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Cover artwork by

Carolina Pereira based on the article Replicating Conditions for the Origin of Life in a Lab on page 27.



Carolina Pereira '17

Carolina Pereira is a senior visualization major from Sao Jose dos Campos, Brazil. Inspired by the intricacy of marine life, Pereira's cover art is based on Replicating the Origin of Life in a Lab and illustrates that, with the right conditions, a phenomenal event can take place. After graduation, Pereira plans to pursue an MBA in marketing with the goal of becoming an art director.

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FROM OUR FACULTY



DR. SARA ALPERN Department of History

hat an honor to be asked to write the forwarding letter for this excellent journal of undergraduate research. Explorations realizes goals I have nurtured throughout my 40 years of teaching and writing here at Texas A&M University. As a history professor, I have always stressed the study of history encompasses more than facts and stories. It facilitates understanding of the human condition and helps expand knowledge of the historical and social contexts that create diversity. History is a field forcing one to use critical thinking when assessing several sources best applied in discussions and especially in written analyses. In virtually all of the classes I have taught here some form of a written component was included, forcing students to think beyond a single fact or viewpoint and offer an evaluation. Even in general history surveys students wrote analyses, albeit rudimentary. My teaching of U.S. women's history as part of the Women and Gender Studies program also required students to integrate interdisciplinary material and to write historical analyses. Clearly courses for history majors-280 and the capstone course, 481-gave me the opportunity to refine my coaching of students as they learned more sophisticated research skills and the craft of writing history. The many Honors history courses required examination of both primary and secondary sources resulting in wide-ranging history papers, some of which were worthy of printed status.

As their advisor, I mentored a number of history Honors students who conducted extensive research and wrote significant papers as year-long University Undergraduate Research Fellows (currently known as the Undergraduate Research Scholars program) prior to the founding of Explorations. The request to write this forwarding letter reminded me of my recommendations for publication of portions of such papers in student journals at other universities and the hope that one day we would have such a journal here at Texas A&M. That wish materialized in Explorations. Since its inception it has flourished as a creative, interdisciplinary and professional journal of superb undergraduate research. Having the opportunity to present original research in whatever field gives students the chance to communicate their discipline to a wider audience, obtain publication credit helpful in applications for graduate school and, hopefully, inspire other students to seek the publication of their research expertise. Congratulations to the professors and student leaders who have made Explorations possible and successful over these last years. I look forward to reading this latest volume with great interest.

Saw Alpern, Ph. D.

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ORTHOPEDIC ROBOTS: D‰GS' BEST FRIEND

Amanda Bass and Nathan Dunkelberger

Introduction

Many animals suffer injury and death for the sake of experimental research studies. According to the United States Department of Agriculture's Animal and Plant Health Inspection Service, approximately 770,000 animals-including 61,000 dogs-were subjects of animal testing by research facilities in the 2015 fiscal year.¹ At the Texas A&M Veterinary Medical Teaching Hospital alone, 1,200 studies were performed on dogs to develop orthopedic therapeutic interventions in 2014.² Because those interventions are not fully developed, many dogs may be injured or, in extreme cases, die. Whereas testing orthopedic surgery techniques on dogs allows us to understand how procedures work on live animals, testing the same technique through our simulator allows us to safely and painlessly understand the procedure without unnecessary pain and death. Reducing the death and injury inflicted on animals is a widely accepted mission that the Department of Agriculture advanced into law through

USING THE JMS AS A RESEARCH TOOL WILL DECREASE PAIN AND DEATHS OF CANINE TEST SUBJECTS...

the Animal Welfare Act of 1966. That act outlines the guidance principle called the three Rs of animal ethics, which encourages researchers to develop alternative testing methods, improve animal welfare, and refine scientific practices when animal research is necessary. The three Rs are replacement, reduction, and refinement. The Biomechanical Environments Laboratory at Texas A&M University has developed a device, the Joint Motion Simulator (JMS) (Figure 1), to advance that mission of animal preservation by providing an alternative analysis method for the orthopedic canine joint model. Using the JMS as a research tool will decrease pain and deaths of canine test subjects by replacing them with a simulation, reducing the number needed in studies, and refining the surgical procedures applied to dogs across the nation.

Materials and Methods

The JMS controls the motion of a canine hip joint through two motor-driven rotations. One motor controls that joint's forward and backward motion, and the other controls the inward and outward motion. Through a program developed in LabVIEW, the motion pattern for each motor can be selected as well as several other input options that control how the simulator behaves. That versatility allows the simulator to closely mimic the motion of a canine hip joint. The device's adaptability and its ability to replicate canine joint motion makes the JMS a valuable tool to promote all three Rs of animal welfare.

Replacement

Replacement is a method to remove the need for dogs in orthopedic testing. When a dog needs a surgical procedure, one approach would be to assign the theorized best method without knowing the comparative advantages or disadvantages of other options. That process can cause the patient pain or injury while imposing additional logistical and monetary hindrances for the surgeon if the best option was not chosen. Our simulator allows surgeons to compare viable treatment options for different scenarios and helps them make the best choice of treatment without experimenting on live animals. The simulator will streamline orthopedic patient care, giving researchers access to a faster, higher-quality, and less-invasive alternative.

Reduction

Reduction attempts to use fewer canine subjects in studies. One proposed use of the simulator is to act as a substitute test method for animal models in developing early-stage orthopedic prototypes. For standard animal testing cases, the researcher must pay for the subjects' upkeep, including feed, housing, and medical bills, as well as comply with the complex animal legislation. Using animal studies is a necessary process when evaluating a concept's safety and efficacy; however, if a different method can replace



FIGURE 1. The Joint Motion Simulator

part of the animal testing, then time, money, and patient stress can be saved. By using the JMS as a research tool in early phases of device development, the researcher will have a faster, cheaper, more accessible, and more humane way to gather data.

Refinement

Refinement seeks to minimize suffering by improving practices carried out on dogs. When orthopedic surgeons are in training, they first practice surgical procedures on artificial joint models and later progress to live animals. Researchers test the resulting treatments' performance rudimentarily by hand, without technical feedback. Later, when surgeons move on to live animals, the skill level to perform those procedures may be lacking. Integrating the JMS into their curriculum will enable surgeons to get more useful performance feedback through the measurement and testing tools available, thus better equipping surgeons to operate on live animals.

Validation Techniques

To ensure that the simulator could accurately represent the motion of a canine hip joint, we measured the accuracy and repeatability of the simulator while following a user-selected motion pattern. We did so on each motor independently and with both motors operating at the same time. Each test scenario was performed 10 times to measure how the simulator behaved over several trials. For each set of tests, the first motion pattern was a sinusoid-a smooth, repetitive oscillation-a standard of motion that allows results to be compared across studies. The second motion pattern was a constant speed of movement, with the start and end points determined by the typical orientation of the canine hip. The third motion pattern represented a canine's walking motion. The canine hip joint normally holds roughly

one-fourth of a dog's weight approximately 25 pounds for a medium to large dog. We tested each motion pattern when the motors were not weighted and when the motors were weighted with 25 pounds. Those motion patterns characterize the simulator's motor capabilities under various conditions, accounting for most possible scenarios.

The JMS was designed to reproduce joint motion, so the next logical step after validating its movement was to determine its suitability for orthopedic studies. Therefore, a study comparing surgical procedures for canines was performed, using the simulator to test

the system under experimental conditions. Toggle suture constructs—three types of surgical devices for the canine hip—were comparatively tested with the simulator to see which type would work best for a canine joint model. A toggle suture keeps the pelvic bone and the femur in their correct positions after a joint dislocation. The device is considered to have failed when the top of the femur is moved halfway out of the pelvic socket.

When evaluating how the sutures perform, researchers need to test them under normal canine conditions. If the simulator's performance in experimental conditions deviates from the intended behavior, it could not meaningfully predict the performance in a living system. A veterinarian attached six sutures of each type to the hip joint of a medium-sized cadaver, and the system was placed into the JMS for testing. The three suture types were the Tightrope, Ethibond, and Securos. The trials were split into three variable range-of-motion phases with different loads and



FIGURE 2. Canine hip motion replicated by simulator showing results ± one standard deviation

speeds. During each phase, the load applied and repetitions changed to mimic the environments that the canine joint would normally experience. For the study, the motion patterns used were smooth, fluctuating waves for both motors representing a simplification of the types of motions the canine hip joint would experience daily. The JMS can test those motion patterns with variable ranges of motion, under different load amounts, and at different speeds. The combination of the simulator's capabilities of the simulator and the surgical technique analysis allows for comprehensive results that account for factors that other simulations commonly ignore. The main measurement, derived from the allowances of the surgical procedure throughout the simulation, was of the distance the femoral head moved out from the pelvic socket. That measurement, along with the number of repetitions until failure, was used to measure how well the sutures performed.

Results

As shown by validation testing, the JMS can mimic the rotational motion of the canine hip joint. The simulator reproduced a simplified model of the canine motion pattern found in the literature.³ While reproducing motions for the canine hip, the simulator accuracy remained within 1.2° of the value in the predicted model throughout our trials, and the average of the position standard deviationsmeasured using the position data from a specific time over 10 trials-remained below 0.8°. Figure 2 shows those results over one testing cycle. When we compared our validation testing data with other validation studies of similar simulators, the JMS clearly excelled at simulating the motion of a canine joint. The data comparison was helpful for understanding how early concepts of those joint devices behaved under natural movements.^{4,5} Our results show that the simulator can be an adequate substitute for subjects during preliminary testing of devices or surgical techniques, reducing the number of live animals needed during a study.

JMS ALSO CAN BE ADAPTED FOR MANY FUTURE APPLICATIONS, SUCH AS A SURGICAL TECHNIQUE ASSESSMENT TOOL.

Its effectiveness was shown in the performance comparative study that used the JMS to test types of sutures. Success was evaluated with two criteria: (1) that the suture lasted through all phases of motion testing and (2) of the specimens that lasted through all three phases, the average displacement of the bones remained low. The Tightrope model had the best performance. All tests using that suture survived to the third phase of motion, showing that the device is best suited to withstand the normal motion and load that would be present in a real canine. All other models did not survive for all phases of testing. The Tightrope model also had the lowest overall average displacement, suggesting that it would be least likely to fail. Information from such tests helps surgeons effectively choose treatment options; thus, the joint simulator has already proven itself to be an effective alternative to inpatient testing.

Discussion

The JMS also can be adapted for many future applications, such as a surgical technique assessment tool. According to a 2012 review of surgical errors, 65% of cases could be attributed to technical error and 29% of cases could be attributed to an error in judgment.⁶ That finding implies that many errors are due to inexperience, possibly as a result of shortcomings in current surgical training programs. The JMS can provide feedback to the user so that mistakes made in practice can be fixed before a real surgery.

Previous studies have concluded that simulators are effective training tools. A simulation model for knee arthroscopy procedures, the Kneetrainer 1, can distinguish between junior and senior surgeon skill levels and can help surgeons develop their surgical technique.⁷ The simulator could replicate those findings and even extend them to a broader line of skills because of its adaptability, offering a way to determine the quality of various surgical procedures. One way to apply the JMS as a surgical trainer is by using its dial indicator. That tool measures changes in position-for this experiment, the distance from the femoral head to the hip-generated by the technique to determines its quality. If the method creates a large displacement in the beginning stages of motion trials or enters a displacement range at which the method is no longer effective, the application can be considered inadequate. Techniques that maintain their position signify quality and longevity of the surgical procedure. Using that method to train surgeons can give trainees access to feedback without the need for live animal trials, thereby improving the overall quality of ensuing surgeries.

Conclusion

The JMS's performance results during the smooth, fluctuating wave, straight-line, and documented canine motion pattern validation tests have shown the system's ability to perform as a reliable research tool. Because the JMS's creators incorporated the three Rs of animal ethics into its design, its presence on the market will improve animal welfare, decrease the number of dogs needed for orthopedic studies, and cultivate a high-quality learning environment for veterinary orthopedic surgeons. The development of the simulator has already helped save dogs from pain associated with animal research and will continue to be dogs' best friend.

THE DEVELOPMENT OF THE SIMULATOR HAS ALREADY HELPED SAVE DOGS ...AND WILL CONTINUE TO BE DOGS' BEST FRIEND.



Amanda Bass '17

Amanda Bass is a senior biomedical engineering major from Houston, Texas. Bass has conducted research in the Biomechanical Environments Lab at Texas A&M and plans to pursue her interests in prosthetics and mechanical exoskeleton development in industry after graduation.

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Nathan Dunkelberger '17

Nathan Dunkelberger is a 2017 Texas A&M graduate with a degree in mechanical engineering. Dunkelberger is currently pursuing a PhD in mechanical engineering with a specialization in rehabilitation engineering at Rice University and plans to work in the field of medical robotics.

