



Scientific Terrapin

VOLUME III, ISSUE I

FLUORESCENCE POLARIZATION

Applications to study DNA binding affinity

MARXISM & COLONIALISM

Exploring the parallels between capitalism and racism

OBSERVING EXOPLANETS

Using photometry to detect transits



solar decathlon

BUILDING A HOME, ONE SUSTAINABLE MATERIAL AT A TIME

PLUS: *Meet three professors studying three aspects of the environment*

Cover images courtesy of Charlie DeBoyace.



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VOLUME III ISSUE I





STAFF LIST 2011

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MISSION STATEMENT

Here is a secret about research that only researchers know: it only looks easy.
Here is the truth about research: it is not easy at all.

It is a seemingly endless literature review, your browser complaining when you open the fiftieth tab, but you are the one who wants to cry when the perfect article denies you access. It is coaxing your cells to grow, until you are willing to sell your soul for data, any data, never mind the gorgeous histology in other people's papers. It is curling in the fetal position when very expensive equipment breaks, right when you need it.

Research is primarily the art of running into walls, finding the sheer stubborn will to shake off the concussion, and charging at the wall again. Some might say performing the same actions and expecting different results is insanity. In research, it's just the scientific method.

The University of Maryland, College Park has long been established as a top national research university. It is consistently named as one of the top fifty research universities and one of the top twenty-five public research universities in the nation. The university acquired \$401 million in research money in 2008, offering a means for looking at the world through a kaleidoscope of perspectives.

But how can a research institution reach its full potential if the undergraduate students are overlooked and pushed to the periphery? Before now, there have been few avenues for students to share their work with the rest of the community. They have had little opportunity to engage in academic discussion and debate. We foster a "culture of research" by providing an outlet for students to publish work across all disciplines, including:

Life Sciences:	biology, chemistry, biochemistry, ecology
Applied Sciences:	engineering, mathematics, computer science, physics, geology
Social Sciences:	economics, government/politics, psychology, business, sociology

We seek to connect student researchers with one another, so they might form intellectual partnerships and friendships. We sponsor workshops and presentations to not only encourage interdisciplinary discourse, but to share research opportunities and practical advice for advancement in their fields.

Scientific Terrapin celebrates the insanely brilliant (or brilliantly insane) student researchers. We salute students for their initiative, their dedication, and their pursuit of knowledge. We herald the work of promising young minds and extraordinary mentors. We offer a stepping stone for burgeoning, bright scientists at the beginning of their careers.

But mostly, we are honored to have ringside seats for the wave of exciting research produced at the University of Maryland.



CALL FOR SUBMISSIONS

We will be accepting submissions for the May 2011 issue of the journal until February 16, 2011. We encourage you to submit your work with a faculty mentor on campus, your findings from an internship, or an abridged Honors thesis or Gemstone paper in a scientific research article. The journal is accepting articles in the fields of life sciences, social sciences, and applied sciences. Submission details and guidelines can be found at our website, scientificterrapin.umd.edu.

Scientific Terrapin models our review process after professional journals. It is designed in a manner to provide authors rigorous and valuable criticism to help them learn about the scientific writing process and to improve the quality of their analysis. Upon submission of a manuscript, a qualified student editorial staff conducts an initial peer review. Components such as quality of analysis, scope of work, and quality of writing are evaluated. The manuscript is then returned to the author with a request for revisions. Revised manuscripts are then shared with University of Maryland faculty members in the field of the work in review. Faculty members evaluate the quality of the work and its contribution to the field. The recommendations of faculty members deem whether the work is published. Any required revisions are returned to the author to make changes. A final version of the manuscript is then prepared to publish in the journal.

ACKNOWLEDGEMENTS

We would like to thank our faculty reviewers for offering their valuable time to review student submissions. We would also like to thank **Dr. Francis DuVinage (Maryland Center for Undergraduate Research)** and **Dr. Kaci Thompson (Howard Hughes Medical Institute)** for their generous funding, wise guidance, and unwavering support.



Professor Profile

meet Dr. Bryan Eichhorn

By: Maggie Beatson

As a college student, Professor Bryan Eichhorn started out on the premed track, but found his true calling after taking an organic chemistry class. “[Organic chemistry] was so cool that I wanted to do that,” he said. “Graduate school is when I really fell in love with research. It was one of the best times of my life.”

Now in his 22nd year at the University of Maryland, Eichhorn primarily conducts research in material science – the creation of new molecules with the ultimate goal of solving the energy and environmental issues – because he wanted his work to

tackle big issues and to have a positive impact on society. One of his latest projects focuses on making new catalysts, a key substance involved in many industrial processes and products. “Catalysts are materials that convert chemical reactions at a lower energy barrier,” Eichhorn said. “Catalysts are used in everything, catalytic converters in cars, for example.” He has been working for the past five years on this specific project and hopes to ultimately create a new catalyst to aid development of fuel cells. “Fuel cells are devices that convert chemical energy to electricity without moving parts,” he said. “They’ve been around for a long time, but they have a lot of problems. All the problems almost entirely come down to materials, so we do material research to try and get that technology to work.” Eventually, he hopes that his research can be used to develop new technologies, such as developing cars based off of the improved fuel cells.

Eichhorn and his team have conducted all of their research

in labs at the University of Maryland with the help of several grants from the Department of Energy, the National Science Foundation and the Navy. Some of their results have been tested on real-world scales

“ To pursue research anywhere requires passion...”

with the help of Maryland engineers who create prototypes to test the fuel cells. Interestingly, the main focus of their research was found inadvertently. “We made [an accidental] discovery on making a new catalyst that can actually work using natural gas in a fuel cell,” Eichhorn said. “If you can do that routinely that can be a very useful technology.”

For Eichhorn, a good part of his job’s pleasure comes from teaching his students and preparing them to help advance technology. “Training students for what some call ‘the third industrial revolution’ is very exciting,” Eichhorn stated. “Distributed power is already going away. Everybody’s going to have personal power plants in their house, at some point, and that’s going to require a lot of material science and technology.”

Eichhorn asserts that conducting research anywhere requires passion because it can be frustrating as the results are so unpredictable. “In research, you never know what’s going to happen,” he said. “You always think you know what is going to happen, but really something else happens, which is why it’s fun.”





Up in the air

the adventures of Professor Jeffrey Stehr

By: Abigail Ahlert

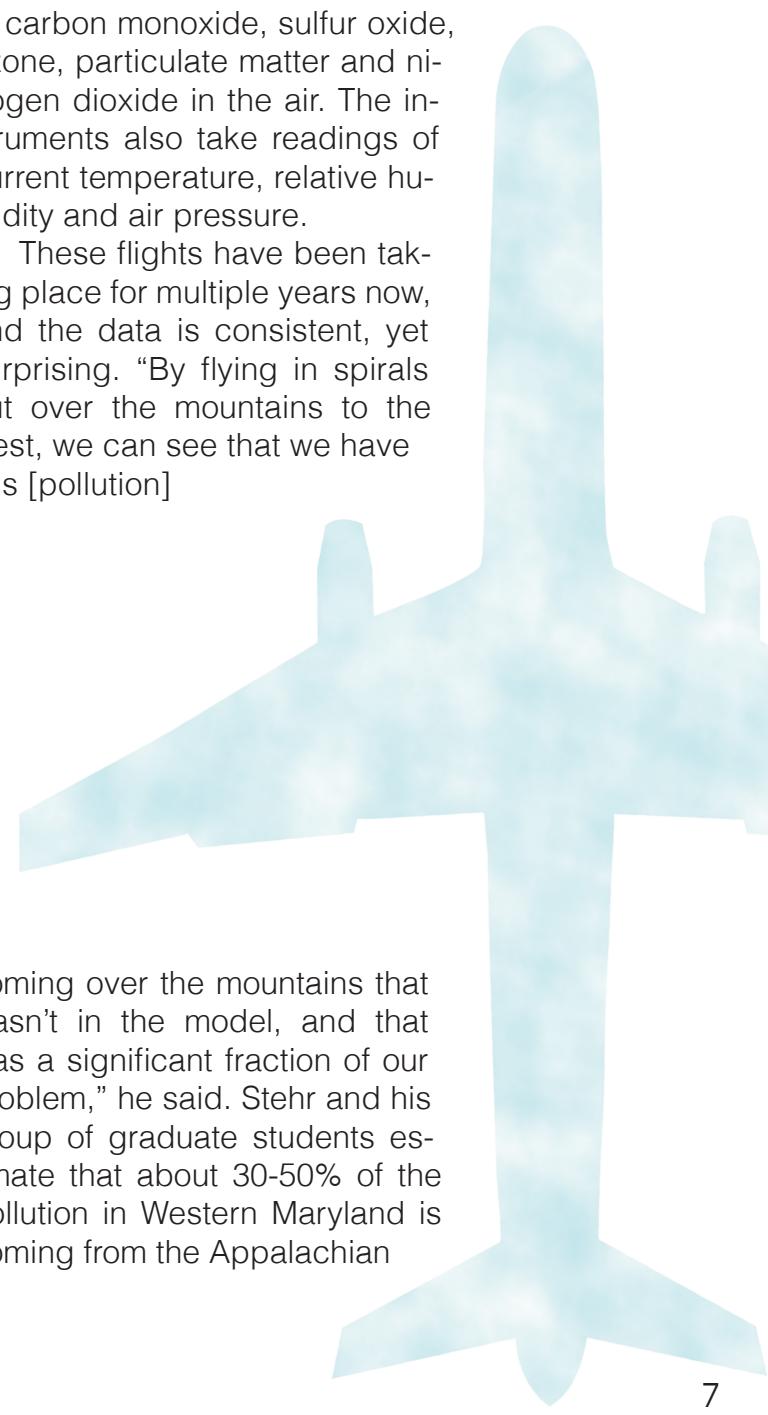
Upon arriving at the office of Professor Jeffrey Stehr, I was not at all surprised when the first thing he asked me was, “So how are you enjoying the Maryland weather?” If anyone is willing (and, indeed, excited) to talk to me about weather, it would be this professor of atmospheric science.

Stehr received his graduate degree in physics from the University of Michigan, and is currently the associate director of the brand new undergraduate Atmospheric and Oceanic Sciences (AOSC) program at the University of Maryland, College Park. He plays an active role in promoting and conducting research with the help of both graduate and undergraduate students while building the foundation for a new major.

Stehr’s research is primarily focused on air pollution and atmospheric chemistry, and his team currently holds a contract with the Maryland Department of the Environment. Their goal is to use measurements of different chemical compounds collected from a small private airplane at different positions and altitudes to model the composition of the atmosphere with more detail and accuracy than others have before. “The idea there is, with this small airplane you can get into these tiny little airports and get all the way down to the ground, then spiral up. By getting that profile with all those measurements, you get to really challenge the model in a way that it’s not used to being challenged,” Stehr said. “Most of the [original] models have been evaluated with surface measurements. Those will tell you a lot—and are relatively cheap compared to what we’re doing—but they really can’t tell you what’s going on aloft.”

Stehr and his team take the plane up on hot days in the summer, when air quality can vary dramatically. The plane heads west or south of Washington, D.C., depending on the wind direction that day. As it flies, eight different instruments measure the amounts of carbon monoxide, sulfur oxide, ozone, particulate matter and nitrogen dioxide in the air. The instruments also take readings of current temperature, relative humidity and air pressure.

These flights have been taking place for multiple years now, and the data is consistent, yet surprising. “By flying in spirals out over the mountains to the west, we can see that we have this [pollution]



coming over the mountains that wasn’t in the model, and that was a significant fraction of our problem,” he said. Stehr and his group of graduate students estimate that about 30-50% of the pollution in Western Maryland is coming from the Appalachian



Mountains and the Ohio River Valley, primarily from its industrial and automobile emissions.

In addition, Stehr is also involved in the Linear Comparison Campaign with the National Aeronautics and Space Administration (NASA). Last summer, Stehr's group took their small plane and equipment around the outskirts of Washington D.C., while a NASA P3 plane took concentration readings within the metropolitan area. The planes were flown at the same time as a satellite taking the same measurements passed overhead. The data was compared and used as part of a NASA project to improve satellite readings of atmospheric conditions.

These affiliations and the results of their research are extremely relevant to areas along the East Coast, especially Washington, D.C.

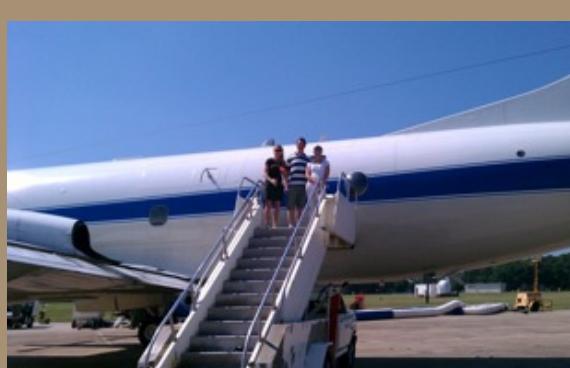
"We are pretty ideally situated to get transport from the Ohio River Valley. On high air pollution days, you can see the way it sets up and just comes right over the mountain," Stehr said.

While Stehr has extensive experience researching atmospheric chemistry, he now has a new role as the Associate Director of Undergraduate AOSC. This major spans multiple different topics, including meteorology, climatology, marine science, atmospheric chemistry and atmospheric physics. Though the major is new to Maryland, the AOSC department is not. It started off as part of a research institute that still exists today — the Institute for Physical Sciences. "At some point they realized that they had a bunch of dynamical modelers, who were really meteorologists, and

they broke off and formed their own department," Stehr explained. After the department was created, graduate students were soon incorporated, and now, after years of battling for support and funding, the undergraduate program has, too, been approved.



Professor Jeffrey Stehr.



Stehr with two graduate students, Heather Arkinson and Lacey Brent, at the NASA Langley Research Center.

The University of Maryland, College Park, is currently the only school in the state to offer an AOSC undergraduate degree. However, it is an increasingly popular field. According to the Bureau of Labor Statistics, employment of atmospheric scientists is projected to increase by 15% over the next 10 years. "This is a major where you can actually go out and get a job," Stehr said. "You can get a job with a bachelor's degree in this major, and in physical sciences, that's kind of tough to come by."

Due to multiple political and economic interests, the Department of Agriculture, NASA, reinsurance firms and consulting firms have all found weather data to be a necessary factor in their work. Stehr believes that climate change is undoubtedly playing a role. "People want to know what's going on with climate change, whether they believe it's going on or not...you need to know what's happening," he said.

With concerns of climate change as a continuously controversial topic, demands for scientific explanations and solutions are high. Between conducting air pollution research and playing a large role in Maryland's addition of the new undergraduate major, Stehr and the AOSC department are doing all they can to not only search for answers, but set the stage for future climate research.

UMD Watershed

redefining what it means to be green

By: Emily Jones

On a rainy fall afternoon, as one crowd in College Park cheered the Terps to a football victory, another crowd huddled in white tents on the Tidal Basin in Washington, D.C., cheering on another team of Terps to an engineering victory as they won the 2011 Solar Decathlon.

The Solar Decathlon was designed by the U.S. Department

land took first place in architecture, hot water use and energy use; second in market appeal and appliances; and third in communication, home entertainment and comfort, leading them to their first overall victory.

Maryland's winning entry, Watershed, was inspired by the Chesapeake Bay and focused on water conservation. The house is divided into two living

the energy efficiency and focus of the design. In the award announcement, they praised the sustainability features of the team's house, specifically stating that "the team's fully scoped attention to water conservation and the seamless integration of the elements of the sustainable design are perfectly relevant, timely, and beautiful."

At the close of the compe-

Watershed Design Breakdown

Constructed wetland filters greywater and rainwater for reuse.



Roof is divided into a garden of succulents to redirect rainwater and a solar panel array to harvest energy.

Solar thermal insulation absorbs sunlight to heat water while liquid dessicant waterfall control humidity.

of Energy in 2002 to educate students and the public about renewable energy solutions that can be feasibly implemented in today's homes. Colleges from across the globe design and build houses which are evaluated based on ten criteria: architecture, market appeal, engineering, design communication, affordability, comfort, hot water use, appliance selection, home entertainment, and energy use. This year, Mary-

modules, separated by a central axis. At this axis, water collects from the two facets of the roof, which host a garden and a solar panel array. Surrounding the structure is a reconstructed wetland of native species, which filters greywater and rainwater for reuse. Inside the home, a patent-pending liquid desiccant waterfall controls the humidity, and reconfigurable furniture allows flexibility in use of space. The judges were impressed by

tition, the Secretary of Energy Stephen Chu spoke of how the competition inspired him. "The ingenuity, the creativity, the talent you have displayed this week give me hope for the future," he said. "You only have to look at these great teams here to see that American innovation is alive and well." Through their unique water conservation design, Team Maryland proved that sustainability can be achievable and affordable.



Playing with fire

fire safety with Professor Peter Sunderland

By: Maia Werbos

Fire is dangerous. Even with the best equipment and protocols for extinguishing fires, once something starts to burn, people and property get hurt. And that's why researchers like Peter Sunderland, professor of Fire Protection Engineering, work on preventing fires.

As an undergraduate, Sunderland always leaned toward engineering, but had many different interests. "Everybody said mechanical engineering was the most general, that you could branch out from there," Sunderland said. He enjoyed working in that industry for a while, but eventually lost interest in what he was doing. "It wasn't challenging enough," he said. Since many of his most successful colleagues had advanced degrees, Sunderland decided to go back to get his Ph.D.

Once he became a graduate student, he realized that academia was right for him — he liked the active, social aspect of academia. "On campus, you're always interacting with people, all the time...the young people and the students...are so alive and excited and impressionable," he said.

Sunderland knew he wanted to teach even while he was doing his Ph.D., but he didn't think he would be able to secure a faculty job until he had more

experience as a post-doctorate researcher. According to Sunderland, a faculty job isn't easy, especially in the first few years. "Universities have found that people straight out of a Ph.D. — they can't do it," he said.

Sunderland also waited a little longer to get an offer from a top-notch school. "Early on I had some offers from not as good schools, but when this one came along I was really excited," he said. He added that the University of Maryland of-

"Soot is the number-one [air-borne] pollutant in the United States today..."

fers a strong fire protection engineering program, which very few United States universities can boast. "This one is the strongest," Sunderland stated.

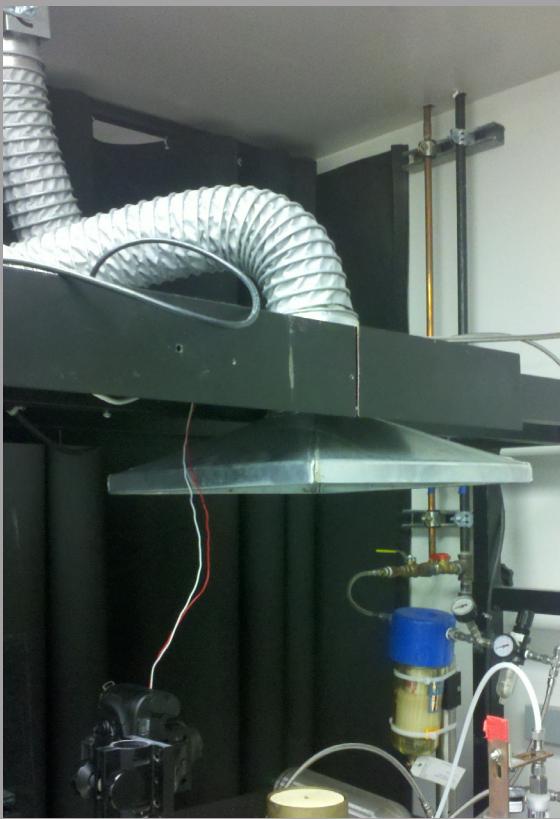
Since arriving at Maryland, he has made broad contributions to research. Currently, his largest project is studying soot. "It's what makes a candle flame yellow instead of blue," Sunderland explained. It can also be a dangerous contributor to climate change. According to Sunderland, soot is

currently the leading source of air-borne pollution in the United States. "It is a much stronger greenhouse gas than methane or CO₂."

Sunderland takes a different tack to studying soot than many other researchers. Most scientists study the formation of soot. Sunderland, however, prefers to study ways of removing soot. So, his experiments focus on soot oxidization. "We look at how fast it oxidizes; how that depends on temperature, species, and the type of soot," Sunderland said.

Fire safety is equally paramount for alternative fuels, like hydrogen. Hydrogen fuel cells are a promising source of energy, because burning hydrogen produces mostly water. But they are also widely seen as too risky to use in cars. Sunderland, however, helped make progress on improving safety by studying the flames that could be produced by small leaks in a hydrogen tank.

