EXPLOYATIONS THE TEXAS A&M UNDERGRADUATE JOURNAL

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Cover Art courtesy of Bailey Jones '13

Bailey Jones is a senior Biochemistry and Genetics major from Houston, Texas. She is also pursuing a minor in chemistry. After graduation, Bailey intends to apply to pharmacy school. In her artwork, she hoped to portray the courage and wonder of discovery as well as the excitement of uncovering fascinating things that have been waiting to be found.

Cover Art inspired by: Finding New Subatomic Particles by Christopher Davis, found on p. 53

Understanding the nature of the universe is a huge undertaking that can be illuminated by finding and studying the tiniest of particles. Because of the rarity of these particles, such as the Higgs boson, mountains of data must be analyzed to find evidence of their existence. Our development of better methods of analysis will allow for cheaper and more effective ways to detect subatomic particles.

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Letters From Faculty

A century and a half after being founded as the land-grant institution for Texas, Texas A&M considers it an honor to provide access to affordable education and unbridled opportunity for anyone. Our ingenuity feeds a global appetite for innovation, resulting in more than \$700 million/year in research projects that create new knowledge and drive economies world-wide. Each year our students walk off our stage and into positions of leadership in industry, academia, health care, business and government; examples of our university mission of teaching, research and service.

Undergraduate students play a vital role in that mission, not just in classrooms but also in laboratories once the sole domain of graduate students and postdoctoral researchers. In the College of Science, our undergraduates are exposed to challenging research opportunities designed to enhance their academic experiences and better prepare them for advanced studies or careers in science. While exploring research first-hand, they also experience the exhilaration of discovery, often side-by-side with world-renowned faculty who are as dedicated to their students as to their own research.

As scientists, we recognize tomorrow's answers are by-products of today's questions — complex puzzles that require an increasingly interdisciplinary, multifaceted approach to ensure that critical breakthroughs rise to the forefront. We realize the key purpose of higher education is to produce two things: discoveries, but moreover, the people who make those discoveries.

We applaud our undergraduate researchers and the tangible global potential they represent. By all Aggie indications, the future of scientific discovery is in good hands.

Dr. H. Joseph Newton Dean, College of Science, Professor of Statistics Texas A&M University

Undergraduates at Texas A&M are fortunate to be studying at a university that is home to internationally known scholars and researchers. In all universities and colleges knowledge is transmitted from teacher to student. In research universities such as Texas A&M knowledge is also created. This allows Texas A&M to offer educational experiences that only a Tier One research university can provide.

As Dean of the College of Liberal Arts, the college that graduates the most undergraduates at Texas A&M, it is very important to me to promote a culture of research at every level. Research is not just for faculty members and PhD students. It is something that I think every undergraduate student should be thinking about.

There are many ways for each undergraduate to get involved in the research life of the university. Seek out courses that professors teach in their areas of research specialization, so that you can learn about a subject from someone who is shaping the development of that field. In Liberal Arts our Freshman Critical Thinking Seminars are designed to give students that opportunity right at the beginning of their study at A&M. And there are many other opportunities within each major. Students can also participate directly in faculty research – working in a lab, or collecting data, or running surveys. Such collaborations have led to joint publications and to presentations at conferences and symposia.

From my point of view as an educator, it's exciting to see what happens when students explore their own interests and projects as independent researchers with guidance from faculty members. The papers in this issue of Explorations are an inspiring illustration of what our students are capable of at Texas A&M. I hope that as you read them you will yourselves be inspired to follow in their footsteps and make your own contribution to the research culture of this Tier One university as we move towards the goal of a consensus top-10 public university by 2020.

José Luis Bermúdez Dean, College of Liberal Arts, Professor of Philosophy Texas A&M University

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Exploiting Return Patterns for Profit in the Stock Market

BETH KRAKOSKY

INTRODUCTION

The stock market attracts everyone from small individual investors to large hedge fund traders. Two major schools of thought have developed with respect to investing one based on the efficient market hypothesis and the other based on technical analysis.

Many economists, especially those in academia, accept the efficient market hypothesis, which says that asset markets are nearly instantaneously efficient. If stock markets are efficient, the stock market price history would not contain information about future returns, and short-run changes in stock prices would not be predictable from past prices. According to this theory, an investor (without inside information) could not consistently beat the market.

By contrast, technical analysis is the practice of trying to forecast future returns by studying historical movements of stock prices, stock market trading volume, and other historical asset market behavioral properties that can reveal predictable price patterns. Technical analysts believe that markets are not efficient, and these analysts attempt to exploit the inefficiencies through various trend indicators based on signals such as those arising from price and volume data. The existence of market inefficiencies has a variety of explanations, including a possible sluggishness of the price response to new information and the hypothesis that human emotional nature, such as optimism and pessimism, causes market prices to fluctuate.

These are but two of many potential explanations for market inefficiency, but regardless of the explanation, stock prices exhibit patterns that one can predict by using technical indicators from past data. To examine which method yields the highest returns, this article tests several different technical trading rules against the buy-and-hold method of investing. The methods used in this study cannot be guaranteed to give superior returns; however, the results do support investing strategies based on technical trading rules.

EXISTING LITERATURE

The evidence on the profitability of technical analy-

sis varies greatly among studies. Brock and colleaguest tested moving-average and trading range break strategies against several efficient-market theory models by using a bootstrap approach, which creates many "pseudohistories" of stock price data on which to test the trading rules. They found that returns during buy periods are larger and less volatile than returns during sell periods, where buy and sell periods are defined by various technical strategies. Their results support the profitability of a set of technical strategies. Kwon and Kish2 extended the Brock group's research, adding the consideration of indicators based on moving averages of trading volume. Kwon and Kish hypothesized that changes in trading volume and price are positively correlated, so including a volume indicator could help confirm a buy or sell signal. Their results show not only that these technical trading rules displayed higher profitability than a buy-and-hold strategy but also that the profit potential appeared to weaken over time, possibly due to technological innovation. Ready presents a different view, conjecturing that the apparent profitability of technical trading rules resulted from data snooping, which is 'the possibility that any satisfactory results obtained may simply be due to chance rather than to any merit inherent in the method yielding the results." (p44) He found support for this hypothesis and concluded that patterns in the historical data would not necessarily persist.

METHODS

This study 4 tests nine trading rules, comparing buyand-hold investing with technical trading based on indicators constructed from short- and long-term moving averages of price and moving averages of trading volume. In time series data, the moving average is a mean of a subset of values that 'moves forward' by dropping the oldest number in the subset and adding a more recent number. Then a new average is taken. This study uses the weekly closing price of the S&P 500 Index,5 including 54 years of data. I chose this series because it is widely used and is considered one of the best measures of the U.S. equities market, covering about 75% of them. I test the trading rules by applying the different technical indicators to the index.

The first strategy examined is the buy-and-hold meth-

od of investing, in which an investor 'buys the index' (the S&P 500 Index). This strategy assumes that the index is bought on the last day of the initial trading week and is held until the last day of the trading week at the end of the specified holding period, such as 1, 5, or 10 years, when it is sold at the closing price for that week.

The second strategy involves moving averages based on the index price. This strategy compares a shortrun moving average of price with a long-run moving average of price in order to generate buy and sell signals. If the short-run moving average (1, 5, or 10 weeks) of stock market closing price is above the long-run moving average (40 weeks), the investor will hold the index. If the short-run moving average is below the long-run moving average, the investor will hold cash, that is, treasury bills. (Here the 3-month T-bill rate is used as a cash equivalent.) While the investor holds 'cash,' he earns an interest rate equivalent to that of the 3-month T-Bill. This technical strategy allows the investor to stop overall losses by quickly exiting the equity market when prices fall.

The third strategy combines the price moving-average

indicators with a trading volume indicator. Because volume and the absolute value of price changes are positively correlated, the general rule is that a buy signal is generated when the moving average for both price and volume is rising and a sell signal is generated when the moving average for price is falling, regardless of the direction of trading volume. This strategy helps confirm the buy or sell signals that simple price moving-average strategies produce. Several variations of this strategy use different lengths for the shortand long-run moving averages of price, and different lengths for the short- and long-run moving averages of volume. This study uses 1-, 5-, 10-, and 40-week moving averages for price and 1-, 5-, and 10-week moving averages for volume.

Figure 1 shows buy and sell signals generated by a price moving-average rule in which the short-run moving average is 10 weeks and the long-run moving average is 40 weeks.

RESULTS

The price moving-average trading rules and the volume moving-average trading rules both exhibited higher annual returns across the 54-year sample period. The buy-and-hold strategy yielded an average annual return of 7.434%. The best-performing price moving-average strategy produced an average annual return of 9.917%, in which the short-run moving average was 1 week and the long-run moving average was 40 weeks. The trading rule that combined price and volume moving averages, in which the short-run moving averages were both 1 week and the long-run moving averages were both 10 weeks, generated an average annual return of





Figure 2: Comparison of level of wealth from different investing strategies

10.174%. Figure 2 shows the level of wealth comparing 1. the buy-and-hold strategy with the two top-performing trading rules: VMA P10V10 and 40WMA.

If an investor were to place \$10,000 in the market at the beginning of the sample period, this is the amount of money the investor would have earned: the buy-andhold strategy would be at a level of \$50,117.38; 40WMA, \$63,828.22; and VMA PIOV10, \$65,141.19. Figure 2 shows a continuing upward trend for technical investors during the late 2000s, whereas the level of wealth for the buy-and-hold investor is volatile and not upward trending. The technical trading rules limit the technical investor's exposure during 2007–2011, whereas the buyand-hold investor experiences the full effect of the financial crisis. This finding explains the widening gap in the level of wealth between technical trading and the buy-and-hold investing strategy during the late 2000s.

SUBPERIOD RESULTS

This section compares how different investors would fare during four different 10-year holding periods: 1970– 1979, 1980–1989, 1990–1999, and 2000–2009. The top-performing technical trading rule was the VMA P10V10. To observe how the methods compare in different market conditions, I compare the performance of this rule with the buy-and-hold strategy over the four different holding periods.

- Technical trading outperforms buy and hold from 1/5/1970 to 12/31/1979. Buy-and-hold average annual return, 2.63%; VMA P10V10 average annual return, 12.69%. The 1970s was a bear market for the stock market because of events such as the oil crisis and the Watergate scandal. Investors who stayed in the market did not see returns as high as technical investors, avoided some of the unstable market conditions. Technical trading became more popular.
- 2. Buy and hold outperforms technical trading from 1/7/1980 to 12/26/1989. Buy-and-hold average annual return, 13.69%. The 1980s saw a recovery from the market hardships of the previous decade. This bull market under President Reagan's administration allowed the buy-and-hold investor to see profitable returns and an upward-trending level of wealth. This period was also successful for the technical investor, but the buy-and-hold strategy did slightly outperform the trading rule. Technical traders who sold during this time missed portions of rising returns during the 1980s.
- 3. Buy and hold outperforms technical trading from 1/2/1990 to 12/27/1999. Buy-and-hold average annual return, 15.05%; VMA PIOVIO average annual return, 12.71%. The 1990s was a period of soaring prices as dot-com companies expanded their investor base and saw unprecedented growth. Day trading be-

came more popular, but the explosive growth in the market allowed the buy-and-hold investor to realize higher returns than the technical trader. Following buy and sell signals caused the technical investor to fail to see critical times of rising market prices.

4. Technical trading outperforms buy and hold from

1/3/2000 to 12/28/2009. Buy-and-hold average annual return, -0.725%; VMA PI0V10 average annual return, 867%. This decade was a discouraging time for investors, with the dot-com bubble burst beginning in 2000 and the housing bubble collapse and financial crisis beginning in 2007. Buy-and-hold investors felt the full force of the falling prices and ended the decade with a negative overall return. Technical traders benefited from following buy and sell signals; these traders were out of the market and earning T-bill returns rather than the negative returns of the stock market.

Comparing returns of buy-and-hold investing with a technical trading rule over the last 40 years reveals that the technical trader beat buy and hold in only two of the four decades examined. However, the average annual returns reveal an interesting insight: the success of technical analysis is more prominent when the index is significantly declining. The technical trading rule returned substantially higher gains during these periods than did buy-and-hold investing. Buy and hold outperformed the technical trading rule during strong bull markets, but this outperformance was relatively small. These results make it evident that using trading rules improves returns in bad markets to a great extent and does not negatively affect returns much during good markets. The success of the technical trading rule in protecting the investor during market declines is evidence of the value of using technical analysis as an investing strategy.

CONCLUSION

This article explores several variations of moving-average trading rules to test the premise of technical analysis versus the efficient-market hypothesis. Using a simple trading process to generate buy and sell signals, the trading rules substantially outperformed the buy-and-hold method of investing,

The methods used in this study cannot be guaranteed to give superior returns into the future, and the better results in the first subperiod may suggest the diminishing success of these trading rules over time. However, the results do suggest that persistent, underlying patterns exist in the market that allow technical analysis strategies to generate excess returns. Inspect-

"...persistent, underlying patterns exist in the market that allow technical analysis strategies to generate excess returns." ing the trading rules under transaction costs further validates the success of technical analysis.⁶ Even with conservatively high transaction penalties to accounts for possibly more expensive trades in the early years of the sample period, all the trading rules tested still outperformed the buy-and-hold strategy.

My findings are consistent with those in the recent literature on

technical trading rules. The persistence of excess returns over time generated by trading rules implies that discounting the usefulness of technical analysis under the premise of the efficient-market theory is becoming more difficult. The theoretical battle between the efficient-market theory and technical analysis is far from over, because this article does not prove the ability of trading rules to forecast future prices from past prices. However this research, along with other recent studies7–9 of technical analysis, is consistent with the ability of trading rules to predict stock returns.

REFERENCES

- 1. Brock W, Lakonishock J, LeBaron B. Simple technical trading rules and the stochastic properties of stock returns. Journal of Finance 1992;47:1731-1764.
- 2. Ki-Yeol K, Kish RJ. A comparative study of technical trading strategies and return predictability. An extension of Brock, Lakonishock, and LeBaron using NYSE and NASDAQ indices. Quarterly Review of Economics and Finance 2002;42:611-631.
- 3. Ready MJ. Profits from technical trading rules. Financial Management 2002 (Autumn):43-61.
- 4. Krakosky B. An evaluation of the performance of moving average and trading volume technical indicators in the U.S. equity market. Texas A&M University EUROP Scholars Program 2011-2012, 1-38.
- 5. Yahoo! Finance (2011, Sept. 9). 'S&P 500 Index historical prices.' Available from http://finance.yahoo. com/.
- 6. FRED Economic Data (2011). '3-month Treasury bill: Secondary market rate.' Economic Research: Federal Reserve Bank of St. Louis. Available from http:// research.stlouisfed.org/fred2/series/.
- Nam K, Pyun CS, Avard S. Asymmetric reverting behavior of short-horizon stock returns: An evidence of stock market overreaction. Journal of Banking and Finance 2001;25:807–824.
- 8. Nam K, Washer K, Chu QC. Asymmetric return dynamics and technical trading strategies. Journal of Banking and Finance 2005;29:391-418.
- 9. Sarantis N. Nonlinearities, cyclical behavior, and predictability in stock markets: International evidence. International Journal of Forecasting 2001;17:459-482.

Using a Worm to Understand the Human Brain

In this study, we take advantage of the simplicity of the nematode worm, Caenorhabditis elegans (Figure 1), to understand sex-specific development of the nervous system. Factors called DM domain proteins control this development in worms but are also present in humans. Thus, we can apply what we learn from our research with the worm to better understand how sex-specific development of the human brain happens and how sex bias in neurological disorders might occur.

In humans and many other animal species, males and females exhibit different behaviors. These behavioral differences between the sexes are thought to stem from differences in brain wiring that are established during development. The causes of these wiring differences in the human brain and nervous system are not well understood. An important question about brain development in each sex arises when researchers consider that many neurological disorders exhibit sex bias; that is, they occur more in one sex than in the other. Human neurological disorders, such as schizophrenia, autism, and attention deficit-hyperactivity disorder, exhibit a sex bias in their occurrence. Autism, for example, is four times more prevalent in males than in females. The causes of these sex biases are almost completely unknown. Many of these neurological disorders are associated with an imbalance of certain neurotransmitters, chemicals that neurons, or

MEAGAN SIEHR

nerve cells, in the brain release to communicate with each other. Because these disorders occur more in one sex and are the result of neurotransmitter imbalances, we can speculate that abnormal brain development of a particular sex is a possible cause of neurotransmitter imbalance. However, the human brain is complex, making it difficult to investigate these disorders in humans. Therefore, scientists often rely on animals with simple nervous systems, such as C. elegans, to better understand the underlying problems that cause human disorders.