A MEADOW WITHOUT ANTIPHON

Kadden Kothmann

A song in a meadow, A fleece without flaw, A crisp morning sunshine, The dew covers all. Now as I remember Our days of yore, Per my song in this meadow, I can't take it anymore. There once was a bluebird Who marked its array, Like all other bluebirds, With anthem display. But you left without word. No time left to spend With this lark in a meadow, And so made us an end. I swore I would find you, Resume where we left. But your beak did not warble, To complete our duet. So, as I lay feathers, My mourning drags on. In this tale of a meadow Without your antiphon.

Antiphonal is the musical descriptor of an antiphon—a calling and responding scheme in Western liturgical song. It is best illustrated by hymns sung with a female chorus followed by a male-responding verse. Through this poem, I use antiphon in a more ecological sense, as the call and response sung by certain species of birds. A mentor of mine, Dr. Dale Rollins, has explained to me the love song between two quail, mainly involving a two-note rooster call and a female's three-note antiphonal reply. Those duets may last for hours and can be joined by other female/male counterparts. The term refers mainly to courtship, but its not exclusive and includes the responses to stimulating communication for locating surrounding individuals. The poem above is my song: my call, without response, without antiphon. That is why it is "A Meadow without Antiphon."

The song is opened by a lark, who sings of his happy surroundings: the morning in a meadow that he shares with an old friend. But he stirs at the memory of their abandoned relationship. In the second stanza, he introduces the fray between himself and his calling partner, who has "marked its array" or has stubbornly



Kadden Kothmann '19

Kadden Kothmann is a junior biomedical sciences major with a minor in rangeland ecology and management from Garden City, Texas. Inspiration for Kothmann's creative piece stemmed from Maya Angelou's poem "Caged Bird" and his desire to put a voice to the common anxiety all people face in relationships. After graduation, Kothmann plans to attend veterinary school.

SO LIKE ANGELOU'S CAGED BIRD WHO SINGS, I POURED MY HEART OUT IN A SONG, THIS POEM.

set its boundaries in the meadow. The physical separation curbs their interaction. The contrast in species gives the birds conflicting personalities, further emotionally separating the bluebird and lark. So when the bluebird leaves, he rejects the relationship and the meadow he shares with the lark. Upset, the lark concludes his song with an intent to resume the duet, only to find his companion gone. In anguish, he buries his friend, lamenting the "meadow without antiphon." His last verse is my worst fear: to lose a loved one in a time when that person is too adamant to remain open to different opinions.

As I found and developed my identity these past few years, I have changed my attitude and opinions toward certain issues that I once neglected. Meeting new open minds has likewise shifted my paradigm, causing me to disagree with my old self and a particular family member, whom I care about deeply. When I was approached about those issues, my side of the argument suffered stubborn opposition. The closed-mindedness eventually became personal and began to sever us. The rejection kept me up at night, and I was living a personal nightmare. So like Angelou's caged bird who sings, I poured my heart out in a song, this poem. I sang of two calling partners, two birds who were the greatest of friends. I sang of all the happy "days of yore" that we spent together. But the pain comes when I remember the rejection. When there is no antiphon, I then sing my worst fear. In the meantime, this poem is my metaphor. It sings that, regardless of my stance, I am willing to put aside differences to maintain a relationship. Similarly, the lark's difference in species, or opinion, does not stop him from seeking to restore his old connection with the bluebird. If only the bluebird understood my conviction, *it might better appreciate its bond shared with the lark.*

Letters from the "Fritz Ritz": German Prisoners of War in the

United States during World War II

Daniel Welch

Introduction

During World War II (WWII), more than 400,000 Axis soldiers, mostly German, were held as prisoners of war (POWs) in the United States.^{1,2} Today, memory of their incarceration has faded and little remains of the camps besides crumbling foundations and the buried debris of daily prison life. Most research concerning German POWs in the United States during WWII has focused





FIGURE 1. George Füssl's depiction of Tunisia, where he was captured in May 1943.

the personal experiences of the German POWs.

In early 1942, U.S. Army planners began to organize the incarceration of Axis POWs in ways that focused on adherence to the Geneva Convention of 1929. That convention established international law that required the host nation to treat enemy POWs as similar to their own soldiers during wartime. Those included provisions financial compensation for the labor the allowed by convention, housing in barracks equivalent to that of the host nation's own soldiers, and adequate food for

the POWs. By holding themselves strictly to the provisions of the conventions, the U.S. government hoped that Nazi Germany would also follow international laws in their treatment of U.S. prisoners overseas.³ Many U.S. citizens criticized the "coddling" of enemy prisoners who had only months before been engaged in combat against their sons, husbands, and fathers. For that reason, the U.S. POW camps were satirically called the "Fritz Ritz," combining a semiderogatory term of the period used to refer to Germans and a slang term for a luxurious standard of living.4



FIGURE 2. George Füssl's sketch of Camp Tonkawa, Oklahoma.

In November 1942, the U.S. Army was introduced into the North African campaign during the Operation Torch landings. By then, the North African campaign had already been raging between the British and German forces for nearly 2 years. Together, the American and British forces encircled and trapped the German Afrika Korps near Tunis by April 1943 (Figure 1).^{5,6} The German Army could not resupply its forces by air, because of Allied aerial superiority, and could not transport its soldiers to Italy, because the Allied naval forces dominated the Mediterranean Sea. After years of intense desert warfare, the Afrika Korps was finally forced to surrender in early May 1943. As a result of that campaign, more than 275,000 German and Italian soldiers became POWs and required transportation to camps in the United States.^{7,8}

During 1942 and the first half of 1943, U.S. construction crews worked at a furious pace to meet the demand

...MEMORY OF THEIR INCARCERATION HAS FADED AND LITTLE REMAINS OF THE CAMPS...

for new prisoner camps. The camps were strategically placed in labor-starved agricultural regions because the Geneva Convention permitted the use of enlisted POW labor in non-war-related industries such as agriculture.⁹ Also the camps were intentionally placed in regions that would make escape attempts by the POWs virtually impossible.

While held in the POW camps, the German soldiers were given many opportunities for recreation and education. During their free time, they were allowed to participate in sporting events, play in the camp orchestra, create artwork, and engage in various other activities. POWs also were given the opportunity to take courses through local U.S. universities for credit that could be transferred back to Germany after the war.¹⁰

Discussion

This project focuses on the personal documents of two German soldiers, George Kellermann and George Füssl, who were captured in North Africa in May 1943 and incarcerated in the United States until early 1946. Kellermann was a 41-year-old Gefrieter (private first-class) and Füssl was a 21-year-old Unteroffizier



FIGURE 3. George Füssl's depiction of a bored POW in the barracks at Camp Florence, Arizona.

(sergeant). Both soldiers arrived in the United States through the U.S. Navy port in Norfolk, Virginia, and were transported by rail and truck to separate POW camps in Texas and Oklahoma. We chose those two soldiers from the translated sample because they had the most information available and could be compared to each other on the basis of their different positions within the German military structure.

Upon arriving at Camp Huntsville, Texas, Kellermann was immediately assigned to work in the local agricultural industry. For that work, he was paid 80 cents per day in camp Post Exchange coupons in addition to the \$3.00 in coupons per month that all German prisoners received. Those coupons could be used at the Post Exchange to purchase items such as candy, tobacco, soft drinks, limited amounts of alcoholic beverages, stationery to write letters, and U.S. government–approved books. Kellermann chose to spend much of his earnings on extra stationery to write to his family in Germany. After examining the letters, we found that Kellermann had a wife, Marie, and a son, Otto, who lived just outside Creglingen, Germany, during his incarceration in the United States.

Füssl, however, was not required to do physical labor by the Geneva Conventions because he was a noncommissioned officer. or noncom. When he arrived at Camp Tonkawa, Oklahoma, Füssl devoted much of his abundant free time to developing an art school for other POWs in the camp and continuing to work on his own artistic pieces (Figure 2). He also used the camp's educational programs to learn about things such as Native American culture and U.S. history. While incarcerated in Florence, Arizona, in 1945 and 1946, Füssl volunteered at

the camp's club for U.S. noncoms and painted murals on the walls of buildings in the town. Much of the inspiration for the art he created during the war was preserved in a sketchbook that his widow donated for research in the early 2000s.

While at the Texas POW camp in Huntsville, Kellermann made some notes about U.S. daily life that he observed among the guards and farmers he worked with. The most striking of those observations were his descriptions of the African American huts he saw on his way to and from the agricultural fields. He describes the houses as being very run down, the families as disheveled, and the general quality of life as being even less than that of the German POWs: "There are sometimes people in such states that you cannot imagine if you have not seen it. Every now and then you could see a white family who made a different impression. There were blacks who were very clean, but rarely. These blacks had to work for the farmer, they are so-called slaves."¹¹ Those observations were not unique to Kellermann's diaries and letters; many other German POWs and U.S. citizens also noted them during the war. Such observations during the war led to a heightened awareness of the need to abolish segregation in the postwar United States.

Füssl's sketches show his distinct curiosity for the other cultures he came into contact with during the war. In North Africa, he made sketches depicting desert life, while his diary indicates that he was learning about Islam and studying the Arabic language during his free time. After his capture, many sketches focused on Native American culture in the western United States. He also made several depictions of the camps themselves and of his comrades in the barracks. Those sketches offer a uniquely humanistic opportunity to view the U.S. POW camp system through the eyes of the German POWs (Figure 3). Füssl's sketches show the daily monotony of camp life alongside the POWs' exciting opportunities to learn new things and meet new people through their incarceration. However, Kellermann's agricultural work in the Texas and California camps was not enough to prevent him from constantly worrying about the well-being of his family in Germany. His wife's letters often took longer than 6 months to reach him in the United States, during which time he constantly worried that she and his son could be in danger from the Allied bombings and their approaching armies. He wrote in his diary that one of his fellow POWs in Camp Huntsville committed suicide: "On April 20, the

birthday of the Führer, we had again a funeral of a comrade from the 3rd Company. He had received bad news from home. One evening, he walked away from the camp, and after 10 days

THERE ARE SOMETIMES PEOPLE IN SUCH STATES THAT YOU CANNOT IMAGINE IF YOU HAVE NOT SEEN IT.

the emotional burdens placed on the German POWs and their families from their prolonged separation.

Conclusions

A great deal of potential information about the personal experiences of German POWs can be gained from translating and analyzing their letters and diaries. Using that information, researchers can better understand the complex system of U.S. POW camps during WWII. Although these two men by no means represent the experiences of most German POWs during the war, their personal experiences are invaluable in developing a comprehensive understanding of camp life during that period.

While incarcerated, German POWs, including Kellermann and Füssl, were given the opportunity to labor for wages, take university classes, and participate in recreational activities. They used those activities to distract themselves from the daily boredom of camp life and from the loneliness they experienced because they were separated from their families in Germany with limited potential for communication. As evidenced in Kellermann's diary, that loneliness was a major problem for many POWs and was occasionally overwhelming to the point of suicide.

Together, those documents tell the unique stories of two German soldiers who were taken into captivity in a foreign land, learned how to adapt to their new surroundings, and ultimately applied what they learned

> through their experiences as POWs to influence changes in postwar Germany. After returning to Germany, the POWs used their education from the camps and the skills that they learned while laboring to revitalize the

they found him. He ended his life by hanging on a tree."¹¹

In general, however, the postal system served to ease

German economy from the ground up. Because of their generally positive experiences in U.S. POW camps, many POWs came away from the war with a favorable view of the United States. Continued research into the personal documents of other German POWs could offer a unique perspective on how Germany's postwar social and economic structures developed. Despite popular negative stereotypes of German soldiers during WWII, their letters and diaries are filled with stories of loss, discovery, and perseverance that anyone can find relatable.



Daniel Welch '17

Daniel Welch is a 2017 Texas A&M graduate from Gun Barrel City, Texas, with a double degree in history and anthropology. Welch was inspired by his Great Uncle who endured the Bataan Death March during WWII and the untold stories of German soldiers from Camp Hearne. Welch's long-term plans include returning to Texas A&M for graduate school and becoming a history teacher.

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DYNAMIC DOUBLING LISTS: AN INSERTION-CENTRIC ALTERNATIVE

Cameron Cassidy

Introduction

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Data structures are the foundation of information storage and retrieval-an important component of computer programs. Storing and retrieving data efficiently is often crucial to creating the fast programs that users seek. Further, time-sensitive tasks, such as autonomous driving and medical applications, require an efficient system. Various data structures govern information storage and retrieval. Fundamentally, those structures use two operations, insertion (storing data) and retrieval (getting data back). A common trade-off is the speed of insertion versus that of retrieval. Thus, picking the appropriate data structure for a program is essential to optimize it in terms of time. The dynamic doubling list, a new data structure, offers faster insertion than its competitors, although it is still subject to that trade-off. The dynamic doubling list vastly decreases that limitation by using a file allocation

technique called multilevel indexed allocation. Over the past year, we developed the data structure and ran tests to evaluate it.