A lot of people looked at the big leaks that explode, and that's something to be concerned about," he said. "But our idea was, instead of looking at these big explosions...to look at the smallest ones you could have with hydrogen." The peril of small leaks is that drivers could have small escapes of hydrogen from their car, just enough to burn, that could



This careful lab setup allows Sunderland and his students to be as safe as possible while studying fire.

cause huge leaks later. “You might be going on a dirt road... some kind of a spark will ignite it, and these flames...even though they’re only like two or three millimeters high... you can’t blow them out,” he said. And as the small flames continue to burn, they can damage the engine, until a larger release happens and causes an explosion.

Aside from soot and fuel cells, Sunderland also has several projects with NASA. One is for studying spherical flames, which form in microgravity. “They look like giant marbles that are glowing,” he said. Another examines the burning of several different items, without actually conducting tests on all of them, by using an apparatus that mimics the burning of solids. “If you want to consider how wood burns in space, and paper, and Velcro, and all the

other materials the astronauts have up there, including like, cotton shirts and stuff, then you have to do hundreds of different tests,” he said. Instead, Sunderland and his research team use a porous piece of metal through which gas flows, which allows astronauts to generalize results more easily.

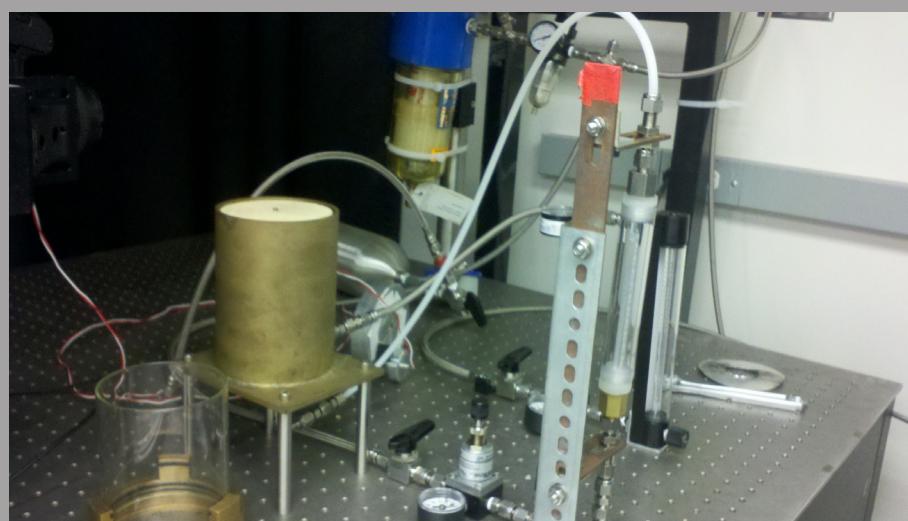
Over time, Sunderland has found that his commitments to teaching and research have changed. Nowadays, he only spends about 30% of his time on teaching during the semester, and about 70% on research, whereas when he began his career, he spent about 50% of his time on teaching and preparation. Nonetheless, most of his time on research is actually more like teaching, because he is mentoring graduate and undergraduate students on their projects. “I hardly ever go in the lab – and

if I [did] I think I’d break something,” he said. Despite the way the university separates research and teaching, Sunderland sees both as collaborative processes of learning more about the world.

For undergraduates interested in research, he says that finding a professor to work with is not difficult. It may help to get good grades. “Usually, if someone wants to work in the lab, they can,” Sunderland said. “Most faculty won’t turn down [student volunteers]...we’re happy to have a chance to work with them.”

As a professor, what he would most like to see are students who engage with their instructors, who raise their hands in class, come to office hours and make an effort to connect with others. After all, research is about collaborating – not only with people near you. “You’re collaborating with everybody – the whole world working on making advances,” he said.

Besides contributing to science, Sunderland stated that researching has its other benefits. “It’s super fun,” he said.



Using this apparatus, Sunderland and the students he mentors can study the burning of soot in a controlled manner.



The Science of Aging

searching for a solution to Progeria

By: Nicholas Hung

Imagine a young child, who, like many other children is new to the world with lots of time to learn and grow. Only, this particular child is lacking something so vital that they are unable to experience life and grow like other children. He is balding so much that superficial veins surrounding his head are visible; his arms and skin are so thin because very little, if any, fat is stored to insulate them; and his skin is wrinkled so that it looks as if he is many times his actual age. This is no ordinary disease, yet it is caused by a single genetic

mutation, a product upregulated in HGPS cells, to cause the arrest of further development within a cell. "It's an interesting system because we only have one mutation, which causes multi-tissue defects," Cao said. She and her colleagues at the NIH also discovered that a natural antibiotic, called rapamycin, reversed cellular senescence in HGPS cells through clearance of accumulated progerin, thus enhancing cell development and proliferation.

Cao and her team, who are now based in the Bioscience Research Building, are currently investigating the cellular mechanisms



HGPS is caused by a single genetic mutation that results in the production of a faulty protein that makes up the structural scaffolding of the cell nucleus. This scaffolding, called the nuclear lamina, has many critical functions besides maintaining the shape of the nucleus, such as controlling gene expression. Here a nucleus from an HGPS patient is shown (left) with an outline demonstrating the abnormal nuclear shape caused by the mutant protein as opposed to the normal shape (right).

mutation. This is Hutchinson-Gilford progeria syndrome (HGPS), a rare and fascinating disease. Research on HGPS is currently being conducted on campus by Cell and Developmental Biology Assistant Professor Kan Cao.

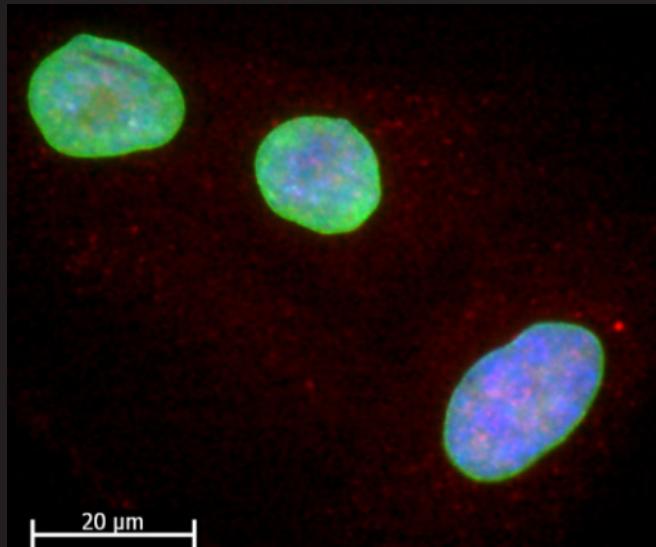
Prior to coming to the University of Maryland last September, Cao worked as a post doctoral fellow at the NIH in Bethesda, MD. There, she was introduced to HGPS and discovered that certain cellular mechanisms, such as telomere dysfunction, act together with other mechanisms like progerin produc-

involved in HGPS, which could hopefully also shed light on common diseases that could be linked with HGPS and regular aging, such as cardiovascular diseases, obesity and even Type II diabetes. "We want to look for more effective treatments for progeria based on what we know," she said. To this end, Cao's lab employs and integrates many diverse biological disciplines, including cellular and molecular biology, biochemistry, genomics and bioinformatics. Funding for her research comes from a variety of sources, including

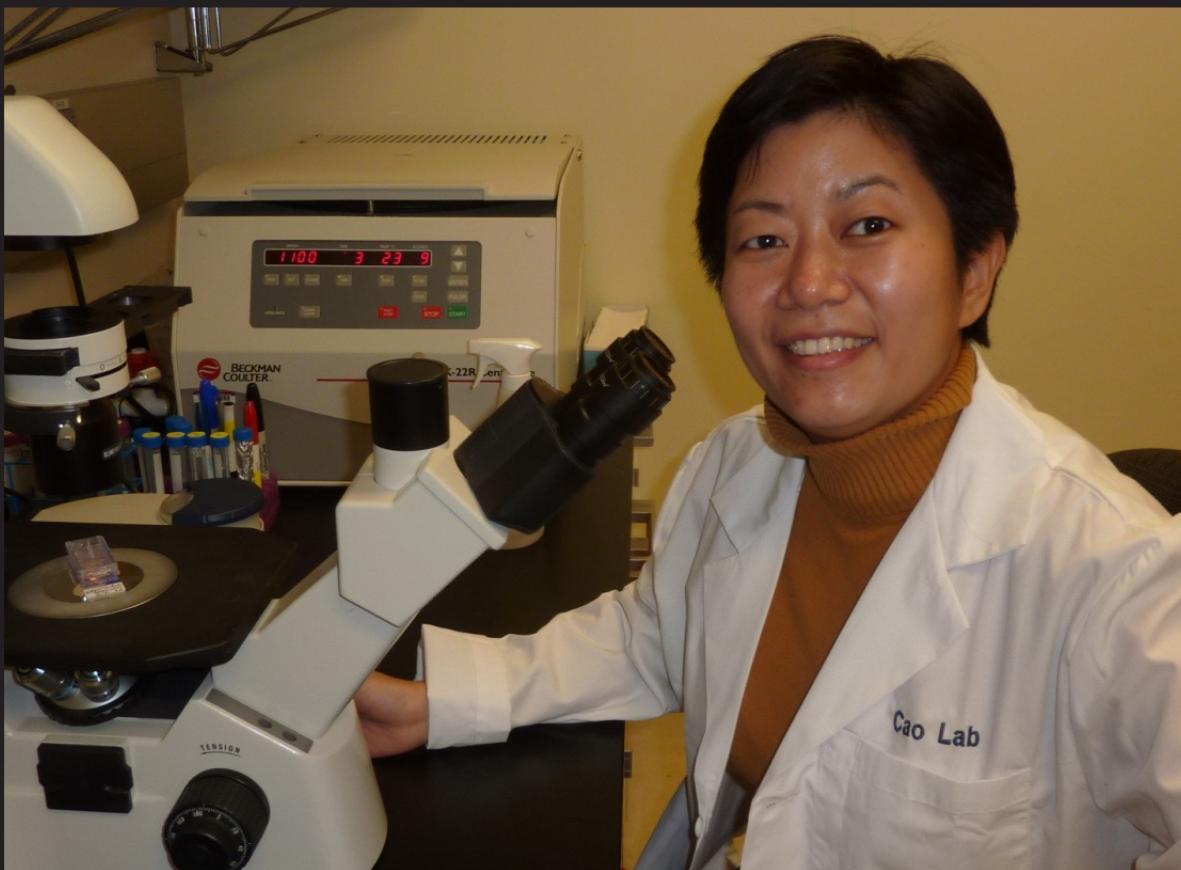
the NIH, the Progeria Research Foundation and the Maryland Stem Cell Research Commission.

While the move did not change her area of research, Cao has found herself tasked with a new job at the University of Maryland – she's now a teacher and a mentor. "The fun part is interacting with young students," Cao said. In her capacity as a mentor, Cao feels that certain traits are shared by most successful researchers and scientists. "I think you have to be smart, have a strong interest in science, and work hard..." Cao said. "Creativity...is also important." However, she explained that, despite said qualities, there are many pathways to being a good researcher. Above all, Cao emphasized the importance of staying interested in science.

For Cao, "the freedom...of pursuing the scientific questions that most interest me" excites and motivates her to continue investigating cellular mechanisms in HGPS in the hopes of finding answers to the questions that could help the daily life and health of people everywhere.



Nuclei of HGPS fibroblast cells stained with several fluorescent dyes. The green dye indicates the nuclear lamina, while the blue dye indicates DNA. A potential treatment for HGPS was applied to these cells for several weeks, clearly improving the abnormal shape of the nucleus.





Bioscience Research Day 2011

investigating infectious diseases

By: Andre DeSouza

Many undergraduate students sitting at the back of Colony Ballroom during Bio-science Research Day's Key-note speech were unaware of the great opportunity they had just missed earlier that day. By noon on November 10th the main event at Bio-science Research Day was well underway underneath the chandeliers of the Grand Ballroom in the Stamp Student Union. Well over a hundred people who had shown up for this event were walking from poster to poster listening to enthusiastic professors, graduate students, and undergraduates explaining their respective projects and their significance. However, this was just one of the many events planned for the day which showcased a wide range of research. Gene Ferrick, who was in charge of the event, said that his goals for the event were to display research being performed at the university and provide individuals with an opportunity to network. There was a myriad of opportunities to do so throughout the day for professors, graduate students, and undergraduates alike.

The day began with the networking panel consisting of representatives from in-

dustry and the federal laboratories, such as the Environmental Protection Agency and the Henry M. Jackson Foundation, who discussed the opportunities available for students outside the realm of academia. Run in a question and answer format, the panel answered various questions from the audience about how it is like to work in their respective industry or government position. They emphasized the various internships that are available to both undergraduates and graduate students that may even have the possibility to turn into jobs. In addition, they described the plethora of science related jobs available in industry and the government and the advantages of these government jobs. They deeply encouraged undergraduates who may be wary to consider working in government and industry positions. After the question and answer portion was over, students were given the opportunity to talk to each person on the panel individually. They received tips about undergraduate internships and career advancements in industry or the federal government.



Students and faculty listen to the keynote lecture at Bioscience Research Day, November 10th, 2011. Image courtesy of Gene Ferrick.

It was an excellent opportunity for undergraduate students to network.

The poster session followed the networking panel and showcased research from different areas of biology as diverse as genetics, neuroscience, immunology, and bioengineering. The projects showcased a variety of research being done at the University. The event provided many different appeals to its visitors. There appeared to be many people who attended the event simply out of interest to learn more about new and fascinating research. Others were professors who were discussing their projects with each other and generating ideas. Although the majority of the presenters were professors and graduate students, undergraduates

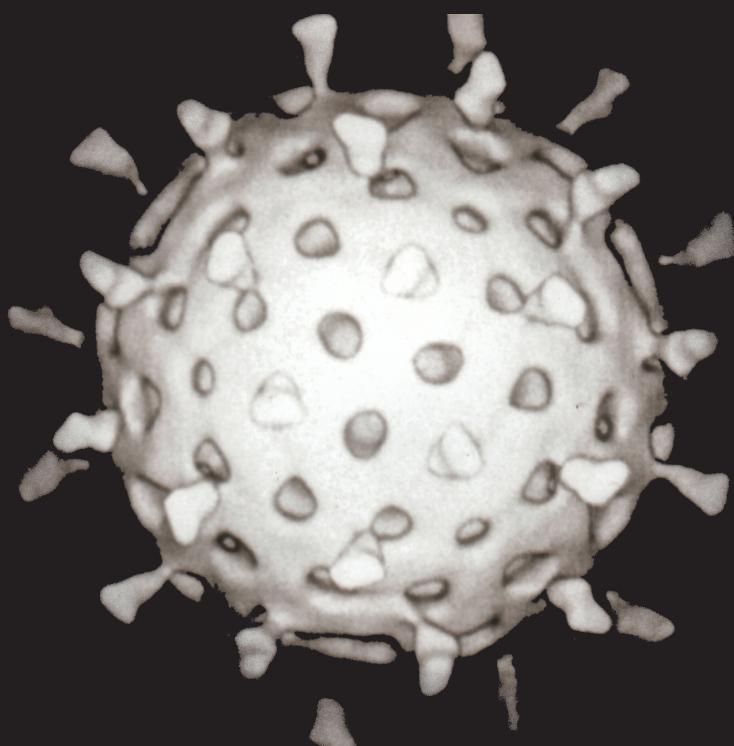
presented their fair share of posters as well. For example, one poster made by an undergraduate highlighted research on the relationship between current conservation efforts in North Carolina and how these efforts utilize ecosystem services. Another undergraduate poster described work on protein interactions in *Thermococcus kodakaraensis*. These are just a few of the posters undergraduates contributed to this event. The biggest appeal of the poster session for undergraduates was the opportunity to learn about research going on in different labs on campus. Attending this event and talking to the various individuals can provide undergraduates with the opportunity to network and find possible labs to work in.

As the poster session



Dr. David Relman presented his keynote address, “*Explorations of Self: Space, time, and stability in the human microbiome*.” Image courtesy of Gene Ferrick.

wound down, people began to migrate to the Colonial Ballroom to listen to the various speakers describe in full detail research which they had been working on. The symposia was based on research on infectious diseases and the crowd listened as the lecturers discussed causes of infectious disease and different methods for combating infectious diseases. A day which had been dedicated to research and innovation ended with an interesting lecture by David Relman on the implications of the human microbiome to human health and disease. This lecture marked the end of a day which was an excellent opportunity for students to learn about new research and about how to get involved in research happening right here at the University of Maryland.



Rotavirus molecule. Image courtesy of Graham Colm.



Maryland Neuroimaging Center

a new era in neuroscience research

By: Poorna Sreekumar

This year, the University of Maryland has added a new research facility to its already sizable arsenal. The Maryland Neuroimaging Center (MNC) opened over the summer and houses various resources for neuroimaging, the most notable being the new functional Magnetic Resonance Imaging (fMRI) scanner and Magnetoencephalograph (MEG).

A fMRI is a device that allows researchers to measure blood flow in the brain, thereby showing what parts of the brain respond to certain stimuli. The MEG records brain activity directly and with great temporal resolution, yet it doesn't have the spatial resolution of a fMRI.

In addition to the new devices, the University also renovated nearly 8,000 square feet to accommodate the machines and office space needed to cultivate a research atmosphere. The MNC was made possible by a \$2 million grant from the National Science Foundation.

One of the unique aspects of the MNC is that it combines several different ways of studying the brain. With this combination, researchers can get a comprehensive look at brain functions which will be essential to the field. Unlike other centers for neuroimaging, the MNC will also be exclusively a research environment with very little clinical use. The

center has desk space, computers and conference rooms and generally provides an atmosphere to foster discussion about ongoing research.

Robert Dooling, the head of the Neuroscience and Cognitive Science (NACS) department, was one of the two main figures, alongside Professor Nathan Fox, in making

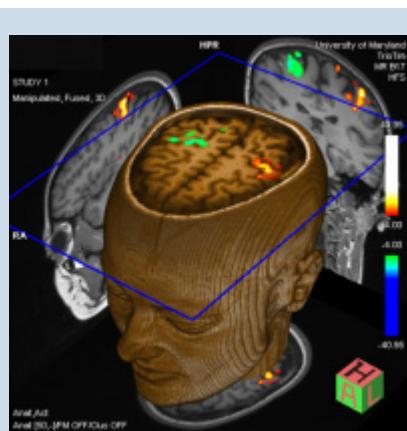


Diagram showing medial (left), horizontal (on head), and coronal (right) cross-sections of the brain as returned by the fMRI, with highlighted areas showing areas of neural activity. Image courtesy of NACS.

the MNC a reality. Dooling recounted that the establishment of the MNC was quite a difficult process, because at the time of the proposal there weren't many researchers on campus using neuroimaging technology. He described it as a chicken and the egg problem – there weren't many researchers using neuroimaging, the need

“The MNC has provided more opportunities... for collaborative research, multiple levels of brain analysis, and even training for undergraduates.”

for a center never arose, but, conversely, researchers didn't consider conducting this type of work because there wasn't a neuroimaging center.

Dooling said that the few people that did do full time neuroimaging often did it at other nearby centers such as NIH. However, both Fox and Dooling recognized the emerging need for more advanced and accessible technology for a university of this size. “Interest has grown considerably since the beginning,” Dooling said. “And there might be future collaborations with other centers such as the FDA and the Children's Hospital.”

