The Center for Diversity in Engineering
Wishes the 2011
REU Students and RET Teachers
All the Best in Your Future Endeavors!!

“Discovery consists in seeing what everyone else
has seen and thinking what no one else has
thought.”
~Albert Szent-Gyorgi

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University of Virginia
Research Experience for Undergraduates
&
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Research Colloquium & Luncheon
Wednesday
July 27, 2011
School of Engineering & Applied Science
Center for Diversity in Engineering
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Welcome

Juliet Trail
&
Wraegen A. M. Williams, PhD

Research Colloquium
Thornton Hall E-316
8:30 am -12:30 pm

Department of Biochemistry & Molecular Genetics
Department of Biomedical Engineering
Department of Cell Biology
Department of Chemical Engineering
Department of Civil & Environmental Engineering
Department of Computer Science
Department of Electrical & Computer Engineering
Department of Mechanical & Aerospace Engineering
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The spindle assembly checkpoint (SAC) monitors proper chromosome attachment to spindle microtubules and is conserved from yeast to humans. The SAC activity of the kinetochore to the Ndc80 complex of proteins has been found to have a dual role in chromosome segregation and checkpoint signaling. Ten mutations in the Ndc80 complex that specifically disrupt the checkpoint were recently identified. These ten mutants contained only four different amino acids and were found within a limited region of the Ndc80 protein. This experiment investigated the method of engineering the mutations using a fusion polymerase chain reaction (PCR) approach involving genomic DNA of yeast and primers designed from the identified mutations in the Ndc80 complex. Fusion PCR allows for primers to fuse fragments into a single molecule with sequences in the desired order. A culture of the yeast strain 3748–4 was grown and the DNA was purified from the overnight culture. The purified genomic DNA was used to run PCR reactions using a set of primers, each encoding for a genetic mutation. Once checked by agarose gel electrophoresis the purified products are fused together in subsequent PCR reactions. This fusion process seeks to transform the mutations into the yeast genome and replace the wild type Ndc80 gene with the mutated version. Due to time limitations on the experiment, the final full length DNA fragment of the Ndc80 mutation is not complete. Following complete fusion we will further our knowledge of the interaction of the Ndc80 complex with the signal transduction pathway. We propose that the mutants in Ndc80 will be alive, viable, and proficient at chromosome segregation, but lack the spindle activity checkpoint. If methods prove to be successful, it will allow us to gain a deeper understanding of the affect of Ndc80 proteins on spindle activity checkpoint.
Mesenchymal stem cells (MSCs) or marrow stromal cells are capable of differentiating into osteoblasts, adipocytes, and chondrocytes, which comprise bone, fat, and cartilage, respectively. Investigating the involvement and recruitment of MSCs to aid in healing skeletal injury is the motivation for this study. To better observe this, an eGFP+ (enhanced Green Fluorescent Protein) bone marrow chimeric rat consisting of an irradiated Sprague Dawley will be rescued with eGFP+ bone marrow; bone healing contributions of the green MSC and other bone marrow cells will be tested by modeling a critical sized tibial defect with implantation of a FTY720 coated allograft. FTY720 is a potent agonist of S1P, a small, bioactive, signaling sphingolipid that regulates vascular and immune systems. The biodegradable coating will deliver the drug to the site of injury, with possible effects on MSC driven bone repair. Before testing this therapy in vivo, it is vital to characterize both the bone marrow MSCs and the release kinetics of FTY720. The FTY720 release occurred via allograft coatings by placing FTY720 loaded, poly(lactic-co-glycolic acid) (PLAGA) coated rat bones in 4% fatty acid free bovine serum albumin in simulate body fluid. The solution was replaced each day and the drug extracted from the solution. The FTY720 amounts will be measured with high performance liquid chromatography (HPLC) and mass spectrophotometery (MS). Additionally, bone marrow cells were harvested from Sprague Dawley rats and cultured using a protocol that called for frequent medium changes and diminished trypsinization time to increase the recovery of a purified population of MSCs. On day one many cells were present, but in the days to follow the population diminished until they were dead by day 6. In the future, we aim to exactly follow the protocol with the correct species and age of rats. For the FTY720 release, the first week demonstrated a burst release followed by a lag phase. In the weeks to come, increased degradation is expected.
Electrospinning is a process by which polymer nanofibers can be created with the use of electromagnetic forces. Nanofibers of polymer solutions such as polylactide (PLA) can be used as scaffolds for cellular-in-growth, proliferation, and new tissue formation in three-dimensions. In the preparation of the polymer solution, 20% ethanol (ETOH) and 10% pyridinium formate (PF) was added to 30% PLA to obtain nanofibers. PLA is a biocompatible, biodegradable polymer and PF is a known volatile organic salt. Recent studies have shown that nanofibers made from H-chitosan solution in chloroform with an addition of PF were non-toxic to cells. We hypothesized that PLA nanofibers made with PF will also be non-toxic and can be used as biocompatible dressing or scaffolding material. To test this hypothesis, nanofibers were electrospun at 25kV with a working distance of 14.5 cm. They were lifted up, made into disks and plated in 24 and 96 well plates. NIH 3T3 (mouse embryonic fibroblast) cells were then seeded on them. The cells were also seeded on 48-well cell crowns coated with nanofibers to account for the fragility of the nanofiber disks. The seeded cells were treated with propidium iodide (PI)/fluorescein diacetate (FDA) staining at different time points to assess cell viability. This live dead stain was used to determine whether PI is biocompatible with NIH 3T3 cells.
**Recognition**
CDE Staff
Kristel Townsend, Juliet Trail & Wraegen Williams