Background

Data structures such as the dynamic doubling list can be understood using the following terms:

- *Computer program.* A collection of instructions that a computer executes to perform a specific task.
- *Programming language*. Keywords and syntax for organizing instructions.
- *Object.* A variable having a value (such as a number, letter, or grouping of the two) used in a programming language; objects can be a complete data structure.
- *Pointer.* The location of an object, or data structure, in the computer's memory. For larger objects, describing an object in terms of its pointer is often much faster than describing the object itself.
- *Array.* The most basic data structure—a systematic arrangement of similar objects stored on individual lines of code.
- *Referencing*. Accessing a pointer to locate an object, for indexing arrays.
- *Append.* To add to the end of a listing data structure.
- *Prepend*. To add to the beginning of a listing data structure.

Previous Listing Data Structures

Of all listing data structures, arrays have the fastest insertion and retrieval time.1 Think of an array as a piece of notebook paper with a single object stored on each line. Just as a sheet of notebook paper cannot get larger, an array also has a fixed size. However, a data structure called the dynamic array offers a solution to the limited size of an array. When the dynamic array is full, a new array twice the size of the old array is created by individually copying each element into the new array. Although copying occurs less often as the array gets larger, insertion can be time-consuming when it is required.² Retrieval from a dynamic array is constant, meaning that the number of objects in the structure does not affect retrieval speed, and it is faster than similar list structures.

The other competitor of the dynamic doubling list is the double-ended queue (deque), whose operation is beyond the scope of this paper. The deque offers faster insertion and slower retrieval than the dynamic array.²

The Dynamic Doubling List

Dynamic doubling lists can substitute for a deque or dynamic array. Fundamentally, the data structure works by creating a dynamic array of pointers to arrays of objects. Each array has twice the capacity of the preceding one, with the first able to hold 10 objects. That feature decreases the frequency of those costly copy operations associated with the dynamic array. And even when it does get full, the dynamic doubling list has to copy only pointers. Thus, only log10 (elements) copies are performed, as opposed to having to copy every element. Because of the logarithmic nature of the array's size, retrieval can be completed using a series of equations to determine the element at some given position.

DATA STRUCTURES ARE THE FOUNDATION OF INFORMATION STORAGE AND RETRIEVAL.





FIGURE 2. Runtimes of the deque, dynamic doubling list, and dynamic array. (Linear operations are too slow to appear and thus are omitted from the graphs.) DDL = dynamic doubling list; deque = double-ended queue.

1 1 1 1 1 1 10 0 1 0 1 11 1 $0 \ 1$ 1 0 1 0 0 1 1 1 0 1 1 0

Methods

The dynamic doubling list was intended to insert objects quickly, so we needed a way to compare the speeds of the three structures. We chose benchmark testing, performed by running the same set of operations on each data structure and timing them separately. For example, we timed 10,000 appends into the dynamic array and repeated that process for the other two data structures. Benchmark testing was done for append, prepend, and retrieval. To ensure accurate results, the median value of 150 tests was used for each data point on the graph. All tests were performed in Microsoft Visual Studio 2010 using C++11.

Results

The dynamic doubling list was roughly 25% faster at appending than the dynamic array and roughly equivalent to the deque. For prepending, the dynamic array was linear—and thus slower than the dynamic doubling list and the deque. The deque was 10% faster



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THE DYNAMIC DOUBLING LIST GIVES PROGRAMMERS ONE MORE TOOL AND THUS MORE FLEXIBILITY.

at prepending than the dynamic doubling list. For retrieval, the dynamic array was the clear winner. The dynamic doubling list is 75% slower than the dynamic array, and the deque is the slowest.

Discussion

We developed an insertion-focused data structure that preserves fast and constant retrieval times. The dynamic doubling list is useful when a program requires a faster insertion speed than the other two data structures can handle, such as for storing a large amount of data. The dynamic doubling list gives programmers one more tool and thus more flexibility. In turn, certain programs can work faster when needed, at the cost of slower performance in less critical times. Therefore, the dynamic doubling list can be thought of as the inverse of a dynamic array, which has fast retrieval but slow insertion.

Acknowledgments

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BEYONCÉ'S BEYONCÉ'S ENDERNACE'S A GATEWAY DRUG TO ACTIVISM IN POPULAR PERFORMANCE

Nicole Green



Introduction

On April 6, 2016, *Elle* magazine released an exclusive interview with Beyoncé discussing her new clothing line, her stances on feminism and police brutality, and her life as a mother. After years of near silence in the press, that interview marked a rare glimpse into Beyoncé's life. What readers did not know then, however, was that within a few short weeks she would suddenly drop her full-length visual album *Lemonade*. The surprise release was not unprecedented, though. In December 2013, the artist also released the self-titled album *Beyoncé* with no warning, marking the beginning of her disappearance from interviews and talk shows. The *Elle* write-up acknowledged that shift, stating that "for three years, the singer has been all but mum in the press, letting the work speak for itself—cultivating a sense of mystery and, in this all-access era, an exotic remove that is itself a show of power—while scattering pixie-dust intimacies via (mostly captionless) pictures on Instagram."¹ That

disappearance from the public stage made her fans pay more attention to her art, which has become one of the only platforms from which she can be heard.

Beyonce's near silence paired with her surprise album drops have transformed each album release into a live performance event in itself: a moment in which all eyes (and popular press discussion) are on her. "You know you that b——— / when you cause all this conversation," Beyoncé says in the closing lines of Lemonade, and cause conversation she certainly did. Lemonade especially sparked discussions on police brutality and black feminism as a result of both explicit and implicit commentary throughout the album's visual and musical components. But the album is not only political; it also offers intimate insights into the personal lives of Beyoncé and her husband, Jay-Z. The personal intrigue and almost mythic mystery surrounding the relatively quiet superstar couple paired with the album's fearless discussion of hot-button issues entices audiences to pay attention. Much of fans' engagement with Lemonade has been related to the authenticity and sincerity that Beyoncé displays, so discussing those concepts is important to exploring the album's political impact. Exploring how Beyoncé negotiates artistry, accessibility, and activism is vital both as an artist and as a consumer of art. This close-reading of Lemonade and discussion of the divide between high art and popular art will wrestle with the importance and efficacy of authenticity and sincerity in performance, ultimately illuminating how those components can enhance the accessibility of activist art, making less digestible political ideas suddenly understandable and relatable to wider audiences.

Close-Reading of Lemonade

Lemonade is divided into 11 chapters titled Intuition, Denial, Anger, Apathy, Emptiness, Accountability, Reformation, Forgiveness, Resurrection, Hope, and Redemption. Each chapter contains one song from the album and incorporates the poetry of Warsan Shire, a female British-Somali poet, as connective tissue within and between tracks while a fluid visual narrative provides continuity throughout. The overarching

...DISAPPEARANCE FROM THE PUBLIC STAGE MADE HER FANS PAY MORE ATTENTION TO HER ART...

narrative of the album tells the story of Beyoncé and Jay-Z healing from his infidelity as we see her move through stages of the process that align with the chapter titles. However, running parallel to that personal narrative is an underlying narrative about the healing process of racial tension in the United States.

For instance, one section of the visual album features the mothers of Trayvon Martin, Michael Brown, and Eric Garner, all victims of police brutality, holding pictures of their deceased sons while staring straight into the camera. Some viewers were heavily engaged in the visual album purely because they apparently were gaining intensely intimate insight into the personal life of Beyoncé. They were exposed to that scene regardless of whether police brutality was an issue they were interested in or thinking about. The track that accompanies that imagery is titled "Forward," one of the few tracks that does not speak directly to Jay-Z in the second person with accusations and expressions of pain. Rather, the lyrics paint a picture of moving forward past hurt and into healing. It sounds as though Beyoncé is choosing to move forward in her personal healing, but the visual narrative tells a different story about healing from racial tensions exemplified by police brutality. The track is double-voiced in a sense, telling one story about an individualized, personal healing process and one about a more massive healing of an entire group. In converging those two narratives, she makes the issue of police brutality accessible to people who may not personally understand the issue but do understand the individual pain and betrayal being depicted.

Contributing even more to the accessibility of political issues, "Forward" follows after arguably the most raw and sincere track, "Sandcastles," in which Beyoncé passionately sings directly to Jay-Z about his betrayal during his only physical appearance in the album. The song is relatable because it is detached from the specifics of the situation, place, history, or culture of the artist the pain she is communicating is relatable. The song's emotional connection to listeners does not require them to be black, female, or people who have been cheated on; it is just about being sad. The sincerity of her personal emotion within "Sandcastles" lays a groundwork that entices viewers so that when "Forward" begins, that same level of connection to the audience is carried over. When the visual story has changed entirely to police brutality in "Forward," Beyoncé is essentially using her rawness from "Sandcastles" to say that her feelings are sincere and important, and therefore equally sincere and important are the political statements she is about to bring up.

The concepts of sincerity and authenticity, as well as their connection with the value and validity of art, have been academically examined at length. In "Inauthenticity, Insincerity, and Poetry," Alex Neill discusses how works of art, specifically poetry, can be viewed as "autonomous objects of aesthetic experience" whose "value lies in the arrangement of words and the experience which that arrangement of words offers us, so that the circumstances of the poem's production (including the [in]sincerity of its author) are neither here nor there with regard to the value."² Essentially, the author's truth—or lack of it—does not affect the value of the final object of

his or her poetry. For the *performance* of poetry (or music), however, that is not the case. The audience is constantly faced head on with the author's humanity and reality because of the physical

...THE PHYSICAL PRESENCE OF HER BODY...REMOVES THAT DISCONNECT BETWEEN THE ARTIST AND HER ART...

presence of the performer's body. We are not just hearing Beyonce's feelings and ideas; we are watching her deliver them. In *Lemonade*, Beyonce's sincerity matters because it makes viewers feel as though they are connected not only to an aesthetic object (the work of art she has created) but also to the person presented through that object. The physical presence of her body in the visual album removes that disconnect between the artist and her art because she is physically a part of her art. Beyoncé conveys a healing process that people can relate to almost any experience of healing. That makes it likely to be relatable on some level to most members of her audience. Had she presented her opinions on police brutality outside her art through a specific discussion of the issue, probably only people who already cared about it would have listened. However, by criticizing police brutality in the context of her sincere and relatable emotion, she makes an activist stance accessible to people who may not have been exposed to or engaged with the issue otherwise.

That is not the only political Easter egg that Beyoncé incorporates into her album; she also comments on class struggle in the art world. Beyoncé and Jay-Z both have a history of citing high-art performances in their work, making high-brow art accessible to mass audiences while also commenting on the divide between the esoteric and the popular. In 2013, Jay-Z borrowed from *The Artist is Present*, Marina Abramovic's 2010 performance installation at the Museum of Modern Art, in his video for *Picasso Baby*. In Dan Fox's book examining the nature of esoteric art, *Pretentiousness: Why It Matters*, he says, "[Jay-Z's] song was a hymn to the material worth of modern and contemporary art, only interesting when seen through the lens of class and race, of a successful black musician and businessman

> working the mostly white art world."³ Fox goes on to discuss how Jay-Z's "superstardom played a dance with the art world's theater of understated but specialized aesthetic authority."³ Essentially,

Jay-Z's popularity did not need the status of high art to elevate his work, but the elite status and aesthetic characteristics of high art performed by a popular black artist's body—a body conventionally underrepresented in the world of high art—implicitly criticized the classist divide within art. That which is considered "high" is often inaccessible to the masses, who are left with only "popular" art because of their limited resources, but Jay-Z worked to complicate that.

Beyoncé uses that same strategy of referring to high art in Lemonade during the visual component of "Hold Up," the album's second track. She struts down the street with a baseball bat, smashing car windows, a nearly framefor-frame quote of Ever Is Over All, Pipilotti Rist's 1997 video installation in the Museum of Modern Art. The original work was said to be whimsical and anarchist, blurring the lines between fiction and reality in its presentation while also commenting on feminism by having a woman very outwardly express her impassioned anger.⁴ The components of "high art" work are maintained in Beyonce's reference to Rist's piece, but now the performance is on the familiar body of a popular performer, creating a much more accessible stage for the high-art components. Both she and Jay-Z complicated the divide between high and popular work in culture, art, and the circulation of images. Both are revered enough as artists to get away with entering the high-art world in their performances even though it is inaccessible to most of their audiences because of class, race, and economic exclusion. Ever Is Over All is a piece of art that much of Beyonce's audience would not have been likely to find or watch. However, when she cites Rist's art on her own body by walking down the street and singing about her anger toward her husband, the sincerity and intimacy of Beyonce's emotion suddenly makes that piece of high-art performance not only intriguing but also accessible.

Reactions to the Album

However, in becoming both political and accessible, *Lemonade* has invited critique. The "bell hooks Institute," a staple contributor to feminist discussion, claimed that the album completely misrepresents feminism because it "does not call for an end to patriarchal domination. [Beyoncé's view of feminism] is all about insisting on equal rights for men and women. In the world of fantasy feminism, there are no class, sex, and race hierarchies that breakdown simplified categories of women and men, no call to challenge and change systems

...BEYONCÉ'S EMOTION SUDDENLY MAKES... HIGH-ART PERFORMANCE NOT ONLY INTRIGUING BUT ALSO ACCESSIBLE.

of domination, no emphasis on intersectionality. In such a simplified worldview, women gaining the freedom to be like men can be seen as powerful."5 The bell hooks Institute claims that Lemonade is not authentically representing feminism as a result of its intense egocentricity portraying one woman's incorrect vision of what feminism should look like. According to that thinking, Beyoncé is essentially disregarding the accepted national conversation on feminism. That stance implies that the sincerity Beyoncé employs in discussing what being a feminist means to her to is misrepresenting or inauthentically communicating feminist ideals. That critique works against the claim that sincerity is promoting the accessibility of the political statements. Therefore, if we understand hooks to mean that Beyoncé is not delivering true feminism, then we may be losing the potency of the political issue as it relates to Beyonce's accessibility.