Currently, the university has a number of faculty involved in research that makes extensive use of neuroimaging technology, in areas such as child brain development and linguistics. Dooling hopes the creation of



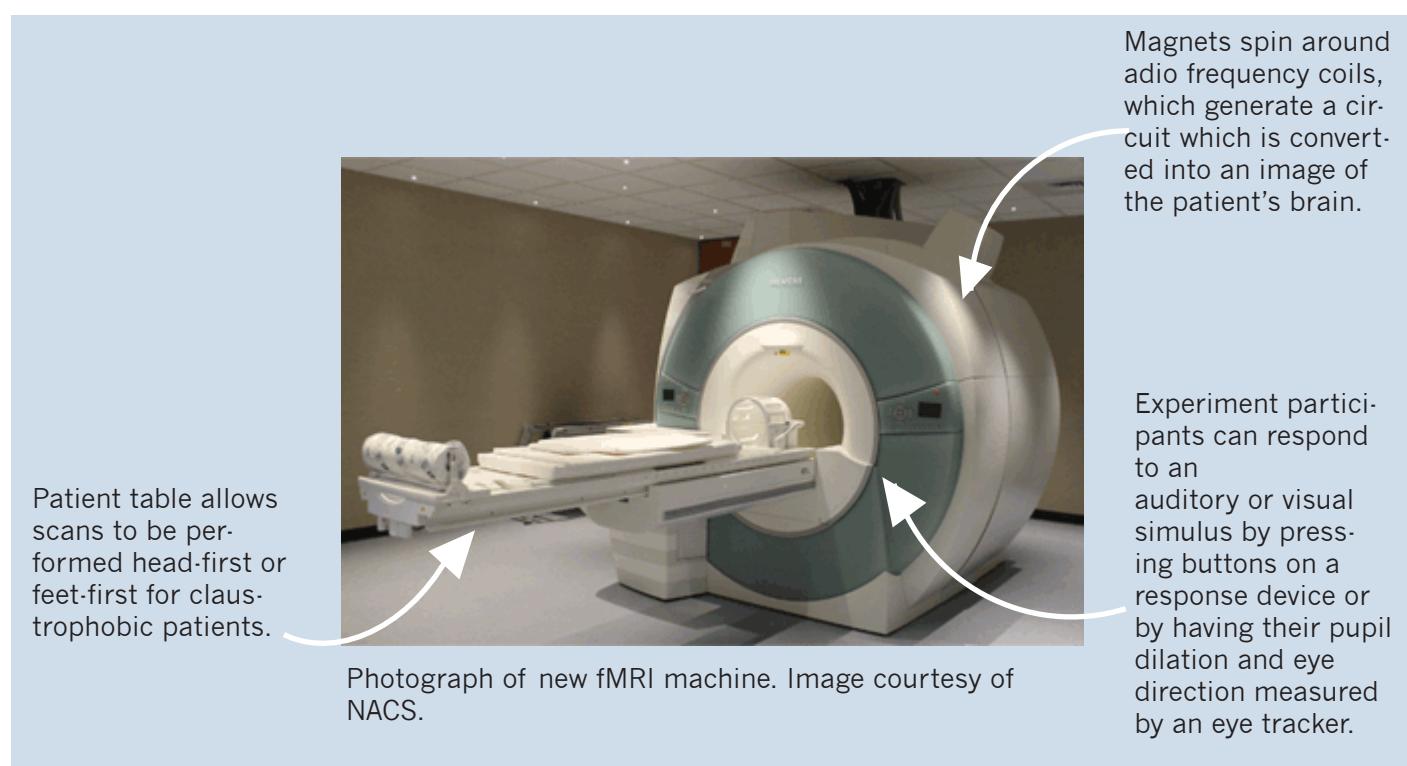
a neuroimaging center will attract more top researchers to the university and bolster the reputation of the NACS department.

One such researcher is Tracy Riggins, the head of the Neurocognitive Development Lab (NCDL), who said that the MNC should also prove to be a useful teaching tool. “The MNC has provided more opportunities for faculty not only for individual research

Riggins is looking forward to gaining a more in-depth view of cognitive development by collaborating further with other researchers.

Currently, Riggins and Elizabeth Redcay of Developmental Social Cognitive Neuroscience Lab are conducting some pilot research about memory in adults. The research, which involves measuring resting state functional connectivity and com-

volving fMRI data at the National Institute for Drug Abuse, it had been restricted to studies involving only drug abuse. Besides allowing her to conduct other sorts of research, the fMRI at the MNC adds another component to the EEG data that the NCDL lab usually collects. The EEG data only shows temporal resolution and doesn’t necessarily answer where in the brain processes are occurring. The



but also for collaborative research, multiple levels of brain analysis and even training for undergraduates. It’s a center for both research and education,” Riggins said. Before the creation of the MNC, Riggins, whose research focuses on the neural bases of cognitive development, collected data using an electroencephalograph (EEG) machine located inside the NCDL. However, with the opening of the MNC,

paring these measures to performances on memory tasks, would have been impossible to conduct without the resources provided by the MNC. “Before the MNC, we were limited in what questions we could ask, we couldn’t ask anything about specific brain structures. But now, the fMRI allows us to ask a whole other set of questions,” she said.

While Riggins has been conducting some studies in-

fMRI on the other hand, shows what brain structures are involved in certain processes, and in the context of Riggins’ research, which structures play a role in memory.

As Dooling said, “The center isn’t just a place to take data as most clinical centers are. It’s really set up for research and it provides a convenient and unique way to analyze brain structure and function.”



Observations of Transiting Exoplanets with Differential Photometry

Brett Morris

Abstract

Preliminary observations and computational methods for analysis are presented for observing celestial objects with time-varying intensity, in particular transiting exoplanets. Transits occur when a planet orbiting a star other than the sun (an exoplanet) passes between the Earth and the host star, slightly dimming the apparent intensity of the star. CCD images of the host star of one such exoplanet, HD 189733b, are recorded during predicted transits at the University of Maryland Observatory (UMO) on a small (152 mm) refracting telescope. Differential photometry algorithms compare the relative brightness of the host star to other nearby, non-variable stars in the field and detect the small change in brightness associated with a planetary transit, on the order of tens of millimagnitudes. The first successful exoplanet observations at UMO are presented and discussed, as well as possible implications for exoplanetary studies conducted by amateur and small observatories.

Introduction

Exoplanets are being discovered by the hundreds today. The two principal methods of exoplanet detection involve: (a) measuring the radial velocity of a star for perturbations caused by a planet, or (b) measuring the change in intensity of a host star as a planet passes between the star and Earth, known as a transit.

HD 189733b has been a favorable exoplanet for transit observations since its discovery by Bouchy et. al in 2005 [1]. It orbits a nearby visual magnitude V=7.67, K dwarf star with a period of 2.2 days

at a distance of 19.2 pc in the constellation Vulpecula [1,2]. The brightness of the host star and its location -- passing through high altitudes in the summer sky for observers in the northern hemisphere -- make it an attractive target for small college observatories and serious amateurs.

Differential photometry is an observing technique used to compare the relative changes in brightness between one star and others nearby in the sky. An average is taken over the instrumental intensity of a set of a few to many stars, called control stars, in CCD images over a period of



time to account for changing atmospheric conditions. The intensity measurements of the star being analyzed for variation, called the target star, are then corrected for the atmospheric effects measured in the control stars, revealing its intrinsic variations.

Observations of transiting exoplanets are being collaboratively compiled and compared by small college observatories and skilled amateurs around the world [4]. Seagroves et al. (2003) argue that this class of observers have distinct advantages to offer for monitoring transiting exoplanets. These advantages include diverse longitudinal locations, strength in numbers for multiple simultaneous follow ups and low-cost observations [3]. Observatories in locations with bright light pollution and low elevation can still prove useful in bright transiting exoplanet observations.

Here I present the first observations of an exoplanet at the University of Maryland Observatory, as well as an original differential photometry algorithm for accessible transiting exoplanet detection for college observatories and serious amateurs. The observing techniques and apparatus are detailed in the Observational Methods section, the differential photometry algorithm is introduced in Analysis, some observations are shown in Results and discussed in the Discussion section.

Observational Methods

Apparatus: All observations discussed here were taken with a 152mm Astro-Physics f/9 refracting telescope on an AP900 equatorial mount temporarily installed at the University of Maryland Observatory (UMO) in College Park, MD, US, located <6 km from the District of Columbia at an elevation of ~100 m above sea level. Images were recorded on an SBIG ST-10

CCD camera with 6.8 square micron pixels in an array of dimensions 2184×1472 . The field of view was approximately $0.5^\circ \times 0.75^\circ$ with a focal reducer in place. The CCD was cooled to -5°C , controlled by MaxIm DL (Version 5.12). The Baader R-CCD red filter was used exclusively in the presented observations.

Observing Techniques: Dark frames are collected by exposing the CCD without sky illumination and recording the background noise, hot pixels and thermal noise, which is then subtracted from each image of the sky. Flat fielding is performed by exposing the CCD to light projected evenly on a screen in the observatory. The isotropic light field becomes attenuated by dust and other imperfections in the optical path of the telescope resulting in systematic variations in the flat field exposures. Several of these exposures are averaged and the resulting image is normalized by the mean pixel intensity. All sky exposures are divided by this “master flat.”

A red filter was used for all photometric observations. A typical photometric event such as an exoplanet transit or a short period pulsating variable star peak event happens over the course of several hours. The altitude of the object of interest can change greatly in that time leading to changing atmospheric extinction throughout the night. This extinction also varies with wavelength, affecting the longer wavelengths less than shorter ones. Thus, the red filter was used to select the light from any color star that is least affected by atmospheric extinction.

Defocusing the telescope is commonly used in differential photometry to spread the light of a bright star over many pixels. The greater imaging area covered by the star reduces some systematic errors

unaccounted for by the dark frames and flat fields associated with focusing large amounts of the light on individual pixels. The decreased intensity of the light on each individual pixel also allows for longer exposures without risk of saturation, which can in effect smooth out some atmospheric noise that happens on short time scales. Transit observations are presented here with and without defocusing.

After the CCD is cooled and dark frames are exposed, the star of interest is found and centered in the field of view. The target star is centered to keep it in the frame despite the imperfect tracking of the telescope. The particular telescope used here, like many others, is in slightly off-polar alignment, causing stars to drift in the field of view throughout the course of a night. A favorable alignment keeps the target star in the frame for as long as possible while also orienting itself to maximize the number of control stars in the frame for comparison. Exposure lengths are adjusted so that the brightest control stars are recording maximum pixel intensities significantly below saturation.

Analysis

A suite of differential photometry software named “oscaar” (for “Open Source Differential Photometry Code for Amateur Astronomical Research”) was developed in Python to generate light curves from the series of images recorded by the CCD. The code has several key phases of analysis which will be discussed here in some detail, namely star tracking, aperture photometry, and differential comparison. This section will discuss analysis of “stars” or “objects” in general. These methods can be used to observe exoplanet transits, variable stars and rotating asteroids among

others.

The drift of the stars due to imperfect telescope tracking is a ubiquitous obstacle to iterative measurement of star magnitude in low-power observatories. The problem of tracking object positions becomes unavoidable for observations of asteroids, for example, which can move significantly with respect to the sky in a few hours. Oscaar takes user input from SAOImage DS9 to record approximate centroid positions and radii of target and control stars chosen by the user in the first image in a photometry set. The explicit choice of objects by the user provides a check against unfavorable objects for photometry. Gaussian functions are fit to the intensities in the regions immediately around the object centroids using χ^2 minimization. The coordinates of the object centroids and the σ parameter corresponding to the radial spread of the object are recorded and used as initial estimates in the fit for the next frame. This method of tracking is not affected by the independent motion of one or more of the tracked objects.

The object centroids and radii provide the basis for the aperture photometry measurements. The source aperture is centered on the fit centroid with radius 5.5σ where σ is again the Gaussian width parameter from the fitting process. This large factor of σ was chosen to loosely enclose >99% of the source light even in poor Gaussian fits. The sky aperture has concentric radii 5.5σ to 7.5σ . The median of the intensities in the sky aperture is interpreted as a measurement of the background intensity of the sky. This background value is subtracted from each pixel intensity in the source aperture and the resulting array is summed to derive the



instrumental intensity of the object. The instrumental magnitude is converted to an astronomical magnitude. These calculations are summarized symbolically for clarity in the Appendix.

The magnitude of the control stars at each time is averaged into one aggregate control intensity measurement of the variations of the stars throughout the period of observation. The differential photometric measurement of the variation in the target star is simply the magnitude of the target star subtracted from this aggregate control intensity. A star with no variability relative to the control stars is represented by a function of constant magnitude throughout time; objects with variability show non-zero and time-varying slopes.

Oscaar is intended for small observatories and serious amateurs. It is commanded by a user edited plain text

parameter file that controls the running parameters of the algorithms and indicates the input files. Users need not interact with the underlying Python code to generate light curves from raw CCD images, and a graphical user interface is provided to display the control and target star differential magnitude light curves. A free open source distribution of oscaar is available online[†].

Results

The first successful observation of an exoplanet at UMO was produced in collaboration with UM undergraduate Harley Katz. A time series of images of HD 189733b and the surrounding star field was collected during a predicted transit [4]. Light curves demonstrating the diminished intensity of the star during the transit were generated by oscaar using 25 bright comparison stars ranging in mag-

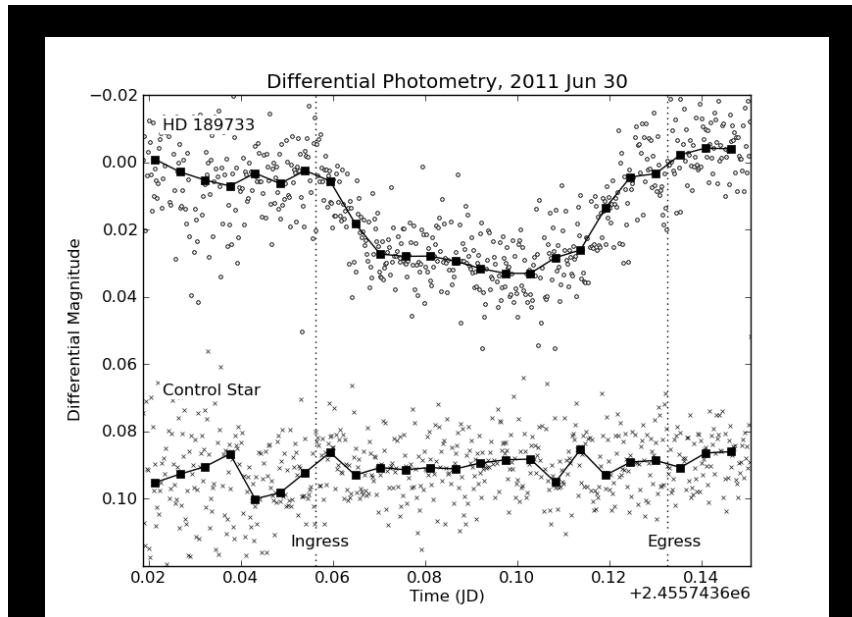
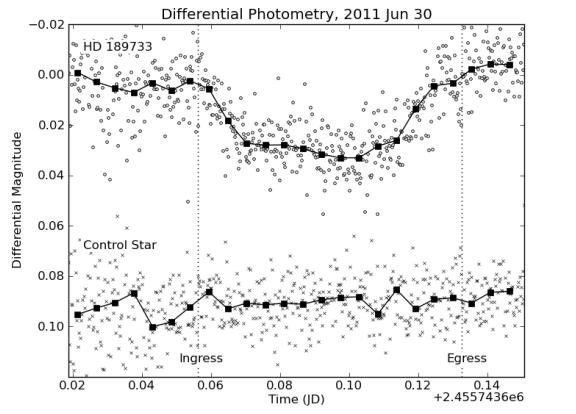


Figure 1

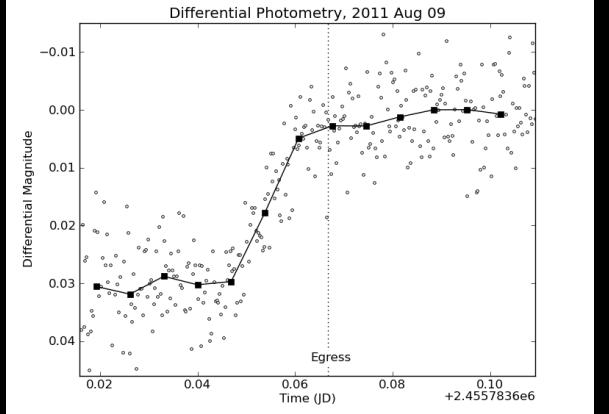
The first successful exoplanet transit light curve from UMO. The set of circles represent the magnitude of host star HD 189733. The set of x's represent the magnitude of a non-variable control star, HIP 98523. The connected dark squares represent 25 point median binning. The control data is given a vertical displacement for clarity.



2



3

**Figure 2**

Second photometric observation of HD 189733b, with natural defocusing (humidity and haze). The connected dark squares represent 22 point median binning.

Figure 3

Third photometric observation of HD 189733b, with intentional defocusing. The observed depth is 29.0 ± 0.4 mmag. The connected dark squares represent 25 point median binning. The transit observation is incomplete due to poor weather at ingress.

nitude from about 8-12 magnitude. This magnitude range is constrained by low signal from stars dimmer than 12 mag and lack of stars above 8 mag. The telescope was well-focused, necessitating short (7 s) exposures. Over 190 minutes, 607 images were collected. The resulting light curve in Figure 1 shows a 28.3 ± 0.5 mmag attenuation of the star light at the predicted time of transit. The expected depth is 28.2 mmag [1].

A second set of observations were collected using the defocusing method. The light was effectively defocused by the extremely humid atmosphere in College Park, which approached 94% humidity toward the end of the transit. The centroid fitting routine produced a mean sigma fit parameter -- corresponding to the radial spread of each star -- 30.5% larger in the naturally defocused run than in the well-focused data set. The widely distributed light decreased the peak intensity at stellar centroids and enabled exposures to be increased to 20 s. 37 control stars were cho-

sen for differential photometry, producing the light curve in Figure 2.

The observations were repeated on a night with 60% humidity (less optically significant) and intentional defocusing of the telescope components. The telescope was focused on globular cluster M13 and defocused such that the intensity of a typical star centroid decreased by a factor of 2.5 in the same exposure time. 28 control stars were tracked in 337 frames with 12 s exposures. The results shown in Figure 3 confirm the benefits of defocusing.

Discussion

The results confirm that exoplanet transit light curves can be collected by small observatories in non-ideal locations. UMO is well within the Washington, DC light pollution “bubble,” which is considered a Bortle-scale 9 or 10 site [5]. College Park is heavily populated, ~100 m above sea level and typically very humid. As discussed in the Results section, a verified method for defocusing can be used to view the star on



nights of high humidity (see Figure 2), which successfully reduces noise in the light curve. In the case of bright transiting exoplanet detection, atmospheric conditions that can otherwise be crippling to astronomical research can benefit transit observations.

Light pollution at UMO significantly increases the background sky intensity, effectively making the signal-to-noise ratio poorer for dim stars. The number of control stars available in a given field is therefore reduced due to the location of UMO. There are still many viable control stars in star fields as dense as the region surrounding HD 189733. The number of stars does not significantly change the light curve in a differential photometric observation of >20 stars. This suggests that more sparse star fields will still produce quality light curves of bright transiting exoplanets at small observatories.

The success of the defocusing technique can be attributed to several factors. The increased exposure length compensates for the decreased intensity of the brightest pixels in each frame. The longer exposure length may be integrating over a time cycle longer than the atmospheric fluctuations that are a source of noise in the shorter exposures. Defocusing also provides a natural form of dithering. The star light is spread out over more pixels, lessening the significance of pixel-to-pixel variations that may have eluded correction in the dark frame and flat field processing.

The imperfect polar alignment of the telescope may be a source of uncorrected systematic error. The target star drifted ~ 275 pixels in the 2011 Jun 30 observation, which significantly spreads the observation over many pixels. The flat fielding normalization and dark frame

subtraction are assumed to remove any systematic effects along the length of the detector and some corrected images were visually inspected to ensure the calibration process successfully removed obvious systematic effects.

It has now been shown that small college observatories like UMO can produce quality light curves of transiting exoplanets. It should be noted that these observations were recorded using standard college observatory apparatus, and can likely be repeated in other small observatories. The quality of these observations is likely to increase as the observing techniques are refined and preliminary observations of dimmer transiting exoplanets suggest that stars dimmer than HD 189733 by several magnitudes can be observed at UMO. Online transit predictions by services like those of Poddany et al. (2010) provide up-to-date ephemerides on observable transiting exoplanets [4]. These accurate predictions minimize observing time for follow-up observations by allowing observers to plan observing sessions to the minute. Poddany et al. (2010) also provide a streamlined, centralized system for updating these ephemerides with new user collected data. The author plans to monitor candidate transiting exoplanets for follow-up observations to constrain ephemerides, and to contribute to these databases with the results that are collected.

Conclusions

Small observatories such as the University of Maryland Observatory are capable of recording light curves of bright transiting exoplanets such as HD 189733b with common apparatus. Rather simple differential photometry algorithms can define

transits of reasonable quality with ~ 20 control stars.

Appendix

Presented here for clarity is a mathematical summary of the flat field normalization and dark frame subtraction process applied to each aperture photometry source.