C. ELEGANS AS A MODEL FOR THE HUMAN BRAIN

The C. elegans nematode is a small, transparent worm with a body length of about 1 mm. The C. elegans worm has two sexes, males and hermaphrodites (females that can produce a limited amount of their own sperm for reproduction). As in humans, a worm's sex chromosomes determine its sex: hermaphrodites inherit two X chromosomes and males inherit only one (whereas in humans, females inherit XX and males inherit XY chromosomes). Signals from these sex chromosomes set off a chain reaction that tells the animal's body to develop as male or female. As with human male and female nervous system development, the development of each sex in the worm causes differences in neuron



Figure 1: The male C. elegans worm wiring and allows for different behaviors.

We focused on the development of the male worm for several reasons. First, he displays a mating behavior unique to the male. A group of male-specific neurons in the tail guide this behavior as he uses them to sense the hermaphrodite during mating. The mating behavior of the male worm is the output of the sensory neurons that make up a sensory 'circuit' in the male's tail. These sensory neurons in the male's tail function the same way sensory neurons in humans do; the neurons perceive touch, taste, and smell. Also, these neurons produce specific neurotransmitters, chemicals important for controlling mating behavior. To understand how these neurons in the male develop, how they produce specific neurotransmitters, and how they induce mating behavior, we need to investigate the biological factors in the worm that control these processes. The biological factors that we study in our research are called DM domain proteins.

DM DOMAIN PROTEINS

MALE DEVELOPMENT

In many animal species, including worms, DM (doublesex/MAB-3) domain proteins guide sex-specific development¹² These proteins are also present in humans, so we assume that they function in humans in the same way as they do in worms. These proteins activate in response to signals from the sex chromosomes. In male worms, these proteins guide the male's development by regulating the activity of other proteins. Specifically, the activity of DM domain protein and the other proteins that it regulates ensures that the male body contains the right number of cells with the appropriate characteristics in the appropriate part of the body. For example, DM domain proteins guide neurons in the male tail to produce the correct neurotransmitters. Generally, we know that DM domain proteins help males develop as males, but we want to know what specific characteristics they control. We can determine what these proteins do by disrupting the worm genes that produce them. By observing what is abnormal in male worms that lack these

proteins, we can understand what these proteins do normally in the male and, more important, what these proteins might do in humans.

NEUROTRANSMITERS

Neurons in the tail of the male worm are needed to sense his mating partner and coordinate the male's body during mating. These neurons also release neurotransmitters to communicate with other neurons and cells. In general, each neuron in the tail releases either acetylcholine or dopamine. These two neurotransmitters are prevalent in neurons of the human brain as well. The patterns of which neurons produce which neurotransmitter in the male's tail are important, especially in behavior. As with the worm, the patterns of which neurotransmitters are produced in the brain are essential for proper brain function in humans.

When we remove DM domain proteins in a male worm, virtually all the neurons in the male's tail now produce dopamine. This finding indicates that DM domain proteins regulate which neurons produce which neurotransmitter. This observation prompted us to ask us how DM domain proteins tell these sensory neurons to produce certain neurotransmitters and what other factors these proteins might interact with to do this.

INTERACTION WITH ANOTHER PROTEIN

We speculated that a second protein, called AST-1, might influence which neurotransmitters are produced in the neurons of the male's tail. AST-1 affects neurotransmitter patterns,³ so we wanted to investigate whether AST-1 was needed in the neurons of the male's tail. Like the DM domain protein, AST-1 is also found in humans and regulates other proteins to produce its desired effect.³ As in our previous analysis with DM domain proteins, we disrupted the AST-1 proteins in males and found abnormal patterns of neurotransmitters in the tail neurons. Therefore, we know that this second protein is also important in aiding production of the correct neurotransmitter in the correct neuron in the tail.

"When we remove DM domain proteins in a male worm, virtually all the neurons in the male's tail now produce dopamine. This finding indicates that DM domain proteins regulate which neurons produce which neurotransmitter."

Through further analysis, we found that DM domain proteins actually interact with AST-1 to stipulate which neurons in the tail produce the neurotransmitter dopamine and which do not. Because we know that the interaction between these two proteins is crucial in establishing patterns of dopamine and that these two proteins are found in humans, we suspect that they have a similar function in the human brain.

NEURAL CIRCUITS NECESSARY FOR MALE BEHAVIOR

The male mating behavior is an output of the sensory neurons in the male's tail. When these neurons in the male tail make contact with a hermaphrodite's body, they release neurotransmitters to other neurons and cells, such as muscle cells. When the muscle cells in the male's body receive signals from the tail neurons, they make the movements that constitute mating behavior. DM domain proteins regulate characteristics of sensory neurons in the tail, but how

do these neuron characteristics affect the signal and the corresponding behavior? We also wanted to know whether neurotransmitter imbalance in these neurons affects male behavior, and if so, how.

To answer these questions, we observed the mating behavior of males that lack DM domain proteins. We expected that male behavior would be abnormal, considering that the neurons that control this behavior are abnormal. Behavior was indeed abnormal in males that lack DM domain proteins. Males that lack the proteins are insensitive to contact with the hermaphrodite's body. Such males cannot make the proper mating movements with their bodies.

These observations indicate several conclusions: First, for proper male behavior, sensory neurons must produce the correct neurotransmitters. Second, DM domain proteins are necessary to relay signals from the sensory neurons to initiate and guide male mating behavior. As in male worms, the DM domain proteins in humans could be involved in neural circuits necessary for sex-specific behaviors.

CONCLUSION

Two biological factors, DM domain proteins and AST-1 proteins, are vital for the development of the male worm and the male's sensory system used in mating. DM domain proteins ensure proper development of these sensory neurons in the male worm's tail as they guide these neurons to produce the correct neurotransmitters. To achieve this result, DM domain proteins interact with another protein, AST-1, to establish the correct patterns of dopamine in these tail neurons. When male worms lack DM domain proteins, male behavior is highly abnormal because of neurotransmitter imbalance.

Many aspects of our research with C. elegans relate to the human brain, nervous system, and neurological diseases. In male worms, DM domain proteins function primarily to establish neuron characteristics. Thus, if a human had a dysfunctional DM domain protein, we

"Thus, if a human had a dysfunctional DM domain protein, we would expect symptoms of neurological disorders to arise only in one sex. This phenomenon could explain the sex biases that occur in many neurological disorders."

would expect symptoms of neurological disorders to arise only in one sex. This phenomenon could explain the sex biases that occur in many neurological disorders.

The human genome encodes both DM domain and AST-1 proteins; thus, they may direct which neurons produce dopamine in the human brain in the same way that they do in male worms. In humans, research has not fully determined how dopamine-producing neurons in the brain are established. Dopamine is necessary for many aspects of human behavior, such as mood, attention, and

movement. Research has linked dopamine imbalances in the brain to several disorders, many of which exhibit sex bias. Thus, current research is investigating how dopamine-producing neurons are established in the brain and elsewhere. Parkinson's disease drives much of this research because the disease involves the loss of neurons that produce dopamine. If we can understand what guides neurons in the brain to produce dopamine, we can better understand the causes of Parkinson's disease and theorize methods for how we might cure it.

By studying how DM domain and AST-1 proteins establish sensory neurons in male C. elegans, we can understand how human male-female brain development takes place and how abnormalities in these proteins could lead to neurological disorders. Indeed, we are using a worm to understand the development of the human brain.

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REFERENCES

- 1. Burtis K, Coschigano K, Baker B, et al. The doublesex proteins of Drosophila melanogaster bind directly to a sex-specific yolk protein gene enhancer. EMBO Journal 1991;10:2555–2582.
- Raymond CS, Shamu CE, Shen MM, et al. Evidence for evolutionary conservation of sex-determining genes. Nature 1998;391:691–695.
- 3. Flames N, Hobert O. Gene regulatory logic of dopamine neuron differentiation. Nature 2009;458:885– 889.

Caffeine's Effect on Creative Production



MARK MIMS & ROBERT WOODWARD

INTRODUCTION

More and more today, the world emphasizes creativity. From corporate executives to college students, creativity is a highly sought after characteristic. Creativity is an elusive trait, and although some are more inclined to it than others, practice and exercises in creative thinking can improve creative performance. This study explores other ways to enhance or inhibit creative thought, specifically caffeine.

PREVIOUS STUDIES

Although researchers have observed the different traits and life experiences that influence creative thought, little research has focused on some of the more organic factors that may affect creativity-specifically, research related to the consumption of substances (of the controlled and uncontrolled variety). As Plucker and Dana pointed out, 'empirical investigations on the impact of common use drugs on creativity are limited'; they also noted that research on less threatening drugs (such as caffeine) are "almost nonexistent." (p607,611) Of those studies that have involved creativity and transient factors, many have largely examined the link between alcohol and creativity. Alcohol, a central nervous system depressant, has been said to aid many people, such as authors and painters, in their creative works. According to one hypothesis, a decrease in our real or perceived inhibitions will lead to more creative thinking.² This idea is similar to Freud's approach of achieving primary processing by using alcohol to suppress secondary processing. Results of experiments studying a link between alcohol and creativity have shown various results. However, a study using the Torrance Tests of Creative Thinking, both figural and verbal portions, showed that although consuming alcohol did not statistically significantly change scores, the perception of having consumed alcohol did statistically significantly increase creativity test scores.³ Using caf-

feine, a central nervous system stimulant, this study will explore the opposite effect.

CAFFIENE'S ROLE

Caffeine is among the most widely used psychoactive drugs in the United States, with the average adult consuming an estimated 170–300 mg daily. Among the most prevalent routes of caffeine consumption are soft drinks, coffee, chocolate foods and drinks, and tea.⁴

The physiological effects of caffeine range from changes in movement and behavior to changes in how the brain works. Most relevant to this study is caffeine's role as an adenosine receptor antagonist and its effect on dopamine transmission. Caffeine inhibits an important pathway in our brain that normally decreases activity in the cortex (associated with creativity). Also, as a result of this inhibition, caffeine increases dopamine transmission, allowing increased neuronal activity.⁵⁶ As a whole, these interactions increase the activity in the cortex in two different ways.

CREATIVITY AND CORTICAL ACTIVITY

The aspect of cortical activity, or 'arousal,' as it relates to creativity, has been substantially studied from many different approaches and angles. Early studies related to cortical arousal led to more specific research relating to whether an 'optimal' level of arousal for creativity exists.⁷⁸ Evidence comes in many forms, most of which directly relate to and emphasize lower-level 'resting' states of consciousness and their link to creativity.

Martindale and Hines used an electroencephalogram, a device to measure brain activity, to link cortical arousal and creativity. Their results showed that, compared with low- or medium-creativity cohorts, highly creative individuals showed the lowest level of cortical arousal when taking a creativity test.⁹ In contrast, all three groups showed high levels of arousal during a standard intelligence test, thus linking lower levels of cortical arousal to higher levels of creativity. Therefore, the experimenters hypothesized that caffeine, which increases cortical activity, will decrease ability to think creatively.

METHODS

PARTICIPANTS

The study was performed as a randomized, single-blind, placebocontrolled experiment. Participants for this study included college-aged (18-24 years) students from Texas A&M University who were enrolled in an educational psychology class. The experiment was held on a Saturday morning in a room selected to minimize distractions.

INSTRUMENTATION

The test used the 2006 version of the Torrance Test of Creative Thinking-figural portion. This test is the most common and reliable measure of creativity.² The test is scored in five norm-referenced and 13 criterion-referenced categories. Of the five norm-referenced categories, fluency (the quantity of ideas produced), originality (the production of unique or uncommon ideas), and elaboration (the amount of detail in an idea) parallel most with accepted ideas of what defines creative thinking. The remaining two, abstractness of titles (unique titles given to pic"Creativity is an elusive trait, and although some are more inclined to it than others, practice and exercises in creative thinking can improve creative performance." tures) and resistance to premature closure (the ability to keep an open mind), were more recently added to the scoring guidelines to provide a more comprehensive score. The 13 criterion-referenced categories, such as humor or richness of imagery, represent characteristics believed to affect creative thought.¹⁰

PROCEDURE

We asked participants to abstain from caffeine for the 24-hour period preceding the study in hopes of clearing at least 75% of the dietary caffeine stored in the body.

When testing began, subjects took the Figural Form A version of the test to establish a baseline creativity score (pretreatment). After the pretreatment test, participants received a piece of unlabeled gum randomly assigned to them according to their experimental number and began chewing. The gum received was, for the treatment group, a piece of Stay Alert spearmint gum containing 100 mg of caffeine (approximately equivalent to that of a large cup of coffeell). The control group received a placebo: a similar-tasting, but noncaffeinated, piece of gum. We chose this level of caffeine for Stay Alert chewing gum because previous clinical testing had used the same level. In accordance with previous studies, we asked subjects to chew the gum for 10 minutes and then allowed 1 hour for the maximum effect of the caffeine to manifest¹²

After the end of the hour, participants completed the Figural Form





Figure 2: Posttreatment means between treatment groups.

B version of the test to obtain posttreatment data. To increase score reliability, the same experimenter scored both tests. We statistically analyzed these data to determine whether a correlation between caffeine intake and creativity exists. We used paired-sample ttests and analysis of variance (ANOVA) to determine statistical significance. We then analyzed test data with regard to the personal information collected from all participants. Results

DESCRIPTIVES

The study consisted of 88 participants. Most reported regular caffeine consumption, with a preference for coffee or sodas. Most participants reported consuming caffeine one to two times per day and reported having consumed caffeine regularly for at least 1 year. Using the caffeine content listed in the 2009 USDA Nutrient Database for Standard Reference, we determined that the average participant consumed anywhere from 35 to 160 mg of caffeine daily.¹³ This finding confirms that the caffeine content in the experimental group was within the reference range of caffeine consumption for most participants. Also, negative side effects and the development of tolerance to effects of caffeine occur after regular consumption of 200 mg or more daily.¹⁴ Most participants reported consuming 100-150 mg of caffeine per day, and thus we could discount the effect of caffeine tolerance as a variable in our analysis.

ANALYSIS

First we asked whether creativity scores increased between the pretest and the posttest. Statistical analysis (Figure 1) shows that total scores and individual scores for fluency increased from pretest (Form A) to posttest (Form B). The score for elaboration dropped slightly.

Are these differences in pre- and posttest findings meaningful? Could caffeine account for this difference? Given the complexity of the data, we used ANOVA to evaluate our data. The ANOVA results also showed a

significant difference in the pre- and posttest scores for total score and fluency for our subjects. The difference in scores for elaboration was negligible.

Because statistically significant differences exist in pre- and posttest scores, are those differences due to caffeine? We separated scores according to whether the subjects had been given the caffeinated or placebo gum, and then we asked whether their pre- versus posttest scores were statistically significantly different. Figure 2 shows the results of this analysis.

CONCLUSION

Our results showed that caffeine affects creative thinking. We found no difference in the pretest scores of the caffeinated versus noncaffeinated group. But after both groups received their gum, their total posttest scores as well as their scores for fluency increased, whereas their scores for elaboration had decreased (Figure 1).

When we further analyzed the posttest scores, the total score, fluency, and originality scores of the caffeinated group all showed a significant drop compared with the noncaffeinated group. Elaboration did not show any significant difference between the two groups. These results show that caffeine may have an overall detrimental effect on short-term creative thinking.

Several possible explanations could account for the changes in test scores, one being item-specific practice. In this scenario, subjects exposed to a repeated procedure, or test, tend to develop better test-taking strategies on later tests. However, using different test forms can mitigate the effect of repeated testing, as this test did by using Form A and Form B.¹⁵

Another explanation may be the novelty effect, in which a subjects will produce their strongest response to a stimulus the first time they encounter it.16 In this study, the novelty effect would artificially inflate the pretest scores. This effect may account for some of the decreases in the posttest; however, it would not account for the significance of the scores between the caffeinated and noncaffeinated groups.

Fatigue from the testing procedure may also have caused lower posttest scores, although like the novelty effect, fatigue probably would not account for the difference in scores between the groups.

A final factor that must be considered is caffeine consumption. Although caffeine may explain the pre- and posttest mean difference between total, fluency, and elaboration scores, a highly significant difference exists between the caffeinated and noncaffeinated total, fluency, and originality scores on the posttest. This finding may show that caffeine overstimulates the brain, inhibiting the ability to generate creative ideas. Fluency is an important component of creative thinking for its ability to generate ideas, and originality is important for generating new ideas. Knowing that a negative correlation among originality, fluency, and caffeine consumption might exist would benefit those who must think creatively.