That critique once again highlights the divide between elite and popular, now in the realm of feminism. Beyoncé is essentially doing the same thing here that she did with *Ever Is Over All*: she takes an elite, educated view of feminism and uses her position as

a popular performer to make it reachable to a wide audience. Suggesting that elite-popular divide, many people responded to bell hooks's blog post claiming that Beyonce's view of feminism fit them more than hooks's did. That conflict reveals a real tension and disconnect between academic feminist ideals and the realistic experiences of daily life for many women. Beyoncé may be inauthentic to "established" and "true" feminism, but she is sincere about her own experiences as a woman and therefore connects to her audience. Patricia Hill Collins discusses the disparity between established feminism and the quotidian experiences of women in Black Feminist Thought: Knowledge, Consciousness, and the Politics of Empowerment. She says that "black feminist thought can stimulate a new consciousness that utilizes Black women's everyday, taken-for-granted knowledge . . . Rather than raising consciousness, Black feminist thought affirms, rearticulates, and provides a vehicle for expressing in public a consciousness that quite often already exists."6 Art such as Lemonade that acknowledges the intersection of race and sex through being both black and a woman is not attempting to create a new image of a black woman with more power, but rather highlight the personal agency that has been held all along. Beyonce's supposedly simplified worldview may be problematic in conveying academic feminism, but that simplification is an important part of the album's being reachable. The viewers who had their first brush with feminist ideals by watching Lemonade may not get the most potent or thorough explanation of the issue's theoretical groundwork, but that everyday feminism is more likely to resonate with viewers' own experiences, in turn making feminism both more accessible and potent for them.

BEYONCÉ CREATES A CROSS POINT BETWEEN POPULAR AND ESOTERIC ART AS WELL AS BETWEEN SCHOLARLY AND MAINSTREAM FEMINISM...

Conclusion

performing By sincere emotions and incorporating political commentary alongside her story of healing, Beyoncé is negotiating the boundaries between quantity and quality. She thereby delivers

something of higher quality in terms of political message than popular media usually manages to do while using the appearance of personal sincerity as her access point. Had Lemonade been only about the politics, only people interested in the politics might have approached it. Instead, it is an album about her and her husband healing, which pulls people in close to the screen so the politics is reachable. Beyonce's notorious mythic elusiveness intrigued the masses, engaging the audience to a degree that activism suddenly became accessible through her virtuosity as a performer. Ultimately, in Lemonade Beyoncé creates a cross point between popular and esoteric art as well as between scholarly and mainstream feminism by portraying emotions that invite the audience to understand and relate to her experiences. The piece is transgressive, subversive, and hugely popular all at once, and in combining all those attributes, it paves a way for other artists to try creating

works with similar political sensibilities without sacrificing the ability to reach popular art audiences.

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Nicole Green '17

Nicole Green is a 2017 Texas A&M graduate from Wimberley, Texas, with a degree in performance studies and a minor in philosophy. Green is passionate about the creation of empathy and community through performance and hopes to either become a professor or work in expressive arts therapy. Green is currently pursuing a master's degree in performance studies at Texas A&M.

SPIRALING THROUGH COLOR

Sarah Brown

Introduction

People are surrounded by color every day and often do not give it much thought beyond the color wheel. With 12 main hues, or color families, that lie perfectly spaced in an organized circular form, the color wheel introduces the concept of color harmony. For example, hues that are opposite from one another on the color wheel are "complementary," and three evenly separated hues (such as red, blue, and yellow) create a "triadic" harmony. However, colors have properties besides hue alone, including color value (how dark or light a color is) and color chroma (more commonly known as saturation, or the intensity of the color). Color scholar Albert Munsell theorized those three properties as multidimensional spirals that spin through all colors as a three-dimensional color solid, or color model.1 By doing so, Munsell created color harmonies that no one had seen before. Focused on hue, value, and chroma working together, I similarly visualized previously unexplored color harmonies by creating a computer program that generates palettes

using formulas that model those spirals inside Munsell's three-dimensional color solid. These color solids essentially become multidimensional systems used to organize color by its properties.

MUNSELL CREATED COLOR HARMONIES THAT NO ONE HAD SEEN BEFORE.

Materials and Methods

Creating a computer program to generate palettes in that way requires a source of information to calculate which colors go into the palette from Munsell's color solid. Computers already calculate colors through certain sets of properties, but do not use Munsell's hue, value, and chroma. A bridge is required between the way a computer interprets color and the way Munsell does. Algorithms for the paths of the spirals

determine the then values used in each with swatch. user inputs to guide them. Finally, some code is needed to generate the final image. Using the programming language Python, the program first refers to a database Wallkill (found on Color's website) of Munsell color values to provide a source to the swatches in his color solid. That database contains nearly 2,400 colors organized **Munsell's** color by properties and includes color values a computer can use to generate them visually.² A few user inputs guide the creation of the spiral, such as altering the size





FIGURE 1. Examples of the two-dimensional spiral palettes

A conical spiral with a high angular frequency.

FIGURE 3. Examples of the conical spiral palettes

of the palette and how many loops the spiral contains. The program spaces each swatch by distributing it evenly along the path of the spiral by each of the three dimensions in Munsell's color solid. The swatches are then composed into a straight line with a Munsell color notation beneath each one (**Figure 1**). The format for those notations is hue value/chroma.

Munsell envisioned three spirals to create those color harmonies: the two-dimensional spiral, the threedimensional spiral, and the conical spiral. In Munsell's color solid, height corresponds to value, distance from the center (or radius) to chroma, and angle from the center to hue. In my program, the user can select the number of swatches desired in a palette for any of the spirals, each boasting its own variables, or sometimes user-defined constants that more directly affect the math that creates the palette itself. For example, the two-dimensional spiral lies horizontally across the Munsell color solid, which causes all its swatches to be the same value (**Figure 1**). Starting from the middle, it increases in chroma while hues vary as they are selected along the spiral itself. This spiral's constants are angular frequency (how many revolutions the spiral makes) and height (which corresponds to value in Munsell's color system).

The three-dimensional spiral twists upward through the Munsell color solid (**Figure 2**). Because it maintains a constant radius, its chroma remains the same while value increases from bottom to top and hues vary as they are selected along the spiral itself. Its constants are angular frequency and radius (which determine the chroma for the spiral).

Similarly, the conical spiral also twists upward through the Munsell color solid (Figure 3). Its sole

MY COMPUTER PROGRAM ALLOWS A USER TO VISUALIZE THOUSANDS OF NEW COLOR HARMONIES.

constant is angular frequency; both the radius and height change, causing both its value and its chroma to rise as it spins in a tornado-like fashion.

Results

My computer program allows a user to visualize thousands of new color harmonies. But after looking more closely at the resulting palettes, patterns began to emerge. When I divided the number of swatches by the number of loops in a spiral, the resulting number can be interpreted to depict the type of color pattern that will emerge in the palette. If the resulting number is a whole number, the user can find preexisting color harmonies. If the resulting number is not a whole number, the user will experience a more dynamic pattern with alternating, yet simultaneously changing, hues (**Figure 4**). For instance, one color incrementally becoming another, alongside an opposite color doing necessarily belong together in regular color harmonies (an artist doesn't typically want the entire color wheel on the same palette). Yet, in the 2-D and 3-D spiral palettes from my program, the entire palette is tied together by the consistency of either the value or the chroma. In the conical spiral, the consistent increasing of both ties the palette together. That is harmonizing on new dimensions of color.

Thus far, I've received positive feedback from my peers on the visual appearance of those palettes, as well as from my color theory professor. One classmate has even asked to use one of the palettes for a class project. Significantly, the palette he chose was one fitting the example above, with 15 swatches and 7 loops, the two simultaneously changing hues. As an artist, he didn't choose a palette that matched one of the better-known color harmonies he found visual beauty in this new pattern. That could mean that the color harmonies Munsell envisioned through this program have even more harmonies hiding within them. It could be something new to unveil in color theory and the creation of art itself.



FIGURE 4. Example of palettes showing hues alternating while simultaneously changing regardless of spiral type

can create is significant. Also, my computer program interprets how hues spin along a continuous spiral path when selected evenly by their angle, arguably a sophisticated way to visualize those palettes.

Discussion

the exact same thing. Instead of red, green,

red, green, you have

red, green, red-orange, green-blue, and so on.

Because more fractions

than

numbers, the number

of varied palettes my

whole

program

exist

computer

Whether or not a particular combination of colors is visually appealing is subjective, but this computer program offers a new perspective on how value and chroma can tie a palette together. Some colors in palettes that my program generated would not This project is significant because it is a previously unexplored leap of thinking from our universally accepted one-dimensional color harmonies. It urges artists to consider balancing and using math and patterns in more than just their colors' hues to truly get the most from all the dimensions in which color comes. The approach could even have a use in data visualization or graphic design, in which visually balancing colors in precise ways is important. In film, the progressive nature of the palettes could lend a hand to the progressive nature of plots as a color scheme. And who says the swatches need to be selected evenly apart from one another along the spiral? The golden ratio (a special number in the world of art composition) could be used to pick swatches along the spiral in a pattern instead of evenly selecting them. The possibilities are endless. Soon, I intend to create a website available to people interested in creating their own spiral palettes, to satiate any other curious minds.

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Sarah Brown '18

Sarah Brown is a senior visualization major from Fort Hood, Texas, with a passion for visual media. Brown's research was inspired by color theorist Albert Munsell and the absence of resources highlighting Munsell's work. Brown hopes to combine her interests in art theory and computer science to create visual narratives.

REPLICATING CONDITIONS FOR THE ORIGIN OF LIFE IN A LAB

Yuncheng Yu



Introduction

How did life originate on Earth? That question has always fascinated and challenged humanity. Attempts to answer it scientifically are currently

at the center of astrobiology research. A commonly accepted answer, proposed almost a century ago, describes the origin of life from ingredients in a "primordial soup" that existed in Earth's prebiotic oceans billions of years ago.¹ Theories suggest that this "soup" was warm with a low concentration solution of relatively simple molecules. Previous experiments showed that those molecules could have been synthesized by lightning under the conditions on Earth at the time.² According to the hypothesis, some of those molecules came together to create life's building blocks, such as DNA and proteins. But how those blocks formed still remains largely unexplained in the "soup" theory, and researchers are looking for clarity. We have developed a laboratory toolbox, inspired by an important discovery four decades ago, to investigate the conditions that could have formed life's building blocks in the prebiotic Earth.

In the 1977 Galapagos Hydrothermal Expedition, an unexpected discovery revealed the existence of deep-

> WE DEVELOPED A LABORATORY TOOLBOX, INSPIRED BY AN IMPORTANT DISCOVERY FOUR DECADES AGO...

sea hydrothermal vents that can support life through undersea chemical synthesis.3 Those hydrothermal vents are hot springs, produced by underwater volcanoes, occurring when cold deep seawater permeates the Earth's crust and contacts hot magma (Figure 1A). Found in regions where tectonic plates diverge in the deep ocean, those vents may replicate scenarios that existed on prebiotic Earth. Thus, hydrothermal vents have attracted significant interest in recent years and are at the center of new theories intended to explain how life originated on Earth.⁴ Interestingly, in March 2017, scientists reported the discovery of fossilized bacteria inside a 4 billion-yearold rock that had formed around hydrothermal vents. That finding could be the oldest evidence of life on Earth.⁵

The recent evidence in support of hydrothermal vents as enablers of early life contrasts with shortcomings in the "primordial soup" theory. One of the main problems in the previous theory is that the synthesis of the complex building blocks of life requires high concentrations of the necessary simpler molecules, such as amino acids and sugars. In the immensity of the primitive oceans, those simpler molecules probably existed at concentrations too low for that synthesis to occur. Meanwhile, pore networks (Figure **1B**) in mineral formations near hydrothermal vents created small compartments or microenvironments. Those hydrothermal microenvironments could have enabled the synthesis of life's building blocks by concentrating simpler molecules on the prebiotic Earth.



FIGURE 1. Replication of hydrothermal microenvironments in the lab. (A) Hydrothermal vent at the bottom of the ocean with a constant heat source of hot magma and constant cooling from deep seawater. (B) Pore networks in nearby rock formations create hydrothermal microenvironments in which convective flow occurs. (C) The convective flow is similar to what occurs in lava lamps, although it happens at a smaller scale in the microenvironments, represented here by our porelike chamber filled with pink solution for visualization and a US quarter coin for scale. (D) Schematic of our experimental setup for replicating a hydrothermal microenvironment, heated at the bottom and cooled at the top.