Given

$\{s_i\}$ is the set of intensities of the source pixels

$\{\sigma_i\}$ is the set of intensities of the sky (background) pixels

$\{d_i\}$ is the set of intensities of the dark frame

$\{f_i\}$ is a set of intensities of the flat field (of which there are several),

The set of the intensities of the normalized average of the flat fields $\{F_i\}$ is given by:

$$\{F_i\} = \frac{\overline{\{f_i\}}}{\text{median}(\overline{\{f_i\}})}$$

The instrumental magnitude of the star is then:

$$I = \sum_{\text{all } s} \left\{ \frac{s_i - \text{median}\{\sigma_i\} - d_i}{\{F_i\}} \right\}$$

And the differential astronomical magnitude is given by :

$$m = 2.5 * \log_{10} I$$

Acknowledgements

The author would like to thank Elizabeth Warner (UMCP), the Observatory Coordinator, for providing access to the facilities at the University of Maryland Ob-

servatory and training with the telescope. Some of the observatory setup procedures were completed with assistance from fellow undergraduate Harley Katz (UMCP) on several occasions. This project was inspired by a conversation with Dr. David Charbonneau (Harvard) and is being continued with Dr. Drake Deming (UMCP).

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Software Applications for the Integration of Plug-In Hybrid Electric Vehicles within the Smart Grid

Shruti Ramaswamy & Dr. Alireza Khaligh

Abstract

Smart Grid is a new solution to the aging power grid. It is a budding web of controls, automation and intelligent technologies that work together to make the grid greener, secure and reliable. Its innovative dual-direction communication between the grid and the user establishes a system of regular updates to a home that details energy consumption on a real time basis. With an increasing Plug-in Hybrid Electric Vehicle (PHEV) market, consumers have another avenue for involvement with the grid. PHEV charging is a heavy load added to a home. If this extra load is not managed properly, the effects of this pressure may prove detrimental for the consumer and may result in unwanted power outages that may affect an entire residential community. Demand Response programs can help efficiently reduce this added pressure and minimize energy costs. This research explores the idea of developing a software application to manage consumer loads dynamically. The program manages times during the day/night a PHEV can be charged such that the total house load is managed and its cost is minimized. In addition to returning specific times to charge the PHEV, the program also seeks to build a smart home that shifts loads dynamically to save the consumer energy and money. The program divides household loads into three categories – critical, deferrable and interruptible, and returns savings calculated using Real Time Pricing, Time of Use Pricing and Flat Rate Pricing options. The goal is to create a user-friendly environment for the consumer to manage energy consumption reliably, effectively and economically.

Introduction

As the world continues to catch up with changing technology, it leans closer to face its dire need for change in the current power driven market. Rigorous policies backed by environmental laws, increasing consumer concerns and demand have

forced utility companies to consider updating the current power grid system from its root. Internally too, utilities are dealing with increasing problems stemming from aging equipment and limited communication between utilities and consumers. A solution, the Smart Grid is built with a

vision to “connect everyone to abundant, affordable, clean, efficient, and reliable electric power anytime, anywhere” [1]. To further this idea, US Department of Energy has created the Office of Electricity Delivery and Energy Reliability to provide stronger leadership and serve as the epicenter of policy and technology development activities in the department related to the electric grid.

In order to meet growing demands and actively encourage consumer participation, America’s electric system needs to be modernized and expanded by government and industry. Involvement will be accomplished using the grid’s two way flow of electricity and information between consumers and utilities. Effective communication will provide consumers with up-to-date information about their energy consumption and money spent using varied price options made available to them. This new autonomy to control and change household load consumption to meet need, unwraps an assortment of Demand Response (DR) programs aimed at giving consumers options to conserve energy and shift loads that will offer them utmost savings.

Incentive programs and a plethora of price based programs give consumers with PHEVs more options to actively participate in programs such as load shifting that will benefit them directly.

The Smart Grid has the infrastructure to enable the efficient use of the new generation PHEVs. The electrification of the vehicle fleet can radically change our dependence on oil. PHEVs rely on battery as opposed to conventional vehicles that consume fossil fuels. While PHEVs are not pollution free, emissions from PHEVs are far less than conventional cars. 1kWh

of energy used in a PHEV releases 0.69kg of carbon dioxide [12] while 1 gallon of gasoline emits 8.8kg of carbon dioxide into the atmosphere [13].

This paper explores the idea of bringing to the consumer a program that will control and give homeowners considerable control over their energy consumption. The purpose of the paper is to build a structure for the basis of the software program from root up. It begins with a brief background on the Smart Grid in “Understanding the Smart Grid.” “A Smarter Home” builds a platform for the advantages of the Smart Grid to be used. A smart solution to assist communication for the consumer is proposed in “A Solution.” “Preliminary Results” presents results of the basic algorithm employed to utilize demand response. Lastly, “Conclusions” and “Future Work” conclude with results and future work on the progress and expected prospects for the software application.

Understanding the Smart Grid

The vision is for the Smart Grid to be a fully automated power delivery network that supervises and controls every customer and module. Built on a basis of two-way flow of electricity and information, the Smart Grid has an inbuilt system of checks and balances between the consumer and utility companies and all components that duly fall in between the two. Its distributed intelligence coupled with Wi-Fi communications and automated system allows real time pricing options and faultless interfaces among all nodes of the electric network.

Features of the Smart Grid:

- **Grid Synergy:** The Smart Grid is a design built to manage change dynamically. Con-



nexion between consumer and utilities will be maintained through secure links at high speed. Consumers will receive real time updates for price and energy and can thus control their energy consumption concurrently rather than having to wait for monthly updates from power companies. Utilities are already investing greatly in Smart Meters and Advanced Metering Infrastructure (AMI) as the first step to secure the prospect of two-way communication between the home and utility company [4].

- An Automated System: In addition to contributing to reliable and secure electricity and information, Smart Grids open up an array of possibilities for utilities and consumers. Distributed Generation (DG) at a residential level including micro turbines, solar photovoltaic cells, wind turbines and grid energy storage enable increased bi-directional power flow between power distributors and end-users. A smarter grid will add resiliency to our electric power system and make it better prepared to address emergencies such as severe storms, earthquakes, terrorist attacks and blackouts. The interactive nature of the Smart Grid will allow for automatic rerouting of information when the equipment fails. This will help minimize outages when they do happen.

- Communications Framework: Fiber optics, microwave, infrared, power line carriers (PLC), wireless radio carriers such as GSM and CDMA [4], transfer massive amounts of data. Together they make up the network most communication is built on. Wireless communication will enable connections between devices, homes and utilities and information will be sent so all data may be received and managed on a real time basis. By establishing a constant

requirement for communication between homes and utilities, security of information can be preserved and constantly improved.

- Increased Grid Visibility: A key component of distribution intelligence is outage detection and response. Today, outages are detected based on customer phone calls from an area. Superior automation technology with the help of smart meters will enable grid operators to detect outages as instantly as power is lost. Operators can thus isolate a sector facing a power outage and send technicians to immediately fix the problem area. Another feature of this automation technology allows for newer and well-developed visualization techniques that interpret large amounts of data into information that can be easily understood by the consumer.

Consumer Benefits from the Smart Grid: Smart Meters provide dynamic information that gives consumers real-time updates on energy consumption and management. Dynamic monitoring of household data gives consumers instant reach to information as opposed to having to wait for monthly statements to determine usage patterns. Customers may now actively participate in three [5] ways. (1) First, customers can reduce their consumption of electricity at peak hours. By reducing their electricity, the drop in demand may be able to ease some pressure off the grid. If this action results in a significant shift in pressure at peak hours, grid operators will notice lesser demand in power that will in turn reduce over all price of power at a peak hour. (2) Secondly, the customer may be able to shift heavy power consuming loads operating at peak hours to off-peak hours. While the same amount of power is demanded off the grid, the consumer may

be able to save money by operating his/her device at hours when the system demand for power is low (3). Thirdly, a customer can alter cost significantly by onsite generation of power. Installation of solar panels and backyard wind turbines can help a customer significantly. A consumer may no longer need to alter his/her energy consumption practices according to peak hours. However, from a utilities perspective, electricity demand patterns will not see significant changes unless an entire residential community adopts onsite generation practices.

Understanding Energy Storage: Energy storage is defined as the conversion of electrical energy from the power grid into a form that can be stored until used again when converted back into electrical energy [6]. Research in different technologies has made available an array of storage options. While energy storage is a heavily researched subject, breakthroughs made in the field have potential to heavily reduce costs and maintain stability in the power grid. Figure 1 describes the potential benefits of energy storage systems.

A Smarter Home

Building a Smart Home: This section focuses on building a home that has various appliances that can be found in a typical house. The appliances are divided into three distinct load profiles: critical, deferrable and interruptible. Loads that fall under critical loads run irrespective of time of day or peak hours. These are critical to a household and operate at all hours. Loads that fall under deferrable loads run at certain hours in continuity. They can however, be shifted to off-peak hours to reduce cost from functioning during peak hours for the homeowner. Loads that fall under interruptible loads can be run and discontinued without consequence and negligible discomfort to the homeowner.

One may note that the household demands peak load between 12pm- 3pm and between 7pm-10pm. It must also be noted that households pay more money during peak hours than off-peak hours. This sort of pricing option falls under Time of Use (TOU) or Real Time Pricing (RTP).

To keep with varied pricing options, the smart meters/advanced metering in-

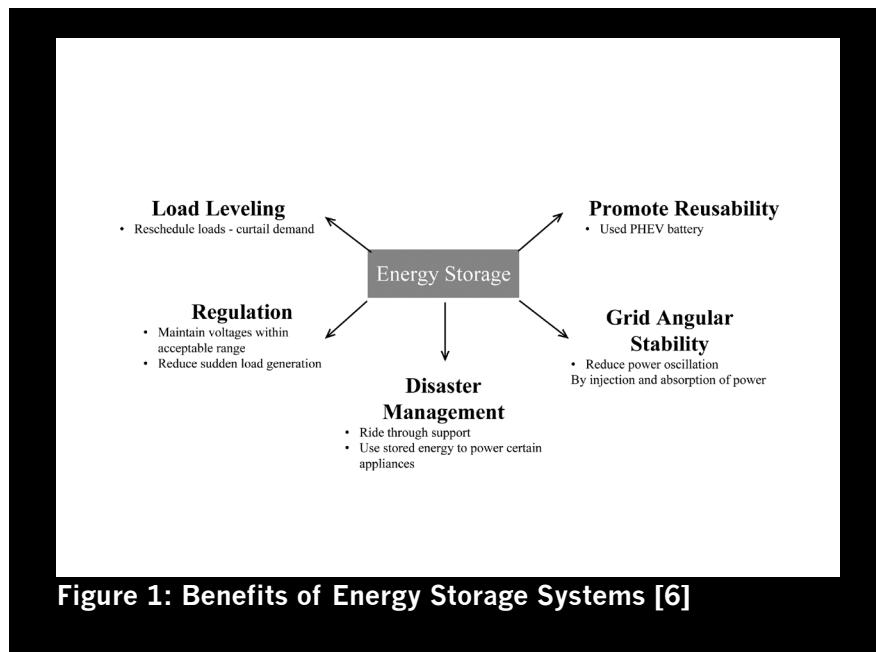


Figure 1: Benefits of Energy Storage Systems [6]

Household Load Profile		
Load Type	Appliance	DR Algorithm
Critical Load	Refrigerator Freezer Charger (Phone) Lighting Heating House Alarm	These loads are unaffected with rise and fall of prices
Deferrable Load	Washer Dryer Fans Light Bulbs PHEV Computer/Monitor	Based on RTP at given hour, loads are shifted to provide an economical solution to the homeowner
Interruptible Load	Microwave Oven Dishwasher Television DVD Player	Turned off when prices are high and restarted by prompt when prices are low again.

Table I
Illustrates the household load profile and an illustration of how the various loads will be handled using DR.

frastructure (AMI) give consumers' constant updates on their load and price. The consumer may shift loads accordingly to off-peak hours to minimize costs on the same. The manual process of monitoring household loads may pose a series of inconveniences for the homeowner as loads may need to be turned on and

off manually at all times. Load shifting is an effective method under consumer control. Figure 2 provides two distinct graphs denoting household loads prior to load shifting and an updated profile of the household load with a PHEV that does not increase with the addition of the PHEV. On the contrary, energy is cur-

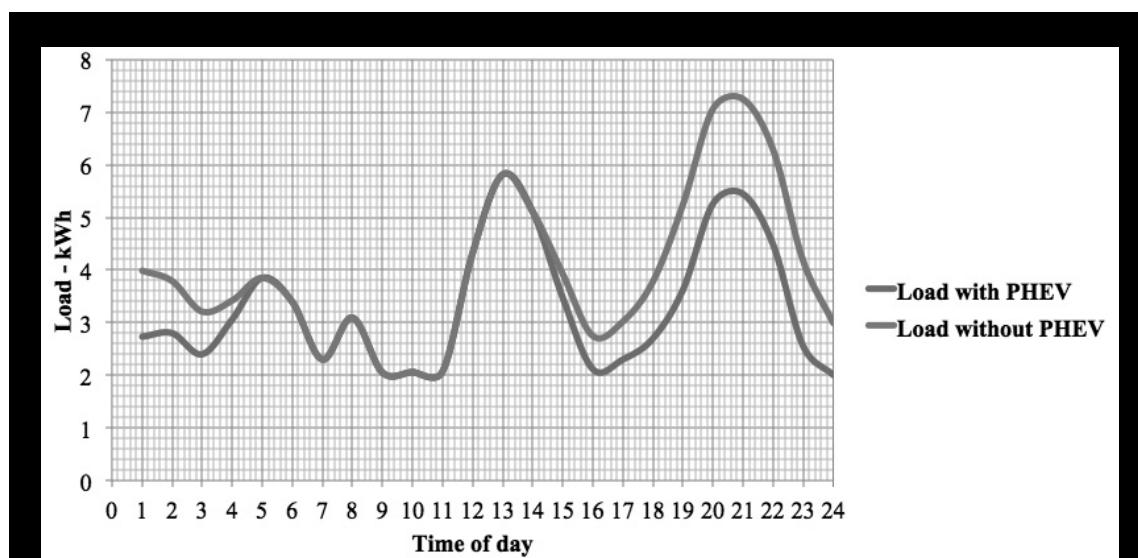


Figure 2: Household Load over 24-hour period [10]

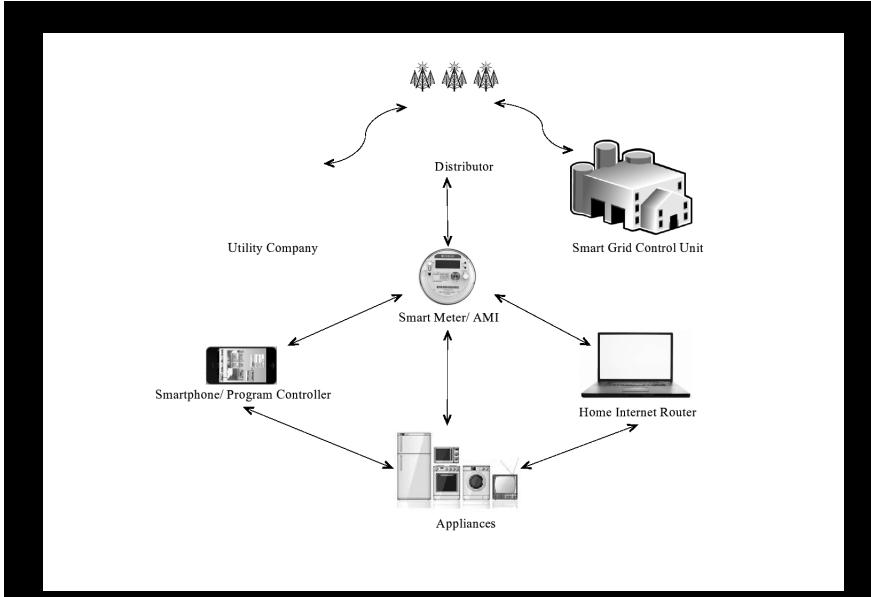


Figure 3: Scope of This Technology

tailed due to effective load shifting. Furthermore, incentive programs, offered by utilities to actively manage load shifting give consumers enough reason to seek an effective solution. Luckily, the technology market provides a relatively easy solution. Increased knowledge on technology and DR programs can be used to build a system that can be customized as per the requirements of the homeowner. Figure 3 describes the scope of such a system that is built to benefit the consumer in numerous ways.

A Solution

The most unique quality of the Smart Grid is its establishment of the two-way information share of electricity and data. This section highlights how such a connection can be used to ease into a homeowner's life and save him/her money by executing simple shifts performed over a 24-hour period. While the future of the program will be a software application available for smart phones, it is essential to understand the similar underlying algorithm that is displayed over a different

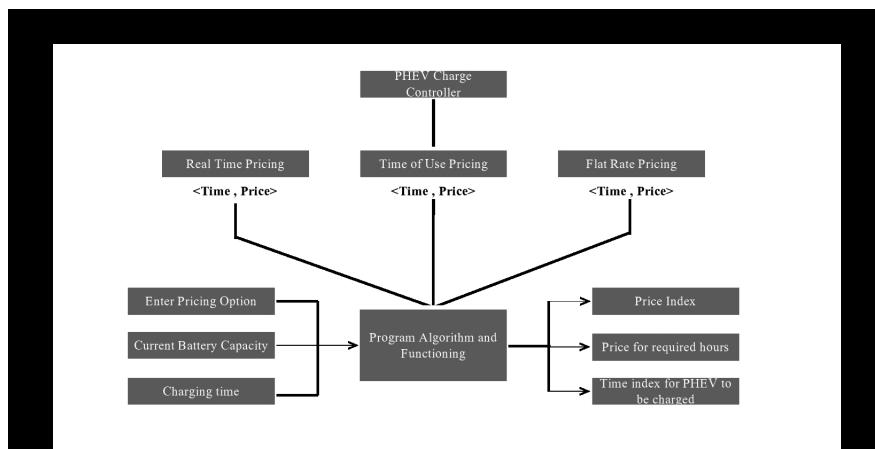
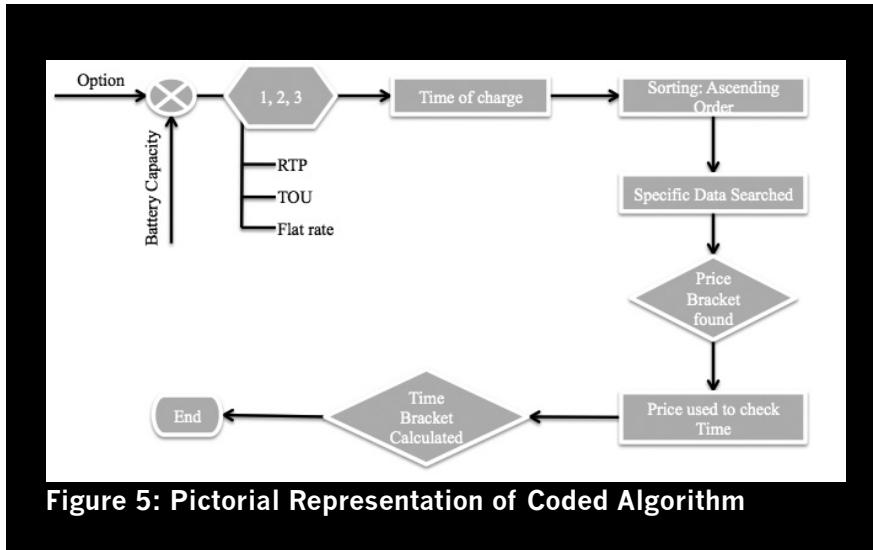


Figure 4: PHEV Charging Time Algorithm



platform to perform the same function.

A JAVA Framework: Created as a JAVA project, the framework consists of two subdivisions of classes that act as separate entities.

Figure 4 deals with PHEV charging under three pricing options- RTP, TOU and Flat rate. Divided into two classes, the PHEV Charge Controller class is the main control unit within which various aspects of the class and base class exist. The program is run with consumer input of his/her choice of pricing option and desired time to start charge. Another input that would be required to calculate this information is the battery capacity that will be extracted from the engine combustion unit of the vehicle itself.

As the program is created using a Chevy Volt battery design, the maximum usable battery capacity is limited at 10.4kWh. It is this 10.4kWh capacity that enables the program to calculate the number of hours left for the battery to attain full charge. The instantaneous result is a price index for the selected hours and a time index that is representative of the number of hours left for the battery to attain full charge. While the controller runs the main program, prima-

ry functions to calculate hours, time and price index are handled by a helping class. Figure 5 depicts the algorithm followed in code to compute the best time to charge the PHEV under given specifications.

Figure 6 integrates the basic algorithm, as portrayed in Figure 4, into a larger program. The larger program, a super class, deals with all of the basic appliances in a household by segregating appliances into three load profiles; critical, deferrable, and interruptible. Like its first subdivision, this part, too, is divided into classes. One class holds the control that begins the program; three other sub classes inherit methods that are used to compute answers specific to appliances concerned with each subclass.

The code uses maps (consisting of keys with values) to store appliances and their associated loads that are then transferred into a larger map that holds the time of day the appliance and its associated load at that particular time. Here, time is used as the common index of reference to attach appliances with their individual associated cost. These values are then arranged to determine cost of the household over a 24-hour period.

