Science and Humanities Scholars

**TITLE**
Carnegie Mellon undergraduate students’ attitudes towards the university’s current athletic facilities and their anticipation for the new CUC Gym.

**STUDENTS**
- Charlton Cheng
- Leeann Choi
- Yifan Leng
- Michelle Ong
- Danielle Peters

**ADVISORS**
- Jared Murray

**ROOM / TIME**
Kirr Commons-1st Floor, Window side / 12-2:30 pm

**ABSTRACT**
Our project topic is relevant to Carnegie Mellon University’s plans to upgrade the current athletic facilities by expanding the Cohon University Center. In the midst of CMU’s heavy workload and stress culture, it is beneficial for each student to maintain a healthy lifestyle by taking advantage of the athletic facilities provided by the university. Therefore, implementing a survey of students’ attitudes regarding the existing university athletic facilities’ gym equipments, layouts and other services offered is relevant and timely. The athletic facilities consist of the Cohon University Center (CUC) Gym, Skibo Gym, and several gyms located in different campus dorms. Since the university has planned major improvements for its athletic facilities in the CUC, it will also be beneficial to understand students’ attitudes on the upcoming improvements. These responses will provide useful information to the university as it seeks to refine its athletic facilities to better cater to the student population. The university can also incorporate this information into future efforts to design and plan the new athletic facilities.

**TITLE**
Effect of initial amplitude on the interfacial and bulk dynamics in Richtmyer-Meshkov instability under conditions of high energy density

**STUDENTS**
- Zachary Dell
- Snejana Abarji

**ADVISORS**
- Jared Murray

**ROOM / TIME**
Rangos 1 & 2/Sigma Xi Group 5 / 10:45 am

**ABSTRACT**
We systematically study the effect of the initial amplitude on the interfacial and bulk dynamics of the Richtmyer-Meshkov instability (RM) induced by strong shocks. The shock propagates from the light to the heavy fluid. The fluid densities differ significantly, with Atwood numbers up to 0.95. The fluid interface is initially perturbed with a cosine wave perturbation. Its amplitude is varied from 0% to 100% of the initial perturbation wavelength. A broad range of the shock strengths and density ratios is considered. Smoothed particle hydrodynamics code is employed to ensure shock capturing and interface tracking. Detailed diagnostics of the flow scalar and vector fields is performed. Whenever possible the simulation results are compared with existing theoretical analyses achieving good agreement. The focus question of our study is how the energy deposited by the shock is partitioned between the interfacial and volumetric components. We analyze the dependence of the initial growth-rate of RM, the velocity away from the interface, and the transmitted shock velocity as functions of the initial amplitude. Particularly, we found that for a Mach number 5 and an Atwood number 0.8, the initial growth rate is highest and the interfacial energy is the largest when the initial amplitude is about a quarter of the wavelength.
Effects of Mobile Applications on Public Health in Honduras

Omobolanie Ayo-Ani
Wendy Chou
Jacqueline Pan
Leslie Tay
Emily Wells
Ming Y. Wu

ADVISORS
Jason Hong

ROOM / TIME
Hoch Commons-2nd Floor, Rangos side / 3-5 pm

ABSTRACT
Developing countries often lack the funding and resources necessary to educate communities on public health, leading to the spread of preventable diseases. Existing research has indicated that distance education through online and mobile settings have proven to be effective in public health education. In Honduras, a steady increase in the mobile phone penetration rate implies that mobile applications could be a viable low-cost solution to public health education that would allow for widespread dissemination of knowledge. Our mobile public health application will use interactive tutorials to educate users on sanitation and hygiene in order to reduce the spread of preventable diseases within local Honduran communities.