...OUR WORK OFFERS EVIDENCE IN FAVOR OF HYDROTHERMAL MICROENVIRONMENTS AS POTENTIAL INCUBATORS WHERE LIFE ON EARTH COULD HAVE EMERGED.

Using the same mechanism as a lava lamp, hydrothermal microenvironments in the pore networks exhibit thermal gradients that generate what is called a convective flow (Figure 1A-C). In the lava lamp, thermal gradients are introduced by the temperature difference between the bottom, where the hot lamp is located, and the top exposed to air. Similarly, but at a smaller scale (volumes on the order of a thousandth of a teaspoon), thermal gradients in the pore microenvironments are established from the temperature difference between the hot magma and the cold deep seawater (Figure 1A-B). Inside the pores, the convective flow can carry around a variety of microscopic materials, from small to large molecules and even microparticles, a phenomenon that could have supplied the conditions necessary to synthesize life's building blocks.

To better understand how those hydrothermal microenvironments could have supported the formation of complex molecules such as DNA and proteins, we applied engineering principles to develop a laboratory toolbox, which we used to replicate and investigate the conditions found inside individual pores in rock formations.⁶ This laboratory toolbox consists of simple and highly versatile porelike chambers that can be subjected to controlled thermal gradients (Figure 1D) complemented with microscopy techniques and computer simulations of the experimental system. Using our toolbox, we studied how the flow patterns caused by thermal gradients could affect the distribution and concentration of microscopic materials inside porelike chambers of diverse shape. Our findings indicate that when highly disorganized flow patterns are achieved inside the chambers, dilute materials, such as microparticles and simple molecules, can be concentrated at specific locations in their inner walls. This localized increase in concentration of simple molecules implies the possibility of relevant molecules coming together to create life's building blocks in prebiotic oceans. Thus, our work offers evidence in favor of hydrothermal microenvironments as potential incubators where life on Earth could have emerged.

Methods and Design

To mimic hydrothermal microenvironments in the laboratory, we considered two aspects: (1) the geometry of small pores in rock formations near hydrothermal vents and (2) the thermal gradients due to the cold ocean water and the proximity of hot magma (Figure 1A-B). Therefore, we created lab-scale hydrothermal microenvironments by fabricating cylindrical chambers from transparent plastic blocks (Figure 1C) in an effort to emulate small pores. After we filled the chamber with liquid, the bottom of the chamber was sealed with aluminum tape and the top was sealed with a thin glass sheet. Then, we placed the porelike chamber on top of a heated surface to establish thermal gradients between the hot bottom of the chamber and its top surface cooled by air (Figure 1D). Pores of different shapes were fabricated by adjusting the ratio between height and diameter. In addition, the heated surface was programmed to maintain a constant temperature. These measures gave us control over a variety of experimental conditions that could be investigated to better understand the phenomena occurring inside hydrothermal microenvironments.

These experiments focused on flow behavior and how flow could locally change the concentration of materials inside the porelike chambers. We used fluorescent nanoparticles to see what was happening inside the pores. A blue light source excited the microparticles so that they emitted green light and could be viewed under a microscope. The fluorescent microparticles acted as tracers and were recorded using a high-speed video camera. When carried by the flow, the microparticles revealed the flow patterns inside the chambers and how they were distributed and eventually deposited on the chamber's inner walls. We also used dye molecules to verify that these observations apply to materials at the molecular level as well. In this way, we see how the flow behavior could locally produce high concentrations of molecules at specific locations within the porelike chambers. If such behavior is proven correct, it has the potential to address the problem of low concentrations of simpler molecules in the "primordial soup", and could provide evidence to support hydrothermal microenvironments as enablers of early life.

Also, we used specialized computer software to simulate and analyze complex flow patterns, transport of materials, and the speed of chemical reactions occurring inside the porelike chambers. The combination of experiments and computer simulations constituted a complete toolbox to investigate the importance of hydrothermal microenvironments for the conditions that could have formed life's building blocks on the prebiotic Earth.

Results

We replicated the conditions expected in hydrothermal microenvironments occurring in porous mineral formations near deep-sea hydrothermal vents. Across our experiments and simulations, we initially studied the convective flow patterns inside porelike chambers. If we look at an individual chamber (Figure 1D), water at the bottom of the pore (closer to the hot surface) is hotter than water at the top (closer to the cool air). Because cool water is denser than warm water, cool water from the top would sink, whereas warm water at the bottom would move to the top of the pore. However, the cold water, now at the bottom, would heat from the hot surface while the warm water, now at the top, would cool from the exposure to air. That is the mechanism that continuously maintains a convective flow in both hydrothermal microenvironments and the lava lamp. In the porelike chambers, the fluid motion exhibited different flow patterns, with various levels of organization, as we changed the thermal gradients and the pore's geometry.

As we traced the motion of microparticles inside hydrothermal microenvironments, we identified



FIGURE 2. Chaotic flow facilitates fast and localized concentration of materials on the inner walls of porelike chambers. (A) Chaotic and periodic flow patterns from experiments and computer simulations of convective flow. (B) Dye molecules and fluorescent microparticles deposited inside pores by convective flow. (C) Computational model of microparticles' distribution on the surface of porelike chambers (D) Two factors, thermal gradient and geometric structure, determine how different types of convective flow could deposit materials on the inner walls of the pores. Both fast and localized concentration of materials occur in the chaotic regime.

two extreme cases for the flow patterns: periodic and chaotic. (**Figure 2A**). Periodic flow trajectories are highly ordered and repetitive, so microparticles cycle in infinite and almost identical loops. In the opposite scenario, chaotic flow is highly disordered, so microparticles essentially never follow the same trajectory twice. The continuum of flow patterns, between periodic and chaotic, offers many possibilities for how the flow carries materials and, perhaps, how they are deposited on the inner walls of the pores in hydrothermal microenvironments.

The most significant observation was the accumulation of microparticles and molecules on the walls of the chambers during the convective flow experiments (**Figure 2B**). We studied two main aspects of this

phenomenon. First, we tried to determine whether materials present in our lab-replicated microenvironments could be deposited on specific locations in the inner walls of the chamber. Second, we looked at how fast the deposition could happen according to the flow conditions inside the pore. To do so, we took advantage of the variety of flow patterns supplied by the thermal gradients

and the geometries of the porelike chambers. The investigation of the two deposition aspects, where and how fast, is intended to find the best scenarios that could produce the high concentrations required to synthesize life's building blocks in hydrothermal microenvironments.

We determined that convective flows more efficiently deposit materials on the chamber walls in comparison with the chamber without flow. But how that deposition happens and its localization depend on the flow trajectories inside the chambers. For periodic flow trajectories, materials are deposited at higher concentrations in specific locations near the top and bottom of the pores (**Figure 2C**). As flow transitions



from periodic to chaotic, the preferential deposition gradually decreases and materials are more uniformly distributed on the chamber walls (**Figure 2C**). The results indicate a plausible mechanism, based on convective flow, for localized concentration of materials in conditions found in hydrothermal microenvironments.

Chaotic flow's positive influence on the rate of deposition on the pore walls was significant, providing up to 1,000 times faster deposition speeds than under no-flow conditions. Thus, we identified the best settings under which both fast deposition and localized concentration of materials on the pore walls could happen. **Figure 2D** summarizes those results, indicating a broad range of optimum

conditions (shown in red) given by various combinations of pore geometries and thermal gradients across the pores. In general, the set of optimum conditions seen in **Figure 2D** emerge when chaotic flow is present.

Chaotic flow, generated by thermal gradients, can quickly deposit materials at high concentrations in specific regions within porelike

chambers. Using this finding, others in our research group later showed that, as a result of high local concentrations, chemical reactions in those chambers can proceed faster.⁶ Taken together, these results could explain how relatively simple molecules, present at low concentrations in prebiotic oceans, were enriched inside hydrothermal microenvironments. Higher concentrations then allowed simpler molecules to create the more complex building blocks of life on Earth.

Conclusion

The "primordial soup", a widely accepted theory for the origin of life on Earth, fails to explain how relatively

simple molecules came together at concentrations high enough to form life's more complex building blocks. However, with the discovery of deep-sea hydrothermal vents, scientists have come upon a promising scenario that could offer a more complete picture of life's early stages.

Small pores in rock formations near hydrothermal vents, exposed to the thermal interaction between the cold deep seawater and hot magma, created hydrothermal microenvironments where life's building blocks could have been synthesized. After engineering a toolbox to replicate conditions that occur inside the microenvironments, we have shown that chaotic convective flow offers a mechanism to quickly concentrate simple molecules in specific locations in the inner walls of the pores. Therefore, our research suggests that, on the prebiotic Earth, simpler molecules could achieve high concentrations inside those hydrothermal microenvironments. Those increasing concentrations allowed simple molecules to



Yuncheng Yu '18

Yuncheng Yu is a senior chemical engineering major with a minor in mathematics from Harbin, China. Yu is passionate about using interdisciplinary approaches to push the boundaries of human knowledge in hopes of improving daily life. After graduation, Yu plans to pursue a PhD in chemical engineering and intends to work in academia. come together to create the building blocks of life. Our findings offer a much-needed explanation lacking in the primordial soup theory.

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Erin O'Hara

I found his story the same way he found ours, with a sharp glint in the corner of my eye. I remember how long I stood there staring, feeling the sweat on my legs collect little bits of the orange Utah sand, before deciding whether I should investigate or just walk home. Some sort of Mars research shit was always going on around here, so I was used to seeing UFOs strewn out on the desert landscape. White buildings with the Mars Society's logo proudly plastered on every panel were sights I trained myself to be blind to years ago, but for some reason, this was different. Its chrome, crumpled metal covered in burn marks and ashes told me that it wasn't one of theirs, one of ours. I decided to approach it.

As I dragged my sneakers through the sand, the details of the wreckage before me grew, as did my confusion. I silenced Morrissey's serenades by plucking my ear buds out, as if the quiet would help me make more sense of this. With fists tightened and forehead scrunched, I didn't even notice the open journal lying in the sand until my foot was on top of it. I squatted and my fingers dusted over the words as I skimmed them. The words turned into realization and questions flooded my mind as I kept scanning the pages. *Why is all this outside of the research facility's fences? There's* *no way this is what I think it is, right?* I wanted to tell myself there must be some misunderstanding, but I knew what it was. I knew it was here because they hadn't found it yet. They would be here soon, the news crews and government officials, including my "Mars research shit" father, asking the same questions I had asked myself. I don't know why I did it, but before I could even question my actions, I quickly grabbed the journal, shoved it under my jean jacket, and took off running. My clammy hands didn't stop clenching the journal tightly and my feet didn't stop sprinting until I heard my bedroom door slam behind me. With a heaving chest and the pounding warmth of blood in my ears, I dropped the journal onto my desk and began to pore over it:

435./5./65./8.

Voyager 1. That's what *They* called it. That's where I found the disc that held everything there is to know about *They.* There was no *They* on board, but at least I know now there is a *They* out there. It has just been a Me for so long. I forgot *Theys* even existed, let alone that I used to be a part of one. My *They* used to do this stuff: Science. Space Exploration. But since *They* have been gone I've been doing: Nothing. I will have to go back and translate this once I can decode the language

of *They*. I hope this makes sense. I am just so happy to have something to do. Something to care about. Something to make me feel not so...Alone. Because I am not Alone. Not anymore.

467./4./61./4.

They are so beautiful. They were just as complex as We used to be. They speak so many languages. Not just this one I use now. They have so many songs. They have numbers. Math. Time. Food. Trees. Animals. Homes. Medicine. Water. Reds. Oranges. Yellows. They have pictures of all those things, too. Image 50 is Flowers. Those are some of the Oranges. So is Image 114. It is Sunset. The "Jimmy Carter" says this is a "token of our sounds, our science, our images, our music, our thoughts, and our feelings". All so different, yet so similar to what We used to be. They showed me where They are. We are in the same solar system. Funny I say We. Like I am already apart of They. There are so many of them. I hope They know how not alone They are. Their planet is the same shape as mine. Circle. Just like this disc I found. Just like those "cells" that They come from. They call my planet "Pluto." I do not know how to tell my time to theirs. But it has been so many times since I began learning. It is exciting. But I have begun to feel alone again. They are so far from me. Their many greetings are becoming...Eerie. Even the funny "German" ones. This song, "Dark Was the Night, Cold Was the Ground," feels like this. I hope this goes away.

Months had already passed since that night, the night I first found him. Months of swarming news reporters, months of analyzing and testing every piece of matter found at the wreckage, months of reviewing all known footage of it, and worst of all, months of hearing my dad talk about it every night. None of those things included me, but while they kept questioning, broadcasting, and fearing, I kept reading. Now I sit on this clanging bus, remembering every detail about him that I can, the ones they will never get to know.