Although all components tested did not reach statistical significance, the statistical analysis of differences in these scores suggests a strong link between caffeine consumption and a decrease in short-term creative thinking ability. These results may have important implications, considering the increasing popularity of caffeinated drinks and the value of creative thinking in real-world situations. Further research with a larger sample population and perhaps a revised testing procedure may be able to better determine the extent of caffeine's interference on both short- and long-term creative thinking.

REFERENCES

- 1. Plucker J, Dana RQ. "Drugs and creativity." In Encyclopedia of Creativity, edited by M.A. Runco and S. Pritzker, pp. 607–611. San Diego, CA: Academic Press, 1999.
- 2. Davis GA. Creativity Is Forever. Dubuque, IA: Kendall/Hunt, 2004.
- 3. Lang AR, Verret LD, Watt C. Drinking and creativity: Objective and subjective effects. Addictive Behaviors 1985;9:395-399.
- 4. Barone J, Roberts H. Caffeine consumption. Food Chemistry Toxicology 1996;34:119-129.
- 5. Fredholm BB, Battig K, Holmen J, et al. Actions of caffeine in the brain with special reference to factors that contribute to its widespread use. Pharmacological Review 1999;51:83–133.
- Lazarus M, Shen H, Cherasse Y, et al. Arousal effects of caffeine depend on adenosine A2A receptors in the shell of the nucleus accumbens. Journal of Neuroscience 2011;31:10067–10075.
- 7. Duffy E. Activation and Behavior. New York: Wiley, 1962.
- 8. Hebb DO. Drives and the C.N.S. (conceptual nervous

system). Psychological Reviews 1955;62:243-253.

- 9. Martindale C, Hines D. Creativity and cortical activation during creative, intellectual, and EEG feedback tasks. Biological Psychology 1975;3:71-80.
- 10. Ball OE, Safter HT, Torrance EP. Streamlined scoring guide for figural forms A and B. Bensenville, IL: Scholastic Testing Service, 2008.
- Chawla J. "Neurologic effects of caffeine." 2006. Available from http://www.emedicine.com/neuro/ topic666.htm.
- 12. Kamimori GH, Karyekar CS, Otterstetter R, et al. The rate of absorption and relative bioavailability of caffeine administered in chewing gum versus capsules to normal healthy volunteers. International Journal of Pharmaceutics 2002;234:159-167.
- 13. U.S. Department of Agriculture, Agricultural Research Service. USDA National Nutrient Database for Standard Reference, release 22. 2009. Available from http://www.ars.usda.gov/services/docs. htm?docid=20960.
- 14. Johns Hopkins Bayview Medical Center. 'Information about caffeine dependence.' 2003. Available from http://www.caffeinedependence.org/caffeine_dependence.html.
- 15. Benedict RH, Zgaljardic DJ. Practice effects during repeated administrations of memory tests with and without alternate forms. Journal of Clinical Experimental Neuropsychology 1998;23:339-352.
- 16. Cosini R. The Dictionary of Psychology. Florence, KY: Psychology Press, 1999.

Impact of Rising Sea Levels on Indigenous Lands

INTRODUCTION

Indigenous culture is an integral part of our continent's history and present reality, though it is now limited to small pockets of land in both North America and Canada. Native-owned lands and reservations provide sustenance, significance, and a home for many people, as well as contain our oldest cultural landmarks. We could lose both the people living on these lands and countless cultural sites if we do not protect them. We must conserve these lands to preserve an important part of our history and modern life.

Climate change is a controversial topic in public discourse, though scientists have no doubt that the current carbon dioxide concentration in the atmosphere is greater than any range we have record of in the last 650,000 years.¹ Tidal stations along the coast have recorded rising sea levels. These stations can help determine both historical and current trends in sea level rise. Climate change and sea level rise will greatly affect indigenous populations and tribal lands in both the United States and Canada. Many indigenous lands are located near the coastline and will thus be threatened with sea level rise as a result of climate change. Scientists do not yet fully understand where or how these



threats will affect these typically rural, socioeconomically disadvantaged communities.

Many possible approaches could address the problems that climate change and sea level rise present. One of our most important goals should be to better understand where the greatest potential impacts may be. Until we understand what we are up against, we cannot adapt to, or mitigate, the impacts. In this study, we used a geographic information system (GIS)—essentially a computer mapping program—to analyze geospatial data. After establishing a list of criteria with the GIS software, we determined the top 10 most atrisk lands.

METHODS

Using GIS, we analyzed sea level rise and its effect on coastal tribal lands. GIS allows us to ask where geographic locations are that have relevant features. We can take many spatial and nonspatial data and combine them into one database for easier study. We processed our data at Texas A&M University's Spatial Sciences Laboratory by using a computer, GIS software, and information from public Internet sources. First we acquired and imported relevant data files. Each data file was considered a layer, each visible in conjunction with other layers. For this project, we used layers that showed us the boundaries of the United States and Canada, the location of all indigenous lands, the location of different sea level rise stations, and the distribution of artificial light throughout the continent. Using GIS, we combined these layers for simultaneous analysis.

We used the following criteria to narrow down the most at-risk tracts of land: historical maximum sea level rise rate, distance to the coast, total area of the affected land, human population on the land, and elevation. We defined any sea level rise over 4 mm per year to be 'significantly detrimental.' Although this quantity sounds small, flat, low-slope coastlines with values exceeding this rate will suffer much land loss. For example, most of the Louisiana coast, with a sea level rise of approximately 10 mm per year and a slope of about 1:100,000, erodes landward about a half-mile every year.

Figure 1: Sea level rise risk and selected lands in North America and Canada.

	Sea Level Rise Rate			
Rank	Name and Location	(mm/yr)	Area (km²)	
1	Northwest Territories	4-31	59,270.94	
2	Louisiana	9-13	1,595.73	
3	North Carolina	4-8	94.24	
4	Alaska			
	(multiple tribes)	4-9	71.48	
5	British Columbia	4-18	10.18	
6	Maine	4-8	2.93	
7	Louisiana	9-13	1.84	
8	British Columbia	4-8	1.637	
9	California	5-9	0.34	
10	Oregon	4-8	0.03	

Table 1: Top Ten most at-risk indigenous lands in North America and Canada

To come up with the top 10 most at-risk lands, we had to narrow down our data sets. The indigenous lands were distributed across North America, so we used GIS to create a new layer that included only lands near the coast. This approach substantially decreased the number of lands and allowed us to focus on areas that sea level rise could affect. Then we combined the new coastal indigenous lands data with the sea level rise layer. We wanted to see the estimated sea level rise for each tract of land, and by combining data we could see how much sea level rise might occur in each area. Once we combined the coastal indigenous lands and sea level rise data, we narrowed down the areas of land to only those that had a historical maximum sea level rise of at least 4 mm.

With the information of which lands were near the coast and had a specified sea level rise rate, we chose 10 areas that are most at risk. We gave priority to lands with a greater area, lands with a higher concentration of lights, and lands not located on a hill or cliff. We used GIS to calculate the total area of each tract of land. We estimated population on the land from a NASA data file. This file showed us the distribution of light on Earth's surface and allowed us to determine whether an area of land was inhabited. We used elevation as a criterion: if a piece of land was located on a cliff or on elevated land, we would have no reason to include it in this study because sea level rise would not affect such land. After using all these factors to narrow down our results, we formulated our list of the most at-risk areas. CONCLUSION

Our results, shown in Table 1, detail the top 10 most threatened tracts of tribal land. Figure 1 shows the severity of sea level rise along the coast. It also highlights one of the larger tracts of land, the United Houma Nation Lands, located in southern Louisiana. These findings could help conserve tribal or culturally significant lands and benefit indigenous people. This research can also help conservationists know which areas are at risk and which areas to focus on for further adaptive planning or management actions. Our study will help preserve or relocate culturally significant landmarks before it is too late. Several types of tribal lands exist, not all subject to federal, state, or local taxation or law, therefore making it easy for policy-makers to overlook the importance of preserving these lands. This issue deserves more attention. If these lands are not preserved, not only will people be displaced but also important cultural sites will undoubtedly be lost. By protecting these lands, we are protecting a part of our history that should never be lost.

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Reference

1. Meehl GA, Stocker TF, Collins WD, et al. 'Global Climate Projections.' In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., pp. 2–18. New York: Cambridge University Press, 2007.

The Platypus:

Duck-Billed Outcast or Crucial Evolutionary Link?

INTRODUCTION

The duck-billed platypus (Figure 1) is an egg-laying mammal native to Australia. This creature has long captivated both the scientific and nonscientific communities. Poet Harry Burrell eloquently described the platypus as follows: 'O! Thou prehistoric link / Kin to beaver, rooster, skink / Duck, mole, adder, monkey, fox / Paleozoic paradox!' After George Shaw discovered this creature in 1798, he asserted that the platypus must be a taxonomic hoax. Shaw proposed that someone had sewn a duck's bill onto the body of a beaver. He even checked a platypus for stitches to ensure that it was a real animal.

The animal's recently sequenced genome has revealed information about the platypus's position in mammalian evolution. The platypus is a monotreme, meaning that it lays eggs, yet it lactates and has fur. Monotremes diverged from placental mammals about 166 million years ago. This makes monotremes the most basal group of mammals, meaning that they were the first group to branch off from the mammalian lineage. Because platypuses occupy this unique position, studies of platypus genetics may reveal important events that occurred in early mammalian evolution and may help clarify our evolutionary past. Rather than the two sex chromosomes typical in mammals, platypuses have 10. Also, genetic analyses have shown that platypus chromosomes are homologous to chicken chromosomes.²

My research focused on a retrovirus in the platypus centromere, the middle portion of a chromosome that facilitates separation during cell division. A retrovirus is a nonliving infectious agent that replicates inside a living host cell. A retrovirus functions by injecting RNA, its genetic material, into this host cell. It then uses an



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enzyme called reverse transcriptase to produce DNA from this RNA. For endogenous retroviruses, this retroviral DNA can be incorporated into the genome of the host cell and inherited across generations, which is common in mammals. For example, endogenous retroviruses are thought to make up about 8% of the entire human genome.³ Researchers found a conserved kangaroo retrovirus in a model marsupial species, the tammar wallaby. This retrovirus produces a novel class of small RNAs and plays a role in centromere function and cell division.4 If the kangaroo retrovirus were found in the platypus genome, it would indicate that the retrovirus was inserted into the genome early in mammalian evolution because of the early evolutionary divergence of the platypus. My project sought to determine whether this particular kangaroo retroviral sequence is conserved in the platypus and whether it might therefore play a larger role in all mammalian cell division. Such research could help advance medical research on diseases caused by chromosomal abnormalities, in addition to revealing more about our evolutionary past.

METHODS

I sought to determine whether platypus DNA contained the kangaroo retrovirus. To get to the DNA in the platypus cells, we first lysed the cell to release the DNA, removed other material, and then isolated the concentrated DNA. The first step was to use the polymerase chain reaction (PCR) to obtain many copies of the particular area of the platypus genome we were interested in (PCR ensures that we have enough DNA to analyze). Then we separated the molecules by size to compare the different fragments of DNA. We then used various methods to search for the kangaroo retrovirus. The first method, fluorescence in situ hybridization (FISH), uses a fluorescently labeled probe from the known sequence of the kangaroo retrovirus that could identify the kangaroo retrovirus sequence if present in the platypus genome. The second method, primed in situ hybridization (PRINS), can find DNA segments too small for FISH to detect. The experimental procedure is similar to that of FISH. We used fluoresFigure 2: PRINS experiments were completed with varying degrees of success, generally with more specific signaling than FISH experiments.



cence microscopy to see whether the fluorescently labeled probes had bound to kangaroo sequences in the platypus DNA. Seeing a small fluorescent signal on the platypus chromosomes through a microscope might indicate the presence of the kangaroo retrovirus. We would then definitively determine whether the kangaroo retrovirus was in the platypus genome by sequencing the portions of platypus DNA to which the probes had bound and comparing them with the known kangaroo retroviral sequence. By sequencing the platypus DNA, we would obtain the order of the individual nucleotides in the part of the platypus genome we had sequenced. This sequence could help us determine whether the kangaroo retrovirus was present in the platypus.

RESULTS

Through five trials of FISH, we had only random fluorescence. Because we knew that the kangaroo retrovirus localized to the centromere in the tammar wallaby, we hoped to find it in the platypus centromere as well. Overall, FISH results were inconclusive because completed slides did not reproducibly identify a definitive location for the retrovirus on a platypus chromosome.

We conducted PRINS experiments to locate the kangaroo retrovirus with various degrees of success, but, like FISH, these experiments did not locate the retroviral sequence anywhere in the platypus genome. Occasionally some signal localized to the centromere (white arrow, Figure 2). This particular experiment seemed to show that the fluorescent probe was binding to a sequence in the centromere of the platypus chromosomes. However, the signal appeared scattered and we could not reproduce these results.

After an overall failure of the FISH and PRINS experiments with the previously engineered primers, we designed new primers. Our previous primers were exact copies of the kangaroo retroviral sequence, which might not be in the platypus genome in that exact form after millions of years of evolution. This time we looked for sequences in the platypus genome, accessible online,⁵ that look similar to the kangaroo retroviral sequence. Ideally, that approach would allow us to find sequences that could still identify the kangaroo retrovirus actually present in platypus DNA. With one particular primer set, we obtained a product through PCR amplification (Figure 3). In this image, the leftmost lane on the gel contained a DNA ladder, used as a reference from which to measure the base-pair length of different DNA sequences. The middle lane contained a positive control of tammar wallaby DNA, which we PCR amplified by using the primers from the platypus genome database. The lower band in this middle lane indicated something we already knew: the tammar wallaby genome contains the kangaroo retrovirus. The rightmost lane in the gel contained the product of PCR amplifying platypus DNA with the aforementioned primers aimed at isolating the kangaroo retrovirus. That this product appeared in both the tammar wallaby DNA and the platypus DNA implied that the sequence was present in both animals, because the primers used were identical.

Our next task was to sequence the platypus PCR product to determine whether it was the kangaroo retrovirus. After attempting to sequence this product many times with low success rates, we determined that the primer set we were using was similar to a repeated sequence in the middle of the kangaroo retrovirus long-terminal repeat (LTR), which explained our previous inconsistent results. LTRs are sequences of DNA in



Figure 3: Shown is the gel electrophoresis analysis of the retrovirus PCR amplification. Depicted on the far left is a 2-log DNA ladder, followed by a positive control using tammar wallaby DNA. The last sample on the right uses platypus DNA. retroviruses that repeat thousands of times. These sequences flank the functional retroviral genes. Viruses use these sequences to insert their genetic information into host cells. We concluded that the functional sequence of the kangaroo retrovirus we had been trying to find through FISH and PRINS is probably not present in the platypus genome. The limited success we appeared to achieve through PRINS experiments consisted of our probes identifying this LTR sequence. In one particular sequencing trial, primers aimed at finding the kangaroo retrovirus found a new and different sequence in the platypus genome assembly. We projected that the kangaroo retrovirus probes found this sequence in our previous FISH and PRINS experiments.

DISCUSSION

Our findings have several implications. First, a question arose: how could we be sure that the kangaroo retrovirus was not present in the platypus genome? Because we exhausted all available methods to determine whether the sequence was present (FISH, PRINS, and PCR), we had to conclude that the sequence was absent from the platypus genome. Even so, our results could still drive further research. For example, the sequence in the platypus genome we found in our final experiment should be investigated further. Several questions came up regarding this sequence. Why was it so similar to the kangaroo retrovirus? Was it perhaps a comparable retrovirus that had degraded? Because we were working over so many millions of years of evolution, we had to consider that a retrovirus inserted into the genome so long ago would probably no longer be identical to its original retroviral sequence.

Overall, researching the anomalous system of the platypus could have many benefits for human medicine. For example, we do not know how the platypus regulates the excess genetic information in its 10 sex chromosomes. In human females, who have two X chromosomes, a process called X-chromosome inactivation prevents the transcription of one chromosome. Human females with XXXXX syndrome have five X chromosomes and experience a variety of phenotypic abnormalities. Discovering how platypuses genetically manage the abundance of genetic information in their 10 sex chromosomes may offer insights into better treatments for women with XXXXX syndrome and people with other chromosomal disorders. Finally, to the casual reader, this type of research addresses a pivotal question: where did we come from, and how much do we have in common with our evolutionary ancestors?

