ΣIGMA

THE RESEARCH CLUB

PRO SCIENTIA ATQUE SAPIENTIA
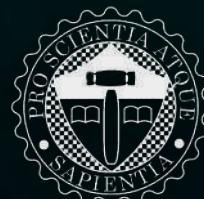
Welcome to the Research Club!

The Research Club is an organization that's geared towards facilitating STEM-related student research. Throughout the school year, the Research Club hosts presentations from renowned scientists, biological lab experiments, preparation sessions for various research competitions, and workshops on applications to summer research programs. We are the main club at Stuyvesant that is dedicated to fostering students' research interests and preparing them for greater opportunities. Each semester, we publish SIGMA, so that members of the Stuyvesant Research Club community have access to scientific material written by their peers. We also encourage our members to annotate articles written by their peers, helping the scientists of tomorrow build up the writing and communication skills necessary for research.

This edition features many of this year's graduating seniors' research reports, which were submitted to Regeneron Science Talent Search Competition and various other prestigious competitions. To mark the start of a new decade, we also have a special "A Decade in Science" section, which highlights some of the many breakthroughs scientists have achieves in this past decade.

The club hopes to motivate its members in actively engaging in scientific discussions and gaining valuable experience by receiving feedback to improve their scientific writing. Throughout this fall semester, we have seen tremendous growth in all of our contributors, and we are glad to publish their work here.

Table of Contents

Performance Investigation of Deep Learning vs. Classifier for Polyp Differentiation via Texture Features

Yeseul Choi

Annotated by Chris Dong, Stephen Lee, Dave Jiang, Aryan Ruparel, Wasi Shahriar, Nina Shin, and Grace Yang

Abstract

Computer-aided diagnosis (CADx) of polyps is essential for advancing **computed tomography colonography (CTC)** with diagnostic capability. In this paper, we present a study of investigating the performance between **deep learning** and **Random Forest (RF)** classifier for polyp differentiation in CTC. Results demonstrated that by balancing the data, both **CNN model** and RF classifier can learn or analyze features effectively, and achieve high performance. This demonstrated that CNN model have the potential to improve the classification task performance when dealing with larger dataset. This study provided valuable information on how to design experiments to improve CADx of polyps.

Introduction

Colorectal cancer begins as polyps, which are abnormal tissue growths on the lining of the colon. The stage of colorectal cancer depends on how deeply the polyp has grown into the colon wall and whether the cancer has spread outside the colon or rectum. Thus, early detection and removal of malignant polyps can prevent cancer from growing and developing, reducing the rate of colorectal cancer. Computed tomography colonography (CTC) has been developed as a new minimally-invasive screening technique3-7, showing its advantages comparing to the traditional **optical colonoscopy (OC)**. Computer aided diagnosis (CADx) of polyps has great potential to reduce CTC interpretation burden and further advance CTC with diagnostic capability8-12. In our previous research work13, we have developed a CADx scheme using texture feature extraction and analysis for polyp differentiation via CTC.

Method

The size of a polyp correlates with the risk of the colorectal cancer20. In this work, we analyzed polyps with size of 6 to 30mm from a CTC database. According to their size, polyps were split into two groups, with 6 to 9 mm polyps (small size), and 10 to 30 mm polyps (medium size). Then we investigated the performance of our models applied to those groups. In general, there are six primary types of polyps: hyperplastic, serrated adenomas, tubular adenoma, tubulovillous adenoma, villous adenoma and adenocarcinoma. Hyperplastic polyps usually do not carry a risk of developing into cancer and are considered **nonneoplastic** in histopathology.

In **computer-aided diagnosis (CADx)**, a radiologist uses a computer analysis of medical images to make his or her diagnosis. This paper investigates two algorithms that can further analyze and categorize polyp images for a doctor to make more accurate diagnoses.

Computed tomography colonography (CTC) uses special x-ray equipment to examine the large intestine for cancer and polyps. During the exam, a small tube is inserted a short distance into the rectum to allow for inflation with gas while CT images of the colon and the rectum are taken.

Deep learning is a machine learning technique based on brain simulations. It uses data to learn how to predict and classify information. This study observed how deep learning classified types of polyps.

Random forest uses multiple individual decision trees, which classify data into separate branches depending on the presence of a specific feature, to make predictions and classifications, similar to deep learning. Random forest was used in this study to classify types of polyps.

CNN models, or convolution neural network models, is a deep learning algorithm that analyzes images (in this case, images of polyps).

Optical colonoscopy (OC) - During a colonoscopy, a flexible tube with a small lens and video camera is passed through the length of the colon.

Nonneoplastic masses are changes in tissue that are not cancerous.

On the other hand, serrated polyps, tubular adenomas, tubulovillous adenomas, and villous adenomas pose the risk of developing into cancer whereas adenocarcinoma is a most common type of colorectal cancer. They are classified as neoplastic in histopathology and could be potentially malignant or malignant.

Results

The dataset used for the experiments in this study consists of 1278 polyps (839 polyps with size of 6-9 mm; 439 polyps with size of 10-30 mm) found through CTC and confirmed by OC. Among them, there are 216 nonneoplastic polyps in the 6-9 mm group and there are 57 nonneoplastic polyps in the 10-30 mm group. For deep learning framework, in order to test the consistency, we created two different CNN models, one with a **sigmoid function** and another with a **softmax function** for the output layer. The sigmoid CNN used two convolutional layers and two max pooling layers, with a dropout = 0.4. This model used the **Adam optimizer** with a learning rate set to 0.00005. Binary cross-entropy was implemented as the loss function. The softmax CNN had two convolutional layers and one pooling layer, with a dropout = 0.3. This model used the **SGD optimizer** with a learning rate set to 0.0005. The loss function was set as categorical cross-entropy. **Batch normalization** and the **ReLU** activation was applied to the convolutional layers on both models. Both models used a batch size of 16. In this work, two-fold **cross-validation** concept was used to evaluate the performance via the mean of area under the curve (AUC). In addition, we randomly generate 50 runs

Conclusion

In this paper, we present an investigation of the classification performance for polyp differentiation in CTC between deep learning and RF classifier. Instead of using image patches, we applied an **extended Haralick feature model** and utilized the GLCM in extracting and encoding the original 3D CT image information into 2D matrices, which were further used for polyp classification in the study. Based on the GLCM features, we investigated the polyp differentiation performance of two state-of-the-art frameworks: the eHM texture features/RF and the GLCM feature matrices/CNN. Experimental results demonstrated that by balancing the data, both the CNN model and RF classifier can learn or analyze features effectively, and achieve high performance. The RF classifier in general outperformed the CNN model with an average gain of 6.4% for the balanced data sets and 5.4% for the unbalanced data sets, showing its effective in feature extraction and analysis for polyp malignancy differentiation. Since deep learning methods require large amounts of data, the CNN model can be improved through the addition of new data with an average gain of 3.6% for the balanced.

A **sigmoid function** has a range from 0 to 1. These values do not necessarily represent probabilities as they do not need to sum to 1.

The **softmax function** turns the output into probabilities of the potential outcomes that sum to 1.

Adam optimizer is a learning rate optimization algorithm which finds the best fit in a set of criteria or constraints.

SGD optimizer trains neural networks (which identify relationships in data) faster than other algorithms.

Batch normalization improves the speed of neural networks.

ReLU is an activation function, which allows a neural network to make non-linear functions for relationships in data.

Cross validation estimates the accuracy of the model (in this paper, the cross validation was used in measuring the accuracy of the RF and CNN models).

An **extended Haralick feature model** allows for the establishment of contrasts between different 3D CT images, while showing a correlation between the different polyps.

Nonpolyposis means that colorectal cancer can occur when only a small number of polyps are present (or polyps are not even present at all). Polyps are abnormal tissue growths that often look like small, flat bumps or tiny mushroom stalks. Colorectal cancer is a cancer that starts in the colon or the rectum.

Biomarker refers to a molecule that indicates the existence of a substance. An example is NeuN which indicates the existence of neurons.

Wildtype refers to the phenotype of the typical form of a species as it occurs in nature.

Knockout A gene knockout is a genetic technique in which one of the organism's genes is made inoperative.

Neurogenesis is the process by which the neurons are produced by neural stem cells.

Heterodimer is a protein composed of two polypeptide chains.

Homologous recombination is a type of recombination in which nucleotide sequences are exchanged between two similar or identical molecules of DNA.

A Nuclear Localization Sequence is an amino acid sequence that "tags" a protein for import into the cell nucleus by nuclear transport.

ATPase are a group of enzymes that catalyze the hydrolysis of a phosphate bond in adenosine triphosphate (ATP) to form adenosine diphosphate (ADP).They harness the energy released from the breakdown of the phosphate bond and utilize it to perform other cellular reactions.

Exploring the Effects of a Missing Class Switch Recombination Protein on Brain Functions in Mice

Shreya Paul

Annotated by Dave Jiang, Stephen Lee, Lawrence Li, Julia Wu, and Amanda Zhong

Abstract

MSH2 is a DNA mismatch repair protein that is used in the DNA repair process and can be found on chromosome 17 in humans. It is a tumor suppressor gene and the loss of this protein can lead to **Hereditary Nonpolyposis Colorectal Cancer**. In this experiment we studied the loss of the MSH2 gene in mice on their brain development, specifically their neuronal density. We counted neurons by staining for the NeuN protein, which is a **biomarker** for neurons. The **wildtype** would have a lower neuron density compared to the **knockout** because the loss of the MSH2 protein might hinder **neurogenesis** in the transgenic mice. Our results indicated that the wildtype did express a much higher neuron density compared to the knockout.

Introduction

MSH2 DNA mismatch repair protein, also known as MutS protein homolog 2, is encoded by the MSH2 gene in humans. MSH2, a tumor suppressor gene, is located on chromosome 2. The MSH2 protein forms a **heterodimer** with MSH6, another DNA repair protein to make the human MutSα mismatch repair complex. Generally speaking, MSH2 protein is used in the DNA repair process, specifically in transcription-coupled repair, **homologous recombination**, and base excision repair (Pitsikas, Lee & Rainbow, 2007, p.22). In mice, the MSH2 gene is located on chromosome 17.
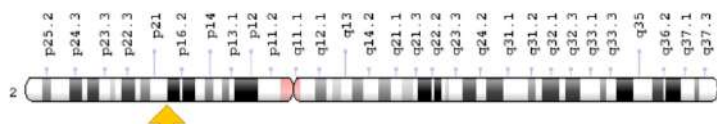

Fig1. The location of the MSH2 gene in humans on

MSH2's role in DNA mismatch repair is that it dimerizes with MSH6 to form the MutSα complex, which is involved in base mismatch repair and short insertion/deletion loops. Conversely, MSH2 does not have a **nuclear localization sequence** (NLS), so it is believed that MSH2 and MSH6 dimerize in the cytoplasm and then are imported into the nucleus together. In the MutSα dimer, MSH6 interacts with the DNA for mismatch recognition while MSH2 provides the stability that MSH6 requires. MSH2 can be imported into the nucleus without dimerizing to MSH6, MSH2 is y dimerized to MSH3 to form MutSβ. MSH2 has two interacting domains with MSH6 in the MutSα heterodimer, a DNA interacting domain, and an **ATPase** domain.

The MutSα dimer scans double stranded DNA in the nucleus, looking for mismatched bases. When the complex finds one, it repairs the mutation in an ATP dependent manner. The MSH2 domain of MutSα prefers **ADP** to ATP, with the MSH6 domain preferring the opposite. Studies have indicated that MutSα only scans DNA with the MSH2 domain harboring ADP, while the MSH6 domain can contain either ADP or ATP (Qiu, DeRocco, Harris, Sharma, Hingorani, Erie & Weninger, 2012). MutSα then associates with MLH1 to repair the damaged DNA.

ADP refers to Adenosine Diphosphate, which assists the flow of energy in living cells.

MutSβ is formed when MSH2 complexes with MSH3 instead of MSH6. This dimer repairs longer insertion/deletion loops than MutSα (Dowen, Putnam & Kolodner, 2010, p. 30). Because of the nature of the mutations that this complex repairs, this is probably the state of MSH2 that causes the **microsatellite instability** phenotype. Large DNA insertions and deletions intrinsically bend the DNA double helix. The MSH2/MSH3 dimer can recognize this topology and initiate repair. The mechanism by which it recognizes mutations is different as well, because it separates the two DNA strands, which MutSα does not (Gupta, Gellert & Yang, 2012, p. 19). Mutations in MSH2, cause DNA damage to go unrepaired during replication, and increase mutation frequency. These mutations can accumulate throughout a person's lifetime and can lead to diseases such as Hereditary nonpolyposis colorectal cancer (HNPCC), also known as **Lynch Syndrome**.

Microsatellite instability refers to the phenotype of the typical form of a species as it occurs in nature.

Lynch Syndrome a type of inherited cancer syndrome associated with a genetic predisposition to different cancer types. This means people with Lynch syndrome have a higher risk of certain types of cancer.

NeuN, also known as Hexaribonucleotide Binding Protein-3, is a neuronal nuclear antigen that is commonly used as a biomarker for neurons. A few neuronal cell types are not recognized by NeuN antibodies, such as cerebellar **Purkinje cells** and Golgi cells, olfactory Mitral cells, retinal photoreceptors and gamma motor neurons, but the majority of neurons are strongly NeuN positive. NeuN **immunoreactivity** has been widely used to identify neurons in tissue sections and to measure the neuron/glia ratio in brain regions (Herculano-Houzel, 2005, p. 25). NeuN immunoreactivity becomes obvious as neurons mature, typically after they have downregulated expression of **Doublecortin**.

Purkinje cells are neurons in vertebrate animals located in the cerebellar cortex of the brain.

Immunoreactivity refers to the ability to react to particular antigens and haptens. Haptens are relatively small molecules that elicit immune response only when attached to a larger carrier such as a protein.

Doublecortin is a microtubule (MT)-stabilizing protein essential for neuronal migration during human brain development. Missense mutations in DCX cause severe brain defects.
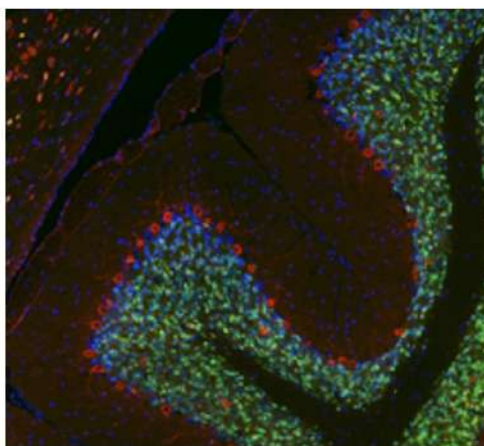

Fig2. Antibody staining for NeuN in the adult rat cerebellum in green.