Figure 7 represents the algorithm of the

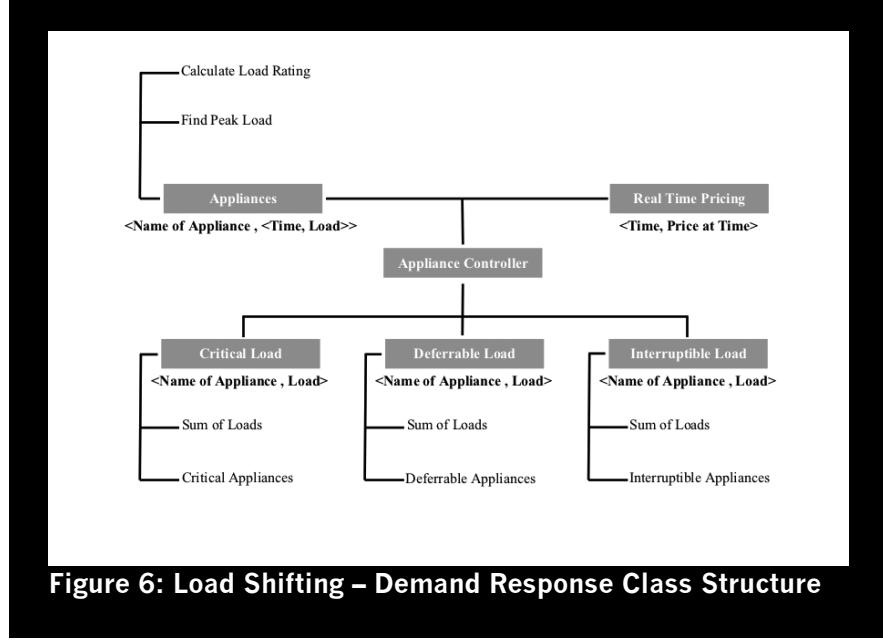


Figure 6: Load Shifting – Demand Response Class Structure

classes covered in code to calculate savings when loads are shifted during times when prices are high which in turn helps to manage loads.

Preliminary Results

The program uses maps to read from three different pricing options namely, RTP, TOU and Flat Rate. After relevant data is accessed from the program, the consumer is prompted to input a time he/she would like to begin charging. Based on the time, the program calculates the best time index to charge the vehicle in order to save the most money.

Table II [11] contains the assumptions made for portrayal purposes with a time and price index. The graph seen in Figure 8 is representative of the results the consumer will see with estimates on savings on price using each pricing model, thereby giving the consumer a better idea of how much he/she can save if the PHEV is charged at suggested times.

To demonstrate how the program will be used, the program uses a few appliances per load type. The functions are used on a smaller scale so inconsistencies can be de-

bugged and fixed instantly. Data is divided into maps and stored as described in Table III. The following graphs in Figure 9 and Figure 10, give the reader a visual portrayal of how the code would internally shift loads if the peak load under the base case scenario (no PHEV) were exceeded.

The max peak is a line measured using load calculations from appliances alone. PHEV load is not measured in this account for peak load so as to show how a smart home may manage its appliances economically with little difference caused by a new PHEV load.

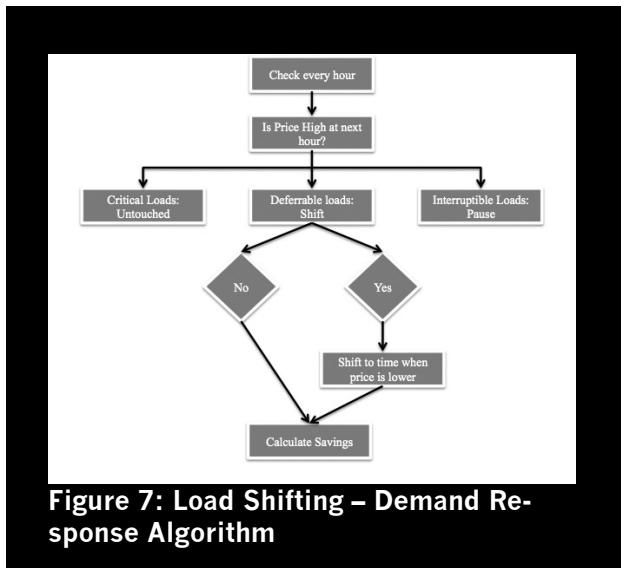


Figure 7: Load Shifting – Demand Response Algorithm

PHEV Charging Price Profile – 1 day		
Pricing Option	Time Index	Total Spent: Yearly
Real Time Pricing	[12am, 1am, 2am, 3am, 4am, 6am]	\$55.84
Time of Use Pricing	[7pm, 8pm, 9pm, 10pm, 11pm, 12am]	\$131.40
Flat Rate Pricing	[7pm, 8pm, 9pm, 10pm, 11pm, 12am]	\$153.30

Assumptions for scenario purposes only:

- Worst Case Scenario
- Current Battery Capacity: 0kWh
- Time the PHEV will be stationed to charge: 7pm

Table II

Household Load Profile		
Load Type	Appliance	DR Algorithm
Critical Load	Refrigerator	These loads are unaffected with rise and fall of prices
Deferrable Load	PHEV Dryer	If household peak load is exceeded, deferrable loads chosen by priority are shifted to more times when prices are lower
Interruptible Load	Television Lighting	Turned off when prices are high and restarted by prompt when prices are low again.

Table III

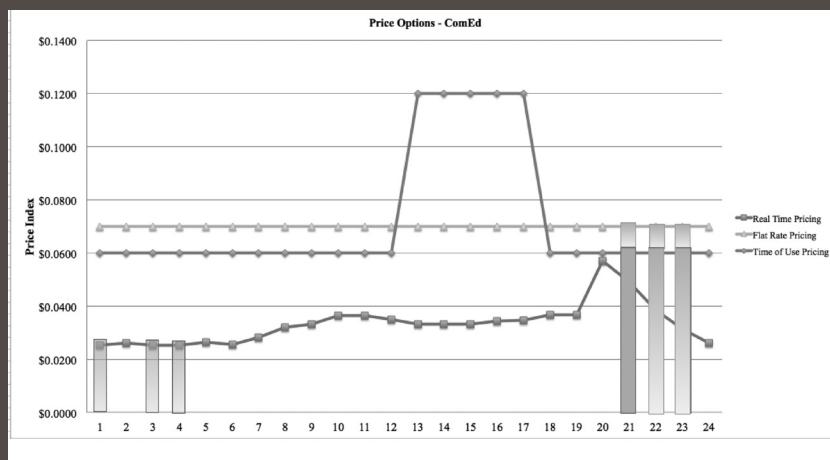


Figure 8: ComEd Pricing Options and PHEV charge based on scenario

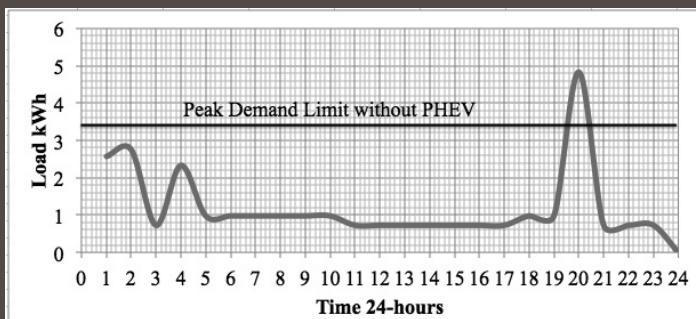


Figure 9: Household loads before any shift

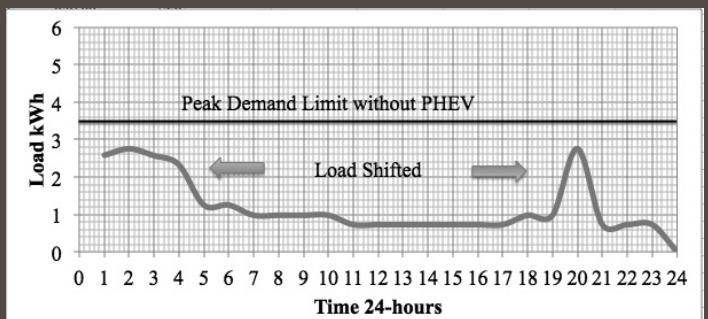


Figure 10: Household Loads after Shifting Load

Conclusion

This paper studies the integration of technology into consumer life to aid and control residential using advanced and superior technology enabled by Smart Grid developments.

The Smart Grid is a budding web with no beginning or end. Consumer homes, generators and electrical appliances will be connected without bias so energy flow is adequately and securely maintained under all conditions. It ensures a two-way flow of electricity and information between the power plant and the smart meter, which will be installed in every home. The paper helps further the use of the smart meter by using its readings to create a scenario of a typical household. This is created to paint a realistic picture of load shifting and PHEV charging with the primary aim of minimizing cost for the consumer.

Using RTP and TOU rates from ComEd for the Chicago area, the program is built keeping the consumer's needs in mind. The Java framework, using parameters for peak price and load, is able to shift loads dynamically as per consumer convenience to determine significant savings per household.

Future Work

Need for Disaster Management:

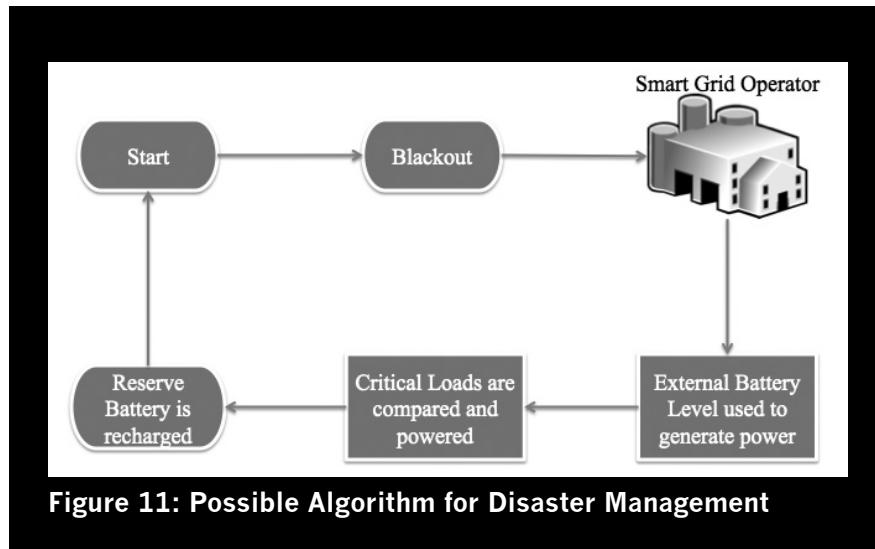
Today, interruption of electricity due to blackouts can begin a series of botches that can affect communications, signals, security and traffic [14]. In places that are too hot or cold or places that require constant heat or cold suffer greatly and in turn begin another domino effect of failures including losses in infrastructure and personal assets. A smarter grid with automated self-healing features and adaptive technology will strengthen the power

grid making it more resistive to natural and man-made attacks. Such a grid will help minimize outages and minimize losses when hit.

The system is built so when an area or sector loses power, it is isolated from the rest of the grid so neighboring areas may function unaffected while the isolated sector is located and power is restored immediately. With the Smart Grid functioning as an interactive web of network and information, each household is built individually yet fully connected to other houses in the community. This way when one house loses power, it is isolated so other houses remain unaffected.

Disaster Management is an important concern that can be tackled using clean and effective programming. Figure 8 depicts a possible algorithm that a program may follow to handle stress and spontaneous failures on the grid. While all of the code is written using JAVA, future work would include working to build a smart phone application so a consumer may be able to control his/her energy consumption at the palm of his/her hand. The technology market is changing quickly and dramatically. Today, a majority of homeowners own smart phones. Hence, a free software application that enables a homeowner to minimize his/her electricity bill and manage energy with his/her smart phone should be made available as soon as possible.

Exploring Storage Options: Significant research is being made on energy storage integrated with the Smart Grid. Research thus far has external storages functioning as individual units to supply power only when needed and recharged at the earliest convenience. One such energy storage container is a disused PHEV



battery that can be installed in a consumer home.

PHEV batteries that have end of life 80% capacity supply power seamlessly and with very little or no struggle. Benefits include: energy arbitrage, ancillary services-regulation, spinning and non-spinning reserve and back-up energy. Energy arbitrage refers to charging batteries at off-peak hours and discharging power to appliances at peak hours to utilize differences in energy prices and minimize cost. Ancillary services are divided into various classes but the most common types include regulation, spinning and non-spinning reserves.

Regulation, the highest quality ancillary services [8], is used to match the frequency and voltage of the grid by unerringly matching dynamic energy demand and supply.

Backup energy refers to using a reusable PHEV battery to supply power in case of an emergency resulting in a blackout. Although PHEV batteries may not be able to supply power to the entire household, the battery could provide enough power to run critical loads such as heating in winter months and home security.

Ethical Considerations

As engineers, we are expected to perform to our highest potential because our work and research may directly or indirectly influence future research in the field. As students, it is harder to understand the direct implications of our work in the real world. We face a constant need to push ourselves to perform to the best of our abilities and work on retrieving data that is accurate and meaningful.

The JAVA program discussed in this paper is developed using an original algorithm. That being said, there is immense room for improvement. Scenarios used to drive a point, are based on educated guesses of an average household that contains basic appliances one may not be able to do without. Thus while the program itself is not ready to be developed into a software application for smart phones, the program does provide a backbone to the algorithm that will be used to accomplish this technological goal.

Acknowledgements

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Efforts Toward Manipulating SMYD Proteins for Bio-orthogonal Profiling of Protein Methylation

Rhiannon Aguilar, Jamie McBean, Joshua Linscott, Minkui Luo

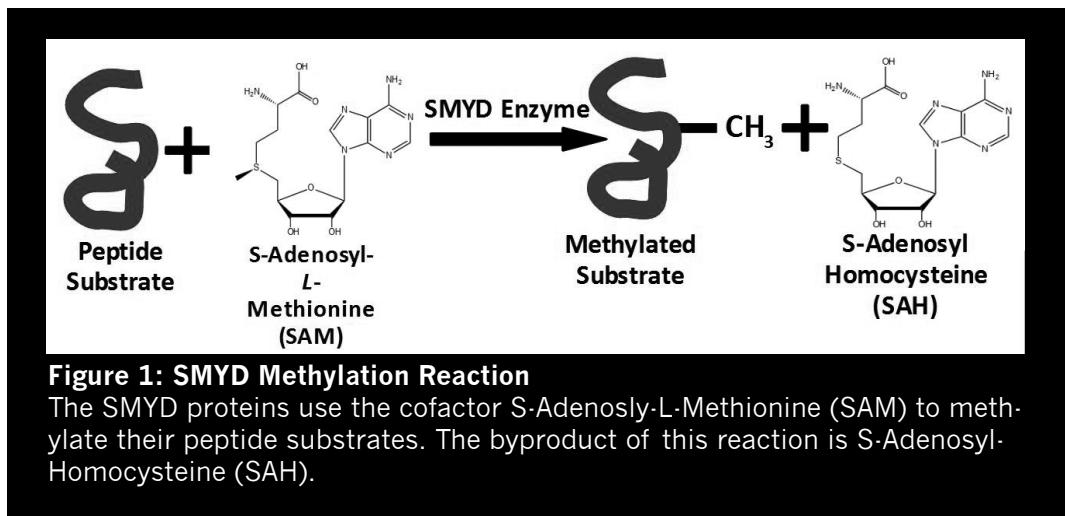
Abstract

The SET- and MYND-domain-containing proteins, or SMYDs, are a family of protein lysine methyltransferases (PKMTs) that use the small molecule S-Adenosyl-L-methionine (SAM) as a cofactor to methylate various histone and non-histone targets. The Luo Laboratory has recently synthesized several synthetic analogues of SAM that can be utilized by engineered PKMTs to add a tag containing a terminal alkyne group, instead of a methyl group, on their substrates. This allows the modified proteins to react with fluorescent dyes via click chemistry for their detection. The goal of this research is to use these cofactors to profile the substrates of the SMYD proteins, a key step toward full elucidation of SMYDs' biological roles. So far, SMYD1, SMYD2, SMYD3, and SMYD5 have been cloned from bacterial pET28-MHL vector into mammalian pcDNA3 vector. Five single mutants of the mammalian vector clone of SMYD3 were made. Each mutation was strategically placed to alter the size and shape of SMYD3's cofactor-binding pocket. These five mutants have been transfected into HEK293T cells. Western blotting was used to confirm transfection success and whole-cell lysates have been screened with four synthetic clickable cofactors. Preliminary results indicate potential success with one of the cofactors across several of the mutants. Repeat experiments will be done to confirm results, and new mutagenesis sites will be explored in the future across all five SMYD proteins, beginning with SMYD2.

Introduction

Epigenetic changes made to gene expression are not directly caused by the DNA's coding nucleotide sequence. Such changes affect a wide spectrum of genes and can be inherited through several generations. The various mechanisms behind epigenetics include chemical reactions involving the DNA backbone or histone proteins, such

as methylation, acetylation, deacetylation, and demethylation. Other mechanisms, such as those involving RNA, are currently being studied [1]. Several classes of enzymes play key roles in mechanisms affecting gene expression, such as the DNA Methyltransferases (DNMTs), Protein Arginine Methyltransferases (PRMTs), Protein Lysine Methyltransferases (PKMTs),



and Histone Deacetylases (HDACs).

The PKMTs use a small-molecule cofactor, S-Adenosyl-L-Methionine (SAM), as the methyl donor [2] (Figure 1). Their targets include histone sites [3], each with an activating or deactivating effect on gene transcription. The histone substrates of many of the PKMTs are well-documented [3]. Additionally, non-histone targets of PKMTs are currently being studied. Several members of the SMYD family of PKMTs, for example, are known to methylate histone sites such as Histone 3 Lysine 4 (H3K4) and H3K36. Recent research has revealed, however, that SMYD2 also methylates p53 and a protein known to cause the cancer retinoblastoma [4], two tumor-suppressing pathways. These recent discoveries demonstrate how little is known about the SMYDs' substrate profiles and how much remains to be studied.

On a larger scale, the SMYDs have been shown to have important biological roles. SMYD1 has been linked to cardiac development; fetal mortality is common in mice with the SMYD1 gene knockout [5]. Overexpression of SMYD3 has been linked to the outgrowth of breast [6] and colorectal [7] cancer cells and its suppression can cause inhibition of the growth of

these same cells. Relevance to vital organ development and cancer metastasis makes the SMYD family an interesting target of study. There is potentially a whole host of unknown substrates for this enzyme family, any of which may give a vital clue to the mechanisms behind the SMYDs' larger biological roles, including those causing disease. It is these substrates that are particularly interesting research subjects.

Substrate profiling of protein methyltransferases has been explored in recent research using synthetic SAM analogues which can be used to label substrates with an easily detectable group donated by the cofactor analogues. Initial efforts to use these synthetic cofactors attempted to use analogues that could be accepted by native enzymes in the cofactor-binding pocket intended for native SAM. However, this method proved to be useful for only a select few of the numerous PMTs [8]. Bio-orthogonal Profiling of Protein Methylation, or BPPM (Figure 2), has been used successfully by the Luo Laboratory as an alternative method of substrate profiling. This method is considered bio-orthogonal because it does not interfere with natural processes of PKMTs. The SAM analogue can only be taken up by the engineered

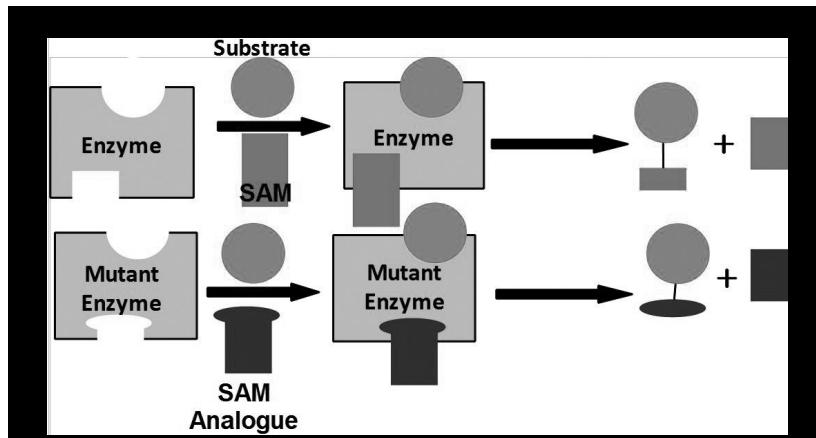


Figure 2: Methodology of BPPM

In nature, a native enzyme reacts with native SAM to produce a methylated protein substrate and SAH as a byproduct. In BPPM, the enzyme is mutated to accept a synthetic SAM analogue, producing a product labeled with the synthetic R-group of the analogue.

enzyme, so the native enzyme is not affected. If the cofactor binding pocket of the targeted PKMT, in this case a SMYD protein, is mutated in the correct way, it can be specifically engineered to take up a synthetic SAM analogue when the native enzyme would only accept SAM. The Luo Laboratory has synthesized several SAM analogues, notably those containing a terminal alkyne group such as 4-propargyloxy-but-2-enyl (Pob)-SAM [9] and (E)-he-2-en-5-ynyl (Hey)-SAM [2]. These SAM analogues have been used recently to profile the substrates of methyltransferases PRMT1 and G9a, respectively, using targeted mutations to their cofactor binding pockets [2], [9]. The terminal alkyne group present on both synthetic cofactors is able to undergo high-efficiency click chemistry with azide dyes, allowing for analysis of labeled substrate proteins.