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REFERENCES

- 1. Moyal AM. Platypus: The Extraordinary Story of How a Curious Creature Baffled the World. Washington, D.C.: Smithsonian Institution, 2001.
- 2. Grützner F, Rens W, Tsend-Ayush E, et al. In the platypus a meiotic chain of ten sex chromosomes shares genes with the bird Z and mammal X chromosomes. Nature 2004;432:913–917.
- 3. Belshaw R. Long-term reinfection of the human genome by endogenous retroviruses. Proceedings of the National Academy of Sciences 2004;101:4894– 4899.
- 4. Carone DM, Longo MS, Ferreri GC, et al. A new class of retroviral and satellite encoded small RNAs emanates from mammalian centromeres. Chromosoma 2008;118:113–125.
- National Center for Biotechnology Information. Ornithorhynchus anatinus (platypus) genome view. 2007. Available from http://www.ncbi.nlm.nih.gov/ projects/mapview/map_search.cgi?taxid=9258.

Standardization of a Pan-Specific Test to Diagnose Lyme Disease in Veterinary Medicine ERIN MCGREGOR

INTRODUCTION

Lyme disease is a vector-borne disease, meaning it is transmitted from an agent (here, an arthropod) to a human or other animal. It is the most common vectorborne disease in North America, with 22,572 confirmed human cases reported to the Centers for Disease Control and Prevention in 2010. Lyme disease is caused by the bacterium Borrelia burgdorferi (Figure 1) and acquired through the bite of an infected tick. Currently Lyme disease is tracked only in humans, not in animals, and no data are available on the number of animal cases nationwide. This is a problem because many infected animals could be reservoirs of Lyme disease, potentially causing high infection rates in humans.

The inefficiency of current testing methods used to diagnose animals contributes to the uncertainty in the number of animal cases. In our research project, we used dogs as models to improve Lyme disease diagnostic tools. Surveillance programs can also use these models. In the first part of our study, we asked how many Texas dogs tested positive for any of several bacterial proteins in order to select a single protein to be used in the final test. To this end, the Texas Veterinary Medical Diagnostic Laboratory provided approximately 180 samples of dog blood for this study. Our hypothesis is that by developing a better diagnostic test to identify the Lyme disease-causing bacterium in many kinds of animals, we will better understand the distribution of Lyme disease. Then researchers could implement prevention programs to control the disease. Moreover, such a test would help establish surveillance programs



to test several different animal species without having to develop a different test for each animal.

We tested for reactions to three bacterial proteins in Texas dogs. The first protein (rOspC) is at highest levels during the early stages of the infection, whereas the second protein (rP66) is present throughout the infection. Therefore, reactions to these proteins allow us to differentiate between early and late stages of the infection in the dogs tested. We wanted to try three different detection methods for the bacterial proteins and then use that information to design the best possible test for use in veterinary medicine and surveillance programs. We started by studying the geographic distribution of Lyme disease-positive dogs in Texas because dogs can be considered an indicator of the presence of Lyme disease.²⁻⁴ Similar approaches will follow for other animals, such as horses, deer, and cattle.

MATERIALS AND METHODS

All animal serum samples used in this study were previously tested using the currently accepted diagnostic method. We acquired 30 positive and 150 negative samples. With all three methods, we analyzed all 30 positive and 50 of the negative samples to determine which procedure appeared to be the most reproducible and sensitive.

RESULTS

After running the three test types, we found some discrepancies. For example, of the 30 samples that tested positive by the current diagnostic method, six were confirmed negative by the other two methods, which constitutes a 20% false-positive result. However, of the 50 that tested negative by the current procedure, 33 were confirmed positive by the other two methods, which indicates 66% false-negative results. Clearly, the current procedure was not very accurate. Figure 2 shows some results obtained during this study. Taken together, the second and third methods had similar results and are much more accurate. We compared the results of all tests, and statistical analysis shows that reactivity to either protein indicated Lyme disease-positive dogs. Using these two testing methods together allows us to select a more precise cutoff value to determine which samples will be positive and which will be negative.

To obtain a geographic distribution of Lyme disease-infected dogs, we mapped our results by counties. Figures 2B and C show the distribution of Lyme disease-infected dogs when analyzed by two different test types (B and C). These maps show areas where Lyme disease

Figure 1: Borrelia burgdorferi B31 strain MSK5 in coculture with mouse peritoneal macrophages. Cells were stained with the Live/Dead BacLight Bacterial Viability kit (Invitrogen, Grand Island, NY).

can be a problem not only for veterinary medicine but also for human health, because they show a distribution similar to that for human Lyme disease (Figure 2C).

DISCUSSION

We conclude that the most commonly used procedure is not an appropriate diagnostic tool for Lyme disease in dogs, because it gave many false negatives (66% of the cases) as well as false positives (20% of the cases). The statistical analysis of all three testing methods led us to conclude that the second protein we worked with (rP66) is a better candidate to develop a competitive test because of its sensitivity. Such a test will result in better diagnostics to be used in veterinary medicine to detect Lyme disease, affecting not only animal but also human health.

As observed in the preliminary maps generated with only 80 samples of dog blood, we have already begun to see a distribution of veterinary Lyme disease similar to that observed in the human population, with the added value that animal Lyme disease is closer to the natural areas where the infection happens. Also, by using the same diagnostic tools in both human and veterinary medicine comparative studies, researchers can better predict distribution and dissemination of the disease in areas where this disease is not well understood. Consequently, when using the same techniques, we observed that most of the human and animal cases are reported around the metropolitan areas of Austin, Dallas/Fort Worth, and Houston, as well as along the border of Mexico. This observation might be due to the fact that both doctors and veterinarians in those urban metropolitan areas are more aware of the disease than those practicing in rural areas. Our laboratory is also collecting ticks from different areas in Texas to correlate the presence of Lyme disease in humans and animals with areas in the state that have many animal hosts for the pathogen, thus representing areas with high risk for infection with the disease.

A diagnostic test that can be used for all animals will

be of great value when establishing surveillance programs. The approach we are trying to develop will decrease the errors that occur in the current testing method. We have had time to test only dog serum thus far. However, we will analyze blood from other animals (cattle, horses, and deer) with the same methods. By testing more samples and different species of animals, we hope to improve diagnostic tests and improve the surveillance of Lyme disease in states where the distribution of the disease and the maintenance of the disease in animals is not well understood.

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REFERENCES

- 1. Piesman J, Gern L. Lyme borreliosis in Europe and North America. Parasitology 2004;129:191-220.
- 2. Bowman D, Little SE, Lorentzen L, et al. Prevalence and geographic distribution of Dirofilaria immitis, Borrelia burgdorferi, Ehrlichia canis, and Anaplasma phagocytophilum in dogs in the United States: Results of a national clinic-based serologic survey. Veterinary Parasitology 2009;160:138–148
- 3. Hamer SA, Tsao JĪ, Walker ED, et al. Invasion of the Lyme disease vector Ixodes scapularis: Implications for Borrelia burgdorferi endemicity. EcoHealth 2010;7:47-63.
- 4. Olson PE, Kallen AJ, Bjorneby JM, et al. Canines as sentinels for Lyme disease in San Diego County, California. Journal of Veterinary Diagnostic Investigation 2000;12:126–129.



Figure 2: Distribution of Lyme disease in Texas. Distribution of human Lyme disease in Texas, 2000–2010 (A); distribution of Lyme disease in Texas dogs when using test 1 (B) or test 2 (C).

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Ostalgia Garden MOLLY STREHL



According to my past photography mentor, Jeff Grimm, photographers should look for things that 'don't belong' to make up a successful image: one that grabs and holds attention. This advice always confused me on photo road trips. Ultimately, it meant that an unusual photo, or one in which something doesn't belong, is more interesting to look at and invokes unique feelings. We would often take trips to West Texas to find unusual sites, such as abandoned architecture, to capture.

On my first road trip to Austin while on Highway 21 in my first year of college, the drive made me happy and carefree as I discovered the once green and lush Lost Pines of Bastrop among the Texas flatland. I found a lovely spot on Pine Loop, one where it was calming and serene to read, take pictures, and soak up nature.

After the terrible fires of Bastrop destroyed so many homes, most of the foliage was now charred and burnt orange. Tall, black sticks remained in place of the once beautiful green, towering trees. Driving through the aftermath of the Bastrop fires showed me how devastating they were.

I drove to my favorite little spot on Pine Loop, and I was surprised at what I found. A single fireplace stood, everything else charred. But then I also came across what appeared to be a collection spot for old memorabilia and pieces of people's lives that survived the fires. I saw license plates attached to trees, an old charred toy car off in the distance, pots hanging from trees, a burned playground train, charred

"The hidden beauties within 'unattractive' things; such burned artifacts can actually symbolize empathy and togetherness, and that new discovery can be literally around the corner..."

and rusted boat models, and a broken Schwinn bicycle resting on a tree, as well as the markings of past visitors.

It was as if the people of the neighborhood added onto this vast colanother after such mass disaster. This quaint accumulation of recent artifacts didn't necessarily besaster completely changed. It was as if placing these objects in the middle of the burned woods where create collective empathy. Merely standing in the site and taking picme, even, and further exemplified what Grimm meant when he said to capture things that don't belong. Finding bikes, toy trains, and other random objects placed so artistically and with emotion in the middle of a burned forest was far from usual. The underlying meaning made this sculpture garden beautiful, yet trag-

An image such as this one reminds me of the hidden beauties within 'unattractive' things; such burned artifacts can actually symbolize empathy and togetherness, and that new discovery can be literally around the corner, even in the woods. Finding such gems in the middle of nowhere—especially if they're there only for a short time—inspires and excites me as a photographer. I've visited the site since; now cleaned up, the land is being used to create another house. But for a time, something unique dwelled in the space, which is all that matters.

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"It was as if placing these objects in the middle of the burned woods where a house once stood was a way to create collective empathy."

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Finding the Perfect KEVIN BARNETT

INTRODUCTION

Membranes, particularly oxygen barriers, are vital to many important technologies. Discovering new membranes that have desirable properties could have a major impact on our future. Imagine a world where cars do not run on gasoline, but on clean hydrogen. What if computers could get even smaller and more efficient? New membrane technology—polymers, in particular makes such ideas possibilities, not just dreams.

Polymeric membranes have thus far made major contributions: they keep food from spoiling quickly, they have made fuel cell technology possible, and they have enabled recent advances in flexible electronics.

DEFINITION OF POLYMERS

Polymers are one of the three main forms of solid material, along with metals and ceramics. Polymers are composed of long chains of repeating structural units, usually carbon based. We use these polymers in rubber for tires, nylon for fabrics, and plastic for building anything from water bottles to automobile parts.

Polymeric membranes, known for their flexibility and selectivity for certain fluids, are ideal. Polymeric membranes can serve as a barrier to oxygen. The discovery of an oxygen barrier, with its many potential uses and desirable properties, is a main goal of the scientific community, with many experiments dedicated toward that end. Layer-by-layer assembly of two different polymers is a relatively new and promising approach to creating an oxygen barrier. With the goal of finding a good oxygen barrier and understanding exactly what makes a

"Oxygen barrier films made of polymers play an essential role in many technologies that affect us daily." polymer a good barrier, my research group performed a gas permeation analysis of a layer-by-layer-assembled polymer membrane.

APPLICATIONS OF MEMBRANE TECHNOLOGY

Membrane technology is growing in importance every day and is replacing other technologies because of the demand for higher-quality products, the deterioration of natural resources, and the desire for economic and environmental sustainability.¹ Membrane-based techniques are often simpler than conventional techniques, and membranes are more easily tailored for specific functions. In general, membranes are also more energy efficient and have less environmental impact.² Membrane technology has made substantial contributions to medicine, food packaging freshwater recovery from seawater, separation of gases, fire prevention, and flexible electronics.

Membrane technology has improved the separation of oxygen and nitrogen in our natural air. Obtaining pure nitrogen and pure oxygen has several uses, and membranes help us obtain these pure gases as efficiently as possible. Pure nitrogen is used to prevent explosions, in industrial chemical reactions, and for small-scale chemical experiments.¹ Pure oxygen is used to help people in ill health breathe, as air supply in spacesuits and scuba tanks, in chemical reactions such as combustion, and in rocket fuel.³ Gas separation technologies using low temperatures or high pressures were in place before membranes were used, but membranes are becoming more important because of their easy operation, low energy cost, reliability, and efficiency.¹

Oxygen barrier membranes, in particular, have dramatically influenced flame retardation, flexible electronics, and food packaging. Oxygen reduces the shelf life of many food products, including meat, poultry, and fresh produce.⁴ Think about the plastic containers that store your food. The right polymer membrane or coating over the food container keeps oxygen from entering and spoiling the food. Without good oxygen barriers, our food would spoil much faster. Fire prevention also depends on oxygen barriers. Houses, clothes, and automobiles are all susceptible to catching fire. But what if we could make any material fireproof simply by adding a polymer barrier coating? This technology is in the early stages, but think how much we could improve safety if we could use oxygen barriers to prevent fire.

Oxygen barriers are also crucial to implementing new flexible electronic technology. The need to protect millions of delicate transistors from oxidation is the current limit to developing flexible electronics. Oxygen barriers in electronics are now made of rigid shells. Developing a flexible polymer oxygen barrier to replace the rigid shells could solve this problem. The flexible electrical circuits would be able to bend, stretch, and conform to almost any shape. This capability would save space and lead to design improvements in cameras, cell phones, cars, and satellites.⁵

ADVANTAGES OF LAYER-BY-LAYER POLYMER FILMS

Oxygen barrier films made of polymers play an essential role in many technologies that affect us daily. Why are polymers the best material for oxygen barriers? One advantage is transparency. We want to be able to see inside containers, which is not possible with materials such as aluminum. Plastics made of polymers are better than glass because they are better barriers to oxygen, do not shatter, and are more recyclable.⁶ Also, manufacturing methods for polymers are adaptable. Polymer chemistry has many different possible combinations, resulting in many different membrane shapes and properties.⁷

Layer-by-layer deposition is a powerful method for creating a polymeric film. Polymers made through layerby-layer deposition are exactly what they sound like: two oppositely charged polymers deposited alternately in layers (Figure 1). A combination of two layers, consisting of two different polymers, is called a bilayer. Because these bilayers contain two different polymers, many different combinations of polymers—each with its own properties—are possible. Different ingredients added between the layers can change the function of the polymer film.⁸ The ease with which bilayers can be manipulated makes them great for exploring new, desired properties, such as oxygen blockage.

My research focuses on oxygen permeation through layered polymer films, with the overall goal of discovering new, useful oxygen barriers.

LAYER-BY-LAYER DEPOSITION

The overall goal of the experiment was to test the oxygen permeance, or how well a gas travels through a membrane. To test the permeance, one must first deposit the polymer on a surface, or substrate. The substrate we use to test the permeance of any gas through a membrane is a porous, stainless-steel tube. However, the pores were too large to coat the tube with a smooth film directly, so we needed to apply a smooth layer before depositing the polymer. We used an air brush to apply a gel. Now that the tube had a smooth layer, we could then deposit the polymer. This process, highlighted in Figure 1, consisted of alternately dipping the tube into the positively charged polymer and the negatively charged polymer, with a rinse and dry step between each dip. Figure 2 shows a schematic of the layers and the resulting tube with a gel coating





Figure 2: Schematic of films over tube (A), picture of film coated over the tube (B), schematic of experimental setup for gas permeation measurement (C), and results showing decreased oxygen getting through film as the film gets thicker (D).

and polymer bilayer.

MEASURING OXYGEN PERMEATION

To determine the permeance of a gas through a membrane, we used our experimental setup of the tube connected to two gas sources, one inside and one outside the tube (Figure 2C). The gas we feed on the outside of the tube is the gas we are testing for permeance—here, oxygen. This gas stream is called the 'feed.' The gas inside the tube is an inert (unreactive) gas present only to sweep the feed gas that permeates the membrane out of the system. This is simply called the 'sweep' gas stream.

For the experiment, we connected the tube with the film coated on top of it to the two gas streams. We changed the concentration of oxygen in the feed stream four times by adding different amounts of inert argon gas for each measurement, and we recorded how much oxygen went through the film for each trial. We repeated this process for different thicknesses of film resulting from different numbers of bilayers, in addition to the untreated tube with no film deposited on it.