This experiment tested the effect of the loss of the MSH2 gene on neuronal density in a **transgenic** mouse without the MSH2 gene (knockout) and its corresponding wild type using NeuN as a biomarker. Mice can easily be genetically manipulated to replicate conditions in humans. The mice were around two months old, which allowed us to study their juvenile nervous system and brain. The mice were perfused, their brains extracted and slices, and the slices underwent **immunohistochemical staining** for **NeuN**.

Results

Fig3. and Fig4. are confocal images of the microscopic slides with the wildtype and knockout brain hemisphere slices respectively. Each fluorescent dot on the image represents a neuron that NeuN marked. The more fluorescence in an image means more neurons present in that image and a higher neuronal density. Inspection by the naked eye shows that Fig3. has more fluorescence than Fig4., which makes us think that the wildtype had a higher neuronal density compared to the knockout. This is supported by Fig5. which compares the average neuron density in different regions of the brain. However Fig3. and Fig4. are very high resolution images and the neuron density differs in different regions of the brain. Instead of analyzing both figures at once, each figure was broken up into several similar sized crops from similar regions of the brain. For example, Fig3. was cropped into six sections: five crops from the upper, middle, and lower cortex and a crop of the hippocampus. The same steps were repeated on Fig4. so that we could compare the neuronal density in different parts of the wildtype and knockout brains and accurately draw conclusions based on that. Fig6. - Fig17. are all zoomed in crops from either Fig3. or Fig4.
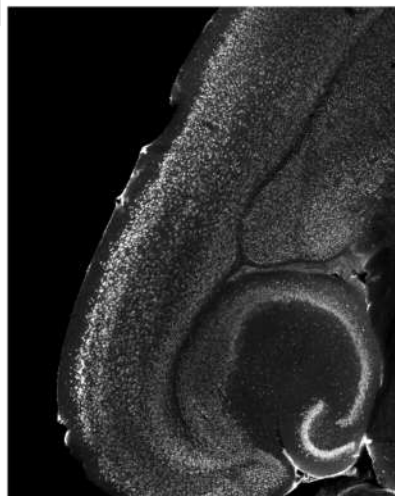

Fig3. Confocal image of wildtype MSH2 mouse brain hemisphere stained for neuron density NeuN protein
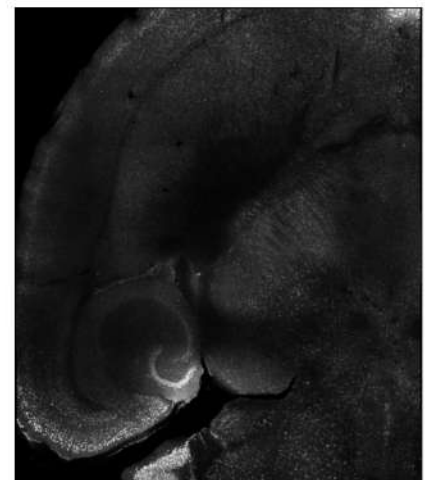

Fig4. Confocal image of knockout MSH2 mouse brain hemisphere stained for neuron density with NeuN protein

Discussion

The higher neuronal density in the wild-type mouse suggests that there is a direct relationship between the loss of the MSH2 DNA mismatch repair protein and brain development in mice. Previous studies also show that MSH2 deficiency can lead to problems in brain development, such as early-onset brain tumors and **lymphoma** (Bougeard, Charbonnier, Moerman, Martin, Ruchoux, Drouot & Frébourg, 2003).

This makes sense because the brain tumor results from an abnormal growth of tissue in the brain. This abnormal growth of brain tissue is caused by uncontrolled cell growth, which results when tumor suppressor genes do not function properly. Since MSH2 is a tumor suppressor gene, it is plausible that the loss of function of the MSH2 protein in the DNA repair process could lead to uncontrolled cell growth with lots of mutations. This could eventually lead to the **prognosis** of cancer.

This experiment supported our hypothesis that the MSH2 knockout will have a lower neuronal density, but further research needs to be done to affirm this phenomenon. The limitations of this study were that we used a very small sample size of two mice, one transgenic and its corresponding wild -type for the MSH2 gene, to come to these results. Additionally more research one the function of the MSH2 protein in neuron development is needed. Does the MSH2 protein play a direct role in neuron growth or does is it only limited to DNA repair?

Conclusion

This study concludes that the loss of MSH2, a DNA mismatch repair protein, negatively affects neuron development in mice. A mouse that is missing the MSH2 gene (knockout) had fewer neurons that were marked by NeuN. This could mean that the knockout had less neurons in various parts of its brain (cortex and hippocampus) compared to the wildtype, or it could mean that the neurons in the knockout as not NeuN positive (recall that NeuN is a good biomarker for most neurons but some neurons can not be identified with NeuN).

Lymphoma is a type of cancer that begins in infection-fighting cells of the immune system called lymphocytes.

Prognosis is the predicted course of a disease based on its development.

Compared to the wild-type mouses, the MSH2 knockout present less neuronal density. This suggests there would be more MSH2 defiency which has been previoulsy linked to higher chance of problems in brain development.

Effective Engagement Strategies in Encouraging the Use of Clinical Services among Seniors with Mental Health Disorders from Various Socio-Demographic Backgrounds

By Justin Lam

Annotated by Chris Dong, Stephen Lee**,** Shrey Patel, Arian Rahman, Wasi Shahriar, Julia Wu, and Amanda Zhong

NYC Department for the Aging: The mission of the NYC Department for the Aging (DFTA) is "to work for the empowerment, independence, dignity and quality of life of New York City's diverse older adults and for the support of their families through advocacy, education and the coordination and delivery of services." It is mainly to help the elderly and

Engagement activities help individuals with mental health conditions form a healing connection with people that support their recovery and wellness.

DFTA's Geriatric Mental Health Initiative places mental health clinicians in senior centers, where they lead educational games and have open conversations with older adults about anxiety and depression.

Clinical services include psychological counseling for mental health issues.

Socio-demopgraphic factors include but are not limited to: age, sex, education, migration background and ethnicity, religious affiliation, martial status, household, employment, and income. They additionally include socio-economic status (SES), which combines information on education and income.

Abstract

Mental health disorders remain prevalent in senior populations, impacting the lives of nearly 1 in 5 older adults. Seniors with mental health disorders do not always receive the mental health care they need, noting financial barriers, fear of stigma, and other challenges in utilizing clinical services. The strategies used to reach aging populations, which is known in the **New York City Department for the Aging** (DFTA) as **engagement activities**, attempt to overcome these barriers and encourage the use of clinical services for seniors who may need them. This study examined the population participating in **DFTA's Geriatric Mental Health Initiative** (DGMH) to determine which factors (race, gender, poverty level, and type or duration of engagement activity) have a strong association with the use of **clinical services**. Asians and White Hispanics were approximately four times less likely as whites to use clinical services ($p < 0.05$). It was also statistically significant that only 34% of seniors from low income backgrounds (100% of federal poverty levels) did not use clinical services, compared to the 67% of seniors from higher income backgrounds (151%of federal poverty levels). Some seniors in clinical services also spent less time in mindfulness and activity-based health promotion structured engagement ($p < 0.05$). Men, African Americans or White Hispanics, and seniors from low income backgrounds also participated in non-clinically related services rather than engagement activities more often than other groups. The results indicate that **socio-demographic factors** and time spent in engagement activities are significant variables in use of clinical services, but they also suggest a need for additional investigation into the causes for the aforementioned group differences.

Keywords: mental health disorders, engagement, clinical services, older adults, race, income, socioeconomic status

Introduction

Maintaining **mental health** and **wellness** is essential in maintaining overall well-being for all people, especially in aging populations. The world's population is aging rapidly; it is expected in the next thirty years for the number of older adults to increase from 900 million to 2 billion. Additionally, stressors that can lead to mental health conditions, such as impaired mobility or other health problems, are more commonplace for seniors.

However, the majority of seniors who experience mental health problems do not seek mental health care (Byers, Arean, & Yaffe, 2012), and the use of these services declined among those with the greatest risk (Leaf, Bruce, Tischler, & Holzer III, 1987). Engagement activities are designed to help eliminate certain stigma associated with utilizing mental health clinical services. The obstacles these engagement methods seek to overcome are characterized as "lack of knowledge" and "lack of intent" barriers (Yeatts, Crow, & Folts, 1992). Some seniors have a "lack of knowledge" regarding services available to them, while others "lack intent" or refuse to seek services because they view seeking such services as culturally inappropriate.

Since the reasons for not utilizing clinical services can vary substantially, strategies in reaching out to these communities were employed with varying degrees of success. For example, **peer support systems** have been shown to have some benefits for veterans and recovering alcoholic (Tracey & Wallace, 2016). Alternative approaches, such as video games and creative art activities, in engaging individuals with mental health conditions also had some degree of success. The use of creative art activities improved mental health issues in both clinical and non-clinical settings (Jensen & Bonde, 2018). A different study took a holistic approach and gauged patients' satisfaction across all service interventions, such as group sessions and **compulsory treatment** (Ruggeri et al., 2003). These studies about engagement and retention strategies were conducted with the goal of successfully reaching out to those with mental health conditions, but only a few have examined the relationship of socio-demographic factors to the success of specific engagement methods.

Minority groups and groups from low socioeconomic status backgrounds may be more likely to harbor negative views towards the use of mental health services, which may suggest the need for personalized methods and targeted policies of reaching out to these populations (Dixon, Holoshitz, & Nossel, 2016; Ault-Brutus, 2012). The Department for the Aging (DFTA) currently hosts various engagement activities to de-stigmatize mental health services and encourage seniors to participate in mental health screenings, which are conducted by clinicians at a senior center. DFTA also offers various non-clinical related services, such as free congregation meals and transportation services. The goal is to identify DGMH engagement strategies that are associated with utilization of clinical services and are effective in reaching different racial and socioeconomic groups.

Mental Health- The state of emotional and mental well-being, including emotions, mood, feelings of self, and how one views the world.

Mental wellness is the state of well-being in which individuals can cope with stress and work productively.

Peer support systems are used to refer to initiatives where colleagues, friends or others provide support by virtue or relevant experience.

Compulsory Treatment is treatment required by the law.

About the DGMH system

(omitted from original study for sake of brevity) - Seniors may choose to either use structured engagement activities or choose to be screened for mental health conditions. Seniors participating in engagement activities may choose to receive a screening afterwards. Those who are screened positive for a condition may use clinical services, choose to opt out of the DGMH system, and / or continue using various senior center services. Some decide to opt out of such services. This serves as a strategy to encourage seniors to partake in services.

Results

The eligible population of seniors participating in NYC Department for the Aging's (DFTA) Geriatric Mental Health Initiative (DGMH) consisted of 4170 seniors, with 1571 seniors assessed for mental health disorders. Table 1 describes the population for the DGMH senior centers in which the majority of individuals were female, white, or had a family income less than 100% of the poverty level. The mean age of the population was 77.15 years.

Table 1 describes the population for the DGMH senior centers in which the majority of individuals were female, white, or had a family income less than 100% of the poverty level. The mean age of the population was 77.15 years in a population of 4170 seniors with 1571 assessed for mental

Table 1: Group differences in the use of clinical services

Variable		Use of clinical services	No use of clinical services	χ^2	p
		n (% row)	n		
Gender				<0.01	1.00
	Female	547 (43.1%)	723		
	Male	213 (43.0%)	282		
Race				160.00	<0.001
	Asian	132 (30.1%)	306		
	Black or African American	42 (43.3%)	55		
	White Hispanic	106 (26.8%)	290		
	White not Hispanic	343 (63.4%)	198		
Poverty Level (% of FPL)				20.54	<0.001
	100 (≤ 100)	87 (34.3%)	167		
	125 (101 to 125)	49 (47.6%)	54		
	150 (126 to 150)	17 (45.9%)	20		
	185 (151 to 185)	18 (66.7%)	9		
	NA (>185)	16 (66.7%)	8		
Structured Engagement				7.48	0.113
	Activity	27 (54.0%)	23		
	AgeTastic	34 (41.0%)	49		
	Education	9 (81.8%)	2		
	Mindfulness	29 (50.9%)	28		
	Thematic Discussion	73 (50.0%)	73		

For seniors with at least one positive screening for a mental health condition, only race and poverty levels were significant factors in clinical service use (Table 1). In summary, non-Hispanic Whites or seniors with a family income greater than 150% of federal poverty level guidelines were more likely to utilize clinical services than other racial or socioeconomic groups (p < 0.05). The time seniors spent in engagement activities, especially mindfulness and health promotion, was a significant variable in their use of clinical services (p < 0.05).

Seniors who did not use clinical services spent 416 days on mindfulness or 215 days on health promotion, while seniors who used clinical services spent 199 days on mindfulness or 84 days on health promotion. Clinical duration was also examined, with race being the only variable associated with clinical duration ($p = 0.025$). Although pairwise comparisons indicated that the differences between any two racial groups were not significant, white Hispanics spent the most time in clinical services (247 days) while Blacks or African Americans spent the least time in clinical services (138 days) on average. The logistics regression used non-Hispanic Whites, seniors with incomes greater than 185% of the poverty level, and seniors who participated in either mindfulness or thematic discussions were used as reference groups for race, poverty level, and type of engagement respectively. It was found that race was the only statistically significant variable in clinical service use. Asians and White Hispanics were 0.17 times or 0.25 times less likely to use clinical services as whites, respectively (Table 2).

Seniors spent less time on health promotion when they utilized clinical services. White Hispanics spent the most time in clinical services and Blacks or African Americans spent the least time in clinical services.

Table 2 shows that out of race, poverty level, and structured engagement, race was the only significant variable that affected clinical service use. Logistics regression was used to model the probability that people of a specific variable (e.g. people of White Hispanic race, 150% FPL, Multiple structured engagements) did or did not utilize clinical service. The more negative the regression coefficient, the lower the odds that people fitting into that variable used clinical service. The race regression coefficients demonstrate that Asians, with the lowest regression coefficient, were least likely to use clinical service, and that White Hispanics, with the highest regression coefficient were most likely to use clinical service.

