliott, D. M., Burdick, J. A., and **Wenk, J. F.**, 2014, "Experimental and Computational Investigation of Altered Mechanical Properties in Myocardium after Hydrogel Injection," *Annals of Biomedical Engineering*, **42(7)**, pp. 1546-1556. (PMCID: PMC4032381)
18. **Wenk, J.F.**, Ge, L., Zhang, Z., Mojsejenko, D., Potter, D.D., Tseng, E.E., Guccione, J.M., and Ratcliffe, M.B., 2013, "Biventricular Finite Element Modeling of the Acorn CorCap™ Cardiac Support Device on a Failing Heart," *Annals of Thoracic Surgery*, **95(6)**, pp. 2022-2027. (PMCID: PMC3702266)

### Mitral valve modeling and mechanics

In terms of valvular structures, I have used finite element modeling to look at the effects of myocardial infarction on mitral regurgitation. One of the most significant studies investigated how infarct stiffness affects the coaptation of the mitral leaflets. This study was conducted with a sheep model of myocardial infarction and showed that stiffening the infarct can reduce the amount of regurgitation through the valve. In follow up investigations, the effects of annuloplasty rings on preventing mitral regurgitation were investigated. It was found that the stiffness and shape of the rings have a significant influence on regurgitation and stress in the leaflets.

19. **Wenk, J. F.**, Zhang, Z., Cheng, G., Malhotra, D., Acevedo-Bolton, G., Burger, M., Suzuki, T., Saloner, D. A., Wallace, A. W., Guccione, J. G., and Ratcliffe, M. B., 2010, "First Finite Element Model of the Left Ventricle with Mitral Valve: Insights into Ischemic Mitral Regurgitation," *Annals of Thoracic Surgery*, **89(5)**, pp. 1546-1553. (PMCID: PMC2887313)
20. **Wenk, J. F.**, Ratcliffe, M. B., and Guccione, J. M., 2012, "Finite Element Modeling of Mitral Leaflet Tissue using a Layered Shell Approximation," *Medical & Biological Engineering & Computing*, **50(10)**, pp. 1071-1079. (PMCID: PMC3477701)
21. Wong, V. M., **Wenk, J. F.**, Zhang, Z., Cheng, G., Acevedo-Bolton, G., Burger, M., Saloner, D. A., Wallace, A. W., Guccione, J. M., Ratcliffe, M. B., and Ge, L., 2012, "The effect of mitral annuloplasty shape in ischemic mitral regurgitation: A finite element simulation," *Annals of Thoracic Surgery*, **93(3)**, pp. 776-782. (PMCID: PMC3432639)
22. Baillargeon, B., Costa, I., Leach, J. R., Lee, L. C., Genet, M., Toutain, A., **Wenk, J. F.**, Rausch, M. K., Rebelo, N., Acevedo-Bolton, G., Kuhl, E., Navia, J. L., Guccione, J. M., 2015, "Human Cardiac Function Simulator for the Optimal Design of a Novel Annuloplasty Ring with a Sub-valvular Element for Correction of Ischemic Mitral Regurgitation," *Cardiovascular Engineering and Technology*, **6(2)**, pp. 105-116. (PMCID: PMC4427655)

## D. FUNDING

### Ongoing Research Support

NIH U01 HL133359 Wenk (PI) & Campbell (PI) 08/03/2017-07/31/2022  
National Heart, Lung and Blood Institute  
*Title:* Multiscale Modeling of Inherited Cardiomyopathies and Therapeutic Interventions  
*Major goal:* To develop a novel finite element framework that incorporates the effects of growth and remodeling due to sarcomere-level genetic mutations and drug therapies.  
*Role:* PI

CMMI-1538754 Wenk (PI) 09/01/2015-08/31/2018  
National Science Foundation  
*Title:* Multiscale modeling of left and right ventricular function  
*Major goal:* To develop a multiscale finite element model that incorporates feature of both the left and right ventricle.  
*Role:* PI

AHA 15GRNT25460003 Campbell (PI) 07/01/2015-06/30/2018  
American Heart Association Great Rivers Affiliate  
*Title:* Transmural variation in cellular level contraction  
*Major goal:* To investigate transmural differences in human myocardium with respect to heart disease and potential effects of mechanical unloading.  
*Role:* Co-I

NIH R01 HL063954 Gorman (PI) 03/10/2015-01/31/2019  
National Heart, Lung and Blood Institute  
*Title:* Surgery to Prevent Postinfarction Ventricular Remodeling  
*Major goal:* Utilize experimental and computational tools to develop hydrogel injection therapies for treating myocardial infarction.  
*Role:* Co-I

### Completed Research Support

AHA 14BGIA18850020 Wenk (PI) 01/01/2014-12/31/2016  
American Heart Association Great Rivers Affiliate  
*Title:* Computer-assisted optimization of therapies for heart failure  
*Major goal:* To develop a fully time-dependent finite element model of the left ventricle that includes transmural variation in contractile properties.  
*Role:* PI

N00014-14-1-0161 Young (PI) 01/01/2014-12/31/2016  
Office of Naval Research  
*Title:* Non-uniform loading of surface vessels  
*Major goal:* To develop software to predict the magnetization of surface vessels undergoing dynamic loading.  
*Role:* Co-PI

Pilot project on NIH P30 GM110787 Campbell (PI) 08/13/2014-04/30/2016  
University of Kentucky Center for Molecular Medicine  
*Title:* Molecular mechanisms of cardiac dysfunction  
*Major goal:* To investigate transmural differences in molecular/cellular level function in rats with aging-associated heart failure.  
*Role:* Co-I

No Award Number Wenk (PI) 07/01/2013-06/30/2014  
University of Kentucky Center for Computational Sciences  
*Title:* Finite element modeling of ventricular mechanics  
*Major goal:* To develop a finite element model of the heart that integrates dynamic cross-bridge cycling.  
*Role:* PI