No one was supposed to find it, the golden record, or

"disc" as he called it. Knowing he had been there all along and seeing him slowly decode, understand, and love us humans brought me hope the same way it was brought to him. I always wondered why I took off with that journal in the first place, why I got myself roped into this mess. I tried to tell myself it was nothing more than a big "screw you" to my father, the government, and whatever authority figure I could think of, but I knew the truth wasn't as exciting as that. I was lonely. And after reading just a single sentence of his, I knew whoever wrote those words was lonely too. I guess the idea of me and this "person" being lonely *together* was something I couldn't just walk away from.

The screeching of the bus's brakes rips me from my thoughts, as I reach for the yellow, paint-chipped bars to catch my fall. The secrets to his universe lay in my backpack, as well as the cell phone with missed calls from my dad that I would have to ignore for the next few days. I knew it was a rash decision to drop everything and ride a Greyhound bus all the way to

Cape Canaveral, but it wasn't my decision to make. She was in Cape Canaveral. In his study of us, one member of They seemed to be at the center of his "research," and after hours of scouring the internet, I had found her. The "greatest minds of our generation" spent so much time devouring the "what?" to find the "why?", but I had the one thing they never even knew they needed, the key to answering that question. I was going to give it to the one person who deserved it. Her. Wanting to experience his words one last time before parting with it forever, I opened the old torn pages to the part where he first mentioned her and began to read:

531./2./43./3.

The alone feeling has begun to go away because of Her. Image 77. The woman in the supermarket. The Yellows in this image are so beautiful. She is so beautiful. Of all that I have seen, nothing feels less alone than her. I realized They all may have gone "extinct" many times

1 forgot Theys even existed,



ago. But that doesn't seem to matter when I see her dark eyes and sweet smile. I think I Love her. We used to Love. But it is hard to Love when it is just you on this empty floating Circle. But I think about her. And I feel like I am a They because of her. And I feel, Alive. I believe this is Love. It is okay if They are all gone. Because They are with me, here. They matter here. They still exist here. She still exists here.

I didn't close the pages until I stood at the bottom of the steps leading up to her bright, orange front door. As my hand slammed the golden knocker, I prepared myself to give the speech I had been silently practicing for hours. As I rubbed my greasy knuckles into my sunken eyes, the knob jingled and the door slowly creaked open. She stood there, hair grayed, face wrinkled, and back hunched, but still with that sweet smile. I could tell by the excitement in her eyes at the sight of a visitor, she had been alone for a while too. Just like me and just like him.

"Yes?"

"Ma'am, I know this is going to sound crazy. And I know that this is no way to introduce myself, but I just really need you to hear me out. I found this months ago in the wreckage you've probably been seeing all over the news. I've been reading it and reading it for quite some time. And after finding out about you, I knew I had to give it to you. You don't have to believe it. I know I didn't for a while. But even if you decide that it is fictional, please just read it. Just hear it. Just hear him. He loved you and you owe him that."

I shoved the journal into her hands and began to feel my cheeks flush and eyes water. I doubt any bit of that

made sense to her, so I spun around and hopped down the stairs. She had it now; that's all that mattered. My loneliness had faded in him, just as his loneliness had faded in us, and now it was her turn to have him, to know him, and to remember him. As my sneakers hit the last step, I heard,

"Wait. Come in. Please?"

I turned to find her sweet smile still beaming down at me, and for a moment I knew why he loved her. I slowly entered her home without a word, and before she could say anything, I flicked to the last page and said, "I think you should start here."

She smirked at me once more and then glanced down at the pages and began to read:

798./1./12./0.

I have decided to go to They. I found some of our old Spacethings. I know They are probably all gone. I know I am likely to not make it. But that is okay. They made this Life have meaning. So it is worth it. Staying here is not. I just hope wherever she is, she knows that she was loved. And she was not alone. None of us ever were. Not even me. I wrote this for her. I spent a long time translating it. I wanted it to be beautiful. I hope she can read it.

"There is no end. We are like Circles. We keep going. We cross paths and loop into each other. Love exists in these loops. Even the ones we do not see. For this, we are not alone. We never end."

let alone that I used to be a part of one.

This short story was inspired by the presence of the golden record on the Voyager spacecraft that are still traveling through space, alone, billions of miles away as I write this, as placed there in the 1970s by Carl Sagan and other scientific minds of the time. Ever since I first learned what the golden record was, its existence and influence have constantly been on my mind. A few science fiction works have tackled the concept of extraterrestrial life finding the golden record, but I wanted to explore a less cliché "sci-fi", more humanistic approach to the subject than I have seen before. Including the golden record on the Voyager spacecraft serves as so much more than a time capsule or a pipe dream of finding extraterrestrial life; for me, it is the perfect example of art and science



Erin O'Hara '20

Erin O'Hara is а sophomore telecommunication media studies major from Katy, Texas with minors in film studies and English. O'Hara's creative piece was inspired by her fascination with the Voyager Golden Record and the perspective of someone whose worldview is solely based on knowledge obtained from the Record. After graduation, O'Hara plans to use her passion for writing to pursue a career in Film or Television Production.

existing as one. That record contained everything that humanity had come to know and create by that time concerning life on Earth. Images of plants, animals, people, food, buildings, mathematical formulas, physics models, our location in the galaxy, and so much more were all held within that simple disc to show what being a human being on Earth is like. Every bit of it is science, every bit of it is art, and every bit of it is who we are. *My* greatest inspiration when working on this short story was the work of Ray Bradbury, in particular The Martian Chronicles. I fell in love with that novel many years ago because even though they were about such original fantasy concepts, I could feel the weight of humanity behind each story so heavily. Bradbury's stories brought *me to the realization that art and science should never be* separate; they are so much stronger when we accept that and hold them together. When I look back at my story, I see Bradbury's influence the most in my development of the extraterrestrial character, and the incredible humanity he has, even though he is not actually a human being. The works of NASA all those years ago and the creative work of Bradbury both came together in creating this piece in an attempt to fuse science and art once more. I wanted to hold a more realistic tone of cosmic loneliness above all other elements in the story. I believe the medium of written words really helps readers feel just as the protagonist of my story does when they read the words in the journal for the first time: an entire universe held on a record and an entire life held on a few pages. I really wanted that feeling to sink in. I also made sure to use a first-person, non-gender-specific point of view to allow readers to place themselves completely in the mindset of the protagonist. I hope when you read this story, you can feel the extreme loneliness and the realization that this loneliness couldn't be further from the truth just as my characters did.



FROM PERIPHERAL SIDE TO PATRIOTIC MEAL Salad as a Gendered Food in United States Cuisine During World War II

Kelsey Hannum

Introduction

By examining salad in early to mid-20th century culinary literature and advertisement, this research examines how socioeconomic factors can transform cuisine and investigates the relationship between food and gender. U.S. food advertisement from the early 20th century often presented salads as analogous to femininity. However, as the growing and eating of vegetables and fruits became both a practical and patriotic activity on the home front during World War II (WWII), salad's feminine associations in advertising weakened. That change encouraged salad's entry into U.S. masculine cuisine during the postwar decade and influenced how it evolved later.

As a central component of life, food is a subject intimately connected with our day-to-day experience and effects both our physical and psychological wellbeing. It interfaces with diverse aspects of our society encompassing diet and health as well as politics and media. Consequently, food serves not only as a medium for cultural expression but also as a source of change. By tracing food's historical depiction in advertisement and propaganda, we therefore gain a better understanding of our past and food's significance in our dialogue about culture today. Even the deceptively modest salad proves noteworthy on inspection; its transformations during and after WWII revealing the malleability and resilience of culture in the United States.

Analysis

During the first half of the 20th century, salad's portrayal in advertisement and culinary literature centered on its feminine connotations, accentuating gender norms and the methods used to propagate them in the United States during that period. To examine the complex nature of



culture and its specific relationship with gender and food, this study examined how salad acquired feminine associations and how salad's reception as a gendered food item changed during and after WWII. Research focused on gaining a well-rounded perspective by analyzing salad's depiction in U.S. food advertisements, cookbooks, and WWII propaganda campaigns.

Salad's entry into gendered cuisine developed alongside increasing marketing efforts...

Acquiring Feminine Associations

Salad's entry into gendered cuisine developed alongside increasing marketing efforts to target and indoctrinate women into consumer culture during the latter part of the 19th century. Its inherent characteristics, such as color and taste, were paired with feminine attributes such as purity, delicacy, and sweetness. Consequently, salad gradually became enmeshed with the reflection, celebration, and attainment of femininity in advertising and culinary literature.

The pervasive idea that women were more invested in the appearance of their food, rather than its taste, influenced salad's classification as a feminine food item in U.S. society and shaped the connection between its consumption and the reflection of feminine virtue. That theory grew from the 19th century tendency to disassociate women from carnal appetites and contributed to a "you are what you eat" mentality, which stressed that women should eat foods that echoed femininity. Under those assumptions, the variety and color that vegetables and fruits naturally offered made them ideal candidates for the feminine palate, for they could be artistically arranged and appreciated.1 Furthermore, fruits and vegetables' light, fresh, pure, and delicate properties harmonized with idealized feminine virtues and distanced the association between women and heartier foods, such as meat. Consequently, foods reflecting feminine qualities

infiltrated advertisements targeted to women and fortified the association between salad's consumption and femininity.

Culinary literature also advertised salads as a medium through which women could showcase their culinary expertise.¹ The cookbook One Thousand Salads, for

> example, declares salads the truest test of a woman's cooking ability, saying, "An ignorant cook can roast a leg of mutton, broil a steak, or bake a potato... but the making of the simplest salad will betray her skill—or the lack of it."² It also stressed that successful salads necessitated the

exercise of uniquely feminine talents, namely intuition, balanced judgment, dexterity, and a passion for cooking. In other words, to craft an appealing salad, the cook had to possess impeccable, womanly finesse.³ The assumption that the creation of salads required a feminine touch strengthened salad's feminine identity and produced a distinct forum at the table for women to express their creativity and proficiency.

Lastly, salad's implicit connection with femininity also stemmed from its role in dieting and health. As a lighter fare, salad became a favored meal replacement in health and beauty articles offering dieting tips, and as a thinner look in women gained ground during the twentieth century, the pressure to be slim intensified. Beyond this direct relationship with dieting, however, salad's nutritional benefits eventually incurred feminine associations as well. As the field of home economics grew alongside efforts to make cooking a science during the late nineteenth century, so did the emphasis on crafting nutritionally balanced meals. Soon meticulous standards, attention to nutrition, and the maintenance of the family's health morphed into hallmarks that pretended to measure the quality of U.S. women, wives, and mothers, entangling salad's nutritional elements with the female domain once more.^{1,4} Serving as both a dieting tool and symbol of a woman's investment in her family's health, salad had become a means to attain the feminine ideal. In summary, to eat and serve salads were to exercise one's womanliness.

Identifying these various influences helps explain why salad developed gendered connotations in U.S. advertising well into the 20th century. Examining salad's depiction within a historical context, however, illuminates how salad's development as a gendered food unfolded. In light of its representation during WWII, salad's affiliation with femininity proved adaptive and negotiable. As U.S. resources, experiences, and history changed, U.S. salads and their gendered connotations changed as well.

Salad Goes to War

Salad retained feminine associations in advertising well into the postwar era. However, salad's reception, depiction, and use as a gendered food transformed before, during, and after WWII. Those changes indicated that the war gave salad a new significance and prompted its entry into masculine cuisine in the postwar decade. To appreciate that change, let's first consider salad's status before the war as a strictly feminine food.

Before WWII, salad held a humble place at the U.S.

dinner table and was viewed with suspicion and disdain, particularly by men. Claims that salads catered to unpalatable feminine tastes and that women intentionally rendered salads inedible by emphasizing the feminine sweet tooth, favoring display over taste, or conspiring to make them as unpleasantly healthful as possible characterized

early-20th-century culinary literature, which mostly men wrote.⁵ In general, salads were depicted as the disastrous gastronomic result of feminized food, inflicted on innocent diners by ignorant or unfeeling women. Beyond taste, salad's status also suffered from the "you are what you eat" mentality. Consuming salad was perceived as a feminine habit and consequently an affront to the male ego. As one cook noted, before WWII "a man would almost as soon admit he wore a girdle as that he liked salad."⁶ Salad's blatant feminine connections distanced it from male diners striving to portray their masculinity through consumption. Thus, salad's feminine associations, both in taste and practice, played a twofold role in stunting its popularity before the war. That hostile attitude toward salad's feminine overtones would not withstand the dietary changes that accompanied WWII, however. As the government imposed rationing measures and meals took a more vegetarian turn, salads entered a new context and gained prestige.

Wartime resource restrictions called for economy, conservation, ingenuity, and patriotism on the home front.7 Those conditions allowed salad to enter the everyday U.S. menu as a main course with relative ease and an overall positive reception. It both solved pragmatic problems and facilitated citizens' fulfillment of patriotic duty. Not only were salad's ingredients accessible and nutritious, but being an adaptable dish, salad also made substitution easier and advanced conservation efforts by using leftover foods. As the availability of more traditional sources of nutrition declined and concern for the state of the nation's health increased, advertising emphasized salad's nutritive benefits and practicality. Qualms about salad's taste and feminine connotations all but vanished during that period.