Table 2: Summary of Multiple Logistics Regression Analysis for Statistically Significant Variables

Variable	Regression Coefficient (coefficient ± SE)	p	OR [lower, upper]
Race			
Asian	-1.78 ± 0.54	0.0010	0.17 [0.055, 0.47]
African American	-1.49 ± 0.90	0.098	0.22 [0.035, 1.31]
White Hispanic	-1.38 ± 0.55	0.012	0.25 [0.081, 0.72]
Poverty Level (% FPL)			
100 (≤ 100)	0.15 ± 0.82	0.85	1.16 [0.22, 5.96]
125 (101 to 125)	0.68 ± 0.87	0.44	1.96 [0.35, 11.26]
150 (126 to 150)	0.24 ± 1.00	0.81	1.27 [0.18, 9.27]
185 (151 to 185)	1.10 ± 1.08	0.31	3.00 [0.38, 30.46]
Structured Engagement			
Activity	0.49 ± 0.79	0.53	1.63 [0.35, 8.15]
AgeTastic	0.24 ± 0.70	0.73	1.28 [0.31, 4.97]
Multiple	0.57 ± 0.44	0.19	1.77 [0.76, 4.23]

This study also examined the use of non-clinically related services among seniors. Females were 1.64 times as likely as males to use transportation services and were 1.33 times as likely as males to use health services. Asians were 1.67 times as likely as African Americans and 1.49 times as likely as non-Hispanic Whites to use congregate meals ($p < 0.05$). It was also statistically significant that 38% of Asians also used technology, compared to the less-than-thirty percent of other racial groups. Seniors in the 100 poverty level group also used congregate meals and health services most often, and were twice as likely as seniors in the 125 poverty level group to use those services.

Table 3 compares the use of engagement and non-clinical services for seniors with one or more mental health disorders. A post-hoc Wilcoxon pairwise comparison (Bonferroni correction) demonstrated that women were 0.66 times as likely as men to use non-clinically related services ($p < 0.001$). Asians and Whites were also 0.5 times as likely as White Hispanics to use those services ($p < 0.01$). The majority of the seniors (57%) had a family income less than 100% of federal poverty levels. Only 10 seniors had a family income greater than 185% of federal poverty levels. The percentage of seniors using engagement activities declined, when compared to their respective groups without mental health disorders. For instance, only 55% of female seniors positive for at least one mental health disorder used engagement activities, while 73.3% of female seniors in the general population participated in structured engagement.

Table 3: Difference in groups' use of engagement activities and non-clinically related services for seniors assessed with at least one mental health disorder

Variable		Use of engagement activities	Use of Non-clinical Services	χ^2	p
		n (row %)	n		
Gender				6.71	0.0096
	Female	347 (55.4%)	279		
	Male	98 (45.0%)	120		
Race				21.71	<0.0001
	Asian	101 (60.1%)	67		
	Black or African American	18 (48.6%)	19		
	White Hispanic	105 (42.9%)	140		
	White not Hispanic	169 (61.7%)	105		
Poverty Level				7.33	0.12

Table 3 shows how non-White Hispanics are the most likely to use clinical services with Blacks /African Americans coming in 2nd with 43.3%. Asians take up 30.1% with White Hispanics being the seniors that use the least services. Males and females are balanced in the percentages of how many of their groups use such services.

Discussion

Previous studies generally agree that minority groups participate less often in clinical services than majority groups (Biegel, Farkas, & Song, 2008; Boneham et al., 2007; Jimenez, Cook, Bartels, & Alegria, 2012). Similarly, a study done by Leaf, Bruce Tischler, and Holzer III determined that individuals of low socioeconomic status are likely to perceive financial barriers in receiving mental health services and are less likely to seek such services.

The results of my study found that racial and socioeconomic groups had differing levels of clinical service use. Minority groups used clinical services less often than non-Hispanic Whites ($p < 0.001$). Higher income populations (>151% of federal poverty levels) also used clinical services more often than low income populations (< 100% of federal poverty levels). The logistics regression analysis for the independent variables (race, poverty level, and use of engagement activities) showed that race was the only variable associated with receiving clinical treatment. Whites were approximately 4 times as likely as White Hispanics and Asians to use clinical services. This difference may be due to "lack of intent" or "lack of knowledge" barriers that are more pronounced in minority populations. For example, language barriers and cultural views can lead to differences in the levels of interest in clinical services, preconceptions of mental health services, and knowledge about these services.

Racial group differences in clinical duration were significant for seniors. White Hispanics had longer clinical durations than Whites and African Americans had shorter durations. A previous study found similar results for clinical duration, finding that Latinos spend more time in clinical services than whites and African Americans (Jimenez et al., 2012). These findings may be due to possible differences in cultural preferences for treatment methods. In past studies, African Americans, for instance, were more likely to see informal support networks, such as family or religious affiliations, as ways to address psychological distress (Conner, Lee, Mayers, et al., 2010) than whites, while Hispanics may be more likely to harbor a general mistrust of medicine and Asians may prefer mental health professionals of similar backgrounds (Chen, Hussey, & Monbureau, 2018). But it remains uncertain whether the differences in clinical duration were due to the group differences in engagement or severity of mental health disorders.

Participation in a structured engagement activity was not a significant factor, but the time a senior spent in the activities, or the activity duration, was significant. In the two types of structured engagement that were associated with use of clinical services, which were health promotion and mindfulness, seniors who used clinical services spent less time in those activities than those who didn't use clinical services. A previous study did find that mindfulness-based interventions and other health awareness activities are known to reduce stress within a senior population reporting anxiety or depression (Young & Baime, 2010). It may be possible that using health promotion and mindfulness activities may reduce the need for clinical services by lessening the impact of stressors that can lead to mental health disorders.

This study also found significant differences in the use of non-clinically related services for racial, socioeconomic, and gender groups. Non-Hispanic Whites and Asians demonstrated greater

Results show that race was the only significant factor in receiving treatment, as Whites were 4 times as likely to use clinical services than others.

Race is also shown to correlate with time spent in clinical services. White Hispanics spent the longest time and African Americans spent the least time. Several cultural differences may explain this, but it is still uncertain.

Results show that seniors who participated in mindfulness and health promotion activities spent less time in clinical services.

Results here show Non-Hispanic Whites and Asians used more engagement activities while African Americans and White Hispanics used more non- clinical services.

Women were more likely to use transportation services than men, according to these results. African Americans were more likely yo use senior services than other groups.

Results show that engagement activities were important in introducing seniors to mental health services and mindfulness/activity based engagement were a key factor in reducing utilization in clinical health services.

There is an association with groups using less clinical services and engagement activities and greater utilization of non-clinically related services.

utilization of engagement activities, while African Americans and White Hispanics had greater utilization of non-clinically related services. Some group differences in the use of certain non-clinically related services may also indicate different levels of appeal for each service. It was statistically significant, for example, that Asians utilized technology classes more often than other racial groups. Past studies were inconsistent in results based on race or ethnicity, which may be due to differences in the examined communities and potential language barriers in using non-clinically related services (Pardasani, 2009; Laditka, Laditka, & Drake, 2006). However, these studies generally found that women used transportation services more often than men and that African Americans were more likely to use senior center services than other groups. Although socioeconomic status was not a significant factor in the utilization of non-clinically related services, overrepresentation of seniors with low socioeconomic status in the population diagnosed with a mental health disorder may explain group differences in the use of non-clinically related services based on gender and race.

Conclusions

The research presented here indicates that engagement with older adults remains a challenge for the New York City Department for the Aging (DFTA). Asians and White Hispanics were less likely to use clinical services than whites. Lower income populations used clinical services less often than higher income populations. Females, Whites and Asians, and seniors from higher income populations also demonstrated greater use of structured engagement than other groups. Use of structured engagement was lower among seniors who had received a positive screening for a mental health disorder.

Although simply participating in engagement activities was not a significant factor in a senior's decision to use clinical services, engagement activities are often the first introduction to mental health services that seniors have in the DGMH system, underscoring their necessity. Furthermore, participating in mindfulness and activity-based engagement with health promotion activities led to less utilization of clinical services. While the intended purpose of engagement activities is to encourage the use of clinical services for seniors who may have a mental health disorder, my study's findings suggest that certain engagement activities can reduce self-perceived need for mental health services.

Future studies can benefit from understanding the relationship of demographic factors, such as gender, race, and poverty level, to outcome data, such as the use and duration of clinical services. Furthermore, groups with lower use of clinical services or engagement activities typically demonstrated greater use of non-clinically related services, such as free meals. These services can raise mental health awareness and break down barriers to mental health services among underserved groups. Understanding how demographic factors can impact both clinical service and structured engagement use can lead to new methods of engagement, especially regarding senior groups that are more difficult to reach out to.

Examining the Effectiveness of Indocyanine Green in Screening for Cancerous Tissue Within Extremities Using Flash Imaging

Ian Fried

Annotated by Chris Dong, Stephen Lee, Lawrence Li, Shrey Patel, and Arian Rahman

Abstract

Today, the effects of cancer are well known, considering the high percentage of daily human deaths which the family of diseases is a source of. In the same vein, even people with the good fortune to survive their sickness experience intense discomfort due to effective-but-grueling treatments. But even the process of diagnosis is not easy, and carries risk; often x-rays and scans need to be taken, and later still in the process of treating or removing individual tumors and growths, imaging is not a convenient process. The process called fluorescence polarization imaging being presented here aims to streamline the process of finding and precisely locating malignant growths. Through the use of a polarized, monochrome source of light and a filtered **CCD** camera with an additional **polarizer** (excluding ambient noise) one can detect the silhouettes and depths of tissue which retain fluorescent dye, like tumors. This leads to the prospect of a cancer-imaging process which is cheap, free of ionizing radiation, and minimally invasive.

Introduction

Fluorescence polarization imaging relies on using relatively normal, accessible equipment to record the shape of malignant masses which retain dye. The dye is fluorescent, meaning that upon being exposed to light and being excited by **photons**, the atoms which are part of the dye will release photons of a lower frequency than the exposing light, causing an instantly recognizable pattern of emission for any body which contains significant amounts of dye. The image which the camera receives here will show markedly clear outlines of fluorescent mass, forming silhouettes which demarcate where healthy flesh stops and cancerous growth begins. This optical method of imaging, as opposed to radiological (which carries risks of poisoning) and pathological (which helps for diagnosis but is not as practical for use in surgery) approaches, is relatively non-strenuous for a patient while being useful for a practitioner to use in treating each case with clarity. If radiation therapy is needed, the doctor can extremely precisely target the afflicted area using this technique.

Charged Coupled Devices (CCD) are sensors used in cameras to capture moving and still images. Captures light and converts it to digital data which is recorded by the camera. A CCD often appears as a small chip-like object.

Polarizers are optical filters that let only some specific waves of light pass through, aiding the in the imaging of tumors.

Photons are the fundamental particle of light. Fluorescence polarization imagine utilize CCDs, which use photons by having them strike the surface of the CCD, and cause it to release electrons. The number of electrons released is proportionate to the brightness of the captured image

IndoCyanine-Green(ICG) in particular is well suited as the dye for this task. Its emissions correspond well to the human body's own parameters for absorbing near-infrared light, resulting in preferable depths of penetration for the light being used.
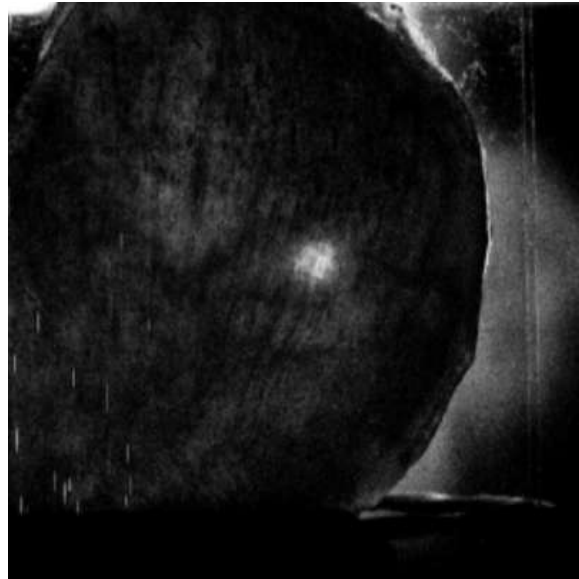

Dye tissue capture - 1.5 cm depth (chicken flesh sample)

The above image was taken from a filtered CCD where tissue retaining ICG is highly contrasted from the rest of the biomass, making the prospect of excising the dyed tissue easier. Different tissues in humans allow for varying depths of useful penetration into the human body, with examples of these metrics shown below:
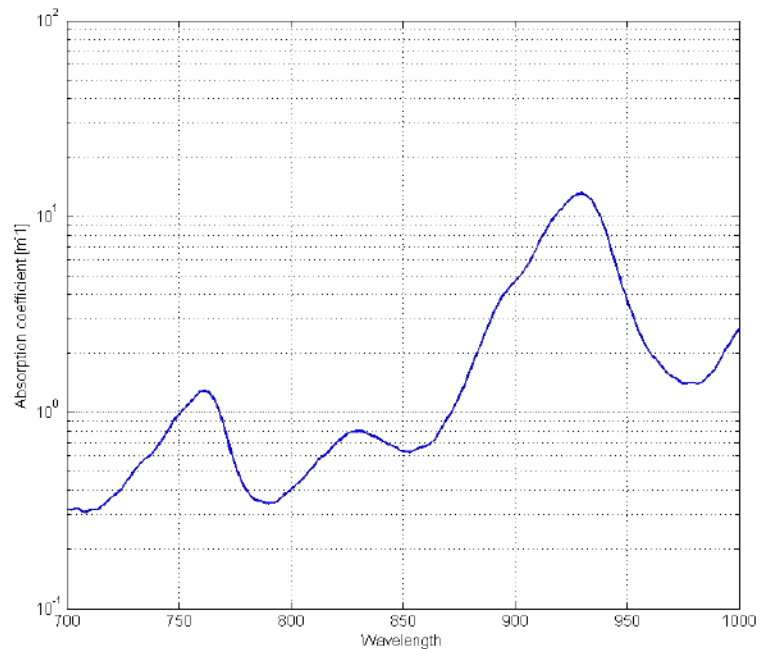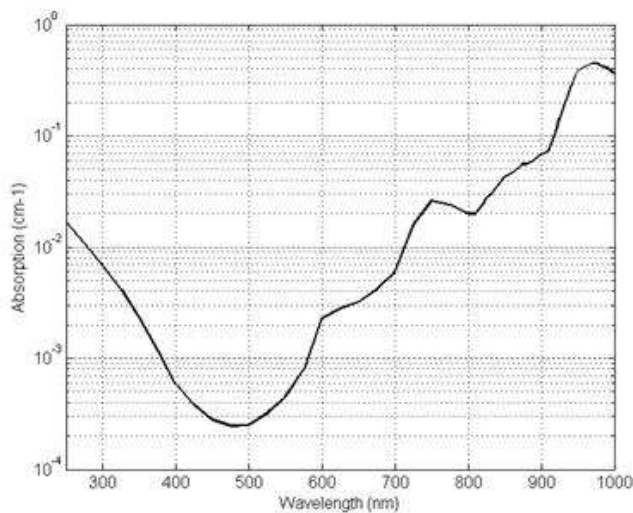

*The absorption coefficient spectrum of fat*
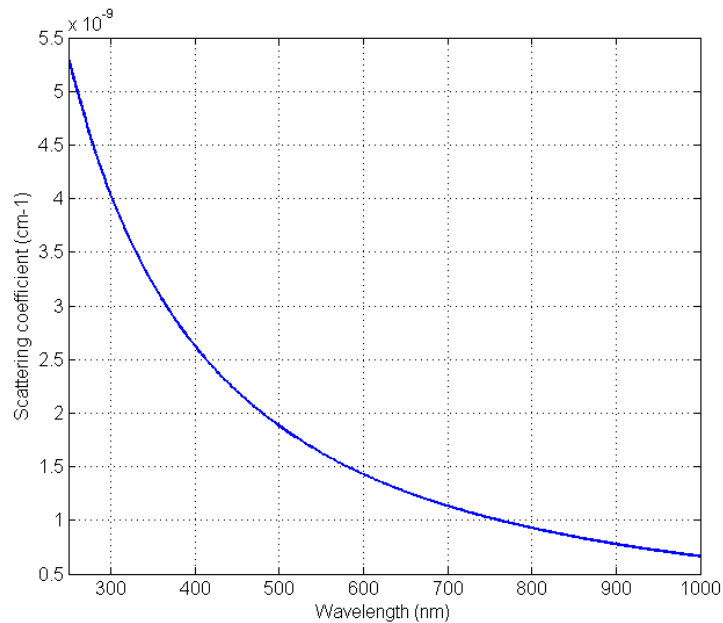
The scattering coefficient spectrum of biological tissue

NOTE: The absorption and scattering coefficients described here imply how much light of a given wavelength tissue absorbs at given thickness, and how much light of a given wavelength scatter at a given thickness, respectively.