Given this method's success in the PKMT family, the goal of our research is to extend it to the SMYDs. Beginning with SMYD2 and SMYD3, the cofactor-binding pockets of the SMYDs will be engineered to accept synthetic SAM analogues,

facilitating labeling of their protein substrates and allowing them to be profiled.

Materials and Methods

Molecular Cloning: DNA sequences were originally contained in pET28-MHL bacterial plasmid vector. The protein inserts were amplified using the Qiagen® HotStar® Hi-Fidelity Polymerase Chain Reaction Kit. To prepare for the SMYD insert, the mammalian plasmid vector pcDNA3, containing an unwanted insert, was obtained and digested with appropriate restriction enzymes (Hi-Fidelity EcoR1, Nhe1 and/or Not1). The PCR product of each SMYD sequence was digested with the same restriction enzymes, and then ligation was done using the T4 DNA Ligase enzyme. All enzymes were obtained from New England Biolabs, Inc®. A 1:6 ratio of insert:vector was used for ligation, and successful reactions were transformed into TOP10 *E. coli* cells. After sequencing, successful clones were subsequently identified and transformed into DH5α *E. coli* cells, where DNA was harvested using the Qiagen® Hi-Speed® Maxiprep kit®.

Mutagenesis: Mutagenesis of Y239, I238, and N181 were performed using the Qiagen® QuikChange® Mutagenesis Kit and transformed into XL10 Gold *E. coli* cells. Successful mutants, as determined by sequencing, were again transformed into DH5 α cells, which amplified the DNA so it could be collected by using the Qiagen® Maxiprep Kit®.

Transfection and Cell Lysates: HEK293T cells were transfected with 4 μ g of DNA in 250 μ L of Opti-MEM and 8 μ L of lipofectamine. They were allowed to grow for 8 hours before being treated with 15 μ M AdOx. 48 hours after the AdOx treatment, they were pelleted and frozen. The frozen cells were thawed and lysed using sonication in a RIPA buffer containing Roche protease inhibitor and 1 mM TCEP. Protein concentrations were measured using the Bradford Assay, and cofactor incubation was carried out overnight in 50 mM 4-(2-hydroxyethyl)-1-pipera-

zineethanesulfonic acid (HEPES) buffer (pH 8.5) with 0.0005% Bovine Serum Albumin (BSA), 0.005% Tween® 20, and 50 nM 5'-Methylthioadenosine/S-adenosylhomocysteine nucleosidase (MTAN). Click reactions were performed using 100 μ M tetramethylrhodamine azide, 1 mM CuSO₄, 2 mM tris(2-carboxyethyl)phosphine (TCEP), and 100 μ M Tris[(1 - benzyl - 1H - 1,2,3 - triazol - 4 - yl)methyl] amine (TBTA). After washing with methanol, water, and chloroform, resulting proteins were analyzed using in-gel fluorescence. The fluorescence assay picture was taken at wavelength 600 nm on a GE Healthcare® Typhoon Trio® Variable Mode Imager. A Western blot was run to confirm successful transfection.

Results

The SMYD DNA sequence contained in the pET28-MHL vector can be used to express the SMYD proteins in *E. coli* bac-

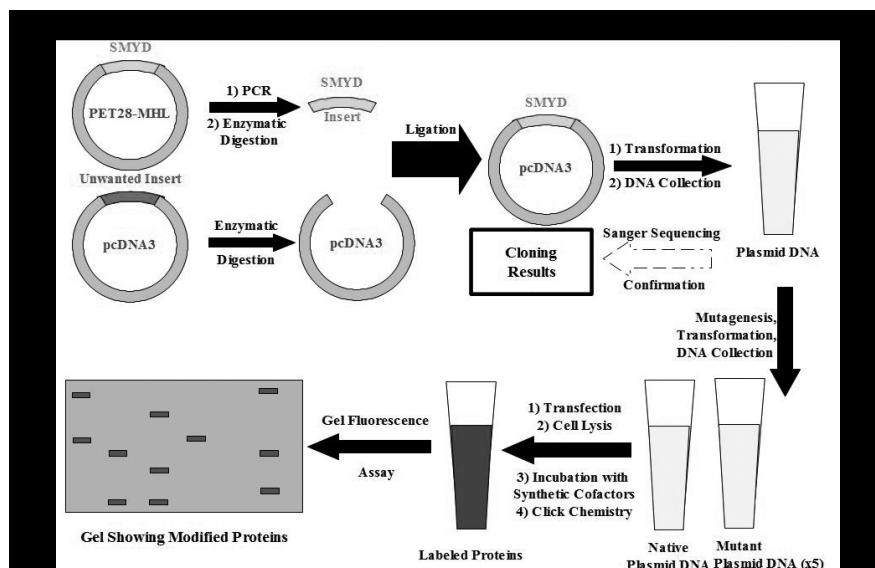


Figure 3: Experimental Outline

The SMYD protein insert, originally contained in the pET28-MHL vector, was cloned into the pcDNA3 vector. The cloned vector was transfected into mammalian cells, which produced the protein. Finally, the click reaction was carried out, and the result was tested using in-gel fluorescence to check for targeted protein labeling.

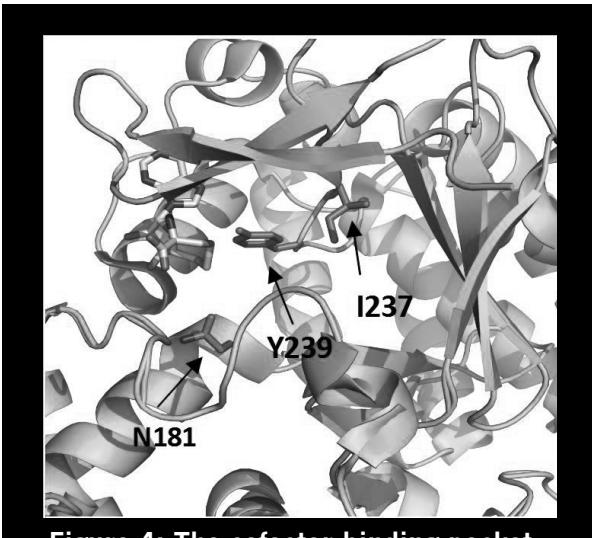


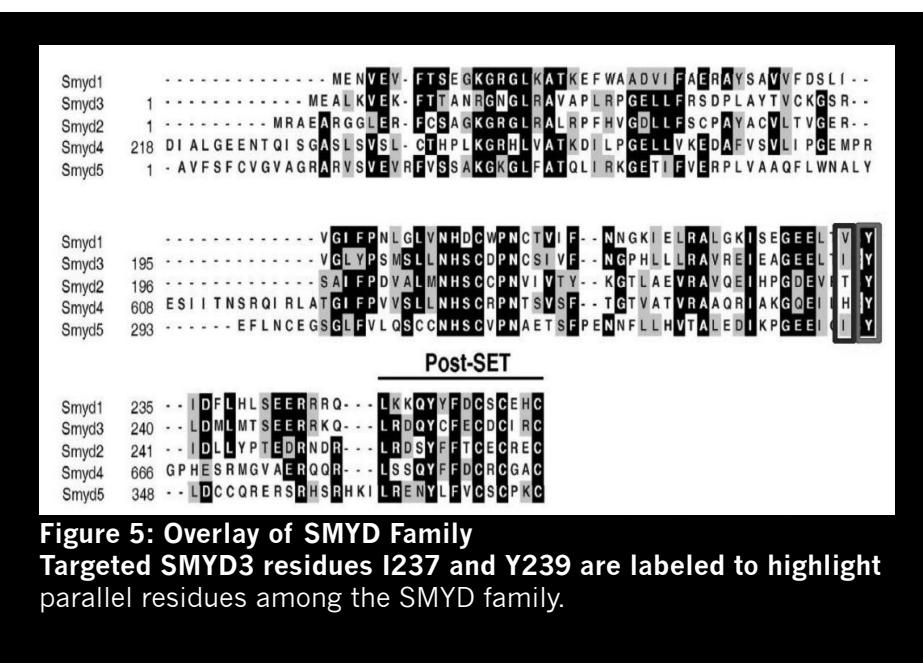
Figure 4: The cofactor-binding pocket of SMYD3

Targeted residues N181, Y239, and I237 are labeled.

teria for *in vitro* experiments. However, a combination of factors made this an unfavorable system for testing the SMYD proteins. First, previous experiments revealed a markedly low activity level of the SMYDs *in vitro*, presenting difficulties when attempting experimentation. In addition, *in vitro* experiments often give inaccurate results, as they are not a thorough representation of the natural environment

where the SMYDs, or any proteins, are active. As an alternative, we decided to transfet the SMYD proteins into mammalian HEK293T cells. Before transfection, it was necessary to clone the SMYD insert from the bacterial vector pET28-MHL into the mammalian vector pcDNA3 which could be used for transfection. Successful clones of SMYD1, SMYD2, SMYD3, and SMYD5 were obtained, and the plasmid DNA stocks were made ready for use.

Of the four cloned SMYD proteins, SMYD3 was chosen for the first experiments, as its well-documented association with cancer cell proliferation makes it a particularly interesting target of study. Before transfection, five single mutations were chosen as the first SMYD3 variants to be screened against several synthetic cofactors. These five mutations—Y239A, Y239G, N181A, N181G, and I237A—are all located in the active site (Figure 4) and are designed to change its shape, making it larger to accept more bulky cofactor analogues. These three mutation sites (Y239, N181, and I237) in particular were targeted based on previous research. It has been



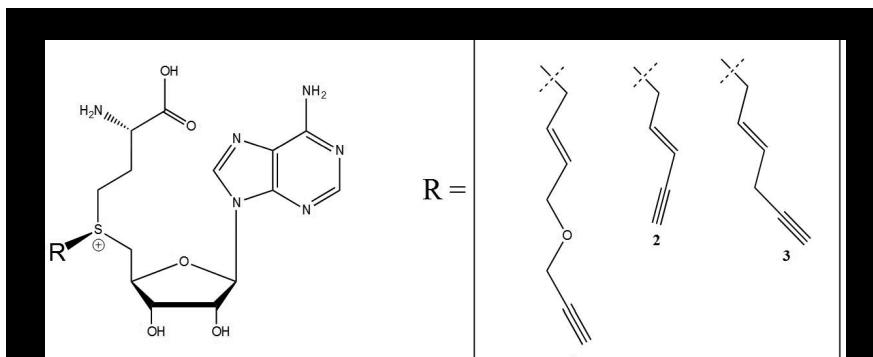


Figure 6: Synthetic SAM Analogs Used

The methyl group of SAM was exchanged for 3 different “R” groups: Pob-SAM (1), (E)-pent-2-en-4-ynyl-SAM (2), and Hey-SAM (3). A fourth, unpublished structure was also used.

noted that residues highly conserved within a family are more likely to be important in maintaining the shape of the active site, and hence more likely, when mutated, to allow the pocket to accept SAM analogues. Y239 is an example of one such highly-conserved residue, as demonstrated by Figure 5 [10] (dark box). I237 (light box), is also partially conserved through the family. It appears in SMYD5 as an isoleucine and in SMYD1 as the similarly-structured valine. An alternative way tar-

geted sites were chosen was by analyzing homologous enzymes to look for analogous residues. If mutations to these analogous residues were found to be successful, the residues in the SMYDs may be targets for useful mutations. While unsupported by formal publication, N181 was chosen because when an analogous asparagine is mutated in SET7/9, another PKMT, the structure of the cofactor-binding pocket is successfully changed without decreasing the measurable enzymatic activity (data

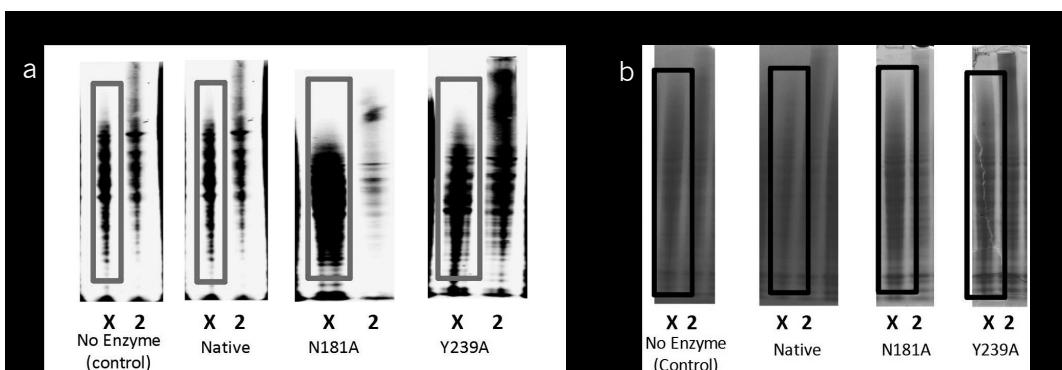


Figure 7a: In-gel fluorescence image

In-gel fluorescence showed significant difference in the amount of protein labeling in mutations N181A and Y239A relative to the two controls. Compound X, the SAM analogue which produced this labeling, is the unpublished structure.

Figure 7b: Protein gel Coomassie stain

Stain showing the amount of protein loaded into each well of the fluorescence gel. The similarly-sized bands show that a similar amount of protein was loaded into each well and that the varying amounts of fluorescence were not caused by varying amounts of protein.



not shown). Therefore, these five mutations were chosen, and all five mutants plus native SMYD3, were transfected into mammalian cells.

After transfection, the cells were lysed and the resulting proteins were collected for screening against several clickable cofactors. Four were chosen; among them were Pob-SAM (1), (E)-pent-2-en-4-ynyl-SAM (2), Hey-SAM (3), and an unpublished SAM analogue (Figure 6). These four cofactors reacted efficiently with the azide dye used, and Figure 7 shows selected results from the in-gel fluorescence image obtained after the reaction, along with the Coomassie stain of the protein gels, used as a loading control. The boxed wells are notable because of the striking difference in the size and darkness of the bands present. The first two boxes (negative control and Native SMYD3) were not expected to label any substrates because the enzyme was not transfected and not mutated, respectively. For the mutants, it was hoped that the bands present would be significantly thicker and darker, indicating that the modified enzyme had taken up the synthetic cofactor and labeled its substrates with the clickable group present

on that cofactor. The presence of thicker bands for mutants N181A and Y239A, in the well containing proteins potentially labeled with group X, suggests that these mutations successfully alter the SAM binding site in a way that it is able to accept compound X and its synthetic R group, which is labeling SMYD3's substrates in the cell lysates. A similar effect seems to be present in the in-gel fluorescence images for compound 2 on the mutant Y239A. However, it is noticeable on the Coomassie stain that there is significantly more protein in the Y239A well for compound 2 than for any other enzyme varieties.

Parallel to the in-gel fluorescence assay, a Western Blot was run to confirm that transfection was successful and that the enzymes were in fact expressed in cells. The pcDNA3 vector into which the SMYD sequences were cloned contained a FLAG-tag, which was expressed along with the SMYD proteins. An antibody to the FLAG-tag was used in the Western blot, and all six transfections were shown to be successful (Figure 8).

Discussion

The results obtained from the fluo-

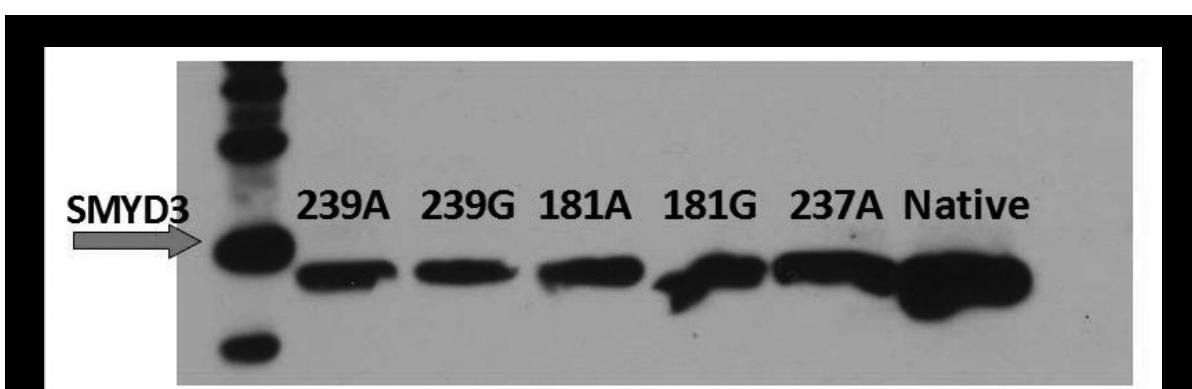


Figure 8: Western Blot Image

The Western blot used the FLAG-tag present on each cloned protein to measure expression of transfected protein in the cells used. Native was over-expressed, as expected, but otherwise all of the transfections were successful and had relatively consistent expression.

rescence assay indicate that there may have been some success in engineering SMYD3 to accept SAM analogues. If this is the case, then more specific tests to identify elucidating a comprehensive profile of the histone and non-histone substrates of SMYD3. However, before this conclusion can be concretely drawn, it is necessary to repeat the experiment several times in an attempt to reduce the background that is present in the image. This is likely due to the presence of excess cofactor that has reacted with the dye independently of enzymatic activity. In future experiments, extra steps will first be taken to eliminate this excess cofactor.

Once the fluorescence assay process has been refined in a way that will allow us to accurately verify substrate labeling by the SMYD3 mutants, further exploration will be done. If one of the five initial mutants was successful, then more specific analysis of the labeled proteins can be done to determine their identities. If none of the first attempts are successful, then other mutations will be attempted within the active site. Instead of single mutants, double, and possibly triple, mutants will be made to alter the size and shape of the cofactor-binding pocket even more, making the likelihood of the mutant accepting the synthetic cofactors significantly higher.

While experiments are run with SMYD3, efforts will also be made to profile the substrates of the other SMYD proteins, with emphasis on SMYD2. Because the active sites of SMYD1, SMYD2, and SMYD3 line up closely, a mutation or combination of mutations that can be shown to be successful in SMYD3 may also be successful when used in SMYD1 or SMYD2. Also, if the experiments are run in parallel, a new mutation in SMYD1 or SMYD2 may

be found that can be applied to SMYD3. These three are the principal targets because their biological significance is evident. SMYD4 and SMYD5 may eventually be added to the list of targets if it is later shown that they also have vital cellular functions. As a result of these preliminary efforts, we are on the way to developing a system that may be used to profile the substrates of the entire SMYD family. Also, once a highly reliable combination of mutations is matched with a synthetic cofactor, such a method can be applied to research beyond simply discovering a list of substrates that react with the SMYDs. Researchers inside and outside the Luo Laboratory may be able to screen biological systems, including particular cancers, to determine which proteins in that particular system may be regulated by a SMYD protein, and what can be done to alter this regulation in a way that will benefit the system.

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Fluorescent Polarization Assays Quantify Human Mitochondrial Transcription Factor A DNA Binding

Deryck Pearson, Fernanda Lodeiro, Akira Uchida, and Craig E. Cameron

Abstract

Human mitochondrial transcription factor A (TFAM) is a DNA binding protein responsible for transcription activation in mitochondria. It is also required for DNA compaction into nucleoids and DNA maintenance. TFAM belongs to the high mobility group (HMG) superfamily, containing two HMG boxes and an additional carboxy-terminal domain. To date, quantitative studies addressing DNA binding specificity have not been performed. A detailed understanding of basic events underlying the specific DNA binding of TFAM as a transcription factor and its role in nucleoid formation has yet to be achieved. The purpose of this study is to develop an assay to further understand what these determinants are, in regards to specific DNA binding. We have used, in the past, fluorescence polarization to study DNA binding. In these assays, increasing concentrations of TFAM are incubated with fluorescently labeled DNA, and the change in polarization is utilized to infer DNA binding affinity. Here, we discuss results obtained with mutant TFAM carrying deletions in the carboxy terminal domain. Our results suggest a key role of this domain in DNA binding. We also describe the development of an alternative approach in which the fluorescent label is located on the protein. This approach may permit the characterization of TFAM binding to various DNA sequences and gain insight into the specificity of DNA binding.