Examining the Relationship Between Education Inequality and Income Inequality

Kelsey Choing
Danielle McKinney
Ariel Zetlin-Jones

ADVISORS

ROOM / TIME
Kirr Commons-1st Floor, Window side / 3-5 pm

ABSTRACT
For our senior project, we are interested in understanding the relationship between income inequality and inequality in educational attainment, as well as understanding the relationship between inequality in educational attainment and GDP growth. Using data on educational attainment from 26 countries globally, we construct educational attainment Gini coefficients, which consider the dispersion of the percentage of years of attainment across shares of the population, as a measure of inequality in educational attainment levels across time and countries. Through this inequality measure, we find that educational attainment is becoming more equitable with time, as evidenced through decreasing values of our educational attainment Gini coefficients, and overall average levels of schooling are increasing globally as well as across developing, emerging, and developed economies. Our analysis reveals an insignificant negative correlation between income inequality and inequality in educational attainment, such that, contrary to our hypothesis, higher levels of income inequality are correlated with lower levels of inequality in educational attainment on a global scale. This relationship becomes significant when restricted to analysis in developed countries. Additionally, contrary to our expectations, there is an insignificant positive correlation between educational attainment inequality and the ten-year average growth rate of GDP per capita globally. This positive relationship is strongest in developed countries. The correlation is negative for developing countries. Overall, our largely insignificant results suggest limited effectiveness of policies targeting these types of inequality and a need for further analysis to better understand what is driving these relationships.

Explicit Bounds for the Pseudospectra of Matrices and Operators
We give several equivalent definitions for the $\epsilon$-pseudospectrum of square matrices and investigate the behavior of the pseudospectra for non-normal matrices. We give a complete characterization of the pseudospectrum of $2 \times 2$ matrices and describe the asymptotic behavior of the pseudospectrum of a square matrix of arbitrary size, as $\epsilon$ approaches 0. We also give explicit upper and lower bounds for the $\epsilon$-pseudospectra of bidiagonal matrices, as well as for finite rank operators.

Studies show that the accuracy of face recognition is correlated with the laterality of processing and is mediated by the right hemisphere. This study sought to determine whether one can bias the perceptual processing of faces by introducing information that enhances the global or local precedence of the right hemisphere prior to the onset of a face stimulus. Specifically, we ‘primed’ participants by presenting local or global information to the right or left hemisphere (using visual half-field paradigms) and then examined the effect of this information on face processing performance. Subsequent analysis revealed local priming enhancement of left hemisphere face discrimination and no performance facilitation for either hemisphere after global priming of facial features. Further exploration of laterality effects may improve the understanding of priming conditions that facilitate selectivity in facial recognition tasks.

We propose a new model for segmenting damaged images. Our model introduces a dynamic artifact class $X:\Omega\to\{0,1\}$ to the Chan-Vese functional, which prevents outliers from skewing the segmentation. Our new functional effectively segments both damaged and undamaged images. We also developed a minimization scheme based on diffusion and thresholding, which runs significantly faster than traditional gradient descent techniques. We include results and comparisons with existing methods.

Increasing Engineered Cardiac Muscle Tissue Alignment in 2D

We give several equivalent definitions for the $\epsilon$-pseudospectrum of square matrices and investigate the behavior of the pseudospectra for non-normal matrices. We give a complete characterization of the pseudospectrum of $2 \times 2$ matrices and describe the asymptotic behavior of the pseudospectrum of a square matrix of arbitrary size, as $\epsilon$ approaches 0. We also give explicit upper and lower bounds for the $\epsilon$-pseudospectra of bidiagonal matrices, as well as for finite rank operators.