The absorption spectrum of water
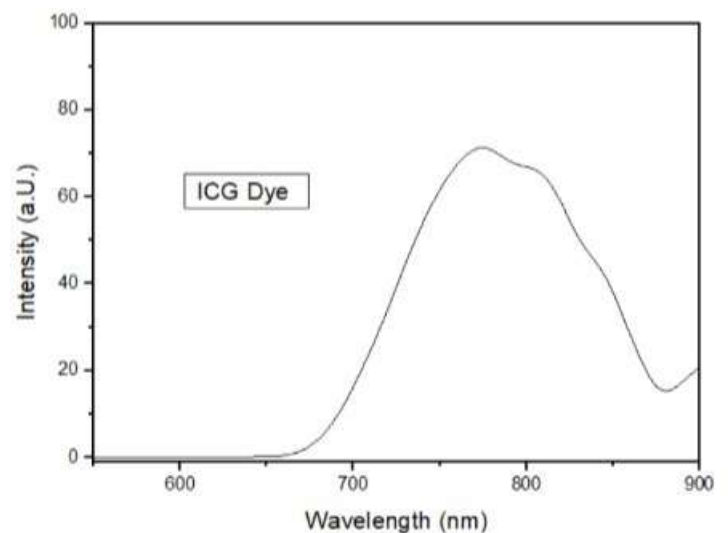
Y-axis: Intensity of given emission

NOTE: Observe the pleasant correspondence of the amounts of absorption/scattering in organic tissue and water, and the emission intensities of the ICG.

The imaging process being proposed in this document is oriented primarily towards application on extremities, because they tend to be the thinner portions of the body and have maximum depths within the range that renders ICG fluorescence useful. At the wavelengths in which scattering within human tissue begins to significantly decrease, ~700 nm and above, ICG will give emissions at its highest intensities at these same wavelengths, between ~700 nm to ~900 nm. Additionally, there is also a positive correspondence between the curves of ICG intensity and absorption coefficients of fat.
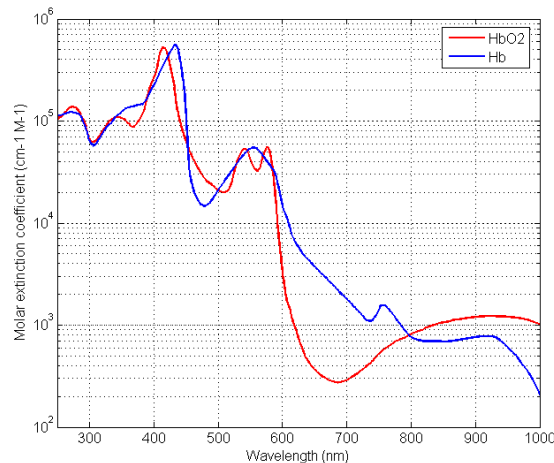
The molar coefficients of oxygenated/non-oxygenated hemoglobin
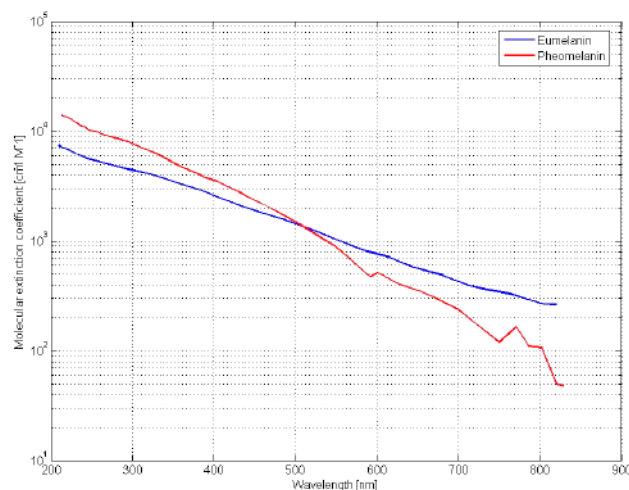
The molar coefficients of eumelanin and pheomelanin

Coefficient for hemoglobin is the measure of how strongly a chemical substance, particularly hemoglobin, absorbs light at a specific wavelength, per molar concentration.

Pigments such as **eumelanin** are found in dark hair, while the pigment **pheomelanin** is found in red hair, among other uses. These pigments are important because they are found in all epidermis cells. This will help show how tumors will affect them.

Conversely, notice how the molar extinction **coefficient for hemoglobin**, both bound and unbound to oxygen, is nearly inversely proportional to the curve for the ICG - at wavelengths which the dye emits most brightly in, blood will be less able to absorb as much light. In the same vein, both **eumelanin** and **pheomelanin** have a somewhat inverse relationship to the dye's curve, though it is far less pronounced than the previous example's graph. The difference in behavior when exposed to near IR light and ICG between blood and say, fat, means there will likely be contrast between the two substances when being imaged.

Materials and Method

The setup advocated in this document, a **Flash** Imaging Apparatus or FIA, is meant to leverage the advantageous properties of ICG-human tissue interaction in a way which should hopefully prove economical without compromising the quality of results. As the diagram in the beginning of this proposal demonstrates, the two elements involved in flash imaging within a setup are just a CCD camera, and a near IR light source, likely some sort of powerful LED due to their extremely low cost. What the diagram omits, is that there would need to be **polarizing filters** for the light source to limit noise in the data generated from the camera, and a long pass filter likely allowing ~700 nm and above wavelengths in front of the oculus for the camera to avoid damaging the equipment and allowing the emissions of ICG to be isolated.

The process would need to take place in a dark environment, like a windowless room with lights turned off, to further reduce light pollution in data and better treat the CCD. But in all likelihood the process need only take a few minutes at most. A patient's extremity already exposed to ICG - perhaps injected directly - is placed into the cavity between the sensor and the source of light. The room is dimmed, the light flashes on until a proper capture is taken, and then flashes off shortly afterward. The image should be available as soon as software processing is complete to show the contrast between substances already mentioned like blood and fat, but also any undesirable bodies like tumors, cysts, or other malignant growths.

Conclusion

Using an FIA setup should hopefully be economically viable for many institutions as well, given that the costliest components would likely be the CCD camera and the filters needed to run it properly, provided the institutions already owns a computer able to run the software needed to process CCD images. After this, the remaining costs include a light source (again, preferably LEDs) along with an ability to order as much ICG as needed for a given number of patient cases. But hopefully, for more minor cases involving a patient's extremities needing imaging, FIAs can be a cheaper, safer alternative to more expensive medical imaging techniques while hopefully being just as useful.

FLASH, or Fast low angle shot magnetic resonance imaging, is a sequence of magnetic resonance imaging used commonly with MRI and cancer detection methods.

Polarizing filters are the filters used in photography to manage reflections, and suppress glare.

Machine Learning in the Search for the Room Temperature Superconductor

Fakharyar Khan

—————————————

Annotated by Chris Dong, Stephen Lee, Shrey Patel, Md Shad, and Wasi Shahriar,

Cryogenic refers to the behavior of materials when applied to low temperatures that are below −150 °C to absolute zero(-273°C)

Quantum computers process calculations based on the state of an object. These computers differ from classical computers as they omit the use of 0s and 1s, allowing the quantum computers to take more data.

To run **Autofeat,** a Python compiler, Cython, was used to translate code into machine language for efficiency. The significance of this is that you can generate regression models.

Abstract

Superconductivity is a phenomenon where at **cryogenic temperatures**, the resistance of certain materials abruptly drops to zero. Because of their potential for 100% energy efficiency superconductors have many applications in **quantum computers**, Maglev trains, and even in MRIs. However, the refrigeration costs required to sustain superconductivity makes its applications on large scale projects impractical. There is therefore, a large scale effort in materials science on the discovery of room temperature superconductivity. The search has been delayed on account of there being no definitive theory for high temperature superconductivity. In this paper, I use a machine learning algorithm called **autofeat** to derive a formula for the superconducting transition temperature and develop a classification model that predicts superconductivity. I believe that this approach will accelerate the theoretical effort behind projects like the Materials Genome Initiative.

Introduction

When a current passes through a material, the electrons collide with positive ions which causes small deviations in the electrons' path. This is what creates a resistance to the flow of electrons. The resistance varies with temperature but at very low temperatures, the resistance of some materials abruptly drops to zero and the material enters a superconducting state. This phenomena was first discovered in 1911 when Heike Kamerlingh Onnes showed that at 4.2 K, mercury becomes superconductive[1].

Superconductors are very useful in quantum computers because if the wire is made out of a superconductor, the current will flow through with no resistance. The implications of 100% energy efficient wires can be seen in the AmpaCity project in Germany where engineers have created a 1 kilometer cable that provides the same power as a 110,000 V power line with 10,000V [2]. Furthermore, superconductors exhibit a property called the Meissner Effect where it expels its magnetic field and produces an external field that is strong enough to levitate the conductor. This has been used in Maglev bullet trains[3] where superconducting coils beneath the trains allow them to levitate which significantly reduces friction. In April 2015, the Central Japan Railway Company's reached more than 600 km/hr.

In 1957, three American physicists, John Bardeen, Leon Cooper and Robert Schreiffer, came up with the first successful theoretical explanation for superconductivity, BCS theory [4]. In BCS theory, an electron in a **lattice** attracts positive ions which causes a distortion and collective excitation (a phonon) of the lattice. Another electron would then be attracted to this region and this creates a Cooper pair. This in turn will influence other electrons, creating a mesh network of **Cooper pairs**. Cooper pairs behave like bosons which means that their wave functions are symmetric under particle interchange and this allows a pair to occupy the same **quantum state**. However, since the Cooper pairs are intermingled with one another, the pairs all must occupy the same quantum state.

In order for the superconducting state to be stable, the system must be at **equilibrium** and so the intertanglement of the Cooper pairs must be strong. The total momentum of each Cooper pair must then be zero as this allows for pairs to exchange electrons without disturbing the system. Now, imagine a current with **momentum mv,** passing through the lattice. The total momentum of each Cooper pair must then be **2mv.** In order for resistance to occur, an electron must be scattered so that its momentum is in the opposite direction of the current. However, this would change the total momentum of the Cooper pair which means that for there to be resistance, the force must be strong enough to break the Cooper pair. But since the Cooper pairs are in a mesh network, the energy needed to break one pair is the energy required to break the network.

The three researchers also used the results from **BCS theory** to derive an approximate formula for critical temperature: Tc ≃ 1.14 ωD e where is the **Debye frequency** of the −1/λ ωD material and λ is the electron phonon coupling strength. While BCS theory was revolutionary, it does have limitations. The original theory neglects electron phonon retardation, assuming that the interactions are instantaneous ($\lambda << 1$). This assumption means that for strong coupling ($\lambda > 1$), BCS theory is inaccurate. Eliashberg theory[5] expands BCS theory to account for this and gives $T_c \simeq \frac{w_{log}}{1.45} exp(- \frac{1.04(1+\lambda)}{\lambda - \mu^*(1+0.62\lambda)})$ where μ* is the **Coulomb pseudopotential** and w_{log} is the logarithmic average of the phonon frequency.

Programs like Quantum Espresso [6] are used to find the value of these parameters and can be very computationally expensive. For this reason, a machine learning model that can derive an approximate formula for critical temperature whose parameters can be more easily calculated, will accelerate the theoretical effort behind projects like the Obama Materials Genome Initiative [7].

Lattices are an ordered array of points that describe the arrangement of atoms, ions or molecules in crystalline solid.

A **Cooper pair** or a BCS pair is a pair of electrons that couple together within a distance of hundreds of nano-meters. This process is repeated by influencing other electrons, giving superconductors their 100% energy efficiency.

Quantum States: any of various states of a physical system and are characterized by a particular energy.

The state of superconducting at **equilibrium** means the forces within the system are stable and balanced. In this case, the system must be balanced for the cooper pairs to remain strong.

Momentum mv can be represented by the equation P=MV. It states that momentum is equal to mass times velocity.

2mv can be shown as P=2MV, stating that momentum is equal to twice the mass times velocity, since there are two electrons in a cooper pair.

The **BCS Theory (Bardeen-Cooper-Schrieffer Theory)** was the first microscopic theory of superconductivity . It describes superconductivity as a microscopic effect caused by the condensation of Cooper Pairs.

Debye frequency is a frequency of a crystal determined by the density of atoms and is the speed of sound in a solid.

Coulomb pseudopotential is the effects of the repulsion between two or more charged bodies on superconductivity

An **out of bag error** shows a measurement for a prediction error of a random forest.