**2011 REU Participants**

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Mechanical Engineering, Class of 2012

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Aerospace & Mechanical Engineering, Class of 2011

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Civil Engineering, Class of 2013

**Erik Bergquist**
Thomas Nelson Community College
Engineering, Class of 2011

**Brittany Bullock**
University of Virginia
Biomedical Engineering, Class of 2014

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“Biofunctionalization of Electrospun poly(3-hydroxybutyrate-co-3-hydroxyvalerate) Nanofibers for Improved Pancreatic Islet Transplantation”
Ritu Linhart, Daniel Bowers, Kenneth Brayman, MD, PhD
& Edward Botchwey, PhD
University of Virginia
Department of Biomedical Engineering
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Diabetes is the seventh leading cause of death in the U.S. today with 200,000 deaths reported each year. Type I diabetes (T1D) is an autoimmune disorder that leads to the destruction of insulin-producing pancreatic β-cells located in the islets of Langerhans. Islet transplantation is the most promising treatment for this disease. However, clinical trials indicate challenges including failure of tissue to revascularize and destruction of islet grafts. One promising strategy is to prevent or limit β-cell death by embedding immunosuppressant drugs such as FTY720 into a biodegradable polymeric nanofiber scaffold. In this study, nanofibrous scaffolds were fabricated by electrospinning poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) at varying concentrations, electric voltages, and collector distances as well as blending it with type-I collagen and polycaprolactone (PCL) in 1,1,1,3,3,3-hexafluoro-2-propanol (HFP). Cell culture studies were conducted with mouse BALB/C islets, GFP rat islets, and human islets to study their viability on the nanofibrous scaffolds. SEM micrograph and confocal image analyses indicated PHBV blended with type-I collagen yielded nanofibers with uniform morphology and a high percentage of viable islets. Water contact angle measurements were conducted with a droplet analysis to study the hydrophobicity levels of the scaffolds with and without blends. Students in a 9-12 high school setting will brainstorm and utilize polymer solutions to prepare their own nanoscale coatings using an air brush paint spray kit and predict the hydrophobicity level of their surface. They will then use a macro lens to measure the water contact angle for their coating using a freeware Drop Analysis plug-in for Image J and confirm their predictions.
Human adipose-derived stem cells (hASCs) have been proven to differentiate into pericytes which aid in the regeneration of blood vessels in tissue. Previous studies have suggested that certain preconditioning techniques can better the likelihood of this differentiation process and promote microvascular stability. In our studies we combined two separate projects in which we subjected the hASCs to a hypoxic environment as well as pretreating the cells with the SDF-1α chemokine in vitro. A static adhesion assay and flow assay were performed on the SDF-1α treated cell population, as well as a control plate of non-treated cells to determine the ability of the cells to adhere to a protein commonly expressed by injured endothelium. Analysis using flow cytometry was used to test for markers associated with those of pericytes. Data showed a 30% increase in the number of adherent cells following SDF treatment compared to non-treated cells. A 48 hour hypoxia treatment was given to a population of hASCs, as well as human bone marrow stem cells (hBMSCs), cultured in DMEM/F12 media. A human ELISA Kit was used to analyze production of vascular endothelial growth factor (VEGF) by hypoxia-treated and normoxia treated BMSCs and hASCs at two time points (t0 and t48) and following treatment with 48-80, a compound known to induce inflammation. We also immunostained, imaged, and counted the cells expressing smooth muscle alpha actin (SMA), which is a marker of pericyte differentiation. Data showed an increase in the expression of VEGF and SMA for the hASCs treated with hypoxia compared to normoxia after t48 hours. These data support the positive effects of biochemical and physical preconditioning of the hASCs on pericyte differentiation. Long term investigation can lead to clinical use of these techniques for growing and stabilizing the smallest blood vessels in patients who suffer from tissue damaging diseases, such as diabetes, heart disease, and chronic wounds.
In this project, we are interested in the distributed power allocation problem in a cognitive radio network (CRN) with both licensed/primary users (PU) and unlicensed/secondary users (SU) simultaneously operating on the same set of communication channels. The PUs are licensed to use a certain radio bandwidth. They may allow the SUs to operate on this bandwidth, but generally require that the quality-of-service (QoS) of their communication should not be affected by the activity of the SUs. We first attempt to model the behavior of nodes in the CRNs with respect to delay in transmitting packets throughout. This is done by writing programs with the computer software MATLAB and running these programs until a trend is seen. After the model is determined to be satisfactory, we then proceed to modify the behavior of the nodes to optimize the transfer of packets between various nodes. We can thus specialize the optimization algorithms to primary nodes and secondary nodes respectively such that we set pricing interference constraints on the SUs. The conclusion is that for fixed prices, if each SU iteratively performs a certain calculation and then they will naturally settle on their best power profiles, and the whole system will be stable (no individual SU can change their power profiles to gain more surplus). The results obtained through this research are useful in fields where it is necessary for routers in a network to modify their routing protocol on the fly, depending on the conditions of the other routers in the network. This applies in situations where time is an essential factor, e.g. in disaster situations, warzones, severe weather and under other such high-pressure conditions.