...economy, conservation, ingenuity, and patriotism...allowed salad to enter the everyday U.S. menu...

Propaganda and patriotism contributed to that change as well. Starting in 1942, victory gardens received government endorsement, primarily because they reserved more canned produce for soldiers, alleviated the burden on commercial farmers, and stretched the ration supply.⁸ Socially, they also promoted community cohesion and provided an accessible, patriotic activity. Supposedly, any citizen with a plot of land or flower pot could start a garden and indirectly "[plant] the seeds of democracy" by their cooperative efforts.⁹ The avid publicity surrounding victory gardens ingrained the growth and consumption of vegetables and fruits into the nation's wartime identity, contributing to salad's increasing popularity at mealtime. Moreover, the fusion of vegetables and fruits with wartime propaganda and patriotism expanded beyond victory gardens when

the government launched dietary reform campaigns. Scholar Mei-ling Yang even suggests that by electing to acclimate the civilian population to leaner meals and healthier diets by relying on propaganda that prioritized fruits and vegetables, the government effectively "feminized the civilian diet."¹⁰ Though perhaps strongly worded, Yang's claim reiterates the new relationship between wartime conditions and the increased promotion of gendered cuisine on the home front.

Salad's Postwar Transformation

Ration restrictions and propaganda afforded salad a new symbolic prestige and stronger foothold in the everyday U.S. dining culture, evidenced by the fact that it received more positive attention in culinary literature in the postwar decade. Furthermore, a new enthusiasm for salad as a main-course dish emerged. After the war, food supply stabilized along with an overall willingness to resume the traditional U.S. diet, centered on meats and sturdy, masculine cuisine. In response, salad had to begin catering to masculine tastes at the dinner table to retain its new status. During the war, salad's economic and rhetorical contribution to wartime aims seemingly minimized its gendered significance in U.S. culture, for during the postwar period the absence of those factors appears to have made salad's feminine associations once again problematic. Although men in culinary literature increasingly began to endorse salads, support proved conditional. Many wanted to reform the salad by incorporating heartier ingredients, simplifying its display, and replacing sweet tastes with pungent ones. One article titled "Hearty Salads Can Be Meal's Hub" coached the reader on how to create a salad that would be "a big hit with the male members of the family," recommending the addition of ham, "sharp cheese," and "tangy French dressing" to fortify the meal.¹¹

Salad had to begin catering to masculine tastes at the dinner table to retain its new status.

Such advice typified recipes for main-course salads published in the postwar decade. As a result, although salad gained greater culinary recognition in the 1950s, pressure to eliminate its feminine associations and conform to masculine preferences increased. Certainly, some of those recommendations were meant to add caloric substance and make the salad a more filling meal, but the relentless appeal to masculine preferences suggests an unwillingness to serve a feminized food at the dinner table. That attempt to masculinize the salad occurred, at least in part, because wartime socioeconomic and political forces had momentarily weakened prejudice toward its feminine connotations.

Conclusion

Salad's development from the mid-19th through the 20th century illuminates culture's inherent complexity, revealing the paradoxical relationship between its powerful influence and simultaneous susceptibility to short-term change, such as that brought by WWII. On the one hand, U.S. gender norms dictated salad's feminine depiction in advertisement; on the other, resource restrictions, propaganda campaigns, and patriotism destabilized earlier assumptions and transformed the feminine salad into a weapon during the war, making it a benign addition to the manly dining repertoire during the postwar period. This study, therefore, not only offers focused insight into the relationship between gender and U.S. cuisine but also exemplifies the dynamic relationship between cultural standards and their environment. The two are connected and contribute to both change and consistency. Understanding culture in those terms reminds us that even though our past is intertwined with our present, culture evolves as we participate in it, and the outcome is rarely fixed.

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USING BACTERIA TO HELP FEED THE WORLD

Lorenzo Washington

Introduction

The world's population is growing rapidly, projected to reach 9 billion by 2050, and the world will need food to match the growing population. About 795 million now people suffer from undernourishment, and that number will only increase as the population grows.¹ However, global agricultural output doesn't have much potential to increase. Climate change, desertification, urban development, and other environmental issues are slowly decreasing the amount of land suitable for farming. Agricultural output is beginning to reach a ceiling, and as that dilemma continues to come to a head, the issue reaches far beyond an empty stomach. Agricultural practices use massive amounts of pesticides, herbicides, and fertilizers. In one year, 11.2 billion pounds of nitrogen fertilizer alone was applied just to corn fields. Other crops total several billion more pounds of nitrogen fertilizer, and herbicides are used on more than 80% of fields.² Those fertilizer and herbicide inputs often have some degree of runoff into water systems or otherwise affect the local environment. Even if we could simply increase agricultural production to meet demands, the environmental fallout would be catastrophic.

That situation puts us in a paradox; synthetic inputs are largely responsible just for maintaining current agricultural yields, but they are contributing to a feedback loop that is making farming much harder. To resolve that paradox, agricultural research is trying to find alternatives to pesticide and fertilizer use while maintaining high levels of production. Naturally, genetically modified organisms and selective breeding have received the most attention,

AGRICULTURAL RESEARCH IS TRYING TO FIND ALTERNATIVES TO PESTICIDE AND FERTILIZER USE WHILE MAINTAINING HIGH LEVELS OF PRODUCTION.

but those avenues have either become controversial or yielded only minuscule improvements. However, using microorganisms to bolster or replace current pesticide and fertilizer use is a less explored avenue that offers ways to maintain crop health while minimizing environmental damage. This project aims to explore that new technology by establishing a better understanding of the signaling response seen in affected plants on the basis of genetic expression.

Background

Certain soil microbes help improve plants' ability to survive and grow. For example, many species of plants rely heavily on relationships with nitrogen-fixing bacteria. However, the extent of those relationships is only recently being understood. Researchers have made a lot of headway into understanding how many of those microbes can help produce a larger crop. The bacterium used for this experiment, Pseudomonas chlororaphis, can significantly increase both root structure and aboveground plant growth of corn plants in comparison with nontreated corn seedlings. However, the real reason we wanted to learn more about the genetic response in corn is because that microbial relationship is one of the keys to induced systemic resistance (ISR). Akin to a universal vaccine, ISR primes the plant's defense system to myriad issues: drought, heat stress, bacterial or insect infections, and nutrient deficiency.³ Combined with the growth effect seen earlier, ISR is like having the effects of fertilizer, pesticides, and herbicides all from the plant-microbe relationship. Perhaps understanding how that occurs in the corn plant could help develop solutions to many of the aforementioned problems that agriculture faces.

To understand that interaction, we looked toward oxylipins. Oxylipins are signaling molecules produced by lipoxygenase (LOX) genes in the plant, a near equivalent to animal hormones. Although understood well in animals, little is known about them in plants. We do know that they are often heavily involved in the plant's response to outside stimuli as diverse as microbe or insect interactions and variations in a light cycle.⁴ Researchers also have a rudimentary understanding of which signaling molecules are responsible for which interactions. Therefore, we devised a way to observe which LOX genes were activated, and to what degree, in response to colonization by the beneficial bacterium *P. chlororaphis*.

Materials and Methods

Thirty genetically uniform, nonmutant corn seeds were individually planted in sterile soil conditions. The soil was steam-sanitized twice to ensure an environment in which the only active microbial activity that affected the plants would be that of P. chlororaphis once it was added. During the growth period, the maize was grown indoors in controlled conditions and watered with sterile, distilled water. Once the seedlings had reached appropriate levels of maturity, approximately 2 weeks, an overnight culture of P. chlororaphis was separated into identical concentrations and injected into the soil around the roots. After the bacterial application, three plants were harvested at each time point: 8, 24, and 48 hours. Three plants were not inoculated and were harvested immediately to serve as a neutral control. After harvest, plants were immediately flash-frozen in liquid nitrogen to preserve genetic material. Each sample was then separated into leaf and root portions, ground into a powder, and the RNA extracted for genetic analysis. After confirming the quality and concentration of the genetic material, we ran a series of quantitative polymerase chain reactions to determine the amount of LOX gene expression-the extent to which the gene was activated. The expression of every LOX that we had the means to test was analyzed in both the leaf and root samples.

The collected data were analyzed. Much of the LOX gene expression showed negligible or no change, but we saw a few notable differences. With genetic expression, a change of more than half of the control amount in either direction is significant. In the leaf tissue, the most drastic observance was LOX-5, which showed an increase in expression of 4.5 times the amount shown in the control at the 24-hour mark. The induction was seen only at that time point; at the 8- and 48-hour mark, LOX-5 showed

slight suppression. Conversely, the root samples showed nearly complete suppression of LOX-5 during the experiment, potentially implying some sort of root-to-leaf signaling. Because LOX-5 appears to be involved in the plant's response to pest infestation, that finding was of particular interest. LOX-6 also showed a notable increase in expression in leaf tissue, with 1.5 times the control level observed at 24 hours before falling to seemingly complete suppression at 48 hours. In other words, at the 48-hour mark, we detected no activity.

The root tissue showed three notable differences in expression: LOX-5, LOX-10, and LOX-12. LOX-10 showed a fairly consistent fourfold induction throughout the experiment, and LOX-12 did so at twofold induction over control levels. LOX-10 appears to be involved in the plant's response to infestation and infection as well. The more intriguing

results were those of LOX-12, which is important in priming induced systemic resistance. Because it was seen induced so clearly in the roots, LOX-12 is promising for future endeavors. *LOX12* is the only LOX gene in the maize genome that shows very little sequence change over about 10,000 years of maize domestication

A DEEPER UNDERSTANDING OF THE RELATIONSHIPS BETWEEN CROPS AND BENEFICIAL MICROBES CAN BE THE BREAKTHROUGH THAT LEADS TO ANOTHER GREEN REVOLUTION.



FIGURE 1. LOX expression in B73 corn leaves treated with *Pseudomonas chlororaphis*.



FIGURE 2. LOX expression in B73 corn roots treated with *Pseudomonas chlororaphis.*

and breeding, suggesting that the gene was selected for by generations of farmers and breeders, although the characteristics behind that selection are not clear. It is intriguing to think that one potential reason that gene was selected was because of its role in plant interactions with beneficial microbes in roots. **Figures 1** and **2** show the observations discussed and other collected data that were statistically significant. The graphs all begin at the time zero and at the levels seen in the control plants; any changes in the lines are deviations from the control levels.

Conclusion

The clear increase in expression for LOX-12 is very promising. Combined with results from previous experiments that show induction from other ISR-

promoting microbes, that finding offers important insight into ISR induction. That information can be used to discover how to reliably increase the effect and implement it for practical use. Corn is responsible for a considerable portion of food production and requires a significant proportion of agriculture input resources. When combined with this microbe's growth-enhancing potential, the technique could serve as a natural enhancement that could either supplement or replace fertilizer, herbicide, and pesticide application. Doing so could not only provide the boost in productivity that agriculture is going to need but could also serve to alleviate the heavy use of fertilizer and pesticides that can have dramatic environmental impacts. Because P. chlororaphis is a fairly common soil bacterium, widespread implementation with corn should not drastically affect soil microbial populations in areas beyond the crops themselves.

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A deeper understanding of the relationships between crops and beneficial microbes can be the breakthrough that leads to another Green Revolution. Most research on microbes focuses on simply improving growth or nutrient uptake, but studying crop-microbe relationships is essential to provide the same benefits as pesticides and herbicides. Microbes may be used less than fertilizers, but the impact they have both for the environment and for society is significant. Experiments such as this one are building blocks for a solid foundation to move forward and address possible solutions to those issues, moving the world into an era of more sustainable agriculture.

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NO PROTEINS, NO PROBLEM: Improving the lifespan of Blood-contacting devices

Mikayla Barry

Introduction

With the rise of chronic illnesses such as diabetes and heart disease, modern medicine has begun to rely heavily on using implantable devices to control symptoms. However, the human body comes with adaptive responses that actively interfere with the devices' long-term function. No area is more difficult than the bloodstream, where the clotting response can be easily triggered. As soon as the device is implanted, proteins in the blood rapidly deposit onto its surface and over time activate nearby platelets, which then initiate clotting.1 Catheters are hollow tubes that deliver medicine and other fluids to blood vessels and are often used in hospitals. For patients who suffer from kidney failure, dialysis catheters are implanted for the long term to make filtering blood regularly easier, but are subject to the clotting response that can clog the tubing or form embolisms, small clots that travel through the bloodstream and can cause a heart attack or stroke.

Silicone is a popular material for catheters because of its flexibility, but it is highly prone to protein adsorption, wherein proteins deposit onto the surface and then induce clotting.² Currently, antithrombotic drugs known as blood thinners are used to prevent the large-scale clotting response of platelets.

ONE MATERIAL IN PARTICULAR CAN PREVENT PROTEINS FROM ADSORBING ONTO THE SURFACE...

Unfortunately, those drugs seriously increase the risk of bleeding complications³ and have limited effectiveness because clotting still causes over 40% of unanticipated catheter removal for dialysis patients.⁴ The effectiveness of implantable blood-contacting devices would therefore be vastly improved with the development of clot-resistant materials.

