**Biaxial Testing**

The four heart valves regulate blood flow through the heart. Only the mitral and tricuspid valves are examined in this project. The mitral valve permits blood flow from the left atrium to the left ventricle but restricts blood flow in the opposite direction; The tricuspid valve serves the same function for blood flow between the right atrium and right ventricle. Degradation and disease can affect these valves, leading to impaired valve function and initializing blood backflow, or \*regurgitation\*. These diseases are often mechanically-based, principally affecting the macro and microstructure of the heart valve and the mechanical behavior of the valve tissue. Computational modeling has recently been used to better understand how disease-driven mechanical and structural alterations impair valve function. These models rely on accurate material data – i.e., data that describes how the tissue will deform when subjected to mechanical loading. A dearth of this material data exists for the mitral and tricuspid valves. As such, our project focused on obtaining and presenting material data for the leaflets of these heart valves.

To examine the valve tissue mechanics, we used biaxial testing methods. These methods apply loads in two tissue directions, and are essential for characterization of \*anisotropic\*, or directionally-dependent, tissue mechanics. Because of extensive fiber networks running through the tissue, heart valve leaflets exhibit significant mechanical anisotropy, and as such require testing by biaxial methods. We also used image-based deformation tracking techniques to improve the quality of data obtained and to avoid error from attachment effects (St. Venant effects). Our study captured the anisotropy and nonlinear mechanical response of each of the three leaflets of the tricuspid valve and the two leaflets of the mitral valve. We further examined how the biaxial testing parameters, such as loading rate, testing temperature, and animal donor (pig vs sheep vs lamb heart tissue), affected the observed mechanical response. To complement the mechanical responses observed in our testing, we carried out a brief structural analysis consisting of quantification of the distribution of chordae tendineae within the valves and a histological examination of the layered microstructure of the heart valves. We expect that the data obtained in our study will help researchers to model the healthy heart valves and to eventually provide a model-based tool for prediction of surgical outcomes.

Our group has also recently been performed similar biaxial testing protocols to examine how the mechanical response of the tissue varies throughout the region of the leaflet. This study found significant differences in the mechanical response of the mitral and tricuspid valve leaflets in various regions, with central regions exhibiting a more characteristic anisotropic response and edge regions exhibiting a more isotropic mechanical response. This brief “regional” study has been submitted for publication and will hopefully be accepted for publication by early 2019.

### Through this project, I gained extensive experience with material behavior modeling and tensor representations of deformation and tissue mechanical response. Through utilizing image-based strain tracking in our samples, I learned about regional image tracking and digital image correlation techniques. In our processing of testing data, I performed software development and figure generation in \*\*MATLAB\*\*. I improved my leadership skills by managing the research team during the data collection, and by ensuring the procedures were uniformly implemented by each member. Finally, I gained valuable writing experience drafting our manuscript, "An investigation of the anisotropic mechanical properties and anatomical structure of porcine atrioventricular heart valves.”, which is available in the \*\*Portfolio\*\* section. This research also led to multiple presentations at various conferences, including the “[Technical Presentation: Biaxial Mechanical Testing and Constitutive Model Development of Atrioventricular Valve Leaflets](http://localhost:1313/publication/talk_at_emi/)”, included in the \*\*Portfolio\*\* section.

**Microstructural Imaging**

The mitral and tricuspid heart valves are composed of leaflets, or thin flaps of membranous tissue, anchored proximally to a fibrous ring known as the valve annulus and distally to a series of chordae tendineae. These leaflets coapt, or come together, during systole to prevent the passage of blood. During diastole, the leaflets recede into the ventricles to permit passage of blood. This leaflet motion is repeated each heartbeat, leading to pronounced cyclic loading and strain on the valve tissue. To handle the imposed loading, the heart valve leaflets are composed of a network of collagen fibers. These fibers are responsible for the anisotropy, or directional-dependence, of the leaflet tissue’s mechanical behavior. Simply put, the local orientations of the fibers dictate the direction of maximum stiffness in the heart valve leaflets. However, part of the versatility and utility of the collagen fibers in bearing load arises from the fibers’ ability to realign to bear the necessary load. That is to say, the orientations of the fibers are likely to change under applied loading. Although previous groups have examined the collagen fibers in an unloaded state, no prior studies have examined and quantified how these local fiber orientations can change under applied loading. Our study seeks to quantify the changes in local orientations of collagen fibers in heart valve leaflets under dynamic applied loading.