Controlled DNA delivery to targeted cells is a desirable trait for gene therapy techniques. Recently, non-viral vectors has piqued the interest of the scientific community due to several desirable characteristics over viral vectors such as increased safety, reduced immune response and ease of. However, non-viral vectors still lag in efficiency when compared to viral vectors. The purpose of this research was to develop a non-viral vector with a higher efficiency yet still maintain the desirable qualities. It was hypothesized that conjugating a current non-viral vector to cationic microbubbles would increase transfection efficiency by delivering a higher concentration of complexes to the targeted area. Linear and branched polyethyleneimine (PEI) complexed with the plasmid DNA was chosen as the vector. Experiments were carried out to determine the best PEI-DNA ratio (N/P ratio) with which to conjugate to the bubbles. Size and zeta potential measurements were carried out as these characteristics are important in determining how well the complexes will conjugate to the bubbles and be endocytoized by cells. HEK-293 and CHO-K1 were the cell lines studied. All N/P ratios were able to transfect the cells with the higher N/P ratios being the most effective. Each N/P ratio expressed a variance in complex size; but lower N/P ratios consistently resulted in negative zeta potentials.
Statistics released by the March of Dimes state that approximately 1 in 4 pregnancies result in miscarriage, with most occurring in the first trimester. Even more disheartening is the fact that a majority of these miscarriages are deemed unexplainable. The placenta serves as the protective barrier that facilitates nutrient and waste exchange between mother and fetus; therefore, proper placental development is a crucial part of embryogenesis. Trophoblast cells are the structural elements of the placenta that originate from the trophectoderm layer of the blastocyst, and differentiate to form the mature placenta. Failure of trophoblast cells to appropriately differentiate can lead to placental dysfunction, which directly affects the growth and development of the fetus, resulting in fetal death or abnormal growth. Thus, the focus of this study is to evaluate how the TANGO1 protein contributes to trophoblast differentiation in mutated and normal trophoblast cells. Previous inquiry has shown that mice homozygous for the Xst199 mutation are phenotypically characterized by an undeveloped placenta, consequently leading to fetal death around mid-gestation. Sectional in situ hybridization was used to further investigate the expression pattern of different trophoblast marker genes during placental development in mice heterozygous for the Xst199 mutation. Results suggest that mutant embryos at E8.5 exhibit a notable difference in the expression of the mPL1 gene. At E10.5 markers specific for trophoblast giant cells appear to be primarily affected, in addition to, markers specific for the labyrinth layer. We have concluded that the loss of TANGO1 leads to placental defects, but more specifically the loss of this protein causes the misregulation of several genes that are vital for trophoblast differentiation.

Traumatic brain injury (TBI) is a serious public health issue that affects an estimated 1.7 million Americans each year. It is the leading cause of death amongst those under the age of 45, and contributes to one-third of all injury related deaths in the United States. At present, the pathobiology of TBI, particularly penetrating brain injury, is not fully understood. In this study, beta amyloid precursor protein (APP) and glial fibrillary acidic protein (GFAP) were chosen as a means for exploring changes associated with penetrating ballistic brain injury (PBBI). APP is a well characterized immunohistochemical marker for axonal injury while GFAP demonstrates activation of brain glial cells, specifically astrocytes. In this study, we use tissue from a penetrating ballistic brain injury (pbbi) model, stained with APP and GFAP as a way to understand the mechanisms through which the brain responds to injury.
“Tracing of Contralateral Neurons in the Anterior Olfactory Nucleus”
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The AON is a thin ring of cells situated behind the olfactory bulb, which is below the frontal cortex, of the mammalian brain. The AON was initially believed to be a simple connection between the olfactory bulb (OB) and the piriform cortex (PC); and its function was to simply relay signals between the two areas. Recent evidence suggests that the AON is a more complex region that is involved in processing signals from the OB, both ipsilateral and contralateral. In the following study, we use fluorescent neurotracers to show the ipsilateral and contralateral projections in the AON through confocal microscopy. Double labeled cells represent the neurons that are involved in both ipsilateral and contralateral projections. A quantification analysis shows the distribution of cells, as well as the percentage of double labeled cells, within regions. These data is expected to support the location of contralateral projections to be in the pars externa region of the AON as well as support the distribution of cells within specialized regions. Hopefully, these results will aid ongoing research of the AON and bring us closer to deciphering its complete function within the olfactory system.