RESULTS & DISCUSSION

Figure 2D shows that, as expected, the oxygen perme-

ance decreased as the number of bilayers, and thus the film thickness, increased. This result made sense: with more bilayers present, oxygen would have to travel through and react with more polymer to reach the other side. The oxygen-to-argon selectivity—the amount of oxygen that permeates through the membrane compared with the amount of argon—also decreased as the number of bilayers increased. This result means that oxygen, which is about the same size as argon, permeated more slowly than argon with an increase in bilayers. This result could be due to chemical phenomena between the polymer film and oxygen.

CONCLUSION

The goal of this experiment was to fully characterize the permeance of oxygen through polymer films with different numbers of bilayers. We observed a low oxygen permeance, which is promising for future studies. Possible future studies may include trying to observe lower oxygen permeance with different polymers or with clay nanoparticles deposited between the bilayers, which have shown excellent oxygen barrier properties. Our procedure can also test hydrogen permeation, and layer-by-layer films have also been used to separate hydrogen gas for use in fuel cells. Trying to find a polymer film with good hydrogen selectivity is also a likely future study. Oxygen barriers, such as the one tested here, are vital to many technologies. If we continue to develop new polymer films, experiment with them, and be creative with them, we can eventually discover a polymeric membrane that can change our future for the better.

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I thank my adviser, Dr. Benjamin Wilhite, and all the other members of our chemical engineering research group who helped with this project, most notably postdoctoral researcher Daejin Kim. This group tested the oxygen permeance of the polymers. I also thank Dr. Jaime Grunlan and his mechanical engineering research group for making the films, performing the layer-bylayer polymer deposition, and otherwise contributing to this project.

REFERENCES

- 1. Li NN, Fane AG, Ho WSW, et al. Advanced Membrane Technology and Applications. Hoboken, NJ: John Wiley & Sons, 2008.
- Strathmann H. Ullmann's Encyclopedia of Industrial Chemistry. Vol. 22. Weinheim, Germany: Wiley-VCH GmbH & Co. KGaA, 2012.
- 3. Want to Know It? Answers to Life's Questions. "Uses of oxygen." 2012. Available from http://www. wanttoknowit.com/uses-of-oxygen/.
- 4. Krohn JV, Todd WG, Culter JD. "Optimizing barrier performance of multi-layer polyethylene films." Document no. 9366/0699. Available from http://www. lyondellbasell.com/techlit/techlit/Brochures/Barrier%20Performance%20Multi-Layer%20Film%209366. pdf.
- 5. Pyramidion. "What could flexible electronics ever do for us?" Available from http:// www.pyramidion.be/index.php?option=com_ content&view=article&id=123:what-could-flexibleelectronics-ever-do-for-us&catid=34:storybook&Item id=69.
- 6. Lange J, Wyser Y. Recent innovations in barrier technologies for plastic packaging. Packaging Technology and Science 2003;16:149–158.
- 7. Drioli E, Giorno L. Membrane Operations. Weinheim, Germany: Wiley-VCH GmbH & Co. KGaA, 2009.
- 8. Yang Y, Halle M, Park YT, et al. Super gas barrier of all-polymer multilayer thin films. Macromolecules 2011;44:1450–1459.

Medicine on the Nanoscale: Nanoparticles to Diagnose and Treat Inflammatory Lung Diseases

STEPHANIE FLOREZ

INTRODUCTION

What do cancer, lung inflammation, genetic diseases, and dermatological diseases have in common? Besides being some of the most prevalent conditions in humans, these and hundreds of others have a molecular origin. Although medical applications and pharmaceutical development have enabled treatment and management options for many diseases, those that involve complex inflammation mechanisms are still difficult to treat with common approaches.

While medicine had unanswered questions on how to treat these conditions, physicist Richard Feynman hinted at the answer in 1959. He introduced to the scientific community a new idea: "What if we had the ability to manipulate individual molecules, using tools that are small enough to work on the nanometer scale?" This concept, known today as nanotechnology, has enabled scientists to design and invent devices as small as a few nanometers, allowing elegant and precise manipulation of materials.¹ Over the past few de-

cades, nanotechnology has entered the medical realm with the emergence of nanomedicine. This achievement has allowed advances that profoundly affected medical conditions, such as miniature electrodes for brain stimulation, accurate diagnostic procedures, and development of medicines specific enough to destroy only the molecules responsible for the condition.

The advantages and applications that nanomedicine brings can apply to a wide array of conditions. For example, nanosized particles can travel inside cells and correct mutations, suppress gene activity, and stop a disease at its point of origin, thus preventing its development² In the Wooley laboratory in the chemistry department, we design such nanoparticles and have investigated their applications in the treatment of several conditions.³ My project was to design and manufacture nanoparticles to suppress the activity of an enzyme that damages tissue during lung injury. A condition prevalent in most developed countries, lung injury kills more than 100,000 people every year.⁴ It may be caused by exposure to pollutants, chemicals, and



Figure 1: Nanomedicine allows scientists to treat inflammatory diseases. A nanoparticle can be assembled to introduce gene sequences inside cells that suppress toxic mechanisms during inflammation.⁶

infections; however, regardless of the cause, lung injury shows the same patterns of inflammation and enzyme activation. The enzyme produced during inflammation in lung injury releases toxic substances that kill tissue, causing further inflammation. By suppressing the enzyme, we could stop the cycle of inflammation. However, because this enzyme is part of a large family of enzymes important for metabolic activity, we must suppress only this specific enzyme.⁵

Nanomedicine can suppress the enzyme by suppressing the gene that codes for it. We can suppress a gene by introducing a complementary sequence into the cell that will prevent the gene from being transcribed and translated into a protein. However, the genetic sequence must be transported specifically to the cell that expresses the enzyme. To ensure specific delivery, nanoparticles can act as transporters that recognize cells with overexpressed enzyme and then deliver the genetic sequence (Figure 1).7 These nanoparticles are called cationic shell crosslinked knedel-like (cSCK) nanoparticles, because of their structural characteristics and charge. cSCKs would vastly improve outcomes of lung injury, because currently no treatment is available and the inflammatory cycle cannot be stopped before inflammatory malignant enzymes produce more toxins. This article will discuss such nanoparticle design, as well as its ability to suppress gene activity for the enzyme that kills tissue during lung injury.

NANOPARTICLE DESIGN AND APPROACH

Because nanoparticles can be constructed from a range of materials, they can have different properties and forms. Much research has been devoted to nanoparticles built from metals such as gold, thus producing solid, spherical nanoparticles that have applications in radiology and cancer treatment.⁸ However, nanoparticles can also be constructed from small molecules that researchers then assemble to form a stable structure. This approach, unlike using metal nanoparticles, allows scientists to tailor the nanoparticles to have characteristics of interest, such as different sizes, shapes, charges, and reactive groups.

In our lab, the assembly process for these nanoparticles begins with polymers, long sequences of repeating molecules, like a chain made up of interconnecting links. Analogous to chains, the properties of the monomers (the individual links) can change the overall properties of the polymer. Our polymer had two different types of chains connecting to one another, giving it a unique characteristic: one segment of the polymer is hydrophobic, or water repelling (due to polystyrene repeating units), whereas the other portion is hydrophilic, or water liking (due to primary amine units). Therefore, when placed in water, these polymers aggregated into spheres, with the hydrophobic segments in the center (because they repel water) and the hydrophilic regions on the outside (Figure 2). Such an assembly is called a micelle and is fragile because it is held together weakly. To provide a robust infrastructure to the nanoparticle, we introduced "crosslinks" that connected the peripheral hydrophilic groups, producing a spherical, nanosized particle with hundreds of polymer endings with reactive sites that can act as "carrying arms" to transport gene suppression materials inside the cell.

NANOPARTICLE BINDING TO DNA & CELL UPDATE

Next, to ensure that the nanoparticles can carry specific DNA gene sequences and deliver them into cells to treat lung injury, we performed gel retardation and



Figure 2: Synthetic scheme for the formation of cSCK nanoparticles. Single molecules can be linked into long chains. Bunches of chains spontaneously form into spheres in water; the interior of the sphere contains molecules that repel water, and the outer surface contains molecules that like water. These spheres are then cross-linked to form a cSCK nanoparticle.⁹

cell studies.

Our nanoparticles are designed to stick to gene sequences like a magnet sticks to a nail. To see whether the cSCKs would bind to the DNA, we carried out a gel retardation assay (Figure 3). In this assay, columns represent equal amounts of radiolabeled DNA added, but as the columns progress to the right, more cSCKs are mixed with the DNA, and we can measure whether the cSCKs are sticking to the DNA. Without any cSCKs added, DNA (because of its negative charge) migrates to the bottom of the column. However, when we added enough cSCKs to complex with the DNA in the column, the DNA band shifts to the top. This assay confirms that when enough cSCKs are added, the cSCK nanoparticles bind tightly to the DNA, which can potentially be delivered to the cells.

After confirming that these nanoparticles can bind to DNA, we used microscopy techniques to see whether the nanoparticles could move into the cells. We took cSCKs with DNA labeled with a red dye and put them on cells. We stained cell nuclei (dark blue) and performed several washes so that no unbound cSCKs remained on top of the slide. Confocal microscopy showed that cSCKs enter the cells (Figure 4), confirming the ability of cSCK nanoparticles to be transported into the cells.

RESULTS AND CONCLUSIONS

Using chemical principles, such as polymerization, and physical principles, such as the formation of micelles, we synthesized nanoparticles that bind to DNA. We can introduce these nanoparticles into damaged tissue cells. We confirmed binding to DNA by using gel-retardation assays, and we verified cell uptake with confocal microscopy. This work shows that cSCK nanoparticles can be used as gene delivery agents and help to diagnose and treat diseases such as lung injury. Furthermore, different monomer compositions can affect the overall polymer's ability to enter the cell, and this hypothesis is currently being studied. In the future, in vivo studies will test the efficacy of the nanoparticles as a diagnostic tool as well as for gene delivery therapeutics.

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REFERENCES

- 1. Barth JV. Engineering atomic and molecular nanostructures at surfaces. Nature 2005;437:671-679.
- 2. Pack DW, Hoffman AS, Pun S, et al. Design and development of polymers for gene delivery. Nature Reviews Drug Discovery 2005;4:581-593.
- 3. Zhang K. Well-defined cationic shell crosslinked nanoparticles for efficient delivery of DNA or peptide nucleic acids. Proceedings of the American Thoracic Society 2009;6:450-457.
- 4. Mehta S. The effects of nitric oxide in acute lung injury. Vascular Pharmacology 2005;43:390-403.
- 5. Kristof AS. Role of inducible nitric oxide synthase in endotoxin-induced acute lung injury. American Journal of Respiratory and Critical Care Medicine 1998;158:1883-1889.
- 6. Elsabahy M, Wooley KL. Design of polymeric nanoparticles for biomedical delivery applications. Chemical Society Reviews 2012;41:2545-2561.
- Koppelhus U. Cellular delivery of peptide nucleic acid (PNA). Advanced Drug Delivery Reviews 2003;55:267– 280.
- 8. Daniel MC. Gold nanoparticles: assembly, supramolecular chemistry, quantum-size-related properties, and applications toward biology, catalysis, and nanotechnology. Chemical Reviews 2004;104:293-346.
- 9. Elsabahy M, Wooley KL. Strategies toward welldefined polymer nanoparticles inspired by nature: chemistry versus versatility. Journal of Polymer Science Part A: Polymer Chemistry 2012;50:1869–1880.

INTRODUCTION

Zombie apocalypses have exploded onto the U.S. pop culture scene, with diehard fans contributing more than \$5 billion to the national economy⁴ Despite being heavily dramatized in the media, zombie outbreaks have real roots in the study of infectious diseases, even being recognized by organizations such as the Federal Emergency Management Agency and the Centers for Disease Control and Prevention² Initially started through biological attacks, mutations, or the introduction of a virus, the infection that makes someone a zombie is transmitted by open wounds, typically caused by a bite from the undead. Such an outbreak is difficult to contain or combat because of its aggressive nature. But as with many classic infectious illnesses, we can predict and study such contagions with computer models that simulate real-life situations. Through mathematical modeling we can study preventive disease methods, which can improve human health.

Although realistically the idea of a zombie apocalypse is improbable, the fundamental methods and techniques involved are closely correlated to real-life examples that government agencies and scientists use to study other diseases. We sought to construct a mathematical model to determine the best methods to contain the outbreak and what effective solutions are available to prevent catastrophic human extinction.

MODEL TENETS AND ASSUMPTONS

To study the disease, we first generalized about and then observed zombie characteristics from popular

Param				
Birth rate (π)	0.0003	Total susceptible	0.0009	
Human infection rate (β)	0.004	Total zombies	376.7127	
Human death rate (δ)	0.0001	Total removed	124.01	Figure 1:
Zombie death rate (α)	0.001	Total days	13	Basic Model
Param				
Birth rate (π)	0.0003	Total susceptible	0.0219	
Human infection rate (β)	0.004	Total zombies	0.0009	
Human death rate (δ)	0.0001	Total removed	500.751	Figure 2a:
Zombie death rate (α)	0.15	Total days	92	Decay Model: Humans Win
Param]			
Birth rate (π)	0.0003	Total susceptible	0.0009	
Human infection rate (β)	0.004	Total zombies	1.1467	
Human death rate (δ)	0.0001	Total removed	499.6121	Figure 2h [.]
Zombie death rate (α)	0.114	Total days	56	Decay Model: Zombies Win
Param				
Birth rate (π)	0.0003	Total susceptible	0.0203]
Human infection rate (β)	0.004	Total latent	0.0001	1
Human death rate (δ)	0.0001	Total zombies	0.0009]
Zombie death rate (α)	0.001	Total removed	503.9958	1
Latency rate (p)	0.15	Total days	137	Figure 3.
Decay rate (Ω)	0.15			Full Model

SUBALINATING A SUBALINATING A SUBALINATION OF A movies, TV shows, and video games. Our model includes the following parameters:

- 1. Zombies are limited to basic cognitive and motor functions.
- 2. Zombies can infect humans at any time.
- 3. Zombies are destroyed once enough damage is inflicted onto the body or head.
- 4. Once a zombie is removed from its environment, no possibility of reanimation exists.

The entire population will fall into three classes of participants: susceptibles (humans), zombies, and removed (dead). Parameters accompanying these classes include infection rate (β), human birth rate (π), zombie destruction rate (α) , and human death rate from natural causes (δ) . These factors control the population in each class and determine survival or extinction. They also combine to form a system of differential equations that define a population ratio that underlies our mathematical model. We used days for our time unit, while we capped our total population at 5 million to simulate the effect of a zombie outbreak in a city. If necessary, we could use these parameters to estimate larger population simulations. Also, zombies will have 2 days to infect freely to simulate a delayed response from humans To fight the infection. Furthermore, a decay parameter (Ω) for the zombie class will represent a realistic scenario where zombies have limited time to infect new hosts before decaying and dying themselves. The first 20 days of the model, including the first 2 days of the infection period, are exempt from the decay parameter because our research showed that around 20-30 days, the bod

METHODS

To develop a comprehensive model that consists of multiple classifications and parameters, we first developed a basic model with minimal restrictions. Once the basic model was complete, we introduced a new participant class, infected, and its latency parameter (ρ). We used the parameter to add a buffer time of 24 hours before infected susceptibles turned into zombies that could infect others. By adding experimental parameters to the basic model, we observed how changes would affect the results. We expected to see whether humanity could mobilize a significant response during the latent time to eliminate the zombie population. We then went back to the basic model and experimented with a new decay parameter, which we introduced to the model to see how decay would affect the population levels after 20 days. We hypothesized that the decay period would play a crucial role in determining the result of the final model. Therefore, we analyzed the decay parameter with models of an outbreak occurring in cold, hot, and neutral climates. Once we tested all the models with individual parameters and determined its values, we developed the final conclusive model by placing all our parameters and classifications into one



RESULTS

Under the basic model (Figure 1), we found no reasonable solutions to prevent a zombie apocalypse. As the zombies begin infecting the susceptibles, no significant method could stop the spread of the disease other than the zombie death parameter. Figure 1 shows the parameter values chosen and the resulting graph data for each class system. After the initial 2-day period, when zombies infect freely, the population of susceptibles drops, whereas the zombie population grows exponentially.

The effect of natural death rate and zombie death rate add a minimal population to the removed class. Under this model, we found that the human population would be eliminated by day 13. Adding the latency period to the basic model—where the infected susceptibles had an incubation period of 24 hours—slowed the rate of susceptibles being infected by zombies, but eventually all succumbed to either the removed or zombie classification, with no real solutions available for human survival.