Random Forest was used to gather data to try to interpret features of superconductivity, using Decision Trees to overlap data samples.

Estimators is a predictor found from a regression algorithm

Recall is the percentage of total relevant results correctly classified by the algorithm.

Precision is the percentage of your results which are relevant.

Push and Pull is an interaction between two aspects of the experiment that affect each other. In this case, higher recall would cause lower precision and vice versa.

A **heat map** is a visual representation of data points and individual values that are represented by colors.

A **confusion matrix** is a layout that shows a visual representation of how an algorithm can work.

Discussion and Results

Classification

To show that the **out of bag error** converges as the number of trees gets large, I recorded the performance of **Random Forest** models that used somewhere between 15 to 1000 **estimators**. As can be seen in the graph of out of bag error versus the number of estimators, the error rate changes rapidly (though it's always within a range of 0.08), but after it reaches 450 estimators, the error stabilizes and seems to converge to an error rate of approximately 0.375
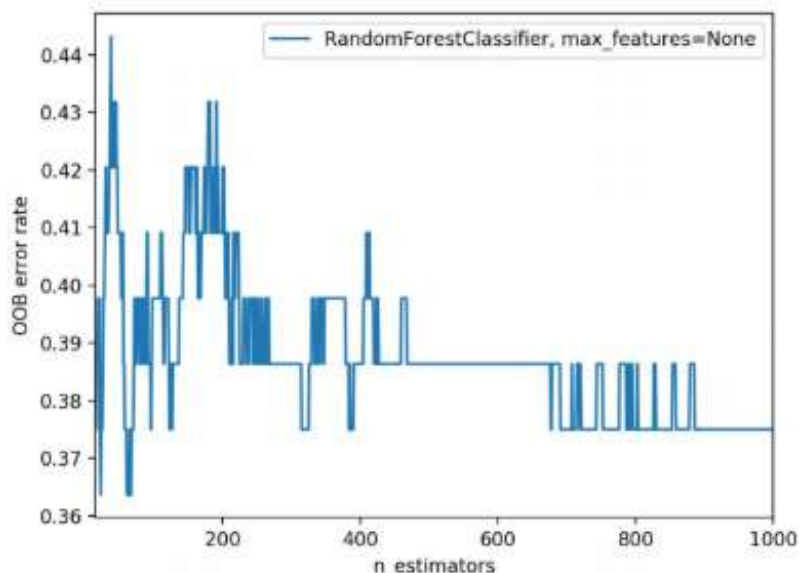
The Random Forest model was tested on 25 non superconductors and the 25 remaining superconductors. The model correctly predicted 58% of the testing set. It had a **recall** of 0.6 and a **precision** of 0.59. Usually classification models there's a **push and pull** between the recall and precision but this model's very balanced. The **heatmap** below shows the **confusion matrix** for the model's performance. The horizontal axis gives the model's predictions and the vertical axis describes the actual predictions. The model's performance is comparable to other successful models [19] that have much larger datasets to train on.

Regression

After 3 steps of Autofeat Regression, the algorithm produced the equation: $T_c = B^2 * \lambda^3 * log(\lambda)^3$. The **R^2** value for this regression equation was approximately 0.166 and the **RMSE** was 5.49. I believe that while the features could describe the transition temperature very well, there wasn't enough data for the model to find the relationships between the features. Many of the data entries were also theoretical values which can be inaccurate and generate **noise in the data**. Autofeat generally doesn't perform well on noisy data which may have contributed to the high RMSE value.

R^2 otherwise known as the coefficient of determination, is used to represent the proportion of variation in an independent variable. In this case it is used for a regression model.

RMSE is the standard deviation of the residuals . This tells us how concentrated the data is around the predicted line of best fit.

Noise in the data is any additional data in the plots of data that do not hold any meaning.
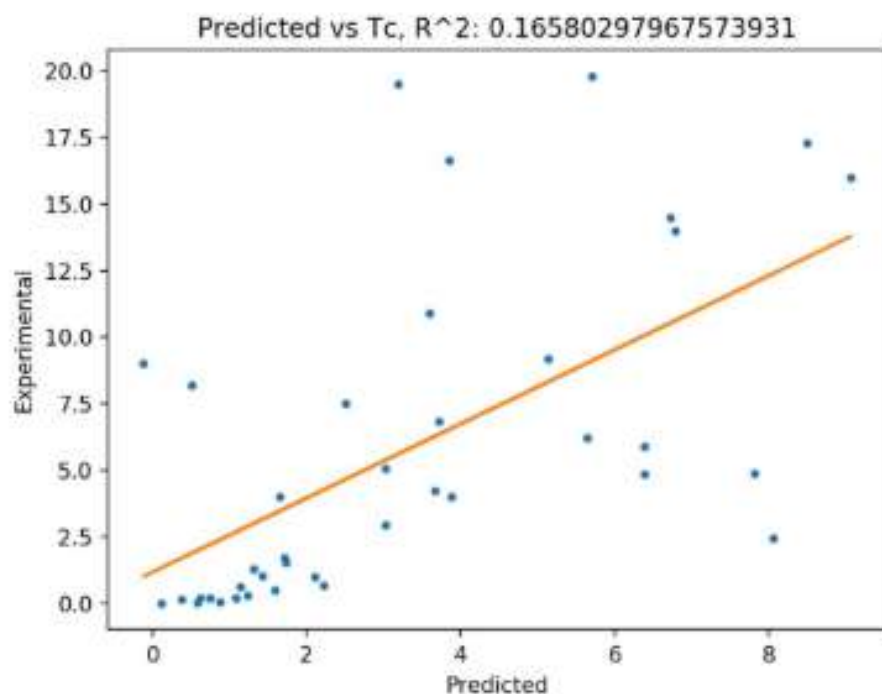
Conclusion

I believe that future endeavors in machine learning for superconductivity should focus on gathering larger datasets. Machine learning algorithms generally require a large amount of data to train and obtain an accurate assessment of its performance. Classification models that are training on a larger scale have the potential to use the elements of the compound to determine superconductivity without running the risk of **overfitting**. There is a lot of potential for machine learning algorithms in materials science but they require ambitious data mining efforts.

Overfitting is when the data is restricted into a specific amount or a group of data points.

Analyzing the Relationship Between Test And Reference Influenza Viruses

Oscar Eng

_____

Annotated by Lawrence Li, Pranav Paranji, Nina Shin, and Grace Yang

Influenza is also commonly known as the "flu."

Cross-reactivity is the reaction between an antibody and an antigen that differs from the immunogen (a type of antigen that invokes a cell mediated immune response.

Antisera is a blood serum containing antibodies against specific antigens, injected to treat specific diseases.

The **titre** is a unit of measurement detailing the concentration of an antibody in a solution where it can still agglutinate (to stick) with antigens.

Hemagglutinin refers to the glycoproteins on red blood cells which cause them to stick together to form a mass. This process is known as hemagglutination. Antibodies are examples of hemagglutinins.

Clonal selection is the process by which a specific B-cell is targeted to undergo clonal expansion.

Nueraminidase is an enzyme that catalyzes the hydrolysis of glycosides. Viral neuraminidase is a type of neuraminidase found on the surface of influenza viruses that enables the virus to be released from the host cell.

Abstract

Influenza is one of the most common and still threatening viruses in our society, killing more than 12,000 people annually. Because of the pathogen's ability to evolve quickly, it often escapes immunity from its host which is why vaccines against it need to be updated every year. In order to create a vaccine that is effective for multiple versions of influenza, the interactions between host antibodies and opposing antigens need to be better characterized. My goal was to create an accurate, cost-effective model that could predict the degree of **cross-reactivity** for future evolving viruses, given sets of known antibodies. The first step was to inject reference antigens of influenza A into ferrets, extract their **antisera** and test antibody reactivity against test influenza A antigens. Data recorded from that step included antibodies' **titre** values that measured the concentration of antisera. My models related antibody reactivity with various variables such as evolutionary distance between viruses and the genomic differences between viruses on their **hemagglutinin** (HA) protein sequence because of its involvement in infection. In general, the smaller the distance between individuals of a species on the evolutionary tree, in terms of the number of amino acid substitutions per alignment site, the better chance to trigger a **clonal selection** of many antibody species. Furthermore, evolutionary distance has a direct relationship with genomic differences in ways that help predict antibody-antigen reactions. My latest model uses evolutionary distance together with HA amino acid positions and with its promising accuracy, it is hoped that the results could be applied to other strains of influenza to generate more effective vaccines.

Introduction

Influenza is an acute disease associated with many symptoms including chills, fever, headaches, and overall weakness [4]. Sometimes, the influenza makes the body more susceptible to other diseases. This disease can be transmitted to different hosts through the air [4] coming in contact with cells of the upper air passages. Next, it penetrates host cells eventually resulting in viral progeny and the infection of other nearby cells in the respiratory tract [4]. The virus will then exit the host cell using **neuraminidase**.

The germ's antigenic properties are determined by the surface glycoprotein hemagglutinin [1] which allows the influenza virus to bind to targeted cells that express a corresponding receptor. The changes in amino acid sequence at exposed **epitope** sites in hemagglutinin trigger a greater diversity of antibodies [3].

During a typical immune response, antigen-presenting **leukocytes** first ingest the reference virus in order to prepare the antigens. After hydrolysis of the antigens, the resulting pieces are transported via **major histocompatibility complex** to the leukocytes' surface. Finally, **clonal expansion** is triggered as **lymphocytes** interact with those antigenic pieces. B-cells' production of antibodies is the result of an immune response from the infection or injection of a particular reference virus. The purpose of antibodies is to bind with the antigens in order to neutralize them or to signal other leukocytes to kill the germ itself [2]. Memory B-cells are long-living and make more antigens so that the body could make more antibodies to fight future influenza infections. The affinity of an antibody is measured using titre values in the context of a **Western Blot Analysis** [3]. Hemagglutinin is an envelope protein found on an influenza virus that binds to **sialic acid receptors** on targeted cells. The protein would also bind to red blood cells to form a lattice [1]. This property is called hemagglutination and it allows researchers to determine levels of influenza virus present in a sample. When influenza viruses are mixed with a specific amount of red blood cells, the red blood cells that are not bound by influenza virus sink to the bottom of a well and form a button.

Materials And Methods

The HA-related antigens of several influenza reference virus samples were injected into ferrets (Mustela putorius furo) in order to trigger the animals' immune system to produce antibodies. Ferrets were chosen because of their high susceptibility to human influenza infections. Antisera, rich in clonally select antibodies, were then extracted from the animals' blood and mixed with various test virus samples to make **HI Assays**. Those are made by adding a fixed amount of virus to every well of a plate. With prepared dilutions of each serum, the dilutions were added along a row of wells. The success of the antisera inhibiting each antigen was measured by using titre values. The treedist, "the ref. year", "test. year", seqdiff, and the agreements were also recorded. Software Anaconda and Python were installed. Several Python Databases were then imported including pandas, numpy, matplotlib.pyplot, scipy, statsmodel, and many others. The recorded data was read and downloaded as a **Dataframe** in Python. The data points were categorized using lists. Those data points were to be used in various statistical tests and models. for loops were Python commands that were used to look through the data lists that were created and to use only certain points in the models and tests. Many of the statistical tests were linear mixed models.

An **epitope** is the part of an antigen an antibody attaches itself to.

A **leukocyte**, also known as a white blood cell, circulates in the blood and other body fluids involved in counteracting foreign substances and disease.

Major histocompatibility complex (MHC) molecules mediate interactions between leukocytes or other body cells.

Clonal expansion is the process during which a B cell with a specific antigen replicates itself. B cells are types of white blood cells that produce antibodies.

Lymphocytes are white blood cells that are made in the bone marrow and function as defense against foreign substances.

Western Blot Analaysis is an analytical technique used to detect specific proteins in a sample of tissue homogenate (homogenized tissue) or extract.

Sialic acid receptors are used by many viruses for cell entry.

In a **HI Assay**, or hemagglutination inhibition assay, influenza virus antibodies prevent hemagglutination (attachment of the virus to the blood cells).

A **Dataframe** in Python is used to organize data in columns and rows.

Results

Various statistical tests and models were created to consider variables predictive of **antibody avidity**. One marks "agreement" and "disagreement" between reference viruses and test viruses at amino acid positions on the HA protein (See Figures 1a and 1b). Agreement determines whether a reference virus and test virus are identical at a given amino acid position (0). Disagreement determines whether a reference virus and test virus are not identical at the amino acid position (1). **T-tests** revealed that for 80% of these positions the **titre values** for the set of reference and test pairs agreeing at a position is significantly different from the titre values for the set of reference virus and test virus pairs disagreeing at a position. Thus, the distributions of titre values for the pairs are dependent on attributes of viruses at these positions. Figure 2 gives a visualization of the differences in distributions at amino acid position 273 on the HA protein. In this case, the average titre value is higher for pairs of reference viruses and test viruses in disagreement at the position than the set in agreement. Given the median **tree distance** as 0.04, we decided to investigate at what number of positions where agreement significantly affects titre values given the tree distance (see Fig. 3).
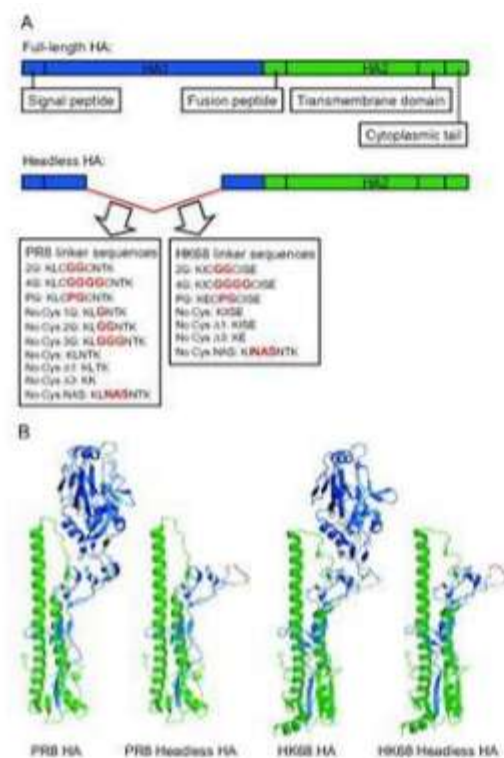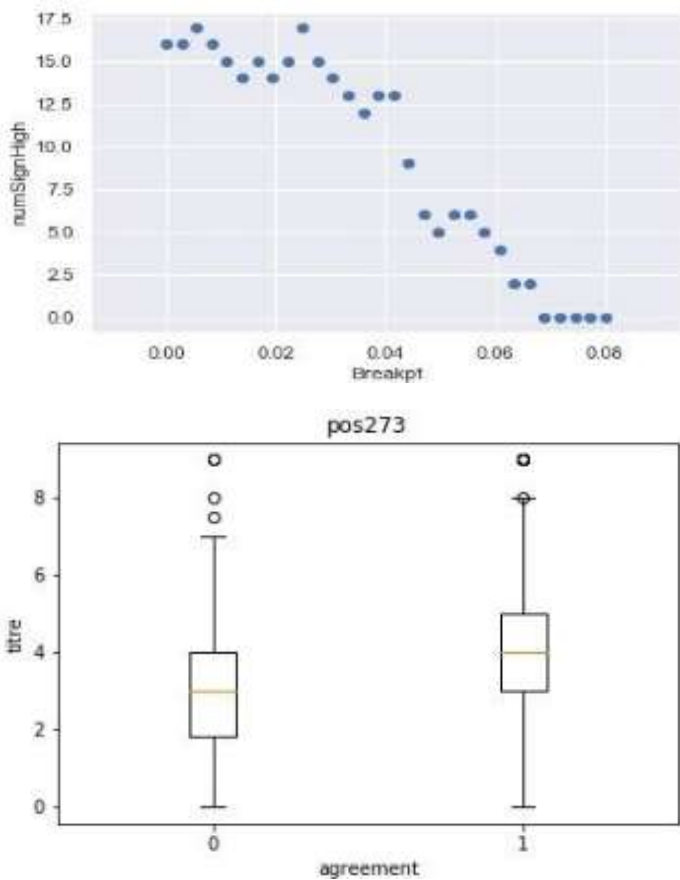
Antibody avidity describes how tightly the antibody binds to the antigen.