“Synthesis of Disperse Silver Nanoparticles”
Caroline Dunn, Zachary Farrell & David Green, PhD
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The properties of functionalized silver nanoparticles, such as size, shape, and chemistry, influence their various applications. I hypothesize that by varying the amount and identity of the surfactant, control can be exerted over these key nanoparticle properties. Silver benzoate is reduced with 9-borabicyclononane (9-BBN) enabling surface functionalization of the resultant silver nanoparticles with either triphenylphosphine (TPP) or dodecanethiol (DDT), to protect against aggregation through formation of a self-assembled monolayer. Carrying out the reaction in a relatively nonpolar solvent mixture, composed of toluene and acetonitrile, diminishes negative electrostatic effects associated with other common nanoparticle syntheses, which take place in solvents such as ethanol and water. Analysis of the particles using transmission electron microscopy (TEM), showed spherical particles that range from 4-9nm in diameter with few non-spherical particles. Particles passivated with TPP resulted in more monodisperse and smaller nanospheres when the concentration of the surfactant was increased. Doubling the starting concentration of TPP resulted in 96% of the particles having a diameter of 8nm or less. Particles functionalized with DDT resulted in lines of nanospheres with an average diameter around 5nm. It can be concluded that varying the amount of surfactant, affects the particle size and polydispersity. A reproducible synthesis of the desired particles will allow further research to be performed on functionalization of the particles with an initiator ligand for Atom Transfer Radical Polymerization (ATRP). Therefore, these nanoparticles represent the beginning of a new platform of high strength materials for use in aerospace, mechanical, and biomedical applications.
Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease caused by degeneration of motor neurons. Although ALS is one of the most common neuromuscular disorders, there is no effective treatment to cure or reverse ALS. It has been suggested that mutant SOD1-associated familial form of ALS pathology is linked to the development of SOD1 aggregates, and so modulating SOD1 mutant aggregation is considered one of promising strategies to treat ALS. We demonstrate that fusing green fluorescent protein fusion (GFP) to mutant SOD1 is an effective way to monitor mutant SOD1 aggregation in a fALS cell culture model and has a great promise as a high-throughput screening method for determining the efficacy of protein therapeutics and small molecules to improve protein folding and reduce aggregation. By directly correlating the folding of the protein upstream from the GFP to cellular fluorescence, we are able to determine improvements in protein folding when cells are in the presence of a therapeutic or drug. The cellular fluorescence of transfected cells co-expressing SOD1A4V-mfrGFP fusion protein and rationally designed protein therapeutics or transfected cells expressing SOD1A4V-mfrGFP cultured with small molecule therapeutics was monitored by flow cytometry to evaluate the ability of the protein or small molecule to improve protein folding. One rationally designed protein and one small molecule showed the ability to reduce misfolding and aggregation of SOD1A4V. These hits will serve as starting points for optimization and could potentially lead to the development of a new treatment for fALS patients with the A4V mutation.
“MRI Assessment of Lower Limb Muscle Impairment”

Diana Webber, Geoffrey Handsfield, Silvia Blemker, PhD
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Department of Mechanical & Aerospace Engineering
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Each year, 10,000 babies in the United States will develop Cerebral Palsy (CP) (National Institute of Neurological Disorders and Stroke, 2011). Currently, treatments are designed for patients with CP based on overall measurements of movement and function, including visual observation of the patient’s gait, motion capture data, and electromyographic data (Handsfield et al., 2010). Frequently, orthopedic surgeries are recommended that target tendons, menisci, ligaments, bone, and cartilage despite the known role of muscle dysfunction as a contributing factor to biomechanical impairments (Meyer et al, 2010). The purpose of this study is to find a method to identify and quantify atrophied and hypertrophied muscles so tailored, muscle-targeted treatments for people with CP can be developed. Magnetic resonance (MR) images of the lower leg were used to measure the volumes and volume ratios of 34 muscles and muscle groups. The main goal of the educational module for classroom extension, inspired by the study, is to teach students water chemistry, respiration, homeostasis, eukaryotic diversity, protein

“Characteristics of Gas Expanded Lubricants for Increased Energy Efficiency”