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Cardiovascular disease is the number one cause of death in most developed countries, yet currently there are no therapies to fully restore cardiac function after a large injury without transplantation. One potential mode of treatment lies in engineering cardiac tissue that can be patched into the site of injury. The contractile part of the heart – myocardium – consists of 2-dimensional laminar sheets of cardiac muscle cells (cardiomyocytes) wrapped around the heart. One of the key factors in developing such engineered cardiac tissue in vitro lies within creating a confluent layer of aligned cardiac muscle cells capable of synchronous contraction, for maximum contractile force. Previous studies in the field have shown that surfaces with extracellular matrix (ECM) proteins micropatterned on them can stimulate cells to form aligned confluent cardiac sheets. However, the degree of cell alignment and the force produced by such engineered tissue can both be significantly increased. Two new patterns were developed; a pattern of 10µm wide lines of fibronectin with 4µm spacing, and a software-generated fiber-like pattern that mimics ECM structure in native chick myocardium. Statistical analysis showed that 10µm 4µm pattern produced greater cell alignment compared to the 20µm 20µm (control pattern), while the synthetic biomimetic pattern showed a statistically insignificant difference. The findings of this study show that the alignment of cardiac muscle cells in 2D can be improved by controlling the structure of the ECM protein.

**ABSTRACT**

**TITLE**
Instruction-Driven Changes in Knowledge Organization

**STUDENTS**
Rachel Walsh, Anna Fisher, Layla Unger

**ADVISORS**
Science and Humanities Scholars, Psychology, Psychology

**ROOM / TIME**
Wean Commons-1st Floor, Connan side / 3-5 pm

Prior research indicates that semantic knowledge becomes increasingly differentiated and organized with age. For instance, with development, knowledge about living organisms becomes increasingly differentiated into taxonomic groups of biologically related organisms. To test whether these changes that have been observed developmentally can be induced in young children using direct instruction, we assessed organization of knowledge about living organisms that belong to three taxonomic categories in a group of preschool children over the course of approximately one month, and administered instruction sessions to half of the children during this time. During the instruction sessions, children were taught about biological features that are shared by organisms that belong to the same taxonomic category (e.g., mammals have fur and give birth to live babies). Our results did not reveal greater increases in the influence of taxonomic categories on semantic organization in children who received instruction versus children who received no instruction.

**ABSTRACT**

**TITLE**
Invasion of Candida albicans into polyacrylamide hydrogel

**STUDENTS**
Tammy Ying, Frederick Lanni

**ADVISORS**
Science and Humanities Scholars, Biological Sciences

**ROOM / TIME**
Rangos 1 & 2/Sigma Xi Group 2 / 10:15 am

My research is aimed at understanding the invasion of hyphal cells (elongated filamentous cells) of the fungus Candida albicans into cross linked elastomer. The proposed theoretical model is that strains use turgor equal to the Young’s modulus of the substrata to gain an invasive phenotype. This was tested experimentally using two approaches. Elastic substratum with varying elastic moduli was used to assess the depth of invasion of wild-type C. albicans. Wild-type and mutant strains deficient in glycerol were also assayed for intracellular osmolality in order to further quantify and prove our hypothesis that C. albicans hyphae use osmotic pressure to drive invasion in solid substrata. My proposal is novel in that it studies the biophysical invasion of C. albicans hyphae into elastomer during biofilm formation. This project is actually part of a larger research question on the effects of the gene RHR2 on biofilm formation and invasion. RHR2 encodes the enzyme glycerol-3-phosphatase, which is responsible for producing glycerol, the suspected osmolyte. In a mutant strain where this gene is missing, the biofilm integrity is compromised along with defects in invasion into substrata. Thus, RHR2 is necessary for biofilm formation and invasion in C. albicans.
ABSTRACT

Transducers are examples of finite state machines that have found applications in group theory. We focus on the structure of these machines and expand upon the results of Nekrashevych and Sidki. From the automata theory perspective, we prove some structure theorems and answer a few decidability questions. From the group theory perspective, we prove some theorems that strengthen the connection between linear algebra and the study of abelian subgroups of Aut(2).