A **T-Test**, tells you how significant the differences are to allow you to determine if those differences could have happened by chance.

The **titre value** is the volume of titrant required to get at an equivalence point with the unknown reagent. Equivalence point is when the a mount of moles of the tritant equals moles of reagent.

The **tree distance** is for the distance between phylogenetic trees.

Fig 1a. This figure features the HA protein.

| 36 | 57 | 74 | 94 | 125 | 128 | 130 | 141 | 146 | 153 | 160 | 170 | 186 | 187 | 189 | 198 | 215 | 222 | 237 | 273 |

Fig 1b. This table represents an HA protein (hemagglutinin) and its various amino acid positions.

The next statistical test visualized the relationship between the seqdiff (the sequence difference) and titre values with the reference virus strain being the changing variable (See Fig 4). In general, titre values decreased with increasing seqdiff. For various reference viruses, the relationships between treedist and titre values were graphed (see Fig 5). I then created a model that predicted titre values given treedist for all the virus pairs given the imaginary line (See Fig 6). Agreement at an amino acid position was not a variable that was considered in this model. Most observed variables do not meet the predictions. Though the test viruses differed from the reference viruses at amino acid position 130, it did not significantly affect the antibody's titre value. In this case, titre values are largest when treedists were the smallest. The titre values correspondingly decreased with treedist. While performing statistical tests, I noticed a connection between amino acid positions, treedist, and titre values in determining accuracy. I also made a connection between reference virus clades and titre values. I put this connection into the model by adding interaction terms of pos*treedist. This increased its accuracy and helped solve the problem because if a new virus evolved, then I would only need its distance from the reference virus and information about its agreements at certain positions to understand how it will react with antisera related to the references. The results needed to be **cross-validated.**

Cross validation is when similar validation techniques are used to test how the results of a statistical analysis will generalize to an independent data set.

Discussion

The antibodies generated from the test viruses reacted differently to the same set of reference virus strains. Due to the **systematic variation** between test and reference viruses, there are various terms for the test viruses in our model. The effect of these terms for reference viruses and test viruses are not to be thought of as "slope terms" in the linear model but rather they affect the intercept of the model. A possible next step in the study is to use data in which reference virus types get paired with a larger set of test virus strains. The HA amino acid positions that give off the highest titre values need to be identified. This data would be needed to provide an updated model. Along with using more accurate data to updated models, we should also considering the application of random effects models to predict titre values. Neuraminidase amino acid positions can also have an application in future studies. When all of the following are considered, potential sample vaccines still need to be tested for their affinity via enzyme-linked assays against a cocktail of influenza strains. Different variations of the HA protein could be created through a **site-directed mutagenesis technique.** These variations should be injected into ferrets. A month later, the ferrets should be injected with **attenuated strains** of influenza before the injections are tried out on humans. Western Blot Analysis is useful for identifying different species of antibodies. The **Enzyme-Linked Immunosorbent Assay** uses sensitivity that could help find an antibody & #39's titre value.

Systematic variation refers to an inaccuracy in observations which are the result of factors not under statistical control.

Site-directed mutagenesis technique is used to make intentional changes to the genetic information of an organism.

Attenuated strains reduce the virulence of the virus, but it keeps the virus viable — this vaccine does not completely kill the virus.

Enzyme-Linked Immunosorbent Assay is a process that uses antibodies directed to a ligand to detect the presence of that ligand in a liquid sample.

2010S

A DECADE IN SCIENCE

Xuan Cheng

Kim Firoozan

Aman Khan

Stephen Lee

Edward Oo

Pranav Paranji

Aryan Patel

Aryan Ruparel

Neil Sarkar

Md Shad

Wasi Shahriar

Nina Shin

Julia Wu

Kai Wei Zhang

Amanda Zhong

2010

March - NASA's discovery of water on the Moon

On March 1, 2010, NASA announced its findings of vast pockets of water discovered on the northern pole of the Moon. Its discovery was profound, opening up the possibility of further exploration on the Moon. With the understanding that ice could provide a natural reservoir for future human endeavors, eyes were set on new scientific pursuits for the future, with the collective hope that a possible moon base could be built. Ice could yield potable water. By separating its oxygen-hydrogen constituent, it could also yield possible rocket fuel and breathable air. The presence of water was discovered by NASA's Mini-SAR radar instrument on India's Chandrayaan-1 lunar orbiter. It detected over 40 craters with widths between 1 to 9 miles, containing an estimated total of 600 million metric tons of water ice. In a statement by Paul Spudis, the executive scientist of the Mini-SAR project, "the new discoveries show the moon is interesting and attractive."
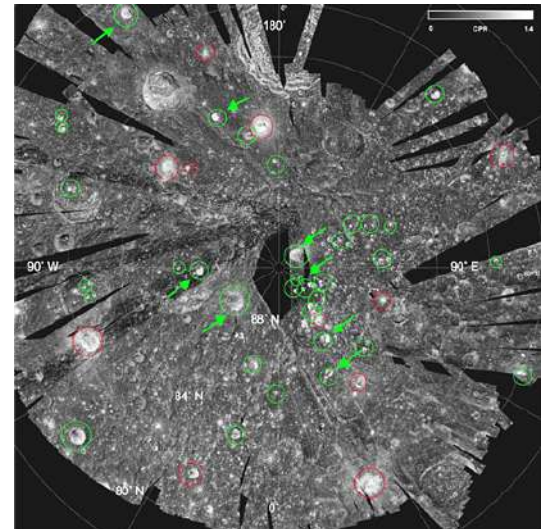

NASA's radar detect over 40 deposits containing ice on Moon's North Pole

Image: Dunbar, B. (2010). NASA Radar Finds Ice Deposits at Moon's North Pole.

July - Scientists Genetically Engineering A Malaria-Proof Mosquito

Researchers from the University of Arizona trued to fight fire with fire when they created a newly designed malaria-resistant mosquito, that was released in the summer of 2010. The scientists were able to introduce a gene that affected the mosquito's gut, effectively blocking the development of the malaria parasite that harbored inside its stomach. It involved genetically tweaking a gene that codes for a "signaling molecule." In disrupting that gene, it also disrupted the communication among the mosquito's cells which in turn impaired the malaria parasite's ability to develop and reproduce. The researchers' ultimate goal was to control the outbreak of malaria by sending off these GM organisms to compete with the preexisting set of mosquitoes. The researchers needed not only to genetically modify the guts of the mosquitoes, but also to engineer them in such a way that they had a selective advantage over the many other mosquitoes and succeeded in natural selection. That was the purpose of tacking on an extra genetic boost: to develop an immunity towards a particular toxin and to propagate their survival.
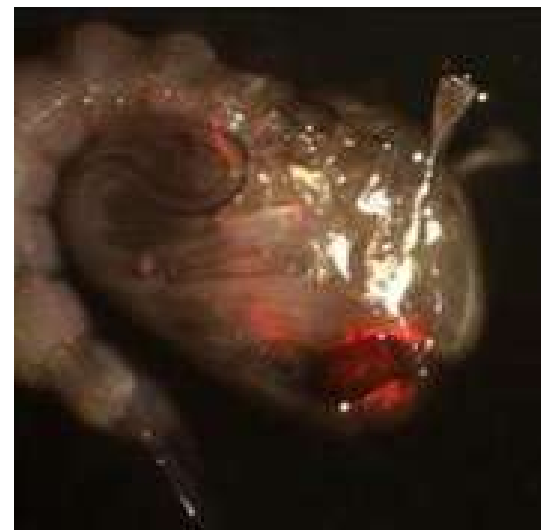

Scientists, at the University of Arizona, engineered a malaria- resistant mosquito, hoping to gain a competitive edge over disease-carrying insects

Image: Gill, V. (2010, July 16). Malaria-proof mosquito engineered.

October - Americans Doctors Conduct The First Trial of Embryonic Stem Cells Treatment

In the charged debate of the testing of embryonic stem cells remains an ethical procedure, the year 2010 gave way to the first ever official embryonic stem cell treatment on human trials. The license to do so was given by the Food and Drug Administration to Geron, a biotech company based in San Francisco, California. The company's mission was to use stem cells in treating spinal cord injuries by turning them into effective nerve cells. Previous experiments were done on paralyzed rats, which had seen hopeful results as they regained limited mobility. In the human clinical stage, the objective of the trials were to confirm if any bodily harm was done to the patients. Doing so provided the next steps for developing and assessing the treatments to provide the necessary benefits to patients. But, it is still years away from a fully-effective treatment. As the first major milestone in stem cell research, we can only anticipate what the future holds for a new era in regenerative medicine.
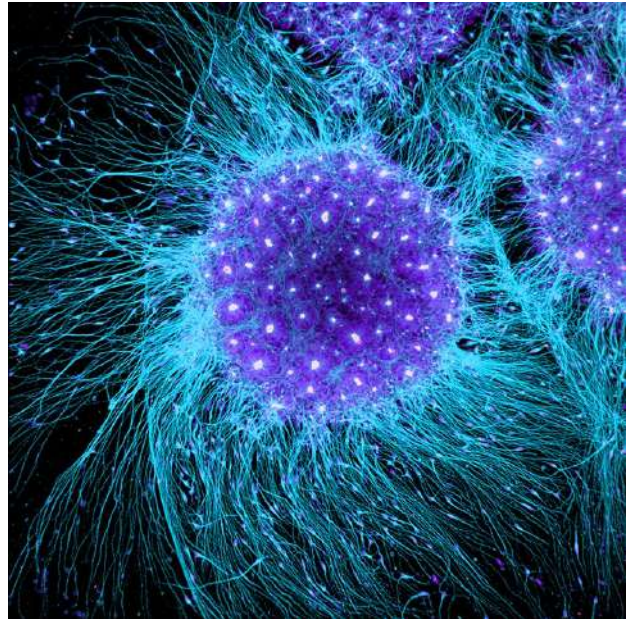
Geron hopes to use embryonic stem cells to treat spinal chord injuries.

Image: Gist Croft/Ali Brivanlou/Rockefeller University

November - Scientists Report a Gene That Can Supposedly Reverse Aging in Mice

The process of aging can be defined as the deterioration of our physical self, from the failure of our physiological functions to the weakening of our immunity. However, experiments conducted by scientists at Harvard Medical School supposedly discovered a gene that could reverse the aging process and regenerate worn out organs. The results were first seen in elderly mice, and with it, a thought that similar efforts could be reproduced in humans. It raised hopes for the possibility of improving the quality of life for those subjected to health issues and diseases such as dementia and cardiac disease, often associated with older age. Even in modern day, the knowledge of the aging process is still relatively foreign, but such experiments have uncovered important insights on what contributes to aging. Although the comparative status between mice and humans is limited, the substantial restoration seen in mice is all the more promising that someday we might just live to be immortal.

2011

May - HIV Treatment for Prevention

On May 12 2011, a study known as HPTN O52 was tested, confirming that the HIV treatment prevents the transmission of HIV. This breakthrough changed all of medical science for decades to come, showing that if an HIV positive person sticks with antiretroviral therapy, the risk of transmitting the virus reduces by 96 percent. The currently estimated 33 million people living with HIV could now live with confidence, protecting their loved ones from HIV. At the time, the companies that made the therapy accessible to all included UNAIDS and WHO. It's been said that "Treatment is Prevention" and in this case, it seems to be that ⅔ of the people with the disease took this to avoid the compromise of the lives of others in society.

July - First Synthetic Transplant of a Fully Synthetic Organ

The first transplant that was carried out was on a 36 year old cancer patient admitted to the University Hospital in Stockholm, Sweden. This new technology did not need a donor, but in fact was created from scratch with the help of technology. After a month of the operation, the cancer patient was doing well with his new windpipe replacement. To form this exact figure, scientists took 3D scans of the patient's windpipe, and at the University College of London, they were able to craft a perfect copy of Mr. Beyene's trachea. Placed in the bone marrow after flown in, Mr. Beyene currently lives in Iceland where he studies for a PHD. He also did not have to take any anti-rejection drugs as other transplant patients do because the bone marrow cells and the lining cells were taken from his nose during the operation allowing them to divide and grow as a synthetic windpipe.


This artificial trachea, made of the patient's own stem cells, is the first synthetic organ to be transplanted.

Image: Roberts, M. (2011, July 7). Surgeons carry out first synthetic windpipe transplant.