Erika Arias & Andres Clarens, PhD
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Lubricants are necessary in the gears and bearings of power turbines in order to effectively transfer power and reduce friction between solid surfaces. A lubricant, known as a gas-expanded lubricant (GEL), has become a mixture of interest for bearings due to the potentially vast increase in the power efficiency of turbines. GELs are tunable, binary mixtures of synthetic lubricants and dissolved CO₂ maintained at moderate pressures. Developing an adaptable lubricant that would increase turbine efficiency will lead to direct energy savings and a decrease in US dependence on foreign petroleum. GELs were characterized in order to develop a fundamental knowledge base necessary to implement these lubricants in gears and bearings. The synthetic lubricant classes characterized were polyakylene glycol (PAG), poly-alphaolefin (PAO), and polyol esters (POE). Using an Anton-Paar rotational rheometer, the viscosity of each lubricant-CO₂ mixture was measured at two different isotherms and three different pressures. It was found that as the mass fraction of CO₂ infused into the PAG, POE, or PAO lubricants increased, the viscosity of the mixtures decreased. Thermal conductivity was measured using a Decagon KD2 Pro equipped with a thermal conductivity needle sensor. The sensor was attached to a pressure vessel to collect data on lubricants of known thermal conductivity at atmospheric pressure. The results suggest that the ethylene oxide content has an effect on the lubricant thermal conductivity for the PAG lubricants; the more ethylene oxide a PAG lubricant contains, the greater the thermal conductivity. It remains to be shown how oxidation and diffusivity are affected by the addition of carbon dioxide in the synthetic lubricants.
“Holiday Travel Trends: Defining and Presenting Traffic Congestion”
Jerinico Batac, Ramkumar Venkatanarayana, PhD, Simona Babiceanu & Brian L. Smith, PhD
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The purpose of this research done for the Virginia Department of Transportation (VDOT) was to evaluate the congestion level during major holidays (Thanksgiving, New year’s Day, Christmas, Independence Day, etc.) on roadways in Virginia and illustrate likely traffic delays to the public based on traffic data provided by INRIX. INRIX is a private company that collects traffic information and provides some of the latest and most up-to-date traffic data sets in the industry. The major tasks of this research were (1) to develop systematic procedure to define congestion for different corridors during holiday periods focusing on intensity and duration and (2) to design and implement a simple graphical interface for presenting congestion levels and likely delays to the public. We began by analyzing the traffic characteristics of each corridor to obtain its free flow speed. The real time speed for each corridor was then compared to free flow speed to determine congestion level and delay. The measurements for individual corridors were then combined spatially using Google Maps to provide a complete and easy to understand picture of the congestion for the whole state during holidays. VDOT can use the outcome of this research to provide concise yet informative traffic information for each corridor in Virginia during holidays to the public. If utilized properly and consistently on a wide scale, it could lead to positive changes in traffic patterns that will alleviate traffic congestion in major roadways during holidays.

“Basic Rotor Dynamics of a Squeeze Film Damper Bearing”
Joshua Storer, Matthew Goodhart, Bradley Nichols & Paul Allaire, PhD
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The orbiting of a rotor from the center axis causes resonance of vibrations to appear through the shaft and into the surrounding structure in any rotating device. At higher speeds, the vibrations become more volatile, introducing forces that could damage the device. Studying how the orbital plots change passing through critical speeds in a squeeze film damper bearing could shed much needed light on the operation of the damper to attenuate the vibrations. To obtain more useful data, disc weights are attached to act as a load, increasing the weight and rotational inertia of the shaft. This initial, fairly balanced test details the different characteristics of the rotor’s orbit between each mode. Critical speeds show increased amplitude of orbital distance, primarily changed in the vertical direction. To test how effective the damper is at attenuating vibrations due to unbalance, small weights are applied, distributed around the discs. Performed around the pre-weighted and weighted critical speeds, these tests will then confirm the effective qualities of the squeeze film damper to greatly reduce the vibrations that cause damage and instability to rotor operation.
“Experimental Investigation of the Performance of Inclined Airfoil Thermosyphons”
Andrew Rowe, Christina Johnson, Donald Jordan, PhD & Pamela Norris, PhD
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The performance of a closed two-phase thermosyphon with an airfoil-shaped body and a slot-shaped cavity, to be used for thermal management in future aircraft, is investigated here. Measurements of the rate of heat transfer out of the thermosyphon, which is defined as its performance, is conducted at steady state by measuring the power input to the evaporator while the condenser is positioned in an airstream. In previous work, the airfoil thermosyphon was oriented vertically in performance testing. In order to test thermosyphon performance in an actual aircraft environment, the thermosyphon must be tested at different angles of inclination ranging from 0º to 90º, measured from vertical. A streamlined structure was built to secure the thermosyphon in the airstream while performance testing was conducted at various inclination angles. The testing was conducted with an evaporator temperature of 150ºF and inclination angles from 0º to 90º in increments of 10º. The inclination performance test shows steady rates of heat transfer from 0º to 70º. At angles greater than 70º the performance decreases by approximately 66%.