One material in particular can prevent proteins from adsorbing (depositing) onto the surface. Poly(ethylene oxide) (PEO) is a polymer, a long-chain molecule made of many repeating units, that has been shown to resist protein adsorption when placed on rigid surfaces such as gold or silicon.² There, PEO physically blocks proteins from the surface through continuous movement and forms an additional barrier by causing water to pack more tightly around it, which prevents proteins from interacting with the surface below, as shown in **Figure 1**.

However, PEO does not work well when mixed with silicone polymer because silicone's chains do not stay



FIGURE 1. PEO prevents protein adsorption

still but twist and move. Over time, the PEO tends to migrate to the middle of the silicone rather than stay on the surface. Instead of trying to prevent the initial migration, we sought to improve PEO's ability to return to the surface. We predicted that improving PEO's solubility within silicone would enable that migration, and we made an additive composed of both PEO and silicone (**Figure 2**).⁵

Methods

The project consisted of several phases: first, the synthesis, or chemical formation, of the additives. We first modified one end of a short silicone chain with a reactive "cross-linker" that can bind with the other silicone chains in dialysis catheters. Doing so ensures that our additive stays inside the catheter material instead of leaching out into the blood. We then took that chain and allowed its other end to react with PEO, forming our final additive.⁵

After making these additives, we mixed them with liquid silicone before allowing the silicone to solidify as it formed a polymer. Several concentrations were made, ranging from 0% to 8.5% additive by weight. We determined that PEO could come to the surface



FIGURE 2. Proposed additive

of this modified silicone by using water in a technique known as contact angle goniometry, in which we measured the angle that a drop of water makes with a material's surface. PEO is hydrophilic, or "waterloving," whereas silicone is hydrophobic, being more soluble in oils than in water. When a droplet of water is placed on the surface of silicone, it remains beaded up, making the contact angle between the top of the droplet and the silicone surface high, usually above 90°. With PEO, however, water spreads out to maximize contact with the hydrophilic surface, making the contact angle very low. If our material has PEO at the surface, water should react by spreading out rather than beading up.

Next, we showed PEO functionality by using a protein test, in which the modified materials were exposed to solutions containing fibrinogen, a blood protein with a critical role in clot formation, for 3 hours. During that time, the additive has the opportunity to prevent the fibrinogen from adsorbing to the surface. The fibrinogen used had been made fluorescent, so the amount of protein on the surface could be determined by the intensity of the light. Reduced light on the material would indicate a similar reduction in protein adsorption, meaning the PEO was working to keep the surface clean.

Results and Discussion

Our first objective was to make sure that our additive worked in bringing PEO, the waterloving polymer, to the surface when mixed into silicone. Our contact angle results showed an interesting pattern for the modified materials (**Figure 3**).⁶

At first, all samples have a very high contact angle, but in less

than a minute the water droplet rapidly flattens out for the samples at or above 1.8%. Those effects show that for the 0.08% sample, the PEO has no effect; the contact angle looks similar to that of silicone. For the others, the eventual angle varied based on



FIGURE 4. Fluorescence intensity of modified silicones exposed to labeled fibrinogen.⁶



FIGURE 3. Contact angle was measured for five minutes on each sample.⁶

concentration, with the lowest reached by the 8.5% sample at nearly 35°. For those, enough PEO comes to the surface to cause a decrease in contact angle.

We now know that the PEO is able to come to the surface, but the fibrinogen test looks for polymer functionality in preventing protein adsorption; its

> results are shown in Figure 4.6 We found a similar relationship between additive concentration and PEO's ability to affect the surface properties of the samples. The inclusion of PEO is insignificant for the 0.08% sample, as fibrinogen binds just as strongly to it as the pure silicone sample. With higher concentrations, however, we see that our additive is able to reduce fibrinogen adsorption, with even the 1.8% sample showing a 99.8% reduction. This finding indicates that our additive will likely also prevent the thrombosis that would happen after adsorption in the bloodstream.

...IT MAY BE USED TO IMPROVE THE SAFETY AND LIFE SPAN OF ALL BLOOD-CONTACTING DEVICES...

Conclusion

To function properly, blood-contacting medical devices such as catheters must be able to prevent the body's clotting response. Instead of using drugs that limit the blood's ability to clot, we designed a material that prevents clotting by stopping proteins from depositing on the surface. This material has shown promise in preventing fibrinogen adsorption, but the more important test is to see how it fares in whole blood. If the material prevents clotting, it may be used to improve the safety and life span of all bloodcontacting devices, improving the lives of millions of people around the world.



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GEOGRAPHICIANALYSIS OF HISTORIC AFRICAN AMERICAN CEMETERY

Laura Everett and Hailey Duncan

A CEMETERY IS NOT A PLACE WHERE PEOPLE WHO DIE GO; IT IS THE PLACE WHERE PEOPLE WHO LIVED ARE. - Rev. Eddie E. Harrison

Introduction

The second s

In 2007, a local coalition reclaimed the Brenham Camptown Cemetery, a predominantly African American burial site that had become neglected and overgrown since the late 1800s. Since 2007, locals have tried to restore the cemetery and preserve its valuable history. To contribute to those efforts, we worked with the Texas A&M Geography Society to conduct a land survey of the cemetery and produce a map of significant features, such as gravestones, trees, and family plot boundaries. The group of two dozen volunteer undergraduate students collected more than 450 location points by using traditional surveying techniques. We used those spatial data to create a map with the geospatial processing program, Esri's ArcMap.

Although 81 gravestones have been identified in the cemetery, the community restoration team estimates that 196 individuals were buried there. To identify potential sites of unmarked graves, a noninvasive geophysical survey was conducted to map anomalies below the ground by using a method known as ground-penetrating radar (GPR). Definitive identification of 150-year-old unmarked graves is challenging in the clay-rich soils; however, the attempt is important to the descendants and community members in order to foster understanding of the cemetery's history for future generations. The map, the profile image created with GPR, and a human geographic analysis of the cemetery's role in the community contribute to the restoration effort. We have given the resulting visual representation and analysis to the Brenham community to be used for historic preservation purposes.

Background

The Brenham area of Central Texas has unique historical and cultural characteristics that allowed accelerated developments in education, racial acceptance, and industry during the Reconstruction Era.¹ For settlers moving west in the early 19th century, the area was an ideal geographic location because its distance from the Gulf's inclement weather provided a fair climate. Those conditions brought slaves, Europeans, and American settlers into

close social contact with one another. The historic African American Camptown Cemetery holds some of the most influential people of color who resided in Brenham before the development of new African American cemeteries at the turn of the century.

The multiracial population and pervasive German culture helped normalize education for all races. The rare establishment of a normal school, an African American public education institution, created an environment in which blacks could learn trades such as brickmaking, food handling, blacksmithing, and bridge building. Those laborers all contributed to Brenham's rapid growth. The emphasis on education led Brenham to establish the first Texas public school system in 1875.

Named after a settlement of federal troops in the area in the wake of emancipation in 1850, Camptown Cemetery was active until the 1950s. Census data indicate that 196 people are buried there, the first being Waltman Bynum in 1881 (personal communication). As a result of inconsistent recordkeeping, unmarked graves probably exist. Today, only 81 headstones remain in the cemetery. After the 1950s, the cemetery was abandoned until 2007, when city officials contacted Brenham's Mt. Rose Missionary Church to lead restoration efforts. Over the last decade, members of the congregation and local historians have worked to clear the overgrown cemetery and conduct extensive ancestral research to preserve the history buried there. The restoration of that site holds immeasurable significance to the descendants of those laid to rest there as people try to weave the stories of the political, religious, and social contributions of Brenham's ancestors. Our research helps in obtaining recognition of the area as a historic district while also uncovering the stories of individual African American figures during Reconstruction.

In addition to extensive genealogical, historical, and cultural analyses conducted in the last decade, Texas A&M geophysics undergraduate student Tate Meehan conducted a noninvasive geophysical survey in 2014. That survey consisted of acquiring magnetic data



FIGURE 1. Signs of neglect at Camptown Cemetery were evident by knocked-over and misplaced grave markers.

beneath the ground to "detect soil disturbances or magnetic bodies within the subsurface" that could indicate potential sites of unmarked graves.³ Meehan also surveyed the cemetery by transmitting a timevarying electromagnetic field into the ground, thereby generating a magnetic field that can be recorded to show areas of known concrete above ground features and subsurface metal.³ However, the geophysical surveys poorly imaged the subsurface conditions in areas where no concrete or metal is present. Thus, we conducted further geophysical tests by using a different technique to determine whether areas of subsidence could indicate potential unmarked graves.

Methods

To map the features in the cemetery, we used a total station, a traditional surveying technique that consists of a laser theodolite mounted on a tripod

and a portable reflecting prism. Once the theodolite is calibrated so that it is level over a determined location and the prism is positioned at the feature to be surveyed, the theodolite transmits a laser beam that the prism then reflects, calculating the distance and angle between the reflector and a reference point. The determined locations are then arranged on a local coordinate grid to centimeter-scale accuracy.

Because many obstacles in the cemetery prevented consistent lines of sight, we created a horizontal control polygon-an octagon with strategically selected ground points so that direct lines of sight existed between adjacent polygon vertices. Each cemetery feature needed a direct line of sight to at least one of those polygon vertices so that nothing blocks the laser while collecting data. After setting up the total station transmitter at the first of those eight vertices, we positioned the prism at the vertex immediately clockwise to the theodolite, known as the "backsight," and recorded the distance. Then we moved the prism to the location immediately counterclockwise to the transmitter, or the "foresight," to acquire the distance and the angle subtended at the theodolite between the backsight and foresight. We moved the transmitter to each of the eight points, measuring backsight and foresight distances and angles. To enhance accuracy, we repeated the polygonal traverse and took the mean of the two results.

Once we established the control polygon, we set up the theodolite at an arbitrary vertex and determined the local coordinates for each tree, stump, gravestone, fence, and family plot boundary in the cemetery. We imported those points into the geographic information system software, ArcMap 10.4, in which polygons were created to connect related points and hence accurately depict the shapes of the features in the cemetery. That approach allows irregular gravestones and disturbed plot boundaries to be realistically represented on the map.

To identify potential sites of unmarked graves, we identified a 27-m path through a series of seemingly grave-sized depressions. We hypothesized that this series of depressions could indicate a row of unmarked graves, marked by soil subsidence. We analyzed that 27-m transect with GPR. We conducted the subsurface survey by emitting 200-MHz radar pulses into the ground every 10 cm. We then processed



FIGURE 2. Cemetery features, including grave markers, family plot boundaries, rose bushes donated by the Antique Rose Emporium, trees, stumps, and other features were mapped using traditional surveying techniques to show their relative locations within the property.

the data to clarify the resulting image. The processed image in **Figure 3** shows soil disturbances, which could indicate unmarked graves.

Results

Figure 2 shows the aboveground map of the cemetery features: 323 trees and stumps, 47 grave markers, several family plot boundaries, and 33 rose bushes planted as part of the restoration process. Because of inaccessible areas of overgrowth, additional grave markers and plot boundaries are probably located along the periphery of the surveyed area. The map offers a comprehensive view of the artifacts preserved in the cemetery and will visually represent its history.

The GPR cross-section image (**Figure 3**) shows bright patches indicating a large disturbed zone. Those anomalies appear at depths of 2.2 m around the positions of 5.3–7.9 m along the transect. That location lies between ground depressions but does not match precisely with one, so whether those signatures indicate potential unmarked graves is unclear. Figure 3 also shows two large concave hyperbola at a depth of roughly 1.8 m, which could indicate tree roots.



FIGURE 3. Ground-penetrating radar was used to create a profile image of subsurface anomalies along the 27-m transect in the Camptown Cemetery that showed an evident series of depressions.

Conclusion

Unmarked graves in Camptown Cemetery are hard to find with GPR because of the presence of clay-rich soils and a humid subtropical environment that accelerates the decay of human remains. Because the potential burials along the surveyed transect may not have involved a casket, few remains probably exist for the GPR to detect.⁵ The GPR survey shows the great challenges associated with delineating unmarked graves in historic cemeteries by using noninvasive geophysical methods in clay-rich soils in a subtropical climate. The approach outlined here could be performed at other important historic cemeteries across the country. Different climate conditions and sandy soils would probably yield more definitive GPR indications of unmarked graves.

The human analysis of this region helps uncover the significance of education, racial acceptance, and industry in Brenham during Reconstruction. Our research helps memorialize people buried in this cemetery and the contributions of African Americans to local history. The map we created visually represents the cemetery's current state, thereby helping document the restoration team's progress. We hope that our work will help the restoration team in gaining legal ownership of the land so that their progress can continue.

Future Work

The map will continue to be used with additional geophysical work that is planned to further explore potential sites of unmarked graves. The local community members who worked to restore the Camptown Cemetery over the last 10 years will continue maintaining the cemetery while conducting additional historical research to preserve the cemetery's stories for future generations.

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