Introduction

Mitochondria are the powerhouses of the cell. Their main role is the production of energy for cellular function through oxidative phosphorylation. Mitochondria also play a role in fatty acid oxidation, metabolism of calcium and iron, biosynthesis of amino acids and heme, and apoptosis [1]. Mitochondria have their own genome that encodes information essential for

the expression of components of oxidative phosphorylation including, mRNA, tRNA and rRNA, which are necessary for protein synthesis *in organello* [2]-[4]. It is very well established that mutations in the genes that encode components of the oxidative phosphorylative system can lead to mitochondrial diseases, typically with manifestations that affect the main energy-consuming organs, such as the heart,

brain and muscles. In recent years, it has been recognized that several human diseases, such as cancer, diabetes, Parkinson's disease, dementia, and diabetes mellitus, all have a correlation with defective mitochondrial function [5]-[10]. One hypothesis explaining this phenomenon is that mitochondrial DNA (mtDNA) can accumulate mutations over the life span of the mitochondria. An underlying reason why mtDNA is highly susceptible to mutation is because it lacks efficient DNA repair mechanisms and it functions in a highly oxidative environment.

Transcription is the process of converting information stored in the form of DNA into RNA. This then allows that information to be converted into proteins for a wide array of functions. Only a single regulatory region, called a displacement loop (D-loop), is contained in mtDNA. Transcription in mitochondria starts from three promoters: the light strand promoter (LSP) and heavy strand promoters 1 and 2 (HSP1 and HSP2). Transcription from the most studied promoter, LSP, requires three protein components: mitochondrial RNA polymerase (POLRMT), mitochondrial transcription factor A (TFAM) and mitochondrial transcription factor B (TFB2M) (Figure 1). We hypothesize that mutations within the mtDNA regulatory region, particularly within the promoters, may affect TFAM binding and/or POLRMT/TFB2M recruitment to the promoter. Thus transcription initiation, and therefore gene expression, may ultimately lead to impairment of mitochondrial function.

TFAM is a member of the high mobility group (HMGB) superfamily of DNA binding proteins defined by the HMG DNA binding domain (HMG box). Proteins from this fold are classified based on

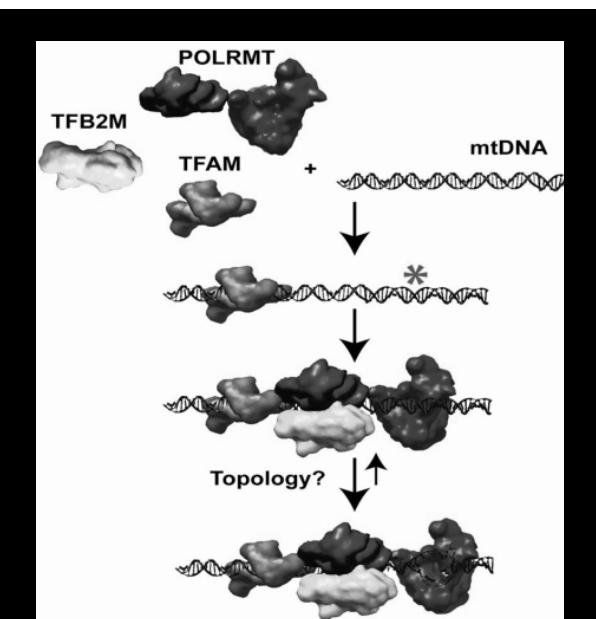


Figure 1: Model of TFAM-DNA binding and mitochondrial transcription initiation. First, TFAM binds the LSP promoter, forming a complex. The complex changes the DNA conformation, allowing the recruitment of POLRMT and TFB2M to initiate transcription [11].

DNA binding: sequence-specific through promoter regions and nonsequence-specific based on the physical structure of DNA.

TFAM has multiple functions. First, it can act as a transcription factor by binding to a specific sequence in the LSP promoter upstream of the initiation site [11]. In addition, it has been shown that TFAM can activate transcription from the HSP1 promoter. The activation is enhanced by the presence of the LSP promoter and takes place at concentrations in which LSP transcription is inhibited [12]. Moreover, TFAM participates in mtDNA packaging into nucleoids and mtDNA maintenance [13], [14]. The protein determinants for each of these functions have not been elucidated.

TFAM has two HMG-box domains, separated by a short link. In addition, it has a carboxy-terminal domain of 26

amino acids [15]. This domain has been implicated in transcription initiation since its deletion abolishes transcription [16]. However, the mechanism underlying this observation has not been described. While it is known where TFAM binds in LSP, it has not been studied in great detail which base pairs are responsible for this interaction and whether mutations in this region in human mtDNA can affect transcription initiation. Here we report the use of fluorescence polarization to study TFAM and DNA interaction. By tagging the DNA we can quantitatively probe the necessary TFAM structures for binding. Then, by tagging TFAM, we should be able to find the target DNA sequences for TFAM binding.

Materials and Methods

Materials: Purified TFAM, TFAMdCT, TFAMd10CT, and TC-TFAM were previously prepared in the Cameron laboratory. DNA oligonucleotides were obtained from Integrated DNA Technologies Inc. and purified by PAGE gel electrophoresis. BSA was obtained from New England Biolabs. The Biarsenical Fluorescein derivative FlAsH was obtained from Invitrogen. All other reagents were received from VWR and Fisher.

Annealing: The non-template strand, 5'-ATGTGTTAGTTGGGGGGT-GACTGTAAA-Fl-3', where Fl means fluorescein, and template strand (reverse complimentary strand) were annealed at 25 μ M in 10 mM Tris-HCl, pH 8.0, 1 mM EDTA, and 50 mM NaCl by using a Progene Thermocycler (Techne). The annealing solution was then heated at 90°C for 1 minute, then cooled at a rate of 5oC per minute until it reached 10°C.

TFAM Titration for TFAM-DNA

Binding: The reaction mixture for anisotropy for measurement was prepared as follows. TFAM was serially diluted in Enzyme Dilution Buffer (10 mM HEPES, pH 7.5, 20% Glycerol, 100 mM NaCl and 1mM DTT) to acquire the appropriate concentrations. Fluorescein-labeled DNA was diluted in annealing buffer. The DNA binding reaction contained 10 mM HEPES, pH 7.5, 10 mM MgCl₂, 1 mM DTT, 0.1 μ g/ μ L BSA, 100 mM NaCl, 0.1 nM DNA, and various concentrations of protein typically in 100 μ L. The samples were then transferred to glass tubes and incubated at 25°C for approximately 30 sec before obtaining the mini polarization (mP) values.

Plots of the change in mP as a function of TFAM concentration were used to determine the equilibrium dissociation constant (K_d) for the interaction between TFAM and LSP binding site. The data was fit to a hyperbola (Eq. 1) using the program KaleidaGraph (Synergy Software, Reading, PA). This procedure was used for wild-type TFAM, TFAMdCT and TFAM-d10CT, two other TFAM variants.

$$\text{Equation 1} \quad mP = (mP_{max} * [TFAM]) / (K_d + [TFAM])$$

Results

TFAM-DNA Binding Characterization using fluorescence polarization (FP): To study TFAM target site we used fluorescence polarization (FP). The advantages of fluorescence polarization include that it is fast, reproducible, reports on the equilibrium in solution and does not require radioactivity materials. FP permits the study of molecular interactions by tracking size changes of fluorescent molecules. The polarization depends on

the apparent size of the fluorescent molecule. As the fluorescent molecule is incubated with its binding partner, binding occurs. The complex formed has a higher apparent size, which polarizes the emitted light. For protein-DNA interactions, the fluorophor can be incorporated in the protein or in the DNA (Figure 2).

To begin our studies we performed FP assays using a fluorescently labeled TFAM binding site and titrating increasing concentrations of TFAM. The data was plotted to a hyperbola and the K_d obtained was 1 nM (Figure 3). This indicates tight binding here.

TFAM carboxy terminal domain is important for DNA binding: As men-

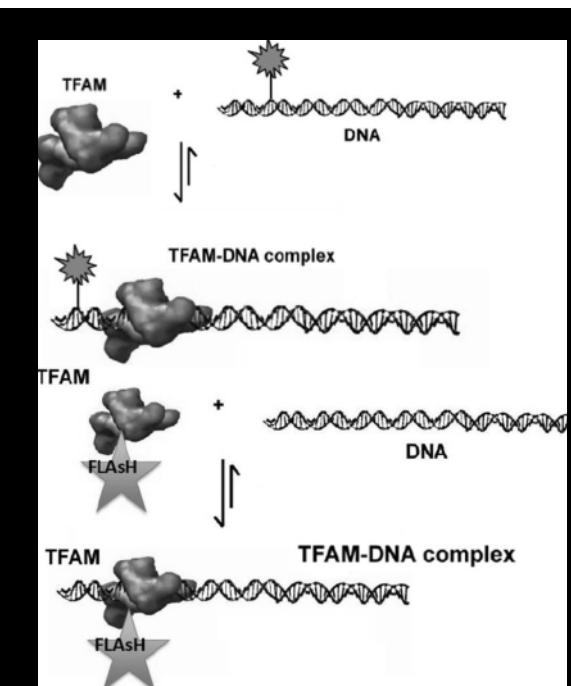


Figure 2: Experimental design to study protein-DNA interaction by FP. **a-** A fluorescently labeled DNA is incubated with increasing concentrations of TFAM. This approach permits the study of determinants for specific binding in the protein. **b-** A fluorescently labeled TFAM derivative is incubated with increasing concentrations of DNA. This approach permits the study of different DNA sequences and dissection of determinants for specific binding within the DNA.

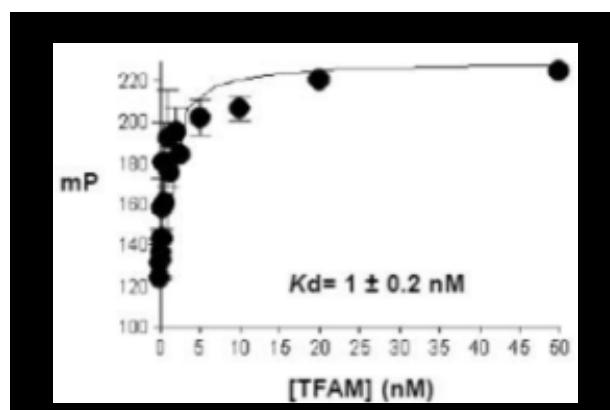


Figure 3: TFAM-DNA Binding. Fluorescein-labeled DNA was used to titrate TFAM concentrations ranging from 0.03125 nM to 500 nM. The data points were plotted using Eq 1 to determine the K_d .

tioned above TFAM contains two HMG boxes and a carboxy-terminal domain (CTD) that have been implicated in transcription initiation. In order to determine the function of the carboxy-terminal domain we used a protein variant in which this domain was deleted (TFAMdCT). We performed the FP assay as described above, titrating TFAMdCT. We found that the deletion of the CT domain greatly decreased the binding affinity (30 fold). The K_d value is 31 ± 4 nM (Figure 4). This result explains the observation that the CT domain fails to activate transcription and suggests that this domain is essential for high-affinity DNA binding [16].

We observed that within the CTD (amino acids 220 to 246) there are 16 amino acids that are highly conserved between mammalian species, while the last 10 amino acids differ (Figure 5). We wanted to know whether these last 10 amino acids are as critical as the entire CTD for DNA binding. We used FP to study the binding of TFAMd10CT to the fluorescently labeled DNA as described previously. We found that the binding affinity was moderately affected, with a K_d value of 9 nM

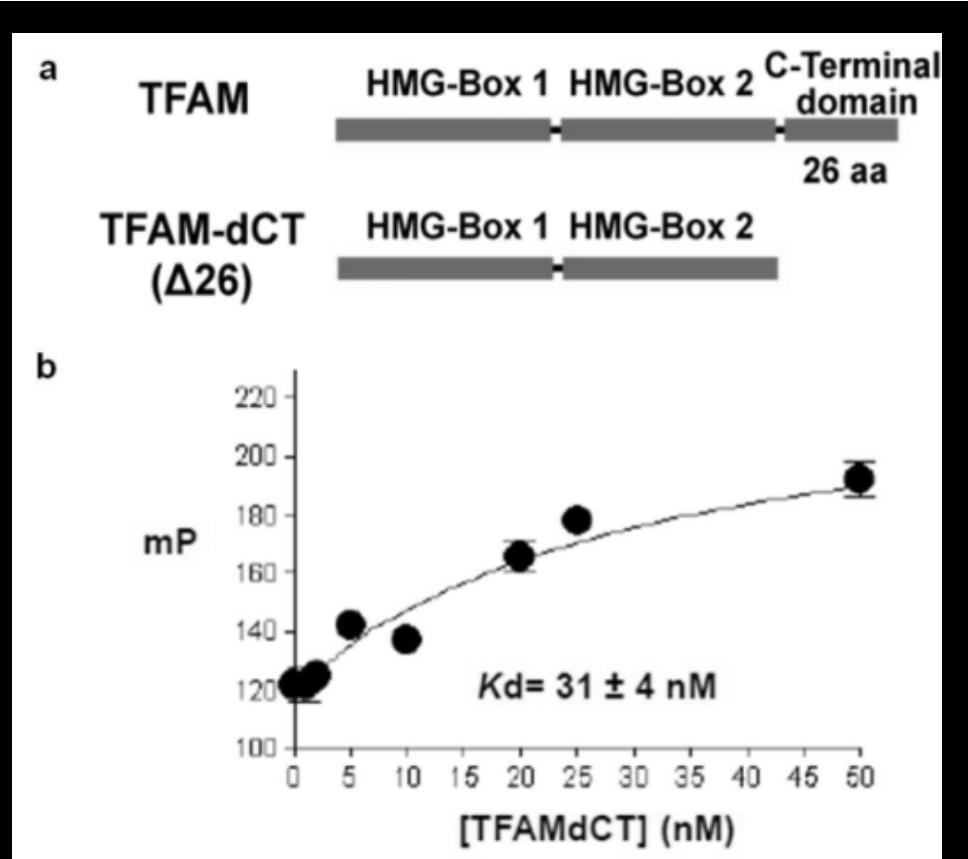


Figure 4: The carboxy terminal domain of TFAM is essential for specific DNA binding. a - Schematic of TFAM domains. b - TFAMdCT-DNA Binding. Fluorescein-labeled DNA was incubated with increasing concentrations of TFAMdCT, ranging from 1 nM to 1000 nM. The data points were plotted using Eq 1 to measure the K_d .

between the full length (TFAM) and the CTD deletion (TFAM-dCT). TFAM-d10CT was able to support transcription in our *in vitro* assays. The Last 10 amino acids contribute to DNA binding by 3-fold, while the whole CTD contributes 30-fold.

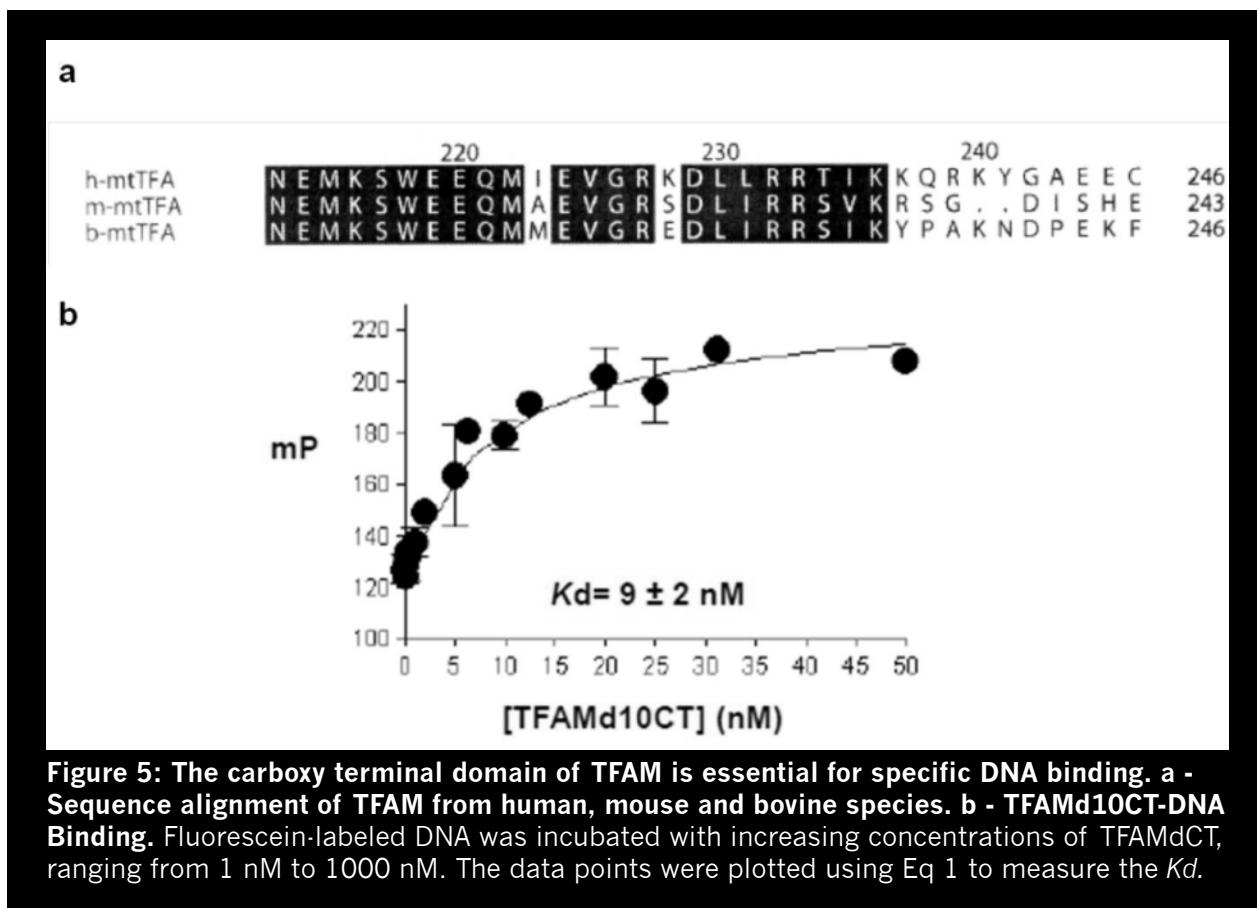
TC-TFAM-DNA Binding Characterization: As depicted in Figure 2b, to study the determinants of binding specificity within the DNA, it is useful to incorporate the fluorescent label into the protein. To do so, we introduced a tetra cystein (TC) motif in the N-terminal region of TFAM. The TC motif can then conjugate the fluorescent dye, FlAsH. It was important to confirm that TFAM function has not been affected by this modification. This was also determined using FP in which

TC-TFAM was titrated.

TC-TFAM binds with relatively tight affinity with a K_d of 3 nM (Figure 6). This result is comparable to the one obtained with wild-type TFAM and indicates that the addition of the TC motif does not impact DNA binding. This finding is in agreement with our results, showing that TC-TFAM functions as TFAM in transcription assays *in vitro*.

Discussion

The present work illustrates the use of FP to study TFAM binding to its DNA cognate. Here we showed that the carboxy-terminal domain has a critical role in DNA binding, explaining previous observations that TFAMdCT does not support

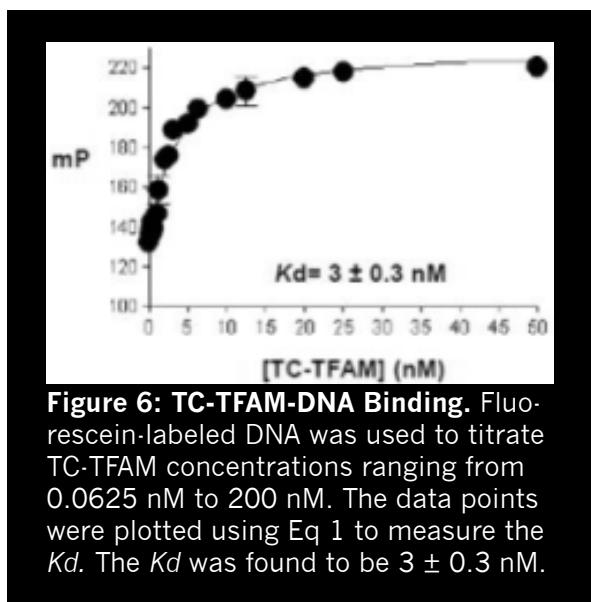


transcription.