To examine these collagen fibers, our group uses a custom-built system reliant upon a novel technique known as “Polarized Spatial Frequency Domain Imaging”. This technique capitalizes on the birefringence, or polarization-dependent, response of the collagen fibers. To determine the fiber directions from this birefringence, our system uses a projector, two polarizers, and a 5 MegaPixel CCD camera to capture high resolution images of the testing sample at various polarization angles. We then analyze the images and compute a model fit comparing the intensity recorded at each pixel to the polarization angle. Based on the model fit, we are able to discern the local collagen fiber orientation. These predicted orientations can then be plotted on colormaps like the ones shown above. Once we are able to fully validate the predictions of our system, we expect to apply load to the tissue to observe the changes in collagen structure, and to report these load-driven changes in a manuscript.

This project has been a foray into imaging systems and has afforded me a glimpse into the complexity and depth of the scientific imaging field. Through research on advanced imaging techniques like spatial frequency domain imaging, rasterized light-scattering, and polarization microscopy, I’ve realized how much data can be gained about a tissue or biomaterial by simply observing it in an appropriate way. Our data analysis pipeline for this microstructural imaging project was implemented in \*\*Python\*\*, with support from open-source software like \*\*GitHub\*\*, Anaconda, NumPy, Matplotlib, and many other open source libraries for Python. Through developing the pipeline, I also learned to refactor code into discrete functions to make a more robust and clearer program. We expect to publish an article about our system and the data obtained, but I have already given a presentation about the ongoing project, as listed below.

**Wind Tunnel**

Student aerospace researchers at the University of Oklahoma had a problem. The students needed a quality wind tunnel to test full-scale UAV propeller designs and to serve as a testing ground for model airfoil designs. The University owned various wind tunnels, but each tunnel was an expensive, high-precision instrument that required difficult-to-obtain departmental permission and didn’t permit simple modifications for research purposes. In addition, none of the viable options had a large enough test-section to accommodate the full scale (~18 inch diameter) UAV propellers students were designed. Our professor started a group with $5000 seed funding to build an appropriate wind tunnel for these student research projects.

To build the desired low-cost and versatile wind tunnel, we started by defining the parameters and constraints of our build. We established the test section size, considered closed vs. open loop tunnels, defined our desired flow velocity in the test section, and used previous articles to examine the diffuser and contraction-angle we would need to help prevent flow delamination and ensure flow uniformity in the test section. We developed simple computer-aided design (CAD) models of various closed and open-loop designs in \*\*Solidworks\*\*, then used Solidworks flow simulation and other \*\*Computational Fluid Dynamics (CFD)\*\* tools to examine the predicted flow uniformity in the test section. Once we decided on an open-loop tunnel design, we decided on a building material and reinforced our model and added supporting struts and beams to the design. We used many wood fabrications tools made available through the Innovation Hub at OU, including a \*\*Computer Numerical Control (CNC)\*\* machine to cut the more complex shapes out of plywood. We used a modular design to assemble and create the structure, building in sections and transporting the completed sections to the Westheimer airport in Norman, the final location for the tunnel. Once the tunnel was completed and assembled, we used a hot-wire anemometer to gain point-wise flow velocity measurements in the test section as part of our uniformity study. Further details about the building process and the uniformity study are included in the below attached conference paper.