August - NASA Research Shows DNA Bases Can Be Made in Space

Since the 1960's, scientists have detected DNA building blocks in space, however on this date, research indicated that the building blocks of our genetic material reached greater diversity than what was actually conceived. According to NASA, this showed that asteroids and comets were capable of making biological molecules and proteins. In fact, scientists also found from a comet with the name of Wild 2 that amino acids are also located on carbon rich meteorites. Additionally, in two of the meteorites that were analyzed, there were 3 types of nucleotide bases that were almost never used in biology. This decreased the likelihood that the meteorites were contaminated from earth like the material that gives off this phenomenon. Astrobiologist Micheal Callahan from NASA expressed, " If asteroids are behaving like chemical factories cranking out prebiotic material, you would expect them to produce many variants of nucleobases, not just biological ones, because of the wide variety of conditions in each asteroid".
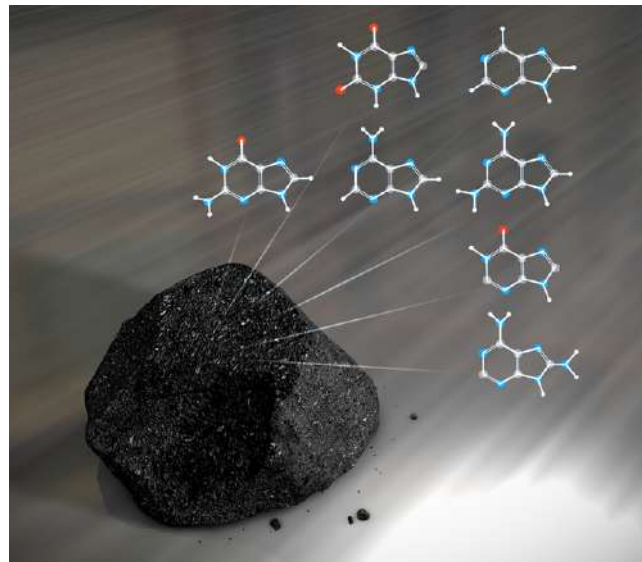
Meteorites, such as asteroids and comets, contain many nitrogenous bases, which are an essential part of DNA.

Image: Bowdler, N. (2011, March 1). Meteorites 'could have carried nitrogen to Earth.

August - Japanese Scientists Develop a Method to Remove Radiation from Water and Soil

Removing cesium from soil was not developed till 2011 when it was used to clean up areas of the world's worst nuclear disasters. Sunflowers, in fact, was the way that the Japanese looked to soak up the radioactive isotopes. These isotopes mimic the nutrients that the plant currently takes up. Therefore the plant cannot distinguish between nutrients like potassium and radioactive substances. The plant material will then be disposed of because it will absorb a lot of cesium in a small concentrated area, making it easier to remove the contaminant than if it were to be in soil. In soil, the concentration would not be as high so it would be harder to get rid of.

Sunflower fields were planted in Japan in order to soak up the radioactive isotopes from the nuclear disasters.

*Image:* Gellerman, B. (2011). Sunflowers used to clean up radiation.

2012

April - Xeno Nucleic Acid

For the past years, we learn that DNA and RNA are the different types of nucleic acids necessary for our growth and development. However, in April of 2012, a polymer called XNA, or Xeno Nucleic Acid, was synthesized. Vitor Pinheiro and Philipp Hollinger of the Medical Research Council in the UK, the creators of this nucleic acid, made XNA capable of storing genetic information and then evolving through natural selection. Additionally, it can be carefully manipulated, unlike DNA. Rather than the pentose sugars that make up DNA and RNA, XNA doesn't have carbon rings that make up its sugars, such as threose or arabinose, and instead lines. Although this is interesting, this won't be of use to biology unless there is a mechanism to read it, so for now, the genetic information is invisible. DNA or RNA Polymerases do not bind successfully to XNA, and thus, this discovery is still looking for an application.

July - Discovery of Higgs Boson

Physicists that have been working at the Large Hadron Collider ended a 50-year-long search when they discovered the Higgs boson. This particle was detected at 125.3±0.6 gigaelectronvolts, and according to a scale determining if a finding is a discovery, this finding is in fact a new particle. This is the particle that is responsible for giving subatomic particles, such as protons or neutrons, their mass. It was also the final piece in the Standard Model of particle physics, describing the interactions and existence of all known forces and particles. Although scientists expected this discovery to help them rectify the Standard Model to be more realistic, they found out that the behavior of this particle conformed greatly to the theory. This would cause new technology to be developed to probe the subatomic universe in 2015 at higher energy scales to find even more particles.
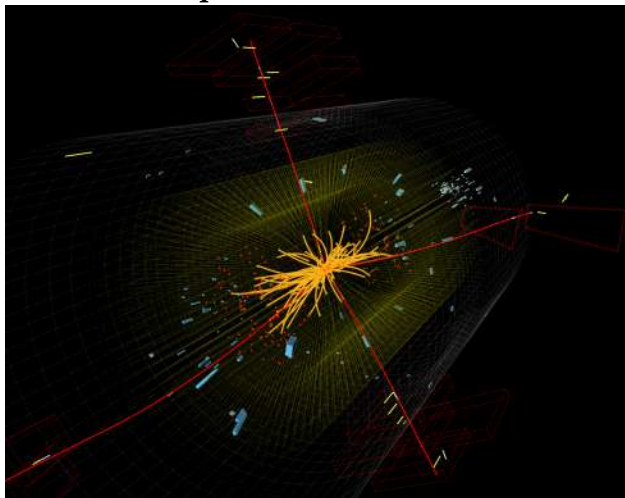
The Higgs boson is responisble for giving subatomic particles thier mass.

Image: CMS/ATLAS/CERN

August - NASA's rover lands on Mars

One of NASA's greatest Mars rovers, being one-ton, six-wheel-drive, and nuclear-powered, named *Curiosity* landed on Mars after an 8-month voyage. Anxiety was coursing through the veins of the members of the mission control as the rover went through "seven minutes of terror", where it had to use a special "sky crane" landing system to safely land on the soil from the atmosphere. The rover, after successfully landing, started to send pictures of valuable geographic data. It scanned layers of sedimentary rock to see if Mars could possibly support life in the future.

The Curiosity rover landed on Mars and began to send pictures back to Earth.

Image: Taylor, A. (2012, January 31). 2,000 Days on Mars With the Curiosity Rover.

October - Scientists Produce Mouse Babies From Stem Cells

At Kyoto University, Mitinori Saitou and his colleagues produced mature mouse eggs and sperm cells from stem cells, then used them to breed healthy mouse babies. The scientists used a well-established method to turn adult human blood cells into induced pluripotent stem (iPS) cells, which have the ability to be genetically reprogrammed to become any cell in the body. But the key, apparently, was putting the induced human pluripotent stem cells into miniature ovaries they created in the lab from mouse embryonic stem (ES) cells. First, they took ES and iPS cells and made immature egg precursor cells. Then they inserted those into clusters of ovary cells. Finally, the eggs were fertilized and implanted into rodent mothers. This procedure, however, has a success rate of a little less than 1%, and mostly produces mouse babies with chromosomal abnormalities. Only 75% of the offspring had the correct number of chromosomes. Overall, this procedure was very damaging but enlightening. In the future, this team, based in Japan, plans to take this to the human level and use human stem cells to create offspring. As of now, this procedure is too risky but as technology becomes more efficient, this is certainly possible.

2013

## January - Genome Editing with CRISPR-Cas 9

Feng Zhang, from the McGovern Institute for Brain Research at MIT, was able to upgrade the CRISPR-Cas9 to able to edit genomes in eukaryotic cells. Zhang and his team were able to cleave genomes in mice and human cells in targeted places. They were even able to engineer two Cas-9 orthologs (genes from different species evolved from a common ancestral gene) from the organisms S. thermophilus and S. pyogenes. This was very significant as it showed that the CRISPR technology could be programmed to target multiple genomics loci and used for homology-directed repair (a mechanism in cells to repair double-stranded DNA lesions).

March - Evidence That Mars Has Conditions Suitable for Life

The Mars Curiosity rover found evidence that Mars could have been home to microbes. Scientists analyzed a sedimentary rock sample that the Curiosity rover had collected from a steam bed in the Gale Crater. They identified several chemical elements in the sample, the most important of which were the essential elemental ingredients of life - carbon, oxygen, phosphorous, nitrogen, hydrogen, and sulfur. This answer gave scientists a long awaited answer: Mars CAN support life.

June - 3D Printing Microbatteries

Extremely tiny lithium-ion microbatteries were created by a team from Harvard University and the University of Illinois using a 3D printer. Though scientists had previously created miniaturized devices, none of them had been powered by tiny batteries. The team from Harvard was able to pack a lot of energy into such a tight space by creating stacks of ultrathin electrodes that they interlaced tightly. The team turned to the 3D printer to accomplish this, which they had to upgrade in many ways to accomplish this task. In doing so, not only did they create a revolutionary new battery, but also used 3D printing to create a battery for the first time.
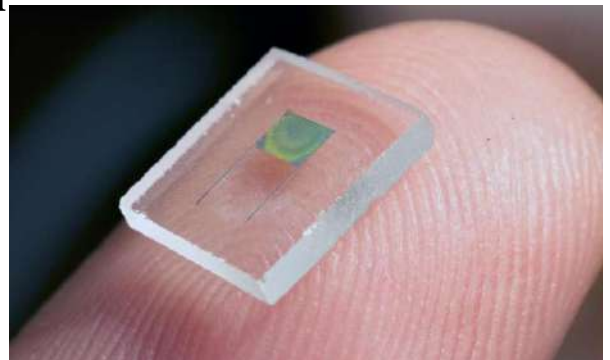
One of the tiny lithium-ion microbatteries made by a 3D printer.

Image: Ferber, D. (2013, June 18). Printing tiny batteries.

July - Naked Mole Rats are Resistant to Cancer

The naked mole rat has an unusually long lifespan of over 30 years. Not only this, but these rats are resistant to cancer! A team of researchers from the University of Rochester and the University of Haifa were able to crack the mystery of why this is so. They found a sugar secreted by the cells of the naked mole rat called high-molecular-mass Hyaluronan (HMM-HA). When secreted, HMM-HA is able to prevent overcrowding of cells, and prevent the formation of tumors. When HMM-HA was removed from the naked mole rats, their contact inhibition (suppression of cell growth by cell contact) mechanism no longer worked. Hyaluronan (HA) is a long sugar polymer that is naturally present in humans, and was used to treat arthritis and was used in skin products.

2014

August - Water from Earth Discovered to Not Be Originated From Comets

Arguably the greatest scientific discovery of the year, it was discovered that water present on Earth was not from comets. This information changed everything we thought we knew about the Earth. This was only attainable due to the landing of the Philae probe on the comet 67P/Churyumov-Gerasimenko. For a few months, its parent craft called Rosetta had been orbiting comets while taking samples of the water found. When researchers analyzed the water, they found how the chemical makeup significantly deviated from the water found on Earth. Thus, scientists now believe asteroids contribute immensely to the oceans on Earth.

September - India sends a mission to Mars

On its first attempt, India successfully sent a mission to Mars, which took considerably advanced knowledge and multiple attempts for the US, Russia, and Europe to achieve. Their $74 million craft, Mangalyaan, was sent to orbit Mars, a great feat for any Asian country. Due to the tremendous budget, the craft was attributed with five instruments which allowed it to measure levels of Martian methane and surface composition.

*India was able to launch a craft to measure Martian methane and surface composition.*

Image: Mars Orbiter Mission. (2014, February 19).

September - Chemists Produce Hydrogen Fuel From Water

September was also the month when chemists at Glasgow made a shocking breakthrough when they successfully attempted to produce hydrogen fuel from water. The team stored that gas in a carbon-free liquid that acts as a sponge to preserve its conditions. This would allow the gas to be produced cleanly, inexpensively, and at a rate of 30 times faster than any method currently in use. Since this gas could one day replace petroleum in the multitude of vehicles in use, these scientists have created a possible future in renewable energy that can sustain the earth.

October - Nuclear Fusion Advancements

Nuclear fusion, a great source for energy, is the production of energy when hydrogen nuclei collide, providing a clean and efficient method of producing energy. In October, a notable scientist stated that there were advancements made to this method of gathering energy where compact fusion reactors can be made to fit in a truck. This compact fusion reactor used "magnetic mirror confinement," which is an innovative way to control and manipulate the reaction. This allowed for the beginning of an ambitious goal to provide more efficient methods to power our lives, which will cause our perception of energy to be changed. It also sets up a future that is greener and cleaner and not dependent on nonrenewable energy.
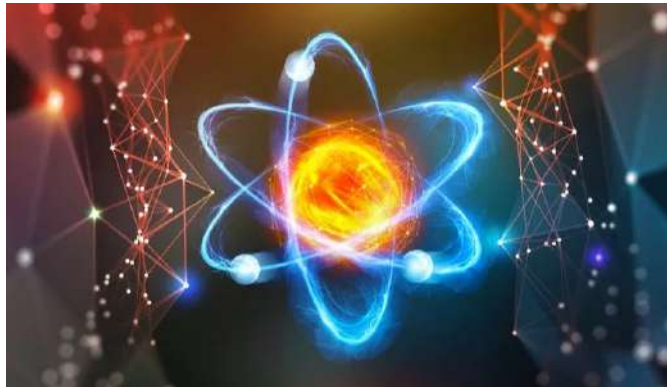
A new compact fusion reactor provides hope for a future that is greener and cleaner.

Image: Hutt, R., & Breene, K. (2014). Scientists just got closer to making nuclear fusion work.

December - Earth is not the only planetary object in our solar system with Oceans

It had been discovered that Earth is not the only planetary object in our solar system that has oceans. For several years, it was noted that Saturn's moon Enceladus might have had a type of liquid on its surface. This year, precisely following the orbit of NASA's Cassini probe, a group of astrophysicists finally established how instead of covering the whole moon, the ocean appeared to only cover the Southern Hemisphere. This is incredible as another planetary object that can sustain life in a manner to Earth exists allows us to experiment and creates a possibility of inhabiting it in the future.

2015

January - Semi-Finalists in the Intel Science Talent Search

Two Stuyvesant students, Daniel Charnis and Kai Pacheco, advanced to become semi-finalists in the Intel Science Talent Search (STS) on January 7, 2015. Daniel Charnis's project was titled "A Novel Methodology based on Hydrodynamic and Molecular Surface Dynamics for Predicting the Quaternary Structure of alpha-kinases: eEF2K Structure Prediction." In his project, he examines the structure of a protein overexpressed in cancer cells. Kai Pacheco's project was "The Automatic Detection and Therapy of Cardiac Arrhythmias Using a Simulated Cellular Automaton," which he created a simulation of Arrhythmias.

March - Turning Leukemia Cells into Macrophages

Scientists learned to turn leukemia cells into macrophages. By exposing B-cell acute lymphoblastic leukemia cells to proteins that bind to certain DNA sequences, the cells could transform into macrophages, immune cells that could help to further fight the cancer cells. This discovery was made when researchers were trying to keep leukemia cells they had collected alive in a culture dish by adding different substances. After adding several different items, the B-cell seemed to have turned into a macrophage.