When we added a decay period to the basic model, the susceptibles population still exponentially declines to near extinction. However, as the total number of susceptibles drops to near zero, the number of infections is limited by the lack of hosts to infect, meanwhile, the decay process begins to eliminate the zombies (Figure 2a). Because zombies decay faster than new ones can appear, we see a sharp increase in the number of zombies for the first 10 days that then quickly falls over roughly 30 days. The human population eventually edges out the zombie population, with 21 survivors by day 92. The decay parameter showed that humans have a greater chance of survival depending on the



Figure 2a: Decay model showing human survival at day 92 with the addition of a high decay parameter.

Figure 2b: Decay model showing human extinction by day 56. At the threshold decay parameter level, the decay of zombie population is noticeably slower, thus ending civilization.

rate of decay. Therefore, we determined that the critical threshold value for the parameter is $\Omega = 0.114$ for a zombie apocalypse and $\Omega = 0.115$ for human survival. Under the apocalyptic model configuration (Figure 2b), we see a similar graph as before, but the rate of humans being infected increases faster than the number of zombies being eliminated, and thus the last human is killed on day 56.

Combined, the full model with all the parameters determined through experimentation and research (Figure 3) shows the comprehensive relationship between parameters and classifications. The human population will decline rapidly, whereas the latent population increases exponentially because of the number of susceptibles that zombies are infecting. Once the maximum latent population is achieved, we soon see the maximum number of zombies as the infected begin to convert. The latent parameter extends the overall time process of the model, but eventually the decay process and the lack of susceptibles to infect quickly eliminate the zombie population. We found the result in favor of humans, with a survival value of 0.0203, or roughly 20 humans by day 137. We also found that if the rate of decay were to fall below the threshold level, the outcome would be in favor of zombies.

CONCLUSION

Hollywood and video game producers seem inclined to forget a crucial element when depicting zombie apocalypses. Undoubtedly, zombies in real life would not be able to avoid decay and still be able to infect new host months or years after the introduction of the disease. Therefore, models run without a decay parameter showed that humanity had no chance of survival. Consequently, we wanted to know how latency and decay would affect the overall result. The latency parameter extended the duration of the model but was not crucial to the outcome. We showed that factors such as climate, which would directly affect the decay ratio, could determine the survival of humanity with a correlation to zombie decay. Values for the decay parameter, Ω = 0.114 and 0.115, were critical threshold values, tipping the result in either direction. If decay were not available, only a high birth rate and an equally high zombie death rate could outpace the infection rate. This scenario, however, would be unlikely and thus not conclusive. Humans could rely on outside factors, such as the environment, for survival. When the decay of zombies is taken under consideration, humans could outlast the limited lifetime of zombies. Therefore, in the event of a zombie outbreak, we would recommend seeking shelter from the undead in extreme environments to increase chances for survival.

REFERENCES

- 1. Ogg JC. 24/7 Wall St. "Zombies worth over \$5 billion to economy." 2011. Available from http://247wallst. com/2011/10/25/zombies-worth-over-5-billion-toeconomy/3/.
- 2. Federal Emergency Management Agency. 'From CDC—Preparedness 101: zombie apocalypse.' 2011. Available from http://blog.fema.gov/2011/05/fromcdc-preparedness-101-zombie.html.

Powering Your Water Heater with Solar Energy

DANIEL MILLER

SOLAR WATER HEATING

Imagine taking a hot shower for as long as you liked but not spending a dime. Could this be a realistic scenario? Residential water heating is a significant portion of U.S. energy consumption. According to the U.S. Energy Information Administration1 and the American Council for an Energy-Efficient Economy,² electric water heating accounts for approximately 88 million kilowatthours of energy every year—about 0.3% of the energy usage of the entire U.S.

Renewable energy sources offer a way to reduce this cost. Using solar power to heat water is efficient and cost-effective. Because the desired product is thermal energy (heat), heat transfer systems may be used to bypass the inefficiencies of electric water heaters. Such systems are known as solar water heaters and are in wide use throughout the world. For example, about 90% of homes in Israel are equipped with solar water heating systems.³ Matching that statistic could save the U.S. about \$22 billion every year.¹

My project focused on optimizing a residential solar water heating system. I sought to maximize the energy gathered. I developed a mathematical model of the system's energy flow to determine the most effective behavior of the system. I then developed a control scheme to implement this behavior. I also adjusted the system to account for excess energy situations.





OVERVIEW OF THE SYSTEM

My Austin home uses the solar water heating system described in my project. Figure 1 shows the most important component of the system: the solar collector panels, or simply the collector. A heat transfer fluid (HTF) is pumped through the collector, where it absorbs energy from the copper plates sitting under glass in the sunlight.

After it is heated, the HTF travels down an insulated pipe to a water storage tank (called the solar tank). The pipe carrying the HTF coils around the solar tank and ascends back to the collector. This configuration forms a closed-loop system in which energy is transferred from the collector to the storage tank. Because the system is closed, the HTF does not directly interact with the water it heats. We can therefore use a mixture of propylene glycol (nontoxic antifreeze) and water for the HTF, allowing year-round operation of the system without risking freeze damage (i.e., burst pipes).

Water enters the base of the solar tank from the city water main at an approximate temperature of 65°F, depending on the ground temperature. This value is simply a rough average of gathered data. The HTF transfer coil heats the water in the solar tank. The heated water exits the tank and is sent to a traditional water heater, where it is regulated to a standard 130°F and distributed to the house as needed.

The described solar water heating system is known as an actively controlled system: the flow rate of the HTF is controllable. My project focuses on controlling this flow rate to optimize the energy gathered. The system is monitored using devices called thermocouples (TCs). A TC measures temperature, like a thermometer. Figure 2 shows the TCs on the collector and solar tank.

THE PROBLEM

A basic control method for this type of system simply measures the difference in temperature between the collector and the solar tank. If this difference exceeds some fixed value, the pump for the HTF activates. When the difference drops below the fixed value, the pump deactivates.

Simplicity is the main advantage of this type of control system; the hardware required is minimal and cheap. However, for two reasons, what this method gains in simplicity, it loses in efficiency.

PROBLEM 1

The first reason is the fixed activation value. Because the pipe carrying the HTF is not perfectly insulated, the HTF loses heat as it travels. The pump that moves



Figure 2: Solar hot water system components.



Figure 3: Recorded temperatures of the collector (COLL-T) and the storage tank (STOR-T) over 24 hours, May 2011. Pump behavior is shown (on or off). (Figure courtesy of Roy Miller.)

the HTF also requires power to operate. If the fixed value is too low, the heat lost in transit will exceed the heat gained from the collector, and the system will lose energy. If the fixed value is too high, the system will not run when it could be gathering energy. Therefore, for maximum energy gain, the value must be perfectly calibrated.

The greatest efficiency occurs when the temperature difference between the collector and the solar tank is a function of the collector temperature. Therefore, if we want to maximize efficiency we cannot simply choose some arbitrary number for the temperature difference.

PROBLEM 2

The second problem with the on-off control method is temperature oscillations (Figure 3). When the system is switched off, the HTF in the collector slowly heats up. However, the HTF in the rest of the system slowly cools to the ambient temperature. When the system activates, the heated fluid moves out of the collector and cooler fluid takes its place. The system senses the cooler water in the collector and immediately deactivates, and the cycle repeats. This cycling is inefficient. Every time the system deactivates, the HTF stops flowing. When the system reactivates, starting the HTF flowing from a standstill requires extra energy. At approximately 10 gallons of HTF, with oscillations occurring as quickly as every 5 minutes, this 'startup' energy is significant. Figure 3 shows the actual collector and solar tank temperatures over a 24-hour cycle in May 2011. The temperature oscillations are visible in the jagged nature of the graph. The figure also shows the on-off behavior of the pump. Ideally, we would see the

collector and tank temperatures tracking much more closely. We would also have motor speeds that could vary with the temperature difference between the collector and tank.

RESULTS

To address the stated problems with the water heating system, we began with a full mathematical model of the energy in the system. This model identified the minimum temperature difference between the collector and the solar tank. We also found that the temperature of the collector should be kept as low as possible. The collector loses heat to its surroundings relatively quickly, whereas the solar tank and HTF pipe are insulated and lose heat more slowly. Combining the two results, we found that the difference between the collector and the tank should be kept as close to our previously calculated minimum temperature difference as possible.

The second step was to develop a control scheme to produce the desired system behavior. The scheme had to account for erratic behavior in the collector, caused by atmospheric effects such as cloud cover, and for sharp temperature changes in the solar tank, caused by water usage in the house. These two behaviors are modeled together as simply a sharp change between the collector and tank temperatures—the side at which the change occurs is mathematically irrelevant.

We used an interdisciplinary tool called a proportionalintegral-derivative (PID) controller to account for this behavior. PID controllers are used in fields ranging from chemical manufacturing to robotic control. Tuning the



controller causes the system to respond quickly to a disturbance without causing oscillations. A disturbance in our system is anything that affects the temperature difference between the tank and the collector, such as someone running the dishwasher or a cloud passing over the house. Figure 4 shows the difference between a tuned and an untuned PID system. Tuning the system prevents the temperature oscillations shown in the untuned response.

IMPLEMENTATION

The next stage involved implementing the controller. We wanted a control system that could measure temperatures in the system and record the data automatically. The control system also needed to implement the PID controller and regulate the HTF flow rate.

We chose a microcontroller-based design. A microcontroller is like a small computer processor. A microcontroller offers a variety of interfaces, including USB and wireless. Microcontrollers are easy to program and can be adapted to many applications. However, because digital devices such as microcontrollers cannot carry out continuous operations such as integration and differentiation, we had to modify our equations to put them in a form that the microcontroller could handle.

EXCESS ENERGY

PROBLEM

This control scheme has one major problem. This issue arises when surplus energy is available. If the temperature of the system rises too high, the HTF pump must be switched off to prevent the solar tank from reaching its safety limit. However, the temperature of the solar collector will continue to rise, even to the boiling point of the HTF. The HTF must then be vented via a pressure-relief valve to prevent an explosion. Even if venting the HTF is not necessary, these temperatures stress the system, reducing the operating life of the components, particularly the HTF. Such a situation is fairly common, particularly during a Texas summer. For example, in summer 2011, the system experienced an energy surplus for 30 consecutive days.

Another issue with this excess energy situation is the waste involved. We want the system to gather as much energy as possible. In this situation, much energy is available, but after the system has hit its limit, little of the energy is harvested.

SOLUTION

To solve these two problems, we considered adding a thermoelectric generator, which would convert the excess energy to electricity. We considered a device known as a Seebeck generator, which requires a heat source and a heat sink. The temperature difference between the sink and source induces a current flow that generates electric power; this process is known as the Seebeck effect (Figure 5). One efficient way to implement a heat sink is to use an underground array of pipes that passively cool the generator. Such a small generator has a negligible effect on ground temperature, so we can regard the heat sink temperature as a constant.

Implementing the thermoelectric generator is relatively simple. By adding a valve on the HTF pipe, we can control the flow of the heated HTF from the collector. Depending on the temperature of the solar tank, the HTF can be directed by the valve to either the generator or the tank, minimizing wasted energy. Figure 2 shows this valve.

CONCLUSION

I used a mathematical model to develop an optimized control scheme for the solar water heater. I also designed a system modification that allows the system to continue gathering energy without hitting a limit at consistently high temperatures.

The next stage of the project—implementing the system modifications—will include the design and programming of a microcontroller circuit board to monitor and control the system. The implementation will also require installation of a Seebeck thermoelectric generator and an accompanying flow-control valve in the HTF pipe. An expensive modification will be to replace the existing single-speed AC HTF pump with a variablespeed DC motor, which the Seebeck generator may partially power.

Ideally, the result will be a self-contained system that requires no outside interference or control to produce the most energy possible from the available solar radiation. For most of the year in Texas, this energy level equates to nearly free hot showers for as long as one could desire.

ACKNOWLEDGEMENTS

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Figure 5: Simplified Seebeck generator used to create the Seebeck effect.

tivating me to pursue this project. I also thank Craig Ireton and Dylan McGarry for teaching me the heat transfer laws and properties required to model the system.

REFERENCES

- 1. Energy Information Administration (EIA); U.S. Department of Energy. Annual Energy Review 2008. Available from http://www.eia.gov/totalenergy/ data/annual/archive/038408.pdf. See appendix A, table A.5.
- 2. American Council for an Energy-Efficient Economy (ACEEE). "Water heating." 2012. Available from http:// www.aceee.org/consumer/water-heating.
- 3. Moskowitz I; Israeli Ministry of Foreign Affairs. "A solar-powered 'light unto the nations." 2010. Available from http://www.mfa.govil/MFA/InnovativeIsrael/ Solar_powered_light_unto_nations-Nov_2010.htm.

Phage Therapy to Treat Bacterial Infection David Migl

INTRODUCTION

Disease-causing bacteria are becoming increasingly resistant to antibiotics, and we are running out of ways to stop them. For example, methicillin-resistant *Staphylococcus aureus* (MRSA) has infiltrated hospitals worldwide, and some strains have recently developed resistance to vancomycin, an antibiotic of last resort.¹ To make matters worse, drug discovery pipelines at major pharmaceutical companies have run dry, and these companies are reducing their antibacterial drug discovery efforts.² Infectious disease threatens to reemerge as a major public health issue unless scientists can develop other ways to treat bacterial infections.

My undergraduate research focused on one such alternative, phage therapy. Bacteriophages, or phages, are viruses that infect and kill bacteria. Phage therapy harnesses the power of these natural bacterial predators by introducing them to the site of an infection, where they swiftly destroy their host bacteria. Using phages to treat bacterial infections represents an exciting new line of research that could give doctors new options to treat drug-resistant bacterial infections.

Phages, which infect only bacteria and are therefore harmless to us, go largely unnoticed in the everyday lives of most people. Nevertheless, phages are the most abundant biological entity in the world and have been waging a silent, unseen war with bacteria for far longer than humans have been using medicine to treat disease. Phages inject their DNA into a host bacterium, hijacking the host's resources to make more copies of themselves, and bursting the cell to release many more phage particles that will repeat the infection cycle. Scientists call phages that follow only this life cycle virulent phages. However, some phages exhibit an alternative lifestyle that allows them to lie dormant inside their host and wait for better conditions before awakening and resuming the normal infection cycle. These phages, called temperate phages, often carry genes that make the bacterium stronger and immune to killing by other phages. For these reasons, scientists generally agree that only virulent phages should be used for phage therapy.

Bacteriophages have several advantages over antibiotics, including ease of production, less chance for resistance to develop, and increased specificity. Scientists can easily isolate many phages from environmental sources such as soil, river water, or sewage. Phages replicate themselves efficiently, and a few phages can make billions of copies of themselves in a few hours from a flask of bacteria. Bacteriophages naturally adapt to bacterial resistance because the same mechanisms that drive drug resistance in bacteria also cause phages to adapt to changes in their hosts.

Finally, bacteriophages target harmful bacteria much more specifically than antibiotics. Unlike antibiotics, which target beneficial and harmful bacteria alike, individual phages infect only a few strains of bacteria, and doctors can tailor a phage treatment to a patient's specific infection. Because antibiotics and phages kill bacteria by completely different means, phages kill drugresistant bacteria just as easily as non-drug-resistant bacteria. Finally, phages will not harm human cells because human cells are vastly different from bacterial cells, and phages cannot exploit human cells. Bacteriophages offer a targeted approach to combating bacterial infections that minimizes harm to the patient.

PROJECT 1:

FINDING BACTERIOPHAGES FOR PHAGE THERAPY

I joined Dr. Ry Young's lab in the Texas A&M biochemistry department to find new bacteriophages for phage therapy. In my first project, I gathered basic biological information about a new phage, called Stau6, which kills *S. aureus*, the notorious bacterium that causes serious soft-tissue, bone, and bloodstream infections.

METHODS

First, my group sequenced the phage's genome by using high-throughput DNA sequencing. An organism's genome is the entirety of its genetic information, and studying a genome is the biological equivalent of peering inside the source code of a computer program. I used bioinformatics software to find genes, and I compared the phage's genes with an online database of all other known genes. Next, I used special enzymes to manually sequence certain segments that the highthroughput machines had missed. Finally, I used other enzymes to fragment the DNA, analyzed these fragments, and precisely located certain regions of genes that remained ambiguous after high-throughput sequencing.

RESULTS & DISCUSSION

I found three distinct regions of genes necessary for bursting the host cell (lysis), making bacteriophage parts, and copying the phage DNA (Figure 1). Although many of the phage's genes were new, with no known function, I found none that would allow the phage to carry out a temperate lifestyle. Thus, my phage passed the first test for becoming a candidate for use in phage therapy. it was virulent.