Through this project, I learned how to plan a project by considering both constraints and requirements and developing a project plan to satisfy features in both essential categories. I gained project experience with applying design and analysis tools (CAD and CFD, respectively), and learned to appreciate the value that these tools can contribute to informing design. I thoroughly enjoyed this project; From the team I worked with, to the manual labor inherent in building a wooden structure, to the enjoyment of leading the team, to the pride of building something that others can use and appreciate, this entire project was a pleasure.

**Adventure**

I appreciate all kinds of adventures. Preferably with friends and my dog, Remi. The pictures above are from a camping trip to the Rocky Mountain National Park in Colorado and from a hike up to King Arthur’s Seat in Edinburgh, Scotland. I don’t want this page to be a list of the places I have been or the adventures I’ve had, but rather I want it to show what I take from these outdoor experiences, why I think everyone should get outside and go do something every once in a while.

Standing on top of a mountain, looking out over a still lake, or scuba diving above a sleeping sea turtle can all help to show people how small we are. Experiences like these help me get perspective. They allow me to realize that the world around us is bigger, grander, and deserving of more consideration than the internal. They help me to see that everything will go on after our time is over, and that’s okay. The best thing we can do is just to enjoy and appreciate our time here, to be kind to the people around and to smile and laugh and appreciate the gift of life. I think the messages and the drive coming from other sources – TV shows, advertisements, and our internal voice – provide a message that everything is about the individual. Individualized diets, individualized religion, and personalized considerations push humans toward believing that, if they aren’t omnipotent, they at least deserve the attention of the those around them. This causes a lot of anger, sadness, and depression as the actions of others and the processes of the world inevitably don’t focus on them. Adventures and quality time spent in the outdoors help to remind me that I am dust, and to dust I shall return. And that’s okay. In some odd way, knowledge of our impermanence helps me appreciate today.

Going on adventures brings people together. Exploring the unknown or embarking on a quest requires people to band together to accomplish what they couldn’t alone. Shared struggle, shared hardship, and shared victories bring people together and help us to relate on a fundamental level. I have come to appreciate the strength and the scars of my friends by trying something with them, by admitting we want to face a challenge together and by attempting it. This admission leads to a sort of shared vulnerability and is a way to build honesty and truth in friendships. And a life full of genuine, open, and supportive friendships is a happy life.

So, if you haven’t felt the tremor of fear on the roof of your stomach as you watch a storm roll in, felt a chill wet wind at your face while standing on the top of a mountain, grab a friend and get out and try it. You won’t regret it.

**Crossfit**

I have been doing crossfit workouts since I was 13 years old. My dad and I, along with some local neighborhood kids, would go out to the track and do the free workout posted on crossfit.com. We made do with whatever equipment we could find, sometimes buying cheap sports equipment from Craigslist. I enjoyed the daily novelty of the workouts, the wonderful feeling after pushing my body, and the time I got to spend with my friends. We eventually moved to a globo-gym so that we could do the prescribed weight training with actual weights (our former weights were cinderblocks or on a good day the odd piece of football equipment left on the track). I first found a gym called Crossfit Bolt by hacking my way through a half mile of brush and scrubby trees at the back of my neighborhood. I walked up covered in burrs (I hid the machete) and was greeted by Matt McCraney. I think one of the first things I told him was that I didn’t think it was a real crossfit gym, because it didn’t have a pullup bar yet. He explained that they had just moved in, and the pullup rig was currently in transit. He was like a big brother to me for the next four years, a steady mentor who cared for me and managed to be both a friend and a coach. We competed together many times, both as teammates and as coach and athlete, and I’m grateful to have shared the formative experiences with such a great person and leader. Matt helped coach me to get to crossfit regionals, and I included a link to an article about that regionals trip and a link to his gym at the bottom.