This approach can be useful to address the impact of each amino acid within TFAM on specific binding. In relation to human disease, this assay represents a fast and accurate measurement to ad-

dress whether mutations within TFAM that can be observed in human populations will have an effect on DNA binding that could impair transcription and cause disease.

On the other hand, the finding that the derivative TC-TFAM maintains its DNA binding properties is very promising. An approach based on fluorescently labeled TC-TFAM should permit a detailed study of determinants for specific binding within the DNA, as well as testing mutations that may be present in human populations within the TFAM binding site. Utilization of this technique can hopefully provide a new tool to better investigate human mitochondrial diseases.



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Marxism and Frantz Fanon's Theory of Colonial Identity: Parallels between Racial and Commodity-Based Fetishism

Jacqueline Crowell

Abstract

Despite Frantz Fanon's and Karl Marx's shared goal of the emancipation of all human beings from oppression, Fanon maintains in his final book, *The Wretched of the Earth*, that the connection between his theory of colonial identity and Marxist ideology cannot be reduced to a superficial doctrine of class struggles. Though Fanon resisted an oversimplified comparison with Marxist theory, this paper argues that Fanon's analysis of the colonizers' fabricated identity of the colonized is derived from the structure of Marx's monetized social relations and the fetishism of the commodity which produces these relations. Marx defines commodity fetishism as the phenomenon in which the commodity is endowed with value through the labor process yet ultimately has a perceived value that is independent of the labor that produced it. Fanon adjusts this concept to the economic and psychological differences of colonialism. Fanon articulates that the colonial social relations are "epidermalized" and expressed through the whiteness of one's skin rather than monetized and expressed through the exchange of the money-form in the commodity market. Beyond the structural similarities between the commodity fetishism in the capitalist society and the colonial racial fetishism, this paper explores the deeper causal relationship between the two phenomena: the alienation of the colonizer which is projected onto the identity of the colonized and the ensuing exclusion of the colonized—from recognition of both their humanity and their identities—which constitutes the colonization of the native selfhood.

In his fifth chapter of *Black Skin, White Masks* entitled "The Lived Experience of the Black Man," Frantz Fanon recounts his journey as an educated black man who hopes to discover "a world we could build together" as he travels from the colonies to the metropolis [1]. During his trip, Fanon discovers the colonization of his selfhood.

This results from the "deep-rooted myth" that fetishizes race and excludes the colonized from membership within the human race by segregating the black natives from the white colonizers and confining the colonized to the status of an animal [2]. In Fanon's racialized division between colonizers and colonized resonates Karl

Marx's dichotomy between capitalists and workers. As Marx explains, this capitalist distinction is symptomatic of the "mysterious character of the commodity-form," which is created by the ostensible detachment of the value produced by the laboring process [3]. This value is perceived as an inherent attribute of the commodity, which generates the expression of capitalism's social relations through the money-form and facilitates the exploitation of the workers by their capitalist oppressors. However, David Marriott asserts in his article "On Racial Fetishism" that there is an "antinomian relation" between the theories of Marx and Fanon because, although Marx's commodity fetishism remains relevant in the capitalist society, it is inadequate to explain Fanon's construction of race in the colonial context [4]. By contrasting Fanon's construction of race with commodity and Freudian fetishism, Marriott construes Fanon's racial fetishism as a stereotype arising from the racial phobias of colonial society. I argue that Marriott's view of the limitations of commodity fetishism extends from an inaccurately rigid interpretation of Marx's theory. Fanon instead employs Marx's commodity fetishism as both a structural and causal model to describe his construction of race as a myth emerging from the colonization of the native identity rather than as an authentic biological characteristic.

Through the development of Fanon's assertion that "a Marxist analysis should always be slightly stretched every time we have to do with the colonial problem," this paper argues that Fanon adapts the commodity fetishism of capitalism and the Marxist connection between humanity and selfhood to explain colonialism's dual deception of racial fetishism [5]. Lack-

ing the integrative exchange processes of capitalist society, colonialism produces social relations that assess value according to the whiteness of one's skin rather than through the money-form. Just as the monetized relations of capitalism result from the fetishism of the commodity, these colonial social relations defined by skin color originate from the fetishism of race which appears inherently valuable as a reified biological fact that actually derive its value from the false constructs of the white colonizers. Furthermore, this colonial racial fetishism originates from the phenomena of commodity fetishism in the capitalist metropolis due to the colonizers' estrangement from the products of their labor. By projecting their alienation within the capitalist system onto the colonized identity and, in turn, confining the colonized to a merely biological existence, the colonizers transcend the bounds of economic oppression through their colonization of the native selfhood.

In his critique of the application of commodity fetishism to Fanon's racial fetishism, Marriott argues that Marx's "one-sided emphasis on the reification of labor" proves insufficient to describe how "not only economic relations that come to be naturalized under the guise of immediacy but the phantasmatic nature of civil society itself" [6]. Marriott construes Marx's commodity fetishism as a concept limited to explaining the economic structure of society which fails to pertain to the all-encompassing presence of race within the colonial context. However, commodity fetishism not only perverts the realities of society's economic base but moreover commodifies the entire social relations of capitalism. This distortion of the subjective interactions of individuals into the



objective symbol of the money-form creates the racialized relations of colonialism. Conversely, Marx explains that, unlike colonial society and prior historical arrangements of production, the capitalist society acquires its unity through social relations defined by exchange due to the lack of perceptible interaction amongst these relations. Because the products of labor are immediately exchanged as commodities, their producers appear invisible throughout the production process and only encounter each other through the exchange of these products as expressed through the “universal equivalent” of the money-form. Through the assessment of all the commodities in terms of their relative exchange-values, instead of their use-values, the money-form reifies and “conceals the social character of private labour and the social relations between the individual workers, by making those relations appear as relations between material objects” [7]. Therefore, in Marx’s analysis of the capitalist society, members recognize themselves and their fellow relations not as human beings but through the money-form, itself a commodity fetishized with this function as a “matter of accident,” that they receive for their commodities [8].

In the theories of Marx and Fanon, both theorists argue that the societies that they analyze each represent “a world cut in two.” Marx argues that this is constituted by the conflict between the “compartments” of the capitalist and the worker, whereas the tension between the colonizer and colonized native replace this class struggle within Fanon’s colonial context [9]. Because colonialism lacks the exchange relations of capitalism, Fanon’s analysis adapts Marx’s theory to colonialism by purporting that the colonial social rela-

tions assess value, not through the money-form, but instead through the whiteness of one’s skin. During the initial phases of expansion, the colonies serve to further the economic interests of capitalist society. Lacking the capitalist bourgeoisie “to create the conditions for the development of a large-scale proletariat, to mechanise agriculture” and employing the colonized as “forced labour,” the colony remains stagnant between its original structure of semi-feudalism and the parasitic colonizers’ disinterest in establishing the exchange processes of capitalism [10]. Fanon thus describes the colonies “as a source of raw material which, once turned into manufactured goods, could be distributed on the European market” [11]. While the workers’ positions as “someone who exchanges, posits exchange value, and maintains exchange value though exchange” integrates them into capitalist society, the institution of colonialism excludes the colonized natives from the cohesive exchange relations of capitalism and thus requires the universal equivalent of whiteness to integrate both the colonizers and the colonized into its exploitative social relations [12].

Without capitalism’s commodified exchange relations expressed through the money-form, the relationships within colonial society assume the form of skin color which preserves the exploitative distinction between the colonizers and the colonized. Whiteness serves as the embodiment of value and indicates “beauty and virtue, which have never been black” [13]. Fanon thus explains that “the cause is the consequence: You are rich because you are white, you are white because you are rich” [14]. Whiteness appears to express the “use-values” of individuals’ characteristics, such as intelligence and

wealth, but it only serves to replace the money-form as the indicator of worth in the colonies. Fanon consequently affirms that, “the [black] native is declared insensitive to ethics, he represents not only the absence of values, but also the negation of values” [15]. Since whiteness constitutes the highest amount of value, blackness constitutes the absolute lack of value. For instance, Fanon observes that “the Antillean is more ‘value’ than the African” because “he is closer to the white man.” Fanon thus concludes that “the black man is comparison” to the colonizers because he constantly assesses his value in terms of his skin color in relation to the universal equivalent of whiteness [16].

Fanon affirms that these social relations expressed through skin color are manifested psychologically by the natives’ obsession for the metaphorical whitening of their skin which he refers to as “lactification.” In her book entitled *I Am a Martinican Woman*, Mayotte Capecia comprehends the apparently inherent value of whiteness; and, “unable to blacken or negrify the world,” she strives for lactification [17]. Her worth is entirely defined by the white world. As a laundress, her white linens earn her extra money. The knowledge that her grandmother was white fills her with pride and makes her own mother seem beautiful. Furthermore, Mayotte’s attempt to add “a little whiteness in life” through her affair with a white soldier represents her desire for lactification and the dominant value of whiteness within sexual relationship in the colonial society [18]. Just as Marx affirms that within the capitalist system, the husband “sees his wife a mere instrument of production,” the member of colonial society views his or her spouse in terms of skin color [19].

This domination and concealment of the colonial social relations by skin color perverts even the personal lives of colonialism’s members.

Although the epidermalized social relations may appear to present the possibility of advancement through lactification, colonialism’s physical indicator of value further perpetuates its unified structure through the necessary separation between the colonizer and the colonized. Fanon demonstrates the efficacy of this structure through his example of Mayotte, for she “is not tolerated in certain circles, because she is a colored woman” despite her relationship with a white man [20]. In the capitalist society, this visible distinction of skin color is unnecessary because the “multitude of sermonizers, counselors, and ‘confusion-mongers’” intervene between the capitalists and the workers, leading the workers to view their wages as fair exchanges for their products [21]. In contrast, the “immediate presence and their frequent and direct action” of the police and armed forces that define colonial society requires a conspicuous demarcation between the colonizer and the colonized. Fanon explains that “since none may enslave, rob or kill his fellow-man without committing a crime,” the colonizers must establish a “principle that the native is not one of our fellow-men” [22]. Just as the capitalists employ their economic authority over the workers yet still appear to maintain their ethical standards of liberalism, the colonizers’ violent exertions of power over the colonized natives require the legitimization of this authority through the manipulation, rather than the concealment, of the difference of skin color that defines the colonial relationships.

The absence of exchange relations within

the colonial society precludes the formation of social relations designated through the money-form, so why do the colonial relations become expressed through the form of skin color? In adjusting Marx's economic analysis of capitalism to colonial society, Fanon answers this question by applying his psychoanalytic theory that the epidermalized social relations arise from the colonizers' psychological compulsion to satisfy the inferiority complex caused by alienation under capitalism. In his argument, Fanon draws from the analysis of French psychoanalysis Octave Mannoni who, in his book *Prospero and Caliban: The Psychology of Colonization*, argues that the inferiority complex of the white colonizers, along with the dependency complex of the colonized natives fostered by their loss of societal stability, creates the patterns of domination which characterizes the colonial context. While rejecting Mannoni's diagnosis of the dependency complex of the colonized, Fanon concludes that "the white colonial is driven only by his desire to put an end to a feeling of dissatisfaction on the level of Adlerian overcompensation" [23]. According to Austrian psychotherapist Alfred Adler, certain individuals compensate for their inferiority complexes by developing superiority complexes in which they degrade the differentiating characteristics of other individuals or groups. Fanon adapts this argument to the colonial complex by explaining that the superiority established by the colonizer arises from the comparison to the colonized where "each understands the other only in relation to what they are not" [24]. The colony consequently serves as an outlet through which the colonizers compensate for their dissatisfaction by asserting their superiority over the colonized

through the endowment of the visible difference of skin color with value. The colonizers recognize the colonized through their blackness, while the colonized recognizes the colonizers through their whiteness. The result is an epidermalized Manichaean society defined by the universal equivalent of whiteness through which all members assess their value, just as the members of capitalist society recognize each other through their respective exchange-values. By confining colonizers to their superior whiteness and the colonized to their inferior blackness, colonialism nurtures an appearance of psychological and social coherence.

The social relations of capitalism and colonialism originate from and conceal the underlying fetishism which distorts the personal identities of these society's members and their interpersonal interactions. However, the relationship between these fetishisms is not merely structural but also causal. Fanon's theory of colonial racial fetishism proceeds from Marx's account of the alienation in capitalist society due to the fetishism of the commodity. Because of the impalpability of labor within the capitalist system, the products' exchange-values "appear to result from the nature of the products," rather than from the labor that is responsible for their value [25]. Labor thus becomes reified as a commodity, and the commodity in turn becomes fetishized with value that appears inherent yet only exists as a result of the labor that created it. Through this phenomenon of commodity fetishism, the process of labor that provides for self-recognition and recognition of one's humanity is commodified and perceived as estranged from the laborer.

Like the commodity fetishism of capi-

talism Fanon's assessment of colonialism's racial fetishism creates a divide between appearance and reality. This fetishism occurs through both the perception of race as a reified biological characteristic that possesses inherent, objective value and the reinforcement of this fetishism by colonialism's "cultural mummification" entailed by the supplanting of the native identity with the colonizers' illusions [26]. It is through this realization of the biological conception of race that Fanon first recognizes his exclusion from the world of his white colleagues. On the public transportation system, he immediately faces "difficulties in elaborating his body schema" because of his skin color [27]. Because of the inferiority associated with his race, Fanon cannot express himself physically. Nevertheless, his physical limitations do not arise from actual biological inferiority. Rather, the colonized is "overdetermined from the outside," for his biological characteristics indicate an inescapable yet imperceptible construction of the colonized identity which results from a colonization of selfhood [28]. Fanon affirms that the explanation of race as "genotypically and phenotypically" determined is merely a myth forged through the colonial culture and history proceeding from the colonizers' psychological and economic needs [29]. Beneath his constrained body-schema, Fanon thus recognizes the existence of a "historical-racial schema" that was "provided not by 'remnants of feelings and notions of the tactile, vestibular, kinesthetic, or visual nature' but by the Other, the white man, who had woven me out of a thousand detail, anecdotes, and stories" and produces the illusion of inferiority attached to his skin color. Colonial society assesses

him in terms of the value that they view as inherent within his biological characteristics without recognizing this value as a product of "legends, stories, history, and especially the historicity" ascribed to him by the colonizers [30]. This fabricated identity maintains the appearance of the colonizers' biological superiority and conceals their oppressive role as the originators of this racial fetishism.

Beyond basing his analysis of racial fetishism on the structure of Marxist commodity fetishism, Fanon also affirms that this racial fetishism originates from the relationship between commodity fetishism and alienation that, by estranging the colonizer from his humanity, induces the projection of the colonizer's estrangement onto the colonized identity. According to Marx, the process of labor constitutes the "means of life" through which individuals reproduce themselves in the external world [31]. However, because commodity fetishism conceals the relationship between the products of labor and their producers, these products appear "as something alien, as a power independent of the producer," resulting in the loss of each producer's selfhood [32]. Unable to view themselves in this material realm as individuals, the workers also cannot view themselves as human beings, for Marx further affirms that "free, conscious activity is man's species character" [33]. Through commodity fetishism, the members of capitalist society are alienated from the labor which facilitates the recognition of their humanity. Once within the colonial context, the subjects of capitalism psychologically compensate for this alienation by exploiting the colonized as the "scapegoat for white society" and projecting their inhuman



ity upon the identity of their colonized subjects [34]. The inability of both the worker and capitalist to express the “life of the species” produces “a feeling of inadequacy in relation to the black man” for which the colonized compensate by the creation of racial fetishism in the colonies [35, 36]. The colonizers “feel they have become too mechanized, [and] they turn to the Coloreds and request a little human sustenance” through the colonization of the native selfhood [37]. They are thus “mystifying and mystified;” the colonizers compensate for their inferiority complex emerging from the capitalist alienation by reducing the colonized to corporeal existence which results in the exclusion of the colonized both from membership within the human species and from the production of an identity independent of the inhumanity ascribed to them by the colonizer [38].

Racial fetishism culminates in the colonization of the native selfhood by defining the colonized as “nothing but biological” and hence excluding them from recognizing themselves as individual members of humanity [39]. Science unsuccessfully attempts to demonstrate that the colonized belong to an inhuman species through “the characteristics of the cell layer of the cortex, the dimensions of the vertebrae, the microscopic appearance of the epiderm” [40]. By confining the colonized to the status of an animal, the colonizers limit membership within the human species to only those who possess the contingent characteristic of whiteness and produce colonialism’s racial fetishism through the appearance of this inhumanity as a biologically constituted fact instead of colonialism’s deceptive creation. This “ontologization

of whiteness” as the sole determination of humanity excludes the colonized from recognizing their selfhood as members of humanity [41]. Reduced to corporeal existence by the colonizers, the colonized possess “no culture, no civilization, and no ‘long historical fact’” with which to form authentic identities and are forced to internalize the fabricated identities provided by their oppressors [42].

During his trip to Paris, Fanon recognizes this loss of selfhood of the colonized that culminates in the “epidermalization” of the individual identity formed by the colonized oppressors and consequently fosters the racial fetishism that pervades colonial society [43]. Upon acknowledging the “historical-racial schema” which symbolizes the colonial racial fetishism, Fanon consequently finds himself, “collapsing, giving way to an epidermal racial schema.” Fanon’s inhumanity, defined by his skin color, instigates him to describe that “I transported myself on that particular day, far, very far, from my self, and gave myself up as an object” [44]. Utilizing the Marxist connection between humanity and selfhood, Fanon explains this process of the colonization of selfhood which precipitates and perpetuates racial fetishism as a result of this ontologization of whiteness. According to Marx, each human being “adopts the species as his object (his own as well as those of other things)” and “because he treats himself as the actual, living species” by reproducing himself in the material world [45]. By recognizing themselves as members of the human species, they also recognize their individual identities. Conversely, colonialism separates the colonized self from the corporeal being, forcing the colonized to refer to the colonizers for

the source of their identities.

While the commodity fetishism of capitalism alienates the workers from their species-being by precluding them from self-recognition through the product of their labor, colonialism reverses this process by precluding the colonized from selfhood through alienation from their species-being. As Fanon explains through the model of the Hegelian master-slave relationship, the colonized subjects “can in no way be equated with the slave who loses himself in the object and finds the source of his liberation in his work.” The biological characteristic of skin color which propagates the illusion of colonialism’s racial fetishism and precludes the colonized from recognizing their species-being subsequently precludes the colonized from recognizing themselves as members of this species. Unable to even reveal their selfhood through the physical reproduction of their identities due to the distortion of racial fetishism, the colonized look “toward the master and abandons the object” and recognize themselves through the colonizer [46]. The colonized must either live without identities, remaining nonbeings; or internalize the inhuman identity created by the colonizer. However, because racial fetishism reduces the colonized to the biological characteristic of skin color, they possess no self with which to internalize this inauthentic identity. Lacking genuine identity, they can only identify with the value imbued into their skin color. This internalization is therefore the “epidermalization” of the racial fetishism fostered by the tales of inhumanity and inferiority through the confinement of the colonized to mere biological existence [47].

In his conclusion of *Black Skin, White Masks*, Fanon quotes Karl Marx’s *The Eighteenth Brumaire*: “The social revolution...cannot begin with itself before it has stripped itself of all its superstitions concerning the past” [48]. Marx continues in this work to explain that the abolition of exploitation in society can only begin by tearing away the “peculiarly shaped feelings, illusions, habits of thought, and conceptions of life,” which even consist of the racial fetishism of colonialism, and recognizing their origin in society’s “material foundation and out of the corresponding social conditions” [49]. According to Marx, the construction of race in the colonies is inseparable from the economic structure of society from which it arises. However, in diminishing race to mere economic terms, Marx appears to have failed in his process of dismantling the structures that conceal oppression. Refusing to view either race or economics purely as equations of the other, Fanon instead affirms that, “All forms of exploitation are identical, since they apply to the same ‘object’: man” [50]. All attempts to reduce exploitation to the distorting effects of race or the commodity are deceptive because they overlook the victims of this exploitation. The liberation of society must therefore focus on the disalienation of its members. Overthrowing oppression and beginning a world free from the illusive shadows of exploitation, a world in which each lives as “a man among men,” also entails extricating oneself from “the Ruse of a black world” as well as the economic doctrine of class struggles [51]. Just as the process of disalienation cannot occur when conforming to the history of the colonizers or waiting for changes in society’s



economic basis, it also cannot be viewed as the reclamation of a lost history of the natives. Disalienation requires stepping into a future that is free from the fetishisms of the past where society's members recognize one another not through their respective skin colors or as quantities of money but solely as human beings.

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