I also experimentally determined that my phage keeps an extra copy of a set of genes at both ends of its genome (Figure 1B), and I determined which genes are included in this set. This finding also clarified the genome structure of a family of phages closely related to Stau6, all of which are virulent phages that are prime candidates for use in phage therapy against *S. aureus*, including MRSA. Knowledge of a bacteriophage's genome helps scientists classify phages and predict the properties of related phages that may be isolated in the future. Through my research project, I established that my new phage, named Stau6, holds promise for treating S. aureus infections.

Unfortunately, several obstacles prevent phage therapy from achieving widespread clinical use. First, the U.S. Food and Drug Administration (FDA) mandates drug approval guidelines that make approval of phage therapy prohibitively expensive for companies. Ideally, doctors would tailor a combination of phages to each patient's infection, but currently each new phage or combination of phages would need to go through its own set of clinical trials. Also, phages' ability to morph to counter bacterial resistance makes FDA regulators uneasy, because the approval process is more suited to small-molecule drugs that have a defined structure and never change. Furthermore, patenting a phage could

prove difficult because phages have been used for therapeutic purposes in some parts of the world since the 1920s. Finally, the natural abundance of phages means that a patented phage may be similar to many other naturally occurring phages, which anyone could easily isolate from the environment. This scenario makes phages financially risky to a pharmaceutical company. These regulatory and patent issues limit the current clinical relevance of bacteriophages.

PROJECT 2:

MINING BACTERIPHAGES FOR THERAPEUTIC PROTEINS

Many researchers are trying to use individual phage parts to fight pathogens. Phages require the coordination of many proteins to replicate, but some of these proteins can individually kill the host bacterium or at the least reduce its disease-causing behavior. Although these individual proteins do not replicate themselves or display complex behaviors like whole bacteriophages, the FDA is much more likely to approve proteins as drugs. For these reasons, I started work on a phage protein that showed promise for treating *Acinetobacter baumannii* infections.

A. baumannii is less notorious than MRSA but just as nefarious; it causes drug-resistant wound infections particularly in wounded soldiers returning from the Middle East.³ Part of its infection strategy involves forming biofilms-secretions of sticky sugars that help bacteria clump together, stick to surfaces, and evade the body's immune system. Biofilms commonly form on catheters, intravenous lines, and wound surfaces and are correlated with the severity of an infection. Other researchers in my lab had found a new phage that infects A. baumannii and determined that it carries a protein that degrades the sugars surrounding the bacteria. Because these sugars are a part of biofilms, I reasoned that this protein should also be able to destroy biofilms and possibly reduce the severity of A. baumannii infections.



Figure 1: (A) Electron photomicrograph of bacteriophage Stau6, courtesy of Dr. Jason Gill. (B) Organization of the Stau6 genome.

METHODS

A former researcher had isolated the gene that encodes the protein responsible for degrading the sugars. To test my hypothesis that the protein degrades biofilms, I put the gene into *Escherichia coli* bacteria and used them to make enough copies of the protein to study. Next, I grew two strains of *A. baumannii* for 2 days on a polystyrene plate. *A. baumannii* formed a biofilm on the surface of the plate. I added the phage protein to the experimental group of *A. baumannii* biofilms, whereas I added water to the control group. After 10 hours I determined how much biofilm was left on the plate by staining the remaining biofilm and measuring how much dye the plate retained.

RESULTS & DISCUSSION

The phage protein reduced biofilms formed by strain 1 by 31% and strain 2 by 74% (Figure 2). Strain 1 is an isolate of *A. baumannii* from a clinical sputum sample, and strain 2 is *A. baumannii* isolated from a patient at Walter Reed Medical Center, in Washington, D.C.

The results in Figure 2 suggest that the phage protein could be useful in removing clinically relevant biofilms. The protein degraded some biofilms from different strains of A. baumannii better than others, emphasizing that doctors would need to precisely diagnose the strain of A. baumannii in a patient's infection before using the protein. The protein could be applied to the surface of a wound, but other strategies would be needed to deliver the protein deep into a wound or onto the surface of an implanted medical device. Finally, that some biofilms remain suggests that I could further optimize the protein's activity or that the biofilm consists of more than just sugars, and additional proteins would be needed to fully degrade the biofilm. Despite these caveats, the protein represents an exciting first step toward combating A. baumannii infections by targeting biofilms.

CONCLUSIONS

During my undergraduate research, I discovered two new phage weapons that might change how doctors treat drug-resistant bacterial infections. Further research is essential to unlock the full potential of phage therapy. Genomic studies like my first project hold promise for discovering new phages, and biochemistry projects like my second are useful for developing individual phage parts into therapeutics. Given that regulatory and financial issues can be overcome, I believe that bacteriophages offer hope for once again gaining the upper hand over our bacterial foes.

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REFERENCES

- 1. Hiramatsu K. Vancomycin-resistant Staphylococcus aureus: A new model of antibiotic resistance. The Lancet Infectious Diseases 2001;1:147–155.
- 2. Projan SJ. Why is Big Pharma getting out of antibacterial drug discovery? Current Opinion in Microbiology 2003;6:427–430. doi:10.1016/j.mib.2003.08.003.
- 3. Dijkshoorn L, Nemec A, Seifert H. An increasing threat in hospitals: Multidrug-resistant Acinetobacter baumannii. Nature Reviews Microbiology 2007;5:939–951. doi:10.1038/nrmicro1789.
- 4. Rodríguez-Baño J, Martí S, Soto S, et al. Biofilm formation in Acinetobacter baumannii: Associated features and clinical implications. Clinical Microbiology and Infection 2008;14:276–278.



Figure 2: (A) Electron photomicrograph of bacteriophage AbauYa¹, courtesy of Dr. Jason Gill. (B) Effect of the phage protein on *A. baumannii* biofilms.

Sharpie Shoes David Ehlig

Seeing a wild pair of personalized shoes given to my cousin first inspired me to draw on my own pair of shoes. Being too paranoid that I would absolutely ruin classic Vans, I stopped at Walmart and bought an \$8 substitute pair and all the Sharpie pens I could find. My first attempt was successful enough (though they are not shown in the picture), but after learning

how certain Sharpie colors bleed into others, I went out and bought a fresh pair to decorate.

My second, and somewhat more humorous, attempt brought about the 'Feet Shoes.' Though these were actually made with fabric paints, I still consider them my favorite pair of Sharpie shoes because of all the



reactions I get while wearing them. (You would be surprised how many people do a double-take with a "Is he really going to cross University barefooted?" kind of look.) So after a few weeks of proudly stomping about in my new pair of 'feet," I went back to Walmart and pestered the lady in the shoe department until four new pairs were mine. Now with a shoe stockpile and ready for business, I made a couple of pairs for friends and then started work on the Mona Lisa shoe. I made this one by using a standard black Sharpie and a silver metallic Sharpie, which allowed me to smear the black ink to create shade effects and make her face more realistic. Though this shoe turned out pretty well, I was too lazy

to draw some other black-and-white famous portrait on its right foot, so I opted for the next-best thing: a giant octopus destroying a pirate ship. This seemed like a good idea until I realized how silly I looked wearing two wildly different shoes.

The last pair shown in this picture is the Spider-Man-Batman pair. When I was younger, I always liked comics and superherces, and my favorites were Spider-Man and Batman, so my goal was to re-create some of the action on my shoes. Using some old comic books as reference, I pieced together and modified some of the scenes until I got my personalized action scene. Around the sides of the shoes and at their heels, I drew some of Spider-Man's and Batman's most notorious villains.

When deciding what to draw on a new pair of shoes, I usually go through many ideas before one idea seems particularly creative or challenging. I first sketch out on paper what I would like to put on each face of the shoe. Then, in pencil, I draw out whatever design I want to create. I later trace over the pencil with black, fine-tipped Sharpies and eventually add the colors.

Aside from enjoying work that stimulates my creativity, I make these shoes mainly because painting my own is the only way to make the shoes that I want. Another one of my favorite things about painting my Sharpie shoes is that when I'm finished, not only did I make something I enjoy looking at, but these shoes also become wearable pieces of artwork that spark interesting conversations. Wearing something that you crafted to be exactly how you wanted is quite rewarding and the design process is the best part.

Finding New Subatomic Particles

INTRODUCTION

Many unsolved mysteries in physics today fall under the purview of high-energy physics. Understanding these mysteries would be a great leap forward in our understanding of both the nature of matter and how the universe began. For years, scientists have known that more than 80% of matter in the universe is made of dark matter (matter that reflects no light and is not directly detectable),¹ but so far the only consensus among scientists is that dark matter is most likely an undiscovered subatomic particle. A long-standing theory called the standard model has accurately predicted many new particles such as neutrinos, quarks, and, the Higgs boson.

Another important theory in particle physics and can be tested is supersymmetry, an alternative to the standard model that also explains dark matter. To create and study particles such as the Higgs boson in highenergy collisions and detect them with sensitive detectors, scientists have built particle accelerators and detectors at Fermilab in Batavia, Illinois, and the Large Hadron Collider (LHC) in Geneva, Switzerland. However, nearly all collisions produce other, already understood particles that look similar to our new particles, so looking for these particles is truly an effort to find something fleeting and rare. Thus, to find new particles such as dark matter or the Higgs boson, we seek to develop better methods to analyze data. In particular, we test a new method on a recent experiment from the Collider Detector at Fermilab to see whether we can improve the sensitivity to new particles.

HOW TO FIND NEW PARTICLES AT FERMILAB & THE LHC

To find new particles in our detectors at Fermilab and the LHC, scientists have to look for some specific signature of the new particles because the particles rarely interact with detectors directly. In an experiment² at Fermilab that looks for dark matter, the detector would register seeing two photons, the particle of light; 'jets,' other known particles; and some imbalance in energy due to the presence of some particles, the dark matter candidate particles, that pass through the detector without direct detection (Figure 1). In general, the mass of a particle will affect how many times it is produced in collisions, with more massive particles produced less often and less massive particles produced more often. Depending on how many of these events occur, we can either prove the existence of a new particle or set exclusion regions for the mass of the particle if it did exist. If we can improve our analysis techniques, we then can more conclusively prove the existence of a particle or exclude larger regions of its mass. We can derive a quantitative measure of how much our new techniques improve the sensitivity of our search by using the real data from the Fermilab experiment. Because the data correspond to 5 years of data collection at an hourly cost of approximately \$10,000, even a small improvement can have enormous value.

Unfortunately, when we look for events from new particles in our detectors, we must account for other processes that would cause our detector to see the same signature as our dark matter event. These events would



Figure 1: Time increases from left to right. Quarks (q and bar{q}) come in, collide, and produce the two χ which then decay in a fraction of a second. Lines on the right are particles that would hit the detector and could indicate evidence of supersymmetry.

Figure 2: Relationship between signal and background. The separation between signal and background increases on the right, but the total number of events decreases.



Figure 3: Comparison of the sensitivity of using one selection criterion and two selection criteria. The red dotted line is the best sensitivity for a single criterion. Values under the red dotted line indicate where using two selection criteria is more sensitive to signal.

be indistinguishable in our detector from the events of interest. For our experiment, these background events would be from other particle interactions; cosmic rays, particles created in the upper atmosphere that hit our detectors; or long-lived particles created by the particle beams in the collider itself. Figure 2 shows the expected distribution of energy of the collisions (called events) from background sources and the dark matter particles (here called signal). If a new particle is present, most of the events will have a large energy.

SELECTION CRITERIA

Because we expect few events from signal, we often simply count the events that have a large amount of energy and compare with our expectations. We call this process 'selecting events' and can apply selection criteria to count all the events above some energy level. Different values of the selection criteria make the experiment more or less sensitive to the signal of new particles depending on the number of signal and background events expected. We then say that our experiment is 'optimized' when we use the most sensitive criterion. Because background events dominate low energies, a reasonable selection criterion could be that energy must be higher than some value.

SINGLE SELECTION CRITERIA

The simplest approach is to use a single selection criterion and integrate all the remaining events. For example, we could use a value of 140 GeV and add up all the events corresponding to energies above 140 GeV. This number of events would correspond to how many background and signal events would be expected in this range of energy. If we take a low criterion, we will find many signal events, but many more background events would be present. Conversely, if we take a high criterion, we will find few background events but also few signal events. Think of this process as trying to take the best slice of pizza from a box: the best slices are covered in toppings, but you would rather not be stuck with a tiny piece just because it is well covered. From the total signal and background events, we use a program³ to calculate the sensitivity of using different selection criteria.

TWO SELECTION CRITERIA

A more sophisticated approach is to use two selection criteria. We can do this by splitting the set created by a single selection criterion into two sets, A and B, and treating them as two separate experiments. We can then use the same program to determine the crosssection limits. Ideally, this method allows for more information to be used, so it should be more sensitive to the signal. We compare the two methods (Figure 3) by holding B fixed and varying A to see in a single dimension whether one or two selection criteria is more sensitive.

CONCLUSIONS

Using two selection criteria can increase the sensitivity of our experiments to the discovery of new particles. Not all choices of two selection criteria are more sensitive than a single, optimized criterion. This finding has important implications for new research in high-energy physics and searches for particles such as the Higgs boson and supersymmetric particles such as dark matter. If we can increase the sensitivity to new particles, we can get more statistically significant results for lower cost, or higher sensitivity for the same experiment. For this experiment in particular, we found an approximately 8% increase in sensitivity by using our method. This increase corresponds to a huge cost improvement; we could get the same results as the 5-year experiment 4 months sooner, saving \$32 million in data collection cost. With higher sensitivity, we can be more confident in our results if we observe an excess of events, hinting at a new particle, or exclude with higher confidence possible masses of new particles. New particles or even exclusions of particles can be used to prove and disprove theories such as the standard model and newer theories such as supersymmetry, a precursor to string theory, an important theory in cosmology that offers a possible explanation of the big bang and the first moments of the universe.

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REFERENCES

- 1. Jarosik N, Bennett CL, Dunkley J, et al. Seven-year Wilkinson Microwave Anisotropy Probe (WMAP) observations: Sky maps, systematic errors, and basic results. Astrophysical Journal Supplement Series 2011;192:1–15. doi:10.1088/0067-0049/192/2/14. Available from http://lambda.gsfc.nasa.gov/product/ map/dr4/pub_papers/sevenyear/basic_results/ wmap_7yr_basic_results_reprint.pdf.
- 2. Lee ÉS. Search for supersymmetry using diphoton events in proton-antiproton collisions at a center of mass energy of 1.96 TeV. Ph.D. thesis. Texas A&M University, May 2010. Available from http://lss.fnal. gov/archive/thesis/fermilab-thesis-2010-10.pdf.
- 3. Conway J. Calculation of cross section upper limits combining channels incorporating correlated and uncorrelated systematic uncertainties. March 21, 2005. CDF note 6428. Available from http://wwwcdf.fnal.gov/physics/statistics/notes/cdf6428_ comb_limits.pdf.

Groundwater Study at Armand Bayou Nature Center

INTRODUCTION

Wetlands are a vital feature in many ecosystems. They help detoxify the surface water that runs into adjacent water bodies. Wetlands along the coast soak up rain to help control flooding during hurricanes. The water that flows underneath the soil, called groundwater, is contained in areas called aquifers. Aquifers help the adjacent water body by constantly resupplying the water body with more water. If groundwater were to run out, such as during extended droughts, the adjacent body



Figure 1: Cross-section of an aquifer that shows the slope of the water and how it is measured using multiple wells.⁴

DEREK MORRISON

of water would be more susceptible to drying up. An example of this was seen during the summer of 2011 all across Texas. Protecting wetlands is important to ensure that the water flowing into our lakes, rivers, and bays is clean and plentiful.

I studied how drought affected two aquifers at the Armand Bayou Nature Center (ABNC). ABNC is in Houston, Texas, situated partially on a wetland. ABNC has safeguarded 2,500 acres of land since 1974 to protect the ecosystem and educate the population about the environment. The center was created when many individuals, corporations, and government agencies acquired the 2,500 acres to honor the loss of a local environmentalist named Armand Yramategui. Yramategui saw that recent land purchases, made by NASA and industries such as oil companies, were encroaching on the local environment. He made wilderness preservation in this area his life's goal. The nature center offers people a way to experience nature close to their home.¹ Since the passing of the Clean Water Act in 1977, the United States has tried to ensure that wetlands do not disappear. According to the Clean Water Act, if the groundwater is connected to a navigable waterway, such as Clear Lake, ABNC could become a protected wetland.²

This project sought to determine the slope and the direction of groundwater flow in ABNC. The slope of the groundwater refers to the difference in height, measured from the same elevation, of the two wells divided by the length between the wells (Figure 1). The groundwater at ABNC is held in two aquifers: a shallow aquifer and a deeper aquifer (Figure 2). The shallow aquifer is located just below ground level, and the water in this aquifer often rises above ground level. An underlying later of clay prevents water in the shallow aquifer from permeating into the deeper aquifer beneath.