I’ve been around since before crossfit was a popular workout regime, and I expect I will still be around if it falls out of popular favor. In my opinion, there is something fundamentally special about crossfit. It provides me a chance to move in a healthy way, in a way that I believe my body developed to move. A perfect squat clean or a series of clean muscles ups is a beautiful thing. It’s timing, it’s grace, it’s strength exercised with control in a manner that is conducive to the way the body was meant to move. Crossfit properly implemented is a combination of Cardiovascular and Respiratory endurance, Stamina, Strength, Flexibility, Power, Speed, Coordination, Agility, Balance, and Accuracy in accordance with the way evolution designed our bodies to move. When I move this way, I am rewarded with a feeling of fulfillment, the ability to consistently move in a healthy manner, and a capacity to go out into the world and do what I desire with the tool that is my body. If you are interested in the science behind design of the crossfit regime, I urge you to watch some videos of Greg Glassman, where he discusses his design for a new fitness program circa. 2004 – 2013. Ad hominem discussions aside, I respect his ideas and have found value in their implementation in crossfit gyms.

Aside from the fitness aspect of crossfit, the program affords me the chance to belong to something bigger than myself. Our gym, Koda Crossfit Norman, recently completed a workout for a former member named Rawson Shephard who took his life from battles with mental health. The workout requires a team to hold a medicine ball off of the ground while completing many other movements. The heavy ball is meant to symbolize the weight of mental health struggles. The workout emphasizes how an individual could never bear the weight the whole time, but through friendship and teamwork, the weight can be supported and shared. It was through ideas like this that I came to appreciate my friends in my gym and how they add fulfillment to my life. I used to have a severe distrust of organizations – political parties, campus groups, religious focus groups, etc. I was talking about this distrust with one of my close friends, and she helped me to see that organizations are how people get things done that are bigger than themselves. She helped to show me that, despite the flaws they sometimes have, organizations can bring people together around an idea, and that can be a very positive force for good. Koda Crossfit Norman and the crossfit tribe itself are organization that I am proud to be a part of and that I believe make a positive impact in the world.

**American Fidelity**

I have only been working for American Fidelity for about one month, so I might not be able to completely describe the projects I will complete over my internship here, but I expect they will revolve around process automation. We use UIPath, a robotic process automation software, to develop software solutions that can save employee time by performing simple business operations. UIPath provides a platform for graphical programming via drag-and-drop functions and \*\*Visual Basic\*\* syntax for data handling and variable manipulation. For example, in our current project we are helping a services group employee to convert all records for a given client– including pdfs, word documents, and text files – into a single pdf file. We use the automation software to sort through the records, delete the repeat documents, check the client number in each document to ensure there are no misplaced files, and compile into a pdf. We are also working on a machine learning based project to forward incoming emails to the proper departments. To learn the appropriate algorithm to use for sorting, we are using a machine learning algorithm management software called DataRobot. To better understand the multiclass logistic regression and support vector machine algorithms used in DataRobot, I recently completed an “Introduction to Machine Learning” course on Coursera. I am enjoying both projects thus far and am excited to contribute to projects that will save my colleagues from sacrificing their valuable time on mindless and repetitive tasks.

**Northrop Grumman**

I spent the summer of 2017 working for Northrop Grumman as an Electronics and Payloads Intern in Melbourne, Florida. Although much of the work that I completed over the internship was classified \*For Official Use Only\*, I have permission to share basic details about the assignments. My work over the summer consisted of 3 basic assignments: \*\*1.\*\* Writing \*\*Visual Basic\*\* code for an employee query macro, \*\*2.\*\* Decomposing official government-issued requirements documents to help guide design and details for a contract bid, and \*\*3.\*\* Examining communications terminals on existing warfighters for potential use on alternative projects, involving heavy research into the schematics and communications infrastructure of existing warfighters. Through these projects, I also learned about the structure of the large government contractor; I learned how the proposals are bid for by a given team, and how a different team develops the product to meet the requirements. I learned about the extensive regulations that accompany fulfilling contracts filed by the federal government, and about the intensive safety factor in any designed product. I’m thankful to Northrop Grumman for the chance to learn about the aerospace industry from a position within one of the biggest defense contractors in the United States.