ABSTRACT

Cellular magnetic resonance imaging (MRI) can effectively, safely, and non-invasively track cells labeled with superparamagnetic iron oxide particles (SPIO). Cellular MRI may lead to a better understanding of the pathogenesis of many diseases. An effective method of tracking engrafted cells in an intact living organism is also crucial for the success of cell therapy, which depends on precise dosing, timing, and delivery of cells to a desired site. Ferumoxytol (Feraheme) is an SPIO particle approved as an iron supplement for the treatment of iron deficiency anemia in adult patients with chronic kidney disease, and is currently the only intravenous, FDA-approved SPIO nanoparticle. However, Ferumoxytol does not effectively label cells ex vivo without transfection agents; the only ex vivo cell-labeling method is the ferumoxytol-heparin-protamine (HPF) nanocomplexes methodology [Nat Med 18, 463-467 (2012)]. The objective of this study is to develop a new ex vivo method for labeling mesenchymal stem cells (MSCs) and macrophages (MØs) with Ferumoxytol, without the use of transfection agents and/or electroporation. MSCs, which are multipotent cells being explored clinically as a therapeutic for many diseases, can be labeled with Ferumoxytol in vivo (i.v. injection) [Radiology 269, 186-197 (2013)], but not readily ex vivo (in cell culture) [Nat Med 18, 463-467 (2012)]. MØs, which are important players in organ transplantation and disease, can also be labeled effectively with Ferumoxytol in vivo [Circ Cardiovasc Imaging 5: 559-565 (2012)], but not ex vivo without transfection agents [Nat Med 18, 463-467 (2012)]. Our hypothesis is that an ex vivo method which mimics in vivo conditions could effectively label MSCs and MØs with Ferumoxytol. Our new ex vivo method for labeling MSCs is: (i) flush bone marrow cells from femurs and tibias of Brown Norway (BN) rat and incubate for 24 hours at 37°C; (ii) remove the supernatant from the adherent cells; (iii) expand the number of MSCs for 7 days; (iv) prepare fresh supernatant by repeating step (i); (v) add another BN rat; (vi) trypsin-EDTA digest MSCs from step (iii) and wash MSCs with phosphate buffered saline (PBS); (vii) add Ferumoxytol (100 µgFe/mL) to the cells and add the supernatant from step (iv); and (vii) allow the cells to incubate overnight, remove the supernatant, and allow the purification and expansion of the cells for 3 days. Steps iv, v, and vi are different from the traditional ex vivo method (which involves adding Ferumoxytol directly to the cell culture). Our new ex vivo MØ labeling method follows a similar procedure. The intracellular iron concentrations of cells labeled by the traditional method were 0.16 ± 0.02 pg/MSC and 0.51 ± 0.02 pg/MØ. Using our new method, the intracellular iron concentrations increase to 2.50 ± 0.50 pg/MSC and 4.30 ± 1.42 pg/MØ. These results are comparable to those obtained using the heparin-protamine labeling method: 2.12 ± 0.11 pg/MSC and 2.56 ± 1.1 pg/monocyte [Nat Med 18, 463-467 (2012)]. The labeled cells exhibit over 95% viability. Labeling efficiency is verified by MRI, transmission electron microscopy, and Prussian blue iron staining. Our new bio-mimic method can be used to label MSCs and MØs with Ferumoxytol, without using transfection agents and/or electroporation, for cell-tracking by MRI.
Modeling Ebola Transmissions

Adrian Botta  Economics and Statistics
Andersen Chang  Science and Humanities Scholars
Abigail Smith  Mathematics
William Eddy  Statistics
Rebecca Nugent  Statistics

Wean Commons-1st Floor, Connan side / 12-2:30 pm

ABSTRACT
The most recent Ebola Hemorrhagic Fever (EHF) epidemic has grown to over twenty-five thousand cases, and over ten thousand deaths. Following the EHF outbreak in 2013-2014, a lot of research has been published in search for a model that could accurately simulate the spread of this disease. While existing research focuses on applying compartmental models to the data from each country and expanding the simpler SIR model into a more complicated SEIHFR model, we use compartmental models to simulate the spread of the EHF virus across the borders of the three countries most affected by the outbreak, Guinea, Liberia, and Sierra Leone. Using the EpiModel package in R, we optimize for the parameters of each model and assess a goodness of fit for each individual country. We then look at ways to combine cross-border movement data in Western Africa to model the spread of disease from one country to another.