“Contraflow: The Ideal Method for a Hasty and Secure Evacuation”
Erik Bergquist, Theresa Jones, Joyoung Lee & Byungkyu Park, PhD
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Contraflow is the use of reversal lanes to allow the increased amount of traffic to flow more efficient in one direction. Usually, contraflow is used during evacuation; an example would be a natural disaster. In recent times the concept of contraflow has been thought to be helpful for a terrorist attack. Using contraflow will allow more vehicles per second to move through an evacuated area than using the road with its normal properties. Using the computer program named DynusT; we are able to use simulations to show the effectiveness and efficiency of contraflow. We can use the normal roadway properties as the control for analysis of efficiency. Then we simply change the properties of the roadway to allow one direction of traffic flow while still using the same number of lanes as the control. This program enables a roadway to allow the comparison of normal conditional roadway properties versus the contraflow design. The simulation shows that contraflow has a higher vehicle per second ratio than that of normal conditions. This project shows that by using contraflow evacuation and opening up more lanes will allow more evacuees to escape danger rather than only having them use the normal amount of lanes quicker and safer.
“Contact Angle Measurements for assessing the Wettability of CO$_2$ in a Saline-Rock/Clay System: Implications for Geologic Carbon Sequestration”
Ian Edwards, Shibo Wang & Andres Clarens, PhD
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Department of Civil & Environmental Engineering
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Geologic carbon sequestration is the process of capturing emitted CO$_2$, transporting to a designated site and storing it deep within the Earth’s subsurface. The contact angle of CO$_2$ in a saline rock/clay solution is a reliable indicator of whether a given geologic region would be a suitable sequestration site. Using a system composed of a CO$_2$ syringe pump and high pressure cell, contact angles are being measured for this purpose. Using the pump, a bubble of CO$_2$ is released and photographed. Using imaging processing software, the bubbles size, shape and contact angle are then determined. At the conclusion of the contact angle measurements, the surfaces of the rock and clay samples will be analyzed to determine the extent to which the material reacted to the CO$_2$ bubbles. As only about 25% of the data in this project has been collected, definite trends and observations cannot be concluded. Should this experimentation conclude with definitive results, the information collected can be used in the effort to geologically sequester carbon dioxide and delay the effects of global warming.

“Peltier Stage: Testing Superhydrophobic Nanocomposite Coatings for Anti-icing”
Camilo Ronderos, Yong Yeong & Eric Loth, PhD
University of Virginia
Department of Mechanical & Aerospace Engineering
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Current solutions to icing and damage from erosion on surfaces are inefficient. The pneumatic boot: a device that inflates to break ice has problems when the ice is thick. Another alternative is melting ice, but that guzzles energy and is temporary if chemicals are used. With the growing demand for energy, wind turbines play a big part to sustain this growth. Yet places with great wind potential cannot benefit from wind turbines because of freezing rain icing and erosion damaging the blades preventing the turbines from storing energy. Instead of removing ice, our coating will give any surface superhydrophobic characteristics, protecting the surface from impact and stopping the water from nucleating and freezing. A superhydrophobic surface, is very difficult to wet, having contact angles greater than 150°. The coatings are applied to polyurethane, fiberglass, and aluminum. Then they are linear abrased to check for durability, submerged in water to observe saturation, and sprayed with water to test superhydrophobicity. Superhydrophobicity testing involves taking pictures of a water droplet on the surface and measuring contact angles and hysteresis angles. The desired results is a durable superhydrophobic nanocomposite coating that can be sprayed onto any material and potentially on the surface of a wind turbine, protecting the wind turbine from the harsh environment and operate more efficiently.
“Using Magnetic Resonance to Determine Lower Limb Muscle Volume in Patients with Cerebral Palsy”
Carrie Lewis, Geoffrey Handsfield & Silvia Blemker, PhD
University of Virginia
Department of Mechanical & Aerospace Engineering
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Leg muscle function is critical for development of a normal walking pattern. Research at the Multiscale Muscular Mechanics lab of the University of Virginia Mechanical Engineering Department has generated axial Magnetic Resonance images that present an inside-the-skin view and accurate portrayal of each individual muscle and its condition, a tool which may be of enormous use in the medical field with Cerebral Palsy patients in the future.

Eleven subjects’ leg muscles, both healthy and impaired, were scanned in .5cm axial slices at UVA’s 3-Tesla Siemens scanner. The individual muscles in each slice were segmented using MATLAB and MSEG software. Researchers were able to identify and reconstruct atrophied muscles of cerebral palsy patients in 3-d illustrations. 25 Inquiry Lessons that correlate with the current research were developed to involve grade K-5 students. The Inquiry Lessons will allow K-5th Grade students to apply the following inquiry skills emphasized by the Virginia Department of Education as they investigate and experiment: observing; classifying and sequencing; communicating; measuring; predicting; hypothesizing; inferring; defining, controlling, and manipulating variables in experimentation; designing, constructing, and interpreting models; and interpreting, analyzing, and evaluating data.