June - Competitors of the International Science and Engineering Fair

Stuyvesant seniors, Anmolpreet Kandola and George Drimba competed at the International Science and Engineering Fair (ISEF). Anmolpreet Kandola won second place for the Grand Prize Award in Animal Sciences. His project was called "Computational Analysis of Neuronal Chromatin Structure and Nuclear PARP-1 and PAR Expression Provides Novel Marker for Detecting Learning Associated Changes in Mice."

September - Discovery of Water on Mars

Free-flowing water was discovered on Mars on September 28, 2015. Flowing salty streaks of water were found on the planet. There was a presence of hydrated salts (perchlorates), which are waterlogged molecules. The discovery of water was a breakthrough because it suggests that Mars may be able to support living organisms since water is essential to life. This could also lead the beginning of work to create life on the planet ourselves by establishing a human colony or other living things on Mars.

November - Detecting Cancer with a New Blood Test

Sweden had developed a blood test for early pancreatic cancer patients that can detect melanoma, lung cancer, and colon cancer and even identify what type of cancer is present. The test detected cancer accurately 96% of the time and identified it 71% of the time. The blood tests analyze the RNA in the blood platelets and observe if any abnormal changes could come from cancer tumors.

2016

February - Detection of Gravitational Waves

2016 started with a grand breakthrough. On February 11, scientists working at the Laser Interferometer-Gravitational-Wave Observatory (LIGO) at Louisiana announced the first-ever detection of gravitational waves. Gravitational waves, conceptualized by Albert Einstein in 1916, are ripples in spacetime, where everything in our universe takes place in. It's a combination of the three spatial dimensions and the dimension of time and can be thought of as like a suspended fabric: objects with mass, even small things like tennis balls, curve spacetime, similar to how balls placed on a suspended fabric create depressions in it.
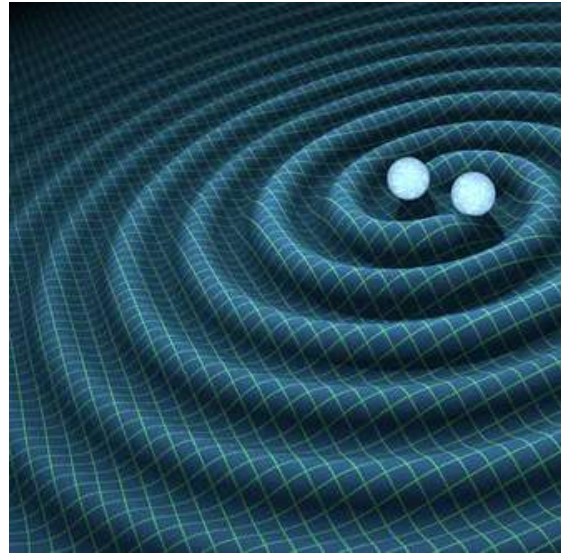
Gravitational waves were detected by scientists in Louisiana.

Image: Louisiana State University, & Lsu. (2016). Louisiana State University.

These curves are essentially what gravity is. Gravitational waves are ripples in the fabric traveling at the speed of light caused by the acceleration of masses. They're extremely weak, but this first detection was from the collision of black holes 1.3 billion light-years away. This had big implications: we're able to detect masses in the universe in a new way, which is extremely helpful, especially with black holes, which often don't have matter surrounding it as did the famous one in 2019.

March - AlphaGo programs defeats second best Go player in the world

On March 19, an AI (artificial intelligence) program, AlphaGo, defeated the second best Go player in the world. Go, a simple board game with origins in China more than 2,500 years ago, is extremely hard to master. Two players place their pieces (one with black stones, the other with white stones) on intersections of aboard. Essentially, the goal is to capture the other player's pieces by surrounding rows or columns of the other player's pieces on each of its two ends with their pieces. It sounds complicated on paper, but the game has a beautiful simplicity that brings with it crazy amounts of possibilities that even games like chess, with many more rules, don't have. This makes Go such a difficult game for AI programs to master. Using a learning algorithm that improves its skills over time, AlphaGo was able to defeat a master at the very game that had been regarded as the "Holy Grail" of AI. The victory showed the potential AI has, paving the way for even more complex tasks.

August - Discovery of planet orbiting the solar system's closest star

On 24 August, astronomers announced the discovery of a planet orbiting Proxima Centauri, the solar system's closest star. Astronomers found this planet using the radial-velocity method, where they look for slight movements planets induce on their stars. Proxima Centauri b is about the size of at least 1.3 Earths, and orbits within the Goldilocks zone of its star, meaning that liquid water can exist on its surface. However, it's victim to the violent bursts of energy from its star, so life on its surface is highly unlikely, although life may very well exist underground. Much more has to be learned about Proxima Centauri b, and with better technology, we may be able to get a look at a potentially habitable planet.
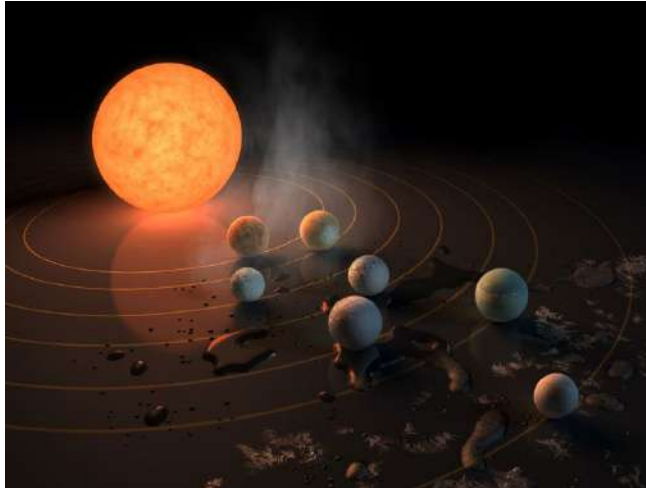
Proxima Centauri b was discovered and could potentially be a habitable planet.

Image: ESO, P. by. (2016, August 24). Potentially Habitable Planet Found Orbiting Star Closest to Sun.

October - CRISPR-Cas9 used to treat patients

On October 28, CRISPR-Cas9 was used to treat a patient, who had lung cancer, for the first time as part of a clinical trial in West China Hospital. CRISPR-Cas9 is a gene-editing tool that's based on a process that bacteria use to fight against viruses. With the Cas9 enzyme, which helps make precise cuts in DNA, we're able to modify people's genetic code, opening a whole new world of possibilities. Of course, this great power calls into question the ethics behind it, but the medical trial was ethically approved. A team of scientists, led by oncologist Lu You, took some of the patient's immune cells and deactivated a gene that produces proteins inhibiting immune response. Since its first use in China, CRISPR-Cas9 has gone through many more developments and challenges.

2017

March - Reusable Rockets- Rocketry's Future

SpaceX's Falcon 9 was successfully launched and landed through booster rocket descent. This is huge news, considering how much these rockets cost: Orbital class rockets (like Falcon 9) cost $60 million, but being able to reuse orbital class boosters (the most expensive part of a rocket), costs can be cut by up to 30 percent, or by $18 million in this case. As John Logsdon, a space policy expert at George Washington University, said, "Reusability has been the holy grail in access to space for a long, long time."

SpaceX 's Falcon 9 is a reusable rocket, which can save space companies millions of dollars per flight.

Image: Selding, P. B. de, & Selding, P. B. de. (2017, April 25). SpaceX's reusable Falcon 9: What are the real cost savings for customers?

April - LHS 1140b - Another Earth Candidate

LHS 1140b, a red planet classified as a "Super-Earth" rotating dwarf star LHS 1140 in the "Trappist-1 System" of the Goldilocks Region just 40 light-years away, is one of the most promising candidates for humanity's next home. It is speculated to have an atmosphere suitable for humans along with surface water.

April - External Wombs - A Potential Solution to Premature Birth

Inside what looks like a large Ziploc bag filled with fluid grows a baby lamb—but one that has not been born yet. Alan Flake, a surgeon at Children's Hospital of Philadelphia, and his team were at the head of this project, producing the first, uterus-like external womb. The goal is to provide babies that are born very prematurely in a familiar environment to develop in.

August - CRISPR in Human Embryos ; A Step Closer to Designer Babies

For the first time, several scientists across the globe in 2017 were able to effectively edit genes in human embryos through CRISPR-Cas 9. Everyone has heard of CRISPR, but for those that are not too familiar, it stands for clustered regularly interspaced short palindromic repeats and is a technique to edit genomic DNA, whether it be human or bacterial. Editing human embryos is another step in the continuing goal of scientists to be able to edit genes of humans before they are born to have desirable traits or to lack undesirable ones.

2018

February- SpaceX Launched A Falcon Heavy Test Flight

SpaceX attempted to launch a Falcon Heavy test flight, which was highly anticipated by people all across the world. The launch was successful, making the Falcon Heavy the most powerful rocket in operation. It can produce 5 million pounds-force (22MN) of thrust and is reusable. The rocket was able to reach sufficient velocity to escape Earth and enter an elliptical orbit around the sun, which passes the orbit of Mars. The objective of this flight was to accomplish these objectives: launch Falcon Heavy into the atmosphere and broadcast it to the rest of the world. It was the second most-watched live stream ever on YouTube with more than 2.3 million views.
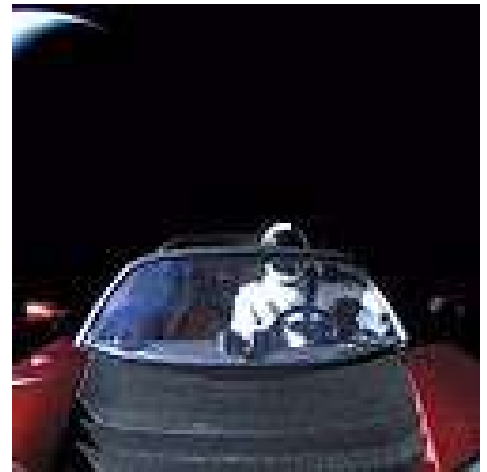

Photo taken during the live broadcast of the SpaceX launch

Image: O'Kane, S. (2018, December 22). SpaceX captured the Falcon 9 rocket's launch and landing in one photo.

March - Scientists Discover Key To Vascular Aging

In March, scientists at Harvard Medical School discovered a key mechanism behind vascular aging and muscle decline in mice. Their study showed that treating the animals with a chemical compound called NMN (Nicotinamide mononucleotide) enhances blood vessel growth and reduces cell death. This boosts the mice's stamina and endurance. This is very important, as the protein-coding regions between mice and humans are 85% identical, meaning the same compound could prolong human life. Further research is being conducted.

October - Astronomers Find Prove The Merging Of Stars

Astronomers reported that GRB 150101B, a gamma-ray burst event detected in 2015, might be directly related to the historic GW170817, a gravitational wave event detected in 2017 and associated with the merger of two neutron stars. The similarities between the two events, in terms of gamma-ray, optical, and x-ray emissions, as well as to the nature of the associated host galaxies, are "striking," suggesting the two separate events may both be the result of the merger of neutron stars, and both may be a kilonova. For example, a luminous flash of radioactive light produces elements like silver, gold, platinum, and uranium, which may be more common in the universe than previously understood, according to the researchers.

November - Scientists Discover Residual Cap On Mars

Scientists can find out more about the changes occurring at the South Pole of Mars. Remnants of a formerly more extensive deposit composed of a dry ice form known as the South Pole residual cap. It is known as residual because it is what is leftover from the much larger cap, which disappears each summer. As the frozen carbon dioxide turns into water, the pits of dry ice enlarge over time. This leads to the exposure of an underground surface below made out of water ice.

2019

April - Scientists Capture The Black Hole

Scientists were able to take an image of a black hole for the first time. Black holes devour light, so getting a picture is very impressive. Several observatories around the world collectively called the Event Horizon Telescope, zoomed in on a galaxy called M87 to get the picture.

June - Genes In Space Competition

At Stuyvesant, we had two honorable mentions in the Genes in Space competition. Aryan Ruparel, Aaron Contreras, Aryan Patel, and Lauren Mei worked as a group and proposed sending organoid cell cultures to space to test the effect of microgravity on Human Growth Hormone and the development of different organoids. Meanwhile, another honorable mention was won by Michael Chan, who proposed testing whether microgravity-induced muscular atrophy in astronauts is caused by the disruption of the function of a calcium channel on the sarcoplasmic reticulum, causing leakage of calcium from this major source of calcium in skeletal muscles.

Photo of the Black Hole Taken from the Event Horizon Telescope

Image: How Scientists Captured the First Image of a Black Hole - Teachable Moments. (2019, April 19).

August - Therapies For Ebola Are Developed

Two new therapies for Ebola were developed and found to have saved about 90% of the patients who were newly infected. The treatments are now offered to all patients in the Democratic Republic of Congo. Previously, Ebola, a hemorrhagic fever virus, had an aura of terror attached to it, as it was seen as incurable and very deadly. In July, the World Health Organization had declared a public health emergency, as it had infected about 2,800 known patients, killing more than 1,800 of them. The New York Times in an article entitled, "A Cure for Ebola? Two New Treatments Prove Highly Effective in Congo" wrote that "The new experimental treatments, known as REGN-EB3 and mAb-114, are both cocktails of monoclonal antibodies that are infused intravenously into the blood." This was a very promising development to a very dangerous and frightening malady.

September - Climate Change Affecting Coral Reefs

A report from the United Nations' Intergovernmental Panel on Climate Change (IPCC) was released and found that sea levels were projected to rise by three feet in the next eighty years. Warm-water coral reefs were expected to die out as a result of climate change and global warming. The authors of the report project that the higher sea levels would affect 680 million people who live in low-lying coastal zones, along with 65 million citizens of small island states. The loss of ocean life from high water levels will also lead to food security risks. In all, the report painted a worrisome picture of the future of Earth if climate change and global warming are not addressed.
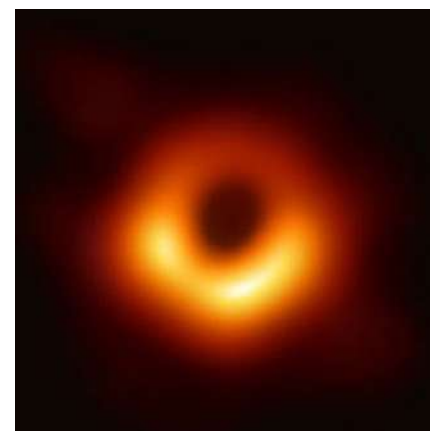
2019

2020

STUYVESANT
RESEARCH CLUB

345 Chambers Street

New York, NY 10282

stuyresearch.weebly.com