NHL Shot Location Adjustment

Andersen Chang  Science and Humanities Scholars
Andrew Thomas  Statistics

Hoch Commons-2nd Floor, Window side / 12-2:30 pm

ABSTRACT
Since 1997, the National Hockey League (NHL) has used the Real Time Scoring System (RTSS) in order to keep track of and record the details of the events that occur in every game. The logging of all of the data in the RTSS is done manually while the game is in progress. We are interested the recorded shot locations in the data; as these locations are judged by human eye, we suspect that they might be inaccurate. We look at the distribution of recorded shot locations at each arena and compare it to the league-wide distribution, which we assume is the expected distribution of shot locations in each stadium, using kernel density estimation. We then try to develop methods to correct for the shot location bias in each arena using iterative regression and gradient adjustment. Ultimately, our goal is to find the best adjustment functions, unique to each NHL rink, to correct the RTSS shot locations.

Online Dominating Set

Fan Yang  Science and Humanities Scholars
William Hrusa  Mathematics

Hoch Commons-2nd Floor, Rangos side / 3-5 pm
We consider a greedy online algorithm that finds a dominating set of a graph. This algorithm is online because vertices of the graph are revealed one by one. From a practical perspective, this algorithm is easy to implement and can be applied to graphs that are not fully known.

We analyze the performance of this algorithm and study how graph operations affect the performance. There are two main results:

1) We calculated expected dominating set sizes of paths, cycles, stars, multi-stars and bipartite graphs using this algorithm.
2) We found examples where adding edges to the graphs actually increases their expected dominating set sizes. Because of its simplicity, this online algorithm can also be used to find chromatic numbers of graphs and etc. We hope our analysis of the algorithm can inspire more applications in the future.

**ABSTRACT**

Wean Commons-1st Floor, Connan side / 12-2:30 pm

**ABSTRACT**

In this project, I consider the reign of King Francis I of France (1515-1547) through the lens of a novel theory of state and social evolution. The period I have selected serves as a case study for the evaluation of the functionality and robustness of an institutional theory of political processes, which I developed over the course of my studies at Carnegie Mellon under the working title of “Legitimacy Theory”.

In brief, the theory understands human populations as fora for the organization of individual and, when they achieve a sufficient scale, community interests according to institutions that moderate interaction and define the sphere of opportunity and action for both the body public and narrower aggregations of people and power. The institutions in question may be expressed explicitly, as when political agencies such as states develop and impose laws, or implicitly, as in the case of culture or similar social convention which arises from the internalization of longstanding accords into traditions and norms. Importantly, the state may encompass subordinate agencies, which serve to project the interests of particular social segments with the will but not the power to assume the role of the state, or at least the will and the power to affect its operation. These distinct interests interact with the state either through formal channels provided by explicit institutions or through the application of their separate power in conditions where the state’s operation may be diverted in their favor.

The Legitimacy Theory provides observations on the efficacy and context of the policies which transformed the French monarchy under Francis I, and this assessment enables a rigorous evaluation of the theory by instantiating it historically. It incorporates the domestic and foreign pressures affecting France during the period into an understanding of the catalysts in the decidedly uncertain movement of the monarchy toward centralization and the rudiments of absolutism. Domestically as well as internationally, Francis’s reign entailed the navigation of the complex landscape of explicit and implicit institutions which underwrote the organization of rival and parallel interests in the noble, clerical and merchant estates. My project’s principal objective is to both construct the theory and evaluate its validity and analytical merit through its application to the case study of the reign of Francis I.