“Evaluating CO₂ Leakage From Sequestration Sites Using Column Studies”
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Global climate change mitigation strategies, like Geological Carbon Sequestration (GCS), are promising. The GCS process of storing carbon dioxide from fossil fuel emissions underground is accomplished by isolating the CO₂ molecule, compressing it, and transporting it by pipeline to an injection site to be stored permanently. Research and development of GCS must continue in order to determine the most effective methods of CO₂ sequestration in geologic reservoirs. In order to establish a working procedure for a larger-scale 6meter column, the current project studied a smaller 1m testing column and a 1ft. column. The 1m column was erected to simulate the conditions of 800m to 3km under the Earth’s surface with temperatures spanning 25°C to 50°C and geological pressures to 3,000psi. The experiments require efficient instruments and methods for obtaining measurements; in the current study, Gas Chromatography (GC), thermal conductivity and electrical resistivity were investigated. The research and experimental practices of the VEST lab GCS project will provide a model framework for the delivery of engaging class lessons. Students will study global climate change mitigation through Geological carbon sequestration (GCS), in ways that highlight technological innovation. The lessons are correlated to International Technology Standards, National Education Technology Standards (NETs), the Virginia Standards of Learning (SOLs) and the National Research Council (NRC) for Teachers.
“Measuring Recurring and Non-recurring Congestion on a Corridor”
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This research was done for the Virginia Department of Transportation (VDOT) using an INRIX database of traffic information for Virginia roadways in 2010. INRIX is a company that gathers traffic data through GPS-enabled vehicles and creates some of the newest and most detailed traffic datasets currently available. The primary task was to develop a procedure to distinguish between recurring (regular) and non-recurring (incident-caused) traffic congestion. In transportation analysis, it is customary to logically divide roads into segments or links. We began by analyzing the real-time speed data from each individual segment. Using counts of speed data within particular bin sizes (2-10 mph), we were able to create a band where traffic speeds on a “normally” congested day should fall. These results can be confirmed by analysis of holidays and other “non-normal” samples with predictable effects. Also, outlying data points that may represent non-recurring congestion can be investigated using an incident database. These measures for individual segments will be combined spatially with neighboring links to give a complete picture of the recurring congestion on the corridor. In addition, travel time can be calculated from speed and link length. This should permit a procedure for the estimation of delay for a particular trip. These procedures will help VDOT use the INRIX data and apply it to future projects. This research should yield an accurate representation of roadway congestion and allow VDOT to plan, and motorists to navigate more effectively.

“Statistical Shape Analysis on a 3D Human Clavicular Model”
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In car collisions, the driver’s shoulder belt subjects the left clavicle to large loading, often causing injury. Previous anthropometry studies have attempted to account for human shape variation, but none have specifically studied the statistical shape models of the human clavicle. In order to better understand the influence of clavicle geometry on its injury tolerance, twenty left human clavicles were evaluated using statistical shape analysis in this project. All 3D layers of the interior and exterior cortical bone contours were reconstructed from CT-scans. One clavicle model was selected as the template and the landmarks on the template were identified by using the equal-size cubic grid method. Registration between the template and the remaining 19 clavicle models was conducted to remove translation and rotation differences, and corresponding landmarks between the clavicle models were then established using coordinates and surface normals. The mean and variation shapes were constructed for ± 3 standard deviations using principal component analysis (PCA). It was found that the first five and seven modes account for over 65% and 73% of the overall anatomical variation, respectively. In addition, these percentages showed a significant dependence on registration method (STL or ICP) and cortical contour type (interior or exterior). The compactness for the clavicle set aligned with STL registration was found to be greater for both interior and exterior contours compared to the ICP registered set. The generalization ability was greater for the clavicles that underwent STL registration for both the interior and exterior contours. Overall, the ICP registration showed the best performance (the smallest compactness and generalization ability) and the first seven modes of the clavicle showed to be sufficient to describe the overall shape variation. The construction of the shape models can be further used to develop specific anthropometric finite element models and to better understand the variation of injury tolerance of clavicle.
“Flame-Acoustic Interactions in the Counter-Flow Field”
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When flames and acoustic waves interact, the traveling waves produce a peculiar noise. This phenomenon of “singing flames” within internal combustion systems, which are the primary source of power in gas-turbine engines seen in air and ground vehicles, heating systems and other applications, is the primary focus. These noises can represent instabilities, or cause problems and disturbances. Research serves primarily to minimize such noises and analyze other reasons why they might occur. The frequency of the traveling waves within a nozzle is a function of the length of the nozzle or chamber the flame burns in. Ultimately, ways to quiet the noise can be found by adjusting the nozzle end-wall boundary condition. The experiment includes a counter-flow setup in which premixed air and nitrogen gas blow against premixed methane gas (fuel) and nitrogen gas, and is then ignited. Results thus far show that a decrease in frequency (and thus an increase in audible noise) is due to changes in three experimental controls: increases in nozzle length, decreases in the air-to-fuel ratio, and decreases in the mass-flow rate of the gases. Increasing length alters the nozzle end-wall boundary condition, creating longer wavelengths, shorter frequencies, and thus louder noises if other parameters are held constant. Increasing fuel produces hotter flames and stronger heat waves that add to the amplitude of the acoustic waves. Nitrogen acts as a shield for safety purposes, and higher flow rates alter the position of the flame within the nozzle for counter-flow setups. Expected results also show that pressure increases would also decrease the frequency within the nozzle. When done correctly, traveling waves hit the end wall boundary at an anti-node and reflect back toward the flame completely in phase, creating maximum noise. When out of phase the opposite affect will cancel the waves, creating little to no noise. If the expected results are accurate and analysis is completed, formulas for which we can alter the end-wall boundary condition can be computed to automatically minimize noise levels.