To investigate the effect of rainfall and bayou level on the slope and direction of flow of the two aquifers, we monitored four pairs of wells (Figure 3). The U.S. Geological Survey triangular method requires three pairs of wells to determine the slope and direction of flow.³ Four pairs of wells were constructed so that we could



Figure 2: Cross-section of well nest, including well stick up and well screens, and corresponding layers of soil and aquifers studied at the ABNC research site.

use two independent triangle configurations to determine the direction of flow and slope for each aquifer. We also examined the similarity between the two triangular configurations.

METHODS

The four pairs of wells were installed at the ABNC near the bayou (Figure 2). Each nest consisted of two wells, shallow and deep. We placed a single monitoring well at a nearby dock to monitor the water level in the bayou. We monitored each well pair, along with the well at the dock, weekly for two summers. The summer of 2010 was a wet season, with 1781 inches of rainfall over the monitoring period, and the summer of 2011 was unusually dry, with 5.8 inches. The 2011 drought was so severe that some days the shallow aquifer was empty. This drastic difference indicates how groundwater flow in a wetland can change during drought.

Using Microsoft Visual Studio, we created a computer program to more fully automate the determination of slope and direction of flow. The program uses the latitude, longitude, and well depths as inputs to determine slope and direction of flow.

RESULTS

Using the method described in Basic Ground-Water Hydrology³ we calculated the slope and direction of flow each week in each aquifer. The water flowed toward the bayou in both aquifers, generally flowing south-southeast. To determine whether an association among slope, direction of flow, rainfall, and bayou levels existed, we averaged the two triangular configurations for each week.

SLOPE

The data showed that when the ground is constantly saturated, as during the wet period of 2010, the slope in both the deep and shallow aquifers increased after a significant rainfall event. When the ground was constantly unsaturated, as during the 2011 drought, we found no correlation between slope and a rainfall event in either aquifer. We also compared the slope and direction of flow for each aquifer with the level of water in the bayou. Both aquifers during the rainy period in 2010 showed a positive correlation between slope and bayou level, whereas no such correlation existed during the dry period of 2011.

Horizontal Hydraulic Gradient



Figure 3: The four well nest locations, the dock well, and the two triangular configurations used to determine the slope and direction of flow at ABNC (Google Maps).

DIRECTION OF FLOW

For both the wet and drought periods, we found no connection between direction of flow and rainfall. We also found no connection, in either year or aquifer, between the direction of flow and the bayou level. Throughout the research period in the wet year, the deep well had a positive association between the direction of flow and slope, whereas the shallow well did not. All through the drought period, both the deep aquifer and the shallow aquifer had negative correlations between the direction of flow and slope.

WELL NEST TRIANGULAR CONFIGURATIONS

In general, the two well nest triangular configurations were similar for both slope and direction of flow. During 2010 the two configurations were more similar than in 2011. Also, the deep and shallow aquifers in both years tended to flow in the same direction with an analogous slope. As with the two configurations, the 2010 data showed a more uniform direction of flow and slope between the two aquifers.

RECHARGE TIME

Another important aspect of wetlands is recharge time: how fast rainfall will affect the levels in the aquifers. In general, the shallower the aquifer is, the faster it will recharge. During this experiment, recharge times were consistent during the wet season. Conversely, during the dry conditions of 2011, we could determine no definite results for recharge times.

CONCLUSION

Armand Bayou flows directly into Clear Lake. Any water (including groundwater) that alters Armand Bay-

ou would also alter Clear Lake, a navigable waterway. Therefore, ABNC could qualify to become a protected wetland. I will share these results with ABNC faculty and staff so that they may pursue this objective.

Drought conditions altered the flow of the water in the aquifers. The slope for both aquifers decreased because of lack of rain. However, the drought conditions did not change the direction of flow of the two aquifers in the same way. The shallow aquifer moved more toward the south, whereas the deep aquifer moved more toward the east. The recharge times were also drastically altered during a drought, probably because the ground needs to be saturated and the vegetation will consume the water, leaving little water to be released in the aquifers. Our research also shows that the data from the two triangular configurations of well pairs were consistent.

REFERENCES

- 1. Armand Bayou Nature Center (ABNC). 'About us.' 2011. Available from http://www.abnc.org/about-us/ abnc-faqs.html.
- 2. Environmental Protection Agency (EPA). 'Laws, regulations, treaties: laws.' 2011. Available from http:// water.epa.gov/lawsregs/lawsguidance/cwa/wetlands/laws_index.cfm.
- 3. Heath RC. Basic Ground-Water Hydrology (4th printing). Denver, CO: U.S. Geological Survey, 1987.
- 4. Portage County. "Hydraulic gradients." 2008. Available from http://www.co.portage.wi.us/groundwater/ undrstnd/gwmove2.htm.

RILEY EMMONS

Riley is a senior Spatial Sciences major from Cedar Hill, Texas. Emmons chose Spatial Sciences because she enjoys helping people and working with animals, and hopes to help both groups in the future using cutting edge technology. Emmons became interested in sea level rise because the issue is both social and scientific. Her goal is to make a positive difference in people's lives through this research.



BETHANY KRAKOSKY

Bethany is a senior Economics (B.S.) major from Oak Leaf, Texas. Krakosky became interested in the theories behind different investing strategies after spending a summer as a research fellow in the Economics Undergraduate Research Opportunities Program (EUROP) during the summer of 2011. These studies culminated in a 2012 Undergraduate Research Scholars Thesis, from which her article is drawn. After graduating, Krakosky plans to work in banking or research for two to three years, and then pursue a graduate degree in finance or economics. Ultimately, she hopes to become a college professor.

KEVIN BARNETT

Kevin is a junior Chemical Engineering major from Cedar Hill, Texas. Barnett feels that sustainable energy is a very important issue facing humans today. He is currently working on research with Dr. Wilhite to improve the effectiveness of preserving food and make items fireproof by preventing the ability of oxygen to permeate through protective layers such as food containers and electronics. Barnett looks forward to a future in researching sustainable energy.

MEAGAN SIEHR

Meagan is a senior Molecular and Cell Biology major from McAllen, Texas. Her research to understand how the brain and nervous system develops and how abnormal development can cause disorders like autism is very important and personal. Her family has been directly affected by neuro-developmental disorders inspiring her research. Siehr plans to attend graduate school and earn a PhD in Molecular Human Genetics at Baylor College of Medicine. In the future she hopes to be able to pursue research in molecular genetics.



STEPHANIE FLOREZ

Stephanie is a senior Biomedical Science and Chemistry double major from Bogota, Colombia. Florez is fascinated by the way nature finds the most elegant and simple way to make things work. Her work using polymer chemistry to construct nanoparticles that can deliver therapeutics to damaged tissues is an example of such elegance of function. Florez' research resulted in a 2011 University Undergraduate Research Fellow distinction. Florez plans to earn an MD/PhD and specialize in ophthalmology or neurology.





ERIN MCGREGOR

Erin is a senior Biomedical Sciences major from Paris, Texas. Her research was inspired by a love of animals and the opportunity to have a major impact on the field of veterinary medicine. McGregor's research towards a better assay for Lyme disease that can be used in all animals earned her a 2012 Undergraduate Research Scholar distinction. Her research project reflects her future goal of becoming a pharmaceutical researcher who will be instrumental in developing new or improved therapies. As a first step, McGregor plans to attend pharmacy school.

DAVID EHLIG

David is a freshman Chemical Engineering major from Kingwood, Texas. Ehlig's creativity was sparked when a cousin was given a pair of personalized shoes and he decided that making his own pair would be both fun and a challenge. Ehlig plans to work internationally as a chemical engineer upon graduation and is contemplating earning a Master's degree.



DEREK MORRISON

Derek is a senior Biological and Agricultural Engineering major from Pasadena, Texas. Morrison's study of the aquifers at the Armand Bayou Nature Center was inspired by time spent there as a child while on family picnics and outings. His fond memories made him leap at the possibility of conducting research that might enable the Nature Center to be placed on the list of protected wetlands, ensuring that many more generations of Texans would be able to enjoy the Nature Center as he did. His research earned Morrison a 2012 Undergraduate Research Scholar distinction. Morrison plans to continue his education at Texas A&M to earn his Master's and Doctorate, eventually becoming a professor.



MARK MIMS

Mark is a 2010 graduate with a Nutritional Sciences major and Creative Studies minor from San Antonio, Texas. Mims' research on the effect of caffeine on creativity perfectly captured his interest in two very diverse topics and proved to be the perfect way to provide a new approach to studying creativity. Mims is currently applying for medical school.



HOLLAND KAPLAN

Holland is a senior Biology and Philosophy double major from Copper Canyon, Texas. His study of the platypus genome was inspired by the unusual position the platypus holds in mammalian evolution and the possibility of illuminating platypus biology. Kaplan's project piqued his interest in genetics and led to his current goal of conducting research on the genetic basis of cardiovascular and kidney disease. He hopes to maintain his interest in philosophy by studying medical ethics and humanities while in medical school.

CHRISTOPHER DAVIS

Christopher is a junior Physics major from Georgetown, Texas. Davis' research was sparked by a need to develop new techniques to analyze data from the Large Hadron Collider buried beneath the Swiss/French border in the search for new subatomic particles. Davis also has a love of international travel and served as a student peer leader for the MSC-Honors International Leadership Conference. His experience with his research project has led David to his goal of earning a PhD in particle physics and engaging in a career in particle physics research.

DANIEL MILLER

Daniel is a junior Electrical Engineering and Applied Mathematical Sciences double major from Austin, Texas. His research improving the efficiency of renewable energy allowed Miller to combine his expertise in engineering with his mathematical knowledge to advance a field he is interested in working in upon graduation. Miller will be extending his project as part of the Undergraduate Research Scholars program. Upon graduation, Miller plans to earn a Master's in Electrical Engineering.

David is a senior Molecular and Cell Biology major and Chemistry minor from Hurst, Texas. His interest in biomedical research led to his project on using phage and phage proteins as anti-bacterial agents. While parts of his project were basic biochemical research, his interest in medical relevance led him to test his proteins on the problem of bacterial biofilms. Migl's project earned him a 2012 Undergraduate Research Scholar distinction. This fall Migl will begin graduate work in Biophysics at Harvard. He plans to run his own research laboratory in a pharmaceutical company to design new drugs.

MOLLY STREHL

Molly is a sophomore Anthropology major from Arlington, Texas. Strehl's photographs of the aftermath of the Bastrop fires reflect her interest in the psychology underlying the design and placement of artifacts in an area affected by disasters. Her photographs also build on a long-standing interest in using photographic composition to capture the unexpected. Upon graduation Strehl hopes to attend graduate school in Chicago and incorporate her love of art in her future career.

ANDY CHO

Andy is a senior Electrical Engineering major with a minor in Mathematics from Orange, Texas. Cho's project on mathematical modeling of infectious disease using the popular zombie apocalypse scenario reflected his desire to work on research that was not only original but also allowed him to present the usual scientific material in an entertaining and intriguing format for all audiences. Upon graduation Cho plans to attend graduate school and pursue an entrepreneurial career in electrical engineering.

DAVID MIGL









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Left to right: Madeline Matthews, Samir Lakdawala, Bobbie Roth, Hilary Porter, Jenny Russell, Rebecca Cross

»SARAH ARMSTRONG / Senior Editor and Designer

Sarah is a senior Economics and Political Science major, and is also pursuing a minor in Mathematics. She has interned abroad, working in grassroots development, and is involved in a variety of organizations on campus, including the Memorial Student Center. Additionally, she has worked as a reporter for a local publication. Upon graduation, she hopes to complete a doctoral program in Economics. Her interests include photography, reading, and traveling.

»ANNABELLE AYMOND / Editor and Designer

Annabelle Aymond is a junior Telecommunication and Media Studies major as well as a Japanese Language minor from Houston, Texas. She loves photography and graphic design, hoping to combine those into a career in the future. She joined Explorations in efforts to refine her design and marketing skills and to make the art community more prominent throughout the wonderful Texas A&M.

»REBECCA CROSS / Editor

Rebecca Cross is a senior Molecular and Cell Biology major from Midland, Texas. She joined the Explorations Board because she loves the opportunity to help showcase the efforts and achievements of some of the brightest, motivated and perseverant minds on campus. After graduation in May 2013, she plans to attend medical school.

»ALIFYA FAIZULLAH / Senior Editor

Alifya is a senior Nuclear Engineer major. When she is not studying or working on Explorations, she enjoys painting and astronomy. She hopes to work in the nuclear industry as a power plant operator, or provide soluctions in fuel cycle and waste management.

«About the Board

»SAMIR LAKDAWALA / Editor

Samir Lakdawala is a junior studying Chemical Engineering with an interest in High Energy Particle Physics Currently, Samir is diligently working on developing methods to improve the efficiency and discriminating power of trigger systems for the CMS experiment at the Large Hadron Collider. After graduation, he would like to work for a company which will allow him to use his knowledge of chemical engineering to make revolutionary changes to the industry. When he is not studying or working on his research, he cooks, plays tennis, and spends time with his family and friends.

»JENNY RUSSELL / Senior Editor

Jenny is from Baton Rouge, Louisiana, and is a senior Political Science major with a minor in Philosophy. She became involved in Explorations because she is passionate about undergraduate research and committed to showcasing the accomplishments of other Aggies. After graduating this December, Jenny plans to attend law school or a master's program in public policy or national security. She is aiming for a career that will let her travel the world.

»MADELINE MATTHEWS / Editor

Madeline Matthews is a junior Psychology/Economics double major from Boerne, Texas. She loves Texas A&M University and believes that every student should participate in the research process whether by consuming or producing She is currently involved in a cognitive science laboratory on campus. After graduation, she intends on applying to graduate school and law school.

»HILARY PORTER / Editor

Hilary Porter is a junior from Fort Worth, Tx. She is double majoring in Anthropology and International Studies on the Arts and Culture track. She hopes to be a museum curator and plans to attend graduate school upon graduation. Her interests include watching foreign films, reading and traveling,

»BOBBIE ROTH / Editor

Bobbie is a senior Environmental Geoscience major from Houston, Texas Her main focus with her studies is water quality and water management. She hopes to gain work experience and further her education by balancing a career and graduate school shortly after graduating with a B.S. in Environmental Geoscience. She loves dancing and watching old movies.



guidelines for submissions

WHO CAN SUBMIT A PROPOSAL

Any undergraduate student currently enrolled at Texas A&M University who is actively pursuing research, creative, or scholarly work or has done so in the past. All submissions must be sponsored or endorsed by a faculty member at Texas A&M University. Explorations publishes student research and scholarly work from all disciplines.

FORMAT FOR PROPOSALS

When submitting your proposal for consideration, please include the following:

- Name
- Email address
- Phone Number
- Department
- Classification
- Area of research
- Name and contact information of your faculty advisor/mentor
- Title of the proposed project
- Your contribution or role in the research
- An abstract of no more than 250 words. The proposal should provide an overview of the project's objectives and methods. It should also include a description of the project's importance to the student's field of study and to others outside the field.

NOTE:

Because Explorations is a multi-disciplinary journal, targeting a general audience, please use non-technical language in your proposal. Necessary technical words must be defined.

FORMAT FOR CREATIVE WORKS

- Only one submission per student
- All creative work requires a faculty endorsement. A faculty member in the field of your work must approve your piece for publication in a serious scholarly journal. If you have difficulty locating a faculty member to review your work, Explorations may be able to provide suggestions.
- All genres of creative work are welcome; however, due to the requirement for faculty endorsement, please remember that your submission should relate to creative work currently being taught at the university.
 - Your work must be accompanied by a descriptive sidebar of 500-700 words. The sidebare must include:
 - Why did you choose this topic?
 - Who are your creative influences?
 - How does this style or medium help you to communicate your idea?
 - What studies were done to develop your piece? How did they contribute to its persuasiveness, depth, vision, or styling?
- Please, limit prose and poetry submissions to 3500 words. This word limit includes your scholarly sidebar, a minimum of 500 words.

Deadline for submissions is to be announced; however, submissions are typically welcome at the end of the fall semester. Please, visit explorations.tamu.edu for more information.

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