**ABSTRACT**

Dowd / 2:00 pm

**ABSTRACT**

Redshift Dependence of the Power Spectrum for Sloan Digital Sky Survey Data Release 11 Quasars

**ABSTRACT**

Dowd / 2:00 pm
ABSTRACT

Matter in the Universe is not uniformly distributed. Some regions are over-dense while some are under-dense. Astronomers traditionally assume that matter density is a Gaussian random field. The matter power spectrum is a vector of summary statistics that describe fluctuations in the matter density of the field. The power spectrum evolves with time. We can constrain the properties of the power spectrum near present day by using galaxy surveys. However, for earlier times there are not enough observed galaxies to provide sufficient constraint. Astronomers use the spatial distribution of quasars to infer the underlying structure of our universe. Quasars are luminous and distant galaxies that surround a super massive black hole. The Sloan Digital Sky Survey (SDSS) recently released its 11th set of data (DR11) which contains a sufficient number of quasars in which to apply effective cosmological probe. We use 137,562 objects from the northern hemisphere of quasars of the Baryon Oscillation Spectroscopic Survey (BOSS) survey that was part of DR 11. Quasars and galaxies are biased tracers of the matter distribution because they only exist in denser regions. We will statistically investigate the bias function to and see if the SDSS DR 11 quasars are capable of yielding scientific insight about matter density or whether they are indicators of un-modeled systematic error.

ABSTRACT

Hormones are molecules that allow cells to communicate with each other and are used by organisms to alter growth and metabolism. The steroid hormones such as estrogen can diffuse across the plasma membrane, bind their receptor in the cytoplasm, migrate to the nucleus and act as transcription factors to alter cell’s physiology and behavior. Naturally occurring steroid hormones include estrogen, progesterone, testosterone and cortisol. Detection of hormones in the environment has raised concerns in recent years because of their potential to affect both humans and wildlife. Estrogens from natural, synthetic, plant, and fungal sources can manifest endocrine disrupting properties and even at low concentrations can have harmful effects due to receptor activation. Estrogenic activity can occur in water sources including waste, drinking and freshwater. In freshwater, estrogens are harmful to the ecosystems, feminizing fish and disrupting the overall populations of organisms in the ecosystem. Estrogenic substances can also be present in what we drink, however since the presence of hormones in water is a relatively new area of study, there have been no previous restrictions or regulations regarding filtration of estrogenic compounds. Due to concern with the compounds in water, our project was to develop a sensor to detect the molecules in water that will bind to the estrogen receptor. We anticipate that our STREAM, Sensor That Reports Endocrine Activating Molecules, will be sensitive and informative of water quality. A BioNetGen model of the sensor and NetLogo model of fish populations were constructed to improve our understanding of these systems.
ABSTRACT

My project is a collection of stories that explore relationships between people in different settings. Specifically, my project will deal with these questions: where does meaning come from in regard to other people? What does it take to have a friendship with someone? How do family ties impact worldview?

As with all writing, some of the impact will be on myself, as I explore the topic through characters I have invented, but I also hope to share my exploration with a wider audience. I hope that my project can ultimately shed some light on the nature of human to human interaction, and can treat the characters and readers with respect and dignity.

TITLE

What’s in a name? An expanded classification of xenologs

ABSTRACT

Horizontal gene transfer (HGT) occurs when a species acquires a gene from a source other than its ancestor. The term "xenolog" is used to refer to genes related through HGT. However, this general term does not distinguish between the many different ways HGT can affect a gene family, depending on how many transfer events occurred, when they occurred, and which species were involved. We propose a formal framework for classifying xenologs into different subtypes, based on comparison of the gene family tree with the associated species tree. Our framework imparts structure and meaning to evolutionary relationships in any gene family history. It also provides the foundation required to develop a software package to automate the classification process. We also show how our conceptual framework can be applied to genes in the S. cerevisiae biotin synthesis pathway. This example demonstrates how our terminology facilitates interpretation of functional relationships between xenologs.