“A Cued Speech Recognition Implementation Using the Kinect”
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Despite recent technological advances, an immense wall exists for the deaf when it comes to phone and face to face communication with those who don’t know Sign Language. This barrier in communication takes a substantial toll on a deaf person’s quality of life and human potential. The goal of this project is to implement a system that enables or enhances communication between deaf and hearing people through the automatic recognition of the visual mode of communication called Cued Speech. Cued Speech combines hand shape and placement with lip shape to differentiate the phonemes of spoken language thereby enabling the deaf to wholly understand it. Assuming the deaf subject to be unable to produce speech and the hearing subject unable to understand or produce Cued Speech, the system will recognize lip shape and Cued Speech hand gestures and translate them in order to produce either text or synthesized speech. The system will use the Xbox Kinect to obtain color and depth video streams. The three dimensional depth values are represented by point clouds to any accuracy of 1mm. Hand detection has been achieved. Future work will include finger detection, static hand shape recognition, hand location, lip shape recognition, and finally vowel phoneme recognition. This project will achieve gestural language recognition with improved accuracy due to the depth data obtained by the Xbox Kinect.
“Energy Dissipation and Minimal Stable Distances of Magnets using Ferromagnetic Logic”  
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Ferromagnetic logic is a new form of computation that uses low amounts of energy to compute logic (~200 kt) when compared to traditional transistor energy dissipation. To understand the amounts of energy needed and the minimal energy configuration, total energy dissipation has to be computed for the system in addition to the minimum stable distances. Researching Minimal Stable Distances of the magnets allows us to establish a nonfluctuating system, as well as establishing viable energy dissipation amounts to start from. We can see from mat-lab simulation, that energy dissipation has a low point in the range of four to six mega pascals which still allow the magnets to completely change orientation from -90 degrees to 90 degrees or vice versa. In addition to this sweet spot of energy, the minimum stable distance for an infinite number of magnets reaches a saturation of 176 nanometers which was verified analytically as well as numerically for a finite number of magnets (173 nanometers). A combination of these numbers causes a viable range for the configuration to be between 4 and 6 mega-pascals and above 176 nanometers. These data points verify that Ferromagnetic logic is a strong alternative for transistor logic because they use much less energy during each calculation and can still be created within a small container. Discovering the fact that Ferromagnetic logic uses very low energy amounts in tight configurations has important implications to the computational community because the largest problem they have been facing (high amounts of heat) can be fixed and faster logic units can be created in the future using Ferromagnetic Logic instead of inefficient transistor units.

“Guiding Fibroblast Cell Morphology through Dielectrically Aligned Nanofiber Scaffolds”  
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The creation of an ideal nanofibrous scaffold for tissue engineering has been the inquiry of many scientists in the research community. In mimicking the extracellular matrix of various tissues, nanofibrous scaffolds seek to provide an increase in the regeneration speed, as well as functional recovery of damaged tissues, through appropriate guidance and cell signaling. Through the process of electrospinning, repulsive forces are used to stretch nanofibers, and arrange them in an aligned array. These scaffolds then have the capability of supporting adhesion and guiding cell extention. Various methods of electrospinning have been studied, however, in this experiment, we focus on the comparison between alignment through a dielectric collector versus a rotating mandrel collector. We have performed previous studies centered on the alignment of nanofibrous scaffolds via rotating mandrel. Now we seek to optimize electrospinning conditions for the dielectric collector. Experiments will focus on seeding cells on fibers produced by wood, aluminum and magnetic collectors with varying gap length, and determining the best cell morphology. A 50:50 or 85:15 poly lactide co glycolide (PLGA) polymer will be dissolved in THF (tetrahydrofuran) and DMF (dimethylformamide) solvents at various ratios to produce small, stretchy fibers. The fibers will then be pumped through an electrically charged needle and stretched across the gap of the grounded collector so as to produce an aligned array of fibers. We hypothesize that nanofibers aligned at patterned plate collectors with dielectric gaps will follow the electric field lines due to the balance of attractive transverse forces across the gap versus repulsive lateral forces between adjoining un-discharged fibers. The ultimate goals are to understand conditions for routinely synthesizing highly aligned fibers of large and small sizes, and to compare cell guidance on electrostatic versus mandrel aligned fibers, in hopes of gaining a deeper understanding of the mechanics of nanofiber alignment.